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# The Okanogan-Wenatchee National Forest Restoration Strategy: adaptive ecosystem management to restore landscape resiliency

**2012 Version**

**Okanogan-Wenatchee National Forest**

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## INTRODUCTION

A concerted effort is needed to restore the sustainability and resiliency of forested ecosystems on the Okanogan-Wenatchee National Forest (OWNF). Numerous assessments of the OWNF, resulting in a long list of peer-reviewed publications, show: (1) increased susceptibility to uncharacteristically large and severe fires; (2) uncharacteristically severe insect outbreaks; and (3) habitats are declining for late-successional and old forest associated species (Lehmkuhl et al. 1994, Hessburg et al. 1999a, Franklin et al. 2007). Additionally, while the Forest's aging road network provides needed access for recreation and forest management, it also degrades the condition of aquatic ecosystems. Roads also require expensive repairs and untimely closures when slopes fail. These resource issues on the OWNF are likely to be exacerbated by climate change (Franklin et al. 2007, Binder et al. 2009, Vano et al. 2009) adding an even greater sense of urgency.

To restore forest sustainability and resiliency, the OWNF needs to substantially increase its restoration footprint, reach across boundaries through collaborative efforts, better integrate across disciplines to accomplish multiple objectives, and adapt to changing conditions and new science. To this end, the OWNF developed the Forest Restoration Strategy (Restoration Strategy). The Restoration Strategy described in this document is our method for implementing our "Restoration Vision" (page 1 of this document). The Restoration Strategy first describes the scientific basis for restoration needs and objectives (Chapter 1). Second, it outlines our approach to an integrated Landscape Evaluation of forest resources to set the context and priorities for [restoration treatments](#) (Chapter 2). Finally, it describes our plan for [monitoring](#) and [adaptive management](#) (Chapter 3). The appendices provide additional specifics on land use allocations (Appendix A), silvicultural treatments (Appendix B), and updates to the Strategy currently in progress (Appendix C).

The first version (September 2010) of the Restoration Strategy obtained substantial input and review across the OWNF. Scientists from outside the OWNF also peer reviewed the Strategy and have continued to assist with its updating and implementation. The Wenatchee Forestry Sciences Lab (WFSL) has been particularly instrumental in the development of Restoration Strategy tools and [projects](#). The collaboration between the OWNF and the WFSL will continue throughout the ongoing development, implementation, and monitoring of the Forest Restoration Strategy.

This document outlines a new planning approach based on principles of landscape-level restoration ecology. This approach can be applied to all forest types, but we focus on the dry and mesic portions of the Forest where concerns about sustainability and resiliency are greatest (Hessburg et al. 1999, Agee 2003, Hessburg et al. 2005). The objectives of the OWNF Restoration Strategy are as follows:

1. Address new science and management direction and adapt to climate change
2. Provide a consistent definition and integrated approach to forest restoration
3. Increase the restoration footprint through a process that identifies high priority, strategic treatment areas
4. Improve planning and project efficiency
5. Improve outcomes through monitoring and adaptive management

## ***Need for Change and a Sense of Urgency***

Many scientific publications from 2000 to 2010 clearly point to the need for and application of a new approach to forest restoration. Of particular interest are the *Mission Creek Fire and Fire Surrogate* study (Agee and Lehmkuhl 2009), the *Birds and Burn* study (Saab et al. 2007), and other studies in forest landscape ecology, spotted owl prey base, and riparian-upslope fire continuity. Each of these studies has produced local science published in reputable journals within the last ten years. Research in climate change has advanced the understanding of likely future trends in forest conditions and interactions with disturbance [processes](#), forest sustainability, ecosystem processes, and the existing road infrastructure.

Other relevant information from the past ten years includes the revised recovery plan for the northern spotted owl (USFWS 2011). This plan presents a significant shift in the management of spotted owl habitat in fire-prone forests, which better incorporates disturbance ecology and habitat sustainability. Implementation of the plan requires a landscape view and the use of fire models to design and evaluate treatment options. The Washington Department of Natural Resources completed a body of work in which Franklin et al. (2008) summarized dry forest science and outlined a forest restoration strategy. Van Pelt (2008) published a useful guide to identify old trees and forests in eastern Washington. The importance of dry forests is further illustrated by a similar publication by the Wilderness Society on the restoration of dry forests of the northern Rocky Mountains (Crist et al. 2009) and an ecosystem management strategy for mixed conifer forests (North et al. 2009).

Aquatic habitat maintenance and restoration in the western United States (and on the OWNF) are often perceived as being in conflict with forest restoration (Rieman et al. 2000). Some researchers suggest that short-term negative effects of fuel treatment on aquatic habitat might often be outweighed by the potential long-term benefits of the treatment (Rieman et al. 2000). However, not treating to avoid short-term effects may inadvertently lead to conditions favorable to uncharacteristic, high-severity disturbances (O’Laughlin 2005). Other researchers reported findings suggesting that, over various time scales from a few years to over a century, the aquatic habitat resulting from disturbances caused by fire (sometimes even high severity fire) is more productive than similar habitats where the fire events were suppressed or altered by human influences (Reeves et al. 1995, Dunham et al. 2003, Benda et al. 2003, Rieman et al. 2005).

Agencies and many scientists interested in interactions between fire and the aquatic environment recognize that vegetation treatments will need to take place in some altered ecosystems of the northwestern U.S. (Bisson et al. 2003, Finney et al. 2007, Noss et al. 2006, Reeves et al. 1995, Rieman and Clayton 1997, USDA and USDI 2006). For example, small Gila trout populations in southwestern U.S. forests are currently threatened by both management activities and degraded habitat resulting from fire exclusion (Rieman and Clayton 1997). When developing fuel treatments that consider the aquatic environment, the potential for success may be greater when particularly damaging roads are obliterated (Rieman and Clayton 1997). Where habitat is less degraded, researchers suggest mimicking natural disturbances, avoiding simplistic treatments, proceeding with caution, and maintaining a strong focus on experimentation and monitoring (Reeves et al.

1995, Rieman and Clayton 1997, Gresswell 1999, Bisson et al. 2003, Luce and Rieman 2005). The OWNF has an extensive, aging, and expensive to maintain road network which interferes with historical hydrological patterns and is a major source of potential degradation to aquatic ecosystems.

Managing forest ecosystems in the face of climate change creates many challenges and a sense of urgency for managers. For example, Littell et al. (2009) predicted that the area burned by fires within the Interior Columbia Basin many increase by two or even three times by the end of the 2040s. Climate change will likely exacerbate insect and disease problems (Binder et al. 2009), alter fish and wildlife habitats (Mantua et al. 2009, Thomas and Lennon 1999), and change hydrologic regimes (Vano et al. 2009). Restoring the resiliency of forests to adjust to a changing climate is a critical issue and one that, in part, resulted in the goal of doubling our restoration footprint in the next 10 years.

In summary, a new strategy is needed because of new science, local monitoring results, and a need to be more efficient in our planning efforts. The OWNF Restoration Strategy emphasizes a restoration paradigm where ecological outcomes for multiple resources drive the development and implementation of projects. This is different from the existing paradigm in which timber production targets often drive forest projects, while the needs of other resources are often overlooked. . The Restoration Strategy allows for wildlife and aquatic restoration and habitat improvement opportunities to be considered simultaneously with vegetation and fire restoration opportunities, providing for integration of resource objectives. The Restoration Strategy enables more efficient project area identification and planning to increase the size of the OWNF’s restoration footprint. Integration among resource disciplines is critical to successful implementation of the Forest Restoration Strategy.

## ***Document Organization***

This document is organized into three parts:

### **[Part I](#)**

This first chapter provides important background information, such as a summary of management direction, descriptions of key concepts, a review of relevant science, and lessons learned from over a decade of implementing the 2000 Dry Forest Strategy (citation?).

### **[Part II](#)**

The second chapter presents the process for an integrated Landscape Evaluation used to determine the need, priority, and location for restoration treatments. This part also addresses the development of a “landscape prescription,” to treat multiple resources, and selection and analysis of a Potential Landscape Treatment Area and projects.

### **[Part III](#)**

The third chapter gives an overview of adaptive ecosystem management and identifies steps the OWNF will take to implement an adaptive approach to forest restoration.

## **Hot Boxes and Hyperlinks**

Throughout the document are “hot boxes” that highlight key issues and important information. For readers of this Strategy with access to the Forest Service intranet, some

key references are hyperlinked in the [Literature Citations](#) section. Citations with the first author's name underlined are hyperlinked directly to full-text PDF documents of the cited literature. Hyperlinks within the body of this document connect the first use of a term to its definition in the Glossary at the end.

## **PART I: BACKGROUND**

### ***Management Direction and Policy***

In 1992, Forest Service Chief Dale Robertson issued direction that ecosystem management is the model by which National Forests and Grasslands should be managed in order to meet multiple-use objectives. In addition to acknowledging the need for collaboration among land managers, scientists, and the public, he explicitly directed the restoration of biological diversity and ecological processes leading to productive and sustainable ecosystems. The Northwest Forest Plan (1994) brought that direction a step closer to the ground. Its Record of Decision (ROD) included a discussion of the statutory basis for ecosystem management and a discussion of ecological process, [pattern](#), and composition as important management principles. It also included direction that, "Except as otherwise noted...the standards and guidelines of existing plans apply where they are more restrictive or provide greater benefits to late-successional forest-related species (than those of the ROD)."

Chief Jack Ward Thomas reaffirmed the ecosystem management paradigm when, in 1994, he issued the *Forest Service Ethics and Course to the Future*, stating that diverse composition, [structure](#), and [function](#) were key elements of healthy and productive ecosystems. According to Doug MacCleery, Senior Policy Analyst for the Forest Service, the overall objectives of Thomas' document, including restoring and protecting ecosystems, "remain essentially unchanged today" (personal communication, 2008). This assertion was formalized by Forest Service direction in FSM 2000, Chapter 2020 Ecological Restoration and Resilience (September, 2008), which establishes as policy that: "All resource management programs have a responsibility for ecological restoration..." and that "strategic plans for meeting ecological restoration goals and objectives are to be developed."

Ecosystem management direction is incorporated into handbook direction as well. The *Silvicultural Practices Handbook* (FSH 2409.17) includes direction to "integrate ecosystem concepts into silvicultural prescriptions" and to incorporate landscape-level analysis into planning and silvicultural prescription development. The *Renewable Resources Handbook* (FSH 2409.19) directs that ecological approaches be incorporated into all projects. The Healthy Forest Restoration Act also mandates ecosystem management: the required fire regime condition class (FRCC) analysis integrates ecological process (fire regime/history) and stand structure and composition into its determination of a landscape's departure from the reference condition.

The OWNF Strategy for Management of Dry Forest Vegetation ("Dry Forest Strategy"), implemented in 1999 (and revised in 2000 to include the Okanogan National Forest), focused on the threat to forest sustainability caused by uncharacteristic wildfire (fire regime outside historical range of variability). The document focused on dry, dense forests

within the low-severity fire regime as the highest priority for treatment. Broad objectives for reduction of fuels and tree densities, and for shifting species composition, were included along with tactical approaches selected from traditional forest management practices. However, the Dry Forest Strategy gave no specific implementation protocols or guidelines. Key ideas from this strategy closely mirrored those of the earlier Forest Service Ethics and Course to the Future:

*... manage for, and maintain, healthy forests... provide goods, services, and values that people desire without jeopardizing the capacity of any ecosystem to maintain its structure, composition, and processes through time...management approach will be adaptive and experimental... learn from mistakes and repeat successes (USFS 2000).*

Clearly, there is ample management direction and impetus to take an adaptive ecosystem management approach to forest restoration. However, implementation of landscape-scale strategic ecosystem restoration is difficult to implement because it requires integration of large amounts of information about multiple resources over broad areas. This Restoration Strategy is the deployment of a set of tools and practices that allow OWNF managers to select high priority areas, design integrated restoration treatments, consider historical and potential future reference conditions, and potentially make a positive impact on multiple forest resources at the landscape scale.

## **Key Concepts**

This section describes some key concepts that provide the scientific foundation of this Restoration Strategy (definitions are in the [Glossary](#)). These concepts establish baseline information so Districts across the OWNF can implement the Restoration Strategy using common references. In addition, this section introduces an approach to the classification of forested vegetation types that is a key part of the Strategy, and forms the basis for comparison with both the historical and future reference conditions.

## **Ecosystem Management**

[Ecosystem management](#) is the overarching principle guiding the design of treatments in all Restoration Strategy projects. Manipulation or management of an ecosystem, such as a watershed, does not, by itself constitute ecosystem management because essential components are lacking.

Christensen et al. (1996) suggest that ecosystem management includes the following:

1. Long-term ecological [sustainability](#) as a fundamental value (guided by historical variability and tempered by potential climate change)
2. Clear, operational goals
3. Sound ecological models and understanding
4. Understanding of complexity and interconnectedness
5. Recognition of the dynamic character of ecosystems
6. Attention to context and scale
7. Acknowledgment of humans as ecosystem components

## 8. Commitment to adaptability and accountability

### Forest Restoration

[Restoration](#) is a key activity used to implement ecosystem management. Restoration aims to enhance the resiliency and sustainability of forests through treatments that incrementally return the ecosystem to a state that is within a [historical range of variability](#) of conditions (Landres et al. 1999) tempered by potential climate change impacts (Millar and Woolfenden 1999). It is the process of assisting the recovery of [resilience](#) and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed (FSM 2020.5). Restoration techniques include activities such as: tree cutting and prescribed fire, decommissioning roads, stabilizing slopes, and removing invasive species.

Knowledge of the historical range of variability of forest landscapes can help clarify the types, extent, and causes of ecosystem changes and can help identify restoration objectives (Hessburg et al. 1994, 1999a, Landres et al. 1999). However, it is important to consider how climate is predicted to change in the future, and potential climate impacts on [disturbance](#) regimes. Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, and can result in drought, introduction of exotic species, and insect outbreaks (Dale et al. 2001). Climate change can also affect species composition and structure, hydrologic cycles, genetic complexity, nutrient cycling regimes, mycorrhizal relationships, a host of food webs, and biodiversity (Malcolm et al. 2006, Lucash et al. 2005, GAO 2007, Bassman 2000, Lensing and Wise 2006, Fenn 2006, Whitlock et al. 2003, Gucinski 2006, Kulakowski and Veblen 2006, Franklin et al. 1989, Gray et al. 2006, Warwell et al. 2007, Lenoir et al. 2008). Forest managers can combine knowledge of changes in forest conditions and ecological functions with climate change predictions to inform restoration activities to produce and sustain a dynamic and resilient forest mosaic.

Restoration should not be construed as a fixed set of procedures for land management (Moore et al. 1999), but rather a broad scientific framework that includes “ecological fidelity” (structural/compositional replication, functional success, and durability) and mutually beneficial human-wildland interactions (Higgs 1997). In other words, restoration consists not only of restoring ecosystems, but also of developing human uses of wildlands that are in harmony with the disturbance regime of these ecosystems (Society for Ecological Restoration 1993, Moore et al. 1999). Timber management, fuels reduction, habitat improvement, and other single resource management activities in and of themselves do not constitute restoration. Yet, when used as tools to accomplish restoration objectives, these activities can meet restoration goals and support sustainable human uses.

Restoration takes time and an initial treatment may not meet restoration objectives. For example, forested ecosystems that are resilient to disturbances often include large, fire tolerant trees, which take time to develop. Restoration activities should be planned to set forests on successional trajectories that lead to desired conditions.

### Aquatic Disturbance

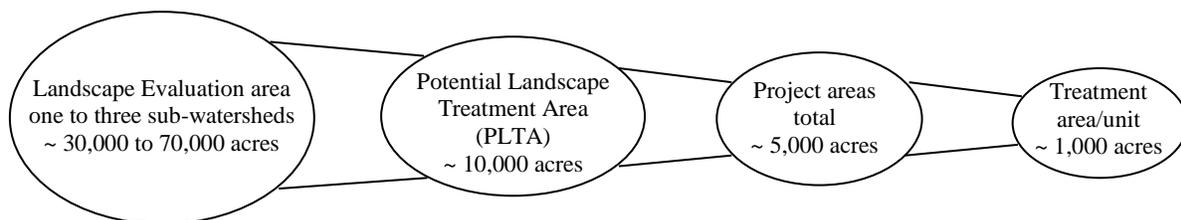
Resilient and functioning aquatic habitats are maintained through time through natural disturbance processes. Scientists studying aquatic disturbance events have characterized them into three categories: *pulse*, *press*, and *ramp*, depending on the duration, intensity,

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and spatial pattern of impacts, (Lake 2000, Reeves et al. 1995). This discussion focuses on pulse and press events because these are most relevant to the OWNF aquatic environment. Pulse events are intense and short term; press events reach a constant level that is maintained over time. An example of a pulse event would be a flood that occurs over a short period. If the watershed where this event occurs is in a natural condition, the disturbance can be absorbed and, in fact, will help maintain the aquatic function through time. A press disturbance could be a change of land use that, over time, interrupts and maintains altered ecological processes. An extensive road network is a classic example of a press disturbance. Road networks can interrupt and alter flow regimes, change wood delivery, and contribute excessive amounts of fine sediment to the stream network. This is considered a press effect because it maintains degraded aquatic conditions over time. Human land use patterns have created increasing anthropogenic press disturbances affecting both the terrestrial and aquatic environments in the western United States, especially in lower elevation dry forests (Rieman et al. 2000).

## Spatial and Temporal Scales

Issues of scale are important within the context of ecosystem management. OWNF Ranger Districts will conduct Restoration Strategy Landscape Evaluations at the scale of one to three 6<sup>th</sup> level Hydraulic Unit Code (HUC) [sub-watersheds](#). Districts use Landscape Evaluations to determine where restoration projects should be completed and are described in detail in the next chapter. Restoration treatments are done at smaller scales, for example an 2,000 acre prescribed burn. Restoration projects, and units within the projects, are the building blocks to affect changes to the landscape. Restoration treatments will need to be implemented and maintained over time because it is unlikely that a single treatment will restore a landscape, and restored areas will require maintenance.



**Figure 1. Illustration of relevant spatial scales in the Restoration Strategy**

## Ecological Subregions

Ecological subregions (ESRs) are areas of similar climate, geology, topography, and aquatic characteristics and, by extension, disturbance history. As part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP), Hessburg et al. (1999a) determined the historical range of variability for ESRs across the OWNF. Understanding this range gives us a set of reference conditions with which to compare current conditions in subwatersheds across the Forest.

## Historical and Future Range of Variability

The purpose of describing the historical range of variability is to define the bounds of system behavior that remain relatively consistent over time (Morgan et al. 1994).

Historical variability is a key component of forest restoration. [Spatial and temporal scales](#) relevant to ecosystem patterns and processes are important to identify and critical to the concept of historical variability (Morgan et al. 1994). Descriptions of historical variability should be site specific, most appropriately at a [sub-watershed](#) or [watershed](#) level (20,000 to 100,000 acres) and at the temporal scale of multiple centuries. Ecosystems are structured hierarchically. Therefore, historical variability should be characterized at multiple spatial scales appropriate to the patterns and processes being described and targeted for restoration.

The future range of variability is a concept described by Gärtner et al. (2008) to provide insights into how systems may adjust to a changing climate. By comparing current vegetation patterns to both historical and future reference conditions, managers gain valuable insights into how systems have changed and how they are likely to change over time. Understanding these changes is key to determining management strategies that provide for more sustainable and resilient forest ecosystems.

In the Restoration Strategy, we use ESRs to understand the future range of variability. We compare a subwatershed to the range of conditions found in its current ESR to determine historical range of variability. For the future range of variability, we use the next warmer, drier ESR as a proxy for reference conditions under climate change.

## **Biological Legacies**

[Biological legacies](#) are known to play important roles in ecosystems, especially those recovering from disturbance (Franklin et al 2007). Biological legacies are the components of a stand or landscape that remain after disturbance, and are critical elements of post-disturbance ecosystem pattern and process. Important structural components typically: 1) persist as legacies even through the most intense stand replacement disturbances; 2) play critical roles as habitat and modifiers of the physical environment; and 3) are difficult or impossible to re-create in managed stands, requiring the need to carry them over from the pre-disturbance stand (NCSSF 2005, Franklin et al. 2007). Biological legacies may include: large, live trees; snags; downed logs; and tree diseases (Franklin et al. 2007).

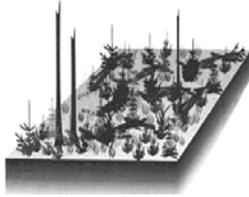
## **Classification of Forest Vegetation**

A host of vegetation classification schemes has been developed. The classification used for the ICBEMP (Hessburg et al. 1999) is the most relevant for our use, as it is the basis for historical range of variability and future range of variability estimates. This classification scheme, developed to facilitate ecosystem management, is part of the interim direction (“Eastside Screens”) for forests East of the Cascade Mountains (and outside of the range of the Northwest Forest Plan) in Oregon and Washington (USFS 1998). It has been the basis of much subsequent research and analysis (Hessburg et al. 1999a, 2000).

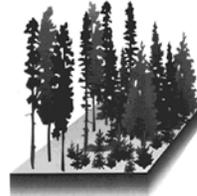
The ICBEMP classification uses combinations of composition, potential vegetation, and forest structure to categorize landscapes. In this classification system, forest cover types are determined from overstory and understory species composition and crown cover. Forest cover is classified according to Society of American Foresters (SAF) cover type definitions (as applied by Hessburg et al. 1999a). Potential Vegetation Type (PVT) is the vegetation that would develop in a similar environment in the absence of disturbance.

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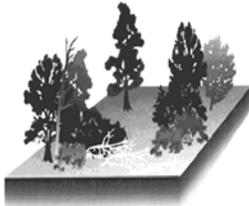
Forest PVT is classified at the series level (Lillybridge et al. 1995) determined from overstory and understory species composition, as well as elevation, slope, and aspect. PVT allows evaluation of both cover type and structure class in the site context. Stratifying a landscape into process-based structure classes allows subsequent analysis of landscape patterns and ecological processes. The seven structural/process classes used by Hessburg et al. 2000 and in this Strategy are shown on the next page.



**Stand Initiation (SI):**  
Growing space is reoccupied following a stand replacing disturbance.



**Young Forest Multi-Strata (YFMS):** Two or more cohorts are present through establishment after periodic disturbances. Large and/or old early seral trees are often at reduced density from fire or logging.



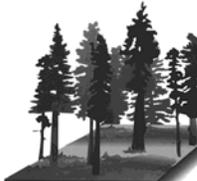
**Stem Exclusion Open Canopy (SEOC):** Below-ground competition limits establishment of new individuals.



**Old Forest Multi-Strata (OFMS):** Two or more cohorts and strata are present including large, old trees.



**Stem Exclusion Closed Canopy (SECC):** New individuals are excluded through light or below-ground competition.



**Old Forest Single-Strata (OFSS):** Single-stratum stands of large, old trees. Relatively few young trees are present in the understory.



**D. Understory Reinitiation (UR):**  
Initiation of a new cohort as the older cohort occupies less than full growing space.

**Figure 2. Schematic and definitions of forest structure classes (O’Hara et al. 1996, Hessburg et al. 2000)**

**Table 1. Description of forest structural classes that correspond to habitat associations for some focal wildlife species (based on Gaines et al. in prep)**

<b>Structural class</b>	<b>Description</b>	<b>Key functions for focal wildlife species</b>
Stand initiation	Single canopy stratum (may be broken or continuous); one cohort <sup>1</sup> seedlings or saplings; grasses, forbs, shrubs may be present with early seral trees.	<b>Black-backed woodpecker</b> – source habitat if created by fire and not salvage harvested.
Stem exclusion open canopy	One broken canopy stratum; one cohort; trees excluding new stems through competition; poles, small or medium trees; understory shrubs, grasses, forbs may be present.	<b>White-headed woodpecker</b> – habitat may be provided depending on cover of large trees and cover of understory.
Stem exclusion closed canopy	Continuous closed canopy; one or more canopy strata; one cohort; lower strata, if present, are same age as upper strata; poles, small or medium trees; understory shrubs, grasses, forbs may be present.	<b>Northern spotted owl</b> – dispersal habitat
Understory reinitiation	Broken overstory canopy; ≥2 canopy strata; two cohorts; overstory is poles, small, or medium trees; understory is seedlings, saplings, or poles.	<b>Northern spotted owl</b> – high-quality habitat depending on the canopy closure and size of overstory trees. <b>Northern goshawk</b> – source habitat depending on the canopy closure and size of overstory trees.
Young-forest multistory	Broken overstory canopy; >2 canopy strata; >2 cohorts; large trees are absent in the overstory; stands are characterized by diverse horizontal and vertical distributions of trees and tree sizes; seedlings, saplings, poles, and medium trees are present.	<b>Northern spotted owl</b> – high-quality habitat depending on the canopy closure and size of overstory trees. <b>Northern goshawk</b> – high-quality habitat depending on the canopy closure and size of overstory trees. <b>White-headed woodpecker</b> – habitat may be provided depending on cover of large trees and cover of understory.
Old-forest multistory	Broken overstory canopy; >2 canopy strata; >2 cohorts; large trees dominant in the overstory; stands characterized by diverse horizontal and vertical distributions of trees and tree sizes; all tree sizes may be present.	<b>Northern spotted owl</b> – high -quality habitat <b>Northern goshawk</b> – source habitat
Old-forest single story	Broken or continuous canopy of large, old trees; one stratum, may be single but usually multi-cohort; large trees dominate the overstory; understory absent or seedlings or saplings; grasses, forbs, or shrubs may be present in the understory.	<b>White-headed woodpecker</b> – source habitat

<sup>1</sup>Trees within a cohort share a common disturbance history; they are those initiated or released after a disturbance (natural or artificial). Tree ages within a cohort may span several decades.

## ***A Review of New Science and Information***

This section provides an overview of new scientific findings that are integral to the development and implementation of the Forest Restoration Strategy. This science is important to our understanding of forest ecosystems and the effects of restoration treatments. The topics covered in this section are: climate change, landscape ecology, aquatic ecology, fire ecology, forest ecology, and wildlife ecology. This section concludes with an integrated summary of the application of key findings in the Restoration Strategy.

### **Climate Change**

Climate projections for eastern Washington suggest that winter snow packs may decline, and the duration and severity of the summer dry period may increase (Bachelet et al. 2001, Mote et al. 2003, McKenzie et al. 2004). East-side forests are particularly dependent on winter snowpack, the timing and quantity of which are expected to substantially change. Climate change is expected to have significant direct and indirect effects on forest ecology in eastern Washington (Mote et al. 2003, Keeton et al. 2007), including:

- Changes in the physiology and ecology of organisms, including trees and forest pests, due to increased temperatures and summer moisture deficits
- Elevational and latitudinal shifts in the distribution of species and forest communities
- In some cases, increased moisture stress will increase tree species vulnerability to insects and diseases, especially on the driest sites in densely forested stands
- Increase in the severity and frequency of summer droughts may lengthen fire seasons and result in larger and more severe wildfires. A statistical relationship between climatic warming, lengthened snow-free seasons, and the frequency and size of wildfires has already been established for some parts of western North America (Westerling et al. 2006).

Climate change is likely to increase the challenges for sustainable forest management in eastern Washington, including issues associated with wildfire and forest insects and pathogens (Franklin et al. 2008). Fortunately, logical management responses to climate change – such as reducing stand densities and fuels, treating landscapes, and restoring drought-tolerant and fire resistant species and tree size classes – are consistent with management responses to other important issues, including forest health, wildfires, old and large tree structures, and protection of wildlife habitat (Franklin et al. 2008).

