A CONCEPTUAL PLAN FOR THE FOREST LANDSCAPE OF FORT CLATSOP NATIONAL MEMORIAL

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PREFACE

The ideas and concepts in this report have at least in part been in operation at Fort Clatsop for 20 years; they are not new. Mr. Ross Peterson gave the park a 20 year head start on historic landscape restoration through his competent and thorough tree planting and culturing techniques, and this report is dedicated to him. Current park staff members Curt Johnson, Curt Ahola, and Frank Walker were helpful in requesting this longer-term look at the Fort Clatsop landscape and in providing resources and advice. This report was funded through Cooperative Agreement CA-9000-3-0004, Subagreement 1, between the National Park Service and the University of Washington.
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INTRODUCTION

This report is the result of a request by Superintendent Frank Walker for an evaluation of the past and present forest management programs at Fort Clatsop National Memorial. What is the desired "end-point" of forest restoration towards which forest management should move? Have the tree plantings made in open spaces and other silvicultural treatments over the past decades been suitable for restoration of an appropriate landscape setting for the historical theme of the park? In answering these questions, this report focuses on the central unit of the park which includes the encampment site, and does not include that coastal beach portion of the park including the salt cairn.

The organization of this report reflects those questions and contains recommendations towards achieving specified goals. It begins with a definition of appropriate goals, which have been implicitly carried out over the last three decades by the park staff and volunteers. The second section contains an evolution of the park forest landscape from prehistoric times to the present, including some basic ecological principles about the major tree species. The third section summarizes landscape restoration actions to date and potential future actions, including actions to deal with disturbance by insects, disease, fire, and wind.
This report is more a conceptual landscape plan than a specific horticultural plan. It does not contain specific recommendations for planting in the developed area of the park, although potential species useful in given situation are mentioned. Such recommendations can be obtained from landscape architects working with traffic flow and interpretive settings. It is also not a hazard tree plan, although it addresses the issue of creation or elimination of hazard. Hazard ratings and treatment are best addressed on a tree by tree basis in the developed area (see Mills and Russell 1980 for an adequate treatment of the subject). Instead, this report focuses on restoring and maintaining the forest landscape as it appeared to the Lewis and Clark party.

FOREST LANDSCAPE OBJECTIVES

The purpose of establishing Fort Clatsop National Memorial in 1958 was: "For the purpose of commemorating the culmination, and the winter encampment, of the Lewis and Clark Expedition following its successful crossing of the North American Continent."

National Park Service Management Policies (1988) define broad guidelines for managing the forests of the park. All of the acreage of the park is zoned historical, which
defines the landscape as a cultural landscape within the Management Policies. In part, the Policies state:

Cultural zones have, as their primary objectives, the maintenance of the historic scene and the protection of the integrity of their cultural resources. The management of their natural resources will support cultural resource objectives.

Trees, other plants, and landscapes in a cultural zone generally will be managed to reflect the scene that prevailed during the historic period, except that soil erosion will be prevented wherever possible.

The management of cultural landscapes will recognize and protect significant historic, archeological, ethnographic, and design values. Treatment decisions will take into account both the natural and built features of the landscape and the dynamics inherent in natural processes and continued human and animal occupation. The perpetuation of significant vistas and historic parkway and park road landscape design features will receive special emphasis.

In addition, the Management Policies recognize the potential for cultural resource preservation, rehabilitation, restoration, and reconstruction, given a variety of existing conditions and the need and ability for management action.

The Fort Clatsop Resource Management Plan (1986), as a subsidiary document to national legislation and policy, defines the primary natural resources objective "To maintain and restore the historic native plant communities of the Lewis and Clark period where ecologically feasible."

Together, these laws, policies, and plans provide an excellent framework within which a conceptual forest
landscape plan can be developed. For the purposes of this plan, the primary objective is to restore a mimic of natural forest species composition and structure that may have existed in the time of Lewis and Clark. In achieving this objective, it must be recognized that forest ecosystems are dynamic and ever-changing. There is no single point in time for which forest composition and structure can be recreated and "frozen". Rather than a snapshot "vignette" of the 1805 forests of Fort Clatsop, we must realistically deal with a "moving picture" of natural forest species composition and structure. The next section of the report describes that "moving picture" of the forest landscape over time.

