# 4

# Research, Monitoring, and Adaptive Management

In this chapter, DNR describes the adaptive management process and research and monitoring program, including near-term priority projects.

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# Research, Monitoring, and Adaptive Management

## In the OESF, DNR intentionally learns and adapts management to new information to continuously improve the integration of revenue production and ecological values.

## Adaptive Management

The concept of adaptive management of natural resources was introduced in the 1970s and 1980s (Holling 1978; Walters 1986) as a way to manage natural resources when knowledge of ecosystem functions or the effects of human actions is incomplete. Incomplete knowledge (uncertainty) is an inherent and pervasive feature of managing natural resources.

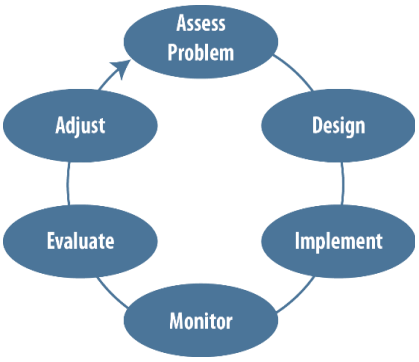
Adaptive management has been defined in the literature in many different ways. DNR has selected the definition by Bunnel and Dunsworth (2009) because of its emphasis on different sources of learning:

> Adaptive management is a formal process for continually improving management practices by learning from the outcomes of operational and experimental approaches.

As DNR interprets this definition, adaptive management is a structured (formal), science-informed process in which key uncertainties are identified; hypotheses around a system's functioning, desired outcomes, and management effects are formulated; actions to test hypotheses are implemented; and the knowledge gained is used to affirm or adjust

management. This process is often depicted as a cycle (Figure 4-1). A modified version of this cycle will be used later in this chapter.

**Figure 4-1. The Adaptive Management Process**
Williams and others 2007




DNR interprets "continually improving management practices" as learning to better integrate revenue production and ecological values. This learning is intentional. Actions are taken not only to manage but also to learn about the managed systems; in other words, to obtain information that increases confidence in ongoing management or provides alternative management solutions.

Uncertainty and other key terms used in this chapter are defined in Chapter 5 (glossary).

## Why Adaptive Management?

Land managers such as DNR often must find a way to continue managing natural systems to reach their land management objectives in the face of uncertainty. Adaptive management is one approach to managing in the face of uncertainty. Other approaches include precautionary and trial and error.

- **Precautionary approach:** When scientific information that an action or policy may be harmful is incomplete, managers err on the side of caution. This approach derives from the precautionary principle[1] in that an activity does not take place until it is proven safe. This approach differs from the strict interpretation of the precautionary principle by acknowledging that not all human actions are irreversibly harmful unless proven otherwise and that economic and social factors should be considered when taking precautions. In the OESF, the precautionary approach is most often implemented by limiting activities in specific areas, such as potentially unstable slopes and high quality habitat, until more information is collected to elucidate key processes and relationships. These limitations or restrictions are designed to alleviate potential ecological harm. At the same time, they also reduce revenue, provide little opportunity for

learning, and in some cases, limit active restoration and habitat enhancement activities.

- **Trial-and-error approach:** Initial management decisions and subsequent implementation are based on the best available science and professional judgment and may include forecasting techniques such as formal risk assessment and scenario planning. Under this approach, managers gain some knowledge through the experience of implementing management strategies. However, such learning is not acquired in an intentional, structured process. For example, key uncertainties are not explicitly stated, reduction of the uncertainties is not a management objective, and a plan for acquiring reliable information through research and monitoring is not developed beforehand. The effects of the implemented strategy may or may not be monitored, and subsequent management decisions are made based on the reactions to a perceived failure of the strategy (Walters and Holling 1990). The most common forces for major changes under this approach are external drivers such as regulations, political pressure, and market conditions. Currently, this is the dominant paradigm in natural resource management worldwide (Willhere 2002).

