NATURAL RESOURCES

WASHINGTON TREE SEED TRANSFER ZONES

Summer 2002

WASHINGTON STATE DEPARTMENT OF
Natural Resources

Acknowledgments

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Summer 2002

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Introduction

Choosing the appropriate seed to reforest a particular site is important for many reasons: producing a long-lived, healthy stand; limiting damage from climate or pests; promoting rapid production of commodities; and maintaining locally adapted gene pools. This document will provide information to land managers responsible for selecting forest tree seed for reforestation. The risk of moving seed from a source environment to a planting environment will be kept within acceptable levels by establishing seed zones and elevation bands within which seed can be transferred. These recommendations will supersede those of the Tree Seed Zone Map that was published for the State of Washington in 1966 (see next page). They apply to seed collected from natural populations of native forest trees unless otherwise noted.

New tree seed zones or seed transfer guidelines are needed because the ones in current use are out of date. The old Tree Seed Zone Map was based only on climatic, vegetative, and topographic information. Now genetics information, which has accumulated over the past 30 years, needs to be incorporated into the recommendations. For example, the old tree seed zones were the same for all species, but it is now known that species differ tremendously in how far they can be moved safely. This guide summarizes published seed zone literature, seed transfer rules, genetics, and geographic variation for tree species used in reforestation, wildlife, and riparian planting. Specific guidelines are given for each species.

These guidelines are meant to improve silvicultural prescriptions, not to replace them. Not all sites within a seed zone will be appropriate for a particular tree species. You must rely on your knowledge of species characteristics to determine which species is most appropriate for the site you plan to reforest. To determine the best source of seed for the area you want to plant, locate the page reference for that species in the table of contents and read the specific recommendation. Then refer to the species map for seed zones and elevations bands. Elevation bands are not mapped, but are considered in the seed transfer guidelines. Also, seed zones are only delineated for areas where the species naturally occurs.

Each of these guidelines are for a particular forest tree species and should not be used for other plants. However, the 1966 Tree Seed Zones encompass areas where environmental variation is fairly uniform and could serve as guidelines for other species where no seed zones have been established.

History of Seed Zones

Foresters in the Pacific Northwest gained an appreciation of the importance of seed source as a result of large scale tree planting following major fires in the 1920s, 30s, and 40s. Seed source was often ignored at that time, and there are now numerous examples around the region of plantations where survival and growth are less than optimum because they were established with a poor seed source. In some cases these problems, although they turned out to be very serious, did not become evident until decades after the sites were planted.

Knowing the origin of seed is crucial to determining where it will survive and grow successfully. By the early 1960s a system was established in Washington that made it possible to certify that seed had been obtained from a particular stand. The system was used by the Northwest Forest Tree Seed Certification Association and administered by the Crop Improvement Association, Washington State University Extension Service. In 1966, a statewide seed zone map was developed by local groups knowledgeable in topography, weather, climate, and tree growth. This map was based primarily upon knowledge of Douglas-fir, but was intended for use with all tree species. The map was revised in July 1973. *(See historic seed zone map on next page.)*

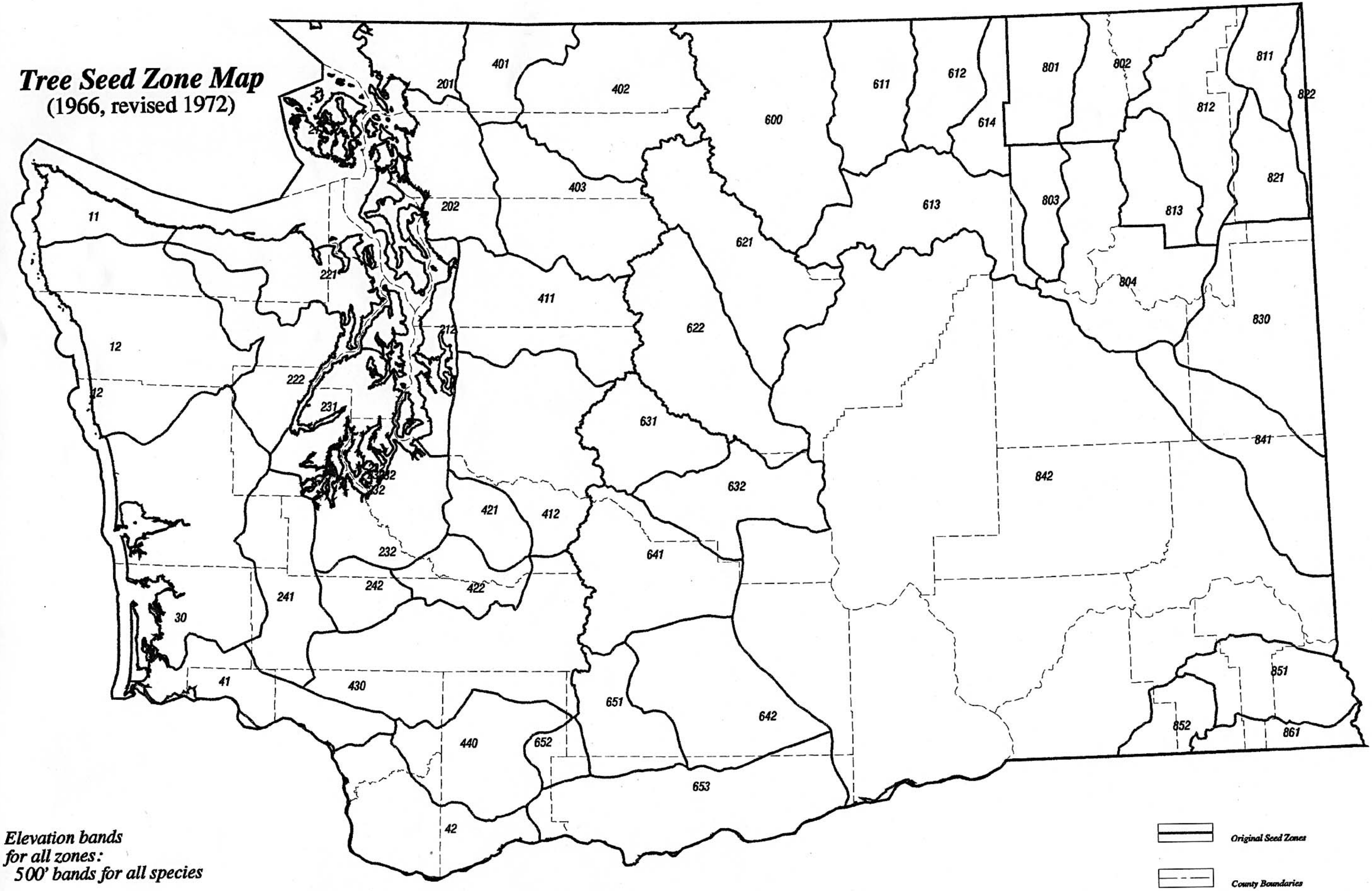
The differences we see among trees are determined in part by genetic differences and in part by environmental influences. Native conifers of the Pacific Northwest have the highest levels of genetic variation found in plants (Hamrick *et. al.* 1992). Forest tree species in this region exhibit large genetic differences in survival, growth rate, frost hardiness and other important traits. Some of these genetic differences exist among populations and some of them exist among individuals within populations. In most cases, genetic differences among populations of a species are the result of adaptation to different environments. For several decades, genetic differences among populations have been recognized as an important consideration when selecting appropriate sources of seed for artificial regeneration programs. The use of seed zones is based on the assumption that the local population, which is the result of thousands of years of natural selection, is best adapted to the site.

The range of each species includes an array of environmental conditions. Within that range there are distinctive habitats for which certain trees within that species are better suited. Tree seed zones divide the range of a species up into areas where the habitats are fairly similar. The size and shape of these zones varies depending upon the environment, the species, and its pattern of genetic variation.

The size of a tree seed zone can range from just a few thousand acres in the mountains of the western United States to many thousands of square miles in the gentle topography of the southeastern United States. This is because the environment varies significantly over short distances in mountainous terrain, but only over long distances in some flatter areas.

The size of tree seed zones is also affected by differences among species. For example, Rehfeldt (1993) found that differences in the length of the frost-free period were especially important in determining how genetic differences would develop among populations and how far their seed could be moved. For Douglas-fir, a difference of more than 18 days in the length of the mean frost-free period between populations meant they were genetically different and seed should not be exchanged. For ponderosa pine, the interval required to delineate population differences was 38 days, while it was 54 days for western redcedar, and more than 90 days for western white pine.

Tree Seed Zone Map
(1966, revised 1972)



Elevation bands for all zones:
500' bands for all species

Developing Seed Zones

The most reliable seed transfer guidelines would be developed after finishing long-term field tests of trees grown from seed collected in many populations from across a geographic region and planted across a range of environmental conditions. However, determining whether trees are adapted to a site takes a long time, sometimes more than 50 years (Roy Silen, personal communication, March 1995). Another valuable approach, when results from long-term tests are not available, is to map genetic patterns of geographic variation with a seedling study. The theory behind this method is that the larger the genetic difference between two populations, the larger the adaptive difference between them, and the greater the risk of moving seed between them. The assumptions behind this technique are that genetic differences between populations are largely adaptive, that the local population is most suited for a particular site, and that a map of genetic variation is also a map of the environment that shaped natural selection. Adaptation to environmental conditions is apparent when genetic and environmental variation are closely correlated; for example, when higher elevation sources set bud earlier. These tests can also identify the fastest growing families; long term tests of Douglas-fir in western Oregon have shown that trees tend to grow at a steady rate and that the fastest growing families can often be determined at an early age. However, this technique must be applied cautiously. A source or family that grows rapidly for a short period of time may not survive for the long term.

Both long-term field tests and seedling studies start by choosing many parent trees from across the area of interest, collecting seed from them, and growing the seedlings in the nursery. For long-term tests, nursery seedlings are then planted at several locations where the site conditions reflect the range of environments for that species in the area under study. Seed transfer recommendations are made after assessing survival, growth, and tree development for many years. The seedling- study approach utilizes the seedlings which are grown in more than one environment while they are still at the nursery. A large number of traits that relate primarily to growth and phenology are measured to determine patterns of genetic variation. Geographic areas or distances within which seed can be transferred without undue risk of maladaptation are estimated from observed genetic patterns. However, one must remember that seedling tests do not evaluate all risks. Seed transfer zones developed from them should be considered provisional until long-term field results become available.

Genetic differences among populations usually develop in response to variation in important environmental factors, especially temperature, length of the growing season, and moisture. A continuous change in these parameters from one location to another is known as an environmental gradient and a continuous genetic change along this gradient is known as a cline. Ideally, seed zones would be determined by knowing how these important environmental factors change across the landscape and how the species adapt to these changes. However, little is known about temperature and moisture in most forested parts of the West. This is because most climatic information is gathered for agricultural use from weather stations in the lowlands. Few weather stations exist in mountainous forested regions. Therefore, genetic researchers in the western United States have based tree seed zones and seed transfer rules on surrogates for climatic data that are easier to measure. Some of the most commonly used variables are elevation, latitude, longitude, distance from the coast, and distance from the crest of major mountain ranges. Because the zones that are developed from these analyses are based on the relationship between genetic variation and geographic factors rather than climatic factors, they may not be appropriate if there are large changes in climate. Other surrogates for climate which have been tested, but have usually turned out to be less useful, are slope, aspect, habitat type and soil type.

Since geographic variation and genetic variation are usually continuous variables, mathematical models that describe the relationships between them can be developed. These models usually provide the best estimate of risk when transferring seed. The larger the predicted genetic difference between populations from the seed source and populations from the planting location, the greater the risk of seed transfer. These models generally use the distance of the transfer, for example, in degrees latitude or longitude and feet of elevation, to estimate the risk of maladaptation. Unfortunately, many of these models are quite complex and people are often reluctant to use them. In addition, the research needed to develop these models has not been published for most of Washington. For these reasons, the recommendations that follow are based on seed zones instead of mathematical models.

Mathematical models have been developed for parts of Idaho and Montana for some species. In some cases, these models may apply to the northeast corner of Washington. These models are available on an electronic web page maintained by the Idaho Panhandle National Forests at their Coeur d'Alene nursery (Mary Mahalovich, personal communication, August 2000). Landowners in the northeast corner of the State may want to consider this source of additional information.

In Washington, there has been very little research specifically designed to determine the limits of seed movement. However, this work has been done in areas that surround Washington, including Oregon, Idaho, and British Columbia. Generalizations derived from studies in these nearby areas can often be applied in Washington. Indications of how far seed can be moved may be obtained from other types of studies as well; for example, ones that are designed to identify the fastest growing trees. Some excellent information can also be obtained from studies of seed collected in Washington and tested in Europe. Some genetic studies are now in progress in Washington and additional ones are planned. As the results of these studies become available, the recommendations in this document may need to be modified.

The areas included in the seed transfer zones in this document are based on the maps of species distributions developed by Elbert Little (1971). In some cases, Little's maps do not reflect current knowledge of the species distribution. In these cases, the seed transfer zone maps have been modified as suggested by local experts.

Since the environmental gradients and genetic clines are continuous, in many cases the borders between seed zones are somewhat arbitrary. If land ownership is split by a seed zone boundary, boundary adjustments may be possible to facilitate land management. This is especially true if a tree seed zone of a given size is moved north or south.

General Seed Transfer Guidelines for Washington

1. These guidelines only apply when planting on sites where the species naturally occurs within the seed zones.

2. Seed mixes should include seed from a number of different random locations within the tree seed zone and elevation band. If seed mixes are comprised of collections made only at one edge of a zone or only at one limit of an elevation band, a safe transfer might be about half a band width (either geographic distance or elevation) . Usually, this restriction would be more important for elevational and longitudinal transfers than for latitudinal transfers (Frank Sorensen, personal communication, March 1995).

3. Seed transfer to a higher elevation usually increases the risk of maladaptation; in other words, the potential for climatic damage. A transfer to a lower elevation will probably decrease productivity and may increase the risk associated with pest damage. If wood production is important and geographically localized collections are made, seed should probably not be transferred down to another elevation band.

4. Except for areas right along the coast, elevation does not have as great an influence as longitude for species on the west side of the Cascades. Latitude has less influence on seed transfer than longitude (Campbell and Sugano 1993, Campbell 1986, Sorensen 1983, and Campbell 1992).

5. Local populations are generally well adapted to local environments and are the safest to use until the best adapted, or better growing sources can be identified with data from long-term provenance tests (Namkoong 1969). This is particularly true for areas where large changes in the environment can occur over short distances, such as the islands in Puget Sound.

6. A seedling's response to its planting environment is significantly influenced by its parents' location (Campbell 1992).

7. Seed transfer zones should generally be smaller at high elevation than at low elevation (Campbell and Sorensen 1978). The size of seed transfer zones should decrease as site severity increases (Adams and Campbell 1982, Sorensen 1979). Therefore, less seed movement is possible at higher elevation Cascades sites. The steeper the genetic gradient and the harsher the planting site involved, the greater the risk of seed transfer (Adams and Campbell 1982). High elevations and harsh climates dictate that seed must be planted fairly close to its origin. However, close to the ocean at low elevation, seed movement becomes much less restrictive. The coastal climate permits most seed sources to survive, but those from harsher environments will grow much less than those from favorable environments which are better able to utilize the site potential.

8. When planting a species near its biological limits, a higher planting density is recommended and early thinning should be delayed to compensate for higher than normal mortality due to fewer seedlings being genetically adapted (Campbell 1975 and 1987). Shorter rotations would also reduce risk.

9. Risk of maladaptation is greatly increased when transferring seed across more than one environmental condition, for example, when transfer is from west to east and also from lower to higher elevation (Adams and Campbell 1982).

10. At both the geographic and elevational limits of a species distribution, natural regeneration should be strongly encouraged (Frank Sorensen, personal communication, March 1995).

11. If ownership or management would benefit by floating the zone boundaries north or south, that usually can be done. Sorensen (1994) stresses that seed zone boundaries do not represent abrupt breaks between populations that have large genetic differences. Instead, zone shapes are chosen to minimize the risk of transfer within their boundaries. The same applies for elevation (*i.e.* a 1000-foot band can be between 1700 and 2700 feet as well as between 2000 and 3000 feet if the former fits the species distribution or land ownership better) with the exception that the bands at higher elevation are often narrower.

12. Local conditions can also affect vigor. If wood production is important and there is a known area within a tree seed zone where growth rates are unusually slow, seed from that area should not be planted on more productive sites even if they are within the same zone and elevation. For example, throughout western Oregon there are many local areas on the east side of high ridges that receive less precipitation than the general area (i.e. they are in a rain shadow). Tree growth in these areas will be less than the growth in the surrounding area and transferring seed from these areas to those with more precipitation may result in reduced growth. This may also be true for the San Juan Islands and the islands in Puget Sound where changes in climate can be abrupt.

13. Relative humidity may be important; for example, transferring seed from a warm, dry area to a cool, moist area may increase the incidence of foliar disease (Nelsen *et al*. 1989).

14. Seed orchard seed is most safely used in the breeding zone of the parents or in the area where the parents have been tested (Campbell 1992).

15. The recommended number of seed parents in a seed lot ranges from 15 to 30. If there is equal representation from each seed parent, then the smaller number is suitable; if there is unequal representation, then the larger number is appropriate (Adams *et al.* 1992). Regardless of the number, the parents should represent a seed zone-wide mix. When specific information about the origin of the seed is maintained, single stand collections are acceptable. This gives the forester the flexibility of combining seed from multiple stands to create a seed zone-wide mix or using mathematical models to determine how far the seed from a single stand can be moved.

16. Small populations of a species separated from the main part of the range may be genetically unusual. If possible, the genetic composition of these populations should be protected by replanting them with seed collected from the isolated population. These populations can also be regenerated naturally. If these options are not practical, seed should be obtained from nearby portions of the main part of the range.

17. Seedlots should be labeled with the most specific information available on collection location and elevation. This will give foresters the most flexibility in using the seed.

Seed Orchard Seed

In some cases, the restrictions on seed movement that are recommended in this document may not apply to seed orchard seed. Many seed orchards are supported by a series of field tests. These tests evaluate the ability of trees in the seed orchard to produce offspring with good growth and survival for a certain planting area. In some cases, the trees in these seed orchards may have been selected to produce offspring that perform well over a large area. In these cases, it may be possible to expand the deployment of this seed beyond what we recommend.

Prior to purchasing and using orchard seed, the purchaser may want to ask the following questions and compare the answers to the guidelines for general seed transfer:

1) What is the origin (*i.e.* geographic location and elevation) of the parent trees in the orchard in relation to the location and elevation of the intended planting site?

2) Are there genetic tests of the seed-producing parents or field tests demonstrating the performance and adaptability of the orchard seed?

3) What geographic area do the tests encompass? How do the test sites relate to the location of the planting site? For how many years have the trees been tested?

4) What are the results of those tests? How much better or worse than average were the seed parents based on the test results?

5) How many seed parents are represented in the seed/planting mix?

6) What is the risk of pollen contamination in the seed orchard? Pollen drifting into the orchard blocks from outside stands or geographically different orchard blocks may reduce gain or increase the risk of maladaptation.

7) What percentage of the trees in the orchard produce seed and pollen? Better adaptation is obtained when there are a number of parents, both male and female, represented in the seed lot.

Abies amabilis

Pacific Silver Fir

In Washington, Pacific silver fir (*Abies amabilis*) occurs in the Olympic Mountains and the Cascade Range (Fowells 1965). It is found primarily on the western slopes of the Cascades, but does extend across the crest where it is a minor component in stands along the upper eastern slopes (Franklin and Dyrness 1973). Occasionally, Pacific silver fir is found near sea level on the western side of the Olympic Mountains, but in that area better growth tends to occur between elevations of 1500 and 4500 feet. In the northern Washington Cascades, Pacific silver fir occurs at elevations of 1900 to 4300 feet, while in the southern Washington Cascades it occurs between 3200 and 5000 feet (Franklin and Dyrness 1973).

Trees that are associated with Pacific silver fir include western hemlock, noble fir, Douglas-fir, mountain hemlock, Alaska yellow-cedar, western white pine, and subalpine fir.

Fowells (1965) noted that temperature has a greater influence on the range of Pacific silver fir than does precipitation. Campbell and Sorensen (1978) stressed that north-to-south seed movement has less risk than east-to-west movement in the Cascades, and that risk increases as elevation increases. A chemical analysis of resins in this species showed no differences between trees near Alaska and trees from northern California (Zavarin *et al*. 1979) suggesting there is little genetic variation within the species. Canadian seed transfer guidelines limit north-to-south movement of this species to two degrees latitude, east-to-west movement to three degrees longitude, and vertical movement to 300 meters (1000 feet) in elevation (BC Ministry of Forests 1995). These guidelines are based on several small, unpublished genetic studies of Pacific silver fir conducted in British Columbia (Cheng Ying, personal communication, August 2000).

The Olympic Mountains have greater annual precipitation, later fall frost, and more summer moisture than the Cascades (St. Clair and Vance-Borland 1998). Since the climate of the Olympic Mountains is slightly different than that of the Cascades and the two areas are geographically separate, the Olympic Mountains should be a separate seed zone.

New recommendations for seed transfer zone boundaries

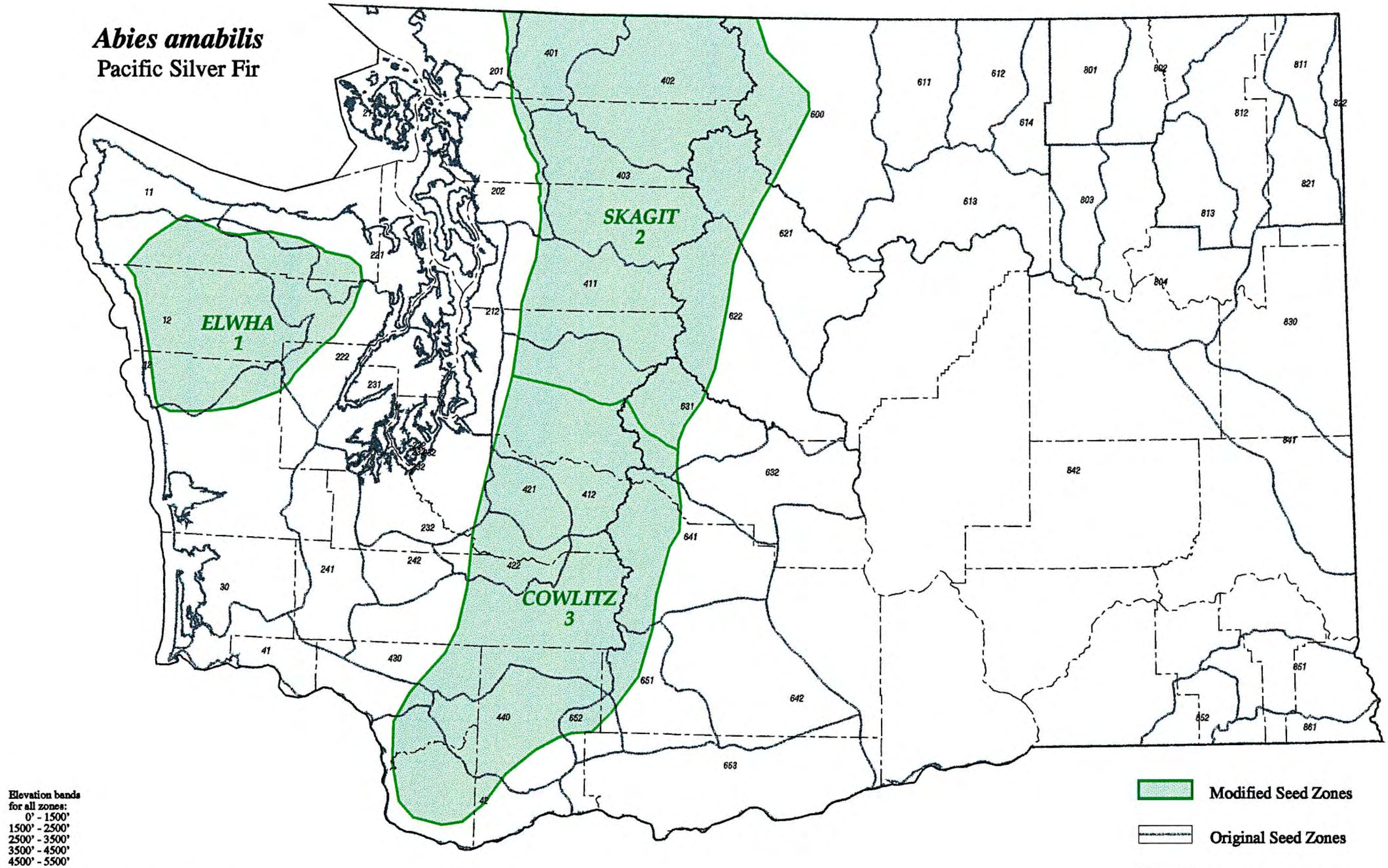
ELWHA (Zone 1): The species range in the Olympic Mountains.