DEVELOPMENT OF THE FOREST LANDSCAPE OF FORT CLATSOP

Fort Clatsop National Memorial (Figure 1) is located within the "Sitka Spruce Zone" defined by Franklin and Dyrness (1973). This vegetation zone is found along the west coast of North America from northern California to southeastern Alaska. It is often described as a variant of the "Western Hemlock Zone" characterized by its coastal location, frequent fogs, and presence of Sitka spruce (Picea sitchensis) as a major dominant. Other major tree dominants within this zone are western hemlock (Tsuga heterophylla), western redcedar (Thuja plicata), red alder (Alnus rubra), and Douglas-fir (Pseudotsuga menziesii). Minor but common trees include Pacific silver fir (Abies amabilis), grand fir
Figure 1. Fort Clatsop National Memorial is located in northwestern Oregon. The Sitka spruce zone is a coastal vegetation type, and Fort Clatsop is in the southern portion of this zone.
(Abies grandis), shore pine (Pinus contorta), western white pine (Pinus monticola), and bigleaf maple (Acer macrophyllum).

The Sitka Spruce Zone has perhaps the mildest climate of any of the Pacific Northwest vegetation zones. Precipitation in the vicinity of Astoria is roughly 200 cm (80 in) per year, and the average temperature is 10.6°C, with only a 12°C average annual range. Summer precipitation averages 14 cm (6 in). These are ideal conditions for coniferous tree growth, and not surprisingly, the forest stands in this zone are among the most productive in the world (Fugimori 1971).

The successional dynamics of these coastal forests are complex because of the types and intensities of disturbances that have interacted with the forests over time. In the absence of disturbance over many centuries, western hemlock and western redcedar would probably dominate the forests of Fort Clatsop. In the presence of major periodic disturbance such as fire which remove almost all of the pre-existing stand, Douglas-fir would initially dominate on upland sites and red alder would initially dominate on wet sites, gradually being replaced by hemlock and cedar. Sitka spruce appears to be a "gap-phase" species that is capable of regenerating in small openings created by windthrow or overstory mortality (Hines 1971). Large fires and blowdowns do occur in spruce-hemlock forests, but smaller scale events
may be equally important forces in forest stand development (Harcombe 1986). Evidence from Fort Clatsop suggests that periodic natural disturbance was a very significant factor in the development of the forests that Lewis and Clark described.

Wind As A Disturbance Factor

Wind appears to have been the most important disturbance factor for the forests of Fort Clatsop, but fire was also important. The two most significant lines of evidence for the importance of wind in stand development at Fort Clatsop are (a) "pit and mound" topography, and (b) prehistoric species composition.

