JANUARY 2010

South Puget HCP Planning Unit Forest Land Plan

Final EIS | ENVIRONMENTAL IMPACT STATEMENT

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

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ENVIRONMENTAL IMPACT STATEMENT

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Peter Goldmark
Washington State
Commissioner of Public Lands

December 2009

Dear Interested Parties:

Forest land planning is being completed to guide on-the-ground activities on 145,000 acres of forested state trust lands. The geographic area spans from the Kitsap Peninsula to the foothills of the Cascade Mountains, east of Seattle and Olympia — the South Puget Habitat Conservation Plan Planning Unit. The plan will guide management activities to enhance habitat for at-risk wildlife species, protect water quality and meet other goals while earning revenue to build the state's schools and universities, and help fund services in counties in which the trust lands are located.

Washington's Department of Natural Resources (DNR), manager of Washington's state trust lands, began this planning process in June 2005 with a series of public workshops designed to collect local information, and map specific areas of ecological, social or economic concerns on the forested state trust in each area of the planning unit. In July 2006, DNR issued a 'scoping notice' under the State Environmental Policy Act (SEPA) to encourage interested citizens, organizations and agencies to help identify significant issues to be included in environmental review. These ideas helped DNR develop a range of three management alternatives.

The alternatives explore possible landscape management strategies that accomplish habitat, financial, and social goals, as presented in the purpose and need statement (scoping notice, Appendix A) — while reflecting public, other agency and tribal interests. All three alternatives are designed to implement Board of Natural Resources policies, and forest management direction in the *2006 Policy for Sustainable Forests*, the *1997 Habitat Conservation Plan*, and to comply with federal and state laws. Alternative A projects future forest conditions based on existing landscape management strategies. Alternative B examines management strategies that reflect local information gathered through this planning process. And Alternative C explores a range of management approaches that stretch the boundaries of existing policy.

A Draft Environmental Impact Statement (EIS) — released in July 2008 for public comment — highlighted the key environmental issues and options facing agency decision makers regarding each alternative. DNR's consideration of public, scientific and other input has resulted in publishing of this Final EIS for the South Puget HCP Planning Unit. Although linking broader plans with local landscapes could be achieved without the aid of a formal planning process, the complexity of the various landscapes shows the benefit of customized strategies when applying policy-level guidance.

We think you will appreciate the new approach taken in this Final EIS for the forested state trust lands in the South Puget planning unit. This document offers ample photos, illustrations and clear text to better assist the reader in understanding what DNR is trying to achieve on these landscapes. This analysis will assist decision-making and ultimately the adoption of an alternative, and will help DNR finalize the plan.

I appreciate your interest in this important work. Thank you.

Peter Goldmark
Commissioner of Public Lands

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Fact Sheet

TITLE

South Puget HCP Planning Unit
Forest Land Plan
Final EIS

DESCRIPTION

This environmental analysis includes three alternatives and their management strategies (Appendix B) that are designed to result in a Forest Land Plan for the long-term management of the South Puget Habitat Conservation Plan (HCP) Planning Unit. The planning unit includes approximately 146,000 acres covering parts of six counties in western Washington. Alternative A represents DNR's current management practices. Alternative B represents management strategies that reflect local information gathered through the planning process to influence on-the-ground activities. Alternative C explores a range of management approaches that stretch the boundaries of existing policy.

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Map in Figure 3-2 from *Google Maps* downloaded 2/21/08

DATE OF ISSUANCE OF FINAL EIS
January 15, 2010

NEXT ACTIONS
January 15, 2010
Under WAC (197-11-655) DNR can select the preferred alternative for managing the South Puget Planning Unit, but all alternatives are available to be selected at this stage. No other agency actions are required.

FUTURE ENVIRONMENTAL REVIEW
The selected management alternative becomes the Forest Land Plan and is part of a phased environmental review process in accordance with 197-11-440 (j). Another phase of environmental review will occur to address site-specific activities as they are proposed in this planning unit.

LOCATION OF COPIES OF THIS FINAL EIS AND SUPPORTING DOCUMENTS

This Final Environmental Impact Statement is available on the Internet at *http://www.dnr.wa.gov/ResearchScience/Topics/Pages/NonProjectActions_PR.aspx*.

Copies of the Final Environmental Impact Statement are available to read at select public libraries throughout the state of Washington. Requests for CD's containing the EIS and supporting documents, and for mailed printed copies should be directed to:

Washington Department of Natural Resources
SEPA Center
P.O. Box 47015
Olympia, WA 98504-7015
Phone (360) 902-2117

Copies of the guiding documents upon which the Alternatives are based — *2006 Policy for Sustainable Forests, 2004 Final EIS for Sustainable Forest Management, 1997 Habitat Conservation Plan, 2006 Riparian Forest Restoration Strategy*, DNR Procedures, Washington Forest Practices Rules— are available for review at each of the five Westside DNR Region offices in Washington, and at the SEPA Center address listed above.

Cost / Availability
Copies of the Final Environmental Impact Statement are available for downloading at no charge from http://www.dnr.wa.gov

CD copies are available at no charge. A very limited number of printed copies are available at no charge, by written request. After these copies are distributed, additional copies will be available for the cost of printing or CD production, per RCW 42.17.

Please send requests to the SEPA Center address above.

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executive summary


Tahoma State Forest (foreground) taken near Poison Creek

Washington's Department of Natural Resources (DNR) manages approximately 146,000 acres of forested state trust lands within the South Puget Habitat Conservation Plan (HCP) Planning Unit. The focus of this Final Environmental Impact Statement (Final EIS) is to provide an analysis of the impacts to the environment from the alternatives—describing proposed changes to DNR's statewide landscape management strategies for implementation in this planning unit. The key management strategies being examined in this planning process are the conservation strategies for the northern spotted owl and recreation management.

Based on comments received after publication of the Draft EIS (2008), this Final EIS provides updates and modifies specific topics. The changes include gaining a better understanding of the risks associated with the thinning levels, addressing the unexpectedly high modeled level of restoration activities in riparian areas, changes to the northern spotted owl habitat definitions and additional analysis of the impacts of the habitat accounting scale in the planning unit. Once these changes were completed, the alternatives were again compared to assess their probable, significant, adverse, environmental impacts.

The Final EIS is organized as follows:

- **Chapter 1** provides background information about the planning unit, summarizes DNR's trust responsibilities, and presents the goals and objectives of a forest land plan.
- **Chapter 2** describes each component of the three management alternatives under consideration, by topic.
- **Chapter 3** describes the evaluation approach and provides information about current conditions by topic.
- **Chapter 4** presents the projected differences between the alternatives by topic over the 100-year planning horizon, discloses the environmental impacts, and states why the impacts may be significant, probable, or adverse, and how they would be mitigated.
- **Chapter 5** provides a full list of cited references.
- **Appendices (on CD-backcover)** provide additional detailed analysis of the impacts on the environment, as well as the new landscape management strategies to implement the components of these alternatives.

Background

Most of the trust lands were granted by the federal government to Washington State in 1889. The legislature (as trustee) provides direction to DNR as trust manager. The state trust lands provide many inherent benefits to all the people of Washington and DNR has a clear legal duty of undivided loyalty to the trust beneficiaries (such as K-12 schools, universities, and other public institutions). Also, the Board of Natural Resources, which represents the trust beneficiaries, guides policies and direction regarding DNR's management of the state trust lands. Providing revenue is one of several trust responsibilities and since 1970, the beneficiaries have received more than $4.5 billion from DNR's management of trust lands statewide.

Forest Land Planning Project Objectives

The objective of forest land planning is to identify efficient and effective landscape management strategies to achieve Board of Natural Resources policy goals while complying with state and federal laws. Currently, management strategies such as procedures, tasks, and traditional practices provide on-the-ground direction for DNR land managers when they plan and execute activities such as timber harvests, road building, or trail maintenance. The combined effect of these management strategies over time is designed to achieve the desired outcomes envisioned in the 2006 *Policy for Sustainable Forests*, which includes the sustainable harvest calculation (2004, 2007) and the contractual obligations of the 1997 *Habitat Conservation Plan* for forested state trust lands mostly in western Washington. Through the forest land planning process DNR evaluated its existing landscape management strategies against alternatives that were developed using current science, local knowledge and expert opinion from both public users and DNR region field staff.

Environmental Impact Statement (EIS) Development Process

The State Environmental Policy Act's (SEPA) environmental impact statement process provides an opportunity for agencies, stakeholders, Tribes, and the public to participate in identifying significant issues related to a proposal. This process, detailed in Chapter 197-11 WAC, ensures that decision-makers understand the environmental consequences of the events or actions resulting from their proposed action. In this Final EIS, DNR analyzed three alternatives—current, preferred, and exploratory—to direct the management of forested state trust lands in this planning unit. As required by SEPA, the alternatives are examined using available information to assess their probable, significant, adverse, environmental impacts.

Several agency environmental analyses have been prepared and are referenced throughout this document. The environmental analyses contained in this document supplement previous analyses, which are incorporated by reference with more detail and current information.

- 1996 *Draft* and *Final EIS* and 1997 *Habitat Conservation Plan*
- 2000 *Draft* and *Final EIS on Alternatives for Forest Practices Rules* and 2001 *Forest Practices Rules*
- 2004 *Final EIS on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington* (commonly referred to as the *Sustainable Harvest Final EIS*); and the 2007 *Addendum*
- 2006 *Final EIS* and 2006 *Policy for Sustainable Forests*

These environmental impact statements and planning documents provide the background for this analysis.

PHASED STATE ENVIRONMENTAL POLICY ACT (SEPA) REVIEW PROCESS

This Final Environmental Impact Statement (Final EIS) is for a non-project action, meaning the actions taken to implement an alternative are not site-specific. No on-the-ground activities are designed as part of this Final EIS. However, these future site-specific management choices for forested state trust lands in the planning unit will depend, in part, on the decisions made during this process. Therefore it is part of a phased review under WAC 197-11-060 (5)(c)(i).

ASSUMPTIONS USED TO ANALYZE ALTERNATIVES

DNR used the Watershed Administrative Units (WAUs) scale to assess where potential impacts may occur. Watershed Administrative Units are areas defined by hydrology and geomorphology, and range in size from about 10,000-to 50,000 acres. The WAU scale was chosen for this analysis because DNR has determined through watershed analysis and previous EISs that it is the best scale for detecting and reporting environmental impacts (DNR 2004). There are 118 WAUs in the South Puget HCP Planning Unit with many different owners and managers. In 68 of these WAUs, DNR manages forestland, and 13 of these WAUs contain DNR-managed trust lands covering at least 20 percent of the total watershed area (Table 3-1, p. 42). Collectively, these 13 watersheds represent 92 percent of DNR-managed forestlands within the planning unit. Appendix F contains information about land ownerships within watersheds in the planning unit containing DNR-managed trust lands. Please note that the impacts to northern spotted owls are assessed by Spotted Owl Management Units (SOMUs), which are similar in scale to WAUs.

The impact analysis relies heavily upon two sources of information: 1) geographic information system (GIS) data related to the current conditions and, 2) forest model projections of future forest conditions. Both sources have assumptions associated with their precision and accuracy to represent either current or future conditions; however, this data is the best available information to assess the relative differences of the proposed alternatives in terms of their impacts on the environment. A description of the 'forest estate' modeling programs, processes, assumptions used, and a sensitivity analysis are described in Appendix C.

The majority of the designated northern spotted owl dispersal management areas under the 1997 HCP are located on DNR-managed lands within the South Puget HCP Planning Unit. In order to systematically assess forest stand and landscape values in providing habitat during the owl's dispersal phase, DNR designed the Northern Spotted Owl Dispersal Assessment Tool (NSO-DAT in Appendix G) with assistance from the US Forest Service and the Washington State Department of Fish and Wildlife. The Dispersal Assessment Tool (NSO-DAT) used an approach based on Ecosystem Management Decision Support (EMDS) software developed by the U.S. Forest Service (Reynolds and others 2000). The Dispersal Assessment Tool evaluates the ability of forest stands to support movement, roosting, or foraging activities of dispersing northern spotted owls. The stand level results from the assessment tool are used to evaluate northern spotted owl habitat connectivity at the landscape scale. This tool is included as a monitoring component in the landscape management strategy to ensure habitat connectivity does not decline from current levels. Sensitivity analysis was performed to assess the model's performance and is included in Appendix G.

DEVELOPMENT OF ALTERNATIVES

In June 2005, DNR began seeking public involvement for the South Puget forest land planning process through a series of public workshops. The workshops were designed to collect local information and to map specific areas of ecological, social, or economic concerns. Strategies were then developed to address them. In July 2006, DNR issued a SEPA 'scoping notice' allowing concerned citizens, organizations, and agencies to help identify significant issues, which assisted in DNR's development of a reasonable range of management alternatives.

The alternatives were written to explore possible landscape management strategies that meet the purpose and need statement (Scoping Notice, Appendix A), while reflecting public, outside agency, and tribal comments. All of the alternatives are designed to implement existing Board of Natural Resources policies and forest management direction as described in the 2006 *Policy for Sustainable Forests*, the 1997 *Habitat Conservation Plan*, as well as in federal and state laws.

Alternative A Current Management (No Action)—Designed to project future forest conditions based on existing landscape management strategies, without including specific local information gathered through the public meetings associated with this planning process.

Alternative B Preferred Direction— Examined management strategies that reflect local information and expert opinion gathered through this planning process, to provide guidance for on-the-ground implementation.

Alternative C Exploratory Option— Explored a range of management approaches which stretch the outer boundaries of existing policy.

A summary of the comments from the scoping meetings and responses to those comments can be found in Appendix A. Comments received on the Draft EIS, a list of commentors, and DNR's responses can be found in Appendix O.

Previously Identified Significant Areas of Controversy and Uncertainty

Additional work was conducted on issues that were identified in the Draft EIS; specifically improvements were made in the representation of habitat yields in the modeling process. Improvements also were made to the thinning options in riparian management areas. Implementation of a new northern spotted owl habitat definition required a concurrence letter from the U.S. Fish and Wildlife Service, which has now been obtained (2009 *Concurrence Letter* in Appendix G).

Development of the Final EIS

DNR used an evaluation approach similar to the Montreal Process (1995) to identify criteria and indicators for assessing forest management and its potential environmental impacts. DNR's criteria are developed from strategies laid out in existing policy and procedures, as well as state and federal laws. Indicators are the measurable elements used to assess whether objectives contained in the criteria are achieved. The criteria and indicators used in this analysis, identified in Chapter 3 and analyzed in Chapter 4, are related to the ecological elements being evaluated in this environmental impact statement. This integrated approach recognizes the interconnectedness of one element of the environment to others, as reflected in topics such as sedimentation's link to soils, roads, fish habitat, and water quality.

The major changes that occurred between the Draft and Final EIS are related to land exchanges, thinning levels in riparian management areas, new northern spotted owl habitat definitions, and modifications to dispersal habitat strategies.

Chapter 4 analyzes projected differences between the alternatives, discloses the environmental impacts, and states why impacts may be significant, probable, or adverse, and how DNR would mitigate them. All of the information is either presented at the HCP planning unit or individual watershed scale. The main focus is to assess how management actions, particularly harvesting of timber, will impact elements of the environment.

POTENTIAL ENVIRONMENTAL IMPACTS

Harvest activities have the potential to result in environmental impacts on specific elements of the environment such as soil from logging equipment and road building, which can cause compaction and increase sedimentation affecting water quality, water quantity, fish, and riparian systems. Forest activities can also result in an increase in some forest pathogens due to wounds made by logging equipment (Otrosina and Ferrell 1995) and have impacts on visually sensitive areas.

Recreational uses, both motorized and non-motorized, also have environmental impacts which can affect soils, damage streambanks, and trample vegetation. The majority of these impacts come from undesignated trail use (refer to Recreation, p. 165).

The new northern spotted owl habitat definitions and geographic accounting units in the South Puget HCP Planning Unit will improve habitat quality and quantity over time compared to DNR's current management. In addition, the northern spotted owl dispersal landscapes will become less fragmented over time. This will benefit dispersing owls and help DNR achieve the 1997 HCP objective of providing a significant contribution to demographic support, maintenance of species distribution, and the facilitation of dispersal on DNR-managed state trust lands within the range of the northern spotted owl. None of the alternatives are expected to result in additional environmental impacts to the northern spotted owl beyond what was analyzed in the Draft and Final EIS for the 1997 *Habitat Conservation Plan*.

FOREST CONDITIONS

A review of the level, distribution, and number of harvest entries over the 100-year planning period shows Alternative B as having the lowest average harvested area. Alternative A has the highest level of variable retention harvest and Alternative C has the highest level of thinning activities.

Under all alternatives, the quantity of forests in structurally complex forest conditions (Niche Diversification and Fully Functional) is projected to increase. The greatest increase in structurally complex forests occurs under Alternatives B and C. The early stand development stages (Ecosystem Initiation, Competitive Exclusion, and Understory Development) continue to decline at a similar rate (Appendix D). This increase will shift the ecological conditions of forested state trust lands in this planning unit towards a mix of forest stand conditions more similar to those found prior to logging in the last century (Agee 1993; Franklin and Dyrness 1973).

RIPARIAN MANAGEMENT

Riparian areas are managed similarly under all alternatives. DNR used the measure of stand development stages in riparian areas to identify possible effects of management activities over time. The current distribution of stand development stages suggests (Table 3-8, p. 61) that many streams may have reduced levels of riparian function, particularly large wood input, because of the relative low proportion of stands in the Biomass Accumulation, Niche Diversification, and Fully Functional stand development stages (Figure 4-6, p. 141).Each alternative leads to a continued increase in acres of complex forests (Text Box 3-1, p. 46); the level of harvest activities to achieve these forest conditions vary between the alternatives (Chart 4-14, p. 167).

The analysis discusses the potential short-term impacts and long-term benefits of actively managing riparian forests. Alternative C has approximately 16,000 acres of additional riparian thinning over eight decades as compared to Alternative A and B. The net result of this projected management is that Alternative C is forecast to have approximately 5,000 more acres of Fully Functional forests than Alternatives A or B.

The distribution of forest stand development stages and corresponding levels of restoration activities over time and space provide a basis for assessing the potential cumulative effects of the alternatives in the forested environment for any given watershed. However, the amount and nature of forests in any landscape are highly variable (soil properties, weather events), and contain a wide range of forest types (conifer mixed with deciduous) and stand structures (stands that fall into a variety of stand development stages), which only can be assessed on a site-by-site basis to determine proper silvicultural treatments. All alternatives are expected to use ground-based or cable yarding methods which can result in soil compaction, rutting, and surface erosion. In analyzing riparian areas at the watershed scale, DNR did not find any watersheds under any of the alternatives that would experience significant adverse environmental impacts.

WETLANDS

Wetland risk is variable throughout the planning unit due to their amount and location; however these impacts are greatly reduced on site as a result of the mitigation provided by current policy and procedures of no net loss of wetland acres or function. At this time DNR does not fully understand the severity of impacts that can be expected from either timber harvests or road building due to the difficulty in mapping wetlands, specifically forested wetlands. However, previous assessments (2001 *Forest Practices Rules* and 1997 *Habitat Conservation Plan*) have shown the severity of impacts from road building to be much greater than those related to harvest activities alone. Therefore, areas containing wetlands with greater amounts of roads and harvesting activities are expected to have a higher likelihood of impacts to wetlands than those with less wetland acres.

WATER QUANTITY

All watersheds containing sub-basins with acres in rain-on-snow zones are forecast to stay above 70 percent in hydrologically mature conditions through the modeled planning period (100 years). Consequently, significant changes in peak flows due to harvest activities are likely to be avoided under each alternative, thereby causing no significant impacts to hydrologic maturity on forested state trust lands. The likelihood and severity of damaging flood events and possible landslides caused by soil saturation or undercutting is reduced by maintaining higher levels of forest stands with a Curtis' relative density (RD) greater than 25 in the rain-on-snow zones.

WATER QUALITY

Trends for riparian harvest treatments are consistently projected to decline over time in all alternatives and none would increase the risk of water quality impacts in the long-term. The greatest possible impacts to water quality are expected in the first four decades, during which the levels of harvest removal are highest; with harvests being highest in Alternative C. Removal of trees from riparian areas is unlikely to cause a temporary increase in water temperature. Stream shade is unlikely to be reduced as a result of restoration activities because of the forested unmanaged near-stream areas and the almost continuous canopy in the remainder of the riparian management zone. However, ground disturbance and changes in the microclimate near the ground could cause an increase in sediment entering water bodies.

FISH

Stand development is a good proxy for many of the key structural elements of fish habitat such as large woody debris (Franklin and others 2002), which can be linked directly to improvements in fish habitat (Beechie and Sibley 1997; *What Are the Current Conditions of Riparian Areas*, p. 60). The current distribution of stand development stages suggests (Chart 3-1, p. 48) that many streams may have reduced riparian function stemming from relatively low levels of large woody debris input, characterized by young forest conditions (Keller and others 1995; Rot and others 2000). Large woody debris sources and inputs increase as the forest progresses through the Biomass Accumulation, Niche Diversification, and Fully Functional forest stand development stages (DNR 2004). A discussion of how harvested acres in riparian areas results in more complex forest structure is found in the riparian section (p. 58). The water quality results section (p. 150) reports how thinnings in riparian areas effects stream temperature and sedimentation.

SOILS

Compaction, erosion, and reduced productivity are the anticipated direct impacts to soil caused by timber harvesting, recreation activities, and road construction and use. The combined effects of compaction and erosion can reduce a soil's productivity which could have long-term effects on forest conditions (Cumulative Effects, p. 159). Major soil displacement events (such as landslides and road/landing construction) can remove the upper soil layers, resulting in a long-term loss in site productivity. Vegetation removal can limit a soil's capacity to hold moisture and can lead to changes in the surrounding microclimate, potentially reducing soil productivity. Erosion and soil displacement can increase sediment levels in water bodies, decrease water quality (p. 151), and reduce the quality of fish habitat (p. 153). Soil compaction also can affect water quantity via reduced infiltration and groundwater recharge, potentially resulting in increased overland flow and surface erosion.

The percent of acres affected varies between alternatives, but Alternative B would have the lowest impact level because it has the greatest number of un-harvested acres and more acres of thinning than variable retention harvest. Alternative C would have the next lowest impact level followed by Alternative A. Refer to Appendix D to compare values in other watersheds.

ROADS

The primary difference between the management alternatives can be summarized by examining the amount of timber removed by watershed or the number of truck trips per decade. Although harvest levels are partially related to overall traffic levels on forest roads, truck traffic or road length are unlikely to be the main causes of sedimentation. For additional information on the impact of truck traffic on elements of the environment, DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-104 to 4-108).

Traffic on forest roads has the potential to increase sedimentation to water and produce dust and exhaust gases affecting air quality (p. 199). Each alternative varies in the ranking of watersheds with the highest number of truck trips, as shown in Table 4-19 (p. 164). The potential for impacts from forest roads on the environment is measured by increased use. Higher road usage from forest management activities combined with recreation could have additional impacts on air quality, water quality, and wildlife habitat (*Forest Fragmentation*, p. 176). The amount of traffic from recreational use is expected to increase based on population demographics; refer to recreation (*Population Demographics*, p. 167).

Road density also can be used as an indicator to assess impacts to wildlife populations through habitat fragmentation. However, the environmental impacts from the road network are reduced by the mitigation measures presented in the roads section (p. 161).

RECREATION

No single environmental setting is considered the most suitable for recreation; instead, each individual site or area has a set of environmental characteristics that make it more or less susceptible to recreation impacts. Alternative A would continue managing recreation under the current system with a level of recreation based on state and federal grants, which can be reduced during budget shortfalls. However, potential recreation-related environmental impacts and subsequent consequences cannot be overlooked if recreation and public access are to be considered sustainable land uses.

The suitability assessment proposed under Alternatives B and C would enable DNR to evaluate multiple resource factors (such as soil types, vegetation, slope, and presence of wetlands) to help determine where, what type, and how much recreation activity is appropriate, by area. Once changes based on the suitability assessment have been identified, many impacts are expected to be mitigated through specific strategies built into Alternatives B and C.

Alternative C includes the option to expand contract services through leases or fees in order to enhance site-specific amenities. This would result in another method to control vandalism, over-crowding (White 1993), litter, and crime (Grewell 2004) and possibly reducing environmental impacts in identified areas.

VISUAL MANAGEMENT

Additional site specific visual-management guidance (Appendix B) has been developed on the amount and placement of leave trees on forested state trust lands, which is similar for all of the alternatives. Generally speaking, harvest activities have the highest potential for visual impacts relative to road building or gravel pits, due to the amount of acres affected over time; therefore, this indicator provides a firm measure of anticipated visual impacts under each alternative.

Alternative B is expected to have lower environmental impacts than Alternative A. Alternative B provides specific strategies for lands identified as being visually sensitive where DNR has the ability to leave between eight and 16 trees per acre and includes specific strategies for Tiger Mountain (Chapter 2, p. 36).

CULTURAL RESOURCES

Alternative C has the greatest potential for impacts to cultural resources, due to the number of acres to be harvested or thinned (Table 4-2, p. 125). Alternatives A and B may impact cultural resources, but affect fewer acres than Alternative C. Despite these relative differences, the impacts to cultural resources are expected to be insignificant under all alternatives, because of concurrent and previous mitigation.

WILDLIFE HABITAT

DNR harvest activities within the planning unit will impact nearly two percent of DNR's land base every year. The percent of harvest entry types shown in Chart 4-4 (p. 129) and the number of harvest entries shown in Figure 4-2 (p. 131) may have a cumulative effect on wildlife species and habitat, especially those sensitive to disturbance. Collectively, these activities could result in short-term wildlife impacts across the landscape, including disturbance and habitat loss, as previously described (Table 3-24, p. 105).

The reduced amount of forest stands projected to be in the Ecosystem Initiation stage under all alternatives could contribute cumulatively to the effects of similar reductions projected to occur on U.S. Forest Service lands. Since the 1990s, deer and elk populations have been declining in the West

Cascades ecoregion due to a decline in foraging habitat (Spencer 2002). Declines in Ecosystem Initiation acres of forested state trust lands could further reduce foraging habitat for these species, while areas serving solely as winter habitat on DNR-managed trust lands are expected to remain suitable.

Silvicultural activities under all alternatives are expected to benefit wildlife habitat for many types of wildlife, specifically wildlife species associated with structurally complex forest stands that have experienced population declines in the Puget Trough and West Cascades ecoregions (refer to Table 3-19, p. 100).

Increasing structurally complex forests in the planning unit along with similar efforts taking place on federal lands—specifically, the Northwest Forest Plan—will benefit many types of wildlife, including marbled murrelets and northern spotted owls. The cumulative effects that DNR management activities have on wildlife are not expected to be significant or beyond those analyzed in the 1997 *Habitat Conservation Plan*.

MARBLED MURRELET

The likelihood that harvest activities will occur within or directly adjacent to marbled murrelet habitat before the adoption of the long-term strategy is low. A forest connectivity assessment was conducted as part of the northern spotted owl analysis in the Elbe Hills, Tahoma, and Black Diamond northern spotted owl management areas. Forest connectivity for northern spotted owls in these areas is expected to increase under all alternatives, with Alternatives B and C seeing a more dramatic increase (*Northern Spotted Owl Habitat Cumulative Effects*, p. 194). The majority of marbled murrelet habitat identified in the Interim Marbled Murrelet Conservation Strategy is located within these areas and it can be inferred that forest connectivity for marbled murrelets would also increase. Though the habitat needs of these two species are different, many of the forest conditions assessed for northern spotted owls also are associated with marbled murrelet habitat, such as canopy closure and patch size.

In addition, with low marbled murrelet detection rates on adjacent lands and the offshore population of marbled murrelets being low in the southern Puget Sound waters (Raphael and others 2008) DNR expects little difference among the alternatives for marbled murrelet habitat and the effects from these management alternatives are not likely to result in significant, adverse, environmental impacts.

NORTHERN SPOTTED OWL HABITAT

The South Puget HCP planning unit contains the majority of designated Dispersal Management Areas on lands managed under the 1997 HCP in western Washington. Due to past timber management activities, the current ecological conditions in these dispersal management areas are dominated by overstocked forests with high tree densities. These overstocked stand conditions do not contribute to the life requirements of dispersing northern spotted owls; however they are included as meeting the HCP definition of dispersal habitat because that definition has no required upper limit of trees per acre.

When the 1997 HCP was written, it recognized the lack of data relating to actual stand conditions and landscape patterns for successful spotted owl dispersal. For the purposes of the HCP, the definition of suitable dispersal habitat was identified as "interim" and it was assumed this definition would be replaced as better data became available (DNR 1997).

MODIFICATIONS TO DISPERSAL HABITAT STRATEGIES

Since the signing of the HCP, new scientific information was published on habitat use by dispersing spotted owls (Miller and others 1997), spotted owl demography during the dispersal phase (Forsman and others 2002), and deficiencies of dispersal habitat definitions in Washington in meeting life requirements of dispersing owls (Buchanan 2004). Based on this new scientific knowledge and understanding of northern spotted owl dispersal requirements, as well as DNR assessments of habitat conditions in forest stands that meet the current 1997 HCP dispersal habitat definition, the question was posed whether DNR could improve northern spotted owl conservation efforts through an adjustment of the HCP dispersal habitat management strategy.

The process to change the habitat definition for this planning unit began in 2006 with numerous meetings and field visits with agency experts (Washington State Fish and Wildlife, US Fish and Wildlife Service, and DNR biologists), to view existing forest stand conditions and discuss habitat changes that result from specific silvicultural treatments. DNR, with assistance from the U.S. Forest Service, developed a modeling protocol to assess habitat conditions, resulting in a new dispersal habitat definition (p. 30).

Under Alternative A, DNR manages designated dispersal management areas according to the 1997 HCP definition for dispersal habitat with a target of maintaining at least 50 percent of each Spotted Owl Management Unit (SOMU) in a dispersal habitat condition. The Draft EIS included a U.S. Fish and Wildlife Service Concurrence Letter (dated September 6, 2006) that identified specific areas for habitat enhancement activities to take place in Spotted Owl Management Units below the 50 percent dispersal habitat target. All the enhancement activities identified in that concurrence letter have been completed and therefore are no longer included as a component in this Final EIS.

Under Alternative B, northern spotted owl dispersal habitat conditions are assessed at the landscape scale instead of the SOMU. The Draft EIS targeted 50 percent of a dispersal landscape to be in Movement, Roosting, and Forging (MoRF) conditions. In the Final EIS, the 50 percent habitat condition includes a target of 35 percent in MoRF conditions, with the remaining 15 percent in the newly defined South Puget Movement habitat (Text Box 2-2, p. 30).

Under Alternative C, the Draft EIS targeted 50 percent of a dispersal landscape in MoRF or better habitat conditions with an additional goal of 30 of the 50 percent in Type B (p. 30) or better habitat. Alternative C now targets 50 percent of a dispersal landscape to include 35 percent in Type B or better and 15 percent in South Puget Movement or Better.

The key differences between Alternatives A and B are:

- Alternative A's minimum habitat definition of dispersal contains forest stands that are too overstocked to be considered as functional habitat for the northern spotted owl, but meet the HCP definition of dispersal habitat. As a consequence, the strategy of Alternative A never reaches a 50 percent threshold of "functional" northern spotted owl habitat, where Alternatives B and C exceed this threshold.
- Alternative B's minimum habitat definition (South Puget Movement habitat) includes all functional habitat; however, Alternative A does not include South Puget Movement habitat as part of its definition.
- Alternative B's landscape management strategy includes a proportional goal of higher-quality habitat to support foraging and roosting life history requirements of the northern spotted owl.
- Alternative B is forecast to achieve desired habitat conditions in the designated landscapes in a shorter time than Alternative A.

Based on the analysis conducted in this document, shifting the accounting of habitat to a larger scale (from SOMU level to landscape level) in conjunction with the new habitat definition, does not affect fragmentation or connectivity as measured by the Integral Index of Connectivity (IIC) scores. When compared, the new strategy under Alternative B is projected to dramatically increase the habitat connectivity over the current strategy (Alternative A) as shown in Charts 4-24 to 4-26 (p. 190).

ADAPTIVE MANAGEMENT

The adaptive management component of the 1997 HCP is an important tool for ongoing modifications of DNR's conservation strategies in order to respond to monitoring information and new scientific developments. The refinement of the definition of northern spotted owl dispersal habitat is one example of the use of adaptive management to successfully implement the conservation objectives outlined in the HCP.

AIR QUALITY

When examining carbon emissions, the coefficient of variance (C_v) values show little difference between Alternatives A and B, as seen in Table 4-46 (p. 190), and represent little variation between decades. Alternative A has the highest emissions overall because more timber is being harvested in the long-term. Alternative B is consistently lower than both Alternatives A and C. Of the alternatives, Alternative C has the greatest variation in emissions over the planning period but also has the lowest mean value due to the removal of the lowest timber volumes through a higher proportion of thinning (Table 4-2, p. 125). The standing timber volume is the same for Alternatives B and C, but more harvestable volume is left standing because of the added northern spotted owl habitat requirements. Based on the mean values in Table 4-46 (p. 200), Alternative C has the lowest overall emissions but also spikes in certain decades and shows that Alternative C has the highest level of emissions in those decades. These spikes could pose a threat to air quality, although infrequently; their effects could be more severe than in other decades.

None of the proposed alternatives create new policies or procedures related to air quality. Impacts related to air quality would result from the projected forest management activities within each of the alternatives (*Harvest Levels by Land Class*, p. 126). The alternatives differ slightly in their effects on air quality, but none has a potential for significant environmental impacts relative to current conditions, beyond those anticipated and disclosed in the 1996 *Draft Environmental Impact Statement for the Habitat Conservation Plan*.

CARBON SEQUESTRATION

The overall average of carbon for the planning unit is currently estimated at 83 tons per acre. All three management alternatives project higher levels per acre at the end of the planning horizon in which Alternative A (95 tons per acre) has the lowest projected value, followed by Alternative C (107 tons per acre), and a slightly higher Alternative B (109 tons per acre). Just as Alternative B produces more volume through its management regimes, it also sequesters more carbon than the other alternatives with a similar trend. Chart 4-27 reflects general trends for carbon sequestration levels for all three alternatives. Again, the management tactics used in Alternative B out-performs Alternative C, and especially Alternative A.

LAND TRANSACTIONS

Since the publication of the Draft EIS for the planning unit, the Board of Natural Resources approved a land transaction (on June 2, 2009) resulting in approximately 20,600 acres being added in this planning unit, referred to as the North Fork Green River Trust Land Exchange. Although this land transaction added more acres to DNR management in this unit, the additional lands were not included in the analyses presented in Chapter 4 of this Final EIS; however, a separate analysis of this land exchange is presented in Appendix J.

The Draft EIS presented two alternatives related to land transactions. Alternative A discussed the purpose behind acquiring lands for short- and long-term benefits for trust assets, where Alternative B included Alternative A's strategies while pursuing additional forestlands in the Cascade Foothills.

As presented in this Final EIS, the adverse impacts of transferring parcels of land out of trust management that are isolated or difficult to manage are likely to be offset by the benefits of acquiring replacement lands. Alternative B's emphasis on acquiring larger blocks of ownership in the Cascade Foothills may lead to less fragmented ownership and greater management benefits than Alternative A.

Summary of the Forest Management Analysis

All of the alternatives meet or exceed the HCP planning unit objectives for older-forest conditions, northern spotted owl habitat, and the 2007 *Sustainable Harvest Level* as well as corresponding revenue targets which are summarized in Table ES-1. When the Draft EIS was published, the overall ranking of the alternatives using the metrics in Table ES-1 was Alternative C, followed by Alternatives B and A. The new analysis of the Alternatives presented in this Final EIS resulted in the same overall ranking (Table ES-1). Alternative B better balances the risks and uncertainties of new landscape management strategies for the northern spotted owl with the benefits of improved landscape conditions and revenue production for the trusts.

The differences between Table ES-1 in the Draft EIS and in the Final EIS reflect the changes

Table ES-1. Summary of Forest Management and Financial Analysis of the Proposed Alternatives for the Planning Unit

Mgmt. Alt.	Harvest Level Decade 1	Gross Revenue Decade 1	Long-term sustainable harvest level[1]	Cumulative NPV[2] after 100 years	Percent of Unit in Older-Forest Conditions[3] by 2067	Date NSO[5] Dispersal Mgmt Area reach 50% SP[6] Movement Habitat	Date NSO NRF[7] Mgmt Area reach 50% South Puget Movement Habitat	Growing Stock Change after 100 years
	MMBF	$ Millions	MMBF	$ Millions	Acres	Decade	Decade	Percent
A	374	95	378	178	16%	*[4]	2057	152%
B	367	106	320	171	21%	2047	2057	170%
C	410	126	313	179	26%	2037	2057	162%

1) Average over a projection of 100 years, 2) Net Present Value, 3) Niche diversification and fully functional forest development stages, 4) Alternative does not reach a 50 percent target of South Puget Movement habitat in the dispersal management area in the 100 year projection, 5) Northern Spotted Owl (NSO), 6) South Puget, 7) Nesting, Roosting, Foraging

to the forest landscape management strategies and corrections to the forest estate models' representation of the alternatives. The changes include: (1) modifications to the northern spotted owl dispersal conservation strategies; (2) a strategy to maintain an active forest management presence on each landscape through an even-flow of harvest volume for each district; (3) inclusion of a forester-designed harvest schedule for the first decade; and (4) a corrected modeling design for riparian areas under the guidance provided in the *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006).

Implementation of the (Alternative B) preferred alternative's forest management strategies is forecast to increase the harvest level in decade one by approximately 10 million board feet (mmbf) per year over the previous forecast volume from the 2007 *Sustainable Harvest Addendum* (37 mmbf/per year versus 27 mmbf/per year). The harvested area also is anticipated to increase from approximately 1,400 to 1,800 acres per year, at the same time increasing the amount of variable retention (from 700 to 1,000 acres) and thinning (from 345 to 780 acres) harvest treatments. This Final EIS analyzes the environmental impacts from all the alternatives and their harvest levels.

With the increase in harvest levels, one might expect that the individual sustainable harvest units (DNR 2006 *Policy for Sustainable Forests*, p. 29) that are within, or partly within this planning area also would increase their harvest levels. However, this is not the case. The only sustainable harvest units (identified in DNR 2004, p. 4-151 to 4-170) that are likely to see a change in their harvest levels are Pierce County State Forest Transfer (recommended increase) and Kitsap County State Forest Transfer (recommended decrease). The reasons for these recommendations are detailed in Appendix C. The increase in harvest level in Pierce County is largely because the preferred alternative's forest management strategies are different from those included in the 2007 *Sustainable Harvest Addendum* analysis; in particular, the landscape strategies related to northern spotted owl dispersal management areas have changed (Chapter 2, p. 29).

Major Conclusions, Environmental Impacts, and Mitigation Measures

The majority of environmental impacts are related to the level and type of harvesting activities occurring in watersheds in which DNR manages 20 percent or more of the land base. The type of timber harvest has an influence on forest conditions, and in the analysis affects the modeling results under each alternative. Forest conditions (and stand development stages) also are used as surrogates for a variety of indicators to draw inferences about the anticipated environmental impacts.

None of the management alternatives are expected to result in any probable, significant, adverse, environmental impacts to any of the resource areas, relative to current conditions, beyond the analysis in the 1997 *Habitat Conservation Plan*, 2004 *Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level*, and its 2007 *Addendum*, the 2006 *Policy* *for Sustainable Forests* or additional analysis provided at the watershed level within this Final EIS.

MITIGATION MEASURES

Mitigation for environmental impacts from the management activities that will take place in this planning unit are provided in DNR's numerous state-wide procedures, the 2006 *Policy for Sustainable Forests*, and through the *Forest Practices Rules* Chapter 222 WAC, specifically road maintenance and abandonment (222-24-050). The 1997 *Habitat Conservation Plan* for forested state trust lands provides mitigation for incidental take for specific federally listed species, including the northern spotted owl (*Strix occidentalis caurina*), marbled murrelet (*Brachyramphhus marmoratus*), and a number of salmonid species. The 1997 HCP also conserves habitat for unlisted species in western Washington.

Next Steps in the Process

All three alternatives meet or exceed the planning objectives laid out in the project scoping notice (Appendix A). Following the publication of the Final EIS, an alternative will be selected by DNR, based on the analysis presented in this document. The final preferred alternative could have various features of the other alternatives and "mix and match" them using the following information:

- Analyses in this Final Environmental Impact Statement.
- Additional analyses (for example, a financial analysis) provided by DNR staff.
- Review of public comments on the Draft EIS (Appendix O).

Any changes made to the selected alternative and its strategies will become a part of the South Puget Forest Land Plan; which is a compilation of the strategies developed in this process and used to guide on-the-ground management of forested state trust lands within the South Puget HCP Planning Unit.


Regeneration Harvest

CHAPTER 1
BACKGROUND INFORMATION

background

The focus of this Environmental Impact Statement (EIS) is the development of a forest land plan for the management of the South Puget Habitat Conservation Plan Planning Unit (the planning unit) through the comparison of a reasonable range of alternatives and their probable significant environmental impacts. The forested state trust lands in the planning unit are commonly referred to as the Elbe Hills, Tahoma, Tahuya, Green Mountain, Sherwood, Tiger Mountain, McDonald Ridge, and Grass Mountain state forests.

This chapter summarizes the responsibilities of Washington's Department of Natural Resources (DNR) and the background and objectives of forest land planning. The chapter also describes the public outreach process and how alternatives were developed and modified through the environmental analysis. The analysis in this document is based on all reasonably available information.[1]

Statewide, DNR manages about 3 million acres of state trust lands — 2.1 million acres of forestlands, about 1 million acres of irrigated and dryland agricultural, grazing lands, and some commercial properties.

DNR also manages 2.4 million acres of state-owned aquatic lands (beds of marine waters, some tidelands, and all navigable lakes and rivers), and is the steward of 31,000 acres in 51 Natural Area Preserves (NAPs) and 88,000 acres in 31 Natural Resource Conservation Areas (NRCAs). DNR's varied additional duties include fighting wildfires and regulating forest practices on all non-federal forestlands in the state as well as regulating surface mining and reclamation.

Forested state trust land management is carried out within the framework of state and federal laws; the state constitution; the federal Enabling Act of 1889; DNR's 2006 *Policy for Sustainable Forests*, 1997 *Habitat Conservation Plan*, and 2004 *Sustainable Harvest Final EIS* and its 2007 addendum; and with oversight and policy direction provided by the Board of Natural Resources (Board). DNR also follows current Washington State Forest Practices Rules.[2]

DNR has a commitment to carry out a localized level of planning to help integrate local information and conditions into this broader policy framework (DNR 2006b). The local level plan is intended to guide management activities implementing the broader policy framework in the planning unit.

Through the planning process, DNR has identified local natural resource issues and created strategies to address them, although site-specific on-the-ground activities (timber sales, road building, recreation trails, or facilities improvements) are not included at this level of planning. The plan offers and analyzes strategies that guide those activities.

This document compares the reasonable alternatives, which have been modified based on comments received since the Draft EIS was published, and provides an assessment of the probable, significant, adverse environmental impacts. The discussion is designed to inform decision-makers and the public about the alternatives — including the mitigation measures that prevent or minimize adverse impacts or enhance environmental quality.

Washington State Trust Lands

Regeneration Harvest in Elbe Hills

What is a Trust?

A trust is a relationship in which a person (or entity), the trustee, holds title to property that must be kept or used for the benefit of another, the beneficiary.

What Are Forested State Trust Lands?

When Washington became a state, Congress used the Enabling Act to grant the new state more than 3.2 million acres of land as a source of financial support — primarily for public institutions (the federally granted lands). An additional 618,000 acres of forestland were acquired, mostly during the 1930s when foreclosed, tax-delinquent, cut-over, and abandoned forestlands were deeded by the counties to the state (the State Forest trust lands).

Unlike many states that sold their trust lands early in the 1900s, Washington retained ownership and continues to manage them to provide a permanent source of revenue and other benefits for the people of Washington (DNR 2006b). Most state-owned lands were ceded to the United States by local tribes and later given to Washington when it gained statehood. The Point Elliot Treaty of 1855 generally applied to ceded lands in the greater Puget Sound area, with Tribes retaining rights for hunting, fishing, and gathering berries and roots where lands appeared “open and unclaimed”.

Who Are the Beneficiaries?

The beneficiaries of the federally granted lands are designated state institutions such as public schools, state universities, and charitable, educational, penal, and reformatory institutions. The Enabling Act established and the State Constitution gave direction for management, including restrictions involving the trust lands. In addition, the Legislature gave further guidance for managing the federally granted trusts by directing that trust lands remain as commercial forests to help fund local services in counties in which the lands are located. Some trust lands also contribute to the state general fund and are earmarked for education.

The beneficiaries of the State Forest trust lands are counties, their junior taxing districts, and the state general fund. The legislature created the State Forest trust lands, and delegated management of the trust lands to DNR.

What is the Trust Mandate?

The 1984 landmark decision *County of Skamania v. State of Washington* identified two key trustee duties, commonly referred to as the trust mandate.[3] Washington's Supreme Court stated that (1) a trustee must act with undivided loyalty to the trust beneficiaries, to the exclusion of all other interests, and (2) a state's duty as trustee is to manage trust assets prudently (DNR 2004).

The Legislature, as trustee, requires the Board and DNR (as the trust land manager) to establish policies to ensure that, based on sound management principles, trust assets are managed sustainably to benefit the trusts.[4]

What Are the Benefits of Forested State Trust Lands?

ECOLOGICAL BENEFITS

By managing trust lands as working forests, DNR ensures long-term, sustainable, healthy ecosystems that have added environmental benefits for the people of Washington and their quality of life. Forested state trust lands benefit all biodiversity components while healthy, productive forests sequester carbon and contribute to clean air. In addition, forest watershed systems are sources for municipal water supplies and provide quality habitat for aquatic organisms.

SOCIAL AND CULTURAL BENEFITS

Forested state trust lands provide important opportunities for public access and recreation. DNR is committed to protecting areas of tribal interest and cultural concern. Many tribes desire to protect and perpetuate their burial sites, cultural objects, sacred sites, gathering sites, trails, landscapes, languages, dances, mythologies, and other connections to their off-reservation ancestral homelands. Tribes continue to use these resources to teach their younger generations through traditional and modern-day practices. DNR is committed to building government-to-government relationships with affected tribes through consultation and communication when culturally sensitive lands are at risk.

Public access to state trust lands is guided by the Multiple Use Act.[5] Recreation activities are supported by developed facilities such as campgrounds, boat ramps, trailheads, and trails in many of the forest areas. There are additional opportunities for dispersed recreation across the majority of forested trust landscapes. Some of these activities include hiking, horseback riding, and trail riding using both motorized and non-motorized vehicles. Statewide, outdoor recreation visitors make more than nine million visits annually to forested state trust lands.

State trust lands contain many historic sites, including remnants of logging, mining, homesteads, and early transportation routes. Cultural sites take many forms: vision quest sites, ceremonial bathing areas, and gear storage locations, as well as plant gathering and hunting sites. Trust lands are managed to protect and preserve these cultural sites.

ECONOMIC BENEFITS

Each year, public institutions receive millions of dollars in trust revenues from timber harvesting and leasing of agricultural lands, communication sites, wind farms, and a few commercial properties. Since 1970 management of these state trust lands has earned $6.7 billion in trust revenue—funds that didn't come from taxes. Of this, the forested state trust lands have produced more than $4.55 billion.

Management of state trust lands also supports local economies by supplying jobs in the forest and agricultural industries to nearby communities. Some niche industries depend on products from trust lands. In addition, these lands often attract recreationists who spend money in these communities.

Finally, the supply of wood and agricultural products from state trust lands helps maintain the infrastructures of the forest and agricultural industries and the rural economies that depend on them. Moreover, this forest management occurs with strict environmental protection, so that local use of wood products from these lands tends to reduce importing products from forests outside Washington that may not be managed sustainably or that do not meet Washington's high standards.

Text Box 1-1. How Do Trust Lands Benefit You?

Forested state trust lands provide more than a quarter of a billion dollars in tax-free revenue each year to specific beneficiaries; the trust lands also provide abundant and diverse social, ecological, and economic benefits to present and future citizens of Washington. More particularly, these trust lands help us keep our air and water clean and provide wildlife habitat and places for people to play — a unique constellation of multiple benefits not provided by any other private or public landowner in Washington.

Regulatory Framework

What Is the State Forest Practices Act?

In 1974, the Legislature passed the Forest Practices Act[6], which regulates activities related to growing and harvesting timber on all non-federal forestlands in the state, including forested state trust lands. The Forest Practice Rules[7] give direction on how to implement the Act.

In July 2001, the Forest Practices Board amended the rules to be consistent with the 1999 *Forests and Fish Report*.[8] The objectives of the Report are to protect public resources, focusing on water quality, salmon habitat, and other aquatic and riparian resources.

Forest Practices field staff in DNR's six regions administer and enforce the rules. The Forest Practices Division provides staff support to the Forest Practices Board and programmatic oversight for the regions and is entirely independent of the state trust land programs that manage the forested state trust lands. DNR's proprietary trust land managers are subject to the same rules and regulations as private landowners.

What is the Federal Endangered Species Act?

The purpose of the Endangered Species Act (ESA) is to prevent the extinction of native species and conserve the ecosystems upon which they depend.[9] Federal wildlife agencies list species that are at some level of threat of extinction.

To comply with the ESA and protect species on 1.6 million acres of forested state trust lands—mostly in western Washington—DNR negotiated a habitat conservation plan (HCP) in 1997 with the US Fish and Wildlife Service (USFWS) and NOAA's National Marine Fisheries Service, collectively referred to as the "federal services".

This multi-species HCP for western Washington takes a landscape approach to minimize and mitigate any incidental impact to threatened and endangered species or their habitats (specifically the northern spotted owl and marbled murrelet) while conducting lawful activities, such as timber harvest or other forest operations. The HCP is intended to offset any harm caused to individual animals through DNR operations by developing improved habitat conditions to support viable species population levels.

What Other Laws Impact DNR Management?

DNR complies with all other applicable state and federal laws. Some examples include the Shoreline Management Act, intended to protect valuable shoreline resources, and the Clean Water Act, which established the basic structure for regulating discharges of pollutants into the waters of the United States. The Clean Air Act, State Environmental Policy Act (SEPA), Multiple Use Act, and certain local laws also affect the management of the state's forested land base managed by DNR.

DNR's Objectives

The purpose of the South Puget forest land plan is to develop management strategies that provide guidance at the operational level. The strategies of each alternative are based on local conditions and issues (ecological, social-cultural and economic) and are implemented throughout the planning area over the long-term. Of course, management strategies also are designed to implement Board policies, which in addition to other benefits ensure revenue to trust beneficiaries and habitat for multiple species.

Although the desired outcomes could be achieved without the aid of a formalized planning process, a forest land plan allows DNR to analyze and demonstrate the effectiveness of its cumulative management actions over the planning unit at multiple points in time.

What Is the Need for this Plan?

Planning the land management logistics for numerous resources and uses addressed in DNR policy is central to this process. Implementation strategies that are customized to apply policy-level guidance at the local level assist DNR in managing the state's diverse landscapes and provide valuable feedback on the policy framework. For instance, strategies can be customized to address different local concerns regarding areas such as Tiger Mountain or Tahuya State Forest while still complying with DNR's state-wide policies.

DNR's management paradigm has seen fundamental changes in recent years. The Board adopted the 2006 *Policy for Sustainable Forests*, 2004 Sustainable Forest Management direction[10] contained in the *Sustainable Harvest Final EIS* (DNR 2004) and an addendum approved in July 2007. Forest land plans will demonstrate DNR's ability to achieve measurable objectives in a specific management unit that meet the intent of Board-adopted policies and direction.

DNR manages approximately 146,000 acres of forested state trust lands in the South Puget planning unit alone, and must manage them consistent with ongoing direction from the Board. DNR managers are expected to meet the varied and sometimes competing public expectations of land use and revenue generation, while balancing wildlife habitat, environmental values, and other social-cultural objectives.

What Are DNR's Goals and Objectives?

The objective for the alternatives is to achieve the desired outcomes central to the purpose and need (refer to scoping notice in Appendix A), such as the social-cultural, environmental, and economic considerations DNR is fulfilling.

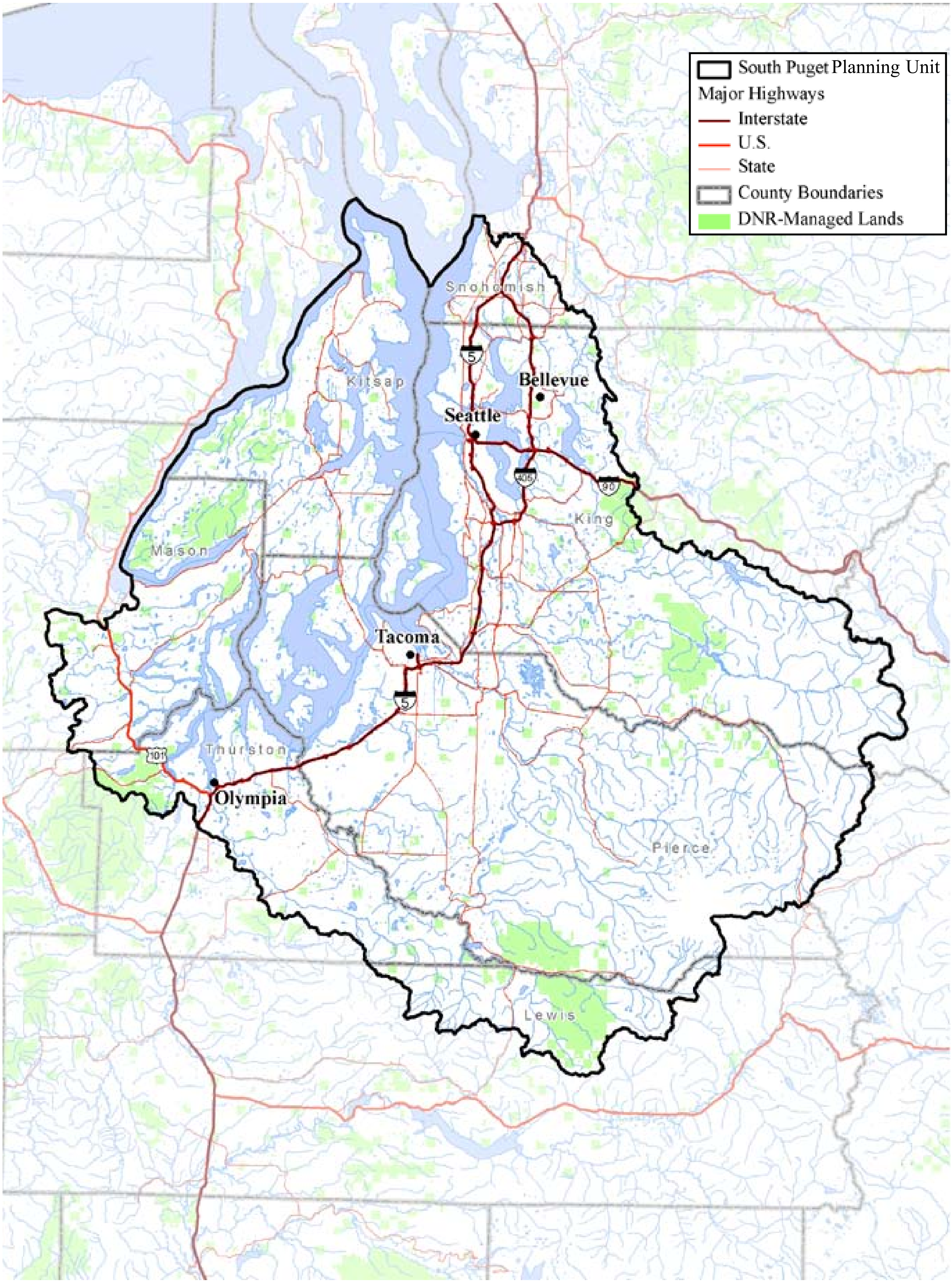
Revenue is generated through the management of trust lands, which includes the sale of timber and the leasing of agricultural and commercial property. In the next ten years (2009-2019), the planning unit is projected to contribute about $79 million from the sale of 265 million board feet of timber.

How will DNR Report on the Implementation of the Selected Alternative?

The selected alternative contains strategies designed to provide on-the-ground guidance for a variety of topics (Appendix B). A watershed-level (WAU) report containing the harvest levels and types will be prepared every 10 years as part of the *Habitat Conservation Plan* decadal comprehensive report. The first selected alternative report will be completed in 2020. This report would compare and track the differences between the projected decadal levels provided in this analysis to actual implementation statistics. During this review a determination will be made on whether there are any needed modifications to the plan and what kind of environmental analysis might be needed.

The selected alternative will be monitored through DNR's planning and tracking system, which is used by field staff to document silvicultural prescriptions for selected forest management units (FMUs). The planning and tracking system documents the type of harvest activities and amount (acres affected) and can be reported at a variety of scales (planning unit, watershed, sub-basin).

Map 1-1. Vicinity Map of the South Puget Habitat Conservation Plan (HCP) Planning Unit
Created by Rebecca Niggemann 9/26/07



Components of the Planning Area

The South Puget planning area boundaries were delineated in the 1997 *Habitat Conservation Plan* (refer to Map 1-1). HCP planning units were delineated by clustering Water Resource Inventory Areas (WRIAs), as defined by the Washington State Department of Ecology (Ecology). The counties and parts of counties in this planning unit that contain DNR-managed trust lands include southern King, Pierce, eastern Thurston, north-central Lewis, Kitsap, and eastern Mason. The Cedar, Green, White, Carbon, Puyallup, Nisqually, and Deschutes rivers also are included in the planning unit.

This planning unit is the most densely populated region in Washington, with more than 50 percent of its area supporting urban environments. Most of the unit is located in the Puget Trough ecoregion. However, small portions are located in the neighboring West Cascades ecoregion.

The Puget Trough

The Puget Trough includes the marine waters of the Puget Sound and the lowlands. Nearly eighty percent of the planning unit is below 3,000 feet in elevation; half — mostly the lands immediately adjacent to Puget Sound — are less than 1,000 feet in elevation. The Olympic Mountain rain shadow strongly influences the climate and precipitation (usually in the form of rain) averages 20 to 70 inches per year. Summers are generally warm and dry, and winters are relatively mild.

Forests in this region are dominated by Douglas-fir with western hemlock and western red cedar as primary species. The conifer forest mosaic is interspersed with hardwood species such as bigleaf maple and red alder. In addition to forests, the ecoregion contains a number of grasslands, wetlands, bogs, riparian areas and estuaries.

The West Cascades

The highlands of the West Cascades ecoregion receive from 50 to 140 inches of precipitation every year, and higher elevations are often packed with snow. This ecoregion is very large and ecologically diverse due to the various ecosystems including riparian areas, wetlands, grassy balds, and oak woodlands. Conifer forests consisting mainly of Douglas-fir and western hemlock mixed with red alder and bigleaf maple cover the landscape at all elevations. Middle elevations in this area also contain Pacific silver fir and noble fir. Although the highest DNR-managed forests in this planning area are at about 5,000 feet, mountain hemlock and silver fir forests are found at about 7,000 feet, along with sub-alpine parklands.

How Did DNR Identify Significant Issues?

Stakeholder Workshops

In June 2005, DNR held three stakeholder workshops to discuss forest land planning for the Elbe Hills, Tahoma, Tahuya, Green Mountain, Sherwood, Tiger Mountain, McDonald Ridge, and Grass Mountain State Forests. Public notices and press releases invited interested parties to attend these workshops. In addition, personal invitations were sent to people and organizations actively involved with DNR. These stakeholders included recreation groups, environmental organizations, and members of the timber industry.


Public Scoping Meeting Participants

A total of 47 people participated in three meetings located in Eatonville, Belfair, and Issaquah. The attendees offered local information and expressed their concerns related to the forested state trust lands in the planning unit. Participants listened to a presentation on the preliminary stages of planning, and then shared information with DNR; their information was collected directly onto forest maps. Participants discussed how they use these forests and their concerns about forest management in specific areas.

Scoping

Scoping — that is, defining the scope of the issues to be addressed in environmental review — has several major purposes during the development of an EIS. First and foremost, scoping helps to limit the focus of an EIS to include only the significant environmental issues. Scoping includes public comment that helps the agency recognize areas of concern and focus on only probable significant adverse impacts and reasonable alternatives.[11] Comments from concerned citizens and organizations also help agencies identify reasonable alternatives to be analyzed in an EIS. The opportunity to comment during the scoping process also helps promote agency and public interaction.

The SEPA process was formally initiated with the scoping notice and a "threshold determination of significance" released on July 12, 2006, followed by a series of public meetings held throughout the planning unit on the following dates:

- July 25, 2006—Nisqually Lodge, Ashford
- July 26, 2006—Mary Theler Community Center, Belfair
- July 27, 2006—Kiwanis Club, Issaquah

In all, about 80 individual comments were received regarding DNR management of forested state trust lands in the planning unit during the scoping comment period (July 12, 2006 through August 11, 2006). These comments capture diverse issues, ideas, and opinions proposed by the public and were summarized by subject and responded to in January 2007. Careful review of this document helped DNR narrow the scope of issues to be considered as alternatives further examined in the Draft EIS.

Development of Forest Management Alternatives

SEPA requires DNR to examine probable, significant, adverse environmental impacts. DNR considered a range of reasonable alternatives, consistent with the scoping notice published on July 12, 2006 (Appendix A).

Alternatives are basic building blocks of an EIS. The alternatives present meaningful comprehensive management options to decision-makers. The management strategies that were considered by DNR determined the characteristics of the alternatives reviewed in the Draft EIS. The three alternatives were developed from ideas and concerns expressed by participants of public meetings, written comments received during the scoping comment period, and from DNR staff, with review and approval of DNR's Planning Project Steering Committee.

Reasonable Alternatives Considered

The focus of this document is to help decision-makers by comparing a reasonable range of alternatives for this planning unit, and their probable, significant, adverse environmental impacts. SEPA requires an EIS to analyze those impacts caused by an agency's proposed actions. The intent is to provide information so that decision-makers can weigh environmental impacts and alternatives as part of their decision-making. The analysis is based upon all reasonably available information.[12]

An EIS evaluates the proposal, including a preferred alternative, if any, and its environmental impacts; current or baseline management strategies; and other reasonable alternatives, including mitigation measures. The alternatives are designed to evaluate whether the proposal objectives defined in the scoping notice can be achieved at a lower environmental cost or decreased level of environmental impact.[13]

Table 1-1. Steering Committee Members

Members	Position	Responsibility
Clay Sprague	Deputy Supervisor for Uplands	Decision Maker
Gretchen Nicholas/ Jed Herman	Forest Resources and Conservation Division Manager	Chair of Committee- Liaison to other Division Managers
Rodney Cawston	Tribal Liaison	Liaison to Tribal Stakeholders
Randy Acker	Region Manager Representation	Liaison to Region Managers and Staff
Craig Partridge	Policy Director	Provides Policy Interpretation
Aaron Toso	Communications Director	Provides Communications Advice

The Project's Steering Committee

The Steering Committee served as decision-makers during the development of the forest land plan strategies and this analysis. The Steering Committee listened to issues and recommendations from DNR's programs and project managers to make their decisions. Each steering committee member was responsible for keeping different entities informed about the progress and process used in the development of this planning proposal.

State Environmental Policy Act Non-Project Proposal

The South Puget forest land plan is a "non-project action" under SEPA. Non-project actions include the analysis of plans, policies, programs, or regulations that contain standards controlling the use of the environment or that will regulate or guide future actions that would occur on the ground.[14] Non-project actions are not site-specific in nature and therefore do not warrant site-specific environmental analysis. Future management choices on the forested state trust lands will depend, in-part, on the decisions made during this process, but no specific on-the-ground activities will be designed as part of this Final EIS.

Text Box 1-2. The Role of the State Environmental Policy Act (SEPA)

SEPA review is required on proposals for project and non-project actions.DNR will propose future project and non-project actions related to this planning effort. They will range from programmatic harvest scheduling scenarios to site-specific proposals for management activities such as the development of recreation sites and timber sales.

The Draft EIS

A range of alternatives were presented in the Draft EIS, published on July 18, 2008. The Draft EIS analyzed the probable, significant, adverse, environmental impacts associated with the direction and strategies of the three alternatives.

Development of the Final EIS

The Final EIS reflects consideration of comments received during the EIS comment period, July 18, 2008 to August 18, 2008. During this time period a series of public meetings were held from 6:00 p.m. to 8:00 p.m. on the following dates and at these locations:

- July 29, 2008—Nisqually Lodge, Ashford, WA
- July 30, 2008—King County Library Administration Service Center, Issaquah, WA
- July 31, 2008—North Mason Timberland Library, Belfair, WA

A summary of the comments received and responses to them can be found in Appendix A. Included in the comment responses are references to the sections they are addressing.

The results presented in this document are meant to provide decision-makers with a clear understanding of the environmental consequences of each alternative.

What Is in the Other Chapters?

Chapter 2 describes the three reasonable alternatives in detail. They reflect management strategies considered by DNR and resulted in the following list of issue topics: product marketing and leasing, land transactions, older forests, forest health, hydrologic maturity, northern spotted owl, recreation and access, and visual impacts. The alternatives described are Alternative A— current management or "no action"; Alternative B — DNR's preferred direction; and Alternative C — exploratory options. Alternative C contains strategies that still fall within the existing policy sideboards but explore different implementation strategies.

Chapter 3 describes the environmental setting and management today of the South Puget planning unit landscapes.

Chapter 4 describes the environmental effects and examines the environmental consequences as well as mitigation measures for significant impacts caused by the alternatives.

End Notes

1 Chapter 197-11 Washington Administrative Code [WAC]
2 Chapter 76.09 Revised Code of Washington [RCW] and Chapter 222 Washington Administrative Code [WAC]
3 County of Skamania v. State of Washington, 102 Wn. 2d 127, 132, 685 P. 2d 576 (1984)
4 Chapter 43.30.215 Revised Code of Washington [RCW] (formerly RCW 43.30.150(2) and (6) and AGO 1996-11. The 2006 *Policy for Sustainable Forests* contains a succinct discussion of the trust mandate and common law duties of a trustee as interpreted by DNR and approved by the Board.
5 Chapter 79.10.100 Revised Code of Washington [RCW]
6 Chapter 76.09.030 Revised Code of Washington [RCW]
7 Chapter 222 Washington Administrative Code [WAC]
8 Chapter 76.09.055 Revised Code of Washington [RCW]
9 16 U.S.C. 1531 et seq.
10 Board Resolutions 1110 and 1134
11 Chapter 197-11-408 Washington Administrative Code [WAC]
12 Chapter 197-11 Washington Administrative Code [WAC]
13 Chapter 197-11-440(5) Washington Administrative Code [WAC]
14 Chapter 197-11-704(2)(b) Washington Administrative Code [WAC]

Looking North to Seattle from Green Mtn

PROPOSED ALTERNATIVES

CHAPTER 2

alternatives


Commercially thinned stand in Elbe Hills

This chapter describes and compares Alternative A (No Action) to the others considered by DNR to develop management strategies to guide on-the-ground implementation of broader policy direction provided in the 2006 *Policy for Sustainable Forests* and the 1997 *Habitat Conservation Plan* (HCP).

Like any private trust manager, DNR must develop and carry out land management strategies which strike the appropriate balance between current and future income production and the long-term preservation of trust assets. To fulfill these mandates, specific governing policies from the Board of Natural Resources (Board) direct the management of forested state trust lands. DNR develops administrative procedures to effectively and efficiently implement Board-approved policies. While complying with all board policies and procedures, DNR retains the flexibility in its field operations to respond to changing or unique circumstances.

Public and agency input resulted in changes from the Draft EIS to the Final EIS including: addition of a catastrophic loss component (p. 27), changes in the alternatives to customize an approach toward habitat for the northern spotted owl (p. 29), a discussion of the impacts of even-flow of harvest activities to visual resources (p. 35), and the hydrologic maturity management strategy for Lake Tahuya (p. 28).

The alternatives are presented by topic, with short descriptions to assist the reader in comparing them. Specific strategies to implement each particular approach are included in Appendix C. The State Environmental Policy Act (SEPA) requires that DNR analyze only probable, significant, adverse environmental impacts, and that the analyses are based on reasonably available information. The level of detail of each analysis is commensurate with the importance of the impact.[1]

Once alternatives were developed, DNR used various analytical tools to evaluate each alternative to understand potential short- and long-term consequences of such actions. Forest modeling tools are used to compare the results of the different alternatives which are presented in Chapter 4; a description of these models are presented in Appendix C. Models produce results that are reviewed for operational feasibility, costs and revenue, and the environmental impacts analyzed in this document.

Text Box 2-1. Creation of the Preferred Alternative

The forest land planning process helps Washington's Department of Natural Resources (DNR) develop management strategies to guide on-the-ground implementation of department policies and procedures. Implementation strategies are not developed with a one-size-fits-all approach, but are varied based on site-specific conditions and information.

The alternatives provided in this Final Environmental Impact Statement (Final EIS) were developed based on DNR management objectives and written and oral comments received during the public comment period in July/August 2008. Those comments received from the public on specific topical issues assisted DNR in modifying the alternatives or providing a more detailed discussion.

The primary purpose of a Final EIS is to present a discussion of probable, significant, adverse environmental impacts of the alternatives, and identify mitigation measures that avoid or minimize any adverse environmental impacts.

DNR developed the preferred alternative, which will be reviewed by the department's Deputy Supervisor for Uplands, and must be approved by the supervisor before implementation may begin.

Risk and Uncertainty in Forest Modeling

Forest management models provide a useful way to generate information comparing potential outcomes of alternative management strategies, both now and into the future. For complex and interrelated problems, such as the management of forests, computer models provide a tool by which decision-makers can explore and consider the potential outcomes of their choices. Models do not supply definitive answers; rather, they provide information useful for understanding potential outcomes of alternatives.

Models have a number of uncertainties, often due to the necessity of simplifying complex data. In the modeling process, assumptions must be made for uncertainties and DNR clearly defines its assumptions. For example, if the health of the forest was not expected to have any significant adverse environmental impacts on the state of the forest then the associated risk of modeling forest health would be considered low. When the risk is low, it may be important to discern only the relative differences between alternatives. When the information is important to decision-makers, or the level of environmental risk is higher, then the assumptions associated with the outputs are more clearly defined (DNR 2004).

However, while DNR may improve its models as it obtains more accurate scientific information, the primary purpose of modeling is the exploration and discovery of potential consequences of management options over time. For more information on DNR's general modeling process and results, refer to Appendix B of the *Sustainable Harvest Final EIS* (DNR 2004). For more modeling outputs and sensitivity analyses related specifically to this process, refer to Appendices C and D.

Purpose of Alternatives

The alternatives were designed to (1) meet the purpose and need statement (p. 7), (2) facilitate analyses of different options, (3) reflect public and tribal comments, and (4) provide direction for on-the-ground operations. The strategies to be implemented throughout the planning area, over the long term, are based on local ecological, social-cultural, and economic conditions. The alternatives are designed to examine a range of options to achieve DNR's goals.

Guided by the overall policy direction of the Board of Natural Resources, alternatives will address goals in the following areas:

Ecological (Ecosystem Health & Productivity)

DNR conservation efforts will focus on sustaining biodiversity, recognized as the fundamental guiding principle of sustainable forest management (DNR 2006b).

Social-Cultural

DNR social and cultural benefits are focused on the direct role that forested state trust lands play in the lives of Washington's residents, including access for varied recreation, educational and other uses and jobs in communities that rely on timber supply and products or on recreation.

Economic

DNR economic efforts are related to revenue production for all state trust beneficiaries.

DNR used efficiency and effectiveness of the various strategies in achieving these goals to develop the alternatives. Each alternative must meet the defined scope of this proposal, as well as all Board of Natural Resources' resolutions, policies, and procedures, while maintaining compliance with state and federal laws. The performance criteria reflecting this policy and legal direction are the alternatives' ability to achieve the desired future forest conditions, timber volume flow, and net present value of the forest over the long-term, while considering Tribal interests, providing recreational opportunities, and determining their environmental effects on natural resources. Alternatives also require the funding and other resources necessary to implement them.

Do the Alternatives Meet the Project Objectives?

All of the alternatives meet or exceed the HCP planning objectives for older-forest conditions, northern spotted owl habitat, and the 2007 sustainable harvest level and revenue targets which are summarized in Table 2-1. When the Draft EIS was published, the metrics for million board feet (MMBF) in Table 2-1

Map 2-1. Administrative Units in the South Puget HCP Planning Unit
Map by Rebecca Niggemann 9/26/07

ranked Alternative C first, followed by Alternatives B and A, respectively. In this document, the alternatives now rank as Alternative C, followed by Alternative A then Alternative B.

The differences between Table 2-1 presented in the Draft EIS and the one below are associated with the changes to the forest estate models representing the Alternatives. The changes include: (1) modifications to the northern spotted owl dispersal conservation strategies; (2) a strategy to maintain an active forest management presence on each landscape through an even-flow of harvest volume for each district; (2) a forester-designed harvest schedule for the first decade; and (3) a corrected modeling design for riparian areas under the direction of the *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006).

Implementation of the preferred alternative (Alternative B) forest management strategies are forecast to increase the harvest level in decade one by approximately 10 million board feet (MMBF) per year over the previous forecast volume from the 2007 *Sustainable Harvest Addendum* (37 MMBF/per year versus 27 MMBF/per year). The harvested area is also anticipated to increase from approximately 1,400 acres per year to 1,800 acre per year at the same time increasing the amount of variable retention (700 to 1000 acres) and thinning (345 to 780 acres) harvest treatments. This Final EIS analyses the environmental impacts from these new harvest levels.

With the increase in harvest levels, it is expected that the individual sustainable harvest units (DNR 2006, p. 29) that are within, or partly within, this planning area would also be expected to increase their harvest levels. However, this is not entirely true. The only sustainable harvest units (identified in DNR 2004, p. 4-151 to 4-170) that are likely to see a changed in their harvest levels are Pierce County State Forest Transfer (recommended increase) and Kitsap County State Forest Transfer (recommended decrease). The reasons for these recommendations are detailed in Appendix C. This increase in harvest level in Pierce County is largely because of the preferred alternative's forest management strategies are distinctly different from those included in the 2007 sustainable harvest analysis; in particular, the landscape strategies related to northern spotted owl dispersal management are quite dissimilar (p. 29).

Direction Applied to All Alternatives

The South Puget HCP planning unit is divided into four administrative units—Snoqualmie, Black Diamond, Elbe Hills, and Belfair. These units represent the major areas managed within the planning unit by DNR's South Puget Sound Region. The administrative units are further broken down into forest blocks including: Green Mountain, Tahuya, Tiger Mountain, Enumclaw, Elbe Hills, and Tahoma (Map 2-1).

Recent western Washington management procedures include the 2006 *HCP Implementation Procedures for the Riparian Forest Restoration Strategy* and Identifying and *Managing Structurally Complex Forests to Meet Older-Forest Targets (Westside)* (Appendix E).

Table 2-1. Summary of Forest Management and Financial Analysis of the Proposed Alternatives for the Planning Unit

Mgmt. Alternative	Harvest Level Decade 1	Gross Revenue Decade 1	Long-term sustainable harvest level[1]	Cumulative NPV[2] after 100 years	Percent of Unit in Older-Forest Conditions[3] by 2067	Date NSO Dispersal Mgmt Area reach 50% SP Movement Habitat	Date NSO NRF Mgmt Area reach 50% SP Movement Habitat	Growing Stock Change after 100 years
	MMBF	$ Millions	MMBF	$ Millions	Acres	Decade	Decade	Percent
A	374	95	378	178	16%	*[4]	2057	152%
B	367	106	320	171	21%	2047	2057	170%
C	410	126	313	179	26%	2037	2057	162%

1 Average over a projection of 100 Years
2 Net Present Value
3 Biomass Accumulation, Niche Diversification, and Fully Functional stand development stages
4 Alternative does not reach a 50 percent target of South Puget Movement habitat in the dispersal management area in the 100 year projection

The *Riparian Forest Restoration Strategy* is designed to achieve restoration of high quality streamside forests to enhance and protect in-stream aquatic habitat supporting federally listed salmon species recovery efforts, and contribute to the conservation of other aquatic and riparian obligate (dependent) species. The quality of riparian areas for habitat is largely determined by the amount of acres in older-forest conditions (refer to Riparian, p. 56). DNR plans on using a combination of various types of active management combined with natural development of unmanaged stands to achieve these riparian objectives. This will result in the restoration of structurally complex forests that provide ecological functions consistent with the HCP riparian conservation strategy objectives (Bigley and Deisenhofer 2006).

DNR manages the planning unit according to the procedure for *Identifying and Managing Structurally Complex Forests to Meet Older Forest Targets (Westside)*. The goal is to achieve functional older-forest structures across 10 to 15 percent of each western Washington HCP planning unit within 70 to 100 years. The identification and review of landscape level management strategies to achieve the 10 to 15 percent older-forest target is presented in Forest Conditions (p. 43).

Alternative A: Current Management (No Action)

This alternative describes DNR's current management direction guided by existing plans and processes which are implemented on a site-by-site basis.

Alternative B: Preferred Direction

This alternative is made up of management strategies that reflect local information gathered through forest land planning efforts to influence on-the-ground activities. The planning focus takes a comprehensive look at the entire South Puget HCP Planning Unit as a whole, instead of on a site-by-site basis. This alternative combines components from the range of alternatives presented in the Draft EIS. Changes made are based on comments received during the Draft EIS comment period, from region and division program staff, or by DNR's Steering Committee (p. 11) whose purpose is to provide oversight for the plan.

Alternative C: Exploratory Options

This alternative explores a range of management approaches to the No-Action Alternative; depending on a given topic. This alternative analysis allows DNR to examine various strategies and approaches that might be possible in the future. Using the planning process, DNR may explore a broader array of possible management outcomes and their potential impacts.

ECONOMIC PERFORMANCE

Close-up of a white pine bough

Financial diversification is important in meeting DNR's obligations to each trust beneficiary. In addition to specific revenue-generating forest activities, the management alternatives related to the topic of economic performance include product marketing and land transactions.

Financial diversification includes marketing and sales of forest products, as well as income from non-timber forest products and services. Land transactions provide the opportunity to consolidate lands for more cost-effective management.

Alternatives Related to Product Marketing

The region's professional forest managers design timber sales based upon a series of considerations that include, but are not limited to: the topography of the site, issues associated with the area (social, ecological, economic), the most cost-effective means of harvest, the road system needed to access the site, tree species composition, and market value of the timber. Once the timber sale has been laid out and the proposal goes through environmental review, a public auction is held and the standing timber is sold to the highest bidder. The timber purchaser usually has two years from the time of purchase to harvest the timber and complete all contractual requirements.

There are three basic methods of selling timber: lump sum, scale, and contract harvest sales.

- Lump sum sales make up the majority of timber sales on forested state trust lands. In a lump sum sale, the purchaser buys all of the designated products camp run (see definition). As with every sale type, DNR sets the minimum opening bid based upon an agency appraisal of the material to be sold.
- Scale sales are those sales in which the estimated volume of designated product to be sold is bid upon and the per-thousand board-feet stumpage value is set by public auction. The successful purchaser pays DNR based on the actual volume removed as the sale is being harvested.
- On contract harvest sales, DNR performs a timber cruise of an area where harvesting is to occur. The estimated volume and value by species and by log grades are determined based upon current log selling prices. DNR then sells at public auction the various log sorts that could be removed from the

Camp Run
A purchaser offers the highest bid price they will pay for the entire product described to be sold. It is the responsibility of the purchaser to evaluate the timber based on the DNR pre-sales information package.

area. The successful bidder for each log sort is determined by comparing the delivered log price to be received at the delivery point against the cost of hauling the logs to the delivery point. DNR seeks the highest net return per thousand board feet for each log sort. Through a competitive bidding process, DNR contracts with contractors to harvest and haul the trees to the companies selected to receive the various log sorts. This contracting process offers the flexibility to modify harvest unit design throughout the process, and determine marketable products to be sold. The amount of volume to be sold as log sorts under contract harvesting cannot exceed 20 percent of DNR's total volume on an annual basis.

Board Foot
One board foot is a volume of wood measured one foot length by one foot wide, and one inch thick.

LEASING FOR SPECIAL FOREST PRODUCTS

DNR manages leases in specific areas of a forest for special forest products. Products from these leases include salal and fir and pine boughs. These leases are very important to local harvesters and an international wholesale market place, although they are very small when compared to the timber sale program. Contracts are developed with local harvesters, usually based on their inquiries for particular areas of forest and for specific forest products. Over the past few years in the South Puget region, leases for forest products have doubled and earn about one-half of the statewide income from these types of leases. Forest Stewardship Council (FSC) Certification provides additional benefits by improving sustainability while maximizing the value of all products.

Alternative A (No Action) Under the management strategies proposed in Alternative A, DNR continues working with a timber sales program dominated by lump sum sales, but including all three different sales types (lump sum, scale sales, contract harvesting sales) that are offered. This management alternative reflects DNR's current direction regarding special forest products: to identify and offer a mix of products to take advantage of existing markets and market value fluctuations to improve the overall financial performance.

Alternative B (Preferred Direction) Alternative B, as in Alternative A, continues lump sum and scale sales, but focuses the contract harvesting sales in designated northern spotted owl dispersal habitat areas. Direct control of harvesting activities allows complex silvicultural prescriptions to be conducted with greater control. Complex contracts which include detailed silvicultural prescriptions are necessary to ensure that when timber is sold as scale or lump sum timber sales the purchaser achieves the desired habitat conditions.

DNR also continues through this alternative to identify and offer a mix of special forest products to take advantage of existing markets and market value fluctuations based upon the conditions of the forest understory.

Alternative C (Exploratory Options) DNR management under Alternative C increases the percentage of contract harvesting in all areas up to 20 percent of the region's annual harvest level, so long as DNR's overall contract harvest volume does not exceed levels specified by law, and extends the time period for forest improvement sales. This management alternative allows DNR more flexibility because DNR hires the harvester rather than the harvester working for the purchasers in selling log sorts; this allows local and small scale timber purchasers an opportunity to bid on DNR timber products.[2]

DNR also examines a profit-sharing component to its special forest products contracts. This program would allow DNR to sell brush leases at public auction to the best bidder.[3]

Alternatives Suggested But Not Analyzed Another management alternative was suggested that emphasized small contract brush sales in Mason County so family businesses could afford to bid on brush leases. This alternative was not analyzed because of the prohibitive costs associated with managing numerous small contracts. DNR sells leases for brush in accordance with RCW 79.13.010 to .180, which authorizes leasing.

Land Transactions

North Fork of Mineral Creek in Tahoma

Financial diversification among trust asset classes is guided by DNR's 1998 *Asset Stewardship Plan* and the Asset Stewardship Council. DNR strives to improve the value of trust lands, increase their income potential, reduce costs, and reduce financial risks to the trusts by diversifying the land base, both among the asset classes and within each asset class. Land transactions are designed to help meet these goals. DNR selectively repositions trust lands through four different processes: land exchanges, public auctions, direct sales to public agencies, and purchases.

> "Funds from trust land sales to other public agencies are deposited into the Real Property Replacement Account Fund. Funds from the sales of trust lands at public auction are either deposited in the Land Bank Account or the permanent fund. The Real Property Replacement Account and the Land Bank Account are used to purchase replacement properties to be managed to benefit the trust."[4]

The management alternatives associated with forestland transactions call for acquiring additional forestlands in areas that are suitable for long-term forest management activities, such as areas adjacent to existing areas of trust ownership.

LAND EXCHANGES

DNR typically exchanges out of trust lands that are isolated or have drawbacks for long-term management, for example: lands in checkerboard of different ownerships and without existing access, or lands that are unproductive or in urban settings. Exchanges promote higher long-term income potential, better habitat management, increased public use opportunities, and lower management costs. In land exchanges, DNR works with other landowners to exchange parcels of land of equal value and of similar size in order to benefit the trust.[5]

DIRECT SALE TO PUBLIC AGENCY OR PUBLIC LAND AUCTION

DNR may dispose of trust properties that are incompatible with trust management objectives, such as isolated or financially unproductive trust parcels. There are two mechanisms that the Legislature has given DNR to accomplish these disposals, depending upon the specific circumstances.

First, all of these parcels are offered at fair market value, as required by the state constitution and state statute. The Board of Natural Resources determines the minimum selling price. When property is sold at public auction, the sale proceeds are deposited in the Permanent Fund of the respective trust or the Land Bank Account. The Land Bank Account funds are then used to purchase replacement properties better suited to natural resource management and/or generating long-term revenue for the specific trust. Funds are held in an interest earning, non-declining fund balance until used for replacement purchases.

Second, the Legislature has granted DNR an exception to the requirement of selling land at public auction when the land is sold to another public agency.[4] The funds from this type of trust land sale can be used, with legislative appropriation, to purchase replacement parcels maintaining the specific trust's land base. These replacement trust lands are designed to provide diversification within the trust's asset portfolio, improving economic return to beneficiaries over time. DNR targets replacement parcels that are more easily managed and have higher long-term economic performance potential than the property sold.

PURCHASES

When state trust lands are transferred or sold at public auction, DNR purchases replacement properties for the specific trust, in order to keep the trust 'whole'. For more information on the complexity of land transactions, refer to Appendix L.

Alternative A (No Action) Under Alternative A, DNR strives to acquire lands that optimize economic short- and long-term trust benefits. DNR continues to transition out of trust lands that are isolated or have drawbacks for long-term management. DNR continues to work with local governments to ensure that local land use decisions related to zoning and access do not reduce trust land values or restrict management options.

Alternative B (Preferred Direction) Alternative B includes all the strategies of Alternative A and, in addition, DNR will actively pursue both acquisition of industrial forestlands in the Cascade foothills and conservation credits (ecosystem services). Adding industrial forestlands in strategic locations of the Cascade foothills will facilitate further consolidation of forested state trust lands, providing additional flexibility in management of the existing land base. The strategy of pursuing conservation credits (ecosystem services) could be applied to the difficult-to-manage areas, allowing DNR to capture revenues on lands previously considered non-productive.

Alternative C (Exploratory Options) In addition to direction proposed in Alternatives A and B, Alternative C examines the sale and transfer of development rights, which keep lands from further development.

Alternatives Suggested But Not Analyzed A management alternative was suggested to emphasize expansion of Natural Resource Conservation Areas (NRCAs) and Natural Area Preserves (NAPs) as a way to protect all sensitive species that might be negatively affected by forestry activities. Increasing the amount of NRCAs and NAPs is outside the scope of this EIS, and is contingent on legislative appropriation, which DNR does not control.

FOREST ECOSYSTEM HEALTH AND PRODUCTIVITY

Looking Over Tahoma State Forest Toward Mt. Rainier

Management alternatives related to elements of the forest ecosystem are important to ecological objectives and the long-term health and productivity of trust assets. These objectives provide the basis for DNR's management and maintenance of the ecological health of forested state trust lands and are designed to ensure sustainable, healthy forest ecosystems.

Forest health considerations specifically include insect, disease or damaging agents, and the stand conditions which influence the forests' susceptibility to them. Older-forest conditions are important across DNR ownership in order to meet ecological function requirements such as life history, habitat for specific wildlife species, and clean water.

Meeting Older-Forest Conditions

Silvicultural treatments, such as DNR's version of "biodiversity pathways" (DNR 2004), can be used to create complex, multi-aged forest stand structures. The phrase *biodiversity pathways* is used to describe management approaches used in forest stands and forested landscapes to simultaneously achieve objectives of conserving biodiversity and generating revenue. By developing stand structures typical of older forests, this approach can be used to meet the older-forest objectives of the *Policy for Sustainable Forests* (DNR 2006b).

The Board has directed DNR to actively manage lands to achieve structurally complex forest conditions, especially in those suitable stands in the Biomass Accumulation forest development stage. This approach is intended to help achieve older-forest structures across 10 to 15 percent of each western Washington HCP planning unit within 70 to 100 years (DNR 2006b, p. 3-177). Older forests with structures that contribute to this goal are represented by stands in the Fully Functional and Niche Diversification forest stand development stages.

Biomass Accumulation stands, under natural (unmanaged) conditions, are stands that have passed their peak density but still contain a large number of trees. These remaining trees are generally large and have enough room and resources to grow and put on woody biomass. Franklin (2002) and Carey (2003a) highlight this stage as Biomass Accumulation, describing the principal ecological process of this stand development stage. The 2004 *Sustainable Harvest Final EIS* describes this stage as Botanically Diverse. The Biomass Accumulation stage is still considered structurally complex, but is differentiated from the Niche Diversification and Fully Functional development stages by the absence of standing large dead trees, and the lack of large woody debris (LWD), decadence, and standing deformed live trees.

Through landscape assessments, DNR will identify suitable structurally complex forest stands to be managed to meet older-forest objectives. Managing stands along developmental pathways requires forest managers to have a comprehensive understanding of the structures and processes in forest stands (Franklin and others 2002; Carey 2003a). By applying innovative silviculture techniques, foresters can accelerate the development of structurally complex forest stand conditions such as snags, decadent trees, down wood, multiple tree species, and multiple ages over time. This biodiversity pathway concept is important on lands targeted to provide the most benefit to wildlife species dependent on older forests.

Alternative A (No Action) Alternative A follows the procedure *Identifying and Managing Structurally Complex Forests to Meet Older-Forest Targets (Westside)*, emphasizing a site-by-site analysis prior to the completion of a forest land plan. Any final harvests currently proposed in structurally complex stands must be analyzed for their role in meeting the 10 to 15 percent target for older forests. Depending upon the analysis results, the stands are either deferred or harvested.

This management alternative defers all stands designated for achieving older-forest conditions over the long term (70 to 100 years) from final harvest. Only harvest activities which enhance or accelerate development of older-stand conditions, such as thinnings, would occur in these designated stands. Once the older-forest condition target of 10 to 15 percent is met, all additional stands meeting older-forest conditions are then available for the full range of DNR silvicultural management.

Alternative B (Preferred Direction) In Alternative B, the forest modeling process is used to identify and prioritize stands in the development stages that are most capable of meeting the 10 to 15 percent older-forest condition target by 2067. Stands may be temporarily deferred from harvest until new stands replace their contribution to the 10 to 15 percent target at this point, existing stands are released for harvesting. Forest models allow DNR to continually review and analyze forest management strategies over time to ensure that DNR is on a trajectory to meet the objective.

Alternative C (Exploratory Options) No other alternatives met DNR's objectives identified during scoping; therefore, no additional evaluation was needed.

Forest Health

Maintaining and improving forest health depends upon avoiding forest conditions that are vulnerable to damage (prevention) and remedying problems as they arise (treatment). Preventive actions include growing site-appropriate tree species at stocking levels where the trees have sufficient energy to tolerate temporary stresses, defend themselves from pests, and recover from minor damage. Treatments may be used directly to suppress pest populations, improve tree vigor, and change stand structure when monitoring reveals threats are present or developing. Some of the threats include insects, disease, noxious weeds, and animal damage.

Forest Growth and Mortality—As trees in the forest grow, some also die. In addition to those removed by harvesting and land clearing, insects, diseases, fire, wind and a variety of other agents also kill trees. On U.S Forest Service Inventory and Analysis Plots in western Washington, the cause of death was most often attributed to physical damage or fire, weather damage, or root disease. Although growth is about four times the mortality in Douglas-fir, western hemlock, and western red cedar, disease can kill a substantial number of live trees.

Insects and diseases also may affect tree growth rates, form, and species composition. They may limit the likelihood of achieving desired tree sizes and structures to meet older-forest targets. Exotic insects and diseases continually threaten Washington's forests and could permanently alter forest structure and ecological function (DNR 2001).

Forest Susceptibility to Damage—Several key factors influence forest susceptibility to insects and diseases, wildfire, and weather damage. Over-crowded forests are more vulnerable to damage because trees may be too tall and thin to withstand severe weather or too weak to defend themselves from invasion by pests. When a forest is dominated by one tree species — a monoculture — pests move easily from trunk to trunk, branch to branch, or root to root. Root diseases persist on affected sites for decades and can readily infect susceptible host trees. Dry summer conditions and extended drought can stress trees, making them more susceptible to insects and disease. Wet spring weather increases the spread of foliage pathogens.

If foresters do not recognize the presence and impacts of root diseases, pathogens, or animal damage, and they fail to adapt their management strategies to reduce impacts, then older-forest structures may not be achieved in desired time frames.

Catastrophic events—Often, natural events such as wildfire, wind events, floods, insect infestations, landslides, ice storms, and volcanic eruptions impact forests in this planning unit. The need for restoration is determined by a number of factors such as economic impacts, social interest, ecological values, and by land management objectives as described in a forest plan (DNR 2006a). Forests can naturally recover from such events, although it may take tens to hundreds of years and sometimes result in modifications to the existing forest. Therefore, local flexibility to implement management objectives is a critical factor in determining the amount, type, and location of restoration treatments. At times, disturbed areas are left to recover naturally, but at other times restoration or other management activities are appropriate, including the commercial removal of dead and dying trees, and the reconstruction of destroyed roads and bridges. Salvage sales or the removal of dead trees must be done promptly to retain economic value because decomposition can begin immediately after tree death.

Recognizing that catastrophic events can occur in this planning unit, sometimes emergency actions are taken during or immediately after a catastrophic event to protect public safety or resources, which is consistent with federal and state laws.

Alternative A (No Action) Alternative A encourages pre-commercial thinning when funding is available. Invasive species are eradicated by DNR only when directed to do so by an authorized agency and on a site-by-site basis. Further, DNR trains foresters to recognize the presence and impacts of root diseases, pathogens, insect infestations, and animal damage. The training results in better adaptations of management strategies that reduce impacts and achieve the desired forest conditions. Local strategies are developed when forest health issues are identified.

Alternative B (Preferred Direction) In addition to Alternative A, DNR seeks funding through forest health initiatives to accelerate forest stand development stages through active thinning. The preferred alternative also includes encouraging partnerships with other entities to enhance DNR's ability to inventory and control invasive species when funding is available.

Alternative C (Exploratory Options) DNR performs an invasive species inventory and develops appropriate forest management strategies to address the identified issues. Also, DNR identifies and thins the backlog of ecologically suppressed stands by 2014.

Alternatives suggested but not analyzed During the scoping process, thinning the suppressed stands in the Natural Resource Conservation Areas (NRCAs) was suggested. This alternative was not evaluated because state trust land managers do not make decisions about land and resource management within state NRCAs and therefore was outside the scope of the EIS.

Hydrologic Maturity


Alder Lake and Dam Near Elbe Hills and Tahoma State Forests

Hydrologic Maturity is defined in the Water Quantity section (p. 65) of Chapter 3.

DNR manages land areas that contribute water, organic matter, dissolved nutrients, and sediments to a particular stream, river, lake, or ocean shoreline. These are called forested watersheds. These watersheds vary in size from small basins around a stream to groups of watersheds, or a Watershed Resource Inventory Areas (WRIAs) that can include hundreds of thousands of acres. The 1997 *Habitat Conservation Plan* planning units are based on groupings of WRIAs, called Watershed Administrative Units (WAUs).

WRIAs were formalized under WAC 173-500-040 and authorized under the Water Resources Act of 1971, RCW Chapter 90.54. Washington's Department of Ecology (Ecology) was given responsibility for developing and managing these administrative boundaries. These WRIA boundaries represent the administrative underpinning of Ecology's business activities. The original WRIA boundary agreements and judgments were reached jointly in 1970 by DNR, Ecology, and the Washington Department of Fish and Game, now referred to as the Washington Department of Fish and Wildlife.

Forested watersheds are water sources for municipal water supplies, irrigation, streams, and subsurface flows throughout the state. They also provide quality habitat for aquatic organisms, as well as recreational opportunities for the public. The condition of the forest in these watersheds has a significant influence on the quality and quantity of the resource (DNR 2004). The nature of the forest cover also can influence the timing and magnitude of peak water flows. Therefore, how DNR manages the forested state trust lands is an important contribution to the overall effort related to water quality and quantity.