SKAGIT (Zone 2): Species range in the Washington Cascades from the Canadian border south to Interstate 90.

COWLITZ (Zone 3): Species range in the Washington Cascades from Interstate 90 south to the Columbia River.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 1000-foot elevation bands should be established.



Modified Seed Zones

Abies grandis

Grand Fir

Grand fir (*Abies grandis*) is found in three different parts of Washington. The largest area is the two-fifths of the state that lies between the east slope of the Cascades and the Pacific Ocean with the exception of the Olympic Mountains. The other two areas are the Okanogan Highlands (in the northeast corner of the state) and the Blue Mountains (in the southeast corner). The latter two areas are connected to some extent by extensive grand fir populations in northern Idaho (Little 1971).

Grand fir occupies different types of sites in these areas. In parts of Vancouver Island and coastal British Columbia that adjoin Washington, it grows from sea level to 1000 feet, where it may receive more than 100 inches of annual precipitation. In western Washington it grows in moist valleys and stream bottoms. Elevations there range from 600 to 1000 feet with 30 to 45 inches of annual precipitation. As you move south through the range along the west side of the Cascades, the elevational range of the species increases. On the east slope of the Washington Cascades, grand fir is found below 4000 feet in elevation. Although range maps show a continuous distribution across the Cascades, there is very little grand fir above 3000 feet on the west side of these mountains in Washington. In the Blue Mountains and parts of Idaho, it is usually found between 2000 and 5000 feet, although it occurs as high as 6000 feet. There it receives between 14 and 39 inches of annual precipitation (Foiles *et al*. 1990). In some places, grand fir has extended its range east of the area indicated by Little in 1971. Although the map of seed transfer zones is based on Little's range map, the written descriptions accommodate these changes.

Some authors mention a green coastal form and a grey interior form of grand fir. With spatially separated populations that occupy very different types of sites, it is somewhat surprising that no taxonomic varieties have been recognized for this species (Foiles *et al*. 1990). Grand fir is thought to hybridize with white fir in the southern and central Oregon Cascades and in the Blue Mountains. Grand fir-like trees in these areas tend to grow more slowly than other grand fir.

No studies have been conducted specifically to determine rules for seed transfer in grand fir. A number of studies have been designed to determine the best sources of grand fir for planting in certain areas. None of these have been conducted in Washington, but studies conducted in Europe, British Columbia, and Idaho have included sources of grand fir from this state. These tests can be used to infer differences among its populations in traits like growth potential, cold hardiness, and time of bud set and bud burst. Populations that are known to differ in adaptively important traits should usually be kept separate from each other.

Many researchers working in relatively mild climates have reported that sources from the Puget Sound area and the southern end of Vancouver Island have the greatest growth potential (Scholz and Stephen 1982; König 1995; Kleinschmit *et al*. 1996; Xie and Yang 1996). Several researchers have reported that populations from the east side of the Cascades have less growth potential than populations from somewhat lower elevations on the west side of the

Cascades (Scholz and Stephen 1982, König 1995, and Xie and Yang 1996). Xie and Ying (1993) reported that higher elevation sources tend to grow more slowly than lower elevation sources. Kleinschmit *et al*. (1996) reported that differences in growth potential were not associated with differences in elevation along a transect across Oregon, but their samples included material from the east and west sides of the Coast Range and the Cascades, which may have masked elevation trends. When a subset of their samples that progressed from the floor of the Willamette Valley to Santiam Pass was examined, there was an obvious trend of decreased growth potential with increasing elevation. Many researchers have reported that sources from further north appear to have a greater growth potential (Steinhoff 1984, Xie and Ying 1993, Kleinschmidt *et al*. 1996, and Magnesen 1996), but this trend does not appear to be related to significant changes in adaptively important gradients within the state of Washington. It may be an artifact of the sampling scheme (*i.e.* northern sources were often collected at lower elevations) or it could be due to introgression from the slower growing white fir in the central Oregon Cascades (Zobel 1973).

Greater growth potential does not always mean greater growth. It can be associated with susceptibility to early fall frosts or late spring frosts in relatively cold climates. Sources from coastal areas tended to be more susceptible to frost than sources from other areas (Steinhoff 1984), sources from lower elevations tended to be more susceptible than sources from higher elevations (Magnesen 1996), and sources from the Rocky Mountains had more frost injury than sources from the Cascades (Scholz and Stephen 1982, and Steinhoff 1984). Artificial freezing tests can be used to evaluate cold hardiness without waiting for fortuitous frosts. Larson (1978) found that coastal sources were less cold hardy in the fall and in the spring than Cascade sources, and that cold hardiness of southern sources tended to be lower than the cold hardiness of northern sources, both in the Cascades and along the coast. Larsen and Ruetz (1980) also found that cold hardiness tended to increase with increasing elevation and distance from the Pacific Ocean.

Xie and Ying (1993) reported that sources from the east side of the Cascades tend to have more foliar disease when planted in the moister west side and that coastal sources tended to have less disease than any of the other sources. Kleinschmidt *et al*. (1996) reported that the amount of lammas growth varied with the latitude, longitude, and elevation of the seed source.

New recommendations for seed transfer zone boundaries

HOH (Zone 1): The coastal areas near the west side of the Olympic Mountains. Consists of the portions of the old 011 and 012 seed zones within the natural distribution of grand fir.

TWIN HARBORS (Zone 2): The coastal areas south of the Olympic Mountains. Consists of the old 030 seed zone and those parts of the old 041 seed zone west of Skamokawa.

PUGET SOUND (Zone 3): Areas around Puget Sound and in the rain shadow of the Olympic Mountains and Vancouver Island. Consists primarily of the old 201, 202, 211, 212, 221, 222, and 231 seed zones as well as the western parts of the old 411 and 412 seed zones. The southern border is a line from near Capitol Peak in the Olympic Mountains southeast toward South Mountain, east to Bay Shore, Lakebay, Tacoma, east to Highway 167 then south to Sumner, Highway 410 to Buckley, and east to the Three Sisters at the 4000-foot contour.

UPPER CHEHALIS (Zone 4): Areas south of the Puget Sound between the coastal zone and the west slope of the Cascades. Consists primarily of the old 232, 241, and 242 seed zones as well as the eastern part of the old 041 seed zone and western parts of the old 421, 422, 430, and 042 seed zones.

SKAGIT (Zone 5): West side of the Cascades north of Interstate 90 (Snoqualmie Pass). Consists primarily of the old 401, 402, and 403 seed zones as well as the eastern portion of the old 411 seed zone and the northeastern part of the old 412 seed zone.

COWLITZ (Zone 6): West side of the Cascades south of Interstate 90 (Snoqualmie Pass). Consists of the old 440 seed zone as well as the eastern parts of the old 421, 422, 430 and 042 seed zones and the southeastern part of the old 412 seed zone.

CHELAN (Zone 7): East side of the Cascades north of Interstate 90 (Snoqualmie Pass). Consists primarily of the portions of the old 600, 621, and 622 seed zones where grand fir occurs, as well as the northwestern portion of the old 631 seed zone.

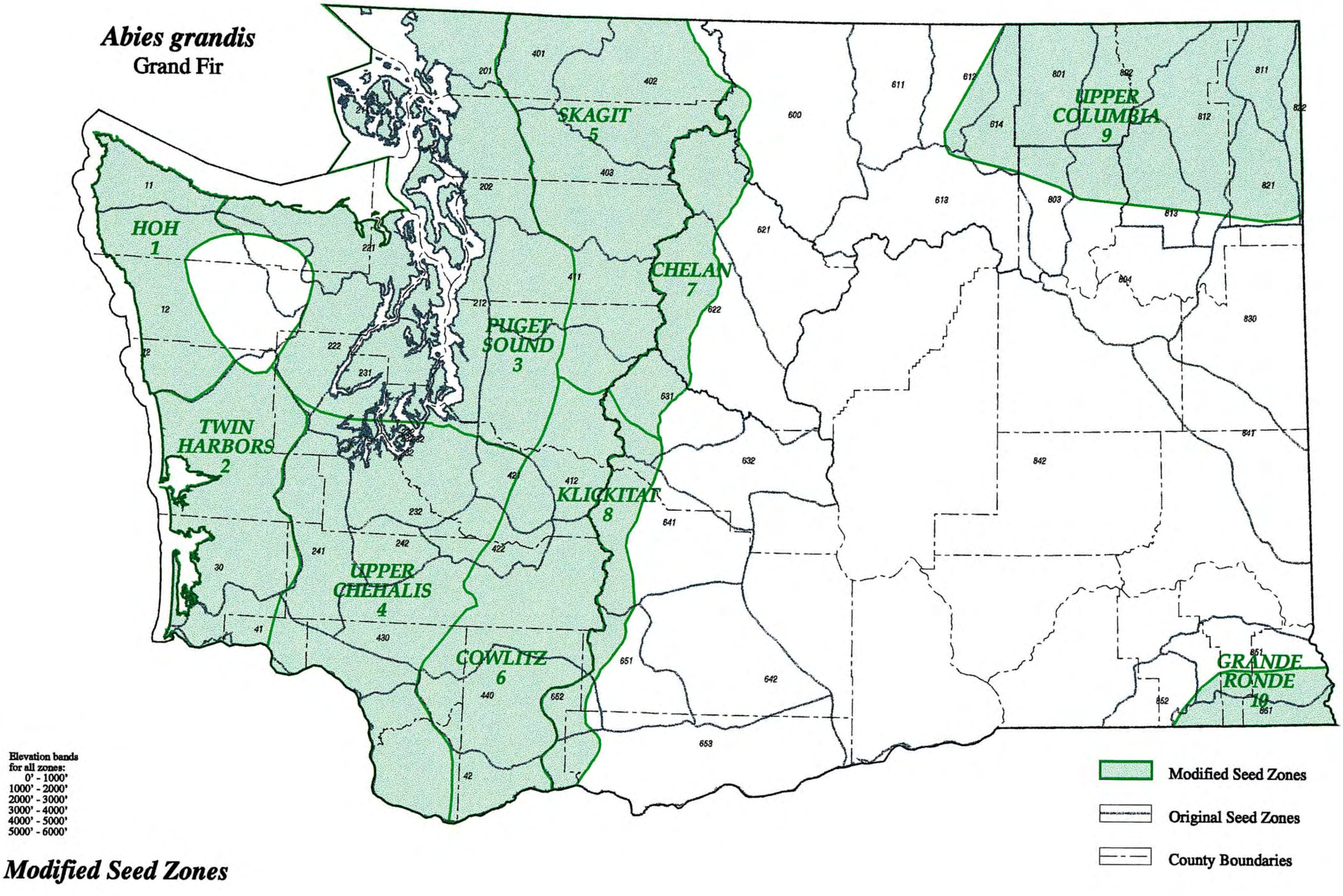
KLICKITAT (Zone 8): East side of the Cascades south of Interstate 90 (Snoqualmie Pass). Consists primarily of the portions of the old 641, 651, 652, and 653 seed zones where grand fir occurs.

UPPER COLUMBIA (Zone 9): Northeast corner of the state. Consists primarily of the old 614, 801, 802, 811, 812 , 821 and 822 seed zones as well as parts of zones 612, 803 and 813.

GRANDE RONDE (Zone 10): Southeast corner of the state and nearby parts of Oregon and Idaho. Consists primarily of those parts of the old 861 and 851 Washington seed zones within the range of grand fir and the old 861 Oregon seed zone.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 1000-foot elevation bands should be established.



Abies grandis
Grand Fir
HOH 1
TWIN HARBORS 2
PUGET SOUND 3
UPPER CHEHALIS 4
SKAGIT 5
COWLITZ 6
CHELAN 7
KLICKITAT 8
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Elevation bands for all zones:
0' - 1000'
1000' - 2000'
2000' - 3000'
3000' - 4000'
4000' - 5000'
5000' - 6000'
Modified Seed Zones
Original Seed Zones
County Boundaries
Modified Seed Zones

Abies procera

Noble Fir

Noble fir (*Abies procera*) is a Cascade Range species (Franklin and Dyrness 1973) that extends south from Stevens Pass, Washington (48° north) to McKenzie Bridge, Oregon (44° north) (Sorensen *et al*. 1990). It also occurs as scattered individuals on a few Coast Range peaks. Noble fir is a major component of the cool temperate Pacific silver fir forest zone and is associated with Pacific silver fir, western hemlock, Douglas-fir, western redcedar, and western white pine. It is primarily a species of the west Cascade slopes, but a few stands are present east of the crest. Generally noble fir occupies a 2000 foot elevation band from about 3000 to 5000 feet.

There is a sharp genetic change, at the McKenzie River in the Oregon Cascades, where noble fir rapidly intergrades into Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.); therefore seed should not be moved north or south across that point (Franklin *et al*. 1978 and Sorensen *et al*. 1990). Progeny from trees north of the McKenzie River grew taller than progeny from trees south of the McKenzie River (data on file for Willamette National Forest genetics program, Eugene, Oregon). A number of European seed source studies suggest patterns of variation for noble fir. Provenances from McKinley Lake, Washington and Molalla, Oregon gave the best growth rates in German tests (Ruetz *et al*. 1990). Provenances generally were not different in early height in the Netherlands (Kranenborg 1988). Washington provenances were taller than provenances from Oregon in Norwegian tests (Magnesen 1995).

Height growth of noble fir in Canadian tests planted three degrees north of its natural range was best for Washington Cascade sources and poorest for Oregon Coast Range sources (Xie and Ying 1994). The authors also reported that when noble fir was planted in the maritime western hemlock zone, survival and growth were suitable for up to 10 years. When the patterns of genetic variation in noble fir were compared with those of other species, it had much less variation within locations and the effect of elevation was not strong (Sorensen *et al*. 1990).

Sorensen and others (1990) concluded that seed can be transferred a relatively long distance north or south with little risk, as long as the planting is restricted to suitable noble fir sites. However, restrictions may be necessary to limit local transfers in elevation and distance from the crest of the Cascades. An unpublished U.S. Forest Service study suggests that no geographic restrictions are needed for noble fir in the Mount Baker-Snoqualmie National Forest, but that two elevational zones are needed (Carol Aubry, personal communication, August 2000). We conclude that safe and adapted noble fir seed can be collected and planted throughout the Cascades from its northern boundary at Stevens Pass south to the McKenzie River. For noble fir in Washington, we recommend a single geographic zone in the Cascades. Seed can be transferred between this zone in Washington and the northern Cascades zone in Oregon. Caution dictates that high elevation areas be planted with high elevation sources (Sorensen *et al*. 1990), thus the Lewis Seed Transfer Zone should be divided into two elevation bands separated at 4000 feet. In Washington, most noble fir will be planted in the lower elevational band. The isolated population in the Willapa hills should be treated as a separate zone with no elevation break.

New recommendations for seed transfer zone boundaries

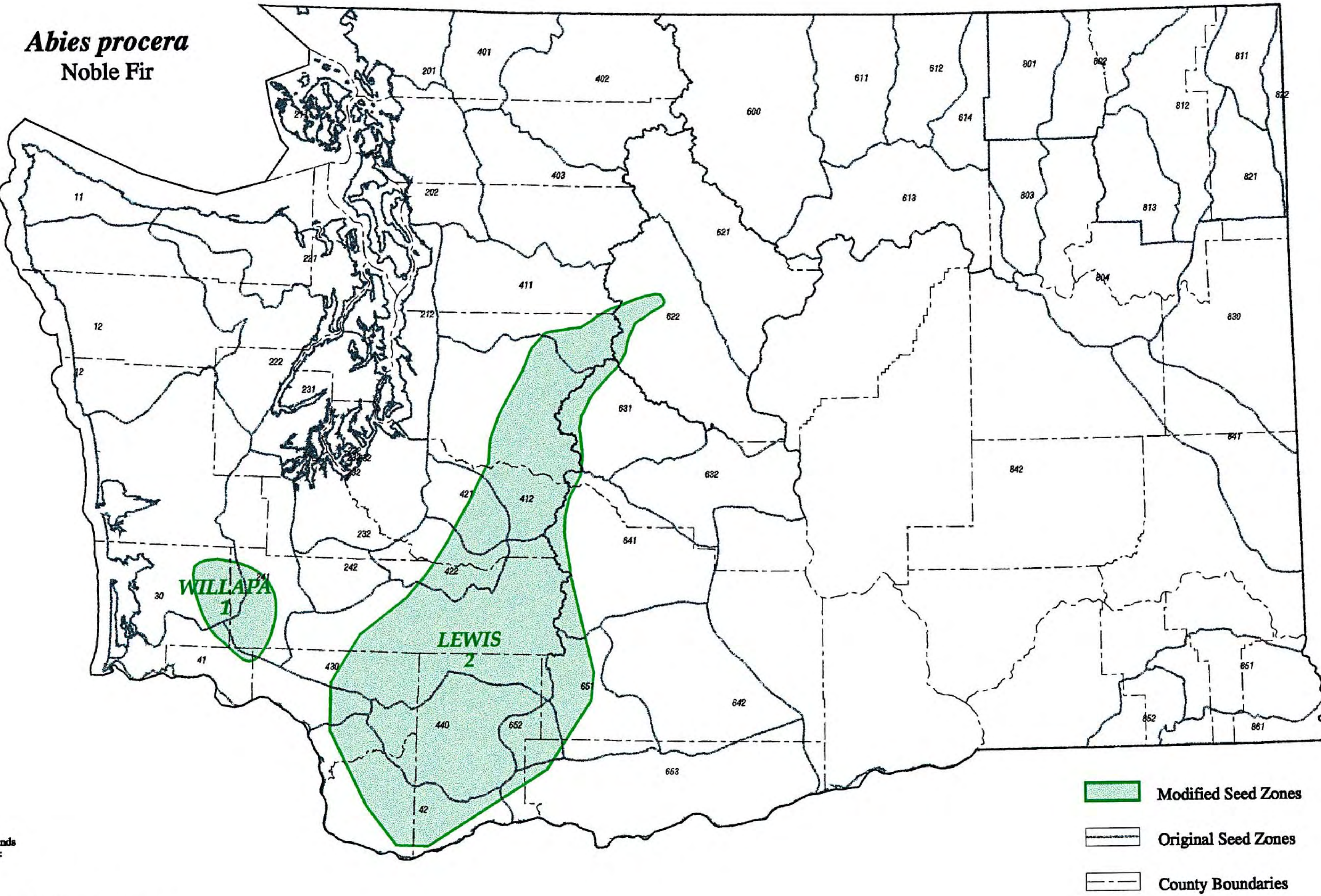
WILLAPA (Zone 1): Consists of all of the natural range of noble fir in the Willapa Hills. Includes small portions of the old 030, 041, and 241 seed zones.

LEWIS (Zone 2): Consists of the natural range of noble fir in the Cascades as well as zone 1 from the northern Oregon Cascades. Includes the old 440, 652, 042, 430 seed zones as well as eastern portions of the old 412, 421, and 422 seed zones.

Elevation bands within geographic seed transfer zones

Two elevation bands separated at 4000 feet.

Abies procera
Noble Fir



Elevation bands
for all zones:
<4000'
>4000'

Modified Seed Zones

Alnus rubra

Red Alder

Red alder (*Alnus rubra*) is the most common and most important hardwood tree of the Pacific Northwest, where it occurs both in pure and mixed stands (Harrington *et al*. 1994). Generally it occurs no further inland than 100 miles and at elevations no higher than 2500 feet (Fowells 1965). In Washington, red alder is prevalent along the coast, throughout Puget Sound, and along the lower Columbia River. The best stands are found below elevations of 1500 feet. (Hibbs *et al*. 1994 and Harrington *et al*. 1994). Only rarely is red alder found east of the Cascade Range (Ager and Stettler 1994).

Conifers associated with red alder include western redcedar, western hemlock, grand fir, Sitka spruce, and Douglas-fir, while hardwoods include vine maple, bigleaf maple, and black cottonwood. Throughout the moist to wet sites of the coastal zone, red alder reproduces abundantly and grows rapidly on disturbed forest land (Franklin and Dyrness 1973).

Adams *et al*. (1996) summarized genetic knowledge of red alder by noting that while the species has considerable genetic diversity, there are conflicting reports about patterns of variation. For example, various researchers have identified different parts of Washington as the best place to obtain seed. Lester and DeBell (1989) found that the fastest growing sources of red alder were from Concrete and Sequim, Washington while Ager and others (Ager and Stettler 1994, and Ager *et al*. 1993) found that the fastest growing sources were from the lower Hoh River. Growth does seem to be influenced by elevation. Not only was each of the previously mentioned, fast growing sources from low elevation, but Ager and others (Ager and Stettler 1994 and Ager *et al*. 1993) found that the best growth within a drainage was always associated with sources from the lower elevations. Researchers in France found the best sources were from warm areas with low moisture demands (Hibbs *et al*. 1994) which are at low elevations in northwest Washington. For red alder from Washington and Oregon, latitude and growth were not consistently correlated (Ager and Stettler 1994). Xie *et al*. (1996) found the fastest growth for populations that were in the south, inland, and at low elevation, which was not consistent with results by Ager *et al*. 1993).