"Pit and mound" topography is a hummocky ground topography caused by uprooting of tree stems by wind, causing the "pit", and subsequent sloughing of the soil material from the base of the uprooted stem, creating the adjacent mound (Figure 2). Usually, the prevailing wind direction creates a pattern of pits on the upwind side and mounds on the downwind (direction of tree fall) side. Several sections of Fort Clatsop contain classic "pit and mound" topography suggesting prevailing winds from the south. Most recent windthrown trees are also oriented in this way. Studies of windthrow in Washington and Oregon suggest most damaging winds are from the southwest (Ruth and Yoder 1953,
Figure 2. The development of pit and mound topography occurs when soil is pulled out with the root wad during a windthrow event. Later sloughing and decomposition leaves a pit on the windward side and a mound on the lee side of the pit.
The frequency of winds strong enough to affect stand dynamics at Fort Clatsop cannot be determined with much accuracy. However, the topographic situation of the park (Figure 3) is such that it should be sheltered from the worst southwest winds by the ridge immediately to the west of the park. This assessment is consistent with that of Meriwether Lewis, who noted on February 15, 1806: "...the S.W. winds are frequently very violent on the coast when we are but little sensible of them at Fort Clatsop, in consequence of the lofty and thickly timbered fir country which surrounds us from that quarter, from the south to the N. East." At Cascade Head, near Otis, Lincoln County, Oregon, which is a more exposed forest to the southwest wind, Harcombe (1986) suggests that small scale events have a larger impact on the forest than large scale blowdowns, comparing the canopy turnover time of 119 years from small scale events to 384 years for blowdown from large scale events (i.e., time for an area equal to the forest area to blow down from either type of disturbance). In fact, both types of blowdown occur, but basing longterm windthrow return intervals on 50 years of record, as Harcombe does, is not a very reliable method of prediction for such an episodic disturbance.
Figure 3. Fort Clatsop is located on the lee side of Clatsop Ridge, a several hundred foot high ridge that protects the site from prevailing southwest storm winds.
In addition to the "pit and mound" topography, prehistoric species composition may also provide a clue to the most important disturbance factor. On a site visit in February, 1988, 21 charcoal samples were collected from buried sites in the park. Each sample was taken from locations unlikely to have been affected by European settlers (as the forest was cut and burned in the historic period). Such locations included log fragments substantially buried in cut banks, and log fragments extracted from beneath 2 m diameter stumps (the several hundred year old trees germinated on the old burned logs). Charcoal identifications were made by Dr. Everett Ellis, Affiliate Professor, College of Forest Resources, University of Washington. Of the 21 samples, 8 were western hemlock, 6 were Sitka spruce, 6 were western redcedar, and 1 was a hardwood (possibly red alder). This ancient fire, or conceivably a series of fires, essentially preserved a sample of the ancient forest by creating the charcoal, which is very resistant to decay. The age of the fire or fires is unknown, but judging from the large trees growing over some of the charcoal pieces it must have been hundreds of years ago. The samples do not represent a random sample of all charcoal on the site, so the fact that 38% of the samples were western hemlock cannot be used to imply that 38% of the trees or basal area of the forest was hemlock. However, the complete absence of Douglas-fir suggests it probably was of low abundance in the area at the time of the fire. The predominance of hemlock, spruce, and
cedar, which are all shade-tolerant and can successfully regenerate under single-tree or small gap openings, implies that wind was an important disturbance process in the prehistoric forest.

Fire As A Disturbance Factor

The presence of buried charcoal at Fort Clatsop is proof that fire did occur in the prehistoric forest. However, the occurrence of charcoal may be evidence of only one fire; had fire been recurrent, more Douglas-fir should have been on-site and preserved in the charcoal record. Fires, although infrequent, play an important role in the adjacent and more interior "Western Hemlock Zone" by opening up growing space for Douglas-fir; even if fires occur once every 500 years, the Douglas-firs that regenerated after the previous fire are usually still dominants in the stand, so a seed source is present for another generation. In the "Sitka Spruce Zone", large fires are known to have occurred; several large fires burned along the Oregon Coast in the 1800's (Morris 1934), including the stand that Harcombe (1986) studied. Further north in Washington, the Quinault Indians record a holocaustic fire centuries ago in the spruce-hemlock type that "...drove the people to the sea. There they stayed in their canoes and whale boats until the fire died and the land cooled..." (Quinault Natural Resources 1983). However, while fire does occur in the "Sitka Spruce Zone" it is
generally thought to be so infrequent that wind is a more important disturbance factor in stand establishment and development (Ruth and Harris 1979, Harcombe 1986). Fahnestock and Agee (1983) calculated a fire return interval for the Sitka spruce type in western Washington at over 1,100 years. When fire does occur in this zone, it burns under unusual weather conditions and has generally severe effects on the stand. The fire at Fort Clatsop was likely a stand-replacement fire, as hemlock and spruce are very susceptible to mortality from fire and western redcedar has only moderate resistance. Apparently, there was little Douglas-fir in the stand at the time. If there was any seed source from Douglas-fir nearby, Douglas-fir was likely a codominant species in the post-fire forest.