LAKE TAHUYA

Lake Tahuya, in DNR's Green Mountain State Forest on the Kitsap Peninsula, is a privately-owned reservoir with lakeshore homes and properties. In 2002, DNR conducted a hydrologic analysis of forested state trust lands surrounding the lake to address perceived flooding issues as a result of harvesting activities in that area. The analysis recommended retaining specific percentages of each sub-basin flowing into the lake in a hydrologically mature condition.

The alternatives relating to hydrologic maturity only apply to sub-basins around Lake Tahuya.

Alternative A (No Action) Using the current strategies in Alternative A, DNR maintains the hydrologic maturity6 criteria for Lake Tahuya. A brief analysis was conducted to provide protections from perceived flooding issues as a result of harvesting activities in that area.

Alternative B (Preferred Direction) The Draft EIS recommended that DNR conduct an independent review of the existing hydrologic maturity criteria. DNR completed the review prior to this Final EIS. Based on the results of this review, DNR decided to continue to maintain the existing hydrologic maturity criteria for Lake Tahuya as described in Alternative A. Refer to Appendix F for additional information related to the original analysis, the independent review, and results.

Alternative C (Exploratory Options) No other alternatives met DNR's objectives identified during scoping; therefore, no additional evaluation was needed.

Northern Spotted Owl Conservation

Northern Spotted Owl

DNR's conservation objective for the northern spotted owl (NSO) is to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal (DNR 1997). The objective provides nesting, roosting, and foraging (NRF) habitat and dispersal habitat in designated strategic areas. The objective also creates landscapes in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat.

The South Puget HCP planning unit contains the majority of designated dispersal management areas on state trust lands managed under the 1997 HCP. Due to

Text Box 2-2. Northern Spotted Owl Habitat Definitions

1997 Habitat Conservation Plan (HCP) Dispersal

- Canopy cover at least 70 percent
- Quadratic mean diameter* of 11 inches dbh** for the 100 largest trees per acre in stand
- Top height of at least 85 feet .
- At least four trees per acre from the largest size class retained for future snag and cavity tree recruitment

South Puget Movement (Same as 1997 HCP Dispersal) plus:

- Canopy closure (instead of cover) at least 70 percent
- Forest community dominated by conifers with at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees)
- Tree density no more than 280 trees per acre greater than or equal to 3.5 inches dbh

Young Forest Marginal

- Conifer-dominated or conifer-hardwood (greater than or equal to 30 percent conifer)
- Greater than or equal to 70 percent canopy closure
- 115-280 trees per acre (greater than or equal to four inches dbh) with
- Dominants/co-dominants greater than or equal to 85 feet high or dominants/co-dominants greater than or equal to 85 feet high with two or more layers and 25 – 50 percent intermediate trees
- Snags/Cavity Trees greater than or equal to two per acre (greater than or equal to 20 inches dbh and 16 feet in height) OR greater than or equal to ten percent of the ground covered with 4 inch diameter or larger wood, with 25-60 percent shrub cover

Sub-mature

- Forest community dominated by conifers with at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees)
- Canopy closure at least 70 percent
- Tree density of between 115 and 280 trees greater than 4 inches dbh per acre
- Dominant and co-dominant trees 85 feet tall
- At least three snags or cavity trees per acre that are at least 20 inches dbh
- At least five percent coverage of down woody debris

Movement, Roosting, and Foraging (MoRF)

- Forest community dominated by conifers with at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees)
- Canopy closure at least 70 percent
- Tree density of between 115 and 280 trees greater than or equal to 3.5 inches dbh per acre
- Dominant and co-dominant trees at least 85 feet tall
- At least five percent coverage of down woody debris
- At least three snags or cavity trees per acre that are at least 15 inches dbh
- At least two canopy layers

*Quadratic Mean Diameter is the diameter corresponding to mean basal area
**dbh is diameter at breast hieght

Text Box 2-2. Northern Spotted Owl Habitat Definitions (continued)

Type B Habitat

- At least two canopy layers with at least 2 species
- At least 20 percent of trees per acres in minor species
- Canopy closure at least 70 percent
- Canopy typically dominated by 75 to 100 trees per acre greater than 20 inches dbh
- Large trees with various deformities
- At least one live tree per acre greater than 21inches DBH with broken tops
- At least one snag per acre greater than 20 inches DBH and 16′ tall
- At least 2,400 cubic feet per acre of down wood

Type A Habitat

- At least two canopy layers with at least 2 species
- At least 20 percent of trees per acre in minor species
- Canopy closure at least 70 percent
- Canopy typically dominated by 75 to 100 trees per acre greater than 30 inches dbh
- Large trees with various deformities
- At least two live trees per acres greater than 21 inches dbh with broken tops
- Two or more snags per acre greater than 30 inches dbh and 16 feet tall
- At least 2,400 cubic feet per acre of down wood

High Quality Nesting Habitat

- Canopy closure at least 70 percent
- At least three live trees per acre greater than 21 inches dbh with broken tops
- At least 16 trees per acre greater than 21 inches dbh
- At least 15 additional trees per acre greater than 31 inches dbh
- At least 12 snags per acres greater than 21 inches dbh and 16 feet tall
- At least 2,400 cubic feet per acre of down wood

past management activities in these areas, the current ecological conditions are dominated by densely stocked forests and young plantations. Neither of these conditions is known to contribute much to the life requirements of dispersing northern spotted owls.

In the alternatives, DNR examines three approaches to managing designated dispersal areas in order to meet the conservation objectives of the HCP. These approaches explore different options designed to create and enhance dispersal habitat. All three alternatives follow the *Sustainable Harvest Calculation Settlement Agreement* (2007)[6] provision that no Type A, Type B, or high quality nesting habitat will be harvested. Refer to Text Box 2-2 for northern spotted owl habitat definitions.

Alternative A (No Action) Under Alternative A, DNR manages designated dispersal management areas (Map 3-5, p. 109) in accordance with the current 1997 HCP dispersal habitat definition, and the strategy described in the HCP. In the HCP strategy, at least 50 percent of each spotted owl management unit (SOMU) in DNR designated dispersal areas must be maintained in a dispersal condition (refer to Text Box 2-2 for a complete definition). SOMUs are based on the 1996 watershed administrative unit (WAU) boundaries.

Alternative B (Preferred Direction) Under Alternative B, DNR incorporates the species' life history requirements for movement, roosting, and foraging (MoRF). The forest stand characteristics that constitute dispersal habitat will be modified from the 1997 HCP definition with the approval of the federal services, to a South Puget Movement definition. The South Puget Movement definition is similar to the 1997 definition, with additional requirements for at least 30 percent conifer trees, and with a forest stand density of no more than 280 trees per acre (refer to Text Box 2-2).

Under this alternative, 50 percent of DNR-managed forestlands in each newly designated dispersal management landscape (multiple spotted owl management units combined, refer to Map 3-5, p. 107) will be targeted to attain and maintain a minimal condition of the South Puget Movement definition.

Recognizing the life history requirement of dispersing owls' need for foraging and roosting opportunities, a second habitat condition is also needed within these landscapes. The habitat condition of MoRF for northern spotted owl habitat (refer to Text Box 2-2) is a forest stand-level habitat condition that contains forest stand structural components needed for movement (tree density, cover, and canopy layering), foraging (snags and coarse woody debris) and roosting (canopy layering). The MoRF habitat type is similar to the 1997 *Habitat Conservation Plan* definition of sub-mature habitat. However, it has additional requirements for at least two tree canopy layers. This definition also changes the minimum snag size from 20 inches diameter at breast height (dbh) to 15 inches dbh while still maintaining the same tree height requirement of at least 15 feet.

Using the MoRF definition, at least 70 percent of the 50 percent landscape threshold will be targeted to attain and maintain the MoRF definition. The desired future condition of each dispersal management landscape resulting from this strategy will be 35 percent of the landscape in a MoRF habitat condition; with an additional 15 percent in a South Puget Movement habitat condition. This alternative allows for more habitat enhancement-type management over time in areas that are currently not on a trajectory to meet dispersal habitat. A detailed procedure has been approved by the U.S. Fish and Wildlife Service to implement this strategy (refer to Appendix G).

Alternative C (Exploratory Options) Under Alternative C, DNR explores other ways to manage dispersal habitat within the context of the 1997 HCP. All the life history requirements of northern spotted owls (nesting, roosting, foraging, and dispersal) are incorporated into this alternative. It targets creation of Type A and Type B habitat while deferring all existing high-quality nesting habitat from harvest (refer to Text Box 2-2).

The management strategy within this alternative targets 15 percent of each new landscape management unit (refer to Alternative B) to achieve the South Puget Movement habitat conditions, with 35 percent in Type B or better habitat. Distribution of habitat is tracked through a monitoring process. Through multiple harvesting entries, DNR focuses on snag creation, coarse woody debris recruitment, and increasing diameter size of dominant trees.

Alternatives Suggested But Not Analyzed No other alternatives met DNR's objectives identified during scoping; therefore, no additional evaluation was needed.

SOCIAL AND CULTURAL BENEFITS

Lake Washington and Mercer Island Aerial View

Forested state trust lands play an important role in providing opportunities for public access and recreation and preserving the visual integrity of Washington's forested landscapes. These landscapes contribute to local, regional, and state economies through the sale of forest products.

Recreation and Access

Today, the public's demand for access to forested state trust lands via trails and roads that have minimal support facilities has expanded in both type and intensity. At the same time, public expectations for environmental stewardship of the forested state trust lands have changed from historical practices. The combination of more people, more advanced recreational technology, and heightened environmental awareness increases public interest in the long-term sustainability of natural resources and current recreational opportunities.

Most recreation and access opportunities can be characterized as dispersed with primitive facilities, and are most often trail-oriented and set within a managed forest. DNR's primary recreation focus is to provide a primitive experience in a natural setting through trails, trailhead facilities, and rustic camping facilities. DNR currently manages campgrounds and day-use facilities such as picnic areas, boat launches, and interpretive areas. In addition to trails and specific sites, DNR also manages forest roads primarily designed and maintained for forest management purposes that provide considerable access for dispersed recreation activities such as hunting, fishing, bird watching, and sightseeing.

Recreation and public access enjoyed on trust lands must be compatible with the primary purpose for their management, which is the generation of revenue to support public schools and other state institutions. Many of the public expectations for public access and recreation are compatible with DNR trust objectives, and DNR therefore provides public access opportunities on forested state trust lands, where appropriate, as directed by the Multiple Use Act.[7]

Kammenga Campground in Tahuya State Forest

Alternative A (No Action) In Alternative A, DNR maintains existing uses compatible with public access and recreation goals. The goals are a safe recreational experience, a quality user experience, and the protection of resources.

To meet all three goals, DNR needs to determine the types and levels of recreational activities the land can sustain, how much recreational activity can be supported without negatively affecting trust management responsibilities, and how much activity can be supported financially.

The strategies in Alternative A emphasize education for recreational users, enforcement efforts to deter inappropriate uses, and engineering using best management practices to address resource damage issues. Additionally, this alternative includes developing a comprehensive inventory and assessment of public uses to determine recreation capacity and identify specific public access issues.

Alternative B (Preferred Direction) The preferred alternative includes Alternative A but focuses on evaluating land to determine the appropriate levels and types of recreational uses. The inventory and assessment described in Alternative A helps DNR to designate and/or define, adopt, relocate, or remove some of the incompatible existing facilities and trails. This alternative also seeks to increase partnerships and expand contracted services.

Alternative C (Exploratory Options) Alternative C includes all of Alternatives A and B and, in addition, explores contracted services, leases, or fees to provide enhanced, site-specific services that DNR does not currently provide.

Alternatives suggested but not analyzed The suggestion received during public scoping to establish a long-term funding source is outside the scope of this project.

Visual Impacts

DNR activities can alter the visual experience of people viewing forest stands and forested landscapes. The visibility of forest management activities— mostly timber harvest — is influenced by the position and distance of the viewpoint from the activities, the topography of the land, and the type of forest management activity. Visual changes can be localized (visible only from a particular viewpoint), or regional (visible from a broader area). The observer's perspective and personal values influence whether the reaction to the visual impact is positive, negative, or neutral.

Visual impacts can be mitigated through a variety of forest management strategies such as the timing, design (including the physical layout and harvest method), and size of timber harvest areas. During the public mapping meetings (referred to as "stakeholder workshops" in Chapter 1), visually sensitive areas were identified. DNR also used modeling software to identify areas of potential concern. The majority of areas identified for visual management are already mitigated through the existing management framework, including riparian and wetland buffers, protection of unstable slopes, and/or the arrangement of wildlife trees.

Maintaining a continual timber management presence in this planning unit is essential to maintain working forests. Normally, timber harvest rotations result in an area being harvested at a specific time, with no harvest activities taking place again for two to three decades. An even-flow of harvest volume and timber management activity is being implemented in each district within the South Puget Region. This will ensure that management is spread out across the region and not concentrated in any one district. An even-flow harvest also visually represents the continued presence of working forests across the landscape. This process is applied to all alternatives and is beneficial for reducing visual resource impacts that might otherwise occur due to harvest concentrations in particular areas.


Alder Lake Timber Sale as Viewed from South Slope Timber Sale in Elbe Hills

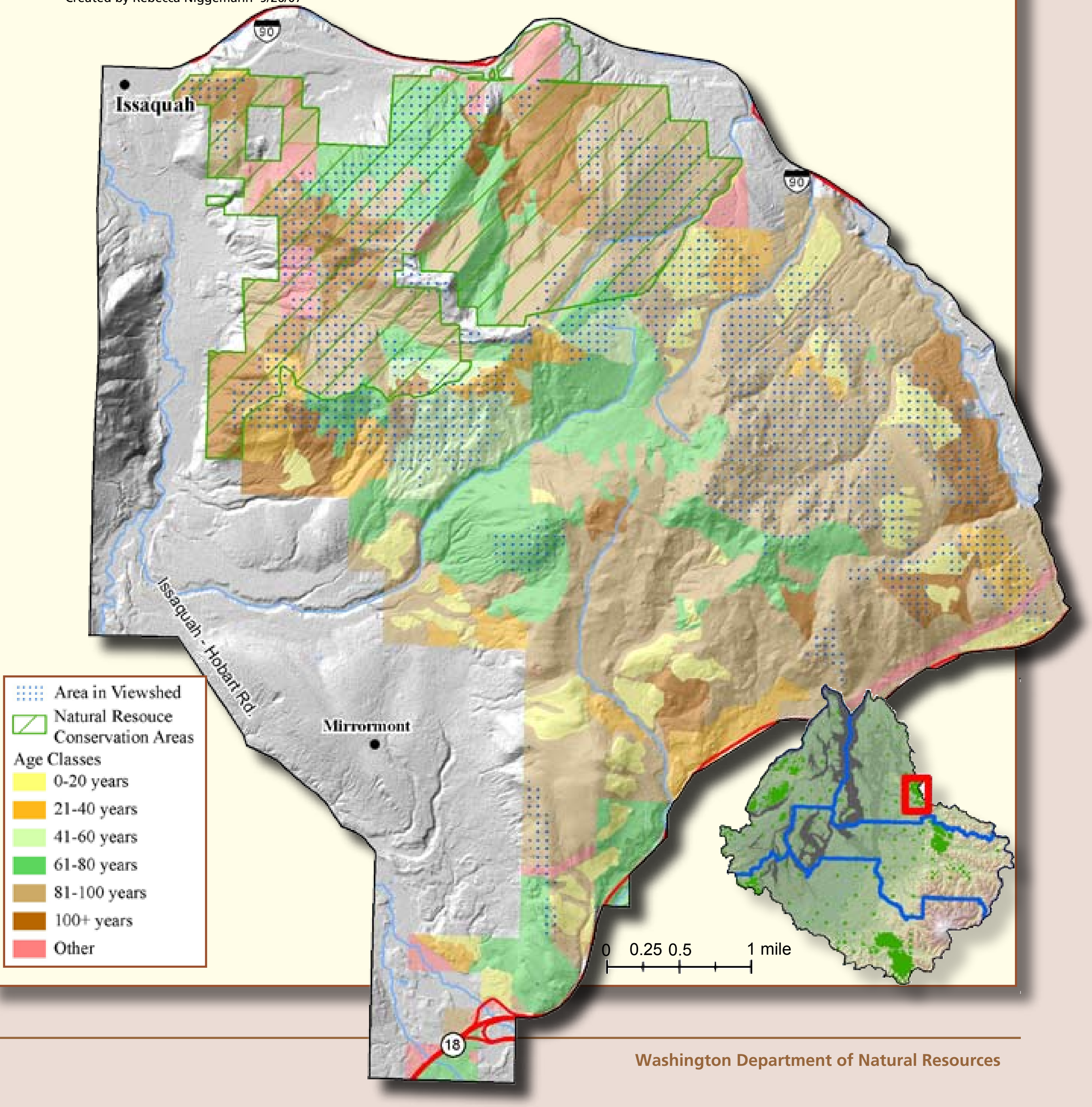
Alternative A (No Action) DNR provides direction for mitigation of local and regional visual issues on a site-by-site basis. The development of DNR's forest management policies included a decision to mitigate visual impacts through various land management strategies (DNR 2006a).

Tiger Mountain (Specific) Visual impacts specific to Tiger Mountain (Map 2-2) were addressed in the 1986 Tiger Mountain Plan. Under Alternative A, Tiger Mountain harvesting activities are determined by area; each watershed is limited to a specified percentage of harvesting activities in the total watershed area during any 10-year period. The objective is to create a well-distributed mosaic of forest stands from different age-classes (DNR 1986). Implementation strategies identified for Tiger Mountain include:

- Harvest no more than one-sixth of each Watershed Administrative Unit (WAU) per decade.
- Inventory forest stands and develop a harvest schedule to determine DNR's ability to meet the specified percentage allotted to each WAU.
- Model the harvest schedule to determine whether a mosaic of forest stands of different age-classes is created over time.
- Continue with a 60-year harvest rotation age.

Map 2-2. Tiger Mountain Age Class Distribution

Created by Rebecca Niggemann 9/26/07



Alternative B (Preferred Direction) Alternative B is built on Alternative A because specific forest management strategies are developed for DNR's administrative units (Map 2-1) to address the local and regional issues identified at stakeholder workshops in June 2005. Some visual strategies will undergo an internal review and analysis to determine if the strategy is feasible. Should the analysis determine that a new forest management strategy is not viable due to economic or environmental concerns, DNR will provide information to interested parties before continuing.

For the majority of lands identified as being visually sensitive, DNR will leave no less than 8 trees per acre but can leave up to 16 trees per acre in both clumped and scattered patterns.

Tiger Mountain (Specific) This alternative is designed to eliminate the rotation age and Watershed Administrative Unit (WAU) restrictions to achieve the desired outcomes for Tiger Mountain while providing more flexibility to accomplish other objectives. The *Tiger Mountain Plan* was approved in 1986, well before the agency adopted the 1997 *Habitat Conservation Plan*, 2004 *Sustainable Harvest Final EIS*, 2006 *Riparian Forest Restoration Strategy*, or 2006 *Policy for Sustainable Forests*. Additionally, two of the WAUs are located in a Natural Resource Conservation Area (NRCA). These plans and strategies were written to provide protection for the majority of social, environmental and economic areas of concern that were described in the 1986 plan.

Changed implementation strategies for Tiger Mountain include:

- No minimum rotation age. Rotation-length is based upon a stand's productive potential and current stand conditions.
- Harvest an average of one-sixth of the available harvest base over the entire forest each decade.
- Do not allow clustering of harvest units.
- For areas identified as visually sensitive, DNR will create a variety of leave tree strategies, with no one strategy being exclusive. Leave trees to be clumped/grouped with an average of 10 to 14 trees remaining per acre.

Alternative C (Exploratory Options) No other alternatives met DNR's objectives identified during scoping; therefore, no additional evaluation was needed.

End Notes

1 Chapter 197-11 Washington Administrative Code [WAC]
2 State law changed in 2009 under Engrossed Senate Bill 6166, which increased the state percent from 10 to 20 percent.
3 Chapter 79.13 Revised Code of Washington [RCW]
4 Chapter 79.17.200 Revised Code of Washington [RCW]
5 Chapter 79.17.010 Revised Code of Washington [RCW]
6 http://www.dnr.wa.gov/htdocs/adm/comm/2006_news_releases/032106_summary.pdf
7 Multiple Use Act - Chapter 79.10.100 Revised Code of Washington [RCW]

CHAPTER 3
EXISTING CONDITIONS & MANAGEMENT TODAY

environment


Looking toward the Olympic Mountains from Green Mountain

This chapter describes the existing environmental conditions of DNR-managed forests in the South Puget Habitat Conservation Plan (HCP) Planning Unit. It describes DNR's current management as the department fulfills its fiduciary responsibility to the trust beneficiaries and its conservation objectives. In addition to forestlands, DNR manages Natural Area Preserves, Natural Resource Conservation Areas, administrative and recreation sites across much of these landscapes.

The environmental setting is the starting point for an examination of the topics being analyzed. The topics are forest conditions and management (including forest health, older forests, and sensitive plants), climate, riparian and wetland areas, water quantity, water quality, fish, soils, roads, recreation, visual management, land transactions, cultural resources, wildlife habitat, marbled murrelet, northern spotted owl, air quality, climate change, and carbon sequestration.

Although we have outlined the evaluation approach below, there are some topics that will be merely described and not analyzed (Climate and Global Climate Change); other topics do not have indicators identified at the planning unit scale and only background information will be provided for them (Plants, Forest Health, and Land Transactions); and still other sections do not follow the conventional approach because of the complexity of their subject matter (Forest Conditions, Northern Spotted Owl, Marbled Murrelets, and Carbon Sequestration).

Evaluation Approach

Criteria and indicators are used to characterize the essential components of sustainable forest management. This provides a framework for answering the fundamental question, "What is important about forests?" (Montréal Process 1995). Formed in Geneva in June 1994, the Montréal Process was intended to advance the development of internationally agreed-upon criteria and indicators for the conservation and sustainable management of temperate and boreal forests. DNR has created a framework for assessing forest management and the potential impacts of forest management practices that is similar to the Montréal Process but has developed its own sets of criteria and indicators related to the ecological elements evaluated in this environmental impact statement.

Criteria

Criteria, as used by DNR in this document, are a set of related indicators which are monitored periodically to assess change (Montréal Process 1995) and a group of conditions or processes by which sustainable forest management may be assessed. They are developed from strategies laid out in existing DNR policies, procedures, and state and federal laws, and also come from recommendations in scientific literature.

Indicators

Indicators are the measureable elements used to assess whether objectives contained in the criteria are achieved. This chapter identifies the indicators used for each of the topic areas listed above. Generally, indicators are based on physical, chemical, biological, or economic information, and can be either qualitative or quantitative in nature. For example, one indicator of water quality might be stream temperature. If data for stream temperature were available, DNR would use temperature as the indicator. In cases where no data is available, DNR uses a substitute or surrogate. In this example, DNR does not have good stream temperature data for trust lands, and forest stand development stages (SDS) are therefore used as a surrogate. Stand development stages can be a substitute measurement for stream temperature because DNR can use stand development data to identify the locations of larger trees that provide increased shade and reduce water temperature. When surrogates are used, they are described in Chapter 4.

Indicators provide information about present environmental conditions and over time can be used to assess the direction of change in forest ecosystems. Understanding the trends or patterns of indicators can provide important information about the condition or viability of a system (Montréal Process 1995).

An Integrated Approach

DNR uses a criteria and indicator approach to identify ways to measure the potential effects of forest management on ecosystems as a whole. DNR recognizes that no single criterion or indicator is an indication of sustainability. Rather, the individual criterion and indicators are considered in the context of their interconnectedness to other topics (such as sedimentation's tie to soils, roads, recreation, and water quality).

Scale of Analysis

For this EIS, DNR has broken down the scale of analysis from the larger planning unit into smaller areas which are discussed below. DNR manages more than 146,000 acres of forested state trust lands in the South Puget planning unit, including portions of landscapes that drain into the Cedar, Green, White, Carbon, Puyallup, Nisqually, and Deschutes rivers. These watersheds vary in size from small stream basins to Watershed Resource Inventory Areas (WRIAs) that contain hundreds of thousands of acres.

As with all planning units, the delineation of the South Puget HCP Planning Unit is based on groupings of WRIAs (DNR 1997). A total of 8 WRIAs are present within the planning unit (Table F-3; Map 3-1). Appendix F describes the six WRIAs containing large blocks of DNR-managed lands.

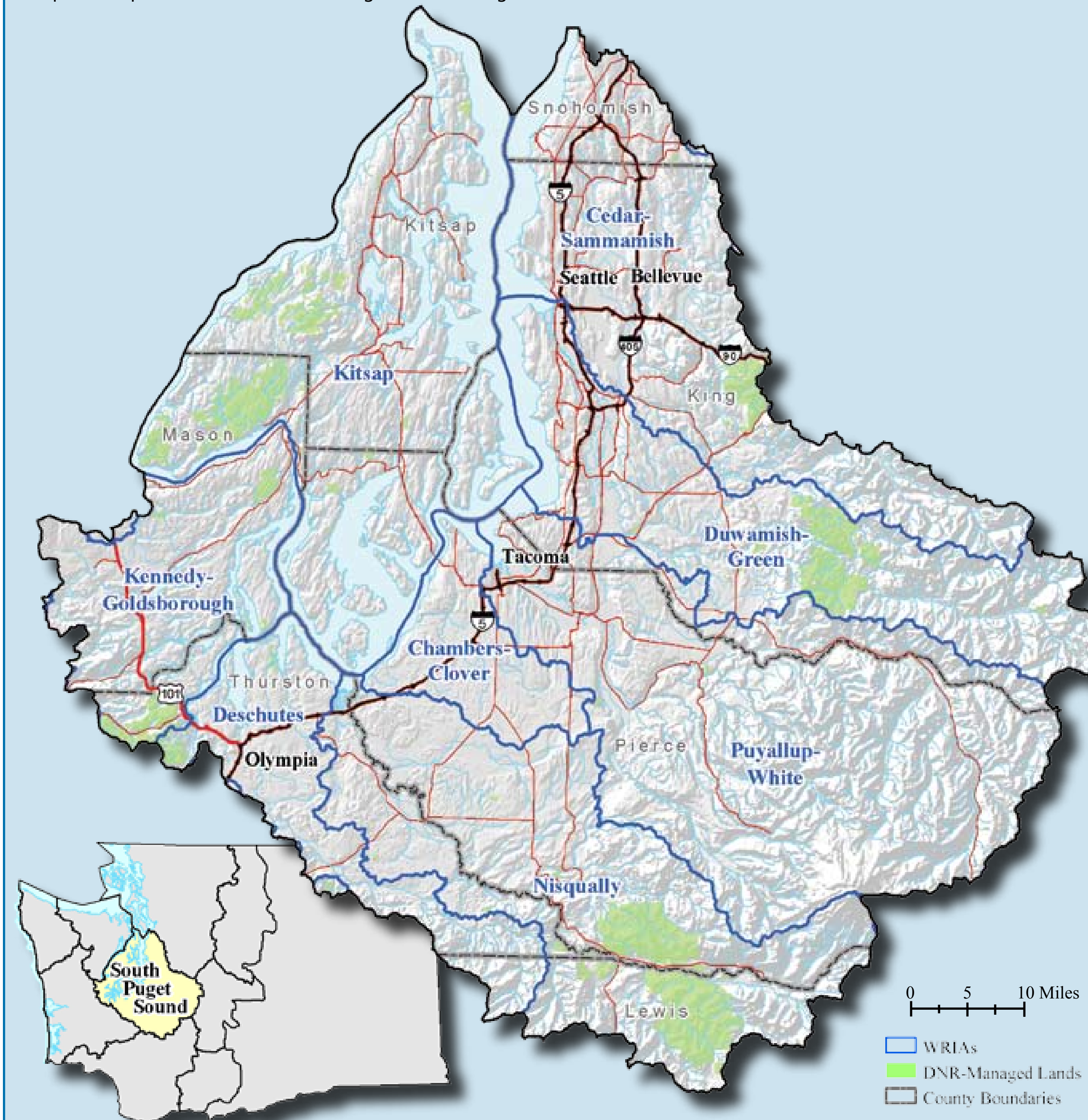
Each WRIA can be further broken down into Watershed Administrative Units (WAU or watershed), equivalent to sub-basins within the larger WRIAs. A WAU or watershed is the land area that drains into a particular lake, river, or ocean. DNR analyzes hydrologic conditions at the WAU scale. Hydrology is the study of water—in this case, of its quantity, quality, and distribution.

Table 3-1. WAUs ≥ 20 Percent* DNR-Managed

	Percent Managed by DNR	Total Acres
North Fork Mineral Creek	79%	13,883
Reese Creek	61%	11,971
Catt	49%	6,893
Kennedy Creek	38%	9,227
North Fork Green	36%	6,602
Howard Hansen	35%	16,499
Lynch Cove	32%	11,063
Great Bend	29%	16,318
Mashel	26%	15,139
Tiger	24%	10,092
Mineral Creek	22%	4,761
West Kitsap	20%	7,261
East Creek	20%	4,052
Total WAU Acres		133,761

*Rounded to the nearest percent

Map 3-1. Map of WRIAs for the South Puget HCP Planning Unit



The boundaries of a WAU are defined by DNR in cooperation with the state departments of Ecology and Fish and Wildlife (WDFW), affected Indian Tribes, local governments, owners of forestland, and the public. The boundaries of WAUs mainly follow drainage divides (ridges), rivers, and other DNR management boundaries (Map 3-2). The WAU boundary dataset is intended for use at the 1:24,000 scale.

There are 118 WAUs in the South Puget HCP Planning Unit with many different owners and managers. In 68 of these WAUs, DNR manages forestland and 13 of these WAUs contain DNR-managed trust lands covering at least 20 percent of the total watershed area (Table 3-1). Collectively, these 13 watersheds represent 92 percent of DNR-managed forestlands within the planning unit. Appendix F contains information about land ownerships for watersheds in the planning unit containing DNR-managed trust lands.

Why Analyze Impacts at the Watershed Scale?

Watersheds have been used by DNR in the past to analyze potential environmental impacts (DNR 1997, 2003, 2004) and are also used here. Map 3-2 portrays current WAU locations.

What Are the Land Management Categories?

DNR's management is influenced by department objectives or regulatory rules. These objectives and rules can be grouped into three distinct management categories.

Uplands with General Ecological Management (GEMs)— These areas are managed under DNR's general policies, procedures, plans, and applicable state *Forest Practices Rules.*

Uplands with Specific Management Objectives (Uplands)— These lands contain designated wildlife habitat, are visually sensitive, or have been identified as needing a specific strategy to address protection of public resources, for example potentially unstable land forms.

Riparian and Wetland Areas (Riparian)— Management in these areas may only be applied towards the goals of maintaining or restoring riparian (streamside) or wetland functions (Bigley and Deisenhofer 2006, p. 2).

Map 3-2. Boundaries of WAUs and DNR-Managed Lands in the South Puget HCP Planning Unit

Forest Conditions and Management

This section describes the condition of DNR-managed forests within the planning unit. In watersheds where DNR manages a higher percentage of the land base, department management activities have the potential to cause negative and/or positive environmental impacts. The current forest conditions are a combined result of past management and disturbance events, such as early logging and burning, windstorms, and wildfires as well as recent forest management activities.

Some general measures are used for describing forest conditions today. These include forest type, the characteristics in each stand development stage, as well as stand density, forest type, site productivity, and forest biomass. Each measure can be influenced by forest management activities such as harvesting, species selection and planting, or thinning. Other influences may include natural disturbances, climate (p. 55), and soil productivity (p. 76).

Which Current Policies Are Likely to Influence Forest Conditions?

DNR's broad forest management guidance comes from the 2006 *Policy for Sustainable Forests*. This policy document is the vision of the Board of Natural Resources and DNR managers for the type of forested landscapes they strive to create now and in the future. These policies are designed to achieve their fiduciary responsibility by generating revenues for the trust beneficiaries while meeting DNR's contractual obligations under the 1997 *Habitat Conservation Plan* (HCP).

The general silvicultural policy directs DNR to manage forested landscapes to meet many objectives as well as to achieve 10 to 15 percent older-forest structure. Other policies (DNR 2006b) direct the protection of existing old-growth forests and management of riparian and wildlife habitat in accordance with the 1997 HCP. The HCP sets out specific conservation strategies for the northern spotted owl, marbled murrelet, riparian management, and other more general conservation strategies. The more general strategies include the protection of unique habitats across the landscape, such as legacy trees , talus slopes, balds, cliffs, caves, snags, oak woodlands, and mineral springs. The process for protecting public resources includes classifying forest practices according to the potential for each practice to impact public resources.[1] These combined forest management policies and strategies have been designed to create forested landscapes with more diverse forest conditions and structurally complex forests than exist today (Chart 3-1; DNR 2004).

Legacy trees are old trees that have been protected from harvest or have survived stand-replacing natural disturbances (Mazurek and Zielinski 2004).

Forest Practices refer to any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber (Chapter 222-16-010 WAC)

A **Forest Stand** is a group of trees that possess sufficient uniformity in composition, structure, age, spatial arrangement, or condition to distinguish them from adjacent groups (DNR Standard Forestry Terms and Tree Names, Jan. 2009).

What Are the Common Forest Types?

Across the planning unit today, stands dominated by Douglas-fir (*Pseudotsuga menziesii*) are the most common forest type (77 percent of the area), with western hemlock (*Tsuga heterophylla*), red alder (*Alnus rubra*) and Pacific silver fir (*Abies amabilis*) occurring less frequently (15, 6, and 2 percent, respectively). DNR data includes many forest types; which were grouped by dominant species for the estimations above.

Before the harvesting that occurred early in the 20th century, a larger amount of western hemlock would most likely have been present, given its role in the natural vegetation of forests in western Washington (Franklin and Dyrness 1973). The current dominance of Douglas-fir most likely reflects its ability to persist and propagate following major disturbances, such as timber harvests and wildfires (Agee 1993; Burns and Honkals 1990), which occurred historically over much of the planning unit.

Most watersheds contain distributions of forest species that are similar to those in the planning unit overall (refer to Appendix D).

What Are Stand Development Stages and Why Are They Important?

As forest stands grow and develop, they can be classified into specific stand development stages, each based on a combination of measureable attributes such as tree heights, diameters, densities,

Text Box 3-1. What Are the Stages of Forest Stand Development?*

DNR has classified stands into six stages of stand development. This classification is based on the work of many authors who have studied how stands develop over time including: Oliver and Larson 1996, Carey and others 1996; Franklin and others 2002; Carey 2003a; Carey 2007; Van Pelt 2007.

Ecosystem Initiation

Open, newly regenerated stands compete with pioneer species, herbs, and shrubs to re-establish site dominance following a disturbance such as a timber harvest. Establishment and occupation of the site by vegetation are the main ecological processes taking place (Carey 2007).

Competitive Exclusion

Competition for direct sunlight, nutrients, water, and space increases (Oliver and Larson 1996) as forest stands near, or exceed, full site occupancy. Intense inter-tree competition for resources is the key ecological process in this stage (Carey 2003a). As the canopy closes, basic changes to understory conditions occur, such as greatly reduced light levels, reduced wind, moderated temperatures, and increased humidity (Franklin and others 2002).

Understory Development

As some trees outgrow one another, tree crowns begin to differentiate and small gaps in the canopy are created by stem breakage and tree mortality. These gaps allow increased sunlight to reach the forest floor. In and around the gaps, newly developed understory begins to add diversity to the forest (Franklin and others 2002). This stage is transitional; stands may return to a competitive exclusion or move into the biomass accumulation stage as the taller trees' crowns re-close.

*It's important to note that, while each stand development stage depends on previous stages, this process is not necessarily sequential or linear. Many factors may influence the transition from one stage to another, including natural disturbances along the way, and initial stocking or beginning conditions. Depending on natural events, a particular stage may recur at multiple points in a forest stand's development or be skipped altogether (Carey 2007).

Text Box 3-1. What Are the Stages of Forest Stand Development? (continued)

Biomass Accumulation

Forest stands now have fewer trees, due to past mortality, tree crowns have clearly differentiated and trees have enough room and resources to grow and rapidly accumulate woody biomass. Because most West Coast tree species (in particular Douglas-fir and western red cedar) are long-lived (300 years plus) this stage can last for up to 100 years or more (Franklin and others 2002). In this stage, forest stands lack the large snags and/or down woody debris, and understory diversity that characterize later stages. The key ecological process in this stage is wood biomass production (Carey 2007; this stage is called "maturation" in Franklin and others 2002).

Niche Diversification

Forests contain live, dead, and fallen trees of various sizes. The key ecological processes are individual tree mortality and decay, with the creation of snags, down woody debris (DWD), and forest gaps that contribute to forest diversity and structural complexity. Forests generally lack the very large trees and snags present in the fully functional stage (Franklin and others 2002).

Fully Functional

All the structural elements necessary for complex old-growth functions are present. Here, time has allowed formation of very large trees, with increasing decay and accelerated formation of DWD. This stage includes a "re-establishment of canopy continuity between the ground and upper tree crowns" (Franklin and others 2002), as shade-tolerant species mature in gaps and branches emerge from tree boles with exposure to sunlight. The key ecological process in this stage is the accelerated mortality of large trees.

canopy layers, understory vegetation, quantities of down woody debris, and snags. Each forest stand development stage reflects major ecological processes occurring at a particular time in a stand's development (Franklin and others 2002). Forest stand development and its associated forest structure can be used as a substitute for measuring ecosystem functions that are difficult to measure directly (Franklin and others 2002). Forest stand structure also can be used to assess a forest's value in terms of the products or services it provides (Carey 2007).

DNR's classification system for forest stand development is based on the attributes of a stand that can be measured (DNR 2004, p. 4-11 and B-31; refer to Appendix C). This system was derived from various descriptions of forest stand development in Pacific Northwest forests by many authors (Carey 2007; Van Pelt 2007; Franklin and others 2002; Carey and others 1996; Oliver and Larson 1996). Text Box 3-1 describes each of the six forest stand development stages.

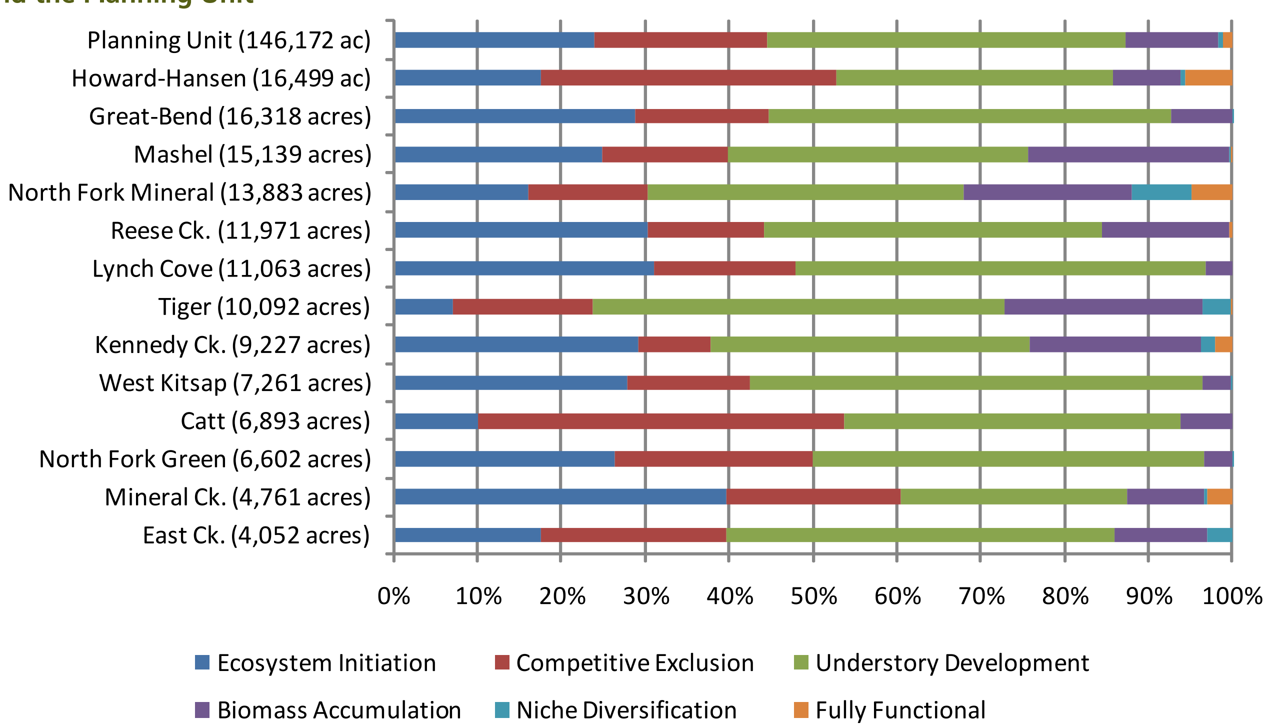
By examining the acreages of forest in different stand development stages over time and how these acreages change, one can infer the potential condition of the environmental resources and the effects of the different alternatives on the environment. For example, the amount and types of wildlife habitat (p. 98), the amount of forest in older-stand conditions (p. 53), the level of susceptibility of the forest to pest and disease (p. 87), the amount of carbon sequestered (p. 118), the level of riparian function achieved (p. 58), and the potential visual impacts (p. 89) can all be assessed by examining the stages of development of a given forest stand.

What Are the Current Conditions in Terms of Stand Development Stages?

For the South Puget planning unit as a whole, the largest proportion of forested state trust lands (40 percent) is currently in the Understory Development stage, followed by the Ecosystem Initiation (27 percent), Competitive Exclusion (20 percent), and Biomass Accumulation (11 percent) stages. Less than two percent are in the most ecologically complex stages (Niche Diversification and Fully Functional) combined (refer to Chart 3-1).

On a watershed basis, most of the 13 selected watersheds show trends similar to that of the planning unit overall (Chart 3-1). However, North Fork Mineral, Catt, and Tiger watersheds contain fewer young stands in the Ecosystem Initiation stage, which is a reflection of fewer variable retention harvests occurring in the recent past within these areas.

Chart 3-1. Percent of Acres Currently in Different Stand Development Stages For Selected Watershed and the Planning Unit



What Is Stand Density and Why Is it Important?

Stand density refers to the degree to which an area is occupied by trees. Measures of stand density indicate the competition between trees in a stand for essential resources such as sunlight, moisture, nutrients, and growing space. DNR uses a measure of stand density called Curtis' relative density (or Curtis' RD, refer to Text Box 3-2) to assess the level of competition between trees in a stand. This measurement allows relative comparisons at different points in space and time.

Forest stands naturally self-thin; some trees will die; other trees get bigger. After a stand-replacing disturbance (such as a harvest activity or fire) and subsequent regeneration, stand density increases until mortality reduces the number of trees to match the capacity of the site to support them.

High stand density results in reduced tree vigor, decreased growth, increased mortality, and susceptibility to stressors such as insects, disease, and drought (O'Laughlin and Cook 2003).

Dense stand conditions also lack attributes important to wildlife (p. 98) and inhibit movement through the forest (dispersal) by northern spotted owls (p. 107). The relative density at which competition-induced mortality is observed varies by species. For example, Douglas-fir plantations generally begin to experience competition-induced mortality at RD 50 (Curtis 1982; Bailey and others 1998), although some stands do not have significant mortality until RD 70. More tolerant western hemlock stands experience mortality at RD 55 and higher, while intolerant red alder stands reach this point at RD of 44 (Puettmann and others 1993) and higher (DNR 2004). For additional discussion on how stand density affects the environment DNR incorporates by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-25 to 4-27).

Natural stands of mixed species have a broader range of tree species and ages and less uniform spacing and therefore tend to reach higher relative densities before significant density-related mortality occurs. In addition, multi-storied stands, which typically have intolerant species in the overstory and tolerant species in the lower canopies, can maintain higher RD values before mortality is induced by competition.

Although the ranges of acceptable stocking densities vary somewhat by a species shade tolerance, this analysis uses average ranges. Four stocking classes are defined based on ranges of RD, as shown in Table 3-2. Optimal stocking in terms of individual tree growth and vigor is generally found when RD is less than 50; this class is termed "optimally stocked". Competition-induced mortality begins to be expressed in the RD range of 50 to 75, depending on species mix and stand structure, as noted above. DNR terms this density class "fully stocked." Mortality becomes more significant when RD exceeds 75. DNR has defined two classes of more severe degrees of overstocking—overstocked and extremely overstocked—and this analysis focuses on these two stocking categories with RD greater than 75.

As a general measure, dense stands with an RD greater than 75 are at elevated risk for not achieving DNR's ecological, social, or economic objectives; stands that reach this RD threshold represent "overstocked" stand conditions, used for comparison of alternatives.

Text Box 3-2. Curtis' Relative Density (RD)

DNR uses a measure of a stand density called **Curtis' Relative Density** (RD) (Curtis 1982) for assessing competition within forest stands. RD represents how the density of a given stand relates to the theoretical maximum density for a particular tree species. RD is calculated by taking the stand basal area (BA) divided by the square root of its quadratic mean diameter (QMD).

$RD = BA/\sqrt{QMD}$

Where:

Basal area (BA) is the cross-sectional area of all tree stems for a given diameter range in a forest stand, and

Quadratic Mean Diameter (QMD) is the tree of average basal area within the same stand and diameter range. QMD may be obtained by dividing the stand basal area by the number of trees per acre, then finding the diameter of this tree.

Table 3-2. Current Area (as percentage of planning unit) by Dominant Species and Relative Density*

Relative Density (RD) Forest Types Classified by Dominant Species	<50 Optimal	50-75 Fully Stocked	75-100 Overstocked	>100 Extremely Overstocked
Douglas-Fir	35%	4%	2%	64%
Red Alder	1%	0%	0%	5%
Silver Fir	1%	1%	0%	1%
Western Hemlock	5%	1%	0%	14%
Total Acres	47,321	38,972	25,320	114,994
Total (all forest types)	**41%**	**34%**	**22%**	**3%**

* Curtis' RD for live trees greater than 4 inch diameter

What Is the Current Stand Density?

Table 3-2 displays the current distribution of stand density acreage by dominant tree species for all forest types. Twenty-five percent of DNR-managed forests are in a dense overstocked condition, defined here as having an RD greater than or equal to 75. However, another 34 percent is on a trajectory to move from a "fully-stocked" to an "overstocked" condition.

Stands dominated by western hemlock have the highest proportion of acreage in overstocked conditions (Chart 3-2). This is not unexpected, as western hemlock is a shade-tolerant species and can grow at higher densities than shade-intolerant species like Douglas-fir and red alder. One can see the differences between species and their tolerance (or intolerance) of relative density in Chart 3-2. The peaks of these distributions represent an approximation by species of the point where each begins to self-thin; although, stands of varied species with multi-story canopies (described above) may tolerate higher levels of stocking compared to monoculture stands.

Table 3-3 illustrates that, for the entire planning unit, Uplands and Riparian land classes have a lower proportion of their acreage (3 and 9 percent, respectively) in forests with overstocked stand conditions than GEM lands (13 percent).

Chart 3-2. Relative Density by Dominant Basal Area Species (≥4 inches dbh)

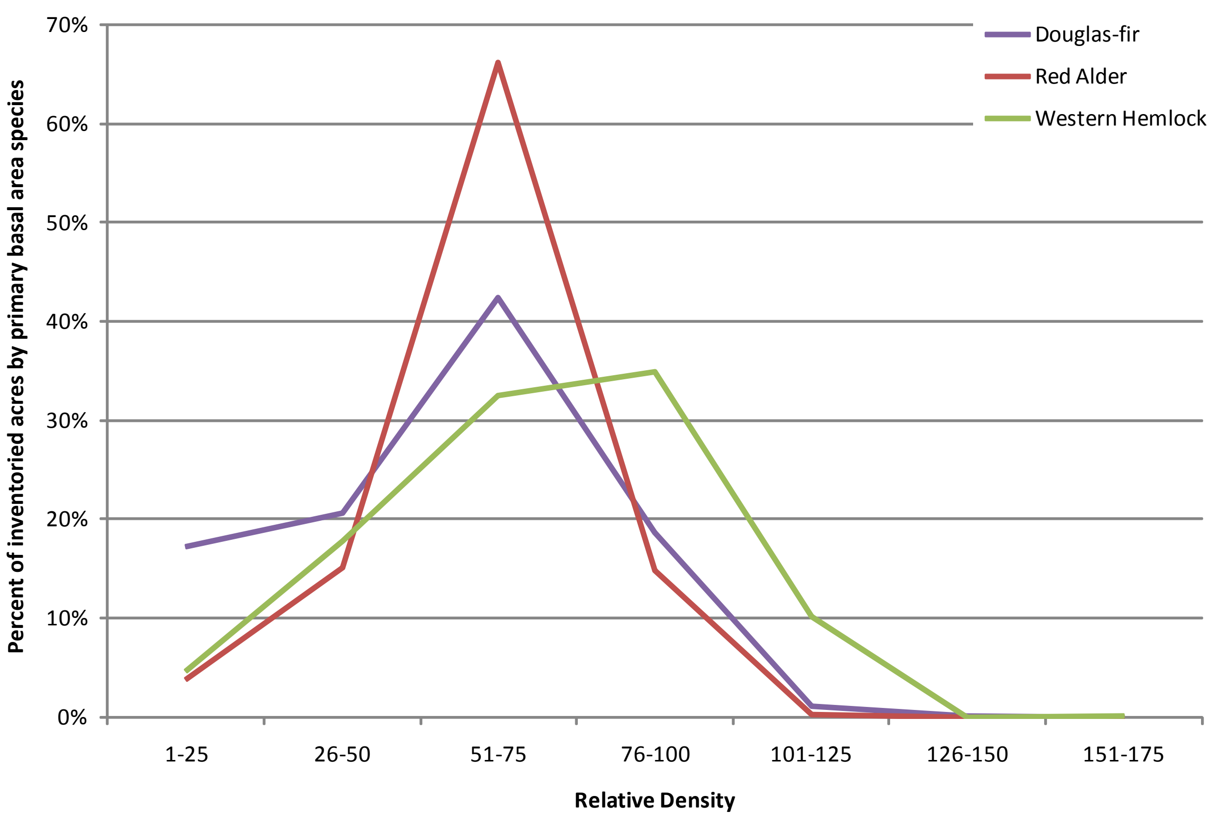


Table 3-3. Current Density* of Forests by Land Class

Land Class	Density Class <50 Optimal	50-75 Fully Stocked	75-100 Overstocked	>100 Extremely Overstocked
Riparian and wetlands (Riparian)	10%	13%	8%	1%
Uplands with specific management objectives (Uplands)	25%	16%	1%	2%
Uplands with general management objectives (GEMs)	6%	4%	13%	0%
Total (All Classes)	**41%**	**34%**	**22%**	**3%**

* Curtis' RD for live trees greater than 4 inch diameter

The current acreage, by watershed, and the percent of overstocked (RD>75) DNR-managed forested area is displayed in Table 3-4. The watersheds with the highest percentage of overstocking are North Fork Green, Howard Hansen, and Catt watersheds.

Table 3-4. Distribution of Currently Overstocked Acreage for Selected Watersheds

Watersheds	Overstocked DNR Acres (RD>75)	Percent Overstocked (RD>75)
North Fork Green	2,838	46%
Howard Hansen	5,855	38%
Catt	2,406	37%
North Fork Mineral	4,893	37%
Tiger	3,318	34%
Mineral Ck.	1,331	30%
East Ck.	992	26%
Reese Ck.	2,259	20%
Mashel	2,272	16%
Great Bend	1,967	13%
Kennedy Ck.	1,054	13%
West Kitsap	898	13%
Lynch Cove	398	4%

What Does Site Productivity Mean and How Is it Measured?

Forest site productivity refers to the capacity of a specific location to produce biomass, and is typically measured in terms of a Site Index (refer to Soils, p. 76). Forest site productivity reflects the potential of the forestland base to generate merchantable forest products (timber), produce habitat, and respond to forest management or natural disturbances. In general, higher productivity sites respond more rapidly to disturbances, are capable of producing higher volumes of timber, and/or reach habitat conditions sooner than lower productivity sites.

What is the Current Site Productivity?

In forested environments, productivity is often expressed as an index of the actual or potential tree growth for a given site. This expression, known as site index, is a species-specific measure of the average height of trees in a forest stand at a specific age (typically 50 or 100 years). Site indexes are commonly grouped into site classes. The classes range from Site Class I (most productive) to Site Class V (least productive). Almost half the land area in the planning unit (46 percent) is classified as Site Class III, which are soils that have somewhat limited growth potential (USDA 1982). Soils considered as Site Class III have an average 50-year Douglas-fir site index of 109 feet (DNR 2008, GIS Soils Layer). Soils throughout the rest of the planning area are divided nearly equally between Site Class I/II and Site Class IV/V. Most of the planning unit (96 percent) has a 50-year Douglas-fir site index between 89 and 127. Refer to Appendix C for more information on site class.

What Is Forest Biomass and Why Is it Important?

Forest biomass is the total mass of living and dead matter within a given area. The change in forest biomass over time is an indicator of growth, the impacts of forest disturbance (for example timber harvesting, insect infestation, and fire) across the forested landscape, and a measure of sustainability for timber production. Forest biomass also provides measures for potential carbon sequestration (p. 118) and older-forest conditions.

The total standing merchantable volume of trees, often used in forestry to measure wood production, is used here as a surrogate for total biomass. Total standing merchantable volume accounts for only

One Board Foot is a volume of wood measured one foot length by one foot wide, and one inch thick.

Table 3-5. Area and Volume by Land Class for the Planning Unit

Land Class	Acres	Long-Term Deferrals* (Percent of Area)	Standing Volume (MBF)**
Riparian and Wetlands (Riparian)	43,869	28%	315,951
Uplands with Specific Management Objectives (Uplands)	78,523	19%	273,217
Uplands with General Management Objectives (GEMs)	23,781	18%	66,782
Total (All Classes)	**146,173**	**65%**	**655,950**

the biomass contained in the tree stems (or boles), and is typically measured in the Pacific Northwest in board feet per acre.

What is the Current Forest Biomass?

The total current standing merchantable biomass in the planning unit is roughly 3.3 billion board feet (Table 3-2). About 30 percent of this is found in Riparian areas, 15 percent in Uplands, and 55 percent in GEM lands; refer to Table 3-5.

How Do Forest Management Activities Influence Forest Conditions?

Management activities have direct effects on stages of forest stand development, tree species composition, and forest density as well as many of the topics included in this EIS that are subject to DNR management—water quality (p. 70), water quantity (p. 65), visual resources (p. 89), wildlife habitat (p. 98), soils (p. 76), roads (p. 82), and northern spotted owls (p. 107).

What Type of Harvest Methods Does DNR Use?

DNR's timber harvesting activities (silviculture) can be broadly summarized as either variable retention or thinning harvests. A discussion of silviculture as used by DNR is incorporated by reference from the 2004 *Sustainable Harvest Final EIS* (p. 2-20 to 2-25).

In the 2008 *South Puget HCP Planning Unit Forest Land Plan Draft EIS*, variable retention harvests were referred to as regeneration harvests, but the name has since been changed to better reflect DNR's current harvesting system. Variable retention harvests remove most trees in a stand (leaving between 8 and 16 trees per acre standing) primarily to produce revenue for trust beneficiaries and have an associated regeneration management activity. The main objective of a variable retention harvest is to initiate a new commercial cohort by removing much of the existing overstory, and generating revenue for trust beneficiaries while retaining important legacy structures or cohorts.

Thinning harvests are a silvicultural treatment that reduces stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality. Thinning harvests can maintain or prolong a forest stand development stage, change the development pathway by adding structure (down woody debris or snags), or encourage the development of a second or third tree cohort in the understory (Text Box 3-3). Thinning harvests generally maintain most of the existing overstory commercial cohort of trees.

Depending on objectives, forest stands may receive only thinnings, only variable retention harvests, or a mix of both. Within the past decade approximately 14,500 acres of variable retention harvest and 7,000 acres of thinning were conducted in the planning unit. DNR uses thinning and variable retention harvests to enhance forest structures in distinctly different ways across forested landscapes (DNR 2004).

Text Box 3-3. Forest Cohort Management

DNR employs a system for managing the components of forests called cohort management. The term cohort refers to a group of individuals with common characteristics. The idea is to manage and track components (cohorts) of forest stands over time in order to achieve management objectives. For example, one forest cohort might be a group of trees developing after a single disturbance, such as a timber sale or wildfire, and consisting of trees of similar age. Other cohorts may relate to ecological functions including snags, very large trees, or downed wood. Still other cohorts may have commercial functions, such as high value products of a certain species, size, or quality (refer to Management of Forest Stand Cohorts, Westside PR-14-006-090 Appendix E).

How Do Young Stand Management Activities Affect Forest Conditions?

Young stand management activities like tree planting, controlling competing vegetation, and pre-commercial thinning can be used to control the numbers and types of trees in the newly developing forest stand. These early forest stand entries are an opportunity to influence the biologically diverse pathways along which forest stands develop into desired future conditions. Tree species composition plays a key role in forest structure, because, over time, different tree species grow at different rates and develop unique foliage, bark, and branch forms, contributing to structural diversity (Carey 2007). The average annual young forest stand management activities from 1997 to 2007 included about 1,500 acres of planting, 1,300 acres of vegetation management (hand-slashing or herbicide use), and 750 acres of pre-commercial thinning.

Older-Forest Conditions

Older-forest conditions are defined as forest stands occupying the most structurally complex forest stages including those in the Niche Diversification and Fully Functional stages (DNR 2006a, p. 47) although structural complexity actually begins in the Biomass Accumulation stage (DNR 2004). Forest stands that are formally designated as "old growth" and defined using the Weighted Old Growth Habitat Index or WOGHI (DNR 2005), also are assumed to meet older-forest conditions.

Why Are Older-Forest Conditions Important?

Older-forest conditions contribute to ecosystem health, complexity, and resilience (Carey 2007). They also contribute to the achievement of many of DNR's management goals, including protection of riparian habitat to support fish (refer to Riparian, p. 58), Wildlife (p. 98), Marbled Murrelet (p. 106), and Northern Spotted Owl (p. 107).

What Criteria Are Used to Assess Older-Forest Conditions?

DNR's general silvicultural policy specifies that 10 to 15 percent of each HCP planning unit should contain or be managed for older-forest conditions (DNR 2006b, p. 47). Refer to Chapter 2: *Alternatives Relating to Meeting Older-Forest Conditions: Alternative A* (p. 25) for additional information.

OLD-GROWTH STANDS

DNR has a separate policy on old-growth stands (DNR 2006b, p. 34). For the westside planning units, DNR developed the Weighted Old Growth Habitat Index (WOGHI) to screen its inventory data for old-growth forest stands which are greater than five acres (DNR 2005; DNR 2006a). Forest stands are assumed to be old growth when they have either a high potential (greater than or equal to 60 WOGHI score) or moderate potential (between 50 and 60 WOGHI scores) for old growth. They are deferred from harvest until a field assessment is conducted to determine if the stand is truly old growth or open for management activities in accordance with DNR's 2006 *Policy for Sustainable Forests*.

How Much Forest Exists In Older-Forest Conditions Today?

Historically, older forests were estimated to have occupied between 54 and 70 percent of all lands in western Washington (National Research Council 2000). Now, most older forests are found on federal forestlands within the region. Currently, less than two percent of forested state trust lands in the planning unit occupy the Niche Diversification or Fully Functional stages (Chart 3-1) of stand development. Of the 820 acres identified as having a high old-growth potential (a WOGHI score of "high"), 507 acres have been preserved permanently within the newly created Charley Creek Natural Area Preserve in the Grass Mountain watershed. An additional 191 acres are protected within the Bald Hills Natural Area Preserve located in the Powell Creek watershed. Remaining scattered acreage with a higher old-growth potential is located within the Kennedy Creek (33 acres), Tiger (26 acres), North Fork Mineral (56 acres), and Middle Deschutes (10 acres) watersheds. Most of the 579 acres with moderate old-growth potential are located in the Mineral Creek (374 acres) and North Fork Mineral (100 acres) watersheds.

How Does Management Affect Older-Forest Conditions?

To achieve increased older-forest conditions, DNR is actively managing forests to attain various objectives that increase structural complexity. This biodiversity pathway approach was fully described in DNR 2004, p. 2-24. More than 50 percent (78,000 acres) of the planning unit is designated as a dispersal management area for northern spotted owls (p. 105), requiring active management to help achieve habitat conditions. Whenever harvest operations occur, DNR's cohort management procedure (Text Box 3-3, Appendix E) helps to ensure that the structural elements that contribute to older-forest conditions are preserved or created.

Threatened, Endangered, and Sensitive Plants and Special Ecological Features

DNR is committed to maintaining and recovering threatened and endangered plants listed under the 1973 federal *Endangered Species Act* (ESA)[2]. Although the ESA has identified only 10 plant species for all of Washington, DNR's Natural Heritage Program recognizes a more substantial number of plants which are assigned a status (endangered, threatened, or sensitive). Potential impacts from DNR management were analyzed under DNR's *Draft* and *Final EIS for the 1997 Habitat Conservation Plan* (DNR 1996). This included protection for unique habitats, which may contain rare plants.

What Guides Special Plant Management?

DNR's policy on special ecological features (DNR 2006b, p. 39) establishes protections for threatened or rare ecosystem types. A detailed discussion of policies and regulations governing plant management can be found in DNR 2004, Appendix C.

What Are Current Special Plant Conditions?

No comprehensive inventory of threatened, endangered, and sensitive plants or ecosystems exists for forested state trust lands. DNR's Natural Heritage Program maintains a Geographic Information System (GIS) database of known occurrences for all lands in Washington. A query of this data shows that 44 of these species may occur within the planning unit (refer to Appendix K). Of these, five species are known to occupy forest environments where timber harvests may occur (refer to Table 3-6).

Plants and ecosystems may respond positively or negatively to disturbances such as timber harvesting as more sunlight becomes available and micro-habitats change. There is no guarantee that forest management will not have impacts to threatened, endangered, and sensitive plants or rare ecosystem types. A more detailed discussion of potential impacts from current forest management can be found in the 2004 *Sustainable Harvest Final EIS* (p. 4-32 to 4-34).

Considering that threatened, endangered, and sensitive plants are so rare, highly dependent on local site conditions, and no systematic survey has been carried out on DNR lands, it is not currently possible for DNR to assess potential differences between alternatives through predictive or data analysis means. However, DNR mitigates for potential impacts to threatened, endangered, or sensitive plants and ecosystems on a site-by-site basis. If an occurrence is identified, foresters consult directly with a Natural Heritage Program scientist.

Table 3-6. Threatened, Endangered, and Sensitive Species Known to Occupy Forest Environments in the Planning Unit Where Timber Harvesting May Occur

Species	Common Name	Habitat	State Status
Chrysolepis chrysophylla	Giant golden chinquapin	Dry, open to thick wooded areas	Sensitive
Cimicifuga elata var. elata	Tall bugbane	Moist, shady woods, lower elevation	Sensitive
Cypripedium fasciculatum	Clustered lady slipper	Coniferous forest	Sensitive
Lathyrus torreyi	Torrey's peavine	Mixed conifer forest	Threatened
Pityopus californica	Pine-foot	Deep coniferous forests	Threatened

Climate

What Is the Climate of Western Washington?

The area of Washington west of the Cascade Mountains is predominantly a marine type of climate; as is obvious by its mildness when compared to other climates at similar latitudes (46° to 49°). Three environmental factors—terrain, the Pacific Ocean, and semi-permanent high and low pressure systems over the northern Pacific—combine to create drastic changes in climate over relatively short distances (Bach 2004; NOAA 1985).

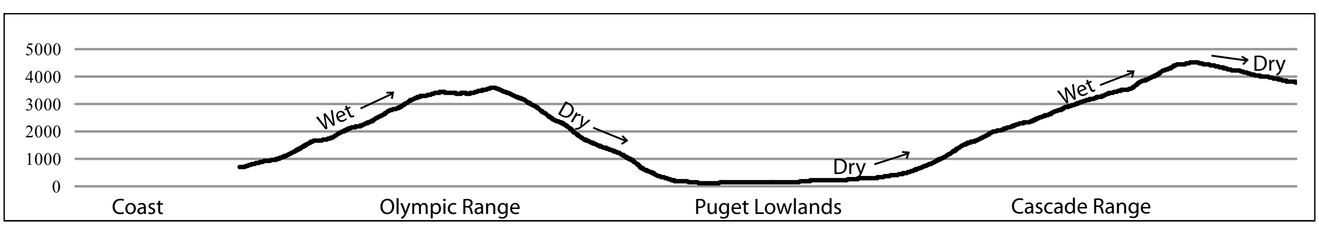
There are two large mountain chains in the western part of Washington, the Olympics and the Cascades. The large Cascade Range divides the wetter western side of the state from a dramatically drier eastside. Moisture-laden clouds form over the Pacific Ocean and are first intercepted by the Olympic coastal range (NOAA 1985). As the clouds move over the land and up in elevation, condensation occurs as the temperature drops, releasing precipitation as it moves up the windward mountain slopes (Agee 1993); therefore, where the Cascade foothills meet the Puget lowlands large amounts of precipitation fall every year. Conversely, during summer months, winds from the east that move dry desert air rise over the Cascades causing high-velocity warm winds to blow in short spells. The profiles in Figure 3-1 (a and b) compare the winter and summer flow of prevailing winds for the region.

Proximity to the Pacific Ocean is very important to the climate of western Washington. The temperature of the Pacific Ocean changes very little throughout the year (though according to the Intergovernmental Panel on Climate Change (2007) ocean temperatures may be on the rise overall); in the winter, the water is warmer than the adjoining land mass and in the summer is slightly cooler. The air over the water is often the same temperature as the water; therefore, nearness to the Pacific Ocean and the Puget Sound translates to similar temperatures for the surrounding land surfaces (Bach 2004). Both rainfall and snowfall increase with a slight increase in elevation and distance from the water. In addition, variations in temperature and length of growing season and fog can also be related to relative distance from these bodies of water (NOAA 1985).

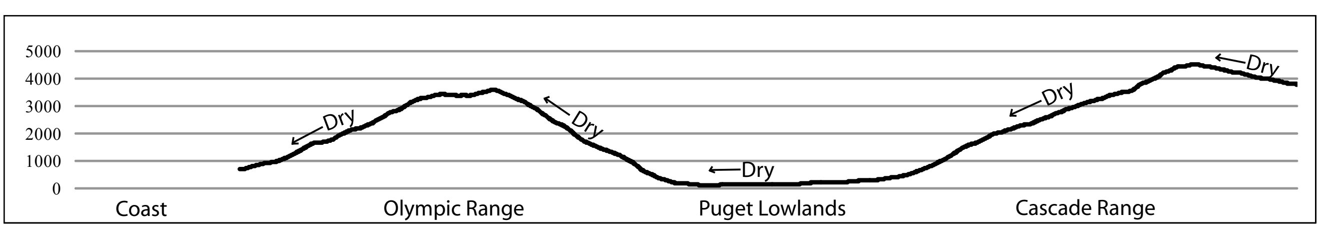
Seasonal Influences

Semi-permanent high and low pressure systems over the Pacific Ocean strongly influence the seasonal changes in Washington. The low pressure system (Aleutian Low) is strongest in the late fall, peaks in the winter, and loses strength and moves northward in the spring. The jet stream brings many cold fronts into the region which are slowed as they ascend the Cascades, bringing low intensity, long duration precipitation events (Bach 2004). As the low pressure system weakens, the high pressure system (Pacific High) gains strength, bringing westerly and northwesterly air that is dry, cool, and stable (Agee

Figure 3-1. Comparison of Prevailing Winds during the Winter (a) and Summer (b). Based on Agee 1993 and Bach 2004.

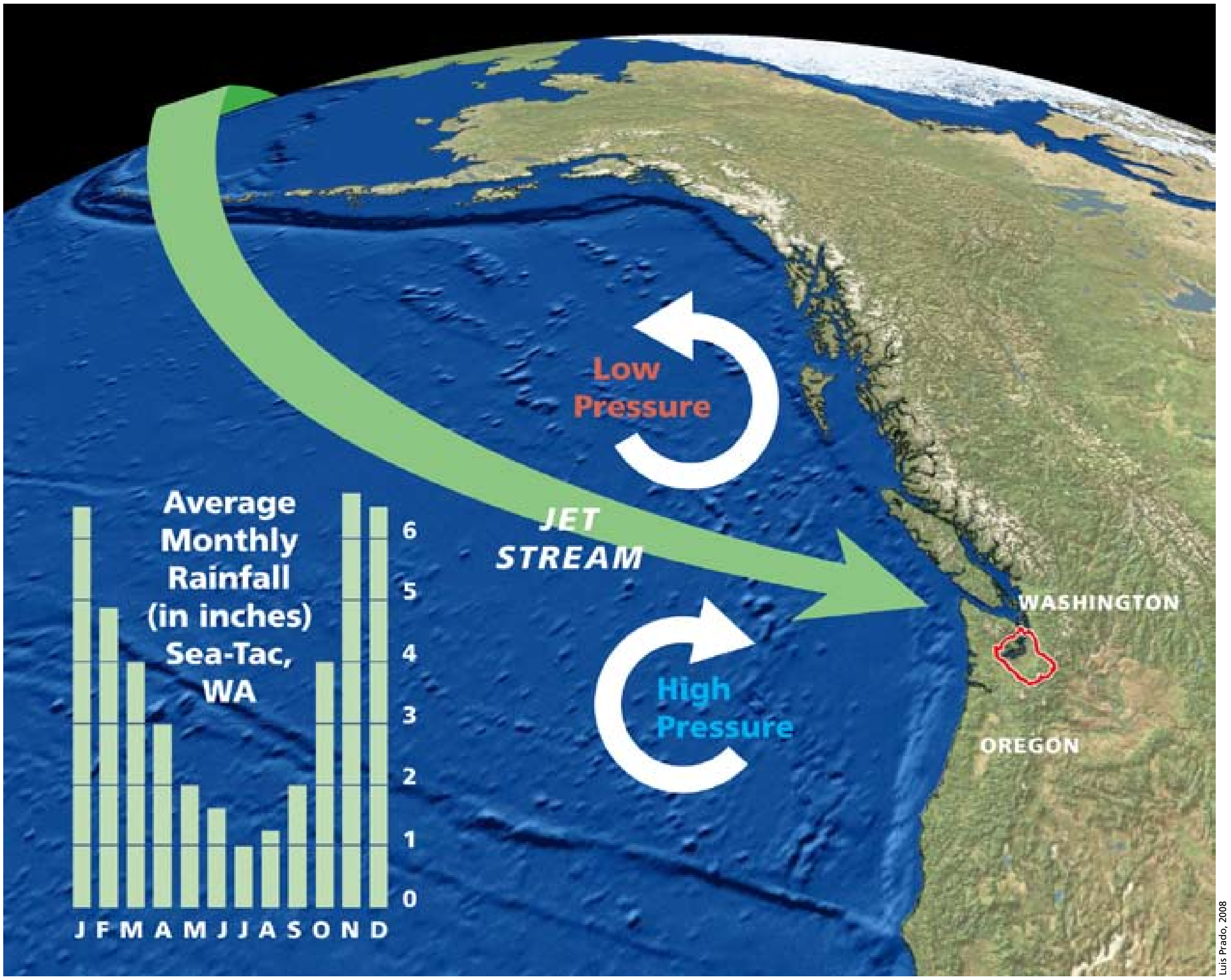


a. This winter elevation cross-cut of the northern part of the planning unit shows prevailing southwesterly and westerly winds bringing moisture-laden air in from the Pacific and diagramming areas where moisture is likely to fall as air parcels move over land masses as described in the paragraph above.



b. In the same profile, westerly and northwesterly flow is shown moving dry air masses toward the coast. These inland flows are more common in the summer and bring warm dry air over the Cascades to the Puget Lowlands and other parts of the coast.

Figure 3-2. Demonstration of air movement in and around the Pacific Northwest caused by high and low pressure systems and the jet stream. Also a chart of average total precipitation.



1993). The dry season begins with the movement of this air mass over the Pacific Northwest in late spring and peaks with the warmest days in July and August (refer to Figure 3-2).

Nearly every winter, especially those associated with La Niña, the polar jet stream will mix with the tropical jet stream in a phenomenon called the Pineapple Express. This event results in exceptionally heavy precipitation, often accompanied by warm westerly winds resulting in premature snow melting, referred to as rain-on-snow events (Bach 2004).

Precipitation Events

Winter in western Washington is cloudy and wet but the summers are generally cool and comparatively dry. December and January are the wettest months of the year, unlike July and August, where several weeks may pass with only light showers. The graph in Figure 3-2 shows the monthly precipitation distribution for a 70-year period at the City of Sea-Tac in western Washington. Annual precipitation averages 40 to 60 inches per year in the Puget Sound area and increases with elevation, with up to 180 inches falling annually along the west slopes of the Cascades (Bach 2004) (refer to Map 3-3). Historically, Mount Rainier and other peaks in the Cascade Range have had record-breaking snow accumulations. Six of the 10 warmest years recorded in Washington since 1918 occurred between 1996 and 2007 (NOAA 2008), which may surprise locals, since many of those years also had above-average rainfall, partnered with severe flooding in western Washington and other parts of the western coastal states. Increased rainfall puts DNR-managed lands at higher risk for landslides (refer to Soils, p. 76) and loss of productivity as soils and nutrients can slough off during extreme precipitation events. For an in-depth description of recent flooding events in western Washington, refer to pages 37 to 46 of *The Weather of the Pacific Northwest* (Mass 2008).

Solar Radiation

Clouds are more prevalent than sun during the winter months in western Washington, where the possible monthly sunshine is only around 25 percent except during the summer, where the sun is visible up to 60 percent in any given month. The region receives one of the lowest percentages of solar radiation in the entire nation on average, meaning general solar exposure is very low. The growing season ranges from April to early November, when the ground is typically frost-free (NOAA 1985).

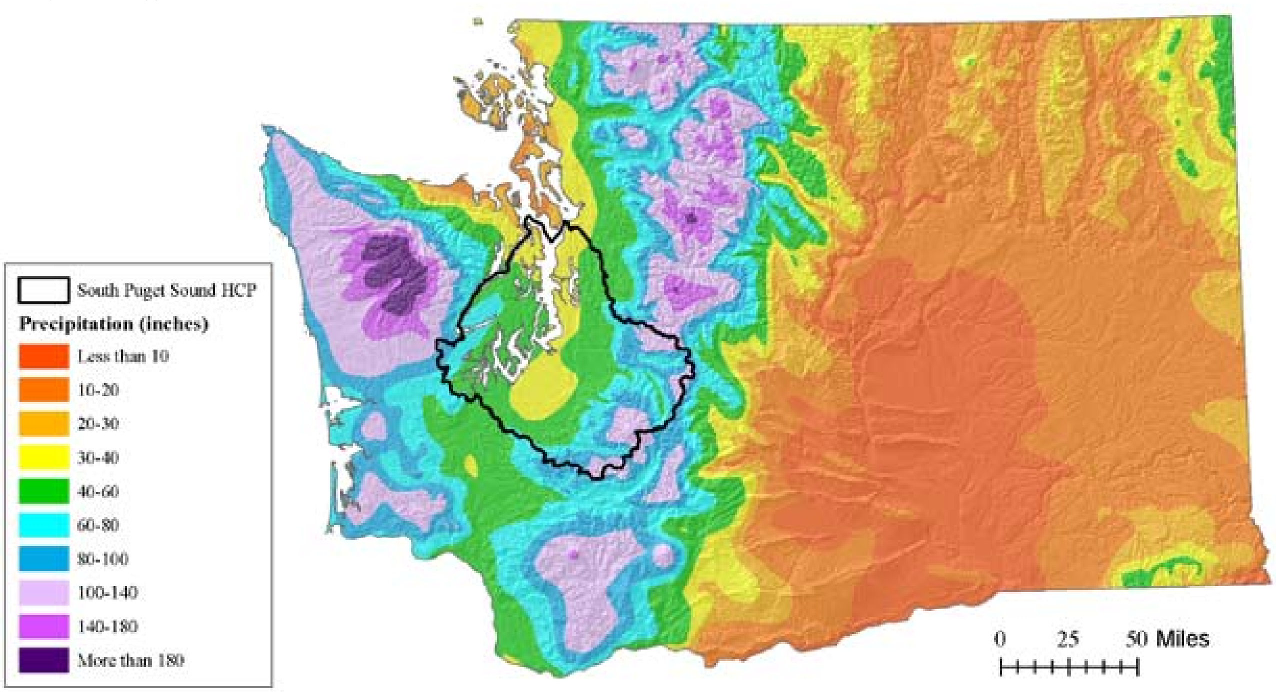
Wind Events

Wind is a common component of western Washington climate but notable disturbances from these winds generally occur only one to two times annually. Wind shapes the forest structure of western Washington more than any other natural disturbance event. During winter months, prevailing winds are generally southwesterly although wind commonly flows in areas of least resistance such as winds flowing into the Puget Sound from land openings to the north, near Seattle, and also through small elevation gaps near the Columbia River Gorge and the Chehalis River Valley. Wind speeds are generally below 10 miles per hour in the lowlands and foothills, but can range from 50 to 70 miles per hour along the coast and have been observed at a consistent 50 to 60 miles per hour during storm events with higher gusts in inland areas. Wind speeds generally increase with elevation and ridge tops have the highest and least predictable winds, as seen in Map 3-8, which depicts higher ridges of the Cascades, especially Mount Rainier, having very high wind speeds compared to the rest of the planning unit. For an in-depth description of recent wind events in western Washington refer to pages 102 to 105 of *The Weather of the Pacific Northwest* (Mass 2008).

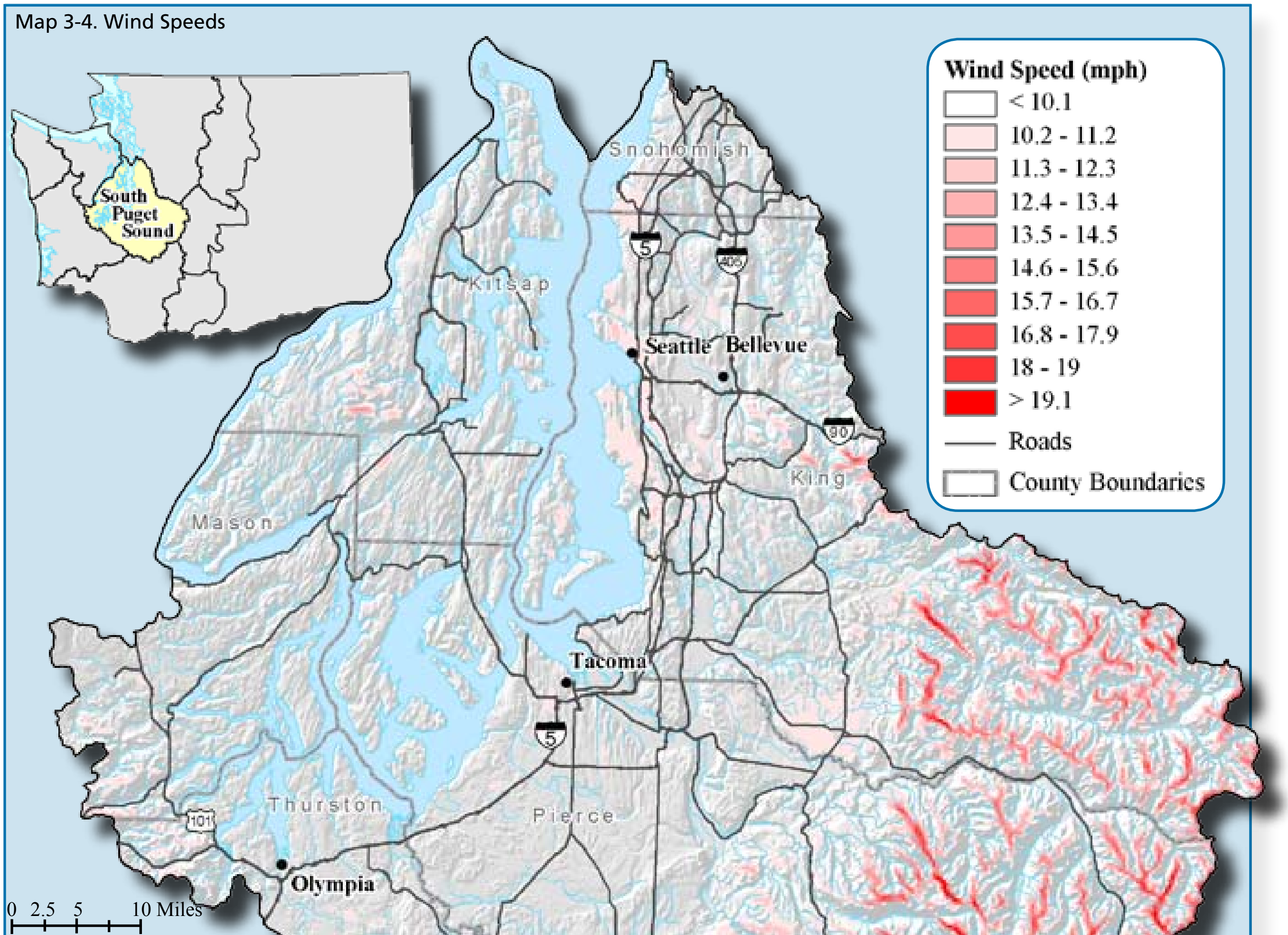
Lightning

While western Washington generally does not experience dry lightning storms, the area does experience 10 to 12 rain storms with lightning per year, usually in the western foothills of the Cascades (NOAA 1985).

Map 3-3. Annual Precipitation in Washington (100-year average)
Map by Rebecca Niggemann 01/25/08



Map 3-4. Wind Speeds



Riparian

Riparian zones are the streamside vegetation, soils, and moisture regimes along streams and other water bodies (DNR 1997). Raedeke (1988) describes riparian systems as having long, linear shapes with high edge-to-area ratios, and microclimates distinct from those of adjacent uplands. Distinct gradients of moisture create obvious changes in communities of plants and animals from those of adjacent uplands (Richardson and others 2005).

Why Are Riparian Areas Important?

Riparian areas provide habitat conditions that are important for salmon and numerous plant and animal species. Riparian forests influence stream conditions such as stream flow levels (Cleaverly and others 2000), temperature (Brown and Krygier 1970), and nutrient concentrations (Tabbacchi and others 1998) and are a major source of sediment and organic materials (Triska and others 1982; Gregory and others 1991). A wide variety of hydrologic, geomorphic, and biotic processes determine the character of riparian areas. Riparian areas have distinctive resource values and characteristics that make them important zones of interaction between terrestrial and aquatic ecosystems (Meehan 1991; Johnson and Ryba 1992).

What Are the Criteria for Managing Riparian Conditions?

The criteria by which riparian management zones are measured include providing adequate shade, reducing sedimentation, and preventing forest chemicals from entering the stream (Bilby and Waserman 1989). Over the past 33 years in Washington, harvesting activities that have occurred near riparian areas have been governed by *Forest Practices Rules* (DNR 2001, p. 3-40), but in 1997, in addition to following these Rules, DNR began managing trust land riparian areas as prescribed in the *Habitat Conservation Plan* (DNR 1997).

On forested state trust lands, riparian functions are protected through the use of riparian management zones, where the extent and type of management activities that can be implemented are restricted in order to meet the 1997 HCP objectives (FEMAT 1993). The extent and type of management activity in riparian management zones are important, particularly those activities that target restoration of riparian functions.

DNR maintains and restores salmonid freshwater habitat on trust lands and contributes to the conservation of other aquatic and riparian obligate species (DNR 1997, p. IV. 55). This requires that any adverse effects of upland management activities be minimized (Bigley and Deisenhofer 2006, p. 2).

What Are the Indicators for Assessing Riparian Conditions?

The most important recognized functions of stream riparian areas include large woody debris recruitment, leaf and needle litter recruitment, stream shade, microclimate, streambank stability, and sediment control. Large trees, in the Fully Functional and Niche Diversification development stages, affect these functions positively. Large trees provide strong root systems, which, in turn, provide critical structure for fish habitat and help prevent streambank erosion (Bigley and Deisenhofer 2006). Therefore, the creation and maintenance of stand structure and composition are vital components of riparian restoration and will be used to measure the indicators of riparian conditions in Chapter 4 (p. 139).

Many authors have analyzed riparian functions (for example, Murphy and Meehan 1991; Forest Ecosystem Management Assessment Team [FEMAT] 1993; Spence and others 1996; DNR 1996, p. IV-145 to IV-175; Washington Forest Practices Board 2001, p. 3-36 to 3-40). A thorough discussion of riparian elements and their relationship to aquatic habitat function is given in the *Sustainable Harvest Final EIS* (DNR 2004) and the 2007 *Addendum* (DNR 2007); therefore, only a brief discussion of these functions follows.

LARGE WOODY DEBRIS (LWD)

Decadence in trees (such as decay columns and cavities) are a particularly important feature of large woody debris, as tree mortality generally provides the greatest source of recruitment to streams (Bilby and Bisson 1998). Large trees must be present in the riparian zone as a source for the recruitment of large woody debris to the stream system that is critical for spawning, rearing, and over-wintering habitat (Bigley and Deisenhofer 2006) for salmonid species. Numerous studies have shown that large woody debris is an important component of fish habitat and aquatic organisms (Swanson and others 1976; Harmon and others 1986; Bisson and others 1987; Maser and others 1988; Naiman and others 1992; Samuelsson and others 1994) and that it is critical for sediment retention (Keller and Swanson 1979; Sedell and others 1988), gradient modification, structural diversity (Ralph and others 1994), nutrient production and retention (Cummins 1974), and protective cover from predators.

LEAF AND NEEDLE LITTER RECRUITMENT

In aquatic systems, some vegetative organic materials (such as algae) originate within the stream while others (such as leaf and needle litter) originate from sources outside the stream. Stream benthic communities are highly dependent on materials from both sources. The abundance and diversity of aquatic species can vary significantly, depending upon the total and relative amounts of algae, leaf, and litter inputs to a stream. The source and level of organic debris input can change in a riparian forest stand. For example, as a riparian forest stand ages, the amount of litter-fall increases (IMST 1999). Decomposition of organic matter increases with temperature which can decrease the amount of time this matter is available to benthic communities (Bates and others 2008).

STREAM SHADE

Stream shade is often the primary factor influencing stream temperature; all aquatic organisms have a temperature range outside of which they cannot exist. Stream temperature also influences water chemistry, which can affect the amount of oxygen present to support aquatic life. Factors that affect shading include stream size, stream orientation, local topography, tree species, stand age, and stand density (DNR 2004).

MICROCLIMATES

Microclimates are a local atmospheric zone where the climate differs from the surrounding area. Removing streamside vegetation can result in changes in microclimatic conditions within the riparian zone, subsequently influencing a variety of ecological processes that may affect the long-term integrity of riparian ecosystems and associated aquatic habitat (Spence and others 1996). Microclimate is also important to stream and riparian species other than fish, such as amphibians (refer to Fish, p. 73; Wildlife, p. 98).

SEDIMENT CONTROL AND SLOPE AND STREAMBANK STABILITY

Sediment can be delivered to the aquatic system as surface erosion (mostly fine sediment) generated from harvest units, skid trails, and roads within the riparian area, particularly at stream crossings (Cederholm and others 1981). Sediment also can be delivered as landslides or debris torrents (coarse and fine sediments), whether initiated naturally (Soils, p. 76) or in harvested areas on unstable slopes (Waters 1995).

Slope stability depends partly on reinforcement from tree roots, especially when soils are partly or completely saturated. In addition to having significant impacts on the stream channel, debris torrents also can affect riparian buffer functions and streamside forests when bank scour removes streamside vegetation (refer to Soils, p. 76).

The stability of streambanks is largely determined by the size, type, and cohesion of the soil profile; vegetation cover; root mass; and the amount of bedload carried by the channel (Sullivan and others 1987). Riparian vegetation can provide hydraulic roughness that dissipates stream energy during high or overbank flows, which further prevent bank erosion. In most cases, vegetation immediately adjacent to a stream channel is most important in maintaining bank integrity.

What Are the Current Conditions of Riparian Areas?

DNR uses stand development stages to assess forest conditions (p. 44) in riparian areas. The Biomass Accumulation, Niche Diversification, and Fully Functional stages are dominated by trees greater than 30 inches in diameter at breast height. The further it is from a stream, the larger and taller a tree must be to supply large woody debris effectively when it falls into the stream (McDade and others 1990). The effectiveness of shade, leaf litter, and microclimates as factors in stream health is similarly dependent on their distance from the stream.

The distribution of stand development stages within the riparian areas as compared to historic unmanaged stand levels shows a reduction in many of the riparian functions because the numbers of adjacent large, fully functioning riparian forest stands have decreased.

Forty percent of the existing riparian areas are in the Understory Development stage, which are forests in transition from highly dense, closed conditions to forests with more complex conditions. The Riparian land class has one of the highest percentages of

Table 3-7. Stream Miles by Ownership within the Planning Unit[1]

	Stream Miles				
DNR Stream Type[2]	DNR Forested Trust Lands	Federal Lands	Private Lands[3]	Other[4]	Total
1	36 (3%)	97 (7%)	732 (55%)	475 (35%)	1,342
2	8 (3%)	12 (5%)	160 (69%)	51 (22%)	231
3	321 (9%)	328 (10%)	2,431 (72%)	321 (9%)	3,400
4	818 (9%)	2,137 (23%)	5,468 (59%)	876 (9%)	9,299
Total (all Types)	1,183 (8%)	2,574 (18%)	8,791 (62%)	1,724 (12%)	14,271

1. The current DNR GIS layer for streams is believed to underestimate the number of Type 3 streams. Consequently, for the purposes of this paper, stream types in the stream layer were modified by upgrading Type 9 and Type 5 streams to Type 4, and Type 4 streams to Type 3.
2. DNR and the Federal Services (U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration Fisheries) have agreed the Washington Forest Practices Board Emergency Rules (stream typing), November 1996 (WAC 222-16-030) meet the intent of DNR's 1997 HCP. A comparison of DNR's permanent water typing system is defined in the rules (WAC 222-16-030) and the HCP stream typing system is discussed in Appendix B of DNR (2006b).
3. The "Private Land" category includes industrial forestland, agricultural lands, and residential, industrial, and commercial lands.
4. The "Other" category includes DNR-managed non-forested land, municipal lands, and water bodies (larger streams, rivers, lakes, and marine shorelines).

Table 3-8. Current Distribution of Stand Development Stages in Riparian Areas

Stand Development Stages	Acres	Percent
Ecosystem Initiation	6,210	15%
Competitive Exclusion	8,433	20%
Understory Development	20,995	49%
Biomass Accumulation	6,353	15%
Niche Diversification	267	> 1%
Fully Functional	559	1%
Total Acres	42,817	

acreage in forests with overstocked (RD≥75) stand conditions. Refer to Stand Development Stages, Text Box 3-1 (p. 46). One percent of riparian forests are currently in the Fully Functional stage (Table 3-8).

DNR's long-term goal for riparian management zones is based on the assumption that structurally complex characteristics affect the function of stream riparian areas positively, and support desirable aquatic habitat, thus aiding riparian obligate species and salmon habitat recovery (DNR 1997). The long-term target for riparian management zones includes older-forest conditions, while the more immediate goals are described in Table 2 of the *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer, p. 8). Currently, it is estimated that two to four percent of riparian areas are in older-forest conditions.

How Does DNR Manage Riparian Areas?

The *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006) provides the framework for how DNR now manages forest stands within riparian zones. The strategy focuses on restoring riparian function by using silvicultural treatments to achieve desired forest stand conditions (Bigley and Deisenhofer 2006, p. 21). Implementation of the strategy is consistent with the biological opinion for the 1997 HCP (USFWS 1997, p. 16). DNR is also currently developing a long-term Headwaters Conservation Strategy for the management of riparian forests along Type 5 waters, designed to increase protection for headwater-associated sensitive sites in order to maintain ecological functions both on site and in-connection to downstream systems.

Type 5 waters are the smallest of the non fish-bearing streams. Type 5 waters may be either perennial or seasonal, with or without a defined channel.

How Does DNR's Management Affect Riparian Areas?

Although the type, frequency, and scale of timber harvest activities (which can only be assessed in site-specific analyses) can be a primary factor in influencing the conditions discussed, other activities can affect riparian functions within the riparian zone.

The current distribution of stand development stages indicates a low to moderate level of fully functioning forest stands within riparian areas, suggesting that many streams on forested state trust lands may have reduced levels of one or more riparian functions (DNR 2004). These areas are likely to remain in this status for the near future because they contain moderate to high levels of early stand development stages. In contrast, many small to moderately sized streams may be approaching a moderate to high level for some riparian functions, such as large woody debris and shade from trees in intermediate development stages. However, these small streams may also have substantial reductions in other riparian functions and lack decadent features important for some wildlife and riparian-dependent species. Overall, riparian areas in this planning unit have a relatively high proportion of early and mid-developmental stand stages and lower proportions of older, more structurally complex forest stand structures.

ROAD NETWORK

The road network is essential for managing forested state trust lands. Roads impact riparian areas through their use and placement which can reduce the amount of sediment input to streams and streambank stability (refer to Water Quality, p. 70 and Soils, p. 76). The number of active roads within 200 feet of a water body (shown in Chart 3-3, p. 81), as well as their density, can be used to quantify the potential for these impacts (refer to Roads, p. 80).

RECREATION

In general, environmental impacts from recreation would include any strategies that result in disturbance within the riparian zone and may increase the risks to riparian functions including vegetation removal, bank trampling, or placement of permanent structures (installation of recreational facilities, boat launches, campsites, roads, or trails). In addition, increases in recreational access to a given area can impact riparian functions negatively through additional pedestrian and motorized vehicle access and use (refer to Recreation, p. 85).

Wetlands

Wetlands are defined as "areas that are inundated or saturated with surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions".[3] Wetlands may be seasonal or permanent and are commonly referred to as swamps, marshes, or bogs.

Why Are Wetlands Important?

Wetlands provide habitat for a multitude of species. Wetlands are essential habitat for amphibians and aquatic invertebrates, and rearing habitat for Coho salmon; they are used by birds and mammalian species for nesting and feeding; and they provide connectivity for wildlife movement and refugia (DNR 2004, p. 4-132).

Wetlands are also an important component supporting water quantity (p. 65) and water quality (p. 68) within a watershed. Therefore, wetlands are indirectly important to the maintenance of fish populations and fish habitat (DNR 2004). Wetlands serve as groundwater recharge zones, and are valued for the hydrologic, biogeochemical, and habitat functions they perform. They also perform an important function augmenting stream-flow during low flow periods, and in moderating peak flows during storm events (refer to Water Quantity, p. 65).

Recognizing the ecological values that wetlands provide to healthy forest ecosystems, DNR strives to minimize activities in or adjacent to them.

What Are the Criteria for Assessing Wetlands?

Broad policy direction for management of wetlands on DNR-managed trust lands is found in the 2006 *Final EIS on the Policies for Sustainable Forests* (p. 3-115 to 3-123). Regarding the amount of wetland on forested state trust lands, the criterion is no overall net loss of naturally occurring wetland acreage and function (DNR 2006b).

Using the 1997 *Habitat Conservation Plan*, DNR measures hydrologic function of wetlands by whether they maintain natural water flow in wetlands, continuously maintains a plant canopy that provides a sufficient transpiration surface and establishes rooting, and ensures stand regeneration.

Since the HCP was written in 1997, DNR has put into place additional guidance to ensure wetland protection, such as in the 2006 *Riparian Forest Restoration Strategy*, Forestry Handbook Procedure for Wetland Management[4], and *Forest Practices Rules*.

What Are the Indicators for Assessing Wetland Functions?

WATER FLOW

Wetlands perform many important hydrologic functions (refer to Water Quantity, p. 65), although they are usually thought of as areas of groundwater discharge, some wetlands serve as areas of groundwater recharge (Ecology 1992). Wetlands also improve water quality by filtering out sediments, excessive nutrients, and toxic chemicals.