Ager *et al*. (1993) found that patterns of genetic variation were related to variation in local climate with annual temperature amplitude explaining the most variation. When seedlings from different sources were grown at a single location, high elevation and interior sources generally showed earlier leaf abscission than coastal and low elevation sources. Leaf abscission was also related to the average date of first fall frost at the seed source (Ager 1988). Coastal and northern sources leafed out earlier than more inland and southern sources, but source elevation and flushing were not correlated in a test of red alder that included only material from Washington and northern Oregon (Ager *et al*. 1993). Cannell *et al*. (1987) divided a collection of coastal red alder that extended from Washington to Alaska into three groups based upon bud set. He also found that the onset of frost hardening occurred two days earlier for each degree of latitude northward that a seed source was obtained. Xie and others (1996) found spring bud flush was strongly controlled by latitude, with northern sources flushing earlier than southern sources. Frost damage became a problem when seed from a source at 50 feet in elevation was transferred to a planting site at 2500 feet in elevation (DeBell and Wilson 1978).

Ager and others (1993) found that variation in red alder was similar to, but slightly less than, its associated conifers; except that the amount of within population variation was much smaller. Xie and others (1996) found somewhat higher levels of within-population variation than was reported by Ager and others (1993), and concluded that the complexities of variation patterns result from adaptation to local climates. It is interesting to note that in natural stands, red alder and western hemlock have the same spring flushing pattern with coastal and high elevation stands flushing first and inland and low elevation stands flushing later.

New recommendations for seed transfer zone boundaries

HOH (Zone 1): Northern boundary is the Washington Coast from Cape Flattery east to Angeles Point; eastern and southern boundary is south from Angeles Point to Elwha and south to the edge of the gap in the species range around the Olympics, following the edge of the species range south along the west side of the Olympics to the southern boundary of the old 012 seed zone near Colonel Bob, then southwest along the old 012 line to the coast near Point Grenville; western boundary is the Washington coast from Point Grenville north to Cape Flattery. Consists primarily of old seed zones 011 and the western half of 012.

TWIN HARBORS (Zone 2): Northern boundary is Point Grenville east along the southern boundary of the old 012 seed zone to the edge of the gap in the species range around the Olympics near Colonel Bob, then east along the southern boundary of the species range to near Capitol Peak in the Olympics; western boundary is the western edge of the old 030 seed zone, approximately South Mountain, Elma, Weikswood, Doty, Huckleberry Ridge, circling around the headwaters of the Naselle River and then straight south along the western edge of Wahkiakum County to the Columbia River at Grays Bay. Consists of old seed zones 030 and western tip of 041.

NOOKSACK (Zone 3): Northern boundary is Washington-Canadian border from Blaine to the eastern edge of the species range east of Black Mountain; eastern boundary follows the edge of the species range south to near Grassmere; southern boundary starts at the edge of species range near Grassmere and goes west to Lyman, Sedro-Woolley, and Blanchard; western boundary follows coast north from Blanchard to Blaine. Consists of old seed zones 201, the northern half of 202, and the western half of 401.

PUGET SOUND (Zone 4): Northern boundary is Washington-Canadian Border at Point Roberts, southeast to Blanchard, Sedro-Woolley, Lyman and the edge of the species range near Grassmere; eastern boundary is eastern edge of the species range south along Cascade slopes to near Spar Pole Hill; southern boundary is westward from Spar Pole Hill to Graham, DuPont, and Olympia; western boundary is Olympia then west along the southern boundary of the old 231 and 222 seed zones to the edge of the gap in the species range in the Olympic Mountains near Capitol Peak, north along the western edge of the gap in the species range to near Mount Carrie, and north to Elwha and Angeles Point. Consists of old seed zones 211, 212, 221, 222, 231, and the northern portion of 232.

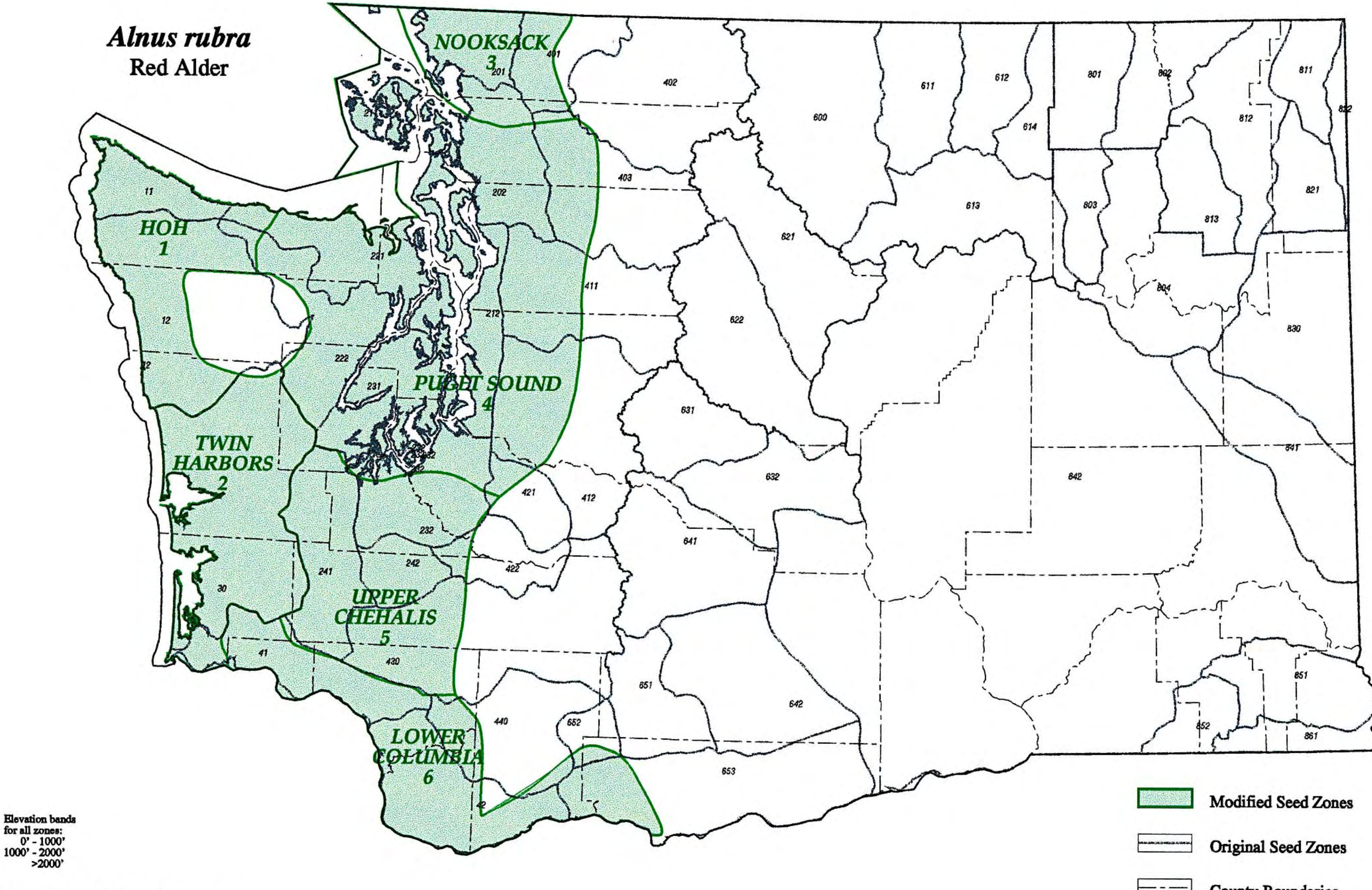
UPPER CHEHALIS (Zone 5): Northern boundary starts at the northern edge of the old 241 seed zone west of Dayton Peak and goes east to Olympia, Dupont, Graham and to the eastern edge of the species range near Spar Pole Hill; eastern boundary is south from Spar Pole Hill along edge of the species range to the southern boundary of the old 430 seed zone west of Goat Mountain; southern boundary follows the southern boundary of the old 430 and 241 seed zones west through Wolf Point and Castle Rock to Huckleberry Ridge; western boundary follows the western edge of the old 241 seed zone north through Doty and Elma to a point west of Dayton Peak. Consists of old seed zones 241, 242, western half of 422 and 430, and southern portion of 232.

LOWER COLUMBIA (Zone 6): Northern boundary is Huckleberry Ridge southeast along the southern boundary of the old 241 and 430 seed zones through Castle Rock and Wolf Point to the edge of the species range near Goat Mountain; eastern boundary is south along the edge of the species range from near Goat Mountain to a point near Silver Star Mountain, and then east to Trout Lake and Dallesport on the Columbia River; southern boundary is the Columbia River from Dallesport to Grays Bay; western boundary is north from Grays Bay along the western edge of Wahkiakum County, north and east along the southern boundary of the old 030 seed zone around the headwaters of the Naselle River to Huckleberry Ridge. Consists of old seed zones 042, eastern three-fourths of 041, the most western portion of 653 and western quarter of 440.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 1000-foot elevation bands should be established.

Alnus rubra
Red Alder



Modified Seed Zones

Chamaecyparis nootkatensis

Alaska Yellow-Cedar

Alaska yellow-cedar (*Chamaecyparis nootkatensis*) occurs in Washington along the west slopes of the Cascade Range at elevations that range from 2000 to 7500 feet, on the ridges of the Olympic Mountains, and in the lowlands of river mouths on the Pacific side of the Olympics (Fowells 1965). Common associates are Pacific silver fir, which has nearly the same range as Alaska yellow-cedar, and mountain hemlock (Franklin and Dyrness 1973). Generally, Alaska yellow-cedar does not form pure stands, but occurs as scattered individuals in this cool moist area where the January mean temperature is 28° F, the July mean is 55° F, and there are 100 inches of annual precipitation. The species range is not continuous along the Cascades, but is separated where the Columbia River cleaves the Cascades.

A nursery test of several coastal British Columbia yellow-cedar provenances detected differences among seed sources for shoot dry weight, shoot-to-root dry weight ratio, and frost hardiness. There were differences among families in height and root collar diameter, but no differences were detected among seed sources for these traits (Cherry and Lester, 1992). Elevation was correlated with provenance shoot-to-root dry weight ratio. Longitude was correlated with shoot dry weight at the provenance level. These preliminary results indicate a need for some seed zone division for Alaska yellow-cedar. Based on preliminary results from field tests on Victoria Island, John Russell (personal communication, March 19, 1999) recommends that there should be more than one geographic zone for Alaska yellow-cedar in Washington, but within the zones only a single elevation band.

Alaska yellow-cedar zones in submaritime British Columbia span two degrees of latitude and 300 meters (1000 feet) of elevation. Along the coast they span four degrees of latitude and 400 meters (1300 feet) in elevation (British Columbia Ministry of Forests, 1995). In Oregon there are two seed zones along the Cascades, a northern one and a southern one, which are separated at the McKenzie River.

New recommendations for seed transfer zone boundaries

ELWHA (Zone 1): The natural range of Alaska yellow-cedar on the Olympic Peninsula.

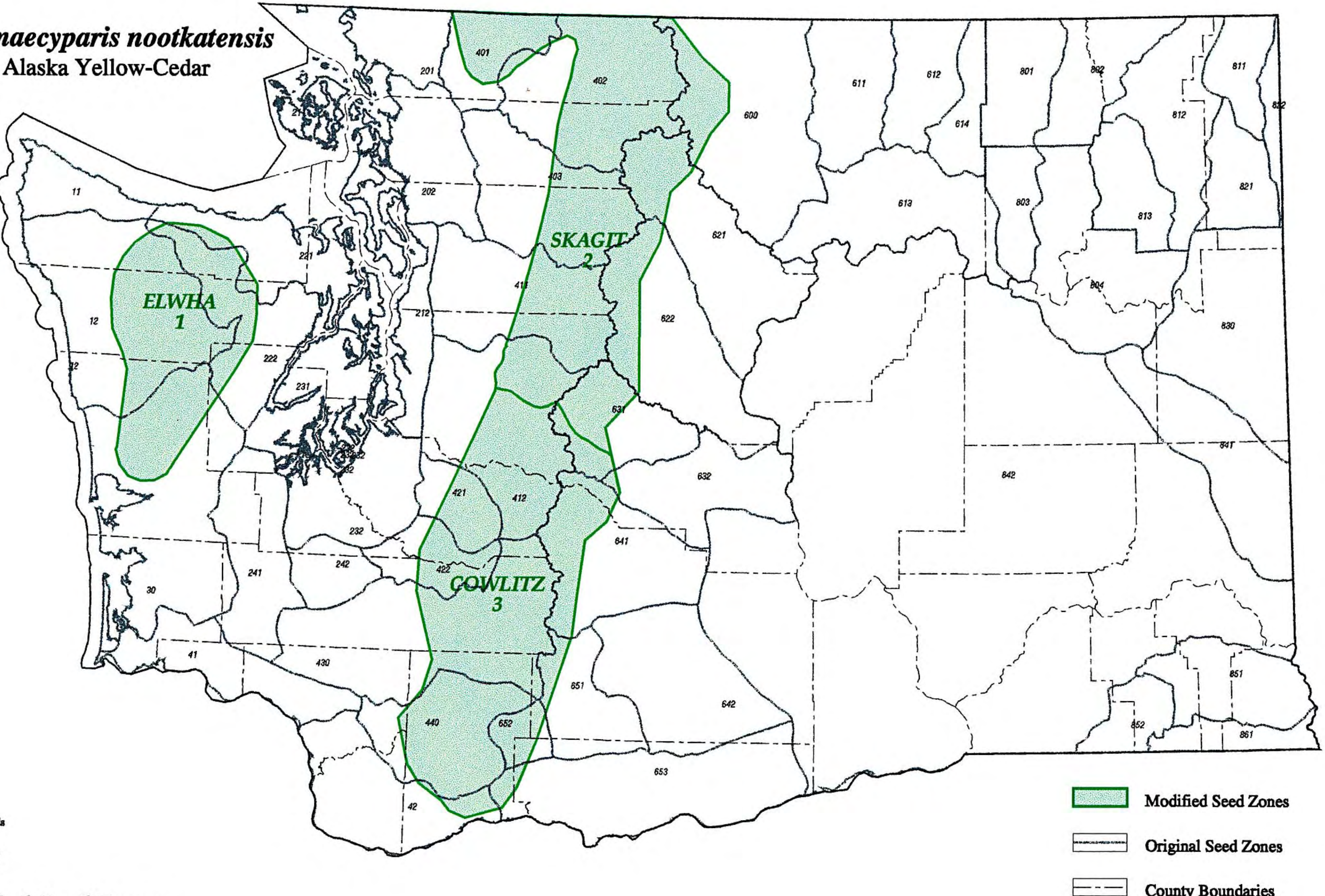
SKAGIT (Zone 2): The natural range of Alaska yellow-cedar in the northern Washington Cascades (north of Interstate 90).

COWLITZ (Zone 3): The natural range of Alaska yellow-cedar in the southern Washington Cascades (south of Interstate 90) and southward to the southern limit of the species range in Washington near the center of Skamania County.

Elevation bands within geographic seed transfer zones

Since provenance tests of Alaska yellow-cedar are young enough to be somewhat unreliable at this time, our recommendation is more cautious than the data suggest. Elevation bands within each zone are: less than 4000 feet, 4000 - 6000 feet, and above 6000 feet.

Chamaecyparis nootkatensis
Alaska Yellow-Cedar



Elevation bands
for all zones:
<4000'
4000' - 6000'
>6000'

Modified Seed Zones

Larix occidentalis

Western Larch

The natural distribution of western larch (*Larix occidentalis*) is centered over the northern Rocky Mountains, where it is one of the fastest growing, most shade intolerant, and most fire tolerant of trees. It is common in the nearby Okanogan Highlands of Washington and is also found in the Blue Mountains and on the east slope of the Cascades of Washington and Oregon. This species grows in a cool, moist zone at elevations from 2000 to 6500 feet. Its upper elevation limit is apparently determined by low temperatures and its lower elevation limit by lack of water. Western larch always grows in mixed stands. Its most common associate is Douglas-fir, but others include ponderosa pine, grand fir, western hemlock, western redcedar, and western white pine (Schmidt and Shearer, 1990).

Little work has been done to determine the seed transfer rules for western larch in Washington. However, some excellent work has been done in the northern Rocky Mountains that is relevant to this state, and in some cases these studies included seed sources from Washington. Rehfeldt (1995) found there were significant differences among populations of western larch in a number of adaptive traits. However, the large genetic differences that also existed within populations tended to mask genetic changes that occurred across the landscape. Thus, western larch showed less genetic differentiation across the same environmental change than other conifers. Elevation was responsible for the largest genetic difference; Rehfeldt recommended limiting movement of this species to 1500 feet in elevation within a locality. A number of traits tended to vary latitudinally, especially tolerance of foliar disease and survival. While differences in these traits between the Blue Mountains and the Okanogan Highlands were large enough to suggest that seed should not be transferred between these areas, they were not large enough to suggest restricting seed movement within each area.

The westernmost of the seed sources in Rehfeldt's (1995) study, which included the eastern Cascades, differed from those in the northern Rocky Mountains, suggesting that it would be prudent to restrict seed movement between the east slope of the Cascade Mountains and the Rocky Mountains as well. Rehfeldt (1982 and 1995) has also suggested that while western larch cannot be moved as far as western redcedar, it can be moved slightly further than ponderosa pine. Because risk of seed movement can vary from place to place within the range of a species, and because we have very little information for the state of Washington for this species, it would be prudent to be somewhat more conservative than Rehfeldt recommends.

Based on adaptive characteristics, Rehfeldt (1982 and 1995) recommended moving seed between northeastern Washington and northern Idaho. However, Fins and Seeb (1986) found there were genetic differences in allozymes between western larch in eastern Washington and northern Idaho and that the Washington populations had several unique and rare alleles. Allozymes are different forms of enzymes that can be used to evaluate the relatedness of groups of plants, but are widely considered not to be related to adaptive characteristics.

They suggested it might be wise to restrict movement of larch seed between the Okanogan Highlands and the northern Rocky Mountains.

There is very little western larch west of the Cascade crest; it occurs only as scattered individuals in a small area in central Skamania County. Local reforestation experience suggests seed transfers between the east and west sides of the Cascades in this area may be risky (Dave Doede, personal communication, August 2000).

New recommendations for seed transfer zone boundaries

YAKIMA (Zone 1): East side of the Cascades where western larch occurs. Consists primarily of the those portions of the old 440, 622, 631, 632, 641, 651, and 652 seed zones where western larch is native.

TWISP (Zone 2): The area where western larch occurs west of the Okanogan River. Consisting of portions of the old 600 and 611 seed zones.

KETTLE (Zone 3): The area where western larch occurs between the Okanogan River and the Columbia River. Consists primarily of portions of the old 612, 613, 614, 801, 802, 803, and 804 seed zones.

PEND OREILLE (Zone 4): The northeast corner of the state east of the Columbia River. Consisting of the old 811, 812, 813, 821, and 822 seed zones, and the northern part of the old 830 seed zone.

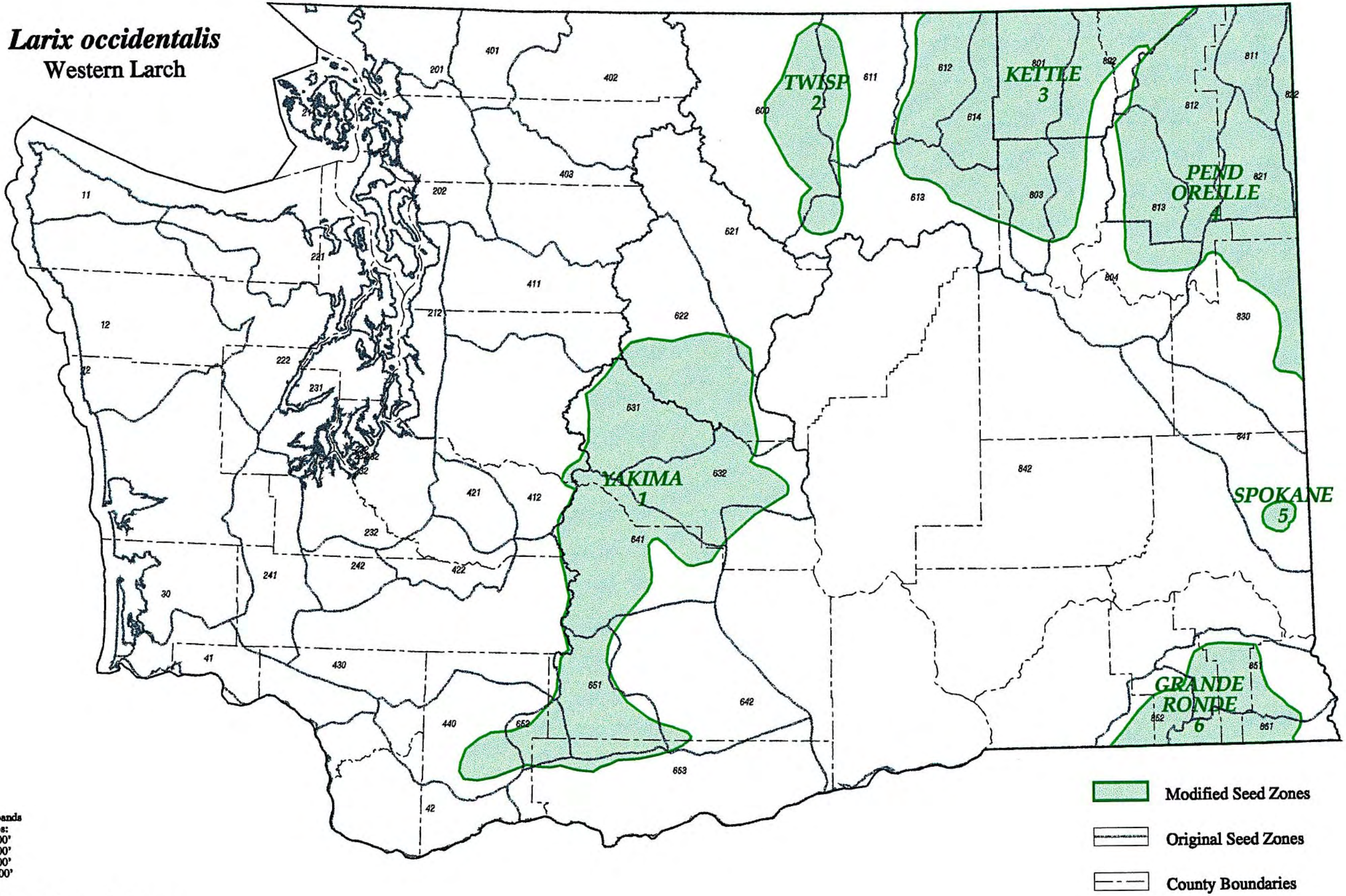
SPOKANE (Zone 5): An isolated population on the east side of Whitman County. Consists of portions of the old seed zone 841 where western larch grows. Use seed from the local area where possible. If this is not practical, seed from nearby parts of Idaho may be used.

GRANDE RONDE (Zone 6): The southeast corner of the state and nearby areas of Oregon. Consists primarily of the old seed zones 851, 852, and 861 and nearby areas of Oregon.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 1200-foot elevation bands should be established.

Larix occidentalis
Western Larch



Elevation bands for all zones:
2000' - 3200'
3200' - 4400'
4400' - 5600'
>5600'

Modified Seed Zones

Picea engelmannii

Engelmann Spruce

Engelmann spruce (*Picea engelmannii*) has an impressive latitudinal range, extending from near the Mexican border to near the Alaskan panhandle. It is most common in the northern Rocky Mountains, where it occupies some of the coldest, highest, forested areas. It is found in cold humid environments, and in spite of its large range appears to be limited to a relatively narrow range of temperatures and precipitation. In Washington it is common in the Okanogan Highlands, but also occurs along the crest and east side of the Cascades, in a small population in the Blue Mountains, and in a very small, isolated population on the Olympic Peninsula (Alexander and Shepperd 1990, Ed Schreiner, personal communication, August 2000).