A Likely Forest Development Scenario

The following forest development scenario is based on the limited evidence available to reconstruct the forests of Fort Clatsop, much of which is summarized above. Up until the fire of several to many hundred years ago, the disturbance pattern appears to be one of infrequent wind disturbance which opened small patches in the stand. This small scale "gap" disturbance created openings large enough for Sitka spruce to become established and share dominance with western hemlock. Western redcedar was also a codominant. Douglas-fir was probably an occasional in the
stand but was not a codominant. The structure of the stand was all-sized, but a significant portion of the stand was large diameter trees. The spruce and western redcedar were probably the biggest trees in the stand. Western hemlock was represented in all size classes, but constituted almost all of the smaller size classes.

The fire that created the charcoal fragments occurred under unusual weather conditions and most likely covered an area far larger than Fort Clatsop. Conceivably, it could also have burned across the marshy terrain along the southern part of the park. The fact that Lewis and Clark saw so many large trees in the vicinity of the fort lends credence to a hypothesis that the fire occurred many centuries (>300 years?) prior to their visit. All the trees at the Fort Clatsop site, except perhaps for a few scattered western redcedar trees, were most likely killed by the fire. Regeneration of western hemlock and Sitka spruce began immediately on this mesic site, along with substantial amounts of brush. Red alder was probably dominant in the wetter forest sites, and along with salmonberry may have delayed conifer establishment in some locations for decades. On the alder sites, Sitka spruce and western redcedar eventually came in, although the latter was heavily browsed by elk. On the relatively driest microsites, which were still pretty moist by Pacific Northwest standards, a few Douglas-fir may have regenerated in the very open
conditions, along with substantial amounts of spruce and hemlock.

Over the next several hundred years leading to the visit by Lewis and Clark, small scale windthrow was again the dominant disturbance process. This maintained the availability of establishment and growing space for Sitka spruce, and allowed understory western hemlock to be released and grow into the overstory. Since wind tends to thin the stand from above, the larger stems had a higher probability of windthrow and provided a structural component of medium and large logs to the forest floor, some of which served as "nurse logs" for subsequent regeneration.

The forest at the time of Lewis and Clark's visit probably had characteristics of old growth forest: large live trees, some large dead standing trees, large downed log material, and a multilayered understory, much of which was small trees. In the Original Journals of Lewis and Clark (Thwaites 1905) Lewis mentions the immense size of many of the tree species he describes. "Fir No. 1", apparently Sitka spruce, was occasionally 12 ft in diameter near the base. "Fir No. 2", apparently western hemlock, was "...much the most common species..." and comprises at least "...half of the timber in this neighbourhood". Snags were not mentioned in the journals but likely did exist; the understory was mentioned in terms of important plant species and accessibility. Travel through the forest was difficult
due to "...fallen timber, brush, and sinkholes" (1/27/06). The importance of wind as a natural process in forest development was underscored by Clark on December 16, 1805: "The rain continues, with Tremendious gusts of wind....The winds violent Trees falling in every direction whorl winds, with gusts of rain Hail & Thunder, this kind of weather lasted all day, Certainly one of the worst days that ever was!..."

When the Lewis and Clark party began cutting trees to build the fort in which they spent the winter of 1805-06, the most accessible and easily carried logs would have been from western hemlock. Western hemlock probably best represented (and perhaps wholly comprised) the tree size classes from which cabin logs could easily be cut, carried, and hewn into a fort wall. That it is the most decay-prone of the species represented at the site was neither known by them nor would have made much difference if they had known, based on their short-term need for shelter. Decay rates for small hemlock logs \((k = .023)\) are twice that for Sitka spruce and four times that of large Douglas-fir logs; a 37 cm (15 in) hemlock log would totally disappear in 120 years, and would be structurally unsound in a small fraction of that time (Lambert and Graham 1982).