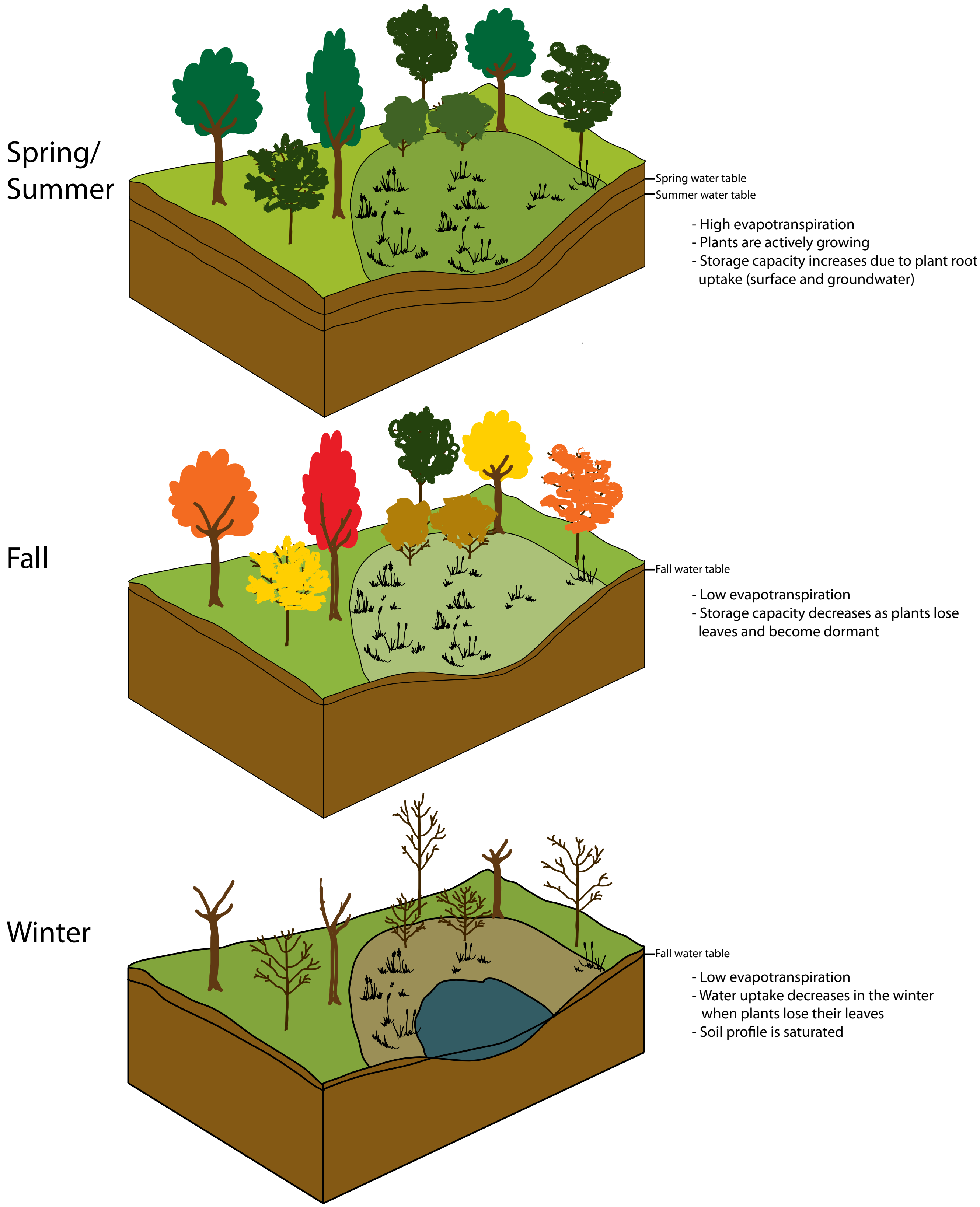
Figure 3-3 depicts the seasonal fluctuations of water flow through the evaporation and transpiration processes of a wetland. This water balance is a single estimate of water loss called evapotranspiration. In depressional wetlands, where there is no significant outlet, and in wetlands where the water table is often close to the ground surface, evapotranspiration may be the most significant factor in removing water from the system (SCS 1993).

BIOGEOCHEMICAL

Water purification functions of wetlands depend on four principal components of the wetland: substrate, water, vegetation, and microbial populations (Hammer 1989; Hemond and others 1987).

These factors control the hydrologic and water quality functions of wetlands: landscape position (elevation in the drainage basin relative to other

Figure 3-3. Wetland Seasonal Fluctuations (modified from Carter 1997)



wetlands, lakes, and streams); topographic location (depressions, flood plains, slopes); presence or absence of vegetation; type of vegetation; type of soil; the in- and out-flows of water; and local climate conditions. Although broad generalizations regarding wetland functions can be made, these functions differ from wetland to wetland (Mitsch and Gosselink 1993; Elder 1987).

VEGETATIVE COVER

The presence of a particular plant does not indicate wetland conditions unless vegetative dominance, hydrology (p. 65), and soils (p. 76) criteria are satisfied. Understory vegetation and trees in wetland buffers help to maintain wetland hydrology near natural levels through evapotranspiration. Wetland hydrology can be disrupted by timber harvest activities within and adjacent to a wetland. Reductions in tree canopy and understory leaf area can decrease evapotranspiration and result in increased groundwater flows, altering the rate at which water is removed (Bigley and Hull 2000).

What Are the Current Conditions of Mapped Wetlands?

DNR's GIS data were used to identify wetland acres, which were discussed in detail in the 2004 *Sustainable Harvest Final EIS* (p. 4-131 to 4-137).

Overall, 73,237 acres (2.3 percent) of the planning unit have mapped wetlands; however many wetland acres in the planning unit remain unmapped. DNR-managed trust lands account for 1,457 of these wetland acres, equivalent to about two percent of the wetlands within the planning unit (Table 3-9). Of these DNR-managed wetlands, 53 percent are mapped as forested and 47 percent are mapped as non-forested.

How Does DNR Management Affect Wetlands?

TIMBER HARVESTING

Timber harvesting and associated management activities can affect wetlands and adjacent lands by potentially altering hydrology (p. 65); changing nutrient pathways; delivering sediment (which can diminish water quality, p. 70); changing species composition, growth, and structure; and reducing shade. The timing and method used to extract products from the forest can influence the effects of the activity on wetlands significantly. Heavy equipment, if used in wetlands, can so concentrate impacts that soil properties on site are altered. Trees in wetlands smaller than one-fourth acre are typically kept as leave tree clumps and become part of a site-based leave tree strategy. While the hydrologic and biogeochemical functions begin to return when tree revegetation occurs, habitat functions can require more time for vegetation to become established.

Specifically, variable retention harvests on wetland sites can alter wetland hydrology and raise the elevation of the water table. Changes in the hydrologic patterns and substrate of wetland sites can influence plant species and growth within the wetland site directly.

ROADS

Construction of roads (p. 82) can have the greatest direct impact on wetlands relative to other management activities because it may permanently eliminate the associated biological functions and potential for future tree growth in the affected area. Additionally, road crossings without adequate provision for cross-drainage can lead to flooding on the upslope side of the crossing and subtle drainage changes on the downslope side (Stoeckeler 1967; Boelter and Close 1974).

Table 3-9. Wetlands in Planning Unit by Ownerships

	Acres				
Wetland Type	**DNR Forested Trust Lands**	**Federal Lands**	**Private Lands**	**Other**	**Total**
Forested Wetlands	766	1,770	15,509	2,047	20,092
Non-Forested Wetlands	691	4,136	42,873	5,446	53,145
Total Acres of Wetlands	1,457	5,905	58,383	7,492	73,237
Percent of Total Wetlands Acres	2%	8%	79%	11%	100%

As mentioned above, activities adjacent to and within DNR-managed wetlands happen only on exceptional occasions where alternative routes are not available for road construction.

RECREATION

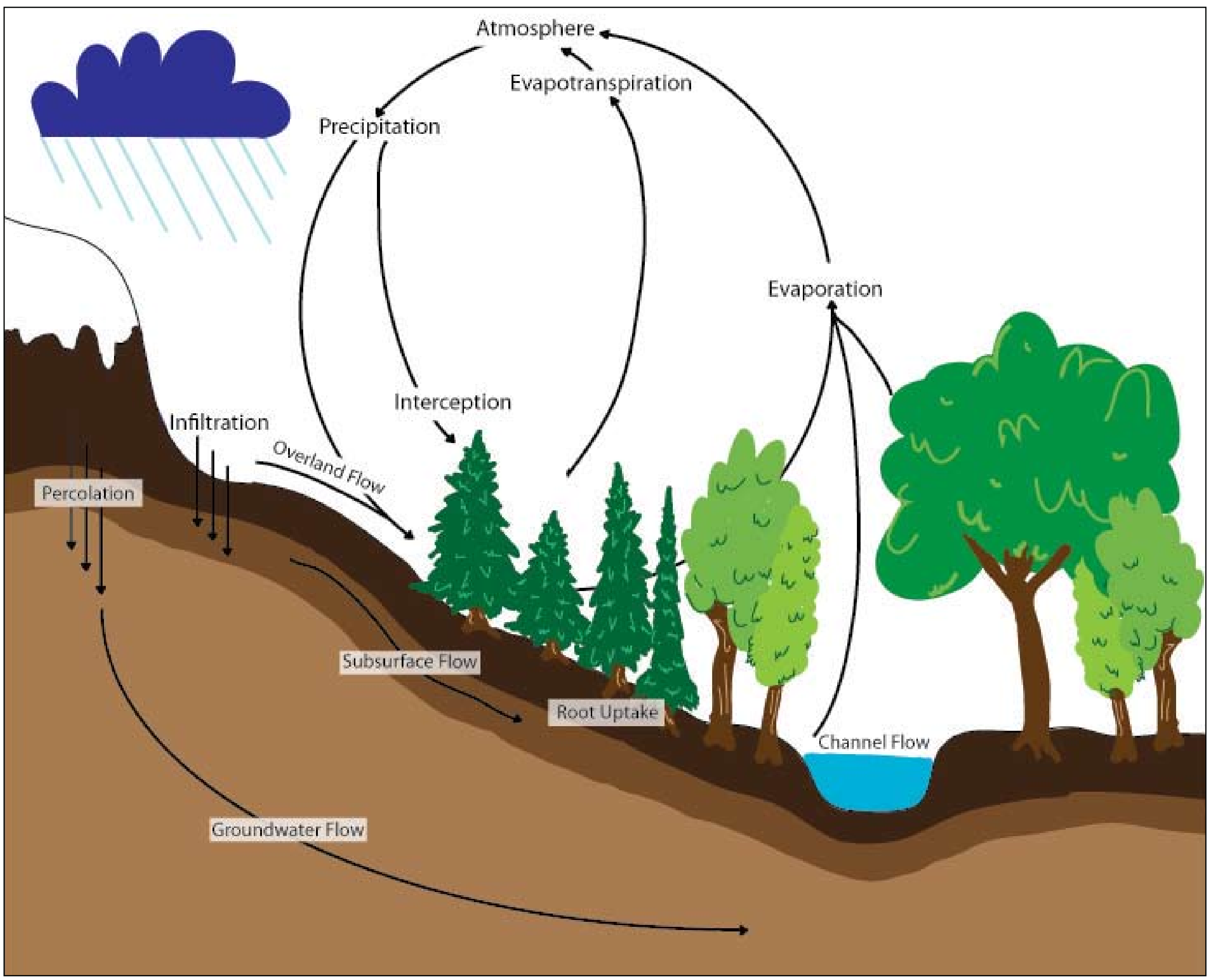
The type of recreation activity and the amount of use an area receives influence the severity of potential impacts on a wetland, with the impacts depending on a variety of factors which include the season of use, group size, and type of use (day use versus overnight/multi-day use, motorized versus non-motorized use).

Water Quantity

Water quantity refers to the amount, timing, and intensity of water movement within watersheds (DNR 2004, p. 4-117). In this section, the importance of water quantity, the indicators of current conditions, and the influence of DNR management activities on water quantity are discussed.

The amount of water flowing through watersheds depends on many factors. The hydrologic cycle provides a basic explanation of how water moves through a forested ecosystem (Figure 3-4). Some of the primary factors that influence water quantity include climate, which influences precipitation; geology and soil qualities, which influence infiltration and percolation processes; and vegetation, which influences interception and evapotranspiration (Fetter 2001).

Figure 3-4. How Does Water Flow through Forested Ecosystems?



Why Is Water Quantity Important?

The amount, distribution, and timing of water flow in a watershed can affect fish habitat, soil erosion processes, and the built environment.

Changes in peak flows, or the highest expected volume of surface water flowing in a stream, can affect streambank stability and channel morphology, water quality, salmonid habitat, and sensitive plant species. Peak flows, which can become large floods, may affect public safety and infrastructure adversely (DNR 2004, p. 4-117). A lack of water or drought may impact fish habitat and water available for human use.

Homeowners around Lake Tahuya, a 150-acre privately owned reservoir on the Kitsap Peninsula, are concerned about how DNR management in the Green Mountain State Forest surrounding the lake may affect peak flows and the potential for lakeshore flooding.

What Are the Criteria for Water Quantity?

Hydrologic maturity is the measure DNR uses to assess the relative risks from water quantity effects due to changes in peak flows (DNR 1997). Hydrologic maturity refers to the percentage of a watershed composed of forests with predominantly closed canopies that have forest structures and compositions that allow them to behave in a manner that is hydrologically similar to a mature forest (DNR 1998, p. 4-171). Since harvesting (particularly variable retention) reduces forest cover, hydrologic maturity is a way of assessing potential effects from forest management on water quantity.

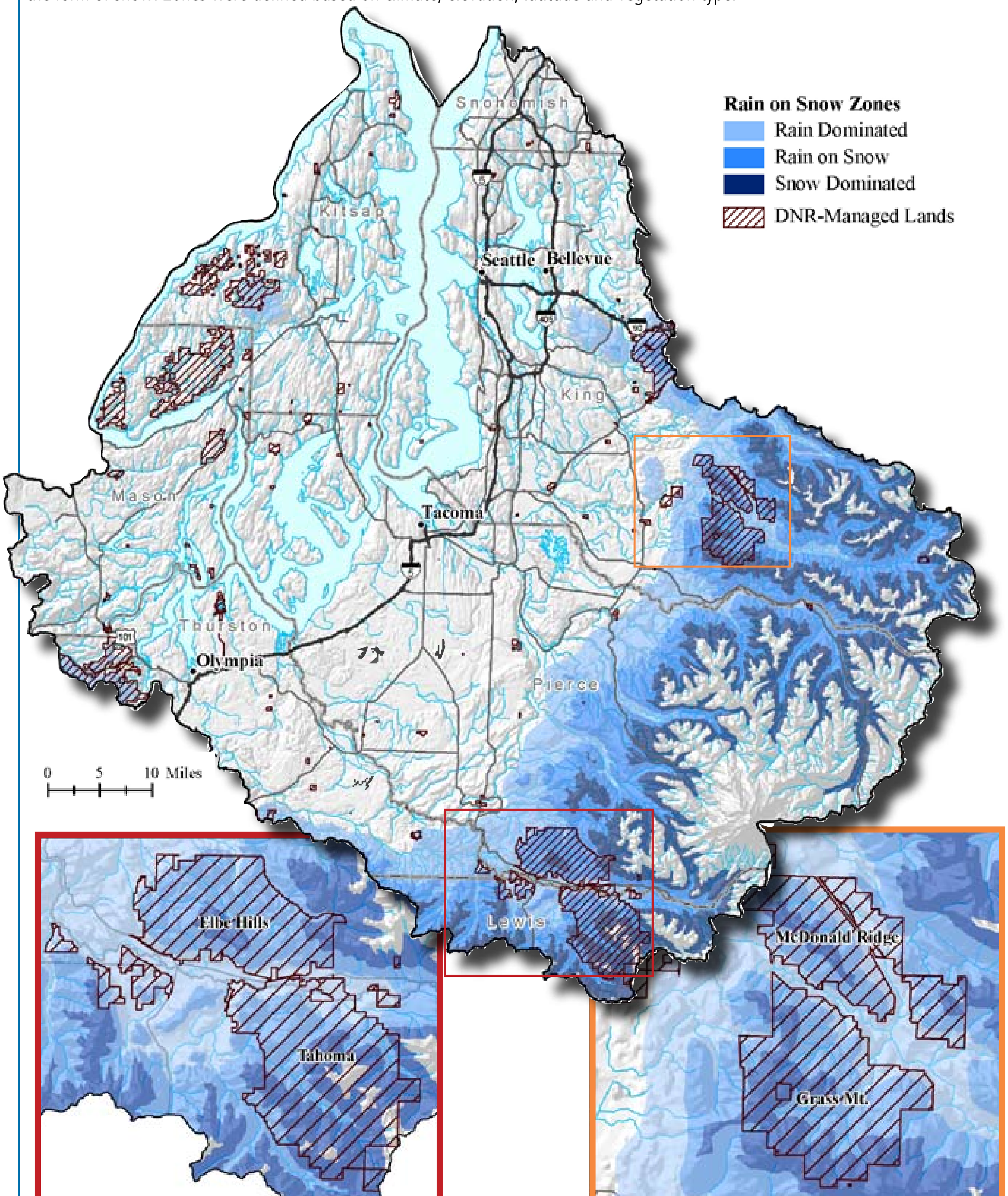
Under DNR's procedure for *Assessing Hydrologic Maturity*[5] at least 66 percent of each sub-basin in the rain-on-snow and snow-dominated zones must remain in a hydrologically mature condition before any variable retention harvests may occur. DNR defines forest stands as hydrologically mature when the cohort is older than 25-years-of-age with an RD (Text Box 3-2, p. 47) greater than or equal to 25. This procedure helps DNR reduce impacts to individual watersheds by spreading harvests out across many watershed sub-basins in areas vulnerable to peak flows caused by rain-on-snow events (Text Box 3-4). For further discussion and

Text Box 3-4 depicts the main processes of the hydrologic cycle (Brooks and others 1997; Fetter 2001) described below.

- **Precipitation** comes in the form of rain or snow at higher elevations (refer to Map 3-3, p. 55).
- **Interception** occurs when precipitation is blocked and stored by vegetation or tree crowns. Some intercepted precipitation is returned to the atmosphere through evaporation and never reaches the forest floor. When vegetation intercepts snow, large differences in snow accumulations can result, in turn producing differing amounts of water during snow melt events.
- **Evaporation** occurs when liquid water on land surfaces, soil, or vegetation is released into the atmosphere as a gas because of changes in temperature, solar radiation, or wind.
- **Evapotranspiration** is the combined effect of water evaporating from vegetative surfaces plus water vapor released through the biological process of transpiration.
- **Infiltration** is the process of water seeping (percolating) into surface soils. Infiltration rates depend on factors that include the physical qualities of the soil, vegetation, and precipitation. Infiltrated water can percolate down to become subsurface or groundwater flow, or can be taken up by roots and be transpired.
- **Surface (overland) flow** occurs when soil infiltration is reduced because of the saturation or compaction of soils, leading to flow over land and eventually to stream channels.
- **Subsurface flow** occurs as infiltrated water flows through pore spaces in the soil and rock that contain both water and air (Fetter 2001). Subsurface water can be stored, taken up by tree roots, move laterally and contribute to stream flow, or percolate downwards into the zone where groundwater is stored.
- **Groundwater flow** occurs in the subsurface zone where all of the soil or rock pores are filled with water (Fetter 2001). The water table marks the top of the zone of groundwater flow. The water in this zone may be stored or it can flow into seeps, springs, or other bodies of water.
- **Channel flow** occurs when water from precipitation, overland flow, or subsurface flow reaches the surface and flows into a channel. Channel flow carries water and nutrients downstream and may impact the built environment during peak flow events.

Text Box 3-4. Rain-on-Snow Zones

Hydrologists have broadly defined three hydrologic zones most likely to affect peak flows: The **Rain-Dominated** zone is the lowest elevation zone where snow events are rare and rain dominates; The **Rain-on-Snow** zone is a mid-elevation band where transient snow falls, often followed by rapid snowmelt during a rain-on-snow event. This zone poses the greatest potential for impacts from changes in water quantity, especially during peak flow events; and the **Snow-Dominated** zone where precipitation falls mostly in the form of snow. Zones were defined based on climate, elevation, latitude and vegetation type.



analysis of the effectiveness of this procedure in minimizing potential adverse effects to peak flows from forest management, refer to DNR 1996 (p. 4-170 to 4-174).

What Are the Indicators for Assessing Water Quantity?

For DNR, three factors influence water quantity: precipitation type and amount, forest cover, and soil type.

PRECIPITATION TYPE, RATE, AND QUANTITY

The precipitation type, rate, and quantity can play a significant role in how water flows through a watershed. Whether precipitation falls as rain or snow can affect the seasonal timing and amount of hydrologic flow (refer to Climate, p. 55). The rate at which precipitation falls affects infiltration rates and thus subsurface and overland flow. Highest peak flows occur during rain-on-snow events when warmer conditions and large amounts of rainfall cause snow packs to melt quickly (Text Box 3-4). DNR has mapped the areas prone to major rain-on-snow events (based on elevation) and focuses on these areas in its hydrologic maturity procedure.

FOREST COVER

The amount of forest cover impacts water quantity by affecting the extent of the precipitation that is intercepted, the level of evapotranspiration, and the amount of snow that can accumulate. Consequently, forest cover affects sub-surface and overland flow (Moore and Wondzell 2005). The amount of forest cover depends on the type of disturbance or harvest (refer to Forest Conditions, p. 45) and the amount of regrowth since the disturbance occurred. Forest cover is another major component of DNR's hydrologic maturity procedure.

SOIL TYPE

Soil type is a factor determining compaction potential and thus infiltration rates (refer to Soils, p. 76). When soil is compacted and/or infiltration is reduced, the amount of overland flow can increase and flooding is more likely (Moore and Wondzell 2005). Table 3-12 illustrates the differences in erosion, compaction, and displacement potentials by WAU in the planning unit. Related to the precipitation intensities that occur, most forest soils within the planning unit have high infiltration capacities (refer to Soils, p. 76).

What Are the Current Conditions of Water Quantity?

Current conditions are assessed based on the hydrologic maturity of forested state trust lands. Of the 185 DNR-identified sub-basins in the planning unit, 26 meet DNR's requirements for management under its hydrologic maturity procedure[6]. All of the 26 sub-basins currently exceed the hydrologic maturity thresholds set forth in the procedure (refer to Appendix F).

Hydrologic maturity can also be used as a general indicator of water quantity conditions at the larger watershed (WAU) scale. Currently, in watersheds where DNR manages at least 20 percent of the area (Table 3-1), hydrologic maturity in all hydrologic zones (rain-dominated, rain-on-snow, and snow-dominated) ranges from 60 to 94 percent (refer to Table 3-10). Table 3-10 shows that, in most cases, less than one-third of each watershed is in a hydrologically immature state, and that few watersheds are at elevated risk of increased peak flows during storm or snowmelt events.

LAKE TAHUYA

Lake Tahuya is privately owned and managed by the Tahuyeh Lake Community Club. The lake was created in 1961 when an earthen dam was constructed, inundating a bog which had been mined for peat. Since that time, homes have been constructed around the lake, and many additional homes built below the dam.

Table 3-10. Percent of Watershed in a Hydrologically Mature Condition (RD>25)

Watershed	Percent of Area
North Fork Mineral	89%
Tiger	88%
Catt	84%
Howard Hansen	78%
West Kitsap	71%
East Ck.	69%
Lynch Cove	69%
North Fork Green	68%
Mashel	68%
Great Bend	68%
Reese Ck.	60%
Kennedy Ck.	60%
Mineral Ck.	56%

DNR actively manages forestlands in the sub-basins draining into the lake. In 2002, because of Community Club concerns over lakeshore flooding and possible increases in water quantity from harvesting activities, DNR conducted a hydrologic analysis for three sub-basins within the Lake Tahuya watershed (Appendix F). The analysis was meant to provide an estimate of the potential change to Lake Tahuya water levels from the influences of forest roads and harvesting. The overall analysis concluded that timber harvesting activities in the sub-basins draining into the lake probably contributed minimally to peak flow and local flooding.

In the 2002 analysis, potential changes in the lake water levels were based on estimates of changes in runoff volume with and without harvesting activities in the three sub-basins. The 2002 analysis considered a total forested area of 3,340 acres, of which 17 percent had been recently cut (or was assumed to have been cut), three percent was roads, and the rest (about 80 percent) was considered hydrologically mature forest. As part of the analysis, a memo from DNR hydrologist Jim Ryan (August 18th, 2002) suggested retaining specific percentages of hydrologically-mature forests within each sub-basin: Gold Creek (retain at least 41 percent), Tin Mine Creek (42 percent), and Grada Creek (40 percent). DNR has followed these recommendations since 2002.

As part of this environmental analysis, DNR hired a contractor to provide an independent peer review of the 2002 analysis for the three sub-basins in the Lake Tahuya watershed. The purpose of the review was to either validate the 2002 findings, or suggest changes to the management of the Lake Tahuya sub-basins if warranted. The review concluded that the 2002 analysis was based on a solid, tested, and generally accepted approach and that the original findings are still valid (Appendix F).

How Does DNR Management Affect Water Quantity?

TIMBER HARVESTING

Reductions in forest cover have been found to generally increase annual water yield (Grant and others 2008; Moore and Wondzell 2005; Chamberlin and others 1991). When trees are removed through harvesting, interception by vegetation decreases and the water content of the soil increases, which may, in turn, increase overland, subsurface, and channel flow.

Logging could result in increased stream flows during the summer (Zeimer and Lisle 1998). Summer water yields have been reported to increase after harvest for a few years before returning to pre-harvest levels (Everest and others 2004). However, because increases in low summer flows from small watersheds are generally widely scattered in time and space within larger basins, these effects are difficult to detect and are considered insignificant in larger downstream rivers.

In snow-dominated watersheds, variable retention harvesting reduces interception by trees, leading to larger and longer-lasting snow accumulations than in areas not harvested, potentially increasing water yield, especially during snow melt events (Grant and others 2008). Studies have shown that harvesting in rain-dominated catchments reduces extreme summer low flow rates for a few years following harvest (Moore and Wondzell 2005).

In examining the relationship between peak discharge, forest removal, and regrowth in 10 small watersheds in western Oregon, Jones (2000) concluded that with 50 years of recorded data, extreme floods and rain-on-snow events are so rare that it is difficult to assess the statistical significance of changes in peak flow. Zeimer and Lisle (1998) concluded that it is difficult to determine the size of large floods because forest practices usually affect only a small portion of large basins.

Soil compaction, which may result from the operation of heavy machinery on some soil types, can reduce soil permeability, decreasing infiltration and thereby additionally contributing to overland flow. When combined, these changes in flows may affect the timing and magnitude of peak flows, particularly as measured in smaller basins (Grant and others 2008; DNR 2004, p. 4-117).

ROADS

Road construction and use greatly compact soils, resulting in less infiltration and therefore in greater volumes of overland flow that can reach streams more rapidly and increase channel flow (refer to Roads, p. 82). Clearing vegetation to construct roads decreases vegetative interception and evapotranspiration (Moore and Wondzell 2005). Although few studies have separated the impacts of roads from timber harvest on peak flows (Grant and others 2008; Moore and Wondzell 2005), it is known that roads can affect the routing of both overland and subsurface flows. New road networks can alter how water is routed (and speed up delivery to stream channels) when the paths of either overland or subsurface flows cross roads.

RECREATION

Similar to road impacts, recreational uses can compact soil, decreasing water infiltration, increasing runoff, altering the routing of overland and subsurface flows, and leading to increased erosion (Webb 1983; Recreation, p. 85; Soils, p. 76).

Water Quality

Water's physical, chemical, and biological characteristics are measured against a set of established standards to define its quality. Water quality is determined by variables that include temperature, sediment and organic input, contaminants, and quantity (DNR 2004; Sharpe and DeWalle 1980). These variables are influenced by factors such as local weather and climate, stream morphology, sources of erosion, levels of chemical use, contaminant migration pathways, and the amounts and types of vegetation near streams.

Why Is Water Quality Important?

The most important function of water is to sustain life, which requires supplies of healthy surface and groundwater. The effects of water quality in this planning unit are mainly related to fish (p. 73) and other wildlife species (p. 98), which are further discussed in their respective sections. Water quality is influenced by the functions of riparian (p. 58) and wetland areas (p. 62), soils (p. 76), roads (p. 82), forest management activities, climate (p. 55), and water quantity (p. 65). DNR management activities—including timber harvest, road construction and use, and recreation—can affect water quality substantially because they can alter both sediment input and temperature.

What Are the Criteria for Water Quality?

DNR's overarching management guidance has been to follow state and federal laws to protect water quality (DNR 1997, 2006a, 2006b; Bigley and Deisenhofer 2006). The federal *Clean Water Act* delegates authority to the state to protect aquatic habitat and domestic water supplies, among other beneficial uses.

The Department of Ecology (Ecology) rules define the acceptable water quality standards for temperature, sediment, and turbidity levels (DNR 2001, Table 3.6-1, p. 3-105). The *Washington State Forest Practices Rules* provide further guidance by setting limits on pollutants in lakes, rivers, and marine waters. These levels were updated by *Washington Administrative Code* (WAC) Chapter 173, Section 201c in December 2006, although there is not a comparative table in the Forest Practices publication. These levels were used in DNR's 2004 *Sustainable Harvest Final EIS*, "to provide for the protection of designated uses, including public water supply; wildlife habitat; and salmon spawning, rearing and migration" (p. 4-127).

Specific objectives aimed at protecting water quality were identified in the 2001 *Forest Practices Final EIS* section on water quality (p. 3-101). DNR uses these objectives to design its best management practices which are employed in day-to-day operations. These objectives are designed to protect areas where groundwater enters into surface water supplies; prevent harvest in riparian management zones within 25 feet of a stream; reduce overall sediment delivery to streams by limiting erosion from timber harvest, roads, and recreation; and follow *Forest Practices Rules* regarding herbicide and fertilization treatments to protect key riparian plant species and reduce impacts to fish and aquatic wildlife.

What Are the Indicators for Assessing Water Quality?

DNR focuses on four measures to indicate the level of water quality: temperature, sediment, turbidity, and herbicide/fertilizer levels. Changes in these variables have an impact on the water quality necessary for beneficial uses, most importantly, aquatic habitat.

WATER TEMPERATURE

Water temperature is affected by solar radiation, groundwater inflow and outflow, and other factors. Extreme fluctuations in water temperature in streams, rivers, and lakes can greatly affect the suitability of habitat for fish and aquatic life. Streamside vegetation shades the water, thereby limiting extreme daily fluctuations in temperature. Groundwater inflow and outflow in streams can also reduce these fluctuations (Water Quantity, p. 65). The lower temperatures that result can maintain higher dissolved oxygen levels (DNR 1996), which benefits fish because reduced levels of dissolved oxygen in streams can adversely affect fish health and reproductive conditions (p. 73) as well as other aquatic life. Groundwater also provides stream recharge in low flow areas (Boyd and Sturdevant 1997) and may be tied to lower stream temperatures. Factors such as air temperature, channel width and depth, and flow volume can also affect stream temperature, but are particular to location and season and therefore are not discussed here.

SEDIMENT

Water quality is affected when sediment is transported and deposited in a water body. The amount and size of sediment is directly related to the amount of water flow moving it downstream. Sediment deposited into streams, lakes, rivers, and wetlands can affect fish habitat. Sediment entering into spawning gravels inhibits the circulation of oxygenated water which can suffocate and kill eggs. For more details on the effects of sediment on fish habitat, refer to DNR 2001 (p. 3-7) and fish (p. 73). Another negative impact of sediment on water can occur when suspended soil particles carry nutrients such as nitrogen into streams, causing changes in stream chemistry (Brooks and others 1997). Increased nutrient levels can lead to algal blooms or aquatic plant growth, which then reduces oxygen levels in water.

TURBIDITY

Turbidity is the measure of cloudiness in the water column attributable to suspended sediment, such as silt and organic or inorganic material. Low turbidity means that the water is clear. As with air quality, solids that are invisible to the naked eye may be harmful (Brooks and others 1997; EPA of South Australia 2008; Princeton University 2006). Increased turbidity in streams may lead to decreased levels of primary productivity and overall food production, which in turn may decrease the numbers of juvenile salmonids and other aquatic wildlife (Haggerty 2004).

HERBICIDE AND FERTILIZER LEVELS

Generally, herbicides and fertilizers are used to enhance a site by removing competing vegetation or improving soil conditions. When herbicides and fertilizers are applied, the weather, timing, type, and method of application can influence their concentration in water and their ability to reach streams or groundwater. Changes in the chemical composition of streams and groundwater resources can indicate run-off and infiltration of fertilizers and herbicides.

What Are the Current Conditions for Water Quality?

The quality of surface water from forested state trust lands is generally good, making forests a valuable source of drinking water that typically requires little treatment (DNR 1996). In addition, as a result of the natural soil filters, groundwater recharged from forestlands is generally of good quality (DNR 2004).

Ecology's most recent water quality assessment for Washington State, which was approved by the U.S. Environmental Protection Agency (EPA) in November 2005 (Ecology 2008b), is the most comprehensive assessment available for compliance with water quality standards in the state. When stream locations identified by Ecology (2008b) were compared with DNR-ownership maps, DNR found only a few temperature-impaired stream segments were near DNR-managed lands within the planning unit. Those stream segments include Gale Creek and up to three segments of the Green River downstream from Howard Hanson Dam.

No watersheds within the planning unit contained greater than five percent of stream segments listed as impaired according to a set of standards for dissolved oxygen or fine sediment (Ecology 2008b).

None of the herbicides or fertilizers that DNR uses were mentioned in the Ecology report, although some of the rivers, lakes, and estuaries that receive runoff from watersheds in the planning unit were listed for ammonia and/or total phosphorus, elements contained by many fertilizers.

The 2004 *Sustainable Harvest Final EIS* cited several monitoring studies that showed significant short-term increases of ammonia, phosphorus, and other nutrients, typically following applications of urea and phosphorus-rich fertilizer. However, none of these studies measured concentrations exceeding water quality standards or detected accelerated eutrophication (algae growth). Streamside vegetation can temporarily degrade surface water quality (DNR 1996) as leaves and litter fall from deciduous trees, especially in the autumn; while these nutrient fluxes could increase ammonia and phosphorous levels, they were not measured in the study.

These findings indicate that DNR forest management activities are not currently diminishing water quality within the planning unit.

How Does DNR Management Affect Water Quality?

By protecting or limiting areas near streams from disturbance such as timber harvest, road construction, and recreation DNR strives to maintain good water quality and to preserve the beneficial uses of water.

LAND MANAGEMENT PRACTICES (including roads)

The soils (p. 76), roads (p. 82), and riparian (p. 58) sections describe the processes which cause sediment to move into streams and how wetlands (p. 62) and riparian areas buffer and intercept displaced sediment. In order to reduce sediment delivery to streams, DNR uses best management practices for timber harvesting and road building outlined and documented in its policies and procedures. DNR limits direct sediment delivery by protecting streambanks and their vegetation from disturbance which generally keeps sediment intact, at least at the source.

DNR rarely uses fertilization treatments on its lands, in this planning unit. In the last 40 to 60 years, the planning unit managers reported using a biosolid ground application fertilizer on less than 100 acres.

RECREATION

Many recreational uses that occur near or through streams, rivers, and lakes can cause numerous water quality issues (p. 70). These issues can include vegetation loss along streambanks and sediment disruptions in the streambed. Both motorized and non-motorized recreational uses can increase erosion and turbidity (Heede 1983) resulting in impacts to fish (p. 73) and other aquatic species (Kolbe and Luedke 1993). However, ORVs can also release gasoline and motor oil into water and soil as a result of inefficient combustion and emission (Havlick 2002).

NITROGEN LEVELS IN THE HOOD CANAL

During the Draft EIS comment period, a commenter expressed concern that nitrogen-fixing plants near the Hood Canal might be leaching nutrients from forested state trust lands into nearby streams and water bodies. Scotch broom (*Cytisus scoparius*), an invasive nitrogen-fixing shrub, may colonize newly-harvested areas in the Puget lowlands, where it competes strongly with young conifer trees. In such cases, DNR actively manages scotch broom to reduce its presence and ensure full stocking of conifers. This action would subsequently reduce the amount of nitrogen-fixation that would occur.

Soils on lands surrounding the Hood Canal are generally young, glacially-derived, and nutrient-poor (NRCS 1980). Studies have shown that when excess nitrogen is available in these soils, much of it is rapidly taken up by plants (Fenn and others 1998). These nutrients may be held in the soil profile or vegetation for many months or years (Fenn and others 1998; Flint and others 2008). A basic conclusion in the Flint and others (2008) study was that the Hood Canal region is nutrient-limited but because of the soil composition (refer to Soil, p. 76) even the nutrient poor plants are not always able to hold nitrogen or other nutrients on-site during major storm events. Therefore, neither DNR nor private management tactics could protect nitrogen leaching from soils or plants into the water system in extreme events, but there is no evidence to show that DNR's current management practices are adding to the nitrogen problem.

The *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006) recommends forested buffers near streams. The strategy is intended to increase biologically diverse mature forests along streams and other water bodies. The vegetation in these areas would further intercept nutrients and filter sub-surface flow. Under this strategy, buffers are maintained on DNR-managed lands near the Hood Canal.

Additionally, within the past decade no nitrogen-based fertilizers have been applied to forested state trust lands with waters that drain into Hood Canal.

Fish

Why Are Fish and Aquatic Species Important?

Fish are important natural resources that have ecological, economic, and cultural significance in Washington. Pacific salmon and trout are good indicators of a properly functioning aquatic ecosystem because they require cool, clean water, complex channel structures and substrates, and low levels of fine sediment (Bjorn and Reiser 1991). Pacific salmon are an important means of transporting marine nutrients from salt water across ecosystem boundaries to freshwater and terrestrial ecosystems (Cederholm and others 1999). In addition, Pacific salmon and trout populations are sources of viable commercial industries and recreation.

Which Fish Species Are of Concern?

Fish species of concern include Chinook (*Oncorhynchus tshawytscha*), sockeye (including resident kokanee [*Oncorhynchus nerka*]), coho (*Oncorhynchus kisutch*), and chum salmon (*Oncorhynchus mykiss*) and steelhead (includes resident rainbow trout [*Oncorhynchus mykiss*]), coastal cutthroat (*Oncorhynchus clarki*), bull trout (*Salvelinus confluentus*), and Dolly Varden trout (*Salvelinus malma*). These species all have commercial or sport fishing value and are known to be sensitive to forest management activities. In addition, the Puget Sound populations of Chinook salmon, steelhead and bull trout, and the Hood Canal population of summer chum salmon, are also listed as threatened under the federal *Endangered Species Act* (ESA). Coho salmon are classified as a federal species of concern and a petition to list the Lake Sammamish population of kokanee is currently under review by the U.S. Fish and Wildlife Service. Refer to the 2001 *Final EIS for Forest Practices Rules* (p. 3-120 to 3-129) for additional details regarding these species. The 2004 *Sustainable Harvest Final EIS* (p. 4-140 to 4-146) contains a thorough discussion of the life histories and habitat requirements of Pacific salmon and trout.

What Are DNR's Criteria for Fish?

The criteria to assess fish are to maintain and restore salmonid freshwater habitat on DNR-managed lands, contribute to the conservation of other aquatic and riparian obligate species (DNR 1997, p. IV.55), and minimize the adverse effects of upland management activities on riparian areas (Bigley and Deisenhofer 2006, p. 2).

What Are the Indicators for Assessing Conditions for Fish?

LARGE WOODY DEBRIS

Large woody debris in streams provides food, cover, and building material for many aquatic life forms; is important for stream nutrient cycling; and offers cover for juvenile and adult fish (Marcus and others 1990). Pools formed by large woody debris accumulations are important habitat for rearing salmon and trout (Heifetz and others 1986; Murphy and others 1986). This debris also slows water velocity in flood events lessening the likelihood of fish spawning habitat being scoured, which would be detrimental to eggs and any fish that may be incubating in the stream gravel (DNR 2004, p. 4-144). Refer to the riparian section (p. 58) for additional discussion of large woody debris.

LEAF AND NEEDLE LITTER

The abundance and diversity of macroinvertebrates— important food sources to salmonids—depend on algae and detrital food sources from leaf and needle litter, branches, and stems originating from the riparian zone. Refer to the riparian section (p. 58) for more discussion of leaf and needle litter.

WATER TEMPERATURE

Water temperature influences virtually every biotic component of stream ecosystems, and cool water is particularly critical to salmon and trout. Water temperature influences salmonids' resistance to some diseases, how fast eggs mature, when fry emerge from the nursery gravels of the streambed, when adult salmon return to their natal streams, and whether they survive the warm summer months to spawn in the fall or winter (Thompson 2005). Refer to the riparian section (p. 58) for additional information on water temperature, stream shading, and microclimates.

COARSE SEDIMENT

Particles of sand, gravel, and soil carried by the flow of a stream on or immediately above the streambed are necessary as a substrate for cover and spawning habitat for fish. Increased coarse sediment particles can fill pools and change water flow in the stream channel (Spence and others 1996). Refer to water quality (p. 70) and soils (p. 76) for additional discussions of coarse sediment.

FINE SEDIMENT

High levels of fine sediment in streams can affect water quality and aquatic habitat adversely, both directly and indirectly. Most directly, spaces between individual pebbles and gravels in a streambed are important; they must be maintained so that eggs can incubate and embryos survive, juvenile salmonids can overwinter, and macroinvertebrates can be produced (Bjorn and Reiser 1991; Furmis and others 1991; Henjum and others 1994; Rhodes and others 1994). Sediments also can contribute nutrients, oxygen-demanding organic materials, harmful minerals, or chemicals that impair water quality and fish survival.

Indirectly, sediments can fill the spaces between the gravel and prevent the flow of oxygen-rich water to fish eggs (Bjornn and Reiser 1991) or can smother fish eggs and developing young found within the gravel (Spence and others 1996; Washington Forest Practices Board 2001). Fine sediment can interfere with feeding behavior and damage gills in fish (Hicks and others 1991), decrease salmon prey, smother insects, and decrease available habitat of macroinvertebrates (Spence and others 1996). Refer to water quality (p. 70) for additional information on fine sediment.

WATER QUANTITY

Peak flow events (such as storms and rain-on-snow occurrences) can destabilize and transport large woody debris, fill pools with sediment, and destroy salmon spawning habitat. It can scour complex channels (streams with riffles, pools, and large woody debris) into uniform channels (streams devoid of riffles, pools, and large woody debris) with limited habitat value (DNR 1997, p. III.64). On the other hand, low water quantity can limit the number of stream reaches that can be used for habitat and spawning and delay salmon from moving from the marine environment into freshwater. Refer to water quantity (p. 65) for additional information.

WATER POLLUTION

Water quality contaminants (for example, petroleum products, chemicals, fertilizers, herbicides, sewage, and heavy metals) can impair the growth of fish severely or kill them (DNR 2004, p. 4-146).

FISH PASSAGE

The most common barrier to fish passage that is influenced by forest management activities are stream crossings by forest roads. Culverts at stream crossings can prevent fish passage because of factors such as excessive outfall drops and high water velocities as well as shallow water depths which can cause riffles between pools to become completely dry or block fish passage (DNR 2004, p. 4-146).

What Is the Distribution of Salmonids in the Planning Unit?

Table 3-11 lists the overall distribution of salmon within the planning unit, while Maps F-1, F-2, and F-3 in Appendix F illustrate their distribution. Forested state trust lands contain approximately four percent of the anadromous salmonid distribution within the planning unit, while accounting for five percent of the resident salmonid distribution. Few streams on DNR-managed land within the planning unit are known to support bull trout, although bull trout may be more abundantly distributed within or adjacent to larger rivers. In the Hood Canal, summer chum populations spawn in rivers that are on or flow out of state trust lands.

Table 3-11. Salmonid Distribution by Landowner (DNR 2008)

Type of Salmonid	Stream Miles				
	DNR Forested Trust Land	Federal Land	Private Land[1]	Other[2]	Total
Anadromous	73 (4%)	99 (5%)	1,438 (74%)	323 (17%)	1,933
Resident	124 (5%)	89 (4%)	1,659 (74%)	383 (17%)	2,254
Bull Trout	2 (>1%)	139 (25%)	268 (49%)	144 (26%)	552

1 The "Private Land" category includes industrial forestland, agricultural, residential, industrial, and commercial lands.
2 The "Other" category includes DNR-managed non-forested land, municipal lands, and water bodies (larger streams, rivers, lakes, and marine shorelines).

What Are the Current Conditions for Fish?

Forested state trust lands are estimated to include approximately 1,183 miles of streams (Table 3-8); an estimated 363 miles (30 percent) are fish-bearing. The fish habitat within streams and rivers is surrounded by Riparian Management Zones to help maintain it and to restore salmonid habitat.

Refer to the riparian section (p. 58), 1997 *Habitat Conservation Plan* (p. III.53 to III.73), and the 2006 *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006) for information about current riparian management. Numerous factors affect the numbers of fish population and many of them are not related to forest management activities on forested state trust lands. Consequently, the analysis in Chapter 4 focuses on fish habitat rather than fish population numbers.

How Can DNR Management Affect Fish?

TIMBER HARVESTING

Timber harvesting may affect fish by changing the forest structure in the uplands and potentially changing the overland flow of water to riparian areas (Water Quantity, p. 65). Forest management activities may influence components of the aquatic ecosystem such as coarse and fine sediments, hydrology, large woody debris, leaf/needle litter recruitment, floodplains and off-channel features, water temperature, forest chemicals (contaminants), and fish passage.

ROADS

Roads have the potential to produce sediment (Megahan and Kidd 1972; Cederholm and Reid 1987; Chamberline and others 1991; Nolan and Janda 1995; Bolda and Meyers 1997) through mass wasting or surface erosion (Beschta 1978; Bilby and others 1989; Coe 2004; Burroghs and others 1976; Clayton 1983; Furniss and others 1991; Larsen and Parks 1997; Larsen and Simon 1993). Surface erosion is particularly affected by road traffic. Sedimentation can increase with traffic use as well as road surfacing and drainage (DNR 2001, p. F1-17). Roads can impact fish by creating barriers to migration; opening the forest canopy, thus raising water temperatures; and altering stream flows. For additional information refer to roads (p. 82).

Salmonids: Fish belonging to a group that includes salmon, trout, and char. This group belongs to the family Salmonidae.

Anadromous salmonid: Salmon that divide their lives between freshwater and the ocean. They are born in freshwater, mature at sea, and return to their natal streams to spawn a new generation.

Resident salmonid: Salmon that spend their entire lives in freshwater.

RECREATION

Recreation activities can affect fish by degrading habitat. Trails can contribute to sediment delivery to streams. Trails used by motorized vehicles have the highest potential for erosion and rutting that could deliver sediment to streams. Additionally, unauthorized user-built trails often cross riparian areas and streams, impacting fish habitat directly by destroying the physical environment or indirectly by destroying large woody debris, introducing pollution and sedimentation, and causing bank instability.

Recreational fishing in streams, rivers, and ponds affects fish by removal. However, populations are monitored carefully by WDFW so that recreational fishing does not deplete fish populations. Some lakes and ponds on forested state trust lands are stocked with trout for recreational fishing. Species released into lakes and ponds located on forested state trust lands include native species such as rainbow trout (*Oncorhynchus mykiss*), triploid rainbow trout, and cutthroat trout (*Oncorhynchus clarki*) (WDFW 2007). In some ponds and lakes where fish were historically introduced, populations have been maintained without stocking.

Soils

DNR (1996) defines soil as "the material at the earth's surface which is capable of supporting plants. It is the ecosystem element located at the interface of the climatic, geologic, hydrologic, and biologic ecosystem elements. It is a dynamic, natural, three-dimensional body composed of weathered mineral and organic material that provides plants with air, water, root anchorage, and nutrients."

Soil is composed primarily of sand, silt, and clay particles which have been physically or chemically weathered from a parent material and are intermixed with decomposing bits of plant and animal materials. Biological and climatological factors control the rate of physical and chemical weathering and the differentiation of soil into distinct horizons. Most often, soils contain three horizons, known as A, B, and C. The A horizon is closest to the surface, includes a large amount of organic material, and is most affected by biological factors such as invading plants and animals and climatological factors such as temperature and precipitation. The B horizon lies below the A horizon and has less organic material, has more and larger fragments of parent material, and frequently shows redeposited material derived from the A horizon. The lowest layer, the C horizon, is compact and largely consists of decomposed or shattered regolith or parent material. Each horizon has unique qualities which determine a soil's productivity, erosion potential, and susceptibility to compaction and displacement. These qualities affect several associated environmental attributes including fish habitat (p. 73), water quality (p. 70), water quantity (p. 65), and tree growth rates.

Why Are Soils Important?

Healthy soil is a critical component of the forest ecosystem. Not only does it serve as the basis for plant growth, it also provides habitat for numerous insects and fungi, creating an environment where organic matter can be recycled back into the ecosystem. Like water, human survival depends on the conservation of both the body and fertility of soil (Kohnke and Franzmeier 1995). As a medium for plant growth, soil serves four functions: 1) it anchors roots; 2) it supplies water; 3) it provides air to plant roots; and 4) it furnishes minerals for plant nutrition (Kohnke and Franzmeier 1995). DNR forest management relies on the productivity and conservation of soil to support a healthy ecosystem and yield desired forest products (DNR 1997).

What Are the Criteria for Managing Soil Productivity?

DNR's criteria for maintaining soil productivity are based on best management practices described in the *Forest Practices Rules* (DNR 2001) and the *Habitat Conservation Plan* (DNR 1997). These soil-related best management practices focus on limiting soil compaction, displacement, and disturbance; minimizing surface erosion; and preventing management-related mass wasting such as landslides. The *Forest Practices Rules* require that landowners comply with the State Environmental Policy Act environmental checklist when proposing forest practices activities on potentially unstable slopes[7] and that forestland be left in a condition conducive to future timber production[8]. Other rules related to soil disturbance include equipment limitation zones[9]; ground-based logging (including rutting and displacement of soils)[10]; and minimizing the road network[11].

What Are the Indicators for Assessing Soil Conditions?

One internationally-recognized indicator of soil conditions and potential management impacts is the percent of a watershed harvested (Montréal Process 1995). Another indicator is the number of times a forest is harvested over a projected time frame. From these indicators, DNR can infer impacts to soil properties, including productivity, compaction, erosion, and displacement (Table 3-12).

PRODUCTIVITY

Soil productivity refers to the soil's fertility or capacity to grow vegetation. Soil is the medium that supports most plants on upland environments (DNR 1997). Therefore, land use activities that affect soil productivity will also affect plants. In general, more productive soils support more biomass (tree volume, wood production), providing important social benefits, and earning more revenue for the trust beneficiaries.

COMPACTION

Compaction is the loss of pore space within a soil profile because an external force pushes particles closer together. It typically occurs when heavy machinery or objects such as logs fall on or move over the soil but it can also result from mineral soil being exposed to the impact of raindrops. Small roots are in the uppermost 2 to 4 inches (5 to 10 centimeters) of soil horizons, which is the area most affected by harvesting, road construction, and recreation trail use. These small roots gather nutrients and water for trees and can be damaged or broken when soil is compacted around them.

Soil pore space is essential to the survival of plants. Water and air enter the soil through pore spaces where tree roots grow, using the water, carbon dioxide (CO_2), and nutrients available to sustain plant growth. Because compaction reduces pore space, the availability of water, carbon dioxide, and nutrients is also reduced, impeding growth (Heilman 1981) by limiting the root's ability to absorb water and nutrients. Moderate or high levels of soil compaction can reduce infiltration rates and overland flow can result, which may lead to surface erosion on sloping terrain. In some soils, compaction can ultimately decrease overall productivity (Cafferata 1992; Grier and others 1989) although several recent studies have shown high levels of compaction as inconsequential for growth in newly planted stands (Ares and others 2007). On the other hand, compaction can be beneficial in some soils as it increases water holding capacity, unsaturated water flow, and root contact with soil (Ares and others 2007).

EROSION

Erosion is the movement of soil particles through particle detachment, transport, and deposition (Megahan 1991). Erosion can be caused by the effects of wind, water, or other forces that detach particles or move the soil. Erosion potential refers to a soil's resistance to detachment of soil particles and their transport (Dyrness 1967). Forms of surface erosion include rainsplash, sheet, rill, gully, and dry ravel. Mass-wasting is the down-slope movement of loose soil and rocks by the force of gravity without the direct aid of a transporting medium such as water, ice, or wind (Nelson 2003).

Erosion potential often depends on slope, soil texture, and vegetative cover (DNR 2001, p. 3-9). Although it is a natural process, erosion can be a management concern for two reasons. First, soil loss affects productivity and can reduce the capacity of a particular site to grow trees. Second, the transported soil (or sediment) particles can have detrimental effects on downslope resources. Sediment transported through surface erosion can deposit in streams, lakes, and wetlands and adversely affect water quality and fish habitat adversely. Sediment transported through mass wasting processes such as landslides can have similar effects on aquatic resources, and can also pose a threat to publicly or privately-owned infrastructure (roads and bridges), private property, and public safety. The type and particle sizes within a given soil affect its erosion potential, which in turn determines the risks to water quality (p. 70) and fish (p. 73).

DISPLACEMENT

Displacement is the localized movement of soil that results from an external force applied to the soil surface. The most common forest activities that result in soil displacement include log yarding that uses heavy ground-based equipment such as skidders, bulldozers, and excavators as well as recreation that involves off-road vehicles. Displacement potential is a measure of the susceptibility of a particular soil to rutting. Ruts can intercept shallow groundwater, concentrate surface flow, and potentially initiate rill and gully erosion.

What Are the General Soil Conditions?

Soil characteristics are variable throughout the planning unit because of the diversity of the soil forming factors. The type of parent material (mineral or rock material from which a soil develops) largely determines the susceptibility of the resulting soil to land use impacts. For areas closer to the Puget Sound, such as the Green Mountain and Tahuya state forests, glacial deposits are the dominant parent materials. Glacially-derived soils tend to be shallow since they are relatively young, having developed over just the past 10,000 years or so. In contrast, volcanic rocks are more prevalent within areas like the Elbe Hills and Tahoma state forests near Mount Rainier (DNR 2008, GIS Soils Layer). These soils tend to be deeper, owing to a longer period of development. Graham and others

Text Box 3-5. Landslides 101

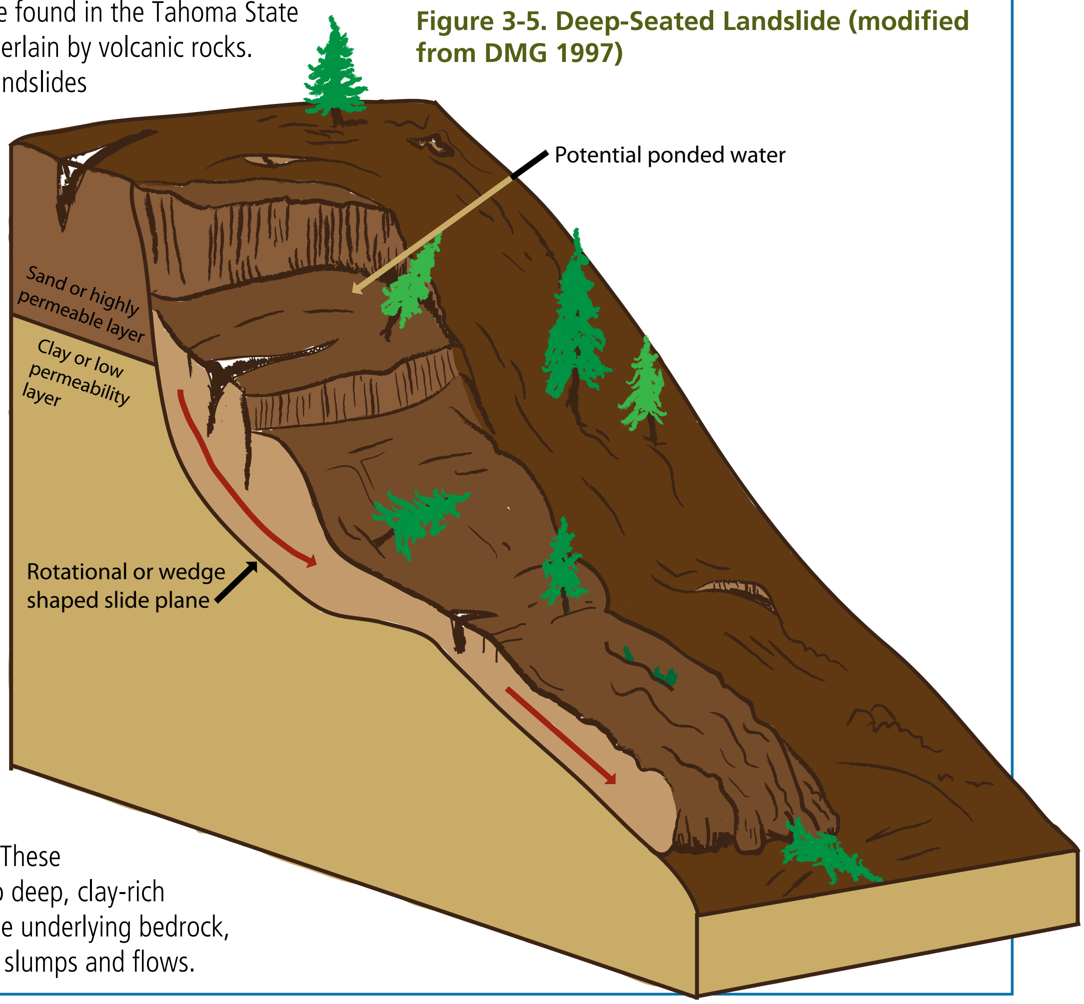
The topography, geology, and climate of the South Puget planning unit predispose the area to mass wasting or the downward movement of soil caused by gravity (refer to Figure 3-6). Steep terrain, glacial and volcanic parent materials, and abundant rainfall combine to make the area prone to landslides.

Generally, landslides can be divided into two categories: deep-seated and shallow-rapid. This section will describe each type, discuss the differences and similarities between the two, and explain the factors that contribute to their occurrence.

Deep-seated landslides are mass soil movements where the slip plane (or rupture surface) is far below the ground surface (refer to Figure 3-5). Oftentimes, landslides with slip planes below the rooting depth of trees (6 to 10 feet [2 to 3 meters]) are considered deep-seated. The most common types of deep-seated landslides in the South Puget planning unit are earth slumps and earthflows. These landslides are characterized by slow, chronic movement (on the order of inches to feet per year) that is commonly triggered by seasonal or inter-annual fluctuations in precipitation, stream undercutting, and large magnitude earthquakes. Because the rate of slope movement is typically slow, the slide mass involved in a deep-seated landslide often appears intact and can be covered with large, mature trees. These landslides can range in size from less than an acre to many hundreds of acres. Deep-seated landslides are characterized by benchy, hummocky, and/or broken ground, extensive seepage, ponded water, ground cracks, and tipped, swept, or otherwise deformed trees (Figure 3-5). Due to the slow, progressive nature of deep-seated slope movement, the absolute age of these landslides is often unknown (Salo and Cundy 1987).

Deep-seated landslides are common in areas dominated by glacial deposits such as the Tahuya State Forest, but they can also be found in the Tahoma State Forest and other areas underlain by volcanic rocks. Most often, deep-seated landslides form when mechanically weak materials overlie more competent (strong) materials. Where glacial sediments dominate, these landslides commonly form where coarse sands and gravels lie atop less permeable clays or silts. Water moving downward through the sand/gravel layers becomes perched atop the clay or silt layer, creating a zone of weakness that may serve as a slip plane or rupture surface. Similar conditions are present in some of the volcanic rocks in the planning unit. These rocks typically weather into deep, clay-rich soils that may slide atop the underlying bedrock, forming deep-seated earth slumps and flows.

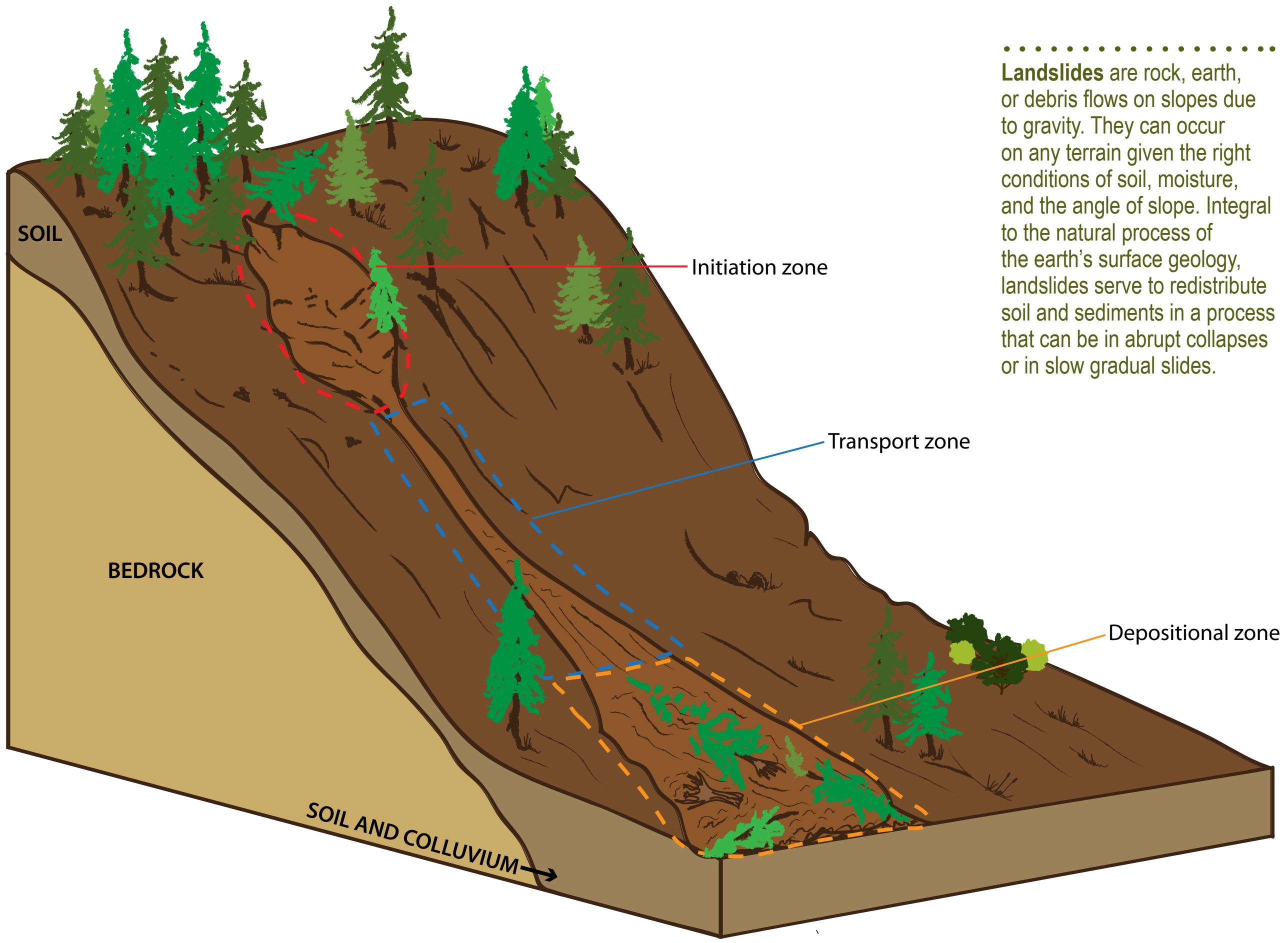
Figure 3-5. Deep-Seated Landslide (modified from DMG 1997)



Text Box 3-5. Landslides 101 (continued)

Unlike their deep-seated cousins, the slip plane of a **shallow-rapid landslide** is relatively close to the ground surface. Landslides with slip planes less than six feet below the ground surface are considered shallow. Also, as the name implies, these landslides move relatively quickly, sometimes as much as feet per second. Shallow-rapid landslides include debris avalanches, debris slides, debris flows, and debris torrents. Debris flows and debris torrents occur when a landslide mass enters a high-gradient stream channel. Upon entering the stream, the landslide mass becomes more liquid and, as a result, more mobile. The mobile slurry of sediment, wood, and water flows down the stream, scouring the channel bed and banks, and increasing in volume as it progresses. Debris flows and torrents may travel a mile or more from their point of initiation and can have devastating effects on roads, bridges, and structures that lie within their travel path. Shallow-rapid landslides are commonly triggered by high-intensity rain or rain-on-snow events but like deep-seated landslides, they can also result from stream undercutting and large magnitude earthquakes.

Figure 3-6. Debris flow (a form of shallow-rapid landslide; modified from DMG 1997)



Landslides are rock, earth, or debris flows on slopes due to gravity. They can occur on any terrain given the right conditions of soil, moisture, and the angle of slope. Integral to the natural process of the earth's surface geology, landslides serve to redistribute soil and sediments in a process that can be in abrupt collapses or in slow gradual slides.

While the underlying geology strongly influences deep-seated landslide formation, the occurrence of shallow-rapid landslides is more directly related to topography and weather patterns. Shallow landslides generally originate in steep (>70 percent or 35 degrees), convergent topography that concentrates shallow groundwater. Landforms with these characteristics are commonly known as bedrock (or colluvial) hollows, convergent headwalls, and inner gorges. These landforms have a higher incidence of shallow landslides relative to more gently sloping terrain. When shallow landslides occur, they are typically triggered by intense rainstorms or storms known as rain-on-snow events (p. 65). During these storms, large amounts of water enter the soil, increasing soil pore water pressures. If the water pressure forcing the soil particles apart exceeds the particles' capacity to stick together, the soils structure fails and a landslide results.

(1990) indicate that volcanic soils with high ash contents are particularly sensitive to the effects of forest operations. In addition to parent material, climate and elevation also play key roles in soil development and help explain variations within the planning unit (refer to Climate, p. 55).

Soil productivity is a measure of a soil's ability to produce biomass. Productivity at any particular site or location also depends on precipitation and temperature, and varies widely over the planning unit. For more information on site productivity, refer to forest conditions, p. 45. (DNR 1980 unpublished metadata).

Using DNR's soil layer data, distributions for soil characteristics were estimated for WAUs in which DNR manages 20 percent or more of the land area. These estimates are summarized in Table 3-12.

How Are Soils Affected by DNR Management?

Timber harvesting, road construction and maintenance, and some recreational uses can cause adverse impacts to soils. These impacts include soil compaction and displacement, surface erosion, mass wasting, and reductions in soil productivity. Sometimes, these processes build on one another and cause more severe impacts; for example, compacted or displaced soils can cause overland flow, leading to the development of rills or gullies and ultimately a loss of productivity. With the exception of adding nutrients directly through forest fertilization (which DNR has not done in the last decade), timber harvest has the greatest potential for altering soil nutrients (Raison and Crane 1986).

TIMBER HARVESTING

Timber harvest can remove some of the nutrients stored in tree branches, limbs, and boles; therefore, the harvest method can determine which nutrients remain in the ecosystem. Undisturbed, these tree components and their nutrients would have been recycled into the soil through decay. The degree of nutrient extraction is proportional to the type of harvesting, the volume removed, and the harvest frequency (Powers and others 1990).

After harvest, the microclimate of the site often is changed to one that favors the accelerated decomposition of residual slash and other organic material, causing an influx of nutrients into the soil (Boyle 1976). Harvesting reduces the overstory, thereby reducing evapotranspiration and canopy rainfall interception. Reductions in evapotranspiration and interception typically result in higher soil moisture levels (refer to Water Quantity, p. 65). Percolation of this newly-available water through the soil profile can accelerate the leaching of mobile nutrients such as nitrates (Blackburn and Wood 1990), raise water tables, and increase water yield.

Ground-based harvest methods have a greater potential for causing adverse soil impacts than cable

Table 3-12. Erosion, Compaction and Displacement Potential by WAU (Percent of Area)*

Watersheds	Erosion				Compaction				Displacement			
	Low	Med	High	Unk	Low	Med	High	Unk	Low	Med	High	Unk
Catt	26	64	9	1	81	14	4	1	3	1	95	1
East Creek	4	83	12	1	1	17	81	1	17	62	21	1
Great Bend	76	15	8	2	19	78	1	2	77	14	8	2
Howard Hansen	1	97	2	0	1	60	39	0	4	44	52	0
Kennedy Creek	41	38	19	1	5	59	35	1	53	27	19	1
Lynch Cove	87	1	10	2	16	81	1	2	86	2	10	2
Mashel	15	85	0	0	3	17	80	0	19	38	43	0
Mineral Creek	23	69	8	1	63	19	17	1	16	7	76	1
NF Green	14	85	0	1	1	52	47	1	6	54	40	1
NF Mineral Creek	19	72	9	1	82	13	4	1	1	3	95	1
Reese Creek	34	63	1	1	51	8	40	1	13	24	62	1
Tiger	40	54	6	0	4	41	54	0	20	56	24	0
W Kitsap	75	3	21	1	35	60	4	1	75	3	21	1
Grand Total	36	56	7	1	26	43	30	1	31	25	43	1

*Source: DNR 2007

methods. Full-suspension cable yarding causes less impact than high-lead methods, which sometimes drag harvested trees on the ground. Full-suspension yarding systems suspend the timber above the ground, resulting in minimal compaction when compared to high-lead methods and ground-based operations. Thinning activities have a lower impact in terms of soil compaction than variable retention harvests (Cafferata 1992). The most common effect on soils from ground-based forest operations is increased compaction (Ares and other 2007). Ruts created by harvest machinery can affect soil drainage and concentrate overland flow. Concentration of overland flow can lead to more severe forms of surface, rill, or gully erosion. Most soil displacement is associated with activities that compact the soil.

On slopes that have been recently harvested, saturated soil may be vulnerable to slides (Chamberlin and others 1991). In extreme cases, areas that are normally considered stable can be at risk of slope failure from prolonged heavy moisture.

Tree removal results in a loss of soil root strength in the upper soil layers. Reduced rooting strength increases the incidence of shallow landslides in steep terrain (>70 percent or 35 degrees) for up to ten years following clearcut timber harvest (Sidle 1985; Burroughs and Thomas 1977). Additional research has shown that shallow landslides can often be linked to zones of soil weakness around individual trees (Burroughs and Thomas 1977). Vegetation and ground cover have been shown to increase infiltration and reduce overland flow, therefore decreasing instability of slopes.

ROAD MANAGEMENT

Of all forest management activities, road construction and maintenance have the greatest potential for causing increases in surface erosion. When roads are constructed, the upper soil horizons are removed and a compacted, firm surface is established and maintained. Roads constructed on slopes require uphill cuts exposing soil to compaction or detachment of soil particles by raindrops. Ditch water is drained by relief culverts built to improve water movement and reduce sediment transport to streams. However, culvert undercutting can be another issue tied to erosion. When there are too few culverts along built roads or when they are undersized their failure produces large amounts of sediment which can be released, moving quickly toward water resources (refer to Roads, p. 82).

Landslide rates associated with roads are much higher than those of timber harvest alone (Simpson 2002). Road building has been shown to decrease slope stability by over-steepening and concentrating drainage water onto unstable slopes (Sidle 1985).

Roads can also impact productivity since roads are highly compacted and susceptible to particle removal by surface erosion and mass wasting. Road construction, road maintenance, and construction of log landings have the greatest impacts in terms of soil compaction. Increased runoff over compacted soils can lead to mass wasting events. For further discussion on roads, refer to DNR 2004 (p. 4-44 to 4-52), DNR 2001 (p. B-13), and roads (p. 82).

RECREATION

Some recreational activities can cause significant soil compaction. However, there are differences in the magnitude of impacts caused by different uses. Horses have been shown to cause substantially more trail erosion than hikers, llamas, or mountain bikers (Wilson and Seney 1994; DeLuca and others 1998). Trail erosion is often greater when soils are wet than when they are dry (DeLuca and others 1998). Generally, areas that experience repeated use by vehicle, horse, and foot traffic have compacted soils. These areas include trails, trailheads, campground parking areas, and established campgrounds. The surface area impacted by these activities is usually a relatively small proportion of the total area of any watershed.

Recreational activities can cause soil erosion, influence sedimentation of streams (potentially destroying critical habitat for salmon and trout), and damage fragile ecosystems (Stull and others 1979). Stream crossing points may be particularly susceptible to impacts. Trail crossings at streams increase the potential for bank erosion or direct sediment deposits into a stream. Although DNR does not harvest in areas directly adjacent to streams, streambanks are at risk from unauthorized user-built recreation trail systems. When tree root systems are destroyed and the soil is no longer held together, streambank stability is reduced, fine sediment is transported into the water, and turbidity is increased (refer to Water Quality, p. 70).

Roads

Almost all roads provide access benefits but often at a risk to the environment. If not properly managed, roads have the potential to damage the environment or provide opportunities for illegal activities. When deciding how to manage roads, DNR weighs the impacts of forest roads carefully with regard to environmental protection, public use, and forestland management needs.

The forest road network is composed of roads that are temporary, used for a single purpose and abandoned, or are permanent and used year-round for a variety of purposes. Road management consists of different phases and the geographic patterns of roads in forest landscapes also differ substantially from place to place. Roads in combination with geology and climate affect elements of the environment that include the hydrologic processes that influence sediment transport, sediment delivery and mass-wasting, wildlife, vegetation, recreational use, and natural disturbances (USDA 2001).

Why Are Forest Roads Important?

Access to forested state trust lands extends from the network of DNR and private forest roads onto county roads as well as state and interstate highways. These roads are necessary for land management activities and public use (DNR 2001). DNR management activities such as timber harvesting, replanting, fire control, and recreation require the presence and use of forest roads. Private residents with in-holdings also use them to access their properties. The greatest source of traffic on these roads is associated with harvest activities, but in some areas, that may be surpassed by traffic for recreational access (DNR 2006b).

What Are the Criteria for Managing Forest Roads?

Under the 1997 *Habitat Conservation Plan*, the criterion for road management is to minimize adverse impacts to salmonid habitat caused by the road network. The *Forest Practices Rules Road Construction and Maintenance*[12] set standards to protect water quality and riparian habitat by requiring that roads be constructed and maintained in a manner to prevent damage to public resources. DNR accomplishes this by minimizing further road-related degradation to riparian, aquatic, and identified species habitat through compliance with the *Forest Practices Rules* mentioned above. DNR can also achieve these goals by appropriate planning, design, construction, and maintenance (DNR 1997). DNR has and will continue to abandon or eliminate roads no longer needed for management purposes consistent with the state *Forest Practices Rules* and the 1997 HCP. DNR's road management accomplishments are presented in Appendix H.

The requirements for road management were designed to protect sensitive areas from the impacts associated with a network of existing roads and the construction of new roads. Locations on steep slopes, areas with unstable soils and high precipitation, or locations within 100 feet of Type 1, 2, and 3 waters and wetlands are given priority for road maintenance and abandonment (DNR 1997).

What Are the Indicators for Assessing Forest Roads?

ROAD DENSITY

Road density, as measured by mile per mile squared, is proposed as an index of several effects of roads in a landscape. Road density is a useful index of the effect of roads on wildlife populations (Forman and others 1997). Some studies have shown that a few large areas with low road density, even in a landscape of high road densities, may be suitable habitat for large vertebrates (Rudis 1995; Forman and Alexander 1998). Habitat effects of roads on the landscape include dissecting vegetation patches, increasing edge-effect, decreasing interior area, and increasing the uniformity of patch characteristics such as shape and size (Reed and others 1996). Whenever forest roads are built, changes in habitat and animal behavior can lead to changes in wildlife populations (Lyon 1983). Refer to Table 3-13 for the road densities within this planning unit.

SEDIMENT DELIVERY

Landslides or mass wasting associated with roads may be a major source of sediment to water resources as well as their riparian buffers (Bescheta 1978; Swanson and Dyrness 1975). Typical causes of mass wasting events from roads are described in soils (p. 76). Traffic generated sediment and erosion from road surfaces, cutbanks, and ditches represent a major source of road-related sediment input to streams (refer to Riparian, p. 58; Fish, p. 73). Increased sediment delivery to streams after road construction is well documented in the research and literature in the Pacific Northwest and Idaho (Bilby and others 1989; Donald and others 1996; Megahan and Kidd 1972; Reid and Dunne 1984; Rothacher 1971; Sullivan and Duncan 1981). Road runoff from heavy precipitation events can be routed directly to the stream network at stream crossings or by road-induced gullies (Wemple and others 1996). Rates of sediment delivery from unpaved roads appear highest in the initial years after building (Megahan and Kidd 1972) and correlate closely with traffic volume (Reid and Dunne 1984; Sullivan and Duncan 1981).

SITE PRODUCTIVITY

Forest roads can affect site productivity (Forest Conditions, p. 43) by removing and displacing topsoil, compacting soil surfaces, altering soil properties, changing microclimates, and accelerating erosion (USDA 2001). Other factors affecting site productivity include the frequency of disturbance, soil moisture, soil type, and road location relative to sensitive soils. Road building changes soil's physical properties including depth, density, infiltration capacity, water holding capacity, gas exchange rate, and nutrient concentrations (USDA 2001). For a discussion on the effects of road building on soil compaction, refer to soils (p. 76).

HYDROLOGY

The influence that roads have on water quantity depends on several factors, including the location of roads on hillslopes, characteristics of the soil profile, subsurface water flow, and groundwater interception (Water Quantity, p. 65). The design and placement of drainage structures, such as ditches and culverts, can affect water flow through a watershed. The proportion of the watershed occupied by roads also influences hydrology (USDA 2001) which can ultimately affect fish populations (Clancy and Reichmuth 1990; Belford and Gould 1989; Evans and Johnston 1980; Furniss and others 1991).

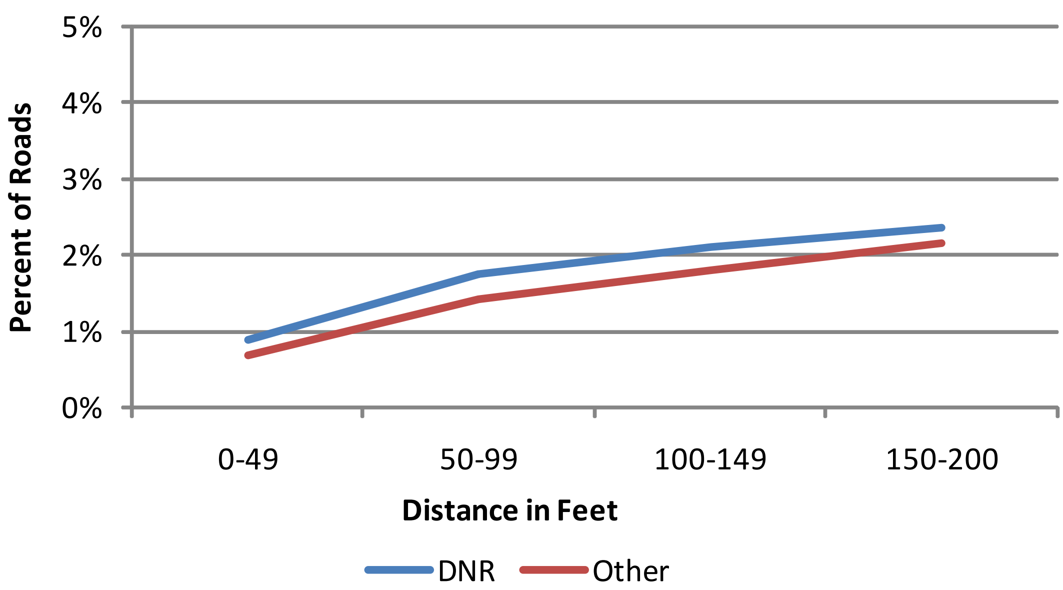
BIOLOGICAL INVASIONS (INVASIVE PLANTS)

Roads may be the first point of entry for exotic (non-native) species into a new area. Studies in western Washington have linked invasive plant movement to highways, roads, trails, railroad tracks, and power line corridors. The study concluded that non-native plants spread along these constantly disturbed areas come from visitors' vehicles that may carry seeds or other propagules capable of sprouting and spreading non-native plants (Fuentes and others 2007; Greenberg and others 1997; Lonsdale and Laine 1994).

RIPARIAN HABITAT

Roads built adjacent to stream channels can pose a higher level of potential impacts than roads built further from water bodies. One example: removing

Chart 3-3. Correlation of the Percent of Roads within 200 Feet of Water Bodies



* Data Source: 1/13/2009 DNR Dataset
*These data only represent distances to Type 1, 2, 3, 4, 5, 9 streams/water bodies.

the tree canopy for a stream-adjacent road can change temperature and light and have both positive and negative effects on fish populations (Fish, p. 73). Chart 3-3 shows the proximity of roads to riparian areas in 50-foot increments.

WATER QUALITY

Roads can alter hydrologic processes (Water Quantity, p. 65) that influence sediment transport, sediment delivery, and mass wasting (Soils, p. 76). Road surfaces can be variable depending on the soil's parent material, traffic, or road surfacing (Reid and Dunne 1984; MacDonald and others 2001). Refer to water quality (p. 70) for additional discussion.

AIR QUALITY

Vehicles moving on unpaved roads produce dust, which can be released into the atmosphere; reducing visibility and suspending particulates in the air that can pose health hazards (USDA 2001). Refer to air quality (p. 113) for additional discussion.

VISUAL QUALITY

Roads can have visual impacts (Visual Resource Management, p. 89), which are amplified when large contiguous harvest units—and their associated roads—are visible from state and local highways.

What Are the Current Road Conditions?

To provide rail access for harvesting old-growth timber, transportation networks were developed early in the 1900s throughout the Elbe, Tahoma, and Black Diamond landscapes, as the distance between the railroads and timber available for harvest increased, roads for hauling timber replaced most railroad lines. Many of these landscapes contain 50- to 75-year-old railroad grades that have been converted to forest roads, as well as newer roads constructed for large trucks. Today, these forest roads provide access to almost every portion of the landscape for management and recreational activities.

The current road inventory is captured on the Forest Practices transportation layer in DNR's GIS system. DNR estimates that approximately 850 miles (DNR 2007) of forest road exist on forested state trust lands within the planning unit, including additional miles associated with easements. Since timber generally is extracted within 800 feet of an existing road (refer to Appendix H, Table H-1), the current road system allows access to approximately 62 percent of the planning unit. Additional roads or road sections would be built, if needed, to access the remaining 38 percent of the planning unit.

The road density for the planning unit varies from 1.6 to 4.9 miles per square mile (Table 3-13) in the watersheds where DNR manages 20 percent or more of the land base, but averages 3.2 miles per square mile.

It is anticipated that 12 miles of additional roads will be built every year for the next decade to access more of the forestland base. In steep terrain, reducing road densities may require longer cable yarding distances, which will raise costs, especially for thinning activities (Hochrein and Kellogg 1988).

How Does DNR's Management Affect the Road Network?

TIMBER HARVESTING

Timber harvesting puts certain pressures on forest roads through the amount and types (kinds of vehicles) of traffic and the road mileage they require.

RECREATION

Recreation is a competing source of traffic with forest management in some areas (DNR 2006a). Public access for recreational activities can be affected by changes to the road system. DNR limits

Table 3-13. Road Density by WAU*

Watersheds	Acres	Miles	Miles/Mile^2
Mineral Ck.	4,731.5	36.9	5.0
Great Bend	15,887.0	103.7	4.2
West Kitsap	6,319.0	41.1	4.2
East Ck.	4,087.6	27.0	4.2
Howard Hansen	16,322.3	103.7	4.1
Kennedy Ck.	8,621.4	50.2	3.7
Reese Ck.	11,665.5	65.8	3.6
Lynch Cove	10,740.4	58.7	3.5
Catt	6,763.4	35.6	3.4
North Fork Green	6,554.3	34.7	3.4
North Fork Mineral	13,800.8	65.9	3.1
Mashel	14,922.4	64.7	2.8
Tiger	9,646.1	24.5	1.6

*Planning Unit Average (Acre Weighted on Watershed Area) Source: DNR 2007 entry to forested state trust lands when public access results (or may result) in damage to the environment or the road system or interferes with a contractor lessee (McClelland, pers. comm. 2007).

Recreation

DNR has defined recreation according to the *Multiple Use Act*[13], where recreation and public access are allowed for a variety of activities and where such uses are compatible with trust objectives (DNR 2006b).

Why Is Recreation Important?

Recreation on forested state trust lands is an important component of the quality of life in Washington (DNR 2006b). Most lands used for recreation are located at low elevations near cities and towns and provide year-round recreational opportunities.

Trends in outdoor recreation show recent growth across a wide variety of activities (Cordell and Bergstrom 1991). While access to private lands is decreasing (Cordell and others 1999), public lands are likely to be choice destinations for increasing numbers of people looking for high-quality outdoor recreational experiences in natural settings.

These trends have particular relevance to this planning unit, because it encompasses the most heavily populated region in the state and its counties' populations are anticipated to grow by 15 to 20 percent by 2030 (Office of Financial Management 2007).

What Are the Criteria for Managing Recreation?

DNR provides public access opportunities on forested state trust lands in accordance with the *Multiple Use Act* so long as these opportunities are consistent with trust objectives to provide financial support for schools and other state institutions while ensuring long-term protection of the environment. Where recreational activities can coincide with these primary purposes, DNR provides trails, trailhead facilities, and a primitive experience in a natural setting (DNR 2006b; DNR 1997).

What Are the Indicators for Assessing Recreation?

POPULATION DEMOGRAPHICS

Population demographics are major determinants of trends in participation for recreation (Cordell and others 1999; Kakoyannis and Stankey 2002). Thus, to understand recreation demand and trends in the planning unit, DNR examines the population trends for the state and region. About two-thirds of the state's population growth is driven by people moving into Washington (OFM 2007). The Washington Office of Financial Management (OFM) estimates that by 2030 (the final year of its population forecasts), the state's population is anticipated to increase by approximately 33 percent (OFM 2007). Increases are expected not only in existing major population centers (for example, along the I-5 corridor), but also in communities that traditionally have been categorized as rural and on the periphery of major population centers. This planning unit encompasses the most heavily populated region in the state; refer to Table 3-16.

ROADS AND PUBLIC ACCESS

Recreation access to DNR-managed lands is mostly for dispersed recreational activities such as hunting, sightseeing, hiking, and berry-picking. DNR also provides primitive recreation facilities that are used for overnight camping and day uses such as picnicking. Some overnight destinations are very popular, requiring DNR to manage a reservation system.

DNR also has trail systems for hikers, horsemen, off-road vehicle users, mountain bikers, skiers, and hang-gliders. Most of these systems provide access to everyone, but organized user groups assist DNR with maintaining and upgrading the trails to keep them open.

DNR's road network provides additional recreation benefits. However, misuse of trust lands (for example, for unregulated dispersed camping and destruction of forest road access barriers) has led to concerns about safety and environmental degradation. In response, DNR has gated some interior roads, a change that improved public safety and reduced management concerns although these roads are still open to non-motorized use. Additionally, access may be restricted for environmental reasons, such as protecting the City of Tacoma's water supply.

RECREATION FACILITIES

During harvesting activities, some facilities, trails, and roads are closed temporarily for public safety reasons. At other times, roads and recreation facilities are closed for repair or replacement. Changes in demand also bring changes in use; in the Tahuya State Forest, a substantial increase in recreational use resulted in DNR's development in 2007 of a recreation facilities plan to meet the high demand for off-road vehicle use (DNR 2007b).

What Are the Current Conditions?

The planning unit has 30 developed recreation sites, over 450 miles of trails, and many thousands of acres of dispersed recreation lands used for hunting, fishing, and sightseeing (Table 3-14). DNR identified the region's main recreational attractions as trails and trail-oriented activities along with environmental education[14]. Day-use recreational activities are varied and include hiking, horseback riding, off-road vehicle use, skiing, mountain biking, hunting, sightseeing, fishing, food and vegetation gathering, hang gliding, and paragliding.

ACCESS

The breadth of user types and groups accessing DNR-managed lands within the planning unit is indicative of the range of recreation opportunities and the variety of terrain in the region. It is challenging to manage the various recreation user groups' interests and needs while still meeting DNR's primary responsibilities. Often the public is not aware of DNR's trust mandate (refer to Chapter 1, p. 5) on forested state trust lands or of the ongoing forestry management activities on lands used for recreation.

Table 3-14. Recreation Opportunities

State Forest or Landscape	Recreation Opportunities	Recreation Facilities		Recreation Emphasis
		Trails Miles	Campgrounds	
Tiger Mountain	Hiking, mountain biking and equestrian use trails; paragliding; day use: environmental education, picnicking	75	0	Day use; non-motorized
McDonald Ridge	Dispersed and not designated or maintained	0*	0	None
Grass Mountain	Dispersed and not designated or maintained	0*	0	None
Elbe Hills	Hiking and equestrian trails; 4x4 trails; day-use: picnic sites, overnight campgrounds, hunting, pleasure driving	50 non-motorized miles with 12 miles of 4X4 trails	2	Day use and overnight; non-motorized and motorized
Tahoma	Groomed ski trails, snow shoeing, mountain biking, hiking, horseback riding on roads, hunting	100 miles snow trails	3 Huts	Day use and overnight; non-motorized
Pleasant Valley	Dispersed and not designated or maintained	0*	0	None
Tahuya	Hiking and equestrian trails; ORV and 4x4 trails; day-use: picnic sites, overnight campgrounds	163 miles multi-use trails; 13 miles 4 x 4 trails	5	Day use and overnight; non-motorized and motorized
Green Mountain	Hiking and equestrian trails, ORV trails, day-use picnic sites, pleasure driving to vista, overnight campground	11 miles multi-use (motorized and non-motorized)	1	Day use and overnight; non-motorized
Sherwood	Dispersed and not designated or maintained	0 *	0	None

* Some forest roads are used by pedestrians and mountain bikers

POPULATION

Available information on current levels of use is shown in Table 3-15. As the population continues to increase, these levels are expected to increase as well.

VOLUNTEER SUPPORT

There has been extensive public outreach to recreational users in the planning unit. DNR has developed partnerships with volunteer-based focus groups, recruited users to participate in a forest watch program, and used volunteers to improve trail systems.

Table 3-15. Estimated Annual Recreational Use in the Planning Unit*

Visit Location	Visits Per Year
Tiger Mountain	375,000
Tahuya	250,000
Green Mountain	50,000
Elbe Hills	45,000
Tahoma	15,000
McDonald Ridge & Grass Mountain	5,000

How Does DNR Management Affect Recreation?

HARVESTING RESTRICTIONS

To protect visitor safety, designated and dispersed recreation sites are sometimes temporarily closed because of harvesting activities. These closures and reroutes normally last while harvesting activities are in progress and the sites are re-opened after they have been completed. At times, trails are relocated permanently to less environmentally sensitive areas away from riparian areas or wetlands.

Timber harvesting activities can affect recreational users but the effect depends on the type of recreational activity and the amount of use an area receives. There are many different types of recreational interests and opportunities which are a challenge for DNR timber management responsibilities. However, Hunt and others (2000) identified some recreation groups (hunters and motorists) to be more accepting of harvesting activities, while others who were surveyed seemed to be less accepting (mountain bikers, cross-country skiers, snowshoers, and hikers).

SEASONAL CLOSURES

Seasonal closures are necessary when recreational activities result in environmental impacts. Most closures are related to specific trails and campsites. Long-term closures can occur when road access is damaged or eliminated during storm events (refer to Climate, p. 55).

ROADS

Roads offer the public a way to access lands and recreational opportunities. The effects of human access and disturbance effects on remote areas tend to increase with higher road density (Forman and Alexander 1998). Illegal off-road vehicle use of forest roads contributes to rutting and road surface destruction and requires extra maintenance.

Forest Health

Forest health is defined in state law as the condition of a forest being sound in ecological function, sustainable, resilient, and resistant to insects, disease, fire, and other disturbances, and having the capacity to meet landowner objectives[15].

Why Is Forest Health Important?

Healthy forests allow DNR to achieve its social, ecological, and economic objectives on forested state trust lands. Unhealthy forests lead to decreased growth, increased mortality, and susceptibility to stressors such as insects, disease, and drought (O'Laughlin and Cook 2003).

What Are the Criteria for Addressing Forest Health?

DNR's policy on forest health emphasizes prevention through treatment of the underlying causes of forest health problems, primarily including species composition and high stand density at a landscape level. In addition to mandating forest health symptoms when they occur, the policy also establishes a clear strategy of cooperating with neighboring landowners, other agencies, and the scientific community to address forest health issues (DNR 2006b).

What Are the Indicators for Assessing Forest Health?

STAND DENSITY

Densely stocked forest stands (RD≥75) lead to decreased tree growth, increased mortality, and reduced resistance to drought as well as insect and disease attacks (O'Laughlin and Cook 2003). By examining the proportion of dense stands within the planning unit, the potential risk can be assessed (Forest Conditions, p. 45).

TREE MORTALITY

Tree mortality is perhaps the most direct measure of forest health and represents the cumulative impact of all the stressors present in the environment (O'Laughlin and Cook 2003). It is important to recognize that some tree mortality is inevitable and desirable. The results of tree mortality, such as standing snags and down woody debris, are essential components of structurally complex forested ecosystems.

SPECIES COMPOSITION

When DNR regenerates forest stands after variable retention harvests, it plants a variety of seedlings, a method that protects stands from being completely overrun by insects and diseases that target specific species, such as white pine blister rust.

What Are the Current Forest Health Issues?

In an informal written survey, DNR staff and specialists thought the incidence of most pathogens had remained consistent over the past two decades and did not identify any pathogens in this planning unit as significant. DNR listed the most current forest health issues as bear damage, Douglas-fir beetle, balsam wooly adelgid (an exotic insect that attacks true firs), invasive plants, and laminated root rot. DNR believes that the incidents of bear damage, along with the introduction/detection of invasive plants, have demonstrated upward trends throughout the period.

How Does DNR Management Affect Forest Health?

TIMBER HARVESTING

Harvesting is the primary tool by which forest managers can intervene to create conditions that increase resistance to insects and disease. Harvesting activities allow managers to reduce forest stand density and alter species composition and are the primary means of treating insect and disease outbreaks directly (Tainter and others 1996). However, if not properly managed, multiple entries into an existing forest stand may cause injury and exacerbate the incidence of disease in the stand.

Commercial thinning may decrease forest health by bringing in seeds and plant propagules on equipment used in other areas. Tree damage in the remaining stand can cause openings for infection by weakening otherwise healthy trees or limiting their access to nutrients. Commercial thinning can open large portions of the canopy and scarify the forest floor, giving invasive species opportunities to establish themselves in new areas (Smidt and Blinn 1995).

In 2004, the Legislature approved the Forest Health Improvement Act, authorizing the Commissioner of Public Lands to contract for the harvest of timber where forested state trust lands have been identified with serious forest health concerns. DNR was directed to implement a plan for state-owned forestlands with the objective of increasing forest resistance to resilience from insects, disease, wind, and fire (DNR 2006c). While the original authorizations for the Forest Health Improvement Program were due to expire at the end of 2007, Senate Bill 5461 eliminated the sunset provision.

As of February 2009, one forest health improvement project has been completed in this planning unit, totaling 400 acres, with another 300 acres scheduled for late 2009.

Visual Resource Management

Looking East towards Mt. Rainier from Elbe Hills with Eager Beaver timber sale in the middle ground.

Visual or scenic resources can be defined as those visually perceived attributes, characteristics, and features of landscapes that evoke varying responses from humans, and provide non-material benefits to them (US Forest Service 1995). The visibility of forestry activities is influenced by several factors. The observer's perspective and personal values influence whether the reaction to the visual impact is positive, neutral, or negative (DNR 2006b).

Why Are Visual Resources Important?

The visual quality of the American landscape has been a subject of discussion throughout the nation's history, but has become an increasingly prominent public issue in the past several decades because of the increased rate and scale of development (Zube 1986).

The appearance of forest stands and forested landscapes can be altered by DNR's management activities including timber harvesting, road building, leasing, and other activities. DNR recognizes the importance of visual quality and that visual management concerns must be balanced with DNR's other obligations and management objectives (DNR 2006b).

Besides visual impacts from management, large-scale natural disturbances such as wildfires, wind events, or epidemics may occur, creating unintended visual impacts.