Most of the genetic studies of Engelmann spruce have focused on the relationships between this species and white spruce, Sitka spruce, and blue spruce. Most of these studies have attempted to determine whether natural interspecific hybrids exist, often with inconclusive results (Daubenmire 1974, La Roi and Dugle 1968, Mitton and Andalora 1981, and Roche 1969). If such hybridization exists, introgression rather than adaptation to environmental factors could be responsible for at least a portion of the genetic variation in this species.

Rehfeldt (1994) conducted the only study designed to develop seed transfer guidelines for this species. This study did not include any samples from Washington, but its conclusions can provide general concepts. He found genetic variation tended to occur along elevational and latitudinal clines. He found that within an area, elevation changes of about 1400 feet were associated with measurable genetic differences between populations. The latitudinal distance associated with genetic differences varied from several hundred miles in parts of the Southwest to 60 or 70 miles in central Idaho. Because risk of seed movement can vary from place to place within the range of a species and because we have very little information for the state of Washington for this species, it would be prudent to be somewhat more conservative than Rehfeldt recommends. In a review paper, Rehfeldt (1993) indicated that genetic variation in Engelmann spruce is similar to ponderosa pine and that both can be moved similar distances both elevationally and climatically. Within the state of Washington the natural distribution of these two species is similar, except that Engelmann spruce occurs on both sides of the Cascades while ponderosa pine is generally restricted to the east side (Alexander and Shepperd 1990).

Shepperd *et al.* (1981) conducted a typical provenance trial of Engelmann spruce in Colorado that included collections from Washington and nearby parts of Oregon, Idaho and British Columbia. They found huge differences between populations from southwest Idaho and east-central Idaho, the same area where Rehfeldt (1994) found very steep genetic differences. However, the differences they found within the state of Washington were much smaller. They speculated that the excellent growth of northern sources, particularly from parts of British Columbia may have been due to introgression from white spruce. Lester *et al.* (1990) recommended that Engelmann spruce seed not be moved from wet to dry or dry to wet bioclimatic zones.

New recommendations for seed transfer zone boundaries

ELWHA (Zone 1): This isolated population on the Olympic Peninsula will make up one seed zone to conserve any unique genes it may possess. Local land managers may want to stockpile a genetically diverse, local collection of this seed in case the population is destroyed.

SKAGIT (Zone 2): Areas within the Engelmann spruce range that are west of the crest of the Cascades and north of the Suiattle River. Consists primarily of the old 402 seed zone and the part of 401 where Engelmann spruce occurs.

GREEN (Zone 3): Areas within the Engelmann spruce range that are west of the crest of the Cascades between the Tieton and Skagit seed transfer zones, including portions of the old 403, 411 and 412 seed zones.

TIETON (Zone 4): High elevation areas along the east side of the Cascades south of the Yakima River, and along the west side of the Cascades south of the Green River. Consists of the western portions of the old 641 and 651 seed zones and the eastern portions of the old 412, 430 and 440 seed zones, as well as the old 652 seed zone and the southern portion of the 631 seed zone.

TWISP (Zone 5): Areas east of the crest of the Cascades, west of the Okanogan River, and north of the Methow River and Early Winters Creek. Consists primarily of the northern 2/3 of the old 600 seed zone and western portions of the old 611 seed zone.

CHELAN (Zone 6): Areas within the Engelmann spruce range that are east of the crest of the Cascades between the Twisp and the Tieton seed transfer zones. When practical, seed for the isolated population within this zone should be locally obtained. Consists primarily of the portions of the old 621, 622 and 631 seed zones where Engelmann spruce occurs.

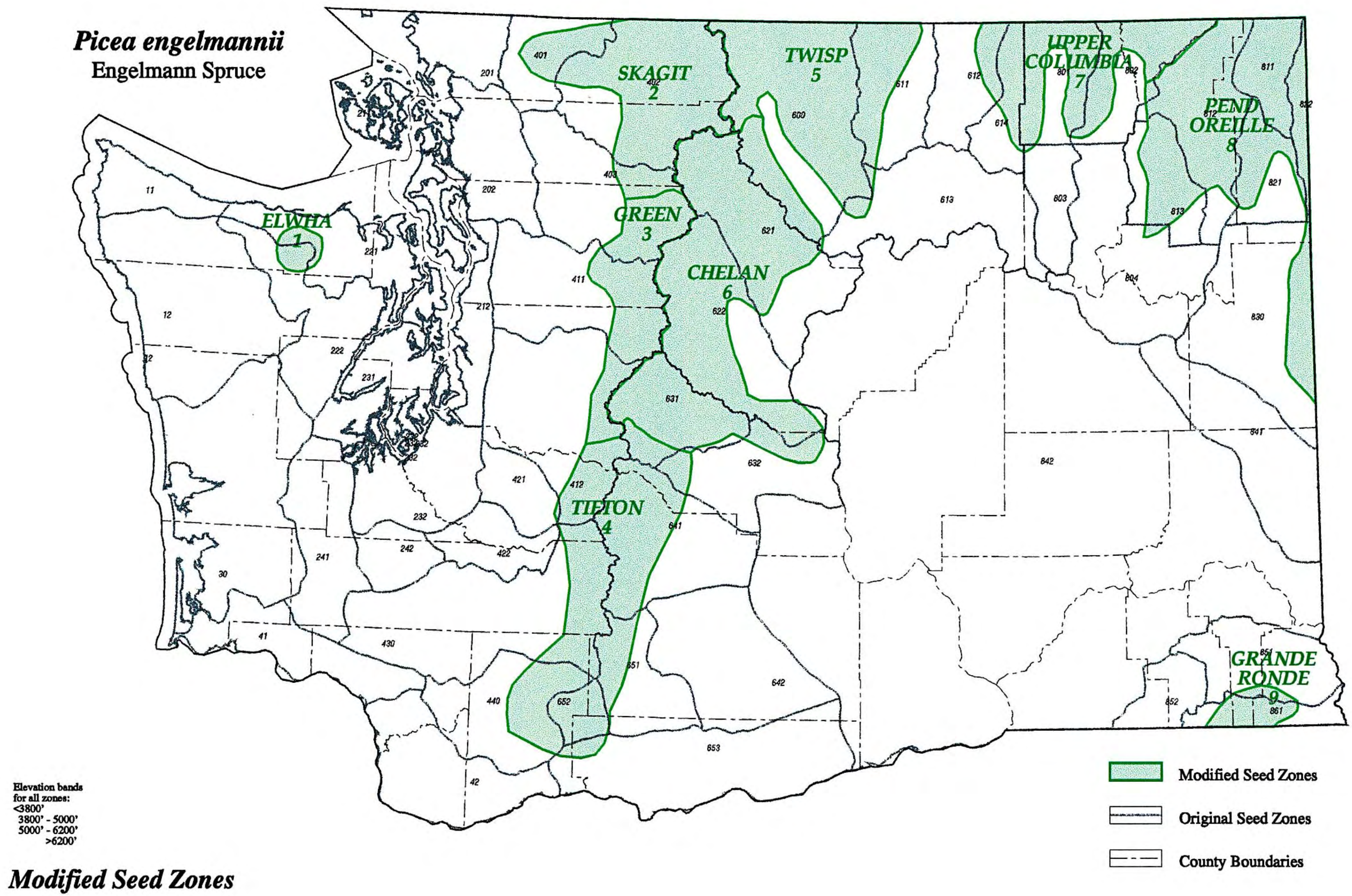
UPPER COLUMBIA (Zone 7): Areas within the natural range of Engelmann spruce that are east of the Okanogan River and west of the Columbia River. Consists primarily of portions of the old 612, 614, 801, and 802 seed zones where Engelmann spruce occurs.

PEND OREILLE (Zone 8): Areas within the natural range of Engelmann spruce that are east of the Columbia River. Seed for the small areas near Spokane can be obtained from nearby parts of Idaho if desired. Consists primarily of portions of the old 811, 812, 813, 821, 822 and 830 seed zones where Engelmann spruce occurs.

GRANDE RONDE (Zone 9): Areas within the Washington portion of the Blue Mountains. Consisting of old Washington seed zones 851 and 861. Can be combined with old Oregon seed zones 852 and 861.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 1200-foot elevation bands should be established.



Picea engelmannii
Engelmann Spruce
ELWHA 1
SKAGIT 2
GREEN 3
TIETON 4
TWISP 5
CHELAN 6
UPPER COLUMBIA 7
PEND OREILLE 8
GRANDE RONDE 9
Elevation bands for all zones:
<3800'
3800' - 5000'
5000' - 6200'
>6200'
Modified Seed Zones
Original Seed Zones
County Boundaries
Modified Seed Zones

Picea sitchensis

Sitka Spruce

Sitka spruce (*Picea sitchensis*) is a coastal tree restricted to a relatively narrow band that occurs on sea-facing slopes and valley bottoms (Harris 1978). It is located mostly from sea level to an elevation of 1000 feet (O'Driscoll 1977). Research by Sara Lipow (personal communication, August 2000) and field observations in Olympia National Park (Ed Schreiner, personal communication, August 2000) suggest that the range of this species extends further up the west side of the Olympic Mountains than Little's (1971) range maps indicate. The Sitka spruce zone is the mildest forest zone in Washington, with few extremes of moisture or temperature (Franklin and Dyrness 1973). The climate is uniformly wet and mild, usually without a pronounced summer drought (Farr and Harris 1979). For example, there are only six days difference in the number of frost free days between Otis, Oregon and Sitka, Alaska, a distance of over 1000 miles (Farr and Harris, 1979). Precipitation is also similar for the two locations, with 250 inches at Otis and 214 at Sitka. Common companion species include western hemlock, western redcedar, and Douglas-fir.

Like most other conifers, over 90 percent of the total genetic diversity of Sitka spruce resides within (rather than between) populations (Yeh and El-Kassaby 1980). However, Sitka spruce is like Douglas-fir, in that a much higher proportion of its total genetic variation tends to be apportioned among populations than is typical for most other western conifers (Ager *et al*., 1993). Variation among families within a location was relatively consistent from one location to another (Campbell *et al*., 1989). Trees from stands that were geographically close had more similar isoenzyme patterns than trees from stands that were geographically separated (Copes and Beckwith, 1977). Sitka spruce was not strongly geographically differentiated for the loci evaluated by Yeh and El-Kassaby (1980). They reported that, on the average, there was little difference among Oregon, Washington, and British Columbia populations, and they all demonstrated similar divergence from Alaskan populations.

Southern sources entered dormancy much later than northern sources, and had more fall frost damage (O'Driscoll 1977, and Birot and Christophe 1983). This north-to-south pattern is also seen in earlier spring bud flushing in the north than in the south (Magnesen 1976, and Falkenhagen 1977). Altitude had less influence than latitude on the timing of fall bud set (Falkenhagen 1977).

Sources north of 46° latitude showed little difference in frost damage when tested in Germany (Kleinschmit and Sauer, 1976), but southern sources flushed before northern ones when tested in Ireland (O'Driscoll 1976). Date of bud set varied by 49 days among provenances when grown in the Netherlands and was highly correlated with latitude, with northern provenances setting bud earlier (Kriek 1976).

There was a north-to-south trend for growth and growing period which increased with decreasing latitude (O'Driscoll 1977, and Birot and Christophe 1983). Among wide-ranging Sitka spruce provenances grown in Denmark, there was little difference in time of bud burst, but large differences in time of growth cessation. This resulted in higher mortality for southern sources than northern ones (Nielsen 1994). Southern sources grew faster than northern ones in France (Birot 1976).

Campbell and others (1989) found that elevation explained bud burst and bud set better than other environmental factors for an Alaskan island population of Sitka spruce. Seedlings that burst bud late tended to be from low elevations, flat slopes, eastern parts of the island, and eastern sides of mountains. Campbell and Ying (Cheng Ying, personal communication, August 2000) found that transfer of seed between the coast and inland areas can decrease growth or increase frost damage. Others have found that southern sources entered dormancy much later than northern ones and were more subject to fall frosts (O'Driscoll 1977, and Falkenhagen 1977). Magnesen (1976) found that northern sources flushed earlier than those from the south.

Campbell and others (1989) stated that transfer from the center to the edge of an island may have more risk than transfer between edges of widely scattered islands. Regulations in British Columbia allow Sitka spruce to be transferred freely throughout the Georgia lowlands; but restricts transfers in elevation to 980 feet up or 650 feet down, and transfers in latitude to one degree south or 4 degrees north in the maritime area (British Columbia Ministry of Forests, 1995). Nielsen (1994) divided Sitka spruce into nine provenance zones, with the two Washington zones separated at about 47.2° north latitude (Pacific Beach at the coast). There was one Oregon zone, and the southern British Columbia zone extended north to about the southern tip of the Queen Charlotte Islands.

New recommendations for seed transfer zone boundaries

HOH (Zone 1): The western half of the Olympic Peninsula. Consists of old seed zones 011 and most of 012, and the portion of old seed zone 221 that is west of Angeles Point.

TWIN HARBORS (Zone 2): Coastal areas south of the Olympic Peninsula. Northern boundary is the northern edge of the old 030 seed zone. The eastern boundary is the eastern edge of the old 030 seed zone from near Capitol Peak in the Olympic Mountains to near Pe Ell and then south to Cathlamet on the Columbia River. Consists of old seed zone 030 and the western tip of 041.

NORTH PUGET (Zone 3): The northern part of the Puget Trough. The eastern boundary follows the eastern edge of the species range from the Canadian border to near the confluence of the White and Clearwater Rivers. The southern boundary starts on the eastern edge of the species range near the confluence of the White and Clearwater Rivers and goes west to Buckley, Sumner, a point north of Tacoma, north to Quilcene, and west to the edge of the gap in the species range in the Olympic Mountains near Mount Constance. The western boundary follows along the edge of the gap in the species range to near Elwha and north to Port Angeles. Consists of old seed zones 201, 202, 211, and 212, the western parts of 412, 411, 403, and 401, and the eastern 3/4 of 221.

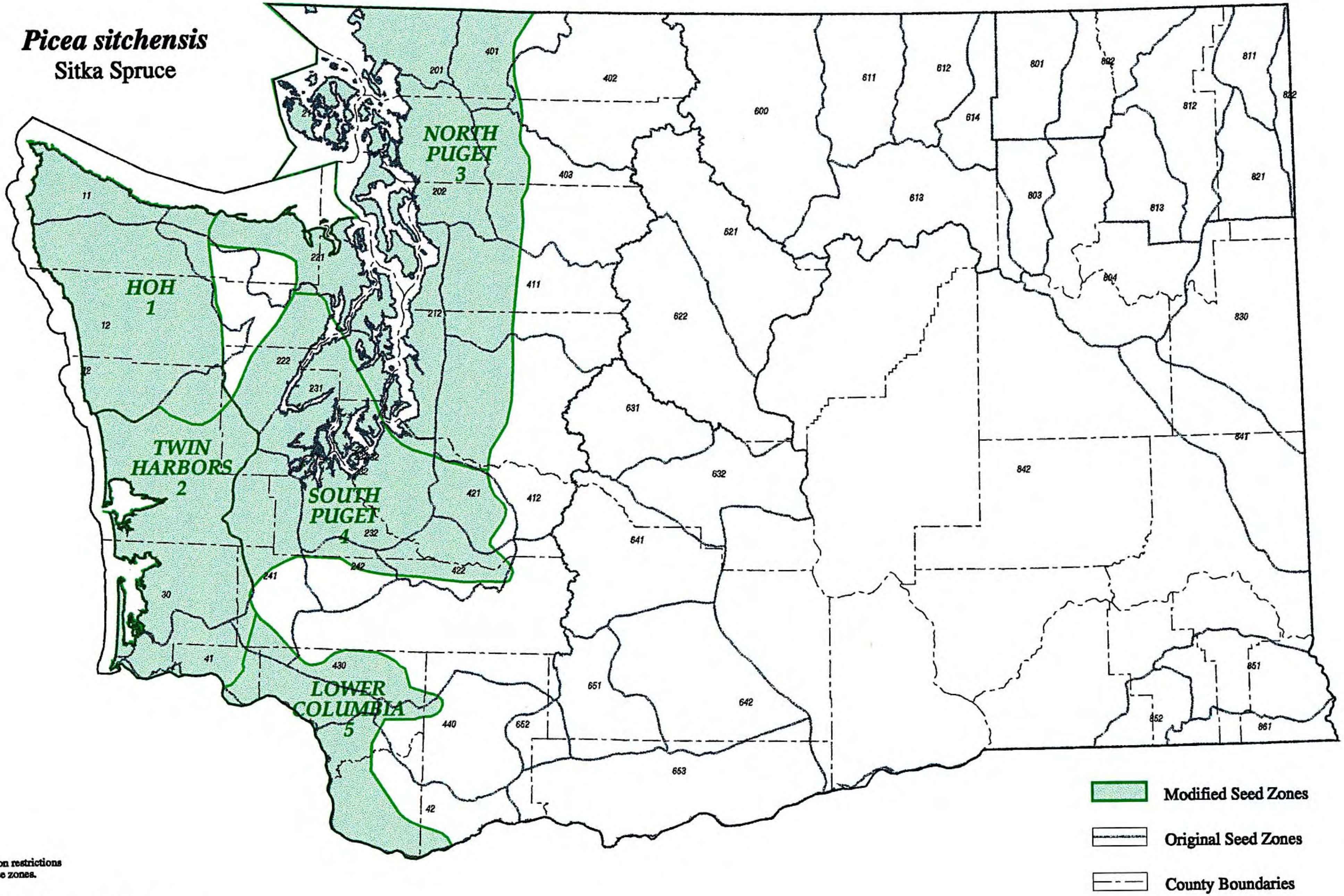
SOUTH PUGET (Zone 4): The southern part of the Puget Trough. The northern boundary starts at the eastern edge of the gap in the species range in the Olympic Mountains near Mount Constance and goes east to Quilcene, then south to a point north of Tacoma, and east to Sumner, Buckley and the edge of the species range near the confluence of the White and Clearwater Rivers. The eastern and southern boundaries follow the edge of the species range to near Pe Ell. The western boundary is the eastern edge of the old 030 seed zone and the eastern edge of the gap in the species range in the Olympic Mountains. Consists of old seed zones 231, 232, 421, 422, the eastern portion of 222, and the northern portions of 241 and 242 within the range of Sitka spruce.

LOWER COLUMBIA (Zone 5): Areas within the range of Sitka spruce along the lower Columbia River, but to the east of Cathlamet. Consists of old seed zone 042, the eastern half of 041, and portions of 241, 430 and 440.

Elevation bands within geographic seed transfer zones

These five geographic seed zones generally cover areas less than 1000 feet in elevation. Therefore, a single elevation band is recommended for all Sitka spruce.

Picea sitchensis
Sitka Spruce



No elevation restrictions within these zones.

Modified Seed Zones

Pinus contorta

Lodgepole Pine and Shore Pine

Lodgepole pine (*Pinus contorta*) has a large natural distribution which extends from Mexico to the Yukon, and from the Pacific Ocean to Alberta and Colorado. Within this area, the species occurs from sea level to 12,000 feet. The species is extremely intolerant of shade, but tolerates low temperatures. It is tolerant of infertile soils and grows on a variety of soils, but they are usually moist. Lodgepole pine has a number of characteristics that can make it an extremely aggressive pioneer species; it has large and frequent seed crops, it has small, widely distributed seed, and the cones are often serotinous (Lotan and Critchfield, 1990).

There is considerable variation within lodgepole pine. It is divided geographically into four subspecies, three of which are found in Washington. Shore pine (*P. contorta* var. *contorta*) is found along the coast and around the Puget Trough. Shore pine has rapid juvenile growth, but tends to be short-lived and small, with large branches. Sometimes it is susceptible to poor form and frost damage. Rocky Mountain lodgepole pine (*P. contorta* var. *latifolia*) is found in most of the inland parts of the state. Rocky Mountain lodgepole pine tends to live longer, grow larger, have better form, and have serotinous cones. Sierra lodgepole pine (*P. contorta* var. *murrayana*) is found mainly in the Sierras and Oregon Cascades, but exists as a few scattered populations on the west side of the southern Washington Cascades. Sierra lodgepole pine tends to be slower growing than either of the other subspecies, have large diameters for its height, and have cones that are not serotinous (Lotan and Critchfield, 1990).

No seed movement studies have been conducted with lodgepole pine in Washington. However, excellent seed movement studies have been conducted with this species in Oregon, Idaho, and British Columbia, and the findings from these projects can be generalized to this state. In addition, many seed source trials, some of which included collections from Washington, have been conducted in Europe with this species.

Rocky Mountain lodgepole pine occupies almost any type of site and Rehfeldt (1983, 1985 and 1988) found that in the Inland Empire this variety of the species must balance the need to grow rapidly in mild environments with the need to become frost hardy early in the year in severe environments. The species accommodates this environmental variation by adapting very specifically to various sites. He found that populations from sites that differ by as little as 650 feet in elevation are likely to be genetically different and should not be interchanged. Populations can be moved relatively long distances geographically, but any movement that results in a change in more than 24 frost free days should be avoided. In a later paper that analyzed plantation data, Rehfeldt *et al*. (1999) recommended that seed movement be limited to 500 feet in elevation at low elevation, and 660 feet at high elevation in southern British Columbia. Ying *et. al.* (1989) found that for Rocky Mountain lodgepole pine, elevation movements as large as 1150 feet were acceptable in British Columbia. However, they found that the coastal influence in British Columbia extended well past the Coast Range (which is comparable to the Cascades in much of Washington) and recommended using extreme caution in moving material from the east side of the range to the interior.

Ying and Liang (1994) evaluated all 4 varieties of lodgepole pine on a test site in the rain shadow of southern Vancouver Island. They found that shore pine outperformed the other three varieties in this environment. For shore pine, they found seed should not be transferred more than 500 feet in elevation. They found seed could be moved 1.5° north or south, but only a short distance east and west. In fact, seed for this site should be obtained only from other sites within the relatively narrow rain shadow of Vancouver Island. They also found that it took as long as 20 years before the problems associated with non-local seed sources became obvious.

Yang and Yeh (1995) looked at genetic differences at the molecular level in lodgepole pine. They concluded that populations of Rocky Mountain lodgepole pine were large and continuous enough so that genetic differences between populations represented adaptational differences due to strong selection pressure. They also concluded that, because shore pine tends to be less common and the populations smaller, the opportunity exists for random differences to develop between populations. Thus, some of the genetic differences among shore pine populations may not be adaptational differences.

There is very little Sierra lodgepole pine in Washington. Sorensen (1992) and Stoneman (1984) investigated Oregon sources of this variety and reached conclusions similar to those found for other varieties. Both determined that broad geographical movement of lodgepole pine was acceptable, but recommended relatively narrow elevation movements.

New recommendations for seed transfer zone boundaries for Shore Pine

HOH (Zone 1): Coastal areas along the Olympic Peninsula. Consists of those parts of the old 012 and 011 seed zones that are within the natural range of shore pine.