The character of the landscape in the vicinity of the fort most likely did not radically change with the building of the fort. The large trees, weighted towards spruce and
cedar, would have been left, and the removal of smaller hemlocks for fort construction would have been equivalent to a low thinning treatment in the general vicinity of the fort. Without the presence of the fort and the stumps, the visual effect of this tree cutting on the tree canopy would have been almost unnoticeable. Although speculative, this hypothesis supports a view of the fort somewhat similar to its condition today: a small structure visually nestled under a mature tree canopy. The overstory trees were much larger than those in the area today.

LANDSCAPE CHANGES SINCE THE HISTORIC PERIOD

The historic period ended in the spring of 1806, and there is little recorded history of the site over the next century. In fact, although the site clearly meets all the descriptive criteria of the Lewis and Clark wintering site, there is no incontrovertible evidence that the reconstructed fort is actually at the real fort site (Hussey 1957).

Major landscape changes at Fort Clatsop began in the 1850's, with the establishment of Moore's lumber mill at the landing site on the Lewis and Clark River (Hussey 1957). At that time, a settler named Carlos Shane had supposedly burned the remains of the fort. Moore's mill operated from 1852 to 1855, and must have utilized timber from the area now in the park. In the 1870's, charcoal was being produced at the site (Hussey 1957) and hemlock was being utilized for tanbark (Smith 1957).
The only known early photography at the site was taken in 1899 by the Oregon Historical Society (reproduced in Hussey 1957), and shows a very modified landscape. Herbaceous vegetation is common in the foreground, dominated by bracken fern (*Pteridium aquilinum*). Fruit trees are scattered across the middle ground of the landscape. In the background, young growth forest is coming up around occasional snags or residual trees remaining from logging (and most likely burning) operations.

A graphical comparison of the landscape in four time periods is shown in Figure 4. The historical situation (ca. 1805) is depicted in Figure 4A; with the exception of the marsh area, about 80 percent of current park land was old growth forest. All of the forest was cut between 1850 and 1900 (Figure 4B). Regrowth (with some additional logging of second growth) resulted in about 50 percent of the park lands being forested in the early 1950's (Figure 4C), although some of this was very young red alder. Planting of much of the open landscape was begun by park employee Ross Peterson in the early 1960's, so that by the late 1980's almost all potentially forested lands had naturally or artificially regenerated forests growing (Figure 4D). Most of the trees planted by Mr. Peterson were Sitka spruce and western hemlock; some Douglas-fir have also been planted.
Figure 4. Landscape changes over time at Fort Clatsop.
A. The prehistoric distribution of old growth forest.  B. Logging removed all of the old growth between 1850 and 1900. C. By 1950 some forest cover was restored.  D. In 1988, most of the historic forest cover is restored, but in young growth forest of a conifer-hardwood mix rather than old growth conifer forest.
Peterson's pioneering work, although done without a formal long-range plan, is a model for other historical landscape restoration projects to follow. Using local stock, and transplanting with special fertilizer, Peterson led an effort to transform the landscape in a 20 year period from a pastoral scene to the first stages of the historical scene. The trees first planted now provide a verdant screen for visitors entering the park, and through further cultural treatment, and time, will provide an old growth spruce-hemlock forest for future generations to enjoy.

CURRENT CHALLENGES FOR LANDSCAPE RESTORATION

The current forest landscape at Fort Clatsop is a mosaic of various successional stages, all of which will converge to a spruce-hemlock-cedar old growth forest over time. Movement through certain stages can be accelerated by cultural treatment, such as thinning or planting. A schematic diagram of such stages (Figure 5) indicates that red alder may dominate the early stages of some stands. Underplanting conifers in such stands combined with felling of alder (as is currently practiced at Fort Clatsop) is a method to accelerate succession past the alder stage, which otherwise will dominate the site for the first 60 years after disturbance. Thinning from below in dense spruce-hemlock stands will provide better resistance to windthrow for the residual trees while accelerating the "stem exclusion" stage.
Figure 5. Development of old growth spruce-hemlock forest beginning with (left) a wet site where red alder initially dominates, or (right) a more mesic site where conifers initially dominate. The time to develop old growth character is shorter where conifers initially dominate.
Areas of the forest at Fort Clatsop where certain treatments would be appropriate are indicated in Figure 6 and Table 1. There are essentially two techniques to employ:

(1) Planting
Almost all of the formerly open areas have already been planted with spruce, hemlock, and Douglas-fir, so large scale planting is not needed anymore. Current emphasis is on underplanting red alder stands with conifers on a very small scale each year. Small underplantings of a quarter-acre here, a quarter-acre there appear to be achieving a type conversion from early successional alder to late-successional conifers at little visual cost.