As the population continues to increase, more people will view the landscapes DNR manages, whether seen from major roads and adjacent rural lands or during visits to DNR forests. Washington's growth management policies have slowed but not eliminated development in rural portions of the Puget Sound region. Approximately 13 percent of growth in King, Kitsap, Pierce, and Snohomish counties occurs in rural areas (PSRC 2005). Such rural development places homes, businesses, and roads within view of forested state trust lands. From 2000 to 2007, county populations increased between five and 15 percent within the planning unit (Table 3-16). Visual sensitivities are possible

Table 3-16. Population Statistics for Washington and Counties within DNR's South Puget Sound Region*

County	2000 Population	2007 Population	Change 2000-2007	
			Difference	Percent
King	1,737,046	1,861,300	124,254	+7.2%
Kitsap	231,969	244,800	12,831	+5.5%
Lewis	68,600	74,100	5,500	+8.0%
Mason	49,405	54,600	5,195	+10.5%
Pierce	700,818	790,500	89,682	+12.8%
Snohomish	606,024	686,300	80,276	+13.3%
Thurston	207,355	238,000	30,645	+14.8%
Total, all South Puget Sound Region Counties	3,601,217	3,949,600	348,383	+9.7%
State of Washington	5,894,143	6,488,000	593,857	+10.1%

*Source: Office of Financial Management (2007) from many viewpoints along roads where the impacts can affect a greater proportion of people than just the local residents.

Figure 3-7. Variable Retention Harvest, Old Fogy Timber Sale, Elbe Hills: Dispersed leave tree pattern, 10 trees per acre left standing

What Criteria Does DNR Use to Manage Visual Resources?

The 2006 *Policy for Sustainable Forests* provides general guidance for managing visually sensitive areas for identified local and regional visual impacts.

What Indicators Are Used to Assess Visual Conditions?

Before harvesting, DNR assesses the type and extent of the harvest and the proximity of roads, and any natural disturbances to assess the harvest's potential visual impacts.

HARVESTING INDICATORS

Studies have shown that as the amount of harvested area visible to an observer increases, the degree of visual impacts increases (BC Ministry of Forests 1996, 1997). Many studies have demonstrated the public's visual preference for harvesting types which retain more large trees rather than fewer smaller trees (Ryan 2005; Picard and Sheppard 2002; BC Ministry of Forests 1997).

Figure 3-8. Variable Retention Harvest: Clumped Leave Tree Pattern, Eager Beaver Aerial, Elbe Hills (as seen from the air), 23 trees per acre left standing

DNR's variable retention harvests generally leave between eight and 16 trees per acre standing after a harvest, depending on land management objectives. The leave trees may be either grouped in small clumps or dispersed uniformly throughout a harvest unit. Figures 3-7 and 3-8 provide examples of what these two patterns look like.

Thinning harvests remove fewer trees than variable retention harvesting methods (at least 70 percent of the board foot volume is usually left standing). Figure 3-9 illustrates what a thinned stand may look like following a harvest used to enhance northern spotted owl dispersal habitat.

ROADS

Researchers have shown that the view from the road is the basis for much of what people know about

Figure 3-9. Thinning harvest Cougarilla Sorts Timber Sale Tahoma: 115 trees per acre left standing

the everyday environment and their mental image of the landscape (WADOT 2007). Roads can have visual impacts, a perspective which is amplified when high forest road densities are coupled with large contiguous harvest units that are visible from populated locations on state and local highways.

ROCK PITS

Well-constructed forest roads require material such as rock and gravel. DNR makes use of local rock from its own lands whenever possible. Rock and gravel pits may cause visual impacts if located in visually sensitive areas.

LEASES AND RIGHTS-OF-WAY

DNR leases trust lands for communication sites which may be located in visually prominent spots, such as peaks or mountain tops. The department has many other lease and rights-of-way agreements for uses such as power lines which may pose visual impacts depending upon their location.

NATURAL DISTURBANCE EVENTS

Many studies have demonstrated the public's negative perception of burned areas following wildfires, with the strength of the reaction depending on the severity and size of the burned area and the time since the event occurred (Taylor and Daniel 1984; Brush 1979; Cotton and MacBride 1987; Scott 1998).

Large insect outbreaks, although rare in this area, can affect the viewer's perception of a forest (Buhyoff and others 1982).

Landslides, whether natural or human-caused (for example a failed road), may cause visual impacts because of their often dramatic nature and because the removal of vegetation is very noticeable, especially in steep terrain (Soils, p. 76).

What Are the Current Conditions for Visual Resources?

Table 3-17 summarizes the main viewpoints and visual conditions of each area in the planning unit. During public and stakeholder meetings for this planning process, no areas of regional visual significance were identified.

MODELING TOOL

DNR uses a visual model to assist foresters in determining areas of potential visual sensitivity from major roads. The model provides a score based on the line-of-sight from a major road toward forested state trust lands. Scores range from 0 to 41, with higher numbers representing the amount of area that can be seen from a road at multiple points. The model is meant to provide a simple first-cut screening tool and does not consider the volume of traffic, number of viewers, or other details.

How Does DNR Management Affect Visual Resources?

Because of the extent of the land base affected, the greatest potential impacts to visual resources come from timber harvesting and road building. Other, more localized visual effects are associated with communication sites, rock pits, and rights-of-way. Some effects, such as those from natural disturbances, cannot be predicted.

Table 3-17. Summary of Scenic Qualities by Area

Area	Planning Unit Acres	Main Viewpoints	Notes
Tiger Mountain State Forest	13,364	City of Issaquah, I-90, SR18, Mirrormont, Issaquah-Hobart Rd., rural residences, forest visitors.	Observed by 13.3 million vehicles/yr on I-90; highest recreationally used forest in planning unit; Fed. Designated Scenic Byway (Mt. to Sound Greenway); scenic management Tiger Mtn. Plan (1986) limits harvest amount, type retaining at least 12 trees/ac after harvest. Restricted # acres/yr. Refer to Map 2-2.
McDonald Ridge	11,861	Towns of Enumclaw, Black Diamond, Maple Valley, SR 169, rural residences.	3,300 ft. ridge east of towns. Most noticeable from rural residences, but not towns. City of Tacoma restricted access: very little recreational use.
Grass Mountain	15,907	SR 169, & rural residences.	City of Tacoma restricted access: very little recreational use. Much of forest block only visible from the west.
Elbe State Forest	22,157	Towns of Elbe, Ashford, Eatonville, Mt. Rainier NP, Mount Baker-Snoqualmie National Forest, SR 706, local visitors & traffic.	Trust lands generally not viewable from towns. SR 706 gets used by majority of 1.1 million/yr visitors to Mt Rainier NP. Ridge to north of 706 blocks views of DNR lands to the north.
Tahoma State Forest	32,096	Towns of Elbe, Ashford. Mineral & rural residences. Mt. Rainier NP, Gifford Pinchot National Forest, SR 706, SR 7, local visitors & traffic.	Valleys stretch south, perpendicular to SR706, allowing views into DNR lands. Possible views from SR 7, Mineral Lake
Pleasant Valley	3,291	Town of Elbe, SR 706, SR 7, Alder Lake, Alder Lake Park, GP National Forest, local residences.	Small area, highly visible from many locations near and on Alder Lake. Example, SR 706, SR7.
Green Mountain State Forest	12,948	City of Bremerton, Silverdale, Lake Tahuya, SR3, rural residences, & forest visitors.	Green Mountain 1,639 ft. elev.; views from rural residences and from Lake Tahuya, Wildcat Lake, William Symington Lake. Highly recreated on.
Tahuya State Forest	23,928	Hood Canal, Twanoh SP, Belfair SP, SR300, SR106, US101, forest visitors, & rural residences	Relatively flat terrain limits potential visual impacts here. Highly recreated on.
Sherwood State Forest	2,786	Rural residences, SR3, Grapeview (unincorporated)	Relatively flat terrain limits potential visual impacts here.

TIMBER HARVESTING

Many studies have shown that the visual quality of forested landscapes decreases as timber harvest increases, and that compared with thinning activities, variable retention harvests can lower scenic quality ratings (BC Ministry of Forests 1996; BC Ministry of Forests 1997; Picard and Shepherd 2002; Brunson and Shelby 1992; Ribe 1999; Ryan 2005). A 2002 focus group study found the subject of forestland management strongly associated with the issue of variable retention harvests, resulting in negative visual connotations (Connections Group 2003).

FOREST ROADS

Maintenance of DNR's road network and construction of new roads create visual impacts. Roads also provide the access needed to view forested landscapes. Roads, if not properly constructed and maintained, can cause slope failures or mass wasting (refer to Soils, p. 76). Rock pits used for road construction can also be a source of sedimentation from erosion of exposed dirt and mass wasting events.

Land Transactions

Land transactions are the repositioning of trust assets achieved through the purchase, sale, or trade of trust lands (DNR 1998). The trust assets are continuously evaluated and prioritized to act on opportunities to "block up" or reposition trust lands to better achieve DNR's goals, including diversification of the trust portfolio.

Why Are Land Transactions Important?

Land exchanges are intended to acquire more lands adjacent to or near other lands DNR already manages or to diversify the trust portfolio. In addition to increasing management efficiency, having larger and more contiguous areas under public ownership could improve wildlife habitat and forest health.

Land transactions are designed to increase the value of the trusts by providing long-term benefits whether economic, ecological, or social in nature. Repositioning of the trust assets is intended to improve DNR's ability to manage the lands and to provide long-term, sustainable revenue to trust beneficiaries.

What Are the Criteria for Managing Land Transactions?

The criteria for managing land transactions are to continually evaluate, prioritize, and act on opportunities to block up or reposition trust lands or to diversify the trust portfolio. In use since the early 1970s, this approach was adopted formally by the Board of Natural Resources in 1998 through the Asset Stewardship Plan. The strategies developed under the management alternatives are designed to accomplish this task.

The Enabling Act of 1889 and the State Constitution restrict the disposal of forested state trust lands, including their sale at anything less than full market value. The Enabling Act also authorizes the exchange of grant lands for lands of equal value. The State Constitution requires that trusts receive full compensation when trust lands are sold, transferred, or otherwise redistributed. Certain state laws[16] contain additional requirements for trust compensation.

DNR management of forested state trust lands is guided by a number of laws, policies, and programs for a brief overview refer to the 2006 *Policy for Sustainable Forests*.

What Are the Indicators for Assessing Land Transactions?

FORESTLAND CONVERSIONS

Forested state trust lands are not immune to the pressures of an increasingly urbanized environment. In order to uphold its fiduciary responsibility to trust beneficiaries, DNR is motivated to preserve the interests of the trusts by strategically repositioning assets where they can continue to be managed for revenue production as well as environmental values.

Fragmentation and parcelization are often an intermediate step on the pathway from working forests to urban or suburban development (DNR 2007; Egan and Luloff 2000; Sampson and DeCoster 2000). Both have impacts on social and environmental values.

Typically, a large tract of industrial working forest is sold in smaller lots for rural residential use when the value of the property for these uses exceeds the value for continued timber production (Alig and White 2007). Prospective returns from growing timber often cannot outweigh land development as land values for developed uses can be 80 to 100 times greater than forestlands (Alig and White 2007).

What Are the Current Conditions?

DNR recently acquired approximately 20,000 acres of forestlands in the Cascade foothills previously owned by Plum Creek Timber Company, under a project called the North Fork Green River Trust Land Exchange. The acreage is within the City of Tacoma's Green River watershed, located in eastern King County. This project exchanged approximately 6,000 acres of state trust land—mostly in isolated parcels in west and southwest Washington—that did not fit the agency's objectives to manage revenue-producing land holdings for state trust beneficiaries. For additional information and analysis related to this exchange, refer to Appendix J.

POPULATION

As the population continues to increase and move into rural areas, the pressure to convert forestlands becomes greater. Washington's population grew by 10.1 percent between 2000 and 2007, reaching an estimated 6.5 million people. The portions of seven counties represented in this planning unit grew by 9.7 percent during the same period (Table 3-16). The 2007 population in these counties was 3.9 million. Three of the five largest municipalities in the state —Seattle, Tacoma, and Bellevue—are located within the planning unit and all were among the top 10 fastest-growing municipalities in the state (OFM 2007).

How Does DNR Management Affect Land Transactions?

HARVESTING AND REVENUE GENERATION

In terms of forest management, land exchanges are done to improve management effectiveness; this can be accomplished by blocking-up or expanding the existing forestland ownership boundaries. The main purpose is to produce long-term revenues by providing a variety of forest products.

ROADS

As lands are acquired, DNR must fulfill the requirements for road management under state Forest Practices Rules (refer to Roads, p. 80). While the additional road maintenance projects are a greater cost to DNR, these lands provide better overall access to the public and more cost-effective management that did not exist prior to the exchange.

RECREATION

Population growth has specific effects on trust lands. Where a decade ago hundreds of people may have recreated on trust lands, now thousands might. As more visitors recreate on trust lands, they collectively come to depend on these lands for recreational opportunities. In these locations, recreational users may not want lands moved out of DNR ownership. However, in other cases, blocking up ownership will be supported by users.

Cultural Resources

Washington State law defines cultural resources for Forest Practices as "archaeological and historic sites and artifacts and traditional religious, ceremonial, and social uses and activities of affected Indian Tribes."[17]

DNR (Stilson pers. comm. 2007) defines cultural resources as objects, sites, structures, buildings, and districts containing evidence of past human activities or playing an active role in maintaining the traditional cultures of the state.

Because both the physical components of cultural resources and management strategies for handling them may vary, cultural resources on DNR-managed lands are divided into four general classes which are not mutually exclusive:

Historic Sites—Sites 50 years or older, which have standing structures that are associated with activities of any of Washington's peoples after the arrival of Euro-Americans.[18, 19] Examples of historic sites include buildings, roads or trails, railroads, logging camps, dumps, and military installations.

Archaeological Sites—Sites more than 50 years in age that lack any standing structure; these may be surface scatters of artifacts, buried deposits, or both. Archaeological sites may be associated with any people who have occupied Washington and can range from a single artifact (an "isolate") to sites with large numbers of artifacts, ecofacts (unmodified materials such as shells or animal bones that reflect food debris), and features (modifications to the landscape such as hearths, pits, and stacked cairns).[19]

Traditional Cultural Properties—Places that have been identified by Tribes and play a significant role in a community's historically rooted beliefs, customs, and practices. These places range from the location of a secret ceremony to prominent natural features of the landscape such as ceremonial bathing areas, gear storage areas, spirit quest sites (Vision Quest), and traditional song and named places. All sites must have long-standing cultural significance to one or more Tribes, although their location may not be shared publicly[20] Traditional cultural properties may also relate to other ethnic groups; they are not limited only to tribes. Often, to remain functional, such a place must maintain the characteristics of purity, privacy, isolation, and permanence.

Traditional Materials—Products of the landscape that continue to have significance to Tribes. Examples may include plants, animals, and minerals that were used for food, medicine, or raw materials pre-historically and historically; they and may still be used today.[20]

Why Are Cultural Resources Important?

DNR recognizes the significance of cultural properties, current cultural uses, and historic and archaeological sites and how they help us understand our past and contribute to state and Tribal heritage. DNR also acknowledges the importance of government-to-government communications and collaboration with the Tribes, as discussed in the Commissioner's Order on Tribal Relations (refer to DNR 2006b, Appendix L), as well as with interested stakeholders. DNR routinely manages cultural resources in the context of its broader mission and in compliance with national standards and Washington statutes, rules, executive orders, and internal policies and the consultation processes of the Department of Archaeology and Historic Preservation (DAHP).

What Criteria Does DNR Use to Manage Cultural Resources?

Washington laws provide the means to identify, study, protect, and perpetuate cultural resources and also create a plan for civil action against people seeking to take, destroy, or otherwise disturb sites and their contents. DNR has also created internal policies, procedures, and interagency agreements similar to these that guide day-to-day operations. These resources include Historical, Cultural and Archeological Sites[21], Identifying Historic Sites[22] (contained in Appendix E), and the 1987 Timber, Fish and Wildlife Agreement. DNR frequently enters into memoranda of agreement with Tribal governments to protect traditional cultural properties and maintain Tribal access to resources and localities important to the practice of traditional cultures. For a more in-depth discussion of the legal background of cultural resources in Washington, refer to Appendix L.

What Are the Indicators for Assessing Cultural Resources?

DNR emphasizes protection of cultural resources for historic sites, archaeological sites, traditional cultural properties, and traditional materials by protecting and minimizing impacts to them, increasing public awareness, and improving data.

PROTECTION AND MINIMIZATION OF IMPACTS

For two years in a row, DNR's Cultural Resource Awareness training has been commended by the Sustainable Forest Initiative Certification Board for its training manual and for using Tribal members to teach parts of the training. DNR intends to have 100 percent of its field staff trained about cultural resource concerns within the next few years; and this goal has been met in this planning unit by accelerating the process and standardizing guidance. Because of its high teaching standard, reference manual, and knowledgeable staff, DNR is able to identify and mitigate for resources in the field on projects large and small.

Although often undocumented, over the last decade as many as 50 sites in timber harvesting areas were protected or mitigated because members of this planning unit were knowledgeable about the potential presence of cultural resources in the planning unit. Other management activities require consultation with a Cultural Resource Specialist. These activities can include land transactions, projects using capital funds (covered by Executive Order 05-05), and follow-up to environmental events such as landslides, windstorms, floods.

PERCENTAGE OF LAND DESIGNATED FOR CULTURAL USE

An important indicator, recognized internationally (Montréal Process 1995), is the amount of area designated to protect cultural, spiritual, and social values. Many DNR-managed lands can be included in this group, which allows Tribal access to specific areas; although actual acreage is difficult to quantify because many traditional areas do not have boundaries. Sites used for Vision Quests, ceremonial bathing areas, and other rituals have changed as time has passed, especially in areas where a growing population encroaches on wilderness.

TRIBAL ACCESS

A closely related indicator, the amount of available access for Tribal, ethnic, or spiritual groups, poses a similar problem of quantifying acres. Most state-owned/managed lands were ceded to the United States by local Tribes and later given to Washington when it gained statehood. The Point Elliot Treaty of 1855 generally applies to ceded lands in the greater Puget Sound area, where reserved rights remain for hunting, fishing, and gathering berries and roots (used for medicines, herbs, tobacco, and other purposes) for local Tribes. This right to fishing and hunting also includes an implied right to have the habitat for these species protected. As is the case above, areas of traditional uses do not have designated boundaries and virtually no state statutes deal directly with Tribal title or property rights. Most access to these sites by Tribes has been coordinated through Tribal consultation with DNR. No activities with significant potential to impact the environment (those to which State Environmental Policy Act applies) move forward on DNR-managed lands without input from local Tribes that may be affected by the action.

IMPROVING DATA

Oftentimes, agency and tribal databases diverge on questions of location, size, and content of cultural resource sites. DNR not only cultivates close Tribal relationships, but also has an information-sharing memorandum of understanding with the Department of Archaeology and Historic Preservation. These open relationships give the highest level of protection to resources by maintaining updated information in a domain accessible to Cultural Resource Specialists throughout a specific region, such as South Puget. However, for fear of exploitation, not all cultural resource sites are recorded by Tribes.

What Are the Current Conditions?

PRE-HISTORIC AND HISTORIC USES OF DNR-MANAGED LANDS

A general description of the pre-historic and historic uses of the Puget Sound area can be found in Appendix D of the 2006 *Final EIS on the Policy for Sustainable Forests*.

Archaeologists believe human occupation began in this area nearly 12,000 years ago, following the retreat of the Ice Age glaciers. Most cultural resource sites in Washington are found near water, possibly because ancient populations, like modern ones, were drawn to marine and riverine resources for food, water, trade, and travel.

In addition to fishing and gathering from the water, hunting implements and large fossilized animal bones signify to researchers that Paleo-Indian people (initial occupation to 7,500 years ago) were also terrestrially-oriented and hunted large game species. Sites from this era within the planning unit are likely to be special purpose (burial grounds) and small resource extraction sites (lithic scatter); larger, more complex sites are probably located below the waters of Puget Sound.

During the Developmental Period (7,500 to 4,500 years ago), more complex societies arose as populations adapted to their environments, but settlement patterns fluctuated with resource availability. A few coastal refuse sites (middens) date from this era, but many are probably hidden under the waters of the Puget Sound and the Pacific Ocean. Forested archaeological sites in this era, as in the previous era, are likely limited to special purpose and small to moderate size resource extraction sites. Many sites of the Developmental Period show continued use through ethnographic and historic times.

By about 3,000 years ago, the Northwest coast ethnographic pattern was fully established, and was characterized by large semi-permanent winter villages at lower elevations, and seasonal forays to resource extraction sites and seasonal camps, often at higher elevations. During the Ethnographic Period (3,000 to 200 years ago), Native Americans on the Puget Sound and most navigable rivers in the area developed food processing and storage technologies as well as complex travel and trade networks from the Pacific Coast to the Columbia Plateau. These cultures were very advanced in their knowledge and development of the resources around them, and manipulated the landscape to improve wildlife habitat and promote the growth of different crops. The landscape that early settlers encountered was largely human-created through the use of fire.

Researchers have the most archaeological information from the past 200 years since the arrival of Euro-Americans, including their patterns of establishment, economies, and relationships to existing inhabitants. Like most Native American settlements, all major early Euro-American communities were built near navigable water. Often, the Euro-Americans settled in exactly the same places as the Native Americans since the land had been cleared and was more attractive than the dense forests. Early historic economies were predominantly extractive and based on logging, mining, shellfish gathering, and salmon fishing.

Most private agricultural development of the state began with the federal Donation Land Claim Act (1850), the Homestead Act (1862), and similar laws that provided free land to settlers and promoted immigration to the Pacific Northwest. Trails and roads soon connected settlements and commercial centers, and small towns gradually arose to provide for settlers' needs. In 1887, the completion of the transcontinental Northern Pacific Railroad opened Washington to trade with the east. Historical sites commonly found in this planning unit include early logging camps, mills, railroads, and cabins.

TYPES OF CULTURAL RESOURCES

All of the classes previously mentioned have been found in and around the planning unit. Archaeological and historic sites have been documented in greater quantity, but DNR will continue to identify cultural resources of all classes in the course of managing forested state trust lands.

The Department of Archaeological and Historic Preservation database was queried November 9, 2007 and the 36 sites were identified within the planning unit are listed in Table 3-18.

UNDERSTANDING CULTURAL RESOURCE LOCATIONS

The archaeology of Washington within this planning unit is not well understood because very few DNR-managed lands have been surveyed for the presence of cultural resources. Areas near ridges and along water are considered high-probability areas for cultural resources and are more commonly surveyed by forestland managers than intermediate management areas not located near major water features. Lowlands, particularly coastlines, are most often surveyed because that is where most development occurs and therefore where most cultural surveys have taken place.

CULTURAL RESOURCES STAFF

DNR employs two full-time Cultural Resource Specialists, who are trained archaeologists and meet the U.S. Secretary of Interior's Professional Qualification Standards.[23] These specialists and the Tribal Relations Manager review projects, programs, and land transactions in detail; are involved in fieldwork; make recommendations regarding cultural resources; work directly with Tribal Cultural Resource professionals; and have access to confidential historical data regarding sites on record at Department of Archaeology and Historic Preservation.

How Does DNR Management Affect Cultural Resources?

Timber harvest and associated road building activities can have various impacts on cultural resources and their functions. For archaeological and historical sites, these activities can result in physical damage or destruction with a loss of cultural, scientific, and historical values (DNR 2006a). Any ground-disturbing activity in areas with potential impacts to cultural resources is of concern to DNR and the Tribes.

TIMBER HARVESTING

Proposed timber harvests are routinely reviewed by DNR Cultural Resource Specialists searching

Table 3-18. Current Archaeological and Historical Site Counts and Contents in the Planning Unit*

Site Type	Count	Site Contents
Historic Bridges	1	
Historic Logging Properties	4	Lumber mills, logging camps, lumber processing features—log chutes, flumes, dumps, holdings, railroads
Historic Outlooks	1	
Historic Objects	4	Historic markers, benchmarks, wagon frames, car parts, machinery
Historic Railroad Properties	2	Tracks, shelters, campsites, stations, trestles, berms, grades, cars, and materials (railroad ties and spikes)
Historic Structures – Not Specified	1	Foundations, function unknown
Pre-Contact Camp, Pre-Contact Culturally Modified	18	Short-term occupation sites
Trees	2	Culturally modified trees, including blazed and peeled trees
Pre-Contact Lithic Material	1	Lithic scatter, quarry, misc. tools and debitage
Pre-Contact Shell Midden	2	Matrix of shell, bone and lithics

*Source: Department of Archaeological and Historic Preservation (2007) for archival evidence and land attributes that suggest the presence of cultural resources. Field surveys of proposed activities are conducted when archival evidence and probability assessments indicate that a site may have cultural value. When cultural resources are found, the specialists work to protect them, often by specifying the direction of felling, designating machinery exclusion zones, or including cultural resource sites within other environmental protection zones, leaving them untouched. This practice is consistent with the procedure *Identifying and Protecting Cultural Resources*[22], found in Appendix E.

Forest management can change species composition to favor resources used by the Tribes. For example, using timber harvesting to open the forest canopy can encourage the growth of berry-producing species and can provide forage for game animals. Fire has been used by Native Americans for centuries to manipulate forests and prairies; it is mentioned in written and oral histories as an instrument for bringing in animals and new growth to feed the Tribes. Cedar growth is also promoted on many forested state trust lands by planting seedlings and removing competing tree species. Forest roads can also enable Tribal elders to access traditional use areas more easily (DNR 2006a).

FOREST ROADS

Forested state trust lands have extensive road networks, varying from temporary logging spurs to double lane paved roads. Almost all road construction involves ground disturbance. Cultural resource review occurs for all new road construction. Where possible, roads are designed to avoid cultural resources. When avoidance is not possible, sites are mapped, data are rapidly gathered in the form of drawings, photos, and descriptions, and (sometimes) artifacts are collected or other forms of mitigation are instituted (Appendix L).[12, 13]

Cultural resource review occurs where road maintenance or abandonment has the potential to disturb the ground. From a cultural resource management perspective, maintenance of existing roads is preferable to building new ones, but road abandonment generally increases protection for cultural resources in the area. Refer to Appendix H for information on road abandonment.

SAND, GRAVEL, AND MINERAL EXTRACTION

Extraction of sand, gravel, and mineral resources in areas near cultural resources has a potential for disturbance. Each project is reviewed by cultural resource staff according to previously mentioned laws and policies.

RECREATION

Recreation generally does not have a high potential to affect cultural resources adversely, but where the potential exists, the typical approach is to design projects that will avoid such effects.

Off-road vehicle trails have a high potential for impacts to cultural resources. Proposals to establish these trails involve close attention to cultural resource archives and field surveys. Where cultural sites are found, trails are designed to avoid them. However, undesignated user-built trails also have the potential to adversely affect cultural resources.

Non-motorized uses have much less potential than motorized uses to impact cultural resources, but any capital improvements, such as new trails and replacement or new camping facilities must undergo review. Cultural resource and recreation staff are currently developing a plan to survey designated and potential trails in recreation areas not tied to specific projects.

LAND TRANSACTIONS

Cultural Resource Specialists routinely review land transactions. Their review emphasizes on parcels leaving DNR's management to identify and establish protection plans for any cultural resources before the lands are sold or leased. Executive Order 05-05 (Appendix L) specifically identified "land acquisition for the purposes of capital improvement" as a trigger for cultural resource review. Recently, Cultural Resource Specialists have also begun to review other land transactions, including non-capital acquisitions, to learn whether cultural resources may require further assessment under DNR management.

Wildlife Habitat

This section addresses potential impacts to habitat for a range of wildlife species across the planning unit. Potential impacts to the northern spotted owl and marbled murrelet are discussed separately.

Under the 2006 *Policy for Sustainable Forests*, wildlife habitat is defined as the combination of resources (food, water, cover) and environment (climate, soils, vegetation structure) that attracts and supports a species, population, and/or assembly of species (scientifically referred to as communities or guilds).

Why Is Wildlife Habitat Important?

Wildlife habitat, regardless of its location—uplands, riparian areas, or wetlands—is important because of the functions it performs for a variety of wildlife species such as providing food and shelter.

What Is the Criterion for Assessing Wildlife Habitat?

The criterion for assessing wildlife habitat is the conservation of biological diversity including ecosystem, species, and genetic diversity (refer to Biodiversity definition sidebar). DNR conservation efforts focus on the preservation of biological diversity as a guiding principle for sustainable forest management (DNR 2006b). DNR's 1997 *Habitat Conservation Plan* (HCP) is a long-term management plan to conserve not only currently threatened and endangered species, but also to help avoid the future listing of additional wildlife species (DNR 1997, 2006b).

What Are the Indicators for Assessing Wildlife Habitat?

Indicators for biological diversity relate to a range of ecosystem conditions and the wildlife species associated with them.

WILDLIFE GUILDS

Guilds are assemblages of species that have similar habitat requirements for foraging, breeding (nesting/denning) and/or shelter. Guilds are defined using different types of ecological overlap, so individual species can belong to several guilds (refer to Table 3-19). The guilds in Table 3-19 were developed for this analysis, to describe species that will benefit from various forest conditions, based largely on Brown (1985) and Johnson and O'Neil (2001). The guilds and species listed are merely examples of how different assemblages of wildlife may respond over time to forest structures and conditions created by DNR to enhance wildlife habitat on forested state trust lands.

The Washington Biodiversity Council defines **biodiversity** as "the full range of life in all its forms". This includes: the habitats in which life occurs, the ways that species and habitats interact with each other, the physical environment, and the process necessary for those interactions.

Wildlife guilds can be used to examine which potential species are associated with certain forest conditions and structures. Species composition may correspond to various forest conditions created under the different alternatives.

STAND DEVELOPMENT STAGES

The amount of forest in the different stand development stages indicates what potential wildlife habitat conditions are present within the planning unit (Table 3-20). Different species are associated with different forest stand conditions within each stand development stage (refer to Text Box 3-1, p. 44). Stand age is not used as an indicator, as the 1997 *Habitat Conservation Plan* found it to be an insufficient indicator of stand structure and ecological function (DNR 1997, p. IV-89; DNR 2004).

NATURAL AREA PRESERVES AND NATURAL RESOURCE CONSERVATION AREAS

Natural Area Preserves protect the best remaining examples of many ecological communities, including rare plant and wildlife habitats. The Natural Heritage Program identifies the highest quality and most ecologically important sites for protection as Natural Area Preserves. Natural Resource Conservation Areas protect outstanding examples of native ecosystems; habitat for endangered, threatened, and sensitive plants and animals; and scenic landscapes. Environmental education and low impact public use are appropriate in Natural Resource Conservation Areas where they do not impair the resource values of the area protected. The number and size of Natural Area Preserves and Natural Resource Conservation Areas is an indication of the level of protection given rare, sensitive, and endangered species.

FOREST FRAGMENTATION

Forest fragmentation occurs when large, continuous forests are divided into smaller blocks by timber harvesting, roads, agricultural clearing, urbanization, or other human development. Forest fragmentation can lead to habitat fragmentation for many species. Not all wildlife species respond to fragmentation in the same way. Some tolerate fragmented habitat, while others can be greatly impacted. Habitat fragmentation

Table 3-19. Wildlife Guilds and Species Benefitting from Various Forest Conditions and Structures

Forest Structures and Conditions	Benefitting Guild	Representative Species
Retained live trees (patches and individual trees)	Feed and/or breed in large trees (generally greater than 24 inches diameter)	Chestnut-backed chickadee, brown creeper, golden-crowned kinglet, Pacific-slope flycatcher, rufus hummingbird, pileated woodpecker
	Arboreal seed eaters	Pine siskin, Douglas squirrel, Townsend's chipmunk
	Arboreal needle/bud eating	Blue grouse, Douglas squirrel, porcupine,
	Arboreal omnivores	Raccoon, Virginia opossum
	Bark probers/gleaners	Hairy woodpecker, northern flicker, red breasted nuthatch, brown creeper
	Foliage gleaning insectivores	Warbling vireo, golden-crowned kinglet, hermit warbler, western tanager
	Perching/hawking (esp. during ecosystem initiation)	Red-tailed hawk, great horned owl, Steller's jay, American crow
Retained and created snags	Primary cavity nesters	Pileated woodpecker, red breasted nuthatch
	Secondary cavity nesters	Chestnut-backed chickadee, saw-whet owl
	Arboreal insectivores (nesting)	Tree swallow, violet green swallow, Vaux's swift
	Large snag dependent	Pileated woodpecker, northern saw-whet owl, western screech owl, black bear, American marten, bats
Retained coarse woody debris, ground cover, organic soil layers	Herbivorous and fungivorous forest floor small mammal (truffles and fungi, seeds, berries, insects)	Deer mouse, Oregon creeping vole, red backed vole
	Small mammal predators	Coyote, bobcat, long-tailed weasel, red-tailed hawk, American marten
	Ground insectivores	Northern alligator lizard, western fence lizard, western toad, Northwest salamander, Pacific tree frog, shrews, moles, black bear
	Large downed wood dependant	Amphibians and reptiles (see row above), black bear, American marten
Created small forest openings, diversity of tree sizes, vertical and horizontal diversity	Understory birds	Dark-eyed junco, fox sparrow, hermit thrush, orange-crowned warbler, olive-sided flycatcher, pine grosbeak, ruby-crowned kinglet, Wilson's warbler, winter wren
	Herbivorous mammals	Columbia black-tailed deer, Rocky Mountain elk, eastern cottontail, deer mice, voles
	Aerial salliers	Western tanager, olive-sided flycatcher
	Foliage gleaning insectivores	Golden-crowned kinglet, warbling vireo, hermit warbler, western tanager
	Understory-gleaning insectivores	Winter wren, song sparrow
	Edge species	Deer, elk , western screech owl, great horned owl, bats (see also Table 3-14)
	Large mammal predators	Cougar, bear
Complex forest structure: Niche Diversification and Fully Functional stand development stages	Late successional specialists	Northern goshawk, northern spotted owl, Townsend's warbler, northern flying squirrel

Table 3-20. Stand Development Stages and Vertebrate Species Associated with Them

Stand Development Stage	Species
Ecosystem Initiation	Rubber boa, terrestrial garter snake, northern alligator lizard, western fence lizard, ruffed grouse, California quail, common nighthawk, mountain bluebird, orange-crowned warbler, rufus-sided (spotted) towhee, white-crowned sparrow, dark-eyed junco, snowshoe hare, mountain beaver, deer mouse, creeping vole, Pacific jumping mouse, striped skunk, Rocky Mountain elk, Columbian black-tailed deer, black bear
Competitive Exclusion	Ruffed grouse, orange-crowned warbler, white-crowned sparrow, snowshoe hare, mountain beaver, common porcupine
Understory Development	Masked shrew, Townsend's chipmunk, common porcupine
Biomass Accumulation	Blue grouse, golden-crowned kinglet, Townsend's warbler, masked shrew, Townsend's chipmunk, Douglas' squirrel, western red-backed vole
Niche Diversification	Blue grouse, northern pygmy-owl, northern spotted owl, pileated woodpecker, Steller's jay, winter wren, varied thrush, masked shrew, long-legged myotis, silver-haired bat, big brown bat, snowshoe hare, Townsend's chipmunk, Douglas' squirrel, northern flying squirrel, western red-backed vole, red tree vole, common porcupine, Rocky Mountain elk, Columbian blacktailed deer
Fully Functional	Blue grouse, marbled murrelet, northern spotted owl, pileated woodpecker, Pacific-slope flycatcher, golden-crowned kinglet, sharp-shinned hawk, northern pygmy-owl, Vaux's swift, Steller's jay, winter wren, varied thrush, Townsend's warbler, western tanager, masked shrew, long-legged myotis, Keen's myotis, silver-haired bat, big brown bat, snowshoe hare, Townsend's chipmunk, Douglas' squirrel, northern flying squirrel, Rocky Mountain elk, Columbian black-tailed deer, black bear

includes reducing in the total area of the habitat, increasing the amount of edge (Table 3-21), decreasing the amount of interior habitat, isolating one habitat fragment from other areas of habitat, breaking up one patch of habitat into several smaller patches, and decreasing in the average size of each patch.

What are the Current Conditions of Wildlife Habitat?

Each stand development stage satisfies different habitat needs for a variety of species and this assessment of the current conditions for wildlife habitat is based on these development stages.

For a description of the current stand development stages and their distributions across the landscape, refer to forest conditions (p. 45). For a listing of species associated with these stand development stages, refer to Table 3-20, and for guilds associated with forest structures and conditions, refer to Table 3-19.

SENSITIVE WILDLIFE SPECIES

The *Endangered Species Act* (1973) protected species and their habitats to ensure their survival. Sensitive species[24] are defined as, "any wildlife native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats." Table 3-22 lists these species and their essential habitat elements as they exist in stand development stages.

NATURAL AREA PRESERVES AND NATURAL RESOURCE CONSERVATION AREAS

DNR currently has seven Natural Area Preserves and three Natural Resource Conservation Areas specific to the protection of rare, sensitive, and endangered species.

Table 3-21. Wildlife Species Closely Associated with High-Contrast Forest/ Shrub Edges

Meets All Habitat Requirements	Ensatina, ruffed grouse, band-tailed pigeon, great horned owl, common nighthawk, rufous hummingbird, western wood-pewee, winter wren, Townsend's solitaire, Swainson's thrush, hermit thrush, American robin, varied thrush, orange-crowed warbler, yellow-rumped warbler, western tanager, black-headed grosbeak, rufous-sided towhee, dark-eyed junco, brown-headed cowbird, purple finch, pine siskin, American goldfinch, masked shrew, vagrant shrew, mountain beaver, deer mouse, American kestrel, red-tailed hawk, common raven, Steller's jay
Meets Foraging Habitat Requirements Only	Blue grouse, Cooper's hawk, northern pygmy-owl, northern saw-whet owl, western screech-owl, ruby-crowned kinglet, Vaux's swift, big brown bat, silver-haired bat, hoary bat, California myotis, Keen's myotis, little brown myotis, American marten, short-tailed weasel, mountain lion, black-tailed deer, red fox, bobcat

Table 3-22. Sensitive Wildlife Species Known or Suspected to Occur*

Species and Status	Habitat		
	Foraging	Breeding and/or Resting	General Upland
Red-Legged Frog (FCo)	Ecosystem Initiation and structurally complex stand development stages	Requires riparian for breeding.	Moist habitats, including shrubby areas with large woody debris.
Western Toad (FCo, SC)	All	Requires riparian for breeding.	Large woody debris.
Northern Goshawk (FCo, SC)	Edges and open forest, Structurally complex.	Structurally complex	Mature and late-successional forests.
Bald Eagle (SS, FCo)	Large trees and snags near water.	All stages, but requires large trees for nesting and protected stands for roosting.	Large trees for nesting, dense and mature forest stands for winter roosts.
Great Blue Heron (SM)	May forage in ecosystem initiation stands.	Biomass accumulation, Structurally complex, (Generally near large water bodies)	Mature forest stands (nesting).
Olive-Sided Flycatcher (FCo)	Ecosystem Initiation	Structurally complex	Large trees adjacent to open areas.
Osprey (SM)	Water (non-forest)	Structurally complex	Large trees for nesting, perching, roosting near large bodies of water.
Turkey Vulture (SM)	May forage in ecosystem initiation stands.	Structurally complex	Mature tree stands for roosting.
Vaux's Swift (FCo, SS)	Aerial foraging over all stages.	Structurally complex	Large snags for nesting.
Willow Flycatcher (FCo)	Ecosystem Initiation	Ecosystem Initiation	Shrubby habitats.
Long-Eared Myotis (FCo, SM)	Ecosystem Initiation	Structurally complex	Large snags and trees for roosting.
Long-Legged Myotis (FCo, SM)	Ecosystem Initiation	Structurally complex	Large trees and snags for roosting.
Townsend's Big-Eared Bat (FCo, SC)	Ecosystem Initiation	Structurally complex	Large trees and snags for nesting.
Yuma Myotis (FCo)	Ecosystem Initiation	Structurally complex	Large trees and snags for roosting.

FCo = Federal Species of Concern, SC = State Candidate, SE = State Endangered, SS = State Sensitive, ST = State Threatened, SM = State Monitor
*Source: Based on Brown (1985) and Johnson and O'Neil (2001)

ECOSYSTEM INITIATION

Forest stand development begins as open, newly established forest stands of rapidly growing young trees and shrubs. Compared to other stages, wildlife diversity increases in the Ecosystem Initiation stage until stands reach more structurally diverse conditions (Brown 1985; Johnson and O'Neil 2001).

Many species use stands in this stage more for foraging than breeding. Brown (1985) identified 70 species in western Washington and Oregon that used Ecosystem Initiation (grass/forb stage in Brown 1985) as the primary foraging habitat, compared to 26 species that use the Ecosystem Initiation stage as primary breeding habitat (refer to Table 3-20). Reptiles, such as northern alligator lizard and western fence lizard, are generally uncommon in forested landscapes, but are known to occur within variable retention harvest areas, where stumps, woody debris, and open canopies provide basking habitat, believed to be important for thermoregulation (Waldien and others 2003).

Ecosystem Initiation stage stands create edge habitat that can increase wildlife use (Hunter 1990; Patton 1992; Johnson and O'Neil 2001). Adjacent stands in the Understory Development and older-forest development stages provide cover and perching habitat adjacent to possible high-quality foraging habitat within the Ecosystem Initiation stage. Such high-contrast edges are known to be used by red-tailed hawks, accipiters (sharp-shinned and Cooper's hawks), and several species of owls (Johnsgard 1988, 1990; Table 3-21). Edges also provide escape and hiding cover, so that species that forage within the relatively open Ecosystem Initiation stands, such as deer and elk, stay near forested edges where they can more easily escape predators (Kirchhoff and others 1983; Yahner 1988).

COMPETITIVE EXCLUSION

No wildlife species in western Washington are found exclusively in the Competitive Exclusion stage (Carey and others 1995) because of its low structural diversity and low or absent shrub cover (Johnson and O'Neil 2001). However, some species use these stands as cover for hiding, escape, breeding, and protection from weather. For example, ruffed grouse nest within this habitat type and use it to escape from predators (Dessecker and McAuley 2001). Therefore, the presence of at least some Competitive Exclusion stage forest stands should contribute to overall biodiversity in terms of wildlife species abundance and distribution (refer to Table 3-20).

Variable retention harvesting creates temporary edges between stands of different ages. Edges are considered "abrupt" or "hard" when the age difference is great between stands, or gradual or "soft" when the age difference is less (DeGraaf 1992, Payne and Bryant 1994). Edges created by variable retention harvests are initially abrupt, and as stands regenerate they become "soft," and then nonexistent as contrast between the two age classes diminishes. (Manolis and others 2002)

UNDERSTORY DEVELOPMENT

Overall wildlife use of the Understory Development stage is low. Johnson and O'Neil (2001) identified only six species closely associated with this stage (the same number as Competitive Exclusion): masked shrew, silver-haired bat, big brown bat, Townsend's chipmunk, and porcupine. The bat species use this habitat only for foraging, where they are known to fly above the tree canopy to feed on insects (Nagorsen and Brigham 1993; Brown 1985).

BIOMASS ACCUMULATION

Biomass Accumulation forest stands contain relatively large diameter trees (at least 15 trees over 30 inches in diameter per acre) spaced sufficiently to allow rapid growth. This stage is often created through commercial thinning of Understory Development stage stands that have returned to high canopy closure conditions and in which a well-developed understory may be lacking, at least initially. Johnson and O'Neil (2001) listed 11 species closely associated with this development stage, although many of the species require remnant

Table 3-23. Current Natural Area Preserves and Natural Resource Conservation Areas

Name	Approximate Acres	Habitat Type
Bald Hill NAP	307	This preserve supports an unusual number of habitats and plant communities, including streamsides, mossy rocks, cliff crevices, seasonally wet grassland, Oregon white oak woodland, and exposed rock outcrops.
Charley Creek NAP	1,172	Native growth forest land is undisturbed by human activity such as harvesting with forests of 110 to 145 years old dominating the site with native plant associations and communities.
Kennedy Creek	194	This site is a good quality remnant of a larger tidal river marsh, providing important habitat for wildlife.
Kitsap Forest NAP	571	Mature and old growth douglas fir and western hemlock dominate this forest with rhododendron, evergreen huckleberry, and sword fern in the forest understory.
Oak Patch NAP	18	Oregon white oak woodland and an Oregon white oak-Douglas-fir mosaic which is extremely unusual on the Kitsap Peninsula, and represents a vanishing woodland community in the Puget Trough. Spring wildflowers such as fawn lilies, chocolate lilies, and camas lilies thrive on this site.
Shumocher Creek NAP	492	A stream and associated wetlands, an upland buffer, and a variety of plant communities that vary in their dominant vegetation. One of the plant communities found at Shumocher NAP, the Skita alder/skunk cabbage/water parsley community.
Skookum Inlet NAP	146	The saltmarsh communities, tideflats, and second growth forest.
Tahoma Forest NRCA	233	The NRCA supports mature and old-growth mid-elevation forest communities ranging from 100 to well over 200 years of age. Douglas-fir and western hemlock dominate the forest overstory, but silver fir and especially noble fir are also common. The understory is generally quite open and includes species such as beargrass, red huckleberry, Pacific rhododendron, vanilla leaf, cutleaf goldthread, and queencup beadlily.
Stavis NRCA	1,559	This area is similar to the historic forest matrix of the Kitsap Peninsula.
West Tiger Mountain NRCA	3,885	The area provides important habitat for large and small wildlife including black bear, cougar, deer, raccoon, eagle, waterfowl, reptiles, and amphibians.
Woodard Bay NRCA	838	This site protects habitat ranging from shoreline to wetlands to mature second growth forest.

snags to be present for breeding. These include long-legged myotis, Vaux's swift, and the pileated woodpecker. Many of the existing stands in the Biomass Accumulation stage lack large snags, which these species need. Trees in this stage are sufficiently mature to produce large cone crops, food for seed eating wildlife such as red crossbill, Douglas' squirrel, and Townsend's chipmunk (Adkisson 1996; Chapman and Feldhammer 1982). Larger crowns and crown growth in this stage likely support use by needle-eating wildlife, including the blue grouse (Cade and Hoffman 1990).

NICHE DIVERSIFICATION AND FULLY FUNCTIONAL

Numerous studies have shown that many species require structurally complex forests for some or all of their life history requirements (summarized in Zobrist and Hinckley 2005). Key elements of structurally complex forests include large live and dead trees (snags) and coarse woody debris of various sizes and conditions (DNR 2004); multiple vertical canopy layers (for example hemlock, vine maple) and within-stand diversity (patches of larger trees and small openings) and a diverse understory of tree and shrub species of varying sizes and shapes.

More species require structurally complex forest stages for breeding than any of the other stand development stages. Brown (1985) listed 70 species in western Washington and Oregon that primarily use structurally complex forests for breeding. Based on habitat associations presented in Johnson and O'Neil (2001) and distribution maps prepared by Cassidy and others (1997), 23 species that breed within the planning unit are closely associated with Niche Diversification and 28 with Fully Functional forest stand development stages. Species that primarily use structurally complex forests as breeding habitat are listed in Table 3-20.

How Does DNR's Management Affect Wildlife Habitat?

One of DNR's long-term management goals is to provide a diversity of stand development stages to support a broader diversity of wildlife species at a landscape or ecoregional scale (DNR 1997, 2004, 2006a).

TIMBER HARVESTING

DNR manages for specific wildlife habitats and specific forest conditions through the combination of silviculture and landscape management strategies, as described in Appendix F of the *Final EIS for Policy for Sustainable Forests* (DNR 2006a) and the 1997 *Habitat Conservation Plan* (HCP). Silvicultural techniques include variable retention harvests and thinning treatments, which have been developed by DNR staff (Holmberg and others 2007) from the forestry literature (Franklin and others 2002; Carey and others 1995). Refer to the *Sustainable Harvest Final EIS* (2004) for more information.

Timber harvesting activities change forest stand conditions and may alter the wildlife species composition associated with them (refer to Table 3-24). Timber harvesting can also fragment forested wildlife habitat by increasing edge and the related edge effects, and these have been shown to have negative impacts to ground nesting birds (Manolis and other 2002).

ROADS

Roads can result in increased habitat fragmentation in core forest areas and a greater amount of edge habitat (Miller and others 1996; Reed and others 1996). Whenever forest roads are built, changes in habitat are likely, which can lead to changes in wildlife populations (Lyon 1983). Andrews (1990) hypothesized that effects of traffic noise on wildlife include hearing loss, increase in stress hormones, altered behaviors, interference with communication during breeding activities, and sensitivity to different frequencies (Reijnen 1995; Reijnen and others 1995; Wasser 1997). Roads also provide a conduit for people to enter the forest (refer to Roads, p. 82). Proposed road locations may need to be altered to avoid wildlife habitat, such as balds, caves, talus slopes, and other habitats. Restricting timing of road building may be needed, especially during the breeding season of sensitive species.

RECREATION

A review of 166 journal articles by Boyle and Samson (1985) found that 81 percent of articles implied negative affects to wildlife from recreational activities (Knight and Cole 1995). Recreation impacts wildlife through death of the individual or by changes to behaviors, vigor, or

Table 3-24. Effect of Timber Harvesting on Wildlife

Harvest Type	Duration	Adverse Impacts	Beneficial Impacts
Regeneration Harvest	Short-term	Eliminates habitat for many species using the forested stand being harvested. Significance depends on stand conditions prior to harvest. Noise may cause wildlife to leave the immediate area, including deer, elk, and bear. Physical disturbance from yarding can reduce shrub layers and habitat for ground-associated species. Possible direct mortality (unintentionally cutting down a nest tree).	Immediately opens stand and promotes shrub growth, supporting foraging habitat for many species (see Table 3-14) under Ecosystem Initiation. Produces breeding habitat for reptiles that are rare or absent in other stand stages. Leave trees provide perches for olive-sided flycatchers, red-tailed hawks, and great horned owls. Wildlife trees provide habitat for cavity-nesting birds such as woodpeckers. High-contrast edge supports species such as western screech owl and accipiter hawks. Created and retained snags and coarse woody debris support cavity-nesting birds, small mammals, and amphibians.
	Long-term	Reduces or eliminates wildlife species that require mature overstories, such as hermit warblers, northern flying squirrels, and red tree voles.	Legacy trees and leave patches will eventually support species that require large trees and snags, such as brown creeper, pileated woodpecker, and many species of bats.
Thinning Harvest	Short-term	Noise and activity may cause wildlife to leave the area. Physical disturbance can reduce shrubs and associated habitat for birds. Potential removal of snags for worker safety reduces habitat for cavity-nesting birds. Possible direct wildlife mortality caused by unintentionally cutting down a nest tree.	Opens stand to provide space for forest birds, such as sharp-shinned and Cooper's hawks. Variable density thinning can create openings used by many types of wildlife that forage within Ecosystem Initiation stage stands. Dead and down wood created and retained within legacy patches provides hiding or nesting cover for amphibians, small mammals, and insects.
	Long-term	Tree removal reduces habitat for species that require denser stands, such as blue grouse.	Encourages development of large trees that are necessary components of structurally diverse stands, eventually supporting breeding habitat for woodpeckers, bats, and other species. Increases structure and remnant cohorts for long-term increase in wildlife diversity and abundance. Trends move toward older-forest conditions and associated wildlife communities.

productivity. This impact to individuals can, in turn, influence population distribution, abundance, and demographics potentially altering community species composition (Knight and Cole 1995).

DNR is currently assessing areas with high recreation use for its compatibility with known wildlife species or their habitats that occur in the areas. Recreation could potentially be moved or limited in sensitive areas identified through this process.

Additionally, recreational activities can result in wildlife leaving or avoiding areas of high recreational use such as campgrounds, trailheads, parking areas, and roads. Deer, elk, and bear are known to avoid areas of high human use, although deer and elk can forage along roads, particularly at night and in the early morning, when human use is low (Gains and others 2003). Off-road vehicles generate loud noises, and many types of wildlife avoid off-road vehicle trails (Stokowski and LaPointe 2000). Deer and elk are known to become habituated to regular, non-threatening disturbances such as a passing car, although heavily hunted populations may be more wary (Freddy and others 1986). However, wildlife are more vulnerable to disturbance at certain times of the year, such as when birthing, or certain times of the day, such as feeding (Knight and Gutzwiller 1995). Motorized access can increase hunting pressure and associated mortality.

Birds and other wildlife may be disturbed by habitat modifications when recreational areas are created. Road building and harvesting activities, as well as the creation of parking lots, picnic areas, and campgrounds can fragment habitat and increase edge. Presumably, forest fragmentation caused by recreation has the same negative impacts as fragmentation caused by other management activities. Even recreational areas that preserve mature (overstory) trees can have a significant influence on the structure of forest vegetation. For example, small shrubs and trees in the forest understory are often removed, which may limit the nesting and foraging opportunities for some bird species (Rohrbaugh 2000).

Marbled Murrelets

The marbled murrelet (*Brachyramphus marmoratus*) is a small, dove-sized seabird in the Alcidae family. They are unique among alcids because they nest on the large moss-covered limbs and mistletoe brooms of trees in Pacific coastal forests. They are a secretive bird that spends most of its time at sea.

Why Are Marbled Murrelets Important in This Area?

Marbled murrelets were listed as a threatened species by the federal government in 1992, primarily due to the loss of older-forest habitat. The greatest identified threat to marbled murrelets in Washington, Oregon, California, British Columbia, and Alaska is the loss of the quality nesting sites which exist primarily in older forests.

Although forested state trust lands in the South Puget HCP Planning Unit are likely not significant contributors of marbled murrelet nesting sites, they do contribute to the overall distribution of the species within its breeding range.

What Is the Criterion for Assessing Marbled Murrelets?

The fundamental biological criterion for assessing marbled murrelet conservation recommended by the Marbled Murrelet Long-term Conservation Interdisciplinary Science Team were lands supporting a marbled murrelet population that is 1) stable or increasing, 2) well-distributed, and 3) resilient.

The 1997 *Habitat Conservation Plan* (HCP) required the development of a conservation strategy for the marbled murrelet; however, due to a lack of information on this species, DNR implemented an interim conservation strategy (DNR 1997, p. IV. 39) until a long-term conservation strategy could be created.

What Are the Indicators for Assessing Marbled Murrelet Conditions?

A determination for identifying the indicators for marbled murrelets will come out of the long-term conservation strategy being developed. This is a separate process which involves the Federal

Services and is beyond the scope of this planning effort. However, when the long-term conservation strategy is completed, it will be applied to this planning unit.

What Are the Current Conditions for Marbled Murrelets?

A small number of marbled murrelets is believed to use forested state trust lands in the South Puget planning unit. Off-shore populations of marbled murrelets are extremely low, indicating that the probability of inland detections is also low within this planning unit as is substantiated by low detection rates on adjacent non-DNR managed lands. In 2007, radar surveys were completed on forested state trust lands with some areas showing potential use by the species (Cooper and others 2007). DNR has assessed 6,000 of 8,000 acres of potential marbled murrelet habitat since 2007. Of the 6,000 assessed acres within the planning unit, there are 579 acres of occupied habitat, 354 acres of suitable habitat, and 4,469 acres determined unsuitable and released for management activities. The occupied and suitable habitat will be deferred from harvest and buffered. The 2,000 acres yet to be assessed will be treated as if occupied until the assessment is complete.

How Does DNR's Management Impact Marbled Murrelets?

DNR has identified suitable habitat on forested state trust lands within this planning unit that is deferred from harvest activities except for certain special circumstances for road building or yarding corridors, as described in South Puget Planning Unit Interim Marbled Murrelet Conservation Strategy (refer to Appendix N).

TIMBER HARVESTING AND ROAD BUILDING

Timber harvesting and road building can lead to forest fragmentation. The USFWS in its listing decision believed that forest fragmentation by timber harvesting increased edge effects, especially predation, which results in reduced nesting success.

Northern Spotted Owl

The northern spotted owl (*Strix occidentalis caurina*) is a medium-sized, nocturnal bird with white mottling on the body and abdomen (Johnsgard 1988; DNR 1997). The chest and head have white spots on them, making the bird distinguishable from its close relative the barred owl (*Strix varia*), which has vertical barring on its chest. Northern spotted owls inhabit structurally complex forests from southwest British Columbia through the Cascade Mountains and coastal ranges in Washington, Oregon, and California (Forsman and others 1984; Gutiérrez and others 1984; Allen and Brewer 1985). It is an indicator species of forest ecosystem health, reliant predominantly on northern flying squirrels (*Glaucomys sabrinus*) for food, which in turn, rely on truffles and other fungal fruiting bodies associated with late-successional western hemlock and Douglas-fir forests in the Pacific Northwest (Carey and others 1992). Refer to the 1997 *Habitat Conservation Plan* (p. lll.1 to lll.22) for a more complete description of northern spotted owl biology.

STATUS OF NORTHERN SPOTTED OWLS

The northern spotted owl has been listed as threatened under the federal *Endangered Species Act* (ESA) since 1990. A scientific evaluation which summarized the status of owl populations for the USFWS 5-year status review stated, "In general, northern spotted owl populations are exhibiting strong declines in the northern portion of their range in Canada, Washington, and parts of Oregon, while populations in the southern portions of their range are generally stable. Declines in Washington appear to be driven by decreased adult survivorship." (Courtney and others 2004)

The major threats to northern spotted owls include loss of habitat from past management activities, disturbances such as fire, and ongoing habitat loss as a result of timber harvest on non-federal lands (Courtney and others 2004). Recently, competition with barred owls has been identified as another major threat (Courtney and others 2004; Gutierrez 2006; Olson and others 2004).

Why Are Northern Spotted Owls Important to DNR?

DNR's 1997 *Habitat Conservation Plan* committed to managing certain forested state trust lands in order to "provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal" (DNR 1997).

Demographic Support—Refers to the contribution of individual territorial spotted owls or clusters of spotted owl sites to the stability and viability of the entire population (Hanson and others 1993, p. 11).

Maintenance of Species Distribution—Refers to supporting the continued presence of the spotted owl population in as much of its historic range as possible (Thomas and others 1990, p. 23; USFWS 1992, p. 56).

Dispersal—Refers to the movement of juvenile, sub-adult, and adult animals (spotted owls) from one sub-population to another. For juvenile spotted owls, dispersal is the process of leaving the natal (birth) territory to establish a new territory (Forsman and others 2002; Miller and others 1997; Thomas and others 1990, p. 303).

DISPERSAL MANAGEMENT AREA DESIGNATIONS

The conservation strategy outlined in the 1997 HCP defined dispersal management areas and is intended to provide habitat, in strategic areas. The strategy is also intended to create a landscape in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat (DNR 1997).

Approximately half (78,047 acres) of the forested state trust lands identified for dispersal management in the 1997 HCP are within this planning unit. There are also two areas (refer to Map 3-5) designated as nesting, roosting, and foraging management areas (approximately 2,419 acres).

NORTHERN SPOTTED OWL DISPERSAL

Dispersal is facilitated by providing forests with adequate food, cover, and flying space for owls as they travel between their natal area and suitable unoccupied habitat (DNR 1997). When juvenile owls disperse (or leave) their natal territories, they experience a transience phase that is characterized by extensive and rapid movement through an area (Greenwood 1980; Miller and others 1997). Miller (1989) observed that juveniles moved an average of 0.75 mile (1.2 kilometers) per day. Forsman and others (2002) estimated average daily movements during the transience phase at between 0.44 to 0.87 mile (0.7 and 1.4 kilometer) per day.

After a few months of the transience phase, most northern spotted owls experience a colonization period. During this time, they settle for a short while in areas over a winter before trying to establish a permanent territory (Miller and others 1997; Forsman and others 2002). During the colonization period, Forsman and others (2002) estimated average daily movements to be between 0.25 to 0.37 mile (0.4 and 0.6 kilometer) per day.

FACTORS IMPORTANT TO DISPERSING NORTHERN SPOTTED OWLS

Buchanan (2004) discussed five factors, previously hypothesized by Carey (1985), that affect the success of northern spotted owl dispersal: 1) amelioration of heat stress, 2) prey abundance, 3) prey availability, 4) predation risk, and 5) ecological adaptation. These factors influence the three dispersing activities of northern spotted owls:

Movement— Can an owl travel from one patch of habitat to another without being predated upon? (Forsman 2002; Miller and others 1997)

Roosting— Is an owl able to perch for resting, heat regulation, and hunting? (Forsman 1976, 1980; Barrows and Barrows 1978; Barrows 1981; Forsman and others 1984)

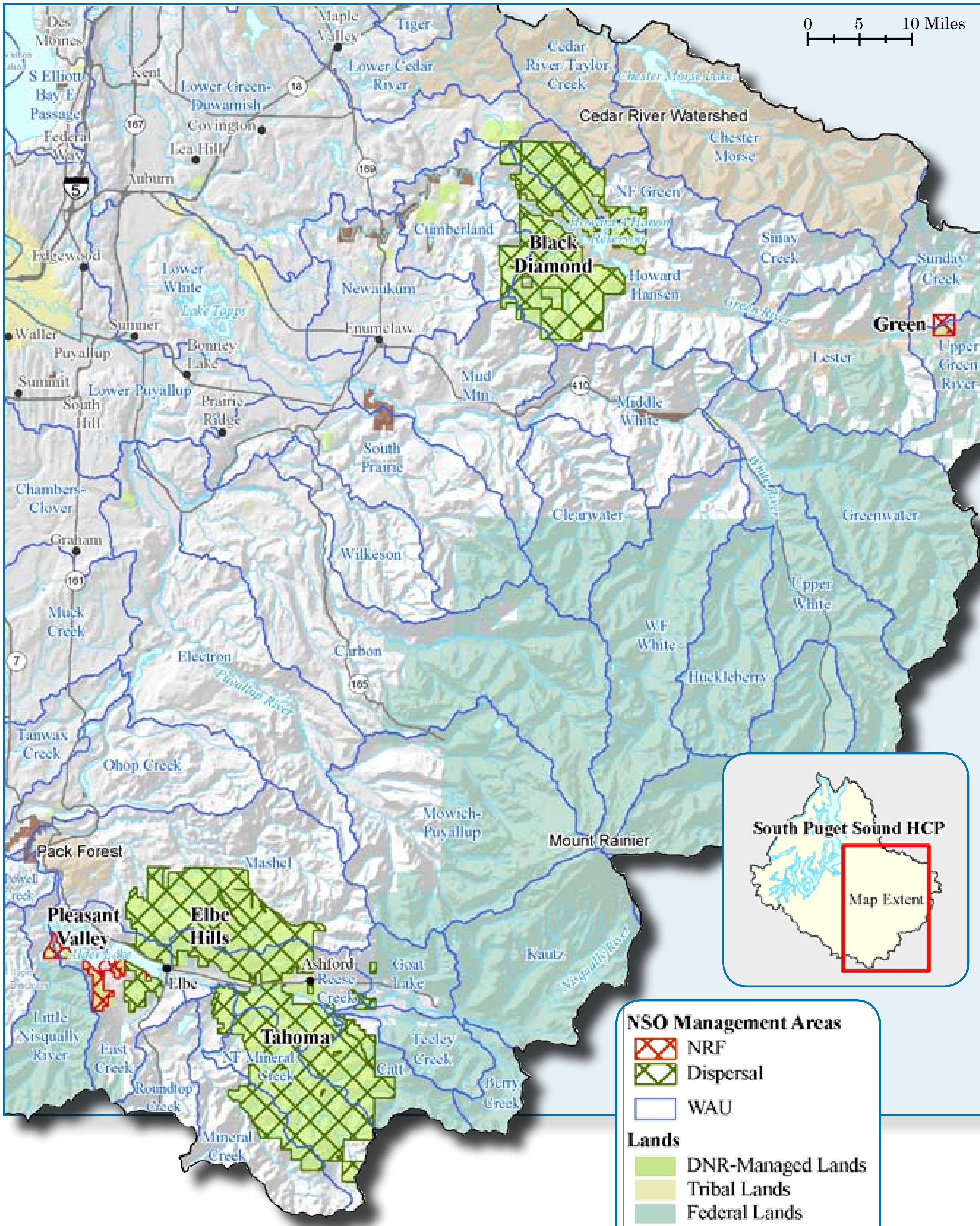
Foraging— Can an owl display hunting behavior? Are prey species abundant and available? (Forsman and others 1984, 2004; Gutiérrez and others 1995; Solis and Gutiérrez 1990).

DNR'S 1997 HABITAT CONSERVATION PLAN DISPERSAL HABITAT DEFINITION

When DNR entered into the 1997 HCP, there was limited published scientific information on the habitat needs of dispersing northern spotted owls. At that time, DNR developed a set of minimum requirements that must be met in forest stands for dispersing owls, with the understanding that

Dispersal Management Areas in the South Puget Planning Unit

For a description of the areas highlighted on the map, see Appendix G.



Map 3-5. Northern Spotted Owl Dipersal Management Areas
Map by Rebecca Niggemann 05/05/08

the definition would be modified in the future as new information became available. The 1997 HCP definition, described in Text Box 2-2, focused on providing cover for dispersing owls.

What Are the Criteria for Northern Spotted Owl Dispersal Habitat?

Congress passed the *Endangered Species Act* (ESA) in 1973 recognizing that our rich natural heritage is of "esthetic, ecological, educational, recreational and scientific value to our nation and its people" (ESA 1973). The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. The law's ultimate goal is the recovery of the species. DNR's conservation objective for the northern spotted owl supports this recovery effort by providing habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal (DNR 1997).

What Are the Indicators for Assessing Dispersal Habitat?

AREA MEETING NORTHERN SPOTTED OWL DISPERSAL HABITAT CONDITIONS OR BETTER

DNR uses a range of spotted owl habitat definitions to track habitat conditions in areas designated for northern spotted owl management. The majority of the definitions come from DNR's 1997 HCP and include Dispersal, Young Forest Marginal, Sub-mature, Type A, Type B, and High-quality Nesting (DNR 1997, p. IV. 11 and Glossary). Two additional habitat types are included as part of this environmental analysis: movement, roosting, and foraging (MoRF) and South Puget Movement conditions (refer to Chapter 2, p. 30 for definitions).

Examining the proportions of the landscape that are classified in these habitat designations is a way to assess the forests' ability to support dispersing owls.

AREA SUPPORTING NORTHERN SPOTTED OWL DISPERSAL LIFE HISTORY REQUIREMENTS

Forest stands are beneficial for dispersing northern spotted owls if they support one or more of their three life history requirements: movement, roosting, and foraging.

Movement—Forest stands that benefit movement ability must have canopies closed enough to allow the northern spotted owls to be protected from predation. These stands must also have adequate flying space available, which is achieved by canopy lift (tree limbs off the ground) and tree densities low enough to not impede flight (Appendix G, NSO-DAT Workshop).

Roosting—Forest stands that benefit roosting ability must have adequate tree height for roosting opportunities, multiple tree and shrub layers for owls to move up and down in the canopy, and a deep enough canopy to provide a thermal buffer (more insulation) against temperature extremes and more protection from predation (Appendix G, NSO-DAT Workshop).

Foraging—Forest stands that benefit foraging ability must have adequate prey abundance, which depends on the amount of snags and coarse woody debris. Multiple vertical canopy layers make prey more available to owls by providing hunting perches and a more heterogeneous (varied) forest, which make catching prey easier (Appendix G, NSO-DAT Workshop).

All three of these life history requirements allow flying space and protection from predators, which are achieved by adequate forest species composition and canopy closure. The percent of the landscape achieving one or more of these life history requirements over time can be used to assess the forests' ability to support dispersing owls.

FRAGMENTATION AND HABITAT CONNECTIVITY

Natal and breeding habitats are likely impacted by forest fragmentation once a certain amount of forested habitat is lost (Courtney and others 2004). Forsman and others (2002) did not report that juvenile or adult dispersing owls cross large segments of unsuitable habitat such as the non-forested Willamette, Rogue, and Umpqua valleys, or large bodies of water. Courtney and others (2004) suggest that fragmentation could impact the rates of recolonization, reduce dispersal opportunities, and create a lower gene pool flow within and between populations.

Comparing habitat connectivity over time assesses the landscape's ability to facilitate dispersal of northern spotted owls.

ACRES HARVESTED IN EXISTING NORTHERN SPOTTED OWL CIRCLES

Owl circles encompass a 1.8-mile radius around a known northern spotted owl site center. These circles were classified by a status numbering system of one to four (USFWS 1991, 1992). Within the planning unit, there are three Status One (reproductive) circles that fall partially onto forested state trust lands managed for dispersing owls. Because of current concerns for northern spotted owl declines in Washington (USFWS 2004), management activities in the first decade in Status One owl circles will be reported.

What Are the Current Conditions for Dispersal Management Areas?

FOREST CONDITIONS

Past timber management activities in the planning unit have resulted in forest conditions dominated by Competitive Exclusion and Understory Development stages (refer to Forest Conditions, p. 43). These overstocked and structurally simple stands are difficult for owls to fly through and contribute little to foraging and roosting habitat.

The current dispersal definition for northern spotted owls (Text Box 2-2) does not target forest stand conditions that provide roosting or foraging opportunities for dispersing owls because there is no requirement for structural complexity, snags, and coarse woody debris. In addition, there is no upper threshold limit on the number of trees per acre, which can result in stands that are too over-stocked (dense) for owls to fly through, thereby affecting movement.

Buchanan (2004) compared various existing habitat conservation plans that were negotiated for managing northern spotted owl dispersal habitat, including DNR's 1997 HCP. He concluded that the proposed strategies rely on habitat definitions that do not provide habitat attributes important for dispersing owls thus resulting in mortality due to starvation or predation.

Overstocked forest stands offer little benefit to wildlife (Johnson and O'Neil 2001). Stand development stages do not change quickly in the absence of disturbance such as fires, windstorms, or harvesting; stands may persist in one stage for several decades (Carey 2007). (Refer to Text Box 3-2). Carey (1995) and Carey and Johnson (1995) found these closed-canopy stands devoid of exploitable prey populations due to the lack of legacy (old-growth) trees. Refer to Chart 3-1 for current forest conditions by forest stand development stage.

DISPERSAL MANAGEMENT AREAS

There are currently three dispersal management areas in this planning unit: Black Diamond, Elbe Hills, and Tahoma (refer to Map 3-5).

HABITAT WITHIN DISPERSAL MANAGEMENT AREAS

Each forest stand is currently classified based on its structural characteristics into one of these habitat types: high quality nesting habitat, Type A, Type B, sub-mature, young forest marginal, dispersal, and non-habitat (DNR 1997) (Refer to Box 2-2 for definitions). Within each designated dispersal management area, a spotted owl management unit (SOMU) is defined and used to track the current amount of owl habitat. WAUs were previously used, but SOMUs replaced them; WAUs were difficult to track because their boundaries were updated regularly. The WAUs were renamed SOMUs to avoid confusion with the existing WAU GIS layer; throughout the remainder of this section, they will

Table 3-25. Estimated Current Dispersal or Higher Quality Northern Spotted Habitat as a Percentage of Designated Forested State Trust Lands in Each SOMU/WAU*

SOMU/WAU Name	Dispersal or Higher Habitat: DNR Forest Inventory Data Estimate	Dispersal or Higher Habitat: Woodstock Model Estimate
Ashford	42%	47%
Busy Wild	50%	46%
Big Catt	37%	54%
Grass Mountain	39%	36%
Mineral Creek	30%	31%
North Fork Green	48%	50%
North Fork Mineral	40%	53%
Pleasant Valley Dispersal	29%	45%
Reese Creek	63%	59%

*Source: DNR 2009
The difference between DNR Forest Inventory estimates and Woodstock modeled habitat levels results from: 1) forest stratification that may place some stands in a forest strata are estimated to be habitat but are not actually habitat on-the-ground, and 2) the model estimate reflects that some harvest treatments (i.e. variable density thinning) will result in northern spotted owl habitat conditions post-harvest, which is not reflected in the DNR Forest Inventory estimates.

be referred to as SOMU/WAU. The 1997 HCP states that dispersal habitat should be maintained on 50 percent of DNR-managed lands selected for a dispersal habitat role. The 50 percent goal is measured at the SOMU/WAU level to ensure there is an adequate distribution of habitat across all dispersal management areas. Table 3-25 lists the SOMU/WAUs and the estimated current percentages of suitable habitat in each.

What are the Current Conditions for Nesting, Roosting, and Foraging Management Areas?

There are currently two nesting, roosting, and foraging management areas in the planning unit (refer to Map 3-5). The Pleasant Valley nesting, roosting, and foraging management area adjoins USFS land designated as a late successional reserve. The Green Mountain (also called Far Out) nesting, roosting, and foraging management area is surrounded by USFS and City of Tacoma lands and is managed for northern spotted owl habitat by city-owned Tacoma Water.

Does the Federal Northern Spotted Owl Recovery Plan Apply to Forested State Trust Lands?

Federal recovery plans are not regulatory documents and do not impose any restrictions on DNR-managed lands. The northern spotted owl final recovery plan (USFWS 2008) relies on federal lands to provide the largest forestland contribution for spotted owl recovery. Non-federal lands are expected to provide demographic support to core owl populations and to ensure connectivity with federal lands. In western Washington, the federal government's recovery plan identifies several areas outside federal lands, called conservation support areas (CSA). They "are expected to increase the likelihood that spotted owl recovery is achieved, shorten the time needed to achieve recovery, and/or reduce management risks associated with the Recovery Strategy and Actions" (USFWS 2008, p. 90). Two conservation support areas are delineated in the planning unit: Mineral (WCSA-04) and I-90 (WCSA-05). All forested state trust lands within or adjacent to these conservation support areas are designated as nesting, roosting, and foraging or dispersal management areas under DNR's 1997 HCP.

How Does DNR's Management Affect Spotted Owl Dispersal Habitat?

TIMBER HARVESTING

In designated northern spotted owl management areas, DNR manages forests using a combination of silviculture (refer to Forest Conditions, p. 45) and landscape management strategies, in designated northern spotted owl management areas. These practices are described in Appendix F of the *Final EIS for Policy for Sustainable Forests* (DNR 2006a), the 1997 HCP and a discussion of silviculture used by DNR is incorporated by reference from the 2004 *Sustainable Harvest Final EIS* (p. 2-20 to 2-25).

Silvicultural techniques (included in Appendix C) include variable retention harvests as well as variable density and commercial thinning treatments, which are developed by DNR staff and others (Carey and others 1995; Franklin and others 2002; Holmberg and others 2007). Forest stands in earlier stages of development, such as Competitive Exclusion and Understory Development (refer to Forest Conditions, p. 45), provide very few benefits to northern spotted owls because they lack coarse woody debris, large snags, and stand densities that allow owls to fly through. In the absence of disturbance such as fires, windstorms, or harvesting, forest stands may persist in these stages for long periods of time (Carey 2007). Actively managing these closed-canopy stands by removing some competition between trees can accelerate the creation of the structurally complex forests needed by owls and their prey (Carey 2003b).Therefore, within designated northern spotted owl habitat areas, forest stands in these stages are either enhanced through thinning or replaced over time using variable retention harvests.

Although the current assumption is that forest stands receiving these early treatments will develop the habitat elements necessary for northern spotted owls, the management practices employed are relatively new. Studies have not yet shown that such stands will be used to the same extent by northern spotted owls as older forests that developed naturally over time.

RECREATION

No studies have been completed to look at the effects of recreation on dispersing northern spotted owls. The preliminary results from a study in the Mendocino and Shasta-Trinity National Forests found that exposure to motorcycle noise significantly increased corticosterone levels in male northern spotted owls relative to controls (Hayward 2008). Corticosterone is produced when animals experience stress (Wasser and others 1997). Within the Elbe Hills dispersal management area, there are eight trails for off-road and 4×4 vehicles. The noise from these trail systems potentially could impact dispersing northern spotted owls negatively.

ROADS

Wasser and others (1997) found that male northern spotted owls living within a quarter-mile of a logging road had elevated levels of corticosterone. Females showed no increase in corticosterone levels related to road proximity.

VISUAL STRATEGIES

Visual strategies of leaving additional legacy trees could benefit northern spotted owls because they would eventually develop into a higher number of snags and more large, coarse woody debris. This development could support higher densities of prey species such as the northern flying squirrel (Carey 1995). Also, stands with additional legacy trees could develop more vertical diversity and improve canopy closure (Courtney and others 2004).

CREATION OF OLDER-FOREST CONDITIONS

The 2006 *Policy for Sustainable Forests* requires 10 to 15 percent of each HCP planning unit to be in older-forest conditions. The creation of older-forest conditions in a planning unit is expected to have a positive effect on northern spotted owls. Research indicates that northern spotted owls are strongly associated with late successional and old-growth forest habitats (DNR 2007, p. III.1). An increase in these conditions could increase the quantity and quality of habitat available for spotted owls, especially if targeted within northern spotted owl management areas.

LAND TRANSACTIONS

Recently, the department acquired additional forestlands adjacent to current DNR dispersal management areas (refer to Land Transactions, p. 90). This acquisition enlarged the extent of forests managed by DNR, increasing connectivity between lands managed for northern spotted owl dispersal and demographic support.

DNR owns a parcel (east of the town of Ashford) between the Elbe Hills and Tahoma dispersal management areas that is designated for dispersal management. It is an important stepping stone for dispersing owls. Trading it out of dispersal management could negatively affect the ability of owls to move through the area by increasing the distance they would have to travel through non-habitat areas. However, if this acreage is transferred with the condition that it continues to be managed under DNR's 1997 HCP, there would be no additional negative effects on the northern spotted owl.

Air Quality

Air quality is the status of the atmosphere in respect to potential pollutants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), suspended particulates, and ground-level ozone (O_3)(Government of Alberta 2006).

Why Is Air Quality Important?

Clean air is essential to humans, animals, and plants for existence. In addition to damaging the natural environment, air pollution also damages buildings. Unclear air (smog) can also have economic impacts by causing illnesses, thus reducing the number of days people can work. The environmental effects of smog can reduce the productivity of forests and crops (EPA 2007).

AIR CONTAMINATION

Many sources of air contamination impact the planning unit. As noted in Chapter 1, the planning unit is the most highly populated area of the state, with over 50 percent of the landscape supporting urban environments. With such a high density of people in the region, it should be no surprise that the most common form of air contamination comes from motor vehicle fumes (EPA 2007), and that as much as 50 percent of the overall greenhouse gas emissions are from transportation (Ecology 2008d). This pollution is mostly composed of hydrocarbons, an organic compound of hydrogen and carbon which is commonly found in petroleum products, coal, and natural gas (National Safety Council 2005). In addition to this major contributor, industrial process losses, industrial fuel use, home heating, and refuse disposal add to air degradation (EPA 2007; DNR 2004).

NATURAL FACTORS

In areas west of the Cascade Mountains, the most common effects to air quality are caused by topography and climate. The Puget Sound is especially susceptible to natural conditions that periodically cause air pollutants to accumulate. High moisture levels, stable atmospheric conditions, and fog all contribute to the ability of the air to hold contaminants in the lower part of the atmosphere (DNR 2004). Although higher moisture levels in the air can hold larger amounts of particulates, precipitation and the air turbulence it causes can dissipate these contaminants. The local and regional wind patterns allow these contaminants to move relatively long distances, although they often are rapidly dispersed.

Cold weather in the late fall and winter is the most common time to notice higher levels of contaminants in the air, when a layer of warm air traps pollution closer to the surface in an inversion layer. When the air is relatively stable, contaminants are generally very concentrated near the source. Under clear skies, light wind, and sharp temperature inversions, these conditions are most obvious. Air pollution is usually removed within a few days by either wind or rain (Parsons and Brinckerhoff 2005).

What Are the Criteria for Determining Air Quality?

The chief criterion is to ensure that all forest management activities (burning, hauling, harvesting, and processing) meet federal *Clean Air Act* standards for ambient air quality. The *Clean Air Act* has been in place since 1970 and the Environmental Protection Agency (EPA) has set national standards in accordance with the best available science.

As standards have remained static at the national level, in recent years many states have set higher standards to reduce emissions. As an agency, DNR will comply with any new standards developed at both state and national levels. Ecology (2006) is pushing for a major movement to improve air quality by reducing diesel exhaust in the air and sulfur content in current fuels.

The Governor's Climate Change Framework legislation[19, 20] will require certain entities to report carbon emissions from motor vehicle fleets that exceed a certain threshold (5,511,500 pounds of carbon per year) by 2010.

What Are the Indicators for Assessing Air Quality?

For the purpose of this EIS, the main indicator of air quality from forested state trust lands is an estimate of overall carbon dioxide (CO_2) emissions using the number of trips and the amount of diesel fuel used per trip to haul the timber extracted from forested state trust lands. As described in Chapter 4 (p. 197), through a simple equation, these values can estimate carbon dioxide emissions and they can be compared to state and national standards.

What Are the Effects of DNR's Management on Air Quality?

There are three primary adverse effects of forest management to local and regional air quality: 1) sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) from trucks, logging equipment, and forest product manufacturing; 2) airborne dust from logging and hauling; and 3) the smoke from prescribed burning. These effects are commonly linked to climate change and are further discussed in the section on p. 115.

POLLUTANTS GENERATED BY TRUCKS, LOGGING EQUIPMENT, AND FOREST PRODUCT MANUFACTURING

Trucks, skidders, loaders, splitters, and even chainsaws use fuels that release high amounts of sulfur dioxide and nitrogen dioxide into the air and contribute to elevated levels of greenhouse gases. In addition, the facilities that manufacture forest products are often run by burning wood waste fuels. Beyond releasing sulfur dioxide and nitrogen dioxide into the atmosphere, burning woodchips releases carbon in the form of hydrocarbons and carbon monoxide, increasing the probability of smog and global warming. The use of diesel fuels also releases large amounts of macroscopic particulate matter into the air.

As of 2003, 2,796 logging trucks were registered in Washington and operated on both forest roads and highways (Lyons 2003). Trucks that travel on both paved and unpaved roads are often considered heavier duty vehicles and are built for higher performance than other on-road vehicles. Their engines do not use fuel as efficiently and are likely to have a longer life span (Ecology 2006).

Diesel engines release large amounts of macroscopic particulate matter into the air and no reported oxidation catalysts and diesel particulate filters are available that could be retrofitted to these vehicles to reduce air pollution (Lyons 2003). Other methods to reduce diesel exhaust would require that trucks be maintained properly; use low sulfur fuels; and not idle for extended periods. Access to low sulfur fuels should not be a problem for logging trucks that haul logs on paved roads, but off-road vehicles used at more remote sites may have limited access to these fuel types (Lyons 2003). Newer equipment and engines are built to burn fuel using cleaner methods and so, if possible, old equipment should be replaced or new equipment should be used more frequently (Ecology 2006).

DUST FROM LOGGING AND HAULING

In general, the adverse impacts of airborne dust and particulate matter caused from driving on forest roads as well as skidding logs are localized and short-term. Forest roads produce the greatest amount of airborne dust, which is generally a function of road quantity, quality, and use. In the early 1990s, DNR adopted a policy limiting the size of harvest units. Although the smaller unit size has many benefits, it has caused an increase in road mileage (DNR 2004).

PRESCRIBED BURNING

Traditionally, prescribed burning was a common method of forest site preparation used to remove unwanted vegetation, add nutrients to soil, and germinate seeds. These planned fires were also used to reduce wildfire risk. In recent years, as air quality concerns have increased, prescribed burning has become less and less common and now is allowed only in very specific conditions. It has been replaced with mechanical and herbicidal vegetation management. Researchers (Holsapple and Snell 1996; Running 2006) have found that prescribed burning releases large amounts of smoke and particulates into the air, but compared to wildfire, its effects seem relatively insignificant. Nearly every year since the mid-1980s, the number of acres lost to wildfire has increased, and with three to four times the particulate emissions as prescribed burning, the latter seems to be the better option (Westerling and others 2006).

DNR may burn 500 to 1,000 acres per decade for site preparation and 300 to 1,000 for wildfire risk reduction in Washington (DNR 1997), although in the past, prescribed burning was rarely used in this planning unit for several reasons: fear of escape, high moisture levels, and reluctance to put smoke into the Puget Sound basin. For these reasons, an estimated value of less than one percent of the listed acres burned by DNR would be located in this area (Keeley, pers. comm. 2008).

How Do Forestlands Improve Air Quality?

Forests reduce the spread of wind-carried particulates by trapping them with leaves, branches, and stems. Forests also retard wind, causing stagnant particulates to drop out of the air and settle into forest soils (DNR 2004).

Global Climate Change

Climate change (also called global warming) is a regional or global-scale alteration in average temperature and weather patterns, especially storm activity over a time scale ranging from decades to centuries. The term refers to both natural- and human-caused differences in climate over a long period. Current science suggests a link between climate change over the last century and human activity, particularly the burning of fossil fuels (NRC 2006; Karl and others 2006; Intergovernmental Panel on Climate Change (IPCC) 2007; PBS 2008).

Why Is Climate Change a Concern?

Since the late 1980s, scientists have suggested a worldwide trend toward global warming, demonstrated through changes in patterns of climatic occurrences such as El Niño and La Niña, typhoons, tsunamis, and disturbances like forest fires (Ecology 2008a). As the science has developed, scientists have stressed that climate change has very site-specific effects that present both positive and negative impacts to the environment and to the cultures and economies tied to the resources they produce.

Researchers (Stewart and others 2005; Hamlet and others 2007; Mote 2003; Mote and others 2005; Barnett and others 2008; IPCC 2007; Oregon Wild 2007; McNulty and Aber 2000; EPA 1998; van Mantgem and others 2009) predict that a warming in the western mountains means more rain during winter months, decreased snowpack, earlier snowmelt and runoff, and reduced summer flows which will consequently lengthen the period of summer drought.

Increased rainfall during winter months may also contribute to greater flooding and soil erosion. Warmer, drier summers in combination with these effects can increase stresses to forests such as fire, pests, and disease (EPA 1998). In addition to less water in streams and lakes, drier weather and increased temperatures could mean drier soils as evapotranspiration increases, causing an additional threat to ecosystem health.

The IPCC (2007) also reported the "warming of the climate system is unequivocal," and it is more than 90 percent likely that the accelerated warming trends of the past half-century are due to human contributions. A recent study published in Science (van Mantgem and others 2009) reported a temperature increase of 0.3° to 0.4° C per decade (although debated among the scientific community) causing widespread tree mortality in the western United States, especially in older trees. In the Pacific Northwest, the tree mortality rate is one of the highest in the nation and on a trajectory to double in the next 17 years (van Mantgem and others 2009) although there most likely will be an increase in tree growth and establishment at high locations. Scientists are worried about the loss of forest biomass and also the underlying implications of what that change will mean to the ecosystems and habitat for species such as marbled murrelet and northern spotted owl.

Climate change could move current plant and animal communities toward the poles and up to higher elevations, but it appears that the rate of climate change will eventually outpace the ability of some species to adapt to changing conditions (Aitken and others 2008). As climates have changed slowly, species have migrated or adapted—a circumstance scientists call species drift (Sherry and others 2007; Hanson and others 2001). These drifts could change relationships between pollinators, predators, and prey as well as other important species interactions (Sherry and others 2007). Many species are not able to move fast enough and are overtaken by more adaptable, non-native species (EPA 1998). For example, in this planning unit, the northern spotted owl has specific life history requirements for nesting, roosting, and foraging within a very small range. Climate change models have not projected specific positive or negative effects; however, in a worst case scenario, these special habitat conditions may be lost and the species may be at risk.

Some studies (O'Neill and others 2008; Aitken and others 2008) have supported the idea of assisted seed migration (planting tree seedlings adapted to future climates) to help crops move into appropriate geographic locations (latitude, longitude, and elevation) to maintain similar levels of productivity in the future.

Running (2006) suggested that earlier snowmelt, higher summer temperatures, longer fire seasons, and expanded areas of vulnerable high-elevation forests were contributing to larger, more intense fires in the west. Forest fires threaten thousands of acres of DNR-managed land annually and contribute greenhouse gases into the atmosphere; however, very few acres burn annually within this planning unit due to seasonally wet conditions (Climate, p. 53). If annual temperatures continue to increase, the moisture levels of plants, down woody debris, and soils may decrease and frequent disturbances (such as forest fires) in this planning unit could become a reality.

What Factors Affect Climate Change?

Several factors affect climate change dramatically. The most widely discussed reason is increased greenhouse gases in the atmosphere, mostly caused by humans. Scientists continue to debate whether climatic variability is the primary cause of climate change and if the change is a cycle in the earth's life similar to former ice ages. For now, scientists have determined that a number of methods may offset the effects of climate change.

How Do Forestlands Counteract the Negative Influences of Climate Change?

Forest management is one of the few human activities that can create biological carbon sinks to help mitigate the accumulation of carbon dioxide in the atmosphere (Kurz and others 2002). Photosynthesis and respiration trap carbon dioxide and release oxygen into the atmosphere. Two possible ways to increase these carbon catching processes could be to increase the forest area or to increase carbon density through active management. Long-term terrestrial storage of carbon dioxide through carbon sequestration has been hypothesized to help reduce the effects of climate change (refer to Carbon Sequestration for more details, p. 118). Additional ways forests may counteract effects include regulating localized microclimates by reducing wind and limiting surface cooling which will maintain current species and vegetation coverage as discussed above.

What Are Washington State Officials Doing to Address Climate Change?

Washington and other western states are participating in a federal grant to examine how the 2.1 million acres of forested state trust lands and 8.5 million acres of private forestland could be used to offset the greenhouse gas that comes from vehicles, the use of fossil fuels to generate electric power, and other carbon dioxide sources.

The Global Climate Change Initiative (signed by President Bush, February 14, 2002) studies carbon sequestration, where trees remove carbon from the air as part of their natural biological respiration process and store the carbon in the wood as standing trees or in the structural lumber (refer to Carbon Sequestration, p. 118). As part of this initiative, greenhouse gas emitters would purchase carbon credits from owners of forestland. The carbon balance for current management of forested state trust lands is thought to be positive (more carbon is fixed than is lost) considering the carbon in the forest and in structural wood products produced from the forest. This is especially true when comparing the production of structural materials with the more carbon-intensive production of materials such as steel or concrete (DNR 2004).

In association with the Western Climate Initiative and in response to House Bill 2815[25], DNR teamed with Ecology and other state agency representatives to create the Forest Sector Workgroup—Climate Action Team. The group provided a forum for stakeholders to develop proposals for reducing greenhouse gas emissions from the forestry sector to achieve Washington greenhouse gas reduction goals. In addition, the team worked on developing a secondary goal—implementing a market-based system of incentives to maintain forestlands for carbon storage and develop methods for measurement, accounting, and verification for it (refer to the Forest Sector Workgroup on Climate Change Mitigation Final Report (2008) for more information on this topic).

DNR also supports the Taskforce on Adapting Forests to Climate Change whose mission is to provide public and private managers with science-based management tactics for different climate scenarios for a variety of objectives. For up-to-data information on the taskforce, visit http://tafcc.forestry.oregonstate.edu.

In February 2009, the Commissioner of Public Lands launched an effort to create jobs, increase renewable energy approaches, and promote healthier forests by using woody biomass from our state's forests. Through this biomass initiative, DNR has an opportunity to be part of the climate change solution, create jobs, and improve forest health. This effort will help bring emerging technologies to the marketplace and help establish another positive and sustainable use of our public's natural resources.

Passed by both the House and the Senate and signed by the Governor, legislation authorizes DNR to create two pilot programs—one customized to eastern Washington and another for western Washington—to demonstrate the use of existing biomass conversion technology in the field. DNR must report back to the legislature in 2010.

The Governor believes that climate change is one of the greatest challenges Washington will face in coming years and all citizens need to work together to address it. By using biomass from state forests, DNR can create renewable energy and reduce our carbon footprint.

What Are the Current Indicators?

Because climate change is a relatively newly accepted science, there are no indicators defined by state or national policies or generally accepted in the scientific community for measuring the change on a small scale such as this planning unit. As DNR learns more about the changes that are taking place and methods become standardized, DNR will be more able to measure the management effects and compare them to current or past conditions.

How Does DNR Mitigate for Climate Change?

DNR uses several tactics which may help with moderate climatic changes. These include maintaining genetic diversity within local populations; operating breeding, testing, and seed selection programs; planting multiple species (not necessarily on every acre); and cultivating stands with moderate densities.

More aggressive strategies may be considered in the future in the event of more severe climate changes. Long-range seed movement may be used as a method to overcome temperature changes across elevations and latitudes where the local climate has changed (van Mantgem and others 2009). This seed movement would likely be more beneficial if the same species were planted from a different seed source in similar climatic conditions than if the species composition were being changed on the site. Changing species outside of historical mixes can have impacts on the ecological interactions in the area. Some studies suggest planting at higher densities to absorb expected losses; however, if projections were inaccurate, these high densities could increase individual plant stresses, decrease forest health, or increase thinning costs. Other studies suggest using shorter rotations to allow for more rapid changes to species composition and choosing appropriate seed sources to keep up with changing climate conditions.

As the scientific community gains more confidence in climate modeling and acquires a better understanding of the science of species interactions, DNR will continue to identify new tactics to grow and preserve the land it manages.

Carbon Sequestration

Carbon sequestration is the annual rate of carbon storage in above- and below-ground biomass over the course of one growing season, as carbon is biologically converted from a gas (carbon dioxide (CO_2) to organic compounds in tree fiber.

Carbon dioxide is exchanged between the atmosphere and forests in several ways. Through photosynthesis and respiration, carbon dioxide is absorbed into the plants. After a plant dies, the decomposition process releases this carbon dioxide back into the atmosphere (Kurz and others 2002).

How Does Carbon Move into Plants?

During photosynthesis, atmospheric carbon dioxide enters the plant's leaves through surface pores, called stomata. Within the plant, a chemical reaction catalyzed by sunlight takes place: carbon dioxide combines with water and creates cellulose, sugars, and other materials. Therefore, carbon from the atmosphere is trapped in new chemical forms in terrestrial plants (Britannica 2009).

How Is that Carbon Stored?

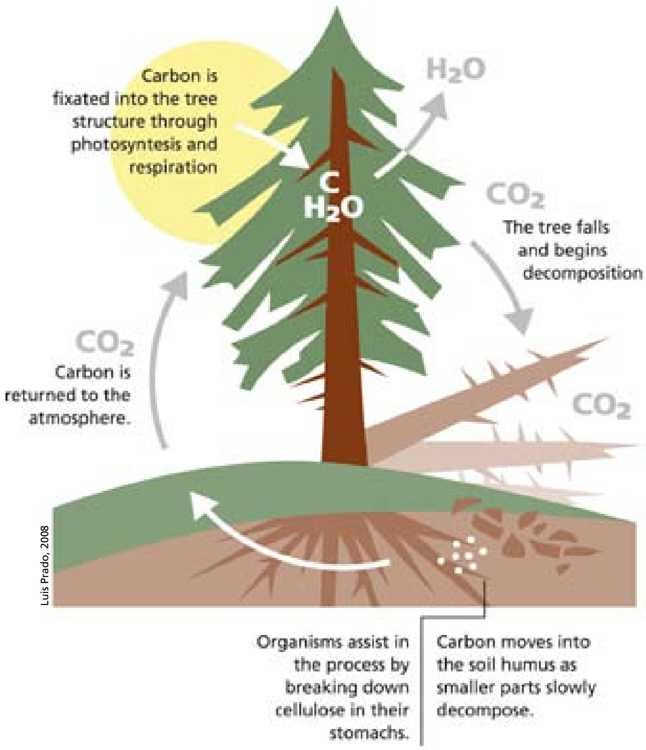
In general, forest trees store most carbon, up to 51 percent, in their trunks. The second largest storehouse of carbon in trees is the branches and stems at 30 percent, followed by the belowground root biomass which holds 18 to 24 percent of the carbon and is usually left when trees are harvested. Three percent is stored in the foliage (leaves or needles), and there can be a net carbon loss when leaves are shed by the tree (McPherson and Simpson 1999).

Carbon can be stored in standing wood, lumber products, soil humus, and decomposing organisms. Therefore, removing biomass from a site for a use such as building materials prevents the carbon from being recycled back into the atmosphere through decomposition or other means (McPherson and Simpson 1999).

How Long Does Carbon Stay in the Environment?

The amount of sequestered carbon remaining in a system depends on factors that include but are not limited to tree growth, mortality, species

Figure 3-10. Carbon Movement through the Decomposition Cycle



composition, age distribution, structure class, period before next harvest, and overall forest health.