TWIN HARBORS (Zone 2): Coastal areas south of the Olympic Peninsula. Consists of parts of the old 030 seed zone that are within the natural range of shore pine, as well as the portion of the old 041 seed zone west of Grays Bay.

ELWHA (Zone 3): East side of the Olympic Mountains. The western boundary consists of the edge of the species range in the Olympic Mountains. The northern, eastern, and southern boundaries start at the edge of the species range near Olympic Hot Springs and go east to Hurricane Hill and Mount Angeles, south to Mount Townsend, The Brothers, and west to the edge of the species range west of Capitol Peak in the Olympic Mountains. Consists primarily of higher elevation parts of old seed zones 221 and 222.

LOWER COLUMBIA (Zone 4): Inland areas within the natural range of shore pine on both sides of the Columbia River. The northern and eastern boundaries consist of the edge of the species range. The southern boundary is the Columbia River. The western boundary consists of the western edge of Wahkiakum County north to where it intersects the old 041 seed zone line. Consists primarily of the old 041 seed zone east of Grays Bay and adjacent parts of Oregon.

ISLANDS (Zone 5): Low elevation areas along the coast to the east of Vancouver Island including Whidbey, Camano, and the San Juan Islands. Eastern boundary is the eastern boundary of the old 201 and 202 seed zones. Southern boundary is the southern edge of the old 202 seed zone and the southern edge of Island County. Consists primarily of old seed zones 201, 202, 211 and the northern part of 212.

KITSAP (Zone 6): Low elevation areas along the Puget Sound not including Whidbey Island. The northern boundary starts on the coast at the northern edge of the Tulalip Indian Reservation and proceeds west along the northern boundary of the old 212 and 411 seed zones to a point west of Silverton. The eastern boundary starts at a point west of Silverton and goes south through Goldbar, Ragnar and the Three Sisters to the edge of the species range near Ashford. The southern and western boundaries follow the edge of the species range from near Ashford west to near Capitol Peak in the Olympic Mountains. Consists primarily of old seed zone 231, the part of 212 south of Whidbey Island, those parts of 232 within the natural range of shore pine, and lower elevation areas of the old 221, 222, 411, 412, and 421 seed zones.

Elevation bands within geographic seed transfer zones for Shore Pine

For Shore pine (zones 1-6), 1000-foot elevation bands should be established within each zone.

New recommendations for seed transfer zone boundaries for Lodgepole Pine

WASHOUGAL (Zone 7): Isolated populations of *P. contorta* thought to be var. *murrayana* on the west side of the southern Washington Cascades. Whenever practical, seed from these isolated populations should be planted in this seed zone. Where that is not possible, seed from the northern part of Oregon's lodgepole pine seed zone 1 may be used. Local land managers may want to stockpile genetically diverse seed collections from these stands in case they are destroyed by fire.

SKAGIT (Zone 8): The west side of the Cascades in the northern part of the state. The northern boundary is the Canadian border from a point west of Black Mountain to the Cascade Crest. The eastern boundary is the Cascade Crest south to Dome Peak. The southern boundary is the line between Skagit and Snohomish Counties. The western boundary follows the western edge of the old 403 and 401 seed zones from the county line north through Little Deer Peak. Lyman, Saxton, and Deming, to a point on the Canadian border west of Black Mountain. Consists primarily of old seed zones 401 and 402, and northern portions of 403.

SNOQUALMIE (Zone 9): The west side of the Cascades in the central part of the state. The northern border is the line between Skagit and Snohomish Counties. The eastern boundary is the Cascade Crest from the county line south to Snoqualmie Pass (Interstate 90). The southern boundary is Interstate 90 west to Ragnar. The western boundary goes north from Ragnar through Goldbar to a point west of Silverton, then west and north along the old 403 seed zone boundary to the Skagit / Snohomish County lines. Consists primarily of high elevation portions of the old 411 and 412 seed zones, and southern portions of the old 403 seed zone.

COWLITZ (Zone 10): The west side of the Cascades in the southern part of the state. The northern boundary is Interstate 90 from Ragnar to the Cascade Crest. The eastern and southern boundaries follow the crest of the Cascades from Interstate 90 (Snoqualmie Pass) south to Mount Adams, Steamboat Mountain and south to the edge of the range near Burnt Peak. The western boundary follows the edge of the species range from Burnt Peak to a point near Ashford and continues from that point north to the Three Sisters and Ragnar. Consists primarily of high elevation portions of the old 421, 422, 430, and 440 seed zones, and southeastern portions of the old 412 seed zone.

TWISP (Zone 11): The east side of the Cascades in the northern part of the state. Northern boundary is the Canadian border. The eastern boundary follows the edge of the interrupted species range to the west of the Okanogan River. The southern boundary follows the edge of the interruption in the species range along the Methow River and along Early Winters Creek to the Cascade Crest. The western boundary is the Cascade Crest. Consists primarily of portions of the old 600 seed zone.

CHELAN (Zone 12): The east side of the Cascades in the central part of the state. The northern boundary goes from the Cascade Crest east along Early Winters Creek to the edge of the species range. The eastern boundary follows the edge of the interrupted species range south along the Methow and Columbia Rivers. The southern boundary is Interstate 90. The western boundary is the Cascade Crest. Consists primarily of the old 621, 622, and 631 seed zones, and the southwestern part of the old 600 seed zone.

TIETON (Zone 13): The east side of the Cascades in the southern part of the state. Includes areas within the natural range of lodgepole pine that are east of the crest of the Cascades and south of Interstate 90. Consists primarily of those parts of the old 632, 641, 651, and 652 seed zones that are within the natural range of lodgepole pine.

KETTLE (Zone 14): Areas within the natural range of lodgepole pine that are east of the Okanogan River and west of the Columbia River. Consists primarily of those parts of the old 614, 612, 801, 802, 803 and 804 seed zones that are west of the Columbia River and within the natural range of lodgepole pine.

PEND OREILLE (Zone 15): Areas in the northeast part of the state that are within the natural range of lodgepole pine and east of the Columbia River. Consists primarily of the old 811, 812, 813, 821 and 822 seed zones, and 804 east of the Columbia River.

SPOKANE (Zone 16): Areas within the natural range of lodgepole pine on the east side of Spokane County and nearby parts of Idaho. Consists of the old 830 seed zone and nearby parts of Idaho, particularly Kootenai County.

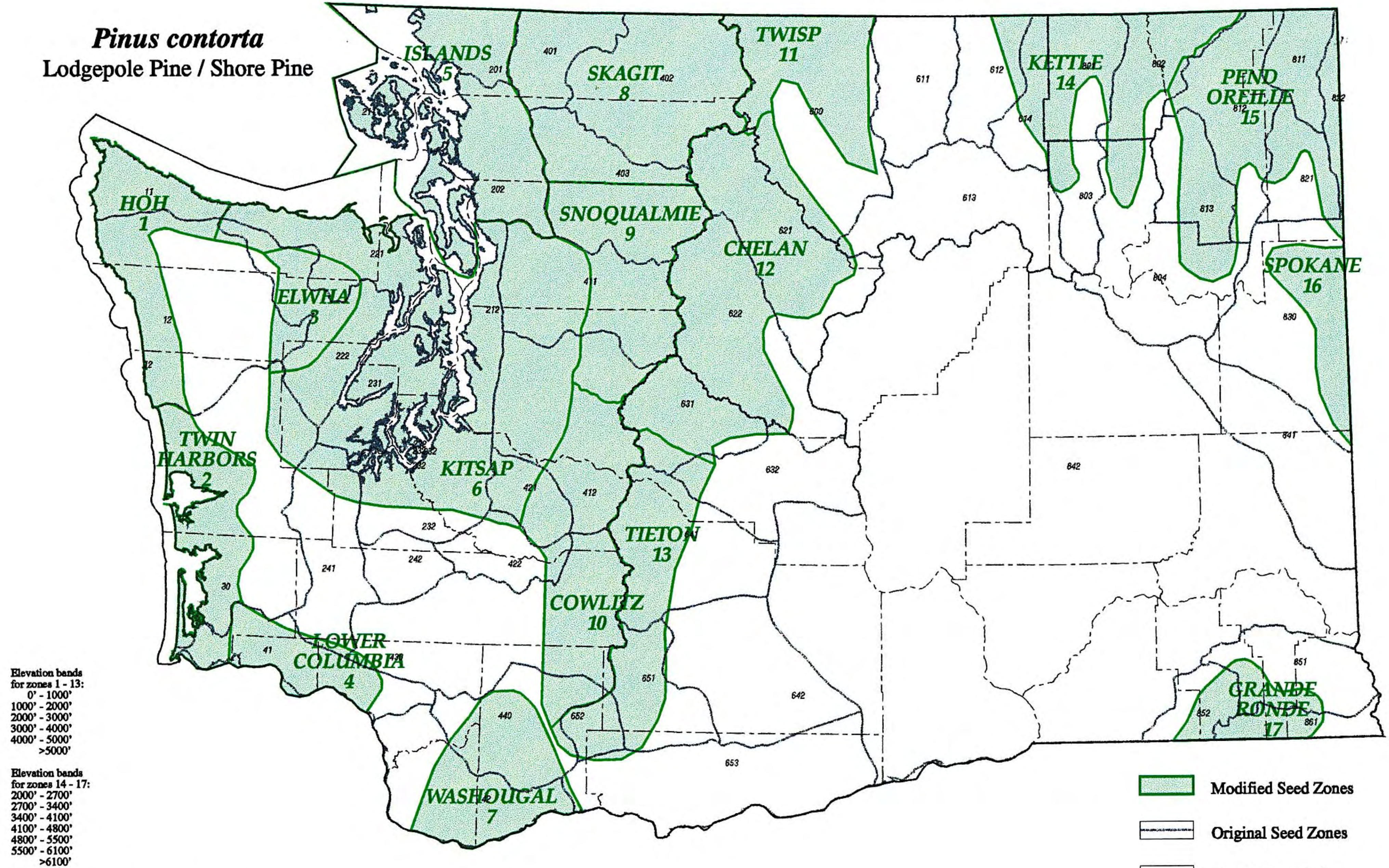
GRANDE RONDE (Zone 17): Areas within the natural range of lodgepole pine in the Washington portion of the Blue Mountains and nearby portions of Oregon. Consists primarily of portions of the old Washington/Oregon seed zones 851, 852, and 861.

Elevation bands within geographic seed transfer zones for Lodgepole Pine

In the Cascades (zones 7-13), 1000-foot elevation bands should be established within each seed transfer zone. In the Okanogan Highlands and the Blue Mountains (zones 14-17), 700-foot elevation bands should be established within each seed transfer zone.

Pinus contorta

Lodgepole Pine / Shore Pine



Modified Seed Zones

Pinus monticola

Western White Pine

In Washington, western white pine (*Pinus monticola*) is found throughout the Cascade Range, the Olympic Mountains, in the Okanogan Highlands, and in a small area of the Blue Mountains in the southeastern corner of the state (Fowells 1965). This species occupies an area with short growing seasons where the majority of the precipitation occurs during the winter. In the Cascades, western white pine grows primarily on the western slopes and only extends eastward a short distance across the crest. Its elevation spread is not large; it is generally found between the Douglas-fir and Pacific silver fir zones (Bingham et al., 1972). In the Olympic Mountains it occurs from sea level to 1800 feet (Fowells 1965). White pine is usually associated with several different tree species growing together in a mixture.

Blister rust, an introduced pathogen, is a serious disease of western white pine. Resistance to this disease is highly heritable with large differences among trees within stands. A number of programs have existed since the 1950s to take advantage of this variation and develop white pine resistant to this disease. One program is operated by the USDA Forest Service and the Inland Empire Tree Improvement Cooperative from Moscow, Idaho. Seedlings from this program that are suitable for parts of northeastern Washington can be obtained from a nursery operated by the University of Idaho. When planning white pine plantings, you should evaluate the risk of this disease in your area and the availability of resistant seed.

There is little genetic variation among sources of western white pine; however, there is large genetic variation within local stands (Rehfeldt 1979, Steinhoff 1979, Steinhoff *et al*. 1983, and Campbell and Sugano 1989). Local elevation did not influence genetic variation. Populations from northern Idaho and the Olympic Peninsula show similar growth and survival when grown in northern Idaho (Steinhoff 1981). Western white pine populations from northern Idaho (Rehfeldt 1979), coastal Washington, and western British Columbia (Steinhoff 1981) show little or no difference in growth or phenology when grown in Idaho. Variation based upon isozyme patterns separates the entire western white pine range into two populations, a broad northern population and a more restricted southern one; separated near the Oregon-California border (Steinhoff *et al*. 1983). Rehfeldt *et al*. (1984) further subdivided the northern population in the central Oregon Cascade at 44° north latitude. Their research indicated that populations west of the Cascades suffered the most frost injury and thus may not be well adapted to Rocky Mountain sites. Throughout all areas they found that genetic variation was not related to elevation of the seed source.

Recommendations for British Columbia, based on 13-year-old provenance plantations, are that California and Oregon sources are not suitable because of poor height growth. Washington and Idaho sources are suitable for coastal sites but not for northern-interior sites. For the northern-interior region use local sources (Meagher and Hunt, 1998).

These reported variation patterns indicate that seed movement should not be restricted very much. Western white pine seed zones should be large compared to those for Douglas-fir. Western white pine seed zones were adopted by the U.S. Forest Service in 1988 for both Washington and Oregon based on these genetic publications and on recommendations from Robert Campbell of the Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon (Campbell and Sugano 1989, and U.S. Forest Service Region Six, April 20, 1988, documentation on file at Regional Office Portland, Oregon). Seed zones and the numbering system cover both states.

New recommendations for seed transfer zone boundaries

These seed transfer rules apply only to sites where white pine occurs or occurred naturally.

TWIN HARBORS (Zone 1): Includes the Olympic Peninsula and nearby areas to the south. Consists of old seed zones 011, 012, 030, 221, 222, and 241.

PUGET SOUND (Zone 2): Includes coastal areas near the Puget Sound. Consists of old seed zones 201, 202, 211, 212, 231, and 232.

SNOQUALMIE (Zone 3): Includes portions of the Puget Trough and the west slope of the Cascades in the northern part of the state. Consists of old seed zones 401, 402, 403, 411, 412, 421, and that portion of seed zone 422 in Pierce County.

LOWER COLUMBIA (Zone 4): Includes portions of the Puget Trough and the west and east slope of the Cascades in the southern part of the state. Consists of the portion of old seed zone 422 in Lewis County, and those portions of the old seed zones 042, 242, 430, 440, 651, 652, and 653 that are within the natural range of western white pine.

CHELAN (Zone 5): The east slope of the Cascades in all but the southern part of the state. Consists of the portions of old seed zones 600, 621, 622, 631, and 641 that are within the natural range of western white pine.

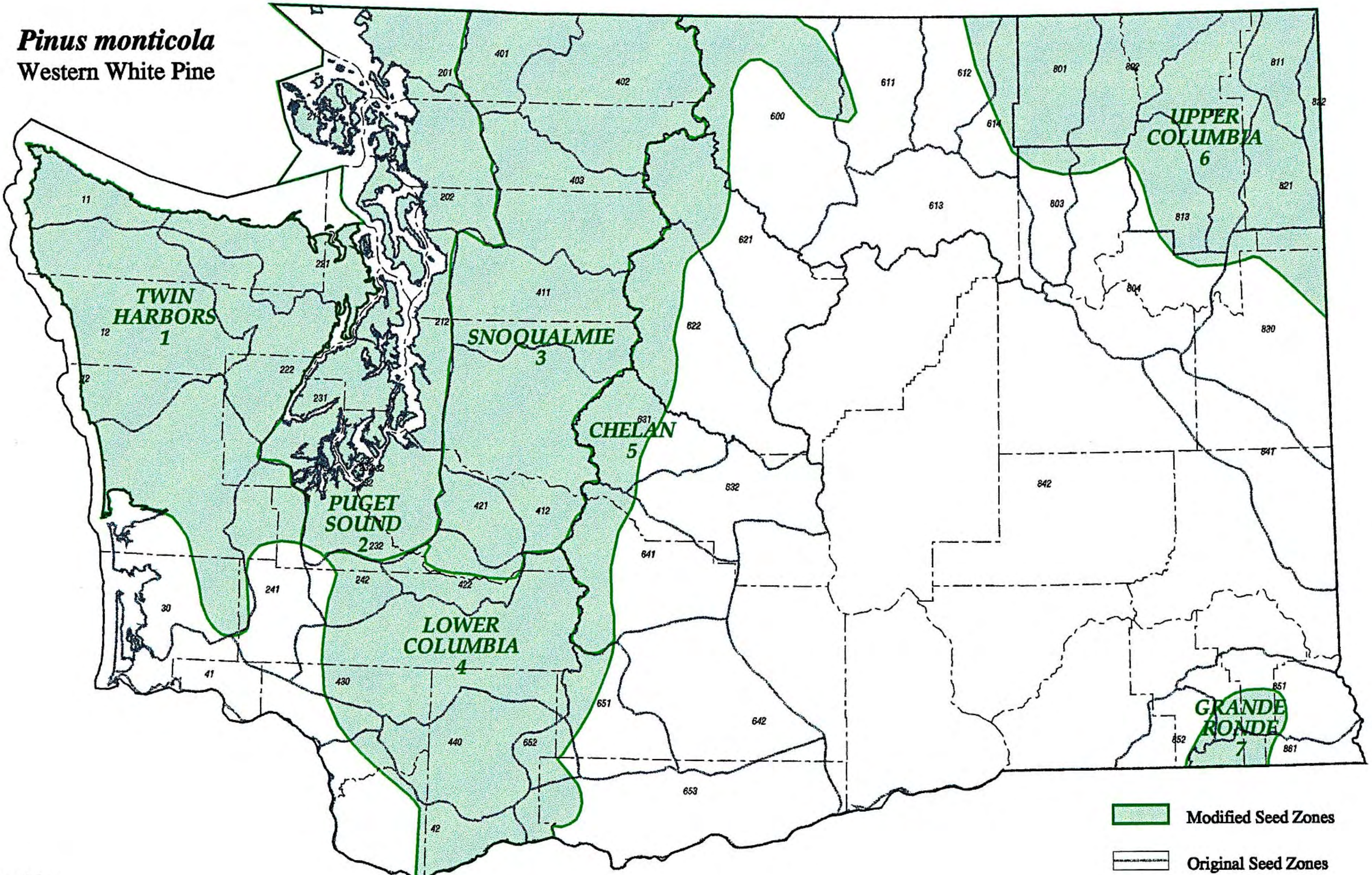
UPPER COLUMBIA (Zone 6): Includes the natural distribution of western white pine in the Okanogan Highlands in the northeast corner of the state. Consists of old seed zones 614, 801, 802, 811, 812, 813, 821, 822, and 830. Seed for this area can also be obtained from nearby parts of Idaho, particularly if it is disease resistant.

GRANDE RONDE (Zone 7): Includes the natural distribution of western white pine in the Blue Mountains in the southeast corner of the state. Consists of old seed zones 851 and 861. Seed for this area can also be obtained from nearby parts of Oregon.

Elevation bands within geographic seed transfer zones

There are no elevation restrictions on seed transfer. Transfers are permitted for all elevations within a zone.

Pinus monticola
Western White Pine



No elevation restrictions within these zones.

Modified Seed Zones

Pinus ponderosa

Ponderosa Pine

Ponderosa pine (*Pinus ponderosa*) is one of the most widely distributed pines in North America. Two varieties are recognized, Pacific ponderosa pine (*P. ponderosa* var. *ponderosa*) and Rocky Mountain ponderosa pine (*P. ponderosa* var. *scopulorum*). A number of races are recognized within each variety. The vast majority of the ponderosa pine within the state of Washington is classified as the north plateau race of Pacific ponderosa pine (Conkle and Critchfield 1988). This race is characterized by almost always having three needles per fascicle; relatively short, thick needles; purple male flowers and cones; and certain biochemical traits (Critchfield 1984).

In Washington, ponderosa pine occurs from sea level to 4000 feet, but is found mainly to the east of the Cascade Crest (Critchfield and Little 1966, and Oliver and Ryker 1990). A rich variety of tree species are associated with ponderosa pine; western juniper on the drier sites; trembling aspen in riparian areas; and lodgepole pine, Douglas-fir, grand fir, western larch, and western white pine on mesic sites (Franklin and Dyrness 1973). The primary range is along the east slopes of the Cascades, extending eastward throughout the Okanogan Highlands. The species is also found in the Blue Mountains of southeastern Washington and in a number of isolated populations to the west of the Cascades, including one near Fort Lewis, one in Mt. Rainier National Park and one in the North Cascades National Park. Local experts suspect the isolated population Little (1971) shows in the Olympic Mountains was planted (Ed Schreiner, personal communication, August 2000). The racial identity of these isolated west-side populations is not clear.

Average annual temperatures are similar throughout the large range of ponderosa pine and fall between 41 and 51° F , but annual extremes vary widely from minus 40° to 110° F. Soil moisture often limits growth of ponderosa pine, particularly during the dry summers that are characteristic of most of its range within the state of Washington (Oliver and Ryker, 1990).

Long-term information on range-wide variation is available for ponderosa pine because some of the earliest seed source tests in North America were established in 1911 at Priest River, Idaho, (Steinhoff 1970, and Weidman 1939) and in 1928 at 6 locations in Washington and Oregon (Munger 1947, and Squillace and Silen, 1962). These tests provided much of the information used to subdivide the species into varieties and races.

Details on adaptability within more limited geographic areas, particularly for the north plateau race were not identified until more recently. Sorensen (1994) found that along the east side of the Oregon Cascades, north to south movement of seed had to be limited by three to five seed zones to control the risk of maladaptation. Sorensen and Weber (1994) also found that seed zones limiting east to west movement of the seed were necessary on the east side of the Cascades in Oregon as well. Rehfeldt (1980, 1986a, 1986b, 1986c, 1988, and 1991) described genetic variation within northeast Washington, as well as nearby parts of Idaho and Montana. He found that two to three seed zones were necessary to limit seed movement in the northeastern part of Washington.

Both Sorensen and Rehfeldt found that adaptation among ponderosa pine populations reflected a balance between the need to grow rapidly in mild environments and to tolerate climatic insult in stressful environments. They found that elevation, which reflects variation in the length of the growing season, was closely related to genetic variation. Lower elevation populations tended to get taller because they grew for a longer period of time, but they were more susceptible to frost damage. Sorensen and Weber (1994) recommended that seed movement be limited to 1000 foot bands below 5000 feet in elevation and 700 foot bands above that point. Rehfeldt (1991) found that populations within a drainage that are separated by more than 1360 feet in elevation, or 35 days in the length of the growing season, tend to be genetically different. Randy Johnson and Nancy Mandel (personal communication, 1999) found that elevation accounted for most of the variation among populations of ponderosa pine on the Wenatchee National Forest. They recommended using 700 foot elevational bands to limit seed movement across all elevations on this Forest.

Isolated populations sometimes contain unique forms of genes. Some people believe the three isolated populations on the west side of the Cascades are remnants of a once widespread community. In any case, it would be prudent for the land managers responsible for these areas to stockpile local seed for future reforestation.