Climate change is also expected to increasingly alter hydrologic regimes of streams and rivers on the Okanogan-Wenatchee National Forest, based on studies that have considered the effects of climate change for the Columbia River basin. A review of scientific information completed by the Independent Scientific Advisory Board (ISAB 2007) identified numerous impacts of climate change. Bisson (2008) summarized expected changes from the ISAB report as follows:

- Warmer temperatures will result in precipitation falling more often as rain rather than snow.
- Snowpack will diminish and streamflow timing will be altered.

- Streamflow magnitude will likely increase, with a shift in the timing of peak flow occurrence earlier in the water year.
- Water temperatures will continue to rise.

Increases in large flood events, wildfires, and forest pathogen and insect outbreaks may reconnect floodplains and increase large wood accumulations. In combination, these effects may increase stream channel complexity (Bisson 2008). Depending on landscape position and stream habitat, dependant species such as trout and salmon may experience negative consequences resulting from climate change. A higher frequency of severe floods could scour streambeds and reduce spawning success for fall spawning fish (Bisson 2008). Smaller snowpacks and earlier spring runoff would affect migration patterns for salmon and could therefore affect their survival in the ocean (Mote et al. 2003, Pearcy 1997). Summer base flows are expected to be lower and last longer, which would shrink available habitat, forcing fish into smaller and less diverse habitat (Battin et al. 2007, Bisson 2008). Summer temperatures in some stream locations that currently support salmon and trout could rise to a point where they become lethal (Crozier et al. 2008). Higher stream temperatures will likely favor non-salmonid species that are better adapted to warm water, including potential predators and competitors (Reeves et al. 1987, Sanderson et al. 2009).

## Landscape Ecology

Understanding of the landscape ecology of eastern Washington has significantly advanced in recent years. Timber harvest, fire suppression, road construction, and domestic livestock grazing have transformed forest spatial patterns and landscape ecology in this area (Hessburg et al. 1999a, Hessburg and Agee 2003). These changes have altered disturbance regimes, and the availability and distribution of wildlife habitats across the landscape (Hessburg et al. 1999a). Comparison of historical to current landscape pattern at the regional scale revealed shifts from early to late seral conifer species in many forests. Patch sizes of forest cover types are now smaller, and current land cover is more fragmented (Hessburg et al. 2000, Hessburg et al. 2005). Also, forest structure classes are more variable. For example, the landscape area in old multistory, old single story, and stand initiation forest structures has declined with a corresponding increase in area and connectivity of dense, multilayered, intermediate forest structures (Hessburg et al. 2000, Hessburg et al. 2005). Patches with medium (16 to 24 inch dbh) and large (greater than 25 inch dbh) trees, regardless of their structural affiliation are currently less abundant on the landscape. Forests are now dominated by shade-tolerant conifers, with elevated fuel loads, severe fire behavior, and increased incidence of certain defoliators, dwarf mistletoe, bark beetles, and root diseases (Hessburg et al. 2000, Hessburg et al. 2005).

Agee (2003) estimated the historical range of variability for east Cascade forested landscapes using historical fire return intervals and the manner in which fire acted as both a cyclic and a [stochastic](#) process. Early successional forest stages were historically more common in high elevation forests than low elevation forests. The historical proportion of old forest (including old forest single story) and late successional forest varied from 38% to 63% of the entire forested landscape.

Spies et al. (2006) summarized the state of knowledge of old-growth forests in dry provinces of eastern Oregon and Washington, and northern California. They found that

historically, old-growth forests ranged from open, patchy stands, maintained by frequent low-severity fire, to a mosaic of dense and open stands maintained by mixed-severity fires. Old growth structure and composition were spatially heterogeneous, varied strongly with topography and elevation, and were shaped by a complex disturbance regime of fire, insects, and disease. With fire exclusion and cutting of large pine and Douglas-fir, old growth diversity across the landscape has declined and dense understories have developed across large areas. Fire exclusion has increased the area of dense, multi-layered forest favored by the northern spotted owl, but also increased the probability of high-severity fire. Landscape-level strategies are needed to address these issues.

A study conducted by Everett et al. (2008) provides insights into how forested landscapes have changed in the absence of fire but without timber harvest. They reconstructed 26 forest stands on the Okanogan portion of the OWNF that had little or no evidence of past timber harvest. They found that from 1860 to 1940, average stand age increased by 26% and number of age cohorts per stand increased by 18%. Stands in stand initiation structural classes declined from 27% to 4%, and stands in older forest structural classes increased from 23% to 49%. Everett et al. (2008) cautioned that estimating the historical range of variability based on 1940 photo records might provide a false metric of structural complexity for dry fir-pine forests in eastern Washington. At this time, Hessburg et al. (1999a) (and subsequent publications) and Gärtner et al. (2008) present the only peer-reviewed works referenced to the future and historical ranges of variability at landscape and stand scales. We therefore use these reference conditions in our Restoration Strategy. However, due to the uncertainty about the conclusions of Hessburg et al. 1999a, we intend to use our monitoring and adaptive management efforts to better understand these ranges.

## **Aquatic Ecology and Road Systems**

Aquatic communities in the western United States have evolved in response to a variety of disturbance regimes, including glaciation, volcanism, and fire. Natural disturbances organize and maintain aquatic systems in western landscapes (Reeves et al. 1995) and shape species' resilience and persistence (Yount and Niemi 1990). Furthermore, disturbances have a dominant role in structuring aquatic communities (Yount and Niemi 1990).

Forest restoration treatments will require a transportation network for access to, and removal of, trees and forest products. However, roads can have negative impacts on aquatic systems. Road networks affect aquatic environments by blocking fish passage, simplifying stream function, altering sediment delivery mechanisms, increasing fine sediment yields, and providing travel routes for grazing animals to streams (Trombulak and Frissell 2000, Roath and Krueger 1982, Young et al. 1967, Williams 1954). According to Rieman and Clayton (1997), "Road construction causes the most severe disturbance to soils on slopes, far overshadowing fire and logging as a cause of accelerated erosion." Numerous studies have identified adverse effects of roads on the aquatic environment (Quigley and Arbelbide 1997, Gresswell 1999, Gucinski et al. 2001). Generally, as the density of roads in a watershed increases, aquatic habitat quality decreases. In a scientific literature review considering the effects of roads, Trombulak and Frissell (2000) stated, "Our review underscores the importance to conservation of avoiding construction of new

roads in roadless or sparsely roaded areas and of removal or restoration of existing problematic roads to benefit both terrestrial and aquatic biota.”

Today, roads are recognized as one of the primary issues affecting the aquatic environment (Gresswell 1999, Trombulak and Frissell 2000, Gucinski et al. 2001, Grace and Clinton 2007). Road management is currently complex for many reasons. One reason is that many historical roads still in use today were built in locations that would not be currently acceptable (Swift and Burns 1999, Grace and Clinton 2007). Roads built decades ago are often located in valley bottoms next to streams and are difficult to relocate (Swift and Burns 1999). The OWNF Dry Forest Strategy (USFS 2000) identified roads as one of the factors impairing watershed function. Today’s recreation use (duration and intensity) on many forest roads currently surpasses the original road design capability and has resulted in dramatic increases in sediment delivery to the stream network (Grace and Clinton 2007). A lack of sufficient maintenance, as well as increased use above original design specifications, increases sediment delivery to water bodies (Grace and Clinton 2007, Luce et al. 2001). Environmental solutions to road issues often call for reconstruction, relocation, or restoration (Swift and Burns 1999, Gresswell 1999, Trombulak and Frissell 2000, Grace and Clinton 2007).

Existing roads are often considered essential for effective fire suppression and fuel reduction management. Brown et al. (2004) calls roads “paradoxical” in relation to fire and fuel management. They state that although roads have negative interactions with some ecological processes and may increase human ignitions, “they decrease response time to wildfire, act as holding lines, and make prescribed fire easier to apply” (page 904). They suggest that building new roads to implement thinning and prescribed fire may be inappropriate in roadless areas. Further, their findings along with others (Lee et al. 1997, Rieman et al. 2000) recognize that active management to improve forest sustainability will likely improve aquatic function. As related to fuels reduction, Brown et al. (2004) recommend focusing thinning in areas with existing road systems, and using minimal impact harvest techniques.

Grace and Clinton (2007) suggest the most acceptable approach to minimizing the harmful effect of the road system on the aquatic environment is to first focus on critical roads and relocate and/or reconstruct them. Part of the Landscape Evaluation process described in the next chapter is the Minimum Road Analysis (MRA). An MRA helps to identify critical transportation needs, high cost road segments, and parts of the road network that may be downgraded, closed, or decommissioned. This process corresponds with Luce et al. (2001), who propose a hierarchical set of questions to identify road treatments that are the most ecologically effective and have the least fiscal and social cost: (1) where are the highest priorities ecologically; (2) within those, where are the most damaging roads; and (3) within those, which ones can we effectively decommission or mitigate?

## **Riparian Ecology and Fire Interactions**

Rieman et al. (2000) suggest that restoration of low elevation mixed fire severity ponderosa pine forests has short- and long-term effects on aquatic ecosystems. In the short term, efforts to restore forests along riparian corridors could increase sediment loads and increase the risk of landslides and debris flows from steep facing drainages (Rieman et al.

2000). Current habitat has been degraded in many of these forest types, and treatments (such as road decommission and relocation, culvert replacement, and thinning to restore old forest structure) could create more suitable habitat in the long term. Land managers will need to consider a variety of spatial and temporal scales, improve scientific understanding, and emphasize experimental design to understand the effects of restoration treatments on aquatic ecosystems (Rieman et al. 2000, Luce and Rieman 2005).

The relative continuity of fire behavior between riparian areas and adjacent uplands is influenced by a variety of factors, contributing to high spatial variation in fire effects to riparian areas. Fire typically occurs less frequently in riparian areas (Russell and McBride 2001; Everett et al. 2003). Riparian areas can act as a buffer against fire and therefore as a refuge for fire-sensitive species. Yet, under severe fire weather conditions and high fuel accumulation, they may become corridors for fire movement (Pettit and Naiman 2007). Fire effects occurring upstream will likely influence downstream conditions (Wipfli et al. 2007), as well as future fire behavior (Pettit and Naiman, 2007). In the eastern Cascade Range, ecological conditions vary dramatically from the Cascade crest east to the arid conditions adjacent to the Columbia River (Wissmar et al, 1994). Depending on geologic and topographic features, riparian conditions and response to fire also vary (Halofsky and Hibbs, 2008). Biophysical processes within a riparian area, such as climate regime, vegetation composition, and fuel accumulation are often distinct from upland conditions (Dwire and Kaufmann, 2003). This can be especially true for understory conditions (Halofsky and Hibbs, 2008). Considering these varied conditions that occur from the stream edge to upslope and from river mouth to mountaintop, riparian response to fire is complex and heterogeneous.

Locally, Everett et al. (2003) studied the continuity of fire disturbance between riparian and adjacent sideslope Douglas-fir forests in the eastern Cascades. Their findings suggest that 150 years ago there were more large trees on side-slopes than in the riparian areas. They found fewer traceable fire disturbance events in riparian forests, which may indicate a reduced disturbance frequency, a more severe disturbance regime, or both. They also suggest the last several decades of vegetation management and fire suppression have caused stand cohorts in the riparian zone and upslope areas to become similar. Everett et al. (2003) cautioned, “Our attempts to protect old trees in the riparian zone buffers at the expense of adjacent side-slopes may be misdirected if old trees have been more historically numerous on the adjacent side-slopes.”

Landform features, including broad valley bottoms and headwalls, appear to act as fire refugia (Camp et al. 1996, Everett et al. 2003). Halofsky and Hibbs (2008) suggested a general rule from their study: the wider the stream, the lower the fire severity. Both of these studies correlated fire severity to vegetation type to varying degrees. Their studies, combined with local knowledge, can help identify portions of riparian reserve/riparian habitat conservation area (RHCA) in which to minimize or avoid reintroduction of fire. Fire events investigated by Everett et al. (2003) indicated significant continuity often occurred between riparian forests and adjacent side-slopes in steep, narrow valleys, troughs and ravines. Because these up-slopes and riparian forests have qualitatively similar fire effects, treatments guided by these findings are likely to restore ecological function of fire regimes at the landscape level (Finney et al. 2007). To design treatments for riparian

reserves that have departed from their reference conditions, position in the landscape relative to elevation, location within the stream network, and climate regime should be carefully considered to ensure understanding of riparian function (Pettit and Naiman 2007). Because the effects of restoration treatments on departed riparian habitats are poorly understood, focused research in an adaptive management framework is recommended.

## **Fire Ecology**

This section includes an overview of recently published science on fire ecology topics such as fire history, and effects of thinning and burning on fire behavior and fuels. Everett et al. (2000) report mean fire-free intervals of 6.6 to 7 years in dry forest types during the pre-settlement period (1700/1750-1860) and lengthened intervals of 38 to 43 years during the fire suppression period (1910-1996). They found a clear shift to a less frequent, but greater severity fire regime, associated with longer recovery intervals (Everett et al. 2000).

Wright and Agee (2004) report mean fire free intervals of 7 to 43 years (1562 to 1995) in dry and mesic forests of the Teanaway drainage in the Cle Elum Ranger District. Sampling within dry forests suggested that historical fires were of low intensity, leaving overstory structure intact. The composition and structure of the historical forest was characterized by a preponderance of very large (>100 centimeters or 39.4 inches dbh) ponderosa pines. Mesic forests exhibited a wider range of fire severities, with moderate and occasional high-severity fires or crown fires. Fire frequency and size declined dramatically about 1900, coincident with timber harvesting and fire suppression (Wright and Agee 2004).

The effects of thinning and burning on fire behavior and fuels have been well studied in the past decade. Evaluating fuel treatments from across the west, the reduction in fire behavior parameters and fuel loading is maximized by the combination of mechanical thinning plus burning (Schwilk et al. 2009). Thinning alone by traditional commercial harvest methods leads to increases in small diameter (<1 inch dbh) surface fuels immediately after treatments (Agee and Lolley 2006), but these fuels decrease to pre-treatment levels within 5 years (Youngblood et al. 2008). Amounts of larger fuels (>1 inch dbh) post-thinning can significantly increase and may not decrease for a long period without the use of prescribed burning. Pre-commercial thinning using mastication equipment can increase total fuel loading and fuel bed depths by as much as two inches, but the magnitude varies by fuel size class (Harrod et al. 2008a). Thinning followed by burning significantly decreases surface fuel loading (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Youngblood et al. 2008, Harrod et al. 2008a) regardless of thinning method.

Canopy closure, canopy bulk density, canopy base height, and surface fuel loading influence torching and crowning fire behavior. Thinning generally reduces canopy closure and canopy bulk density, and increases canopy base height (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Harrod et al. 2007a, Harrod et al. 2007b, Harrod et al. 2008a, Harrod et al. 2009). Burning alone is less effective at altering these characteristics in mature stands (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Harrod et al. 2007b, Harrod et al. 2009, Schwilk et al. 2009), but can reduce surface fuel loading (Youngblood et al. 2008), thereby decreasing surface fire behavior and the potential for fire to move into the canopy. However, burning alone can be effective in young coniferous forests for thinning stands from below, reducing surface fuels, and raising canopy base

height (Peterson et al. 2007). Crown fire severity is generally mitigated by fuel treatment (prescribed fire only, thinning only, or combination), as compared to stands with no treatment (Pollet and Omi 2002, Finney et al. 2005).

## Forest Ecology

This section includes an overview of recently published science relevant to forest ecology topics such as stand development, effects of thinning and burning treatments on overstory and understory plant species, the role and recruitment of snags and old trees, and spatial patterning of trees within forest patches.

Everett et al. (2007) reconstructed stands on the Okanogan portion of the OWNF that showed little or no evidence of timber harvest. Historically, frequent fires maintained low tree abundance in these stands, but fire cycles lengthened in the 1860s as euro-settlement progressed. Average stand density had already increased by 194% of the 1860 levels by the start of effective fire suppression in 1915. From the 1930s to 1960s, average stand density peaked at 258% of 1860 levels and tree densities began declining to 173% of the 1860 levels by 2000. In the absence of fire and without human intervention (such as timber harvest), the sampled stands had increased representation of shade-tolerant species and increased in overall mean stand age (Everett et al. 2007).

Thinning and burning have different effects on overstory. The influence of thinning treatments on the overstory is more predictable, as compared to other variables, because there is greater control in tree removal. Thinning treatments throughout the western United States have the greatest effect on reducing stand density and increasing mean diameter (Schwilk et al. 2009). Most thinning treatments focus on removing smaller trees, but overall tree density can be reduced up to 60% (Stephens and Moghaddas 2005a, Youngblood et al. 2006, Harrod et al. 2007b, Harrod et al. 2009). Prescribed burning has less effect on overstory characteristics, and generally does not reduce tree density or basal area of the dominant overstory. Burning is most effective at reducing seedling and sapling density (Harrod et al. 2007a, Harrod et al. 2007b, Harrod et al. 2008b, Harrod et al. 2009, and Schwilk et al. 2009).

Snag density generally decreases following mechanical thinning and increases following burning, including thinning and burning combinations (Stephens and Moghaddas 2005b, Schwilk et al. 2009, Harrod et al. 2009). Snag reductions following thinning can be significant. For example, about 70% of snags were cut during thinning operations in the Mission Creek watershed on the OWNF (Harrod et al. 2007b, Harrod et al. 2009). The proportion of snags cut declines with increasing snag diameter, from 78% in the sapling size class, to 50% in the large size classes. Conversely, snag densities increase following burning (0% to 14%, depending on size class) or thinning and burning (45% to 100%, depending on size class) treatments (Harrod et al. 2007b), but burning increases the chance that existing snags will fall as compared to untreated or thin-only sites (Harrod et al. 2009). Snags recruited through prescribed burning are hard snags with little decay. It is important to retain legacy snags in a variety of decay classes (Bull et al. 1997).

## **Old trees**

Old trees are the most critical structural attributes in dry forest ecosystems (Franklin et al. 2008). Old trees have distinctive attributes related to crown structure, bark thickness and color, heartwood content, and decadence (wounds, rots, brooms, etc.). These characteristics are usually developed between 150 and 250 years of age (Van Pelt 2008, Franklin et al. 2008). These old trees are often large and lead to large snags and down logs. Large, old ponderosa pine, western larch, and Douglas-fir trees are the most likely to survive wildland fire, particularly if ladder fuels are managed (Pollet and Omi 2002, Harrod et al. 2008b), and they play important roles in post-fire recovery processes (Covington et al. 1997, Allen et al. 2002). The old tree component of most dry and mesic forest ecosystems within the OWNF is lacking (Harrod et al. 1999, Hessburg et al. 2000), largely because past selective harvesting focused on the removal of these trees.

Understanding the structural composition of old forests is important to developing prescriptions for restoration treatments. Several studies have investigated the historical density of large, old trees. For example, Covington et al. (1997) reported a density of 37 to 111 trees per hectare in the southwestern United States. At a study site on the Wenatchee River Ranger District, Harrod et al. (1999) estimated a mean of 50 overstory trees per hectare, with a range of 27 to 61 per hectare, depending on plant association. Youngblood et al. (2004) estimated a mean of 50 overstory trees per hectare, ranging from 15 to 94 trees per hectare at three study sites in eastern Oregon.

## **Spatial patterns of dry forests**

Historically, dry forest stands were clumped at fine scales (< ½ acre) and clumps were composed of even-aged groups of trees (Harrod et al. 1999). Stands were uneven-aged and composed of these even-aged groups. Average tree diameters were considerably larger than they are in contemporary stands. This clumpiness is consistent with the patterns of stand development described by Cooper (1960) and White (1985), in which seedlings are established in a patchy fashion due to frequent fire within occasional ‘hot spots’ that result from accumulated fuel. This process resulted in up to 30% of stands in non-forest openings composed of grass or shrub plant communities (*Figure 2*). Present day stands exhibit less clumping, particularly of large trees, than historically (Harrod et al. 1999). Current stands tend to be homogenous and high density, lacking important spatial patterns.



**Figure 3. Examples of dominant tree patterns within stands that consist of tree clumps and canopy openings**

Spatial patterns influence important ecological processes, such as fire spread and insect outbreaks. Historically, natural openings limited the potential for crown fire and created a diversity of habitats, promoting a diverse understory. When trees died in clumps, accumulated fuels created areas for seedling establishment following fire. On average, low-density stands maintained by fire were at or below critical thresholds for serious bark beetle outbreaks. However, beetles were present and largely confined to high-density clumps that were likely above the critical threshold for bark beetles. Disturbance processes function differently in clumped stands with gaps, as compared with more evenly spaced stands. Insects cause mortality of high-density clumps allowing fires to burn dead wood and create openings for establishment of new clumps (Agee 1993, Harrod et al. 1999).

Long and Smith (2000) define tree clumps as several trees in close enough proximity that their crowns are interlocking. Youngblood et al. (2004) measured stand pattern within three old ponderosa pine stands in Oregon and northern California. For one stand, trees were randomly spaced at all scales. For the other stands, they reported these clumps ranged in diameter from 6 to 80 feet, with random tree spacing at scales under 6 feet, and clumpy tree distribution at scales larger than about 6 feet. In a study conducted in ponderosa pine forests in northern Arizona, researchers found that in unharvested stands, large trees were aggregated at scales up to 92 feet and that clumps averaged 0.02 to 0.03 hectares in size (Sanchez Meador et al. 2009).

Complex patches are those with more structural and species complexity than the surrounding area. Often, these provide habitat for wildlife species such as woodrats and/or flying squirrels (Lehmkuhl 2006a, 2006b), which are important prey items for northern spotted owls and raptors. Patch characteristics include large snags, soft down logs, and mistletoe brooms. Additional requirements for flying squirrels are canopy cover over about 55% and fruit and seed producers such as Douglas maple, Oregon grape, serviceberry, rose, snowberry, and huckleberry. Lehmkuhl et al. (2008) suggests that retaining these conditions within riparian buffers could provide adequate habitat for small mammal

species associated with riparian areas. On uplands, retaining about 15% cover in coarse woody debris within a stand could be expected to provide adequate truffle supplies for these species (Lehmkuhl et al. 2004).

## **Understory vegetation**

Understory vegetation comprises the vast majority of plant biodiversity (Gildar et al. 2004, Dodson et al. 2008) and is important for a variety of ecosystem functions (Allen et al. 2002). Understory species provide habitat and forage for many wildlife species, are important for regulating sediment transport and hydrologic regimes (Minshall et al. 1997, Beche et al. 2005, Pettit and Naiman 2007), and are important for nutrient cycling (Franklin et al. 2008). Intact native plant understories may be resistant to invasion by non-native plant species, which can decrease understory diversity (Harrod and Reichard 2001, Harrod 2001 and references therein).

Understory response to typical forest restoration treatments (thinning, burning, and thin and burn) is varied, but understory vegetation is largely unchanged, particularly several years after the initial treatment. Most studies have found that understory cover and frequency is maintained or increases 1 to 2 years post-treatment (Collins et al. 2007, Dodson et al. 2008) and these measures, including species richness, will be maintained or increased up to 19 years (Harrod et al. 2007a, Harrod et al. 2008b, Nelson et al. 2008). These findings are consistent with a large body of research completed in other areas in the western United States. This research suggests thinning and burning treatments in dry coniferous forests have few detrimental effects on native understory vegetation (Abella and Covington 2004, Metlen et al. 2004, Metlen and Fiedler 2006, Moore et al. 2006, Collins et al. 2007, Knapp et al. 2007, Dodson et al. 2007). Pre-treatment condition has a strong effect on understory dynamics (Dodson et al. 2008). Stands that are very dense before treatment have low cover and species richness, and mechanical thinning coupled with drought can reduce the abundance of understory plants in the short term (Page et al. 2005, Dodson et al. 2008). Thinning and burning together may maximize benefits of restoration in areas where understory richness is low prior to treatment (Dodson et al. 2008).

There are potential benefits of prescribed fire on increased resistance of native plant communities to non-native invasion or as a method of invasive species control (Harrod and Reichard 2001, Di Tomaso and Johnson 2006). Non-native species cover and richness tend to increase after treatment; however, they constitute a minor portion (less than 2 percent cover) of the resulting understory plant community (Collins et al. 2007, Dodson et al. 2008). A long-term study in the eastern Cascade Range found that cover and richness of non-native herbs showed small increases with intensity of disturbance and time (up to 19 years) since treatment (Nelson et al. 2008). Thinning and burning may promote low levels of invasion by non-native species, but their abundance appears limited and relatively stable over time. Di Tomaso and Johnson (2006) found that multiple burns may control some non-native biennial species and that timing of burns may be important for controlling non-native annual species.

## Wildlife ecology

Over the past decade, scientists have produced a large volume of new information about the ecology of wildlife species and communities in the dry forests of eastern Washington. Much of this research enables a better understanding of the effects of forest restoration treatments on wildlife.

### Small mammals

Lehmkuhl et al. (2008) studied the similarities and differences between small mammal communities in dry forest riparian habitats compared with dry forest upland habitats on the Cle Elum and Wenatchee River Ranger Districts. They found that small mammal communities contained several species that were highly associated with riparian forests. Some of these species were generally thought to be associated with moister forests found closer to the crest of the Cascade Range. Species richness and abundance were generally higher within 65 to 115 feet of the stream, indicating that current riparian reserve buffer widths would provide adequate habitat to conserve small mammal riparian associated species (Lehmkuhl et al. 2008).

Lehmkuhl (2009) studied small mammal communities as part of the fire and fire surrogate study conducted on the Wenatchee River Ranger District. The deer mouse (*Peromyscus maniculatus*), yellow-pine chipmunk (*Neotamias amoenus*), and Trowbridge's shrew (*Sorex trowbridgii*) were the dominant species. Half of the study units were relatively mesic habitats and supported a richer assemblage of small mammals that included all of the captured species compared to the relatively species-poor dry units. Management practices that reduce overstory density and allow greater wind penetration and drying, reduce large down wood, and shift understory dominance to grass likely will shift mammal species assemblages to favor species associated with the dry end of the moisture gradient (Lehmkuhl 2009).

Lehmkuhl et al. (2006a) studied the demography of the northern flying squirrel in dry forests on the Cle Elum Ranger District. Their results suggest that thinning and prescribed burning in ponderosa pine and dry mixed conifer forests to restore stable fire regimes and forest structure might reduce flying squirrel densities at stand levels by reducing forest canopy, woody debris, and the diversity and biomass of understory plants, truffles, and lichens. A similar result was found for dusky-footed wood rats (Lehmkuhl et al. 2006b). Lehmkuhl et al. proposed that patchy harvesting and retention of large trees, woody debris, and mistletoe brooms might ameliorate the impacts to these species. Negative small-scale impacts could be a trade-off for increased resistance and resilience of dry forest landscapes to now-common, large-scale stand replacement fires (Lehmkuhl et al. 2006a).

Munzing and Gaines (2008) monitored American marten abundance within dry and moist late-successional forest habitats on the Cle Elum and Wenatchee River Ranger Districts. They did not detect any marten in two years of sampling within late-successional dry forests. Their results corroborate those of Bull et al. (2005) indicating that conservation efforts for American marten should focus on mesic and moist forest, not dry forest habitats. Restoration treatments in dry forests are unlikely to affect American marten.