Smaller pieces of wood debris return carbon to the atmosphere faster than large ones. Mulching, chipping, and burning return carbon to the atmosphere rapidly, especially in moist environments. Carbon can be held in wood after it is cut down so long as it does not decompose; wood from conifer trees that is used for building materials can survive for around 50 years (on average) before gradually decomposing (Norse 1990).

What Is the Best Carbon Sequestration Environment?

Healthy, vigorously growing trees will absorb more carbon dioxide than diseased or otherwise stressed ones (McPherson and Simpson 1999). In recent years, scientists have debated whether fast-growing, short-lived trees or slow-growing, long-lived trees can sequester and maintain more carbon (Kurz and others 2002). Although rapidly growing trees sequester more carbon dioxide initially than slower growing ones initially, the advantage can be lost if the fast-growing trees die earlier.

McPherson and Simpson (1999) reported that, as long as trees were growing, their rate of carbon dioxide uptake through photosynthesis would be higher than their level of respiration. Therefore, more carbon can be sequestered by actively growing trees than older trees at other stages.

How Is Carbon Released Again into the Atmosphere?

Carbon is released into the atmosphere from standing forests in two ways. Burning is the most rapid method of returning carbon to the atmosphere. Decomposition occurs much more slowly and is the second primary means of returning carbon to the air from a standing forest (McPherson and Simpson 1999).

How Can We Measure the Benefits of Carbon Sequestration?

The USFS 1605(b) Team (led by Richard Birdsey) has been working to analyze forest carbon sequestration activities since the early 1990s when the *Energy Policy Act* (1992) was adopted. Section 1605(b) of that legislation established a voluntary reporting program for greenhouse gas emissions and reductions and the methods for calculating and reporting them. In 2006, a small USFS-staffed team updated tables and methods that estimate how various carbon components of forest ecosystems change over time (Smith and others 2006). DNR is using the methodology and equations from *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States* (Smith and others 2006) to develop a carbon assessment system for forested state trust lands.

Does DNR Have a Carbon Sequestration Program?

There is no local carbon program currently in place, but at a national level, there are tax credits and additional benefits to private landowners who increase the amount of carbon their forested lands can hold.

End Notes

1 Chapter 79.09.050 Revised Code of Washington [RCW]
2 Endangered Species Act (1973) P.L. 93-205 - 87 Stat. 884
3 Chapter 222-16-010 Washington Administrative Code [WAC]; Code of Federal Regulations 230.41a (1); U.S. Army Corps of Engineers Experimental Laboratory 1987
4 Procedure 14-004-150, Appendix E
5 Procedure 14-004-060, Appendix E
6 Procedure 14-004-060, refer to Appendix E of this EIS
7 Chapter 222-16-050 Washington Administrative Code [WAC]
8 Chapter 222-30-020 Washington Administrative Code [WAC]
9 Chapter 222-16-010 Washington Administrative Code [WAC]
10 Chapter 222-30-070 Washington Administrative Code [WAC]
11 Chapter 222-24-010 Washington Administrative Code [WAC]
12 Chapter 222-24 Washington Administrative Code [WAC]
13 Chapter 79.10.100 Revised Code of Washington [RCW]
14 Unpublished 2004 Inventory and Assessment
15 Chapter 76.06.020 Revised Code of Washington [RCW]
16 Chapter 79.17.200 and Chapter 79.11.010 Revised Code of Washington [RCW]
17 Chapter 222-16-010 Washington Administrative Code [WAC]
18 Chapter 27.34.020 Revised Code of Washington [RCW]
19 Chapter 27.53.030 Revised Code of Washington
20 Timber/Fish/Wildlife Cultural Resources Committee; FFR Addendum; 2003 Cultural Resources and Protection Management Plan, Executive Order 05-05 (Appendix L)
21 Policy 06-001
22 Procedure 14-004-030
23 36 CFR Part 61
24 Chapter 232-12-297 Washington Administrative Code [WAC]
25 E2SHB Section 4(3)(g)

ENVIRONMENTAL EFFECTS & COMPARISON OF ALTERNATIVES

CHAPTER 4

Tahuya River

analysis of effects


Mount Rainier from Eatonville

Chapter 4 presents an analysis of the environmental impacts for the three management alternatives, by topic, over the 100-year planning horizon. Chapter 4 examines whether there are any probable, significant, adverse environmental impacts, and mitigation for them. The information is presented at either the planning unit or individual watershed/Spotted Owl Management Unit (SOMU) scale. The chapter focuses on assessing how management actions—specifically timber harvesting—will impact the elements of the environment.

Environmental impacts are expected with all three alternatives with more substantial effects in some watersheds than others. This Final EIS is a non-project document, meaning that at this level we cannot with certainty say that the actions proposed will result in probable, significant, adverse environmental impacts that will not be mitigated. This analysis describes the impacts using the forecasts of activity levels under the different management alternatives at the watershed scale, thereby identifying the probable, significant, adverse impacts on the environment. Future actions resulting from this analysis such as proposed timber sales, road building, recreational facilities, and other projects will consider additional environmental analysis at the project level where necessary.

Not all topics included in Chapter 3 are found in Chapter 4 because measurable or predictable information is not available for all criteria and indicators. The topics listed in the following section were included in Chapter 3 but do not have separate sections in Chapter 4.

- Older-forest conditions are not discussed separately because the stand development stages associated with older forests (Niche Diversification and Fully Functional) are included and discussed as part of forest stand development trends in the forest conditions section (p. 122).
- Plants are discussed in Chapter 3 in terms of what is currently known and how DNR manages areas that are known to contain special plants and ecological features. There is no program to track these species and their abundance/movement cannot be predicted, so no analysis was included in Chapter 4.

- Climate presents current conditions and trends for western Washington, but the long-term impacts of the three alternatives cannot be predicted.
- Forest health is contained in the forest conditions section in Chapter 4 since their indicators are the same including stand density, tree mortality, and species composition.
- Land transactions occur infrequently and are difficult to predict. A 20,600-acre land transaction completed during this EIS was analyzed and the analysis is included in Appendix J.
- Because global climate change is a relatively newly accepted science, no indicators have been defined by state or national policies or generally accepted in the scientific community for measuring small-scale change.

Forest Conditions and Management

In Chapter 3, the current forest conditions were described in terms of forest types, forest stand development stages, forest stand density (Text Box 3-2, p. 49), forest biomass, and timber harvest methods. The forest conditions section and the indicators contained within it create the foundation for other analyses which follow later in this chapter.

DNR-Managed Lands

The planning unit contains approximately 3.1 million acres, of which DNR manages approximately 146,000 acres, about five percent of the total land area. Table 3-5 in Chapter 3 presents the acreage in the planning unit acres by land classes: Uplands with General Ecological Management (GEMs), Uplands with Specific Management Objectives (Uplands), and Riparian and Wetlands (Riparian). Table 4-1 lists the 13 watersheds in which DNR manages at least 20 percent of the land base; they represent approximately 92 percent of the land base that DNR manages in the planning unit. A breakdown of these watersheds by the above-mentioned land classes is contained in Appendix D.

Table 4-1. Watersheds (WAUs) with ≥ 20 Percent DNR-Managed Trust Lands

WAUs ≥ 20 % DNR-Managed Trust Lands	Total Acreage	Total DNR-Managed Acreage	Total Forested Acres	Percent of Area by Watershed
North Fork Mineral Ck.	17,545	13,883	13,166	79%
Reese Ck.	19,011	11,971	11,188	63%
Catt	13,732	6,893	6,469	50%
Kennedy Ck.	23,378	9,227	8,378	39%
North Fork Green	18,446	6,602	6,229	36%
Howard Hansen	46,483	16,499	15,466	35%
Lynch Cove	37,754	11,063	10,205	29%
Mashel	57,043	15,139	14,318	27%
Great Bend	65,531	16,318	15,027	25%
Tiger	40,654	10,092	9,718	25%
Mineral Ck.	21,692	4,761	4,450	22%
East Ck.	20,285	4,052	3,808	20%
West Kitsap	41,879	7,261	6,779	20%
Subtotal (WAUs ≥ 20% DNR ownership)	423,433	133,761	125,201	32%
Total Planning Unit Acres (all watersheds)	3,100,000	146,173		5%

Table 4-2. Average Acres Harvested per Decade by Alternative

Alternative	Thinning Acres[1]	Maximum Acres[2]	Standard Deviation[3]	Variable Retention Acres	Maximum Acres	Standard Deviation	Total Acres
A	5,667	12,495	2,498	12,010	14,651	2,077	17,677
B	5,355	7,775	1,222	10,592	13,691	1,334	15,947
C	6,609	16,652	5,741	11,047	17,513	3,704	17,656

1. Average for all 10 decades
2. Maximum acres harvested in any one decade
3. Calculated from the average of all 10 decades

Table 4-3. Total DNR Acres Harvested Compared to the ≥ 20 Percent Watersheds (WAUs) over 100 Years

Alternative	Total Harvested Acres	Total Harvested Acres (WAUs ≥ 20%)
A	176,773	152,835
B	159,471	136,768
C	177,548	151,365

Harvest Types

In any year, the amount of timber harvested on DNR-managed lands in this planning unit is less than two percent of the total area (146,000 acres). Most of this environmental analysis looks at the potential effects of management on those 146,000 acres that DNR manages.

Timber harvesting methods influence forest conditions and are analyzed to help explain the potential impacts under each alternative. Table 4-2 shows the projected average differences in acreage by harvest types (thinning vs. variable retention harvests; refer to Appendix C for treatment descriptions). Trends for each harvest type are shown by decade in Charts 4-1 and 4-2.

Table 4-3 presents the total acres harvested over the 100-year planning horizon. To achieve management objectives, some forest stands may require multiple thinnings. For additional information, refer to *What Type of Harvest Methods Does DNR Use?* (p. 52). Since each entry into a forest stand is tallied as a separate harvest activity, the number of acres harvested appears high when compared to the approximately 146,000 acres in the planning unit. The number of repeated harvest entries on the same sites over the 100-year planning horizon is shown in Charts 4-4, Chart 4-5, and Figure 4-2.

The acreage of thinning activities (commercial, as well as heavy variable density and light variable density combined) under Alternatives A and B quickly declines and then continues at a steady rate. Under Alternative C, thinning acreage declines less rapidly, but does so until the ninth decade (Chart 4-1) a result of the amount of thinning needed to reduce stand densities and place forest stands on a trajectory to achieve specific objectives in the Uplands and Riparian areas. This range of projected harvest levels is consistent with harvesting trends over the past 10 years. For a discussion of stand density, refer to Chapter 3 (p. 45).

The main purpose of variable retention harvests (Chart 4-2) is to generate revenue; thinnings can be done for a variety of reasons, including reducing stand density to enhance habitat conditions or placing forest stands on a trajectory to become more structurally complex in the Niche Diversification and Fully Functional stages (refer to Text Box 3-1). For an interpretation of peaks in harvest activity, refer to stand density (p. 45).

Chart 4-1. Acres Thinned per Decade by Alternative

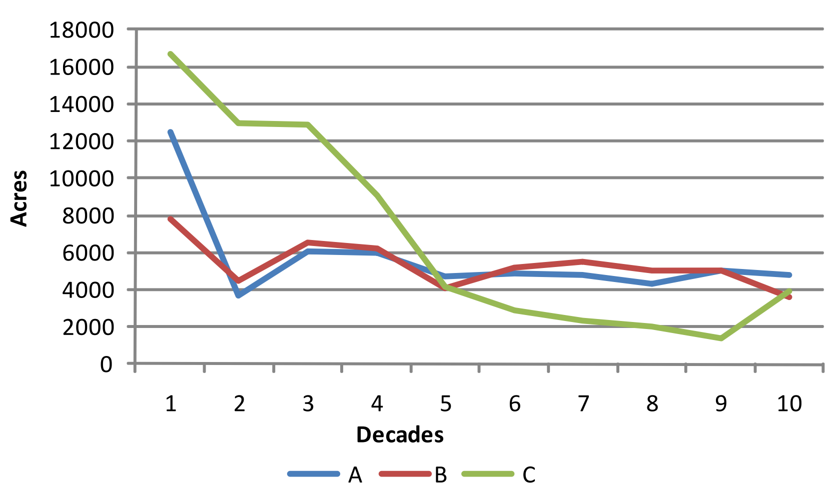


Chart 4-2. Variable Retention Harvest Methods by Alternative

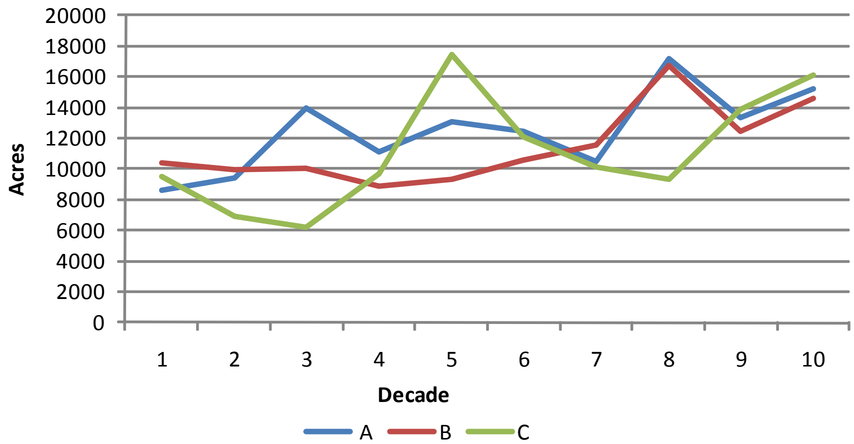


Figure 4-1 compares harvest levels by land class by showing the acreage differences on the same scale. (Data showing similar information for Riparian at a more readable scale can be found in Chart 4-11).

The level and type of harvest activities have an effect on forest stand development stages over time. Refer to *What Type of Harvest Methods Does DNR Use?* (p. 52). Appendix D contains charts which provide this information for each alternative and land class (GEMs, Uplands, and Riparian). All of the alternatives perform in a similar manner in Riparian areas in terms of the enhancement of structurally complex stand development stages (Niche Diversification and Fully Functional). Refer to Figure 4-6.

Harvest Levels by Land Class

Riparian restoration activities most likely will be conducted in conjunction with activities in the Uplands and on forest stands less than 70 years of age, resulting in lower levels of harvest activities over-time. Further trends are observed when harvest levels are broken out by the land classes (GEMs, Upland, and Riparian) defined in Chapter 3 (p. 44).

- For GEMs (16 percent of DNR-managed lands) the harvest level remains relatively constant over each decade for all alternatives and affects just under four percent of DNR's land base in this planning unit.
- The Uplands land class contains the greatest share (54 percent) of area in the planning unit. The projection of harvest levels for Uplands is approximately 10 percent per decade.
- In the Riparian land class, which encompasses 30 percent of the DNR-managed land in the planning unit, the harvest level declines steadily with no harvest activities occurring after the seventh decade as a result of the implementation of the Riparian Forest Restoration Strategy (Bigley and Deisenhofer 2006). Refer to harvest activities in Riparian (p. 139) for additional information. Alternative C is projected to have the highest impact in the Riparian land class because it includes the greatest number of restoration activities, followed by Alternatives A and B (Figure 4-1).

Harvest Activities by Watershed

Table 4-4 shows the average area harvested per decade over the 100-year planning horizon within watersheds where DNR manages greater than 20 percent of the land base; the data is presented by harvest type (thinning vs. variable retention harvest). Data for all watersheds is found in Appendix D. The greatest amount (by acre) of harvest activities is forecast to take place in the Mashel, Great Bend, and Howard Hansen watersheds. Some harvests are intended to alleviate overstocked forest conditions and improve the quality of northern spotted owl dispersal habitat (p. 107) and are designed to reduce the number of acres in the Competitive Exclusion stand development stage (Table 4-5). For eight of the 13 watersheds the total amount of harvest (thinning and variable retention harvest combined) is highest under Alternative A. For the remaining five watersheds, the total harvest is highest under Alternative C. It should be noted that in some cases, the difference between the amount of acreage is just a few acres.

Figure 4-1. Total Harvest Activities by Land Class, Alternative, and Decade

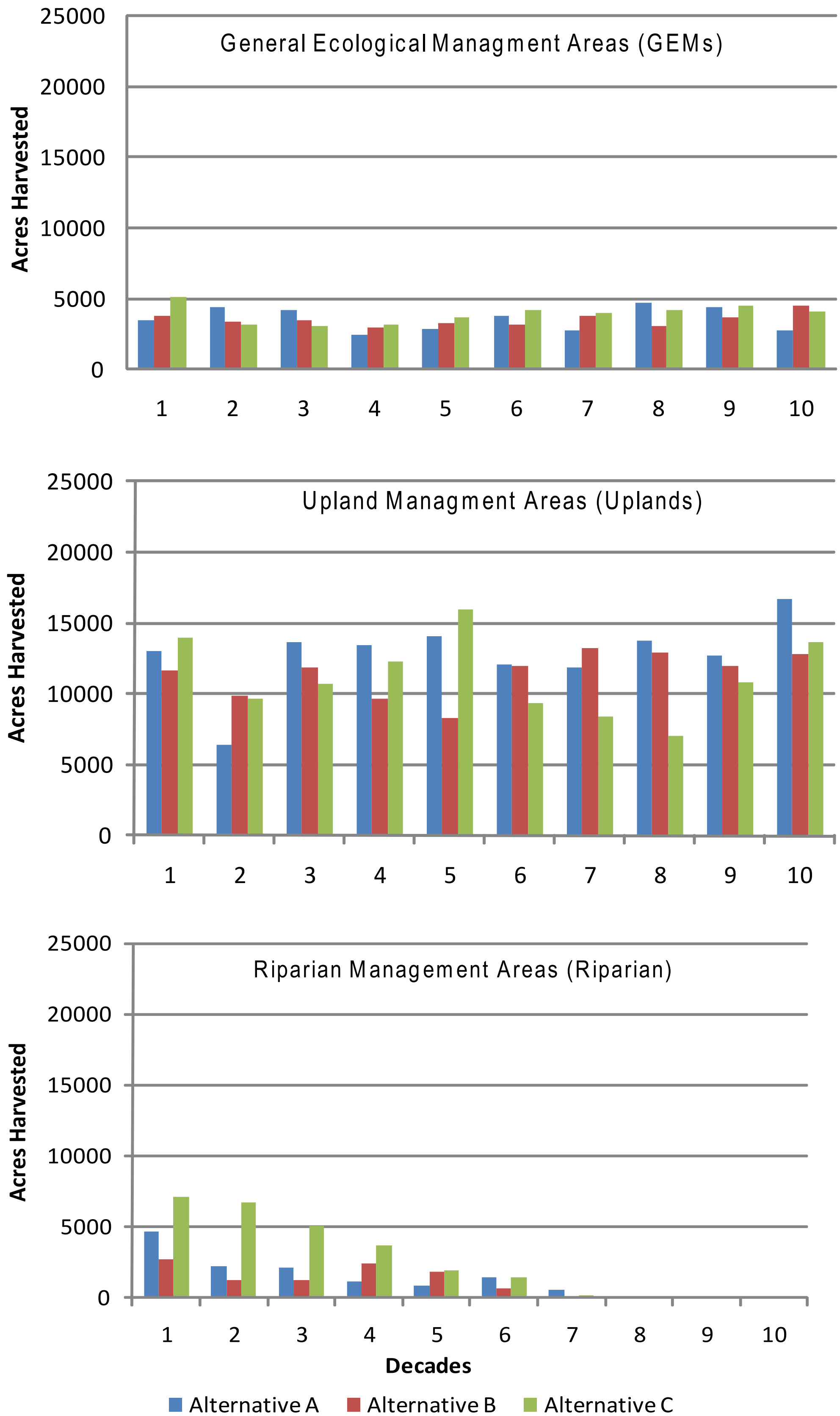
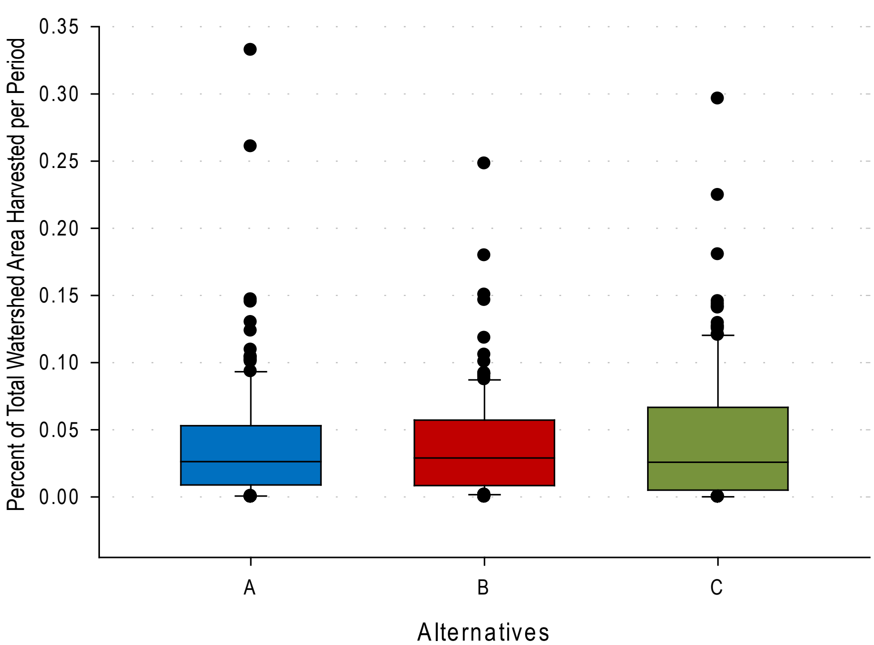


Table 4-4. Average Thinning or Variable Retention Harvest (VRH) Activities Over 100 Years by Total Acres and Percentage of Watersheds (WAUs) ≥ 20 Percent of DNR-Managed Lands

WAUs (acres in watershed)	Alternative A			Alternative B			Alternative C		
	Total Harvest	Thin	VRH	Total Harvest	Thin	VRH	Total Harvest	Thin	VRH
Howard Hansen 16,499 acres	1,710 (10%)	745 (44%)	965 (56%)	1,186 (7%)	632 (53%)	564 (47%)	1,275 (14%)	566 (44%)	710 (56%)
Great Bend 16,318 acres	1,820 (11%)	287 (16%)	1,533 (84%)	1,703 (10%)	218 (13%)	1,485 (87%)	2,283 (14%)	712 (31%)	1,571 (69%)
Mashel 15,139 acres	1,967 (13%)	888 (45%)	1,079 (55%)	1,777 (12%)	896 (50%)	881 (50%)	1760 (12%)	812 (46%)	948 (54%)
North Fork Mineral 13,883 acres	1,799 (13%)	733 (41%)	1,066 (59%)	1,482 (11%)	633 (43%)	849 (57%)	1,609 (12%)	644 (40%)	965 (60%)
Reese Ck. 11,971 acres	1,585 (13%)	689 (43%)	896 (57%)	1,575 (13%)	813 (52%)	762 (48%)	1,373 (11%)	616 (45%)	756 (55%)
Lynch Cove 11,063 acres	1,326 (12%)	128 (10%)	1,199 (90%)	1,258 (11%)	89 (7%)	1,169 (93%)	1615 (15%)	382 (21%)	1,233 (79%)
Tiger 10,092 acres	409 (4%)	132 (32%)	277 (68%)	408 (4%)	123 (30%)	285 (70%)	643 (6%)	400 (62%)	242 (38%)
Kennedy Ck. 9,227 acres	1,277 (14%)	1,10 (9%)	1,167 (91%)	1,291 (14%)	74 (6%)	1,217 (94%)	1,565 (17%)	379 (24%)	1,187 (76%)
West Kitsap 7,261 acres	505 (7%)	59 (12%)	446 (88%)	487 (7%)	60 (12%)	427 (88%)	562 (8%)	135 (24%)	427 (76%)
Catt 6,893 acres	924 (13%)	476 (51%)	449 (49%)	869 (13%)	430 (49%)	439 (51%)	830 (12%)	365 (44%)	465 (56%)
North Fork Green 6,602 acres	781 (12%)	341 (44%)	440 (56%)	647 (10%)	352 (54%)	295 (46%)	610 (9%)	314 (51%)	296 (49%)
Mineral Ck. 4,761 acres	742 (16%)	392 (53%)	350 (47%)	558 (12%)	348 (62%)	210 (38%)	607 (13%)	319 (53%)	288 (47%)
East Ck. 4,052 acres	438 (11%)	186 (42%)	253 (58%)	436 (11%)	237 (54%)	199 (46%)	404 (10%)	200 (50%)	204 (50%)

[1]Includes multiple entries

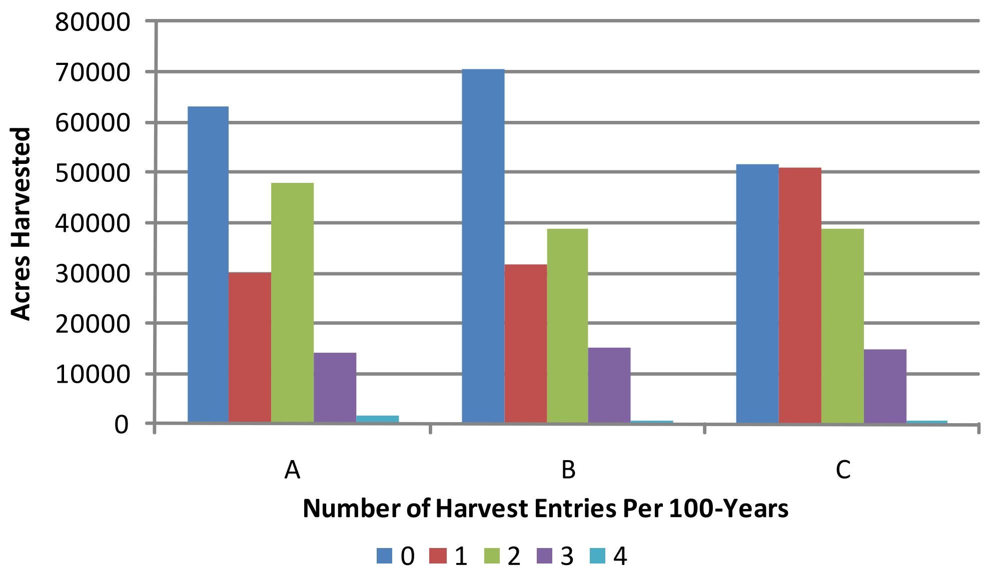
Chart 4-3. Distribution of the Percent of Total Area Harvested of Watersheds with ≥ 20 Percent DNR–Managed Lands.



Differences by Watershed

DNR examined the distribution of harvest area impacted over time using the watersheds as a spatial unit and time (each decade) as a sample (Chart 4-3). This provides a comparative metric to examine the harvest activities by alternative and identify outliers to the general pattern of harvest. For an explanation for the values of a box plot, refer to Figure 4-4.

Chart 4-4. Number of Harvest Entries over 100 Years by Alternative



The alternatives are projected to have similar harvest area distributions as a percent of each watershed over time (Chart 4-3). Any of the 13 watersheds will likely have between one and five percent of its area impacted by harvest activities per decade. Alternative C has more watersheds with greater than five percent harvested than Alternatives A and B. Each management alternative has a number of watersheds that are forecast to have harvested areas—mostly thinning activities—of up to nearly 35 percent over the 100-year planning horizon, which includes multiple entries (Table 4-4).

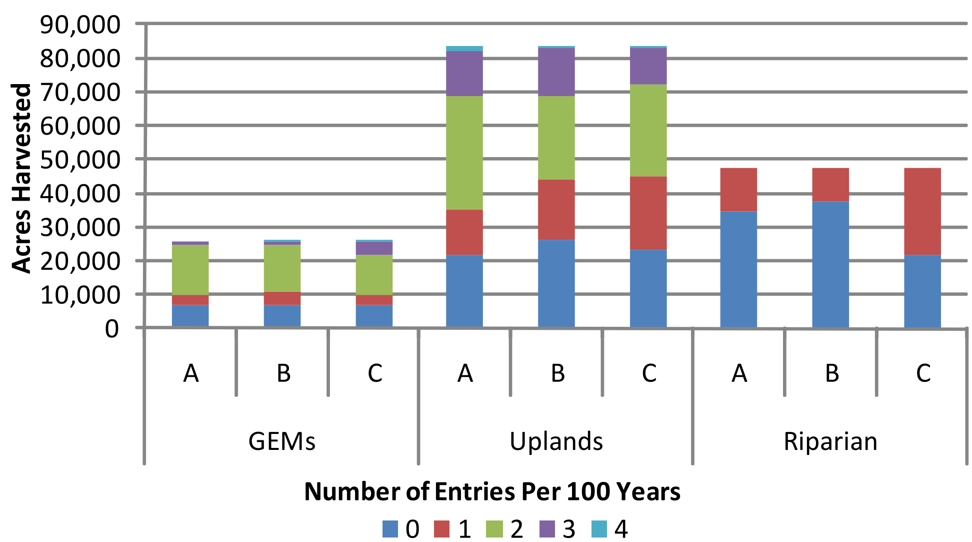
In terms of a percentage of trust lands harvested in each watershed, the highest levels occur in the Mineral Creek, Kennedy Creek, Reese Creek, and North Fork Mineral watersheds. By acreage, the highest levels of harvest occur in the Mashel, Great Bend, Howard Hansen, and Reese Creek watersheds (Table 4-4). Refer to Appendix D for additional information related to the total harvested acres by watershed, by decade, and alternative.

Differences in Harvest Entries

Chart 4-4 presents the number of harvest entries over the 100-year planning horizon. As a result of heavy thinning activities used to place forest stands on a trajectory toward better wildlife habitat (p. 173) Alternative C is forecast to have the highest number of single-entry harvests. DNR-managed trust lands left un-harvested—Alternative A (43%), Alternative B (48%), Alternative C (35%)—include Upland and Riparian areas unavailable for harvest. However, differences in harvest levels emerge when looking at the different land classes (Figure 4-1).

In looking at the number of stand entries by alternative (Chart 4-4), it is also important to understand in which land classes these multiple entries are projected to occur (Chart 4-5). In accordance with the Riparian Forest Restoration Strategy (Bigley and Deisenhofer 2006), Riparian areas generally receive only a single-entry. Under Alternative A, 30 percent (13,101 acres) of Riparian

Chart 4-5. Number of Projected Harvest Entries by Land Class Over 100 Years



areas are entered for restoration activities; under Alternative B, 23 percent (10,065 acres); and under Alternative C, 60 percent (26,202 acres). These Riparian restoration activities only occur in conjunction with Upland harvest activities. In the Uplands and GEM land classes, the same area or harvest unit may be entered more than once as shown in Chart 4-5.

Of the watersheds in which DNR manages more than 20 percent of the land base, the Great Bend, Kennedy Creek, and Lynch Cove watersheds have the greatest amount of acres with two harvest entries, while Howard Hansen, Tiger, and West Kitsap watersheds have the highest amount of area with no harvest entries (Figure 4-2). In general, a greater proportion of forested state trust lands are projected to experience two harvest entries rather than multiple (three or more) entries over the next 100 years.

The number of harvest entries potentially could result in higher risks of soil erosion and compaction. For more information, refer to *The Percent of a Watershed Harvested Affects the Likelihood of Soil Impacts* (p. 158). These harvest entries also could result in increased sedimentation, which could affect fish (p. 152), water quality (p. 150), and water quantity (p. 147). However, the particular impacts will vary by watershed, with differences in site conditions and the level, type, and number of harvest entries.

The number of harvest entries could result in more roads remaining active due to the number of times a forest stand is harvested in certain watersheds (p. 161). However, additional roads could provide added benefits for recreation visitors (p. 165) although adding roads may impact visual sensitivities (p. 171).

Forest Stand Development Trends

Different harvesting methods can affect the trajectory and landscape-level distribution of stand development stages (Text Box 3-1) Stand development stages are an important tool for assessing forest conditions and are indicators of many environmental conditions (p. 45).

Forest modeling allows DNR to project forest trends and examine how the forested land changes over time in terms of the acreage distributions of stand development stages (refer to Appendix D; the charts in Appendix D represent DNR's forest land base within the planning unit and include all land classes). Generally speaking, observed trends for the distribution of stand development stages are similar among the three alternatives. The largest difference between alternatives is related to the Fully Functional stand development stage. Trends associated with the different land classes also are presented in Appendix D. While there are differences between the land classes in the number of some stand development stages, these differences between the alternatives are minor. Alternatives B and C develop more acres in the Biomass Accumulation, Niche Diversification, and Fully Functional stand development stages earlier than under Alternative A.

As shown in Chart 3-1, few stands currently occupy the Niche Diversification and Fully Functional stand development stages. Over time, the trends show that as less complex forest stand development stages (Ecosystem Initiation, Competitive Exclusion, and Understory Development) decline, structurally complex stand development stages (Niche Diversification and Fully Functional) increase (Appendix D).

For the planning unit as a whole, Alternatives B and C achieve a higher level of structurally complex forests (Chart 4-6) over 100 years than Alternative A.

Figure 4-2. Number of Harvest Entries in Watersheds with ≥ 20 Percent DNR-Management Over a 100-Year Period

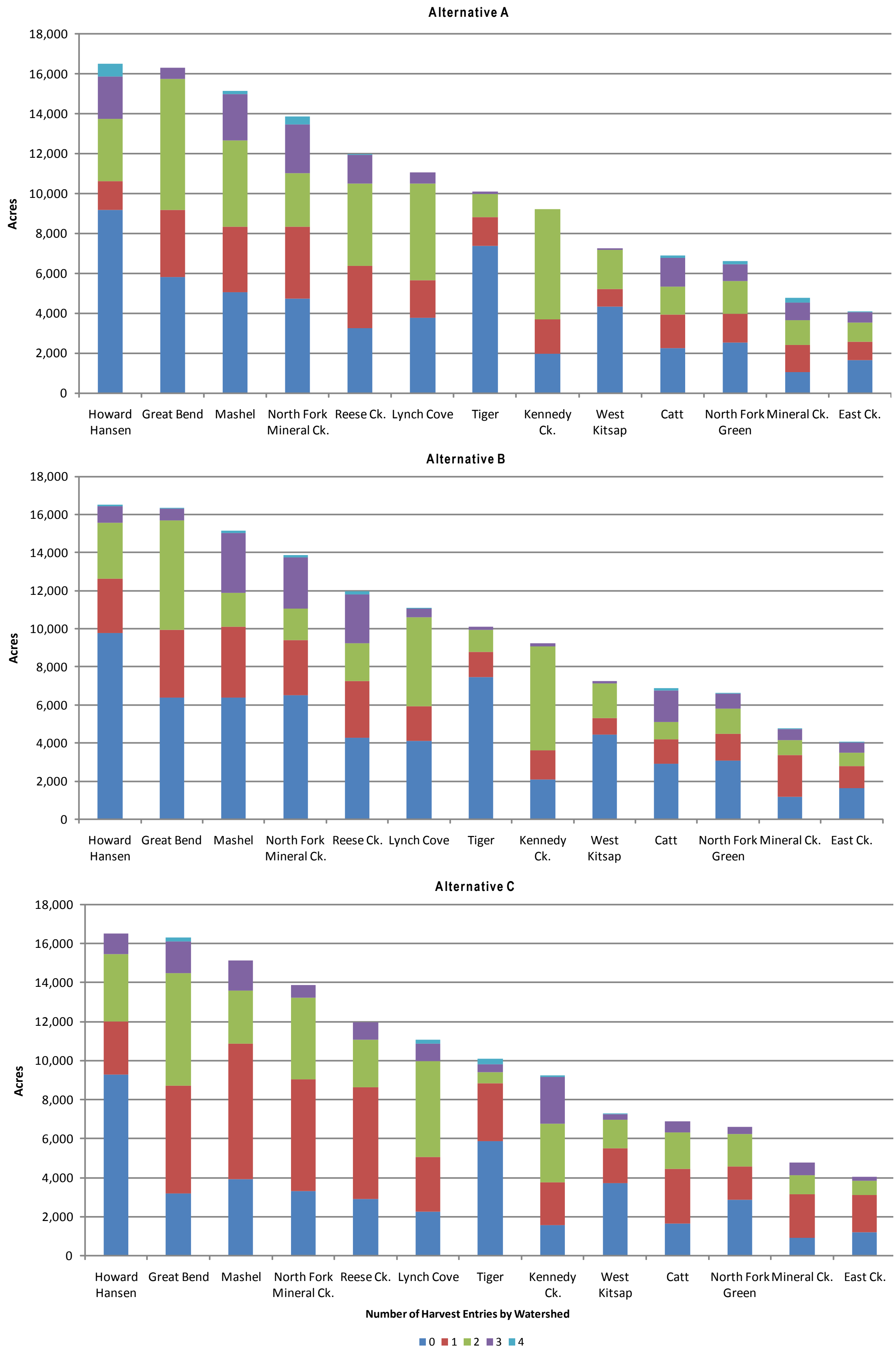
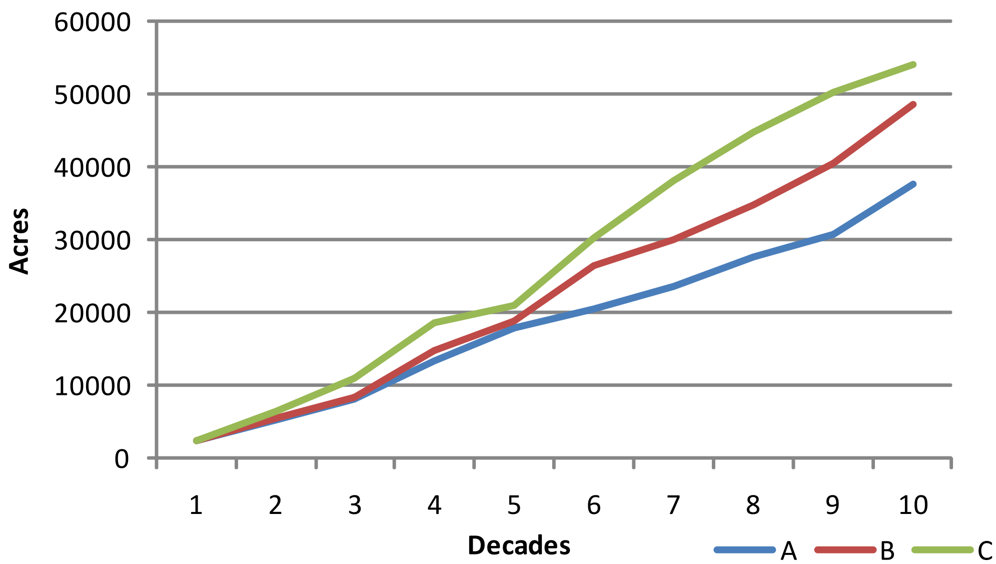


Chart 4-6. Acres of Structurally Complex Forests (Niche Diversification and Fully Functional Stand Development Stages) for all Land Classes, by Alternative and Decade



As mentioned in Chapter 3 (p. 53), DNR strives to achieve and maintain 10 to 15 percent of its forested state trust lands in older-forest conditions, defined as the Niche Diversification and Fully Functional stand development stages (Chart 4-6). DNR is projected to achieve this goal between decades four and five. By 2109, these alternatives will have reached the following proportions of forested state trust lands in older-forest conditions: Alternative A (26%), Alternative B (33%), and Alternative C (37%). Most of these older-forest conditions are found in upland and riparian areas and occur as a result of meeting all of DNR's stated objectives.

Watershed Trends

Differences between the alternatives in the watershed-level distribution of stand development stages can be observed over the 100-year planning period as a result of different watershed management objectives.

Table 4-5 shows the percent of change in each stand development stage from 2009 to 2109 for each alternative. The Mashel, North Fork Green, North Fork Mineral, and Reese Creek watersheds are expected to have the highest numbers of acres in the Niche Diversification and Fully Functional stand development stages because of the harvest types used in these areas to meet specific objectives under the 1997 *Habitat Conservation Plan* related to northern spotted owls (p. 178). Positive numbers in Table 4-5 represent increases in acreage for those stand development stages shown. Negative values represent losses of acres in a particular stand development stage which could either mean a harvest occurred or that the stand complexity increased and the acres were transferred to a more complex stand development stage.

The Catt and Kennedy Creek watersheds do not have objectives requiring structurally complex forests because they are managed primarily for trust revenue production, which results in smaller increases of acreage in the Niche Diversification and Fully Functional stand development stages.

Biomass

Forest biomass, as measured in total standing volume, is expected to increase over time so long as tree growth exceeds mortality and harvest removal. Biomass is an indicator for air quality (p. 199) and carbon sequestration (p. 201). Total standing volume can be used as a surrogate (substitute) for biomass (Smith and others 2003). Chart 4-7 demonstrates

Table 4-5. Acres and Percent (%) Change in Forest Conditions for Watersheds ≥ 20 Percent DNR Ownership (2009-2109)

Alternatives	N. Fork Green		
	A	B	C
Ecosystem Initiation	-900 (-13%)	-88 (-1%)	-277 (-4%)
Competitive Exclusion	-475 (-7%)	-1,226 (-19%)	-1,178 (-18%)
Understory Development	-1,622 (-24%)	-1,972 (-30%)	-2015 (-30%)
Biomass Accumulation	1,199 (18%)	1,595 (24%)	1,211 (18%)
Niche Diversification	422 (7%)	585 (9%)	535 (8%)
Fully Functional	538 (8%)	1,216 (18%)	1,835 (28%)

Table 4-5. Acres and Percent (%) Change in Forest Conditions for Watersheds ≥ 20 Percent DNR Ownership (2009-2109)

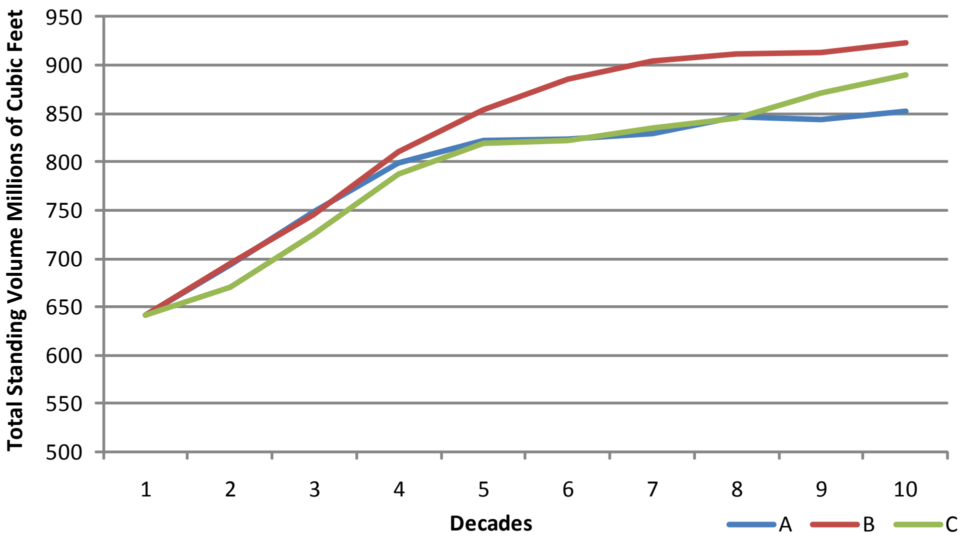
Alternatives	North Fork Mineral			Reese Ck.			Catt		
	A	B	C	A	B	C	A	B	C
Ecosystem Initiation	1,650 (12%)	2,228 (16%)	3,029 (22%)	-1,681 (-14%)	1,285 (-11%)	-2,163 (-18%)	427 (3%)	692 (5%)	841 (11%)
Competitive Exclusion	-3,915 (-28%)	-3,477 (-25%)	-4,189 (-30%)	174 (1%)	76 (1%)	-56 (-1%)	-2,538 (-18%)	-2,205 (-15%)	-2,779 (-20%)
Understory Development	-3,681 (-26%)	-5,116 (-37%)	-5,794 (-42%)	-1,375 (-12%)	-2,472 (-21%)	-1,927 (-16%)	-1,283 (-10%)	-1,303 (-10%)	-1,360 (-10%)
Biomass Accumulation	712 (5%)	1,525 (11%)	1,525 (6%)	-87 (-1%)	750 (6%)	354 (3%)	589 (4%)	1,056 (7%)	682 (5%)
Niche Diversification	1,784 (13%)	2,692 (20%)	2,692 (8%)	396 (3%)	721 (6%)	390 (3%)	536 (4%)	765 (6%)	502 (4%)
Fully Functional	1,682 (12%)	2,162 (15%)	2,162 (35%)	1,662 (14%)	3,084 (26%)	4,279 (36%)	711 (5%)	990 (7%)	2,114 (15%)

Alternatives	Howard Hansen			Lynch Cove			Great Bend		
	A	B	C	A	B	C	A	B	C
Ecosystem Initiation	-645 (-3%)	-492 (-3%)	-710 (-4%)	-144 (-2%)	264 (-2%)	867 (7%)	-1063 (-7%)	-60 (2%)	321 (-1%)
Competitive Exclusion	-4,200 (-26%)	-4,588 (-28%)	-4,388 (-27%)	-1,343 (-13%)	-402 (-4%)	-760 (-8%)	-614 (-3%)	-256 (-6%)	-1,012 (-1%)
Understory Development	-433 (3%)	-2,410 (-15%)	-1,639 (-10%)	-2,675 (-24%)	-2,968 (-27%)	-3,398 (-31%)	-4,912 (-30%)	-5,200 (-28%)	-4,657 (-32%)
Biomass Accumulation	1,143 (6%)	2,474 (15%)	1,762 (10%)	533 (5%)	482 (4%)	505 (5%)	839 (5%)	741 (6%)	1,101 (4%)
Niche Diversification	1,364 (9%)	1,940 (12%)	1,548 (10%)	2,060 (19%)	2,134 (19%)	1,044 (10%)	2,538 (16%)	1,358 (17%)	2,754 (8%)
Fully Functional	1,646 (15%)	3,127 (24%)	3,497 (26%)	530 (5%)	487 (4%)	1,692 (15%)	1,563 (10%)	3,445 (9%)	1,522 (21%)

Alternatives	Mineral Ck.			W. Kitsap			East Ck.		
	A	B	C	A	B	C	A	B	C
Ecosystem Initiation	-1,268 (-17%)	-1,123 (-24%)	-1,428 (-30%)	-581 (-8%)	-733 (-10%)	-484 (-7%)	-44 (-1%)	-116 (3%)	-249 (-6%)
Competitive Exclusion	-613 (-12%)	-362 (-7%)	-476 (-10%)	-378 (-5%)	-505 (-6%)	-416 (-5%)	-156 (-3%)	-337 (-8%)	-294 (-7%)
Understory Development	183 (4%)	-863 (-18%)	-214 (-4%)	-2,843 (-39%)	-2,176 (-30%)	-2,615 (-36%)	-846 (-21%)	-1,112 (-28%)	-926 (-23%)
Biomass Accumulation	684 (14%)	1,319 (30%)	689 (14%)	1,117 (16%)	1,109 (15%)	1,122 (14%)	259 (7%)	639 (16%)	598 (15%)
Niche Diversification	323 (7%)	478 (10%)	291 (6%)	1,154 (16%)	1,261 (18%)	812 (12%)	214 (6%)	481 (12%)	476 (12%)
Fully Functional	329 (7%)	568 (12%)	1,155 (24%)	1,095 (15%)	1,057 (15%)	1,514 (21%)	595 (15%)	871 (21%)	817 (20%)

Alternatives	Tiger			Kennedy Ck.			Mashel		
	A	B	C	A	B	C	A	B	C
Ecosystem Initiation	-33 (0%)	117 (1%)	39 (0%)	138 (1%)	-505 (6%)	1,441 (15%)	-1512 (5%)	-1310 (-8%)	-2289 (-15%)
Competitive Exclusion	-1,270 (-13%)	-1,201 (-12%)	-1,310 (-13%)	2,180 (24%)	1,462 (16%)	1,058 (12%)	-220 (-8%)	-500 (-4%)	26 (0%)
Understory Development	-4,415 (-44%)	-4,308 (-43%)	-4,014 (-40%)	-1,860 (-20%)	-210 (-2%)	-1,798 (-19%)	1,288 (-21%)	-3,312 (-21%)	-2,245 (-14%)
Biomass Accumulation	436 (4%)	810 (8%)	315 (3%)	-1,154 (-12%)	-1,181 (-12%)	-1,055 (-11%)	-1,664 (-17%)	-509 (-4%)	-1,369 (-9%)
Niche Diversification	964 (10%)	1,030 (10%)	1,272 (13%)	178 (2%)	213 (3%)	81 (1%)	468 (7%)	792 (6%)	448 (3%)
Fully Functional	3,585 (36%)	3,622 (36%)	3,769 (38%)	784 (10%)	761 (10%)	813 (11%)	3,128 (11%)	5,344 (35%)	6,034 (40%)

Chart 4-7. Change in Total Standing Volume Over Time



that the projected total volume on forested state trust lands increases for all alternatives, with the greatest increase in biomass shown in Alternative B, although not significantly different from the other alternatives.

Stand Density

Forest stand density is an indicator of forest conditions because it influences stress and competition between individual trees (p. 49). As a coarse indicator, stands with Curtis' RD of 75 or greater are likely to be at increased risk of forest health problems (p. 87) and to be able to provide reduced habitat for wildlife—specifically for northern spotted owls (p. 107).

Stand density is a useful measure in even-aged monocultures but it is difficult to apply in uneven-aged forest stands, and RD therefore is not used as an indicator in the sections of this EIS that deal with wildlife and northern spotted owl habitat. When these sections refer to overstocked stands they generally refer to forest stands with stem densities above 280 trees per acre. Often, stands with tree stocking levels over 280 trees per acre have relative densities above 75, although this is not always true, especially when multiple canopies are present with large diameter trees.

All three alternatives follow a similar trend for densely stocked stands (Figure 4-3). However, Alternative C has lower levels for the entire planning horizon (Table 4-6), most likely a result of increased levels of thinning (Table 4-4).

For GEMs, Uplands, and Riparian areas refer to Chapter 3 (p. 44). There are slight differences between the management alternatives related to stand density, as shown in Figure 4-3.

For GEMs, the acres of overstocked stands (higher relative densities) remain fairly constant with little change between the alternatives. For Uplands, overstocked acreage peaks around the sixth decade. These spikes can best be explained by an examination of forest types (Chart 4-8) and age classes (Charts 4-9(a) and (b)). There is a steady increase in acreage of Douglas-fir/western redcedar forest stands until the sixth decade, with a slight rise again in the eighth decade. These peaks likely result from past harvest practices in which many forest units were clear-cut and replanted. These young plantation forests, mainly Douglas-fir and western redcedar, continue to increase in density (Text Box 3-2) and age (Charts 4-9(a) and (b)), which will require another round of harvest activities either by thinning or variable retention harvest methods. The increase in Douglas-fir and western redcedar during the last decades is most likely due to the retention of older-forest stands in the Uplands (54% of land base) and Riparian areas (30% of land base), which currently do not receive any harvest treatments.

Table 4-6. Average Acres in Densely Stocked Conditions (RD ≥ 75) Over 10 Decades

Alternative	Acre Average over 10 Decades	Percent of Total DNR Managed Acres
A	29,425	20%
B	29,867	20%
C	25,398	17%

Figure 4-3. Acres of Densely Stocked Forest Stand Conditions (Curtis' RD>75) for the Planning Unit, by Alternative, Decade, and Land Class

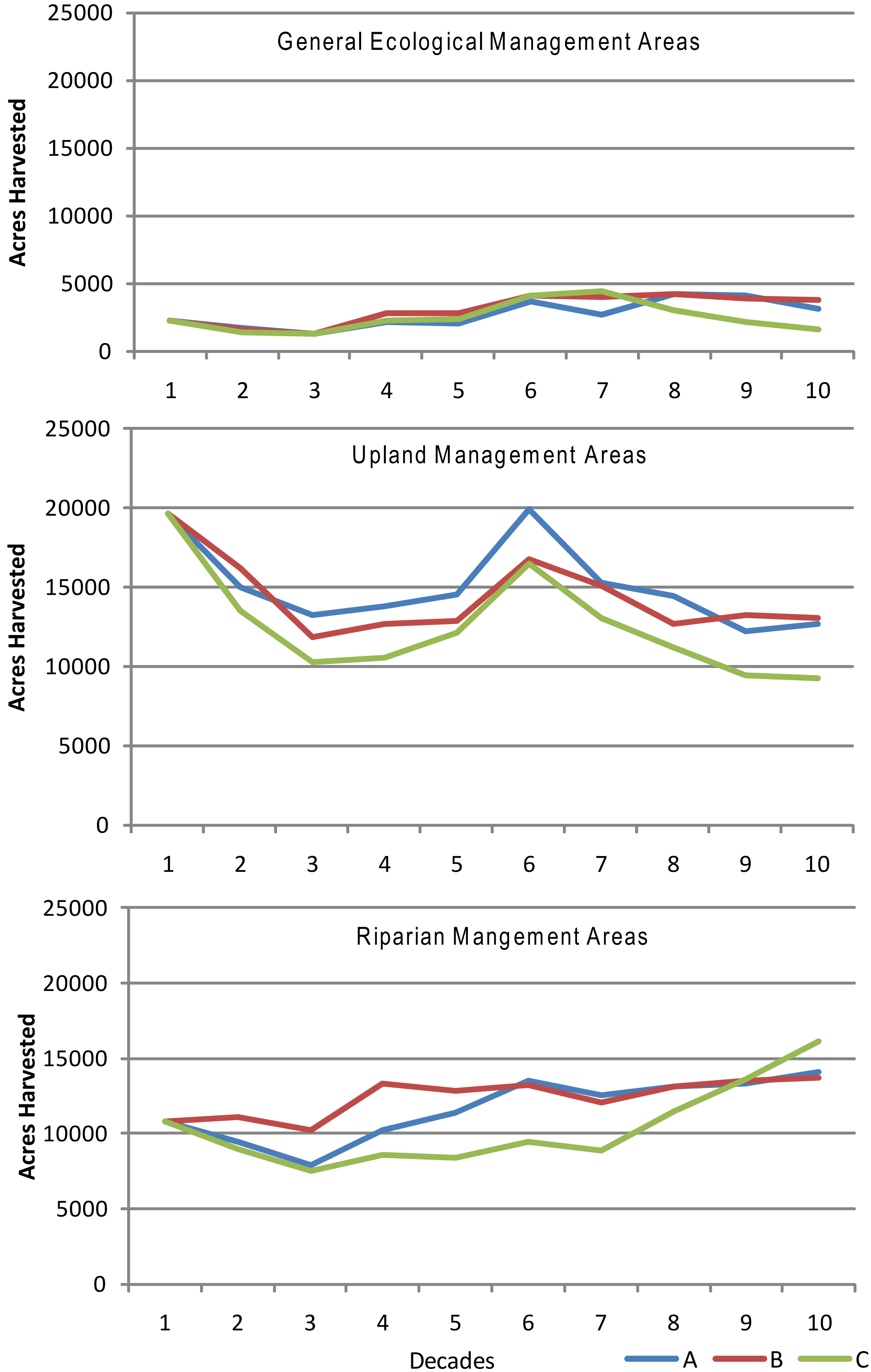
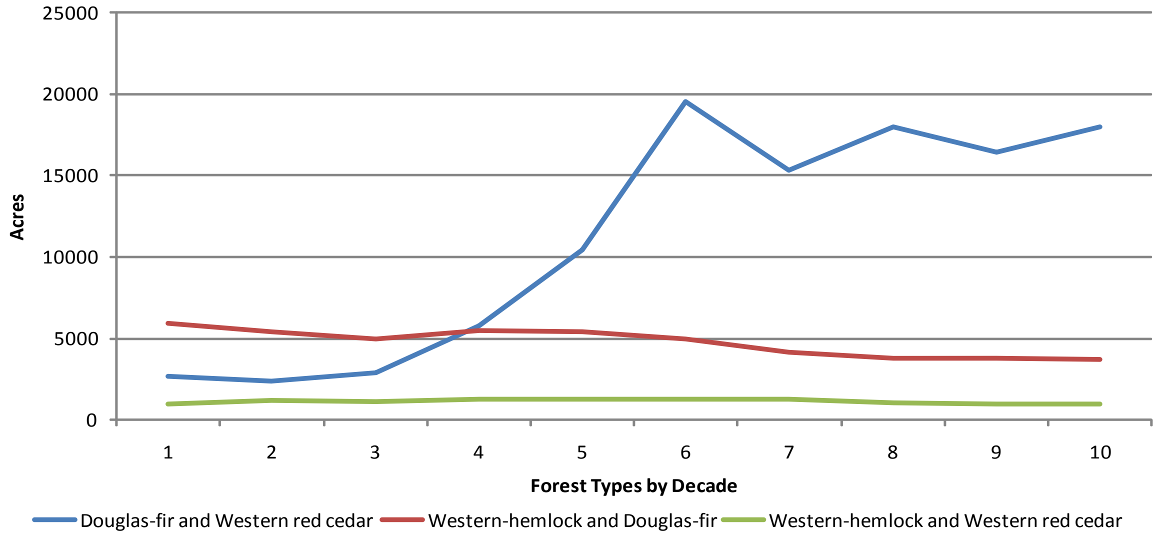


Chart 4-8. Forest Types with Relative Density** (RD) ≥ 75 (Alternative A)



*Refer to Appendix C for forest type descriptions; ** RD described in Text Box 3-2, p. ##

Chart 4-9 (a). Age Distribution for Douglas-fir/Western Red Cedar Series

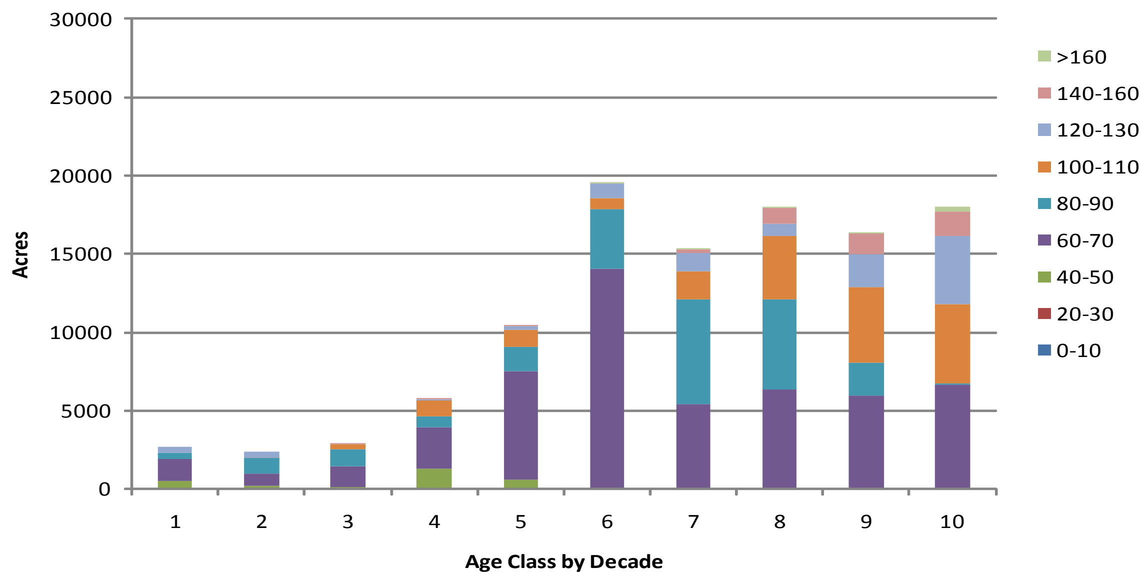


Chart 4-9 (b). Age Distribution for All Other Forest Types

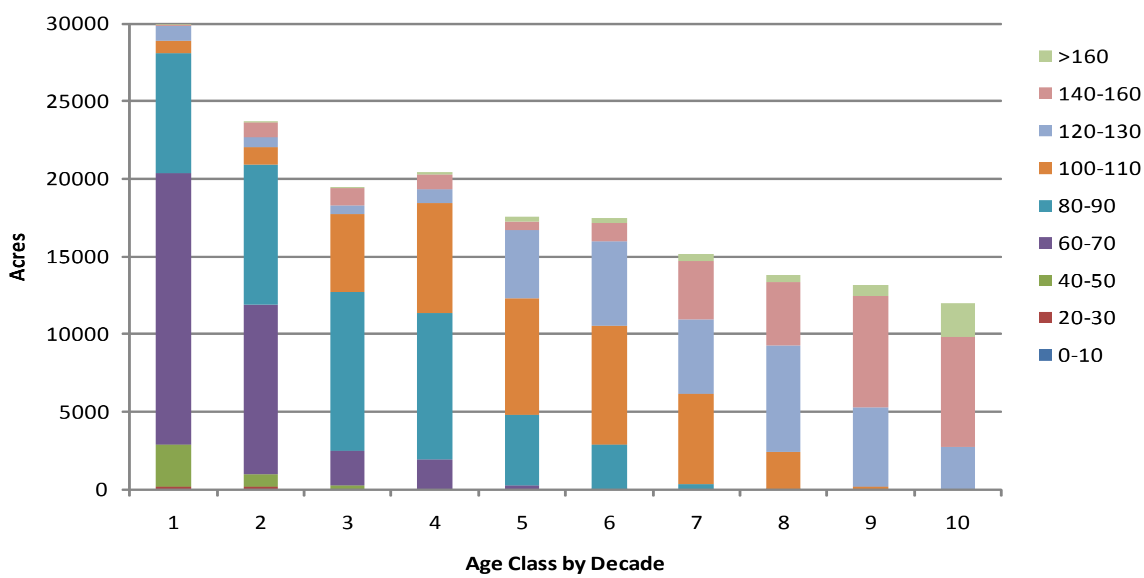
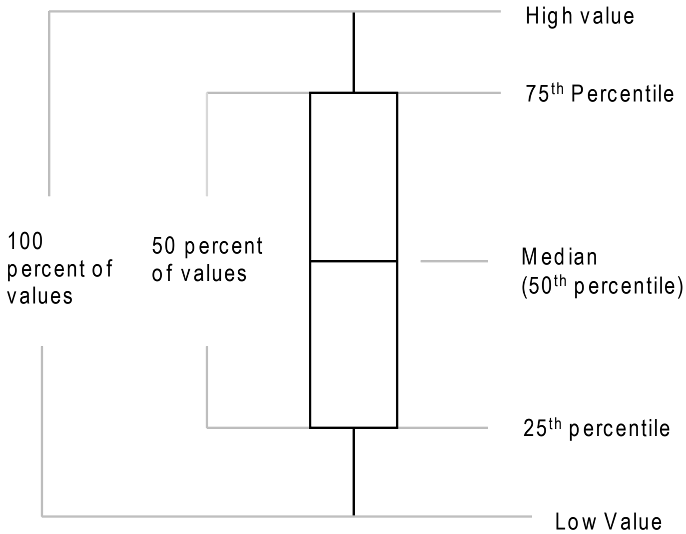


Figure 4-4. Box Plot Interpretation (modified from Few 2004)



Under all alternatives, the quantity of forests in structurally complex forest conditions (Niche Diversification and Fully Functional) is projected to increase. The greatest increase in structurally complex forests occurs under Alternatives B and C. The early stand development stages (Ecosystem Initiation, Competitive Exclusion, and Understory Development) continue to decline at a similar rate for all alternatives (Appendix D). This increase in structurally complex forests will shift the ecological conditions of forested state trust lands in this planning unit towards a mix of forest stand conditions more similar to those found before the logging of the last century (Agee 1993; Franklin and Dyrness 1973).

DENSITY AT THE WATERSHED LEVEL

DNR examined stand density at the watershed scale over time. Figure 4-5 summarizes the projected data over 10 decades into a format that provides a distribution of watershed area with an RD of 75 or greater. DNR considered watersheds that had 30 percent or more of trust lands in overstocked conditions at risk from impacts related to forest health. For all alternatives in the early part of the planning period, the Catt, Howard Hansen, North Fork Green, North Fork Mineral, and Tiger watersheds have more than 30 percent of their land bases with an RD of 75 or greater.

Direct, Indirect, and Cumulative Effects to Forest Conditions

PLANNING UNIT SCALE

A review of the level, distribution, and number of harvest entries over the 100-year planning period shows Alternative B as having the lowest average harvest area. Alternative A has the highest level of variable retention harvest and Alternative C has the highest level of thinning activities.

By land class (Figure 4-1), the majority of timber harvests occur in Uplands, as expected because Uplands represent the largest proportion (54%) of DNR-managed trust lands in the planning unit.

Increasing forest stand complexity should provide increased resilience after natural disturbances, whether the disturbance is fire, wind, or a forest health epidemic (Carey 2007). The increase in structurally complex forests (Chart 4-6) should benefit wildlife species that depend on complex forest structure (refer to Wildlife, Table 3-20), and should enhance riparian and water quality conditions (Figure 4-6) because larger trees provide more shade, which results in cooler stream temperatures, more leaf and needle litter, and a wider variety of microclimates (p. 165).

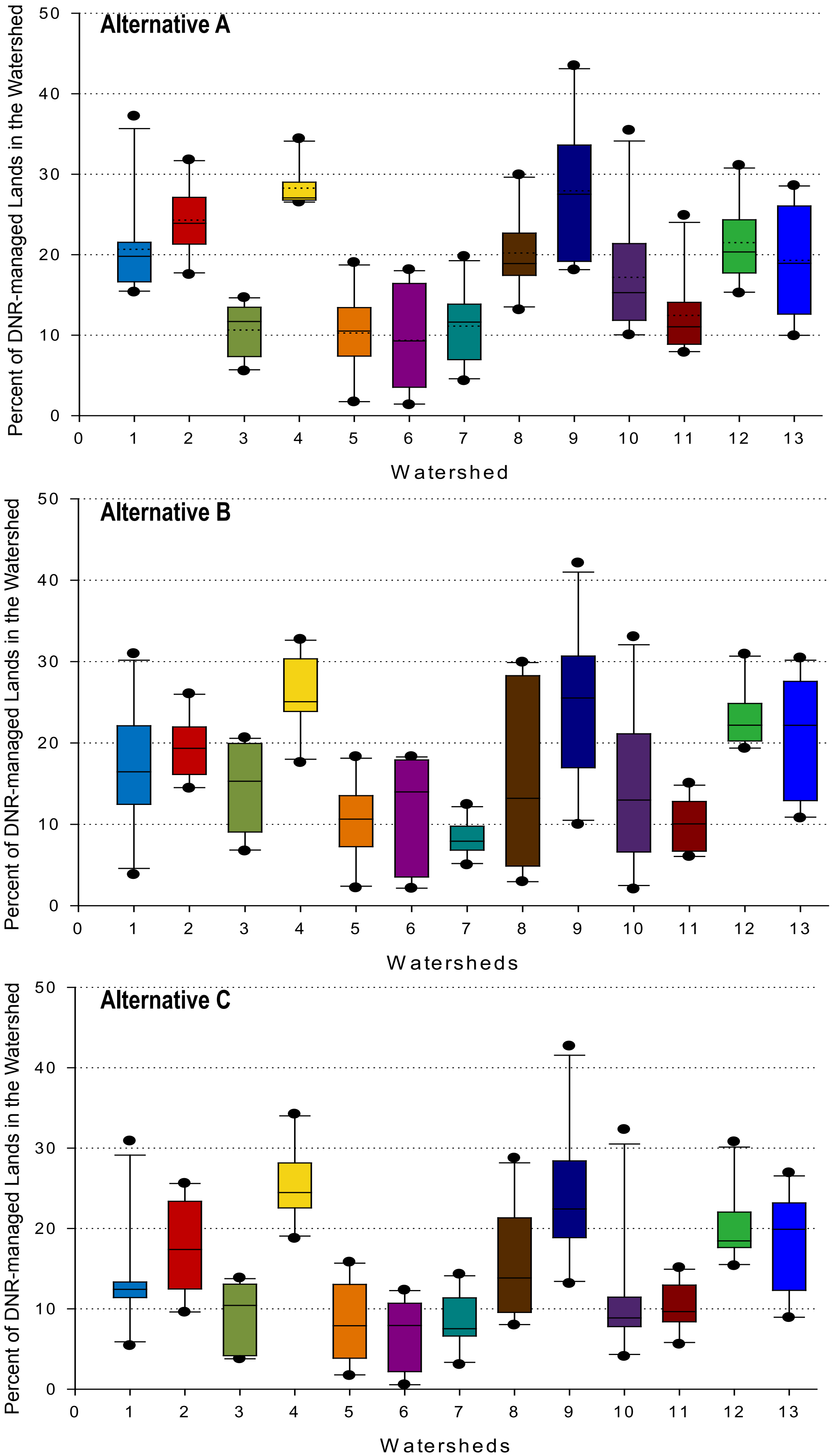
WATERSHED SCALE

At the watershed scale (Table 4-4), Howard Hansen, Great Bend, Mashel, and Reese Creek watersheds (WAUs) have the highest acreages of harvest activity. The harvest activities applied in Howard Hansen, Mashel, and Reese Creek WAUs also result in the highest levels of fully functional forests (Table 4-5). The Great Bend WAU followed by Lynch Cove and Kennedy Creek WAUs have the highest percentage of variable retention harvest activities.

SOIL

Logging equipment used during harvest activities has the potential to increase soil compaction and sedimentation with adverse impacts to water quality and quantity, fish, and riparian systems. The

Figure 4-5. Forest Stand Density in Watersheds under All Alternatives



Watershed Numbers

1. Catt
2. East Ck.
3. Great Bend
4. Howard Hansen
5. Kennedy Ck.
6. Lynch Cove
7. Mashel
8. Mineral
9. North Fork Green
10. North Fork Mineral
11. Reese Ck.
12. Tiger
13. West Kitsap

amount of sediment that reaches a stream depends on two processes: the availability of sediment and the ability of sediment to travel from its source to a stream. DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-106 to 4-109) which discusses the impacts on soils from harvesting activities. For an analysis of impacts in this planning unit from these alternatives, refer to soils (p. 155).

FOREST HEALTH

The level of thinning activity is highest under Alternative C and it may have the greatest potential for significant adverse environmental impacts relating to several forest pathogens entering through wounds made by logging equipment (Otrosina and Ferrell 1995), including Armillaria root disease, Annosum root and butt rot, and hemlock dwarf mistletoe. Although thinning activities increase the risk of introducing some pathogens, more frequent harvest entries also can provide more opportunities for managers to treat established disease pockets.

VISUAL MANAGEMENT

Potential adverse environmental impacts to visually sensitive areas could be reduced by favoring thinning over variable retention harvests. The choice one silvicultural system rather than another is site-specific. The alternatives presented in Chapter 2 for visual management (p. 37) give flexibility to. forest managers, with Alternative B providing the most specific direction. Refer to visual management (p. 170) for additional analysis.

ROADS

Potential adverse environmental impacts resulting from forest roads include increased sedimentation affecting both water quality and fish habitat. DNR incorporates by reference the 2001 *Forest Practices Rules Final EIS*, which (beginning on p. 3-7) presents an analysis of the effects of sediment, peak flows, and roads in riparian areas and wetlands on water quality and fish. Roads can increase wildlife habitat fragmentation and impact air quality while creating more opportunities for public access and dispersed recreation activities. Refer to roads for additional analysis (p. 161). Higher levels of thinning activities under Alternative C would likely result in the maintenance of a higher number of forest roads, which could result in higher impacts than under Alternatives A and B.

Mitigation from Forest Activities

Following DNR's Forest Practices Rules, agency policy, and procedures, and the conditions set forth in the 1997 *Habitat Conservation Plan* provides mitigation. In 1997, DNR began implementing its multi-species habitat conservation plan, ensuring habitat for a multitude of species and special ecosystems. In terms of forest conditions, while the potential exists for significant adverse environmental impacts from harvesting activities, on-site mitigation conducted prior to and during any harvest activities lessens the possibility of unwanted results.

Riparian

Criteria and Indicators for Riparian

Chapter 3 (p. 58) describes the general characteristics of riparian areas, their importance, and the criteria used to evaluate the environmental impacts to them. The criteria are related to the maintenance and restoration of salmonid freshwater habitat which contributes to the conservation of other aquatic and riparian obligate species.

Riparian function is measured by the following set of indicators: large woody debris, leaf and needle litter recruitment, stream shade, microclimates, sediment control, and streambank stability (Gomi and others 2002; Bilby and Bisson 1991; Liquori and others 2008). Chapter 3 contains a general discussion of how these indicators influence riparian functions. To assess and compare the differences between the management alternatives, DNR used two surrogates. The first surrogate is stand development stages and it is a good measure for the amount of large woody debris, leaf and needle litter recruitment, and stream shade. The second surrogate is riparian buffers (specifically their size), which can be used to draw inferences about microclimates, sediment control, and streambank stability.

Measuring Riparian Function

STAND DEVELOPMENT STAGES

Forest stand development stages are commonly used to measure forest structural conditions, including those in riparian areas. There is a close tie between stand development stages and the indicators of ecosystem function (Carey 1998;

Jules and others 2008; Franklin and others 2002; Spies and others 1994). Structural features that can be described and predicted into the future (such as stand diameter distribution, canopy layers, decadence, and thus stand development stages) are the best surrogates for ecological functions (such as large woody debris, shade to maintain cool stream temperature, and microclimates). Forest stands in the Biomass Accumulation, Niche Diversification, and Fully Functional stages contain large trees (more than 30 inches diameter at breast height) which in turn provide benefits to riparian systems such as large woody debris input and stream shading. Large trees in the riparian areas also provide leaf and needle litter (an important food and nutrient source), influence stream temperatures, and affect riparian microclimates. These riparian functions were discussed and analyzed in the 2004 *Sustainable Harvest Final EIS* (p. 4-35 to 4-52) and are incorporated here by reference.

RIPARIAN BUFFERS

As described in Chapter 3, riparian buffers reduce sediment by filtering surface water runoff, protect unstable slopes by retaining root structures, moderate peak flows, provide shade which helps regulate stream temperatures, and contribute large woody debris which is important for aquatic systems and wildlife habitats (DNR 1996, 2004; Liquori and others 2008). Riparian buffers also provide varied microclimates which are affected by solar radiation, soil temperature, soil moisture, air temperature, wind velocity, and humidity (Moore and others 2005; Jackson and others 2001; Spence and others 1996; Forest Ecosystem Management Assessment Team 1993). Leaf and needle litter contributed by trees within riparian buffers provide up to 60 percent of the total energy input into stream communities for benthic invertebrates (DNR 2004; Brosofske and others 1997; Wipfli and Gregovich 2002).

Under Washington's Forest Practices Rules, riparian buffers are required on the equivalent of Type 1 through 3 waters, discontinuous buffers on equivalent of Type 4 streams, but none on the equivalent of Type 5 waters (DNR 2001). On forested state trust lands, however, all Type 4 waters have 100-foot buffers on both sides of the stream (DNR 1996, 1997). DNR is also developing a Headwaters Conservation Strategy designed to increase protection for Type 5 waters on sensitive sites to maintain ecological functions both on site and in connection to downstream systems. In general, the following buffer widths are applied to both sides of a stream (Table 4-7); these stream buffers are enlarged if an area is prone to windthrow (Bigley and Deisenhofer 2006).

Table 4-7. Buffer Widths by Stream Type (applied to both sides of a stream)

Type 1 & 2	*Si_{100}: average 145 ft. (min. 100 ft. max. 215 ft.)
Type 3	*Si_{100}: average 145 ft. (min. 100 ft. max. 215 ft.)
Type 4	100 ft.
Type 5	**As necessary when guidelines are finalized

*Site potential height of mature conifer is defined as the height of the tallest 40 trees per acre at 100 years (SI_{100})
** DNR is conducting research to investigate adequate protection of Type 5 Waters.

Carefully designed thinnings, tailored to the specifics of each riparian stand condition, can be used to accelerate the development of structural complexity and thus the ecological functioning of riparian forests (Bigley and Deisenhofer 2006). Currently, about one percent of riparian areas are estimated to be in the Niche Diversification and Fully Functional forest stand development stages (refer to Table 3-8). Riparian restoration activities are generally carried out only in conjunction with upland harvest activities, since road building and yarding corridors need to be considered in concert with restoration activities. Permitted harvests and other restoration activities are required to maintain existing habitat structures such as down wood and snags to accelerate the development of structurally complex forests.

Expected Changes in Riparian Areas

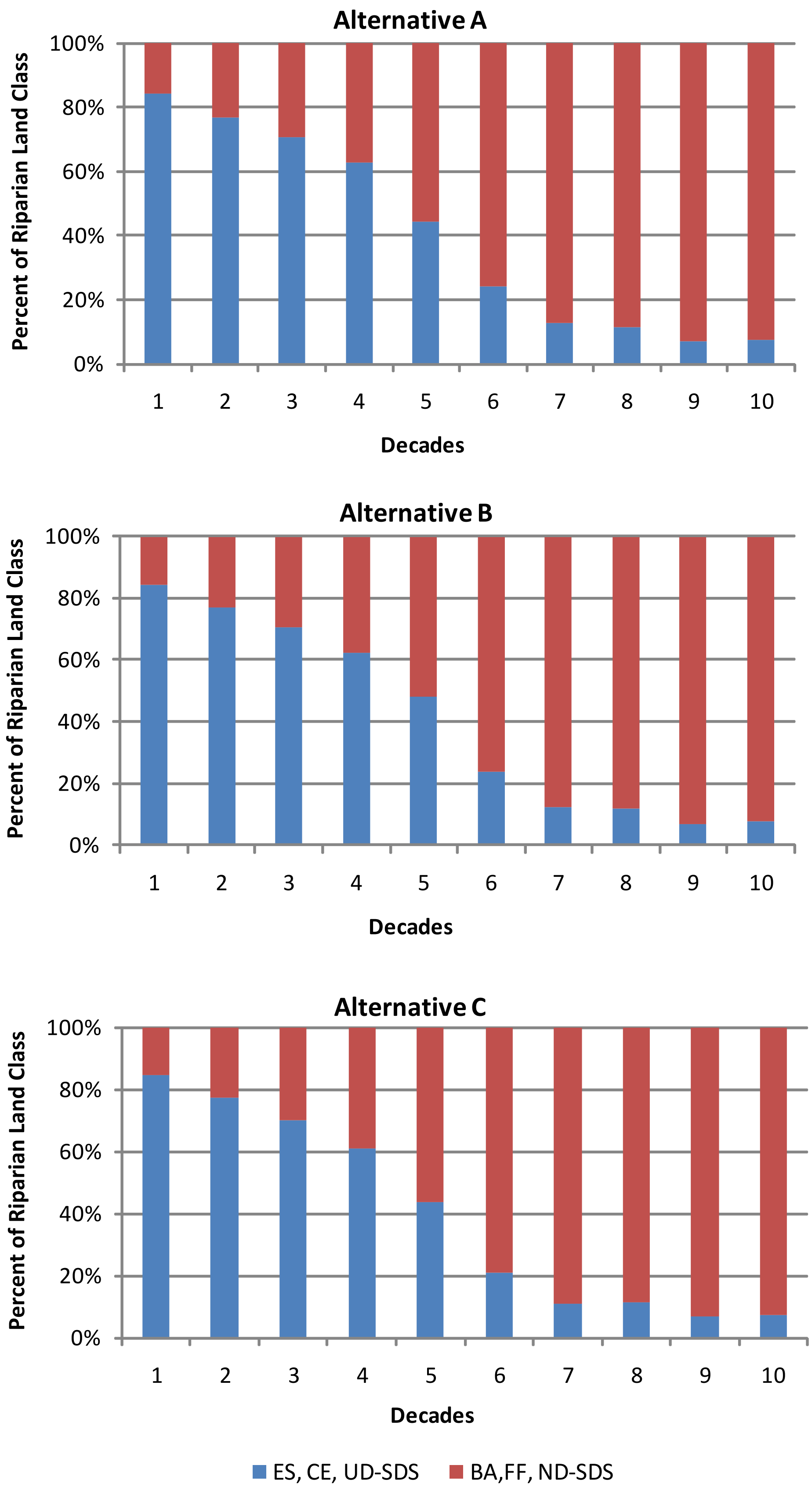
STAND DEVELOPMENT STAGES

Stand development stages are used to evaluate changes in forest conditions across the landscape (Franklin and others 2002). All of the management alternatives result in similar forest stand development trajectories because they are trying to achieve the same objectives created by incorporating DNR policy into the modeling process. As riparian forests move towards the Biomass Accumulation stage and beyond, they rapidly increase in structural complexity and in riparian function (Naiman and others 2000; Spies 1997; Bilby and Ward 1991). Figure 4-6 illustrates the relative change between the alternatives. Alternatives diverge in the fifth decade, where the benefit of more active restoration is reflected in a greater percentage of structurally complex forest stands. Areas not actively restored undergo a slow natural progression of stand development that can be stalled in the Competitive Exclusion stage for decades by high stand density (Bailey and Tappeiner 1998).

Under all of the alternatives, riparian areas will continue to increase in complexity at a steady rate (refer to Chart 4-10). While each alternative develops over time, more acres in the Biomass Accumulation, Niche Diversification, and Fully Functional forest stand development stages the level of activities required to achieve these conditions varies by alternative. Biomass Accumulation does not, by definition, include a lot of large down woody debris or large snags but it is a stage that indicates the potential for future delivery of large woody debris to streams. However, the best indicators of riparian function are related to the structural characteristics of Fully Functional forests as shown in Chart 4-10.

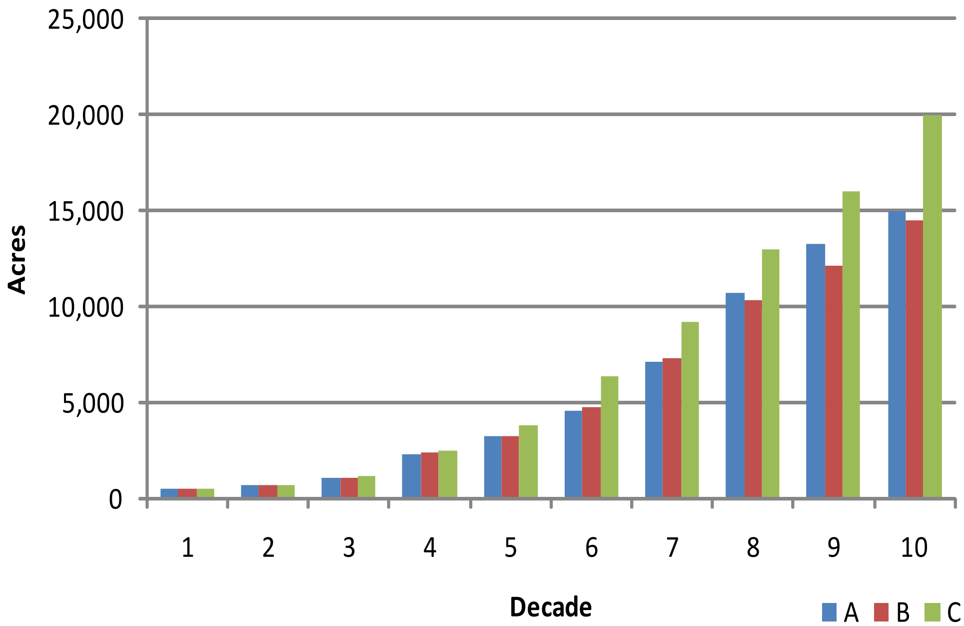
Chart 4-11 illustrates the forecasted harvested acres in riparian areas under the three alternatives to achieve the conditions forecast in Chart 4-10. The level of activities required to achieve these conditions varies by alternative.

Figure 4-6. Comparison of Stand Development Stages by Alternative



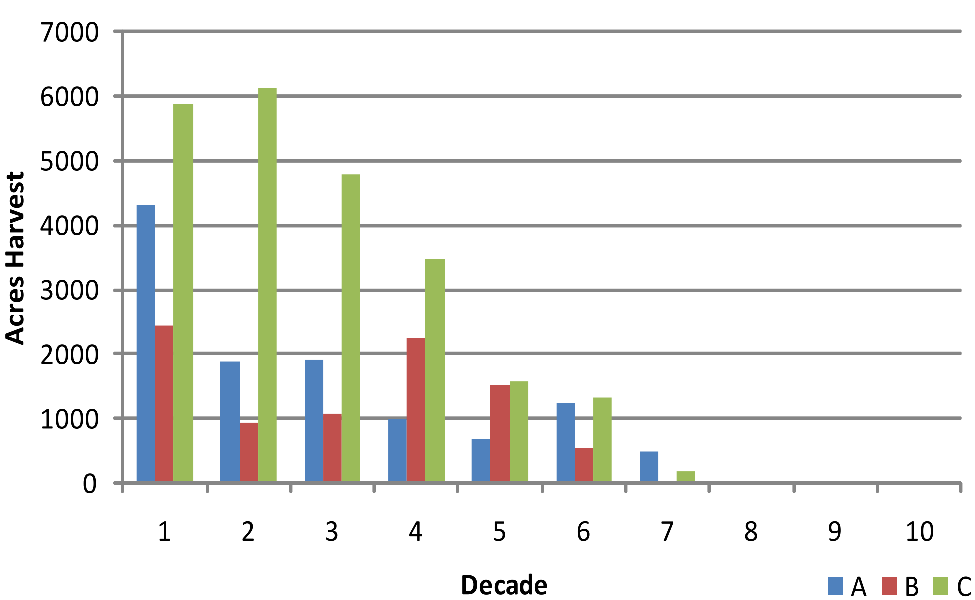
* EI -Ecosystem Initiation, CE –Competitive Exclusion, UD –Understory Development, BA –Biomass Accumulation, ND –Niche Diversification, FF –Fully Functional

Chart 4-10. Riparian Areas in the Fully Functional Stand Development Stage



The modeling of riparian restoration activities in all of the alternatives assumes that once stands reach 70-years of age, there would be no subsequent restoration thinning (harvest activities) regardless of the functional stage of the forest. Operationally, thinning activities may occur in stands greater than 70-years of age with written approval from the HCP Implementation Manager and in consultation with the Federal Services (Bigley and Deisenhofer 2006). The impact of this assumption is seen as a sharp decline in activities across all alternatives with time. While there are more than 43,800 acres in the Riparian land class (Table 3-5), the total acreages in riparian areas being affected per decade are comparatively low. Chart 4-11 shows the same information as Figure 4-1 but on a different scale; Figure 4-1 also provides a comparison to the other land classes.

Chart 4-11. Harvested Acres in Riparian Areas by Decade and Alternative



HARVEST ACTIVITIES

The modeling results shown in Chart 4-11 represent the area of active riparian forest restoration by alternative over the planning horizon, while Table 4-8 shows harvested acres for the first decade in WAUs in which DNR-managed lands amount to 20 percent or more of the total acres. Compared to Alternatives A and C, Alternative B has the lowest harvest levels to carry out projected restoration acitivies in riparian areas. Table 4-9 shows the percentage of change from Alternative A (no action). It is important to refer to Table 4-8 for the actual modeled acres related to restoration activites in the first decade. While the modeling results are only predicted outcomes based on current conditions, they provide an idea of where thinning activities could occur to improve riparian conditions over the long-term.

Table 4-8. Harvested Acres in Riparian Areas in Decade One by Alternative

Alt	Catt	East Ck.	Great Bend	Howard Hansen	Kennedy Ck.	Lynch Cove	Mashel	Mineral Ck.	North Fork Green	North Fork Mineral	Reese Ck.	Tiger	West Kitsap	Tot.
A	501	68	532	26	224	167	583	149	76	841	598	446	106	4,316
B	266	60	279	64	191	57	354	87	68	366	332	293	40	2,457
C	328	76	1,275	80	527	378	758	152	92	768	714	543	200	5,891

Table 4-9. Difference from Alternative A (No Action) for Harvested Riparian Acres in Decade One

Alt	Catt	East Ck.	Great Bend	Howard Hansen	Kennedy Ck.	Lynch Cove	Mashel	Mineral Ck.	North Fork Green	North Fork Mineral	Reese Ck.	Tiger	West Kitsap
B	-21%	-4%	-12%	+23%	-4%	-18%	-13%	-16%	-3%	-24%	-16%	-12%	-19%
C	-16%	+4%	+36%	+32%	+31%	+35%	+11%	+1%	+7%	-4%	+7%	+8%	+27%

Direct and Indirect Impacts for Riparian

DNR used the measure of stand development stages in riparian areas to identify possible effects of management activities over time. The current distribution of stand development stages suggests (Table 3-8) that many streams presently may have reduced levels of riparian function, particularly large wood input, because of the relative low proportion of stands in the Biomass Accumulation, Niche Diversification, and Fully Functional stand development stages (Figure 4-6).

Alternatives A and B are forecast to have approximately the same acreage of forest stands in the Fully Functional stand development stage in riparian areas (Chart 4-10). The modeling results suggest that in Alternative C, for every additional acre thinned over Alternative B, there is the potential of creating one-third of an acre more of Fully Functional forest in riparian areas. The net result is that Alternative C is projected to develop 5,000 more acres of Fully Functional forests than Alternatives A or B because of an additional 16,000 acres being thinned over eight decades.

DNR used the measure of how many acres were harvested to show how restoration activity levels could result in both short-term (Table 4-8; 4-9) negative effects and long-term benefits (Chart 4-10) aimed at promoting more Fully Functional forests that would produce higher levels of riparian functions. The differences between the alternatives can be distinguished by the level of harvest activities within the Riparian Management Zone (Chart 4-11). Harvesting activities are highest in the first decades, specifically under Alternative C (as shown in Chart 4-11), which maintains the growth of leave trees and re-establishes understory vegetation, thus placing riparian areas on a path to achieve desired future riparian conditions. Disturbance associated with the harvest levels is projected to be higher in Alternative C and is more likely to result in short-term impacts to riparian indicators (Chart 4-11)—such as shade, microclimate, and sedimentation. The long-term benefits from these restoration activity levels are greatest under Alternative C, with Alternatives A and B performing very similarly (Chart 4-10).

Relative to current conditions, large woody debris recruitment, leaf and needle litter production, and shade conditions are expected to improve under all alternatives. Short-term impacts include reductions in leaf and needle litter production; long-term reductions in shade and large woody debris may occur from the removal of riparian trees (Bailey and Tappeiner 1998). The extent and duration of the reduction depends on where and how many trees are removed, site-specific conditions, and the particular function being considered during design of the restoration activity (Deal and Tappeiner 2002; DNR 2001; Tappeiner and others 1997).

Differences to microclimates are linked to the level and type of riparian disturbance. Forest management activities including road-building, stream crossings, and yarding corridors are expected to change the forest structure in riparian areas resulting in localized adverse impacts at the microclimate scale. The slight changes that can occur with forest openings related to road building and stream crossings can in turn influence thermal and moisture environments under forest canopies and affect microclimates (Moore and others 2005); however these changes are expected to be localized and not widespread.

Riparian buffers can decrease the magnitude of increases in stream temperature and changes to riparian microclimate, but warming has been observed in streams with and without adjacent timber harvest activities. Various studies demonstrate that streams may or may not cool after flowing from clearings into shaded environments, and further research is required in relation to the factors controlling downstream cooling (Moore and others 2005; Liquori and others 2008).

Cumulative Impacts to Riparian Resources

The distribution of forest stand development stages and corresponding levels of restoration activities over time and space provide a basis for assessing the potential cumulative effects of the alternatives in the forested environment for any given watershed. However, the amount and nature of forests in any landscape are highly variable (soil properties, weather events), and contain a wide range of forest types (conifer mixed with deciduous) and stand structures (stands that fall into a variety of stand development stages), which can only be assessed on a site by site basis to determine proper silvicultural treatments. All alternatives are expected to use ground-based or cable yarding methods which can result in soil compaction, rutting, and surface erosion (refer to Soils, p. 155). In analyzing riparian areas at the watershed scale, DNR did not find any watersheds under any of the alternatives that would result in significant adverse environmental impacts.

ROADS AND RECREATION

Besides harvesting activities, roads (p. 150) and recreational activities (p. 165) also affect riparian indicators. DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-44 to 4-52). DNR is also incorporating by reference the 2001 *Final EIS on Alternatives for Forest Practices Rules* (Appendix F), which discusses long-term impacts caused by permanent roads in riparian areas. Road management is implemented uniformly across all alternatives.

The adverse impacts to riparian areas from recreational activities are expected to be reduced under Alternatives B and C by the removal or relocation of those activities from certain areas. However, more managed recreation options provided by contracting or leasing services under Alternative C have the potential to increase recreational use in certain areas, resulting in probable increases in the impacts to riparian areas from road and trail use (Table 4-25). However, some environmental impacts are expected to be mitigated by a continued recreation management presence (such as contractors) when contrasted with free, unmanaged use (Bates 1999).

Riparian Mitigation

RIPARIAN FOREST RESTORATION STRATEGY

The modeling projections demonstrate that older-forest stand conditions within riparian areas can be achieved. These older forests provide many of the measurable benefits described under riparian indicators (p. 58). Riparian areas are managed under the 2006 *Riparian Forest Restoration Strategy* to protect and improve instream and riparian habitat conditions. The riparian strategy was developed as part of the 1997 *Habitat Conservation Plan*. Management of riparian areas is accomplished through thinning harvests to accelerate tree growth in the remaining trees, increase wind firmness, and aid in the development of a desired tree species (Bigley and Deisenhofer 2006).

FOREST PRACTICES RULES

In 2001, the *Forest Practices Rules* were modified to more fully address the impacts of forest practices on water quality, salmon habitat, and other aquatic and riparian resources (DNR 2001). These rules are applied to all harvest activities on non-federal forestlands in the planning unit.

The 2001 *Forest Practices Rules* provide specific mitigation strategies to protect riparian areas. Harvest prescriptions and mitigation measures include avoidance, short-term deferral from harvest, specific harvest and yarding methods, restoration, active downed wood accumulation, and large woody debris management. Site-specific harvest planning determines the combination and configuration of restoration activities to best meet stand-level objectives and minimize effects to riparian areas. The modeling and analysis results show that implementation of the policies and rules do not indicate probable, significant, or adverse environmental impacts that are not already mitigated through the existing policies and rules.

The environmental impacts caused by restoration activities in riparian areas are mitigated on-site during the implementation phase following Forest Practices Rules.

Wetlands

Chapter 3 (p. 62) describes the general characteristics of wetlands, why they are important, and the criteria DNR uses in managing them on state trust lands.

Criteria and Indicators for Wetlands

The criteria for wetlands follow DNR policy, which states that there will be no net loss of naturally occurring wetland acreage and function (DNR 2006b). However, as mentioned in Chapter 3, the accuracy of the available data on wetland acreage for both state and federal lands statewide varies from wetland to wetland because the methods used for identifying these areas (aerial photography interpretation) often underestimate actual wetland acres.

The indicators of wetland function are water flow, biogeochemical factors, and vegetative cover. Acres of wetlands in a watershed may suggest the predisposition of an area to higher risk of losing wetland function than areas with fewer acres. Changes in DNR-managed wetland acreages are not well tracked. The Riparian land class includes streams, stream buffers, wetlands, and wetland buffers. While this classification includes lands that are not true wetlands, it allows for a comparison of activities in areas that are likely to contain wetlands. Harvest levels in riparian buffers will be used as a measurable surrogate for determining potential net acreage losses and/or losses of functions tied to vegetative cover. Road density will be used to compare impacts to watersheds containing wetlands.

Table 4-10. Wetland Acres within Watersheds with ≥20 Percent DNR-Managed Acres*

Watersheds (WAUs)	Wetland Acres	Percent of Total DNR-Managed Acres
Great Bend	306	3.03%
Lynch Cove	254	1.54%
Mashel	196	2.85%
West Kitsap	46	0.39%
Reese Ck.	35	0.25%
North Fork Mineral Ck.	21	0.53%
Kennedy Ck.	16	0.11%
Tiger	14	0.16%
Catt	12	0.07%
Howard Hansen	11	0.14%
East Ck.	4	0.04%

* Rounded to the nearest integer. North Fork Green and Mineral Ck. are not included because they have no identified wetland acres.

Wetland Results

WETLAND ACRES

The number of wetland acres may indicate watersheds that are at higher relative risk for loss of wetland acres or wetland function from timber harvesting and associated activities (like road building). Watersheds in this planning unit have very few acres that have been identified as wetlands. Refer to Table 4-10 for total wetland acres in these watersheds and the percent of wetlands in each.

