North Coast Land Conservancy

Boneyard Ridge

Forest Management Plan

November 2016

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There are many silvicultural methods that can be applied to this forest. The management recommendations contained in this plan can be implemented literally, but are more intended to provide guidance when preparing for and implementing forest management activities. In particular, timber harvests may vary in size and location based on current market conditions, revenue needs, logging costs, operational constraints and the recommendations of other forestry and natural resource specialists.

North Coast Land Conservancy
Forest Management Plan

# of acres plan covers:	340
County and state:	Clatsop County, OR
Forest certification number:	
USDA Farm & Tract #:	
Date plan prepared:	November 2016
Plan Preparers	
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Signatures	
Date: 1/9/17	Date: 3/15/17
Kirk Hanson Northwest Certified Forestry	Forest Owner

Updated: 3/15/17

TABLE OF CONTENTS

BACKGROUND AND SITE INFORMATION:

Legal Description:
Township 6N
Range: 10W
Sections 32 & 33

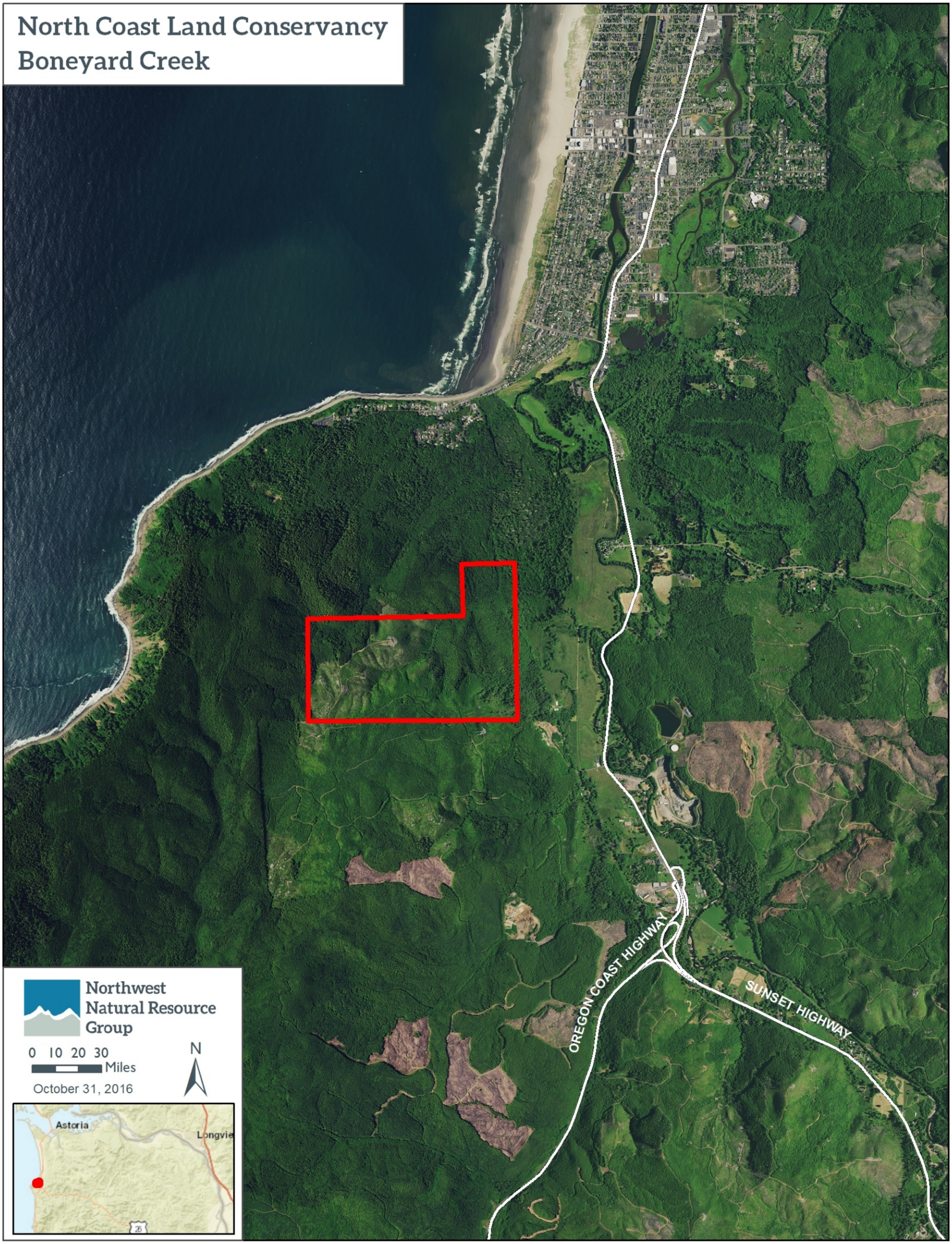
Nearest City or Town:
Seaside, OR

Parcel Number:
Clatsop County parcels: 610000003300, tax map 6.10, acct 7814

Property Size:
340 acres

Date of Land Acquisition
July 26, 2016

Watershed
Circle Creek - Necanicum River


North Coast Land Conservancy
Boneyard Creek
OREGON COAST HIGHWAY
SUNSET HIGHWAY
Northwest Natural Resource Group
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October 31, 2016
Astoria
Longvie
26

INTRODUCTION

Looking north across FMU 2 towards Seaside, OR.

The Boneyard tract is a 340 acre forested property located in Township 6 North, Range 10 West, Sections 32 and 33. It lies on the eastern flank of Tillamook Head, forming a scenic backdrop to the ocean beaches of Seaside and Gearhart. The property has been managed for timber production by industrial owners for many years; however, it currently has a good distribution of forest age classes and species diversity, and it contains fish-bearing tributary streams of Circle Creek, a third order coastal salmon stream. Most significantly, it provides potential connectivity between two important conservation properties – the 364 acre Circle Creek property, already owned by NCLC and Ecola State Park, at 1,024 acres a rare jewel of older forest on the North Coast.

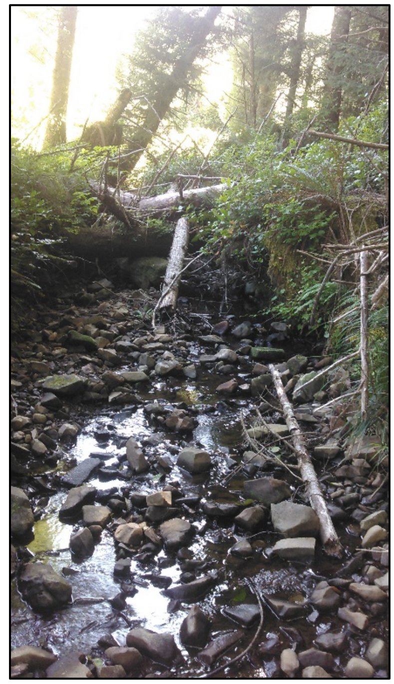
Elevation ranges from approximately 20 feet above sea level in the northeastern corner of the property, where it is adjacent to a forested wetland, to approximately 720 feet in the western portion of the property. Generally the property is fairly steep, and historically was logged using tower and cable systems.

The property currently consists of relatively young (less than 60 years old), dense, even-aged stands of trees managed for timber production. The forest does have a robust distribution of age classes (1 – 56 years), which by itself provides some inherent habitat diversity. Furthermore, the property contains a relatively diverse mix of native tree species. Compared to other industrial ownerships in the region, both the distribution of ages and the species diversity are somewhat unusual. Due to its location very near the coast, the site is subjected to high winds during winter storms, and blowdown of timber is part of the natural disturbance regime. A minor amount of blowdown in the older stands has occurred in recent years.

Biological legacies such as large woody debris and snags that would be typical of older natural forests are mostly absent from the uplands due to past commercial wood utilization. Shrubs and native understory plants are present in limited quantities due to vegetation management practices to control shrubs in favor of planted conifer seedlings. In the established stands, the density of overstory trees largely preclude the presence of much understory vegetation. Some invasive species, notably Scotch broom and non-native blackberries, exist in the younger plantations and along roads.

Conservation Significance

The North Coast Land Conservancy's primary goal in acquiring this forest is to protect the conservation values of the upper watersheds of Boneyard Creek and Little Muddy Creek — coastal temperate rainforest, salmon-bearing streams, and the forested wetlands—into perpetuity, and to connect our other conservation properties in the Necanicum estuary and Circle Creek to its headwaters on Boneyard Ridge. North Coast Land Conservancy's secondary goal is to achieve the desired future conditions, defined in the following section—late seral forest, early successional habitat, and freshwater habitat—through long-term adaptive management that implements both passive and protection stewardship strategies that include long-term monitoring , tree density manipulation, and snag and down wood creation.



Cobble substrate in Little Muddy Creek.

Opportunities for permanent protection of coastal temperate rainforest on the scale of the Boneyard Forest are infrequent, particularly in Clatsop County, where 94% of land is designated as forest land, 67% of which is in private ownership (Oregon Forest Research Institute 2013). In contrast, in Tillamook County only 33% of forestland is privately owned and state and national forests constitute large percentages of the forestland. Even in federal forests within the North Coast Adaptive Management Area of the northern Coast Range, old-growth forest covers less than 1% of forestland. It is also important to note that there is very little federal forestland in Clatsop County, so forestland conservation requires the acquisition of working forests and opportunities to protect intact old-growth forestland are scarce if not non-existent. In Clatsop County, only 2.5% of forestland is conserved by national historic, state, and county parks and land trusts.

A number of factors made the Boneyard Forest acquisition a tremendous opportunity for North Coast Land Conservancy:

- geography on the prominent and ecologically significant Tillamook Head
- connectivity to other conserved lands, including multiple NCLC reserves
- feasibility of conserving an entire watershed in one strategic acquisition
- 1/3 of the property (120 acres) consists of riparian habitat and forested wetland
- a number of important species are known to occupy the site including: coastal coho, cutthroat trout, northern pygmy owl, pileated woodpecker, olive-sided flycatcher and

willow flycatcher, Rufous hummingbird , northern red-legged frog, Columbia torrent salamander and Pacific giant salamander

- proximity to the Circle Creek Conservation Center makes management and access simpler
- State Parks has drafted their Management Plan for the adjacent Elmer Feldenheimer Reserve, which serves as an important management resource
- State Parks will be implementing similar adaptive management strategies on the adjacent land, and there is great opportunities for collaboration
- Foresters have identified that the current state of the Boneyard Forest is ideal for lower cost long-term management strategies (e.g. the stands have great diversity in age and species)

FOREST MANAGEMENT OBJECTIVES

Desired Future Condition

Early Successional Habitat

Early successional habitats are an important component of diverse landscapes. The abundance of shrubs provides food plants for wildlife species, openings within a forested landscape provide for an additional layer of structural complexity, and open areas provide habitat for a diverse array of plant species. Quality early successional habitat is becoming increasingly rare within the north Oregon coast due to industrial forest management practices which typically remove or suppress understory vegetation while tree species are becoming established (Elmer Feldenheimer Management Plan, 2014). The Boneyard Forest currently has extensive early successional habitat as a result of recent timber operations. North Coast Land Conservancy recognizes that this habitat managed for conservation, will provide significant habitat for many wildlife species including deer, elk, native pollinators, and birds. Over time, these early successional habitat areas will transition to older forests, and new early successional habitat will develop through natural disturbances such as wind storms and landslides. The components that we will consider to quantify the desired future conditions of early successional habitat include:

- Presence of native forbs and nectar species for native pollinators
- Diverse mix of species
- Minimal presence of exotic and invasive plant cover

Freshwater Habitat

The riparian areas across the Boneyard Forest were calculated using a 100 foot buffer on streams of all sizes to estimate the total area of freshwater riparian habitat on the property. The riparian areas along with the forested wetlands on the northeast portion of the property total over 120 acres of riparian and wetland habitat. This means that 1/3 of the Boneyard Forest contains freshwater habitat, including everything from high gradient and low gradient stream reaches to the forested Circle Creek swamp. The components that we will consider to quantify the desired future conditions in freshwater habitat include:

- Native plant species diversity
- Presence of large wood in streams for healthy fish habitat
- Wetlands free of impact from road systems
- Healthy depressional wetlands with amphibian habitat

Late Seral Forest

Old growth spruce and hemlock stumps in FMU 5.

The desired future conditions for the Boneyard Forest are older forests with gap regeneration creating a patchy understory of native shrubs and tree regeneration. This is very similar to approaches adopted by other conservation-oriented landowners in the vicinity, such as the City of Cannon Beach and The Nature Conservancy's Ellsworth Creek Watershed.

In restoring a forest to "old growth" conditions, it is important to carefully describe what that means for a particular location. Records of what the forest along the North Coast looked like prior to commencement of logging by white settlers are spotty, but the general understanding is that the forest displayed the following characteristics (Kohm and Franklin 1997):

- Old, large trees of a variety of species: There were some very large, very old trees of a mix of species, including spruce, cedar, and hemlock. The oldest trees could have been 300 years or more for hemlock, 500 years or more for spruce, and 800 years or more for cedar.
- Large snags and down wood: There were some very large down logs on the forest floor and in the stream channels, providing nurse logs for regeneration, and habitat for a wide variety of species. Large snags persisted for many decades, even after high intensity fires.
- A diversity of ages, with gaps in the canopy to foster shrubs and natural regeneration: The forest contained trees of a wide variety of ages. The eventual collapse of even just one large old growth tree would create a gap in the canopy that would stimulate the growth of native shrubs and regeneration of tree species. Periodic wind events helped maintain a patchy distribution of old trees and gaps with younger trees. Large areas of trees of the same age were relatively rare. Recovery after fire generally spanned several decades, resulting in a more uneven age distribution.
- Woody debris in streams to create pools and other habitat elements for fish
- In addition, the following desired conditions reflect modern conditions:
- Minimal amounts of non-native plants
- Stable, well designed and built roads that do not contribute sediment to streams and allow for access consistent with management objectives

More specifically, the forest structural elements that are lacking in the young stands of the Boneyard Forest that would contribute to greater forest biodiversity and stability are:

- Vertical heterogeneity
- Horizontal heterogeneity
- Dead wood

Vertical heterogeneity is the diversity of canopy layers in the forest. In many managed forests, a single canopy layer (age class) dominates the site, with relatively little understory vegetation.

Horizontal heterogeneity is the degree to which the trees are spatially grouped in a non-uniform way. For example, inclusion of areas of hardwoods or shrubs and patchy distribution of trees contributes significantly to the number of ecological niches the forest contains. This is a key driver of biodiversity (Hayes and Burris 2006).

As a general rule, both forms of structural diversity provide for increased plant diversity and therefore habitat niches. For example, native shrub diversity is strongly correlated with bird diversity. The more variety of food sources and nesting structures provided by the vegetation (particularly shrubs), the more bird species will be able to occupy those habitats.

More specifically on the Oregon Coast, the marbled murrelet is an endangered seabird that feeds in the ocean and nests inland in forests with large-branched trees. Suitable nest trees are typically spruce, hemlock, Douglas-fir or cedar that are very large (at least three feet in diameter) and have very large branches. The murrelet lays a single egg on a platform of moss or lichens on a branch large enough to hold it. Typically these are branches that are horizontal and at least 12 inches in diameter. Such branching structures do not typically develop in uniform stands.

Dead wood such as snags and down wood provide necessary nesting, caching, roosting, and hiding sites for a variety of birds, mammals, and amphibians. Presence of snags in particular is correlated with biological diversity, because more than 50 species of birds and mammals in Oregon use snags for nesting, feeding, and shelter (Logan 2002). In general, the larger the snag, the greater are the opportunities for the use by a variety of wildlife species. Large quantities of snags and down wood are a defining characteristic of "old growth". Managed forests in Northwest Oregon typically have very few snags and down logs because of the potential commercial value for sawlogs and pulp, as well as safety and operational considerations. This is true as well for the Boneyard Forest.

Resource Management Goals & Strategies

Goal 1. Protect the ecological integrity of the Boneyard Forest.

Strategy 1. Use the Boneyard Forest management plan as a tool to prioritize actions on the property.

Strategy 2. Monitor property for changes (e.g., invasive species infestations, windthrow) that may require immediate alterations in the current management plan.

Strategy 3. Work with local wildfire suppression agencies to ensure conservation values are protected in the event of a wildfire.

Strategy 4. Establish baseline plant community data from natural resource inventories to track changes in plant communities and to inform future long-term ecological needs.

Strategy 5. Assess wildlife and salmonid use in Boneyard Creek, Little Muddy Creek, Un-named Creek, and in associated wetland complexes.

Goal 2. Provide research and educational opportunities on the Boneyard Forest.

Strategy 1. Work with the Outreach Program to offer community events on the property.

Goal 3. Remove unnatural disturbances.

Strategy 1. Control and remove invasive species (please refer to the Attachment M for a description of our approach to invasive plant management).

Strategy 2. Maintain and monitor existing roads for future management access in a way that does not threaten the conservation values and ecological systems of the site.

Goal 4. Enhance forest and riparian structural complexity and diversity through active habitat development.

Strategy 1. Consider tree density manipulation to "unnatural" young and uniform stands of trees to place them on a trajectory that is more likely to result in the desired conditions.

Strategy 2. Install riparian planting in riparian zones with low vegetative diversity.

Strategy 3. Large wood placement in streams

HISTORY & REGIONAL CONTEXT

History & Culture

Clatsop County was named for the Clatsop Indians, one of the many Chinook tribes living in Oregon. Lewis and Clark wintered at Fort Clatsop during their 1805-06 expedition to the Pacific Coast. Astoria was established as a fur trading post in 1811 and named after John Jacob Astor. Astoria did not remain a fur trading center for long, as settlers soon became aware of the fishing and timber resources in the area. The first post office west of the Rocky Mountains was established in Astoria in 1847. Seaside was founded in the early 1870's by Ben Holladay, pioneer railroad builder, with his construction of the Seaside House, the famous luxury hotel for which the city was named. Timber, fishing, agriculture, and recreation have been the main sources of income in Clatsop County.

The North Coast Land Conservancy purchased this property from Lewis and Clark Oregon Timber, LLC in July 2016. The timber company conducted commercial forestry operations, including: construction of gravel logging roads, installation of culvert drain pipes at stream crossings, and construction of metal gates at key road access points. Prior to Lewis and Clark Oregon Timber LLC, Crown Zellerbach owned most of the land throughout the northern Oregon coastal hills, and managed the forests for industrial timber production. Logging of the original old growth forests across this site likely began around 1918 and industrial forest management continued on the property until the present.

Clatsop County is recognized as a major timber growing area in North America. The potential productivity is high because of the favorable climate, fertile soils, and well suited timber species. Eighty-two percent of Clatsop County is classified as commercial forest land. Sixty-eight percent of the commercial forest land is privately owned. The rest is publicly owned, mainly by the state, Clatop county, and municipalities.

The town of Astoria is a major center for the forest products industry on the north coast of Oregon. This is due in part to the presence of an excellent deep-water port that makes possible the export of raw logs and finished lumber to both foreign and domestic markets. Where once the county had several large sawmills that provided thousands of direct and indirect jobs produced lumber, plywood, veneer, and wood chips suitable for pulp, now only two remain in the City of Warrenton. Wood chips suitable for both high-grade and low-grade paper products are shipped to paper mills outside the county, both domestic and foreign. There are several smaller sawmills and a few specialty mills that produce products such as shakes and shingles from western red cedar.

Regional Landscape

The topography of Clatsop County is dominated by steep mountains, dissected terraces, and broad river valleys. Much of Clatsop County consists of old marine sediment that has been uplifted and pierced by intrusive basalt and covered by basalt flows. Most of the higher mountain peaks are basaltic material, including breccia basalt, tuff breccia, and basaltic flow rock. The uplifting action has caused landslides and mixing of the basalt and sedimentary material. Many areas in the county are unstable when disturbed.

Tillamook Head, immediately southwest of the Boneyard Ridge Forest, extends into the Pacific Ocean just south of Seaside. With an elevation of more than 1,100 feet, it influences the climatic conditions of the surrounding area. In summer, fog often remains in the Seaside area for days, while a few miles away the sun is shining. During stormy periods in fall, winter, and spring, Tillamook Head influences the pattern and intensity of storms.

The Necanicum River is the major drainageway in the southwestern part of the county. Its headwaters are in the Humbug Mountain area. The South Fork Necanicum River has its headwaters in the Sugarloaf and Kidders Butte area. Other creeks drain Davis Point, Twin Peaks, and other mountainous areas and add to the flow of the Necanicum River. The river flows through the center of Seaside and forms an estuary bay where it has its confluence with Neawanna and Neacoxie Creeks and discharges into the Pacific Ocean.

Climate

The climate of Clatsop County is greatly tempered by wind from the Pacific Ocean. Summers are fairly warm, but hot days are rare. Winters are cool, but snow and freezing temperatures are not common except at higher elevations. Weather data from Seaside, Oregon adjacent to the Boneyard Ridge Forest, shows the average annual winter temperature is 43^{o} F with an average daily minimum of 37^{o} F. Average summer temperature is 59^{o} F with a daily maximum of 67^{o} F. Precipitation averages 76.20” a year, however, only 25% of average annual precipitation falls between April and September. In summer, rainfall is extremely light, and often several weeks pass without precipitation. Rains are frequent during the rest of the year, especially late in fall and in winter. Fog is common during the summer months. In most winters, one or two storms over the whole area bring strong and sometimes damaging winds, and in some years the accompanying heavy rains cause serious flooding.

Geology

Soil consists of layers of mineral and organic matter on the surface of the earth. Soil is formed by the interaction of five basic factors: climate, living organisms, parent material, topography, and time (15). The physical and chemical processes that result from the interaction of these factors determine the characteristics and properties of a soil. The influence of any one of these factors varies from place to place, but the interaction of all the factors determines the type of soil that forms.

Soil formation in Clatsop County has been greatly influenced by climate. Moist marine air moving inland from the Pacific Ocean moderates extremes of air and soil temperature in winter and summer. Because of this there is an area in Clatsop County, termed the isomesic zone or fog belt that has the longest growing season. Farther inland, the direct influence of moist marine air diminishes and the extremes in air and soil temperature increase, which results in a shorter growing season.

The primary soil type underlying the majority of the Boneyard Forest is of the *Klootchie-Necanicum-Ascar* soil series. This soil type consists of soils that form on basalt mountains. A two inch organic mat exists of the surface comprised of moss, needles and twigs. Soils have moderate permeability and are considered well-drained to a depth of 40-60 inches. The typical profile of these soils contains the following stratum:

- 0 to 12 inches - dark reddish brown silt loam
- 12 to 25 inches - reddish brown silt loam
- 25 to 43 inches - reddish brown gravelly loam
- 43 inches - weathered basalt

Slopes are 3 to 90 percent. Elevation is 100 to 1,600 feet.

Klootchie soils are deep and well drained. The upper layer is dark reddish brown silt loam. Below this are reddish brown silt loam and gravelly loam over partially weathered basalt.

Mean site index for stated species: Western hemlock – 160 (based on 100-year site curve); 113 (based on 50-year site curve)

Estimated total production per acre: 111,020 board feet (International rule, one-fourth-inch kerf) from a fully stocked stand of trees 70 years old

Growth at culmination of mean annual increment (CMAI): 254 cubic feet per acre in a stand of 50-year-old trees 1.5 inches or larger in diameter at breast height

Mean site index for stated species: Douglas-fir – 156 (based on 100-year site curve); 119 (based on 50-year site curve)

Mean site index for stated species: Sitka spruce – 162 (based on 100-year site curve)

Necanicum soils are deep and well drained. The upper layer is dark reddish brown gravelly loam and very gravelly, loam. Below this are dark brown and dark yellowish brown very gravelly loam and yellowish brown extremely cobbly loam over fractured basalt.

Mean site index for stated species: Western hemlock - 133 (based on 100-year site curve); 97 (based on 50-year site curve)

Estimated total production per acre: 86,730 board feet (International rule, one-fourth-inch kerf) from a fully stocked stand of trees 70 years old

Growth at culmination of mean annual increment (CMAI): 205 cubic feet per acre in a stand of 50-year-old trees 1.5 inches or larger in diameter at breast height

Mean site index for stated species: Douglas-fir – 150 (based on 100-year site curve); 115 (based on 50-year site curve)

Mean site index for stated species: Sitka spruce – 162 (based on 50-year site curve)

Ascar soils are moderately deep and well drained. They are dark reddish brown, extremely gravelly loam over basalt breccia.

Forest Zone

The following has been summarized from Franklin-Dyrness, 1988.

Native vegetation in the Pacific coast fog belt is within the Sitka spruce (*Picea sitchensis*) zone, as described by Franklin and Dyrness. Picea sitchensis characterizes this long narrow zone which stretches nearly 2,100 miles along the Pacific Northwest Coast. The Picea sitchensis Zone is generally only a few kilometers in width, except where it extends up river valleys. Although the zone is generally found below elevations of 500 feet, it goes to 2,000 feet when mountain masses are immediately adjacent to the ocean. This zone could be considered a variant of the western hemlock (*Tsuga heterophylla*) zone distinguished by Sitka spruce, frequent summer fogs, and proximity to the ocean.

Range of the Sitka Spruce forest zone. *Image courtesy of Wikipedia.*

The Sitka spruce zone has what could be considered the mildest climate of any northwestern vegetation zone. Extremes in moisture and temperature regimes are minimal; the climate is uniformly wet and mild. Precipitation averages 78 – 120 inches, but frequent fog and low clouds during the relatively drier summer months are probably as important in ensuring minimal moisture stresses. Fog drip adds precipitation as a consequence of condensation in tree crowns

The plant community consists primarily of conifers such as Sitka spruce and western hemlock. Douglas fir also occurs, but as a minor species. Red alder is the most abundant hardwood tree in more recently disturbed areas, and big leaf maple occurs as a minor species. Abundant moisture and modified air and soil temperatures in the fog belt result in a long growing season that promotes a large accumulation of organic matter.

The coniferous forest stands in this zone are typically dense, tall, and among the most productive in the world. Constituent tree species are Sitka spruce, western hemlock, western red cedar, Douglas fir, grand fir (*Abies grandis)*. The first three are by far the most common. Shore pine (Pi*cea contorta*) is common along the ocean. The coast redwood (*Sequoia sempervirens)*, CA bay tree *(Umbellularia californica*), and Port Orford cedar (*Chamaecyparis lawsoniana*) are found in this zone in southwestern Oregon.