## Northern spotted owl

Research and monitoring efforts have been underway to better understand the demography of the northern spotted owl (Lint 2005, Anthony et al. 2006, Davis et al. 2012), and trends in the availability of spotted owl habitat (Davis and Lint 2005, Davis et al. 2012). A study was recently completed on the Wenatchee River Ranger District on the ecology of barred owls and implications for the recovery of the northern spotted owl (Singleton et al. 2010). The ability to model the trade-offs between reducing fire risk and protecting spotted owl habitat has advanced considerably (Ager et al. 2007, Lehmkuhl et al. 2007a, and Kennedy et al. 2008, Gaines et al. 2010). This body of research has identified the following management implications:

- The spotted owl population is declining at a rapid rate in the Wenatchee and Cle Elum study areas.
- Wildland fire was an important factor in the loss of spotted owl habitat in the east-Cascades province.
- Barred owls have successfully invaded, and now occupy moist forest types at greater densities than dry forests. Some habitat partitioning may be occurring between barred and spotted owls based on slope position and forest type, suggesting that dry forest habitats may be important for spotted owl recovery.
- Models can be successfully used to inform managers on the tradeoffs between protection of dry and mesic forest, spotted owl habitat and treating habitat to alter landscape fire behavior and restore forest structure. In addition, these models can be used to identify strategic locations on forest landscapes where treatments would be particularly effective at reducing landscape fire flow.

### HOT BOX 1

#### The Revised Northern Spotted Owl Recovery Plan and Forest Restoration

The revised recovery plan for the northern spotted owl (USFWS 2011) outlines a habitat management strategy for the fire-prone forests on the east side of the Cascades Range. The strategy for east-side forests in the revised plan is meant to be successful on its own and does not rely on other conservation or management plans, a significant shift from previous conservation strategies. The habitat management strategy described in the revised recovery plan is intended to maintain spotted owl habitat within an environment of frequent natural disturbances. No habitat reserves are identified, as disturbance regimes are assumed to preclude long-term persistence of static habitat management areas. Rather, a landscape approach is recommended to promote spotted owl recovery within the broader goal of ecological sustainability.

The impetus for this change in strategy comes in large part from the findings of an independent scientific review (Courtney et al. 2008) of the 2008 recovery plan in which the Sustainable Ecosystems Institute (SEI) Review Panel reached the following conclusions regarding the recovery of spotted owls on the east side of Oregon and Washington:

- The threat from wildfire was underestimated in the draft recovery plan for the dry forest provinces, and was inadequately addressed. This threat is likely to increase given both

## HOT BOX 1

### The Revised Northern Spotted Owl Recovery Plan and Forest Restoration

current forest conditions and future climate change.

- In some circumstances, owls may remain in, or rapidly re-colonize, habitats that have experienced a low-severity fire. Hence, it is incorrect to assume that all fires result in habitat loss. In other circumstances, owls or their habitats are lost as a consequence of large-scale, high-severity fires. It is important to recognize such variation of fire effects when developing a conservation strategy.
- In east-side habitats of the Washington and Oregon Cascade Range, the only viable conservation strategy will be to actively manage fire-prone forests and landscapes to sustain spotted owl habitat. However, this needs to be closely monitored through an adaptive management process.
- A simple reserve network is unsustainable in east-side, fire-prone habitats. Conservation strategies must be designed and implemented at the landscape level to be viable.

Based on these findings and the recommendations made by the scientific review panel (Courtney et al. 2008), as well as additional recent scientific information, the Revised Spotted Owl Recovery Plan recommends that dynamic, disturbance-prone forests of the eastern Cascades should be actively managed in a way that reconciles the overlapping goals of spotted owl conservation, response to climate change and restoration of dry forest ecological structure, composition and processes, with three primary objectives:

- 1) Develop and maintain adequate spotted owl habitat in the near term to allow spotted owls to persist in the face of threats from barred owl expansion and habitat alterations from fire and other disturbances.
- 2) Restore landscapes that are resilient to fire and other disturbances in the near term, and more resilient to alterations projected to occur with ongoing climate change.
- 3) Restore function of a variety of ecological services provided by late-successional and old forests.

In particular, Recovery Actions 6, and 32 and a set of principles specific to dry forest restoration are relevant to the Restoration Strategy.

- **Recovery Action 6:** “In moist forests managed for spotted owl habitat, land managers should implement silvicultural techniques in plantations, overstocked stands and modified younger stands to accelerate the development of structural complexity and biological diversity that will benefit spotted owl recovery.”
- **Recovery Action 32:** “Because spotted owl recovery requires well distributed, older and more structurally complex multi-layered conifer forests on Federal and non-federal lands across its range, land managers should work with the Service as described below to maintain and restore such habitat while allowing for other threats, such as fire and insects, to be addressed by restoration management actions. These high-quality spotted owl habitat stands are characterized as having large diameter trees, high amounts of canopy cover, and decadence components such as broken-topped live trees, mistletoe, cavities, large snags, and fallen trees.”

The dry forest restoration principles include the following:

## HOT BOX 1

### The Revised Northern Spotted Owl Recovery Plan and Forest Restoration

- An emphasis to restore ecosystem components outside of spotted owl core areas or high value habitat. Where treatments occur within core areas or high value habitat, monitoring owl response to treatment or application of treatments as part of adaptive management to improve understanding of effects to owls is recommended.
- Implementation of restoration treatments at a landscape scale with specific reference to the Forest Restoration Strategy.
- Development and retention of large and old trees, snags and downed logs is an important element of spotted owl habitat management because these features take the longest to develop once removed. Restoration of large, fire-tolerant tree species to their former role in dry-forest landscapes would provide the habitat —anchors for spotted owls and other species. This includes the retention of large trees and snags following wildfire as well as active treatment around residual target trees.
- Restoration of heterogeneity within and among stands is emphasized. The pattern and distribution of high-quality habitat should be based on a number of ecological criteria including: existing spotted owl locations, desired patch sizes, topography, barred owl locations, prey base, risk of loss from fires, future fire behavior, insects, and diseases. Habitat patch sizes are not defined and will be informed by local conditions. The size and spacing of habitat patches should be determined by interdisciplinary teams of appropriate experts.

### Other bird species

Three studies have improved understanding of the effects of forest restoration treatments on forest birds. The Pendleton Ecosystem Restoration study (Gaines et al. 2007) and the Fire and Fire Surrogate study (Lyons et al. 2008, Gaines et al. 2009, Gaines et al. 2010) both occurred on the Wenatchee River Ranger District, and the Birds and Burn study (Saab et al. 2007) occurred on the Methow Ranger District. Based on this body of research we offer the following implications for managers to consider:

- Thinning from below followed by prescribed fire can effectively restore habitat for many avian focal species, including neotropical and migratory species (Gaines et al. 2007, Lyons et al. 2008, Gaines et al. 2010).
- Spring burning (without mechanical treatment) may not accomplish the desired restoration of habitat structure (reducing canopy closure, removing small trees, creating canopy gaps, creating large snags) for avian species if conducted when conditions are too cool and moist (Gaines et al. 2010).
- Large trees (and snags) in dry forests provide important habitat for foraging (Lyons et al. 2008) and nesting (Gaines et al. 2010), and are a key component in maintaining or restoring the viability of focal avian species.

- More focused research with larger sample sizes is needed to understand effects of spring burning on ground-nesting species. In particular, the relationship between timing and intensity of prescribed burns and effects on avian nesting and survival require more study (Gaines et al. 2010).

Saab et al. (2007) studied the effects of prescribed burning on avian communities across a network of study sites in the western United States, including a site in the Methow Valley. They found that overall, a greater percentage of migrant and resident birds responded with higher abundance and density to prescribed burns during the year of the treatment than in the year after (Russell et al. 2009). Fewer species responded one year after treatments, indicating that the influence of prescribed burning is short-term. Responses were variable for migratory birds, whereas residents generally had positive or neutral responses. They found that prescribed burns not only reduced snag numbers but also recruited snags of all sizes, including large size classes. The retention of large-diameter trees and snags allows for population persistence of cavity-nesting birds (Saab et al. 2007).

Snags provide habitat for a variety of cavity-nesting birds. Snags also become down logs that provide nutrient cycling, soil stabilization, water storage, and habitat for prey species (Bull et al. 1997). Forests within the historically low fire-severity regime (e.g., ponderosa pine) would have had more stable snag recruitment over time (Harrod et al. 1998). Therefore, the standards for snag densities, conditions, and arrangement should be supportable under the disturbance regimes of the area (Everett et al. 1999) and will require consideration of wildlife habitat needs. The arrangement of leave snags in patches or clumps was found to be more important to cavity nesters than dispersed or isolated snags (Saab and Dudley 1998, Haggard and Gaines 2001). Large-diameter ponderosa pine (> 19 inches.), Douglas-fir, and western larch were important snags to retain because they meet the requirements of multiple species of cavity excavators (Haggard and Gaines 2001, Lyons et al. 2008) and have the longest residence times (Everett et al. 1999). In addition, the most suitable snags for cavity excavation were found to be large diameter snags that incurred defects, especially broken tops, prior to fire (Lehmkuhl et al. 2003).

Lehmkuhl et al. (2007a) studied avian species associated with streamside riparian forests and adjacent uplands within dry forests on the Cle Elum and Wenatchee River Ranger Districts. They found that riparian forests had the greatest number of strong characteristic, or indicator species, compared to dry and mesic upland forests. Their results indicate that current standards and guidelines for riparian buffer zones would allow for avian refuge and wildlife corridor functions along streams.

## **Snails**

Gaines et al. (2005) developed a predictive model of habitat attributes for the Chelan Mountain snail species complex that is endemic to the Chelan and Entiat Ranger Districts. Their results suggest that thinning to restore forest structure would not negatively influence the species as long as canopy closure remained greater than ten percent. The effects of spring and fall burning on the Chelan Mountain snail have also been monitored. Both burning regimes retained the presence of live snails on all treated plots. Some plots showed a reduction in the population density of snails immediately post-treatment but these numbers generally recovered within a year of the burn (Gaines et al. 2011).

## **Roads and wildlife**

Like aquatic species, terrestrial wildlife species can be influenced by human activities associated with roads. Literature reviews by Gaines et al. (2003), Wisdom et al. (2000), and Singleton and Lehmkuhl (1998) provide a solid scientific foundation for discussion of the interactions of roads and wildlife. Much of the research on the effects of roads on wildlife has investigated wide-ranging carnivores and ungulates. Lesser-known species could benefit from additional research, especially those less mobile species where roads may inhibit movements or fragment habitats. The most commonly reported interactions included displacement and avoidance where animals were reported to alter their use of habitats in response to roads or road networks (Gaines et al. 2003). Disturbance at a specific site was also commonly reported and included disruption of animal nesting, breeding or wintering areas. Collisions between animals and vehicles are also common on higher speed roads and affect a diversity of wildlife species, from large mammals to amphibians. Finally, edge effects associated with roads or road networks constructed within habitats, especially late-successional forests, were also identified in this study. The response of wildlife to roads and human activities that occur along roads are often species-specific and can vary depending on animal behavior (nesting, dispersal, foraging, etc.), road type, and traffic patterns. The Restoration Strategy does not currently model road-wildlife interactions, but this is flagged as an item to include in a future iteration.

## **Maintaining wildlife populations through land management planning**

Broad-scale assessments that address ecosystem diversity can address the need to plan for viable populations of most native, and desirable non-native, terrestrial wildlife species. As part of its Land and Resource Management Plan (LRMP) revision process, OWNF managers developed a supplemental 8-step process to address those species for which such assessments may be inadequate. Part of this process was to identify 209 species of conservation concern and 36 primary focal species. Habitat capability for all species is reduced compared to historical conditions. Thus, the team developed conservation strategies including habitat conservation and restoration, and amelioration of threats (Suring et al. 2011). While the Forest-wide LRMP revision is underway, this Restoration Strategy addresses habitat needs for five focal wildlife species at the stand and sub-watershed levels by conserving existing habitat and helping to create future habitat.

## ***Summary of New Science Applications in this Strategy***

This section summarizes key science findings that are relevant to OWNF Restoration Strategy Landscape Evaluations (see Part II) and planning for restoration treatments.

### **Scientific findings relative to Landscape Evaluations**

- Comparison of current and historical landscape pattern reveals shifts from early- to late-seral conifer species. Patch sizes of all forest cover types are now smaller, and current land cover is more fragmented.
- Across forest landscapes, the area in old multi-story, old single story, and stand initiation forest structures has declined with a corresponding increase in area and connectivity of dense, multilayered, intermediate forest structures.

- Dry forest landscapes are now dominated by shade-tolerant conifers, with elevated fuel loads, severe fire behavior, and increased incidence of certain defoliators, dwarf mistletoe, bark beetles, and root diseases.
- The old tree component of most dry and mesic forest ecosystems is lacking, largely because past selective harvesting focused on the removal of these trees.
- In high severity fires, riparian overstories within dry forest landscapes have a high degree of continuity with adjacent overstories on side-slopes, indicating that treatments to disrupt continuity between riparian and uplands may be appropriate if ecological processes are considered and treatments are fitted to site conditions.
- Dry and mesic forests provide important habitat for the northern spotted owl and may provide areas of lesser competition from barred owls. Restoration treatments are needed to reduce the risk of landscape fire flow and should be placed in strategic locations. Fire modeling has advanced considerably providing important tools for managers to use to identify the location of strategic restoration treatments.
- Impacts of roads and forest treatments spread uniformly across large spatial scales press aquatic conditions outside of the range of expected conditions, which in turn reduces the ability of aquatic species to persist over time.
- Roads affect aquatic environments by blocking fish passage, simplifying stream function, altering sediment delivery, and increasing fine sediment yields.
- Roads and road networks affect wildlife habitats and can result in road-related mortality. Fragmented habitats cause wildlife to avoid, or be displaced from, areas adjacent to roads.
- Generally, as the density of roads increases within a watershed, the quality of aquatic and terrestrial habitats decreases.

### **Scientific findings relative to restoration treatment planning**

- Old and/or large trees are ecologically important to dry and mesic forest ecosystems. There is a lack of old trees on the OWNF. Large trees are most resilient to fire disturbances and provide important habitat functions when live, and as snags or downed wood.
- Present day stands exhibit less clumping, particularly of large trees, than historically. Current stands tend to be homogenous and high density, lacking important spatial patterns.
- Thinning and burning treatments in combination are most effective at decreasing stand susceptibility to uncharacteristic wildfire.
- Mechanical thinning reduces snag numbers, but burning can increase the number of snags, including large snags.
- Thinning and burning treatments in dry coniferous forests have few detrimental effects on native understory vegetation.
- Non-native plant species may increase after treatment (thinning and burning), but the magnitude is minor even many years post-treatment.

- Thinning to reduce tree density and favor early seral tree species can reduce landscape vulnerability to impacts of uncharacteristic insect and disease outbreaks.
- Riparian understory response to fire is often less severe than corresponding understory response to fire upslope.
- In addition to traditional aquatic contributions, riparian areas provide habitat for a unique community of small mammals and birds compared to adjacent upslope forests. Aquatic and terrestrial biota dependent on riparian areas warrant attention when considering restoration treatments in riparian habitat. In some instances, protection may be the most appropriate consideration, while in many situations some type of treatment is warranted to restore ecological processes.
- Spatial variability such as clumps, gaps, and complex patches within treated stands provide important structural diversity for birds and mammals, such as flying squirrels and woodrats. Complex patches should retain large pieces of down wood, and tree diseases such as mistletoe, to provide important habitat components.
- Several focal bird species, including the white-headed woodpecker and western bluebird, may respond favorably to thinning and burning restoration treatments. Restoration treatments should retain the largest trees and provide variable tree distribution.

## **PART II: INTEGRATED LANDSCAPE EVALUATION AND PROJECT DEVELOPMENT**

This part of the Restoration Strategy explains the Landscape Evaluation and project planning for restoration treatments. It employs the scientific findings described in Part I in a process that enables managers to efficiently and effectively plan restoration projects.

### ***The scientific basis for a Landscape Evaluation***

Restoration of forest ecosystems requires a landscape perspective, which is essential for effective restoration of ecological processes and functions. Forest ecosystems are dynamic and consist of complex interactions between vegetation, wildlife, aquatics, and disturbances, particularly fire. Tools exist to analyze interactions among these key ecosystem components at landscape scales (see process outlined below). Yet, our ability to describe, analyze, and quantify interactions among individual species and changes to forest communities or disturbance regimes is more limited.

Determining what variables, or ecological indicators, to use in Landscape Evaluations is difficult. Managers must strike a balance between choosing a few key variables to provide important insights into landscape conditions, and not evaluating so many variables that the process becomes complicated, inefficient, and impossible to implement. An alternative to developing overly complex restoration models that include all ecosystem components is to alter structure and composition of vegetation and reintroduce processes such as fire (Kenna et al. 1999), while restoring aquatic environments. As Reynolds and Hessburg (2005) point out, “Landscape Evaluations concerned with the restoration of ecosystems might be based on a set of ecological indicator measures compared against reference conditions for those same indicators.”

Recent studies of OWNF landscapes suggest key variables that are meaningful at the landscape scale. Reference conditions have been established for both the historical range of variability (Hessburg et al. 1999a, Hessburg et al. 2004, Reynolds and Hessburg 2005) and the future range of variability, representing a likely climate change scenario (Gärtner et al. 2008). Based on these research results, the five ecological indicators selected for Landscape Evaluation are:

1. forest landscape pattern and departure
2. risk of insect infestation
3. stand-level fuels and fire movement potential
4. wildlife habitat amount and arrangement
5. aquatic/road interactions and road network evaluation

The literature suggests that focusing on these indicators will result in restoration for a suite of individual species, forest communities, and aquatic systems (Reynolds and Hessburg 2005).

Restoration plans that change vegetation structure are important for restoring wildlife habitat, physical processes (hydrology and sediment flow), and spatial patterns. The Landscape Evaluation process described here allows managers to analyze large areas and

prepare restoration plans that address multiple resources at the landscape scale. Forest managers face tremendous challenges in determining the strategic placement of treatments that restore landscape fire behavior processes while also integrating consideration of other important resource values. Such values include reducing risks to human communities, and increasing the sustainability of habitat for federally listed species (Collins et al. 2010).

### ***Landscape Evaluation tools***

Tools such as GIS and ArcFuels can help to address this complexity (Ager et al. 2007, Collins et al. 2010). However, the problem of integrating data layers into management alternatives remains. The Ecosystem Management Decision Support framework (EMDS 3.0.2, Reynolds 2002, Reynolds et al. 2003) provides a useful tool for integrated landscape evaluation and planning (Hessburg et al. 2004, Reynolds and Hessburg 2007). EMDS supports an explicit two-phase, integrated approach to conducting a Landscape Evaluation. The analysis phase examines the state of the system, comparing current conditions with reference conditions and helping to establish priorities. The decision support phase of EMDS integrates multiple variables and helps interdisciplinary teams and line officers consider the types and locations of treatments to implement. This second phase helps address the issues revealed in the first phase.

We use EMDS as the primary tool in Landscape Evaluations for a few reasons. First, it allows the synthesis of large amounts of diverse information, such as the comparison of current landscape conditions to the historical and future range of variability (Hessburg et al. 2004, Reynolds and Hessburg 2005, Gärtner et al. 2008). Second, analytic steps used by an interdisciplinary team in a Landscape Evaluation are transparent and repeatable in EMDS. Third, treatment options (including no action) can be evaluated with EMDS using a “gaming” approach that models the outcomes of possible restoration actions.

### ***Efficient and Effective Projects in a Landscape Context***

The Landscape Evaluation helps to define restoration treatments and locations by establishing the context of a restoration project area within the broader landscape. In essence, it sets priorities for where restoration should occur in order to affect larger landscape change. A key outcome of a Landscape Evaluation is the identification of Potential Landscape Treatment Areas (PLTAs). Two to four PLTAs may be identified from each Landscape Evaluation. One to three projects may occur in each PLTA. Information from the Landscape Evaluation is used to develop integrated and site-specific purpose and need statements for projects within the PLTAs, and is carried forward into project planning.

The project development guidelines in this section should support interdisciplinary in designing restoration projects using the best available science about forest ecosystems and climate change. Project-level planning considers two spatial scales: project area-wide considerations (the arrangement and interaction of forest stands), and the patch-scale (characteristics of a single forest stand). In addition to the Landscape Evaluation and project planning described here, the National Environmental Policy Act (NEPA) process for a specific project, requiring site-specific effects analysis and public involvement, must

still be followed. We anticipate the Restoration Strategy process for planning and implementation of restoration projects will improve effectiveness and efficiency because:

- Each Landscape Evaluation can support multiple project NEPA decisions.
- Purpose and need statements and proposed actions will be better supported with landscape- and patch-level information. This should result in fewer misidentified proposed treatment areas and missed treatment opportunities, improving layout efficiency of projects. Currently, specialists often redo analyses because site-specific conditions do not match the conditions assumed during project planning.
- Better integration across resource disciplines will reduce resource conflicts and provide a high level of ownership in restoration projects.
- Landscape Evaluations will provide better information on which to base decisions about the location, scope, and priority of various potential projects, so that limited resources for treatments are used where they provide the greatest benefits.
- A focused project design and integrated purpose and need statement should simplify the NEPA process by reducing unresolved conflict and limiting alternative development (36 CFR Part 220, Section 220.7 [b][2][i]).
- Treatment options can be modeled in [EMDS](#) to show potential outcomes and effects. This should make treatments more effective and simplify NEPA effects analysis.
- A variety of nonprofit organizations and regulatory agencies have reviewed and offered support for the Restoration Strategy. This support, and the transparency of the process, should enable smooth consultation and public involvement processes.
- Integrated Landscape Evaluations across ownership boundaries and resource areas allow for collaboration and funding opportunities to accomplish additional work.

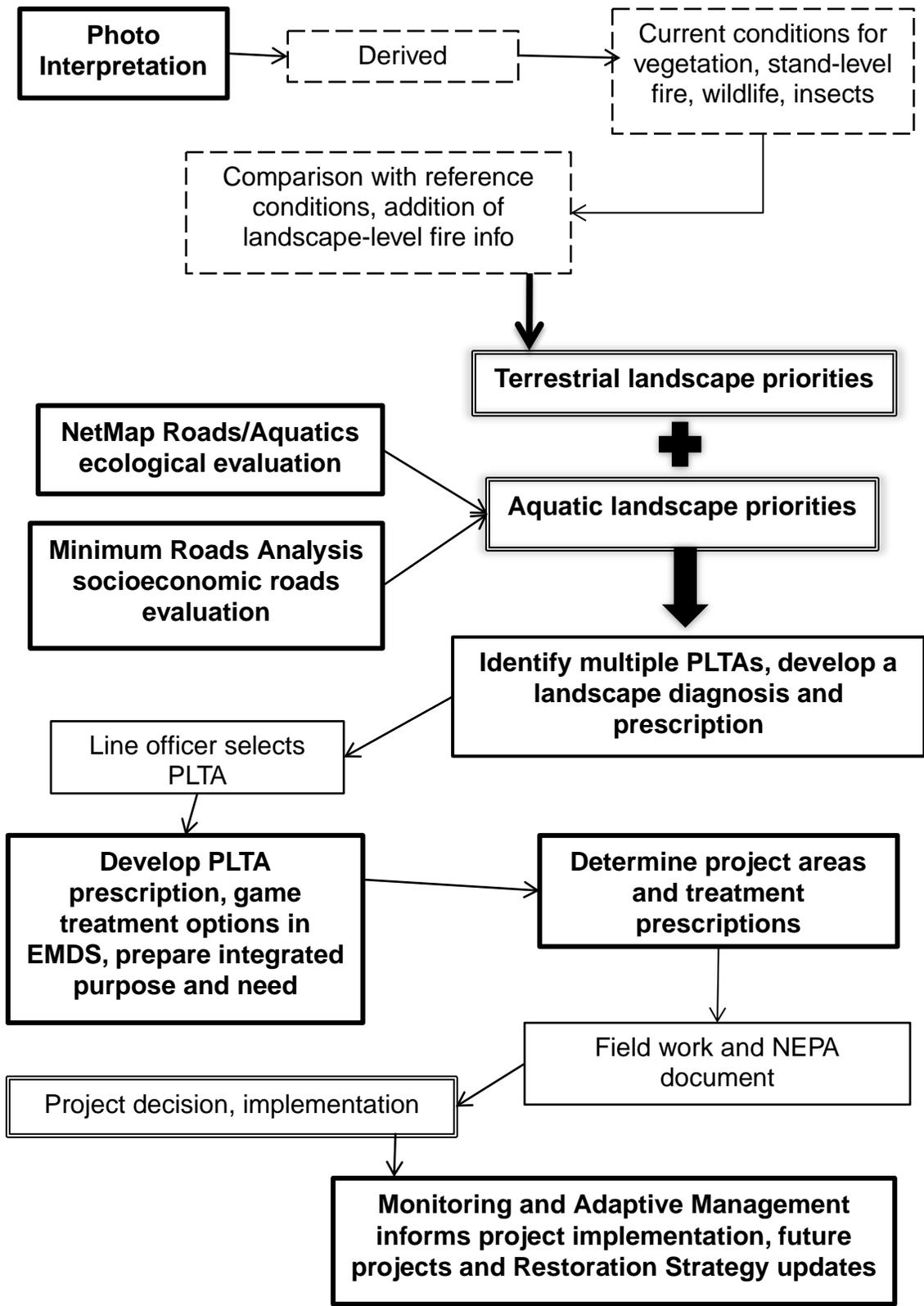
### ***Overview of the complete process***

Implementation of the Restoration Strategy begins with the selection of one to three adjacent sub-watersheds, for a total area of 30,000 to 70,000 acres. At this time, there is no prioritization process by which to select important sub-watersheds across the Forest or within a Ranger District for a Landscape Evaluation. More information about this prioritization, which is currently under development, is in Appendix C. Ranger Districts currently select sub-watersheds for Landscape Evaluations based on data availability, expectation of restoration opportunities, stakeholder input, existing plans, and extent of Forest Service land within the subwatershed.

The next step is photo interpretation of the landscape. Photo interpreters use aerial photos in a GIS environment to delineate and attribute polygons across a sub-watershed. The attributes are features like the dominant tree species and number of canopy layers. EMDS then uses scripts to derive additional attributes from the photo interpreted ones. Derived attributes include forest structure class, wildlife habitat, insect risk, and stand-level fire risk. EMDS then compares current attributes to reference conditions to show priorities for each resource (vegetation, fire risk, insect risk, wildlife habitat). Finally, we give these resources relative weights and EMDS integrates them into a map of combined priorities. Using [NetMap](#) and [Minimum Road Analysis](#) (MRA) outputs, the team reviews ecological and socio-economic priorities for roads and aquatics. We intend to integrate NetMap and

MRA outputs with EMDS outputs to create an aquatics component, but currently Districts review these in parallel. Additional data may be incorporated in the consideration of roads and aquatic resources in the future.