HARVESTING IN RIPARIAN AREAS

Under the proposed management alternatives, the differences in environmental impacts to wetlands are a function of the acreage harvested and the amounts of related harvest activities that occur adjacent to the wetland buffers or in the buffers to achieve goals of the *Riparian Forest Restoration Strategy*. The first comparison is the percentage of riparian and wetland area disturbed under each alternative. Because wetlands and wetland buffers were not separated from the stream data in the model, the Riparian land class was used to compare alternatives. It is important to note that wetlands found within riparian areas receive protective buffers and are not subject to thinning, and forested wetlands outside of riparian areas are subject to thinning but not variable retention harvests.

The differences between the management alternatives can be distinguished by the level of harvest activities within the riparian management zone (Chart 4-11). The riparian section of this document contains the analysis for riparian areas highlighting the first decade (Table 4-8), because it has the highest harvest levels over the planning horizon. Of all the watersheds with at least 20 percent in DNR-management, acres receiving the highest harvest levels include North Fork Mineral, Great Bend, Mashel, and Reese Creek—generally varying between Alternatives A and C. Over the planning horizon, levels of riparian restoration activities will decrease (p. 139).

ROADS

The roads section (p. 161) reported that North Fork Green, Howard Hansen, Tiger, and West Kitsap have the highest number of inoperable acres in areas where roads most likely will not be constructed. Refer to Table 4-17 for the watersheds with harvestable acreage 800 feet from the existing road network.

Assessed Risk of Impacts to Wetland Functions

Great Bend, Lynch Cove, and Mashel watersheds may be at a higher risk of losing wetland function than other watersheds in the planning unit. This risk, however, is only assessed relative to other watersheds with at least 20 percent DNR-managed acres, and none of these watersheds has more than three percent of its acreage identified as a wetland. There is no existing system for tracking wetland losses or impacts; therefore, DNR can only identify areas with potential impacts.

Higher harvest levels increase the likelihood that some environmental impacts will occur in specific watersheds over others. North Fork Mineral and Reese Creek have the highest percentage of DNR-managed acres; however Great Bend and Mashel have the greatest amounts of forested acres available for DNR management activities (with the exception of Howard Hansen) (Table 4-1), so the actual percent of total acres in these watersheds being negatively impacted could be equal to or lower than those areas receiving lower harvest levels. Harvest levels under Alternative C potentially will have the greatest impact on wetland acres because it proposes the highest level of harvest, followed by Alternative A, then Alternative B.

Construction of roads can have direct impacts on wetlands because roads may permanently eliminate or severely change the biological functions of the wetland areas they cross. Road building can result in hydrologic changes caused by compaction, siltation, and vegetation removal, which in turn result in altered floodwater behavior, decreased infiltration, and increased runoff. Additionally, road crossings in wetlands without adequate cross-drainage provisions can lead to flooding on the upslope side and subtle drainage changes on the downslope side of crossings (Stoeckeler 1967; Boelter and Close 1974). Under all alternatives, roads are built to access harvesting units. Road building designs avoid wetlands and their adjacent buffers when possible, but sometimes such areas cannot be avoided and mitigation takes place on a site-specific scale.

The impacts to forested and non-forested wetlands were analyzed in the 1996 *Draft EIS for the Habitat Conservation Plan* (p. 4-488 to 4-490) which DNR is incorporating by reference as well as the 2004 *Final EIS for Sustainable Harvest* (p. 4-131 to 4-137). No significant risk of adverse environmental impacts is expected because of on-site mitigation and environmental review during each timber sale and road building activity.

Direct, Indirect, and Cumulative Impacts to Wetlands

Wetland risk varies from site to site throughout the planning unit. Based purely on the number of wetland acres in them, some areas may experience more impacts. Great Bend, Lynch Cove, and Mashel watersheds have the greatest number of wetland acres. Great Bend and Mashel watersheds also were identified as areas with the most acreage to receive restoration activities in riparian areas. In addition, these areas have a high probability for comparatively greater amounts of road building than other watersheds. Therefore, one could deduce that wetland acres in Mashel and Great Bend have the highest likelihood for impacts. Conversely, there are watersheds with little or no identified wetland acres that may be affected very little or not at all.

Wetland risk is variable throughout the planning unit due to their amount and location; however these impacts are greatly reduced on site as a result of the mitigation provided by current policy and procedures of no net loss of wetland acres or function. At this time DNR does not fully understand the severity of impacts that can be expected from either timber harvests or road building due to the difficulty in mapping wetlands, specifically forested wetlands. However, previous assessments (2001 *Forest Practices Rules* and 1997 *Habitat Conservation Plan*) have shown the severity of impacts from road building to be much greater than those related to harvest activities alone. Therefore, areas containing wetlands with greater amounts of roads and harvesting activities are expected to have a higher likelihood of impacts to wetlands than those with less wetland acres.

Wetland Mitigation

While the water quality of wetland sites can be affected by harvest activities, depending on their type and intensity, their effects can be transient (Shepard 1994). Harvests and associated activities can disrupt surface and sub-surface flows, deliver sediment to wetlands, diminish water quality, disrupt nutrient pathways, and lead to the draining of wetland sites. To mitigate these impacts, buffers are placed on all forested and non-forested wetlands one-quarter acre and larger. Wetlands less than one-quarter acre often are protected from harvest equipment entering them by strategically placed legacy trees. Region field staff are trained on wetland identification and all harvest and associated activities are reviewed on the ground to identify wetlands as part of the planning process[1].

Avoiding wetlands during road planning and construction is a primary method to prevent probable, significant, adverse environmental impacts. Where wetlands cannot be avoided, the 2006 *Policy for Sustainable Forests* and 1997 *Habitat Conservation Plan* require on-site and in-kind equal acreage mitigation for wetland losses. Such mitigation should result in no significant net effect to the acreage or to the hydrologic and biogeochemical function of the wetland.

Water Quantity

Criteria and Indicators of Water Quantity

This section analyzes the effects of timber harvesting on water quantity conditions in the planning unit. Water quantity is an important factor to consider, as DNR manages forests in rain-on-snow zones which can be affected by reductions in the forest canopy.

Hydrologic maturity is the measurable criterion which DNR uses to assess the potential effects of forest management on water quantity. A forest is considered in a hydrologically mature condition when its cohort (defined in Text Box 3-3) is over 25-years in age and has a relative density (RD) (Text Box 3-2) greater than 25.

The three indicators of water quantity discussed in Chapter 3 are precipitation type and amount, vegetative cover, and soil type. The variability of precipitation and the likelihood of extreme precipitation events are difficult to plan for. Therefore, this analysis does not take into account actual precipitation rates, types, or quantities. Rather, as in the soils section, DNR identified areas prone to damage from extreme events (such as rain-on-snow) as a surrogate, shown in Text Box 3-4.

Vegetative cover is reported and discussed in the context of RD (surrogate) for this analysis. Forests with an RD less than 25 are considered to be hydrologically immature. DNR policy does not allow more than 34 percent of forests located in rain-on-snow zones to be in a hydrologically immature state[2].

Soils are an important component in the understanding of water quantity. Various soil conditions affect the manner and rate of water movement through a watershed. General soil conditions are discussed in the soils section (Chapter 3, p. 76), but the site-by-site analysis necessary to understand the complexity of a water/soil relationship cannot be performed at this level of analysis. In fact, future actions resulting from this plan (such as timber sales or road building) will consider additional site-specific environmental review. As part of that review, local conditions in relation to both soil and water quantity will be taken into account when considering the harvest level and specialists will be consulted if concerns arise.

Water Quantity Results

None of the sub-basins in the rain-on-snow zone are projected to exceed the threshold of 34 percent in a hydrologically immature condition under any of the alternatives. None of the 100-year averages for the watersheds with at least 20 percent DNR-managed acres has greater than 30 percent of their acres in hydrologically immature conditions and 100-year averages for watersheds that contain acres in rain-on-snow zones are less than 20 percent (Table 4-11).

Table 4-11. 100-Year Average Percent of Watersheds in Hydrologically Immature Conditions

Watersheds (WAUs)	A	B	C
Howard Hansen	12%	9%	11%
Great Bend*	23%	27%	27%
Mashel	15%	14%	15%
North Fork Mineral	13%	15%	16%
Reese Ck.	15%	17%	16%
Lynch Cove*	25%	30%	30%
Tiger	5%	7%	6%
Kennedy Ck.*	29%	29%	30%
West Kitsap*	16%	18%	19%
Catt	12%	16%	16%
North Fork Green	15%	14%	13%
Mineral Ck.*	17%	15%	17%
East Ck.	13%	11%	12%

* Represents WAUs that do not contain rain-on-snow zones.

Some watersheds have greater than 34 percent of their acreage (which are highlighted in red) in a hydrologically immature state in a few decades (Table 4-12) but these are all areas that do not contain sub-basins in rain-on-snow zones including Great Bend, Lynch Cove, Kennedy Creek, West Kitsap, and Mineral Creek. There are no general trends across watersheds or alternatives; however, over time the averages for alternatives in the watersheds are similar.

Impacts from Forest Activities on Water Quantity

All watersheds containing sub-basins with acres in rain-on-snow zones are forecast to stay above 70 percent in hydrologically mature conditions through the 100-year modeled planning period. Consequently, significant changes in peak flows due to harvest activities are likely to be avoided under each alternative, therefore causing no significant impacts to hydrologic maturity on forested state trust lands. The likelihood and severity of damaging flood events and possible landslides caused by soil saturation or undercutting is reduced by maintaining higher levels of forest stands with an RD greater than 25 in the rain-on-snow zones.

At the larger geographic scale, watersheds with greater amounts of hydrologically immature forests (RD $\leq$ 25) such as Kennedy Creek, Great Bend, Lynch Cove, and Mineral Creek are primarily in rain-dominated zones. Soils in these areas were assessed in the soils discussion section (p. 155) and they contain the lowest risk areas of the 13 watersheds with more than 20 percent DNR-managed acres. Furthermore, 90 percent of the land base within the Great Bend, Lynch Cove, and West Kitsap watersheds consists of areas with less than 30 percent slope, which reduces its erosion capability. Rain-dominated areas are at a much lower risk for flash flooding than rain-on-snow zones (Grant and others 2008). The likelihood of extreme flooding in these watersheds is lower than watersheds in rain-on-snow zones; however, because of the lower level of hydrologic maturity, the effects from flooding may be of higher severity.

Precipitation intensity and magnitude cannot be predicted, although simulations suggest large events happen at intervals of roughly 20, 50, and 100 years (van Heeswijk and others 1996). These events can cause extreme flooding, mass soil movement (Text Box 3-5), and slope failures leading to low water quality, degraded or lost fish habitat, damage to the built environment (trails, roads, and bridges), and loss of timber resources. Planning for the protection of natural resources under these scenarios is not often possible and mitigation techniques cannot prevent all damage in these severe events; however, reasonable mitigation measures are taken where possible.

Table 4-12. Percent of Total DNR-Managed Acres in Each Watershed (WAU) with a Relative Density Less Than 25 (hydrologically immature) by Alternative

		Decade									
Watershed	**Alt**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Howard Hansen 16,499 acres	A	15%	7%	1%	9%	14%	19%	14%	14%	14%	13%
	B	15%	10%	6%	8%	9%	8%	7%	6%	10%	13%
	C	15%	8%	2%	9%	8%	17%	14%	19%	11%	12%
Great Bend* 16,318 acres	A	24%	29%	30%	24%	22%	21%	21%	18%	21%	20%
	B	24%	36%	37%	30%	22%	21%	19%	26%	26%	29%
	C	24%	37%	37%	28%	19%	20%	24%	29%	30%	26%
Mashel 15,139 acres	A	22%	19%	4%	7%	12%	18%	22%	17%	13%	12%
	B	22%	22%	7%	13%	18%	9%	8%	15%	13%	14%
	C	22%	20%	6%	6%	6%	22%	27%	21%	10%	7%
North Fork Mineral 13,883 acres	A	6%	9%	7%	15%	15%	22%	15%	13%	15%	18%
	B	6%	10%	15%	19%	13%	11%	14%	18%	20%	22%
	C	6%	8%	11%	17%	22%	23%	18%	14%	14%	28%
Reese Ck. 11,971 acres	A	26%	18%	4%	2%	12%	22%	18%	22%	18%	12%
	B	26%	24%	11%	13%	14%	11%	15%	19%	17%	15%
	C	26%	20%	6%	4%	7%	24%	29%	21%	10%	8%
Lynch Cove* 11,063 acres	A	24%	26%	31%	28%	29%	28%	21%	17%	18%	27%
	B	24%	33%	39%	33%	28%	22%	25%	28%	33%	31%
	C	24%	32%	38%	32%	28%	27%	27%	28%	29%	36%
Tiger 10,092 acres	A	8%	5%	4%	7%	6%	4%	3%	2%	4%	7%
	B	8%	11%	9%	10%	8%	6%	3%	3%	5%	8%
	C	8%	7%	6%	7%	8%	7%	4%	3%	4%	7%
Kennedy Ck.* 9,227 acres	A	25%	25%	32%	36%	29%	18%	23%	34%	44%	26%
	B	25%	30%	35%	28%	29%	33%	34%	31%	28%	19%
	C	25%	35%	24%	18%	34%	40%	34%	33%	22%	40%
West Kitsap* 7,261 acres	A	22%	19%	17%	18%	17%	13%	11%	12%	16%	18%
	B	22%	23%	20%	19%	19%	18%	15%	15%	16%	16%
	C	22%	22%	21%	18%	15%	15%	17%	21%	20%	19%
Catt 6,893 acres	A	9%	10%	7%	15%	10%	15%	10%	10%	15%	16%
	B	9%	11%	16%	20%	14%	14%	18%	17%	19%	19%
	C	9%	10%	14%	17%	14%	21%	19%	22%	16%	22%
North Fork Green 6,602 acres	A	24%	17%	1%	2%	6%	16%	26%	26%	18%	11%
	B	24%	20%	7%	9%	6%	9%	9%	12%	21%	23%
	C	24%	18%	4%	6%	5%	9%	10%	16%	22%	20%
Mineral Ck.* 4,761 acres	A	37%	12%	1%	4%	15%	30%	30%	25%	11%	10%
	B	37%	16%	8%	7%	7%	5%	15%	17%	22%	13%
	C	37%	12%	3%	5%	6%	23%	31%	29%	12%	7%
East Ck. 4,052 acres	A	15%	12%	4%	12%	14%	14%	11%	20%	20%	14%
	B	15%	13%	6%	13%	15%	8%	12%	11%	8%	12%
	C	15%	14%	3%	3%	8%	19%	27%	18%	7%	9%

* Represents WAUs that do not contain rain-on-snow zones.

It is difficult to separate the effects of roads from harvests because almost all harvested areas have roads. Permanent and temporary roads, as well as skid trails can decrease percolation and infiltration and increase overland flow and even change flow routing (Grant and others 2008). Soil compaction caused by ground-based harvesting equipment such as skidders or tractors can reduce the ability of water to flow downslope at and below the ground surface (Moore and Wondzell 2005). All of the alternatives will manage around the same amount of roads over the planning period, and skid trails were not analyzed; therefore, DNR expects similar impacts to water quantity for each of the alternatives. This damage could reduce the amount of water flowing downhill by puddling and potentially decreasing subsurface storm flow. Refer to roads (p. 150) and soils discussion (p. 155) for more information.

Water Quantity Mitigation

Prior to planning harvest activities, each timber sale is reviewed by following the procedure *Assessing for Hydrologic Maturity*[2], to ensure it meets the criteria established for hydrological maturity. The *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006) provides specific riparian buffer targets for forested state trust lands. These buffers often protect streams during flood events by capturing sediment and debris and controlling peak flow volumes. Riparian and wetland buffers account for between 18 and 39 percent of watershed area in the 13 watersheds with at least 20 percent in DNR-managed acreage. Refer to the riparian (p. 139) and wetland (p. 145) discussions for more information.

There is wide variability in peak flow and storm flow volume increases described in the reviewed literature from harvested watersheds (Ziemer and Lisle 1998; McDonnell 2003). The degree of forest removal and type of harvest applied can help explain some of the variation (Moore and Wondzell 2005). Increases in summer flows also may result from reduced transpiration in an entire watershed and may be detected from thinning, but generally decline to an insignificant level within several years (Moore and Wondzell 2005; Ziemer and Lisle 1998). DNR's policy of maintaining significant canopy cover and structure within riparian buffers is a means of ameliorating harvest effects on the watershed level.

It is difficult to forecast the intensity of events on the landscape in areas where DNR does not manage large amounts of acres within a watershed (Table 4-1); activities in upstream areas that are not managed by DNR may have critical impacts on the lower reaches of a watershed. According to Grant and others (2008), "the impact of forest harvest in the Pacific Northwest on peak flows is substantially less than that of dams, urbanization, and other direct modification of channels."

Water Quality

Water Quality Criteria and Indicators

As described in Chapter 3, it is DNR's mandate to protect beneficial uses of water by protecting areas where groundwater enters surface water as well as key riparian plant species. These goals, outlined in the *Forest Practices Rules* and the 1997 *Habitat Conservation Plan*, are designed to restrict harvest activities within stream buffers, reduce erosion, and ensure adherence to the rules for applying pesticides, herbicides, and fertilizers.

To measure the effects of land use on water quality, DNR identified as indicators: water temperature, sediment levels, turbidity, and water chemistry. Turbidity and water chemistry were assessed by Ecology (p. 70) and are not further investigated in this EIS. Although several of these factors can be measured directly, DNR is assessing their impacts by using the riparian acres harvested and stand development stages as measureable surrogates for assessing the alternatives' protection of the shade components of riparian buffers and their limitation of the transport of sediment into water.

Water Quality Results

As discussed in Chapter 3 (p. 70), DNR used an Ecology assessment from 2008 to identify stream locations with potential issues. This report found that within the planning unit few stream segments had water temperature impairments, and no watersheds in which more than five percent DNR-managed lands were listed as having problems with dissolved oxygen, or fine sediment (measured by turbidity). Pesticide use (water chemistry) was also discussed in Chapter 3.

RIPARIAN ACRES HARVESTED

If there were any difference in water quality when the alternatives were compared, the level and type (acres thinned vs. variable retention harvest) of riparian disturbance would be the best relative indicators. Refer to *Discussion of Riparian Results* (p. 139) for a description of harvesting activities associated with riparian management zones.

Increases in water temperature often can be caused by increases in direct solar radiation as a result of near-stream forest canopy removal (Moore and others 2008). The potential impacts to water quality from forest thinning harvests are anticipated to be avoided by the use of unmanaged inner zones adjacent to the streams and the maintenance of existing near-contiguous canopy cover over the entire stream reach. By tracking differences between alternatives in the amount of riparian acreage harvested, DNR is able to identify potential water quality issues. Chart 4-11 shows potential harvesting trends for riparian areas. The activity levels are highest in the first decade and decrease until the seventh decade—following the current guidance that only one harvest entry is allowed for riparian restoration purposes in forest stands less than 70-years of age. Alternative C has the highest harvest levels followed by Alternative A, then Alternative B.

STAND DEVELOPMENT STAGES

Forest stands within the Fully Functional, Niche Diversification, and Biomass Accumulation stand development stages (p. 58) contain large trees that provide shade adequate to decrease water temperatures. These stand development stages were compared, by alternative, in the riparian section (p. 139). Figure 4-6 compares the acres of more structurally complex stand development stages (Biomass Accumulation, Niche Diversification, Fully Functional) to those in less structurally complex stages (Ecosystem Initiation, Competitive Exclusion, Understory Development). The trend projections of the management alternatives are similar with stand complexity increasing over time.

Over the short term, all three alternatives are expected to produce a near-complete shading of the stream environment (Chan and others 2004). Sources of shade will vary; in stands remaining in the Competitive Exclusion stage, shade is provided by dense, primarily conifer canopies. In riparian forests that have reached the Biomass Accumulation stage and beyond, shade is from a combination of conifer canopies and shrub vegetation. Stream shading on forested state trust lands is projected to increase steadily over time under all alternatives. The diversity of vegetation in the later developmental stages brings about an increased level of leaf litter and other features of the desired ecosystem functions for these forests (Anderson and others 2007; Franklin and others 2002). As trees grow in size and riparian stands mature into more complex stand development stages (Chart 4-10), the probability of significant, adverse, environmental impacts is reduced.

Direct, Indirect, and Cumulative Impacts to Water Quality

As discussed in Chapter 3, no DNR-managed watersheds in the planning unit contain streams listed for sediment concerns (Ecology 2008b). However, as discussed in the soils section, some watersheds may be predisposed to erosion which, if not properly mitigated at the site, could move sediment toward streams and other water bodies.

RIPARIAN ACRES HARVESTED

Information about the frequency and occurrence of stream-associated wetlands, sensitive soils, and unique habitats is not available in GIS data as inputs to the forest estate model. Trends for riparian harvest treatments (restoration activities) are consistently projected to decline over time in all alternatives, and none would increase the risk to water quality in the long term. The greatest possible impacts to water quality are expected in the first four decades when the levels of harvest removal are highest (Table 4-13), with harvests being highest in Alternative C. Removing trees from riparian areas is unlikely to cause a temporary increase in water temperature. Stream shade is unlikely to be reduced as a result of restoration activities because of the unmanaged buffer areas adjacent to the streams and the almost-continuous canopy in the remainder of the Riparian Management Zone, but these activities could cause an increase in sediment entering water bodies because of ground disturbance and changes in the microclimate near the ground.

Table 4-13. Average Percent of Total Acres Harvested in Riparian Areas per Decade

	Decades									
	1	2	3	4	5	6	7	8	9	10
Alternative A	11	5	5	3	2	3	1	0	0	0
Alternative B	6	3	3	6	4	1	0	0	0	0
Alternative C	16	15	12	8	4	3	0	0	0	0

Riparian buffers can reduce the magnitude of stream temperature increases and changes to riparian microclimate, but substantial warming has been observed for streams within both unthinned and partial retention buffers (Moore and others 2008). Immediately following harvest, short-term, localized sedimentation may increase in some areas, but the vegetation in the inner and no-harvest portion of the Riparian Management Zones would prevent most sediment from entering streams.

STAND DEVELOPMENT STAGES

Figure 4-6 shows the movement from less complex stand development stages to Fully Functional, Niche Diversification, and Biomass Accumulation stages. (The riparian section has a more detailed discussion of the differences between alternatives.) As the riparian areas become more complex, multiple canopies develop and trees become taller with larger crowns. The presence of very large trees (≥21 inches dbh) is important for maintaining stream shade and cool water temperatures (Bigley and Deisenhofer 2006). These changes in forest structure improve stream shade, decrease water-level temperature fluctuations, and when a buffer is maintained, help avoid extremely high stream temperatures. Over the long term, improved riparian function (brought on by more complex stand development stages and larger trees) would likely lead to improved water quality on forested state trust lands; DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-123) which also analyzed these findings.

Water Quality Mitigation

Restoration activities in stream buffers were discussed in the riparian section (p. 139) and Table 4-7 shows the buffer widths. Wetland buffer functions also are described in the wetlands results section (p. 145). Although restoration harvest activities are allowable throughout the riparian buffer areas under the *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006), none of the alternatives includes activities within the 25-foot wide inner-zone, except for yarding corridors and roads. Increased shade levels over time would result in lower stream temperatures, which would benefit most aquatic biota. In addition, no harvest activities will be conducted on identified mass-wasting units within Riparian Management Zones. Some research has shown (Rashin and others 2006; Gomi and others 2005) that so long as appropriate mitigation measures are implemented regarding roads and culverts, adverse impacts are less likely to occur. Consequently, none of the alternatives are likely to have a significant adverse impact on streambank stability or sediment filtering capacity. All of these mitigation strategies are described in the 1997 *Habitat Conservation Plan*, with additional measures in the 2004 *Sustainable Harvest Final EIS*, and the 2006 *Riparian Forest Restoration Strategy*.

Fish

Chapter 3 (p. 73) describes the general characteristics of fish, their importance and distribution, the species of concern, and the general effects of DNR management activities related to harvesting, roads, and recreation.

Criteria and Indicators for Fish

The criteria to assess fish are based on the assumption that improved forest conditions—through DNR riparian area management—will positivity influence fish by maintaining and restoring salmonid freshwater habitat on DNR-managed lands. Increasing stand complexity also can contribute to the conservation of other aquatic and riparian obligate species (DNR 1997) and minimize the adverse effects of upland management activities on riparian areas (Bigley and Deisenhofer 2006).

Fish habitat is measured by the following set of indicators: large woody debris, leaf and needle litter recruitment, water temperature, coarse and fine sediment, water quantity, water pollution and fish passage. Chapter 3 contains a general discussion of how these indicators can be used to measure the environmental conditions necessary for fish.

To assess the alternatives and compare them, DNR is using measurable surrogates for indicators where no data or limited data is available. Stand development stages will be used as a surrogate for large woody debris, leaf and needle litter recruitment, and water temperature. Riparian buffers are used to draw inferences about water temperature, coarse and fine sediment delivery, and fish passage. For water quantity, DNR uses the surrogate of level of hydrologic maturity of the forestlands at the watershed scale to assess environmental effects. Refer to the riparian section (p. 139) for an explanation of why these surrogates were chosen.

Results for Fish

As riparian forest conditions improve, it is assumed that fish will benefit directly. Changes to the riparian area are evaluated in riparian (p. 139), water quality (p. 150), roads (p. 161), and soils (p. 155). Please refer to the charts, tables, and discussions mentioned in those sections.

STAND DEVELOPMENT STAGES

All of the management alternatives are projected to increase the area of complex forests in riparian areas over the next 100 years (Figure 4-6). Chart 4-10 shows that each of the alternatives increases the number of acres of riparian areas in the Fully Functional stand development stage.

RIPARIAN BUFFERS

Harvest Acres in Riparian Areas—A comparison of harvested acres in riparian areas by alternative presented in Chart 4-11, shows that Alternative C has the highest level of harvest activities. Table 4-8 shows the acres harvested in riparian areas by alternative during the first decade for WAUs within greater than or equal to 20 percent of DNR-managed lands. Table 4-13 (Water Quality, p. 150) compares the average percent of total harvested acres in riparian areas per decade, showing that Alternative C has the highest harvest percentage of the management alternatives.

Roads in Riparian Areas—Chart 4-12 compares DNR's forest roads to other roads (county and state) in the planning unit and shows that DNR has less road mileage in proximity to water bodies. Table 4-18 shows the number of stream crossings on DNR-managed lands by watershed.

WATER QUANTITY

Table 4-11 shows the 100-year average (by percent) of watersheds in hydrologically immature conditions. Table 4-12 shows the percent of total DNR-managed acres in each watershed (WAU) with an RD less than 25 (Text Box 3-2), considered by DNR to be hydrologically immature. Refer to the water quantity section of this chapter for how this indicator is assessed (p. 147).

WATER POLLUTION

Water pollution (water chemistry) is discussed in the water quality section of Chapter 3 (p. 70). Ecology's most recent water quality assessment (Ecology 2008b) found that none of the herbicides or fertilizers that DNR uses were mentioned as contributors to water pollution in this planning unit.

Direct, Indirect, and Cumulative Impacts to Fish

Many aspects of fish habitat can affect the ability of fish to live and move in a watershed system. Chapter 3 describes how fish are influenced by habitat conditions, characterized here by riparian forest condition.

STAND DEVELOPMENT STAGES IN RIPARIAN AREAS

Stand development is a good surrogate for many of the key structural elements of fish habitat such as large woody debris (Franklin and others 2002), which can be directly linked to improvements in fish habitat (Beechie and Sibley 1997; p. 56). The current distribution of stand development stages suggests (Chart 3-1) that many streams may have reduced riparian function stemming from relatively low levels of large woody debris input, attributable to young forest conditions (Keller and others 1995; Rot and others 2000). Large woody debris sources and inputs increase as the forest progresses through the Biomass Accumulation, Niche Diversification, and Fully Functional forest stand development stages (DNR 2004). A discussion of harvested acres in riparian areas expected to achieve more complex forest structure is found in the riparian section (p. 139), and the water quality results section (p. 150) reports on thinnings in riparian areas and the effects on stream temperature and sedimentation.

WATER QUANTITY

For all of the alternatives, all watersheds containing sub-basins with acres in rain-on-snow zones are forecast to stay above 70 percent in hydrologically mature conditions through the 100-year modeled period. Consequently, significant changes in peak flows due to harvest activities are likely to be avoided under each alternative; thereby causing no significant impacts to hydrologic maturity on forested state trust lands. Peak flow events (such as storms and rain-on-snow occurrences) can destabilize and transport large woody debris, fill pools with sediment, and destroy salmon spawning habitat. They also can scour complex channels (streams with a diversity of riffles, pools, and large woody debris) into uniform channels (streams devoid of riffles, pools, and large woody debris) resulting in limited habitat value (DNR 1997). In watersheds containing rain-on-snow zoned acres, the likelihood and severity of damaging flood events and possible landslides caused by soil saturation or undercutting is reduced by maintaining higher levels of timber with an RD greater than 25. Refer to the water quantity results (p. 147) for additional discussion.

ROADS

Permanent road networks are perhaps the longest-lived influence of forest management on fish and related aquatic ecosystems (Trombulak and Frissell 2000). The amount of new road construction needed to access the forest land base is similar under all alternatives; however, the greater amount of thinning in Alternative C would likely result in the maintenance of a higher number of forest roads, which could result in higher impacts than Alternatives A and B. New roads and any stream crossings, whether for motorized or non-motorized transport, will be built to meet current road standards, requiring adequate fish passage. Habitat fragmentation from roads can have a major impact on fish (Trombulak and Frissell 2000). Any sub-standard stream crossings currently causing fish passage problems as discussed in DNR's Road Maintenance and Abandonment Plan will be replaced. With these changes, fish passage at man-made structures (bridges and culverts) is expected to improve under all alternatives (refer to Appendix H for additional details related to road management).

Sediment production from roads is a function of a multitude of factors discussed in the roads section (p. 161). Road use (intensity) is expected to change based on the amount of timber removed in certain watersheds, by alternative, which can be found in Appendix H. For additional discussion on the impacts of sediment on water quality, refer to the water quality discussion (p. 150).

RECREATION

Impacts to fish habitat from recreational activities are mainly related to trails built by users to no particular standard; they have the potential to cause water quality concerns. Refer to recreation (p. 165) for additional information.

Mitigation for Fish

Overall, for all proposed management alternatives, the likelihood and severity of adverse cumulative effects to watershed resources, including fish, from all the alternatives is low, both for individual watersheds and for the planning unit as a whole. The *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006) was developed as part of the implementation phase of the 1997 *Habitat Conservation Plan*. Although restoration harvest activities are allowable throughout the riparian buffer areas under the *Riparian Forest Restoration Strategy* (Bigley and Deisenhofer 2006), none of the alternatives include activities within the 25-foot wide inner zone, except for yarding corridors and roads. These previous analyses (DNR 1996, 2001, 2004, 2006a) indicate that none of the alternatives demonstrate the potential to result in substantial adverse effects, in either the short-term or the long-term. For additional discussion of mitigation for fish indicators refer to *Riparian Mitigation* (p.139) and *Water Quality Mitigation* (p. 150)

The *Forest Practices Rules* were modified in 2001 to more fully address the impacts of forest practices on water quality, salmon habitat, and other aquatic and riparian resources (DNR 2001). The environmental impacts caused by restoration activities in riparian areas are mitigated on-site during the implementation phase.

Soils

This section analyzes the effects of timber harvesting and associated road building and use on soil conditions in the planning unit. In addition, there is a discussion of mitigation techniques designed to protect this essential ecosystem element.

Criteria for Managing Soil Productivity

The criteria for assessing soils include limiting soil compaction, displacement, and disturbance; minimizing surface erosion; and preventing management-related mass wasting events. Most of the criteria were described in the *Forest Practices Rules* (DNR 2001) and the *Habitat Conservation Plan* (DNR 1997).

Indicators for Assessing Soil Conditions

The indicators described in Chapter 3 include soil productivity, compaction, erosion, and displacement but not all of them are easily measured. For this analysis, percent of watershed harvested, number of harvest entries, and harvest types will be used as surrogates for the original indicators. Many general effects to soils were discussed in Chapter 3, including erosion, compaction, and displacement potentials in watersheds with at least 20 percent in DNR-managed acres (Table 3-12).

Risk Assessment

RISK OF EROSION, COMPACTION, AND DISPLACEMENT

Using the information presented in Chapter 3, each watershed was assigned a ranking based on the combined value of the medium and high risk potential for three of the indicators described above (erosion, compaction, and displacement). A medium risk means that there is a possibility for impacts from ground-based harvest systems. A high risk means impacts cannot be avoided during ground-based harvesting when soil moistures are high. When examining erosion, compaction, and displacement potentials, DNR considers the physical characteristics of a soil, slope gradient, soil drainage, and seasonal wetness. Table 4-14 presents these rankings and the total for the three indicators used to identify which watersheds are prone to the highest combined risk level. Most areas are not prone to all three risks at the same level.

Table 4-14. Watershed (WAUs) Ranking for Soils Risk (1=highest risk, 13=lowest)

Watersheds	Erosion	Compaction	Displacement	Totals
Howard Hansen	1	3	3	7
North Fork Green	3	2	4	9
East Ck.	2	1	7	10
Mashel	4	4	8	16
North Fork Mineral Ck.	5	12	1	18
Catt	7	13	2	22
Reese Ck.	8	10	5	23
Tiger	9	5	9	23
Mineral Ck.	6	11	6	23
Kennedy Ck.	10	6	10	26
W. Kitsap	11	9	11	31
Great Bend	12	8	12	32
Lynch Cove	13	7	13	33

SLOPE GRADIENT

Within the 13 watersheds with more than 20 percent in DNR-managed lands, 57 percent of the total area has slopes less than or equal to 30 percent slope gradient (Appendix M). More than half of the total DNR-managed lands in these 13 watersheds likely will be at a higher risk of soil impacts because ground-based harvesting methods likely will be employed. Soils on slopes greater than 30 percent can be at equal or greater risk when areas are cable-yarded without proper log suspension. While more than half of the DNR-managed lands have slopes less than or equal to 30 percent, there are three watersheds where nearly 90 percent of the area falls into this category: Great Bend, Lynch Cove, and West Kitsap.

PERCENT OF WATERSHED HARVESTED

In Chart 4-3, the combined thinning and variable retention harvest values of Alternative A were higher than either Alternatives B or Alternative C in eight of the 13 watersheds represented; the other five were highest in Alternative C. The central range of values was near five percent of the total watershed, although there were outliers that extended up to 25 percent.

The highest average percents of DNR-managed lands forecast to be harvested per watershed are in Mineral, Kennedy Creek, Reese Creek, and North Fork Mineral while the highest average acreages harvested are in Mashel, Great Bend, Howard Hansen, and Reese Creek watersheds(Table 4-4).

HARVEST TYPE

Table 4-3 presents the total acres of DNR-managed lands harvested compared to the total acres of DNR-managed lands harvested in watersheds where DNR manages 20 percent or more over the planning horizon. On average, of the 13 watersheds with more than 20 percent DNR-managed lands, Alternative B is projected to have the lowest area harvested with either thinning and/or variable retention harvests over the planning horizon at 136,768 acres, Alternative A is projected to have the largest area harvested at 152,835 acres, with Alternative C projected to have 151,365 acres harvested. In general, Alternative C will have the highest thinning levels and Alternative A will have the highest variable retention harvest levels.

Appendix D presents the acreages and percent of total acres harvested by watershed and harvest type (thinning/variable retention). The analysis in this section presents a sampling of that information. Table 4-15 has harvesting values for Mineral Creek in the third decade for all alternatives—the highest harvest levels of all watersheds with over 20 percent DNR-managed lands in all decades.

The highest percentages of DNR-managed lands thinned in each watershed are projected to be in Mashel, Reese Creek, Catt, and Mineral Creek. Mineral Creek, as stated, has the highest percentage of total watershed harvested (33%) for all alternatives in one decade; where, in Alternative A during the third decade, 88 percent is projected to be thinned and 12 percent to be harvested through the variable retention method (Table 4-15). Alternatives B and C have lower overall percentages of harvest (25% and 30%, respectively) but slightly higher percentages of thinnings to variable retention harvests (97/3 and 94/6, respectively). However, when looking at the harvest levels for all alternatives in these watersheds (Appendix D), the range of harvest in the total watershed per decade is between five and eight percent; Alternatives A and B generally have close to a 50/50 balance of thinning to variable retention harvest while with Alternative C, the ratio is closer to 40/60.

The WAUs with the highest levels of variable retention harvests include Great Bend, Lynch Cove, Kennedy Creek, and West Kitsap (only Alternative A). Kennedy Creek is projected to have 22 percent harvested in Alternative C, although the ratio of thinning to variable retention harvest is 61/39, which would result in about 1,900 acres of variable retention harvest in Kennedy Creek during the first decade. The high value of 22 percent to be harvested in Kennedy Creek is an extreme outlier compared to the projections for the 100-year planning horizon, which has a mean of only four percent for all 10 decades. For these watersheds, during the 100-year planning horizon, Alternative C consistently has the highest number of harvested acres in any given year above Alternatives A and B. The average number of acres harvested in Alternative C will be two to three percent greater than Alternatives A and B. However, when comparing the ratios of thinning to variable retention harvests, Alternative C has less variable retention harvest (near 25/75) while Alternatives A and B generally have ratios closer to 10/90.

Table 4-15. Mineral Creek Harvest Percentages for Decade Three

Alternative	Total Harvested (Decade 3)	Total Thinned	Total Variable Retention Harvest
A	33%	88%	12%
B	25%	97%	3%
C	30%	94%	6%

Table 4-16. Number of Forest Entries by Percent of Acres

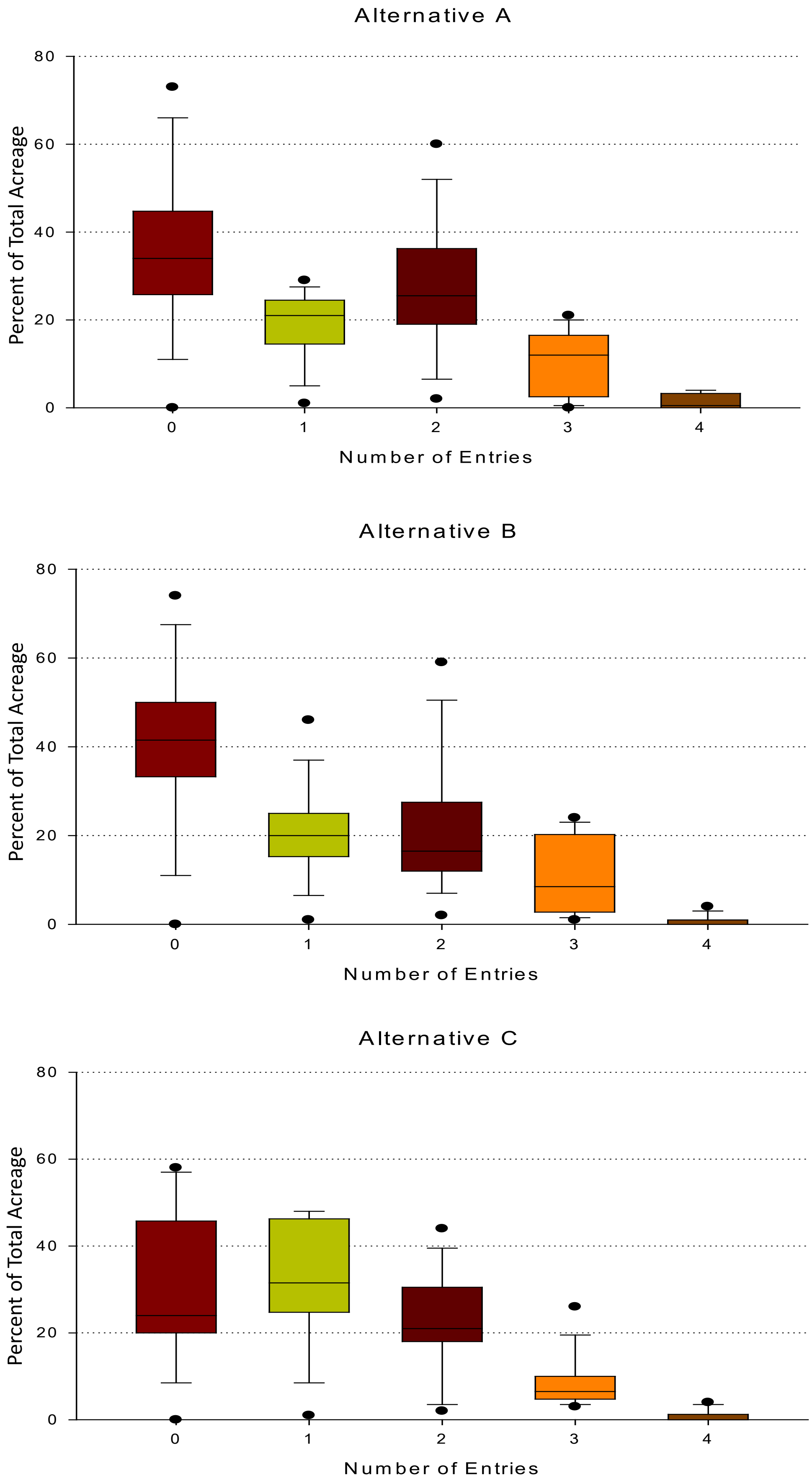
	Number of Entries				
Alternative	0	1	2	3	4
A	39	20	29	10	1
B	44	22	23	11	0
C	32	35	24	9	1

NUMBER OF HARVEST ENTRIES

The percent of acres receiving a certain number of harvest entries is presented in Table 4-16, by alternative. Alternative B has the greatest percentage of acres with zero entries (no harvest) but also has the most acres with three entries (although the values for Alternatives A and C are very similar).

For all watersheds with at least 20 percent DNR-managed lands, and for the three alternatives, the number of harvest entries presented as percent of the total area with 0 to 4 harvest entries are shown in Figure 4-7. Alternative C has the highest variability in values for zero and one entry, and has a higher median and mid-range of values for one entry than both Alternatives A and B. Trends for Alternatives A and B are fairly similar; however, although the value ranges are comparable for two and three entries, their medians show that values in Alternative A tend to be a little higher than Alternative B. Alternative C has a greater percent of acreage receiving only one harvest entry than either Alternative A or B.

Figure 4-7. Harvest Entries by Acres for All Alternatives



In general, for all three alternatives, 35 percent or more of each watershed with over 20 percent in DNR-managed acres is projected to remain unharvested during the next 100 years. In the Howard Hanson, Tiger, and West Kitsap watersheds more than 50 percent of the acreage is forecast to remain unharvested during the planning period. For additional information related to harvest entries, refer to forest conditions (p. 129).

Soils Discussion

CURRENT CONDITIONS DETERMINE THE POTENTIAL FOR SOIL DAMAGE

Slope gradient, topography, soil type, and parent material determine the potential for soil damage such as erosion, compaction, and displacement (Table 3-12, refer to Appendix M for definitions). On average, of the 13 watersheds with more than 20 percent DNR-managed lands, the potential for erosion is significant because more than 50 percent of the land base is at least a medium risk for erosion (Table 3-12) based on the physical characteristics of the soils but only seven percent is at high risk—widespread erosion can be avoided only if surface disturbances caused by management activities (such as certain harvesting practices) are limited. For the same watersheds, nearly 75 percent of the total lands are at medium risk of compaction and 30 percent are at high risk, especially when soil moistures are high. Displacement has the highest percentage of acres in the high risk category (43%), although it may be the least severe of the three indicators. The impacts of displacement are often indirect. When soil is displaced, the surface layer or "duff" is often removed, increasing the potential for erosion at the site (DNR 1980, unpublished metadata).

The slope of an area is a very important factor for several reasons. Primarily, if a slope is greater than 30 percent, then alternative harvesting methods (such as cable yarding) may be used to reduce the risk of erosion on a site, although under certain conditions, traditional harvesting methods may be used in areas with up to 40 percent slope gradient. Second, poor soil management (such as removal of upper soil layers and duff or high compaction from road building) has the potential to reduce a soil's natural productivity (DNR 1996).

PERCENT OF A WATERSHED HARVESTED AFFECTS THE LIKELIHOOD OF SOIL IMPACTS

Generally, forest vegetation stabilizes soils, reduces soil erosion, and slows sediment transport to streams (DNR 2004); therefore, the higher the percentage of an area harvested, the greater the potential for adverse soil impacts. Vegetation cover also protects soil from incoming solar radiation which can lower soil moisture, decrease decomposition rates, and possibly decrease soil productivity by changing ground level micro-climates. The direct impacts of timber harvesting such as compaction, erosion, and displacement are expected to be much higher for Alternative A in a majority of the watersheds, followed by Alternative C. Watersheds with relatively high levels of harvesting such as Kennedy Creek, Lynch Cove, and Mineral Creek are at much higher risk of soil impacts when compared to Tiger and West Kitsap watersheds which will experience only approximately half that harvest level. The impacts of the different harvest methods will be analyzed in the next section.

HARVEST TECHNIQUES

DNR uses a variety of harvest systems to achieve desired silvicultural objectives, with the choice of system depending on the slope and topography of the area (DNR 2004). Ground-based systems generally have the greatest potential to impact soils adversely because the weight of the machinery can lead to compaction or displacement. For both thinning and variable retention harvests, heavy machinery typically makes several passes over the ground surface, potentially damaging root systems and increasing soil bulk density. Soils are most susceptible to these effects during wet seasons and equipment use may cause little or no damage when the ground is frozen. Cable- and helicopter-yarding are generally used to yard logs on slopes over 30 percent (although ground equipment may still be used on certain slopes of more than 30%). These methods typically have minimal soil impacts so long as they are done correctly. The creation and use of yarding corridors and skid trails also can pose threats to soils because they often lead to soil compaction and displacement. Steeper slopes are commonly at higher risk of soil damage. More than 40 percent of the planning unit could be at elevated risk of some form of soil damage if harvest operations are poorly planned and/or executed. Harvest methods will be determined on a site by site basis, by slope gradient, topography, and soil type. Most often, areas identified as having a high risk of mass wasting are avoided.

THINNING VERSUS VARIABLE RETENTION HARVEST

The percent of area forecast to be thinned is similar for most watersheds in Alternatives A and B but Alternative C has much higher thinning levels for several watersheds including Kennedy Creek, Lynch Cove, Tiger, and West Kitsap. For all alternatives, the trends for variable retention harvests are very similar. Alternative A has the highest overall area of variable retention harvests followed by Alternative C and then Alternative B. All types of harvesting can result in short-term surface erosion until the site is re-vegetated (within 5 years of a harvest), which increases the probability for sediment transport to streams. Often, watersheds with higher levels of variable retention harvests have lower percentages of acres with soils impacted than those watersheds with more thinnings.

NUMBER OF HARVEST ENTRIES COULD IMPACT THE SEVERITY OF IMPACTS TO SOILS

Adverse impacts to long-term soil productivity are directly related to the frequency and intensity of forest management activities (DNR 1996). Compacted soils often require several decades to recover (Cafferata 1992); therefore, frequent entries can lead to persistent, long-term soil compaction. Following the methodology in the *Sustainable Harvest Final EIS* (2004, p. 4-97) each alternative was given a rank based on the percent of acreage impacted per decade by harvest type (refer to Appendix M). Therefore, Alternative A has the highest rank for expected soil impacts, followed by Alternatives C and B. Although Alternative A is projected to have the greatest area with variable retention harvests, it also is projected to have the greatest percentage of acres with more than two entries; thus, a greater number of acres will be receiving more intense management under Alternative A as often or more often than Alternatives C and B. Compaction is more likely to occur as the number of entries increases, and Alternative A therefore is more likely to lead to compacted soils than the other alternatives. Alternative B has the lowest probability of reducing long-term soil productivity because it has the fewest acres affected overall.

Direct and Indirect Impacts to Soils

SOIL IMPACTS FROM ROAD USE AND MANAGEMENT

The most significant management-related impacts to soils result from the creation and use of roads and landings because these areas are cleared of vegetation, their upper soil horizons are often removed, and their lower soil horizons are compacted. Multiple entries increase the number and aerial extent of temporary roads, potentially contributing to higher levels of surface erosion. Road mileage, density, and placement are not likely to change much between alternatives. The harvest type often determines whether a temporary or permanent road is built and the effects of these roads vary. The general impacts of road use and management are discussed in the roads section (p. 160).

RECREATIONAL ACTIVITIES AND SOILS

Recreational access can cause additional compaction and erosion on forest roads, in campgrounds, and on trails. As addressed in the recreation section (p. 165), proximity to developed or urbanized areas can have a substantial effect on the amount of use and impacts that a recreational area receives. Recreational impacts are expected to vary across the landscape. Alternatives B and C propose using suitability assessments to identify any sensitive areas which will help managers decide where to place future recreation sites in order to have the lowest environmental impacts. Alternative A would not have this additional assessment tool.

Potential Cumulative Effects to Soils

Compaction, erosion, and reduced productivity are the anticipated direct impacts to soil caused by timber harvesting, road construction, and recreation. The combined effects of compaction and erosion can reduce a soil's productivity, which in turn could have long-term effects on forest conditions (p. 124). Major soil displacement events (such as landslides and road/landing construction) can remove the upper soil layers, resulting in a long-term loss in site productivity. Vegetation removal can limit a soil's capacity to hold moisture and lead to changes in the surrounding microclimate, potentially reducing soil productivity. Erosion and soil displacement can increase sediment levels in water bodies, decrease water quality (p. 150), and reduce the quality of fish habitat (p. 152). Soil compaction also can affect water quantity via reduced infiltration and groundwater recharge, potentially resulting in increased overland flow and surface erosion.

Considering that some soils are subject to a loss in productivity through compaction, erosion, and displacement, the Risk Assessment provides a ranking system (although only as one watershed relates to another) to determine potential productivity loss for each watershed. Examination of this ranking in combination with estimates of percent of watershed harvested shows that with the exception of Mashel (ranked fourth of 13 watersheds for risk related to erosion, compaction, and displacement; refer to Table 4-14), the acres forecasted to be harvested are at the lowest risk for compaction, erosion, and displacement when compared to the other watersheds with greater than 20 percent of their acreage in DNR management.

Different harvest methods often produce varying degrees of soil impacts. The degree of soil impacts often coincides with the number of entries in an area. Mashel, Reese Creek, Catt, and Mineral Creek watersheds are projected to have the greatest percentage of thinning and are projected to have percentages above the average for all watersheds with two or more entries. On the other hand, the watersheds with high percentages of variable retention harvest entries are forecast to have values well below the average for two or more entries (with the exception of Alternative C in Kennedy Creek which has a high thinning level). Compared to the other WAUs, West Kitsap has the third highest level of zero harvests.

The additive effects of the three indicators can heighten the risk of soil damage. For example, the Howard Hansen watershed was rated at highest risk for erosion and third for both compaction and displacement. The combined ratings placed it at the top of the list for areas predisposed to soil damage. However, 75 percent of the watershed has slopes that exceed 30 percent and it therefore may receive alternate harvesting methods (cable and/or helicopter), which should help mitigate soil impacts. In addition, the same watershed, although containing the most DNR-managed acreage, was ranked between eighth and twelfth for percent of total acreage harvested. No more than 10 percent of the watershed is projected to be harvested in any given decade, with the average harvest rate being less than five percent of the watershed per decade. In the Howard Hansen watershed, the maximum decadal harvest level projected for each alternative (10, 7, and 6 percent for Alternatives A, B, and C, respectively) has high levels of thinning compared to variable retention harvests (81/19, 70/30, and 88/12 for Alternatives A, B, and C, respectively). Retaining more vegetation via thinning should protect soils from harvest-related impacts.

Howard Hanson watershed has one of the lowest values for multiple entries compared to the other watersheds and has nearly 60 percent of its land base with no harvest entries under all three management alternatives. These lower levels of multiple entries should protect soils by limiting compaction and erosion. Therefore, although relative to the other watersheds the area may be particularly susceptible to erosion and compaction because of its slope, projected timber harvest methods, and timing (spread among decades), the likelihood of adverse soil impacts is fairly low. The percent of acres affected varies between alternatives but Alternative B would have the lowest impact level because it has more unharvested acres and more acres of thinning than variable retention harvest. Alternative C would have the next lowest impact level, followed by Alternative A. Refer to Appendix D to compare values in other watersheds.

Without knowing the specific conditions of a harvest unit—including the harvest method, timing, soil properties, time since last harvest, and weather—it is difficult to assess the level of expected impacts at a specific site. Site conditions and their related impacts are assessed on a site-by-site basis.

Soils Mitigation

There are several procedures in place at DNR that protect soil integrity during management activities. Normally, when procedures change they provide additional protections; therefore, any future changes are not expected to cause additional impacts.

Assessing Slope Stability (PR 14-004-050) — In western Washington, the Shaw/Johnson model (and LIDAR, where available) is used as a screening tool for assessing slope stability. In areas where there is a heightened landslide potential, a licensed geologist commonly visits the site (or conducts an office review of proposed timber sales using LIDAR and orthophotography) to analyze landslide risk and help develop appropriate mitigation measures.

Maximum Size for Even-Aged Final Harvest Units (PR 14-005-050) — This procedure is designed to limit the area of regeneration harvest units to 100 acres unless a larger area is approved by a region manager.

Road Construction and Maintenance (WAC Chapter 222-24) — These regulations provide information related to the construction and maintenance of forest roads.

Public Access and Recreation (WAC Chapter 332-52) — These recreation rules are designed to define acceptable recreational behaviors in balance with DNR's obligations to the trusts it manages.

There are a number of resources that DNR uses when preparing timber sale contracts that help mitigate the impacts of timber harvesting activities on soil. Mitigation measures are often based on the harvesting method or type, slope gradient, timing, and the site characteristics. On some special projects, geologists and hydrologists are consulted to help identify areas to avoid and locations for skid trails. Additional mitigation methods also are identified to protect soils from unnecessary compaction or erosion especially near streams, on steep slopes, or on roads (such as redirecting waterflow using waterbars). All harvesting contracts provide regulations for the width of skid trails, allowable soil compaction levels, and acceptability of tree rub; however, only some contracts prescribe where skid trails and log decks should be built. DNR uses rutting as a primary identification method of negative on-site impacts. Contracts also may include seasonal timing restrictions, ground pressure regulations for ground-based equipment, suspension, or deflection requirements for cable yarding, and other harvesting regime-specific guidelines. Because of careful assessment of lands while developing contracts and the consistent rules included within them, DNR does not anticipate differences in impacts between alternatives for contract logging.

Roads

Chapter 3 (p. 82) describes the current road network and why roads are important for management and access. It also describes the criteria and indicators used in this analysis: road density, sediment delivery, site productivity, hydrology, invasive plants, and riparian habitat as well as water and air quality.

Indicators for Assessing Forest Roads

To assess and compare the differences between the alternatives, DNR is using road density as a surrogate for measuring hydrology and invasive plants, since these elements are not directly measured by DNR. DNR uses the proximity of the road network to water bodies and stream crossings as a surrogate to assess the impacts from the road network on sediment delivery, riparian habitat, and water quality.

The number of truck trips needed to remove the estimated harvest volume and the number of recreational visitors per year will be used as a surrogate to measure impacts to air quality.

Forest Road Results

FOREST ROAD DENSITY

Road density is a useful measure for describing the extent of the forest road network. In this planning unit, the average road density is 3.2 miles per square mile (Table 3-13). Forest roads include those currently maintained and used, as opposed to abandoned roads, which do not require maintenance, and orphaned roads (includes railroad grades) which have not been used for forest practices activities since 1974. Cederholm and others (1981) found that sedimentation in streams increases with road density, but the greatest sediment increases were related to road construction rather than to vehicle traffic during timber extraction. However, the proportion of a watershed occupied by roads has an influence on hydrology (p. 150), with corresponding effects on geomorphic processes and sediment loads in roaded areas (Luce and Wemple 2001).

The decision to build more forest roads is based on the distance from an existing road to a harvest unit. For this analysis, DNR has chosen 800 feet as the maximum distance from a road that timber can

Table 4-17. Harvestable Acres 800 Feet from the Existing Road Network

Watersheds	DNR Acres > 800 ft from existing forest road	Harvestable Acres > 800 ft.	Inoperable Acres > 800 ft.	Total DNR-Managed Acres
North Fork Mineral	5,249	4,969	280	13,883
Reese Ck.	3,683	3,382	302	11,971
Catt	2,165	2,127	38	6,893
Kennedy Ck.	2,034	1,612	422	9,227
North Fork Green	2,328	839	1,488	6,602
Howard Hansen	4,723	1,797	2,925	16,499
Lynch Cove	2,805	2,377	428	11,063
Great Bend	3,673	3,358	314	16,318
Mashel	6,167	5,882	285	15,139
Tiger	6,200	2,573	3,626	10,092
Mineral Ck.	797	667	130	4,761
West Kitsap	2,125	836	1,288	7,261
East Ck.	986	907	79	4,052
Total Acres	42,935	31,326	11,605	133,761

be harvested without constructing additional forest roads (Appendix H), unless aerial harvesting is used. Currently, 32 percent of the land base is beyond 800 feet of an existing road. The 32 percent includes riparian and wetland buffers, potentially unstable slopes, and special habitats in which DNR avoids constructing forest roads. The watersheds with the greatest acreage beyond 800 feet of an existing road are North Fork Mineral, Mashel, and Tiger. North Fork Mineral and Mashel have a lower density of roads because historical logging in this area was done using railroad systems instead of roads. The railroad grades still exist as orphaned roads, and are often reconstructed for use as forest roads, which then become part of the active road network and subject to maintenance requirements.

Tiger watershed has fewer roads because one-third of DNR-managed trust lands in the watershed are managed and protected as a state natural area under the West Tiger Natural Resources Conservation Area[3]. The natural area is not included in the harvestable land base.

Table 4-17 shows the amount of the DNR–managed land base further than 800 feet from an existing road, along with the amount of harvestable and inoperable lands. DNR assumes that, in order to gain access in the future, additional roads will be needed or different harvest methods will be used. North Fork Green, Howard Hansen, Tiger, and West Kitsap watersheds have the highest number of inoperable acres where roads will most likely not be constructed.

ROAD PROXIMITY TO WATER BODIES AND STREAM CROSSINGS

Roads—specifically at road crossings—are a significant source of sediment to water resources. Another measurement for assessing the impacts from roads is the proximity of the road network to water (Chart 4-12). Sediment production from roads is a function of a multitude of factors that include road grade, road length, road age, surface material and condition, cut slopes, local climate, and soil.

Chart 4-12 shows that a lower percentage of DNR roads as compared to other roads (state highways, county roads) are near streams, lakes, or other water bodies. The delivery of road runoff and sediment to streams generally decreases as the distance between a road and a stream increases, as discussed in Chapter 3 (p. 82). For additional information on the impacts of sediment on water quality, refer to *Water Quality Discussion* (p. 150). It follows that road sediment delivery is highly dependent on stream density in a watershed, as this affects both the number of road crossings (Table 4-18) and the proximity of the roads to the stream channel network (Chart 4-12). The surface material of the road is another factor since unpaved roads can increase surface erosion rates by two or more orders of magnitude relative to undisturbed hillslopes (MacDonald and Coe 2007; Sugden and Woods 2007).

ROAD USE

Road use can cause rutting and result in surface erosion. Surface erosion from road use is variable and depends on factors such as slope, precipitation intensity, soil type, soil rock content, and traffic (Sugden and Woods 2007). The mean annual precipitation appears to be the primary control on road-stream connectivity (p. 55). Vehicle exhaust affects air quality (p. 199) and traffic on gravel roads produces dust. Road impacts increase with road use, and include not only harvest-related traffic but also use by recreational visitors (Table 3-15).

The actual miles of forest roads are not expected to vary much between management alternatives; while some roads are built, others are abandoned in accordance with *Forest Practices Rules*: Road Maintenance and Abandonment Plans[4]. However, road use (intensity) is expected to change based on the amount of timber removed in certain watersheds by alternative (refer to Appendix H). The average number of truck trips by decade and alternative for the selected watersheds are shown in Table 4-19.

ROAD DENSITY

When comparing the road density (Table 3-13) to the watersheds with the highest amount of truck trips per decade (Table 4-19), Alternative A has higher road usage compared to the other alternatives. Each truck is assumed to be hauling 4.5 thousand board feet (mbf) of timber. However, the watersheds with the highest number of truck trips (Table 4-19) change by alternative and watershed. For example, under Alternative A, Mashel has the highest number of trips while North Fork Mineral is highest under Alternatives B and C.

Direct and Indirect Impacts from Forest Roads

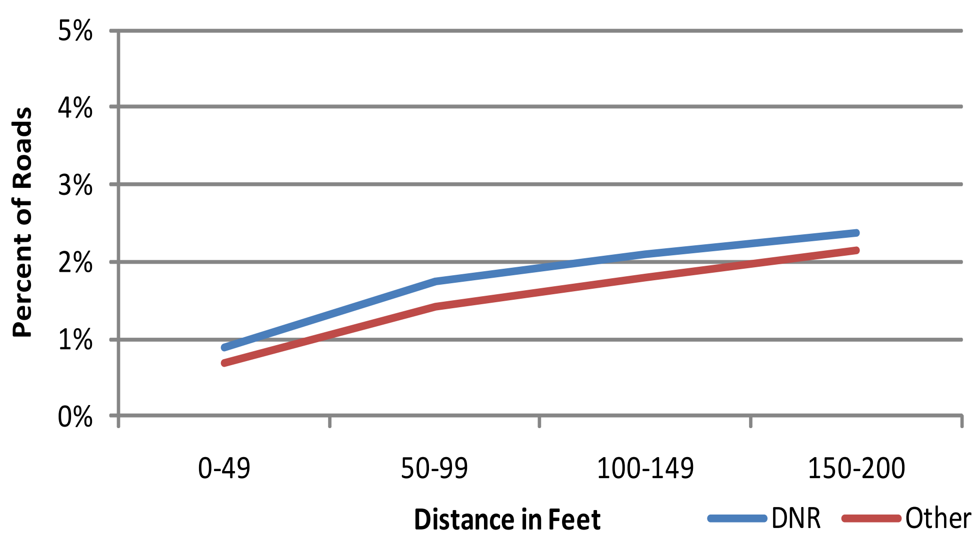
WATER QUALITY

Road crossings have a direct impact on water quality. Stream crossings are the primary delivery route for road-generated sediment (Duncan and others 1987). Best and others (1995) examined 111 stream crossings on unpaved logging roads and found that stream diversions at road crossings are the most important causes of fluvial erosion in the watershed. Most road-generated sediment is produced by traffic or from surface erosion immediately preceding construction during the first couple of storm events (Coe 2004). However, DNR implements measures to ensure that the original channel and gradient are maintained.

GUIDANCE FOR ROAD USE

Guidance on road use is provided in the Forest Practices Board Manual with specifics on how to reduce road damage and sediment yield from road surfaces. Most resource concerns can be avoided when good road construction techniques and adequate road maintenance practices are used (DNR 2001). Some of the best methods are timing restrictions (closing or limiting access) and following road maintenance requirements. Most of the recommendations found in the Forest Practices Board Manual are related to forest management activities, but forest roads are also used for recreational activities such as off-road vehicle use (p. 166).

Chart 4-12. Relative Comparison[1]: Percent of DNR Forest Roads to Other Roads[2] Proximity in to Water[3] (in feet)



1. Only stream types 1, 2, and 3 are included. This was done to reduce the influence of stream mapping error differences in DNR vs. non-DNR lands.
2. All road types (interstates, highways, dirt roads) are shown, as are all road activity status (maintained, abandoned, orphaned).
3. Wetlands are included. Non-road features are not shown (for example: trails, ferry routes and railroads).

Table 4-18. Number of Stream Crossings on DNR-Managed Lands by Watershed and Water Type[1]

Watersheds	State Lands Water Type					
	1	2	3	4	5	9
Catt	3		2	2	49	64
East Ck.	1		1	10	20	37
Great Bend	1		18	6	30	42
Howard Hansen		1	3	22	108	47
Kennedy Ck.			8	9	26	22
Lynch Cover			4	5	2	14
Mashel			9	10	39	37
Mineral Ck.			3	7	37	64
North Fork Green				13	43	15
North Fork Mineral	1		14	22	102	100
Reese Creek			11	16	34	47
Tiger			6	7	35	18
West Kitsap			3	3	4	8
Grand Total	6	1	79	132	529	515

1. For Types 4, 5 and 9 the number of crossing is likely an underestimate, since these small streams are greatly under-represented on DNRs current hydrography (stream network maps) Only DNR -managed lands within the South Puget HCP Planning Unit were used in this analysis.

Source: Prepared by Chris Snyder, 20090619

Cumulative Effects from Forest Road Use

The primary difference between the three management alternatives can be summarized by examining the amount of timber removed by watershed or the number of truck trips per decade. Although harvest levels are partially related to overall traffic levels on forest roads, truck traffic or road length are unlikely to be the main causes of sedimentation. For additional information on the impact of truck traffic on elements of the environment, DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-104 to 4-108).

Traffic on forest roads has the potential to increase sedimentation to water and produce dust and exhaust gases affecting air quality (p. 197). The ranking of watersheds with the highest amount of truck trips varies by alternative, as shown in Table 4-19. The potential for impacts from forest roads on the environment is measured by increased use. Higher road usage from forest management activities combined with recreation could have additional impacts on air quality, water quality, and wildlife habitat (p. 145). It is worth noting that the amount of traffic from recreational use is expected to increase based on population demographics (refer to recreation) (p. 165).

Another factor to consider is the distance of a harvest unit from a maintained forest road. In attempting to determine where roads might be needed in the future, Table 4-17 shows the acres within the selected watersheds beyond 800 feet of an existing road. Mashel (6,167 acres) and North Fork Mineral (5,249 acres) have the highest amounts of acreage further than 800 feet from an existing forest road along with the greatest amount of harvestable timber, so greater shares of road construction (either temporary or permanent roads) would most likely be located in these watersheds.

Higher road densities provide increased access to the forest. Watersheds with greater than average (3.2 mi/mi^2) road density are: Mineral Creek (5.0 mi/mi^2); Great Bend (4.2 mi/mi^2), Howard Hansen (4.1 mi/mi^2); and Kennedy Creek (3.7 mi/mi^2). Higher road densities provide more vehicle access which can result in seed transport of exotic plant species into new areas (Fuentes and others 2007). Road construction can decrease site productivity by altering soil properties, changing microclimates, and accelerating erosion (p. 155). Road density also

Table 4-19. Decade Average of Truck Trips for Watersheds with ≥ 20 Percent DNR-managed Acres, by Alternative

Watersheds	A	B	C
North Fork Mineral	8,518	8,154	8,672
Great Bend	8,129	6,427	7,445
Reese Ck.	8,160	5,879	6,097
Lynch Cove	6,174	6,163	6,453
Catt	3,997	7,580	2,416
Mashel	9,664	6,420	5,080
Kennedy Ck.	7,349	3,419	2,962
Howard Hansen	7,272	2,084	6,475
Tiger	2,058	4,906	2,298
North Fork Green	4,018	2,972	4,480
Mineral Ck.	3,104	2,179	2,580
East Ck.	1,999	2,174	2,097
West Kitsap	2,186	1,635	1,531
Total	72,628	59,992	58,586

can be used as an indicator to assess impacts to wildlife populations through habitat fragmentation. However, the environmental impacts from the road network are reduced by the mitigation measures described below.

The Howard Hansen and North Fork Mineral watersheds have the highest numbers of forest road stream crossings (Table 4-18) along with some of the highest harvest levels per decade (Appendix D). Much of the North Fork Mineral watershed that is more than 800 feet from an existing road (Table 4-17) is operable (available for harvest), meaning more roads and stream crossings could be needed in the future to access the timber, possibly resulting in higher impacts to this watershed than the others.

Forest Road Mitigation

While the impacts to the environment from forest roads are important to understand, all three alternatives are expected to have a similar road network and thus, similar impacts. Roads are constructed and maintained according to *Road Construction and Maintenance*[4]. DNR roads are designed to protect water quality and riparian habitat by constructing and maintaining them to limit the delivery of sediment to waters. New roads are constructed according to the *Forest Practices Rules*, including specifications to minimize sediment delivery to streams. Proper road design and maintenance, in addition to best management practices, are important steps toward reducing road-related sedimentation (Coe 2004). DNR's road design, construction, and maintenance practices are conducted to Forest Practices and agency standards to reduce road-related sedimentation.

Road maintenance is an essential part of management. Timing of this construction and erosion control methods are two of the most important ways to reduce sediment delivery from roads (Ecology 2008b). Roads that are no longer used or maintained are likely to continue to deliver sediment to streams (DNR 2001). According to Arnaez and others (2004), the best means for reducing sediment yields are to adjust the design of forest roads to fit the topography, apply well-established best management practices, and minimize the mobilization of sediment. These practices, which are outlined in the Forest Practices Board Manual, are currently used by DNR and will continue to be implemented in the planning unit.

Public Utilities and Services

DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* which discusses the potential effects of forest harvest on the transportation infrastructure, using the assumption that higher projected harvest volumes would result in increased logging truck traffic. Since forest land planning is designed to implement the sustainable harvest volume, set in 2004 and amended in 2007, none of the alternatives presented in this Final EIS is expected to result in any significant adverse impacts on transportation infrastructure (DNR 2004). Some trust revenues are available for maintenance and improvements to public utilities and services (DNR 2004).

Recreation

Chapter 3 (p. 85) gives a general description of why recreation is important and the criteria DNR uses for the management of recreation on forested state trust lands. The criteria include the *Multiple Use Act*[5] and the 2006 *Policy for Sustainable Forests*.

Indicators Used to Measure Recreational Impacts

The indicators used in this analysis are population demographics, public access and road use, and recreational facilities. Chapter 3 provides a general discussion of these indicators and how they influence recreation. Demographic trends are useful because they provide estimates of potential uses by age and activity; these factors then provide a basis for analyzing environmental impacts.

DNR's road network, along with paved state and county roads, are main access points for the general public to trust lands for recreational purposes, and by examining access areas and the types of recreational uses visitors seek, DNR can infer the types of impacts recreation might have on elements of the environment. Road miles (open vs. closed) are used as a measure of availability and therefore some measure of impact to resources.

Recreational opportunities are measured by the number of facilities, trails, and yearly visitors. These opportunities may be affected by levels of harvest activity across the three management alternatives.

Recreation Results

POPULATION DEMOGRAPHICS

As Washington's population continues to increase over time (Chart 4-13), it is assumed that probable impacts on the environment will increase as well.

The age of the population is useful in projecting future recreational needs and trends. A key consideration in estimating recreational participation is the distribution of an activity by a particular age group (IAC 2003). In Washington, the majority of recreational users are in the age group 35 to 49 (IAC 2003). Table 4-20 provides a population forecast for the three largest counties in the planning unit (OFM 2007a, 2007b) and Table 4-21 shows the percentage of the population (2008) by age groupings in the same counties (OFM 2008).

Table 4-22 provides a forecast of recreational activities based on the age of participants using the entire U.S. population (USDA 2004). Appendix I lists the recreational uses that DNR provides in this planning unit while Table 4-22 shows the top five activities (highlighted in blue) in this planning unit.

Participation in recreation using off-road vehicles is highest for 16- to 30-year-olds (Cordell and others 2005). Chart 4-14 forecasts the expected rise in the state's population of individuals 16 to 30 years of age (OFM 2008). On average, off-road vehicle users are significantly younger and more likely to be male with slightly higher incomes for their age group (Cordell and others 2005). However, according to OFM, all age groups are expected to grow considerably through 2020, but older age groups (over 30) are expected to demonstrate the most growth as shown in Chart 4-13.

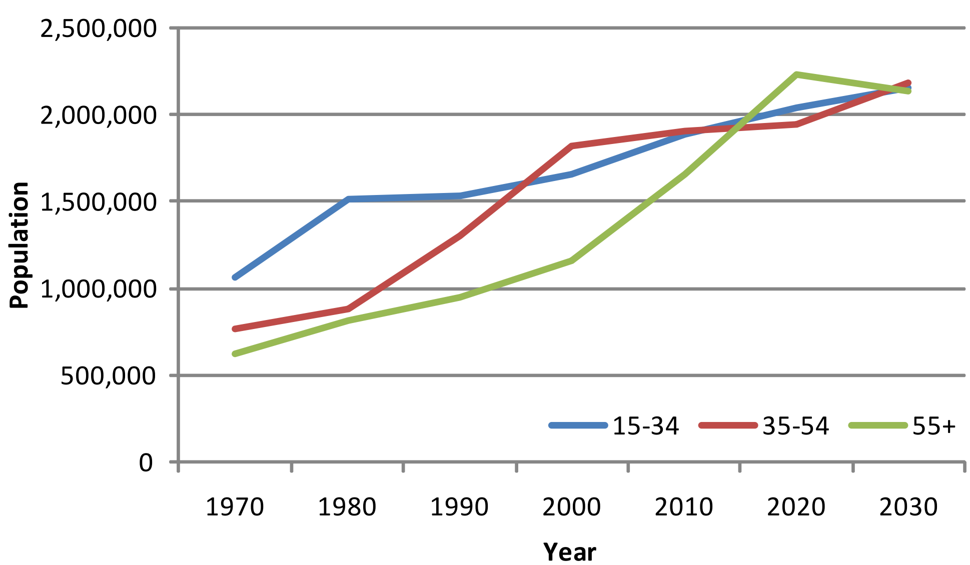
Another trend to look at is the number of vehicle registrations over the last 26 years (Table 4-23), which show that off-road vehicle registrations have doubled each decade, which is fairly consistant with the state's population trends and the increased popularity of this activity.

PUBLIC ACCESS AND ROADS

While road maintenance issues, seasonal wildlife closures, and vandalism restrict or limit access to the majority of DNR roads in the planning unit, there are 97 miles of roads open year-round and 42 miles open seasonally (closed in mid-late fall to mid-spring). They give access to the 450 miles of trails and many recreational sites in the planning unit (Table 3-14). Many recreational opportunities on state trust lands are located at low-elevation sites with year-round access from state or county roads, which may explain their high use. The majority of the state's population lives within an hour's trip of this planning unit, and the primary use of DNR's recreational facilities is trail-based day-use.

The majority of the Grass Mountain and McDonald Ridge areas are closed to all public access (including non-motorized use) except by permit in order to protect the City of Tacoma's water reservoir. DNR-managed lands west of the watershed boundary at McDonald Ridge are open for non-motorized day-use recreation. The only access to these lands is through private land holdings. These access areas are expected to remain constant over time; however, temporary closures occur when management activities pose a threat to public safety.

Chart 4-13. Projected Age and Growth Rate of Washington's Population (1970-2030)



State Population by Age: 1970-2030 from November 2008 Forecast; contains 1991-1999 Intercensal Estimates Developed in 2002. Updated 11/10/2008.

Table 4-20. Population Forecasts for King, Pierce, and Kitsap Counties (2000-2030)

	Population Estimate			
	2000[1]	2030[2]		
County	Baseline	Low	Intermediate	High
King	1,737,034	2,016,312	2,262,977	2,548,112
Pierce	700,820	903,819	1,050,953	1,213,326
Kitsap	231,969	245,397	314,610	396,879

1. 2000 population estimates based on Census 2000, U.S. Census Bureau.
2. OFM provides Low, Intermediate, and High population forecasts through 2030 for planning purposes. The range in population forecasts is based on economic and other assumptions.
Source: OFM 2007.

Table 4-21. Percent of Population by Age Group and County (2008)

Age	King County	Pierce County	Kitsap County
15-34	30%	29%	27%
35-54	23%	22%	22%
55-69	19%	18%	20%

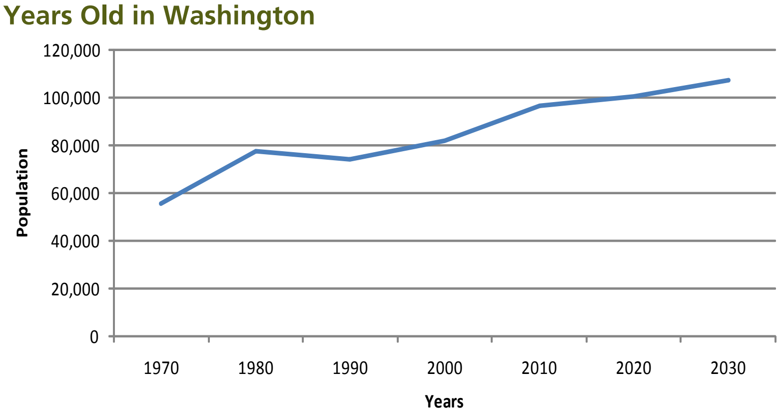
Source: OFM 2008 Data

Table 4-22. Recreational Activity by Percent of Age Groups*

Activity	Age 16-34	Age 35-54	Age 55+
Visit a wilderness or primitive area	62%	52%	33%
Day hiking	51%	50%	33%
Developed camping	49%	45%	26%
Visit a farm or agricultural setting	38%	40%	34%
Primitive camping	47%	38%	19%
Drive off-road	42%	32%	16%
Hunting (any type)	38%	30%	20%
Mountain biking	41%	31%	11%
Big game hunting	34%	30%	17%
Backpacking	30%	22%	8%
Small game hunting	24%	16%	10%
Horseback riding on trails	20%	16%	8%
Mountain climbing	13%	10%	6%
Migratory bird hunting	13%	7%	7%
Rock climbing	11%	5%	3%

*Rounded to the nearest integer
Source: 2000-2004 National Survey on Recreation and the Environment. USDA Forest Service

Chart 4-14. Projected Population Trend for People 16 to 30 Years Old in Washington



Source: OFM, November 2008 Forecast

RECREATION FACILITIES

The current recreational opportunities are shown in Table 3-14. State budget cuts enacted during the 2009 Legislative session reduced DNR's recreation program budget. Funding provided by the Non-Highway Off-Road Vehicle Activities (NOVA) was granted by the Legislature to Washington State Parks for at least the next two-year budget cycle, and will result in reduced services at some DNR-managed recreation areas. While these cut-backs are considered temporary, there is no guarantee the funds will be restored to their previous level and that cuts will not occur again in the future.

DNR's Recreation Program is committed to providing the public with a safe, enjoyable, and sustainable recreational experience while helping ensure that allowed activities are low-impact, and mitigated where necessary. When DNR is unable to meet these commitments or its ability to maintain or manage facilities is impacted by budget constraints, DNR must reduce services (Table 4-24). These reductions are focused on recreation facilities that do not provide access to a trail system, have fewer than 2,000 visitors per year, and have a high maintenance cost-to-visitor ratio. Some unintended impacts to the environment could occur as other facilities absorb additional visitors or as one use replaces another as a result of reductions in services.

Direct, Indirect, and Cumulative Impacts from Recreation

POPULATION DEMOGRAPHICS

Various types of land management activities impact recreational use in different ways. While timber harvests on DNR's forested state trust lands generally are considered to be compatible with pleasure driving on forest roads, motorized trail use, hunting

Table 4-23. Registrations of Recreational Vehicles in Washington

Decade	Motorcycles	Off-Road Vehicles
1980	135,777	13,058
1990	103,301	36,462
2000	114,624	61,308
2006	189,596	104,956

Registered Recreational Vehicles DOL

and other activities, harvests discourage hiking and backpacking because they alter the landscape and are less attractive to those users (IAC 2003).

Research indicates that recreational activity drops significantly as a population ages (IAC 2003). For example, in the US, nearly 80 percent of 6- to 12-year-olds participate in at least one outdoor recreational activity, while less than 35 percent of adults over age 65 participate in at least one outdoor activity. It should be noted that the population of 70- to 90-year-olds tends to be healthier and more mobile than in the past, thus prolonging that group's participation in certain recreational activities (Wood and others 1990). While participation may drop rapidly for some activities as a population ages, other activities will likely increase or, at a minimum, remain constant, especially as more focus is placed on healthy, active living.

Increases in the population ultimately will result in additional environmental impacts. Off-road vehicle use is a popular recreational activity in the planning unit, occurring primarily in the Tahuya State Forest, has an estimated 250,000 visitors per year (Table 3-15). Off-road vehicle use results in environmental impacts to air, soils, and water; these impacts can be reduced when users stay on designated trails built to specific standards. Most environmental impacts occur on undesignated trails (built by users), which are not built to any specific standards. These undesignated trails currently surpass the mileage of designated trails by a factor of three to one. Tiger Mountain, a non-motorized area used primarily for walking, picnicking, and bicycling on forest roads, has 375,000 visitors per year. The type of recreational activities occurring on Tiger Mountain generally will have less significant environmental impacts than in motorized areas; however, creating undesignated hiking or biking trails can produce similar impacts.

In general, the potential for recreational activities to result in environmental impacts depends on several factors, including the popularity of the area, season of use, group size, frequency and type of use, visitor behavior, and mode of travel. At most recreational sites, a combination of factors ultimately influences the overall level and severity of environmental impacts (Wilson and Seney 1994; Deluca and others 1998).

All trail uses have the potential to create a substantial environmental impact, especially if a trail is poorly placed, designed, or maintained (Marion 2006; Schlichte 1998). For instance, a mountain bike trail that is poorly positioned and maintained could result in more environmental issues than a well-positioned and maintained horse trail (Marion 2006). However, these impacts are lessened (but not eliminated) with some non-motorized recreational activities. The type of recreational activity (hiking vs. horseback riding) and the amount of use an area receives (seasonal vs. year-round) influence the types and severity of environmental impacts. Additionally, impacts are influenced by the slope gradient, rainfall intensity, soil properties, and the poor location of many undesignated trails. For example, a trail's placement in riparian areas or on steep slopes (Wilson and Seney 1994; Marion 2006; Schlichte 1998) contributes to the severity of impacts.

PUBLIC ACCESS AND ROAD USE

Public access and a growing population will affect certain elements of the environment through increased use of roads, trails, and recreational facilities. Undesignated motorized or off-road vehicles are one of the top threats to the health of

Table 4-24. Reduction in Recreational Services

Facilities Removal	Sites will not have amenities such as outhouses, picnic tables, signs, and/or garbage cans. The public can still recreate in these areas, but they will need to pack out what they pack in. In many areas, gates to access roads will be locked, and the only way into a site will be on foot.
Day-Use	No overnight camping.
Reduced Services	Facilities are maintained at a reduced level from 2008.
User Supported	Recreation uses and groups pick up more responsibility for maintenance and costs to prevent service reductions.

Source: DNR Press Release June 18, 2009

national forests (Cordell and others 2004). The use of these vehicles in unsuitable areas can increase the amount of silt and turbidity in a stream by increasing erosion (Moyle and Leidy 1992). In addition to off-road vehicles affecting soils, air, water, and vegetation, motorized recreation is considered to be a threat to wildlife species (Kassar 2009) (p. 175). The impacts from recreational use on forest roads on elements of the environment are discussed in roads (p. 161).

FACILITIES AND TRAILS

Typical recreation-related impacts from motorized or non-motorized use affect soils though compaction and erosion (Recreation, p. 165; Soils, p. 155); however, erosion is often greater when soils are wet than when they are dry (DeLuca and others 1998). Undesignated trail use from off-road vehicles often causes damage to streambanks, leading to increased erosion and sedimentation in streams and rivers. Additionally, when riparian areas are used by off-road vehicles, fuels may leak or spill (Kassar 2009).

Vegetation is primarily impacted by trampling, although some vegetation types can tolerate it better than others (Cole 1995). Wildlife also can be impacted by disturbances at certain times of the year (birthing) or certain times of the day (feeding) (Knight and Gutzwiller 1995). For additional information, refer to wildlife (p. 175).

Other potential impacts include litter and illegal dumping, unmanaged human waste, and vandalism. Serious recreation-related environmental impacts tend to be those that affect large areas, are intense, sustained over an extended time, and/or affect rare or unique ecosystem attributes (Cole and Landres 1996). When these impacts are identified, DNR relies on variety of tools for mitigation, including closing, limiting, or redirecting public access when necessary (DNR 2006b).

A reduction in services at facilities and trails has the potential to increase environmental impacts because adequate maintenance and enforcement may be lacking, which also raises concerns for the safety of users. The effects of current budget reductions on recreational opportunities are outlined in Table 4-25. Descriptions of these reduced services are in Table 4-24.

ALTERNATIVE COMPARISON OF RECREATIONAL OPTIONS

No single environmental setting is considered the most suitable for recreation; instead, each individual site or area has a set of environmental characteristics that make it more or less susceptible to recreational impacts. Alternative A would continue managing recreation under the current system with the recreation afforded to the public based on state and federal grants, which can be reduced during budget shortfalls. However, potential recreation-related environmental impacts and their consequences should not be overlooked if recreation and public access are to be considered sustainable land uses.

The suitability assessment proposed under Alternatives B and C would enable DNR to evaluate multiple resource factors (such as soil types, vegetation, slopes, and presence of wetlands) to help determine where, what type, and how much recreational activity is appropriate, by area. Once changes that are based on the suitability assessment have been identified, many of the impacts currently occurring could be mitigated through specific strategies built into Alternatives B and C.

Table 4-25. Recreational Opportunities Affected by Budget Reductions

		Effective Date
Facilities Removals	Kammenga Canyon Campground	7/1/2009
	Lilliwaup Creek Campground	7/1/2009
	Melbourne Lake Campground	7/1/2009
	Spillman Campground	10/15/2009
Day Use Only	Aldrich Lake Campground	7/1/2009
	Howell Lake Campground	7/1/2009
	Twin lakes Campground	7/1/2009
Reduced Services	Mine Creek	7/1/2009
	Paw Print Trailhead	7/1/2009
	Tiger Summit Trailhead	7/1/2009
User Supported Only	Green Mountain Horse Camp	7/1/2009
	Green Mountain Vista Trailhead	7/1/2009
	Poo Poo Point Trailhead	7/1/2009
	Tahuya River Horse Camp	11/1/2009

Recreation Program Reduced Services, June 2009

Alternative C includes the option of expanded contract services through leases or fees to enhance site-specific amenities and serve as another method to control vandalism, over-crowding (White 1993), litter, and crime (Grewell 2004) and possibly reducing environmental impacts in identified areas. Revenue from user fees can help reduce management costs, reduce congestion at certain times and sites by offering lower rates on weekdays and in less-popular seasons (Grewell 2004), and also create economic disincentives to visitors (Kline 2001). Fees can have multiple purposes which could include encouraging or discouraging particular uses, promoting personal contact with visitors, nurturing public support, and generating revenue to support facilities maintenance (Martin 2000). A federal fee demonstration project conducted in a wilderness area found that campers and day-use recreationists favored fees if they were used for restoration and maintenance of damaged sites, litter removal, and trails (Vogt and Williams 1999). Recreation fees shift the burden to those who spend more time recreating (Grewell 2004).

Public misuse or abuse and user conflict can cause poor visitor experiences on forested state trust lands and adverse impacts to the environment. Misuse often stems from the public's misinformation and expectations of unrealistic levels of recreation, facility development, and permitted uses. Often the recreating public is not aware of DNR's trust responsibilities or the forest management activities that occur on forested state trust lands. In addition, although not subject to modification by this process, Natural Resource Conservation Areas are managed with conservation objectives that allow low impact public use that may conflict with some visitors' expectations about recreational uses and potentially displace recreation visitors to other areas.

TIMBER HARVESTING AND RECREATION

Average harvest levels projected under the alternatives by harvest method, Table 4-2 could temporarily have negative effects on existing recreational activities in and around recreation areas. Trails are the most affected areas since trails in active timber harvest areas would be closed, moved, or decommissioned as a result of harvest activities—generally if closed, it would be only

Table 4-26. Recreation Impacts by Alternative

	Alternative		
	A	B	C
Facilities/ Trails	• Reservation system for select sites • User focus meetings • One enforcement officer and two trail stewards • Uses restricted to some areas	• Reservation system for select sites • Increase user focus meetings • One enforcement officer and two trail stewards • Implement inventory by adopting, relocating, or removing incompatible facilities and trails	• Reservation system for select sites • Increase user focus meetings • One enforcement officer and two trail stewards • Implement inventory by adopting, relocating, or removing incompatible facilities and trails. • Contracted Services, leases and fees to enhance sites.
Likelihood of impacts to soil, water, plants, and roads	**<u>High</u>** Management based on an assessment tool to define areas where recreation is appropriate. Tahuya and Tiger Trail Steward Duties: works weekends and high use times to enforce recreation rules, provide emergency response and promote safe recreational use of DNR-managed lands - coordinates volunteer events - provides oversight of schedules recreation events	**<u>High/Moderate</u>** Identified areas are adopted and improved, relocated, or removed.	**<u>Moderate/ Low</u>** Areas are identified for adoption, improvements, or relocation removal. Some areas are considered for fee management, leases, or contract services.
Low impact areas	Tiger, Grass Mountain, McDonald Ridge, Tahoma.	Tiger, Grass Mountain, McDonald Ridge, Tahoma	Tiger, Grass Mountain, McDonald Ridge, Tahoma
Moderate impact areas	Green Mountain, Elbe	Green Mountain, Elbe	Green Mountain, Elbe, Tahuya
High impact areas	Tahuya	Tahuya	

Low impact areas: elimination of off-road vehicles, no access, highly organized user groups. Moderate impact areas: combination of motorized and horse trails/campgrounds. High impact areas: motorized uses with many unknown user-built trails systems.

for the duration of the harvest related activities. Higher harvest levels would likely increase these potential effects, and Alternative C would have the greatest impacts followed by Alternatives A and B, respectively.

In reviewing the current recreational opportunities (Table 3-14), impacts from harvesting activities could affect campgrounds, picnic areas, and day-use areas negatively with noise, dust, and traffic. Higher harvest volumes could likely increase these potential effects; however, since the harvest levels are similar over the long term, the difference in impacts by alternative and watershed is expected to shift over time.

Higher harvest volumes, in certain decades, will result in more truck traffic on DNR-managed roads also used by the public for recreation purposes; this potentially could affect a proportion of the recreation visitors. Estimates of truck traffic that would be generated are presented in the roads section, by alternative (Table 4-19). For additional information on the impact of truck traffic on recreation, DNR is incorporating by reference the 2004 *Sustainable Harvest Final EIS* (p. 4-180).

Mitigation for Recreation

Managing recreation resources with input from established user groups can help eliminate some of the problems that have been identified. In the Tahuya State Forest, DNR instituted a voluntary forest watch system. Volunteers from the off-road vehicle community provide a presence that encourages users to follow DNR rules and regulations, and minimizes impacts from activities on some trail systems. However, the reduction of services at specific facilities and sites, while still allowing use, may result in additional environmental impacts which are not mitigated in all three alternatives. Table 4-26 provides an overview of recreational alternatives and the likelihood of their impacts on elements of the environment.

Visual Management

Criteria and Indicators for Visual Management

Chapter 3 (p. 89) gives an overview of visual resource management, its purpose, and the criteria DNR uses for addressing visual concerns. The criteria provide guidance for managing local and regional visual impacts and are contained in the 2006 *Policy for Sustainable Forests* (DNR 2006b) and the *Visual Management* procedure[6]. The state *Forest Practices Rules* governing timber harvesting[7] provide additional guidance for even-aged harvest methods related to the size and timing of harvest units as a way to reduce large open areas; however, this rule does not apply to salvaged timber which has been damaged by wind, disease, insects, fire, or other natural causes.

DNR uses harvest type (variable retention vs. thinning) as an indicator of visual impacts. As a preliminary screening tool, regional staff assesses proposed harvest activities on a site-by-site basis, scoring each based on the number of places a harvest unit is visible from surrounding roads. Rock pits and communication sites also can have visual impacts that are evaluated site by site. While natural disturbances may have associated visual impacts, they are inherently unpredictable, spatially variable events and are not part of this discussion.

Results for Visual Management

HARVESTING LEVELS AND TYPES

A summary of the average acres harvested by decade and alternative (Table 4-2) provides the range of acres affected by variable retention and thinning harvests (p. 52). Charts 4-1 and 4-2 depict a visual depiction for each decade and alternative by harvest type. The ratio of variable retention to thinning acres is a useful measure of visual impacts (Table 4-27) although not all thinnings are performed because of visual impact concerns.

In comparing the average harvest levels over 10 decades (Table 4-2), some trends can be observed. Overall, there will be more variable retention harvesting activities than thinnings (Table 4-4), but this will depend on the specific objectives for a particular area. Overall, Alternative B has the lowest

Table 4-27. Harvest Levels and Types by Alternative in Decade One (2009–2019)

	Harvested Acres by Alternative			Change from Alternative A	
Harvest Type	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. B**	**Alt. C**
Thinning	12,495	7,775	16,652	-23%	+20%
Variable Retention	8,634	10,401	9,545	+10%	+5%
Total Harvest	21,129	18,176	26,197	-8%	+8%

level of variable retention and thinning harvests followed by Alternatives A and C. However, in the first decade, Alternative B has higher levels of variable retention harvests and lower levels of thinning (Table 4-27).

Watersheds with the highest average variable retention acres to be harvested during the 100-year period are Great Bend, Lynch Cove, Kennedy Creek, and West Kitsap (Table 4-4). Under each alternative, as a percentage of DNR-managed lands within each watershed, the area harvested (by either thinning or variable retention methods) is Great Bend (A-11%, B-10%, C-14%); Lynch Cove (A-12%, B-11%, C-15%); Kennedy Creek (A-14%, B-6%, C-24%); and West Kitsap (A-7%, B-7%, C-8%). These averages indicate that Alternative B would have the lowest impact on visual sensitivities. However, Great Bend, Lynch Cove, and West Kitsap have some of the flattest ground in the planning unit, so the ability of anyone to view harvest activities in these watersheds would be reduced (Appendix M).

Direct, Indirect, and Cumulative Impacts to Visual Management

Specific visual-management guidance (Appendix B) has been given on the amount and placement of leave trees on forested state trust lands and this guidance is similar for all three alternatives. Generally speaking, harvest activities have higher potential for visual impacts than road building or gravel pits because of the amount of acres affected over time; therefore, this indicator provides a firm measure of the visual impacts anticipated under each alternative. The predominant concern from visual resources arises when timber is harvested on forested state trust lands adjacent to privately-owned lands or when harvesting activities on state and private lands are close to one another, potentially leading to local visual impacts.

Focus group research suggests that members of the public cannot always differentiate between forestry activities on forested state trust lands and those on private lands (The Connections Group 2003). However, the study revealed that when asked, people seem to react more favorably to thinning activities than other harvest types.

A study conducted by Picard and Sheppard (2001) found that thinning harvests are generally perceived as having a lesser visual impact than variable retention harvests when the harvested area is viewed from a distance. More positive assessments are given when the viewer is close to the thinned area (Sturtevant and others 2005).

Alternative B is expected to have lower environmental impacts than Alternative A. Alternative B provides specific strategies for lands identified as being visually sensitive where DNR has the ability to leave between eight and 16 trees per acre; the alternative includes specific strategies for Tiger Mountain (Chapter 2, p. 36).

Mitigation for Visual Management

Public outreach and education, identified as a potential mitigation strategy under Alternative B, may be effective and have widespread positive benefits for DNR. Public acceptance of forestry activities is affected by value judgments as well as by the actual visual impacts of those activities (Bliss 2000). In a 2002 DNR focus group study, the extent of visual impacts and the purpose of harvesting (funding of school construction) were key factors in whether participants supported forestry activities (Connections Group 2003). Although minimizing impacts on visual resources is important, educating the public about the role of DNR timber-harvesting practices is also important so that the public can develop and voice informed opinions. This approach may become particularly important in the future, as sustainability-based forestry models become more popular while current concepts of visual quality persist (Gobster 1999; Sheppard 2000).

Unpredictable natural disturbance events, such as insect outbreaks, may cause significant visual impacts which may be difficult to mitigate. Mitigation measures designed to lessen impacts to an acceptable level under all alternatives are described in the 2006 *Policy for Sustainable Forests* and the *Visual Management* procedure[7]. DNR identifies and mitigates visually sensitive areas, addressed on a sale-by-sale basis or through the forest land planning process, in which specific strategies are developed to help design timber sales that minimize visual impacts in identified areas (DNR 2006b). DNR also complies with state *Forest Practices Rules*[7], which specify minimum age and tree sizes that must be met before any new harvests on adjacent lands may occur, regardless of ownership. The rules were specifically designed to help reduce the cumulative visual effects of multiple adjacent harvest areas across different ownerships in a short period of time.