Sitka spruce forests are generally found in more productive micro-sites along valley bottoms or riparian terraces. Stands are typically dominated or codominated by Sitka spruce but often have a mixture of other conifers present, such as western hemlock (often a codominant), and western red cedar. The understory of mature forests is rich with shade-tolerant shrubs and ferns, including salal (*Gaultheria shallon*), evergreen huckleberry (*Vaccinium ovatum*), swordfern (*Polystichum munitum*), *Dryopteris* spp., and deer fern (*Blechnum spicant*), as well as a high diversity of mosses, lichens, dicotyledonous herbs and cryptogams.

Natural Succession

The natural disturbance regimes are mostly small-scale windthrow or other gap mortality processes, occasional widespread intense windstorms, and very few fires.

Early successional trends following disturbance in the *Picea sitchensis* Zone are similar to those encountered in the western hemlock zone. There is a stronger tendency, however, toward development of dense shrub communities comprised of salal, salmonberry, red huckleberry, sword fern and vine maple.

There are two major kinds of seral forest stands in the zone: (1) coniferous, containing varying mixtures of spruce, hemlock and Douglas fir, and (2) the red alder. Alder reproduces abundantly and grows extremely fast on disturbed forest land within the zone. In many cases, it overtops conifer regeneration, resulting in a pure or nearly pure alder forest. Replacement of alder by other tree species is often very slow, even though it is a relatively short-lived species. This is partially because of the dense shrubby understories of salmonberry and other species typically associated with alder stands. Alder is noteworthy for its soil-improving properties; this species fixes significant amounts of nitrogen in this region and can have other effects on nutrient cycling, soil chemistry, and microbiology as well.

Succession in most mature conifer forest types in this zone is toward replacement of mixed spruce, hemlock, cedar and Douglas fir forests by hemlock. Much of the forest regeneration in conifer stands takes place on rotting logs, "nurse logs," which often support hundreds of hemlock and cedar seedlings. Some of these survive, and their roots eventually reach mineral soil. The consequences are often readily visible in forests as lines of mature trees growing along the remains of the original nurse logs.

Pre-settlement Forest Condition

Excerpt from the Forest Landscape Restoration Plan for the South Willapa Bay Conservation Area (The Nature Conservancy, 2007).

Halocene Forest

Vegetation assemblages in the maritime PNW have changed in response to climatic variation during the Holocene (10,000 yrs Before Present [BP] to current time). In the early Holocene, forest vegetation on the western Olympic Peninsula—which we assume to be representative of the planning area—transitioned from a pine-spruce-mountain hemlock-fir (*Pinus-Picea-Tsuga mertensiana-Abies*) community to an alder-Douglas-fir-bracken fern (*Alnus-Pseudotsuga-Pteridium*) community (Heusser C.J. 1977). This shift in species composition was apparently brought about by increasing temperatures coupled with a relatively droughty precipitation regime. Warming continued, apparently reaching a maximum during the Hypsithermal at approximately 7,000-8,000 BP (Heusser C.J. 1977). Modern vegetation assemblages developed about 5,000-6,000 years BP, concurrent with decreasing temperatures and increasing precipitation. Perhaps the most noticeable change in vegetation composition is the arrival and proliferation of western red cedar. In western Washington western hemlock and Sitka spruce increased in abundance simultaneous with the arrival of western red cedar (Whitlock 1992).

Sediment cores taken from a small lake in northern coastal Oregon just south of the mouth of the Columbia River provide a proxy record of fire and vegetation history for the planning area (Long C.J. and Whitlock 2002). Throughout the 4,600 year record the pollen (and spore) assemblage is dominated by red alder (*Alnus rubra*), western hemlock, Sitka spruce, western red cedar and sword fern —the characteristic modern flora of the locale. Charcoal and magnetic susceptibility data indicate that fire episodes occurred during the period 4,600-2,700 years B.P. more frequently (140 +/- 30 years) than the period 2,700 B.P. to present (240 +/- 30 years). The earlier of these two periods is characterized by a relatively greater abundance of alder and sword fern pollen, indicating that burned areas may have been occupied by a seral community analogous to the red alder/sword fern formation—a closed canopy community—described by Bailey and Poulton (1968) on the Tillamook Burn. Overall, fire appears to have been a significant disturbance agent over the last 4,600 years in these coastal forests.

Coastal Forests of the Early 20th Century

Powell et al. (2003) examined bearing tree records from section corners of the 1908 public lands survey, and estimated composition of the forests in the Ellsworth Creek watershed approximately 30 miles north of this property. Western hemlock was the dominant species in terms of total volume in almost every plot. From Powell's data, the maps were produced displaying the location and abundance of Sitka spruce, western red cedar, and Douglas-fir. Sitka spruce appeared along the mainstems of creeks and in valley bottoms, while western red cedar was very abundant overall and generally missing where spruce was prevalent. Douglas-fir was present in minor amounts and red alder seemed to be very uncommon (Powell et al. 2003).

NATURAL RESOURCES & EXISTING INFRASTRUCTURE

Forest health

The term *forest health* is often used in an anthropogenic context where it denotes factors within a forest, or external vectors that influence a forest, that reduce the forests ability to meet specific management objectives such as optimum timber productivity, wildlife habitat, or other ecosystem services. The effects of disease, pests, stocking density, non-native plant species, climate change and other natural or anthropogenic causal factors are all important influences on the ever changing composition and functions of a forest. Depending on whether management objectives sway more towards timber production or habitat enhancement, these disturbance agents may be either tolerated, moderated or intentionally stimulated.

In the case of NCLC, the long-term objectives for this forest are to develop late seral structure and functionality through which the natural disturbance regimes typical to this region reshape the composition of the forest over time. Moderating stocking density and invasive species will be focal points for active management. Tolerating natural disturbance agents such as disease and wind will comprise passive, or at least non-anthropogenic, management practices.

A formal forest health survey was not conducted as part of this forest management plan. Therefore, the following summarizes forest health agents that are common to coastal forests.

Pathogens

Annosus Root Rot

Annosus root rot, caused by the fungus *Heterobasidion annosum*, is a common pathogen in western hemlock and Sitka spruce. It produces a dark brown conk and brown-heart rot that weakens the bole of trees and typically leads to stem breakage or mortality from bark beetles or other agents. It spreads through root graft and pervasive aerial spores that germinate readily on live bare wood, such as fresh stump surfaces, bole exposure from logging damage, or top or major branch breakage. It grows slowly, however, and effects are usually not noticeable until trees reach at least 120 years old. Combined with wind, it is probably the largest cause of tree mortality and snag recruitment for mature western hemlock in this forest type and a major limiting factor on the development of large, old hemlocks and to a lesser extent Sitka Spruce. Thinning has

Conks on the trunk of a hemlock snag killed by annosus root rot in FMU 4.

been shown to significantly increase infection levels as spores germinate on cut stumps and spread through root grafts to live trees. This has not proven to be a serious concern in plantations that are harvested well before age 120. As none of the stands are over 100 years old, mortality from annosus appears to be confined to the old growth stands and legacy hemlocks in younger stands. However, it is likely that the fungus is present in many trees and that thinning will increase infection levels. In stands heavily dominated by hemlock, this poses a challenge to the long-term goal of developing old growth structure.

Hemlock Dwarf Mistletoe

Hemlock dwarf mistletoe (*Arceuthobium tsugense*) is a vascular, parasitic plant that affects western hemlock, and occasionally Sitka Spruce and Douglas-fir, in this forest type. Mature female plants forcibly discharge seeds an average of 15 feet, and the sticky seeds adhere to branches and stems of new hosts. The flowers, fruits, and seeds are a source of food for several invertebrates and bird species, and birds can spread the seeds. Seeds then germinate and the roots mechanically enter host tissues to extract water, nutrients, and sugars. Host branches usually respond with swelling and by producing a "witches broom" that may grow to weigh several hundred pounds in older trees and provide preferred nesting platforms for marbled murrelets and other species. Young western hemlock trees that are lightly infected (less than 1/3 of branches infected), and that are free to grow in the open, can outgrow dwarf mistletoe infection and leave the dwarf mistletoe in the lower crown. Severe infestations cause growth loss, reduction in wood quality, and an increase in mortality. Damage is more serious in stands over 100 years of age than in younger stands.

Swiss Needle Cast

Swiss needle cast, caused by the fungus *Phaeocrytopus gaeumannii*, is native to Pacific Coast forests and while long considered innocuous, it has become a major concern in Douglas-fir plantations within approximately 18 miles of the coast in Oregon and Washington in the last few decades. During wet springs when adequate moisture is present, the fungus germinates, infects needles on Douglas-fir trees, and causes them to yellow and drop prematurely. Although it rarely kills trees outright, Swiss needle cast can reduce growth rates by up to 35% and make trees more susceptible to other agents of mortality. While the causes of the recent increase are not fully known, the large-scale replacement of spruce-hemlock forests with pure Douglas-fir plantations is thought to be a chief factor. In young plantations with more western hemlock, infection levels are generally lower and tend to vary more from tree to tree.

Laminated Root Rot

Laminated root rot pockets, caused by the fungus *Phellinus weirii*, is typically rare in spruce-hemlock forests and commonly found in natural and planted Douglas-fir stands. It spreads through ectotrophic mycelium in roots and root grafts and moves outwards from infection centers at a rate of approximately 30cm per year, slowly creating an expanding pocket of mortality. Spread by spores is thought to be unimportant compared to vegetative spread, but little is known about how new infection centers get started in stands without previous history of the fungus.

Pests

Spruce weevil

Sitka spruce is susceptible to the white pine weevil (previously known as the Sitka spruce weevil *Pissodes strobi*). The weevil lays its eggs on the terminal shoot, and larvae then mine the phloem and girdle the leader, causing it to die and curl. Damaged trees are often overtopped and suppressed by other species. Surviving spruce may have forked and crooked tops and a bushy appearance. Weevil infection is highest in warmer, drier areas, while areas immediately adjacent to the coast are low hazard due to cool climate. Weevil populations and attack rates typically stabilize and begin to decline as trees reach heights of 30 feet. Additionally, an overstory of red alder can significantly reduce the susceptibility of spruce to the weevil by "hiding" it beneath a hardwood canopy.

Dead spruce leaders caused by the spruce weevil in FMU 3.

Invasive species

Although a formal survey of non-native invasive plants was not conducted as part of this management plan, several common invasive species were observed during the site evaluation in October 2016, and additional species can be expected on this property given their occurrence on adjacent properties. The majority of the invasive species observed during the site evaluation occurred either along forest roads, or within the younger plantations comprising FMU's 2 & 3. These species included:

1. Himalayan blackberry (*Rubus armeniacus (discolor*))
2. Tansy ragwort (*Senecio jacobaea*)
3. Scotch broom (*Cytisus scoparius)*

In addition, the following herbaceous invasive plants may be present throughout the property, and should be monitored for.

1. Creeping buttercup (*Ranunculus repens*)
2. Self-heal (*Prunella vulgaris*)
3. Curly dock (*Rumex crispus*)
4. Velvetgrass (*Holcus spp.*)

5. Bluegrasses (*Poa spp*.)
6. Creeping clover (*Trifolium repens*)
7. Thistle (*Cirsium spp*.)

Wildfire

Although wildfire is comparatively quite scarce in coastal areas than on the eastside of the Cascade Mountains, it is still a relevant natural disturbance regime in this area. Fires tend to be most destructive in young, dense stands and stands with an abundance of downed woody debris and/or standing dead trees. Given the higher potential for public use on or near this land, combined with increasingly drier summers, fire risk is a growing concern for this property.

Naturally caused catastrophic stand-replacing forest fires typically only occurred once every 750 years or more. With roads and recent clearcuts over the area, there are significant fuel breaks across the landscape. Additionally, modern fire suppression resources are in very close proximity to this property, making the opportunity for a stand replacing fire on a landscape level very remote. However, smaller sized natural fire events may periodically occur, resulting in gaps throughout the forest. These may be human caused or lightning caused events.

Freshwater and Hydrologic Resources

Streams

This property contains two fish-bearing tributary streams that flow into Circle Creek and thence into the Necanicum River, an important salmon stream of the North Coast. The central stream, informally known as Boneyard Creek, is classed by the Oregon Department of Forestry as a “medium” fish-bearing stream. The second stream, which flows through the northwest corner of the property and is known as Little Muddy Creek, is classed as a “small” fish-bearing stream while on the Boneyard Forest, but becomes a “medium” fish-bearing stream just prior to entering Circle Creek. A third small unnamed stream drains the southeastern portion of the tract and becomes a “small” fish-bearing stream upon entering the Circle Creek Preserve. The headwater streams of this system have not been surveyed for fish presence. The streams are fairly low-gradient along the eastern boundary, where the Circle Creek floodplain interacts with the foot of the Tillamook Head formation. They become steeper as they come out of the headwater reaches, draining narrow draws.

Riparian buffers

Mature conifer-dominated riparian zone along the lower reach of Boneyard Creek near the eastern property line.

Most of the length of Boneyard Creek has a mature forested riparian area on either side of it. This buffer is chiefly comprised of 45-55 year old western hemlock and Sitka spruce with small populations of red alder scattered amongst it. The composition of the riparian forest is complex, with understory regeneration, snags and consistent inputs of large woody debris, much of which both spans and enters the stream channel. The upper riparian areas of Boneyard Creek were clearcut between 11 – 18 years ago, and are now comprised of young hemlock and spruce plantations.

West-facing flank of Little Muddy Creek with clearcut in foreground and wind-battered forested buffer along stream.

Little Muddy Creek has an intact mature forested buffer along its western flank, but the eastern flank was recently clearcut to within 50' of the stream, leaving a fragile buffer of 50+ year old hemlock and spruce. Significant portions of this buffer have blown over, contributing large volumes of coarse woody debris to the stream channel.

The stream channels of both creeks appeared relatively intact, with ample pools caused by significant volumes of coarse woody debris, and complex substrate comprised of gravel and cobbles.

Wetlands

Wetlands, other than those associated with the floodplain of the aforementioned streams, only exist in the northeastern corner of the property where slopes taper off and merge with the forested wetlands that dominate the western portion of the Circle Creek Preserve. These wetlands are dominated by aging red alder and scattered hemlock and spruce. Tree stocking is very sparse, and the dominant vegetation is salmonberry. Standing and running water was evident across this area during the site evaluation in late September 2016.

Amphibians and Reptiles

Constant effort amphibian monitoring has established the presence of eight salamander species and two frog species, including the following:

- Northwestern salamander (*Ambystoma gracile*)
- Long-toed salamander (*Ambystoma macrodactylum*) – present at Ecola Creek
- Pacific giant salamander (*Dicamptodon tenebrosus*)
- Oregon Ensatina (*Ensatina eschscholtzii*)
- Dunn's salamander (*Plethodon dunni*)
- Western red-backed salamander (*Plethodon vehiculum*)
- Columbia torrent salamander (*Rhyacotriton kezeri*)
- Rough-skinned Nnwt (*Taricha granulose*)
- Pacific tree frog (*Pseudacris regilla*)
- Northern red-legged frog (*Rana aurora aurora*)

Most notable is the presence of two stream dependent species, Columbia torrent salamander (*Rhyacotriton kezeri*) and Pacific giant salamander (*Dicamptodon tenebrosus*). Unlike pond breeding species like Northwestern salamander (*Ambystoma gracile*) and rough-skinned newt (*Taricha granulosa*), these species require clear running streams with gravel substrates and low siltation for reproduction.

Fish

Limited qualitative stream surveys were done in November 2005 and (for this report) June 2012. Three fish species were noted: Cutthroat trout (*Oncorhynchus clarkii*), prickly sculpin (*Cottus asper*), and coho salmon (*Oncorhynchus kisutch*).

Stream segment of Little Muddy Creek with recent clearcut to upper right. Note gravelly/cobbly substrate.

Upland Wildlife Habitat

This property contains a broad matrix of upland habitat types including mature spruce-hemlock forests, early seral timber plantations, and recent clearcuts. Each of these habitat types appeal to different wildlife species and provide different habitat functions. Mature forests tend to provide thermal cover, denning and nesting opportunities and protection from predators, but very little forage, except in small gaps or in the understory of alder patches. These areas provide habitat for woodland wildlife, such as black-tailed deer, elk, cougar, black bear, fox, coyote, woodpeckers, ruffed grouse, and mountain beaver. Early seral habitats, such as young plantations and clearcuts on the other hand, provide much higher foraging options given the breadth of forbes, shrubs and mast producing species inherent to them.

Birds

There is very good data for the occurrence of bird species on and near the Boneyard Creek property. No fewer than 90 species occur, or are likely to occur, and many of these are forest breeding neotropical migratory species. The adjacent forests of Ecola State Park and the Feldenheimer Forest have been surveyed for Marbled Murrelets with inconclusive results. Murrelets require large trees with substantial lateral branching and heavy moss cover. These conditions do not exist in the Boneyard Forest, but could be managed for future breeding sites. The recent invasion of the region by Barred Owls most probably precludes any likely development of viable Spotted Owl habitat. Efforts to locate Spotted Owls in adjacent habitat have not been successful.

Species of concern that have been noted on the property as likely breeders include Northern Pygmy Owl, Pileated Woodpecker, Olive-sided Flycatcher and Willow Flycatcher. Watch-list species include Rufous Hummingbird and Hermit Warbler.

Mammals

Most mammal data comes from casual encounters and from identification through tracks and scat. There are several sizable Wapiti (*Cervus elephus*) herds in the area and many Columbia Black-tailed Deer (*Odocoileus hemionus columbianus*). Coyote (*Canis latrans*) and Raccoon (*Procyon lotor*), also have a well-established presence. Scat and tracks from American Black Bear (*Ursus americanus*) and Cougar (*Puma concolor*) have been noted at several locations. At least two unidentified bat species (Vespertilionidae) were noted on a trail camera set up near the stream corridor at the east end of Boneyard Creek. Most Oregon bat species are ranked S2 or S3 by ORBIC. An effort to capture and identify bats in the Boneyard Riparian Corridor would be of interest.

Forest Roads

This property has an extensive network of old forest access roads that have not been used or maintained in several decades, as well as newly maintained roads utilized for the timber harvest in FMU 6. This road network provided ample access to all parts of the property, and allowed both ground-based and cable-yarding equipment to be moved to all points in the terrain.

The road network throughout the western portion of the property follows ridgelines, with spurs that reach out to the tip of geographic promontories where landings were established for cable-logging equipment. The mainline was recently improved to provide access to FMU 6 for the clearcut that took place in 2015. New culverts and cross drains were installed during this road improvement process to provide optimal drainage. The road surface is comprised of 2" minus pit run rock and was constructed with an inslope grade that channels surface water to a ditch on the upslope side of the road. Ditches follow nearly every road segment and collect both surface water from the road, as well as runoff from the upslope forest. 18 inch black corrugated plastic culverts were installed at the low point of all drainages that intersect the road. During the site inspection at the end of September 2016, all culverts appeared to have been installed correctly, with inlets set at grade. Outlets of most of the culverts are perched, resulting in an outfall drop that ranges from a few inches to a few feet. All outfall drops were either armored with rock to dissipate the water and mitigate the potential for downslope erosion, or, in one case, had a plastic flume to dissipate stormwater. No significant erosion was observed. Ditches were beginning to fill with grasses, shrubs and other vegetation, and will require periodic cleaning in order to function properly during future storm events.

Newly improved mainline through western portion of property.

Newly installed culvert.

The road system through the eastern portion of the property has largely been abandoned, and access is limited to foot traffic. An intact, though unmaintained, road runs north from the facilities at the Circle Creek Preserve along the base of the east-facing slope before terminating at Boneyard Creek where the stream crossing was recently removed. Although a road still continues north of Boneyard Creek, it is no longer accessible by vehicles, and was actively abandoned, with its surface roughened and wood placed across it, near the northern tip of the property. At Boneyard Creek, another former road follows the south side of the creek up the drainage, but terminates at the confluence of a tributary flowing from the south where another stream crossing was removed. Another former road continues west up a steep drainage before terminating along a ridgeline where multiple cable logging landings were established decades ago. This road has been naturally abandoned, as multiple small slumps and slides have obscured portions of the roadbed and shrubs, trees and other natural vegetation has colonized the majority of its length. Given that the entire eastern side of the property is no longer accessible by vehicles, the forests across this area will either need to be reserved in a permanent conservation status, or managed using either pre-commercial thinning applications or commercially thinned by helicopter.

Stream crossing abandoned on tributary to Boneyard Creek.

Abandoned road along base of east-facing slope north of the Circle Creek Preserve facilities.

Forest Vegetation

Forest Inventory

To gain a thorough picture of existing forest conditions, a detailed forest inventory was conducted of the Boneyard Forest by Atterbury Consultants in August 2015. Stand types originally were delineated on aerial photographs using GIS data, then verified in the field during the timber cruise. Variable radius sample plots on a 200'x 300' rectangular grid were measured in FMU's 1, 4, 5 and 6, and 1/100th acre fixed area plots were installed in the young plantations comprising FMU's 2 and 3 to determine species stocking. All plot centers were marked on the ground with pink flagging.

The total property is approximately 346 acres in size and contains approximately 115 acres of merchantable age timber (FMU's 1 & 4). Approximately 102 acres are comprised of an 11 year old conifer plantation (FMU 2), 70 acres contain an 18 year old conifer plantation (FMU 3), and 23 acres are in a recently planted clearcut (FMU 6). Approximately 14 acres are comprised of forested wetlands (FMU 5) and are therefore inoperable. The remaining 22 acres contain additional inoperable ground, such as riparian zones.

Western hemlock and Sitka spruce comprise most of the volume across the Boneyard Forest. Douglas fir, western red cedar and red alder are important components in some stand types. Minor species include grand fir, big leaf maple, and black cottonwood. Western hemlock, Sitka spruce, and red alder are dominant in the older stands. The majority of the younger plantations are stocked primarily with western hemlock and Sitka spruce, although red alder and shore pine are naturally regenerating within these units also.

FMU 1

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
10.2	46	Sitka Spruce Western hemlock	160	13"	142'	40%

FMU 1 consists of a mix of 46 year old western hemlock and Sitka spruce with scattered red alder. This unit is perched on steep slopes on the western side of Little Muddy Creek. There is no road access to this unit, so commercial timber management is limited to helicopters. Given its proximity to the creek, this stand should be retained as-is and allowed to develop towards late seral habitat that provides optimum riparian function.

Typical stand structure in FMU 1.

This stand is well stocked for its age, with a variable density that ranges from 80 – 180 TPA, but trends towards the higher end of the range. Both the spruce and hemlock occupy dominant and codominant positions in the canopy, but newer cohorts of hemlock also occupy intermediate and understory layers. There is a wide diameter distribution through this unit, ranging from 8 – 24 inches DBH, but averaging approximately 13 inches. The relatively dense canopy is effectively suppressing most natural understory conifer regeneration, as well as most understory shrubs and ground covers.

Blowdown within the riparian buffer on the east side of Little Muddy Creek.

There are small pockets of blowdown throughout this unit, and due to the new clearcut harvest on the unit on the east side of the creek, there has been a significant amount of additional blowdown, most of which is concentrated along the riparian buffer left on the east side of the creek. The added light to the forest floor will likely stimulate a new generation of understory conifer regeneration, and therefore contribute to a mixed canopy forest structure over time.

FMU 2

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
102	11	Sitka Spruce Western hemlock	330	NA	NA	NA

Uniform stocking across FMU 2.

FMU 2 is comprised of a well-stocked Sitka spruce and western hemlock plantation that was planted after clearcut harvesting. The unit encompasses the entire headwaters of Boneyard Creek, as well as slopes leading down to Little Muddy Creek. Stocking is fairly uniform throughout the unit, however, density varies with small gaps in some areas due to seedling mortality, as well as pockets of high density where naturally regenerated seedlings have infiltrated the planted seedlings. Red alder has naturally regenerated prolifically along road cuts and other areas of disturbed soils, but so far has not shown itself to be unduly competitive with the conifers. The canopy has not yet closed on this stand, therefore all trees are in an optimum and non-competitive growth phase.

FMU 3

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
70	18	Sitka spruce Western hemlock	630	9"	37'	100%

FMU 3 is comprised of a young 18 year old plantation of Sitka spruce and western hemlock that was replanted after clearcut harvesting. This unit encompasses a combination of moderate slopes that could be logged using conventional skidders, and steeper slopes that will require cable logging. The stocking across this unit is much higher than FMU 2, largely due to a high degree of naturally regenerated spruce, hemlock and alder that has colonized the empty spaces between the original seedlings. The canopy of this unit is just beginning to close, and competition between individual trees is increasing. Red alder has colonized road margins, log landings and other areas of disturbed soils throughout the unit, and in most cases has outgrown and overtopped the surrounding conifers. Shore pine and Douglas fir have also seeded into this unit, but are a minor species and not particularly competitive.

Spruce and hemlock in FMU 3, with red alder overtopping the conifers.

Dense red alder thicket that has colonized the disturbed soils on a former log landing.

FMU 4

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
107	56	Western hemlock Sitka spruce	180	15”	108’	40%

This unit comprises the bulk of the merchantable age timber across the eastern extent of the property. The stand consists primarily of 56 year old western hemlock and Sitka spruce and the heterogeneous composition indicates that the forest naturally regenerated following clearcut harvesting in the 1960’s. Red alder occurs both as scattered individuals and in small clumps. Douglas fir also occurs as scattered individuals and western red cedar was present at lower elevations along streams. The topography across most of this unit is very steep, with the exception of the extreme northern end where slopes taper off towards the forested wetland that borders the eastern property line.

Typical stand composition with 180 TPA towards the northern end of FMU 4.

Area of low stocking (<80 TPA) that was "thinned" by a major windstorm.

Stocking densities vary widely across this unit, ranging from relatively open stands with less than 80 TPA, to extremely dense hemlock dominated thickets that exceed 360 TPA. In areas of higher density there is relatively little understory vegetation. In areas of lower density, and beneath red alder clumps and within root rot pockets, understory shrub and groundcover diversity increases significantly and includes sword fern, oxalis and red huckleberry.