The stands are underplanted, primarily with large stock of western hemlock but also with spruce, and then the alders are cut down once the planted trees have become established. In roadside areas, the larger alder stems are removed. The underplanted trees are released and will dominate the site within a decade. The operations are present are conducted in such a subtle way that the visitor is unaware cultural treatment has been applied.

Past plantings involving spruce have been plagued with top-kill from the white pine weevil (**Pissodes strobi**), also known as the Sitka spruce weevil (Wright 1971). This native pest kills the top leader of the tree, and is primarily a
Figure 6. Suggested areas of the park where silvicultural treatments might be appropriate. Letters refer to descriptions in Table 1.
Table 1. Description of suggested silvicultural treatments indicated in Figure 6. The types of planting and thinning treatments are described in the text. Areas on the map that are not marked are of lower priority for treatment or do not need any treatment.

A. This area has very thick young regeneration less than 20 years old at present (>1000 per acre) and could benefit from a thinning.

B. The alder in this area could be thinned out gradually, releasing the conifer understory. This operation is underway by park staff already.

C. Alder in this area is mixed with conifer, and is approximately 30 years old. Alder thinning is advisable.

D. This is a pure young alder stand with salmonberry understory. Some small western redcedar is present but is heavily browsed. Salmonberry clipping around each planting spot is advised.

E. A low thinning of conifers is needed, with underplanting of conifers in small alder openings, followed by alder cutting.

F. Older conifer (60 yrs?) needs some removal of alder to encourage understory conifers.

G. Salal opening has been planted to spruce. Watch weevil damage, may need some thinning of spruce in 10 years if all trees survive and grow.

H. Thick young growth conifer could benefit from a thinning.

I. Young hemlocks will be filling in the vista to the river, and will need thinning to maintain vista, with eventual lower branch pruning similar to larger trees downslope (which have already been pruned).

J. Hemlock along the downslope side of the trail is very thick and will soon block views; some thinning is recommended.

K. Continued underplanting and alder removal is desirable.

L. Pure young alder with salmonberry. See D.

M. Quite variable stand structure in this area. Leave alders near creek or in areas with sedges; thin them on slopes or benches after underplanting or to release current conifer understory.

N. Alder increases away from the road. In thinning, preferentially remove alder, or underplant with conifers and subsequently thin alder.

O. Thinned conifer stand, will need another low thin in 10 years.
factor in young plantations. The natural stands of Sitka spruce have evolved with the weevil, and the young stands at Fort Clatsop should survive the damage they are now undergoing. The topkill encourages multiple leaders to develop, which can lead to later breakage of the stem at that point if leader dominance is not soon resolved. Many of the largest spruce now growing at Fort Clatsop show evidence of past weevil damage. There is no control technique effective for the white pine weevil, so the best strategy is continued monitoring to see if mortality results (Wright 1971) and replanting is needed. In this area, at least, mortality appears to be sporadic if present at all (John Christie, personal communication). In 1988, the weevils were present in all areas but were slowing height growth rather than causing significant mortality.