Cultural Resources

This section analyzes the impacts to cultural resources from different management actions. The general effects of harvesting, roads, extraction of sand, gravel, and minerals, recreation, and land transactions are described in Chapter 3 (p. 94).

Criteria and Indicators for Cultural Resources

DNR's criteria for cultural resources are in place to identify, study, protect, and perpetuate significant cultural resources and maintain Tribal access.

Indicators of management progress include the protection and minimization of impacts, the percent of land designated for cultural use, the acreage available for Tribal access, and improvement of data. DNR does not have the information available to provide a quantitative analysis of the impacts to cultural resources but provides a qualitative analysis related to the level of disturbance caused by harvest activities in the planning unit.

DNR Cultural Resources Protection

PROTECTION AND MINIMIZATION OF IMPACTS

This analysis has identified the number of DNR staff trained in cultural resource awareness in the planning unit as a measure of protection to cultural resources. Although no particular value can be assigned to one informed person, DNR hopes that employees trained in cultural resource concerns will be able to identify and protect these items in the field. Therefore, the goal of training 100 percent of field staff should add a measure of protection to cultural resources on future projects.

TRIBAL ACCESS AND LANDS DESIGNATED FOR CULTURAL USE

As stated in Chapter 3, actual acreage of cultural use and Tribal access cannot be adequately estimated because although acreage may not be specifically designated for these uses and changes over time, many acres are used annually by these groups. From a legal standpoint, DNR has no standing (or intent) to deny access to lands that were previously ceded. Because of DNR's open communications with many Tribes, most uses are prearranged and access is granted to gated areas by request, so long as the use does not interfere with trust duties. DNR is committed to consulting with Native American Tribes in the area, including the Suquamish, Muckleshoot, Puyallup, Nisqually, Squaxin Island, and Skokomish, as well as other interested parties about areas of cultural importance to them.

DNR acquires and manages Natural Area Preserves (NAP) and Natural Resource Conservation Areas (NRCA) for the protection of undeveloped landscapes and habitats for Washington's flora and fauna (DNR 1997). Although this process will not modify the existing Natural Area Preserves and Natural Resource Conservation Areas; they can protect cultural resources by removing development pressure. Projects with the potential to affect cultural resources within these areas, such as the removal of infrastructure and buildings, are reviewed by Cultural Resource Specialists, providing further protection. Table 4-28 shows each Natural Area Preserves and Natural Resource Conservation Areas and the acres associated with it, a total of 9,415 acres in this planning unit.

Forest management can change species composition to favor resources utilized by the Tribes. For example, using timber harvesting to open the forest canopy can encourage the growth of berry-producing species and can provide forage for game animals. Cedar growth also is promoted on many forested state trust lands by the removal of competing tree species.

Table 4-28. Acres of DNR-Managed lands in Natural Area Preserves (NAP) and Natural Resource Conservation Areas (NRCA)

Name	Approximate Acres
Bald Hill NAP	307
Charley Creek NAP	1,172
Kennedy Creek NAP	194
Kitsap Forest NAP	571
Oak Patch NAP	18
Shumocher Creek NAP	492
Skookum Inlet NAP	146
Tahoma Forest NRCA	233
Stavis NRCA	1,559
West Tiger Mountain NRCA	3,885
Woodard Bay NRCA	838
Total	**9,415**

Minimization of Effects to Cultural Resources

Surveys are conducted on lands identified as having a high probability of containing cultural resources. Cultural resource finds are confirmed and recorded with the Washington Department of Archaeology and Historic Preservation. As appropriate, the affected Native American Tribe is notified. DNR, the Department of Archaeology and Historic Preservation, and the affected Tribe or Tribes determine the potential impacts that the land management activity will have on a cultural resource; then DNR, the Department of Archaeology and Historic Preservation, and the affected Tribes determine the appropriate mitigation measures.

DNR's Forest Resources and Conservation Division's approach to cultural resource management emphasizes communication among its own staff, as well as with Tribes, Department of Archaeology and Historic Preservation, forest landowners, and other parties with an interest or expertise in the lands DNR manages (Stilson pers. comm. 2008).

Under the procedure for identifying historic sites[8], before an activity can take place on the ground, the following steps must be taken to minimize impacts to cultural resources.

1. Check the Department of Archaeology and Historic Preservation or TRAX databases for known state recorded sites.

2. Contact, as appropriate, Tribal personnel to identify any known Tribally recorded sites.

3. Check the General Land Office maps for known not recorded sites (USGS and Army Mapping Service historic maps created between 1898 and 1950).

4. Check the Cultural Resources layer in the State Uplands Viewing Tool (GIS data) or other sources for predictive models of the project area.

5. For unknown unrecorded sites, check U.S. Geological Survey or DNR hydrological and topographical layers for high probability areas such as flat areas near permanent water, ridges, saddles, springs, and artificial landscape alterations (buildings, cemeteries, fields, roads).

The planning process is likely to increase knowledge of cultural resources on DNR-managed lands. DNR GIS data and tools (such as the State Uplands Viewing Tool) continue to be developed, making cultural resources information readily available to qualified DNR staff and other qualified, interested parties.

These processes greatly reduce the possibility that land management activities will affect cultural resources negatively. However, negative impacts are still possible, since even full-scale surveys sometimes fail to locate existing cultural resources. However, if fully implemented, DNR protection practices reduce the potential for impacts to cultural resources for all alternatives.

Comparison of Alternatives

Alternative C has the greatest potential for impacts to cultural resources because of the number of acres to be harvested or thinned (Table 4-2). Alternatives A and B may impact cultural resources, but affect fewer acres than Alternative C. Despite these relative differences, the impacts to cultural resources are expected to be insignificant under all alternatives because of concurrent and previous mitigation.

Mitigation for Cultural Resources

DNR complies with all WACs and RCWs that provide rules and tactics for dealing with cultural resources, such as the Indian graves and records code[9]. DNR also is working with the Tribes at this time to create contract language to protect sensitive sites during contract harvesting. This section within a contract later will be known as an Inadvertent Discovery Plan, which will give step-by-step procedures to contractors who unexpectedly find cultural resources in the areas they are working.

Wildlife Habitat

In this section, DNR analyzes the impacts to wildlife habitat from a variety of management actions. Chapter 3 discusses the importance of wildlife habitat, defines wildlife guilds and their linkage to forest stand development stages, current wildlife conditions, and sensitive wildlife species. The general effects of DNR's management activities from harvesting, roads, and recreation are also described in Chapter 3 (p. 98).

Wildlife habitat is the combination of resources in the environment that attract and support a species, population, and/or an assembly of species. Wildlife habitat is important because of the functions (such as providing food and shelter) it performs for a variety of wildlife species (refer to Chapter 3, p. 98).

Criteria and Indicators for Wildlife Habitat

The criteria for assessing wildlife habitat are the conservation of biological diversity, the protection of threatened and endangered species, and the avoidance of future listings of additional wildlife species (DNR 1997)[10].

In order to measure the effects of management activities on wildlife habitat, DNR identified wildlife guilds, stand development stages, Natural Area Preserves, Natural Resource Conservation Areas, and forest fragmentation as indicators. Stand development stages are used directly as an indicator of wildlife habitat (Table 3-20) as well as a surrogate indicator of wildlife guilds (Table 3-19), which are associated with habitat conditions found within the different forest stand development stages. The surrogate indicators for forest fragmentation are the percent of a watershed (WAU) in the Ecosystem Initiation stage over time and road density (p. 161). Currently, in the planning unit, a range of habitats and ecosystems are protected within Natural Area Preserves and Natural Resource Conservation Areas. However, it is impossible to anticipate the amount and location of future Natural Area Preserves and Natural Resource Conservation Areas because the funding and decisions are made externally to DNR; consequently, there are no appropriate surrogates identified at this time. For current conditions in Natural Area Preserves and Natural Resource Conservation Areas and the habitat types they protect, refer to Table 3-23.

Results for Wildlife Habitat

STAND DEVELOPMENT STAGES

The trends shown in Chart 4-6 show that there is a general increase in structurally complex forest acres (Niche Diversification and Fully Functional stand development stages) across the planning unit, with Alternatives B and C having the greatest increases. Table 4-5 reports the projected acres and percent change in forest conditions over the planning horizon (2009–2109) by alternative, for watersheds in which DNR-managed trust ownership represents at least 20 percent of the acreage in any given watershed. Appendix D contains charts reporting the projected trend in each forest stand development stage by alternative.

FOREST FRAGMENTATION

The number of acres of forests in the Ecosystem Initiation stage is a surrogate for the indicator of forest fragmentation. Initially all alternatives show decreased acres of forests in the Ecosystem Initiation stage but Alternatives B and C slightly increase while Alternative A maintains a somewhat steady level (Chart 4-15).

At the watershed (WAU) level (refer to Table 4-5), North Fork Mineral WAU has the largest increase in forest acres of the Ecosystem Initiation stage, while Reese Creek and Mineral Creek have the largest decrease of acres in the same stage.

Direct and Indirect Cumulative Impacts Wildlife Habitat

STAND DEVELOPMENT STAGES

Wildlife species and guilds respond in a similar fashion to shifts in stand development stages over time. Wildlife species and guilds associated with a particular forest stand development stage can be

Table 4-29. Summary of General Trends in Stand Development Stages between the Alternatives*

General Trend	Alternative A	Alternative B	Alternative C
Ecosystem Initiation stand development stage forests decrease in the short- and mid-term	Results in greatest foraging habitat reduction among all alternatives in the first five decades, then the trend is similar to Alternative B.	Generally more consistent levels, with a projected low point in decade seven.	Fluctuates the most by decreasing in the first five decades and then generally increasing throughout the remainder of the planning horizon.
Competitive Exclusion stand development stage forests increase in short-term	Increases in the first two decades.	Similar to Alternative A.	Similar to Alternative A.
Long-term decrease in Competitive Exclusion stand development stage forests	Decreases after the second decade until the fifth decade where it remains with minor fluctuations.	Similar to Alternative A.	Similar to Alternative A.
Understory Development shift mid-term to Biomass Accumulation stand development stage forests	Rapid shift begins in fourth decade, reaching highest level of Biomass Accumulation in seventh decade. Understory Development continues decline over the long term.	Similar to A, but greater shift in seventh decade (more Biomass Accumulation, less Understory Development).	Similar to A for increased Biomass Accumulation but greater decline in Understory Development in the seventh decade.
Structurally complex (Biomass Accumulation, Niche Diversification and Fully Functional) stands gradually increase over the long term (Chart 4-6, p. ##)	Lowest levels of all the alternatives, but still generally increase.	Similar trend as Alternative C, but slightly lower levels.	In the fifth decade, Alternative C begins to result in slightly higher levels of Fully Functional stand development stage through the end of the modeling period.

*Refer to Appendix D

found in Table 3-20 and needed structural elements are found in Table 3-21, Table 3-22, and Table 3-23.

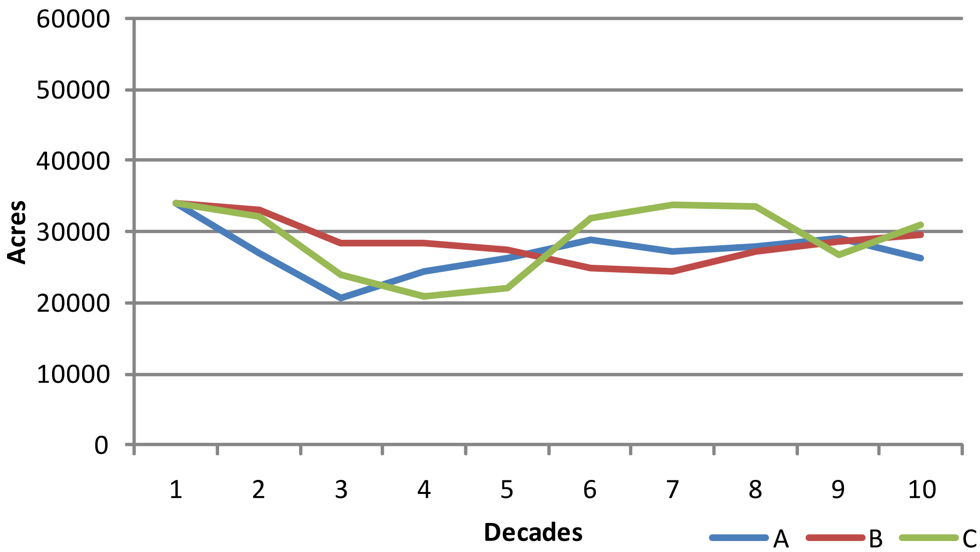
Potential effects from the short- and mid-term decreases in Ecosystem Initiation stand development stage forests are a reduction of foraging habitat for many species, including deer and elk, shrub-associated birds, and small mammals. The decrease in this stand development stage also reduces breeding habitat for reptiles, including garter snakes and western fence lizards. The short-term increase in forests in the Competitive Exclusion stand development stage is linked to a reduction of Ecosystem Initiation stand development forests, and results in relatively lower wildlife values. A beneficial trend over the long term is the decrease in Competitive Exclusion stage forests (refer to charts in Appendix D) and the increased area and value of wildlife habitat in structurally complex forest stand development stages.

There is a mid-term shift from Understory Development to more structurally complex forests that increases habitat for seed- and needle-eating wildlife, such as blue grouse, Douglas' squirrel, and red tree vole. The short- and mid-term benefit of this necessary step is the growth of large trees and the creation of structurally complex forests (Niche Diversification and Fully Functional). Over the long term, the gradual increase in structurally complex forest stands (Chart 4-6) provides habitat for species that are currently absent or uncommon, including many species that have experienced regional population declines, such as northern goshawk, northern flying squirrel, Vaux's swift, Townsend's warbler, and several species of bats. Refer to Table 4-5, to identify changes in stand development stages.

FOREST FRAGMENTATION

The planning unit is projected to decrease in the amount of forested acres in the Ecosystem Initiation forest stand development stage for all of the alternatives from current conditions (Chart 4-15). Alternative C decreases during the first half of the planning period and then returns to current levels. It is not known if such a fluctuation would have any potential impacts to wildlife. While acres in the Ecosystem Initiation stage are a crude measure of forest fragmentation, an inference can be made that as the percent of Ecosystem Initiation stage decreases, forest patches would be closer together and contain less edge.

Chart 4-15. Comparison of Alternatives in the Ecosystem Initiation Stand Development Stage



As discussed in Chapter 3, roads can have a negative effect on wildlife species and their habitat. Under all three alternatives, DNR's permanent road network resembles existing conditions for all future periods. Road maintenance may be greatest under Alternative C because thinning activities are expected to occur on more acres (Table 4-2). However, these impacts are expected to be insignificant because of the mitigation methods provided in the 2001 *Final EIS on Alternatives for Forest Practices Rules* (p. 3-175 to 3-186 and Appendix F), which DNR is incorporating by reference.

Habitat configuration is not evaluated in this analysis, as it was for northern spotted owls. In the northern spotted owl dispersal management areas, habitat connectivity is projected to increase under all the alternatives specifically under Alternatives B and C (p. 180). It is assumed that species requiring habitat conditions similar to those of northern spotted owls (Table 3-19, Table 3-20) would also benefit from the increased habitat connectivity.

Forest roads also can increase habitat fragmentation to core forest areas and produce a greater amount of edge habitat (Miller and others 1996; Reed and others 1996). Table 4-17 shows the watersheds (WAUs) acres with and without access for timber harvesting, unless aerial harvest methods are used. The Chapter 3 wildlife section contains a discussion of the general effects of roads on wildlife habitat.

MANAGEMENT ACTIVITIES IMPACT ON WILDLIFE HABITAT

Timber harvest activities change forest stand conditions and may alter the associated wildlife species composition. The projected average harvest levels by decade for the two harvest types (variable retention and thinning) are shown in Chart 4-1 and Chart 4-2. The projected average harvest levels by land class and by decade are shown in Figure 4-1. Table 3-24 provides a list of the adverse impacts and benefits of the different harvest techniques on wildlife. Chapter 3 contains a general discussion of the effects of timber harvesting on wildlife habitat.

RECREATION IMPACTS ON WILDLIFE HABITAT

All management alternatives address increasing recreational pressure three ways: through the education of recreational users, enforcement efforts to deter inappropriate uses, and engineering to address resource damage (p. 165). For example, in the Elbe State Forest, DNR maintains gates on several roads to protect deer and elk from disturbance during winter and calving seasons. In addition, DNR's recreation program develops site-specific plans to manage recreational uses that are believed to be affecting resources or creating land-use conflicts.

The alternatives include differences that may increase the effectiveness of identifying and addressing impacts of recreation on wildlife. Under Alternative A, DNR assesses recreational impacts on a project-by-project basis. Under Alternative B, DNR would conduct a more systematic evaluation of recreational use, using a recreation assessment model to determine the appropriate level and type of recreational uses on DNR-managed lands. This approach would increase the likelihood that DNR could identify and alleviate potential conflicts between people and wildlife on forested state trust lands.

Under Alternative C, DNR explores expanded contract services not currently provided. No specific increased services are being considered at this time, but services could include those intended to manage access, such as gatekeepers, which could reduce impacts of increasing recreational pressures on wildlife habitat. However, other services, including leases for privately operated campgrounds, could attract more people, possibly resulting in additional impacts to wildlife habitat.

Cumulative Effects to Wildlife Habitat

Every year, DNR's timber harvest activities will impact nearly two percent of DNR's land base every year within the planning unit. The percent of harvest entry types shown in Chart 4-4 and the number of harvest entries shown in Figure 4-2 may have a cumulative effect on wildlife species and habitat, especially those sensitive to disturbance. Collectively, these activities could result in short-term wildlife impacts across the landscape, including disturbance and habitat loss, as previously described (Table 3-24).

The reduced amount of forest stands projected to be in the Ecosystem Initiation stage under all alternatives could contribute cumulatively to the effects of similar reductions projected to occur on adjacent USFS lands. Deer and elk populations have been declining in the West Cascades ecoregion since the 1990s because of a decline in foraging habitat (Spencer 2002). Declines in Ecosystem Initiation acres on forested state trust lands could further reduce foraging habitat for these species, while areas serving solely as winter habitat on DNR-managed trust lands are expected to remain suitable.

Silvicultural activities under all three alternatives are expected to benefit habitat for many types of wildlife, specifically for wildlife species associated with structurally complex forest stands that have experienced population declines in the Puget Trough and West Cascades ecoregions (refer to Table 3-19).

The benefits of increased structurally complex forests on forested state trust lands also affect federal lands that contain most of the remaining structurally complex forests. Two of the three conservation objectives of the 1997 HCP multi-species strategy are aimed at directly developing more diverse forest habitats that support habitat protection and restoration on federal lands:

- To contribute to the demographic support of populations of unlisted species with large home ranges within federal forest reserves.
- To facilitate the dispersal of these wide-ranging species among federal forest reserves (DNR 1997, p. IV. 147).

Increasing structurally complex forests in the planning unit along with similar efforts taking place on federal lands—specifically, the Northwest Forest Plan—will benefit many types of wildlife, including marbled murrelets and northern spotted owls. The cumulative effects that DNR management activities have on wildlife are not expected to be significant or beyond those analyzed in the 1997 *Habitat Conservation Plan*.

Wildlife Habitat Mitigation

DNR complies with state *Forest Practices Rules* while implementing existing policy and procedures. Mitigation is provided by following *Forest Practices Rules*, agency policy and procedures, and conditions set forth in the 1997 *Habitat Conservation Plan* (a multi-species habitat conservation plan, ensuring habitat for a multitude of species and special ecosystems).

On-site mitigation conducted prior to and during any harvest activities lessens the probability of certain events occurring. Some examples of on-site mitigation are avoidance of unique habitats, legacy tree distribution, timing restrictions, and buffers for some species habitat.

Marbled Murrelet Habitat

This section analyzes the impacts to marbled murrelet habitat from a variety of management actions. The general effects of harvesting and roads are described in Chapter 3 (p. 106).

Criteria and Indicators for Marbled Murrelet

Chapter 3 described marbled murrelet biology, the importance of the species, and the criteria DNR uses for evaluating impacts to it on forested state trust lands.

The criteria for assessing marbled murrelet habitat is DNR's provision that habitat supports a marbled murrelet population that is 1) stable or increasing, 2) well-distributed, and 3) resilient (Raphael and others 2008). The four indicators DNR uses for assessing whether the criteria have been met will be determined as part of the marbled murrelet long-term conservation strategy and are outside the scope of this planning effort (Raphael and others 2008). Until a marbled murrelet long-term strategy is developed, the *Interim Marbled Murrelet Conservation Strategy for the South Puget Planning Unit* will be followed. This strategy can be found in Appendix N.

Effects of Timber Harvest Activities on Marbled Murrelet Habitat

There are no proposed changes for how marbled murrelet habitat is managed as part of this planning process; however, the alternatives include differing amounts of area and harvest types varies between alternatives (Chart 4-1 and Chart 4-2). These differences could potentially result in differing degrees of forest fragmentation across the planning unit (p. 191). Forest fragmentation is thought to increase predation and decrease nesting success for marbled murrelets (Manley and Nelson 1999; Raphael and others 2008).

Mitigation for Timber Harvest Activities for Marbled Murrelet Habitat

All occupied sites are protected by the *South Puget Planning Unit Interim Marbled Murrelet Conservation Strategy* until the long-term conservation strategy is finalized. All suitable nesting habitat identified as part of the *Interim Marbled Murrelet Conservation Strategy* is deferred from harvest until surveys can be completed or a long-term conservation strategy is in place (Appendix N).

An occupied site is where marbled murrelets have been observed flying at or below the forest canopy level and strongly indicates that the site has some importance for breeding. Occupied sites include known nest sites (Evans Mack and others 2003).

All identified potential marbled murrelet habitat is treated as if occupied until the adoption of the long-term conservation strategy or a field assessment and habitat determination is made. Any additional habitat identified during the period of the *Interim Marbled Murrelet Conservation Strategy* will be reported to the Services annually and managed as suitable habitat. Occupied sites, suitable nesting habitat, and identified potential habitat are protected by a 300-foot managed buffer (as per WAC 222-16-080(1)(j)(v)), or a 165-foot no-touch buffer. Smaller buffers may be sufficient in certain topographic situations (for example, managed buffers on ridge tops may not need to extend onto the opposite slope). Timing restrictions for timber harvest activities within a quarter-mile of an occupied site are also applied (Appendix N).

Summary of Risk and Cumulative Impacts

The likelihood is low that harvest activities will occur within or directly adjacent to marbled murrelet habitat before the adoption of the long-term strategy.

A forest connectivity assessment was conducted as part of the northern spotted owl analysis in the Elbe Hills, Tahoma, and Black Diamond northern spotted owl management areas. Forest connectivity for northern spotted owls in these areas is expected to increase under all three management alternatives, with Alternatives B and C seeing a more dramatic increase (p. 180). The majority of marbled murrelet habitat identified in the Interim Marbled Murrelet Conservation Strategy is located within these areas and it can be inferred that forest connectivity for marbled murrelets also would increase. Though the habitat needs of these two species are different, many of the forest conditions assessed for northern spotted owls—such as canopy closure and patch size—also are associated with marbled murrelet habitat.

In addition, with low rates of detection of marbled murrelet on adjacent lands and the offshore population of marbled murrelets being low in the southern Puget Sound waters (Raphael and others 2008), among the alternatives DNR expects little difference for marbled murrelet habitat and the effects from these alternatives are not likely to result in significant, adverse, environmental impacts.

Northern Spotted Owl Habitat

This section analyzes the impacts to northern spotted owl habitat from different management actions. Chapter 3 (p. 107) describes northern spotted owl biology, status, and species importance.

Scale and Time Frame of the Alternatives

Northern spotted owl habitat is assessed on multiple spatial scales: forest stands, spotted owl management units (SOMUs), dispersal management areas, and northern spotted owl landscapes (DNR 1997). Within dispersal management areas, SOMUs are defined and used to track the current amount of northern spotted owl habitat. SOMUs are modified 1997 Watershed Administrative Units (WAUs) that are now kept static because WAUs regularly are updated based on improved hydrological information. Under the three management alternatives, ecological indicators were chosen to evaluate projected values of modeled habitat changes over the 100-year planning period under the three management alternatives. An assessment was conducted at the stand level. The scores are reported at the SOMU, dispersal management area level, and for some indices at the landscape level.

Criterion and Indicators for Northern Spotted Owl Habitat

The criterion for assessing northern spotted owl habitat is DNR's provision of habitat which makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal (DNR 1997). There are four indicators DNR uses for assessing the criterion—the amount of area that meets desired northern spotted owl habitat conditions, the area that supports northern spotted owl dispersal life history requirements, the area's fragmentation and habitat connectivity, and the number of acres harvested in existing northern spotted owl circles. Refer to *What Are the Indicators DNR Used to Assess Dispersal Habitat?* (p. 105) for a description of each indicator.

Northern Spotted Owl Habitat Results

This section presents analyses of the habitat conditions that alternatives create for northern spotted owls over time. Four analysis methods were used:

- The first method assesses the amount of habitat using DNR northern spotted owl habitat definitions of South Puget Movement and Movement, Roosting, and Foraging (MoRF)(Text Box 2-2).
- The second method is a dispersal assessment tool specifically designed to evaluate the value of forest stands in providing northern spotted owl dispersal habitat.
- The third method evaluates habitat configurations on areas managed for dispersing northern spotted owls.
- The fourth method evaluates the number of acres harvested in existing Status One northern spotted owl circles (p. 107).

AREA MEETING NORTHERN SPOTTED OWL HABITAT DEFINITIONS

The first assessment method uses DNR's 1997 HCP northern spotted owl habitat definitions as well as definitions developed as part of this planning process. These habitat definitions were built into yield tables representing the growth and yield of forest stands under different silvicultural treatments. The modeled habitat was produced using Remsoft's Woodstock modeling software (Appendix C) for each alternative.

Chart 4-16. South Puget Movement and Higher-Quality Habitat for All Dispersal Management Areas over 10 Decades

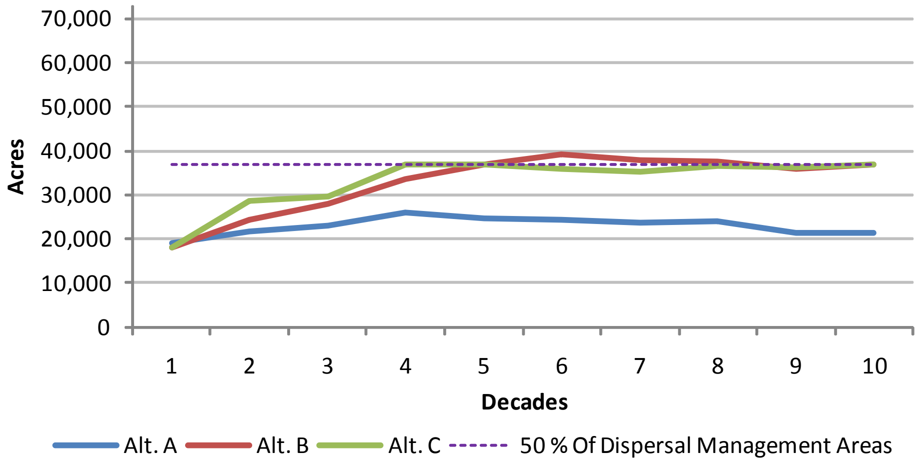


Table 4-30. Decades to Reach 50 Percent South Puget Movement or Movement, Roosting, and Foraging (MoRF), by Spotted Owl Dispersal Management Area*

Landscape	Decades to reach 50 percent movement habitat			Decades to reach 35 percent MoRF habitat		
	Alt A	Alt B	Alt C	Alt A	Alt B	Alt C
Elbe	3 (46%)	2	1	0 (25%)	6	6
Tahoma	5 (41%)	4	3	7 (20%)	6	8
Black Diamond	5 (58%)	5	4	6 (20%)	7	9 (33%)

* Values in gray with gray background represent the decade that the highest value (in percent of area)

Table 4-31. Decades to Reach 50 Percent South Puget Movement or Movement, Roosting, and Foraging (MoRF) by SOMU*

SOMU	Decades to Reach 50 Percent South Puget Movement Habitat			Decades to Reach 50 Percent MoRF Habitat		
	Alt. A	Alt. B	Alt. C	Alt. A	Alt. B	Alt. C
Ashford	0 (41%)	5	4	0 (28%)	6	6
Big Catt	5 (39%)	5	3	9 (20%)	9	8
Busy Wild	3 (49%)	2	1	0 (24%)	6	7
Grass Mt.	5 (37%)	5	4	7 (23%)	7	7 (31%)
Mineral Ck.	4 (44%)	5	4	8 (16%)	6	9 (33%)
N. Fork Green Ck.	5 (43%)	5	4	6 (16%)	7	- *
N. Fork Mineral Ck.	5 (45%)	3	3	7 (24%)	6	8
Pleasant Valley	0 (35%)	4	3	2 (9%)	7 (28%)	9 (22%)
Reese Creek	3 (37%)	4	4	8 (20%)	7 (29%)	8

* Values in gray with gray background represent the decade that the highest value (in percent of area)

South Puget Movement Habitat or Higher-Quality Habitat Conditions—As described, the first method for comparison of the alternatives is to examine the amounts of South Puget Movement and higher-quality habitat (high-quality nesting, Type A, Type B, Young Forest Marginal, and Movement, Roosting, and Foraging (MoRF)) that is projected over 10 decades (Chart 4-16).

Chart 4-16 shows projections for all dispersal management areas combined. The dashed red line shows the number of acres it takes to meet the habitat goal of fifty percent in the dispersal management areas and is included as a reference for comparing how the alternatives are achieving landscape level goals. Charts for individual SOMUs are presented in Appendix G. Alternatives B and C produce more acres of South Puget Movement and higher-quality habitat compared to Alternative A. The targeted 50 percent habitat threshold is reached by the third or fourth decade with Alternative B and C (Tables 4-30, 4-31). Alternative A increases the acres of South Puget

Table 4-32. Acres of South Puget Movement and Higher-Quality Habitat for 10 Decades by Northern Spotted Owl Landscape*

Landscapes	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Elbe Hills	6,807	1,539	9,531	4,897	10,367	871	10,649	8,734	10,392	757	10,451	8,734
Tahoma	8,768	1,648	10,304	4,721	12,240	3,489	15,957	4,602	12,465	3,018	14,853	4,602
Black Diamond	6,981	1,281	8,524	4,412	9,581	2,786	12,068	4,304	9,607	2,492	11,701	4,304

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Table 4-33. Acres of South Puget Movement and Higher-Quality Habitat for 10 Decades by SOMU*

SOMU	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Ashford	1,849	537	2,853	1,250	3,186	237	3,419	2,673	3,206	224	3,432	2,673
Big Catt	1,818	447	2,348	1,014	2,684	801	3,675	976	2,903	806	3,572	976
Busy Wild	4,958	1,046	6,678	3,612	7,181	668	7,942	6,061	7,186	547	8,107	6,061
Grass Mt.	5,174	787	5,959	3,436	6,955	1,901	8,946	3,421	6,844	1,620	8,390	3,421
Mineral Ck.	1,140	419	1,864	574	1,741	814	2,702	574	1,452	470	2,279	574
N. Fork Green Ck.	1,807	585	2,646	860	2,626	913	3,599	883	2,763	916	3,978	883
N. Fork Mineral Ck.	4,557	863	5,197	2,207	5,973	1,577	7,440	2,126	6,007	1,446	7,145	2,126
Pleasant Valley	336	57	463	265	584	137	779	363	575	127	777	425
Reese Creek	1,253	212	1,621	926	1,842	430	2,233	926	2,104	435	2,436	926

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Movement and higher-quality habitat marginally, but never achieves the 50 percent habitat threshold. In the Ashford, Busy Wild, and Pleasant Valley SOMUs, South Puget Movement and higher-quality habitat decline during the planning period under Alternative A (Appendix G).

The average number of acres in South Puget Movement and higher-quality habitat over 10 decades also is compared in a tabular format. Table 4-32 reports the averages for the northern spotted owl landscapes and Table 4-33 reports the averages by Spotted Owl Management Unit (SOMU).

Each table in this section provides the standard deviation, as well as the maximum and minimum, to reflect the amount of variation within each alternative across the 100-year planning period. Comparison charts for each Northern Spotted Owl Landscape and SOMU are provided in Appendix G.

Table 4-34. Acres of Movement, Roosting, and Foraging (MoRF) or Higher-Quality Habitat for 10 Decades by Northern Spotted Owl Landscape*

Landscapes	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Elbe Hills	3,658	1,084	5,471	1,982	6,141	1,965	8,771	3,954	6,119	2,688	9,633	2,340
Tahoma	3,944	1,509	5,968	1,978	6,968	3,685	11,401	2,058	5,277	3,849	12,249	1,646
Black Diamond	3,783	889	5,076	2,385	5,818	2,825	9,331	2,487	5,007	2,013	7,787	2,487

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Table 4-35. Acres of Movement, Roosting, and Foraging (MoRF) or Higher-Quality Habitat for 10 Decades by SOMU

SOMU	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Ashford	1,179	379	2,050	756	2,103	620	2,879	1,289	2,119	800	3,123	1,013
Big Catt	781	436	1,395	264	1,416	940	2,567	462	1,179	937	2,840	336
Busy Wild	2,479	771	3,421	1,225	4,039	1,354	5,924	2,666	4,000	1,900	6,510	1,327
Grass Mt.	3,031	555	3,944	2,003	4,448	1,892	6,777	2,003	3,729	1,279	5,421	2,003
Mineral Ck.	494	151	691	296	1,336	986	2,499	296	691	417	1,426	255
N. Fork Green Ck.	752	358	1,186	233	1,370	942	2,554	233	1,279	741	2,393	484
N. Fork Mineral Ck.	2,133	811	3,143	730	3,308	1,497	5,102	810	2,552	1,904	5,914	800
Pleasant Valley	84	31	122	37	192	142	376	58	178	63	301	104
Reese Creek	537	275	931	117	909	346	1,361	476	856	648	2,069	198

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Movement, Roosting, and Foraging (MoRF) and Higher-Quality Habitat Conditions— Another way to compare the alternatives is to examine the amount of Movement, Roosting, and Foraging (MoRF) and higher-quality habitat (high-quality nesting, Type A, and Type B) that is projected over the 10 decades (Chart 4-17), using the 1997 Habitat Conservation Plan habitat definitions (DNR 1997, p. IV. 11) and MoRF definitions (Text Box 2-2). Alternative B targets 35 percent of the dispersal management areas to be in MoRF or higher-quality habitat, represented by the dashed red line.

Chart 4-17. Acres of Movement, Roosting, and Foraging (MoRF) and Higher-Quality Habitat for All Dispersal Management Areas, over 10 Decades

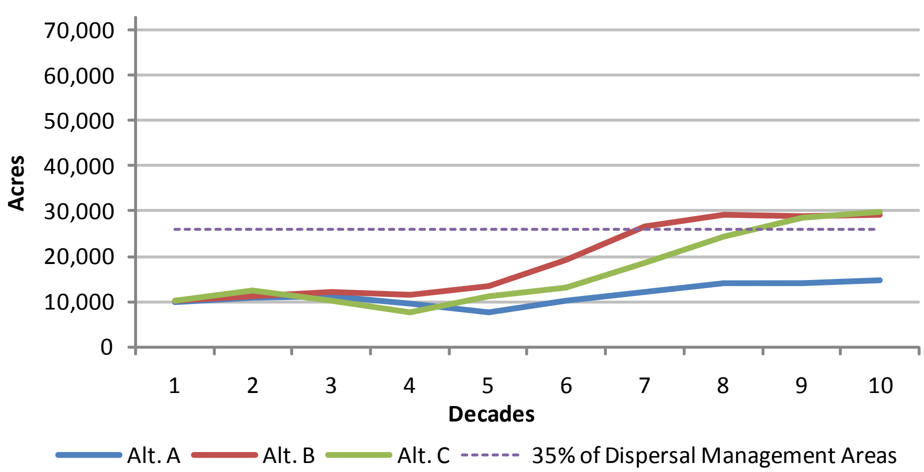


Chart 4-17 shows that the three alternatives are similar until decade four when Alternative B produces marginally more acres of Movement, Roosting, and Foraging (MoRF) and higher-quality habitat than Alternative C and moderately more than Alternative A. Alternative B reaches the 35 percent habitat threshold two decades before Alternative C, where the trend for Alternative A is relatively flat and never achieves the 35 percent habitat threshold.

As with South Puget Movement and higher-quality habitat, the average number of acres in Movement, Roosting, and Foraging (MoRF) and higher-quality habitat over the 10 decades are compared in table format. Table 4-34 reports the averages for the Northern Spotted Owl Landscapes and Table 4-35 reports the averages by Spotted Owl Management Unit (SOMU).

AREA THAT SUPPORTS NORTHERN SPOTTED OWL DISPERSAL LIFE HISTORY REQUIREMENTS

The Northern Spotted Owl Dispersal Assessment Tool (NSO-DAT) was built by DNR with assistance from the USFS and the WDFW. The NSO-DAT models for the Draft EIS (DNR 2008) were designed and prototyped using software produced by the USFS called the Ecosystem Management Decision Support (EMDS) system (Reynolds 1999). The NSO-DAT models for this Final EIS were conducted in ArcGIS (ESRI) software using Python language. The model's design focuses on three biological requirements essential to dispersing juvenile owls: movement, roosting, and foraging.

The NSO-DAT modeling project is described in detail in Appendix G, which contains five parts: 1) details of the development of the stand-level habitat evaluation model, 2) results from the model by area, 3) forest stand scores with 75 and above (Table 4-36), 4) landscape model development and results, and 5) a model sensitivity analysis. The landscape assessment model incorporates stand scores to examine habitat connectivity in both the Elbe-Tahoma and Black Diamond landscapes.

Northern Spotted Owl Dispersal Assessment Tool (NSO-DAT) Stand Level Models—These models use the EMDS modeling structure, a knowledge-based structure that combines the necessary spatial base data using fuzzy logic rules to determine the degree of truth for an assertion (Reynolds 1999; Reynolds and others 2000). These evaluations generally are arranged in a hierarchical network which breaks down the overall goal of the assessment into finer and finer sub-components until measurable indicators are reached (Reynolds 1999; Reynolds and others 2000). Indicators are measurements or aspects of the environment that serve as the most basic input into the model. Examples of indicators for dispersal habitat suitability might include tree diameters, presence of snags (standing dead trees), percent of canopy cover, and forest composition (Table 4-36). Evaluation criteria are standards with which an indicator value is compared to decide the strength of evidence. The assessment tool scores the strength of evidence (that is, the comparison between the evaluation criteria and the data) between 0 and 100 for all indicators.

Canopy cover is defined as the proportion of the forest floor covered by the downward vertical projection of the tree crowns (Jennings and others 1999).

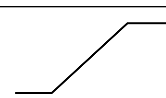
The 1997 *Habitat Conservation Plan* dispersal definition bases habitat evaluation on threshold criteria. An advantage of NSO-DAT is that it allows a more flexible criterion to produce a finer gradation of results than a strict threshold value. Evaluation criteria curves for a given indicator are constructed by determining the curve shape and value of inflection points on that curve (Table 4-37). The evaluation criteria curves are derived from a variety of sources, including literature, existing data sets, professional judgment, or a synthesis of these sources (Tables 4-34, Table 4-37, and Appendix G).

The output of the evaluation process is three stand-level models, assessing the life history requirements of dispersing northern spotted owls: 1) support for movement, 2) roosting, and 3) foraging (Figure 4-8).

Table 4-36. Example of an NSO-DAT Indicator (Forest Composition)

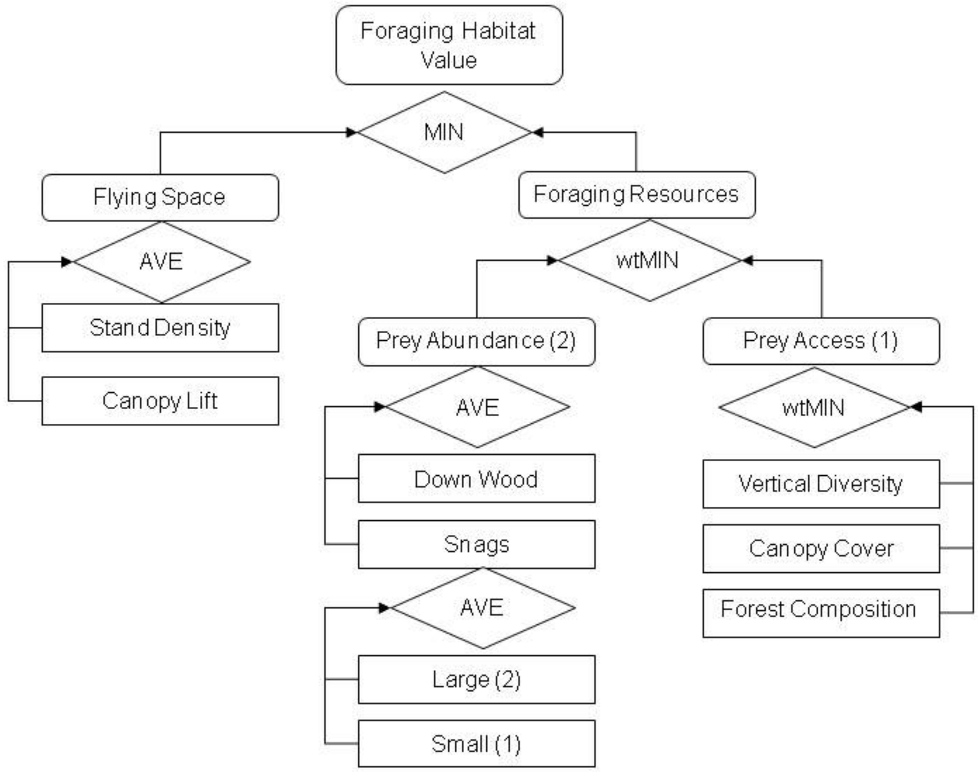
Indicator	Forest Composition
Rationale	A certain percentage of conifers in the forest is important for thermoregulation and cover from predators.
Literature	Thomas and others (1990) noted that northern spotted owls are virtually always found in conifer-dominated forests. Hansen and others (1993) found a definition of mixed conifer stands as 30-70% conifers. In contrast, Herter and others (2002) found 5-8% of roost sites on lands not classified as habitat by DNR, and these were primarily areas of high hardwood canopy cover (< 70% conifer).
Measure	Percent of stand basal area in conifers (trees > 3.5 inches dbh)
Data Source	Calculated from Forest Visualization Simulator tree lists
Criteria	SAG (1993; Hansen and others 1993) and the HCP (DNR 1997) used a minimum of 30%. The Science Team judged this too low — especially in winter, when deciduous trees provide little cover — and set the lower limit at 50% and an upper limit at 90%.

Table 4-37. NSO-DAT Indicator Evaluation Criteria Curve Example

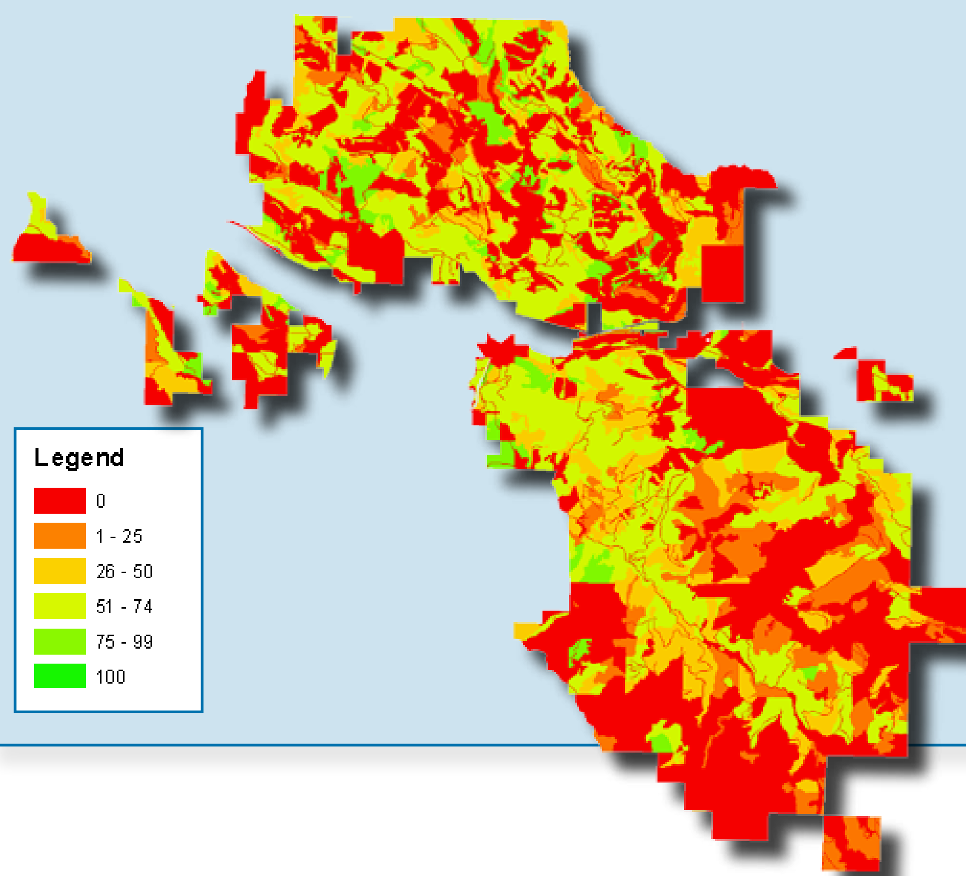
Indicator:	Forest Composition		
Shape of Curve	Evaluation Score	Thresholds	Units
	1	90	% Conifer
	-1	50	% Conifer

Northern Spotted Owl Dispersal Assessment Tool (NSO-DAT) Scores—Each evaluated forest stand receives three scores, one for each of the models: foraging, roosting, and movement. NSO-DAT scores are normalized into a common scale and range from no support (score of 0) to full support (score of 100), as shown in Table 4-36. These scores reflect the quality of the habitat according the criteria set by northern spotted owl experts, listed in Appendix G. An NSO-DAT score is essentially a habitat suitability index reflecting the conditions assessed by the combination of indicators. The higher the score, the higher the likelihood the area meets all the habitat criteria selected by the experts (refer to Appendix G for additional details). Scores can be used to produce spatially explicit maps (refer to Map 4-1). This impact analysis uses scores of 75 and above because they represent stands with strong or high support of the habitat elements needed for dispersing northern spotted owls.

Figure 4-8. NSO-DAT Model for Foraging Habitat



Map 4-1. Example Map of NSO-DAT Foraging Model Scores for Current Conditions (refer to Appendix G for other examples of NSO-DAT Model Maps)



Foraging Model NSO-DAT Scores — The average number of acres with NSO-DAT foraging model scores of 75 and above over 10 decades provides a way to compare the alternatives. This is illustrated in Chart 4-18 for all dispersal areas; Table 4-39 reports the averages for the individual northern spotted owl landscapes, and Table 4-40 reports the averages by SOMU. In Chart 4-18 the red dashed line shows the 35 percent threshold goal of attaining Movement, Roosting, and Foraging (MoRF) and higher-quality habitat.

Table 4-38. NSO-DAT Scores

EMDS Scores	Level of Support
0	No Support
1 to 25	Very Low Support
26 to 50	Low Support
51 to 74	Moderate Support
75 to 99	Strong/High Support
100	Full Support

Chart 4-18. NSO-DAT Foraging Score of 75 and Above for All Dispersal Management Areas

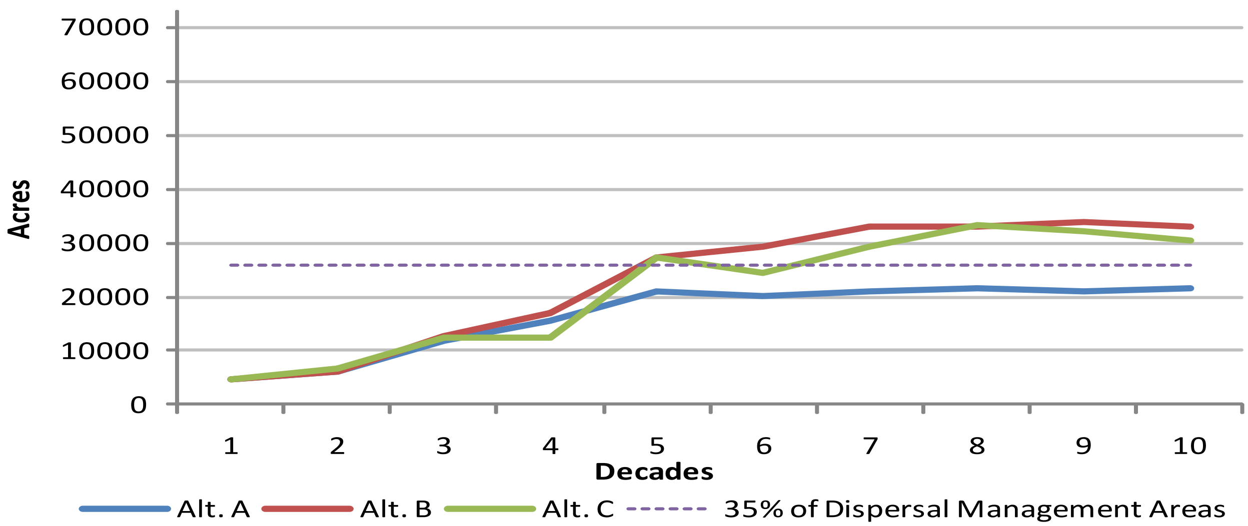


Table 4-39. NSO-DAT Foraging Scores 75 and Above for 10 Decades by Northern Spotted Owl Landscape*

Landscapes	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Elbe Hills	4,624	1,445	6,638	1,618	7,069	2,746	9,389	1,618	6,644	2,539	9,491	1,618
Tahoma	5,508	3,116	8,393	795	7,564	4,659	11,689	795	6,823	4,685	12,095	795
Black Diamond	5,524	2,307	7,923	2,024	7,515	4,115	11,967	2,024	7,074	3,658	10,742	2,039

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Table 4-40. NSO-DAT Foraging Scores 75 and Above for 10 Decades by SOMU*

SOMU	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Ashford	1,326	500	2,164	395	2,233	900	2,982	395	2,198	853	3,069	395
Big Catt	1,211	797	1,977	0	1,609	1,084	2,728	0	1,634	1,176	3,024	0
Busy Wild	3,299	981	4,475	1,223	4,837	1,853	6,408	1,223	4,447	1,721	6,422	1,223
Grass Mt.	4,271	1,562	6,056	1,877	5,764	2,953	9,377	1,877	5,143	2,449	7,884	1,844
Mineral Ck.	713	253	969	318	1,017	549	1,857	317	829	437	1,348	318
N. Fork Green Ck.	1,254	755	1,949	146	1,752	1,189	3,061	146	1,932	1,219	3,189	146
N. Fork Mineral Ck.	2,778	1,745	4,443	238	3,729	2,490	6,029	238	3,199	2,411	6,016	231
Pleasant Valley	191	102	289	29	265	192	507	29	259	171	442	29
Reese Ck.	807	341	1,085	240	1,210	583	1,693	240	1,162	715	2,046	240

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Roosting Model NSO-DAT Scores — The average number of acres with NSO-DAT roosting model scores of 75 and above in the 100-year planning period provides a way to compare the alternatives between one another. This is illustrated in Chart 4-19; averages are reported in Table 4-41 by Northern Spotted Owl Landscapes and in Table 4-42 by Spotted Owl Management Unit (SOMU). The red dashed line on Chart 4-19 shows the 35 percent threshold goal of attaining Movement, Roosting, and Foraging (MoRF) and higher-quality habitat.

Table 4-41. NSO-DAT Roosting Scores 75 and Above for 10 Decades by Northern Spotted Owl Landscape*

Landscapes	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Elbe Hills	6,888	1,920	9,576	4,781	10,091	518	10,853	9,400	10,204	500	10,998	9,576
Tahoma	9,255	1,100	11,071	7,467	12,562	2,458	15,473	7,467	12,246	1,920	13,556	7,467
Black Diamond	8,317	1,009	9,240	6,152	10,877	2,486	13,407	6,152	10,510	1,876	12,053	6,152

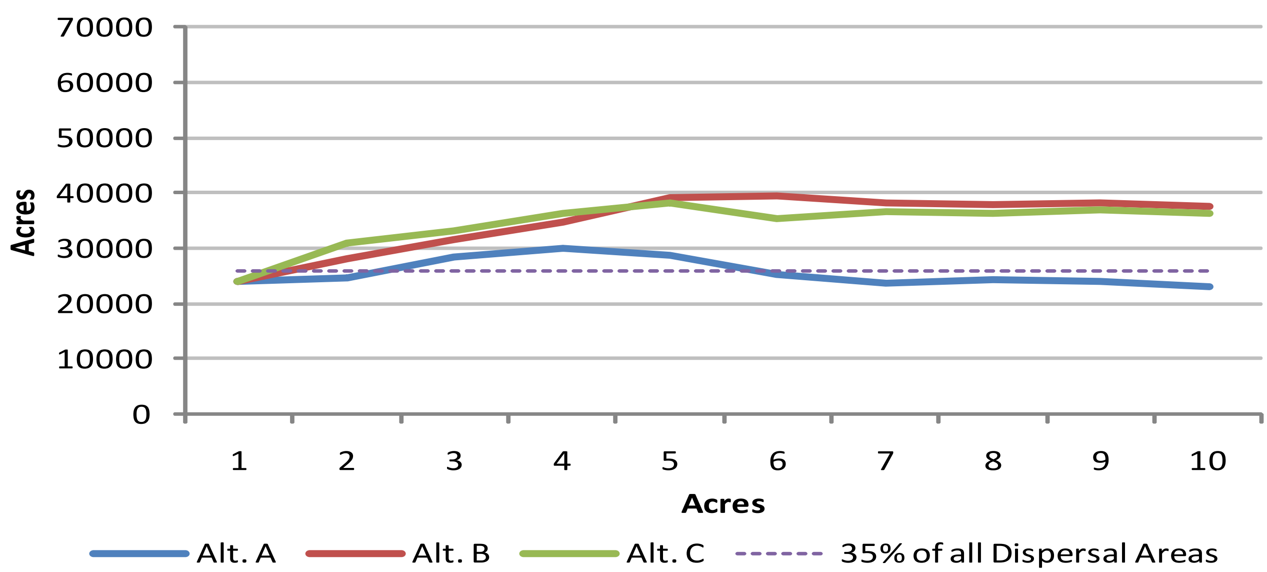
*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Table 4-42. NSO-DAT Roosting Scores 75 and Above for 10 Decades by SOMU*

SOMU	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Ashford	1,990	750	3192	1,273	3,282	204	3,658	3,010	3,303	135	3,524	3,139
Big Catt	1,938	391	2,354	1,130	2,680	677	3,586	1,573	2,807	654	3,328	1,573
Busy Wild	4,898	1,198	6,384	3,508	6,809	330	7,236	6,384	6,901	378	7,576	6,384
Grass Mt.	6,134	687	6,948	4,495	7,956	1,748	10,033	4,495	7,433	1,229	8,636	4,495
Mineral Ck.	1,108	171	1,541	952	1,856	624	2,384	979	1,371	192	1,605	979
N. Fork Green Ck.	2,183	461	2,725	1,216	2,921	814	3,678	1,499	3,077	682	3,694	1,657
N. Fork Mineral Ck.	4,922	777	5,789	3,262	6,161	1,197	7,457	3,262	6,016	1,016	6,640	3,262
Pleasant Valley	316	60	399	225	576	143	841	321	539	153	772	321
Reese Ck.	1,288	275	1,652	998	1,865	185	2,229	1,652	2,053	156	2,224	1,652

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Chart 4-19. NSO-DAT Roosting Score 75 and Higher for All Dispersal Management Areas



Movement Model NSO-DAT Scores — The average number of acres with NSO-DAT movement model scores of 75 and above over 10 decades provides a way to compare the alternatives. The red dashed line on Chart 4-20 shows the 50 percent threshold goal of South Puget Movement and higher-quality habitat. Table 4-43 reports the averages for the Northern Spotted Owl Landscapes and Table 4-44 reports the averages by Spotted Owl Management Unit (SOMU).

Chart 4-20. NSO-DAT Movement Score 75 and Higher for All Dispersal Management Areas

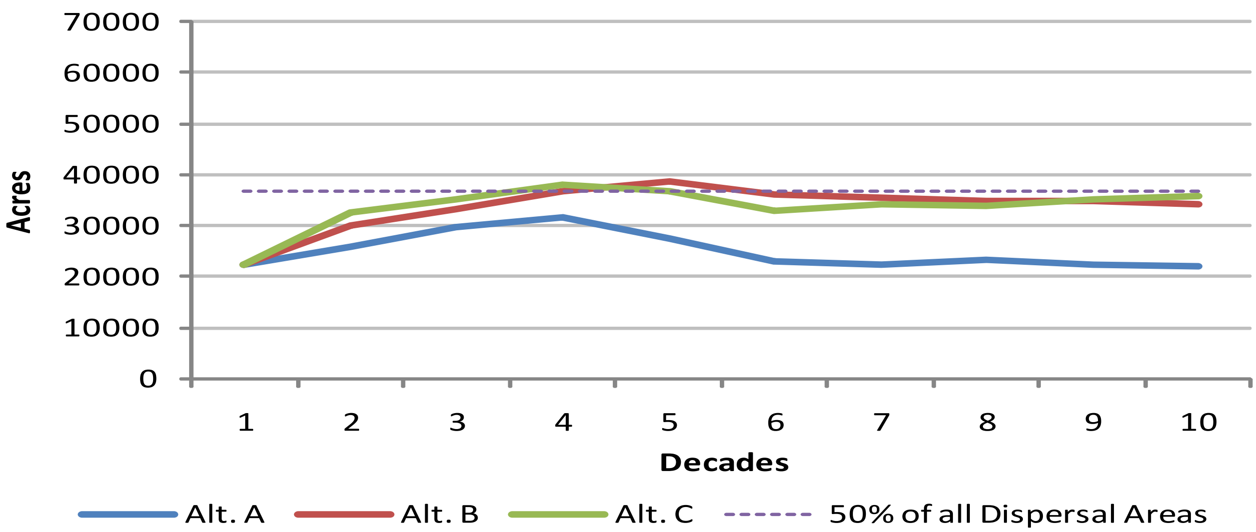


Table 4-43. NSO-DAT Movement Scores 75 and Above Acre for 10 Decades by Northern Spotted Owl Landscape*

Landscapes	Alternative A				Alternative B				Alternative C			
	Avg	SD	Max	Min	Avg	SD	Max	Min	Avg	SD	Max	Min
Elbe Hills	6,960	2,082	9,884	4,818	9,969	653	10,739	8,800	10,477	885	11,672	9,580
Tahoma	9,311	1,540	12,001	6,314	12,272	2,517	15,634	6,314	12,070	2,699	14,200	6,314
Black Diamond	8,395	1,135	10,096	5,893	10,867	2,179	12,817	5,893	10,622	1,842	12,130	5,893

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

Table 4-44. NSO-DAT Movement Scores 75 and Above for 10 Decades by SOMU

SOMU	Alternative A				Alternative B				Alternative C			
	Av	SD	Max	Min	Av	SD	Max	Min	Av	SD	Max	Min
Ashford	1,992	766	3,168	1,286	3,154	237	3,448	2,700	3,381	278	3,777	3,071
Big Catt	1,891	400	2,261	1,177	2,649	686	3,559	1,177	2,701	680	3,312	1,177
Busy Wild	4,968	1,325	6,717	3,533	6,815	423	7,362	6,100	7,096	611	7,895	6,509
Grass Mt.	6,182	806	7,435	4,489	7,977	1,592	9,912	4,489	7,556	1,201	8,764	4,489
Mineral Ck.	1,068	254	1,649	636	1,535	527	2,260	636	1,294	260	1,595	636
N. Fork Green Ck.	2,212	434	2,661	1,404	2,890	683	3,481	1,404	3,066	663	3,595	1,404
N. Fork Mineral Ck.	5,029	974	6,375	3,080	6,218	1,236	7,685	3,080	6,042	1,150	7,524	3,080
Pleasant Valley	301	78	428	193	536	142	699	193	503	167	772	193
Reese Ck.	1,322	270	1,765	1,069	1,870	249	2,199	1,422	2,086	257	2,345	1,422

*Averages (Avg), Standard Deviation (SD), Maximum acres (Max), and Minimum (Min)

HABITAT FRAGMENTATION AND CONNECTIVITY

The Northern Spotted Owl Dispersal Assessment Tool (NSO-DAT) provides a basis for evaluating stands as input into analyses which incorporates quality, quantity, and the configuration of forest stands across landscapes. DNR chose the Integral Index of Connectivity (IIC) because it integrates total habitat area, habitat quality, and connectivity between habitat patches (Pascual-Hortal and Saura 2006). This part of the analysis focuses on the differences between the management alternatives for dispersal management areas (Appendix G). The comparison of alternatives presented below reflects modeled output data. Refer to Appendix C for a discussion of how Woodstock data was used, and Appendix G for how the NSO-DAT data was modeled. The three alternatives are compared at the planning unit level with all dispersal management areas combined.

IIC scores calculated for the Elbe-Tahoma and Black Diamond landscapes include a one-mile buffer placed around the landscapes over the planning period. These IIC scores are scaled to values between zero and one; a score of one would indicate the landscape and buffer is completely covered by habitat scoring 100 on the NSO-DAT roosting and foraging models. The IIC scores were calculated separately for the two movement thresholds; 400 meters (1,300 feet) for the colonization phase (Charts 4-21 and 4-26) and 1,400 meters (4,600 feet) for the transience phase (Chart 4-22 and 4-24).

Chart 4-21. Integral Index of Connectivity (IIC) Scores for Elbe/Tahoma NSO Landscape for Colonization Phase (400m)

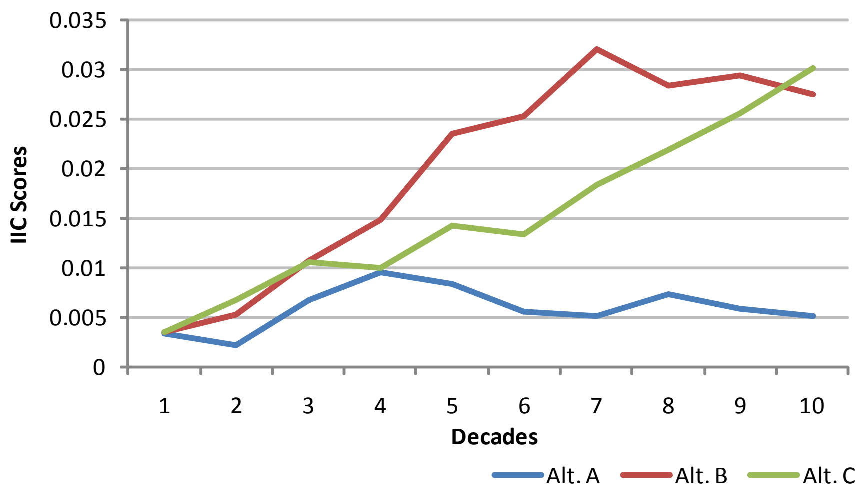


Chart 4-22. Integral Index of Connectivity (IIC) Scores for Elbe/Tahoma NSO Landscape for Transience Phase (1400m)

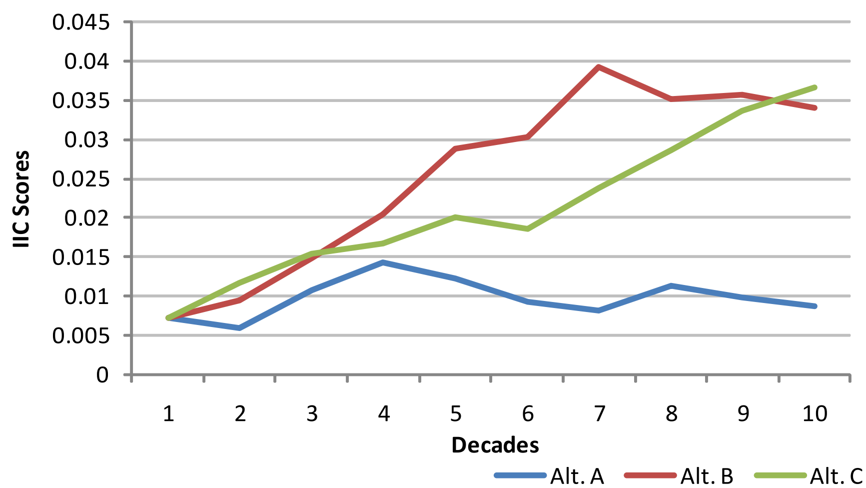


Chart 4-23. Integral Index of Connectivity (IIC) Scores for Black Diamond NSO Landscape for Colonization Phase (400m)

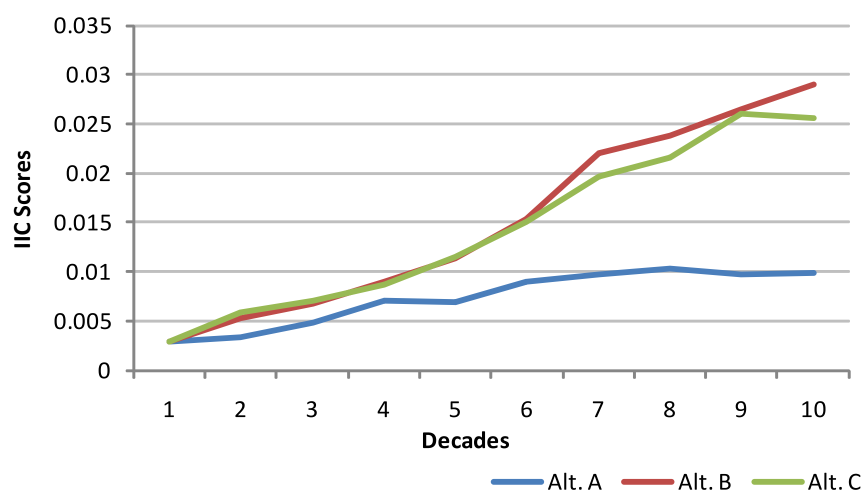


Chart 4-24. Integral Index of Connectivity (IIC) Scores for Black Diamond NSO Landscape for Transience Phase (1400m)

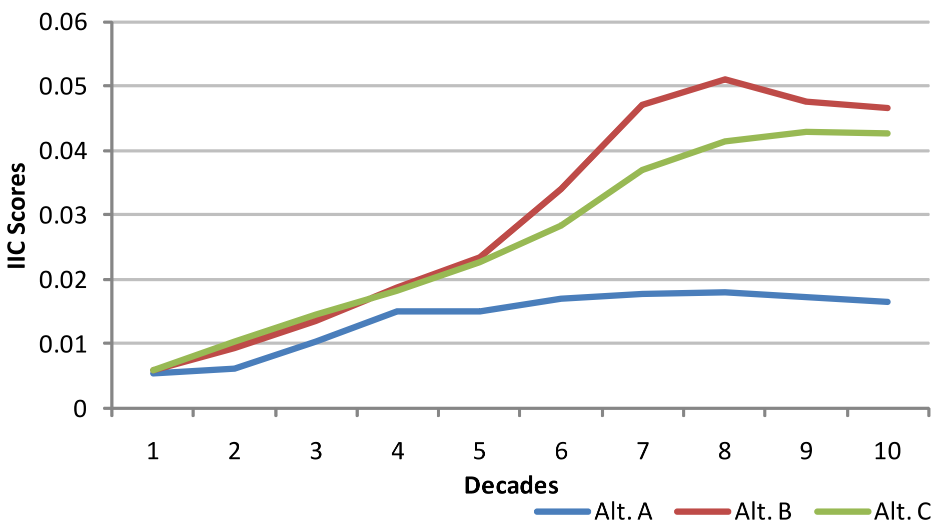


Table 4-45. Theoretical Potential Landscape Connectivity IIC Scores

	400 m (Colonization Phase)	1400 m (Transience Phase)
Elbe/Tahoma	0.2507	0.2559
Black Diamond	0.1635	0.2094

Table 4-46. Harvest Activities (by Acres) in All Status One Owl Circles on Forested State Trust Lands Managed for Dispersal (2007-2017, Woodstock model)

Harvest Type	Alternative A	Alternative B	Alternative C
Variable Retention Harvest	168	572	142
Thinning	7	5	1,207
Variable Density Thinning	1,184	470	385
Total	1,359	1,047	1,734

Theoretical Potential Landscape Connectivity IIC scores are calculated to assess the maximum IIC score that could be achieved assuming DNR dispersal management areas are completely covered by habitat scoring 100 on the NSO-DAT roosting and foraging models (Table 4-45).

ACRES HARVESTED IN THREE EXISTING NORTHERN SPOTTED OWL CIRCLES

In 2007, the harvesting restrictions in status one (reproductive) owl circles were lifted. Table 4-46 shows the amount of harvest expected in these circles under each alternative until 2017.

Northern Spotted Owl Habitat Discussion

AREA MEETING NORTHERN SPOTTED OWL HABITAT DEFINITIONS

South Puget Movement and Higher-Quality Habitat—Alternative A never reaches the 50 percent South Puget Movement habitat threshold because compared to Alternatives B and C, Alternative A targets a lower-quality habitat condition and maintains a portion of overstocked stands in the landscape for a longer time (Chart 4-16). Alternatives B and C reach the 50 percent threshold by the fifth decade; while Alternative A never reaches more than 35 percent.

Alternative C (Chart 4-16) is projected to produce marginally more acres of South Puget Movement and higher-quality habitat than Alternative B because of the forests' response to thinning activities done in the first few decades under Alternative C (Chart 4-1). Alternative B is projected to produce marginally fewer acres of South Puget Movement and higher-quality habitat, but it reduces risk by disturbing fewer forested acres in the first few decades and it results in similar habitat conditions in later decades (Chart 4-16).

Colonization phase dispersal is the overwintering period where northern spotted owls tend to remain in one place for a few months (Forsman and others 2002).

Transience phase dispersal is when northern spotted owls tend to move rapidly and randomly without an established territory (Miller 1989).

Movement, Roosting, and Foraging (MoRF) and Higher-Quality Habitat—Chart 4-17 shows little difference between the alternatives in the first four decades for Movement, Roosting, and Foraging (MoRF) and higher-quality habitat due to the current conditions. All the alternatives take time to develop the structural complexity (such as snags, down wood, and multiple-story canopies) that are key components of Movement, Roosting, and Foraging (MoRF) and higher-quality habitat. While Alternative C produced marginally more acres of South Puget Movement and higher-quality habitat, Alternative B produces more acres of Movement, Roosting, and Foraging (MoRF) and higher-quality habitat, which is likely a more beneficial habitat condition for dispersing northern spotted owls. Alternative B also reaches the 35 percent threshold a decade before Alternative C. In addition, Alternative B, when evaluating all dispersal areas, does not experience modeled dips in desired habitat conditions as Alternatives A and C do. While these dips for Alternatives A and C go slightly below current conditions, it is not known what specific effect they could have on northern spotted owls. However, it is probable that any habitat loss could be potentially adverse.

AREA SUPPORTING NORTHERN SPOTTED OWL DISPERSAL LIFE HISTORY REQUIREMENTS

NSO-DAT Foraging Model — At the scale of dispersal management areas and SOMUs, the comparison of spotted owl habitat created by the three alternatives is accomplished by looking at NSO-DAT foraging scores of 75 and greater. The foraging model was chosen because it is the most restrictive of the three NSO-DAT models. The habitat conditions for foraging are the hardest to achieve because of the requirements for snags and coarse woody debris.

Under all three alternatives, the general trend is for foraging habitat to improve, with Alternatives B and C producing more acres of northern spotted owl foraging habitat faster than Alternative A (Chart 4-18). Alternative B produces marginally more acres of northern spotted owl foraging habitat than Alternative C. In the second half of the planning period, all three alternatives start to achieve a similar trend of maintaining and not increasing the amount of habitat, most likely because of the goal of creating northern spotted owl habitat in 50 percent of the dispersal management areas.

NSO-DAT Roosting and Movement Models — The roosting and movement models have trends similar to the foraging model (Charts 4-22 and 4-23). Alternatives B and C show a steady upward trend for the first half of the 100-year planning period and then maintaining that general level for the second half. Alternative B is projected to create slightly more movement and roosting habitat than Alternative C. Alternative A shows little change from current conditions, likely because the 1997 dispersal habitat target is easily met and maintained.

A major component of the northern spotted owl movement model is adequate canopy cover. At the forest stand level, this attribute reduces the risk of predation. Predation is the primary source of mortality for dispersing owls (Forsman and others 2002; Miller and others 1997). The northern spotted owls' major predator is the great horned owl, which prefers to hunt in open areas (Johnson 1993). The second major component of the movement model is the upper threshold for the number of trees which provides adequate flying space for northern spotted owls. Alternatives B and C are projected to provide more movement habitat in all of the planning decades, with a corresponding increase in protection from predators and improved flying space for the northern spotted owl. More movement habitat will increase the spotted owls' dispersal ability to move through additional forest stands.

The amount of roosting habitat is projected to increase more rapidly under Alternatives B and C than under Alternative A. This increase in roosting habitat is likely to result in an increase in forest structures providing thermoregulation and protection from predators. The increased canopy depth and vertical diversity associated with roosting habitat provide more opportunities for owls to move vertically within a forest stand. Vertical movement helps regulate the owls' body temperature. Thermoregulation is important during summer months reducing the chance that the spotted owls will overheat (Weathers and others 2001). In addition, Buchanan (2004) suggests that because northern spotted owls often do not establish territories for a couple of years, it would benefit dispersing northern spotted owls if the landscape contained more structurally complex forest.

Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when surrounding temperature is very different.

HABITAT FRAGMENTATION AND CONNECTIVITY

The Integral Index of Connectivity (IIC) values for Alternatives B and C show a marked increase over time for both Elbe/Tahoma and Black Diamond northern spotted owl dispersal landscapes (Map 4-2, Charts 4-21 to 4-24). Alternative B produces the best habitat scores over the entire planning period, with a more pronounced difference in the Elbe/Tahoma Landscape (Charts 4-21 and 4-22). However, Alternative C achieves a similar level in the final decade. Alternative A scores are below both Alternatives B and C and generally do not increase over time (Chart 4-21 and Chart 4-22).

While the index scores for both landscapes are low (less than 0.2), the comparison to the theoretically optimal scores for such landscapes shows that the maximum possible scores do not exceed 0.26 (Table 4-45). The IIC heavily influenced by inclusion of a one-mile buffer around each landscape, an area not managed by DNR which accounts for up to two-thirds of the area. Since the scores are dominated by the contributions from the quality of the habitat area, the index numbers are small and differences between the distance thresholds are difficult to detect (Charts 4-21 to 4-24). On the Elbe/Tahoma landscapes in the first decade, the IIC score for the 1,400-meter (4,600-foot) threshold is more than double the 400-meter (1,300-foot) score. This difference declines over time as more habitat fills in, with scores in the tenth decade differing by 60 percent for Alternative A (0.005 versus 0.008) to approximately 20 percent for Alternatives B and C. Trends are similar but more pronounced on the Black Diamond landscape because the lands are more fragmented.

IIC scores for Theoretical Potential Landscape Connectivity (Table 4-45) are calculated to assess the maximum IIC score that could be achieved, assuming DNR dispersal management areas were completely covered by habitat that scored 100 on the NSO-DAT roosting and foraging models. This is a modeled measure of the theoretical potential of connectivity rather than an actual potential, not all DNR lands can achieve perfect habitat conditions. It is a reference point for IIC scores and helps the inference of the influence of dispersal management areas in buffered, modeled landscapes. Also, it is important to note that it is not known if the difference between the maximum possible scores and the scores resulting from the alternatives is ecologically significant. The scores used in this analysis are for comparisons between the proposed alternatives.

ACRES HARVESTED IN EXISTING NORTHERN SPOTTED OWL CIRCLES

Alternative C has the greatest number of acres harvested during the first decade within existing spotted owl circles, but the activities proposed are intended to increase structural diversity and improve habitat in the future (Table 4-46). Alternative A has the second highest number of acres harvested in the first decade. While Alternative B has the lowest number of acres harvested in the first decade, it also has the highest number of variable retention harvest activities. Variable retention harvest is generally conducted in northern spotted owl management areas when a forest stand is in a condition that is not contributing toward habitat goals and less intensive management techniques (such as thinnings) are not likely to change the current habitat condition. In 1996, DNR analyzed these types of impacts on northern spotted owl circles as part of the development of the 1996 *EIS for the 1997 Habitat Conservation Plan* (p. 4-50, Table 4.2.15). As part of the HCP implementation, DNR moved from management by owl circles to conservation of habitat on a landscape scale. The current alternatives fulfill this landscape approach.

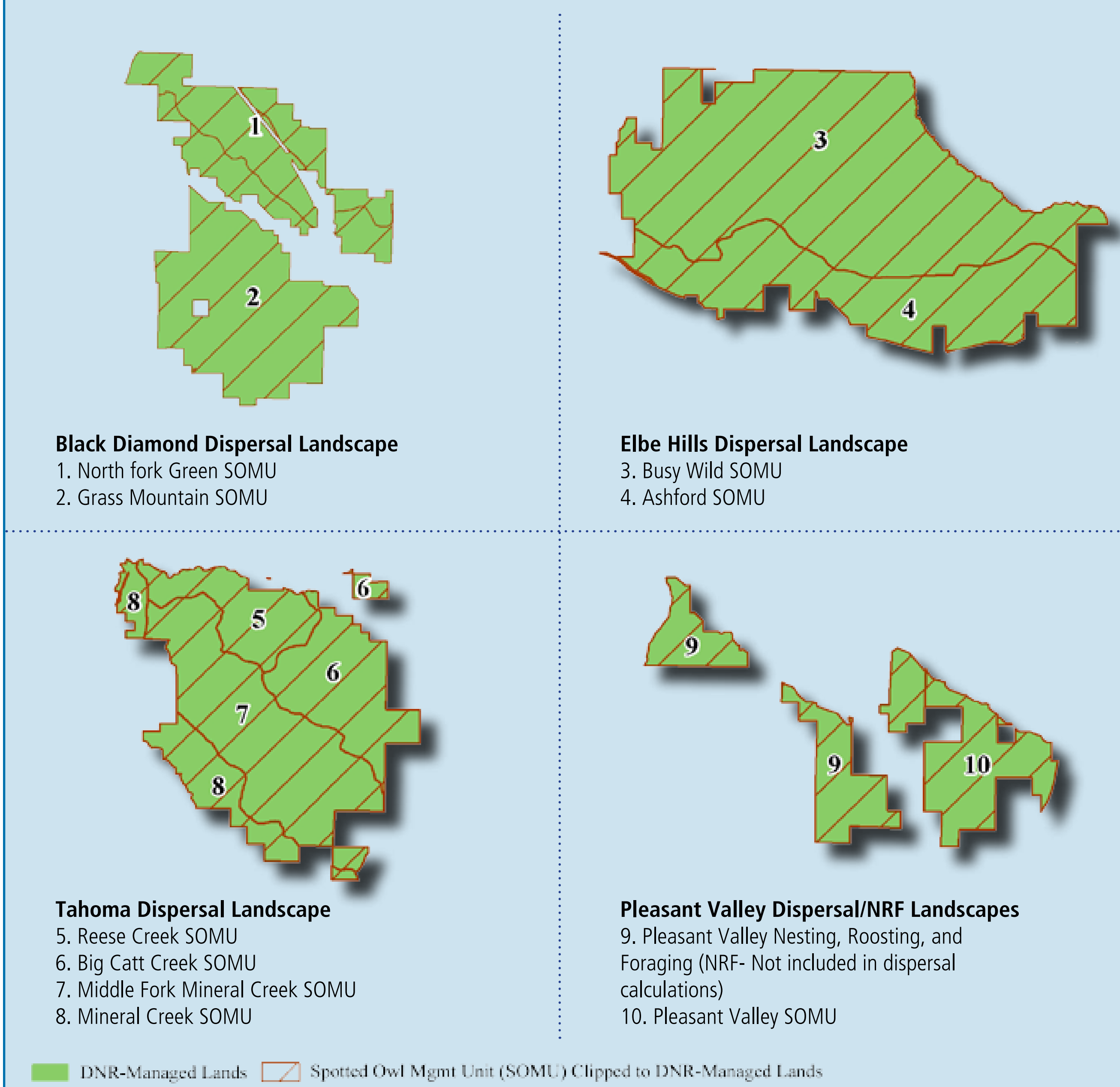
EFFECTS ON INTERACTION BETWEEN BARRED OWLS AND NORTHERN SPOTTED OWLS

Over the past 50 years, the barred owl has rapidly expanded its range in North America and may now be entirely sympatric with the northern spotted owl (Courtney and others 2004). However, very few studies have been designed specifically to evaluate these interactions (Courtney and others 2004), and no studies have been completed which analyze the effect of habitat changes on them. Gutierrez and others (2006) found theoretical evidence for strong competition between barred and northern spotted owls. Hamer and others (1988, 2007) found that barred owls use the same habitats as northern spotted owls as well as habitats not used by northern spotted owls. Northern spotted owl surveys in 2005 and 2006 on DNR-managed lands in southwest Washington incidentally obtained 533 barred owl detections, including 152 detections of barred owl pairs (Minkova 2007). While these detections do not represent individual birds (some birds were detected more than once), when compared to barred owl detection rates in the same area in the late 1980s, this information shows a dramatic increase in barred owl detections in the last two decades (Minkova 2007). For a similar period of time, the number of occupied spotted owl sites on DNR-managed areas in the surveyed area decreased from 29 to six. While the study was not designed to prove causal relationship between the barred owl and northern spotted owl abundance, the increase in barred owl presence may be a negative influence on spotted owl occupancy. Until more scientific information is available defining differences in habitat use by the two species, it is not possible to evaluate the impacts of the alternatives on their potential competition.

EFFECTS OF CHANGING FROM SOMU(s) TO LANDSCAPES

Alternatives B and C propose changing the spatial unit used to account for habitat thresholds from SOMUs, which are modified 1997 WAUs, to a landscape scale (p. 29). The spotted owl landscapes are an aggregation of SOMUs. Refer to Map 4-2.

Map 4-2. Aggregation of Northern Spotted Owl Management Units*



*The SOMUs for this map were clipped to only include dispersal management areas.

When evaluating the proposed change in management scale, the assessment methods of NSO-DAT and acres meeting desired habitat conditions (South Puget Movement and Movement, Roosting, and Foraging and higher-quality habitat) show there is no negative effect on the number of acres of habitat created. This is somewhat confounded since Alternatives B and C target habitat conditions in a distinctly different way than Alternative A. To account for the possibility that habitat conditions created under the three alternatives confound the results, another model run of Alternative B was conducted which targeted habitat at the SOMU scale. A comparison of these results showed that different management scales had little effect on increasing or decreasing the projected amounts and distributions of habitat (Appendix G). Shifting the accounting of habitat to a larger scale (from SOMU/WAU level to landscape level) does not appear to affect fragmentation or connectivity adversely as measured by IIC scores (Appendix G).

SENSITIVITY OF NSO-DAT MODELS TO UNCERTAINTY

Modeling and projecting northern spotted owl dispersal habitat is subject to a number of uncertainties, including knowledge of the owls' habitat needs. The NSO-DAT use of evaluation criteria curves instead of single thresholds is one way the model addresses the uncertainty of the northern spotted owl's habitat needs. Another way to address uncertainty is to vary the evaluation criteria and other model inputs and re-run the model. In consultation with a WDFW representative, DNR identified four principal areas of uncertainty; three in stand characteristics (snags, coarse woody debris, and their combination) and one indicator at the landscape level (the costs of moving through unfavorable habitat types). These changes were applied to the base NSO-DAT model one at a time (for example the evaluation criteria for snags were changed) and the model was re-run. Comparisons of the resulting landscape scores showed variation from the baseline model by -26 percent to +41 percent in the initial period and -26 percent to +15 percent in the final planning period. The largest increase in scores was under the scenario where the down wood requirement was dropped from 5,700 cubic feet per acre to 2,400 cubic feet per acre, and the largest decrease occurred in scores under the scenario where the cost of moving through unfavorable habitat types was increased. Further details on the sensitivity analysis can be found in Appendix G.

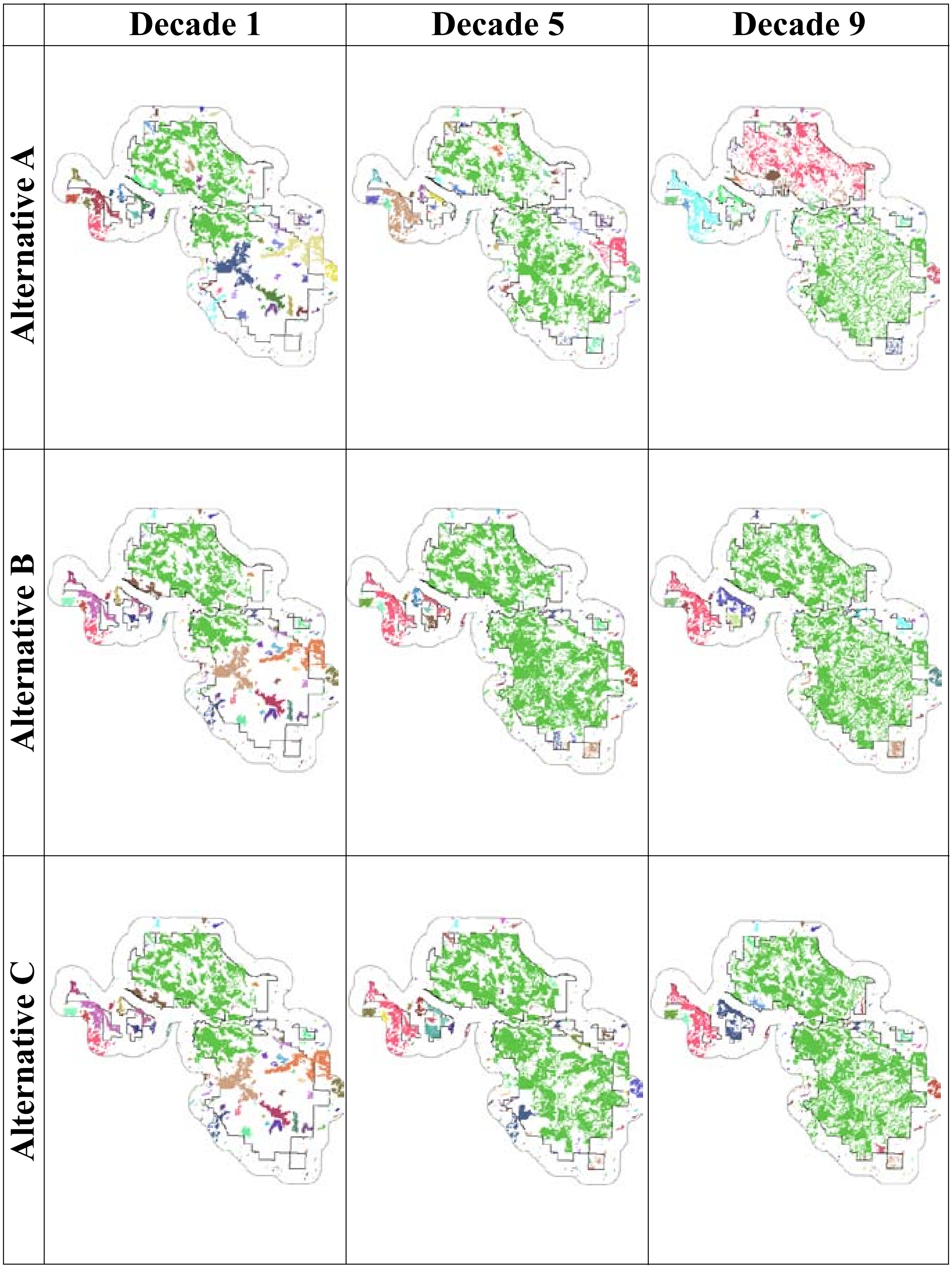
Northern Spotted Owl Habitat Cumulative Effects

According to the indicators for areas meeting habitat definitions and NSO-DAT model scores, Alternatives B and C provided more northern spotted owl habitat faster than Alternative A (Chart 4-16 to Chart 4-20, Tables 4-32 to 4-35, Tables 4-39 to 4-44).

The cumulative effects of management actions upon spotted owls are defined by the ability of dispersing owls to move through the landscape. Dispersal management areas are located on forested state trust lands to help maintain the species' distribution and facilitate its dispersal. The extent to which a landscape facilitates dispersal depends on not only the habitat quality of forest stands and their size, but also on their spatial configuration. If habitat is available on only one side of a management area, owls may be unable to disperse successfully to other locations in that management area.

This landscape-level modeling approach builds on the forest stand-level assessment models by considering the spatial arrangement of the evaluated DNR-managed forest stands in relation to one another and on adjacent non-DNR lands. The DNR landscape model uses a graph-theoretic approach which involves identifying suitable patches of roosting and foraging habitat and calculating the distances between them and comparing them to the estimated dispersal capability of the species to assess the landscape's connectivity (Bunn and others 2000; Singleton and others 2002; Theobald 2002). DNR incorporated the concept of varying landscape permeability (Singleton and others 2002) into the landscape model; the concept evaluates the higher cost to an animal of moving through areas of poor habitat rather than areas of better habitat. Other terms used in the literature that relate to landscape permeability include landscape resistance and cost pathways. Refer to Appendix G for a detailed explanation of the methodology used.

Figure 4-9. Colonization Phase Habitat Connectivity (400m) in the Elbe-Tahoma Landscape*



*Connected Habitat Shares the Same Color; DNR-Managed Lands are Outlined in Black and a One-mile Buffer Zone is Outlined in Grey

Elbe/Tahoma— Figure 4-9 demonstrates estimated connectivity between habitat patches in the Elbe/Tahoma landscape. The colored areas are habitat patches with NSO-DAT roosting and foraging scores that are greater than zero. The ability of northern spotted owls to move between these habitat patches was estimated by using the average daily movement distances from the transience (1,400 meters) and colonization (400 meters) dispersal phases (Forsman and others 2002; Appendix G). Patches in the same color represent habitat clusters (groups of patches) with links between them that are less than the respective (transience or colonization) movement distance. By the end of the planning period, all alternatives show better habitat connectivity for dispersing spotted owls, although Alternative B has more connections than Alternative A.

The IIC values for the Elbe/Tahoma (Charts 4-24 and 4-25) show that Alternative B provides the highest values for the majority of the planning horizon and Alternative C only achieves the same level at the end of the planning horizon.

Black Diamond— Figure 4-10 demonstrates estimated connectivity between habitat patches in the Black Diamond landscape. The Black Diamond landscape begins decade one with isolated clusters of habitat but by the middle of the planning period, the patches are large enough to be combined into larger clusters. Alternative C has a slightly more connected habitat clusters than Alternative B and Alternative A has the fewest.

The IIC values for Black Diamond (Charts 4-23 and 4-24) show that Alternatives B and C are similar, with Alternative B having marginally higher IIC values than Alternative C. Alternative A, which does not see a substantial increase in habitat connectivity over time (Charts 4-23 and 4-24), would provide landscapes with only marginally better connectivity than current conditions. Alternatives B and C would have higher levels of connectivity, potentially facilitating northern spotted owl dispersal and recovery.

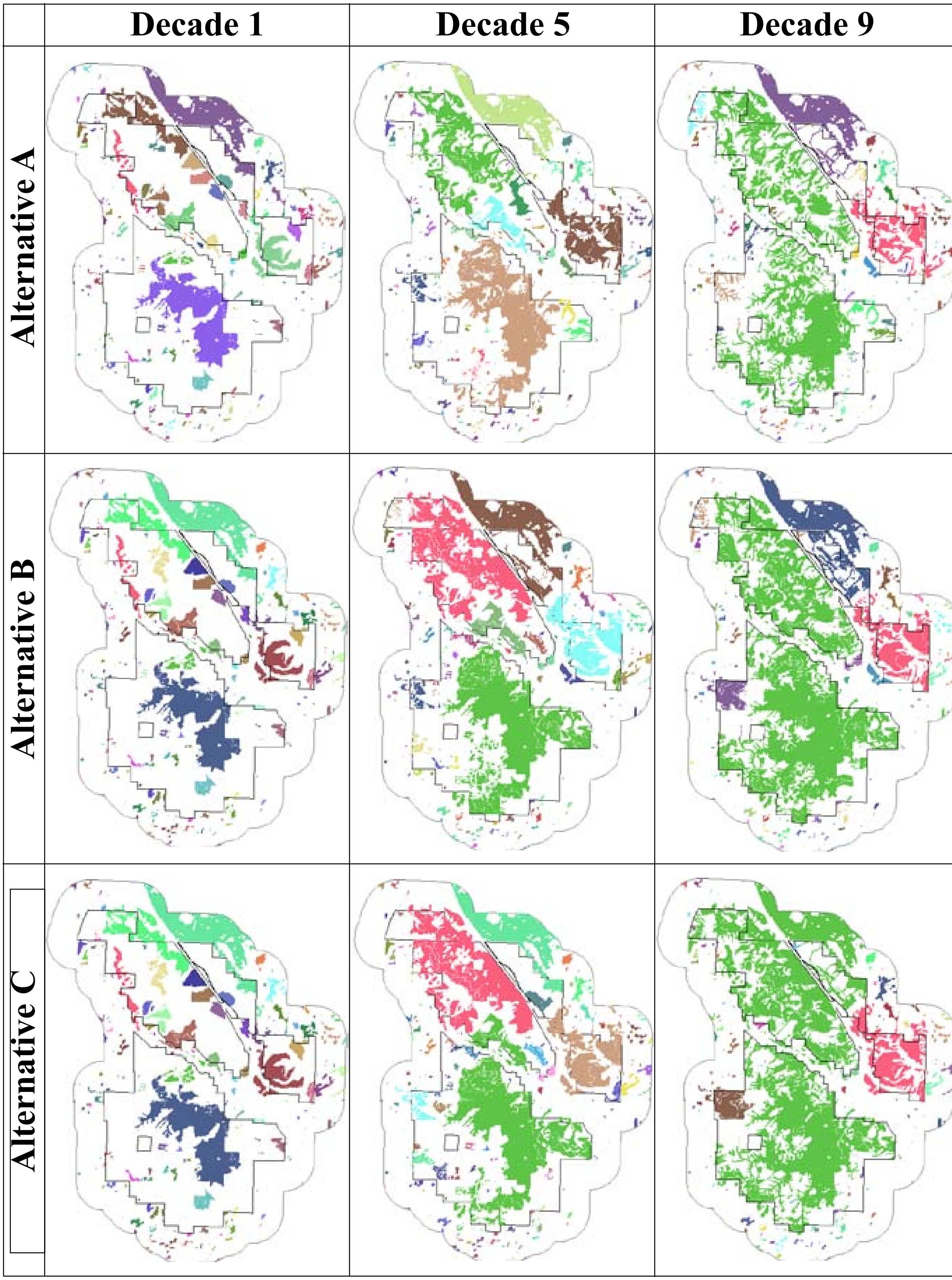
Similar to IIC values, the Landscape Coincidence Probability (LCP) index assesses habitat connectivity while integrating total habitat area and quality (refer to Appendix G for a detailed explanation of the methodology used). Yet, rather than examining overall connectivity, LCP measures the probability that two randomly placed points in the landscape belong to the same patch or component (refer to Appendix G for a discussion of Graph Theory). For this particular analysis, the index answers the following question: *What is the probability that two northern spotted owls randomly placed within our landscape (in either habitat or non-habitat) could find each other*? Like IIC, LCP is also bounded between zero and one but unlike IIC, LCP sets a value to represent probabilities.

In part because they are correlated, LCP values have trends similar to the IIC scores (Charts 4-21 to 4-24). Compared to Alternative A, Alternatives B and C indicate an increasing probability over time that northern spotted owls are more likely to be in the same group of habitat patches. The ecological significance of these probabilities is not known, but it can be inferred that higher LCP values increase the probability of a successful dispersal event, since greater LCP scores suggest larger and/or better-connected habitat through time. Landscapes generated under Alternative A are not as well connected and/or contain less habitat; therefore, under this alternative, there is less likelihood of owls finding each other or of moving successfully through the landscape.