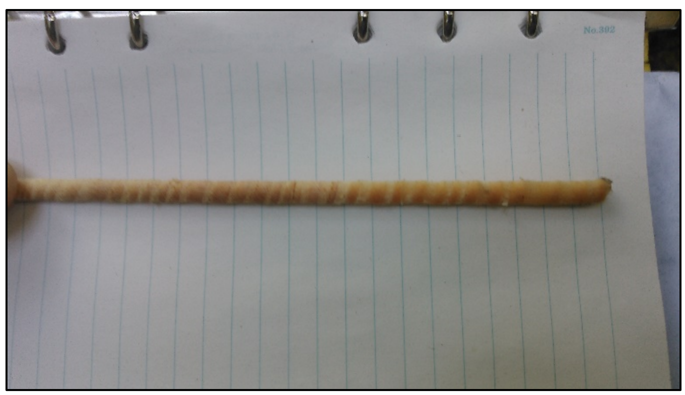
Highly stocked stand at 360 TPA dominated by western hemlock.

Across the entire unit there is a tremendous degree of structural heterogeneity. The red alder clumps throughout the stand serve as canopy gaps and are supporting a new cohort of western hemlock that are naturally regenerating in the understory. The alder is beginning to reach the end of its biological lifespan, and as it declines it will accentuate the canopy gaps and "release" the hemlock in its understory.

Canopy density on ridge in FMU 4.

On many of the south-facing slopes, severe wind events have blown down both small patches of trees as well as dramatically thinned the stand in these areas. These wind events have also broken out tree tops, and snapped trees along their length, leaving many snags. Annosus root rot pockets are also creating canopy gaps by killing off patches of western hemlock. Although no conifer regeneration was observed in these pockets, they were providing opportunity for a multitude of shrub species to enter the stand. Between wind disturbance and root rot, a significant volume of woody debris is periodically being added to the forest floor. However, woody debris contributions are site and disturbance based, and not continuous across the entire unit.

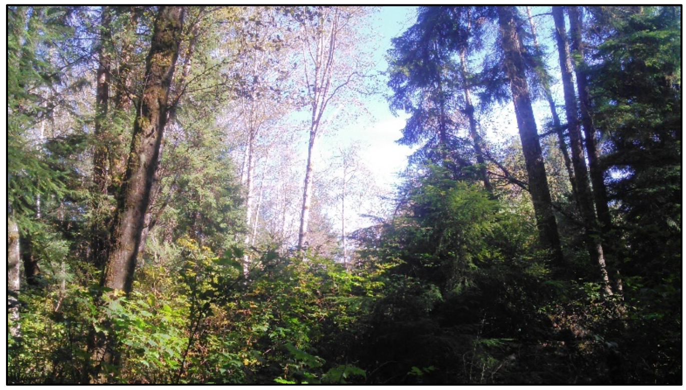
Growth on the dominant and co-dominant trees appears to be quite strong across this unit. Increment cores indicate annual incremental growth to be between ¼" – ½" DBH, which strikes a good balance between timber quality and carbon sequestration. Both natural disturbances that either thin or create canopy gaps, and/or manual thinning of the forest, will promote future optimal growth.



Annual growth rings on 46 year old Sitka Spruce in FMU 4.

FMU 5 & 6

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
14	41	Red alder	<80	13”	85’	>45%



Mixed alder/hemlock forested wetland in FMU’s 5 & 6.

FMU’s 5 & 6 comprise a forested wetland that has formed along the base of the east facing hills of the Boneyard Forest where it meets the valley of the Circle Creek Preserve. The stand consists primarily of 41 year old red alder with a mix of western hemlock and Sitka spruce of varying ages. The average red alder has a diameter of 13 inches and an average height of 85 feet. The stocking density is highly variable, but overall averages less than 80 trees per acre. Tree growth mostly is in large clumps, with vast salmonberry dominated open gaps between them. The ground is very wet and shallow channels of running water were evident during the site evaluation towards the end of September 2016. Skunk cabbage was common throughout the site, alluding to the perennially saturated soils. This forested wetland is an extension of a much larger forested wetland that continues well into the adjacent Circle Creek Preserve.

The red alder is beginning to fall apart, indicating it is nearing the end of its biological lifespan, and will likely stay in decline for many years to come. Spruce and hemlock continue to naturally regenerate on the higher ground through the wetland, and over time will return this area to a conifer dominated forest within a few more decades.

FMU 7

Total acres	Age	Dominant spp.	Trees per acre	Average DBH	Avg. height	Avg. crown ratio
23.5	1	Sitka Spruce Western hemlock	350	NA	NA	NA

FMU 7 clearcut in 2015 from ridgeline down to within 70' of Little Muddy Creek.

FMU 7 comprises a site that was clearcut in 2015. The harvest unit extended from the ridgeline east of Little Muddy Creek down the slopes to within approximately 50' of the creek. A modest forested riparian buffer was left along the eastern edge of the creek, although vast sections of it have blown down. The unit was immediately replanted the following winter to a standard plantation density of approximately 350 TPA with a combination of Sitka spruce and western hemlock. As of the site inspection for this management plan towards the end of September 2016, all seedlings appeared relatively healthy. At this early stage in the stand's development, brush and other understory plants have not yet recovered, therefore seedling competition is virtually nil.

FOREST MANAGEMENT STRATEGIES

Ecological Forestry Principles

Basic Concepts of Ecological Forestry

Ecological forestry includes management of forests for multiple goals, including timber production, but emphasizes maintenance and restoration of physical and ecological processes associated with old-growth forests. Restoration of old-growth structure, composition, and ecological functions in young-managed forests has become an increasingly prominent management objective throughout the Pacific Northwest coastal region over the past 20 years. The possible role for silvicultural intervention in achieving this objective is now a common theme for scientific research. From this research, a suite of silvicultural tools are emerging that appear to be useful in achieving this objective, including thinning (manipulation of stand densities and species composition), creation of canopy gaps and undisturbed leave islands ("skips"), girdling, topping, and/or dropping of overstory trees, and underplanting of tree species.

Highly overstocked hemlock dominated stand in FMU 4.

Truncating or completely bypassing the competitive exclusion stage of forest structural development is the core idea underlying the theoretical basis for restoration of late successional characteristics in young managed conifer forests in this region. In practice, competitive exclusion is abbreviated by reducing stand density (accomplished with either precommercial or commercial thinning), or planting at low densities following harvest in order to minimize the competitive exclusion stage if natural regeneration is not abundant. Reducing stand density increases the relative amount of resources (light, water, nutrients) available to the residual trees. Thinning stimulates establishment and development of understory shade tolerant conifers. Therefore, thinning provides a mechanism to accelerate the rate of development of old-growth canopy structure in young, single cohort stands, particularly in coastal stands dominated by western hemlock. The rate of understory development in natural stands is also related to overstory composition; understory plant community development proceeds particularly slowly in stands with a strong dominance of western hemlock in the overstory. Decreasing overstory density also increases the amount of resources available to understory herb and shrub species because the residual trees left following thinning cannot capture all of the available resources on the site. Understory vegetation in thinned stands has been shown to be more similar to old-growth than unthinned young stands.

Ecological Forestry Strategies for the Boneyard Forest

The field of ecological forestry and the use of silvicultural tools for improving the ecological functions of forests while balancing societal needs to produce timber and generating revenue to cover restoration costs are relatively new concepts. Most research is still in the early stages. The list below highlights the key concepts that will be considered for developing stand-level prescriptions:

1. Forest management prescriptions intended to improve stream habitat should be inclusive of both upland and riparian forests. Some considerations include:

    a. Riparian areas should be thinned in order to promote the growth and recruitment of larger wood to stream systems.
        i. Thinning should: (1) occur in very dense and/or preferably very young (<25 years old) stands; (2) to occur within 50-150 feet of the stream; (3) to include some no-cut areas in the 50-150 foot zone; (4) to maintain hardwood and understory vegetation cover and diversity with limited exceptions in areas where release of dominant conifer is needed; (5) to be coupled, when possible, with in-stream restoration efforts that 'tip' or mechanically place wood into streams; (6) to maintain sufficient cover and shade over the stream to limit temperature changes and prevent invasion of exotic species; and (7) to include monitoring of natural recruitment of snags and large wood to the forest floor over time and supplementing these with mechanical means if natural processes are insufficient.

    b. In upland areas, increasing cover of mature forests (>35 years old) throughout large areas of the watershed (>70%) will help to maintain physical and hydrologic processes that regulate aquatic habitats.

    c. Thinning trees in mass wasting zones to increase diameter growth and/or dropping and leaving trees in mass wasting zones may help to increase the amount of large wood delivered to streams through episodic debris flows and landslides.

2. Thinning that retains non-dominant conifer (e. g. western red cedar) and hardwood species, and enhances tree crown growth that results in reductions of the height to diameter ratio, will likely help forests become more resistant to wind disturbance and shift the landscape from a high to a low severity wind disturbance regime.
3. Thinning combined with gap creation and underplanting that increases the species and age class diversity of the stand will likely result in stands that are more resilient to high-severity wind disturbance, pest/pathogen outbreaks, and unforeseen changes resulting from climate change.
4. Large trees and branches are important components of old-growth habitat; thinning to release dominant trees will likely spur diameter and branch growth.

5. In order to enhance forest habitat complexity, thinning will be spatially variable, retain pairs and clumps of large trees, and enhance species diversity through retention of non-dominant conifers (e. g. cedar) and hardwoods. This can likely accelerate development of structures and conditions associated with old-growth biodiversity faster than in unthinned areas or more evenly thinned areas.
6. Thinning will likely accelerate development of marbled murrelet nesting features, such as large branches, more quickly than not thinning. However, in areas where potential nesting habitat already exists, a more uniform, light thinning is recommended to reduce the risk of nest predation. This is also true for areas near or adjacent to areas where habitat suitability is currently rated as high.
7. Creation and recruitment of snags and large woody debris following thinning is often assumed, as the changing wind dynamics within a stand often lead to new damage and at least short term blow down. Recruitment should be monitored over time. If natural recruitment following thinning is insufficient, efforts should be made to increase the abundance and distribution of these structural features at varying stages of decay on the landscape through mechanical means.
8. Protection of existing understory vegetation, particularly older tall shrubs, should be included in the operational layout to retain the important biological structure and habitat that this layer provides. Loss of ecological functions resulting from damage of existing vegetation, especially tall shrubs, can take decades to recover.
9. Large "gaps" or openings should be used in some areas to increase the age and diversity of tree species and provide natural early-seral habitat and forage on the landscape.
10. Unstable slopes should generally be protected or harvested with minimal ground disturbance and light thinning. Exceptions may arise in areas where intentional creation of large-diameter trees in mass wasting zones is carefully planned.
11. Inclusion of leave areas ("skips") of varying sizes should be considered to protect sensitive aquatic areas (e. g. , seeps, forested wetlands), unstable slopes, structural features (e. g. , large shrubs), and species that may be dispersal limited or otherwise sensitive to ground disturbance or canopy openings (e. g. , lichens, fungi, amphibians). Additionally, the spatial configuration of the leave areas can be designed to assist sensitive species.
12. Some large contiguous areas or stands should likely remain unthinned to retain diversity on the landscape, to protect against unforeseen negative outcomes of thinning, and to provide refugia for certain species with wide dispersal abilities that are sensitive to disturbance or open canopies (e. g. flying squirrels, Hermit thrush).
13. Thinning, particularly thinning that leaves needles and other fine organic materials on site, is not currently believed to have significant impacts on soil nutrients and productivity. Creation of gaps that provide ecological benefits through formation of early-seral habitat and establishment of non-dominant conifers can also provide additional sources of timber. Thus, design of thinning operations that remove logs for sustainable timber production while enhancing ecosystem function should be possible.

Riparian Buffers

According to Oregon Department of Forestry (ODF) regulations, riparian forested buffers must be retained along all medium and large sized fish bearing streams. During clearcut harvesting, a

70 foot buffer must be retained along medium fish bearing streams and a 50 foot buffer must be retained along small fish bearing streams. No timber may be harvested within 20 feet of the stream bank and limited harvesting can occur between 20 feet and the outer buffer boundary. However, since no future clearcut harvesting is proposed for the Boneyard Forest, these buffer rules are inconsequential. Forest cover in riparian areas adjacent to all streams will be managed using the same principles applied to upland forests, including reduction of stand density, promoting the growth of larger diameter and taller trees, fostering natural understory regeneration, retention of hardwoods, and diverse understory shrub development.

Riparian corridor on Little Muddy Creek with recent wood recruitment from buffer along clearcut to east.

Large wood appeared to be ample in most of the stream segments and riparian areas adjacent to or within mature forests. These segments constitute the lower gradient fish-bearing streams on the property. As stream gradient increases, the streams eventually pass out of the mature forested areas and into the younger plantations where forested riparian buffers are currently not required to be left during timber harvests. Downed wood in these areas is in an advanced stage of decay and is quickly losing its functional value to both soil conservation, water quality and wildlife habitat. Research has shown that clearcutting upland areas increases stream flow rates, in particular during winter seasons and storm events. Increased stream flow and more extreme rates of hydrologic "flashiness" in higher gradient streams can cause scouring and channel incising, and deliver higher rates of sediment downstream. Adding wood to these higher order streams can slow stream velocity, trap sediment and stabilize soils until natural recruitment can take over these functions.

Annual Allowable Harvest

The concept of an annual allowable harvest typically pertains to forests that will be managed on a sustained yield basis for perpetual timber production. Given that the desired future condition for the Boneyard Forest is to restore late seral characteristics and functionality, vs. the perpetual production of commercial timber products, the annual allowable harvest rate cited below has more academic value for this forest if NCLC were to consider managing for both sustained yield and late seral habitat – goals that are not necessarily mutually exclusive.

The total property is approximately 340 acres in size and contains approximately 115 acres of merchantable age timber (FMU's 1 & 4). Approximately 102 acres are comprised of an 11 year old conifer plantation (FMU 2), 70 acres contain an 18 year old conifer plantation (FMU 3), and 23 acres are in a recently planted clearcut (FMU 6). Approximately 14 acres are comprised of forested wetlands (FMU 5) and are therefore inoperable. The remaining 22 acres contain additional inoperable ground, such as riparian zones.

The NRCS soil productivity rates listed earlier in this document estimate that this land is capable of producing at least 968 board feet of timber per acre per year once a stand reaches 55 years of age. These production rates are based on naturally regenerated forests that have not received any prior forest management, therefore, the NRCS production rates can be deemed conservative compared to forests that are actively managed. As such, the 115 acres of mature forest on this property should grow a total of at least 111 MBF of timber per year from this point into the future. The younger plantations will not be included in this estimate and can be revisited when they reach commercial age. The basic definition of a "sustained yield" is harvesting less than annual growth. Therefore, given a maximum sustained yield of 90 percent of annual growth, with careful management this forest should be capable of producing at least 100 MBF of timber per year, while retaining and adding to existing timber volumes.

Harvest Systems

On the pathway towards achieving the desired future condition of late seral habitat, the Boneyard Forest is capable of producing multiple timber products that can provide revenue that can be used to support restoration and conservation efforts. Slope limits the kinds of equipment that can be used in forest management, and highlead cable logging is the most common method as it is more efficient and less damaging to the soil surface than either tracked or rubber tired equipment. However, cable logging is typically used when clearcut harvesting, and using this method to thin a stand increases the planning and logistical complexity, and therefore the cost. Cable logging also requires more simplified harvest prescriptions (e.g. those that are within reach of the yarding corridor), and limits the ability of forest managers to implement more complex prescriptions, such as gaps. Helicopter logging, though more expensive, is an alternative to using cable systems, and may provide both a lower impact and more versatile approach to achieving the desired future stand conditions. Ultimately a combination of cable and helicopter logging may be used across the Boneyard Forest depending on access limitations to ground-based vehicles, age of the stands being thinned, and other variables.

The following harvest methods will be used across the property:

Pre-commercial thinning

Pre-commercial thinning is recommended for stands that exceed 350 - 450 TPA. Forest stands that exceed this density will typically enter the stem exclusion phase between the ages of 15 – 25 years depending largely on soil productivity. This phase is characterized by a dense canopy with sufficient shade to kill lower branches, suppress understory vegetation, and lead to suppression-based mortality of non-dominant trees. Live crowns gradually begin receding, and once they diminish below 35 percent, the growth of the tree shifts from girth production to height production as trees compete for sunlight. In order to keep these stands in optimum growth, and to minimize the risk for natural disturbance, they should be pre-commercially thinned.

The object of pre-commercial thinning is not to maintain an even spacing amongst all trees, but rather to favor healthy trees, both hardwood and conifer, that have dominant crowns and good log quality - a technique referred to as "best tree selection". Stands exceeding 350 TPA should be thinned to approximately that density. The first thinning of a stand typically occurs "from below", selecting the smaller diameter, suppressed and poorest quality trees first. Thinning in this manner typically results in a variable density spacing amongst retained trees that averages approximately 12 ft – 15 ft.

Trees should be cut within six inches of the ground using either a chainsaw or handheld saw. Cut trees should be brought down so they are not leaning on the retained trees. Care should be taken not to damage the trunk of leave trees during thinning. It is crucial that the best trees within a given area be left, rather than rigid adherence to an exact spacing requirement. If high quality leave trees occur in close proximity to each other, they may be left as a clump to help ensure stability against wind disturbances. Leave trees shall be those that have the largest live crown, tallest height, straightest stem, and show no signs of defect (e.g. broken tops, scars, leaning, etc.). The resulting slash can be piled into habitat piles measuring a minimum of 10 ft across and 6 ft high and/or downed logs measuring a minimum of 20 ft long and 12 inches in diameter, cut into firewood and removed, piled and burned, chipped, or any combination thereof. Thinning should be avoided during the prime bird nesting season between March 15th-June 30th.

Variable density thinning

Variable density thinning techniques are typically employed during the second and subsequent thinning entries of a stand. Variable density thinning involves varying the thinning intensity to produce a mosaic of unthinned, moderately thinned, and heavily thinned patches. Thinning with skips and gaps can also create this mosaic. Variable density thinning helps generate a more complex forest structure by promoting tree growth at different rates. It also encourages understory development through a diversity of species, a variety of patch types, and growth of tree seedlings and saplings. Variable-density thinning can improve forest health by increasing (a) resistance to disturbance, (b) ability to recover after disturbance, and (c) biological diversity that allows ecosystems to function well through climatic variation.

Variable density thinning typically occurs across both species and diameters, reducing stand density by no more than one-third of the standing trees per entry. If original stand density is approximately 350 TPA, then the first entry will reduce the density to approximately 180 - 220 TPA. During the second entry thinning, stand density will be reduced further to approximately 120 TPA. When selecting trees for harvest, most thinning is still conducted from below. However, dominant overstory trees may be selected for harvest if they will release a vigorous understory tree that has ample live crown. Thinning in this manner produces a more complex forest canopy and stimulates natural regeneration in the understory, thereby minimizing the need for manual planting. Gap creation can also be implemented during the second or third entry thinning in order to further enhance stand structure and horizontal heterogeneity.

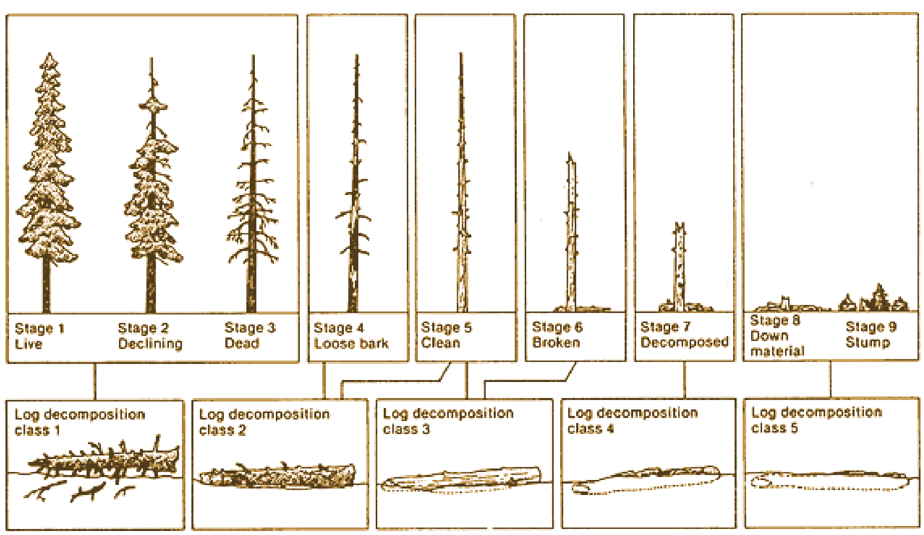
Structure and Biodiversity Enhancement Guidelines

Snags and Downed Woody Debris

Snags provide important structures for cavity-dependent bird and small mammal species, food sources for woodpeckers and other foragers, and a slow release nutrient resource for the forest in general. West of the Cascades in Oregon and Washington, 39 species of birds and 14 species of mammals depend on cavity trees for their survival. Terrestrial amphibians, small mammals, and birds also depend on large coarse woody debris for protection and foraging for insects, fungi, and seeds.

Snags fall into two primary decay class categories:

1. Hard snags, with the bark is still intact and with firm heart and sapwoods, and
2. Soft snags, which may have some bark remaining but with the wood beginning to soften.



Snag and downed log classifications

Downed logs fall into five primary categories based on their decay class:

1. Class 1, bark is still intact and heart and sapwood is still firm
2. Class 2, log is in contact with ground; bark is beginning to deteriorate and inner wood is soft.
3. Class 3, log is in contact with ground; bark has completely fallen off and log is beginning to become incorporated into the forest floor
4. Class 4, log is partially buried and wood is very soft
5. Class 5, log is barely distinguishable from surrounding forest floor

The mature stands across FMU's 1 and 4 contain an abundance of snags and downed logs, largely due to both wind and disease disturbances. Although the distribution of dead wood is not uniform across this unit, as it tends to be concentrated around disturbance pockets, no further manual recruitment is deemed necessary as continued disturbance can be expected to maintain a steady input of dead wood.

Across the younger plantations of FMU's 2, 3 and 6 very little large diameter dead wood remains. Snags are entirely absent, and most dead wood on the ground is either small diameter or in an advanced decay class due to its age. Recruitment of new dead wood into these stands will take decades. Natural disturbance based dead wood recruitment will need to be monitored, and if the stands are not on a trajectory to achieve the targets listed above, manual augmentation may be required through manual felling. Manual snag and downed log recruitment are often most efficiently accomplished during commercial logging, and non-merchantable sections of the tree (e.g. tops and defective portions of boles) can be left on-site. In particular, riparian areas and stream channels should be targeted for manual wood felling or placement in order to mitigate erosion and reduce the velocity of surface water.

Gap Creation

Openings in the forest canopy of various sizes and configurations are called gaps. In coastal forests, wind storms and disease create gaps in mature forests that provide opportunities for increased shrub and tree diversity. FMU 4 has multiple examples of natural gap creation through mature alder patches, annosus root rot pockets, and blowdown along some south-facing slopes. Therefore, no further manual gap creation is deemed necessary for this stand, as

Snag	**Minimum Size**	**#/acre**
Hard	17' tall x 15" dbh	2-5
Soft	17' tall x 15" dbh	2-5
Downed woody debris	**Minimum size**	**#/acre**
Class 1	16' x 20" dia.	1-3
Class 2	16' x 20" dia.	1-3
Class 3	16' x 20" dia.	1-3
Class 4	16' x 20" dia.	1-3
Class 5	16' x 20" dia.	1-3

Snag and downed log recruitment targets

continued natural disturbance can be expected to add to the structural heterogeneity of this stand.

As the younger plantations begin to mature and reach the point of their second commercial thinning, they should be evaluated for naturally occurring gaps. Gaps can range from ¼ acre to several acres in size. If less than 15% of the canopy across any particular unit is in gaps, then gaps should be created through manual cutting. This can be accomplished through expanding the width of portions of yarding corridors, removing a majority of the dominant and co-dominant trees in an irregular polygon, or other methods. Once an initial pattern of gaps has been created, and once stand density has been reduced to less than approximately 160 TPA, natural disturbance events can be expected to continue to drive future gap creation.

Timber Management Recommendations

Note: an economic analysis of these management options has been provided in the appendices to this plan.

FMU 1

Given the steep slopes and proximity to Little Muddy Creek, as well as the lack of road access to FMU 1, this unit should be left unmanaged and natural disturbance events allowed to continue to shape its composition. The new wind dynamics created by the clearcut in FMU 6 will likely lead to a period of increased blowdown and storm breakage over the next few years, contributing a significant volume of snags and downed logs to the unit. With the increased light in this stand due to both the adjacent clearcut and additional blowdown, natural understory conifer regeneration can also be expected.

FMU 2

FMU 2 should be monitored for invasive species and natural regeneration for the next 4 – 8 years. Natural regeneration will increase stocking densities and recruit additional species such as red alder, western red cedar, Douglas fir and shore pine. Once the stand begins closing canopy, it should be pre-commercially thinned as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed. Once the average diameter of the dominant and codominant trees reaches 14” DBH, the stand should be commercially thinned using the variable density thinning guidelines earlier in this plan, and then thinned approximately every 15 years thereafter until the stocking density of the dominant and codominant trees are reduced to approximately 80 – 100 TPA. Thinning can be accomplished either by cable or helicopter. From that point, natural disturbance events can be expected to continue to shape the structural composition of the stand.

FMU 3

FMU 3 should be pre-commercially thinned within the next five years as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed. Once the average diameter of the dominant and codominant trees reaches 14” DBH, the stand should be commercially thinned using the variable density thinning guidelines earlier in this plan, and then thinned approximately every 15 years thereafter until the stocking density of the dominant and codominant trees are reduced to approximately 80 – 100 TPA. Thinning can be accomplished either by cable or helicopter. From that point, natural disturbance events can be expected to continue to shape the structural composition of the stand.