(2) Thinning Established Spruce-Hemlock Stands

There are several types of thinning treatments that can be applied to stands depending on management objectives. A low thinning (Figure 7) removes primarily suppressed trees and relieves competition for nutrients and moisture; it requires a minimum of marking skill because it removes trees whose crowns have dropped below the general canopy level. It maintains the windfirmness of the existing stand, but is generally so light a treatment that the residual trees do not develop as much added windfirmness as they might with a
Figure 7. Example of how a low thinning might be marked, removing stems in suppressed or lower canopy positions. 0 = overtopped trees; I = intermediate crown class trees; C = codominant trees; D = dominant trees.
heavier thin (Ruth and Harris 1979). A crown thinning generally removes dominant and codominant trees from the stand to release more promising trees in the same category. In commercial applications limbier trees are often preferentially removed; for the noncommercial objectives at Fort Clatsop a crown thinning is not as applicable. Selection thinning is another commercial application where selected large, poorly formed trees are removed from the stand, opening growing space for subordinate trees. Typically in spruce-hemlock, heavy or repeated selection thinnings are not favored due to increased wind damage potential (Ruth and Harris 1979).

In several areas at Fort Clatsop, 40-50 year old spruce-hemlock stands have been thinned to reduce stocking. These thinnings have been "low thinnings", removing the smallest, most suppressed stems from the stand. The effect is to speed up the natural thinning process, by removing those stems most likely to be crowded out of the stand anyway. The thinnings have not opened the crowns of the stand to any significant degree, and from the standpoint of wood production may not have been as heavy as they might have been. However, the objective of silvicultural treatments is not to produce timber, but to develop a sustaining old-growth forest, and for that reason, the thinnings so far have been very adequate. They have maintained the protection of the stand from wind and have not created
excessive amounts of debris on the forest floor. Opening the crown of the stand too far will enable the residual trees to capture the same amount of stand growth on fewer stems, but also subject the stand to accelerated wind damage.

Future thinnings in closed canopy stands should favor spruce and western redcedar at the expense of western hemlock. In most situations spruce will be among the dominants anyway and be less likely to be suppressed. Spruce is unlikely to regenerate underneath current stands, so higher proportions in the overstory are desirable to maintain a high spruce component until the patchy forest structure caused by natural windthrow opens up more mature stands sometime in the future. Western redcedar appears to be somewhat underrepresented in the current stands and is desirable both for its rot resistance and windthrow resistance; therefore, it should be retained in thinning operations wherever possible. Alder should be always be a target for removal by thinning except near riparian areas, where it should maintained as a component of the stand.

Specific recommendations for all treatments are not possible in a plan as conceptual as this one. However, some general guidelines can be formulated. No stands should be thinned until about age 20 unless initial stocking exceeds about 400-500 trees per acre. In the young stands, residual tree
density should be kept high enough to prevent more tree regeneration or brush becoming established on the site. In commercial stands, precommercial thinning at age 10-15 to 200-300 stems per acre will result in 10-12 inch diameter at breast height (dbh) trees at age 25-30 (Greene and Emmingham 1986). At Fort Clatsop, a higher average density of about 400 trees per acre at age 10 (average spacing of about 10 feet) would provide early stocking control so that later thinnings would be light and not create excessive debris. Stocking levels of 400 trees per acre would also provide closed canopy forest by about age 20, but not result in individual tree growth quite as high as if stocking were somewhat lower.

Where initial stocking control has been implemented, possibly only one low thinning at age 30-40 may be necessary. In stands where no initial stocking control was done (some of the current 30-40 year old stands) perhaps two thinnings should be done spaced apart by a decade or more.

The marking of low thinnings can be designed by looking up into the canopy and marking those stems whose crowns are suppressed below the general level of the canopy (Figure 7). For stands needing two thinnings, this first thinning will probably create enough debris that a second thinning should be delayed for a decade. By then, some of the intermediate canopy class stems will have become suppressed, as dominants
and codominants left from the first thinning will grow relatively faster. This second thinning should also be a low thinning and will probably be the last treatment needed.

These thinnings provide a tradeoff between maintaining maximum vigor for individual trees and maintaining windfirmness in the stand as a whole. Heavier thinnings tend to maximize individual tree growth, and can produce windfirm trees if there are no intense storms during the first decade after the thinning.