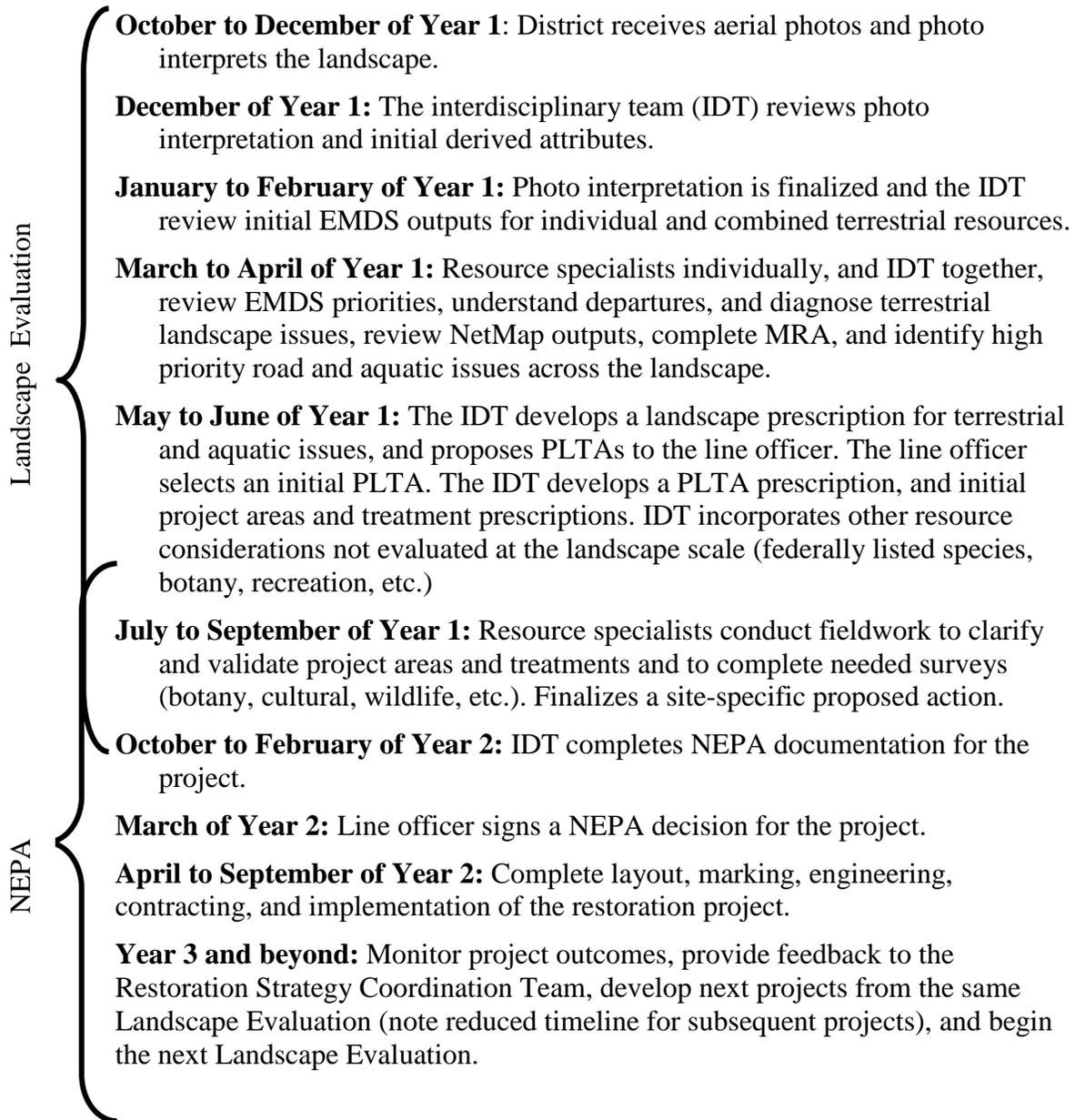
At this point, the interdisciplinary team together, and resource specialists individually, review individual resource priorities and integrated priorities. They start with “red” (high priority) areas on the EMDS output maps to examine landscape and class metrics. These metrics provide information about why certain areas are high priority. Specialists can use this information to start addressing and testing various treatment options. Based on this review, the team develops a landscape diagnosis and prescription and one or more suggested PLTAs. They present this information to a line officer, who selects the first PLTA in which to complete projects. Once the line officer selects a PLTA, the team uses the landscape diagnosis and prescription to develop a generalized prescription for the PLTA. This becomes an integrated purpose and need statement. Finally, the team begins the process of developing project areas, writing treatment prescriptions, conducting fieldwork, integrating other resources, and preparing a NEPA document.



**Figure 4. Schematic of the Restoration Strategy process. Thick boxes are group evaluation processes. Dashed boxes are processes that occur within EMDS. Double-lined boxes are outcomes.**

### ***Timeline for Completing a Landscape Evaluation and Project Planning***

An efficient timeline for the completion of a Restoration Strategy Landscape Evaluation and project-planning phase is the key to successful implementation. The following is an ideal scenario based on the first three implementations of the Restoration Strategy.



## ***Landscape Evaluation description***

This section describes the process for completing a Landscape Evaluation. There are three objectives for conducting an evaluation at the landscape scale:

1. Provide a context for restoration activities so that project planners can clearly identify and display how their project moves the landscape toward more sustainable and resilient desired conditions.
2. Identify logical project areas and priority areas, using the information generated from the Landscape Evaluation.
3. Describe desired ecological outcomes and better estimate outputs.

The described Landscape Evaluation generates information about key ecological patterns, processes, and functions, which are important indicators of landscape conditions (Reynolds and Hessburg 2005):

- structure and vegetation composition (pattern)
- the flow of fire across the landscape (process) given local winds, topography, and fuel conditions
- the movement of water across the landscape (process) and its interaction with road networks and aquatic species
- areas where wildlife habitat (function) is likely to be the most sustainable and integrated with restoration treatment areas
- road network evaluation (function) to understand the roads needed for management and identify a road system that is sustainable and affordable

Other variables may be added, but must have three key characteristics. First, they must be relevant to the task of identifying priority areas for treatment. Second, they must be appropriate at the landscape scale. Third, they must have spatially explicit data available to understand their status. It is important not to add unnecessary complexity to this process.

The Landscape Evaluation relies on knowledge from a wide range of resource disciplines. Knowledge about disturbance ecology and fire modeling, forest and vegetation ecology, wildlife ecology (in particular, how habitats interact with forest disturbances), aquatics (in particular, how the road network interacts with the stream network), and road engineering (to identify the road system that is needed and affordable) is of specific importance to the function of the interdisciplinary team. Other members of the team with knowledge of human uses that occur within the Landscape Evaluation area may be important. The team should focus on developing outcomes (e.g., ecologically sustainable forests) and not focus on any particular level of output (e.g., board feet of timber produced).

## ***Steps to completing a Landscape Evaluation***

The following steps outline the Landscape Evaluation process: (Step 1) determining the Landscape Evaluation area; (Step 2) evaluating vegetation pattern and departure; (Step 3) examining risk of insect outbreak; (Step 4) estimating fire flow and burn probabilities ;(Step 5) identifying key wildlife habitats and restoration opportunities ;(Step 6) examining important areas for aquatic species and ecological risk from roads; (Step 7) evaluating socio-economic priorities for the road network; (Step 8) developing an integrated

landscape prescription and proposing PLTAs; and finally, (Step 9) selecting a PLTA and developing a PLTA prescription and project areas.

Different disciplines will be responsible for a proportionally larger amount of work in each of the steps, but each step is interdisciplinary and integrated. Steps 2 through 5 occur concurrently and use the EMDS tool. Steps 5 and 6 may occur simultaneously with Steps 2 through 5. All steps through number 6 must be completed prior to Step 7. Examples in this section are from the preliminary results of the pilot Landscape Evaluation of the Nile, Dry, and Rattlesnake subwatersheds on the Naches Ranger District.

### **STEP 1 - Select the Landscape Evaluation area**

The size of the Landscape Evaluation has ecological and planning efficiency implications. An area encompassing two or more adjacent sub-watersheds (6<sup>th</sup> level HUCs) totaling between 30,000 to 70,000 acres is recommended. We base this recommendation on prior applications of EMDS (Reynolds and Hessburg 2005, Hessburg et al. 2005). This size evaluation area is optimal for a few reasons: it partially coincides with previous watershed assessments; it generally provides a range of elevations and forest types; and it is useful in evaluating hydrological influences of forest restoration treatments. This size should be large enough to evaluate some cumulative effects of ecological indicators.

### **STEP 2 – Evaluate vegetation pattern and departure**

This step compares landscape vegetation pattern between the current and reference conditions and identifies restoration needs based on departure from reference conditions (Hessburg et al. 1999a, Reynolds and Hessburg 2005). Reference conditions include both historical range of variability (Hessburg et al. 1999a) and the future range of variability (Gärtner et al. 2008).

This section includes three sub-steps: (2a) determine the current landscape vegetation pattern; (2b) determine the reference landscape pattern (2c) evaluate departure of the landscape. The results from this step are integrated with the fire and insect risk, wildlife habitat, and road and aquatic results in Steps 3-7.

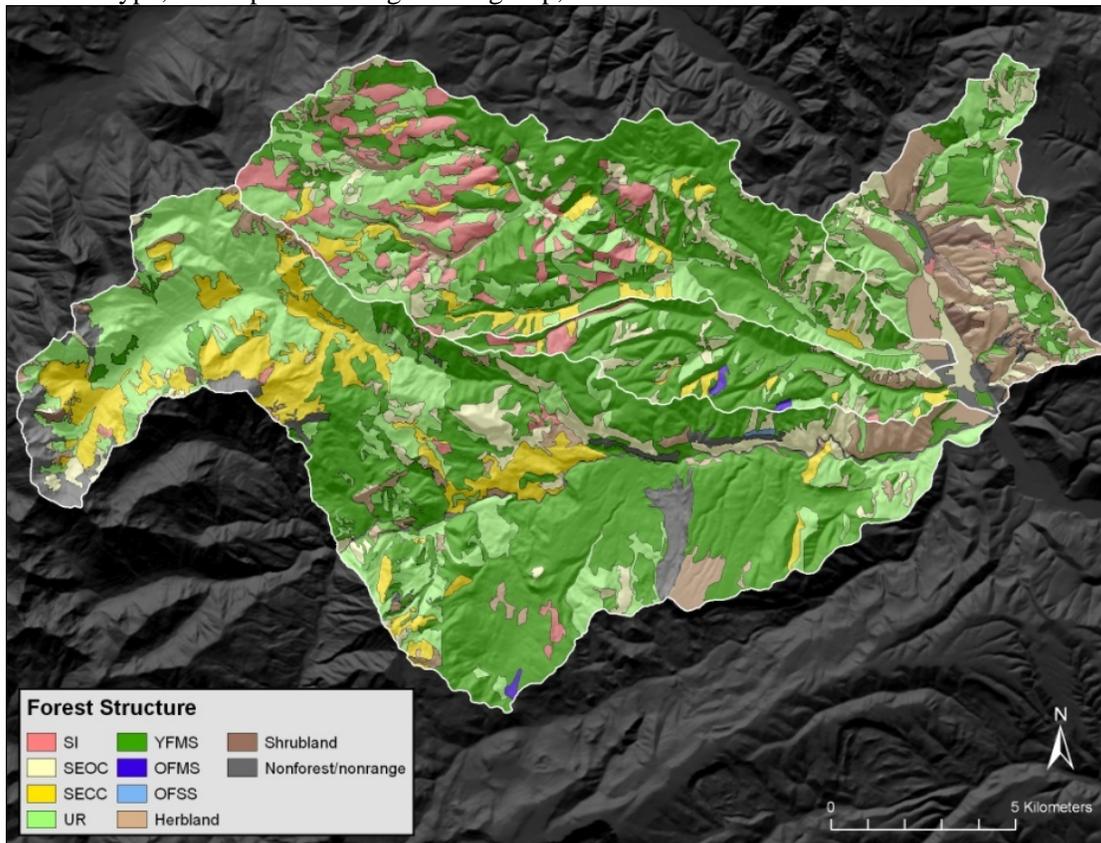
#### **STEP 2a--Determine the current vegetation pattern**

Polygons (patches of similar vegetation) are delineated in a Geographic Information Systems (GIS) platform, using recent aerial photography. A selected set of vegetation patch attributes are recorded for each polygon. Details of the patch delineations are described in Hessburg et al. 1999a. Limited field verification may be used to calibrate the photo interpreter's polygon attributions. However, an experienced photo interpreter with good imagery and good knowledge of the landscape should need little, if any, field validation. A series of automated scripts within GIS error-check the data and derive additional attributes from those recorded by the photo-interpreter. Once this is complete, the IDT reviews the photo interpretation of the landscape. The product of Step 2a is a series of maps of vegetation patch types (*Table 2*) for the current landscape (*Figure 5*).

**Table 2. Examples of combinations of potential vegetation, cover types, and structure classes**

Forest cover and potential vegetation group (CTxPVG)
Forest structure class (SS)
Forest structure and potential vegetation group (SSxPVG)
Forest cover and structure (SSxCT)
Forest cover and structure and potential vegetation group (SSxCTxPVG)

CT=cover type, PVG=potential vegetation group, SS=structure class.



**Figure 5. A map of current forest structure classes on the landscape. Various combinations of cover type and potential vegetation are the products developed in Step 2a.**

### **STEP 2b – Compare with reference landscape patterns**

In this step, we use reference conditions for the Landscape Evaluation area based on the landscape’s ecological sub-region (ESR) (Hessburg et al. 1999a) and the appropriate climate change scenario. The historical range of variability is derived from landscape reconstructions summarized in Hessburg et al. (1999a). These results are summarized in the science overview, landscape ecology section in Part I of this Strategy. Reynolds and Hessburg (2005) incorporated historical range of variability information into EMDS. The future range of variability (FRV) addresses climate change impacts (Gärtner et al. 2008) and is also incorporated into EMDS for this process. The FRV compares current conditions with the next warmer, drier ESR in the landscape area. For some ESRs, the next

warmer, drier ESR has non-forest vegetation. For these cases, we created a blend of ESRs to create a warmer/drier proxy for the future that is still forested.

## STEP 2c--Evaluate vegetation departure

In this step, silviculturists and the IDT review the departure of current landscape vegetation from the historical and future reference conditions using EMDS (Reynolds and Hessburg 2005, Gärtner et al. 2008). Landscape departure includes changes to potential vegetation, cover types, and structure classes, and various combinations of these (*Figure 5, Table 2*). Both [landscape](#) and [class](#) metrics are necessary in assessing departure. It is important to look at both sets of metrics for a variety of variables to fully understand vegetation departure.

The Restoration Strategy team chose a subset of 7 landscape metrics used by Hessburg et al. (1999):

**Patch Richness (PR):** *Number of patches* often has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area is held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret.

**Shannon Diversity Index (SHDI):** *Shannon's diversity index* is a popular measure of diversity in community ecology, applied here to landscapes. Shannon's index is somewhat more sensitive to rare patch types than Simpson's diversity index

**Hill Index N1 (N1):** A transformation of SHDI, this index is more suited to describing the more common patch types, discounting the more rare species. It represents the number of 'abundant' species.

**Hill Index N2 (N2):** A transformation of Simpson's Index, this index discounts the rare patch types even more than N1. It represents the number of 'very abundant' species."

**Modified Simpson's Evenness Index (MSIEI):** The observed modified Simpson's diversity index divided by the maximum modified Simpson's diversity index for that number of patch types. It is sensitive to rare patch types being present."

**Contagion Index (CONTAG):** *Contagion* is inversely related to edge density. When edge density is very low, for example, when a single class occupies a very large percentage of the landscape, contagion is high, and vice versa. In addition, note that contagion is affected by both the dispersion and interspersion of patch types. Low levels of patch type dispersion (i.e., high proportion of like adjacencies) and low levels of patch type interspersion (i.e., inequitable distribution of pairwise adjacencies) results in high contagion, and vice versa.

**Interspersion and Juxtaposition (IJI):** *Interspersion and juxtaposition index* is based on patch adjacencies, not cell adjacencies like the contagion index. As such, it does not provide a measure of class aggregation like the contagion index, but rather isolates the interspersion or intermixing of patch types.

The Restoration Strategy team chose a subset of seven class metrics used by Reynolds and Hessburg (2005):

**Percent Land (PL):** the percentage the landscape composed of the class (e.g. Young Forest Multi-Story). This metric allows an understanding of how the amount of a class has changed from reference conditions.

**Aggregation Index (AI):** is calculated from an adjacency matrix. It shows the frequency with which different pairs of patch types appear side-by-side on the map. This metric shows how similar patches relate to each other, or proximity in current landscapes versus reference conditions. AI helps to relate patterns to ecological processes (such as risk of contagion for insect outbreaks or fire flows).

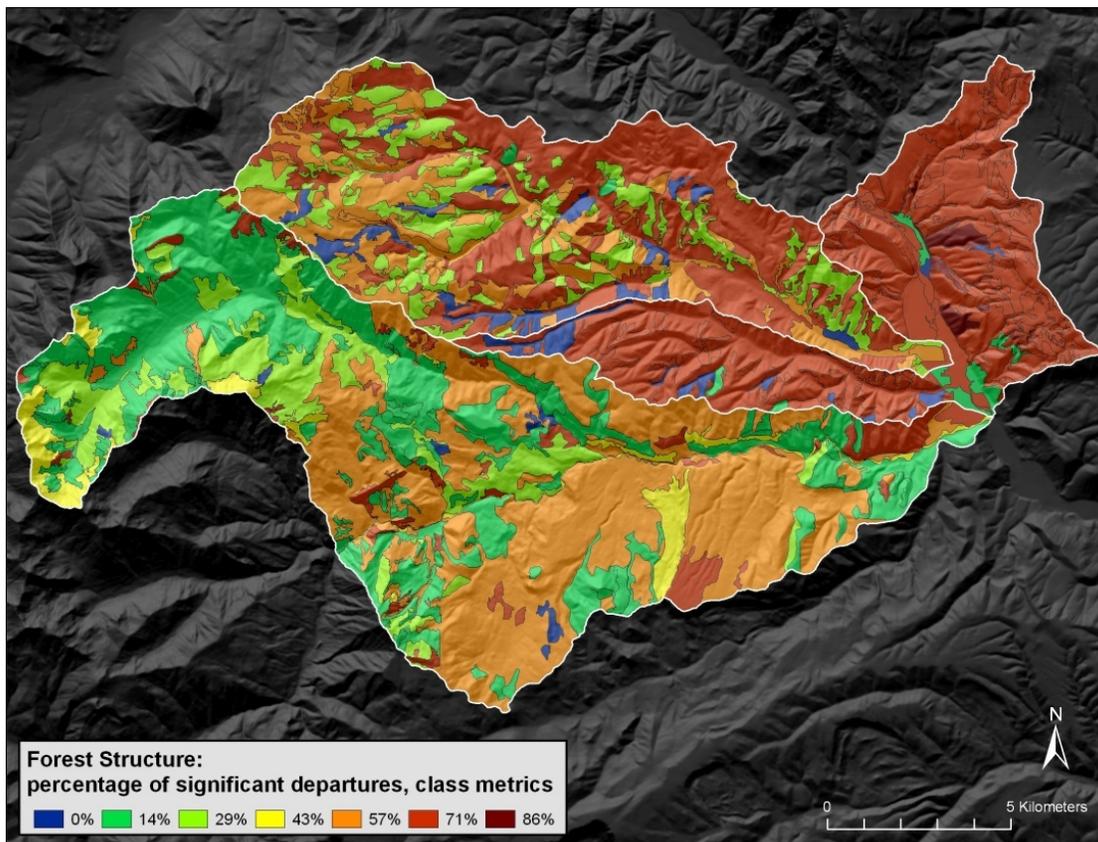
**Patch Density (PD):** is a limited, but fundamental, aspect of landscape pattern. It expresses the number of patches on a per-unit-area basis, which facilitates comparisons among landscapes of varying size.

**Largest Patch Index (LPI):** Quantifies the percentage of total landscape area represented by the largest patch. As such, it is a simple measure of dominance that shows relative size of the largest patch compared with reference conditions.

**Edge Density (ED):** Reports edge length on a per unit area basis that facilitates comparison among landscapes of varying size

**Mean Nearest Neighbor (MNN):** The average distance to the nearest neighboring patch of the same class attribute.

**Mean Patch Size (MPS):** The average area of all patches of the same class attribute.



**Figure 6. Step 2c - A map of the landscape evaluation area showing the degree of departure between current and reference conditions for class metrics**

### STEP 3 - Evaluate risk of insect infestation

In this step, the vulnerability of the landscape, and its component patches, to insects and diseases is evaluated and compared with the reference conditions (Hessburg et al. 1999b). Each patch is assigned to a vulnerability class based on vegetation factors for specific insects and diseases. These factors are based on the information from Step 2. Spatial statistics are used to evaluate how vulnerable the landscape is to the propagation of specific insects.

The product of this step is a vulnerability rating of insect infestation for the present and reference landscapes. This rating does not inform managers about current insect or disease outbreaks. Interdisciplinary teams should use additional data on current conditions, and support from Forest Health Protection, to guide decisions about treating existing insect and disease outbreaks, as well as addressing areas at risk as part of a landscape or PLTA prescription.

Another product of Step 3 is a table of spatial statistics describing the current landscape's degree of departure in total area of vulnerability classes and their connectivity. In essence, this shows how "insect habitat" has changed over time in its amount and configuration. The factors affecting landscape and patch vulnerability to Douglas-fir beetle and spruce budworm are displayed in Table 3.

**Table 3. Vulnerability factors and rating criteria used in the evaluation of insect and disease risk based on Hessburg et al. (1999b)**

Vulnerability factor	Rating criteria	
	<i>Western spruce budworm</i>	<i>Douglas-fir beetle</i>
Site quality	Plant association group	Plant association group
Host abundance	Host crown cover	Host crown cover
Canopy structure	Number of canopy layers	Number of canopy layers
Patch (stand) density	Stand total crown cover	Stand total crown cover
Host age	Estimated age class	Estimated age class
Patch vigor	Degree of overstory differentiation	n/a
Host patch connectivity	Proportion of area within a 1.135 km radius occupied by host	Proportion of area within a 1km radius occupied by host

**HOT BOX 3**  
**Consider the Role of Each Stand on the Landscape**

## HOT BOX 3

### Consider the Role of Each Stand on the Landscape

New approaches to forest management are needed within the context of forest restoration. There are now more diverse objectives for the landscape and its component stands, including: providing barriers to the spread of fire; promoting resilience to characteristic wildfire; providing habitat for northern spotted owls and white headed woodpeckers; sustaining hydrologic function; and promoting landscape-level patterns that serve ecological structure and function goals. To accomplish these objectives, managers should be explicit about the intended role for each stand, or group of stands, in the landscape context. Here are some simplified examples:

**Role - Old forest single story (OFSS) in the pine cover type as white-headed woodpecker habitat.** Create this structural class by removing understory trees, and conducting periodic under-burning to maintain open conditions. Traditionally, silviculturists under-planted stands in anticipation of an overstory removal, but such removal would compromise OFSS function.

**Role - Stem exclusion closed canopy (SECC) in the Douglas-fir cover type as a barrier to fire spread.** SECC can be maintained by thinning from below. However, stands with widespread dwarf mistletoe infection should not be thinned, as this would increase broom mass and ladder fuels, thus fire hazard. Mistletoe stands may need to be regenerated in some cases. Commercial thinning may be used in stands with enough deep-crowned trees to balance objectives for crown bulk density, understory shading and wind reduction, and desired growth rates.

**Role - Stand initiation or understory reinitiation ponderosa pine cover type within the Douglas-fir series.** Develop this structural class by regeneration harvest favoring ponderosa pine. Traditionally, these sites were planted at high density to maximize timber volume production. Now, depending on seed source, wait for natural regeneration. If planting is necessary, plant at a low and variable density so the stand initiation (SI) function isn't compromised. Over time, SECC or young forest multistory (YFMS), or stem exclusion open canopy (SEOC) conditions should develop and the stand may be burned or thinned as needed.

## STEP 4 - Fire movement potential

### *Landscape Fire Risk*

In this step, use landscape-level fire modeling. This modeling is done at the [sub-basin](#) (4<sup>th</sup> level HUC) scale, which encompasses approximately 700 square miles. FlamMap fire modeling software uses forest-wide fuels layers (re-sampled to 90m pixels), 90<sup>th</sup> percentile fuel moistures, and representative weather conditions (to condition fuels). Custom wind grids, derived for the three or four most likely prevailing wind directions, are also used as an input to the model. The landscape model is repeatedly ignited with 1,000 random fire starts at a time and allowed to burn for six hours, until the majority of the landscape has been exposed to fire (~50,000 modeled ignitions).

Each model run creates multiple map outputs for each sub-basin, including: fireline intensity, crown fire activity, rate of spread, flame length, and node influence (the number of pixels that burned downwind of the ignited one). The node influence changes as a result of ignition locations, so node influence for each individual run is composited to represent the sum of all 50,000 ignitions. This composite node influence is then combined with fireline intensity to create an index that shows the relative importance of each pixel (*Figure 7*). This index is subsequently filtered to find clusters of pixels that create more meaningful areas to consider dangerous (since a two-acre area is not useful at the landscape scale).

### ***Patch/Stand Level Fire Risk***

Photo interpreters use aerial photos to determine cover type, structural stage, and logging activity type (if present). Cover/structure attributes are then combined and used to assign one of 192 fuel characteristic classes to each stand polygon. Fuel characteristic classes are then used to model, for each polygon, a variety of fire behavior, smoke, and fuel consumption variables, such as crown fire, fireline intensity, rate of spread, flame length, and fuel loading. We can consider the representation of each of these fire behavior variables in the context of the historical and future ranges of variability using spatial statistics (see the description of class metrics in Step 2c). These statistics describe, for example: how large the patches of a particular crown fire risk level might have been historically, how close together the patches were, and how much edge they shared with adjacent patches.

**Figure 7. A map showing probability of landscape-level fire movement produced from Step 3**

## **STEP 5 - Habitats for Focal Wildlife Species**

The objectives of this step are: (1) determine the location and amount of habitat for focal wildlife species currently present within the Landscape Evaluation area; (2) compare the current amount and configuration of habitats for focal wildlife species to historical and future reference conditions; and (3) identify habitat restoration opportunities and priorities that can be integrated with other resource priorities and carried forward into project level planning. The information about wildlife habitats generated from this step is incorporated into EMDS for integration in Step 7.

Focal wildlife species were selected because they are either federally listed or identified as a Region 6 focal species (USFS 2006a, Gaines et al. in prep). The focal species are closely associated with forested habitats and their populations are influenced by changes to forest structure. Habitat generalists and wide-ranging carnivores were not selected as focal species because they are generally evaluated at broad spatial scales. These include species such as the grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), and gray wolf (*Canis lupus*).

### **Focal Wildlife Species and Habitats**

Focal species used to evaluate wildlife habitats include the northern spotted owl (*Strix occidentalis caurina*), northern goshawk (*Accipiter gentilis*), white-headed woodpecker

(*Picoides albolarvatus*), American marten (*Martes americana*), , and black-backed woodpecker (*Picoides arcticus*). The habitat definitions used in the Landscape Evaluation for these species are described in Table 4. The northern spotted owl is a federally protected threatened species that is associated with late successional forests. Its habitat is addressed in Landscape Evaluations that occur within the Northwest Forest Plan area. The revised spotted owl recovery plan (USFWS 2011) identified an “east-side strategy” that integrates disturbance ecology and high-quality spotted owl habitat within the broader context of ecosystem restoration. East side northern spotted owl recovery is implemented through this Restoration Strategy by identifying sustainable habitat levels in Landscape Evaluations. In addition, the recovery plan identifies the need to retain or restore large trees and snags as an important component of spotted owl habitat (USFWS 2011). This is one of the reasons that the Restoration Strategy specifically addresses large trees (see Part II, Project Development).

The northern goshawk is a Pacific Northwest Region (R6) focal species (USFS 2006a) and was highlighted in the east-side screens (USFS 1998). Like the northern spotted owl, the goshawk is associated with late-successional forests (see Gaines et al. in prep for a summary of habitat relations). The northern goshawk is only assessed in Landscape Evaluations that occur outside of the Northwest Forest Plan area. The white-headed woodpecker, American marten, and black-backed woodpecker are all R6 focal species (USFS 2006a) and are being evaluated in revision of the OOWNF Forest Plan (LRMP). These species are associated with a wide variety of cover types and structural classes. Gaines et al. (in prep) presents an extensive literature review that summarizes the habitat relations of these species. This information was used to develop the habitat definitions presented in Table 4.