FMU 4

FMU 4 already has a high degree of structural diversity, and natural disturbance events are continuing to thin and open the stand up. Therefore, an argument can be made for non-management within this stand, and allowing natural disturbance to continue to shape its composition. However, this stand also contains a high volume of merchantable timber, and low impact logging practices could accelerate structural development while generating revenue that could be used to fund additional conservation efforts. Two active management options are proposed below:

1. Non-commercially thin
   Although this stand has timber of a commercial age and size, a non-commercial thinning approach could be used to reduce stand density in certain areas, release understory trees and enhance gap creation through cutting-and-dropping. During this process, additional downed woody debris can be targeted to areas of the stand where there is a paucity of dead wood, as well as riparian areas. This treatment would be applied to strategic locations, and not the entire stand. No more than 1/3 of the trees would be felled (<20% - 40% of basal area depending on stand density) in a given treatment area. Following this thinning, natural disturbance events can be expected to continue to shape the structural composition of the stand.
2. Single-entry commercial thin by helicopter
   Through this approach, commercial timber would be selected for removal using the variable density thinning and gap creation guidelines provided earlier in this plan. Gap creation would be favored to make log extraction more feasible, and a slightly higher volume of timber would be removed to ensure the operation is economically feasible. However, no more than 30% - 45% of the trees would be removed, comprising no more than 40% of the basal area. Following this thinning, natural disturbance events can be expected to continue to shape the structural composition of the stand.

FMU 5 & 6

Given the wet soils across FMU 5, and the relatively low timber value inherent to the stand, this unit will be set aside as a no management area. Over time the decadent red alder will go into decline, and natural regeneration of spruce and hemlock will convert this unit to an uneven-aged conifer-dominated stand. The unit should be monitored for invasive species.

FMU 7

FMU 7 should be monitored for invasive species and natural regeneration for the next 15 - 20 years. Natural regeneration will increase stocking densities and recruit additional species such as red alder, western red cedar, Douglas fir and shore pine. Once the stand begins closing canopy, it should be pre-commercially thinned as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed. Once the average diameter of the dominant and codominant trees reaches 14” DBH, the stand should be commercially thinned using the variable density thinning guidelines earlier in this plan, and then thinned approximately every 15 years thereafter until the stocking density of the dominant and codominant trees are reduced to approximately 80 – 100 TPA. Thinning can be accomplished either by cable or helicopter. From that point, natural disturbance events can be expected to continue to shape the structural composition of the stand.

APPENDIX I. MANAGEMENT PLAN IMPLEMENTATION TIMETABLE

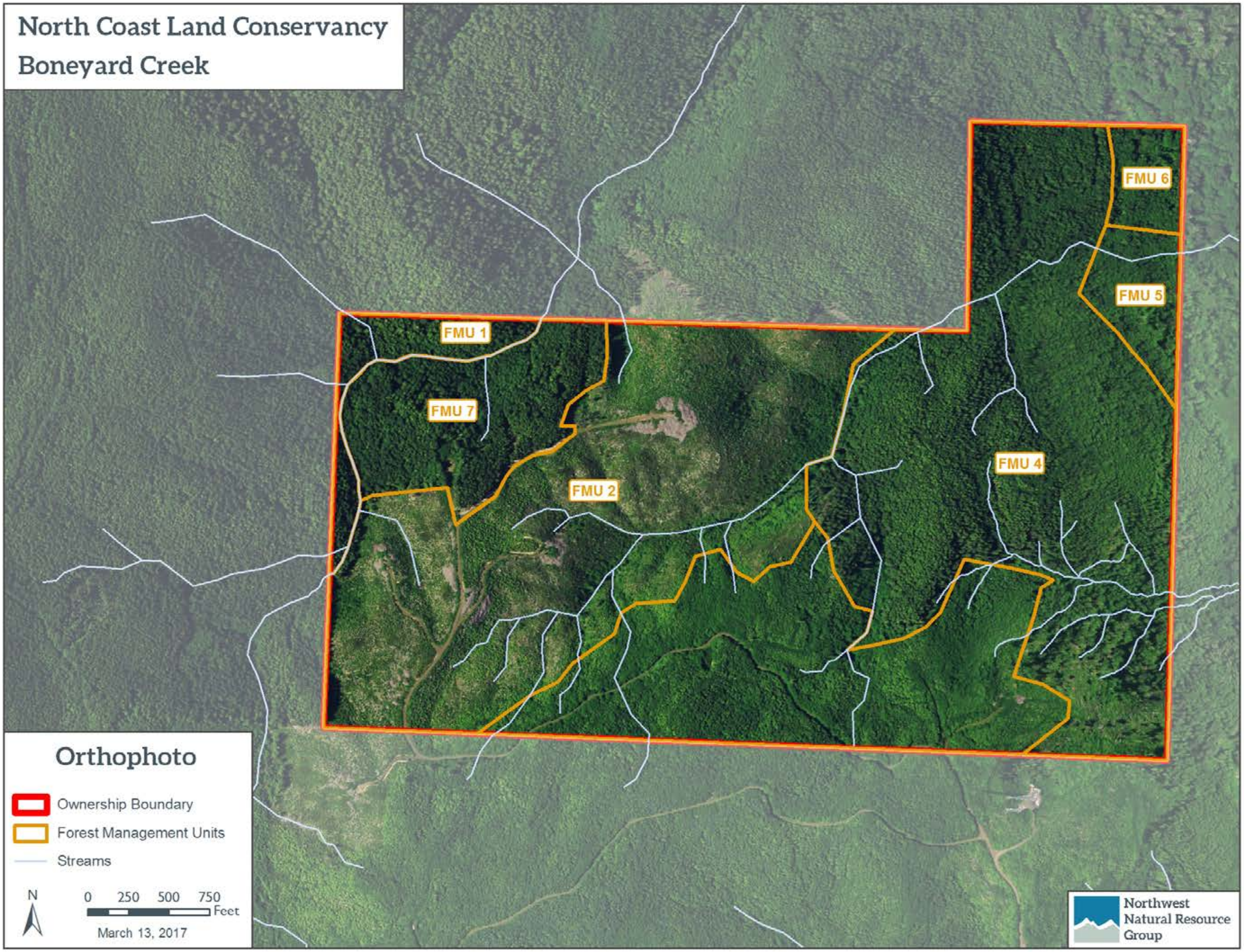
Year	Management Practice or Activity	FMU	Comments
2017 - 2022	Clean road ditches and drainage systems		Road ditches and culverts should be monitored and cleaned at least every five years, or as necessary to prevent vegetation from plugging the drainage system.
2017 - 2022	Evaluate seasonal stream segments for woody debris placement		Stream segments that do not have mature forested buffers should be evaluated for manual wood placement. If placement is deemed necessary, wood will have to be placed by helicopter as road access is not available to these locations.
2017 - 2022	Remove invasive species from road margins		To prevent roads from being a vector for invasive species to other locations both within and adjacent to this property, all invasive plants should be removed from the margins of the mainline road, as well as any road spurs.
2017 - 2022	Pre-commercially thin	3	FMU 3 should be pre-commercially thinned within the next five years as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed.
2017 - 2022	Commercial variable density thin (optional)	4	Commercially thin using the variable density thinning and gap creation guidelines provided earlier in this plan. Gap creation should be favored to make log extraction more feasible. No more than 30% - 45% of the trees would be removed, comprising no more than 40% of the basal area.
2017 - 2022	Pre-commercially thin (optional)	4	This treatment would be applied to strategic locations, and not the entire stand. No more than 1/3 of the trees would be felled (<20% - 40% of basal area depending on stand density) and left on site in a given treatment area.
2017 - 2027	Monitor for invasive species and remove as necessary	7	Monitor FMU for invasive species until stand closes canopy. Remove invasive plants as necessary.
2026 - 2031	Pre-commercially thin	2	Once the stand begins closing canopy, it should be pre-commercially thinned as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed.
2026 - 2031	Commercial variable density thin	3	Once the average diameter of the dominant and codominant trees reaches 14” DBH, the stand should be commercially thinned using the variable density thinning

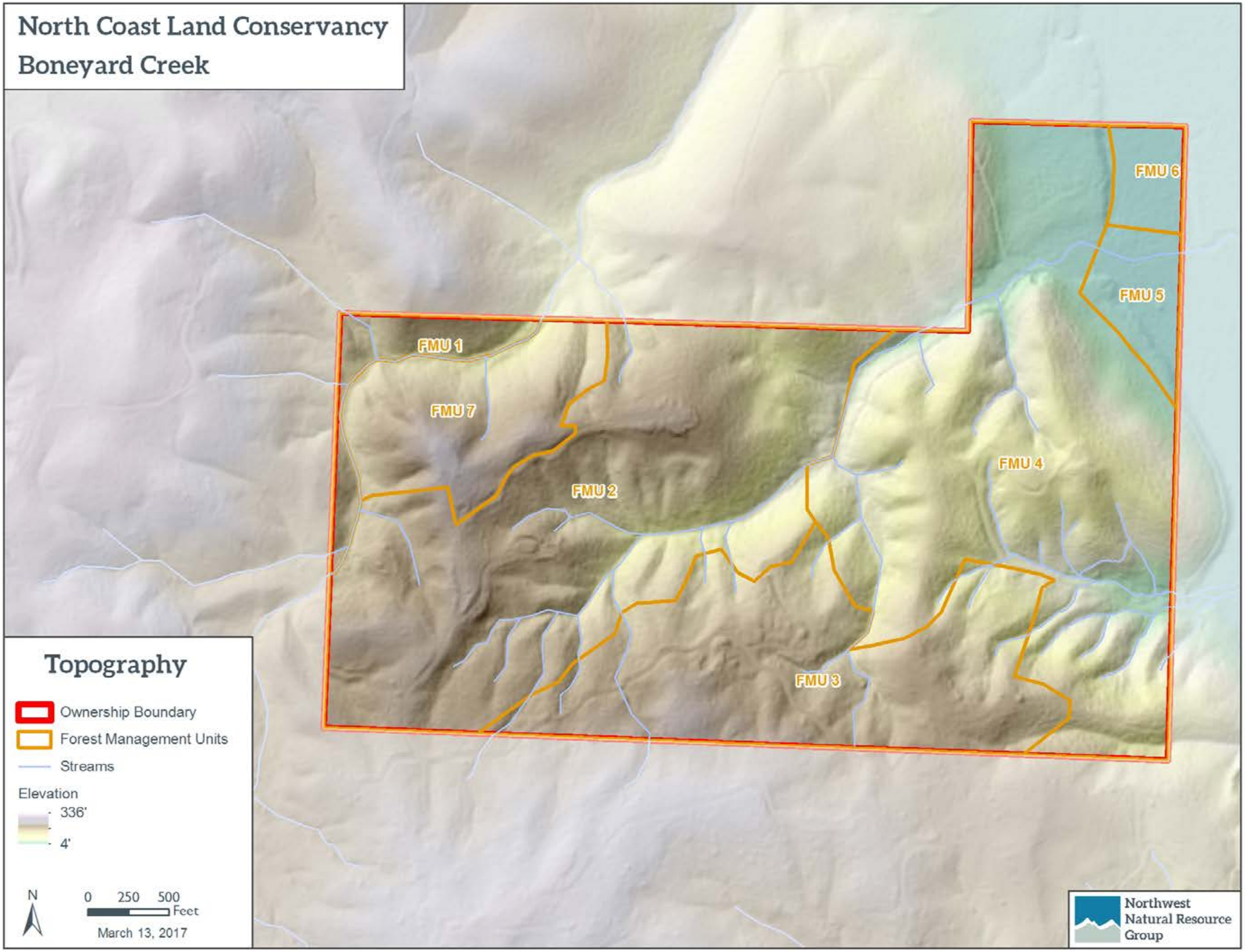
			guidelines earlier in this plan. Approximately 30% - 45% of the trees will be removed, reducing stand density to 180 – 220 TPA.
2036 - 2041	Commercial variable density thin	2	Once the average diameter of the dominant and codominant trees reaches 14" DBH, the stand should be commercially thinned using the variable density thinning guidelines earlier in this plan. Approximately 30% - 45% of the trees will be removed, reducing stand density to 180 – 220 TPA.
2041 - 2046	2nd commercial variable density thin	3	Once the canopy closes and live crowns begin to recede on the dominant trees, this unit should be thinned again to approximately 120 TPA. Gap creation can also be implemented to further enhance stand structure and horizontal heterogeneity.
2051 - 2056	2nd commercial variable density thin	2	Once the canopy closes and live crowns begin to recede on the dominant trees, this unit should be thinned again to approximately 120 TPA. Gap creation can also be implemented to further enhance stand structure and horizontal heterogeneity.
2036 - 2051	Pre-commercially thin	7	Once the stand begins closing canopy, it should be pre-commercially thinned as per the guidelines earlier in this plan. Red alder should be thinned, but otherwise retained. Spruce that has deformed tops due to the weevil should be removed.
2046 - 2051	Commercial variable density thin	7	Once the average diameter of the dominant and codominant trees reaches 14" DBH, the stand should be commercially thinned using the variable density thinning guidelines earlier in this plan. Approximately 30% - 45% of the trees will be removed, reducing stand density to 180 – 220 TPA.
2061 - 2066	Commercial variable density thin	7	Once the canopy closes and live crowns begin to recede on the dominant trees, this unit should be thinned again to approximately 120 TPA. Gap creation can also be implemented to further enhance stand structure and horizontal heterogeneity.

APPENDIX II. FOREST MANAGEMENT COSTS/REVENUE

See Forest Operations Plan

APPENDIX III. PROPERTY MAPS


North Coast Land Conservancy
Boneyard Creek
FMU 1
FMU 2
FMU 4
FMU 5
FMU 6
FMU 7
Orthophoto
Ownership Boundary
Forest Management Units
Streams
N
0 250 500 750
Feet
March 13, 2017
Northwest Natural Resource Group



North Coast Land Conservancy
Boneyard Creek
FMU 1
FMU 2
FMU 3
FMU 4
FMU 5
FMU 6
FMU 7
Topography
Ownership Boundary
Forest Management Units
Streams
Elevation
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4'
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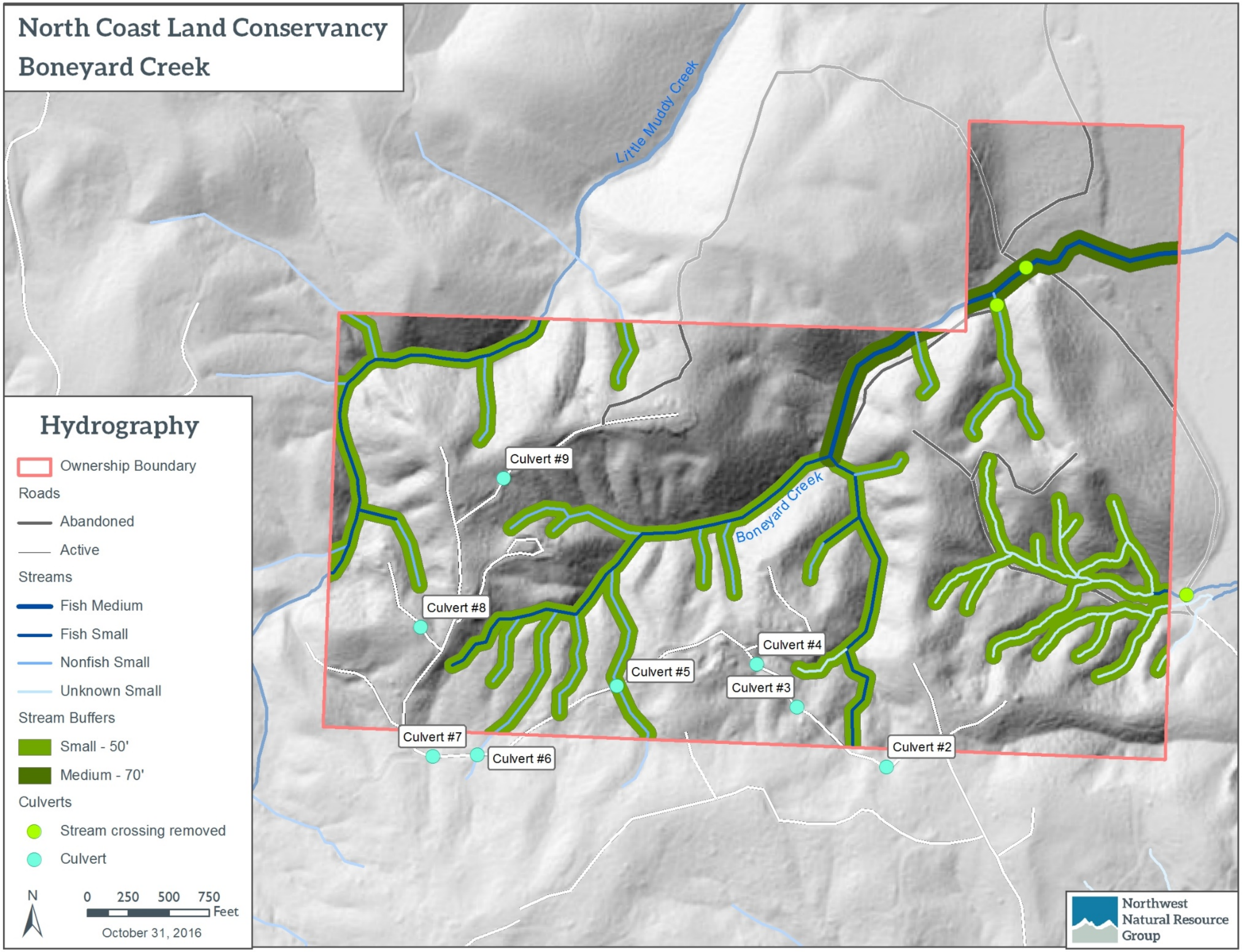
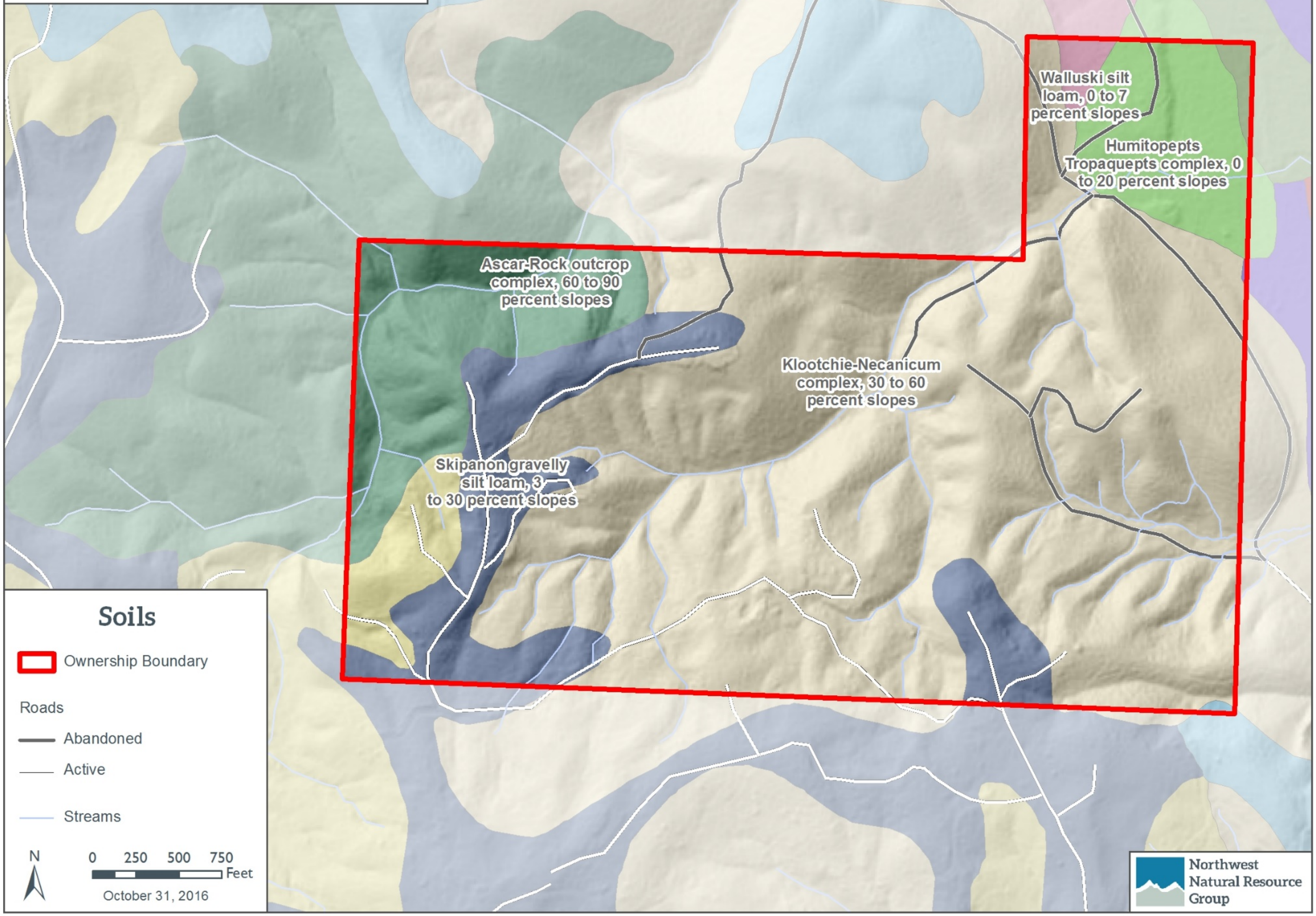
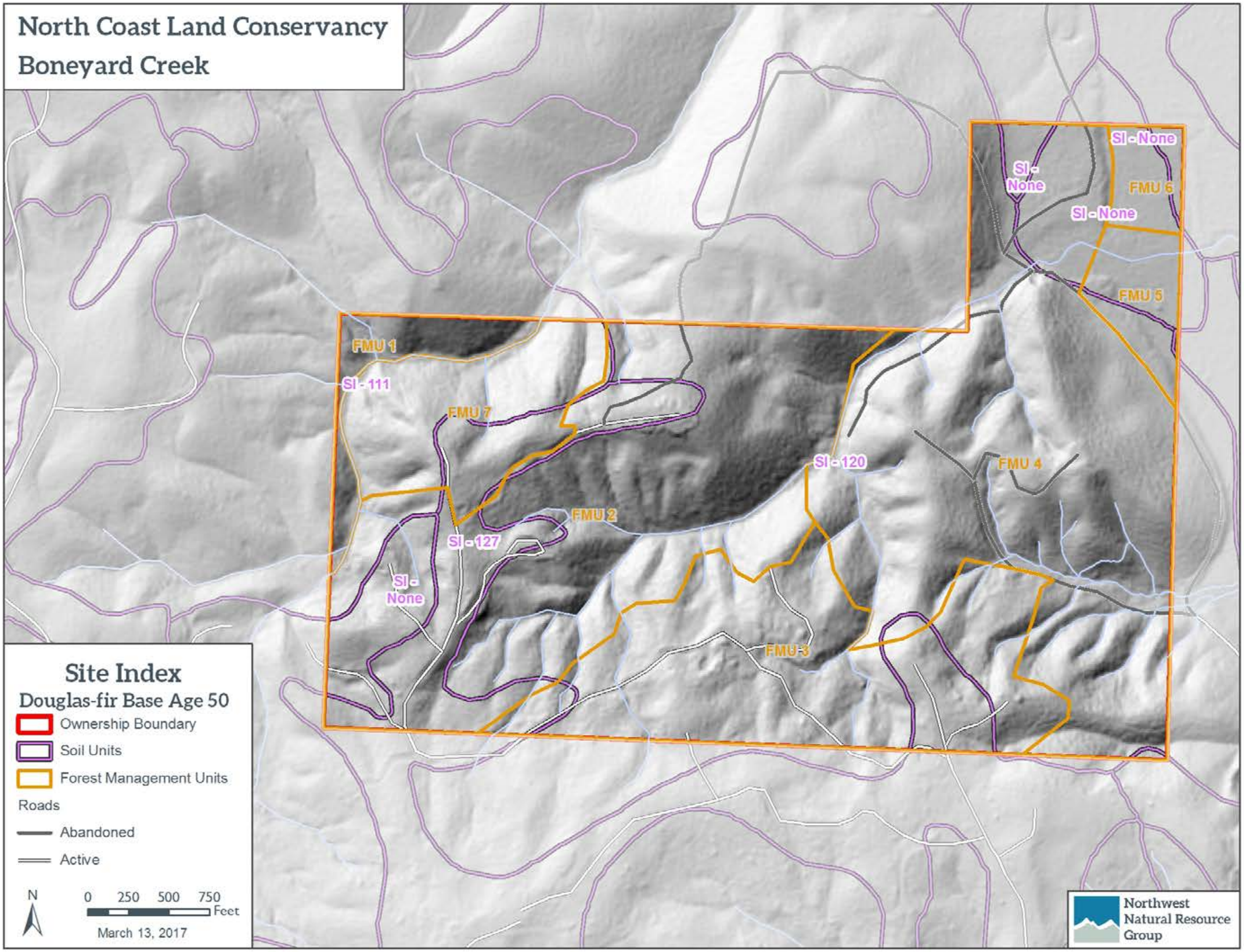
Feet
March 13, 2017
Northwest Natural Resource Group


North Coast Land Conservancy
Boneyard Creek
Little Muddy Creek
Boneyard Creek
Culvert #9
Culvert #8
Culvert #5
Culvert #4
Culvert #3
Culvert #7
Culvert #6
Culvert #2
Hydrography
Ownership Boundary
Roads
Abandoned
Active
Streams
Fish Medium
Fish Small
Nonfish Small
Unknown Small
Stream Buffers
Small - 50'
Medium - 70'
Culverts
Stream crossing removed
Culvert
N
0 250 500 750
Feet
October 31, 2016
Northwest Natural Resource Group

North Coast Land Conservancy
Boneyard Creek




North Coast Land Conservancy
Boneyard Creek
FMU 1
SI - 111
FMU 7
FMU 2
SI - 127
SI - None
FMU 3
SI - 120
FMU 4
FMU 5
FMU 6
SI - None
SI - None
SI - None
Site Index
Douglas-fir Base Age 50
Ownership Boundary
Soil Units
Forest Management Units
Roads
Abandoned
Active
N
0 250 500 750
Feet
March 13, 2017
Northwest Natural Resource Group

APPENDIX IV: ECOLOGY OF SPRUCE-HEMLOCK FORESTS

By: Andrew Larsen and Derek Churchill

Natural Disturbances

Disturbances play important roles in structuring the coniferous forests of western North America (Agee 1993, Franklin et al. 2002, Veblen et al. 1994). Their variation in type, extent, intensity and frequency lead to unique post-disturbance conditions and forest developmental pathways. Stand replacing disturbances initiate the forest development sequence while chronic, small-scale disturbances are important agents of tree mortality and pattern formation within the development sequence. Wind is the primary disturbance in coastal Sitka spruce Zone forests. Storms with hurricane force winds—potential stand replacing events—have swept the western Washington coast approximately once every 20 years in the last 200 years (Henderson et al. 1989). Of these events, the "21 Blow" of 1921 and the Columbus Day Storm of 1962 were the most significant, with estimated 7 and 11 billion board feet of timber volume blow down in the storms, respectively. In addition, smaller windstorms blow down or damage individual trees or groups of trees on a much more frequent basis. Additional complexity is introduced by feedbacks between wind-created edges along canopy gaps and blowdown areas, which expose additional trees to wind disturbance (Greene et al. 1992). As a consequence, wind disturbance become chronic, and blowdown patches can be seen to grow and migrate across coastal forest landscapes at annual to decadal time scales in complex wave and partial wave patterns (Harcombe et al. 2004). The net effect of this variable-intensity wind disturbance regime is a complex landscape mosaic of different patch types and sizes, often with high within-patch heterogeneity.