Two protection problems in addition to wind damage potential are created by thinning operations: (1) increase in fire hazard, and (2) potential increase in root rot spread. Fire hazard is generally not extreme in the spruce-hemlock type, due to moist weather which inhibits fire spread and encourages rapid decay of debris. As long as debris is bucked and spread close to the ground, as has been done in recent thinnings, the fire hazard problem should be minimal. If stem material can be utilized for firewood, its removal is encouraged; insignificant nutrient loss is associated with stem removal. Smaller material should be removed 30 to 50 ft back from roadside areas or trails, to avoid the interaction of risk and hazard where people might accidentally start fires.
The root rot problem is encouraged by spores of decay fungi which infect freshly cut stumps. The spores of *Fomes annosus*, or annosus root rot, will travel down the stump into the roots of the dead trees and infect the live roots of neighboring trees, eventually causing them to blow over or die from slowed growth and suppression. The spread of *Fomes* can be inhibited by painting each stump soon after it is cut with a borax solution, which prevents stump infestation.

The deca-hydra form of borax (\(\text{Na}_2\text{B}_4\text{O}_7\cdot10\text{H}_2\text{O}\)) is preferred for solutions. One local contact is McKesson Chemicals (503-243-3830) in Portland, although other chemical companies probably stock it, too. The treatment requires about 3-5 pounds per acre. Mix up a 10:1 solution of water:borax with a dye. The dye can be any color that denotes the stump has been already treated. Adding common table sugar in equal amounts helps dissolve the borax. Another way is to paint the stump with a water-dye mix and sprinkle on the borax with a large salt shaker. The stump must be treated while fresh: within 30 minutes of cutting, to be most effective. Another stump treatment recommended in Canada is the application of zinc chloride (\(\text{ZnCl}_2\)) (Morrison and Johnson 1975). However, this chemical is not registered for use in the United States, and borax appears to be effective (personal communication, Professor Robert Edmonds, College of Forest Resources, University of Washington).
Long-Term Disturbance Management

Protection from wind will be an important part of future forest management at Fort Clatsop. Management of wind damage is a delicate balance; wind can destroy large patches of forest that have been carefully cultured over time, but some wind damage in the long term is essential and inevitable for maintenance of natural forest species composition and structure. The key is to manage stands so as not to accelerate the natural pattern to levels unacceptable for park objectives.

Certain landscape positions are more vulnerable than others to wind disturbance (Figure 8). In an opening the lee side of the opening is more vulnerable than the windward side, and along road corridors open to the major wind patterns, curved sections at the end of straight wind-aligned sections are most vulnerable. Fort Clatsop is fortunate in having a protected position relative to southwest winds, and having natural openings in the direction of the other most potentially damaging winds: south to southeast. These natural openings will likely maintain stunted and open grown spruce which will act to deflect the wind vertically. Trees along these natural edges will likely suffer the most wind damage over time (Figure 9). Another area where some accelerated wind damage may occur is along the county road as it enters the forest from the south.
Figure 8. A. Landscape positions vulnerable to windthrow. B. An example of a cutting pattern to minimize windthrow effects. Note that the lee side of the cut border (arrow) would be very vulnerable to windthrow during the period that the new stand is developing.
Figure 9. Potential wind vulnerability over time for the forests of Fort Clatsop. The strongest potentially damaging winds will be from the south or southeast.
There is potential for clearcutting of the forest to the west and northwest of the park, which will open those boundaries to potential windthrow. The difference in forest structure between the park and those adjacent lands will become more pronounced over time as the park forests become larger. Fortunately, the position of those potential cut boundaries is favorable to the park in terms of alignment relative to damaging winds; only occasional windthrows at the stand edge are forecast for those boundaries.

As the stand matures, there will be occasional storms creating small patches of windthrow similar to that described by Lewis during the winter of 1805-06. But such windthrow is vital to the rejuvenation of the spruce-hemlock mix by opening gaps in the overstory, and the logs thrown to the forest floor will be recreating the structure of the forest that Lewis and Clark experienced.

Storms of an intensity to blowdown the entire park forest are conceivable, but its protected location suggests that smaller scale blowdown is the much more common process in the development and maintenance of natural forest structure.
LITERATURE CITED