**Table 4. A description of habitats for focal wildlife species used in the Landscape Evaluation**

Focal species/habitat	Potential vegetation type/cover type/structure class <sup>1</sup>
Northern spotted owl	<ul style="list-style-type: none"> <li>• LSOF<sup>2</sup>, OFMS</li> </ul>
Northern goshawk	<ul style="list-style-type: none"> <li>• ABAM<sup>3</sup> – OFMS or YFMS w/o logging<sup>4</sup></li> <li>• PIPO, PSME, or TSHE/THPL – OFMS or OFSS or YFMS w/o logging</li> <li>• LAOC<sup>9</sup> - OFSS or YFMS w/o logging</li> <li>• PICO or ABGR - YFMS w/o logging</li> </ul>
White-headed woodpecker	<ul style="list-style-type: none"> <li>• PIPO and series in PIPO, WD-PSME/ABGR/ABCO and SIZE_OS (large and medium) and TOTL_CC &lt;=40% and elevation &lt;=5000ft</li> <li>• PIPO and series in PIPO, WD-PSME/ABGR/ABCO and STRUCTURE OFSS or SIZE_OS=large and SIZE_US=medium or SIZE_OS=medium and OS_CC&gt;=30% and TOTL_CC&lt;=40% and elevation &lt;=5000ft</li> </ul>
American marten	<ul style="list-style-type: none"> <li>• ABGR or PIAL/LALY – YFMS w/o logging</li> <li>• ABAM or ABLA2/PIEN - OFMS or YFMS w/o logging</li> <li>• LAOC – OFSS or YFMS w/o logging</li> <li>• PSME, TSHE/THPL or TSME – OFMS or OFSS or YFMS w/o logging</li> </ul>

Black-backed woodpecker	<ul style="list-style-type: none"> <li>• ABLA2/PIEN – OFMS</li> <li>• PIPO or PSME – OFMS or OFSS</li> <li>• LAOC – OFSS</li> <li>• PICO – YFMS</li> <li>• &lt;10 years post high severity fire w/o post-fire harvest</li> </ul>
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<sup>1</sup>The cover types and structure classes are described in Part I. Abbreviations for cover types in this table are YFMS, OFMS, and OFSS (see Figure 2)

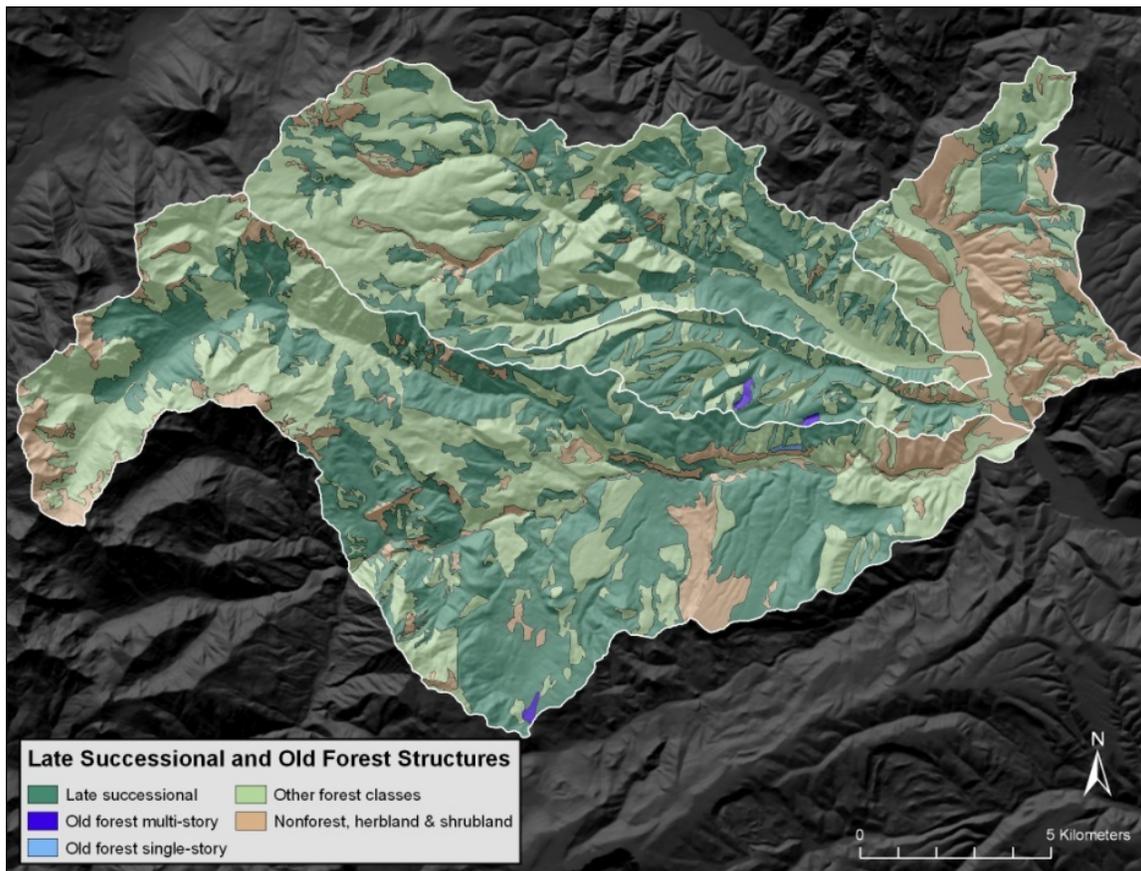
<sup>2</sup>LSOF = late-successional/old forest

<sup>3</sup>Abbreviations not related to structure classes are species where the first two letters indicate the genus and the second two letters indicate the species (e.g. ABAM = *Abies amabilis*)

<sup>4</sup>For a definition of logging see Hessburg et al. 1999a

**The products from this step include:**

- A map showing the location and amount of potential and existing habitat for each of the focal species (*Figure 8*). Note that these are habitat maps, and not maps of actual wildlife locations. Data on currently occupied habitat may be combined with Landscape Evaluation results in project planning.
- A map of the historical and future references conditions for habitat for each species.
- Tabular data showing the degree of departure in habitat amounts and configuration between current and reference conditions. Habitat is described by the vegetative species and structure classes in Table 4.



**Figure 8. A map of a Landscape Evaluation area showing the location of some focal wildlife species' habitats (e.g. late successional forest for Northern spotted owl). This map is the result of Step 5.**

## **STEP 6 - Aquatic/road interactions**

The objective of this step is to identify the roads or road segments that have the greatest impacts on the aquatic environment and are therefore a priority for restoration work. The components of the aquatic/road interactions evaluation include hydrologic connectivity, fish distribution, slope/soil stability, and stream channel confinement. These components can be evaluated using NetMap (an add-in modeling component for ArcGIS), and data from stream habitat and fish surveys, the INFRA database, and other local sources.

### ***Hydrologic connectivity***

Identify flow routes connecting to the road system by intersecting ten-meter digital elevation models with road segments (output is a relative ranking). A NetMap tool provides road density within a stream segment's local contributing watershed area.

### ***Fish distribution***

NetMap gives areas of intrinsic potential habitat for Chinook and Steelhead. Use this information in conjunction with the existing fish distribution layer for listed fishes and other native salmonid species. NetMap cannot currently model intrinsic potential habitat for any other species, although this may be developed in the future. This combination of data sources should show high priority stream reaches for restoration to benefit aquatic ecosystems.

### ***Slope/soil stability***

Slope/soil stability is modeled by combining the soil layer with the digital elevation model, and assigning slope breaks appropriate for the landscape being analyzed. At this time, default slope breaks are 0 to 35 percent, 35 to 60 percent, and greater than 60 percent. Road segments at greater slopes correlate with known risk of sediment delivery potential. Another NetMap tool ranks risk for shallow landslides by road segment.

### ***Stream channel confinement***

Use the stream channel confinement layer developed for forest planning that identifies stream channels with less than three percent gradient within 98 feet of roads. Figure 9 shows an example NetMap output for this component.

### ***Known issues***

The NetMap suite of tools provides information on areas of high risk, and therefore high priority for restoration. However, an additional source of information is known issues in the Landscape Evaluation area. For example, degraded roads segments or stream crossings, or areas in which multiple slides have occurred should be flagged and used to help develop PLTA prescriptions and project plans. We are currently developing a prioritization process for road segments from an Engineering perspective. Additional consideration might be given to road segments with known structural or stability problems where road reconstruction would be a priority, especially if there is a potential public safety issue.

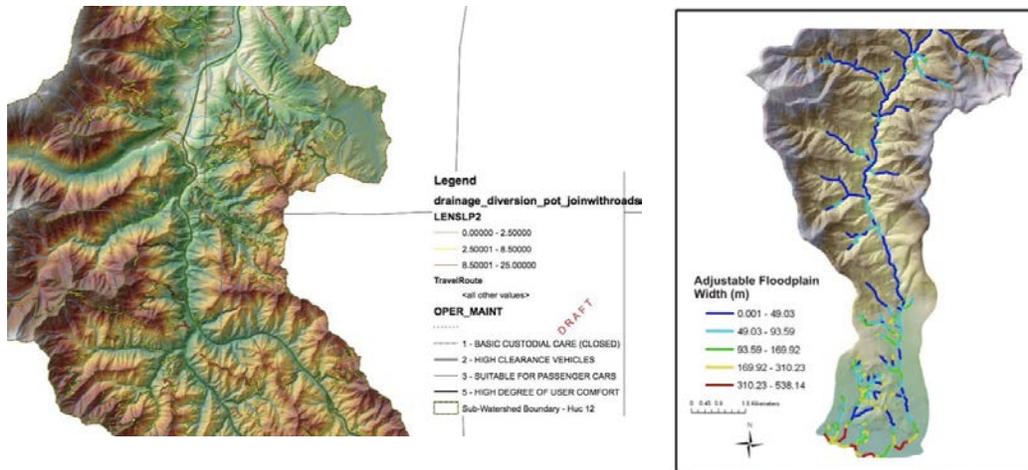


Figure 2-30. NetMap estimates width (combined left and right sides of channel) of the floodplain based on user defined bankfull depth(s) above channel.

**Figure 9. Example NetMap outputs showing road slopes (left) and floodplain width and channel confinement (right). These are not from Rattlesnake/Dry/Nile Landscape Evaluation.**

## STEP 7 – Minimum Road Analysis

The purpose of a Minimum Road Analysis (MRA) is to identify the minimum road network needed for recreation and management and to move toward decommissioning or differently managing non-essential road segments. MRA is a mandated process that must occur in all sub-watersheds Forest-wide by 2015 as part of a larger effort to align Forest road networks with dwindling infrastructure maintenance budgets. Those areas that are undergoing a Landscape Evaluation will also have an MRA completed prior to, or simultaneous with, that evaluation.

An MRA used in conjunction with a Landscape Evaluation helps to determine socio-economic priorities for roads, alongside the ecological restoration priorities analyzed in Steps 2-6. The goals are: to improve water quality, and fish and wildlife habitats; to identify the roads most at risk of failure (e.g. slumping, culvert blow-out); and to determine how to best mitigate road impacts while also considering the road network needs. Site-specific mitigations will be determined as part of the project development stage. These are the steps to complete an MRA:

1. Determine areas of highest ecological priority:
  - a. Review watershed analysis reports for areas of concern
  - b. Review aquatic/road interaction components listed in Step 6
  - c. Conduct a risk versus need analysis with an interdisciplinary team
2. Determine needed access:
  - a. Review planned resource management programs (vegetation management, grazing, noxious weeds, etc.).
  - b. Identify land management requirements (required access, easements, permits)
  - c. Identify recreation/forest user infrastructure (campgrounds, trailheads)
  - d. Identify fire suppression and prevention infrastructure (lookouts, firebreaks)

- e. Develop a need value for roads and road segments with an interdisciplinary team
- 3. Determine ability to address maintenance needs with anticipated funds:
  - a. Ensure that dollars are available for critical repairs or improvements.
  - b. Determine a target maintenance budget based on all roads within the sub-watershed
  - c. Develop expected future conditions for the road network and analyze budgetary requirements to address these conditions

**Table 5. An example outcome of a Minimum Road Analysis. This one comes from the Roaring/Mills/Tillicum sub-watersheds on the Entiat Ranger District.**

Maintenance Level	Current Miles	Maintenance Cost	Planned Miles	Maintenance Cost
5	0	\$0	0	\$0
4	0	\$0	0	\$0
3	8.8	\$13,534	0	\$0
2	212	\$136,528	214	\$137,816
1	203	\$12,586	71	\$4,382
Decommission			139	\$0
<b>Total</b>		<b>\$162,648</b>		<b>\$142,198</b>

Ultimately, the Restoration Strategy team intends to integrate Steps 6 and 7 with the terrestrial portion of the Landscape Evaluation in EMDS. While the aquatic and road analyses are still done as parallel processes, it is important to use their results both for selecting a PLTA, and for selecting project areas and designing restoration treatments.

### **Step 8 - Integration of Landscape Evaluation results**

This step integrates the results from the vegetation pattern analysis (Step 2), insect risk evaluation (Step 3), the fire movement modeling (Step 4), wildlife habitats (Step 5) aquatic/road interactions (Step 6), and Minimum Road Analysis (Step 7). Then, other management direction and resources are considered, and potential landscape treatment areas (PLTAs) are suggested. The product is a PLTA that will carry forward to project-level planning.

Resource specialists should review the individual resource outputs from EMDS in Steps 2 through 5 and present findings to the interdisciplinary team (IDT). The IDT should review the integrated terrestrial resource output from EMDS as a team. It is important to consider departure from both the historical and future ranges of variability as part of this exercise. The IDT should delve into the class and landscape metrics that inform areas of high priority and begin to understand which areas are important to treat and how treatment may be accomplished for multiple resources.

At this point, there is an opportunity to collaborate with groups or agencies with natural resource information or expertise. These groups may be able to provide other information useful in selecting or defining a PLTA. It is also beneficial for these groups and agencies to

understand the Landscape Evaluation process and the way in which a PLTA and project are subsequently derived.

**Please note:** *The process outlined in this Restoration Strategy does not replace the NEPA and other requirements for project-level planning. Rather, following the Restoration Strategy, allows project-level planning to be supported by a solid scientific and analytical foundation at an ecologically significant scale, with attention paid to multiple resources in an integrated fashion. Project planning in a traditional NEPA process occurs once a PLTA, landscape prescription, PLTA prescription, and integrated purpose and need are completed.*

### **Step 8a - Developing an integrated landscape prescription**

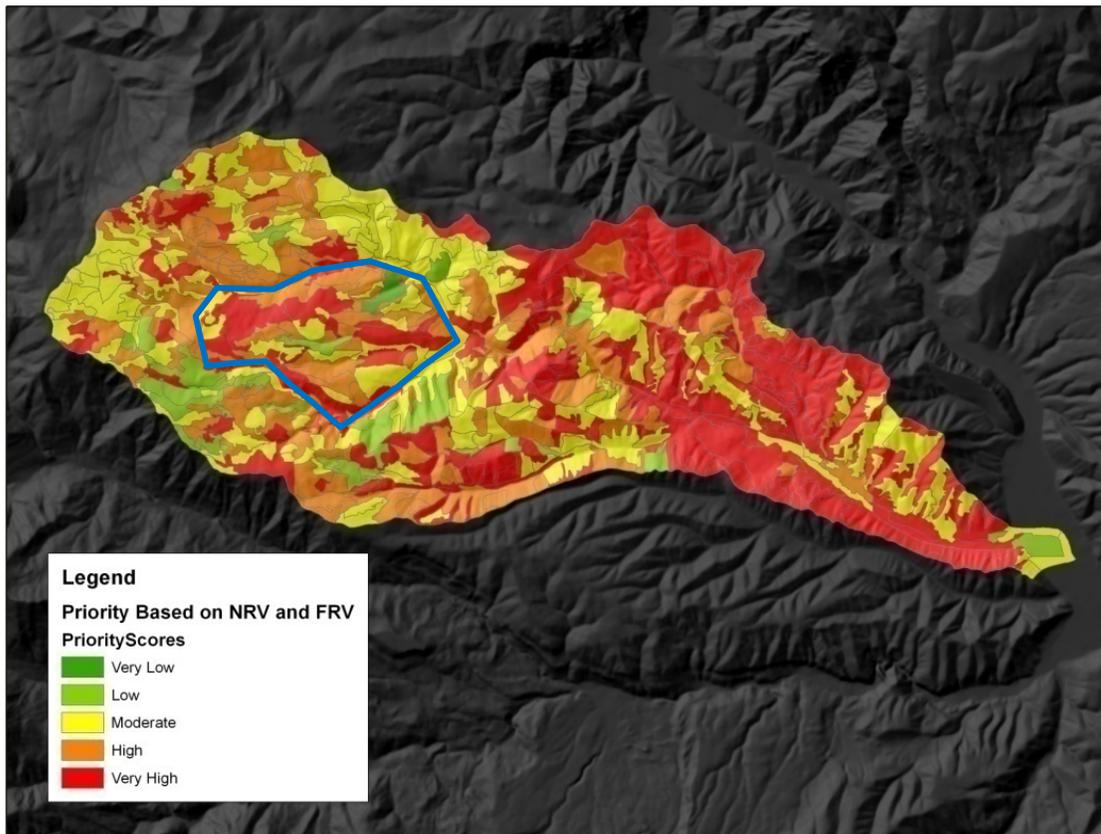
Steps 2 through 7 provide information used to develop a landscape prescription. The information generated from the landscape vegetation and habitat evaluation, fire and insect risk modeling, and road and aquatic analysis, should allow the interdisciplinary team to quantify the amount and location of restoration treatments that accomplish multiple objectives. Such objectives include strategically altering fire behavior across the landscape, enhancing the sustainability of wildlife habitat, restoring landscape vegetation pattern, and reducing the ecological and economic costs of the road network.

Integration of all of these resources and reference conditions is accomplished with EMDS (Reynolds and Hessburg 2005). Using EMDS, the interdisciplinary team (IDT) can evaluate a variety of landscape treatment options and assess how the options affect key resources (e.g. wildlife habitat). Land allocations and other direction in the current Forest Plan are also important considerations (see Appendix A). Line officers and IDT members will work together to select and weight decision criteria. As the IDT develops treatment ideas, these options or scenarios can be tested in EMDS. By changing the photo interpretations of different patches to match expected post-treatment conditions, EMDS will show the potential landscape effects of a variety of treatment options. Some of the questions the IDT should consider in developing a landscape prescription are:

- What are the critical areas and thresholds (amount of area that needs to be treated) for restoration treatments based on modeled fire behavior in order to reduce fire risk to human developments and wildlife habitats?
- What treatments best restore landscape pattern and processes while meeting other resource objectives?
- What combination of treatments provides habitat and restores patch sizes for wildlife focal species?
- What are sustainable levels of high-quality spotted owl habitat or late-successional habitat, and how can sustainability of this habitat be enhanced through strategic placement of restoration treatments?
- Where are the priority roads for restoration that reduce negative ecological impacts on hydrology and aquatic habitat?

The final products of this step are a landscape diagnosis and generalized prescription. These help the IDT propose one or more PLTAs with treatment options for line officer decision (*Figure 10*). By summarizing needs and treatment options at the landscape scale, IDTs capture the full

benefit of a Landscape Evaluation, and can clearly communicate its results to line officers, collaborators, and other interested parties.



**Figure 10. A hypothetical Potential Landscape Treatment Area (PLTA) identified from the Landscape Evaluation and selected for high priority restoration need for multiple resources, as well as land allocation and logistical considerations.**

### **Step 8b - Developing and selecting a PLTA**

PLTAs will generally be 5,000-10,000 acres in size. One or more NEPA projects may result from each PLTA. This process confers huge efficiency and credibility advantages to the NEPA process. It is efficient because attention is focused on smaller, more manageable areas where treatment goals are already identified (by the landscape prescription), thereby reducing the amount of front-end field time for the IDT. It increases credibility in that proposed actions can be highly specific as to site, treatment, and integration of multiple objectives and resources, thus meeting a key NEPA mandate. The NEPA process for a specific project would entail the usual site-specific analysis and public involvement. Generally, IDTs suggest multiple PLTAs and potential treatments to a line officer. All these PLTA options will have restoration benefits for multiple resources.

Line officers will often select a PLTA based on logistical considerations, input from affected parties, socioeconomic issues, or other resource considerations. Eventually, some of these considerations may be addressed in EMDS making the decision-making process even more transparent. Once a PLTA is selected to go forward, other possible PLTAs

should be re-analyzed. After one or more projects occur in the first PLTA, landscape priorities can change, necessitating another look at potential treatments and locations. Also, if the PLTA boundary changes, re-analysis of the new PLTA is necessary to ensure integrated priorities for all resources are considered.

### **Step 8c - Developing a PLTA prescription and initial project areas**

Once the line officer has selected a PLTA, the IDT develops a PLTA prescription that addresses the identified landscape level issues. The IDT should use EMDS again to test PLTA treatment options and to begin developing restoration projects. The PLTA prescription should incorporate consideration of all resources to the extent possible. So, a PLTA prescription should address landscape-level issues for terrestrial resources based on EMDS information, as well as landscape and local issues for roads, hydrology, and aquatic resources.

The team should review each road in the PLTA with regard to the need for the road and the risk to resources. Options for treating roads include: (1) Maintain at current maintenance level and include repair or heavy maintenance/storm proofing; (2) upgrade the condition of the road, consistent with local hydrologic processes; (2) lower the maintenance level; (3) place the road in storage/closure (Maintenance Level 1); (4) relocate road segment(s), or (5) decommission the road. This is also the point at which logistical considerations are important. For example, how can the PLTA be accessed? What are the patterns of recreation use in the area? Are there known cultural resources within the PLTA? What sorts of restoration treatments may be viable in different parts of the PLTA?

#### **HOTBOX 4**

#### **Climate Change and the Forest Restoration Strategy**

Climate change is “one of the most urgent tasks facing the Forest Service.” “As a science organization, we need to be aware of this information and to consider it any time we make a decision regarding resource information, technical assistance, business operations, or any other aspect of our mission” (Kimbell 2008). Because addressing climate change is so important, the Okanogan-Wenatchee National Forest conducted a Climate Change workshop in 2008 (Gaines et al. in prep). The results of the workshop were key management adaptations that scientists and managers identified to address current and predicted climate change impacts. The Restoration Strategy addresses several of these adaptations.

##### ***Adaptations Relevant to Landscape Evaluations***

- Use landscape-level planning to identify restoration treatment areas, including the most effective locations to reduce fire flow, restore patch sizes, and sustain wildlife habitats (Finney 2001, Ager et al. 2007, Franklin et al. 2008).
- Use landscape-level planning to evaluate the interaction between hydrologic regimes and roads. Identify problem areas, and areas where access is needed for management or recreation, to prioritize road restoration opportunities (Binder et al. 2009).
- Landscape planning should occur across ownerships in order to evaluate ecological patterns, processes, and functions (Hessburg et al. 2005, Franklin et al. 2008).

## **HOTBOX 4**

### **Climate Change and the Forest Restoration Strategy**

- Use the range of variability (historical and future) to determine where treatments are needed to restore landscape pattern, functions, and processes (Hessburg et al. 2005, Gärtner et al. 2008).
- Reduce the impacts of roads on water quality, quantity, and flow regimes (Binder et al. 2009).
- Decouple roads or remove roads to keep water on the landscape (Binder et al. 2009).
- Relocate roads and other structures that are at risk from increased peak flows (Woodsmith 2008).

#### ***Adaptations Relevant to Project Development***

- Use the range of variability (historical and future) to guide stand-level restoration of structure, species composition, and spatial pattern (Harrod et al. 1999, Franklin et al. 2008).
- Match treatment unit sizes with desired patch sizes determined from landscape-level planning (Hessburg et al. 2005).
- Use thinning (mechanical and through prescribed fire) to reduce biomass, provide more vigorous growing conditions, and reduce vulnerability to uncharacteristic wildfire and epidemic insect outbreaks (Hessburg et al. 2005, Franklin et al. 2008).
- Retain the most fire-tolerant tree species and size classes commensurate with the forest type (Harrod et al. 1999, Franklin et al. 2008).
- Retain and restore old and large trees, as they are the most difficult to replace and most resilient to disturbances (Harrod et al. 1999, Hessburg et al. 2005, Franklin et al. 2008).

### ***Project (proposed action) Development and Assessment***

In this section, a process is outlined for developing a site-specific proposed action (NEPA project) within a PLTA. All projects help to implement the landscape prescription and move the landscape toward resiliency because the Landscape Evaluation guided selection of the project/NEPA analysis area and suggested landscape-level restoration needs for a variety of resources. That information stepped down to selection of a PLTA and now to the design of a project. The four steps outlined in this section move the IDT from PLTA to project in keeping with the objectives of the Restoration Strategy.

#### **STEP 1 - Conduct field work to refine the PLTA prescription and address other resources**

The goal of this step is to gather information necessary to develop an integrated site-specific purpose and need. Field reconnaissance may validate assumptions about ecological need and operational feasibility for a proposed action. The IDT should do a group field visit to the PLTA to collaboratively review multiple resources. A group field visit helps to confirm the ecological issues raised, and solutions proposed, in the Landscape Evaluation. Collaborators may be included in a field visit after the IDT has done an initial

review of the project area. This helps to build support for the developing project and to identify additional issues that may not have been raised within the IDT.

The IDT could address the following questions (and more) in a field visit:

1. Do the landscape vegetation pattern results seem appropriate, or are there major differences on the ground in tree sizes, canopy layers, or species?
2. Where do opportunities exist to address existing insect and disease issues and to mitigate risk of future issues?
3. Does the stand-level fire modeling make sense? Are there additional issues with fuels or other resources that require protection in the area?
4. Are the potential wildlife habitats well identified? Are there additional habitats for focal or other species that should be addressed in the proposed action?
5. Are there riparian areas or hydrological issues, apart from road interactions, that should be addressed?
6. Are the at-risk road segments mapped correctly? Are there existing road or trail issues or stream crossings that should be addressed?
7. Are there botanical issues to be investigated in the area, such as invasive species, rare plants, or degraded meadows?

Once the IDT has done a field review, and potential actions and project areas are better defined, resource specialists may begin typical survey efforts. For example, specialists may conduct spotted owl nest site surveys, cultural resource surveys, and botanical surveys as needed within the context of the project area and District priorities.

## **STEP 2 - Develop an integrated purpose and need statement**

The next step is for the IDT to use the PLTA prescription and field information to create an integrated purpose and need. The purpose and need addresses specific management objectives, with a clear focus on restoration. It might read like the following framework, although it should be more specific about project locations and objectives.

**Example Purpose and Need framework:** The primary purpose and need of this project is to restore landscape-level ecological function and resilience to disturbance and climate change impacts. There is a need to maintain and restore forest structure and species composition, to reduce the risk of uncharacteristically large and severe wildfire, to restore and reconnect wildlife habitats for focal species, and to reduce the impacts of roads on aquatic species and hydrologic systems, to ensure that all of these forest resources are sustainable for the long term. A secondary purpose and need is to make the road network more affordable to maintain, while still providing access for management and recreation. A third purpose and need is to reduce the spread of invasive species, and to restore hydrology and remove conifer encroachment in high alpine meadows.

## **STEP 3 - Develop a proposed action**

The proposed action for a Restoration Strategy project will be based on the PLTA prescription and the purpose and need. The proposed action should include quantified amounts and locations of treatments, including when, where, and how much vegetation thinning, prescribed fire, and/or road work should occur. This will be informed by the goal of moving the landscape pattern toward the restoration objectives and validated through “testing” in EMDS. The proposed action should clearly tie to the purpose and need and state where the Landscape Evaluation informed actions. If actions related to thinning and prescribed fire developed from using EMDS, but actions related to invasive weed control developed from field reconnaissance or other District priorities, this should be clearly stated. It is important to differentiate actions and issues evaluated at the landscape scale versus those not supported with the Landscape Evaluation process.