Fires, while rare, also perturb coastal Sitka spruce Zone forests. The incidence of fire in these forests is low because ignition sources are infrequent and ignitions rarely coincide with fuel moisture levels conducive to carrying wildfire. The limited available fire history data for Sitka spruce forests indicates that stand replacement fires occur only during extreme weather conditions associated with dry east winds (Agee 1993). Long and Whitlock (2002) estimated a fire return interval of 240 ± 30 years over the past 2700 years at a site just south of the project area in northwest Oregon. In the Sitka spruce Zone forests of the Olympic Peninsula fires have burned with a return interval of approximately 900 years (Henderson et al. 1989). A major stand-replacing fire event—the Nestucca Fire— burned Sitka spruce Zone forests at what is now the Cascade Head Experimental Forest in northwest Oregon sometime between 1845 and 1849 (Morris 1934, Munger 1944). The Nestucca fire started in the Willamette Valley and was pushed over the Coast Range by strong east winds. It is unknown if this significant fire was of natural or human origin. In any case, stand replacement fire events are certainly possible in the Sitka spruce Zone, although the probability of occurrence is quite low.

Reconnaissance in the largest old-growth patch on Long Island revealed occasional isolated fire-scarred western redcedar snags, confirming that fire has been present to some degree in recent centuries. As the old-growth patch has no evidence of a recent stand-replacement event, these solitary fire-scarred snags likely represent trees that were struck by lightning and subsequently smoldered and charred, with the fire remaining small in extent. Recent lightning strikes in 2005 on Long Island and within the Ellsworth Creek watershed provide circumstantial evidence in support of this idea.

Landslides are another major disturbance type that affects coastal forests, (Powell et al. 2003, Skaugset et al. 2002, Wegmann 2004). Shallow, rapid translational landslides appear to comprise the bulk of soil mass movements in the Ellsworth Creek watershed, although deep-seated landslides are also apparent (Wegmann 2004). They can be categorized as either debris slides, where the debris is deposited at the foot of the failure scarp, or debris flows, in which material has a high water content, is mobilized down slope, and enters the stream channel network (Skaugset et al. 2002). By creating sites with exposed mineral soil in the terrestrial uplands, landslides create opportunities for early successional species to establish and thus maintain diversity in upland forest plant communities. Another important function of landslides, specifically debris flows, is to transport sediment and large woody debris from terrestrial uplands to the stream network. They reconfigure aquatic ecosystems (Montgomery D.R. and Buffington 1998) and deliver pulses of the basic habitat elements required for streams to develop optimal habitat function (Reeves et al. 1995).

Forest Development Pathways

Old-growth Sitka spruce Zone forests are structurally similar to old-growth Douglas-fir forests (Franklin et al. 2005). The well studied structural development of Douglas-fir forests (Franklin et al. 2002, Zenner 2005) is helpful in understanding structural development in Sitka spruce forests, especially in managed stands as historic clear-cutting was typically a high severity disturbance that placed new stands on an even-aged trajectory similar to Douglas-fir stands after a high severity fire. However, the dominant disturbance in natural Sitka spruce Zone forests—wind—differs from that of Douglas-fir forests, which are influenced relatively more by fire. The silvics of the major species are also different. Thus, while reviewing the developmental sequence of Douglas-fir forests, we will also identify the key differences of Sitka spruce Zone forests.

Franklin et al. (2002) present an eight stage conceptual model for Douglas-fir forest development following stand-replacing disturbance. Each structural stage is named for the dominant structural development processes at that point in development. Many developmental processes operate at any one time in stand structural development, however; forests do not develop in an orderly fashion. General trends are certainly identifiable, but high variability in natural forests is the rule rather than the exception.

The developmental sequence is initiated in the disturbance and legacy creation stage. The type and intensity of the stand replacing disturbance create the substrate and biological legacies (living organisms, dead organic matter, and biologically-derived spatial patterns that persist following a disturbance) that set the stage for stand development. Stand replacement windstorms create a complex substrate of overturned rootwads with depressions of exposed mineral soil, downed logs, and intact pre-disturbance forest soils that is very different from the predominance of exposed mineral soil after a high intensity fire. In addition a larger number of live trees tend to persist through windstorms as opposed to high intensity fire. Much recent research on biological legacies has focused on residual live green trees, including their distribution (Keeton and Franklin 2004, Keeton and Franklin 2005) affects on stand volume growth (Acker et al. 1998, Zenner et al. 1998), influence on spatial patterns of regenerating trees (Goslin 1997), contribution to stand structural complexity (Zenner 2000), and influence on rates of forest succession (Keeton and Franklin 2005). In all these examples, the influence of the stand-initiating disturbance, and especially the biological legacies, is apparent decades or even centuries later in stand development.

Following disturbance and legacy creation, stands enter the cohort establishment stage. This stage is characterized by the establishment of a new cohort of conifer tree seedlings that is highly variable in time and space. The establishment of tree populations is limited or facilitated by five broad factors: seed availability and dispersal; environmental conditions; competition with non-tree vegetation; seed and seedling loss to herbivory and pathogens; and repeat disturbance prior to the sexual maturity of the new cohort. The first three factors operate in serial progression. Environmental conditions only limit tree regeneration after viable seed reaches the site, and competing non-tree vegetation only becomes limiting after tree species germinants have survived the initial environmental filter. The last two factors operate more-or-less throughout the tree establishment process.

In the moderate, moist Sitka spruce Zone cohort establishment is typically a relatively rapid process. Both spruce and hemlock are prolific seed producers (Ruth and Harris 1979) and seedlings typically establish at very high densities. Western redcedar also establishes, but at lower densities. The growing conditions are also quite favorable for competing non-tree vegetation however; if seed source is limiting immediately following fire a dense shrub layer may establish, limiting further tree seedling recruitment (Tappeiner et al. 2002). Because the dominant disturbance in the Sitka spruce Zone is wind, advanced regeneration often survives in its relatively sheltered position in the understory and can dominate the new cohort. Cohort establishment thus precedes the disturbance and legacy creation stage.

The next structural development stage following cohort establishment is distinguished by closure of the tree canopy. Canopy closure brings about extremely rapid shifts in the environmental conditions at the site. Understory light levels shift from nearly full sun to quite dark. Temperature and moisture regimes become moderated by the tree canopy, as well as understory wind speeds. Community composition begins to change following canopy closure. Shade intolerant, early successional herb and shrub species begin to be excluded from the site and successful establishment of additional tree seedlings ceases.

With the development of a closed, interlocking canopy forest development enters a developmental period marked by intense competition and biomass accumulation. At extreme levels, competition results in the mortality of those plants unable to capture enough resources to compensate for respiration costs. Competition in the moist Sitka spruce Zone forests is assumed to be primarily competition for light, which is generally thought of as a one-sided process (Cannell and Grace 1993, Cannell et al. 1984, Ford 1975, Ford and Diggle 1981) . In one-sided (asymmetrical) competition for light, a tall plant does not compete with a short plant, at least not above the level of the highest foliage on the shorter plant, while short plants compete directly with adjacent taller plants.. Alternately, two-sided or symmetrical competition occurs when plants share scarce resources in proportion to their size. If symmetrical competition is occurring even small plants will adversely affect the growth of large plants, as in the ponderosa pine/grand fir (*Pinus ponderosa/Abies grandis*) stands studied by McDowell and colleagues (2003), where water use by young grand fir limited growth of old-growth ponderosa pine. Competition for belowground resources is generally thought of as a two-sided process; the ability of a plant to extract limited belowground resources is proportional to the size of its root system. In reality, both one-sided and two-sided competition likely occurs in Sitka spruce Zone forests. However, stand structural development is likely influenced more strongly by one-sided competition for light than by two-sided below ground competition.

Competition related tree mortality prevails during the competitive exclusion/biomass accumulation stage. Growth rates and early canopy differentiation determine the “winners”. Slower growing species such as western redcedar are often out-competed and decline in relative abundance. The spatial outcome of competitive tree mortality is an overall homogenization of the forest stand structure. Subordinate trees and plants die, and recruitment of additional tree seedlings is excluded (Harcombe 1986) resulting in a canopy structure characterized by a single uniform layer of foliage (Van Pelt and Nadkarni 2004). Dense clumps of trees self-thin, reducing within-stand variation in tree density. Trees surviving competitive mortality tend to be distributed in a spatially regular pattern (Kenkel 1988). While competition related mortality dominates tree demography, ecologically significant competition-independent tree mortality due to disturbance typically occurs during the competitive exclusion/biomass accumulation stage. For example, in a young Cascadian Douglas-fir-hemlock forest (Lutz and Halpern 2006) found that while the frequency of suppression mortality of trees was 2.5 times greater than that of mortality due to disturbance, nearly four times more biomass was lost to disturbance mortality.

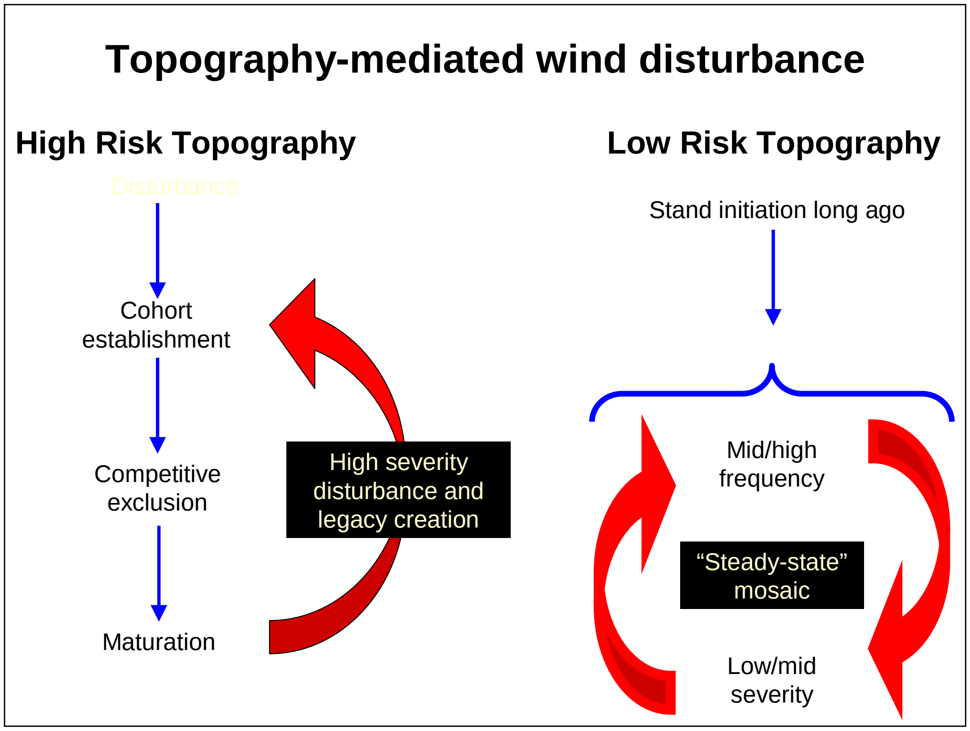
Gradually, the developing stand transitions from the competitive exclusion/biomass accumulation stage into the maturation stage. Maturation is marked by the attainment of maximum height and crown spread. As overstory trees slow their crown expansion the intensity of competition for light lessens. Consequently, the dominant agents of tree mortality shift from competition related processes to density-independent processes, such as small scale disturbance, pathogens and insects. Understory light levels increase, allowing the development and re-establishment of understory plants and shade-tolerant tree species in the lower canopy. However, this process can be very slow in mature stands with a strong western hemlock component—a common scenario in the Sitka spruce Zone. Working in mid-elevation forests in the Oregon Cascades Stewart (1986, 1988) found that shade tolerant tree regeneration was delayed and understory plant community development was limited in stands with hemlock-dominated overstories , relative to Douglas-fir dominated stands. The denser hemlock canopy likely transmits less light, restricting understory development. By extension, Sitka spruce Zone forests that established with a high initial western hemlock overstory component my experience delays in maturation relative to stands that established with a relatively large Sitka spruce overstory component.

Once understory trees have established, further small-scale canopy disturbances create opportunities for growth of shade-tolerant trees into the middle and overstory strata (Winter et al. 2002), resulting in a vertically continuous canopy and a diversity of live tree sizes. This stage is termed vertical diversification. As overstory trees which have grown to substantial size at this developmental stage succumb to mortality, woody debris loads increase from the low levels typical of the early maturation stage to those typical of old-growth forests. In coastal forests, much of the overstory tree mortality at this stage arises due to interactions between pathogens (root and butt rots) and wind. Large branch systems develop during vertical diversification, as does decadence in live trees (e.g. stem rot, cavities, bark scarring, broken tops, etc.), creating diverse canopy habitat for animals and epiphytes.

The horizontal diversification stage follows vertical diversification and describes the process by which a forest stand develops a spatially heterogeneous structure in a horizontal plane. Horizontal diversification subsumes many tree birth, death and growth processes, of which the net effect is to transform the homogenous young stand (i.e. a stand in the competitive exclusion/biomass accumulation stage) into a spatially heterogeneous forest. Horizontal heterogeneity, defined as the presence of multiple patches within a forest stand which together form a fine scale structural mosaic, is considered an emergent property of old-growth forests (Franklin and Van Pelt 2004) and is thought to originate primarily from a combination of spatially-aggregated tree mortality and competitive interactions between different subpopulations of trees (Franklin et al. 2002, Larson and Franklin 2006).

The final developmental stage identified by Franklin et al (2002) is pioneer cohort loss, which is simply the loss of the last members of the original stand initiation cohort. In the Douglas-fir forests described by Franklin et al. (2002) this represents a potential loss of forest structure and function since Douglas-fir generally does not regenerate in canopy gaps. The analogue for Sitka spruce Zone forests would be the loss of large, dominant spruce. However, in spruce forests the pioneer cohort loss stage does not have the same consequences for forest structure, composition and function as in Douglas-fir forests because spruce is capable of regenerating in canopy gaps (Taylor 1990), thereby maintaining a spruce component over time spans greater than the longevity of the original spruce cohort.

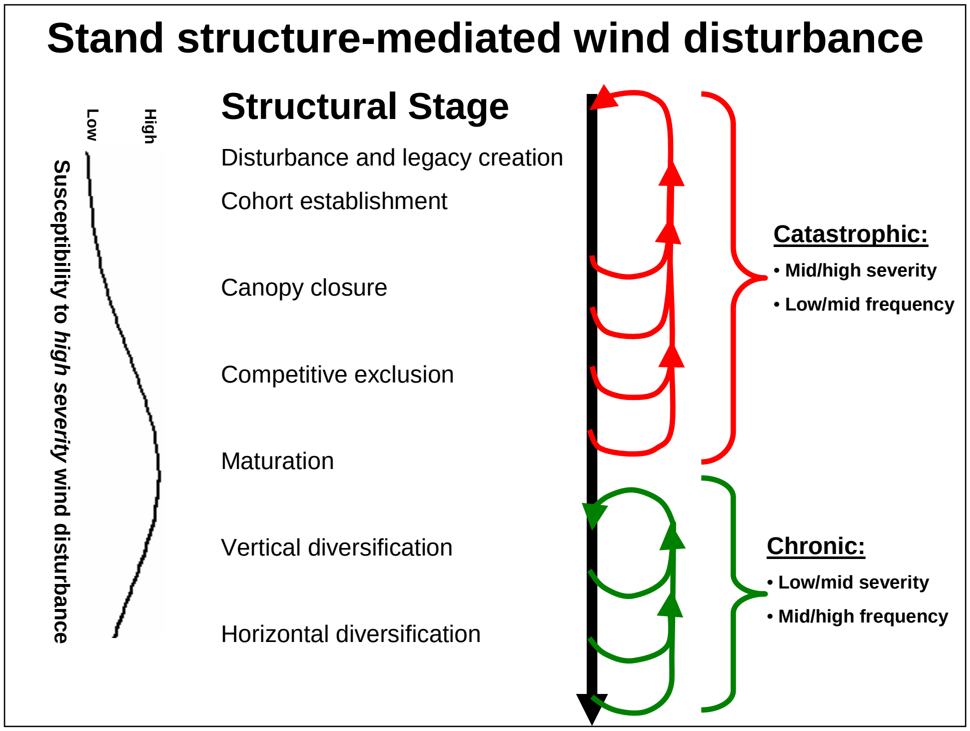
Two major stand development pathways exist in coastal spruce-hemlock-cedar forests and arise from variation in severity of the dominant disturbance, wind (Figure: 1). Sites with greater exposure to wind tend to experience high severity disturbance and stand development follows a catastrophic pathway (i.e., Franklin et al. 2002). Due to their prolific seed production and rapid early growth, western hemlock, and to much a lesser extent, Sitka spruce tend to be the dominant species in this pathway. Relatively less exposed sites experience chronic, low severity wind disturbance, which manifests as small scale, canopy-thinning disturbances (Winter et al. 2002). The chronic disturbance pathway tends to select for wind resistant, western redcedar and leads to relatively open, cedar dominated stands that are increasingly resistant to wind disturbance over time (Weetman and Prescott 2001). At the landscape scale, topographic heterogeneity create a mosaic of young, even aged stands developing along the catastrophic pathway following high severity wind disturbance and old-growth, all aged stands maintained by low and moderate severity wind disturbance (Kramer et al. 2001, Weetman and Prescott 2001).



The effects of topography on wind disturbance and forest development

Long term studies of forest development following stand replacement fire at Cascade Head Experimental Forest provide additional insight into forest structural development in the Sitka spruce Zone. Stand replacement fire burned the Northern Oregon Coast Range in circa 1845 (Morris 1934, Munger 1944), including the area now designated as the Cascade Head Experimental Forest. Following fire, stand structural development proceeded along the sequence described by Franklin et al. (2002) up to the end of the competitive exclusion stage and beginning of the maturation stage (Harcombe 1986). Permanent plot studies then demonstrate accelerating mortality and biomass loss in maturing forests (Acker et al. 2000, Greene et al. 1992, Harcombe et al. 1990) from a complex pattern of wind disturbance (blowdown). Harcombe et al. (2004) used aerial photographs to characterize this wave like pattern as it advanced through Cascade Head over a 40 year period.

Susceptibility of a forest stand to windthrow increases with stand age in coastal forests (Harmon et al. 2004, Harris 1989, Jane 1986, Rebertus et al. 1997, Wimberly and Spies 2001) (Figure 2). As trees grow taller they become less able to withstand the physical forces of high velocity winds, leading to increased incidence of mechanical failure either by uprooting or stem breakage. Stem, butt and root rots in older (larger) trees also increase the likelihood of windthrow (Edmonds et al. 2000). Also, once gaps in the canopy have been created, the remaining trees are more exposed and susceptible. Topography interacts with prevailing wind directions (storm tracks) such that different locations will have greater or lower susceptibility to windthrow (Kramer et al. 2001). On sites predisposed to catastrophic windthrow by the local topographic context, forest structural development will be truncated, seldom reaching the later stages (i.e. vertical and horizontal diversification) of forest structural development.



The influence of stand structure and wind disturbance on forest developmental pathways.

In the case of the Cascade Head, both topographic position and decreased resistance to wind disturbance due to unstable, single cohort stand structure dominated by tall, slender trees have contributed to the observed pattern of partial blowdown waves (Harcombe et al. 2004). These waves initiated from discreet canopy gaps that have slowly spread and coalesced through time. A similar phenomenon has been observed in other coastal, wind-disturbed forests (Rebertus and Veblen 1993, Rebertus et al. 1997). Thus, the implication is that conversion of wind resistant cedar dominated old-growth stands (*sensu* Weetman and Prescott 2001) to even aged hemlock dominated stands has decreased the resistance to wind disturbance, particularly on sites with only moderate topographic protection from storm tracks.

Red alder aggressively invades many sites in the Sitka spruce Zone following disturbances. Consequently, pure stands of red alder, or mixed alder - conifer stands often develop following logging or natural disturbance (Deal et al. 2004). Red alder is a short lived species; two major successional pathways are possible in maturing alder stands. Spruce, hemlock and cedar are all able to persist in the understory of alder stands. Thus, a common successional sequence is a gradual transition from alder to conifer dominance. Beach and Halpern (2001) found that distance to seed source was the most important explanatory variable for patterns of conifer seedling abundance in alder dominated riparian forests. Substrate (woody debris) was positively related to hemlock and spruce seedling abundance, while conifer seedling abundance declined with increasing herb and shrub cover. The same study found no relationship between conifer seedling abundance and overstory cover, suggesting that alder does not competitively exclude conifer seedlings from the understory. If conifer seed is not available, or if conifer seedling establishment is otherwise limited (e.g. by competition with understory plants or herbivory), shrubs may increase in dominance as the alder component senesces, further excluding conifer establishment and maintaining a stable shrub community (Spies et al. 2002). Having some portion of the landscape maintained in brushfields is not necessarily undesirable; the condition likely occurred naturally. However, management action (e.g. planting conifer seedlings) may need to be taken on some sites if past harvesting has removed local conifer seed sources.

Mixed alder - conifer stands have the potential to develop heterogeneous stand structures with multiple canopy layers and large diameter conifers (Deal et al. 2004). Rapid initial height growth by alder leads to canopy stratification, with understory conifers persisting under an overstory of alder. Alder is a short lived species however and mortality of overstory trees facilitates the eventual recruitment of suppressed conifers into the overstory of mixed alder – conifer stands. Sitka spruce appears to be particularly adept at responding to release from overstory alder competition (Deal et al. 2004).

Stream Geomorphology, Disturbances, and Habitat, including Riparian Areas

Stream geomorphology can be characterized at multiple spatial scales ranging from geomorphic provinces to channel reaches. Three basic types of channel reaches exist: (Montgomery D.R. and Buffington 1998).

Colluvial reaches: These are typified by low volume, ephemeral flows and poor sediment sorting, as debris flows are the primary sediment transport process in colluvial reaches.

Bedrock reaches: These occur where sediment transport capacity exceeds sediment supply, preventing the accumulation an alluvial sediment bed.

Alluvial reaches: These occur where alluvial sediments accumulate and assume several different morphologies (cascade, step-pool, plane-bed, pool-riffle, and dune-ripple) depending on the ratio of sediment supply to transport capacity. These five types tend to arrange themselves within the channel network according to stream gradient, with cascades morphologies typically found in steeper areas and pool-riffle and dune-ripple reaches occupying low gradient locations. However, in-channel large woody debris alters sediment delivery-transport relationships, forcing channel reaches to assume different morphologies than would be expected in the absence of large wood in the stream channel. In-channel woody debris can create suitable aquatic habitat in stream reaches that would otherwise be of low habitat quality.

Disturbance regimes and processes change throughout the stream network (Montgomery D. R. 1999). As stream channels increase in size, dominant disturbance processes transition from landslides and debris flows to floods and channel migration/avulsion events. The frequency and magnitude of stream disturbance regimes shifts from infrequent and high magnitude disturbances in small streams to higher frequency and more moderate intensity in larger channels. Debris flows are primarily responsible for delivery of large woody debris in high gradient headwater channels; while downstream transport, bank erosion, and stand mortality are the primary causes of recruitment in low gradient, larger channels. Also, habitat heterogeneity within channel networks is hypothesized to be strongly influenced by large deposits of large woody debris in tributary junctions (Benda et al. 2004).

Riparian vegetation influences instream microenvironmental conditions, nutrient inputs and the quality and quantity of allotochonous organic inputs (Naiman et al. 2000, Naiman et al. 1998, Spies et al. 2002). Aquatic biota respond to changes in the quantity and quality of allotochonous inputs from riparian forests (Bisson and Bilby 1998).

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APPENDIX V. FOREST CARBON DYNAMICS

Carbon Overview

The forest management prescriptions recommended in this forest management plan will increase carbon storage over time and will result in long-term additional carbon storage relative to intensive forest management practices. This carbon analysis is on overview of carbon dynamics based on computer forest growth models. These results are informative and accurate to the extent of the models and data used; however, they do not meet reporting requirements for any specific forest carbon offset protocol.

Forest Carbon Measurement and Offsets

The world's forests provide an important carbon sink countering increasing greenhouse gas emissions. Forest management practices can influence carbon uptake and storage in woody biomass and soils. Large, long-lived conifers, a climate that favors slow decomposition, and infrequent large-scale natural disturbance result in the Pacific Northwest serving as some of the most important U.S carbon stores. Carbon storage is one of many resources forests can produce, along with a bevy of commercial wood products, wildlife habitat, clean air and water, recreation, and aesthetic values. Maximizing carbon storage may not necessarily optimize other important forest functions, such as wildlife habitat and revenue, but accounting for forest carbon is the first step in understanding the tradeoffs in forest management practices.

Ecologically-based silvicultural practices, as proposed in this forest management plan, can lead to increases in carbon storage in the Pacific Northwest. Forest management practices that increase ecosystem functions, such as carbon sequestion, beyond what may be provided by conventionally managed forests, can be referred to as Improved Forest Management (IFM) practices. IFM practices that increase carbon sequestration include: extending rotations, decreasing harvest intensity, retaining old legacy trees, retaining dead wood such as large snags and downed logs, and minimizing soil disturbance. Quantifying the additional carbon sequestered by various forest management practices is the foundation of forest carbon offsetting.