The Cascade Range in Washington is divided into northern and southern physiographic regions at Snoqualmie Pass (Franklin and Dyrness, 1973). The northern portion is comprised of ancient sedimentary rocks while the southern portion is primarily andesite and basalt flows. Mean annual precipitation is fairly uniform at a constant elevation along the entire eastern slope, but decreases rapidly from west to east. Temperature is also fairly constant at a given elevation throughout the northern two-thirds of the Cascades, but becomes warmer south of Mount Adams. Summer aridity divides the eastern slopes into a drier area south of Ellensburg. These north to south differences, while not large, suggest that the area be divided into northern and southern seed zones. The eastern half of the Okanogan Highlands is slightly wetter than the western half. Temperature is mostly influenced by mountains and valleys with no general east to west pattern (St. Clair and Vance-Borland, 1998).

New recommendations for seed transfer zone boundaries

PUGET (Zone 1): An isolated population occurs near Tacoma on the grounds of Fort Lewis. There is only one elevation band.

RAINIER (Zone 2): An isolated population occurs on the east side of Mount Rainier. There is only one elevation band.

ROSS (Zone 3): An isolated population occurs to the east of Ross Lake on the west side of the Cascade Crest. There is only one elevation band. Seed from nearby westside populations in Canada could be used if no seed is available from this population.

CHELAN (Zone 4): Northern boundary starts at the western edge of the ponderosa pine range along Sawtooth Ridge, follows the northern boundary of old seed zone 621 to Goat Mountain and east to Bridgeport. Eastern boundary is the edge of the ponderosa pine range from Bridgeport to the Wenatchee Mountains, approximately 10 miles south of Wenatchee. Southern boundary follows the southern boundary of the old 622 seed zone along Wenatchee Mountain, northwest to Three Brothers and the western edge of the species range. Western boundary follows the edge of the species range north to Sawtooth Ridge.

YAKIMA (Zone 5): The portions of the ponderosa pine range on the east slope of the central Washington Cascades between the Chelan and White Salmon seed zones. Includes parts of old seed zones 631, 632, and 641.

WHITE SALMON (Zone 6): The portions of the ponderosa pine range on the east slope of the southern Washington Cascades. Northern boundary follows the line between Cowiche Mountain and Darland Mountain. Includes portions of old seed zones 042, 440, 651, 652, 653, and 642.

OKANOGAN (Zone 7): Northern boundary is the Canadian border from the western limit of the species range to the Okanogan River. Eastern boundary is the Okanogan River from the Canadian border to the Columbia River, and along the Columbia River to near Bridgeport. Southern boundary proceeds west from Bridgeport to Goat Mountain and follows the northern boundary of old seed zone 621 along Sawtooth Ridge to the western limit of the ponderosa pine range. Western boundary is the western limit of ponderosa pine range near Lake Chelan north to the Canadian border.

KETTLE (Zone 8): Northern boundary is the Canadian border from Okanogan River to Columbia River. Eastern and southern boundaries are the Columbia River from the Canadian border to Grand Coulee Dam, and then west along the southern limit of the ponderosa pine range to Bridgeport. Western boundary is the Columbia River from Bridgeport to the Okanogan River and north along the Okanogan River to the Canadian border.

PEND OREILLE (Zone 9): Northern boundary is the Canadian border from the Columbia River east to the Washington/Idaho border; eastern boundary is the Washington/Idaho border south to Highway 2 at Newport; southern boundary is west from three miles south of Newport to north side of Deer Lake, south to Loon Lake, west along Chamokane Creek to a point northeast of Blue Mountain, then north and west along the Stevens County line to near Cedonia on the Columbia River; western boundary is the Columbia River north to the Canadian border. Consists of the old seed zones 811, 812, 813, 821, and 822.

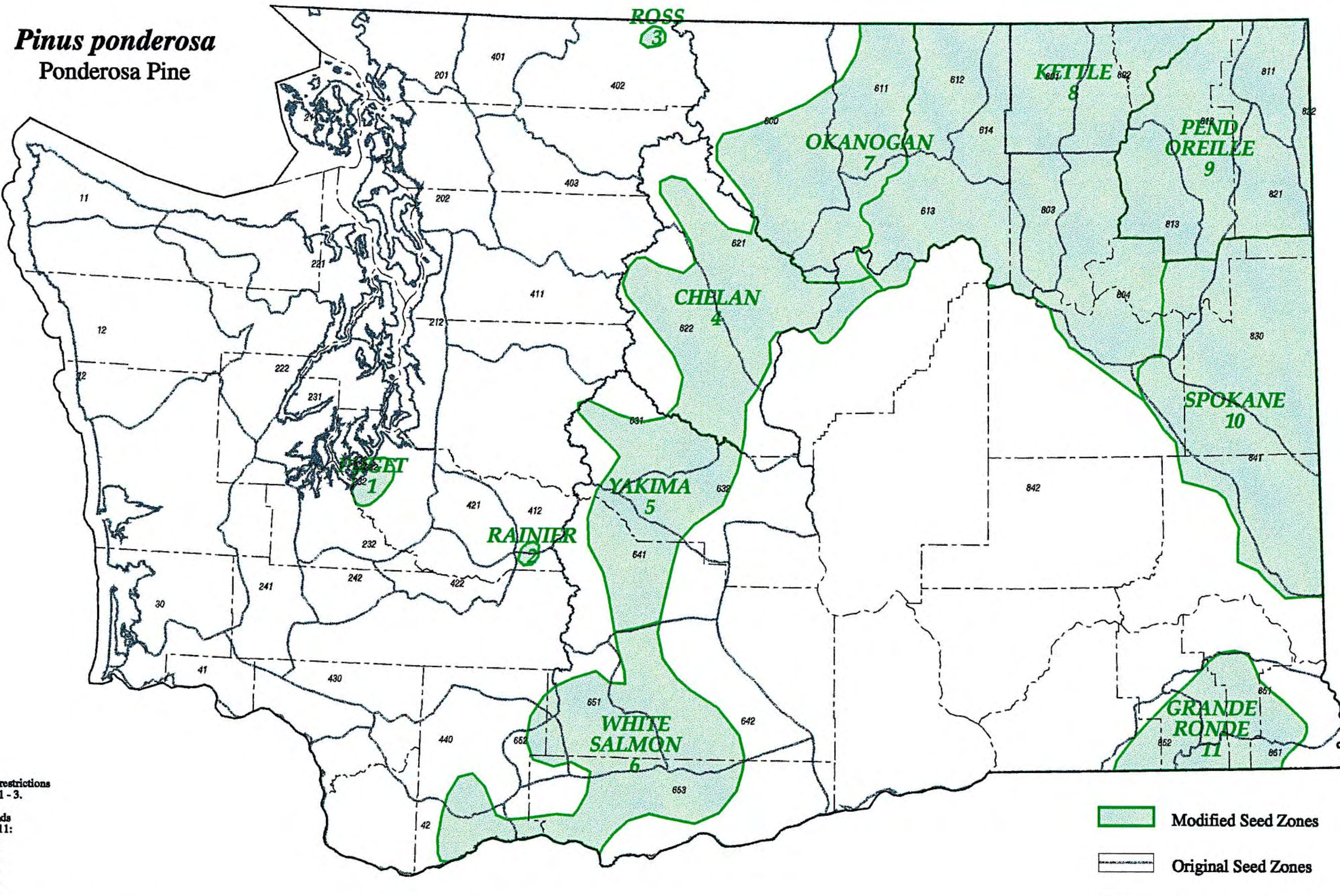
SPOKANE (Zone 10): Northern boundary is east from the north edge of Deer Lake to three miles south of Newport; eastern boundary is Washington/Idaho border south to Highway. 3, six miles east to Pullman; southern boundary follows the edge of the species range (including an isolated population in Whitman County) approximately from Washington/Idaho border at Idaho's Highway 3 northwest to Mockonema, Saint John, Rodna, Blue Stem, and Davenport; western boundary is from Davenport to a point between Mondovi and Reardan, and north to Chamokane Creek. Consists of the old seed zones 830, 841, and a portion of 804.

GRANDE RONDE (Zone 11): All portions of the natural range of ponderosa pine in the Blue Mountains. Includes parts of old seed zones 851, 852, and 861.

Elevation bands within geographic seed transfer zones

Puget, Rainier and Ross: a single elevation in each of these zones. In all other seed movement zones, 1000-foot elevation bands should be established.

Pinus ponderosa
Ponderosa Pine



Modified Seed Zones

Populus trichocarpa

Black Cottonwood and Populus Hybrids

Black cottonwood (*Populus trichocarpa*) is the largest broadleaf tree species of the Pacific Northwest (Fowells 1965). This tree is found throughout Washington at all elevations from sea level to 5000 feet, except for an area in the middle of the state centered around Grant County. It occurs mostly on river bottom lands, but can also be found on moist upland sites (Franklin and Dyrness, 1973).

Cottonwood stem cuttings root readily when they receive adequate amounts of moisture. Usually, the species is clonally propagated using unrooted stem cuttings and seedlings generally are not available from nurseries (Heilman *et al*. 1990). Individual clones differ for many traits including growth rate, cold hardiness, form, and disease resistance. The use of selected cottonwood clones has the potential to produce major gains for specific traits, but also increases risk of loss or poor performance due to insects, disease, or climate.

In addition to differences among clones, there are differences among populations. On the west side of the Cascades, populations that differ in latitude, longitude, and elevation tend to be genetically different. These genetic differences reflect regional climatic gradients (Weber *et al*., 1985). Longitude is a better predictor of population performance than either latitude or elevation and material from mesic sources tends to grow better on mesic sites than material from xeric sources (Stettler *et al*., 1993).

A number of common garden studies have shown there are genetic differences in growth, leaf flushing, photosynthetic rate, and Melampsora rust resistance between populations from the upper and lower portions of river valleys in Washington when they are grown at one location (Dunlap *et al*. 1993, 1994, and 1995). Genetic differences between populations from opposite sides of mountain ranges tend to be stronger than differences between populations on the same side of the same mountains (Dunlap *et al.* 1993, and Stettler *et al*. 1993). Material collected at upper elevations tends to be different from material collected at lower elevations (Dunlap *et al*., 1993). Bud set and growth cessation tend to occur earlier in eastern than in western sources when they are grown at the same location. Cottonwoods from separate river systems can be distinct in branching habit and leaf shape (Dunlap *et al*. 1993).

Clones collected from elevations below 2000 feet tend to initiate growth earlier than clones from middle and upper elevation sources when planted at a common low elevation site. In addition, clones from middle elevations (2000 to 4000 feet) tend to be earlier than clones from above 4000 feet, when planted at the same site (data on file at Ochoco National Forest, Prineville, Oregon).

Many commercial cottonwood growers use hybrids between different species, for example, between black cottonwood and eastern cottonwood (*Populus deltoides*). A large number of these hybrids have been developed by Washington State University and grown successfully in Oregon, Washington and southern British Columbia (Heilman *et al*. 1990). The characteristics of these hybrids vary depending upon which species and which clones within species are crossed. Hybrids that use black cottonwood from eastern Washington for one parent tend to be more tolerant of cold weather than hybrids that use black cottonwood from western Washington (McCamant and Black, 1995). Growing hybrid cottonwood for pulpwood has been a major success in south central and western Washington.

Since new hybrid clones are continually being made available, consult with the developer, your State Forestry Extension agent, or the Washington State University poplar specialists to choose ones appropriate to your needs. When planting any hybrid material, one should know where it has been tested and the test results. When selecting hybrids, plant only ones that have been tested and proven resistant to diseases and suitable for the climate in your planting area. Only male clones should be planted in urban areas, as they will not produce the fluffy white seeds which some people find objectionable.

Some non-native cottonwoods are useful for specific purposes. A notable example is Lombardy poplar (usually a single male clone, native to central Europe) that has been grown successfully over a large portion of the globe, as a wind break.

Depending on landowner objectives, material selected for planting can range from local black cottonwood clones to hybrid cottonwood clones developed for specific geographic locations or for specific growth and wood properties. When planting to reestablish local populations or to provide streamside vegetation for wildlife or fish habitat, native material may be considered more appropriate. Conservation and riparian restoration plantings with native material should use local material to safeguard local genetic diversity (Stettler *et al*. 1993).

General guidelines: (1) upper and lower elevation cottonwoods originating along a river drainage or from scattered areas are genetically different; (2) there are genetic differences between the two sides of the Cascades; (3) genetic differences are greater across mountain ranges then parallel to them; (4) know the genetic makeup of hybrid cottonwoods and their recommended planting zone; (5) A single genotype (clone) may be planted or a mixture of clones may be used.

Recommendations for hybrids and other non-native cottonwoods:

LOMBARDY AND WHITE POPLAR (*Populus alba*): Plant anywhere in the state below 4000 feet.

HYBRIDS FOR COMMERCIAL POPLAR PLANTATIONS: There are many clones available and new ones are constantly being developed. Consult with the developer or State Extension Forester for the latest recommendations.

New recommendations for black cottonwood

HOH (Zone 1): The coastal area on the west side of the Olympic Mountains. Consists of old seed zones 011 and 012.

PUGET SOUND (Zone 2): The east side of the Olympic Peninsula and most of the area surrounding Puget Sound. The eastern boundary follows the 2000 foot contour along the Cascade Mountains. Includes portions of old seed zones 201, 202, 211, 212, 221, 222, 231, and the western portions of 411 and 412.

CHEHALIS (Zone 3): The southwestern corner of the state from the coast east to the 2000 foot contour along the Cascade Mountains. Includes old seed zones 030, 041, 241, 232, and the western portions of 242, 430, and 042.

SKAGIT (Zone 4): The northern half of the Cascade Mountains west of the crest. The western boundary is the 2000 foot contour. The southern boundary is Interstate 90. The eastern boundary is the Cascade Crest. Includes old seed zones 401, 402, 403, eastern portion of 411, and northeastern corner of 412.

TOUTLE (Zone 5): The southern half of the Cascade Mountains west of the crest. The western boundary is the 2000 foot contour. The northern boundary is Interstate 90. The eastern boundary is the Cascade Crest. Includes the eastern portions of old seed zones 042, 242, 412, 421, 422, 430, and all of 440.

CHELAN (Zone 6): The northern half of the Cascade Mountains east of the crest. The southern boundary is Interstate 90. Includes old seed zones 600, 621, 622 and 631.

YAKIMA (Zone 7): The south central portion of the state, from the Cascade Crest east to, and including, a strip along the east side of the Columbia River. The northern boundary is Interstate 90. Includes old seed zones 632, 641, 642, 651, 652, 653 and the southwestern portion of 842.

OKANOGAN (Zone 8): The Okanogan highlands. Includes old seed zones 611, 612, 613, 614, 801, 803 and the northern portion of 842.

UPPER COLUMBIA (Zone 9): The northeastern corner of the state. Consists of the old seed zones 802, 804, 811, 812, 813, 821, 822 and 830.

SNAKE (Zone 10): Consists of the old seed zone 841, and the southeast portion of 842.

GRANDE RONDE (Zone 11): The southeast corner of the state. Includes old seed zones 851, 852, and 861.

New recommendations for seed transfer zone boundaries

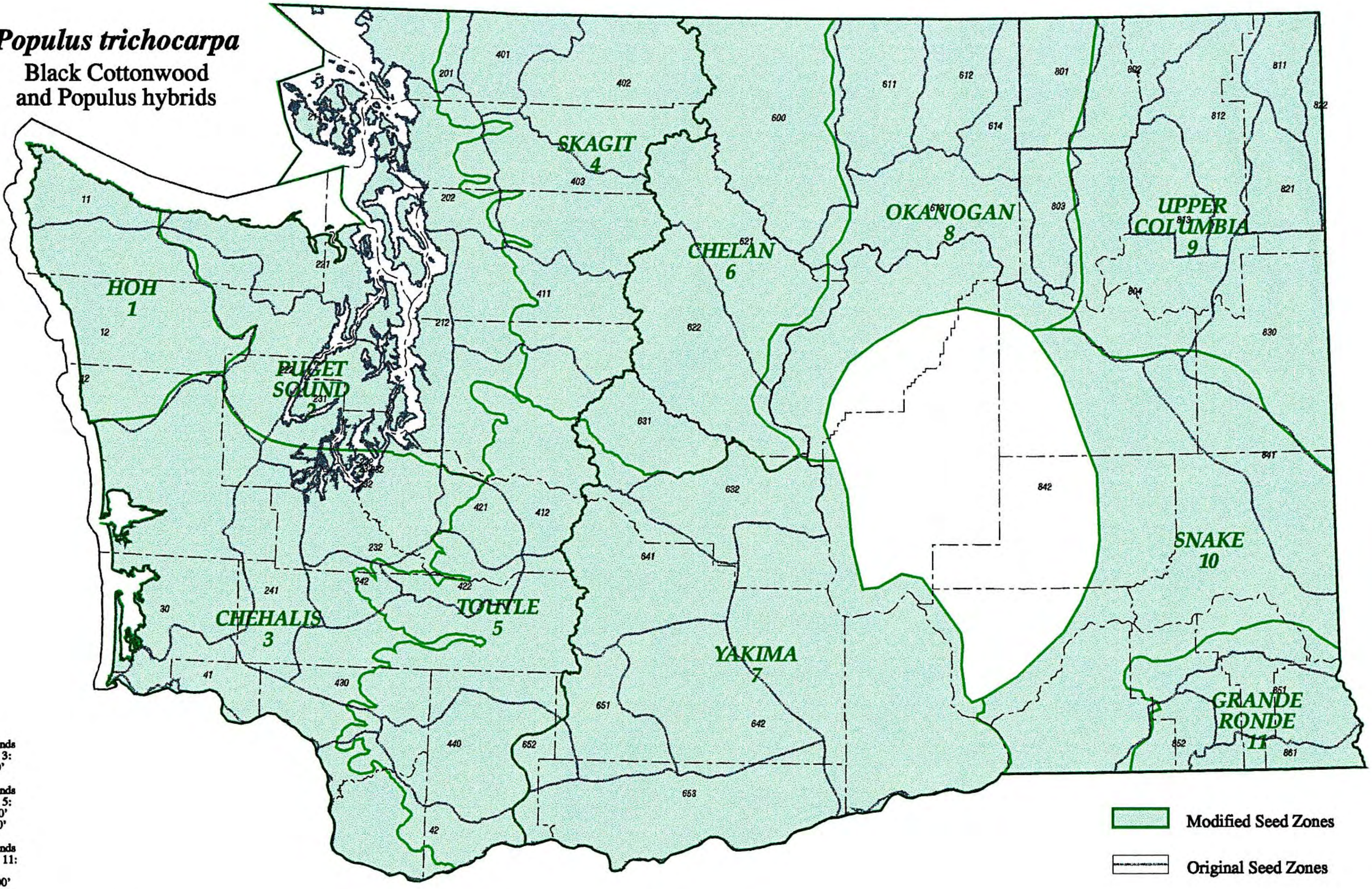
Zones 1 through 3 – a single elevation band (0 - 2000 feet).

Zones 4 and 5 – two elevation bands split at 3500 feet.

Zones 6 through 11 (Eastside zones) – three elevation bands as follows:

below 2000, 2000 - 3500, and above 3500 feet.

Populus trichocarpa
Black Cottonwood
and Populus hybrids



Elevation bands
for zones 1 - 3:
0' - 2000'

Elevation bands
for zones 4 - 5:
2000' - 3500'
>3500'

Elevation bands
for zones 6 - 11:
<2000'
2000' - 3500'
>3500'

Modified Seed Zones

Pseudotsuga menziesii

Douglas-Fir

Douglas-fir (*Pseudotsuga menziesii*) has the largest north-to-south distribution of any commercial conifer in North America. It is the predominant species west of the Cascades in Washington. Douglas-fir is also found along the east slope of the Cascades, in the northeastern section of the state, and in a small area in the southeastern part of the state (Hermann and Lavender, 1990).

Two taxonomic varieties of Douglas-fir are recognized, the coastal form (*P. menziesii* var. *menziesii*) and the Rocky Mountain form (*P. menziesii* var. *glauca*), and both are found in Washington. The varieties differ in a number of important traits. The coastal variety grows faster and gets considerably larger than the Rocky Mountain variety, which tends to be more shade tolerant and more cold hardy. Coastal Douglas-fir is a seral or early successional species, while Rocky Mountain Douglas-fir can be both a seral and a climax species (Hermann and Lavender, 1990). In Washington, the division between the two varieties is generally thought to occur at the break in the natural distribution of Douglas-fir in the Okanogan Valley (Little 1971). Sorensen (1979) notes that an area of intermediate types exists along the transition zone between the two varieties. In that area, trees that resemble the coastal variety tend to be found on wetter sites, while ones that resemble the Rocky Mountain variety tend to be found on drier sites (Frank Sorensen, personal communication, 1999).

To the west of the Cascades at low elevations, Douglas-fir has three primary associates: Sitka spruce, western hemlock, and western redcedar. Hardwood species are rare throughout this area; conifers outnumber them 1000 to 1 (Kuchler 1946). At higher elevations, Pacific silver fir, Engelmann spruce, and noble fir are found with Douglas-fir. In eastern Washington, where it is drier and cooler, associates include ponderosa pine, lodgepole pine, and western larch.

In Washington, Douglas-fir is found from sea level to about 5000 feet in elevation. Along the coast, temperatures are mild and relatively uniform, both diurnally and annually as well as north to south. The average annual temperatures, both for January minimums and July maximums, are similar between Bellingham and the Columbia River. Temperatures decrease with elevation as one moves up the Olympic Mountains or up the west slope of the Cascades. Minimum temperatures are considerably lower on the east side of the Cascades, particularly in the northeastern section of the state. Temperatures tend to fluctuate more on the east side of the Cascades as well, both on a diurnal and an annual basis. There can be as much as 70 inches of annual precipitation in the coastal lowlands and considerably more in the Olympic Mountains and along the west slope of the Cascades. Annual precipitation decreases greatly east of the Cascades; some parts of the range of Rocky Mountain Douglas-fir receive as little as 20 inches a year. Growing seasons tend to be long near the coast with as many as 200 frost-free days around Grays Harbor and the Puget Sound. The number of frost-free days decreases at higher elevations and on the east side of the Cascades, with some areas in the northeastern section of the state having as few as 50 frost-free days (Franklin and Dyrness, 1973; St. Clair and Vance-Boreland, 1998).

A species that occupies such a large geographic area with contrasting climatic conditions might be expected to possess enormous genetic variation. Researchers working with allozymes have found that Douglas-fir has an enormous amount of genetic diversity, and that more than 95% of it resides within local populations and not among them (Yeh and O'Malley, 1980). This pattern is similar to the outward appearance of Douglas-fir; there are large differences in appearance among trees within a single stand, but the average Douglas-fir from one location looks very similar to the average Douglas-fir from another location. Allozyme studies have also shown there is a sharp difference between the coastal and Rocky Mountain varieties of the species, in fact over 75% of the variation in allozymes among populations is accounted for by differences among the varieties (Li and Adams, 1989). Allozymes also show variation within varieties of Douglas-fir as well. Yeh and O'Malley (1980) found evidence of clinal variation within the coastal variety in British Columbia, and Li and Adams (1989) found evidence of a north to south trend in the Rocky Mountains.