To avoid the appearance of a “big gulp” Environmental Assessment (EA), it is critical that each part of the proposed action has a clear restoration objective as part of the overarching goal of landscape resilience. It is also important to emphasize the integrated, multiple resource approach of this Strategy. As such, actions that do not contribute to ecological restoration should not be included in the EA, even if they occur within the project area. If the IDT wishes to treat areas outside of the Landscape Evaluation sub-watersheds, the best way to accomplish this is through a separate NEPA document (preferably a Categorical Exclusion). If it would not be possible to treat these areas without completing a separate EA, the IDT, line officer, and Restoration Strategy team should consider the relative merits of including them in the Restoration Strategy EA versus postponing those additional treatments. Another NEPA item to notes is that actions (not mitigations) can be written

into an EA, and signed off on by a line officer, without funding in place to ensure their accomplishment.

#### **Step 4 - Develop prescriptions for individual resources**

In this step, resource specialists develop restoration prescriptions for their individual resources as part of the integrated proposed action. Some creativity may be needed to design prescriptions for each resource that either do not compromise other resources, or demonstrate clearly what trade-offs exist and why the IDT believes these are acceptable. Appendix B gives detailed information on silvicultural treatments in a landscape restoration context. Road treatments may include relocation, reconstruction, storm-proofing (including upsizing of culverts), closure (storage) and decommissioning. Treatments for wildlife habitats may not show immediate improvement, but rather require maintenance over time, and the passage of time itself. For example, development of old forest structure does not occur in a single treatment. Project-level prescriptions are the place to address the treatment of specific wildlife features, such as spotted owl nest sites.

Long-term maintenance of restored sites will likely include light burning, and eventually, allowance of unplanned fire. The current focus is on increasing the area treated, but with a long-term goal of most disturbances being within the range of variability. Maintenance burning may be written into the initial EA. Also keep in mind that the latest guidance for EAs is that, barring issues raised in the public involvement process, only one alternative is needed – no action. If the proposed action is altered to accommodate further analysis or input from collaborators, there is no need to create a separate alternative beyond that of no action.

## PART III: ADAPTIVE ECOSYSTEM MANAGEMENT

Adaptive management is a system of management practices that does three things. First, it clearly identifies desired program outcomes. Second, it requires monitoring to determine if management actions are leading to desired outcomes. Third, if outcomes are not being achieved, it facilitates management changes to ensure outcomes can be met or reevaluated. Adaptive management stems from the recognition that the behavior of natural resource systems is often unpredictable (36 CFR 219.16; FSM 1905). Adaptive management promotes action within uncertainty by essentially testing, learning, and doing simultaneously. Managers develop greater understanding while acting to promote ecological outcomes. Adaptive Management was first developed in the 1970s (Holling 1978). It has been applied to a range of resource and ecosystem management problems throughout North America and elsewhere in the world (e.g. Bouris 1998). Adaptive management is much more than a technical, science-based process. Rather, it is a bold approach to management, which requires creativity, curiosity and a long-term commitment to structured learning (Murray and Marmorek 2003).

Adaptive management is Forest Service guidance at several levels. At the national level, adaptive management is described in the Land Management Planning Handbook (FSH 1909.12 Chapter 20) and as a critical component of the *Forest Service Strategic Framework for Responding to Climate Change* (USFS 2008). At the regional level, the adaptive management process for the Northwest Forest Plan is described in the Record of Decision on pages E12-15. At the forest level, the *Wenatchee National Forest Late Successional Reserve Assessment* includes a chapter (Chapter IX) on monitoring and adaptive management and states, “There is a direct relationship between monitoring and the ability to carry out adaptive management. Information gained by monitoring should help to validate the appropriateness of management actions and provide insights into course corrections should they be needed”. The *2000 Okanogan-Wenatchee National Forest Dry Forest Strategy* (pages 22-24) includes the following statement, “...management approach will be adaptive and experimental; they will learn from mistakes and repeat successes.” More recently, the Revised Northern Spotted Owl Recovery Plan identified the need to take an adaptive management approach in the implementation of the strategy for fire-prone provinces (USFWS 2011). Finally, the forest service manual (FSM 2000, Chapter 2020 Ecological Restoration and Resilience) states that “adaptive management, monitoring, and evaluation are essential to ecological restoration.”

Figure 11 depicts the basic adaptive management process. A number of such depictions exist, but this is simple, complete, and widely applicable. As shown, the process involves establishing objectives, defining outcomes and indicators, developing a strategy, implementing actions, monitoring for outcomes and indicators, evaluating effectiveness, and adapting actions, strategies, and objectives based on monitoring results. This is a process of continuous improvement.

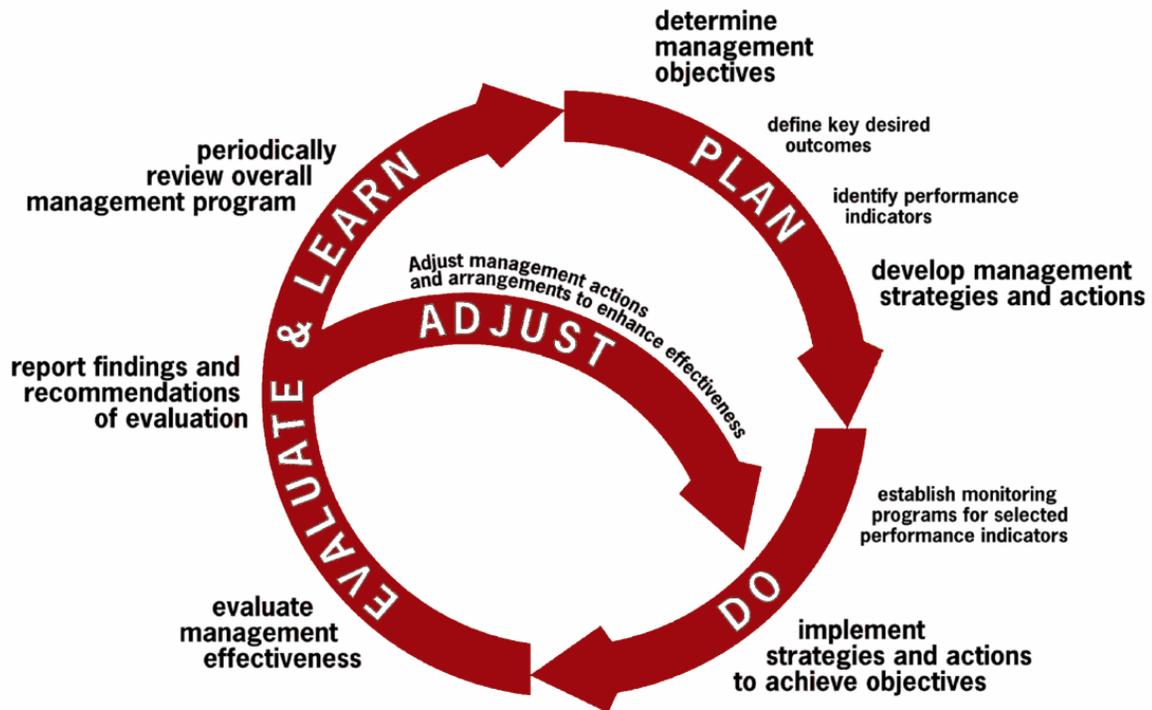


Figure 11. The adaptive management cycle. This depiction was created by [CSIRO Marine and Atmospheric Research](#) based on Walters (1986).

### ***Principles for Adaptive Management on the OWNF***

The OWNF will adaptively manage the Restoration Strategy and its implementation following the principles of Salafsky and Margolius (2001). These principles describe the characteristics of individuals, projects, and organizations that contribute to effective adaptive management.

#### **Principle 1: Do adaptive management at the District level**

The people who design and implement projects should also be involved in monitoring and adaptive management. To accomplish this:

- District IDT members should direct project-level experimentation, monitoring, and adaptive management
- Staff at all levels should learn about the adaptive management process and be involved in changes to the Restoration Strategy and its Monitoring and Adaptive Management Plans

#### **Principle 2: Promote institutional curiosity and innovation**

Effective adaptive management fundamentally requires a sense of inquisitiveness, and a willingness to try new things. To foster institutional curiosity:

- Promote innovation by highlighting changing conditions, and providing flexibility at a variety of levels

- Promote individual curiosity and innovation starting with top managers. Encourage experimentation and networking to develop new ideas

### **Principle 3: Value failures**

Effective adaptive management requires that we value failure instead of fearing it. A willingness to fail indicates that we are pushing ourselves to get better. As an agency, and as individuals, we should:

- Create an environment in which failure is tolerated if the approach was reasonable and creative, and learning and change has occurred
- Analyze negative outcomes to learn from our mistakes, and question positive outcomes to determine if more could be done

### **Principle 4: Expect surprise and capitalize on crisis**

Effective adaptive management requires that a project or organization both expects the unexpected, and is prepared to act quickly during periods of turmoil. Often, strange and surprising results lead to new insights and understanding. Take these opportunities by:

- Using surprises to point to flaws in understanding; incorporate new understanding into new approaches and policies
- Using crises as opportunities for action, redirecting or reorganizing for future creative success

### **Principle 5: Encourage personal growth**

Effective adaptive management requires individuals with a commitment to personal growth and learning. To foster this:

- Encourage employees to be committed to continual learning by providing time to keep up with new science, get training, and network with peers and partners
- Recognize and reward employees who try new things

### **Principle 6: Create learning organizations and partnerships**

Effective adaptive management requires projects and organizations to capture the learning that individuals develop for use in the future. Since many projects are implemented through partnerships, it is also important to ensure that knowledge, skills, and information resources are shared. To promote collaborative learning:

- Work directly with outside partners on the majority of projects. Include these partners in as much of the IDT process as possible
- Build effective teams of project partners by identifying partners with a commitment and ability to contribute, and offering them specific ways to influence processes
- Ask outside organizations to participate in monitoring of projects and adaptive management of strategies

### **Principle 7: Contribute to global learning**

Effective adaptive management requires learning at personal, organizational, and global levels. Practitioners around the world are struggling with similar problems and challenges. Learning from each project should inform policy and management on the OWNF, which

should influence the Forest Service generally, which should help guide the efforts of other natural resource management agencies, and researchers, in the United States and abroad. To accomplish this sharing of information at multiple levels:

- Insist on use of the best available science in all projects and programs
- Encourage interagency networking and information sharing
- Promote and market work in forest restoration, and include OWNF employees involved in restoration to take detail opportunities elsewhere
- Encourage publication of findings related to the Restoration Strategy in peer-reviewed and widely accessible venues

### **Principle 8: Practice the art of adaptive management**

Adaptive management is more than just science; it is also an art. To consistently engage in adaptive management:

- Treat it as a craft; accept that ease and facility with this practice is gained over time
- Pay attention to intuitions; the subconscious mind can often process large amounts of information and uncertainties and arrive at unique conclusions
- Practice and commit to continuous improvement; accept inspiration from all sectors and engage in creative and collaborative exploration

### ***Challenges in implementing Adaptive Management***

Clearly, there is ample direction, and benefit, to using an adaptive approach to ecosystem restoration. Yet, real and perceived barriers to implementing such an approach remain. Allen and Gunderson (2011) describe nine “pathologies” in the implementation of adaptive management, including:

1. lack of stakeholder engagement
2. difficulty experimenting over large spatial and temporal scales and within complex institutions
3. suppressing, rather than learning from surprises
4. following a strict formula, rather than optimizing learning opportunities
5. procrastinating on action in favor of excessive learning and discussion
6. failing to use learning to modify policy and management
7. avoiding hard truths and being unable to take risks
8. lacking leadership and direction in the process
9. focusing on planning, rather than action

To avoid facing these pathologies, the OWNF has committed to the adaptive management plan described in the next section, which uses the nine principles for success adapted from Salafsky and Margolius (2001).

To address the nine pathologies above, the Forest Restoration Strategy (FRS) Team proposes the following:

## **Stakeholder engagement**

The FRS Team has engaged stakeholders (both internal to the OWNF and to the Forest Service), external partners, and the public in a variety of ways. For internal OWNF engagement, the FRS Team sought review of the initial Restoration Strategy by at least one representative of each Ranger District across the Forest. The FRS Team made changes to the first version of this document based on that review. Second, the FRS Team has repeatedly visited each Ranger District on the Forest to answer questions, resolve issues, and develop a path to implementation of this Restoration Strategy. Third, each District to complete a Landscape Evaluation has participated in an After Action Review to provide feedback on changing the Restoration Strategy and its implementation. Fourth, the Forest Supervisor chartered an official Restoration Strategy Coordination Team, including key players from each resource discipline, to address issues and make changes to the Restoration Strategy. Finally, the FRS Team has developed a number of communications materials, including PowerPoint presentations, graphics, a SharePoint site, and process overview documents, to help OWNF internal stakeholders understand the Restoration Strategy and its implementation.

To involve Forest Service stakeholders outside the OWNF, the FRS Team developed: a congressional briefing document; a field visit, presentation, and documents for the Regional Forester; and an internal website. To engage collaborators and the public, the FRS Team: developed a video and had partners post it on their websites; developed a set of pages on the external website about the Restoration Strategy; and worked closely with The Nature Conservancy, the Tapash Collaborative, the Chumstick Coalition, the Provincial Advisory Committee, nonprofit organizations, and regulatory agencies to review, update, and change the implementation of the Restoration Strategy.

The OWNF is committed to continuing ongoing stakeholder engagement with many aspects of the Restoration Strategy. The FRS Team is currently working with partners to develop a Monitoring Plan, to improve future range of variability estimates, and to improve integration of road and aquatic considerations (see Appendix C). The OWNF will rely heavily on partners to assist in two ways with implementation of the Restoration Strategy. First, a number of restoration treatments may not be affordable given current Forest budgets and constraints. Partners with an interest in accomplishing certain treatments may be able to help fund them, once a NEPA decision is in place. Second, monitoring is a key feature of Adaptive Management and is crucial to understanding the outcomes of the Restoration Strategy and successfully modifying it. However, nothing beyond basic implementation monitoring and required surveys for certain resources, is currently funded within the Forest budget. Collaboration will be the key to accomplishing programmatic effectiveness monitoring for ecological outcomes. The OWNF may need to rely heavily on partners and volunteers to complete needed surveys as part of a collaboratively designed monitoring plan.

## **Experimentation**

The Restoration Strategy is designed to address the challenges of spatial and temporal scale. The large (4 million acre) size of the OWNF also helps to address the issue of spatial

scale. The OWNF also has adjacent state- and tribally-managed forest lands. Thus, a lot may be learned from the range of ecosystems and the vast size of the overall landscape. The ecological modeling in EMDS, the core feature of the Restoration Strategy, enables planning and, to some extent, outcome verification, over large areas. Addressing large temporal scales is more challenging. By incorporating future range of variability and late successional old forest scripts, the FRS Team has begun to address this challenge.

In addition, aspects of the Restoration Strategy will be integrated into (though not directly referenced by) the revised Forest Plan (Land and Resource Management Plan or LRMP). A Forest Plan is generally followed for at least 15 years and includes a framework for monitoring. This should help the Restoration Strategy to be implemented, investigated, and adapted. An identified need exists to design specific research experiments to understand treatments in LSOF and in riparian areas. The FRS Team will develop this and other research as it drafts a monitoring plan.

## **Optimizing learning and learning from surprises**

### **Employee education**

To optimize learning by individuals, there are several employee education needs. It is important to cultivate a number of individuals at each Ranger District with skills in photo interpretation and GIS, and a strong understanding of landscape ecology and ecological modeling. To develop these skills, the OWNF will host regular internal training workshops and bring in guest speakers and instructors whenever possible. Recent examples of this include two internal photo interpretation workshops in October 2011 and the presentation by Gordon Reeves on NetMap in July 2010.

### **Restructure around restoration**

As of January 2012, dozens of positions are vacant across the Forest, and more retirements are being encouraged as part of agency budget cuts. The Forest Leadership Team has not decided how to fill these vacancies, but the FRS Team has suggested a strategic look at the positions to ensure that restoration is fully immersed in the changing culture of the OWNF. The FRS Team believes that this “crisis” of employee retirements can be recast as an opportunity to put restoration at the heart of OWNF operations. If this were to occur, restoration would become more of a focus of a variety of employees’ daily work. As such, employees would be able to give more attention to identifying and capitalizing on learning opportunities, and responding to surprises in an adaptive fashion.

### **Information needs**

The Restoration Strategy has several outstanding information needs, including: better data on a variety of resources, an improved understanding of the historical range of variability, and high quality aerial photos and stand exams forest-wide. Investing in fulfilling some of these information needs should help to spur additional learning from, and adaptation of, the Restoration Strategy. It is easier to sort signal from noise if there is greater certainty with the initial data inputs. That said, dollars and employee hours are extremely limited on the OWNF. Therefore, we should maximize the use of tools that allow us to model our current conceptions, and then input additional data as it is available. In keeping with the spirit of

the next section (committing to action), it is important to prioritize implementation of the Restoration Strategy, even if certain information needs continue to go unmet.

### **Working with scientists**

The OWNF enjoys close relationships with a variety of scientists and researchers. The OWNF also has a number of employees with advanced degrees, and/or experience with conducting and publishing peer-reviewed research. Maintaining close ties with research and researchers should help to encourage adaptive management and optimize learning from the Restoration Strategy. One recent example is implementation of a research study into the effects of silvicultural restoration treatments in the Upper Swauk sub-watershed (Cle Elum Ranger District) on the prey base for spotted owls by John Lehmkuhl of the Wenatchee Forestry Sciences Lab. Findings from this study should inform future Restoration Strategy project prescriptions for silviculture and wildlife.

### **Committing to action**

To avoid the pitfall of endless planning, the OWNF should prioritize implementation of the Restoration Strategy on all seven Ranger Districts. The FRS Team can make some immediate and ongoing changes to the Restoration Strategy, its implementation, and the data behind it. However, these changes should not jeopardize or delay the actual initiation of a first round of Landscape Evaluations and restoration treatments. This is important for a few reasons. First, the OWNF has a goal of doubling the amount of restoration work done by 2020. Second, there is often more to be learned from implementation and monitoring than from untested improvements. Third, encouraging all Districts to participate in the process develops skills, and commitment to the Strategy, which should help this change to become permanent. The purpose of adaptive management is to enable action in the face of uncertainty, and to learn from any outcome to foster continuous improvement.

### **Modifying policy**

#### **Budget and performance metrics**

There is substantial high-level policy support for ecological restoration, climate change adaptation, and the use of adaptive management (See Part I). Yet, some conflicts exist between implementing the Restoration Strategy and some higher-level policy and guidance. First, Forest Service budget codes and performance metrics often do not align with the objective of ecological restoration. Goal 1 of the Forest Service Strategic Plan for Fiscal Years 2007-2012 is “Restore, sustain, and enhance the nation’s forests and grasslands” (USFS 2006b). However, the budget and performance metrics associated with this goal are typically board feet produced and acres burned. These metrics may be achieved in service of ecological restoration, but they may simply be met in the easiest locations.

Second, budgets for planning and for road decommissioning are small and declining. The agency is working on several fronts to remedy these issues, including deploying an Integrated Resource Restoration budget, the Collaborative Forest Landscape Restoration Program, stewardship contracting, and funding for Watershed Action Plans. The OWNF is

committed to making planning more efficient through the Restoration Strategy so that acres treated are the most ecologically important.

An additional long-range budget issue is the need for restoration work to “pay its own way.” Until the timber market improves, and a market for biomass is established, many restoration-related silvicultural goals are uneconomical. Although wildlife and aquatic habitat improvements are funded to an extent, the major source of funding for the Forest Service is the timber and fire budget. With the timber budget contingent upon economical sales, some restoration objectives may not be achieved.

### **Forest Plan integration**

A Forest Plan may not prescribe an additional planning or analysis process. However, the FRS Team and the Forest Plan Revision Team are working closely together to ensure that the principles of the Restoration Strategy are reflected in the new Forest Plan. As the Forest Plan Revision evolves, it may also guide changes to the Restoration Strategy. The two plans are based on much of the same data and science (though the Forest Plan is much broader in scope). With restoration tenets embedded in the general guidance for the OWNF, it will be further supported as an element of local guidance.

### **The Endangered Species Act and National Environmental Policy Act**

Some environmental regulations, including the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA) can make environmental management for resilience more challenging (Benson and Garmestani 2011). These regulations are relatively inflexible in their requirements, and thus make rapid adaptations to monitoring results somewhat difficult. Allen and Gunderson (2011) suggest that adaptive management is not appropriate in many cases of endangered species management. If managing an endangered species involves both high risk and high uncertainty, Allen and Gunderson (2011) recommend scenario planning, instead. They suggest the use of adaptive management only in less risky situations. The FRS Team does not believe that restoration treatments pose a significant risk to threatened, endangered, or sensitive species, and thus recommends adaptive management of all aspects of the Restoration Strategy.

The Shipley Group (2010) provides some guidance for using adaptive management in the NEPA context. Their suggestions include: selecting an appropriate adaptive management model (a blend of research and programmatic in the case of the Restoration Strategy); making a commitment to monitoring; designing a monitoring plan to address implementation, effectiveness, and validation; being explicit about contingencies and thresholds and writing these into NEPA documents; and increasing stakeholder involvement at all stages of the process. The adaptive management plan outlined in the next section borrows strongly from the Shipley Group’s recommendations.

### **Leadership and risk taking**

Allen and Gunderson (2011) suggest a few things about leadership. First, stakeholders should not be in decision-making roles. External stakeholders are involved in collaboration and planning but are not involved in decision-making in the Restoration Strategy. Second, strong and beneficent leadership is critical. The OWNF Forest Supervisor and Deputy Forest Supervisor are both strong supporters of the Restoration

Strategy and its adaptive management. Third, Allen and Gunderson (2011) suggest a strong facilitator should be a feature of all engagements with stakeholders. The FRS Team currently interacts directly with a variety of stakeholder groups. However, it may be useful in future engagements with stakeholders to have a designated facilitator on hand.

Allen and Gunderson (2011) also call out the need for some risk-taking in adaptive management. They suggest that making small changes has marginal value and does not achieve the promise of an adaptive approach (achieving lofty, important goals in uncertain contexts). Some examples of potentially large changes that may be suggested by adaptive management of the Restoration Strategy include: different inputs to fire suppression decision-making; different management of threatened, endangered and sensitive species; or new ways of managing road networks. Making such large changes will require courage and clear data from a well-designed monitoring plan.

## ***An Adaptive Management Plan for the Restoration Strategy***

### **Goal and objectives**

The ultimate goal of the Restoration Strategy is in our vision statement on page 1, “forest resources will become more resilient to disturbances and climate change impacts.” The other elements of the vision on page 1 are essentially mission (work collaboratively and strategically across landscapes to double our restoration footprint within the next 10 years) and strategy (focus on desired restoration outcomes and measurable successes; continue to adapt based on new science, changing conditions, and monitoring data) statements. Social and economic objectives are included in the following outline. However, affecting large-scale changes in socio-economic conditions is not the main focus of this Restoration Strategy.

The OWNF would like to promote social satisfaction and economic prosperity, but this is not the main focus of the Restoration Strategy. For example, the creation of a viable market for biomass would have benefits including low-cost energy for local communities, mitigation of climate change, and an enhanced ability to fund many restoration treatments. The OWNF is currently working with the Tapash Collaborative, the Chelan County Biomass Working Group, and others on the goal of creating a biomass market. This and other socio-economic achievements are related to, and affected indirectly by, the Restoration Strategy. However, the focus here is on ecological objectives and the few social and economic outcomes that help to achieve them.

Objectives of the Restoration Strategy help us understand if we are moving toward that goal. To promote understanding of each of the following objectives, they are parsed in several ways: short- versus long-term, ecological versus socio-economic, and outcomes versus outputs. Outputs are completed products, e.g. acres treated. Outcomes are results. In the short-term, these suggest progress toward objectives. In the long-term, they suggest objectives are being met. The following is an outline of Forest-wide Restoration Strategy objectives, accounting for climate change.

1. Long-term outcomes

- 1.1. Ecological

- 1.1.1. Landscape patterns limit most terrestrial disturbances in scope and severity
- 1.1.2. Most aquatic disturbances do not cause major damage to roads because hydrological systems are mostly intact and decoupled from the road system
- 1.1.3. Aquatic species populations are stable and can withstand aquatic disturbance events
- 1.1.4. Most waterways have sediment levels within the range of variability
- 1.1.5. The landscape fire regime is within the range of variability
- 1.1.6. Fuels build-up has generally been reduced by restoration treatments and limited fire suppression over time
- 1.1.7. Vegetation patterns are within the range of variability
- 1.1.8. Insect and disease outbreaks are limited in size and severity
- 1.1.9. Wildlife habitat is sufficient and appropriately arranged on the landscape
- 1.1.10. Wildlife populations are stable
- 1.1.11. Road networks have limited impacts on waterways, fish, and wildlife
- 1.1.12. Invasive species dominance and spread is limited
- 1.2. Social and economic
  - 1.2.1. Number of similar strategies adopted
  - 1.2.2. Number of collaborators and amount of time invested
  - 1.2.3. Consultation process for Restoration Strategy projects is smooth, with no findings of jeopardy
  - 1.2.4. NEPA documents for Restoration Strategy projects are not appealed or litigated
  - 1.2.5. NEPA documents are completed in the expected timeframe
  - 1.2.6. The Restoration Strategy is not a financial burden to the OWNF
  - 1.2.7. The size of the road network aligns with the road maintenance budget
  - 1.2.8. Road networks provide sufficient access for management and recreation
- 2. Short-term outcomes
  - 2.1. Ecological
    - 2.1.1. Increased acreage of potential habitat for focal species
    - 2.1.2. Improvement in modeled arrangement of wildlife habitats
    - 2.1.3. Reduction in streams' sediment loads in restored areas
    - 2.1.4. Improvement in hydrology in restored areas
    - 2.1.5. Preservation of large and old trees and improved spatial patterns in restored areas
    - 2.1.6. Improved forest structure and pattern in restored areas
    - 2.1.7. Reduction in modeled risk of catastrophic fire in restored areas
    - 2.1.8. Reduction in modeled risk of insect outbreak in restored areas
  - 2.2. Social and economic

- 2.2.1. All seven Ranger Districts have implemented one or more Restoration Strategy projects
- 2.2.2. District employees are able to implement and communicate about the Restoration Strategy with limited support from the Supervisor's Office
- 2.2.3. OWNF employees generally understand and support the Restoration Strategy and integrate it with their programs of work
- 2.2.4. The Restoration Strategy garners financial support through grants and collaborators

### 3. Outputs

- 3.1.1. Acres of forest treated
- 3.1.2. Stream length improved
- 3.1.3. Acres of wildlife habitat improved
- 3.1.4. Miles of road improved, closed, or decommissioned
- 3.1.5. Number of environmental assessments completed
- 3.1.6. Number of stewardship contracts awarded
- 3.1.7. Number of partner hours invested
- 3.1.8. Grant dollars leveraged
- 3.1.9. Bi-annual iterations and ongoing improvements to the Restoration Strategy

## Indicators and performance measures

The following description of potential indicators, or measures of Restoration Strategy success, ties to the long-term outcomes described in the previous section. Each numbered indicator below (e.g. 1.1.2) is a measure of the long-term outcome with the same number. In some cases, multiple indicators may be used as measures, or proxies for measuring, outcomes. This list is by no means exhaustive or supported with existing data or data collection efforts. Short-term outcomes and outputs should be relatively easy to measure and understand. The FRS Team has discussed the formulation of a “decoder ring,” which would help to translate simple outputs, like board feet of timber, into more meaningful outputs, like restoration acres. This is further described in Appendix C.