Carbon Offsetting

Voluntary carbon markets and regulated markets such as California's cap-and-trade market[1] and the Northeast states' Regional Greenhouse Gas Initiative[2] allow payment for landowners whose forests increase the amount of carbon storage in the United States. Furthermore, many

[1] http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

[2] http://www.rggi.org/

non-regulated organizations, municipalities, and individuals account for carbon in forest ownerships to offset emissions as part of voluntary climate change action plans.

Landowners may wish to pursue payment for forest carbon, though these projects are rare in the Pacific Northwest. Carbon credits are the saleable units that result from carbon offset projects, verified under authorized methodologies such as those approved by California's cap-and-trade program, reported in metric tons of carbon dioxide equivalents (Mg CO_2e). CO_2e is the mass of atmospheric carbon effectively offset as a direct result of the IFM project. Forest owners who maintain carbon stocks above a certain baseline volume may sell credits after third-party verification of actual carbon storage. To be financially viable, most forest carbon offset projects occur on large forested tracts (e.g. > 1,000 acres). The most financially promising projects involve forests that have large carbon stocks at the beginning of a project relative to intensively managed forests[3]. IFM projects typically involve long reporting windows up to 100 years, requiring the forest owner to commit to the IFM for that time period.

Legitimate carbon offsets are awarded as the difference between carbon stored under a proposed IFM project and carbon stored under a baseline or "business as usual" management scenario. Baseline carbon is typically based on recent and/or planned management activities, or a regional average. The increase in carbon above a baseline is referred to as "additionality". Additional carbon frequently includes deductions for leakage (displacement of carbon emissions), risk buffers (hedging against future loss of carbon due to natural disaster or excessive logging) and uncertainty in forest measurement data. Additionality is a fundamental concept in carbon offsetting.

Methods

The recommended forest management practices proposed in this forest management plan were modeled in the U.S. Forest Vegetation Simulator[4]. FVS Fire and Fuels Extension was used to generate carbon reports for carbon storage in aboveground live biomass, live and dead roots, snags and logs, shrubs, long-lived wood products, landfilled carbon, and carbon emissions and energy use from harvesting and processing wood products. FVS uses biomass equations developed in primary literature and selected by Forest Service model developers to calculate carbon[5].

An intensive harvest scenario involving clearcutting and replanting units on 40-year rotation cycles was modeled as the Business as Usual (BAU) baseline scenario. Units were clearcut as they reached sufficient merchantable volume, accounting for regulatory riparian buffers and leave-trees. These units were replanted with 400 TPA Douglas-fir and PCTd to 250 TPA 10 years

[3] Gordon Smith, Stockholm Environmental Institute, personal communication.
[4] Dixon, G.E., comp. 2002. Essential FVS: A user's guide to the Forest Vegetation Simulator. Revised April 2007. USDA Forest Service Internal Report. Fort Collins, CO Forest Management Service Center. 209p.
[5] http://www.fs.fed.us/fmsc/fvs/whatis/fvs_carbon.shtml

after planting. Similarly, a no-management scenario involving no cutting or other active management was modeled in FVS to provide a basis of comparison. Finally, the management recommendations in this plan extend to 2056. The 2056-2116 portion of the simulation assumes a thin-from-below for all species to Curtis Relative Density 25 in 20-year intervals following last harvest prescribed in the management recommendations.

Results

Following the recommended management actions over a 50-year timeframe, modeled total carbon storage nearly doubles from its current amount of 47,926 metric tons carbon dioxide equivalents ($MTCO_2e$) to 101,914 $MTCO_2e$. On a per-acre basis, that is an increase from 141 to 300 $MTCO_2e$ per acre across the property's 339 forested acres, or 3.2 tons/acre/year. The results are similar to original carbon calculations from previous analyses. The cutting on the new prescriptions is heavier, but with a five-year delay in follow-up harvest and an extra 10 years added to the model timeframe, the carbon results differ in only small ways.

Figure 1 shows the total carbon storage that takes place under the recommended forest management practices. *In-forest carbon* includes carbon stored in live and dead roots, tree trunks, bark, branches and leaves, shrubs, and dead wood. *Carbon stored in wood products and landfill* shows the carbon that is removed from the forest upon harvest. Over time, the carbon stored in wood products and landfill is emitted as the wood products decompose. The *Carbon Emissions* portion of the figure shows the emissions resulting from decomposing harvested wood products and emissions from energy use in harvesting and processing wood products. The *Net Carbon Balance* shows the net carbon storage after subtracting the emissions resulting from the forest management practices.

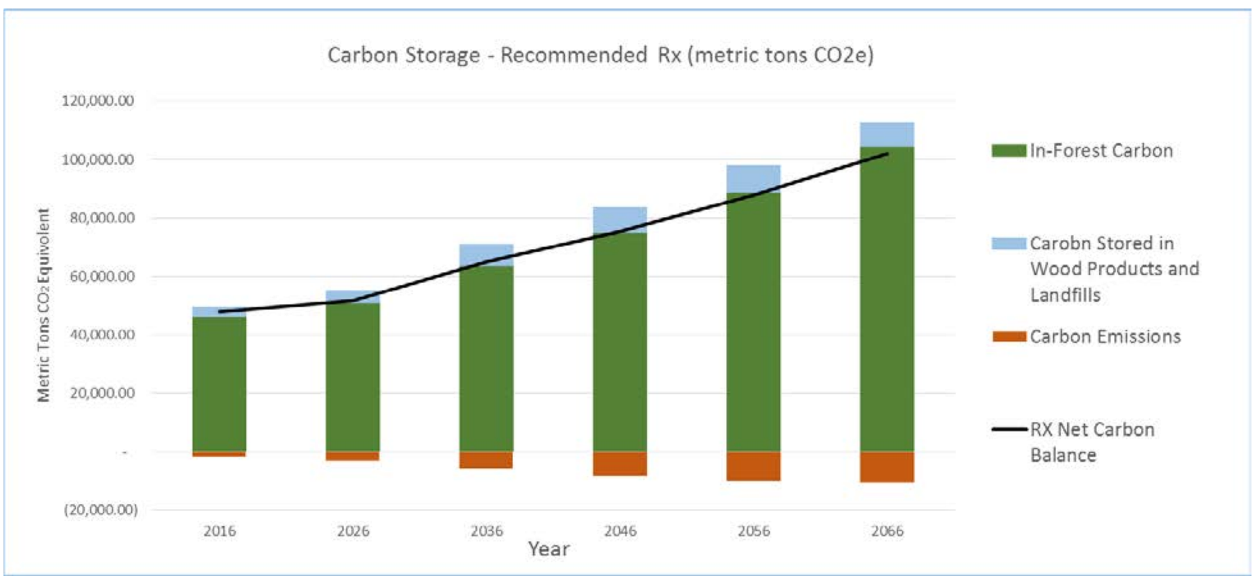


Figure 1: Carbon storage under the management practices recommended in this plan. Rx Net Carbon Balance shows the sum of in-forest carbon, carbon stored in wood products and landfills, and carbon emissions – in this case Net Carbon Balance happens to app

Figure 2 shows an increase in carbon stored in the respective FMUs, accounting for the acreage of each unit over the 100-year analysis horizon. The 50-year management portion of the timeframe shows a shallower rate of increase in carbon, compared to the second 50 years, due to the thinning activity occurring in the units. Although the products made from that removed timber is accounted for in the total carbon, much of the timber carbon is lost due to mill and use efficiencies and emissions.

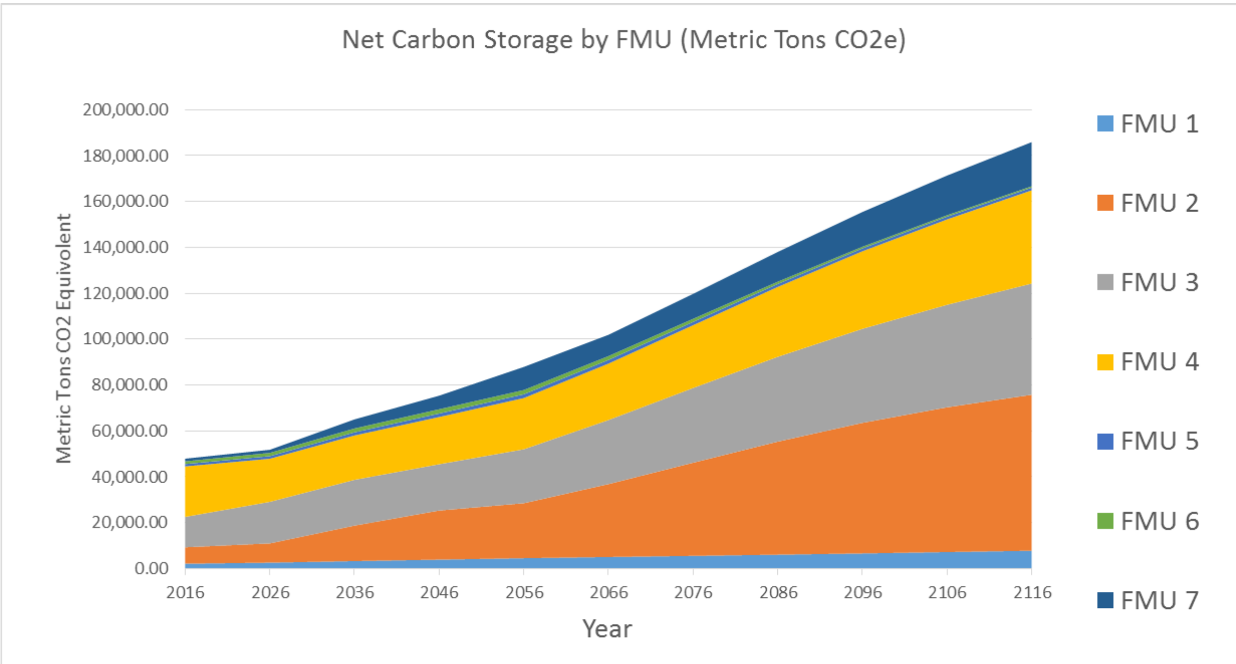


Figure 2: Net carbon within each FMU under the proposed management activities.

Figure 3 compares the recommended forest management practices with a no-harvest scenario and an intensive management scenario, clearcutting and replanting in 40 year intervals. The 100-year long-term (LT) average of the 40-year clearcut scenario was used as a Business as Usual baseline for calculation of additional carbon.

This plan's proposed management retains a majority of the property in tree cover throughout the model timeframe. It may be surprising that this less-intensive management practice results in only modest carbon benefits compared to clearcutting and replanting. However, the rapid growth rates of plantation forests results in re-attainment of substantial carbon mass. From an ecological and wildlife habitat standpoint, the proposed management in this plan provides much better quality habitat and several diverse habitat niches, including large old trees, mixed species, and diverse early seral patches.

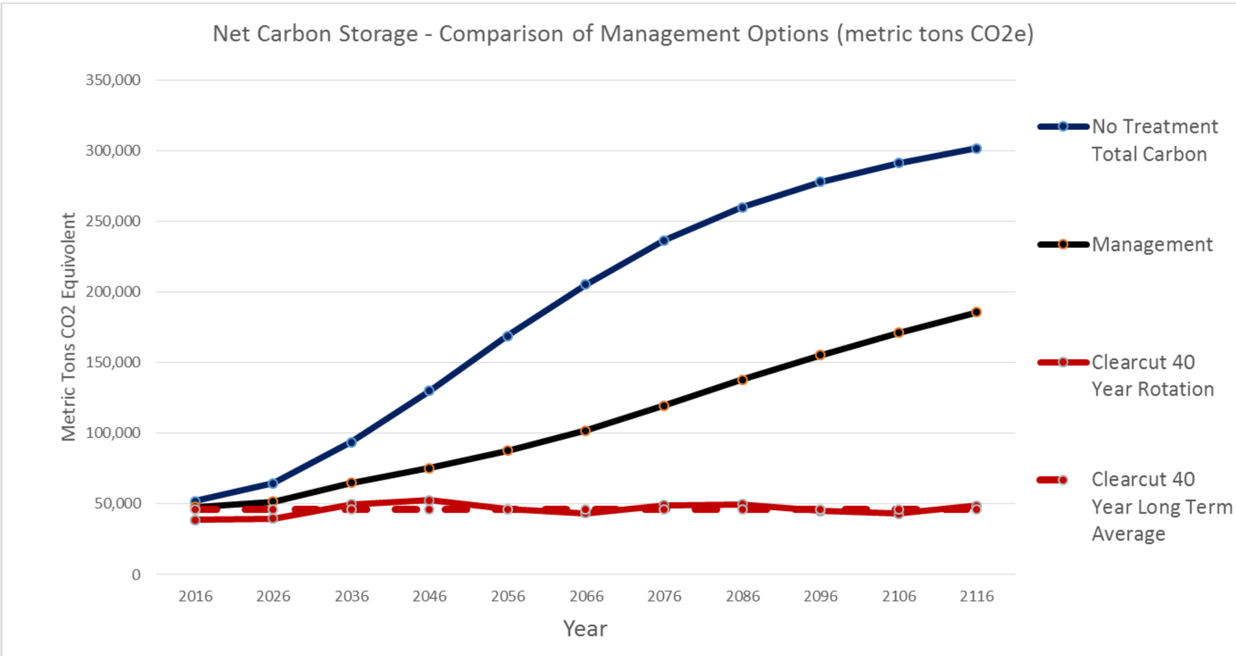


Figure 3: Comparison of carbon storage for no-treatment, this plan's proposed management (Rx), and clearcutting in 40-year rotations.

Increased harvest intensity reduces carbon storage. Carbon stored in harvested wood products and landfilled products do not entirely compensate for carbon stored in-forest. No-treatment management maximizes carbon storage, but reduces financial revenue from timber sales to zero. While payment for carbon storage could be an option, high cost of certification and long commitment periods discourage many forest owners from enrolling in forest carbon offset projects. No-treatment tends to increase old forest habitat but does not provide mixed-age or early seral habitat. The proposed management optimizes wildlife habitat, carbon, and revenue. These results highlight how forest managers must evaluate the impacts of management decisions and weigh tradeoffs based on the forest owner's goals.

Additional Carbon Storage Relative to Intensive Management Practices (Business as Usual)

Carbon accreditation methodologies allocate carbon credits based on additional carbon stored above a business as usual scenario. "Additional" carbon storage is calculated as the increase in carbon year-over-year (calculated in this case in 10-year increments), after crediting the increase in carbon above the 100-year average of the intensive management scenario. Compared to an intensive forest management scenario typical of industrial-style management in the region, the recommended management results in 55,830 $MTCO_2e$ additional storage (164 $MTCO_2e$/acre) over a 50-year timeframe (Table 1). Annualized, the management recommendations store an additional 3.3 $MTCO_2e$ per acre per year compared to intensive management. Over a 100-year timeframe, total additional carbon equals 139,833 MTCO2e (412 MTCO2e/acre, 4.1 MTCO2e/acre/year).

Accounting Period	Total C Storage above Baseline (Metric Tons CO_2e)	Metric Tons CO_2e/acre/year
50-yr	55,830	3.3
100-yr	139,833	4.1

Table 1: Additional carbon for the proposed treatments compared to 40-year clearcut rotations.

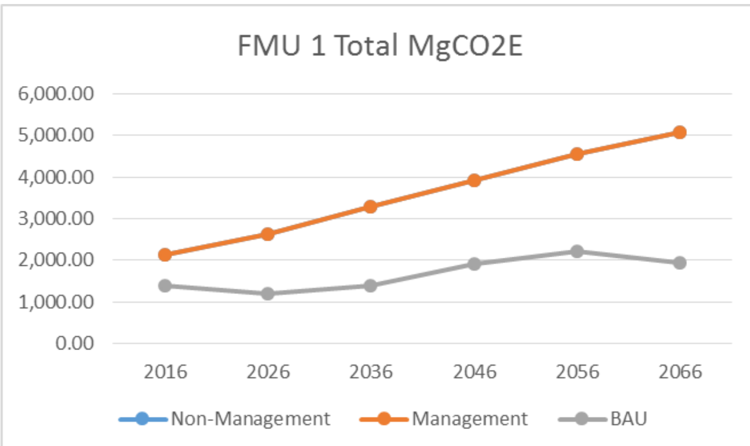
Carbon Summary – Forest Management Unit Analysis

The carbon numbers used here are derived from the carbon output reports from the FVS models that were simulated for each forest management unit (FMU). Results are reported in metric tons of carbon equivalents $MTCO_2e$. Acreages and carbon for riparian management zone (RMZ) portion of each of the units were included in these results. Carbon for unmanaged simulations were applied to RMZ acres.

Each section compares the carbon for that unit between a non-management, management, and business as usual (BAU). The non-management results are from modelling the growth of the units without any management activity. The management results are from the designated prescriptions. In the case of FMU 1, 5, and 6, the results are the same since those have no management prescription. The business as usual (BAU) results are for 40 year Douglas-fir clear-cut rotations. FVS reports results post-harvest, creating the differences in starting point of carbon among management scenarios in year 2016.

FMU 1 (7.7 acres; 10.5 acres including riparian zones)

The composition of FMU 1 is primarily mature conifers, split between western hemlock and Sitka spruce. Over time, this conifer dominated unit will rapidly increase its total carbon storage due to the large size and long life of the conifer trees. There is a consistent upslope in the non-management and management scores due to the trees continuing to grow with minimal mortality.

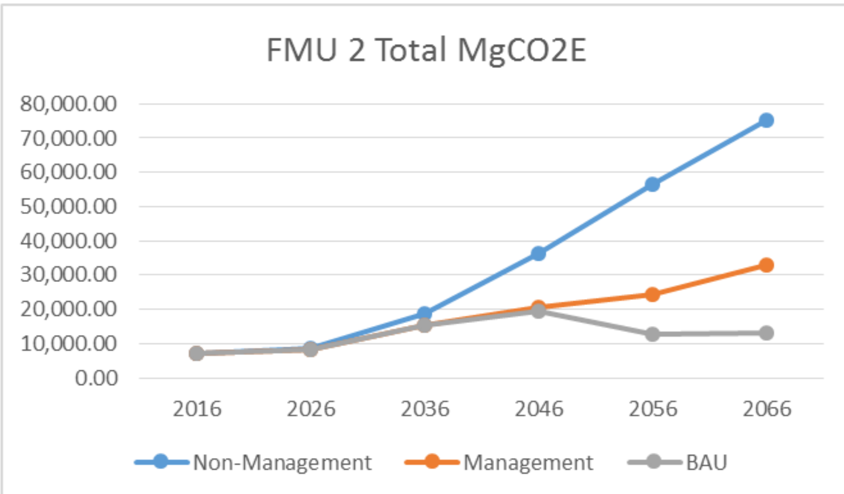


FMU 1 Total MgCO2E	Non-Management	Management	BAU
2016	2,148.08	2,148.08	1,404.80
2026	2,625.87	2,625.87	1,208.15
2036	3,290.38	3,290.38	1,398.62
2046	3,925.74	3,925.74	1,924.89
2056	4,547.12	4,547.12	2,207.91
2066	5,075.37	5,075.37	1,933.23

FMU 1 MgCO2E / Acre	Non-Management	Management	BAU
2016	205.36	205.36	134.30
2026	251.04	251.04	115.50
2036	314.57	314.57	133.71
2046	375.31	375.31	184.02
2056	434.72	434.72	211.08
2066	485.22	485.22	184.82

FMU 2 (101.3 acres; 105.1 acres including riparian zones)

FMU 2 is a conifer dominated unit with some red alder. Through time, FMU 2 sees a consistent increase in stored carbon, with a significant divergence between the non-management and management carbon. The management model incorporates harvesting and the removal of material resulting in a reduction of carbon sequestration in FMU 2 when compared to the non-management at the same time periods.

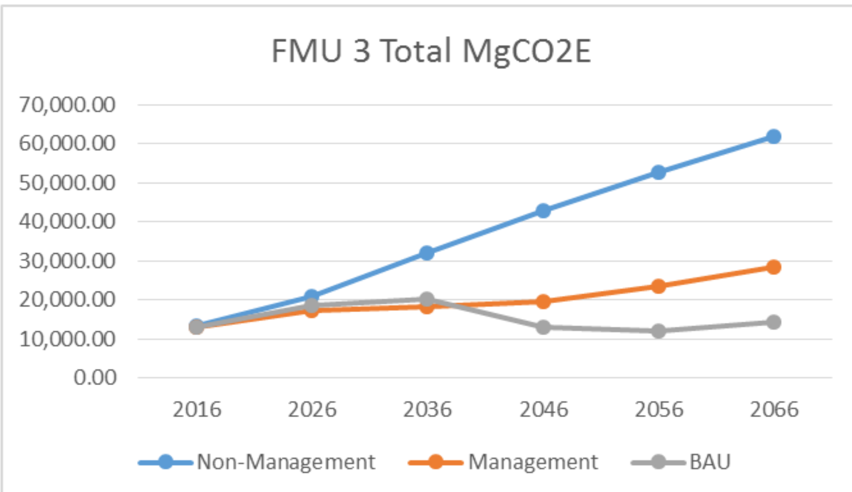


FMU 2 Total MgCO2E	Non-Management	Management	BAU
2016	7,175.00	7,175.00	7,169.40
2026	8,469.53	8,387.99	8,149.08
2036	18,894.60	15,315.37	15,271.45
2046	36,395.42	20,483.36	19,662.87
2056	56,482.03	24,451.23	12,678.47
2066	75,191.54	32,841.29	13,074.51

FMU 2 MgCO2E / Acre	Non-Management	Management	BAU
2016	68.24	68.24	68.18
2026	80.55	79.77	77.50
2036	179.69	145.65	145.23
2046	346.13	194.80	187.00
2056	537.16	232.54	120.58
2066	715.09	312.33	124.34

FMU 3 (73.5 acres; 75.9 acres including riparian zones)

FMU 3 exhibits similar attributes as FMU 2 and the carbon results are also similar. There is a consistent increase in carbon storage as time progresses with a divergence, similar to FMU 2, between non-management and management models due to material removal in the management model carbon data. The curves show a concave shape indicating carbon sequestration increasing at a decreasing rate.

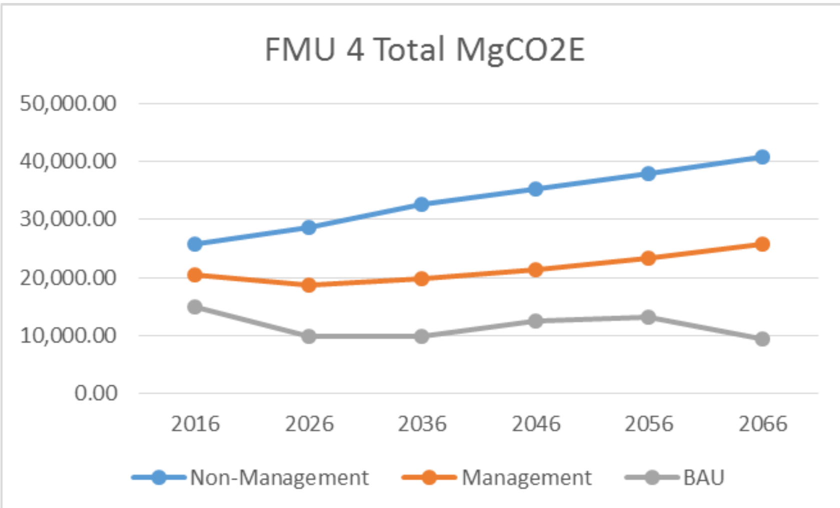


FMU 3 Total MgCO2E	Non-Management	Management	BAU
2016	13,464.92	13,213.98	12,929.81
2026	20,988.96	17,202.41	18,632.13
2036	31,961.28	18,412.30	20,360.68
2046	42,893.02	19,736.45	13,017.51
2056	52,816.69	23,579.32	11,943.14
2066	61,717.14	28,361.67	14,305.96

FMU 3 MgCO2E / Acre	Non-Management	Management	BAU
2016	177.31	174.01	170.26
2026	276.39	226.53	245.35
2036	420.88	242.46	268.12
2046	564.83	259.90	171.42
2056	695.51	310.50	157.27
2066	812.71	373.47	188.39

FMU 4 (97.7 acres, 107.6 acres including riparian zones)

FMU 4 shows a steady increase in the carbon storage due to all the harvest activity happening in 2016, indicated by the slightly negative slope between 2016 and 2026. As the conifers grow larger they store more carbon and their long lifespan allows the carbon storage to continue to rise. FMU 4 starts substantially lower than other units because a heavy thin takes place in 2016. Conversely to FMUs 2 and 3, the curves show a convex shape indicating carbon sequestration increasing at an increasing rate.

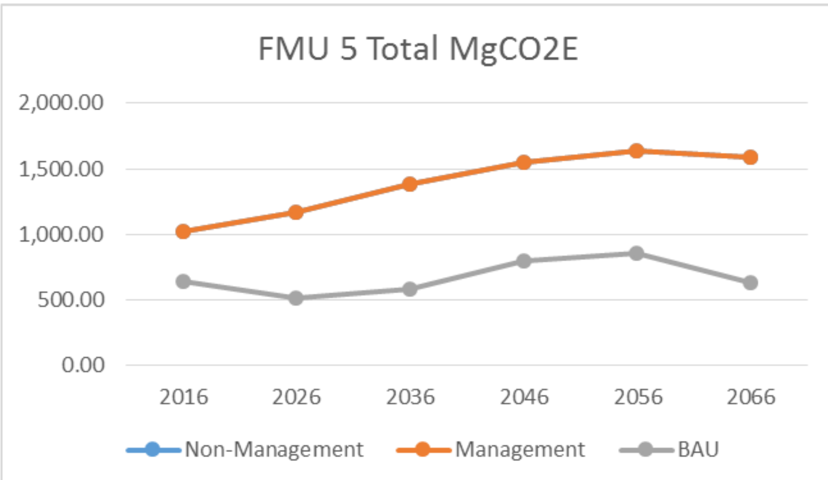


FMU 4 Total MgCO2E	Non-Management	Management	BAU
2016	25,829.16	20,546.88	15,001.84
2026	28,714.00	18,687.08	9,863.28
2036	32,572.43	19,785.82	9,828.54
2046	35,318.52	21,353.46	12,497.43
2056	37,910.56	23,332.38	13,030.35
2066	40,865.38	25,749.57	9,360.49

FMU 4 MgCO2E / Acre	Non-Management	Management	BAU
2016	240.14	191.03	139.47
2026	266.96	173.74	91.70
2036	302.83	183.95	91.38
2046	328.36	198.53	116.19
2056	352.46	216.92	121.14
2066	379.93	239.40	87.03

FMU 5 (5.7 acres; 7.7 acres including riparian zones)

FMU 5 is primarily red alder. Due to alder's short life span and limited natural regeneration, it is expected for FMU 5 to show an increase in carbon storage in the short term, but as the alder trees begin to die off, the carbon storage of the unit will decrease again. The model shows it maxing out in year 2056. There is a small uptick in the later model intervals due to the small conifer cohort outliving the red alder cohort and for natural alder regeneration growing.