Northern Spotted Owl Habitat Mitigation

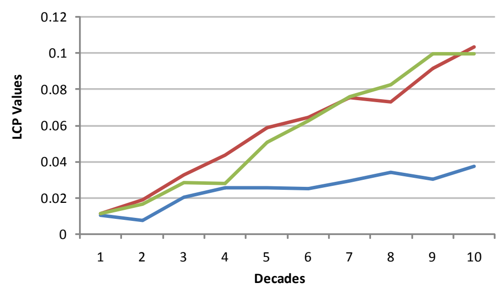
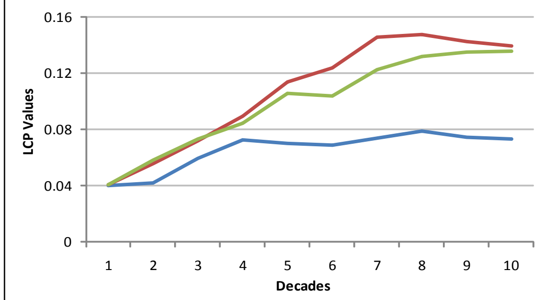
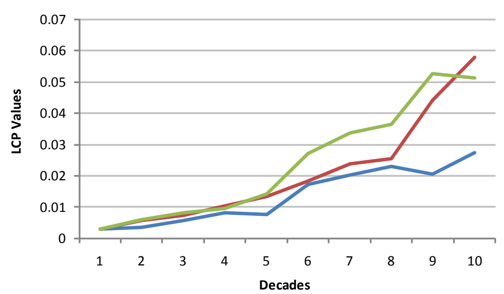
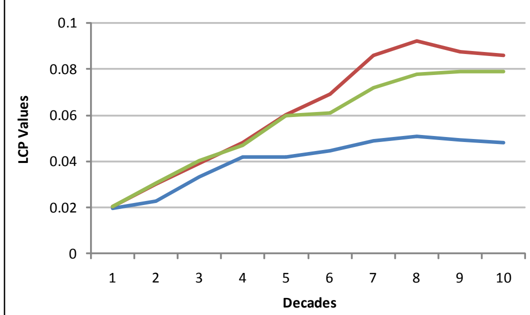
Alternatives B and C propose moving from the Spotted Owl Management Unit scale (SOMU) to a landscape scale to meet the goal of developing 50 percent DNR-managed forest lands in desired habitat conditions (each alternative has different desired habitat conditions; refer to Chapter 2, p. 29 and Map 4-1). Currently, under Alternative A, there is no requirement for monitoring the configuration of habitat. The 1997 *Habitat Conservation Plan* depends upon the SOMUs achieving 50 percent of desired habitat conditions to provide the spatial distribution. These SOMUs are different sizes, with no limitations on where habitat is located in each SOMU. It is not known if habitat is becoming more or less connected over time. As mitigation for changing from the SOMU scale to the landscape scale, it is proposed to monitor the distribution of the habitat created by tracking IIC values. The

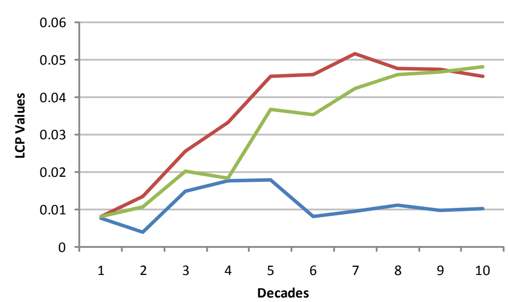
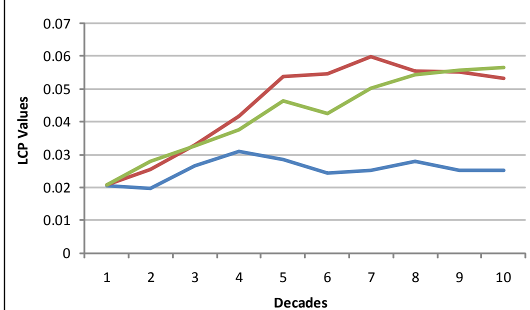
Figure 4-10. Colonization Phase Habitat Connectivity (400m) in the Black Diamond Landscape*



*Connected Habitat Shares the Same Color; DNR-Managed Lands are Outlined in Black and a One-mile Buffer Zone is Outlined in Grey

Figure 4-11. Landscape Coincidence Probability (LCP) Values for Colonization and Transience Phases in Northern Spotted Owl Landscapes

<table>
<tr><th>Area</th><th>Colonization Phase (400m)</th><th>Transience Phase (1400m)</th></tr>
<tr><td>All NSO Dispersal Landscapes</td><td>
</td><td>
</td></tr>
<tr><td>Black Diamond NSO Landscape</td><td>
</td><td>
</td></tr>
<tr><td>Elbe Hills/ Tahoma NSO Landscape

Alt. A
Alt. B
Alt. C</td><td>
</td><td>
</td></tr>
</table>

monitoring would require that the distribution of habitat not go below current levels. (These index values were chosen as a threshold because there are no scientific recommendations for dispersal habitat configuration, although the assumption is that more connected landscapes of higher-quality habitat would benefit dispersing northern spotted owls more than disconnected low-quality habitat.) The projections are that habitat connectivity will increase under Alternatives B and C and remain similar to current levels under Alternative A (refer to Charts 4-21 to 4-24).

The modeling and analysis results of the new owl strategy (Appendix G) show that its implementation does not indicate probable, significant, or adverse environmental impacts that are not already mitigated by the strategies in the 1997 *Habitat Conservation Plan.*

Monitoring of connectivity values for these areas will be documented in the *Habitat Conservation Plan 10-Year Comprehensive Review Report*. Refer to Appendix G for a description of proposed IIC values, habitat configuration, and monitoring strategies.

Air Quality

This section contains an analysis of the impacts of DNR's management activities on air quality and a discussion of mitigation measures. Potential impacts caused by other forms of air contamination and natural factors are discussed in Chapter 3 (p. 113).

Criteria and Indicators for Air Quality

DNR follows national air quality standards established by the Clean Air Act (1970) and the Environmental Protection Agency. DNR will continue to comply with new standards at both a state and national level as they change.

For the purposes of this analysis, the estimate of carbon emissions of diesel fuel used to haul timber removed from DNR-managed state trust lands to a processing site or a mill is a primary indicator of air quality.

Results for Air Quality

This section describes the methodology and analysis involved in calculating carbon emission estimates from merchantable timber volume for all alternatives over the 100-year planning period.

Chart 4-25 shows that the merchantable timber volume being removed under Alternative A is the highest of the alternatives, followed by Alternative B, and then Alternative C. Since this measurement is the basis of all other calculations in this section, it is important to point out that although Alternative B has a higher overall removal level, it is more consistent than Alternative C, which peaks much higher (Decades 4-5) and dips much lower (Decades 6-8).

It is assumed that each logging truckload consists of 4.5 thousand board feet per trip and each trip has two parts: one way empty and one way with a full load. Using decadal estimates for the WAUs with more than 20 percent DNR–managed lands, DNR divided the average amount of timber removed per decade by 4.5 thousand board feet, giving the number of haul trips per decade. DNR then divided these values by 10 to get the average number of haul trips per year.

A typical semi-truck achieves a fuel efficiency of approximately six miles per gallon for diesel fuel. In the planning unit, the average haul distance per truckload is 50 miles, or 100 miles round-trip. Therefore, for every 4.5 thousand board feet hauled to a mill, nearly 17 gallons of diesel fuel is used. Using the annual haul trip estimation, DNR multiplied the value by 17 (gallons used per 100 mile haul trip) to find the number of gallons of diesel consumed per year on average.

According to an Ecology estimate, each gallon of diesel burned releases 22.38 pounds of carbon dioxide into the atmosphere. After creating an estimate of average fuel consumption per year, the estimate was multiplied by 22.38 (pounds of carbon dioxide emitted per gallon of diesel), producing estimates of overall carbon dioxide emissions per year from hauling timber from forested state trust lands in this planning unit. The information is shown in Chart 4-26, a box plot that shows many details of the 10-year carbon emission data. Each box represents the middle 50 percent of values for the 10 decades; the larger the box, the greater the deviation in values. Therefore, Alternative C has a greater variability of values than Alternatives A and B. The values of a box plot are

Chart 4-25. Merchantable Timber Volume in Million Board Feet (mmbf)

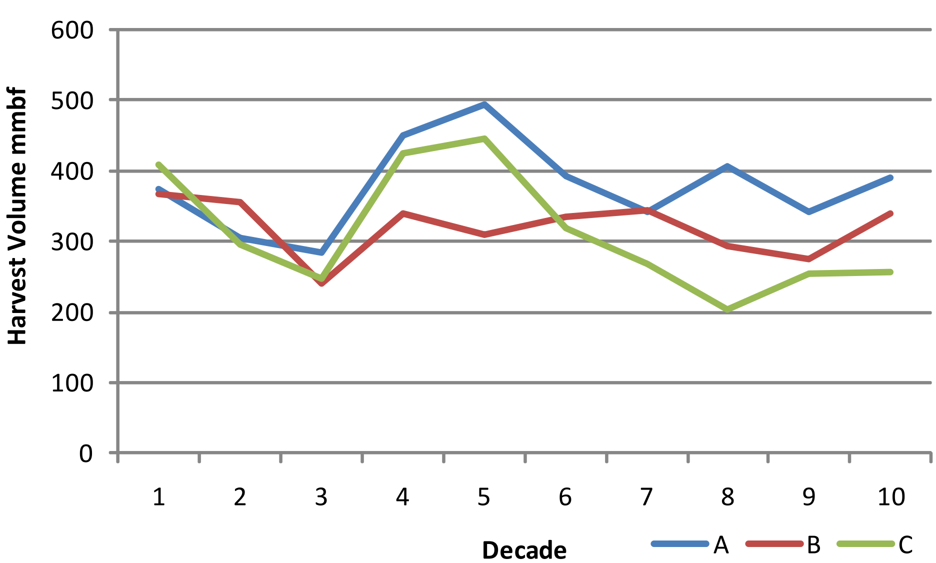
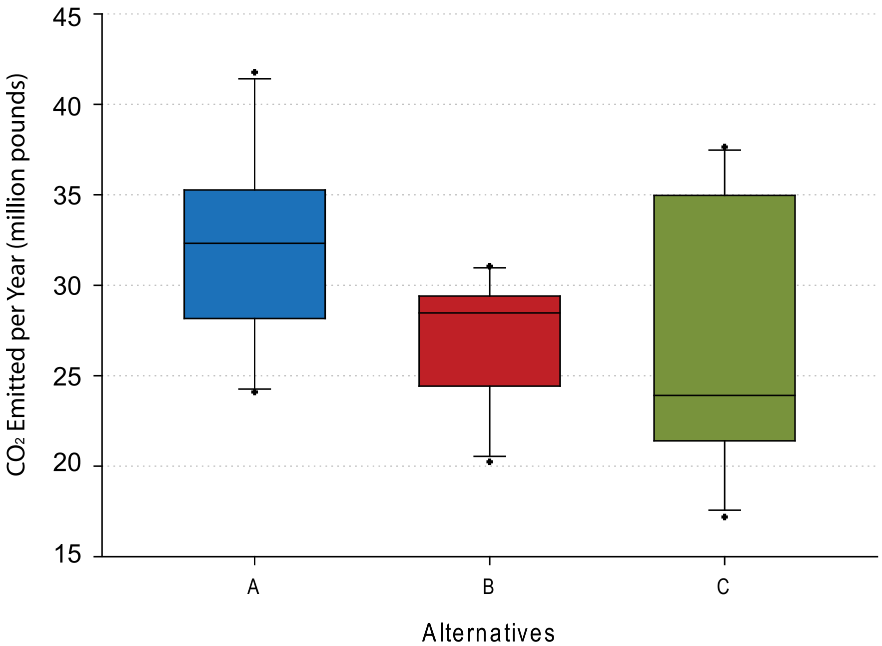


Chart 4-26. Carbon Emissions in Millions of Pounds over 10 Decades for All Alternatives



shown in Figure 4-4; the lines (whiskers) extend to the 10th and 90th percentiles. The dots represent the fifth and 95th percentiles.

By showing estimates for decade one with the mean and standard deviation, the coefficient of variance (Cv) can be determined, which shows the continuity in the data (or lack thereof, in the case of Alternative C) for a specified length of time. Table 4-47 shows estimated values for the first decade's carbon emissions, the 100-year mean, standard deviation, and coefficient of variance. The coefficient of variance places a comparable value on each alternative's average deviation from the mean, where higher values show greater variation in the sample. As Chart 4-26 shows, Alternative C has a much higher coefficient of variance than either Alternative A or Alternative B, although it has the lowest overall mean.

Coefficient of Variance is equal to the standard deviation divided by the mean for all ten decades in the planning period.

Table 4-47. Estimated Pounds of CO_2 Emitted per Year

Alternative	Decade 1	Mean	Std dev	Cv
A	31,583,329	31,984,059	5,113,533	0.16
B	31,052,205	27,036,919	3,213,301	0.12
C	34,651,565	26,443,479	6,779,094	0.26

Direct, Indirect, and Cumulative Impacts for Air Quality

The coefficient of variance values show little difference between Alternatives A and B for carbon emissions, as seen in Table 4-46, representing little variation between decades. Alternative A has the highest emissions overall because more timber is harvested in the long term; Alternative B is consistently lower than either of the other alternatives. While Alternative C has the greatest variation in emissions over the planning period, because it removes the lowest timber volumes through a higher proportion of thinning, it has the lowest mean under all three alternatives (Table 4-2). Although the standing timber volume is the same under Alternatives B and C, more harvestable volume is left standing because of the added requirements for northern spotted owl habitat (p. 105). Based on the mean values in Table 4-46 (carbon emission), Alternative C has the lowest overall emissions, but spikes in certain decades (Chart 4-26) mean the alternative has the highest level of emissions in those decades. These spikes could pose a threat to air quality, although they are infrequent, their effects could be marked in those decades.

None of the proposed management alternatives creates new policies or procedures related to air quality. Impacts related to air quality would result from the projected forest management activities within each of the alternatives (p. 124). The alternatives differ slightly in their effects on air quality, but none has a potential for significant environmental impacts relative to current conditions, beyond those anticipated and disclosed in the 1996 *Draft Environmental Impact Statement for the Habitat Conservation Plan*.

The Governor's Climate Change Framework legislation[11, 12] will require certain entities to report carbon emissions from motor vehicle fleets that exceed a certain threshold (5,511,500 pounds of carbon per year) by 2010. From the calculations above, hauling timber from state trust lands falls well below this threshold although the total emissions do not include those of the personal vehicles that belong to people who travel to and from work or recreation sites along forest roads.

ROADS

The management alternatives presented in this analysis are likely to have similar amounts of roads. Road mileage and trip numbers increase and decrease with distance from a mill and the amount of timber hauled. Therefore, more thinning activities likely will result in more temporary roads and greater traffic for short periods on them, increasing the amount of airborne dust and particulates (p. 164).

RECREATION

The amount of recreation in these areas has increased over the past decade and the trend is likely to continue as air quality diminishes in urban settings. Refer to *Indicators Used to Measure Recreational Impacts* (p. 165).

Through the multiple-use concept7, DNR allows the public to access most roads within the landscape. Public access increases overall road usage. DNR road quality meets or exceeds the standards set by the Washington Forest Practices Board, which recognizes maintenance as the best way to limit airborne contaminants from logging roads. Management of public access and road maintenance will not differ between alternatives.

Off-road vehicles used for recreation are another concern for air quality. These vehicles are not held to the same emissions standards as vehicles registered for and operated on roads. They run on inefficient two- and four-stroke engines that emit carbon monoxide, hydrocarbons, nitrogen oxide, and particulate matter which are a concern for human health and contribute to greenhouse gases (US DOT 2001).

MITIGATION

Dust abatement practices (such as spraying water or dust abatement materials on road surfaces or restricting use), especially in dry areas, can mitigate air quality impacts under all alternatives.

Another way to mitigate impacts to air quality is to keep prescribed burning levels below the anticipated 1997 HCP level (DNR may burn 500 to 1,000 acres per decade for site preparation, and 300 to 1,000 for wildfire risk reduction). The total amount of prescribed burning is likely to remain below the level anticipated in the 1997 HCP.

Carbon Sequestration

Estimating the effects of the proposed alternatives on carbon sequestration is complex. Many factors affect sequestration and storage; some components of an alternative may contribute to a net removal of carbon, while other components may offset those gains.

Expected Natural Succession

Forest stands follow successional development pathways depending on their initial state and the disturbances that occur over time. The amount of carbon sequestered in forests depends on the balance between wood biomass growth and carbon loss as a result of tree mortality and decay. Some trees in the Ecosystem Initiation and Competitive Exclusion stand development stages (refer to Text Box 3-1) will die over the next two to four decades (representing natural mortality losses). However, the remaining trees will continue to grow and sequester additional carbon. Stands in Competitive Exclusion, Understory Development, and Biomass Accumulation stages are acquiring more carbon than they are losing to mortality. More structurally complex stands, such as Niche Diversification and Fully Functional forests, maintain a carbon balance (neither gaining nor losing carbon).

Harvesting timber for dimensional lumber is a method of long-term storage of carbon. Thinning may increase the total amount of sequestered carbon in a forest if the thinned material is used as dimensional lumber. In unthinned forest stands, some trees die when competing for light, water, and nutrients. The carbon from these trees is released back into the system and can, through decomposition, be released into the atmosphere (McPherson and Simpson 1999).

Differences Based on Stand Development Stages

Alternatives B and C rely more heavily than Alternative A on thinning as a harvesting method. Thinning converts a portion of the trees that would die into lumber, thereby increasing the net amount of stored carbon. Carbon stored in structural lumber is likely to last much longer than in decaying trees. Alternatives that concentrate tree growth in crop trees—which are harvested and converted to wood products—may allow carbon to be stored for longer periods.

Although total acres for variable retention harvests are less than for thinning under all alternatives, Alternative A uses variable retention harvesting as a primary means to achieve harvest volume targets. Variable retention harvesting generally leaves large, healthy trees on site and is followed by replanting. The modeled data trends (Appendix D) show that in all land classes, Alternative B has the most consistent acreages in Ecosystem Initiation throughout the 100-year planning period, while Alternatives A and C decrease initially and recover in about the fifth decade. Young, vigorously growing trees in the Ecosystem Initiation stage of stand development are rapidly performing photosynthesis and storing carbon from the air. Other stand-dynamic trends are similar between alternatives in upland areas.

There are more obvious differences in stand-dynamic trends for GEMs than for Uplands and Riparian. These differences are most likely linked to the diversity of thinning options for Alternative B and, especially, Alternative C. Over the 100-year planning horizon, the number of acres in Competitive Exclusion and Understory Development stages varies the most among the alternatives. Opening up these forest stands may remove some large trees used for building materials and allow other trees to increase their diameter and grow faster.

Under Alternatives B and C, many stands have longer overall rotation lengths because of intermediate thinning strategies. These methods could increase above-ground carbon storage over Alternative A, which has shorter total rotation lengths and a lower amount of thinning.

Table 4-48. Quadratic Mean Diameters (QMD) for All Alternatives

QMD	A	B	C	Total
0-15	140,230	142,898	136,529	419,657
15-30	157,618	174,346	168,726	500,690
30- 45	3,870	4,148	3,769	11,787
Total	331,128	322,372	309,972	963,472

Alternative A is the lowest producer of mid-range-diameter trees (Table 4-48) but produces large trees similar to Alternative C; the trends are also very similar to Alternative B. Alternative A also harvests more timber (Chart 4-24) than Alternatives B and C, but uses less thinning to reduce within-stand competition and tree mortality. More trees potentially could die and decay under Alternative A, releasing carbon into the atmosphere. Although Alternative B has a higher overall removal level, its decadal removal levels are more consistent than Alternative C, with higher peaks in the fourth and fifth decades and much lower harvest levels in decades six to eight. The higher volumes of timber removed per decade, achieved through a combination of variable retention harvests and thinning activities would most likely be processed into long-term building products that would sequester carbon well-beyond expectations during this planning period.

There are variable harvest differences and carbon sequestration levels for all three alternatives throughout the planning horizon.

Differences Based on Carbon Model Estimates

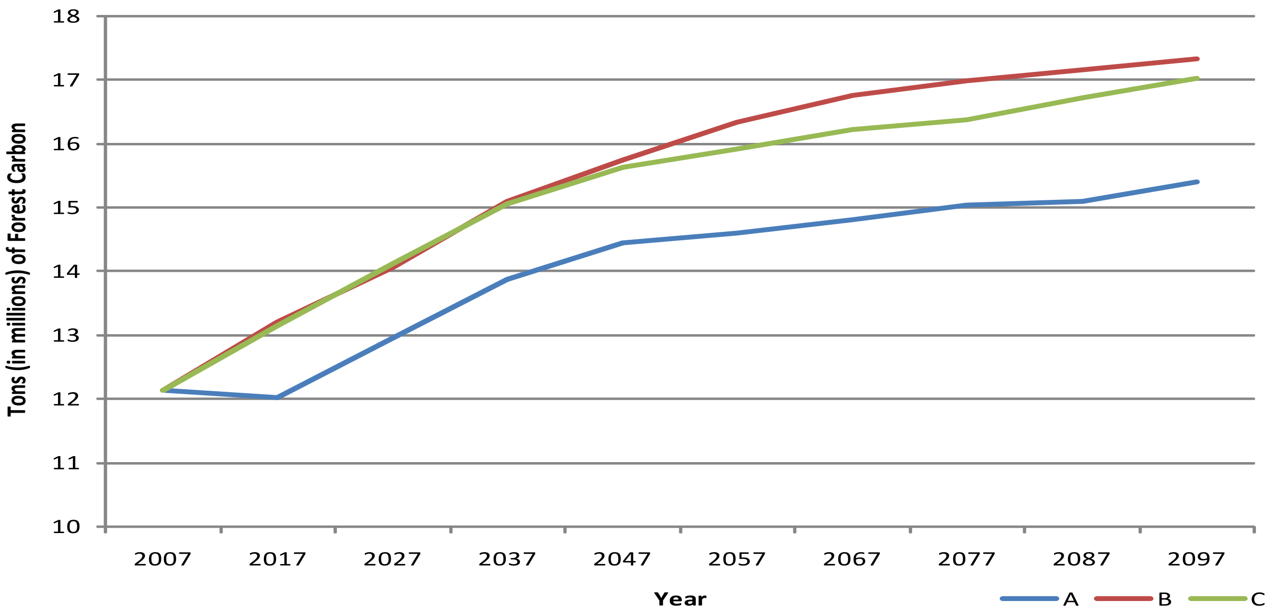
Following methods described by Smith and others (2006), DNR created estimates for forest carbon in the planning unit. First, DNR used current forest conditions to model standing biomass by age and species for all alternatives. Then, a harvest activities database was used to determine the volume removed for all alternatives, by age and species. The removal was then broken down by the type (saw vs. chip), although the values of end uses (no matter the method of removal) were combined. Third, the rate of variable retention harvests for each alternative was estimated. Finally, these volume rates were converted to carbon using values and equations described in Smith and others (2006) and followed through the 100-year planning period to establish whether the volume is maintained in the

Table 4-49. Modeled Carbon Estimates (in tons) for All Alternatives

	Carbon in end uses[1]			Carbon in landfills			Carbon maintained in forests		
Alternative	2007	2047	2087	2007	2047	2087	2007	2047	2087
A	361,893	849,622	1,446,096	4,589	11,692	19,214	12,132,104	13,093,424	13,764,471
B	360,777	820,891	1,284,555	4,431	11,362	18,380	12,132,104	14,388,776	15,776,290
C	459,464	911,730	1,371,313	4,570	12,610	19,584	12,132,104	14,302,759	15,032,960

1. End uses are milled lumber often used in structures.

Chart 4-27. Comparison of Carbon Stored in Forests and In Use (in millions of tons)



forest, in structural lumber, in a landfill, or lost in some other way. These values can be found in Table 4-49. Carbon maintained in forests does not include carbon in the soil.

This method's results are similar to those of stand development stage changes over time for the alternatives, but assign more specific values to volumes and areas. The overall average of carbon for the planning unit is currently estimated at 83 tons per acre. This average equates to the amount of carbon in a 30- to 40-year-old stand. All three alternatives project higher levels per acre at the end of the planning horizon. Alternative A (95 tons/acre) has the lowest projected value, followed by Alternative C (107 tons/acre), and a slightly higher Alternative B (109 tons/acre). Just as Alternative B produces more timber volume through its management regimes, it also sequesters more carbon than the other alternatives with a similar trend. Chart 4-27 shows general trends for carbon sequestration levels for all alternatives. Again, the management regimes used in Alternative B out-perform those used in both of the other alternatives, especially Alternative A.

Although the benefits of Alternative B in the initial decades are only slightly higher than those of Alternative C, these similar levels of carbon sequestration are achieved by quite different harvesting techniques and could result in different impacts. Refer to forest conditions (p. 124) to identify both positive and negative impacts of these harvesting methods.

End Notes

1 Procedure 14-004-150, Appendix E
2 Procedure 14-004-060, Appendix E
3 Chapter 79.71 Revised Code of Washington [RCW]
4 Chapter 222-24 Washington Administrative Code [WAC]
5 Chapter 79.10.100-.280 Revised Code of Washington [RCW]
6 Procedure 14-004-080, Appendix E
7 Chapter 222-30 Washington Administrative Code [WAC]
8 Procedure 14-004-030, Appendix E
9 Chapter 27.44 Revised Code of Washington [RCW]
10 Endangered Species Act (1973). P.L. 93-205. 87 Stat. 884
11 House Bill 2815
12 Senate Bill 6516

REFERENCES

CHAPTER 5

References

Adkisson, C.S. 1996. Red Crossbill (*Loxia curvirostra*). In A. Poole, ed. The Birds of North America Online. Cornell Lab of Ornithology, Ithica, New York. Available online at: http://bna.birds.cornell.edu/bna/species/256.

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington D.C.

Aitken, S.N., S. Yeaman, J.A. Holliday, T. Wang, and S. Curtis-McLane. 2008. Adaptation, Migration or Extirpation: Climate Change Outcomes for Tree Populations. Evolutionary Applications. 1: 95–111.

Alig, R.J. and E. White. 2007. Projections of Forestland and Developed Land Areas in Western Washington. Western Journal of Applied Forestry. 22(1): 29-35.

Allen, H.L. and L.W. Brewer. 1985. A Review of Current Northern Spotted Owl (*Strix occidentalis caurina*) Research in Washington State. General Technical Report PNW-GTR-185. USDA Forest Service, Pacific Northwest Research Station, Olympia, WA.

Anderson, P. D., D. J. Larson, and S. S. Chan. 2007. Riparian buffer and density management influences on microclimate of young headwater forests of western Oregon. Forest Science. 53: 254–269.

Andrews, A. 1990. Fragmentation of Habitat by Roads and Utility Corridors: A Review. Australian Zoologist. 26(3-4): 130-141.

Ares, A., T. Terry, C. Harrington, W. Devine, D. Peter, and J. Baily. 2007. Biomass Removal, Soil Compaction, and Vegetation Control Effects on Five-Year Growth Douglas-fir in Coastal Washington. Forest Science. 53(5): 600-610.

Arnáez, J., V. Larrea, and L. Ortigosa. 2004. Surface Runoff and Soil Erosion on Unpaved Forest Roads from Rainfall Simulation Tests in Northeastern Spain. Catena. 57(1): 1-14.

Bach, A. 2004. Northwest Washington Climate. Explorations in Environmental Studies, Western Washington University, Bellingham, WA. Available online at: http://myweb.facstaff.wwu.edu/wallin/esci301/NWclimate.doc.

Bailey, J.D., and J.C. Tappeiner. 1998. Effects of Thinning on Structural Development in 40- to 100-year-old Douglas-fir Stands in Western Oregon: Forest Ecology and Management. 108(1-2): 99-113.

Barnett, T.P., D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, and M.D. Dettinger, 2008. Human-Induced Changes in the Hydrology of the Western United States. Science. 19: 1080-1083.

Barrows, C. and K. Barrows. 1978. Roost Characteristics and Behavioral Thermoregulation in the Spotted Owl. Western Birds. 9:1-8.

Barrows, C.W. 1981. Roost Selection by Spotted Owls: An Adaptation to Heat Stress. The Condor. 83: 302-309.

Bates, Nicole A. 1999. Pay to Play: The Future of Recreation Fees. Parks & Recreation.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, eds. 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 p.

Beechie, T. J. and T. H. Sibley. 1997. Relationships Between Channel Characteristics, Woody Debris, and Fish Habitat in Northwestern Washington Streams. Transactions of the American Fisheries Society. 126: 217-229.

Belford, D.A. and W.R. Gould. 1989. An Evaluation of Trout Passage through Six Highway Culverts in Montana. North American Journal of Fisheries Management. 9(4): 437-445

Beschta, R.L. 1978. Long-term Patterns of Sediment Production following Road Construction and Logging in the Oregon Coast Range. Water Resources Research. 14(6): 1011-1016.

Best, D. W., H. M. Kelsey, D. K. Hagans, and M. Alpert. 1995. Role of Fluvial Hillslope Erosion and Road Construction in the Sediment Budget of Garrett Creek, Humboldt County, California. Chapter M *in* K.M. Nolan, H.M. Kelsey, and D.C. Marron, eds. U.S. Geological Survey Professional Paper 1454. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California.

Bigley, R. and F. Deisenhofer. 2006. Implementation Procedures for the Habitat Conservation Plan Riparian Forest Restoration Strategy. Washington State Department of Natural Resources, Olympia, WA.

Bigley, R. and S. Hull. 2000. Managing Wetlands on State Forest Lands in Washington. Washington State Department Natural Resources, Olympia, WA.

Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. The Generation and Fate of Road-surface Sediment *in* Forested Watersheds in Southwestern Washington. Forest Science. 35(2): 453-68.

Bilby, R.E. and L.J. Wasserman. 1989. Forest Practices and Riparian Management in Washington State: Data Based Regulation Development. Pages 87-94 *in* R.E. Gresswell, B.A. Barton and J. L. Kershner, eds. Practical Approaches to Riparian Resource Management. U.S. Bureau of Land Management, BLM-MT-PT-89-001-4351, Billings, MT.

Bilby, R.E. and P.A. Bisson. 1998. Function and Distribution of Large Woody Debris Pacific Coastal Streams and Rivers. Pages 324-338 in Naiman, R. J. and R. E. Bilby, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, New York, NY.

Bilby, R.E. and P.A. Bisson. 1991. Allochthonous Versus Autochthonous Organic Matter Contributions to the Trophic Support of Fish Populations in Clear-cut and Old-growth Forested Streams. Canadian Journal of Fisheries and Aquatic Sciences. 49: 540-551.

Bilby, R.E. and J.W. Ward. 1991. Characteristics and Function of Large Woody Debris in Streams Draining Old Growth, Clear-cut, and Second-growth Forests in Southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences. 48: 2499-2508.

Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, and J.R. Sedell, 1987.Large woody debris in forested streams in the Pacific Northwest: Past, present, and future. Pages 143-190 *in* E.O. Salo and T.W. Cundy, eds. Streamside management: forestry and fishery interactions. Institute of Forest Resources, University of Washington, Seattle, WA.

Bjorn, T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Pages 83-138 *in* W.R. Meehan, ed. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19, Bethesda, MD.

Blackburn, W.H. and J.C. Wood. 1990. Nutrient Export in Stormflow following Forest Harvesting and Site-preparation in East Texas. Journal of Environmental Quality. 19(3): 402-408.

Bliss, J.C. 2000. Public Perceptions of Clearcutting. Journal of Forestry. 98(12): 4-10.

Boelter, D.H. and G.E. Close. 1974. Pipelines in Forested Wetlands. Journal of Forestry. 72: 561.

Bolda, K.S. and W.J. Meyers. 1997. Conducting a Long-term Water Quality Monitoring Project: A Case Study on the McCloud River, California. Journal of Soil and Water Conservation. 52(1): 49-54.

Boyd, M., and D. Sturdevant. 1997. The Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight answers. Oregon Department of Environmental Quality, Portland, OR.

Boyle, J.R. 1976. A System for Evaluating Potential Impacts of Whole-tree Harvesting on Site Quality. Tappi 59(7): 79-81.

Boyle, S.A. and F.B. Sampson. 1985. Effects of Non-Consumptive Recreation on Wildlife: a Review. Wildlife Society Bulletin. 13: 110–116.

Brown, E.R., ed. 1985. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington (2 Parts). Publication R6-F&WL-192-1985. USDA Forest Service, Pacific Northwest Region, Portland, OR.

British Columbia Ministry of Forests. 1996. Clearcutting and Visual Quality: A Public Perception Study. Available online at: http://www.for.gov.bc.ca/hfd/pubs/docs/Frr/Frr270.pdf. Accessed December 19, 2007.

British Columbia Ministry of Forests. 1997. Visual Impacts of Partial Cutting Summary Report : A Technical Analysis and Public Perception Study. Available online at: http://www.for.gov.bc.ca/hfd/library/documents/bib43191.pdf. Accessed December 19, 2007.

Brooks, K.N., P.F. Folliott, H.M. Gregerson and L.F. DeBano. 1997. Hydrology and the Management of Watersheds, 2nd Edition. Iowa State University Press, Ames, IA. 502 p.

Brosofske, K.D., J. Chen, R.J. Naiman, and J.F. Franklin, 1997. Harvesting Effects on Microclimatic Gradients From Small Streams to Uplands in Western Washington. Ecological Applications. 7: 1188-1200.

Brown, G.W. and J. T. Krygier. 1970. Clear-Cut Logging on Stream Temperature. Water Resources Research. 6: 1133-1139.

Brunson, Mark and B. Shelby. 1992. Assessing Recreational and Scenic Quality: How Does New Forestry Rate? Journal of Forestry. 74: 744-747.

Brush, R.O. 1979. The Attractiveness of Woodlands: Perceptions of Forest Landowners in Massachusetts. Forest Science. 25: 495-506.

Buchanan, J.B. 2004. In My Opinion: Managing Habitat for Dispersing Northern Spotted Owls—Are the Current Management Strategies Adequate? Wildlife Society Bulletin. 32(4): 1333–1345

Buhyoff, G.P., J.D. Wellman, and T.C. Daniel. 1982. Predicting Scenic Quality for Mountain Pine Beetle and Western Spruce Budworm Damaged Forest Vistas. Forest Science. 28(4): 827-838.

Bunn, A.G., D.L. Urban, and T.H. Keitt. 2000. Landscape Connectivity: A Conservation Application of Graph Theory. Journal of Environmental Management. 59: 265-78.

Burroughs, E.R., Jr., G.R. Chalfant, and M.A. Townsend. 1976. Slope Stability in Road Construction: A Guide to the Construction of Stable Roads in Western Oregon and Northern California. U.S. Department of the Interior, Bureau of Land Management, Portland, OR.

Burroughs, E. R., and B. R. Thomas. 1977. Declining Root Strength in Douglas-fir After Felling as a Factor in Slope Stability, Research Paper INT-190, Intermountain Forest and Range Experiment Station, Ogden, UT.

Cade, B.S and R.W. Hoffman. 1990. Winter Use of Douglas-fir Forests by Blue Grouse in Colorado. Journal of Wildlife Management. 54: 471-479.

Cafferata, P. 1992. Soil Compaction Research. Pages 8-22 *in* A. Skaugset, ed. Forest Soils and Riparian Zone Management: The Contributions of Dr. Henry A. Froehlich to Forestry. Oregon State University, Corvallis, OR.

California Division of Mines and Geology (DMG). 1997. Factors Affecting Landslides in Forested Terrain: California Division of Mines and Geology Note 50, 5 p. http://www.consrv.ca.gov/cgs/information/publications/cgs_notes/note_50/Documents/note50.pdf

Carey, A. B. 1985. A Summary of the Scientific Basis for Spotted Owl Management. Pages 100-114 *in* R. J. Gutierrez and A. B. Carey, eds. Ecology and Management of the Spotted Owl in the Pacific Northwest. General Technical Report PNW-GTR-185. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Carey, A.B. 1995. Sciurids in Pacific Northwest Managed and Old-growth Forests. Ecological Applications. 5: 648-661.

Carey, A.B., 1998. Ecological Foundations of Biodiversity: Lessons from Natural and Managed Forests of the Pacific Northwest. Pages 127–133 *in* J.A. Trofymow and A. MacKinnon, A., eds. Proceedings of a Workshop on Structure, Process and Diversity in Successional Forests of British Columbia, February 17–19, 1998, Victoria, BC. Northwest Science. 72 (Special Issue 2)

Carey, A.B. 2003a. Biocomplexity and Restoration of Biodiversity in Temperate Coniferous Forest: Inducing Spatial Heterogeneity with Variable-density Thinning. Forestry. 76(2): 127-136.

Carey, A.B. 2003b. Managing for Wildlife: A Key Component for Social Acceptance of Compatible Forest Management. Pages 401-425 *in* R.A. Monserud, R.W. Haynes and A.C. Johnson, eds. Compatible Forest Management. Kluwell Academic Publishers, Norwell, MA.

Carey, A.B. 2007. Aiming for Healthy Forests: Active, Intentional Management for Multiple Values. General Technical Report PNW-GTR-721. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Carey, A.B., C. Elliott, B.R. Lippke, R. Bruce, J. Sessions, C.J. Chambers, C.D. Oliver, J.F. Franklin, and M.G. Raphael. 1996. Washington Forest Landscape Management Project – A Pragmatic, Ecological Approach to Small-landscape Management, Report No. 2. Washington State Department of Natural Resources, Olympia, WA.

Carey, A.B., S.P. Horton, and B.L. Biswell. 1992. Northern Spotted Owls: Influence of Prey Base and Landscape Character. Ecological Monographs. 62(2): 223-250.

Carey, A.B. and M.L. Johnson. 1995. Small Mammals in Managed, Naturally Young, and Old-growth Forests. Ecological Applications. 5: 336–352.

Cassidy, K.M., C.E. Grue, M.R. Smith, and K.M. Dvornich, eds. 1997. Washington State Gap Analysis Project Final Report (5 Volumes). Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, WA.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative Effects of Logging Road Sediment on Salmonid Populations in the Clearwater River, Jefferson County, Washington. Pages 39-74 *in* Proceedings From the Conference Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest? Rep. 39. State of Washington Water Research Center, Pullman, WA.

Cederholm, C.J. and L.M. Reid. 1987. Impacts of Forest Management on Coho Salmon (*Oncorhynchus kisutch*) Populations of the Clearwater River, Washington: A Project Summary. Pages 373-398 *in* E.O. Salo and T.W. Cundy, eds. Streamside Management: Forestry and Fishery Interactions. University of Washington Press, Seattle, WA:.

Cederholm, C.J., M.D. Kunze, T. Murota and A. Sibatani. 1999. Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. Fisheries. 24 (10): 6–15.

Chamberlin, T.W., R.D. Harr, and F.H. Everest. 1991. Timber Harvesting, Silviculture, and Watershed Processes. Pages 181-205 *in* W.R. Meehan, ed. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19. American Fisheries Society, Bethesda, Maryland.

Chan, S., P. Anderson, J. Cissel, L. Larsen, and C. Thompson. 2004. Variable density management in riparian reserves: Lessons learned from an operational study in managed forests of western Oregon, USA. Forest Snow and Landscape Research. 78: 151–172.

Chapman, J.A. and C.A. Feldhammer, eds. 1982. Wild Mammals of North America. John Hopkins University Press, Baltimore, Maryland.

Clancy, C.G. and D.R Reichmuth. 1990. A Detachable Fishway for Steep Culverts. North American Journal of Fisheries Management. 10(2): 244-246.

Cleaverly, J.R., J.R. Thibault, J. Pearce and C. Dahm. 2000. Seasonal 3-D Eddy Covariance Evaportranspriration Estimates from a Middle Rio Grande (New Mexico) Riparian Ecosystem. Bulletin of the North American Benthological Society. 17: 134.

Clayton, J.L. 1983. Evaluating Slope Stability Prior to Road Construction. USDA Forest Service Research Paper RP-INT-307. Intermountain Forest and Range Experiment Station, Ogden, UT.

Climate Action Team- Forest Sector Work Group. 2008. Forest Sector Workgroup on Climate Change Mitigation Final Report. Available online at: http://www.dnr.wa.gov/Publications/Forest_Sector_Workgroup_Final_Report_v.2.pdf.

Coe, D. 2005. The Hydrologic Impacts of Roads at Varying Spatial and Temporal Scales: A Review of Published Literature as of April 2004. Nooksack Indian Tribe. Unpublished report.

Cole, D.N. and P.B. Landres. 1996. Threats to Wilderness Ecosystems: Impacts and Research Needs. Ecological Applications 6: 168-184.

Cole, D.N. 1995. Experimental trampling of vegetation. I. Relationship Between Trampling Intensity and Vegetation Response. Journal of Applied Ecology. 32(1): 203-214.

Connections Group, The. 2003. Sustainable Harvest Focus Groups. Washington State Department of Natural Resources, Olympia, Washington. Available online at: http://www.dnr.wa.gov/Publications/lm_sh_focusgrp_report.pdf.

Cooper, B.A., R.J. Blaha, N.A. Schwab. 2007. A Radar Study of Marbled Mullets in the North and South Puget Planning Units Draft Report. Prepared for Washington State Department of Natural Resources. Prepared by ABR, INC.–Environmental Research and Services. Forest Grove, Oregon.

Cordell, H.K. and J.C. Bergstrom. 1991. A Methodology for Assessing National Outdoor Recreation Demand and Supply Trends. Leisure Sciences. 13(1): 1-20.

Cordell, H.K., C.J. Betz, J.M. Bowker, D.B.K. English, S.H. Mou, J.C. Bergstrom, R.J. Teesley, M.A. Tarrant, and J. Loomis. 1999. Outdoor Recreation in American Life: A National Assessment of Demand and Supply Trends. Sagamore Publishing, Champaign, IL. 449 p.

Cotton, L. and J.R. McBride. 1987. Visual Impacts of Prescribed Burning on Mixed Conifer and Giant Sequoia Forests. General Technical Repeport PSW-101. USDA Forest Service Pacific Southwest Forest and Range Experimental Station, Berkeley, CA.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. 2004. Scientific Evaluation of the Status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Cummins, K.W. 1974. Structure and Function of Stream Ecosystems. BioScience. 24: 63-1-64-1.

Curtis, R.O. 1982. A Simple Index of Stand Density for Douglas-fir. Forest Science 28(1): 92-94.

Deal, R.L., and J.C. Tappeiner. 2002. The Effects of Partial Cutting on Stand Structure and Growth in Western Hemlock-Sitka Spruce Stands in Southeast Alaska. Forest Ecology and Management. 159: 173-186.

DeGraaf, R.M. 1992. Effects of Even-aged Management on Forest Birds at Northern Hardwood Stand Interfaces. Forest Ecology and Management. 47: 95-110.

DeLuca, T.H., W.A. Patterson IV, W.A. Freimund, and D.N. Cole. 1998. Influence of Llamas, Horses, and Hikers on Soil Erosion from Established Recreation Trails in Western Montana, USA. Environmental Management, 22(2): 255-262.

Dessecker, D.R. and D.G. McAuley. 2001. Importance of Early Successional Habitat to Ruffed Grouse and American Woodcock. Wildlife Society Bulletin. 29(2): 456-465.

DNR *See* Washington State Department of Natural Resources

DMG *See* California Division of Mines and Geology

Donald, J.A., B.C. Wemple, G.E. Grant and F.J. Swanson. 1996. Interaction of Logging Roads with Hillslope and Channel Processes During the February 1996 Flood in Western Oregon. EOS Transactions, American Geophysical Union: AGU Fall Meeting, December 15-19, 1996, San Francisco, CA. American Geophysical Union, Washington, DC. 77(46): F273.

Duncan, S.H., Bilby, R.E., War, J.W., Heffner, J.T. 1987 Transport of Road-surface Sediment Through Ephemeral Stream Channels. Water Resources Bulletin. 23(1): 113-119.

Dyrness, C.T. 1967. Erodibility and Erosion Potential of Forest Watersheds. Pages 599-611 *in* W.E. Sopper and H.W. Lull, eds. Forest Hydrology. Pergamon Press, Oxford, England.

Ecology *See* Washington State Department of Ecology

Egan, A.F. and A.E. Luloff. 2000. The Exurbanization of America's Forests. Journal of Forestry. 98(3): 26-30.

Elder, J.F. 1987. Factors Affecting Wetland Retention of Nutrients, Metals, and Organic Materials. Pages 178-184 *in* J.A. Kusler, and G. Brooks, eds. Proceedings of the National Wetland Symposium: Wetland Hydrology. Association of State Wetland Managers, Berne, NY.

Encyclopedia Britannica. 2008. Carbon Dioxide. Encyclopedia Britannica Online. Available online at: http://www.britannica.com/eb/article-9020249/carbon-dioxide.

Encyclopedia Britannica. 2009. Photosynthesis. Encyclopedia Britannica Online. Available online at: http://www.britannica.com/EBchecked/topic/458172/photosynthesis. Accessed 17 Sep. 2009.

EPA of South Australia. Water Glossary. Available online at: http://www.epa.sa.gov.au/water_glossary.html. Accessed January 13, 2009.

EPA *See* United States Environmental Protection Agency

Evans, W.A. and B. Johnston. 1980. Fish Migration and Fish Passage: A Practical Guide to Solving Fish Passage Problems. Revised edition, EM-7100-2. U.S. Department of Agriculture, Forest Service, Washington, D.C. 163 p.

Evans Mack, D., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. Methods for Surveying Marbled Murrelets in Forests: A Revised Protocol for Land Management and Research. Pacific Seabird Group Technical Publication Number 2. Available online at: http://www.pacificseabirdgroup.org.

Everest, F.H., D.J. Stouder, C. Kakoyannis, L. Houston, G. Stankey, J. Kline, and R. Alig. 2004. A Review of Scientific Information on Issues Related to the Use and Management of Water Resources in the Pacific Northwest. General Technical Report PNW-GTR-595. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

FEMAT *See* Forest Ecosystem Management Assessment Team

Fenn, M.E., M.A. Poth, J.D. Aber, J.S. Baron, B.T. Bormann, D.W. Johnson, A.D. Lemly, S.G. McNulty, D.F. Ryan, R. Stottlemyer. 1998. Nitrogen Excess in North American Ecosystems: Predisposing Factors, Ecosystem Responses, and Management Strategies. Ecological Applications. 8(3): 706-733.

Fetter, C.W. 2001. Applied Hydrogeology, 4th ed. Upper Saddle River, New Jersey: Prentice-Hall.

Flint, C.M., R.B. Harrison, B.D. Strahm, A.B. Adams. 2008. Nitrogen Leaching from Douglas-fir Forests after Urea Fertilization. Journal of Environmental Quality. 37: 1781-1788.

Forest Ecosystem Management Assessment Team. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Number 1993-793-071. U.S. Government Printing Office, Washington, D.C., USA.

Forest Service *See* USDA Forest Service

Forman, R.T.T., D.S. Friedman, D. Fitzhenry, J.D. Martin, A.S. Chen and L.E. Alexander. 1997. Ecological Effects of Roads: Toward Three Summary Indices and an Overview for North America. Pages 40-54 *in* K. Canters, A. Piepers and D. Hendriks-Heerma, eds. Proceedings of the International Conference "Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering", 17-21 September 1995, Maastricht-The Hague, Netherlands. Delft, Netherlands. Ministry of Transport, Public Works and Water Management.

Forsman, E.D. 1976. A Preliminary Investigation of the Spotted Owl in Oregon. M.S. Thesis. Oregon State University, Corvallis, OR.

Forsman, E.D. 1980. Habitat Utilization by Spotted Owls in the West-central Cascades of Oregon. Ph.D. Thesis. Oregon State University, Corvallis, OR.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and Breeding Dispersal of Northern Spotted Owls. Wildlife Monographs. 149: 1-35.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and Biology of the Spotted Owl in Oregon. Wildlife Monographs. 87: 1-64.

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. General Technical Report PNW-GTR-8. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. Carey, D.A. Thornberg, D.R. Berg, D.B. Lindenmayer, M.E. Harmon, W.S. Keeton, D.C. Shaw, K. Bible and J. Chen. 2002. Disturbances and Structural Development of Natural Forest Ecosystems with Silvicultural Implications, Using Douglas-fir Forests as an Example. Forest Ecology and Management. 155: 399-423.

Freddy, D.J., W.M. Bronaugh, and M.C. Fowler. 1986. Responses of Mule Deer to Disturbance by Persons Afoot and Snowmobiles. Wildlife Society Bulletin. 14(1): 63-68.

Fuentes, T.L., L.L. Potash, A.R. Risvold, K. Ward, R.D. Lesher, and J.A. Henderson. 2007. Non-native Plants on the Mt. Baker – Snoqualmie National Forest. Pages 95-116 *in* T.B. Harrington and S.R. Reichard, eds. Meeting the Challenge: Invasive Plants in Pacific Northwest Ecosystems. General Technical Report PNW-GTR-694. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road Construction and Maintenance. Pages 297-323 *in* W.R. Meehan, ed. Influences of Forest and Rangeland Management of Salmonid Fishes and their Habitats, Special Publication 19. American Fisheries Society, Bethesda, MD.

Gaines, W.L., P.H. Singleton, and R.C. Ross. 2003. Assessing the Cumulative Effects of Linear Recreation Routes on Wildlife Habitats on the Okanogan and Wenatchee National Forests. General Technical Report PNW-GTR-586. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Gobster, P.H. 1999. An Ecological Aesthetic for Forest Landscape Management. Landscape Journal. 18(1): 54-64. Available online at: http://www.ncrs.fs.fed.us/pubs/jrnl/1999/nc_1999_Gobster_001.pdf.

Gomi, T, R. C. Sidle, and J. S. Richardson. 2002. Understanding Processes and Downstream Linkages of Headwater Systems. BioScience. 52: 905–916.

Government of Alberta. 2007. Glossary. Available online at: http://environment.alberta.ca/ETG_Glossary.aspx.

Graham, R.T., D. Minore, A.E. Harvey, M.F. Jurgensen, and D.S. Page-Dumroese. 1990. Soil Management as an Integral Part of Silvicultural Systems. Presented at: The Symposium on Management and Productivity of Western-Montane Forest Soils. Boise, ID. April 10-12, 1990.

Grant, G.E., S.L. Lewis, F.J. Swanson, J.H. Cissel and J.J. McDonnell. 2008. Effects of Forest Practices on Peak Flows and Consequent Channel Response: A State-of-Science Report for Western Oregon and Washington. General Technical Report PNW-GTR-760, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Greenberg, C.H., S.H. Crownover and D.R Gordon. 1997. Roadside Soils: A Corridor for Invasion of Exotic Shrub by Non-Indigenous Plants. Natural Areas Journal. 17(2): 99-109.

Greenwood, P.J. 1980. Mating Systems, Philopatry and Dispersal in Birds and Mammals. Animal Behaviour. 28(4): 1140-1162.

Gregory. S.V., F.J. Swanson, W.A. McKee and K.W. Cummins. 1991. An Ecosystem Perspective of Riparian Zones. BioScience. 41: 540-551.

Grewell, Bishop. 2004. Recreation Fees- Four Philosophical Questions. Property and Environment Research Center Policy Series Issue Number PS-31. June.

Grier, C.C., K.M. Lee, N.M. Nadkarni, G.O. Klock, and P.J. Edgerton. 1989. Productivity of Forests of the United States and its Relation to Soil and Site Factors and Management Practices: A Review. General Technical Report PNW-GTR-222. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Gutiérrez, R.J., M. Cody, S. Courtney, and A.B. Franklin. 2006. The Invasion of Barred Owls and its Potential Effect on the Spotted Owl: A Conservation Conundrum. Biological Invasion. 9(2): 181-196.

Gutiérrez, R.J., D.M. Solis and C. Sisco. 1984. Habitat Ecology of the Spotted Owl in Northwestern California: Implication for Management. Pages 368-373 *in* Proceedings of the Society of American Foresters National Convention, October 16-20, 1983, Bethesda, MD.

Haggerty, S.M., D.P. Batzer, and C.R. Jackson. 2004. Macroinvertebrate Response to Logging in Coastal Headwater Streams of Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 61: 529–537.

Hamer, T.E. 1988. Home Range Size of the Northern Barred Owl and Northern Spotted Owl in Western Washington. M.S. Thesis. Western Washington University, Bellingham, WA.

Hamer, T.E., E.D. Forsman, and E.M. Glenn. 2007. Home Range Attributes and Habitat Selection of Barred Owls and Spotted Owls in an Area of Sympatry. The Condor. 109(4): 750-768.

Hamlet, A.F., P.W. Mote, M.P. Clark, D.P. Lettenmaier. 2007. 20th Century Trends in Runoff, Evapotranspiration, and Soil Moisture in the Western U.S. Journal of Climate. 20: 1468-1486.

Hammer, D.A. 1989. Constructed Wetlands for Waste Water Treatment. Lewis Publishers, Inc., Chelsea, MI. 831 p.

Hanson, E., D. Hays, L. Hicks, L. Young and J. Buchanan. 1993. Spotted Owl Habitat in Washington: A Report to the Washington Forest Practices Board. Washington Forest Practices Board, Olympia, WA.

Hanson, A.J., R.P. Nielson, V.H. Dale, C.H. Flather, L.R. Iverson, D.J. Currie, S. Shafer, R. Cook and P.J. Bartlien. 2001. Global Change in Forests: Responses of Species, Communities, and Biomes. BioScience. 51(9): 765-779.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr., and K.W. Cummins. 1986. Ecology of Coarse Woody Debris in Temperate Ecosystems. Advances in Ecological Research. 15: 133-302.

Havlick, D.G. 2002. No Place Distance: Roads and Motorized Recreation on America's Public Lands. Island Press, Washington, D.C.

Heede, B.H. 1983. Control of Rills and Gullies in Off-road Vehicle Traffic Areas. Pages 245-264 *in* R.H. Webb and H.G. Wilshire (eds.). Environmental Effects of Off-road Vehicles: Impacts and Management in Arid Regions. Springer-Verlag, New York, NY.

Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. Effects of Logging on Winter Habitat of Juvenile Salmonids in Alaskan Streams. North. American Journal of Fish Management. 6: 52.58.

Heilman, P. 1981. Root Peneration of Douglas-fir Seedlings into Compacted Soil. Forest Science. 37(4): 660-666. Society of American Foresters.

Henjum, M.G., J.R. Karr, D.L. Bottom, D.A. Perry, J.C. Bednarz, S.G. Wright, S.A. Beckwitt, and E. Beckwitt. 1994. Interim Protection for Late-Successional Forests, Fisheries, and Watersheds, National Forests East of the Cascade Crest, Oregon and Washington: A Report to the United States Congress and the President. The Wildlife Society, Bethesda, MD.

Hemond, H.F., T.P. Army, W.K. Nuttle and D.G. Chen. 1987. Element Cycling in Wetlands--Interactions with Physical Mass Transport. Pages 519-537 *in* R.A. Hites and S.J. Eisenreich, eds. Sources and Fates of Aquatic Pollutants. Advances in Chemistry Series 216. American Chemical Society, Washington, D.C..

Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins, and L.D. Melampy. 2002. Roost Site Characteristics of Northern Spotted Owls in the Nonbreeding Season in Central Washington. Forest Science. 48(2): 437-446.

Hicks, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell. 1991. Responses of Salmonids to Habitat Changes. Pages 483-518 *in* W.R. Meehan, ed. Influences of Forest and Rangeland Management on Salmonid Habitat: American Fisheries Society Special Publication 19. American Fisheries Society, Bethesda, MD.

Hochrein, P.H. and L.D. Kellogg. 1988. Production and Cost Comparison for Three Skyline Thinning Systems. Western Journal of Applied Forestry. 3(4): 120-123.

Holmberg, P. (compiler). 2007. Thinning Forest Stands, East- and Westside: An Interactive Self-Study and Reference Pamphlet. Washington State Department of Natural Resources, Olympia, WA.

Holsapple, L.J. and K. Snell. 1996. Wildfire and Prescribed Fire Scenarios in the Columbia River Basin in Relationship to Particulate Matter and Visibility *in* R.E. Keane, J.L. Jones, L.S. Riley, and W.J. Hann, eds. Compilation of Administrative Reports: Multi-scale Landscape Dynamics in the Basin and Portions of the Klamath and Great Basins. USDA Forest Service, Bureau of Land Management, and Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA.

Hunter, M.L. 1990. Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity. Prentice Hall, Englewood Cliffs, NJ.

IAC *See* Washington State Interagency Committee for Outdoor Recreation

IMST (Independent Multidisciplinary Science Team). 1999. Recovery of Wild Salmonids in Western Oregon Forests: Oregon Forest Practices Act Rules and the Measures in the Oregon Plan for Salmon and Watersheds. Technical Report 1991-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, OR.

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Synthesis Report. Summary for Policy Makers. Available online at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

Jackson, C.R., C.A. Sturm and J.M. Ward. 2001. Timber Harvest Impacts on Small Headwater Stream Channels in the Coast Ranges of Washington. Journal of the American Water Resources Association. 37: 1533-1549.

Johnsgard, P.A. 1988. North American Owls: Biology and Natural History. Smithsonian Institution Press, Washington, D.C.

Johnsgard, P.A. 1990. Hawks, Eagles and Falcons of North America: Biology and Natural History. Smithsonian Institution Press, Washington, D.C.

Johnson, A.W. and D.M. Ryba. 1992. A Literature Review of Recommended Buffer Widths to Maintain Various Functions of Stream Riparian Areas. King County Surface Water Management Division (SWM) Special Report.

Johnson, D. H. 1993. Spotted Owls, Great Homed Owls, and Forest Fragmentation in the Central Oregon Cascades. M.Sc. thesis, Oregon State University, Corvallis, OR.

Johnson, D.H. and T.A. O'Neil, eds. 2001. Wildlife Habitat Relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Jones, J.A. 2000. Hydrologic Processes and Peak Discharge Response to Forest Removal, Regrowth and Roads in 10 Small Experimental Basins, Western Cascades, Oregon. Water Resources Research. 36(9): 2621-2642.

Jules, M.J., J.O. Sawyer, E.S. Jules. 2008. Assessing the Relationships Between Stand Development and Understory Vegetation Using a 420-year Chronosequence. Forest Ecology and Management. 255: 2384-2393.

Kakoyannis, C. and G.H. Stankey. 2002. Assessing and Evaluating Recreational Uses of Water: Implications for an Integrated Management Framework. General Technical Report PNW-GTR-536. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray, eds. 2006. Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, D.C.

Huff, M.H., R.S. Holthausen, and K.B. Aubry, tech. cords. 1992. Biology and Management of Old-growth Forests Habitat Management for Red Tree Voles in Douglas-fir Forests. General Technical Report PNW-GTR-302. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Kassar, Chris. 2009. Environmental Impacts of ORVs on the Rubicon Trail. Center for Biological Diversity. Submitted to the California Regional Water Board in Support of the Center's Comments Regarding the Clean-up and Abatement Order for the Rubicon Trail.

Keller, E.A. and F.J. Swanson. 1979. Effects of Large Organic Material on Channel Form and Fluvial Processes. Earth Surface Process. 4: 361-380.

Keller, E.A., A. MacDonald, T. Tally, N.J. Merrit. 1995. Effects of Large Organic Debris on Channel Morphology and Sediment Storage in Selected Tributaries of Redwood Creek, Northwestern California. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwest California. US Geological Survey P1-P29.

Kirchhoff, M.D., J.W. Schoen, and O.C. Wallmo. 1983. Black-tailed Deer Use in Relation to Forest Clear-cut Edges in Southeastern Alaska. The Journal of Wildlife Management. 47(2): 497-501.

Kline, Jeffery. D. 2001. Tourism and Natural Resource Management: A General Overview of Research and Issues. General Technical Report PNW-GTR-506. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Knight, R.L. and D.N. Cole. 1995. Wildlife Responses to Recreationalists *in* Knight and Gutzwiller, eds. Wildlife and Recreationists: Coexistence through Management and Research. Island Press, Washington, D.C.

Knight, R.L., and K.J. Gutzwiller. 1995. Wildlife and Recreationists: Coexistence through Management and Research. Island Press, Washington, D.C.

Kohnke, H. and D.P. Franzmeier. 1995. Soil Science Simplified, 4th edition. Waveland Press, Prospect Heights, IL. 162 p.

Kolbe, C.M. and M.W. Luedke. 1993. A Guide to Freshwater Ecology. Texas Commission on Environmental Quality, Austin, TX.

Kurz, W.A., M. Apps, E. Banfield and G. Stinson. 2002. Forest Carbon Accounting at the Operational Scale. The Forestry Chronicle. 78(5): 672-679.

Larsen, M.C. and J.E. Parks. 1997. How Wide is a Road? The Association of Roads and Mass-wasting in a Forested Montane Environment. Earth Surface Processes and Landforms. 22: 835-848.

Larsen, M.C. and A. Simon. 1993. A Rainfall Intensity-duration Threshold for Landslides in a Humid-tropical Environment, Puerto Rico. Geografiska Annaler. 75A(1-2): 13-23.

Liquori, M., D. Martin, L. Benda, R. Coats, and D. Ganz . 2008 Scientific Literature Review of Forest Management Effects on Riparian Functions for Anadromous Salmonids. Report to the California State Board of Forestry and Fire Protection.

Lonsdale W.M. and A.M. Laine. 1994. Tourist Vehicles as Vectors of Weed Seeds in Kakadu National Park, Northern Australia. Biological Conservation. 69(3): 277-283.

Luce, C.H., and B. Wemple. 2001. Introduction to Special Issue on Hydrologic and Geomorphic Effects of Forest Roads. Earth Surface Processes and Landforms 26, 111–113.

Lyon, L.J. 1983. Road Density Models Describing Habitat Effectiveness for Elk. Journal of Forestry. 81(9):592-613.

Lyons, K. 2003. Assessment of Potential Strategies to Reduce Emissions from Diesel Engines in Washington State. Publication Number 05-02-005. Washington State Department of Ecology, Olympia, WA.

MacDonald, L.H., R.W. Sampson, D.M. Anderson. 2001. Runoff and Road Erosion at the Plot and Segments Scales, St. John, U.S. Virgin Islands. Earth Surface Processes and Landforms. 26: 251-272.

MacDonald, L.H. and D. Coe. 2007. Influence of Headwater Streams on Downstream Reaches in Forested Areas. Forest Science. 53(2): 148:168.

Manley, I.A. and S.K. Nelson. 1999. Habitat Characteristics Associated with Nesting Success and Predation at Marbled Murrelet Nests. Pacific Seabirds. 26: 40.

Manolis, J.C., D.E. Andersen, and F.J. Cuthbert. 2002. Edge Effect on Nesting Success of Ground Nesting Birds Near Regenerating Clearcuts in a Forest-Dominated Landscape. The Auk. 119(4): 955-970.

Marcus, M.D., L.E. Noel, and M.K Young. 1990. Rating Salmonid Habitat Research Needs in the Central Rocky Mountains. Fisheries. 15: 14-18.

Marion, J. 2006. Assessing and Understanding Trail Degradation: Results from Big South Fork National River and Recreation Area. USDI, National Park Service.

Martin, S.R. 2000. Donations as an Alternative to Wilderness User Fees: the Case of Desolation Wilderness. Pages 142-147 *in* D.N. Cole, S.F. McCool, W.T. Borrie, and J. Loughlin, eds. Wilderness Science in a Time of Change Conference, Volume 4: Wilderness Visitors, Experiences, and Visitor Management. 23 May 1999, Missoula, MT. Proceedings RMRS-P-15-Vol-4, USDA Forest Service., Rocky Mountain Research Station, Ogden, UT.

Mass, Cliff. 2008. The Weather of the Pacific Northwest. University of Washington Press, Seattle, WA. 336 p.

Maser, C., R. F. Tarrant, J. M. Trappe and J. F. Franklin. 1988. From the Forest to the Sea: A Story of Fallen Trees. General Technical Report PNW-GTR-229. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

McDade, M.H., Swanson, F.J., McKee, W.A., Franklin, J.F., and Van Sickle, J. 1990. Source Distances for Coarse Woody Debris Entering Small Streams in Western Oregon and Washington. Canadian Journal of Forest Research. 20: 326–330.

McDonnell, J.J. 2003. Where Does Water Go When it Rains? Moving Beyond the Variable Source Area Concept of Rainfall-Runoff Response, Hydrological Processes. 17: 1869-1875.

McNulty, S.G. and J.D. Aber. 2000. Climate Change Impacts on Forest Ecosystems. Acclimations. March/April 2000. U.S. Climate Change Science Program, Washington, D.C. Available online at: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/2000.04/Frsts.html.

McPherson, E.G. and J.R. Simpson. 1999. Carbon Dioxide Reduction through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters. USDA Forest Service General Technical Report PSW-GTR-171. Pacific Southwest Research Station, Albany, CA. Available online at: http://www.fs.fed.us/psw/publications/documents/gtr-171/gtr-171-cover.pdf.

Meehan, W.R. 1991. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. Special Publication. 19. American Fisheries Society, Bethesda, MD.

Megahan, W.F. 1991. Erosion and Site Productivity in Western-montane Forest Ecosystems. Pages 146-159 *in* A.E. Harvey and L. F. Neuenschwander, eds. Proceedings – Management and Productivity of Western-montane Forest Soils. General Technical Report INT-GTR-280. USDA Forest Service, Intermountain Research Station, Ogden, UT.

Megahan, W.F. and W.J. Kidd. 1972. Effects of Logging Roads on Erosion and Sediment Deposition from Steep Terrain. Journal of Forestry. 70(3): 136-141.

Miller, G.S. 1989. Dispersal of Juvenile Northern Spotted Owls in Western Oregon. M.S. Thesis. Oregon State University, Corvallis, OR.

Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat Selection by Spotted Owls during Natal Dispersal in Western Oregon. Journal of Wildlife Management. 61: 140–150.

Miller, J.R., L.A. Joyce, R.L. Knight, and R.M. King. 1996. Forest Roads and Landscape Structure in the Southern Rocky Mountains. Landscape Ecology. 11(2): 115–127.

Minkova, T. 2007. Northern Spotted Owl Surveys on DNR-Managed Lands in Southwest Washington. Washington Department of Natural Resources. Olympia, WA. Unpublished Report.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands, 2nd ed. Van Nostrand Reinhold, New York, NY. 722 p.

Moyle P.B. and R.A. Leidy. 1992. Loss of Biodiversity in Aquatic Ecosystems: Evidence form Fish Fauna. Conservation Biology: The Theory and Practice of Nature Conservation. Chapman and Hall, New York, NY.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian Microclimate and Stream Temperature Response to Forest Harvesting: A Review. Journal of the American Water Resources Association. 41(4): 813-834.

Moore, R.D. and S.M. Wondzell. 2005. Physical Hydrology and the Effects of Forest Harvesting in the Pacific Northwest: A Review. Journal of the American Water Resources Association. 41(4): 763-784

Mote, P.W. 2003. Trends in Snow Water Equivalent in the Pacific Northwest and their Climatic Causes. Geophysical Research Letters. 30: 1601.

Mote, P.W., A.F. Hamlet, M. Clark, D.P Lettenmaier. 2005. Declining Mountain Snowpack in Western North America. Bulletin of the American Meteorological Society. 86: 39-49.

Murphy, M.L. and K.V. Koski. 1989. Input and Depletion of Woody Debris in Alaska Streams and Implications for Stream-side Management. North American Journal of Fisheries Management. 9(4): 427-436.

Murphy, M.L. and W.R. Meehan. 1991. Stream Ecosystems. Pages 17-46 *in* W.R. Meehan, ed. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19, Bethesda, MD.

Nagorsen, D. and M. Brigham. 1993. Royal British Columbia Museum Handbook: Bats of British Columbia., University of British Columbia Press, Vancouver, BC.

Naiman, R.J., R.E. Bilby, and P.A., Bisson, 2000. Riparian Ecology and Management in the Pacific Coastal Rain Forest. BioScience. 50; 996–1011.

National Oceanic and Atmospheric Administration. 1985. Climates of the States: Narrative Summaries, Tables and Maps for Each State with Overview of State Climatologist Programs (3rd ed.), Volume 2, Gale Research Company, New York, NY. Available online at: http://www.wrcc.dri.edu/narratives/WASHINGTON.htm.

National Oceanic and Atmospheric Administration. 2008. 2007 was Tenth Warmest for U.S., Fifth Warmest Worldwide. National Oceanic and Atmospheric Administration, Washington, D.C. Available online at: http://www.noaanews.noaa.gov/stories2008/20080115_warmest.html.

National Safety Council. 2005. Environmental Health Center: Glossary. Available online at: http://www.nsc.org/EHC/glossary.htm.

Natural Resource Conservation Service. 1980. Soil Survey of Kitsap County. Available online at: http://soildatamart.nrcs.usda.gov/Manuscripts/WA635/0/wa635_text.pdf.

Nelson, Stephen A. 2003. http://www.tulane.edu/~sanelson/geol111/masswasting.htm.

NOAA *See* National Oceanic and Atmospheric Administration

Nolan, K.M. and R.J. Janda. 1995. Impacts of Logging on Stream-sediment Discharge in the Redwood Creek Basin, Northwestern California. Pages L1-L8 *in* K.M. Nolan, H.M. Kelsey, and D.C. Marron, eds. Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California. Professional Paper 1454. U.S. Geological Survey, Washington, D.C.

Norse, E.A. 1990. Ancient Forests of the Pacific Northwest. Island Press, Washington, D.C..

OFM *See* Washington State Office of Financial Management

O'Laughlin, J. and P.S. Cook. 2003. Inventory-based Forest Health Indicators. Journal of Forestry. 101(2): 11-17.

Oliver, C.D. and B.C. Larson. 1996. Forest Stand Dynamics. John Wiley & Sons, New York, NY.

Olson G.S., E. Glenn, R.G. Anthony, E.D. Forsman, J.A. Reid, P.J. Loschl, and W.J. Ripple. 2004. Modeling Demographic Performance of Northern Spotted Owls Relative to Forest Habitat in Oregon. Journal of Wildlife Management. 68: 1039–1053.

O'Neill, G.A., N.K. Ukrainetz, M.R. Carlson, C.V. Cartwright, B.C. Jaquish, J.N. King, J. Krakowski, J.H. Russell, M.U. Stoehr, C. Xie, and A.D. Yanchuk. 2008. Assisted Migration to Address Climate Change in British Columbia: Recommendations for Interim Seed Transfer Standards. Technical Report 048, B.C. Ministry of Forests and Range, Research Branch, Victoria, B.C.. Available online at: http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr048.htm.

Oregon Wild. 2007. The Straight Facts on Forests, Carbon, and Global Warming, Version 1.4. Oregon Wild, Eugene, OR. Available online at: http://www.oregonwild.org/.

Parsons Brinckerhoff. 2005. Air Quality. Pages 3.13-1 to 3.13-9 in Tukwila South Project Draft Environmental Impact Statement. City of Tukwila, Tukwila, WA. Available online at: http://www.ci.tukwila.wa.us/dcd/tuksouth/draftEIS/TukSouth-3.13AirQuality.pdf.

Pascual-Hortal, L. and S. Saura. 2006. Comparison and Development of New Graph-based Landscape Connectivity Indices: Towards the Prioritization of Habitat Patches and Corridors for Conservation. Landscape Ecology. 21(7):959–967.

Payne, N.E, and F.C. Bryant. 1994. Techniques for Wildlife Habitat Management of Uplands. New York, NY: McGraw-Hill.

Patton, D.R. 1992. Wildlife Habitat Relationships in Forested Ecosystems. Timber Press, Portland, OR.

PBS *See* Public Broadcasting System

Picard, P. and S.R.J. Sheppard. 2002. Visual Resource Management in British Columbia: Part I, the Effects of Visual Resource Management on Timber Availability: A Review of Case Studies and Policy. B.C. Journal of Ecosystems and Management 1(2): 73-84.

Powers, R.F., D.H. Alban, R.E. Miller, A.E. Tiarks, C.G. Wells, P.E. Avers, R.G. Cline, R.O. Fitzgerald, and N.S. Loftus, Jr. 1990. Sustaining Site Productivity in North American Forests: Problems and Prospects. Pages 49-79 *in* S.P. Gessel, D.S. Lacate, G.F. Weetman, and R.F. Powers, eds. Sustained Productivity of Forest Soils: Proceedings of the 7th North American Forest Soils Conference. University of British Columbia, Vancouver, Canada.

Princeton University Staff, G.A. Miller, C. Fellbaum, R. Tengi, P. Wakefield, H. Langone, and B.R. Haskell. 2006. WordNet Search 3.0. Available online at: http://wordnetweb.princeton.edu/perl/webwn/. Accessed January 13, 2009.

PSRC *See* Puget Sound Regional Council

Puettmann, K.J., Hann, D.W., Hibbs, D.E. 1993. Evaluation of the size-density relationships for pure red alder and Douglas-fir stands. Forest Science. 39(1): 7-27.

Public Broadcasting System. 2008. Glossary: National Geographic's Strange Days on Planet Earth. Vulcan Productions and National Geographic Television and Film. Available online at: http://www.pbs.org/strangedays/glossary/C.html.

Puget Sound Regional Council. 2005. Growth Management by the Numbers: Population, Household, and Employment Growth Targets in the Central Puget Sound Region. Puget Sound Regional Council, Seattle, WA.

Raedeke, K.J. 1988. Introduction. Pages xiii-xvi *in* K.J. Raedeke, ed. Streamside Management: Riparian Wildlife and Forestry Interactions, Contribution No.59. University of Washington, Institute of Forest Resources, Seattle, WA.

Raison, R.J. and W.J.B. Crane. 1986. Nutritional Costs of Shortened Rotations in Plantation Forestry. Proceedings 17. IUFRO World Congress. Ibariki, Japan. Div. 1, p. 63-72.

Ralph, S.C., Poole, G.C., Conquest, L.L., and Naiman, R.J. 1994. Stream Channel Morphology and Woody Debris in Logged and Unlogged Basins of Western Washington. Canadian Journal Fisheries and Aquatic Sciences. 51: 37.51.

Raphael, M.G., S.K. Nelson, P. Swedeen, M. Ostwald, K. Flotin, S. Desimone, S. Horton, P. Harrison, D. Prenzlow Escene, and W. Jaross. 2008. Recommendations and Supporting Analysis of Conservation Opportunities for the Marbled Murrelet Long-term Conservation Strategy. Washington Department of Natural Resources. Olympia, WA.

Reed R.A., J. Johnson-Barnard, and W.L. Baker. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. Conservation Biology. 10(4): 1098-1106.

Reid, L.M. and T. Dunne. 1984. Sediment Production from Road Surfaces. Water Resources Research 20(11): 1753-1761.

Reijnen R. 1995. Disturbance by Car Traffic as a Threat to Breeding Birds in the Netherlands. PhD Thesis. Institute for Forestry and Nature Research, Wageningen, Netherlands.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995. The Effects of Car Traffic on Breeding Bird Populations in Woodland. III. Reduction of Density in Relation to the Proximity of Main Roads. Journal of Applied Ecology. 32(1): 187-202.

Reynolds, K.M. 1999. EMDS Users Guide (Version 2.0): Knowledge-based Decision Support for Ecological Assessment. General Technical Report PNW-GTR-470. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Reynolds, K.M., M. Jensen, J. Andreasen, and I. Goodman. 2000. Knowledge-based Assessment of Watershed Condition. Computers and Electronics in Agriculture 27(1): 315–334.

Rhodes, J.J., D.A. McCullough, and F.A. Espinosa Jr. 1994. A Coarse Screening Process for Evaluation of the Effects of Land Management Activities on Salmon Spawning and Rearing Habitat in ESA Consultations. Tech. Rep. 94-4. Columbia River Intertribal Fish Commission, Portland, OR. 127 p.

Ribe, R. 1999. Regeneration Harvests Versus Clearcuts: Public Views of the Acceptability and Aesthetics of Northwest Forest Plan Harvests. Northwest Science. (73): 102-117.

Richardson, J.S., R.J. Naiman, F.J. Swanson, and D.E. Hibbs. 2005. Riparian Communities Associated With Pacific Northwest Headwater Streams: Assemblages, Processes, and Uniqueness. Journal of the American Water Resources Association. 41(4): 935–947.

Rohrbaugh, R. 2000. Recreational Impact. Birdscope. 14(2): 6.

Rot, B.W., R.J. Naiman, and R.E. Bilby. 2000. Stream Channel Configuration, Landform, and Riparian Forest Structure in the Cascade Mountain, Washington. Canadian Journal of Fisheries Aquatic Sciences. 57: 699-707.

Rothacher, J. 1971. Regimes of Streamflow and their Modification by Logging. Pages 40-54 *in* Proceedings of a Symposium, Forest Land Uses and Stream Environment, October 19-21, 1970. Oregon State University, Corvallis, OR.

Rudis, V.A. 1995. Regional Forest Fragmentation Effects on Bottomland Hardwood Community Types and Resource Values. Landscape Ecology. 10(5): 291-307.

Running, S.W. 2006. Is Global Warming Causing More, Larger Wildfires? Science. 313: 927-928.

Ryan, J.A. 2002 (Sept). Hydrologic Analysis of the Tahuya Lake Watershed. Washington Department of Natural Resources, Land Management Division internal report. Unpublished. Olympia, WA.

Ryan, R.L. 2005. Social Science to Improve Fuels Management: A Synthesis of Research on Aesthetics and Fuels Management. General Technical Report NC-257, USDA Forest Service, North Central Research Station. St. Paul, MN. 92 p. Available online at: http://www.ncrs.fs.fed.us/pubs/gtr/gtr_nc257.pdf. Accessed December 21 2007.

Salo, E.O. and T.W. Cundy, eds. 1987. Streamside Management: Forestry and Fishery Interactions. Institute of Forest Resources, Contribution No. 57. University of Washington, Seattle, WA .

Sampson, N. and L. DeCoster. 2000. Forest Fragmentation: Implications for Sustainable Private Forests. Journal of Forestry. 98(3): 4-8.

Samuelsson, J., L. Gustafason and T. Ingelog. 1994. Dying and Dead Trees: a Review of their Importance for Biodiversity. Swedish Threatened Species Unit, Uppsala, Sweden. 110 p.

SCS *See* Soil Conservation Service.

Scott, J.H. 1998. Fuel Reduction in Residential and Scenic Forests: A Comparison of Three Treatments in a Western Montana Ponderosa Pine Stand. Research Paper RMRS-5. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. 19 p.

Sedell, J. R., P. A. Bisson, E J. Swanson, and S. V. Gregory. 1988. What we know about large trees that fall into streams and rivers. Pages 47-81 *in* C. Maser, R. F. Tarrant, J. M. Trappe, and J. E Franklin. From the Forest to the Sea: a Story of Fallen Trees. General Technical Report PNW-GTR-229. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Sharpe, W.E. and D.R. DeWalle. 1980. Water Quality. *in* R. Lee, ed. Forest Hydrology. Columbia University Press, New York, NY.

Sheppard, S.R J. 2000. Beyond Visual Resource Management: Emerging Theories of an Ecological Aesthetic and Visible Stewardship. Pages 149-173 *in* S.R.J. Sheppard and H. Harshaw, eds. Forests and Landscapes: Linking Ecology, Sustainability, and Aesthetics. IUFRO Research Series, No. 6. IUFRO, Wallingford, England.

Sherry, R.A., X. Zhou, S. Gu, J. Arnone III, D.S. Schimel, P.S. Verburg, L.L. Wallace and Y. Luo, 2007. Divergence of Reproductive Phenology under Climate Warming. Proceedings of the National Academy of Sciences of the United States of America. 104(1): 198-202.

Schlichte, K., Donda, Z., and P. Wolff. 1998. Assessment, Mitigation of New Trail Technology, and Monitoring of Trail Erosion Impacts on the Tahuya State Forest. Washington State Department of Natural Resources. Olympia, WA.

Sidle, R.C. 1985. Factors Influencing the Stability of Slopes. Pages 17-25 *in* Proceedings of a Workshop on Slope Stability: Problems and Solutions in Forest Management. General Technical Report GTR PNW-180. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Simpson Resource Company. 2002. Draft Environmental Impact Statement for the Final Green Diamond Resource Company Aquatic Habitat Conservation Plan/ Candidate Conservation Agreement with Assurances, Del Norte and Humboldt Counties, CA.

Singleton, P.H., W.L. Gaines, and J.F. Lehmkuhl. 2002. Landscape Permeability for Large Carnivores in Washington: A Geographic Information System Weighted-distance and Least-cost Corridor Assessment. Research Paper PNW-RP-549. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 89 p. Available online at: http://www.treesearch.fs.fed.us/pubs/5093.

Smidt M. and C.R. Blinn. 1995. Logging for the 21st Century: Forest Ecology and Regeneration. FO-06517. Extension Service, University of Minnesota.

Smith, J. E., L.S Heath, and J.C. Jenkins. 2003. Forest Volume-to-Biomass Models and Estimates of Mass for Live and Standing Dead Trees of U.S. Forests. General Technical Report NE-GTR-298. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 57 p.

Smith, J. E.; L. S. Heath, K. E. Skog, and R.A Birdsey. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. General Technical Report NE-GTR-343. USDA Forest Service, Northeastern Research Station, Newtown Square, PA. 216 p.

Soil Conservation Service. 1993. Wetland Groundwater Processes. WRP Technical Note HY-EV-2.2. Available online at: http://el.erdc.usace.army.mil/elpubs/pdf/hyev2-2.pdf.

Solis, D.M. and R.J. Gutierrez. 1990. Summer Habitat Ecology of Northern Spotted Owls in Northwestern California. The Condor. 92(3): 739-748.

Spence, B.C., G.A. Lomnicky, R.M. Hughes and R. P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. Funded jointly by the U.S. EPA, U.S. Fish and Wildlife Service and National Marine Fisheries Service. TR-4501-96-6057. Man Tech Environmental Research Services Corp., Corvallis, OR. Available online at: http://www.nwr.noaa.gov/1habcon/habweb/habguide/ManTech/front.htm.

Spencer, R. 2002. Washington State Elk Herd Plan: North Rainier Elk Herd. Washington Department of Fish and Wildlife, Olympia, WA.

Spies, T.A. 1997. Stand Structure, Function, and Composition. Pages 11-30 *in* K.A. Kohm and J.F. Franklin, eds. Creating a Forestry for the 21st Century: The Science of Ecosystem Management. Island Press, Washington, D.C.

Spies, T.A., Ripple, W.J., Bradshaw, G.A., 1994. Dynamics and Pattern of a Managed Coniferous Forest Landscape in Oregon. Ecological Applications. 4: 555–568.

Stewart, I.T., D.R., Cayan, and M.D. Dettinger. 2005. Changes Toward Earlier Stream Flow Timing Across Western North America. Journal of Climatology. 18: 1136–1155.

Stoeckeler, J.H. 1967. Wetland Road Crossings: Drainage Problems and Timber Damage. Research Note NC-27. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Stokowski, P.A. and C.B. LaPointe. 2000. Environmental and Social Effects of ATVs and ORVs: An Annotated Bibliography and Research Assessment. University of Vermont, Burlington, VT.

Stull, R., S. Shipley, E. Hovanitz, S. Thompson, and K. Hovanitz. 1979. Effects of Off-road Vehicles in Ballinger Canyon, California. Geology. 7(1): 19-21.

Sturtevant, V., M.A. Moote, P. Jakes, and A.S. Cheng. 2005. Social Science to Improve Fuels Management: A Synthesis of Research on Aesthetics and Fuels Management. General Technical Report NC-GTR-257. USDA Forest Service, North Central Research Station, St. Paul, MN. Available online at: http://www.nrs.fs.fed.us/pubs/gtr/gtr_nc257.pdf.

Sugden, B.D. and S.W. Woods. 2007. Sediment production from forest roads in western Montana. Journal of the American Water Resources Association. 43(1): 193-206.

Sullivan, K.O. and D.H. Duncan. 1981. Sediment Yield from Road Surfaces in Response to Truck Traffic and Rainfall. Weyerhaeuser Research Report. Weyerhaeuser, Western Forestry Research Center, Centralia, WA. 46 p.

Swanson F.J. and C.T. Dyrness. 1975. Impact of Clear-cutting and Road Construction on Soil Erosion by Landslides in the Western Cascade Range, Oregon. Geology. 3(7): 393-396.

Swanson F.J., G.W Lienkaemper, J.R. Sedall. 1976. History, Physical Effects, and Management Implications of Large Organic Debris in western Oregon Streams. General Technical Report PNW-GTR-56. USDA Forest Service, Pacific Northwest and Range Experiment Station, Portland, OR.

Tabacchi, E., D.L. Correll, R. Hauer, G. Pinay, A. M. Planty-Tabacchi, and R. C. Wissmar. 1998. Development, Maintenance, and Role of Riparian Vegetation in the River Landscape. Freshwater Biology. 40: 497–516.

Tainter, F.J. and F.A. Baker. 1996. Principles of Forest Pathology. John Wiley & Sons, New York, NY.

Taylor, J.G. and T.C. Daniel. 1984. Prescribed Fire: Public Education and Perception. Journal of Forestry. 82: 361-365.

Tappeiner, J.C., D.W. Huffman, D. Marshall, T.A. Spies and J.D. Bailey. 1997. Density Ages and Growth Rates in Old-growth and Young-growth Forests in Western Oregon. Canadian Journal of Forest Research. 27: 638-648.

Theobald, D.M. 2002. Modeling Functional Landscape Connectivity. ESRI User Conference Proceedings 2002. Available online at: http://gis.esri.com/library/userconf/proc02/pap1109/P1109.htm.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Winslow, B.B. Noon, and J. Verner. 1990. A Conservation Strategy for the Northern Spotted Owl: Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI National Park Service, Portland, OR.

Thompson, J. 2005. Keeping it Cool: Unraveling the Influences on Stream Temperature. Science Findings. 73: 1-5.

Timber, Fish, and Wildlife Cultural Resource Committee. 2003. Natural Resources and Protection Management Plan.

Triska, F.J., J.R. Sedell, and S.V. Gregory. 1982. Coniferous Forest Streams. Pages 292-332 *in* R. L.Edmonds, ed. Analysis of Coniferous Forest Ecosystems in the Western United States. UN/IBP Synethesis Series 14. Hutchinson Ross Publishing Co., Stroudsburg. PA: 419 p.

Trombulak, S.C. and C.A Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14: 18–30.

Unites States Census Bureau. 2000. Available online at: http://www.census.gov/main/www/cen2000.html.

United States Department of Agriculture. 1982. Soil Survey of Thurston County, Washington. United States Department of Agriculture Soil Conservation Service in Cooperation with Washington State Department of Natural Resources and Washington State University, Olympia, WA.

United States Department of Transportation (USDOT). 2001. About Transportation and Climate Change. Center for Climate Change and Environmental Forecasting. Available online at: http://climate.volpe.dot.gov/national.html.

United States Environmental Protection Agency. 1998. Climate Change and Oregon. EPA 236-F-98-00/U. Washington, D.C., U.S. Environmental Protection Agency, Climate and Policy Division.

United States Environmental Protection Agency. 2007. CO: What is It? Where Does It Come From? Available online at: http://www.epa.gov/air/urbanair/co/what1.html.

United States Fish and Wildlife Service. 1991. Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls. U.S. Fish and Wildlife Service, Portland, OR.

United States Fish and Wildlife Service. 1992. Draft Recovery Plan for the Northern Spotted Owl. U.S. Fish and Wildlife Service, Portland, OR.

United States Fish and Wildlife Service. 1992. Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls (Revised). U.S. Fish and Wildlife Service, Portland, OR.

United States Fish and Wildlife Service. 1997. Intra-service Concurrence Memorandum and Biological Opinion for the Washington Department of Natural Resources' Habitat Conservation Plan. Fish and Wildlife Service, Olympia, WA.

United States Fish and Wildlife Service. 2004. Northern Spotted Owl Five-year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, OR.

United States Fish and Wildlife Service. 2008. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, OR. 142 p.

United States Fish and Wildlife Service, National Marine Fisheries Service, United States Environmental Protection Agency, Office of the Governor of the State of Washington, Washington State Department of Natural Resources, Washington Department of Fish and Wildlife, Washington State Department of Ecology, Colville Confederated Tribes, Washington State Association of Counties, Washington Forest Protection Association, and Washington Family Forestland Association. 1999. Forests and Fish Report. Washington State Department of Natural Resources, Olympia, WA.

Urban, D. and T. Keitt. 2001. Landscape Connectivity: A Graph-theoretic Perspective. Ecology. 82(5): 1205-1218.

USDA *See* United States Department of Agriculture

USDA Forest Service. 1995. Landscape Aesthetics: A Handbook for Scenery Management. Agriculture Handbook Number 701. USDA Forest Service, Washington, D.C.

USDA Forest Service. 2001. Forest Roads: A Synthesis of Scientific Information. General Technical Report PNW-GTR-509. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Available online at: http://www.fs.fed.us/eng/road_mgt/science.pdf.

USDA Forest Service 2000-2004. National Survey on Recreation and the Environment. Southern Research Station. Athens, GA. Data downloaded on June 25, 2009 from: www.srs.fs.usda.gov/trends/RECUPDATES/region11.html#nbtp.

USFS *See* USDA Forest Service

USFWS *See* United States Fish and Wildlife Service

Van Heeswijk, M., J.S. Kimball, D. Marks. 1996. Simulation of Water Available for Runoff in Clearcut Forest Openings During Rain-on-snow Events in the Western Cascade Range of Oregon and Washington. USGS Water-Resources Investigations Report 95-4219.

van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, T.T. Veblen. 2009. Widespread Increase of Tree Mortality Rates in the Western United States. Science. 323: 521-524.

Van Pelt, R. 2007. Identifying Mature and Old Forests in Western Washington. Washington State Department of Natural Resources, Olympia, WA.

Vogt, C.A. and Williams, D.R. 1999. Support for Wilderness Recreation Fees: The Influence of Fee Purpose and Day Verses Overnight Use. Journal of Park and Recreation Administration. 17(3): 85-99.

Waldien, D., J. Hayes, and B. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. Northwest Science 77(1): 64-71.

Washington State Department of Ecology. 2006. Focus on Reducing Diesel Exhaust. Washington State Department of Ecology, Air Quality Program. Available online at: http://www.ecy.wa.gov/programs/air/cars/DieselEmissionPage.htm.

Washington State Department of Ecology. 2007. Washington State's Water Quality Assessment [303(d) & 305(b) Report]. Available online at: http://www.ecy.wa.gov/PROGRAMS/wq/303d/2002/2002-index.html.

Washington State Department of Ecology. 2008a. Extreme Weather. Available online at: http://www.ecy.wa.gov/climatechange/extremeweather_more.htm.

Washington State Department of Ecology. 2008b. Surface Water Quality Standards. Available online at: http://www.ecy.wa.gov/programs/wq/swqs/index.html.

Washington State Department of Ecology. 2008c. What is Climate Change? Available online at: http://www.ecy.wa.gov/climatechange/whatis.htm.

Washington State Department of Ecology. 2008d. Air. Available online at: http://www.ecy.wa.gov/air.html.

Washington State Interagency Committee for Outdoor Recreation (IAC) March 2003. Estimates of Future Participation in Outdoor Recreation in Washington State.

Washington State Department of Licensing 2009. Registered Recreational Vehicles. Available online at: http://www.dol.wa.gov. Accessed 26 June 2009.

Washington State Department of Natural Resources. 1986. Tiger Mountain State Forest Management Plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 1987. Timber, Fish and Wildlife Agreement. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 1996. Forest Practices Board Emergency Rules (Stream Typing). Forest Practices Board, Olympia, WA.

Washington State Department of Natural Resources. 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 1998. Final Asset Stewardship Plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources 2001. Final Environmental Impact Statement on Alternatives for Forest Practices Rules. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2003. Draft Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2004. Final Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2005. Definition and Inventory of Old Growth Forests on DNR-Managed State Lands. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2006a. Final Environmental Impact Statement on the Policy for Sustainable Forests. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2006b. Policy for Sustainable Forests. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2006c. A Report to the Legislature: Forest Health Improvement Program. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2007a. Addendum for Final Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2007b. Tahuya State Forest Off-Road Vehicle Recreational Facilities Plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2008. South Puget HCP Planning Unit Forest Land Plan Draft Environmental Impact Statement. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Transportation. 2007. Visual Impacts. Pages 459.1-459.9 *in* Environmental Services Office. Environmental Procedures Manual M 31-11. Washington State Department of Transportation, Olympia, WA.

Washington State Interagency Committee for Outdoor Recreation. 2003. Estimates of Future Participation in Outdoor Recreation in Washington State. Interagency Committee for Outdoor Recreation, Olympia, WA.

Washington State Office of Financial Management. 2007a. 2007 Population Trends. Office of Financial Management Forecasting Division, Olympia, WA. Available online at: http://www.ofm.wa.gov/pop/poptrends/poptrends_07.pdf.

Washington State Office of Financial Management. 2007b. Official April 1, 2007 population estimates. Office of Financial Management, Olympia, WA.

Washington State Office of Financial Management. 2008. Intercensal and Postcensal Estimates of April 1 County Population by Age and Sex: 1980-2008. Available online at: http://www.ofm.wa.gov/pop/coagemf/default.asp. Accessed on 26 June 2009.

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive Physiological Measures of Disturbance in the Northern Spotted Owl. Conservation Biology. 11(4): 1019-1022.

Waters, TF. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. Bethesda, MD.

Weathers, W.W., P.J. Hodum, and J.A. Blakesley. 2001. Thermal Ecology and Ecological Energetics of California Spotted Owls. Condor. 103(4): 678–690.

Webb, R.H., H.G. Wilshire, and M.A. Henry. 1983. Natural Recovery of Soils and Vegetation Following Human Disturbance. Pages 279-302 *in* R.H. Webb and H.G. Wilshire, eds. Environmental Effects of Off-road Vehicles: Impacts and Management in Arid Regions. Springer-Verlag, New York, NY.

Wemple, B.C. and J.A. Jones. 2003. Runoff Production on Forest Roads in a Steep, Mountain Watershed. Water Resource Research 39(8).

Westerling, A.L., H.G. Hidalgo, D.R. Cayan and T.W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science. 313: 940-943.

White, C. 1992. Legislative History of Outdoor Recreation Fees. US Army Corps of Engineers, Waterways Experiment Station. Vol. R-92-3 August.

Wilson, J.P. and J.P. Seney. 1994. Erosional Impact of Hikers, Horses, Motorcycles, and Off-Road Bicycles on Mountain Trails in Montana. Mountain Research and Development, 14(1): 77-88.

Wipfli, M.S. and D.P. Gregovich. 2002. Export of Invertebrates and Detritus from Fishless Headwater Streams in Southeastern Alaska: Implications for Downstream Salmonid Production. Freshwater. Biology. 47: 957-969.

Wood, T.J., J. Bolek, and K. Doucette. 1990. Retirement Centers: the Trend toward Resort-Style Living. Pages 83-95 *in* J.T. O'Leary, D.R. Fesenmaier, and T. Brown, eds. Proceedings of the National Outdoor Recreation Trends Symposium III. Indianapolis, IN.

Yahner, R.H. 1988. Changes in Wildlife Communities near Edges. Conservation Biology. 2(4): 333-339.

Ziemer, R.R. and T.E. Lisle. 1998. Hydrology. Pages 43-68 in R.J. Naiman and R.E. Bilby, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer Verlag, New York, NY.

Zobrist K.W. and T.M. Hinckley 2005. A Literature Review of Management Practices to Support Increased Biodiversity in Intensively Managed Douglas-fir Plantations. Final Technical Report to the National Commission on Science for Sustainable Forestry (NCSSF). University of Washington, Seattle, WA.

Zube, E.H. 1986. Landscape Values: History, Concepts, and Applications. Pages 3-19 *in* R.C. Smardon, J.F. Palmer, and J.P. Felleman, eds. Foundations for Visual Project Analysis. John Wiley & Sons, New York, NY.