Indicators of short-term outcomes and outputs should be part of the monitoring plan, with a description of current data, its quality, and any additional data needs or gaps in knowledge. In the process of developing the monitoring plan, the FRS Team and collaborators will need to consider available data, time, and funding to determine appropriate and useful indicators. Resource specialists will need to review and update these as the monitoring plan evolves and new data becomes available. Collaborators should be involved in the development of indicators, monitoring protocols, and monitoring activities. Hatry (2006) gives tips for measuring performance, including: focus on the critical few results that matter; keep it simple; link it to decisions; involve stakeholders and report results widely; data are a necessary expense; and success is not instant, but don't give up on measurement.

A final caution is Campbell's Law: “The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social pressures it is intended to monitor” (Cook and Campbell 1976). Hatry (2006) suggests a few ways to avoid this trap. First, it is important

not to extrapolate beyond the power of any performance measure. Second, examine indicators and measures in context, using breakouts and benchmarks, and considering a variety of explanations for any figure. Third, hold people accountable for efforts and outcomes, and not for any one measure or indicator.

## 1. Indicators of long-term outcomes

### 1.1. Ecological indicators

- 1.1.1. Terrestrial disturbances generally do not require management intervention
- 1.1.2. ERFO requests related to funding are limited in number and dollar amount
- 1.1.3. Surveys of aquatic species indicate population numbers are sufficient and do not fluctuate drastically outside of the expected range
- 1.1.4. Most waterways meet standards for limited sediment
- 1.1.5. Large-scale fire suppression efforts are rarely needed
- 1.1.6. Stand-level fuels maintenance is irregular and inexpensive
- 1.1.7. Most vegetation maintenance is for economic, and not restoration purposes, as natural disturbances largely address vegetation pattern objectives
- 1.1.8. Insect and disease outbreaks rarely require management intervention
- 1.1.9. Field verified wildlife habitat meets recommendations for amount and arrangement
- 1.1.10. Surveys of terrestrial species indicate population numbers are sufficient and do not fluctuate drastically outside of the expected range
- 1.1.11. Wildlife habitat shows limited fragmentation and spawning success is at expected levels
- 1.1.12. Surveys of invasive species indicate that their spread is limited. Surveys of native organisms are stable and ecological patterns and processes are intact and functional

### 1.2. Social and economic indicators

- 1.2.1. Similar restoration strategies are adopted throughout the East Cascades
- 1.2.2. Numerous collaborators are involved in the implementation and updating of the Restoration Strategy
- 1.2.3. Regulatory agencies approve of Restoration Strategy projects
- 1.2.4. The public understands and approves of Restoration Strategy projects
- 1.2.5. The NEPA process for Restoration Strategy projects is efficient
- 1.2.6. Resource programs implementing the Restoration Strategy do so within their programmed budgets and personnel hours
- 1.2.7. Needed road maintenance occurs each year without deficit spending
- 1.2.8. Management activities occur efficiently and recreation users are generally satisfied

## **Actions, cause-effect models, thresholds and contingencies**

The Shipley Group (2010) suggests that prior to developing a monitoring plan, a general list of potential project actions is helpful. For the Restoration Strategy, this list would include things like closing road segments, spring prescribed burning, or mechanical thinning. These actions should be specific, and large actions should be broken down into component parts where effects may be measured. Based on these actions, the FRS Team should develop cause-effect chains that are transparent and understood by stakeholders. These cause-effect chains can help to improve modeling efforts if they are well-calibrated and validated. Such modeling should be able to estimate changes over time, reflect changes to key measures, and incorporate changes outside of management control.

Another Shipley Group (2010) suggestion is that thresholds and contingencies should be built into programs, as well as NEPA documents. If there are threshold measures that would trigger immediate changes in management actions, these should be spelled out at both the program and project levels. Contingency plans may be built into the Restoration Strategy program, and into any specific NEPA projects. These may be analyzed as part of the NEPA process. By establishing thresholds and contingencies ahead of time, and clearly defining and analyzing these in a NEPA document, adaptive management may occur promptly without the need to go through a second planning cycle before implementing changes. If rates of implementation or coordination processes may affect actions, the effects of these should also be clearly spelled out.

### ***Monitoring plan***

A monitoring plan should be drafted by the FRS Team, other OWNF employees, and collaborators as soon as possible. It should address implementation, effectiveness, and validation monitoring. DeLuca *et al.* (2010) call out the dire need for monitoring of restoration projects and suggest that it can occur in spite of limited budgets through a combination of: (1) multiparty teams of volunteers on most restored sites; (2) a statistical sampling strategy for more intensive monitoring on some sites; (3) remote sensing of a select set of variables over a broader affected landscape. Moir and Block (2001) further assert the need for monitoring programs to address longer temporal scales and suggest public involvement in the monitoring process. Ringold *et al.* (1996) suggest that the monitoring process itself should be adaptive. They propose monitoring plans that include: (1) refinement and specification of qualitative objectives; (2) use of consistent, harmonized and available methods; and (3) clear priorities for obtaining data at relevant scales.

### **Implementation monitoring**

Implementation monitoring evaluates whether projects were implemented as intended. It helps to understand if outputs, and some short-term outcomes, were achieved. Hot Box 5 suggests some general implementation monitoring questions. Resource specialists will need to design specific monitoring protocols to address these questions and more. Monitoring protocols should be based on local conditions, the landscape context, project actions, research questions, and stakeholder interests.

## **HOT BOX 5**

### **Some Implementation Questions for Restoration Strategy Projects**

- Were large and/or old trees and snags protected?
- Was the desired within-stand spatial variability achieved?
- Did project treatments move stands toward achieving desired landscape patterns? Is the modeled landscape vegetation departure reduced as a result of the project?
- Were fuels and the risk of landscape fire reduced?
- Was insect risk reduced and were existing insect infestations addressed in a landscape context?
- Did the project improve hydrological function and enhance wildlife habitat?
- Was the road network improved or reduced as a result of the project?

### **Effectiveness and validation monitoring**

Effectiveness monitoring helps to understand whether outputs, and achievement of short-term outcomes, are helping to progress toward desired long-term outcomes. Validation monitoring addresses key assumptions and uncertainties, often by implementing a research program and regularly publishing results. Effectiveness and validation monitoring are more intense and typically more expensive than implementation monitoring. They will require partners' support to design and implement. This will require a base level of funding so that OWNF employees can work with partners, develop funding proposals, and collect data. Some suggestions for implementing effectiveness monitoring on the OWNF are:

- Use the area ecology program as a source of funds and a program that can provide expertise on monitoring study design and implementation. For this to happen, the area ecology team will need to coordinate with the OWNF Forest Supervisor, Colville Forest Supervisor, key forest staff, and Regional Office staff to re-orient the program, develop a charter, and identify key personnel and responsibilities.
- Some of the responsibilities of the personnel involved in the area ecology program should include developing and maintaining partnerships with universities, other resource agencies, NGOs, and Forest Service research labs. These partnerships will be vital to obtaining the needed funding and quality of monitoring. In addition, some important resource information needed for the landscape and project level assessments would be developed and kept up-to-date by this group.
- Maintain regular meetings between Forest personnel and the Wenatchee Forestry Sciences Lab. These meetings provide opportunities to hear what is happening with the latest monitoring and research, and to identify future needs and collaboration.
- Present frequent formal results to the Provincial Advisory Committee.

The monitoring plan that the FRS Team develops should address validation monitoring for a few key topics. First, there is a need to validate the models of the historical and future ranges of variability through time, focused research, and evaluation of outcomes. Second, the FRS Team is interested in the effects of treatments in riparian areas and near and/or in

owl habitats. Third, there is a need to develop models of road impacts on wildlife and aquatics and evaluate the effects of road treatments on wildlife and aquatic habitats. Finally, there is a broader question of how resilience may be achieved given climate change impacts. Are there resources that may not be sustained on the future landscapes of the OWNF? How much restoration is “enough” to allow sufficient landscape resilience and to prevent a fundamental change in forest ecosystems in the East Cascades? How will invasive species impact resilience on these landscapes and what should be done to prevent, remove, and/or accommodate them to accomplish the goal of resilience?

**HOT BOX 6**  
**Some Effectiveness and Validation questions for  
the Restoration Strategy**

- Have strategically placed restoration treatments reduced severe fire and sustained other resource values?
- Has the strategy of active restoration for potential and future habitat contributed to northern spotted owl recovery objectives?
- Have restoration treatments effectively provided source habitats for focal wildlife species such as the white-headed woodpecker?
- How have prescribed fire treatments affected the mortality of large and old trees?
- Have restoration treatments retained and recruited snags and downed wood?
- Have road restoration treatments reduced sediment delivery to streams?

***Working with collaborators on monitoring and adaptive management***

To work effectively with collaborators on monitoring and adaptive management, it is important to obtain concurrence on Restoration Strategy goals, adaptive management objectives, and monitoring activities. It is also important that collaborators have an up-front and long-term commitment to monitoring. They should be involved in review of data, and in adaptations to the Restoration Strategy and its implementation (Shiple Group 2010). Much research has evaluated collaborative environmental groups to determine success factors. One recent study found that presence of a neutral facilitator, participants’ feelings of ownership, authority to act, and early-stage group successes were significantly correlated with implementation success at the group level (Belton and Jackson-Smith 2010).

***Implementing this adaptive management plan***

The OWNF should create a culture that enables an adaptive approach to ecosystem restoration. Some suggestions for enabling that cultural shift include:

- Be effective, efficient, and strategic in planning and implementing quality restoration projects. Project teams should be evaluated based on performance, and held accountable by the FLT while funded work is completed. Project teams should be supported by the FLT and their staff. Actions and decisions should be judged by how they help meet ecosystem management goals and objectives.

- Develop and implement restoration projects that are consistent with the best available science. This requires that personnel stay current with new scientific information and collaborate often with research personnel.
- Ensure collaboration with partners, with the public, and among resource experts on teams. Strive to balance social, economic, and ecological issues to sustain and manage natural resources for the long term.
- Devote one Forest Leadership Team (FLT) meeting per year to learning about the results of implementation, effectiveness, and validation monitoring, and making decisions that adapt restoration project planning and implementation as needed.
- Change the existing Forest fuels review process into an integrated review process for forest restoration projects.
- Conduct an After Action Review at each District after a decision is signed on its first Restoration Strategy NEPA document.
- Continue to involve all resource disciplines in the Restoration Strategy Coordination Team and ensure that all affected employees are familiar with the Restoration Strategy, its objectives, and adaptations made and in progress.
- Continue to integrate the Restoration Strategy with other large-scale planning efforts, including the Forest Plan revision, Watershed Condition Framework, Terrestrial Condition Framework, and progress on the Climate Change Performance Scorecard.
- Continue to develop Restoration Strategy communications products and opportunities for all levels of the agency, potential partners, employees, and the public. This should generate increased attention, involvement, and impetus for adaptive management.

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## APPENDIX A - Considerations for implementing forest restoration within land allocations

1. **Roadless area inventories** – Roadless areas pose limits on the kinds of treatments that can be implemented. By intersecting the fire modeling results with the roadless area inventory, the location of strategic restoration treatment areas can be identified and treatment options that do not require road construction can be discussed by the interdisciplinary team to determine their feasibility.
2. **Late-successional reserves, managed late-successional areas, and critical habitat units (LSR, MLSA, CHU)** – These areas are likely to change due to the revised spotted owl recovery plan through the revision of the Okanogan-Wenatchee National Forest Plan. However, this is likely a couple years off. In the interim it is imperative that LSR, MLSA, and CHU be evaluated as part of the landscape within dry forests where treatments are needed to restore forests and reduce the risk of fire flow across the landscape. These restoration treatments should: 1) be supported by the Landscape Evaluations; 2) be implemented in strategic locations where a Landscape Evaluation shows they are necessary to reduce landscape fire risk to old forest habitats; 3) be designed to emphasize old-forest-associated species, such as the white-headed woodpecker, flammulated owl, and pygmy nuthatch, where treatments are identified; and 4) consider the sustainability of existing and future habitat for the northern spotted owl and associated late-successional species.
3. **Matrix, General Forest** – Historically, the emphasis for general forest and matrix was on timber production, maximized for the former and programmed for the latter. However, traditionally implemented production forestry is generally inconsistent with fire, endangered species, and restoration objectives. Consequently, these areas are now considered with the rest of the landscape and any treatments that are proposed are guided by restoration principles.
4. **Riparian Reserves/Riparian Habitat Conservation Areas (RRs, RHCAs)** – Riparian and upslope forests have significant continuity in disturbance events, especially overstory fire severity (Everett et al. 2003), thus making it important that the management of riparian forests take into consideration the types of disturbance that typically affect these areas (Agee 1988). Treatments within RR/RHCAs are appropriate when they help restore the mosaic of conditions expected to occur in the riparian zone at a watershed scale. Any treatment proposed should maintain understory processes, improve riparian conditions long term, and avoid headwalls entirely. Restoration treatments should promote maintenance or restoration of primary constituent elements of critical habitat for aquatic species.
5. **Deer and Elk Winter Range** – Previously, the retention or creation of winter thermal cover was deemed the most important habitat variable for winter survival of deer and elk. However, studies have shown that thermal cover is not as critical as

other factors such as forage quality and quantity, and human disturbance (Cook et al. 1996, 1998). The forest plan for the Okanogan National Forest identifies explicit standards for the amount of thermal (snow intercept and winter) cover of 30-40 percent on deer winter range. However, the plan states that where natural forest vegetation is not present to support optimal cover amounts, we should manage existing vegetation to approach cover objectives on a sustained basis (MA5-6B).

The Wenatchee National Forest Land and Resource Management Plan relies on a Habitat Effectiveness Index that considers road density, thermal cover, and forage (Thomas et al. 1986). By emphasizing the reduction of road density and enhancement of forage, thermal cover can be reduced and still meet forest plan standards for deer and elk winter ranges. In this manner, the potential conflict between restoring forests and not meeting the winter range thermal cover standards can be resolved.

6. **Key Watershed Direction for portions of the Forest contained within the area of the Northwest Forest Plan** -- No new road construction should occur in identified roadless areas. Road density outside of roadless areas should be reduced. If funding to reduce road density is not available, there should be no net increase in road miles within key watersheds.

## APPENDIX B - Silvicultural Considerations for Restoration Treatments

### ***Key ecological features for silvicultural restoration prescriptions***

Four key ecological features should be included in prescription development: snags, spatial patterning, old and large trees, and density of young and understory trees.

#### ***Snags***

DecAID (Mellen-McLean et al. 2009) was used to update snag management recommendations for dry and mesic forests. Estimates (histograms) of the range of variation of snag densities and distributions were developed using two sources of information: Harrod et al. (1998) and inventory data for unharvested plots (including plots with no measurable snags) available in DecAID. For the analysis, a single distribution histogram was developed by calculating weighted averages by structural stages. These estimates were used to develop desired reference conditions for snag density and distribution by size classes (*Table 5*).

**Table 6. Desired snag distribution reference conditions for dry and mesic forests by small and large size classes**

Snag Size Class	Percent and number/acre of dry forest landscape in snag density classes				
	0-4	4-12	12-20	20-28	>28
>10 in. dbh	82.2	13.7	2.1	1.4	0.4
Snag Size Class	Snags/acre by tolerance level (TL) <sup>1</sup>				
	30% TL		50% TL		80% TL
10-20 in. dbh	3.4		5.0		6.8
>20 in. dbh	1.4		1.8		2.1
Snag Size Class	Percent and number/acre of mesic forest Landscape in Snag Density Classes				
	0-6	6-18	18-30	30-42	>42
>10 in. dbh	70.0	18.0	4.7	4.1	2.8
Snag Size Class	Snags/Acre by Tolerance Level (TL) <sup>1</sup>				
	30% TL		50% TL		80% TL
10-20 in. dbh	3.8		8.3		39.2
>20 in. dbh	1.2		4.6		10.7

<sup>1</sup>See Mellen-McLean et al. (2009) for a discussion of tolerance levels

#### ***Spatial Pattern***

The spatial pattern of trees is a product of ecological interactions among site, vegetation, climate, disturbance, and chance (see the summary of spatial patterning in the Forest

Ecology section of Part I). Different forest types have within-stand spatial patterns that are characteristic of their disturbance and mortality processes. Restoring and maintaining this characteristic heterogeneity is an essential element of the Forest Restoration Strategy. Incorporating the following information into silvicultural prescriptions should result in more ecologically meaningful pattern:

- Recent evaluations of historical stand conditions have provided visual and quantitative descriptions of characteristic spatial pattern (Arno 1995 and 1997, Harrod et al. 1999, Youngblood et al. 2004, Larson and Churchill 2008).
- Several investigators indicate that canopy gaps and clumps have a negative exponential, or reverse-J, distribution (e.g., several small and few large) at multiple scales, including at the stand level (Hessburg and Povak, unpublished data, Franklin pers. comm.).
- Churchill (unpublished paper on file at Okanogan-Wenatchee NF) has developed a method for determining site-specific reference conditions for spatial pattern and applying them to operational silvicultural prescriptions and tree marking guides. More traditional relative-density methods can be used to complement this approach.
- Historical disturbance regimes and stand development processes created a range of spatial patterns at the stand scale. It is as important to restore a range of patterns across different stands as it is to create heterogeneity within stands. The specific conditions in each stand, particularly the existing old trees, and information from historical structure and spatial pattern, can be used to determine appropriate pattern for individual stands. Almost all reconstructions of historical stand structure have found clumped spatial patterns (Agee 1993, Sanchez Meador et al. 2009, Harrod et al. 1999, Youngblood et al. 2004).

Silvicultural prescriptions should address the following three components of horizontal pattern (*Figure 12*):

### **1. Clumpiness:**

A clump is defined as two or more trees in close enough proximity that their crowns are interlocking (Long and Smith 2000).

Clump sizes should range from about 0.01 acres to 0.5 acres (Harrod et al. 1999).

There should be a range of clump densities across a stand. Retaining some clumps of extremely high density is important for sustaining ecological processes. For example, reconstruction of reference stands near Rimrock Lake on the Naches Ranger District indicated the stand density index (SDI) was as high as 700 and 1200 at the 0.01 and 0.05 acre plot size, respectively (Unpublished data on file at Okanogan-Wenatchee NF). The basal areas of clumps can range as high as 650 to 1800 ft<sup>2</sup> per acre, based on stand reconstructions for ponderosa pine and Douglas-fir (Graham et al. 2007, Sherlock 2007). These levels indicate that clumps of ponderosa pine within a stand can tolerate drought

stress and bark beetles at densities much higher than the stand average thresholds often given for bark beetles (e.g., 230 SDI – Oliver and Uzoch 1997; 180 SDI – Cochran et al. 1994). Clumps of large and/or old dwarf mistletoe infected trees, especially Douglas-fir or larch, can be used to create structures that function as wildlife habitat and that will succeed to snag habitat as a function of the disease, or by fire mortality.

It is often useful to retain as much as 10-15 percent of a stand as unthinned clumps for general or specific ecological purposes (Franklin pers. comm.). These should be located strategically in order to be ecologically effective.

## 2. Canopy gaps:

Canopy gaps should range in size depending on fire regime (*Table 6*) and have a negative exponential size class distribution. Up to a third of the stand could exist as canopy gaps (Harrod et al. 1999).

Retaining occasional trees within gaps will reflect the complex recruitment and mortality processes that affect gaps.

Canopy gaps can be used to maintain diseases within their reference conditions (as informed by the Landscape Evaluation). For example, they can be used to isolate dwarf mistletoe infected trees that are retained for their age or the ecological function they provide.

**Table 7. Gap sizes by fire regime**

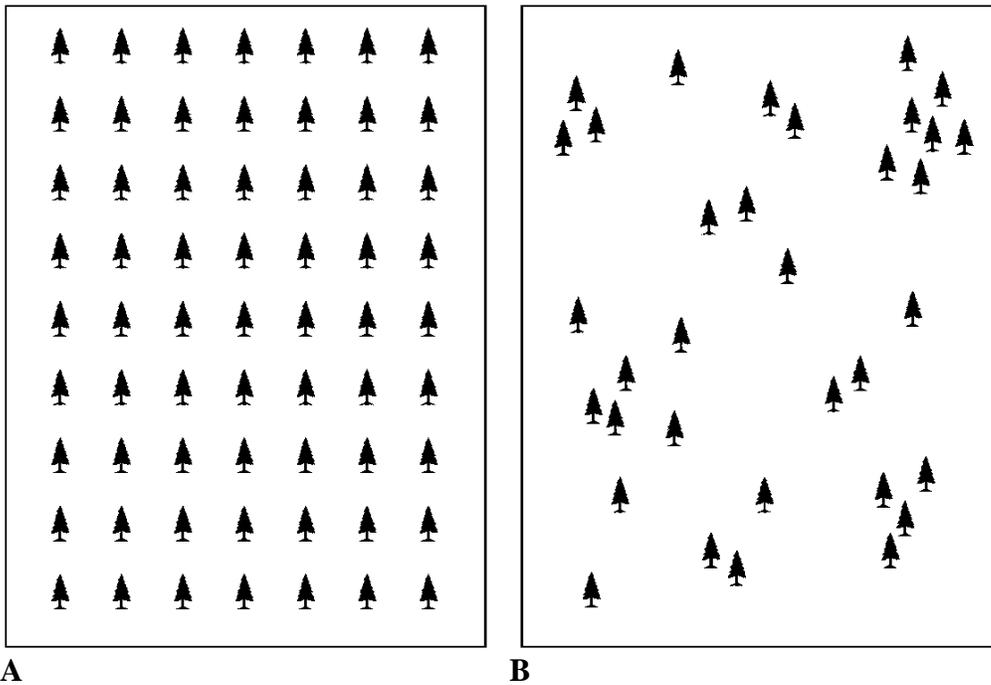
Fire Regime	Gap description	Author
Low Severity	Median 0.6 ac Range 0.05-0.9 ac	Agee (1998) ( <i>summarizing several authors</i> )
Mixed Severity	Mean 14 ac Median 1.5 ac Range 1.2-227 ac	Agee (1998) ( <i>summarizing several authors</i> )

## 3. Complex patches:

Complex patches are those with more structural and species complexity than the surrounding area. Patch characteristics include large snags, soft down logs, and mistletoe brooms. Microsites, topography, and existing conditions may be used to select locations to leave complex patches (for more in-depth description of complex patches see the Forest Ecology section of Part I).

Many stands do not currently include the structural complexity for these patches. With time, retained dense clumps will develop the desired characteristics.

Many forest restoration treatments will increase the within-stand proportion of ponderosa pine. Complex and unthinned patches can be used to retain other species, such as Douglas-fir and grand fir, thus increasing habitat diversity



**Figure 12. Examples of stands without (A) and with (B) the desired spatial characteristics of clumps, gaps, and complex patches**

***Large and old trees***

One of the primary objectives of the Forest Restoration Strategy is to restore the density of large and old trees (*Hot Box 5*), and consequently the various functions they provide on the forest. The guiding principle is that old trees will be retained and will be supplemented by enough of the largest, younger trees to achieve old, large tree restoration objectives (*Table 7*). There is strong scientific rationale for retaining old trees, even those in close proximity to each other.

- Actions that will retain large and old trees include:
- Leaving an untreated buffer around large and old trees if treatment of smaller and younger trees would jeopardize them.

Reducing their vulnerability to fire by removing fuels from around them or by using prescribed burn lighting patterns that limit heat intensity at the base of the tree.

Reducing understory competition around old ponderosa pine trees by removing all or most of the younger trees and shrubs from within one to three times the drip line of the crown.

The proportion of trees removed and the removal distance should vary in order to meet process, structure, and composition objectives.

Intra-cohort thinning should not occur within clumps of old trees. The most ecologically effective clumps in most stands are composed of old trees and there is strong scientific rationale for retaining all of them, even those in close proximity to one another (Appendix C). The ecology of old trees and stands is different from that of the young trees and stands that many earlier management guidelines and practices were developed to address.

Concepts useful for managing old trees and stands are described in Appendices B and C.

Density objectives for large trees should be based on the structure classes used during the Landscape Evaluation, which informed the landscape prescription and the NEPA purpose and need description. Specific old and large tree objectives would vary by site condition and be explicitly described in the desired condition for the stand. The ranges of tree densities shown in Table 7 are intended to be broadly applied across the forest to meet most structural and functional stand-level objectives. However, it is expected that within the ranges provided in Table 7 for a particular structural/functional objective, site-specific conditions (such as local plant association or productivity information) would inform which end of the range of tree density objectives (*Table 7*) would be appropriate for each proposed treatment unit.

The densities in Table 7 are intended to address typical forest conditions and in some cases they will not be consistent with site-specific conditions or objectives. In these cases, deviations may be prescribed if they are supported by established science and site-specific data gathered and evaluated following established scientific methods (Harrod et al 1999, Larson and Churchill 2008).

**Table 8. Density objectives for large, old trees by plant association groups and structure classes.** The following table is based on: stand reconstructions (Harrod et al. 1999, Youngblood et al. 2004, unpublished data on file at Okanogan-Wenatchee NF); quantitative definitions of structure classes (Hessburg et al 1999a.); and the relationship between overstory density and the establishment and growth of early seral trees (Becker and Corse 1997). Site-specific conditions and objectives can define desired density for project-area stands.

Structure class	Warm/dry Plant Association Groups		Mesic Plant Association Groups	
	Minimum trees/ac over 20 in dbh	Maximum trees/ac over 20 in dbh	Minimum trees/ac over 20 in dbh	Maximum trees/ac over 20 in dbh
Stand Initiation	0	16	0	16
Stem exclusion open canopy and closed canopy	17	34	17	66
Understory reinitiation, Young forest multi-story	11	25	11	25
	Minimum trees/ac over 25 in dbh			
Old Forest multi-story and single story	18			

***Density of young and understory trees***

Young and understory tree density should be managed to create or maintain the spatial pattern described above and to be consistent with site and disturbance processes. Some general guidelines for each structural stage are presented below.

**Stand initiation:** Rely on natural regeneration or planting at a lower density.

**Stem exclusion closed canopy:** Depending on stand conditions and age, use large overstory tree restoration methods, or relative density and/or crown bulk density approaches.

**Stem exclusion open canopy:** Depending on stand conditions and age, use large overstory tree restoration methods, or relative density and/or crown bulk density approaches.

**Understory reinitiation:** Understory density should be limited to that growing space not allocated to the desired overstory trees.

**Young forest multistory:** Understory density should be limited to that growing space not allocated to the desired overstory trees.

**Old forest single story:** These stands will likely not be planted.

**Old forest multistory:** Tree density should be as described for spotted owl or goshawk habitat.

<b>HOTBOX 7</b>	
<b>Defining Old and/or Large Trees</b>	
<b>Defining “Old” Trees in Dry Forest Ecosystems</b>	
<p>There are four species of trees within dry forest ecosystems on the east-side that are important in terms of the development of old tree structures: ponderosa pine, western larch, Douglas-fir, and grand fir. We recommend using the guide to the identification of old trees developed by Van Pelt (2008) to define old trees for the Okanogan-Wenatchee Forest Restoration Strategy. This guide provides a rating system that relies on tree characteristics to determine the general age of the tree. The following ratings should be used to define and identify old trees:</p>	
Ponderosa pine.....	Score of $\geq 6$
Western larch.....	Score of $\geq 7$
Douglas-fir.....	Score of $\geq 7$
Grand fir.....	No Score (see below)
<b>Defining “Large” Trees in Dry Forest Ecosystems</b>	
<p>Several efforts have been made to define large trees for purposes of classification (e.g., Lehmkuhl et al. 1994, Hessburg et al. 1999a) and to describe historical stand conditions (e.g., Harrod et al. 1999, Youngblood et al. 2004). In the east-side forest health assessment, Lehmkuhl defined large trees as 20-24 inches dbh and Hessburg et al. (1999a) used trees &gt;25 inches dbh to describe large tree forest types. Harrod et al. (1999) compared the current and historical density of large trees and used trees &gt;20 inches as a definition of large. Youngblood et al. (2004) measured overstory trees within dry forest stands that had experienced limited human disturbance and found that the frequency of large live ponderosa pine trees generally peaked between 16-20 inches dbh.</p> <p>The potential for a site to grow large trees varies. Generally, conditions in the Okanogan-Wenatchee National Forest are such that large trees vary from 20-25 inches dbh. Thus, we recommend the following distinction in describing large trees:</p>	
Large.....	20-25 inches dbh
Very large....	>25 inches dbh

## ***Why There Should be no Standard Basal Area Objective for Dry Forest Treatments***

Over the years, a misunderstanding of basal area has grown into a misapplied basal area objective of about 60 square feet following dry forest treatments. Reasons include the universal misapplication of references such as the average 70 square feet in Harrod et al. (1999) and rules of thumb such as this one: “bark beetle risk is acceptable at about 60 square feet of basal area” (Paul Flanagan personal communication).