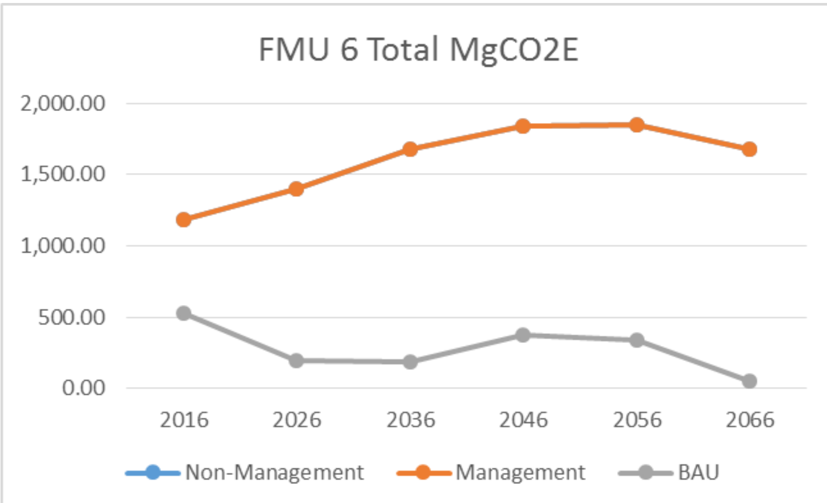


FMU 5 Total MgCO2E	Non-Management	Management	BAU
2016	1,023.60	1,023.60	637.99
2026	1,168.88	1,168.88	512.39
2036	1,381.72	1,381.72	583.80
2046	1,545.31	1,545.31	800.14
2056	1,632.47	1,632.47	859.61
2066	1,589.89	1,589.89	636.40

FMU 5 MgCO2E / Acre	Non-Management	Management	BAU
2016	132.08	132.08	82.32
2026	150.82	150.82	66.11
2036	178.29	178.29	75.33
2046	199.40	199.40	103.24
2056	210.64	210.64	110.92
2066	205.15	205.15	82.12

FMU 6 (6.2 acres, no riparian zone acres)

Our expectations for FMU 6 are analogous to FMU 5 due to having a nearly identical composition of red alder dominance. FMU 6 shows different carbon storage, despite being very similar units, due to localized variability between the two units.

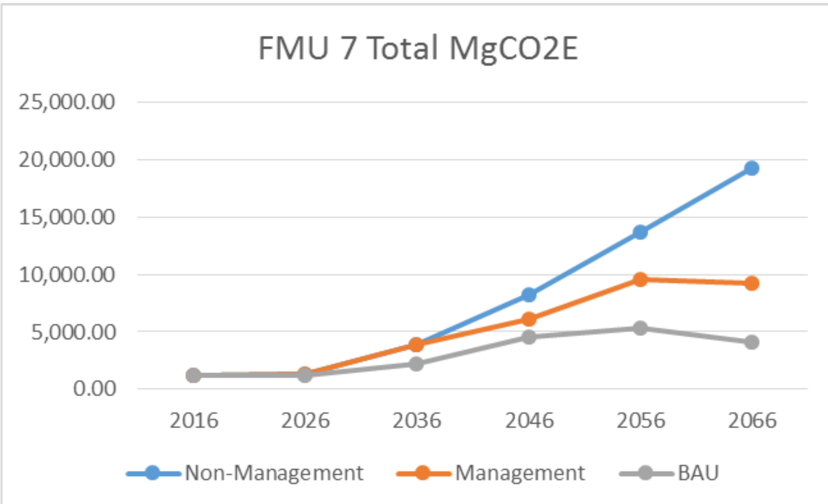


FMU 6 Total MgCO2E	Non-Management	Management	BAU
2016	1,181.67	1,181.67	526.80
2026	1,402.05	1,402.05	193.59
2036	1,680.31	1,680.31	188.52
2046	1,843.88	1,843.88	376.36
2056	1,853.80	1,853.80	336.32
2066	1,678.27	1,678.27	48.08

FMU 6 MgCO2E / Acre	Non-Management	Management	BAU
2016	190.59	190.59	84.97
2026	226.14	226.14	31.22
2036	271.02	271.02	30.41
2046	297.40	297.40	60.70
2056	299.00	299.00	54.25
2066	270.69	270.69	7.75

FMU 7 (24 acres; 26.2 acres including riparian zones)

FMU 7 is a different from other units in that it was clear-cut and planted anew at the beginning of the analysis cycle. We see the carbon relatively flat for the first time interval and for intermediate management interval in 2046. The carbon for the Management decreases in 2066 due to the thinning in 2061. The non-management and management model exhibit the same relationship as those in FMUs 2 and 3, except that the slope of the carbon accretion remains steep. Divergence between BAU and the Management simulations is due to an earlier PCT in the BAU scenario.



FMU 7 Total MgCO2E	Non-Management	Management	BAU
2016	1,155.27	1,155.27	1,153.85
2026	1,342.68	1,342.68	1,171.04
2036	3,888.32	3,894.91	2,246.39
2046	8,236.22	6,096.35	4,512.23
2056	13,694.20	9,523.02	5,306.14
2066	19,262.85	9,212.56	4,094.04

FMU 7 MgCO2E / Acre	Non-Management	Management	BAU
2016	44.09	44.09	44.04
2026	51.25	51.25	44.70
2036	148.41	148.66	85.74
2046	314.36	232.68	172.22
2056	522.68	363.47	202.52
2066	735.22	351.62	156.26

APPENDIX VI. MODELING OLD-GROWTH STRUCTURAL DEVELOPMENT

Old Growth Structural Index

For forest managers with conservation and restoration objectives, old-growth forests are a valuable point of reference for habitat and ecosystem services. Promoting forest characteristics that are commonly found in old growth forests correlates to increased habitat niches for old-growth dependent biota, and high-value ecosystem services including water quality and carbon storage. While younger forests also provide valuable, if different, habitat niches and services, old growth forests offer a unique set of habitats and ecosystem services that tend to be scarce on forested landscapes. We use the Old Growth Structural Index (OGSI) model developed by the Landscape Ecology, Modeling, Mapping, and Analysis[6] (LEMMA) group at Oregon State University (OSU) to assess conifer forest conditions for old-growth forest characteristics.

Overview

The OGSI score is a unitless value from zero to one hundred. The higher the number, the more the forest resembles old growth conditions. OGSI depends on four main characteristics: 1) the number of live large-diameter trees, 2) the number of snags, 3) the amount of downed wood, and 4) the diversity of live-tree diameters within a stand. We used inventory data to calculate OGSI for current stand conditions, and use results from the Forest Vegetation Simulator[7] (FVS) forest growth computer model to calculate OGSI for future stand conditions. An OGSI score was calculated for each unit in 10-year intervals. Each stand has an OGSI score for the management recommendations provided in this plan, as well as a comparison to a no-cut scenario. Forest growth was projected 100 years into the future. Model results increase in uncertainty the further into the future. Since the OGSI was developed for conifer-dominated forests, we exclude red alder-dominated units 5 and 6 from this analysis.

Modeling Details

OGSI scores are calculated using the Treelist and Downed Wood Cover output reports from FVS. The calculation is done with an R program using code adapted from the LEMMA group at OSU. Four intermediate scores, large trees per hectare (LTPH), snags per hectare (STPH), downed wood score (DCOV), Diversity Density Index (DDI), are weighted together to get the final OGSI score. DDI is an aggregate value representing four DBH size classes.

The LTPH value is critical to the final index score in that, it relies on an accurate forest cover type (dominant species) designation. Different cover types have different break diameters for

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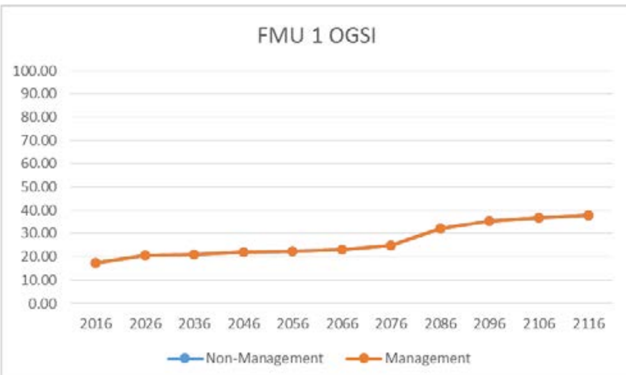
[6] http://lemma.forestry.oregonstate.edu/

[7] http://www.fs.fed.us/fmsc/fvs/

what is designated a large tree. For our purposes, the dominant cover type was determined by the species holding the majority TPA in each unit.

FMU 1

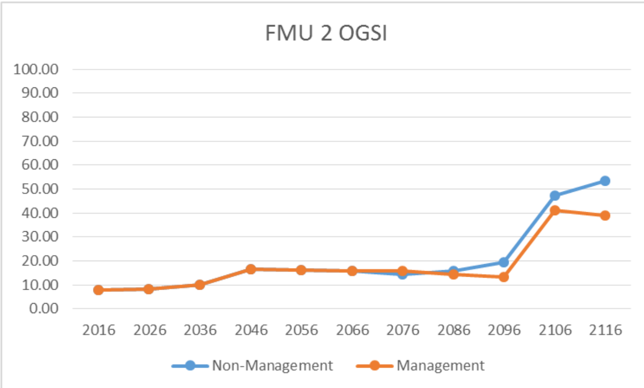
FMU 1 is designated as a western hemlock-dominated unit. No active management is prescribed for FMU 1, thus the non-management (baseline) and management (model) scenarios are identical. The LTPH score is relatively low due to the young age of the stand, resulting in a low to medium OGSI score ranging from 17.43 – 37.96. Western Hemlock has a DBH break diameter of 39 inches. FMU 1 showed few trees of that size throughout the management period.



FMU 1	Non-Management	Management	Difference
2016	17.43	17.43	0.00
2026	20.63	20.63	0.00
2036	20.81	20.81	0.00
2046	22.14	22.14	0.00
2056	22.22	22.22	0.00
2066	22.93	22.93	0.00
2076	24.90	24.90	0.00
2086	32.08	32.08	0.00
2096	35.49	35.49	0.00
2106	36.82	36.82	0.00
2116	37.96	37.96	0.00

FMU 2

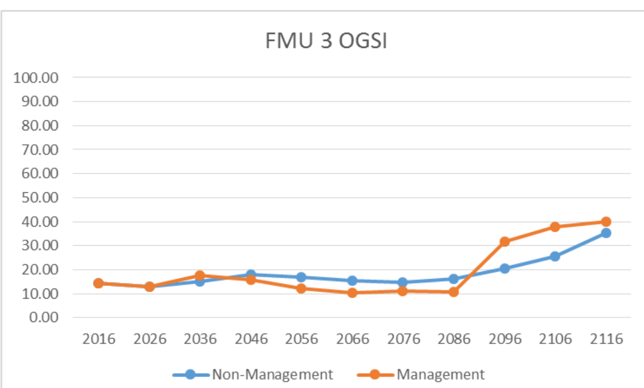
The FMU 2 non-management and management OGSI results track each other until 2086 when the non-management OGSI surpasses the management OGSI for FMU 2. The scenarios achieve maximum OGSIs of 53.36 (non-management) and 39.7 (management). The non-management scenario develops more snags and much more downed wood than the management scenario, resulting in the higher OGSI. The management prescription removes trees from the forest, rather than allowing natural mortality in-stand to create snags and logs. Even though thinning is taking place in the management scenario starting in 2026, the OGSI scores are match until the non-management forest conditions meet thresholds sufficient to increase the score. Although the non-management OGSI exceeds the management, the management scenario has greater large trees and greater diversity of diameters late in the model run. Since this is a young stand, understandably the OGSI score is low for several decades as the stand matures.



FMU 2	Non-Management	Management	Difference
2016	8.04	8.04	0.00
2026	8.17	8.17	0.00
2036	10.00	10.00	0.00
2046	16.70	16.70	0.00
2056	16.20	16.20	0.00
2066	15.95	15.92	-0.03
2076	14.59	15.75	1.16
2086	15.85	14.32	-1.53
2096	19.58	13.28	-6.30
2106	47.21	41.06	-6.15
2116	53.36	38.98	-14.39

FMU 3

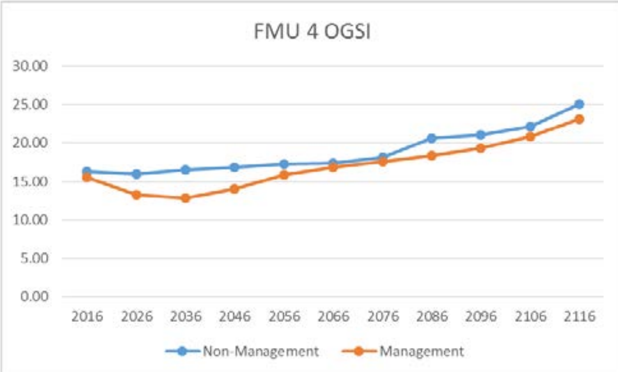
FMU non-management and management OGSI scores track very closely through the 100-year model timeframe, achieving a maximum OGSI of 35.2 (non-management) and 39.91 (management). These results are particularly interesting when compared to FMU 2. FMU 3 is about 7 years older than FMU 2, but in other aspects these stands have similar initial species composition and the same management prescription. Similar to FMU 2, this is a young stand that matures for several decades before increasing in OGSI. Although FMU 3 more closely resembles the old growth characteristics of an unmanaged stand, the total carbon storage is relatively low compared to the unmanaged FMU 2 scenario. FMU 3 has more large trees, snags, and downed logs than FMU 2 in both the non-management and management scenarios, but substantially lacks in diameter diversity. FMU 3 management scenario OSGI exceeds that of non-management in 2106, where the management actions result in larger trees and a greater diversity of tree diameters.



FMU 3	Non-Management	Management	Difference
2016	14.41	14.41	0.00
2026	12.97	13.01	0.04
2036	15.02	17.54	2.53
2046	17.81	15.92	-1.89
2056	16.82	12.13	-4.69
2066	15.33	10.55	-4.78
2076	14.61	10.96	-3.65
2086	16.09	10.65	-5.44
2096	20.40	31.77	11.37
2106	25.37	37.83	12.46
2116	35.20	39.91	4.71

FMU 4

After an initial drop following treatment in 2016, the management OGI score is slightly lower but closely tracks the non-management scenario. Similar to other units, the management scenario has substantially less dead wood in snags and logs, but has slightly more large trees than the no-management scenario.



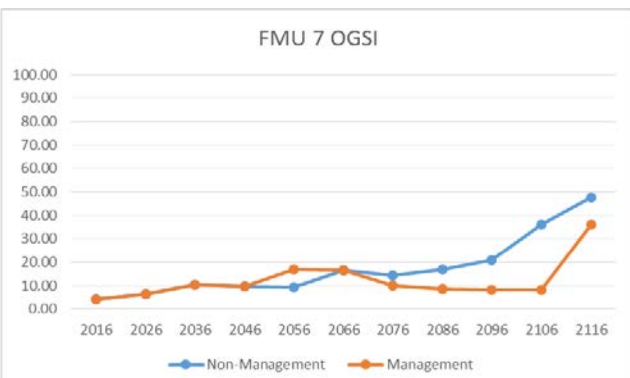
FMU 4	Non-Management	Management	Difference
2016	16.30	15.58	-0.72
2026	15.98	13.22	-2.76
2036	16.56	12.86	-3.70
2046	16.82	14.05	-2.77
2056	17.33	15.82	-1.51
2066	17.44	16.90	-0.54
2076	18.12	17.57	-0.55
2086	20.61	18.38	-2.22
2096	21.02	19.38	-1.64
2106	22.18	20.84	-1.34
2116	25.04	23.16	-1.88

FMU 5 and FMU 6

FMU 5 and FMU 6 are excluded from this analysis because they are not conifer-dominated stands for which the OGSI was developed.

FMU 7

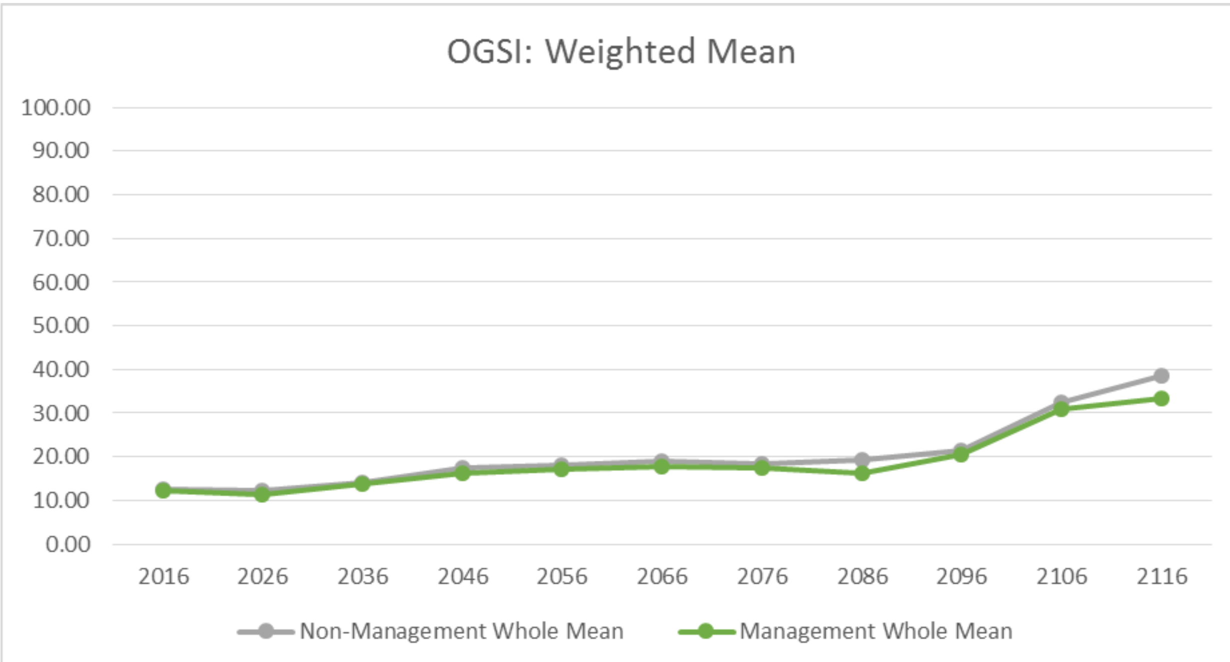
Similar to other stands, this is a young stand that matures for several decades before increasing in OGSI. After 100 years there are no trees that exceed the 39.4 inch DBH requirement for large-diameter large trees in either managed or unmanaged scenarios. The non-management and management OGSI scores track each other until year 2066 when the non-management OGSI increasing at a greater pace than the management OGSI. By 2116 the non-management is nearly 40 points higher than the management OGSI (47.6 compared to 8.1). This divergence is mainly due to the management scenario being devoid of large downed wood and large snags, due to harvest tree removal.



FMU 7	Non-Management	Management	Difference
2016	4.43	4.43	0.00
2026	6.35	6.35	0.00
2036	10.53	10.53	0.00
2046	9.85	9.85	0.00
2056	9.31	16.81	7.50
2066	16.45	16.43	-0.02
2076	14.52	9.93	-4.60
2086	16.77	8.75	-8.02
2096	20.93	8.33	-12.60
2106	35.96	8.15	-27.82
2116	47.59	36.04	-11.56

Entire Property

Average OGSI scores weighted to account for stand acreage for the entire property were determined for both the non-management and management scenarios. These averages show that no management overall yields a greater level of old growth conditions on the property by roughly 10 points. The increase in OGSI is mainly due to more snags and logs than the management scenarios. In some stands in some years, management scenario large trees and diameter diversity exceeded non-management.



Property Weighted Mean	Non-Management	Management
2016	12.45	12.22
2026	12.12	11.28
2036	14.22	13.66
2046	17.56	16.26
2056	18.04	17.05
2066	18.94	17.65
2076	18.29	17.30
2086	19.25	16.20
2096	21.43	20.59
2106	32.57	30.97
2116	38.48	33.51

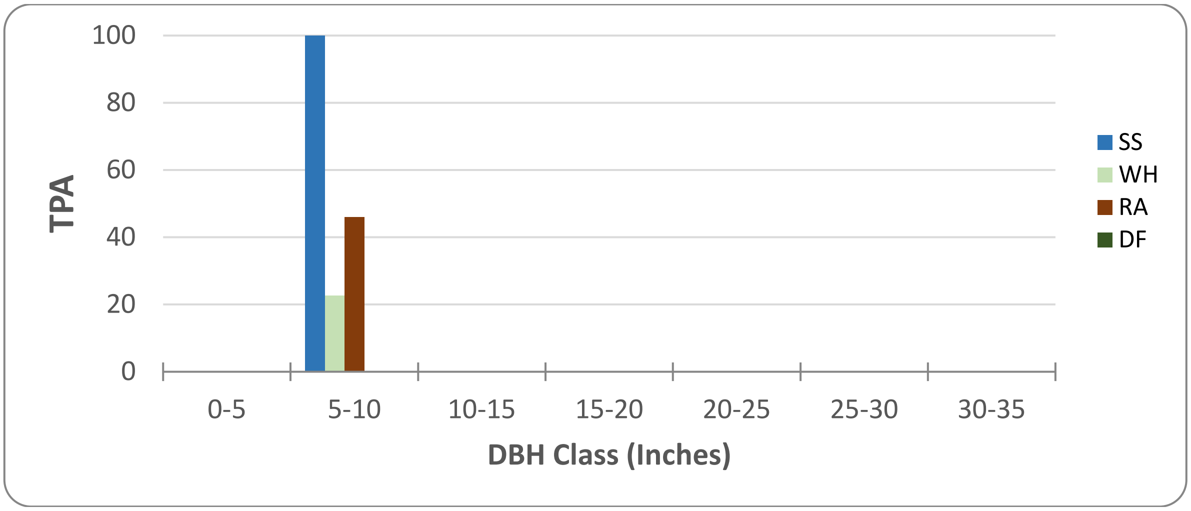
Conclusions

Generally, management scenarios increase tree size and diameter diversity compared to unmanaged stands. Repeated thinning that preserves a proportion of large trees results in more rapid tree growth and ultimately larger trees. Thinning also allows more light to reach the forest floor compared to no management, increasing viability of understory and midstory trees. While no-management's total old-growth score is slightly higher than the with-management scenarios, the with-management scenarios result larger live trees and greater diversity in tree size. Over longer time frames, we would expect the with-management scenarios to exceed the no-management scenarios. As the dead wood components of the with-management increase, the larger live trees and more diverse tree sizes will add up to a robust forest on a trajectory towards old-growth characteristics.