Although molecular evidence proves that genetic variation exists, studies of adaptive traits are needed to develop recommendations for seed zones. In spite of the fact that most of the genetic variation within Douglas-fir is allocated to differences within populations, researchers who study adaptive variation in both the coastal variety (Campbell 1979) and the Rocky Mountain variety (Rehfeldt 1993) consider this species an environmental specialist. This is because there is a much stronger association between variation in adaptive traits and variation in the environmental parameters that control them in Douglas-fir than in most other tree species.

Growth is an important adaptive trait, particularly in a species that will tolerate little or no shade. Numerous researchers have shown that variation in growth is associated with environmental parameters. In their work with coastal Douglas-fir in northwest Oregon, Silen and Mandel (1983) found that the potential for height growth increased with decreased elevation, decreased latitude, or increased longitude. Similarly, in his work with Rocky Mountain Douglas-fir in northern Idaho and northeast Washington, Rehfeldt (1979a) found differences in growth that were associated with elevation, latitude and longitude. Summaries of seed source studies done in Germany (Kleinschmit *et al.*,1985) and France (Breidenstein 1990) indicate that growth can vary from north to south and elevationally along the west slope of the Washington Cascades. A number of authors have generalized their findings by pointing out that the best growth potential tends to be found in families from the best environments (Rehfeldt 1979a and 1983a, and Silen and Mandel, 1983).

The timing of bud burst in the spring and bud set in the fall are important adaptive traits because they determine the length of the growing season and susceptibility to frost damage. Research with the Rocky Mountain (Rehfeldt 1983) and coastal (Campbell and Sorensen, 1973) varieties of Douglas-fir has shown that a delay in bud set of just one week can increase the susceptibility to fall frost injury by 18% and 25%, respectively. The timing of bud burst and bud set has been shown to be related to elevation, latitude, longitude, and distance from the ocean (Campbell 1974, Campbell and Sorensen, 1973, and Rehfeldt 1979a). Laboratory freezing tests have shown that during the fall acclimation process, the coastal variety of Douglas-fir is much less cold hardy than the Rocky Mountain variety (Rehfeldt 1977), that within the coastal variety, trees from the coastal areas are less cold hardy than trees from the west slope of the Cascades (Aitken *et al*., 1996), and that within the Rocky Mountain variety, cold hardiness is related to elevation and geographic location (Rehfeldt 1986c).

The fact that variation in growth and variation in bud phenology are related to many of the same environmental parameters has resulted in some controversy.

Rehfeldt (1979a and 1983a) has repeatedly demonstrated with Rocky Mountain Douglas-fir that increased growth is associated, in general, with increased susceptibility to frost damage. However, Stonecypher *et al.* (1996) failed to find any relationship between growth and either bud phenology or frost damage in coastal Douglas-fir from near Grays Harbor. Work with coastal Douglas-fir in Oregon (Aitken *et al*. 1996) showed a weak relationship between cold hardiness and growth for trees from the west slope of the Cascades and no relationship for trees from near the coast, suggesting that the degree of association between these variables varies across the range of this species.

Researchers seeking to develop seed movement guidelines with nursery studies typically measure dozens of adaptive traits and environmental parameters. To simplify the analysis of these complex data sets they sometimes combine these traits into a few somewhat abstract variables that summarize most of the variation. Recommendations for seed transfer are then made based on differences among native populations in these synthetic variables. Thus, some recommendations may be made without demonstrating that genetic variation in a particular trait is associated with variation in a particular environmental variable (Campbell 1986). These recommendations are sometimes expressed as complex formulas that may include the latitude, longitude, elevation, slope and aspect of both the seed source and the planting site. In some cases, the genetic variation in Douglas-fir is so specialized and so complex that use of these formulas may be more logical than the use of traditional seed zones.

Very little research designed specifically to develop Douglas-fir seed zones for the state of Washington has been completed to date. However, general conclusions can be drawn from the large amount of seed movement research done with this species in other areas. Preliminary results from a large seed movement study that includes many seed sources from Washington generally support these generalizations (personal communication, Brad St. Clair, September 1999). Land managers are encouraged to check periodically for publications that will result from this study.

Past recommendations for geographic limits to seed movement.

For interior southern British Columbia, transfer limits are 2° north, 1° south, 3° west, and 2° east (British Columbia Ministry of Forests, 1995).

For maritime British Columbia, transfer limits are 3° north and 2° south (British Columbia Ministry of Forests, 1995).

For submaritime British Columbia, transfer limits are 2° north and 1° south (British Columbia Ministry of Forests, 1995).

Within the southern half of Washington, seed that has been shown to be widely adapted in field tests can be moved within the Puget Trough and coastal areas (Stonecypher *et al.* 1996).

In northeastern Washington and northern Idaho, seed should not be moved more than 1.6° north or south, or more than 2.7° east or west (Rehfeldt 1979).

The distance seed can be transferred varies in central Idaho, but can be as short as 40 miles under the most limiting conditions (Rehfeldt 1983).

In southwestern Oregon, seed can be moved relatively far north or south. The distance it can be moved east to west varies, but can be as short as 30 miles (Campbell 1986).

At the junction between the coastal and Rocky Mountain varieties in central Oregon, east to west transfers of as little as 17 miles were the equivalent of a 980 foot elevation change (Sorensen 1979).

Past recommendations of elevation limits to seed movement.

For interior British Columbia, transfer limits are 1000 feet up or 650 feet down. (British Columbia Ministry of Forests, 1995).

For maritime and submaritime British Columbia, transfer limits are 1150 feet up or down. (British Columbia Ministry of Forests, 1995).

In the Grays Harbor and Willapa Bay area, seed that has been shown to be widely adapted can be moved up and down within a 2000 foot elevation band (Stonecypher *et al*. 1996).

In northeastern Washington and northern Idaho, seed should not be moved more than 460 feet up or down (Rehfeldt 1979a).

In central Idaho, seed should not be moved more than 330 feet up or down (Rehfeldt 1983a).

In southwestern Oregon, moving seed up or down in elevation is less risky than moving seed from east to west (Campbell 1986).

New recommendations for seed transfer zone boundaries

HOH (Zone 1): Northern boundary is coast from Cape Flattery to Angeles Point; eastern boundary is from Angeles Point south to Elwha, Aurora Peak and Sugarloaf Mountain, and then along 4000 foot contour to Kimta Peak, and on to Quinault Ridge; southern boundary is from Quinault Ridge west along the old 012 seed zone line to Macafee Hill and Point Grenville. West boundary is the Pacific Ocean. Consists of the old seed zone 011, and the western portion of 012.

ELWHA (Zone 2): Northern boundary is from Aurora Peak to Mount Pleasant and along the 4000 foot contour east to Mount Zion; eastern boundary follows 4000 foot contour south to Mount Jupiter and Mount Washington; southern boundary continues along 4000 foot contour westward to Mount Tebo, Colonel Bob, and Quinault Ridge; western boundary continues along 4000 foot contour north toward Kimta Peak, Sugarloaf Mountain, and Aurora Peak. Consists of the eastern portion of old seed zone 012, and portions of 221 and 222.

TWIN HARBORS (Zone 3): Northern boundary is from Point Grenville east along the old 030 seed zone boundary to Macafee Hill, Quinault Ridge, Colonel Bob, and Capitol Peak in the Olympic Mountains; eastern boundary follows the old 030 seed zone from Capitol Peak southeast to South Mountain, south to Elma, Weikswood, southeast along Doty Hills to Doty, Pe Ell, junction of Huckleberry Ridge and Long Ridge, southeast to headwaters of Elochoman River and down Elochoman River to Cathlamet on the Columbia River; southern boundary is Columbia River west to the coast; western boundary is the Pacific Ocean. Consists of old seed zone 030, and the western portion of 041.

ISLANDS (Zone 4): Northern boundary is Washington state line from Point Roberts east to near Sumas; eastern boundary follows the approximate 2000 foot contour from a point on the Canadian border near Sumas south to three miles east of Granite Falls; southern boundary is from a point three miles east of Granite Falls west to Interstate 5 at the northern side of Tulalip Indian Reservation, south around Whidbey Island to Port Ludlow, Uncas, Mount Zion, Mount Pleasant, Elwha, and Angeles Point; western boundary is the west coast of the western coastal islands. Consists of old seed zone 211, and portions of 201, 202, 212, and 221.

KITSAP (Zone 5): Northern boundary is Mount Zion east to Uncas, Port Ludlow, south end of Whidbey Island, Interstate 5 at northern edge of Tulalip Indian Reservation (the southern edge of the old 202 seed zone) to a point three miles east of Granite Falls; eastern and southern boundaries start at a point three miles east of Granite Falls and follows the approximate 2000 foot contour south along the Cascades through Fall City and Spar Pole Hill to Clay City, then follows the southern border of the old 232 seed zone through Porcupine Ridge, Crawford Mountain and Grand Mound, then along Highway 12 to Oakville and Elma; western boundary starts at Elma and goes north along the western edge of the old 030 seed zone to South Mountain and Capitol Peak in the Olympic Mountains. Consists of old seed zones 231, and 232, the western parts of 411, 412, 421 and 422, the northern one-third of 241, the eastern half of 222, and that portion of 212 south of Whidbey Island.

LOWER COLUMBIA (Zone 6): Northern boundary is from Elma to Oakville, Grand Mound, Crawford Mountain, and Porcupine Ridge; eastern boundary follows 2000 foot contour south from Porcupine Ridge through Windy Knob and Crazy Man Mountain, to Wolf Point, then along the northern edge of the old 042 seed zone through Green Knob, Gumboat Mountain, Stabler, and Big Huckleberry Mountain to Cook on the Columbia River; southern boundary is Columbia River from Cook west to Cathlamet; western boundary is from Cathlamet northward along the Elochoman River, then along the western edge of the old 241 seed zone through Long Ridge, Huckleberry Ridge, Pe Ell, Doty, Doty Hills, Blue Mountain, Weikswood, and Elma. Consists of old seed zone 042, the eastern half of 041, the western half of 430, the southern two-thirds of 241, and the western two-thirds of 242.

SKAGIT (Zone 7): Northern boundary is Canadian border from near Sumas (2000 foot contour) east to Cascade Crest; eastern boundary is Cascade Crest south from Canadian border to half-way between White Mountain and Bench Mark Mountain; southern boundary is from Cascade Crest between White Mountain, and Bench Mark Mountain west along the southern boundary of the old 403 seed zone through Monte Cristo and Vesper Peak to a point 3 miles east of Granite Falls; western boundary is north from a point three miles east of Granite Falls along the approximate 2000 foot contour to a point on the Canadian border near Sumas. Consists of old seed zones 401, 402, 403, and the eastern portions of both 201 and 202.

SNOQUALMIE (Zone 8): Northern boundary is 2000 foot contour three miles east of Granite Falls west along the southern boundary of the old 403 seed zone through Vesper Peak and Monte Cristo to the Cascade Crest between White and Bench Mark Mountain; western boundary is Cascade Crest south to Highway 410; southern boundary is west from Highway 410 at Cascade Crest to Mount Rainier, Mount Wow, to three miles east of Ohop at 2000 foot contour; western boundary follows 2000 foot contour northward through Spar Pole Hill and Fall City to a point three miles east of Granite City. Consists of the eastern portions of old seed zones 411, 412, and 421.

TOUTLE (Zone 9): Northern boundary is from three miles east of Ohop at 2000 foot contour to Mount Wow, Mount Rainier, Highway 410 at Cascade Crest; eastern boundary is Cascade Crest from Highway 410 south to Big Huckleberry

Mountain, southern boundary goes west along the southern edge of the old 440 seed zone through Gumboat Mountain to Wolf Point; western boundary follows approximate 2000 foot contour from Wolf Point north to Crazy Man Mountain, Windy Knob, Porcupine Ridge, to a point three miles east of Ohop. Consists of old seed zones 440, 422 above 2000 feet, and the eastern two-thirds of 430.

CHELAN (Zone 10): Northern boundary is Canadian border from Cascade Crest east to the limit of interrupted Douglas-fir range about nine miles west of Highway 97; eastern boundary starts about nine miles west of Highway 97 at the Canadian border and follows the eastern limit of the Douglas-fir range south to the Columbia River and along the Columbia River to a point east of Wenatchee on the Columbia River; southern boundary starts at a point east of Wenatchee on the Columbia River and follows the southern border of the old 621 seed zone boundary through Sugarloaf Peak and Seven-Fingered Jack to the Cascade Crest; western boundary follows Cascade Crest northward to Canadian border. Consists of old seed zones 600, 621, and western portions of 611 and 613.

YAKIMA (Zone 11): Northern boundary is Fortress Mountain at Cascade Crest, east along the southern border of the old 621 seed zone through Seven-Fingered Jack, Sugarloaf Peak and Burch Mountain to the edge of the species range west of Wenatchee; eastern boundary follows the edge of the species range to near Cowiche Mountain; southern boundary starts at edge of the species range near Cowiche Mountain and goes west along the southern border of the old 641 seed zone through Darland Mountain to Cascade Crest near Tieton Peak; western boundary follows Cascade Crest northward to Fortress Mountain. Consists of old seed zones 622, 631, 641, and western portion of 632.

WHITE SALMON (Zone 12): Northern boundary starts at the Cascade Crest at Tieton Peak and goes east along the southern boundary of the old 641 seed zone through Darland Mountain until it reaches the edge of the species range near Cowiche Mountain; eastern boundary follows the edge of the species range south from Cowiche Mountain to the Columbia River near Burdoin Mountain; southern boundary follows the Columbia River from near Burdoin Mountain west to the Cascade Crest at Cook; western boundary is Cascade Crest north from Cook at the Columbia River to Tieton Peak. Consists of old seed zones 651, 652, and the western portions of 642 and 653.

KETTLE (Zone 13): Northern boundary is Canadian border from the western edge of the interrupted Douglas-fir range east to the Columbia River. Eastern boundary is the Columbia River from the Canadian border south to the southern edge of the Douglas-fir range. Southern and western boundaries are the southern and western limits of the interrupted Douglas-fir range northward to the Canadian border.

PEND OREILLE (Zone 14): Northern boundary is Canadian border from Columbia River east to the Washington state line. Eastern boundary follows the Washington state line from the Canadian border to the southern limit of the interrupted Douglas-fir range south of Spokane. Southern boundary is southern limit of the interrupted Douglas-fir range from Washington state line to the Columbia River. Western boundary is the Columbia River.

PULLMAN (Zone 15): The isolated population of Douglas-fir occurring near Pullman. If local seed is not available, use seed from nearby parts of Idaho. Consists of the southern tip of old seed zone 841.

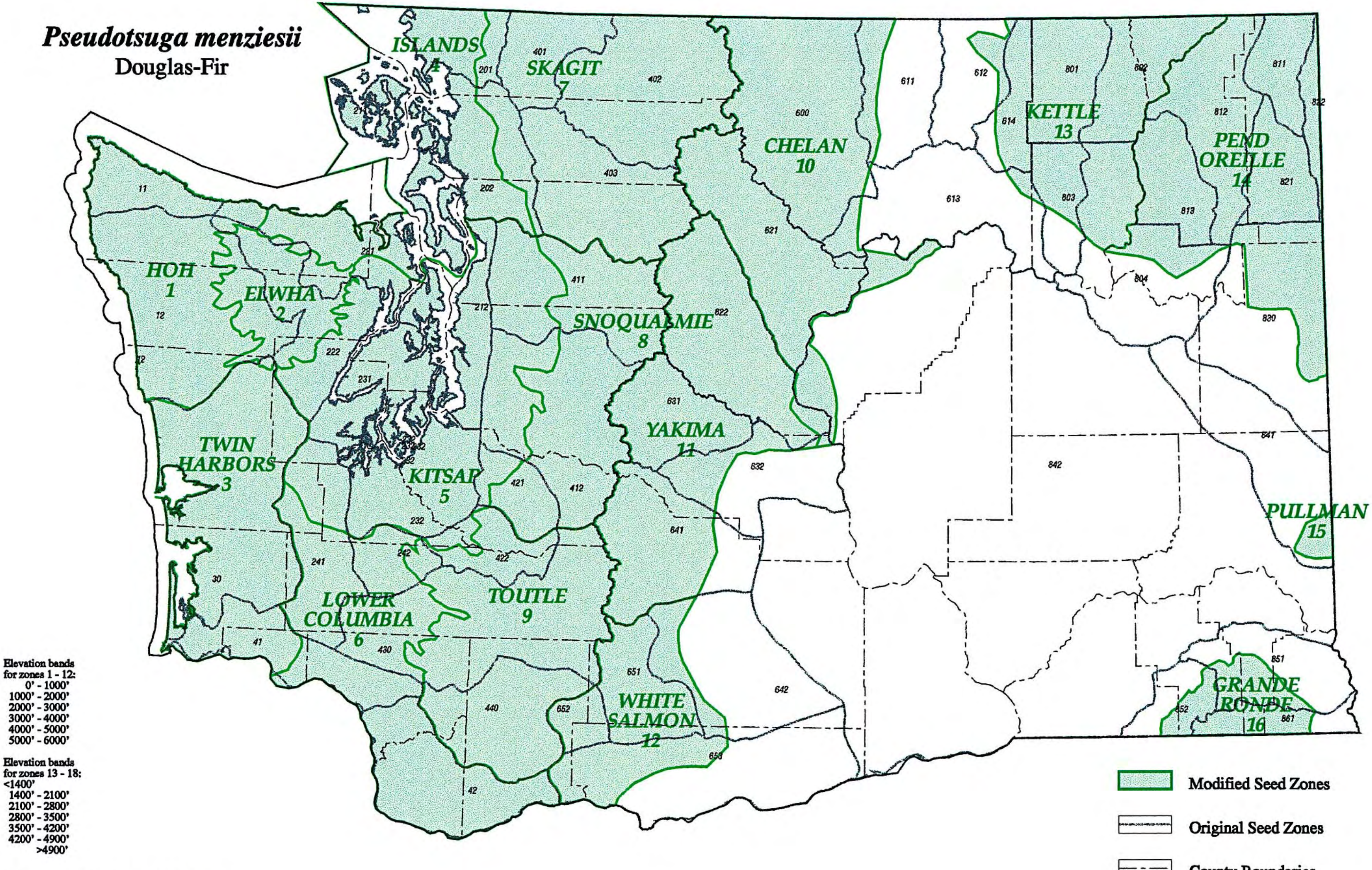
GRANDE RONDE (Zone 16): This zone generally conforms to the Umatilla National Forest in Washington. The southern boundary follows the Oregon border from near Route 3 to near Mill Creek. The western, northern, and eastern boundaries follow the species range in the Blue Mountains. Includes the southern portions of 851, western half of 861, and eastern one-quarter of 852 of the old Washington seed zones. If Washington seed is not available, seed from nearby parts of Oregon may be used.

Elevation bands within geographic seed transfer zones

Zones 1-12(Hoh, Twin Harbors, Elwha, Islands, Kitsap, Lower Columbia, Skagit, Snoqualmie, Cowlitz, Chelan, Yakima, White Salmon): Establish 1000-foot elevation bands in these seed movement zones.

Zones 13-18(Kettle, Upper Columbia, Pend Oreille, Spokane, Pullman, Grande Ronde): Lowest elevational band will be areas below 1400 feet, use 700-foot elevational bands above that point.

Pseudotsuga menziesii
Douglas-Fir



Modified Seed Zones

Taxus brevifolia

Pacific Yew

Almost all places where Pacific yew (*Taxus brevifolia*) occurs in Washington are west of the crest of the Cascades. It is especially common on the Olympic Peninsula up to elevations of 3500 feet and at low to moderate elevations in the Cascades. There are small populations in the Okanogan Highlands (in the northeast corner of the state) and in the Blue Mountains (in the southeast corner). The latter two areas are connected to some extent by populations in northern Idaho (Little 1971). Although it is not shown in Little's range maps, Pacific yew also occurs at scattered locations along the east slope of the Cascades (Tom Brannon, personal communication, August 2000).

Among the species in this book, Pacific yew is unusual because it is extremely shade tolerant and typically found as an understory tree or small shrub. The species is very tolerant of environmental extremes; for example, it is found in some of the wettest and in some of the driest areas where forests grow in the state (Bolsinger and Jaramillo 1990). This suggests that there is ample opportunity for adaptive variation.

Pacific yew was largely ignored until it was discovered to be a source of a compound that showed potential for treating certain types of cancer in the late 1980s. As a result, no studies have been conducted specifically to determine seed transfer rules and only a few studies have examined genetic variation in this species.

Three groups of investigators have looked at genetic variation in allozymes of Pacific yew. Allozymes are different forms of enzymes that can be used to evaluate the relatedness of groups of plants, but are widely considered not to be related to adaptive characteristics. All three groups found that levels of genetic variation in this species were typical of what one would expect for similar species. All three also found that most of this variation was due to differences within regions; for example, differences among stands or among individuals within stands. El-Kassaby and Yanchuk (1994) found that isolated populations from the dry eastern side of Vancouver Island were very different from all other populations tested. They also found that populations from two widely separated coastal islands and Rocky Mountain populations formed three genetically distinct groups. This suggests that large differences in precipitation or discontinuous populations can result in genetic differences in this species. Doede *et al.* (1993) found that although differences among most widely scattered regions were small, the Sierra Nevada populations tended to be different from the other regions. They also found weak trends associated with latitude and elevation. Wheeler *et al.* (1995) found there was little relationship between geographic distances between populations and genetic differences between populations. They hypothesized that random events such as long distance seed dispersal by animals, founder effects, and genetic drift, rather than adaptive variation, are largely responsible for the differences they found among populations.

Wheeler *et al.* (1995) and Doede *et al.* (1993) and their associates examined the concentrations of taxol-like compounds in various populations of Pacific yew and found these results generally supported the conclusions they reached based on allozyme data.

Only Wheeler and his coauthors (1995) examined traits of apparent adaptive value; height, caliper, time of bud burst, and number of growing points. There were highly significant differences among populations within regions and among families within populations, but differences among regions were not significant, supporting the conclusions drawn from their allozyme data. Since they found differences among stands within an area to be large, the authors suggest that whenever possible, seed from the same stand be used. However, if this is not practical, the seed can be moved a long way. Other authors (Bolsinger and Jaramillo 1990) have noted the existence of shrub-like and tree-like forms of Pacific yew. Wheeler *et al.* (1995) found no difference in the progeny grown from populations of differing growth forms and concluded these differences are due to the environment, not the genotype of the plants.

If seed is needed for isolated populations of Pacific yew from the east slope of the Cascades, seed from that location or nearby populations should be used.

New recommendations for seed transfer zone boundaries

The large differences among populations within regions and among families within populations suggests that it is appropriate to move Pacific yew a long way. However, the lack of definitive information suggests some caution. The following seed zones should be recognized:

TWIN HARBORS (Zone 1): A relatively narrow strip along the coast. Consists primarily of the old 011 and 030 seed zones, and western portions of the old 012 and 041 seed zones.

ELWHA (Zone 2): The higher elevation portion of the Olympic Peninsula. Consists primarily of the northwest portion of the old 222 seed zone, eastern parts of the old 012 seed zone, and the southwestern part of the old 221 seed zone.

PUGET SOUND (Zone 3): Portions of the Puget Trough north of Tacoma and the west side of the northern Washington Cascades. The southern boundary is a line from near Capitol Peak in the Olympic Mountains, southeast toward South Mountain, east to Bay Shore, Lakebay, Tacoma, east to Highway 167, then south to Sumner, Highway 410 to Buckley and along the White River to the edge of the species range. Consists primarily of the old 201, 202, 211, 212, 231, and 401 zones, and the western portions of 402, 403, 411, and 412 zones.