It is inappropriate to assign a basal area target of about to all dry forests, due to the inherent variability among dry forest sites. Basal area is a mensurational tool and only represents competitive processes indirectly as a proxy for leaf area. Consequently, its ecological meaning is less straightforward than that of Stand Density Index (Dave Perry, Oregon State University, pers. comm.).

As is widely known, basal area’s utility for describing tree density is limited without an accompanying diameter description, but there are other important aspects to bear in mind. Consider two young pine stands, one less than 50 years old so the proportion of heartwood is very low, and another over 100 years old so the proportion of heartwood is quite high. Both stands could average 120 square feet of basal area per acre but tree density and diameter would be quite different for each stand: 150 twelve-inch diameter trees in the young stand and 24 thirty-inch diameter trees in the older stand. Because the proportion of physiologically inert heartwood is so much higher in the old stand, 120 square feet of basal area in the old stand represents considerably less resource use and competition than does the same basal area in the younger stand. As another example, a young stand that has recently been thinned to 60 square feet of basal area with a residual stand diameter of 6 inches will result in an SDI of 306 per acre. This resulting density would not meet our dry forest objectives.

In spite of the preceding discussion, basal area used appropriately, can be a useful tool for describing a stand or marking objectives. Basal area can support understanding of the relative competitive changes from various levels of density reduction for a particular stand when accompanied by a measure of diameter distribution. Most importantly, it can be used to communicate marking objectives. For example, basal area can be used as a means to quantify gap and clump creation or to translate SDI objectives.

### ***Weak Rationale for “Thinning” Old Trees***

Given our direction to restore forest ecosystems, there is little, if any, rationale for intra-cohort thinning of old trees. On the other hand, inter-cohort, or understory density reduction, is supported as a means to favor old trees although the response appears to vary among tree species. Competitive relationships among trees in young, closed, evenly spaced conifer stands are different than they are within older, more variable ones. In young stands, self-thinning is occurring and competition is the primary cause of mortality that is distributed somewhat evenly across the stand. In old stands, after the period of rapid height growth and crown expansion, mortality is mostly density independent. In young stands, growing space, made available as subordinate trees are killed by dominant trees, is rapidly filled by those survivors and the competitive process continues. In older stands, as the trees

approach their maximum size, growth slows and self thinning finally ceases as the stand “falls off the self-thinning curve.” Explanations for this include the reduced ability of older trees to capitalize on released growing space (White and Harper 1970) and the canopy architecture of older stands (Zeide 1987; David Perry, Oregon State University, pers. comm.). This “falling off” is incorporated in Forest Vegetation Simulator (James Long, Utah State University, pers. comm.).

Density management regimes based on the self-thinning curve have a long history (Curtis 1970, Long 1985) and have been commonly used by silviculturists to prescribe thinnings in young, dense, evenly spaced, even-aged stands. More recently, Cochran (1992) suggested an application of SDI for uneven-aged ponderosa pine stands, and its qualified extension to uneven-aged, mixed species stands (Pat Cochran, USDA Forest Service, pers. comm.) However, these concepts and the management thresholds derived from them are based on stand level averages. They do not address resource use at the neighborhood scale. This shortcoming limits their applicability in most of our dry forest, with its mixed-species, multi-aged, clumpy stands. It is inappropriate to use them as a justification or guide for intra-cohort thinning of old stands or clumps of old trees in mixed age stands.

Yet, thinning may result in increased growth and vigor of old trees. Increased growth for old trees following density reduction in old stands has been reported (Latham and Tappeiner 2002, McDowell et al. (2003). These authors suggest, with some ambiguity, that the density reduction was from understory removal. Others (Wallin et al. (2004; Dolph et al. 1995) unambiguously report increased growth and vigor for old ponderosa pines following understory density reduction. McDowell et al. (2003) report that the growth effect can last for up to 15 years. Site and individual tree characteristics (Latham and Tappeiner 2002) and tree/stand history (Kaufmann 1995) appear to be important factors.

This kind of understory thinning often brings increased resistance to insects, as a function of increased vigor. However, applying these results as a rationale for intra-cohort thinning of old stands and clumps is insufficiently supported in the literature. Donald Goheen (USDA Forest Service, pers. comm.) suggests the pattern of bark beetle-caused mortality is different in stands engaged in self-thinning (where large-scale tree mortality can occur), versus in older stands (where tree mortality is often patchy, excepting the effect of regional drought). This is supported by Edminster and Olsen (in Long 2000) and Youngblood et al. (2004). This kind of mortality among older trees is likely the process, along with fire, by which successional processes were historically maintained in our dry forests (Agee 1993).

### ***Sample Prescriptions to Address Old and Large Trees and Spatial Patterning***

**Example 1:** This prescription excerpt implements the results of a site-specific stand-reconstruction to create spatial pattern. It retains most large trees, and all old and very large trees.

**Table 9. Prescription/Marking Guide**

<b>Project Wildcat</b>	<b>Unit 44 version 2</b>	<b>Name Dahlgreen</b>	<b>Date May 28, 2009</b>
Locate	series	Dry/mesic dry	Data exam/recon

Acres 48	Aspect S	Slope <35	Elev 32-3600
NWFP Matrix	Wen FP ST 1	Act Code: HTH	

**Table 10. Stand Description (exam 15% error at 68.3 confidence)**

spp	dbh	tpa	growth	aveBA	ave space	LCR	CC	MBF
DF>PP	>25	7	+20/20	35	80	>40		
DF>>P	21-25	13	+20/20	40	60	>40		
	16-20.9	13		20	60	>35		
	9-15.9	5		5				
Stand average		40		100	30		SVS 25-30	7-9

Stand Structure after treatment: SEOC becoming OFSS with time: Key Feature large trees, esp. PP

Spacing: Leave an average of 40 trees/ac.

- Leave 5 clumps/ac w/ 2-4 trees and 2 clumps/ac w/  $\geq 5$  trees. Clumps have trees w/in 20 ft of another tree. Spacing outside clump should be at least 45 ft on two sides.
- Leave 18 tpa as individuals with average spacing about 50 ft. Vary spacing for tree condition with average spacing about 50 ft and minimum about 30 ft.

Guidelines:

- Retain all old trees, established before about 1900. Note, that is younger than Van Pelt (2008) rating greater than 6 for PP and 7 for DF
- Around old PP, remove 100yr age class DF for 1-2 driplines—OK to keep 1-2 large/vigorous DF occasionally-use judgment.
- Thin from below removing mostly trees <21 inch to meet tree density/LCR objectives. Removal of trees >21 isn't expected. Maybe on east end as needed to prevent mistletoe spread to the west. Remove INT DF w/LCR <40 (Can go to <35 for clumping; check growth). Retain occasional understory/INT w/LCR > 40 (+-2/ac)
- Remove 100 yr PP w/LCR <30% or with Van Pelt fig. 69 form C or D (check growth)
- In areas of +- pure younger PP leave BA 40-60 and/or open around them for 2-4 driplines.
- On slope > 10-15% leave BA nearer low end. On flatter ground and mesic on west edge stay nearer 100.
- Retain GF as part of complex patch on SW, otherwise they're not an issue either way.
- Retain complex patch at point 41 on SW corner wet area.
- Canopy gaps (fewer than about 5 tpa) between 1/10 to 1/2 ac will be created in patches of INT trees or where DF mistletoe buffers are created.

**Example 2:** This prescription excerpt is not based on an explicit clump/gap objective. Instead, it uses stand conditions and objectives to create spatial pattern. It retains most large trees, and all old, very large trees.

**Table 11. Prescription/Marking Guide**

<b>Project Gold Spr</b>	<b>Unit 6</b>	<b>Name Dahlgreen</b>	<b>Date 1-10</b>
Locate Naches	Series GF	Dry/mesic	Data recon/CSE
Acres 123	Aspect West	Slope <30	Elev 26-3400
NWFP Mtrx +90 & MLSA/AWD	Wen FP GF +- 95% & MP1	FWS none	Act Code: HSA

**Table 12. Stand Description (exam 11% error at 68% confidence)**

spp	dbh	Current TPA	Post mech TPA	Post-mech BA	Current CC	Desired CC	Acceptable CC
	>25	<1	<1	4	2	2	2
	16-25	17	13	27	18	14	20-22
	9-16	39	13	15	23	8	
	5-9	3	0	0	1	0	
	<5	n/a	n/a	n/a	n/a	n/a	
stand average/ac (68% confidence interval)		59 (53-65)	27 (24-31)	46 (41-51)	43 (38-48)	24 (21-27)	
Range across unit				0-120			

Stand Structure after treatment: YFMS (assuming SS currently > 10% cover).

Pattern: Gaps created by: a) dripline thinning around old PP ; b) around OS WL; c) releasing PP/WL advance regen; d) removing about 65% of trees from about 45% of the stand (due to mistletoe infection) and about 25% of the trees elsewhere. Clumps provided by uninfected DF. Basal area across unit will range from 0 to 120 ft. Complex patches: moist sinks on SE boundary and where found elsewhere.

Residual density/spacing: See Table.

Guidelines

1. Old trees: retain all Van Pelt rated DF  $\geq 7$  and PP  $\geq 6$  and WL  $\geq 7$
2. Retain all trees over 25 inches and all between 21 and 25 inches, except rare removal for old PP release, or DF dwarf mistletoe containment.
3. Around Van Pelt  $\geq 6$  rated PP, retain only 0-2 younger trees for 1-2 driplines.
4. Thin uninfected DF clumps from below removing only INT and COD trees with poor growth (below about 15/20ths, narrow bark fissures, and/or LCR < 40% for DF and <35% for PP).
5. Release advanced PP/WL regen by removing OS DF to open sky for 90-130 degrees, east to west and neighborhood basal area < 30.

6. For about 1 acre around retained WL, remove DF to about 20% canopy cover.
7. Retain all WL except for mistletoe infected ones < 21 inches.
8. Retain all old and >25 inch dwarf mistletoe-infected DF. Retain infected trees between 21-25 inches as groups of 3 or more. Isolate all retained trees. Remove individual infected DF under 25 inches and all under 21 inches, as well as adjacent, apparently uninfected ones.
9. Confine GF to less than about 6 acres on moist areas, usually clumped, preferably as unthinned patches. On dry, upslope areas retain them if > 25 inches.
10. Retain wildlife trees
  - Buffer snags >25 inches as needed.
  - Retain live trees with dead, broken, forked tops or obvious sign of use

## **APPENDIX C – Restoration Strategy changes and integration with other planning efforts**

### ***Updates currently underway***

A number of updates to the Restoration Strategy are currently in progress and not ready to for full description in the main body of this document. Expect to see complete descriptions of these changes in future iterations of the Restoration Strategy. To give OWNF employees and partners clarity and advance notice, we offer the following descriptions of updates the FRS Team is currently working on.

### **Roads/aquatics integration and improvements**

The FRS Team is working with OWNF Fish Biologists and Hydrologists to further develop the roads/aquatics piece of the Strategy. This group has a few goals. First, they want to develop models to prioritize treatments exclusively from the perspectives of Engineering, Fish Biology, and Hydrology (not just the intersection of these). Second, they want to integrate the consideration of roads and aquatics into the EMDS modeling of priorities. The current mode of running three parallel processes (EMDS, NetMap, Minimum Road Analysis) makes it challenging to develop integrated priorities, PLTAs, and treatments. Third, they want to build additional data into EMDS for roads and aquatic issues. Feedback from a number of resource specialists suggested that the NetMap tools alone did not provide a sufficiently in-depth look at restoration priorities for roads or aquatic ecosystems. The FRS Team is working to locate and relate various Forest data to enhance this piece of the Restoration Strategy effort. A final consideration is the integration of restoration priorities in this Restoration Strategy with watersheds of concern or interest at the Regional or National levels. The FRS Team will work with the Forest Fish Biologist and Hydrologist to better coordinate the Restoration Strategy and other aquatic priorities.

### **Additional Improvements**

There may be opportunities to add additional elements to the Wildlife Component of the Landscape Evaluation. The initial Evaluation contains analyses for 5 wildlife species. We have begun to examine adding analyses for additional species of management interest, such as deer and elk (specific to winter range).

### **Future range of variability (FRV)**

The current approach to modeling FRV is to use the next warmer, drier ecological sub-region (ESR) as a proxy. This has already presented issues for Landscape Evaluations on the Cle Elum and Entiat Ranger Districts, as some of their sub-watersheds are on the cusp of being non-forested systems if conditions are warmer and drier. The FRS Team and the Wenatchee Forestry Sciences Lab wish to develop a more nuanced approach to modeling FRV, including the use of [Vegetation Dynamics Development Tool](#) (VDDT), which is a state-and-transition landscape modeling tool. The FRS Team is currently working with partners and with the Pacific Northwest Regional Office of the Forest Service to determine

how to accomplish this work. Another FRV consideration is a scenario that may be warmer and wetter.

### **Sub-watershed prioritization**

The science review of the first iteration of the Restoration Strategy identified a need to prioritize sub-watersheds across the OWNF in which to conduct Landscape Evaluations. While a Landscape Evaluation highlights priority areas for restoration within a sub-watershed, OWNF managers do not necessarily have clear and strategic reasons to go to one sub-watershed or another to look for restoration opportunities. To keep with the ideal that restoration projects should be chosen for clear, defensible, communicable, landscape-scale reasons, the FRS Team is working with other OWNF program managers to develop a forest-wide sub-watershed prioritization process. The FRS Team intends to use the Terrestrial and Watershed Condition Frameworks, and the revised Forest Plan as the basis of the prioritization. Other considerations will be policy, available data, and logistics.

### **Decoder ring**

Richy Harrod and Randy Whitehall have been working on a method for converting “restoration acres” into required reporting metrics, such as board feet of timber and acres of treated fuels. The goal is to design a conversion formula that gives an accurate picture of progress without under-counting or double-counting. Such a “decoder ring” would enable Ranger Districts to report restoration acres and the OWNF Supervisor’s Office to translate those acres into the required reports. This approach standardizes reporting across the Forest, and takes some pressure off Districts as they work to implement the Restoration Strategy. Development of the decoder ring has proved challenging for a number of reasons. If the Integrated Resource Restoration (IRR) budget approach is implemented in Region 6, the decoder ring may no longer be needed. If there continues to be a need for a decoder ring approach, the FRS Team will continue working on it.

### ***Integration with other planning efforts***

A number of large planning processes are ongoing at the OWNF. The Forest is revising its Land and Resource Management Plan (LRMP or “Forest Plan”), working on an Access Travel Management plan to designate the uses of various roads, and doing Minimum Road Analysis Forest-wide. To clarify the interconnections of these planning efforts, especially as they relate to the Forest’s road network, the Forest Plan Revision team devised a [document](#) that OWNF employees can access on the intranet. Others interested in this document may contact [Margaret Hartzell](#), Forest Plan Revision Team Leader.

### **Forest Plan Revision**

A new Forest Plan is supposed to be in place on the OWNF within a few years. This is a substantial update to the current plan and reflects similar thinking as is presented here in the Restoration Strategy. A Forest Plan sets the desired conditions that various projects help to implement. The Restoration Strategy will help to guide the process of moving toward desired conditions for some aspects of vegetation, fire and insect risk, wildlife and fish habitat, hydrology, and road networks. The draft revision of the Forest Plan and the

current Restoration Strategy are well aligned on issues like spotted owl habitat and climate change adaptation. Members of the FRS Team and the Forest Plan Revision Team are coordinating to ensure alignment between these efforts.

## **Watershed Condition Framework and Terrestrial Condition Framework**

The Forest Service Headquarters Office in Washington, DC (WO) has created new processes to enable National Forests to rank aquatic and terrestrial habitats according to their quality (high, medium, or low) on a number of factors. WO correspondence from October 24, 2011 describes these frameworks as follows:

*We developed the national Watershed Condition Framework (WCF) to consistently evaluate watershed condition, prioritize watersheds for restoration, create action plans that include a suite of essential projects, and track and monitor restoration accomplishments. However, by design, the WCF focused on physical and biological factors that affect water quality, quantity, and aquatic resources. As a consequence, the Washington Office Sustainable Landscape Management Board of Directors organized a team to develop the Terrestrial Condition Framework (TCF) as a companion to the WCF. The TCF Team... is developing a national framework of analysis and reporting units using the Landtype Association (LTA) for assessing terrestrial indicators using the national hierarchy of ecological units.*

As the TCF develops, and the WCF begins to be implemented, the FRS Team will work closely with the WO and with other OWNF resource specialists to ensure coordination between implementation of these frameworks and the Restoration Strategy.

## GLOSSARY

Term	Definition
<b>Adaptive Management</b>	A system of management practices based on clearly identified outcomes and monitoring to determine if management actions are meeting desired outcomes, and facilitate management changes that will best ensure that outcomes are met or reevaluated. Adaptive management stems from the recognition that ecological systems can be unpredictable and outcomes are uncertain (36 CFR 219.16; FSM 1905).
<b>Biological Legacies</b>	“Biological legacies are defined as the organisms, organic matter (including structures), and biologically created patterns that persist from the pre-disturbance ecosystem and influence recovery processes in the post-disturbance ecosystem. Legacies occur in varied forms and densities, depending upon the nature of both the disturbance and the forest ecosystem” (Franklin et al. 2007). Other biological legacies can include fire refugia areas that either escape fire due to landscape position (ex: rocky areas, ridgetops) or are unburned islands within a mixed fire event (Camp et al. 1997).
<b>Class Metrics</b>	Class metrics measure the aggregate properties of the patches belonging to a single class or patch type. Some class metrics go about this by characterizing the aggregate properties without distinction among the separate patches that comprise the class. Another way to quantify the configuration of patches at the class level is to summarize the aggregate distribution of the patch metrics for all patches of the corresponding patch type. In other words, since the class represents an aggregation of patches of the same type, we can characterize the class by summarizing the patch metrics for the patches that comprise each class.
<b>Disturbance</b>	Disturbance is a temporary variance in average environmental conditions that causes a pronounced change in an ecosystem. Ecological disturbances include fires, floods, windstorms,

Term	Definition
	<p>and insect outbreaks, as well as anthropogenic disturbances such as forest clearing and the introduction of exotic species. Natural disturbances are influenced mainly by climate, weather, and location. Disturbances can have profound immediate effects on ecosystems and can greatly alter the natural community. Because of the impacts on populations, disturbance effects can persist for an extended period of time (Dale et al. 2001).</p>
<p><b>Ecosystem Management</b></p>	<p>Ecosystem management is driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem structure and function (Christensen et al. 1996). It emphasizes management of systems rather than their component parts, while integrating economic and social values (Harrod et al. 1996). The goal of ecosystem management is to achieve sustainability of ecosystem structures and processes necessary to deliver goods and services, rather focusing on short-term delivery of products.</p>
<p><b>Ecosystem Management Decision Support (EMDS)</b></p>	<p>This software tool is composed of two parts. The first, called NetWeaver, helps to derive attributes from photo interpreted data, and compare current landscape conditions with historical and potential future reference conditions. The second part, called Criteria Decision Plus, supports relative weighting of multiple resources to show integrated priorities.</p>
<p><b>Forest Restoration</b></p>	<p>Restoration is the activity used to implement ecosystem management. Restoration aims to enhance the resiliency and sustainability of forests through treatments that incrementally return the ecosystem to a state that is within a historical range of conditions (Landres et al. 1999) tempered by potential climate change (Millar and Woolfenden 1999). It is the process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed (FSM</p>

<b>Term</b>	<b>Definition</b>
	2020.5). In forest restoration, active techniques are largely tree cutting and prescribed fire, but also include actions focused on roads, weeds, livestock, and streams.
<b>Function</b>	Function in an ecosystem is the role that any given process, species, population, or physical attribute plays in the interrelation between various ecosystem components or processes (Lugo et al. 1999). For example, standing snags in forests provide habitat for many wildlife species and when snags fall, they serve as substrate for seedling establishment and wildlife cover. Downed wood creates aquatic habitat complexity (Naiman et al. 1992; Benda and Sias, 2003) which in turn supports listed fish species (Lichatowich 1999, ISAB 2007). Functional roles can be lost or diminished by management practices that do not incorporate ecosystem interrelations.
<b>Future Range of Variability</b>	The future range of variability is a concept described by Gärtner et al. (2008) and provides insights into how systems may adjust to changing climate. By comparing current vegetation patterns to both historical and future reference conditions, managers will gain valuable insights into how systems have changed and how they are likely to change over time. Understanding these changes is the key to determining management strategies that provide for sustainable and resilient forests.
<b>Landscape Metric</b>	Landscape metrics measure the aggregate properties of the entire patch mosaic. Some landscape metrics go about this by characterizing the aggregate properties without distinction among the separate patches that comprise the mosaic. Another way to quantify the configuration of patches at the landscape level is to summarize the aggregate distribution of the patch metrics for all patches in the landscape. In other words, since the landscape represents an aggregation of patches, we can characterize the landscape by summarizing the patch metrics.
<b>Historical Range of Variability (HRV)</b>	Historical range of variability refers to the

Term	Definition
	<p>fluctuations in ecosystem composition, structure, and process over time, especially prior to the influence of Euro-American settlers (Morgan et al. 1994, Swanson et al. 1994, Fulé et al. 1997, Landres et al. 1999, Agee 2003). Such variations include a diverse array of characteristics such as tree density, population sizes of organisms, water temperature, and sediment delivery. This concept can be applied at multiple spatial scales from the site to biogeographic region, and at multiple temporal scales from decades or centuries for landform erosion to millennia for geologic processes (Swanson et al. 1994, Landres et al. 1999).</p>
<p><b>Minimum Road Analysis (MRA)</b></p>	<p>Minimum Road Analysis is a required process for all National Forest System (NFS) lands (FS Handbook 7709 Chapter 20). It aims to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of NFS lands. The analysis is conducted at a watershed level and helps to inform socio-economic restoration priorities for road networks.</p>
<p><b>Monitoring</b></p>	<p>The systematic collection and analysis of repeated observations or measurements used to evaluate changes in condition and progress towards meeting a management objective. This could include: <i>Implementation Monitoring</i> – helps to evaluate how closely management plan guidelines were followed. <i>Effectiveness Monitoring</i> – helps to evaluate whether the management plan achieves the desired conditions. <i>Validation Monitoring</i> – helps to evaluate if the underlying assumptions regarding cause and effect relationships are correct. Monitoring is an integral part of adaptive management.</p>
<p><b>NetMap</b></p>	<p>We use the NetMap watershed data and analysis software tool to look at eight outputs: drainage density, road density, road crossing density, number of road crossings, roads segments by slope, landslide density by road segment, and intrinsic habitat potential for steelhead and Chinook.</p>
<p><b>Pattern</b></p>	<p>Pattern is the spatial distribution of ecological</p>

Term	Definition
	<p>characteristics of forest or other ecosystems. Like process, pattern changes over time and space. Discernable patterns can be described at the level of tree- or shrub- clumps, or at the level of large-scale vegetation types in a biophysical zone. Patterns in forest ecosystems arise from broad differences in topography, geomorphic processes, climate regime, and large-scale disturbances (Hessburg et al. 2000).</p>
<b>Process</b>	<p>A process as defined in the dictionary is a sequence of events or states, one following from and dependent on another, which lead to some outcome. Processes that are important to ecosystems are disturbances that include both one-way fluxes and cycles (Lugo et al. 1999). For example, the process of soil erosion, the movement of soil particles from one location to another, represents a flux, while frequent fire in a dry forest stand would be considered a cycle. Many disturbances in ecosystems are merely processes that occur at different temporal and spatial scales.</p>
<b>Project</b>	<p>When we use the term “project” in this document we mean a scope of work that may be captured in a single Environmental Assessment document (EA) under the National Environmental Policy Act (NEPA). As such, a project may include multiple types of treatments in multiple sub-units throughout a Landscape Evaluation area. Treatments may be implemented in stages over the course of up to five years.</p>
<b>Resilience</b>	<p>Resilience is defined as, “the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary” (Walker et al. 2004).</p>
<b>Restoration treatments</b>	<p>We use “treatments” in this document to describe a suite of actions that may include selective harvesting of trees, thinning of small trees and shrubs, prescribed burning in a variety of seasons, and moving, improving, closing, or decommissioning road segments.</p>

Term	Definition
<b>Spatial and temporal scales</b>	Scale refers to physical dimensions of observed entities (e.g. a watershed) and phenomena (e.g. fire), and to the scale of observations (O'Neill and King 1998). Scale has both spatial and temporal dimensions. Ecosystem processes, structures, and functions occur at different scales and, therefore, ecosystems can be thought of as hierarchically organized. For example, frequent fire in ponderosa pine forests historically created small clumps of even-aged trees that resulted in uneven-aged stands with a generally regular, open structure. At the scale of a watershed, the ponderosa pine vegetation zone was highly variable and influenced by precipitation zones, soil types, variation in fire size, and higher fire frequency than is experienced by any one individual stand. In this example, ponderosa pine pattern varied with space and with time (with fire more frequent at larger scales).
<b>Stochastic</b>	A stochastic process is one whose behavior is non-deterministic. Meaning, the outcome of the process is determined partly by the effects of predictable elements, but mostly by one or more random elements. For example, the trajectory of ecological change can be influenced by predictable elements, like site conditions, and also by stochastic factors such as availability of colonists or seeds, or weather conditions at the time of disturbance (Webster 2010).
<b>Structure</b>	Structures are the living and non-living physical components, and their spatial arrangement, within an ecosystem. Multi-layered stands are structurally diverse, but so are landscapes with multiple patches of stands of different ages. Ecosystem structures are important because processes are influenced by structures and management is typically focused on the manipulation of structures.
<b>Sub-basin</b>	A 4 <sup>th</sup> level Hydrologic Unit Code (HUC) area, typically covering a few hundred thousand acres to over one million acres. Examples include the Methow, Entiat, and upper Yakima Sub-basins.

Term	Definition
<b>Sub-watershed</b>	A 6 <sup>th</sup> level HUC, typically covering 10,000 to 40,000 acres. This scale will be used to identify “Key Sub-watersheds” in the Okanogan-Wenatchee Forest Plan Revision. Examples include Cub Creek, Upper Entiat, and North Fork Teanaway.
<b>Sustainable</b>	“Sustainable development... meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN 1987). Sustainable forest management is, “The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems” (FAO 2001).
<b>Watershed</b>	A 5 <sup>th</sup> level HUC, typically covering 40,000 to a few hundred thousand acres. Key Watershed Identification and Watershed Assessments completed under the NW Forest Plan typically were done at this scale. Examples include the Chewuch, Mainstem Entiat River, and the Teanaway.