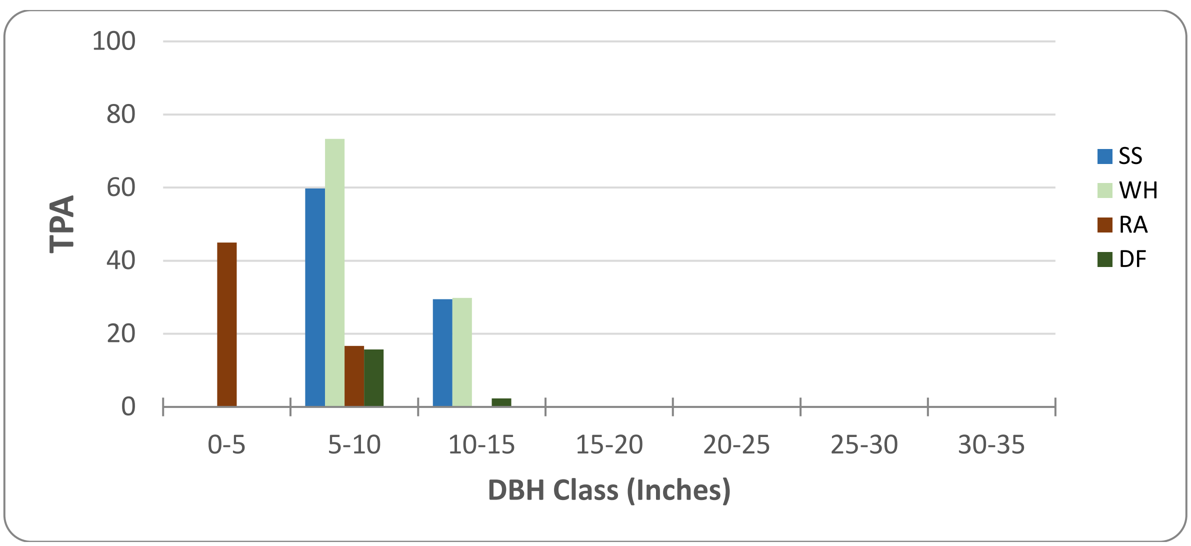
APPENDIX VII: SUMMARY FROM FVS GROWTH & YIELD MODELING

Comparison of Similar FMUs: First Commercial Entry, 30-Year WH/SS FMUs

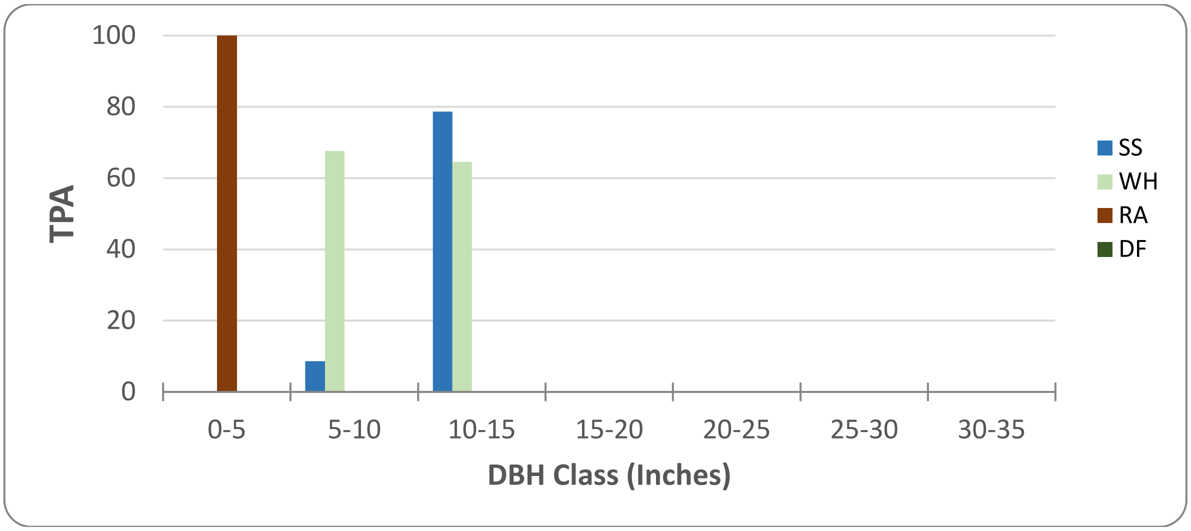
FMU 2: 2036 Cut Tree Diameter Classes



FMU 3: 2026 Cut Tree Diameter Classes

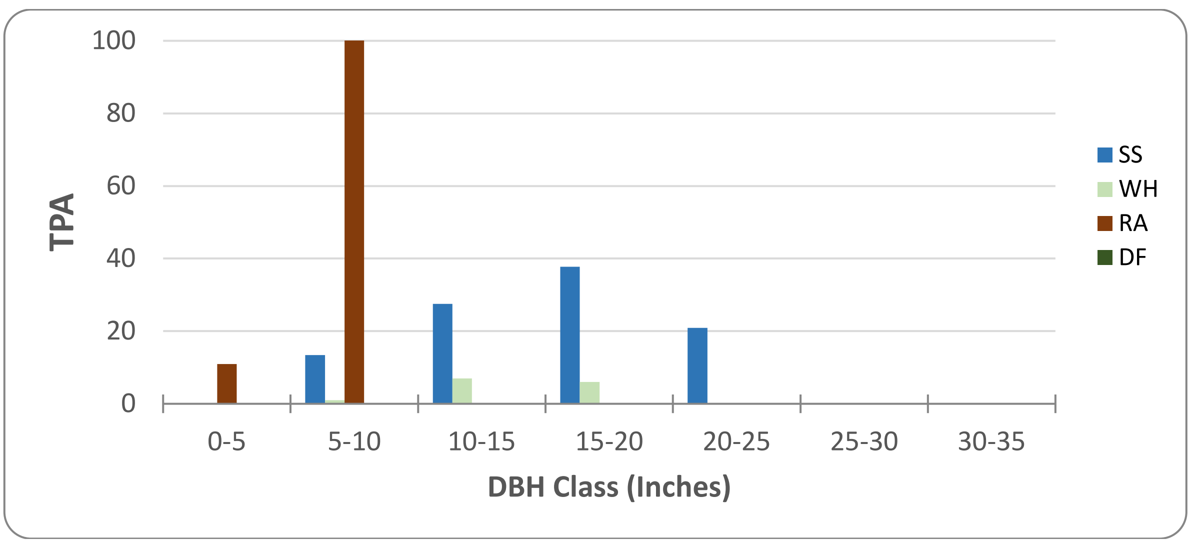


FMU 7: 2046 Cut Tree Diameter Classes

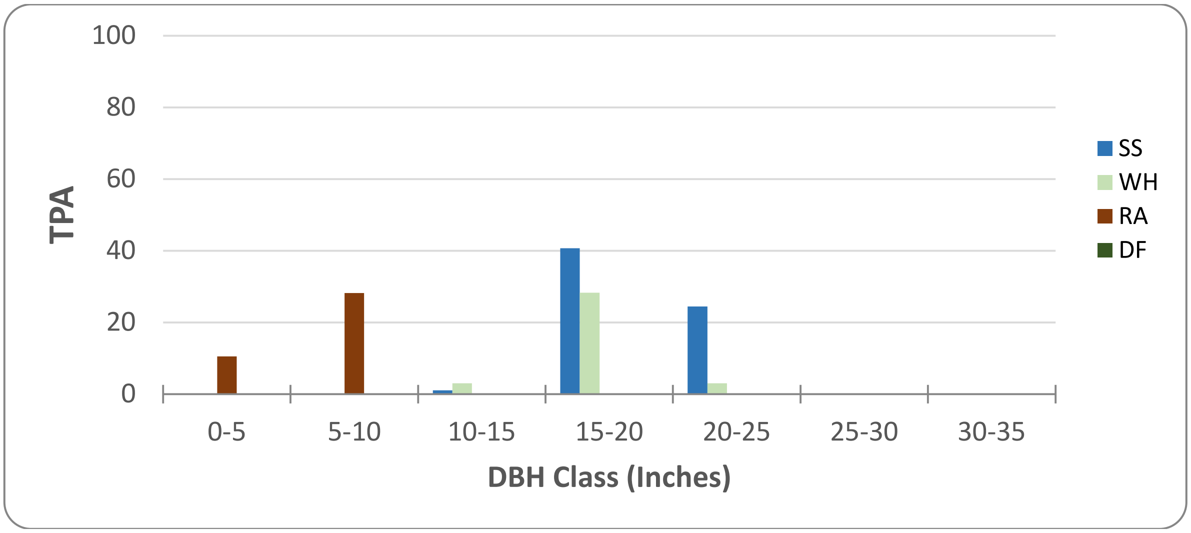


Comparison of Simlar FMUs: Second Commercial Entry, 45-Year WH/SS FMUs

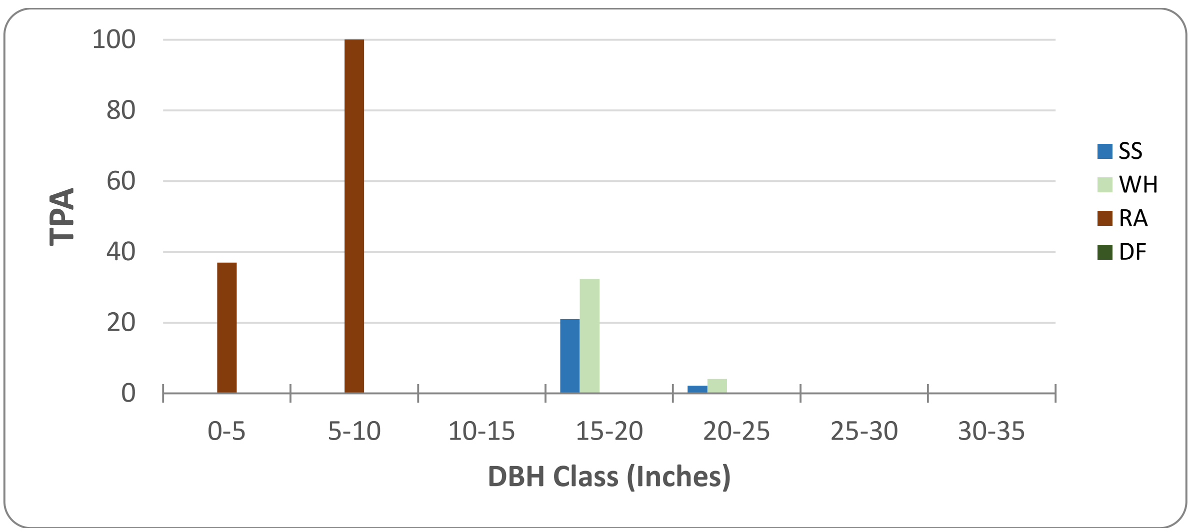
FMU 2: 2051 Cut Tree Diameter Classes



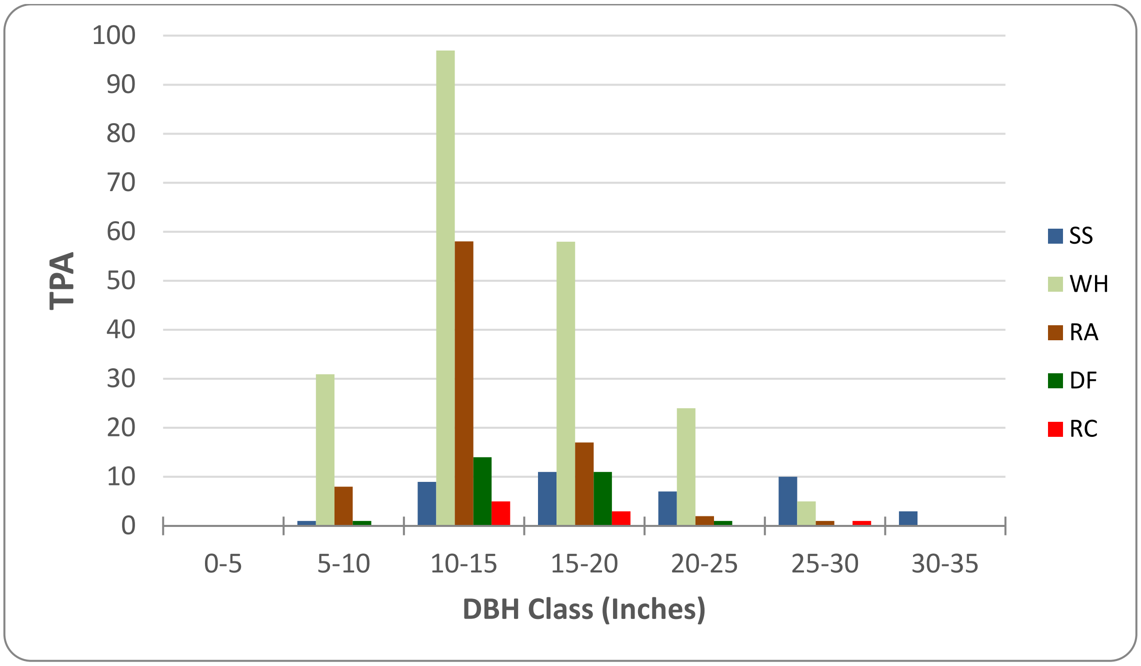
FMU 3: 2041 Cut Tree Diameter Classes



FMU 7: 2061 Cut Tree Diameter Classes



FMU 4: 2016 Cut Tree Diameter Classes



Log Sorts and Prices used in this analysis

Mill Prices	DF	WH	SS	RA	RC	BM
Per MBF						
Saw1	$800	$600	$500	$750		$400
Saw2	$600	$535	$500	$750		$400
Saw3	$585	$530	$400	$600		$400
Chip & Saw	$450	$420	$350	$450		$300
Camprun					$1,200	
Per Ton						
Pulp	$30	$30	$30	$30		$30

Harvest Volume Summaries: Total MBF Logs, All Sorts (Helicopter and Cable)

Total Saw MBF	Stand								
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**RMZ**	**Total**
2016	-	-	-	754	-	-	-	-	**754**
2026	-	-	469	-	-	-	-	-	**469**
2036	-	377	-	-	-	-	-	-	**377**
2041	-	-	711	-	-	-	-	-	**711**
2046	-	-	-	-	-	-	313	-	**313**
2051	-	971	-	-	-	-	-	-	**971**
2056	-	-	-	-	-	-	-	-	**-**
2061	-	-	-	-	-	-	401	-	**401**
Total	-	**1,348**	**1,181**	**754**	-	-	**714**	-	**3,997**

Harvest Volume Summaries: Total Tons Pulp (Cable Only)

Total Pulp Tons	Stand								
Year	1	2	3	4	5	6	7	RMZ	Total
2016	-	-	16	76	-	-	-	-	**92**
2026	-	-	344	-	-	-	-	-	**344**
2036	-	450	-	-	-	-	-	-	**450**
2041	-	-	75	-	-	-	-	-	**75**
2046	-	-	-	-	-	-	122	-	**122**
2051	-	395	-	-	-	-	-	-	**395**
2056	-	-	-	-	-	-	-	-	**-**
2061	-	-	-	-	-	-	43	-	**43**
Total	-	**845**	**435**	**76**	**-**	**-**	**165**	**-**	**1,521**

Harvest Volume Summaries: Per Acre MBF Logs, All Sorts (Helicopter and Cable)

Saw MBF/Acre	Stand							
Year	1	2	3	4	5	6	7	RMZ
2016	-	-	-	7.7	-	-	-	-
2026	-	-	6.4	-	-	-	-	-
2036	-	3.7	-	-	-	-	-	-
2041	-	-	9.7	-	-	-	-	-
2046	-	-	-	-	-	-	13.0	-
2051	-	9.6	-	-	-		-	-
2056	-	-	-	-	-	-	-	-
2061	-	-	-	-	-	-	16.7	-

Harvest Volume Summaries: Per Acre Tons Pulp (Cable Only)

Pulp Tons/Acre	Stand							
Year	1	2	3	4	5	6	7	RMZ
2016	-	-	0.2	0.8	-	-	-	-
2026	-	-	4.7	-	-	-	-	-
2036	-	4.4	-	-	-	-	-	-
2041	-	-	1.0	-	-	-	-	-
2046	-	-	-	-	-	-	5.1	-
2051	-	3.9	-	-	-	-	-	-
2056	-	-	-	-	-	-	-	-
2061	-	-	-	-	-	-	1.8	-

Harvest Summary by Stand: Logging Volume, Costs, and Revenue

Unit 1							
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_1	No Action	0	0	$ -	$ -	$ -
2026	2026_1	No Action	0	0	$ -	$ -	$ -
2036	2036_1	No Action	0	0	$ -	$ -	$ -
2046	2046_1	No Action	0	0	$ -	$ -	$ -
2056	2056_1	No Action	0	0	$ -	$ -	$ -
TOTAL							**$ -**

Unit 2

Unit 2		Helicopter					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_2	No Action	-	-	$ -	$ -	$ -
2026	2026_2	PCT 350 TPA	-	-	$ 28,885	$ -	$ (28,885)
2036	2036_2	Commercial Thin	377	-	$ 147,157	$ 139,255	$ (7,902)
2051	2051_2	Commercial Thin	971	-	$ 378,672	$ 499,887	$ 121,215
2056	2056_2	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 84,428**

Unit 2		Cable					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_2	No Action	-	-	$ -	$ -	$ -
2026	2026_2	PCT 350 TPA	-	-	$ 28,885	$ -	$ (28,885)
2036	2036_2	Commercial Thin	377	450	$ 145,256	$ 152,745	$ 7,489

Year	ID	Rx	MBF Saw	Pulp Tons	Costs	Revenue	Net
2051	2051_2	Commercial Thin	971	395	$ 356,865	$ 511,749	$ 154,884
2056	2056_2	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 133,488**

Unit 3

Unit	**3**	**Helicopter**					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_3	PCT 350 TPA	-	-	$ 20,959	$ -	$ (20,959)
2026	2026_3	Commercial Thin	469	-	$ 183,062	$ 181,769	$ (1,293)
2041	2041_3	Commercial Thin	711	-	$ 277,400	$ 417,995	$ 140,595
2046	2046_3	No Action	-	-	$ -	$ -	$ -
2056	2056_3	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 118,343**

Unit	**3**	**Cable**					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_3	PCT 350 TPA	-	-	$ 20,959	$ -	$ (20,959)
2026	2026_3	Commercial Thin	469	344	$ 174,668	$ 192,074	$ 17,406
2041	2041_3	Commercial Thin	711	75	$ 257,409	$ 420,244	$ 162,835
2046	2046_3	No Action	-	-	$ -	$ -	$ -
2056	2056_3	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 159,282**

Unit 4

Unit	4	Helicopter					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_4	Commercial Thin	754	76	$ 293,991	$ 415,367	$ 121,377
2026	2026_4	No Action	-	-	$ -	$ -	$ -
2036	2036_4	No Action	-	-	$ -	$ -	$ -
2046	2046_4	No Action	-	-	$ -	$ -	$ -
2056	2056_4	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 121,377**

Unit	4	Cable					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_4	Commercial Thin	754	76	$ 271,376	$ 415,367	$ 143,991
2026	2026_4	No Action	-	-	$ -	$ -	$ -
2036	2036_4	No Action	-	-	$ -	$ -	$ -
2046	2046_4	No Action	-	-	$ -	$ -	$ -
2056	2056_4	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ 143,991**

Unit 5 (no management)

Unit	5						
Year	ID	Rx	MBF Saw	Pulp Tons	Costs	Revenue	Net
2016	2016_5	No Action	-	-	$ -	$ -	$ -
2026	2026_5	No Action	-	-	$ -	$ -	$ -
2036	2036_5	No Action	-	-	$ -	$ -	$ -
2046	2046_5	No Action	-	-	$ -	$ -	$ -
2056	2056_5	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ -**

Unit 6 (no management)

Unit	6						
Year	ID	Rx	MBF Saw	Pulp Tons	Costs	Revenue	Net
2016	2016_6	No Action	-	-	$ -	$ -	$ -
2026	2026_6	No Action	-	-	$ -	$ -	$ -
2036	2036_6	No Action	-	-	$ -	$ -	$ -
2046	2046_6	No Action	-	-	$ -	$ -	$ -
2056	2056_6	No Action	-	-	$ -	$ -	$ -
TOTAL							**$ -**

Unit 7

Unit 7		**Helicopter**					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_7	No Action	-	-	$ -	$ -	$ -
2026	2026_7	No Action	-	-	$ -	$ -	$ -
2036	2036_7	PCT 350 TPA	-	-	$ 6,840	$ -	$ (6,840)
2046	2046_7	Commercial Thin	313	-	$ 121,966	$ 131,766	$ 9,801
2061	2061_7	Commercial Thin	401	-	$ 156,473	$ 264,924	$ 108,450
TOTAL							**$ 111,411**

Unit 7		**Cable**					
Year	**ID**	**Rx**	**MBF Saw**	**Pulp Tons**	**Costs**	**Revenue**	**Net**
2016	2016_7	No Action	-	-	$ -	$ -	$ -
2026	2026_7	No Action	-	-	$ -	$ -	$ -
2036	2036_7	PCT 350 TPA	-	-	$ 6,840	$ -	$ (6,840)
2046	2046_7	Commercial Thin	313	122	$ 114,596	$ 135,427	$ 20,831
2061	2061_7	Commercial Thin	401	43	$ 145,210	$ 266,215	$ 121,004
TOTAL							**$ 134,995**

Harvest Volume by Species and Sort

			Merchantable Log Grade: BF/Acre						Pulp wood /Acre
Stand	Cut Year	Species	Saw1	Saw2	Saw3	CnS	P/U	TOTAL BF	Tons
UNIT 2									
2	2036	SS	0	0	0	2,120	0	2,120	2.2
2	2036	WH	0	0	0	568	0	568	0.5
2	2036	RA	0	0	0	1,035	0	1,035	1.7
							Subtotal	**3,723**	**4.4**
2	2051	SS	0	2,712	4,365	1,474	0	8,550	0.3
2	2051	WH	0	0	361	89	0	450	0.0
2	2051	RA	0	0	0	580	0	580	3.6
							Subtotal	**9,580**	**3.9**
UNIT 3									
3	2026	SS	0	0	117	2,493	0	2,610	0.9
3	2026	WH	0	0	721	2,435	0	3,156	2.3
3	2026	RA	0	0	0	331	0	331	0.8
3	2026	DF	0	0	0	285	0	285	0.7
							Subtotal	**6,383**	**4.7**
3	2041	SS	0	3,135	2,623	1,040	0	6,797	0.0
3	2041	WH	0	519	1,874	481	0	2,875	0.0
3	2041	RA	0	0	0	0	0	0	0.1
3	2041	DF	0	0	0	0	0	0	0.0
							Subtotal	**9,672**	**0.1**
UNIT 4									
4	2016	WH	0	357	2580	1188	0	4124	0.5
4	2016	RA	0	190	1121	858	0	2169	0.3
4	2016	SS	0	348	319	154	0	822	0.0
4	2016	DF	0	15	339	126	0	480	0.0
4	2016	RC	0	18	52	52	0	123	0.0
							Subtotal	**7,717**	**0.8**
UNIT 7									
7	2046	SS	0	0	4,893	1,747	0	6,641	0.5
7	2046	WH	0	0	4,787	1,603	0	6,390	3.0
7	2046	RA	0	0	0	0	0	-	1.6
							Subtotal	**13,031**	**5.1**
7	2061	SS	0	3,352	2,423	636	0	6,411	0.0
7	2061	WH	0	3,792	5,786	729	0	10,306	0.0

7	2061	RA	0	0	0	0	0	-	1.8
							Subtotal	**16,717**	**1.8**

Harvest Revenue by Species and Sort

			Revenue/Acre						Total Revenue
Stand	Cut Year	Species	Saw1	Saw2	Saw3	Chip & Saw	Camprun	Pulp	Total$/Acre
UNIT 2									
2	2036	SS	$0	$0	$0	$ 705	$ -	$ 67	$ 772
2	2036	WH	$0	$0	$0	$ 226	$ -	$ 15	$ 242
2	2036	RA	$0	$0	$0	$ 443	$ -	$ 51	$ 494
								Subtotal	**$1,507**
2	2051	SS	$0	$ 1,288	$ 2,689	$ 490	$ -	$ 9	$ 4,477
2	2051	WH	$0	$ -	$ 182	$ 35	$ -	$ 0	$ 218
2	2051	RA	$0	$ -	$ -	$ 248	$ -	$ 107	$ 355
								Subtotal	**$5,049**
UNIT 3									
3	2026	SS	$0	$0	$ 45	$ 829	$ -	$ 26	$ 899
3	2026	WH	$0	$0	$ 363	$ 972	$ -	$ 69	$ 1,404
3	2026	RA	$0	$0	$ -	$ 142	$ -	$ 24	$ 166
3	2026	DF	$0	$0	$ -	$ 122	$ -	$ 21	$ 143
								Subtotal	**$2,612**
3	2041	SS	$0	$ 1,489	$ 2,188	$ 346	$ -	$ -	$ 4,023
3	2041	WH	$0	$ 264	$ 1,205	$ 192	$ -	$ -	$ 1,661
3	2041	RA	$0	$ -	$ -	$ -	$ -	$ 31	$ 31
3	2041	DF	$0	$ -	$ -	$ -	$ -	$ -	$ -
								Subtotal	**$5,714**
UNIT 4									
4	2016	WH	$0	$181	$1,479	$474	$0	$14	$2,134
4	2016	RA	$0	$135	$747	$367	$0	$8	$1,249
4	2016	SS	$0	$165	$254	$51	$0	$1	$470
4	2016	DF	$0	$8	$197	$54	$0	$1	$259

4	2016	RC	$0	$0	$0	$0	$140	$0	$140
								Subtotal	**$4,252**
UNIT 7									
7	2046	SS	$0	$0	$ 1,860	$ 581	$ -	$ 16	$ 2,457
7	2046	WH	$0	$0	$ 2,410	$ 640	$ -	$ 90	$ 3,139
7	2046	RA	$0	$0	$ -	$ -	$ -	$ 47	$ 47
								Subtotal	**$5643**
7	2061	SS	$0	$ 1,592	$ 2,195	$ 211	$ -	$ -	$ 3,998
7	2061	WH	$0	$ 1,927	$ 4,822	$ 291	$ -	$ -	$ 7,041
7	2061	RA	$0	$ -	$ -	$ -	$ -	$ 54	$ 54
								Subtotal	**$11,092**

COST ASSUMPTIONS	COST	PER	
No Action	$0	Acre	
Logging Costs & Admin	($/mbf)	Unit	
Stump to truck (Cut to Length)	$225	MBF	
Stump to truck - thin (Fellarbuncher - skidder)	$150	MBF	
Stump to truck - regen (Fellarbuncher - skidder)	$80	MBF	
Stump to truck - thin (Cable)	$250	MBF	
Stump to truck - helicopter	$280	MBF	6.5 MBF/hr and $2,300/hr
Haul to Hampton in Tillamook	$80	MBF	30 miles ($100 per hour cost)
Timber sale admin	$30	MBF	
Road Costs	Station (100')	Unit	Per Foot
New temp road per station (Gentle terrain)	$150	Station	$1.50
Road upgrades & maintence	$100	Station	$1.00
Road to trail conversion	$100	Station	$1.00
Road obliteration	$200	Station	$2.00
Culvert replacement	$600.00	Each	each
Planting Costs	$ per tree	Unit	
Site prep (necessary if no harvest)	$1.00	Tree	
Bare root seedlings	$0.55	Tree	
Planting labor	$0.45	Tree	
Layout & contract admin	$0.30	Tree	
Mesh browse control for red cedar +extra labor	$1.00	Tree	
Shrub & browse control for planting	$ per tree	Unit	
Herbicide followup shrub contol: yr 1	$1.00	Tree	Need 1 treatment
Manual followup shrub control: yrs 1,3, & 5	$1.00	Tree	Need 3 treatments
Admin: Layout & admin	$0.20	Tree	
Non Commercial Drop & Leave	Per Acre	Unit	
PCT	$250	Acre	
Commercial Size Conifer (drop 50 tpa)	$250	Acre	
Commercial Size Hardwood (drop 15 tpa)	$150	Acre	
Layout & contract admin	$35	Acre	
Invasive Treatments	Per Acre	Unit	
Post thin Invasives control: herbicide yrs 1,3	$80	Acre	
Post thin Invasives control: Manual yrs 1,3,5	$60	Acre	
Heavy Scotchbroom or Him. Blackberry Treat	$650	Acre	Machine cutting + Herbicides

Ivy treatment	$1,500	Acre	Hand cut + Herbicides
Followup treatment Scotchbroom, HBB, or Ivy	$200	Acre	Manual w herbicide: yrs 1,2,4
Layout & contract admin	$30	Acre	