UPPER CHEHALIS (Zone 4): Portions of the Puget Trough south of Tacoma and the west side of the southern Washington Cascades. Consists primarily of old seed zones 042, 232, 241, 242, 421, and 422, the western portions of 430 and 440, and the eastern part of 041.

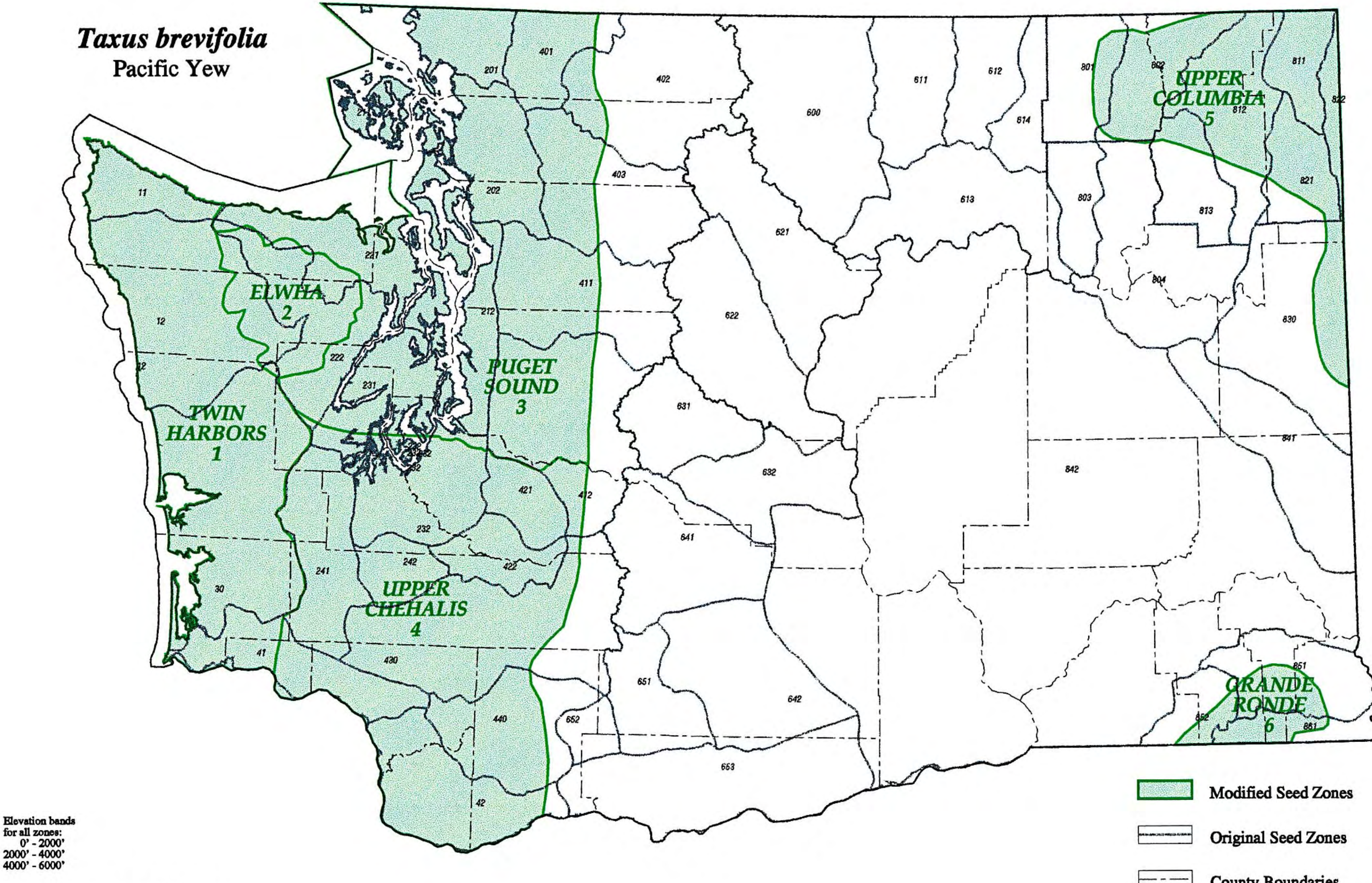
UPPER COLUMBIA (Zone 5): Northeast corner of the state and nearby areas of Idaho and British Columbia. Consists of those portions of the old 801, 802, 811, 821, 822, and 830 seed zones where Pacific yew occurs.

GRANDE RONDE (Zone 6): Southeast corner of the state and nearby areas of Oregon and Idaho. Consists primarily of the old Washington seed zones 851, 852, and 861; and Oregon's old seed zone 861.

Elevation bands within geographic seed transfer zones

Within each seed movement zone, 2000 foot elevational bands should be established.

Taxus brevifolia
Pacific Yew



Modified Seed Zones

Thuja plicata

Western Redcedar

Washington is in the heart of the western redcedar (*Thuja plicata*) range and this species is found on most types of sites where trees grow within the state. It is common along the coast, in the Olympic Mountains, along the Puget Trough, and along the west slope of the Cascades. The species also occurs in scattered populations along the east slope of the Cascades and is common in the Okanogan Highlands. Western redcedar tolerates a wide range of annual precipitation, ranging from a high of 260 inches along parts of the coast to a low of 28 inches in parts of the interior. This species is very tolerant of shade. It is found at elevations that range from sea level to 7500 feet. Western redcedar is not particularly tolerant of frost and is often damaged by late spring or early fall freezes. Where adequate water exists, its range seems to be limited by low temperatures (Minore 1990).

No field studies of adaptive variation in western redcedar have been conducted in Washington, but studies in other areas suggest genetic differences among populations are less than for most other conifers. Rehfeldt (1994) found that populations in the northern Rocky Mountains had to be separated by 2° latitude or 2000 feet in elevation before he could say they were genetically different. Frost damage was common in his test plantations and he recommended caution in breeding for increased growth in this species. John Russell (personal communication, 1998) tested a wide range of populations in southern Vancouver Island. His plantations also experienced frost damage. He found huge differences in survival between populations from northern California and Vancouver Island (about an 8° difference in latitude) and small differences between populations in the Queen Charlotte Islands and Vancouver Island (about a 4° difference in latitude). He found no differences in survival among coastal populations from the same latitude that differed in elevation by more than 2500 feet. He found distinct differences in survival between populations from coastal, intermediate, and interior sources of western redcedar.

A number of biochemical studies (Copes 1981, von Rudolff and Lapp 1979, and Yeh 1988) and a number of biometric studies that used material from a limited area (Bower and Dunsworth 1988, and Jeffers 1962) lend support to the idea that genetic differences among populations of western redcedar are relatively small.

Recommendations for seed transfer zone boundaries

TWIN HARBORS (Zone 1): A strip along the coast that includes the west side of the Olympic Mountains and extends into the Puget Trough in the southern half of the state. Consists primarily of the old 011, 012, 030, 041, 232, 241, and 242 seed zones; and western portions of the 042, 421, 422 and 430 seed zones.

PUGET SOUND (Zone 2): Portions of the Puget Trough north of Tacoma. Consists primarily of the old 201, 202, 211, 212, 221, 222, and 231 seed zones, and the western portions of the old 411 and 412 seed zones.

SKAGIT (Zone 3): West side of the Cascades north of Snoqualmie Pass at Interstate 90. Consists primarily of the old 401, 402, and 403 seed zones; the eastern part of the old 411 seed zone; and the northeastern part of the old 412 seed zone.

TOUTLE (Zone 4): West side of the Cascades south of Snoqualmie Pass at Interstate 90. Consists of the old 440 and 652 seed zones, the eastern parts of the old 421, 422, 430 and 042 seed zones; the southeastern part of the old 412 seed zone; and western parts of the old 653 seed zone where western redcedar occurs.

MID COLUMBIA (Zone 5): East slope of the Cascades where western redcedar is native. Consists of the old 600 series seed zones north of the Yakama Indian Reservation and west of the Okanogan River where western redcedar is found.

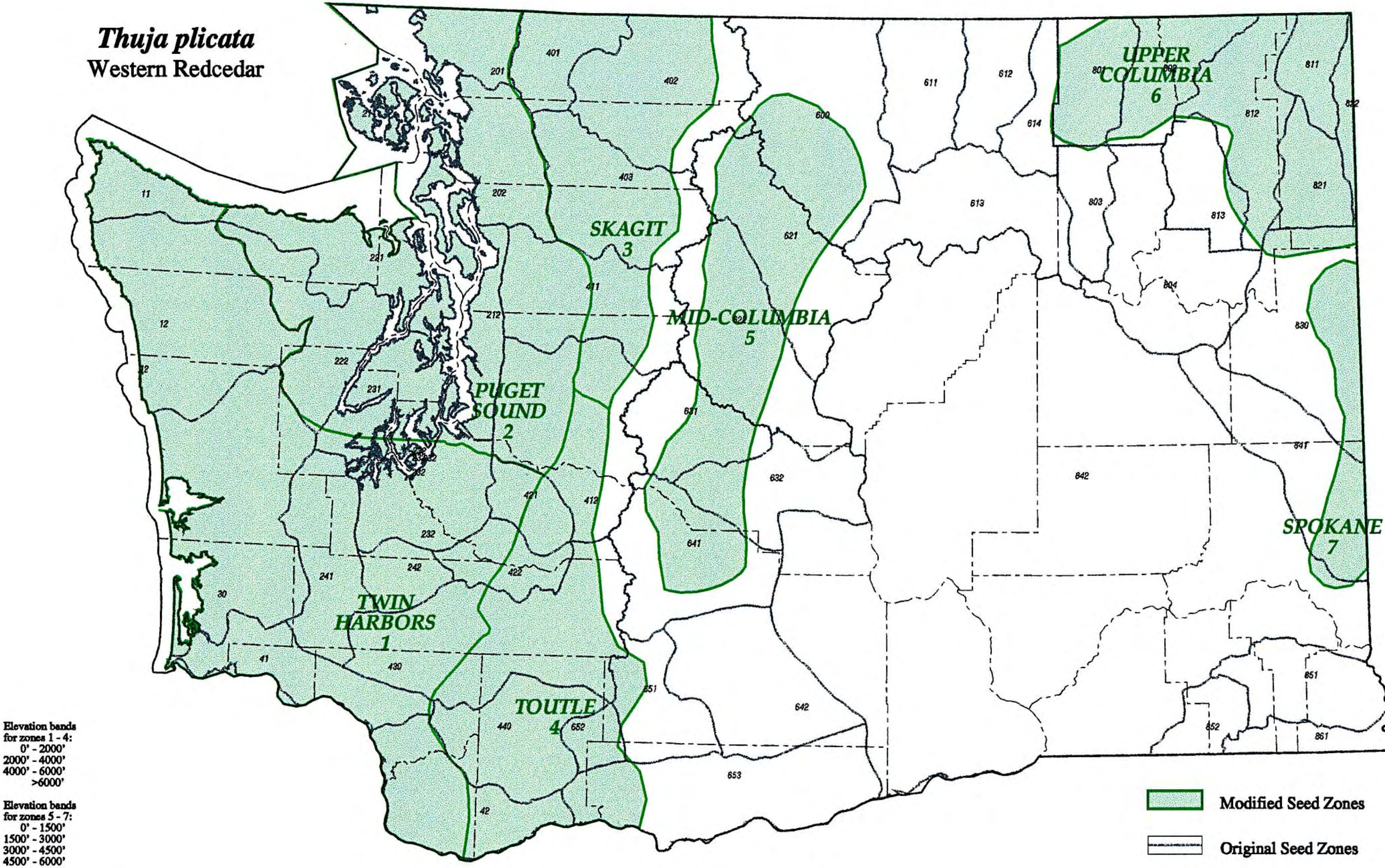
UPPER COLUMBIA (Zone 6): Northeastern corner of the state. Consists of the portions of the old 801, 802, 811, 812, 821, and 822 seed zones where western redcedar occurs.

SPOKANE (Zone 7): Isolated populations of western redcedar scattered on the east side of Spokane and Whitman counties. Consists of portions of the old 830 and 841 seed zones where western redcedar occurs. Where possible, use seed from these isolated populations. Where that is not possible, seed from nearby portions of northern Idaho may be used.

Elevation bands within geographic seed transfer zones

Within the Twin Harbors, Puget Sound, Skagit, and Toutle seed movement zones, 2000-foot elevational bands should be established. Within the Mid-Columbia, Upper Columbia, and Spokane zones, 1500-foot elevation bands should be established.

Thuja plicata
Western Redcedar



Modified Seed Zones

Tsuga heterophylla

Western Hemlock

Western hemlock (*Tsuga heterophylla*.) is a major component of the Washington coastal forests. This species ranges from the coast to the west slopes of the Cascade Range. In addition, a few scattered western hemlock occur along streams and north slopes in the northeastern corner of the state (Fowells 1965). In the Cascades, it occurs up to elevations of 2000 to 2300 feet. In the Olympics, it ranges from sea level to 3600 feet (Franklin and Dyrness, 1973). Conifer species in this zone include western hemlock, Douglas-fir, western redcedar, grand fir, Sitka spruce, western white pine, and lodgepole pine. Hardwoods include red alder, bigleaf maple, black cottonwood, and Oregon ash.

Some coastal British Columbia populations grew taller than others when tested on Vancouver Island, but there was no relationship between elevation of the populations and height growth (Piesch 1976). There was no difference in height growth of seed sources from Tillamook, Seaside, Cathlamet, and Clallam Bay when tested at Tillamook, Oregon (Foster and Lester 1983). The climate is very similar for these four areas. Pollard and Portlock (1986) found that seed for coastal Vancouver Island provenances could be moved as much as two degrees in latitude and from sea level to 1900 feet. Kuser and Ching (1980) recommended that western hemlock seed not be moved more than two degrees north or more than 1300 feet higher than the place of origin. Their work indicated that coastal, Cascade, and Priest River, Idaho populations are different and that seed should not be transferred among those areas. Low elevation Priest River seed sources (1300 feet) were not the same as high elevation (2300 feet) sources from along the same river. Dates of bud burst for Cascade sources separated by as much as 95 miles varied by about six days.

Seed germination was earlier, by about four days per degree of latitude, for both coast and Cascade sources. High elevation Coast Range sources germinated earlier than low elevation sources (Campbell and Redlined 1982). However, germination date was not related to elevation for the Cascade sources. The difference between sources from the Coast Range and sources from the Cascade Mountains in the relationship between germination date and elevation supports establishing separate breeding zones for these two areas.

Foster and Lester (1983) concluded that the coastal area from Clallam Bay, Washington south to Tillamook, Oregon should be one breeding zone. The elevation for this area varies from sea level to 1000 feet. The British Columbia Forest Code (1995) permits unrestricted movement within the Georgia lowlands, three degree north or south transfer with 300 meter elevation change in the maritime zone, and two degree latitude and 200 meter elevation transfer within the submaritime zone.

New recommendations for seed transfer zone boundaries:

HOH (Zone 1): The western part of the Olympic Peninsula. Consists of the old seed zones 011 and 012, and the portion of old seed zone 221 west of Angeles Point.

TWIN HARBORS (Zone 2): Coastal areas south of the Olympic Peninsula. Consists of the old seed zone 030, and those portions of 041 west of Kelso.

NORTH SOUND (Zone 3): The eastern part of the Olympic Peninsula and areas surrounding the northern part of the Puget Sound. The eastern boundary starts at the eastern limit of the species distribution along the Canadian border near Black Mountain and follows the eastern limit of the species distribution southwest until it reaches the edge of the old 201 seed zone, then goes south along the eastern edge of the old 201 and 202 seed zones to an area about 6 miles east of Granite Falls, then continues south through Sultan until it meets Interstate 90 near Snoqualmie, east to Ragnar and south through Selleck and Enumclaw to the Three Sisters. The southern border goes from the Three Sisters west along the northern border of the old 421 seed zone to Sumner, then west to Tacoma, north to Bremerton and Mount Jupiter and south to The Brothers, Mount Washington, and Rock Peak, then west to the edge of the old 030 seed zone. The western boundary follows the western edge of the old 030 and 012 seed zones north to just north of Fairholm, then east along the edge of the old 221 seed zone to a point west of Elwha and north to Angeles Point. Consists of the old seed zones 201, 202, 211, and 212; 221 east of Angeles Point; and portions of 222, 231, 232, 411, and 412.

UPPER CHEHALIS (Zone 4): The Puget Trough south of Seattle. Northern boundary starts at the border of the old 030 seed zone west of Rock Peak, goes east to Rock Peak, north to Mount Washington, The Brothers, and Mount Jupiter, then southwest to Bremerton, Tacoma, Sumner, and along the old 421 seed zone boundary to the Three Sisters. The eastern boundary starts at the Three Sisters and goes south to the confluence of the Mowich and Puyallup Rivers and National; then west to Porcupine Ridge and Meridian Hill, then east to Alpha and Morton; and south to Crazy Man Mountain, Hatchet Mountain, Wolf Point, Green Knob, Spotted Deer Mountain and the Columbia River just west of Mount Pleasant. Southern boundary is Columbia River from Mount Pleasant to Kelso. Western boundary is Kelso to the intersection of the Cowlitz, Wahkiakum, and Lewis County lines, and north to the west edge of the old 030 seed zone at Pe Ell, then north along the old 030 seed zone boundary to a point just west of Rock Peak. Consists of the old seed zone 241, parts of 222, 231 and 232, western portions of 042, 242, 421, 422 430, and 440, and 041 east of Kelso.

SKAGIT (Zone 5): Areas where western hemlock occurs in the northern Washington Cascades. Northern and eastern boundaries are the edge of the species distribution, southern boundary is Interstate 90 from the eastern limit of the species distribution to a point near Snoqualmie. Western boundary starts at Interstate 90 near Snoqualmie and goes north through Sultan to a point 6 miles east of Granite Falls and along the old 202 and 201 seed zone boundaries to the northern limit of the Western hemlock distribution near Van Zandt. Consists of the old seed zone 403, southern parts of 401 and 402, the eastern half of 411, the northeast portion of 412, and areas of 621, 622 and 631 where western hemlock occurs.

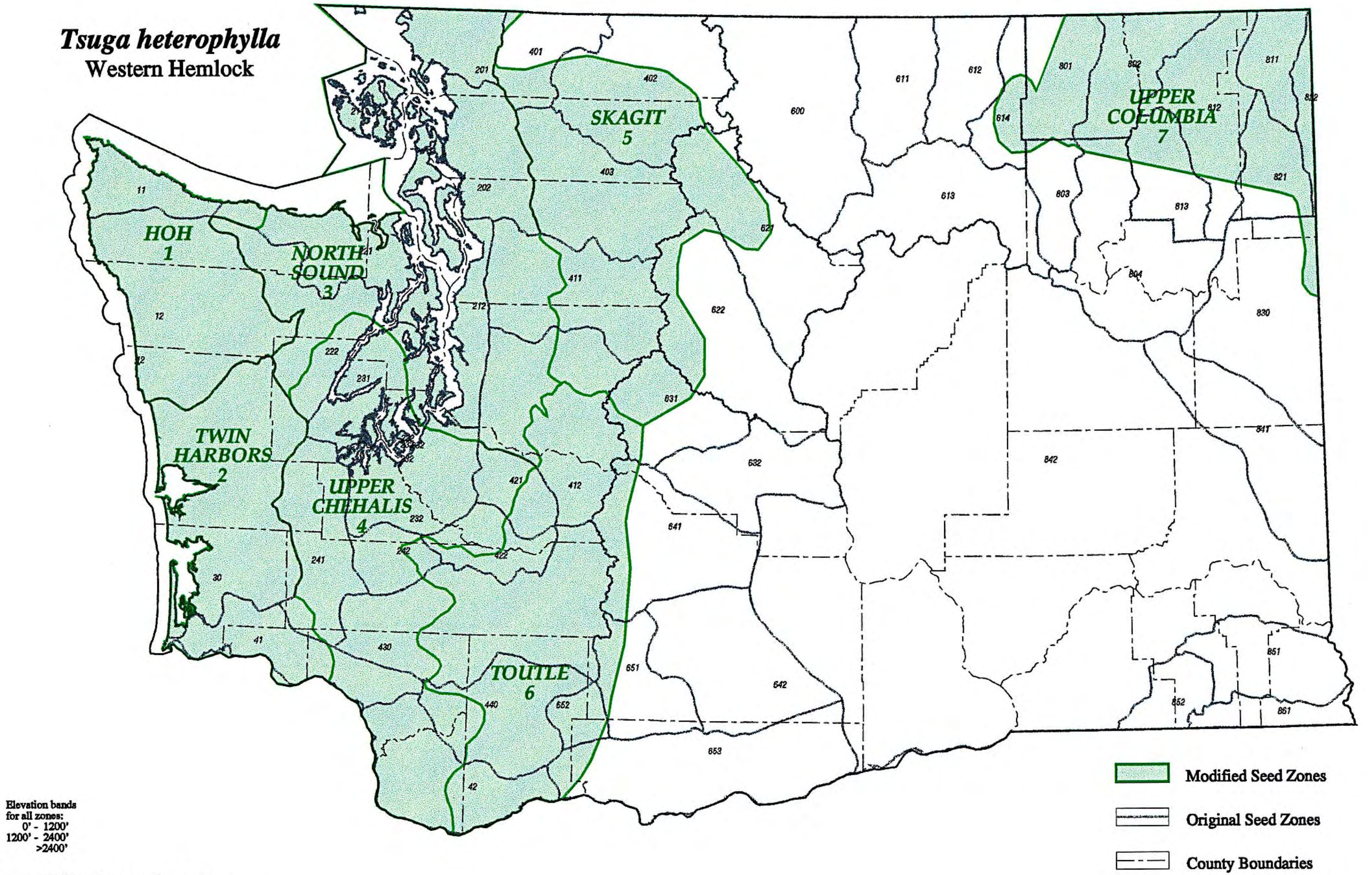
TOUTLE (Zone 6): Areas where western hemlock occurs in the southern Washington Cascades. The northern boundary is Interstate 90 from near Snoqualmie to the eastern limit of the species distribution. The eastern boundary is the eastern limit of the species distribution. The southern boundary is the Columbia River from the eastern limit of the species distribution to just west of Mount Pleasant. The western boundary starts at the Columbia River just west of Mount Pleasant and goes north through Spotted Deer Mountain, Green Knob, Wolf Point, Hatchet Mountain, Crazy Man Mountain, and Morton; then west to Alpha and Meridian Hill and east to Porcupine Ridge and National and north to the confluence of the Mowich and Puyallup Rivers, Three Sisters, and Interstate 90 near Snoqualmie. Consists of old seed zone 652; the eastern portions of 042, 421 and 430; the southeast portion of 412; the southern half of 422; and the western portions of 641,651 and 653.

UPPER COLUMBIA (Zone 7): Includes portions of old seed zones 614, 801,802, 811, 812, 821, 822 and 830 within the natural range of western hemlock.

Elevation bands within geographic seed transfer zones

In all seed movement zones, 1200-foot elevation bands should be established.

Tsuga heterophylla
Western Hemlock



Modified Seed Zones

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