Multiple considerations—regulatory, social, economic, and ecological—play a role in the selection of adaptive management over the other two approaches (refer to discussions in Lee 1999 and Failing and others 2004). Five considerations are central to determining whether adaptive management is prudent (Williams and Brown 2012):

- In spite of uncertainty about the outcomes, active management is required for an organization to meet its objectives.
- Clear and measurable management objectives guide decision making. These objectives and associated metrics are used to evaluate whether actions have the desired effect.
- Research and monitoring can be designed and conducted to reduce uncertainties. In other words, it is possible to implement information-gathering activities that are economically feasible and that are reasonably expected to produce relevant information in an acceptable timeframe.
- Decision makers have the ability and interest to act on new information to make changes to management. Opportunities exist to apply learning to management.
- Decision makers and stakeholders are actively involved and make a sustained commitment of time and resources.

DNR believes that **the OESF meets all five of these considerations** and has three additional reasons to select adaptive management:

- The idea of management actions that continue to change in response to new information and insights is fundamental to the concept of sustainable forest management (Lindemayer and Franklin 2002, DNR 2006).

- The adaptive management approach conforms to the original OESF vision for "applying non-traditional silvicultural practices, testing new concepts, measuring outputs, and revising forest practices to optimize both commodity production and ecological values" (Commission on Old Growth Alternatives for Washington's Forest Trust Lands 1989, p. 24).

- Adaptive management is a commitment in the HCP. The HCP identifies adaptive management (referred to as the "systematic application of knowledge gained") as one of the six management processes recommended for the OESF. The HCP also described "a process of integrating intentional learning with management decision making and course adjustments" as an important component of the experimental approach to management (DNR 1997, p. I.15). Finally, the HCP Implementation Agreement listed specific adaptive management practices to be implemented by DNR (DNR 1997, p. B.10 through B.11). In addition, the Federal Services consider adaptive management as a tool to address uncertainty in the conservation of species covered by habitat conservation plans (refer to *Habitat Conservation Planning Handbook* [USFWS and National Marine Fisheries Service {NMFS} 1996 and its addendum [USFWS and NMFS 2000]).

Text Box 4-2 lists some of the key characteristics of adaptive management.

**Text Box 4-2. Key Characteristics of Adaptive Management**

- Learning is triggered by the explicit acknowledgement of risk and uncertainties about the response of a particular system to management actions. Reducing these uncertainties (in other words, learning) is a focus of adaptive management.
- It is an intentional learning process based on the scientific method, as opposed to an ad-hoc reaction to a management problem.
- Interpreting research, monitoring, and operational findings and making recommendations to managers are critical steps in the process.
- A structured decision-making process, defined in advance, is used to close the loop between gathered information and management decisions.
- The implications of management adjustments that may result from the new information are clearly understood.
- Multiple iterative steps are used to ensure that improvement is continuous.

# Goal and Scope of Adaptive Management

The goal of adaptive management in the OESF, as stated in Chapter 2, is to continually improve the integration of revenue production and ecological values by learning from the outcomes of operational and experimental approaches. The scope is described as follows:

- The **ultimate focus of adaptive decision-making is on management**, and learning is valued in terms of its contribution to improving management (Walters, 1986). Adaptive management, and the research and monitoring that occurs as part of this process, is focused on uncertainties related to the goals, objectives, and management strategies for revenue production and the four major HCP conservation strategies (northern spotted owl, riparian, marbled murrelet, and multispecies) presented in Chapter 3. The knowledge gained through the adaptive management process is expected to increase DNR's confidence in ongoing management practices or to

prompt DNR to change its management of natural resources in the OESF.

- Adaptive management is a **science-informed process.** However, DNR acknowledges that scientific findings may not be the sole driver for decisions within the adaptive management process; political, social, and economic realities also are expected to affect decision making. For example, when making decisions, DNR must consider its fiduciary responsibilities as a trust lands manager, as well as its responsibilities per the HCP, the *Policy for Sustainable Forests*, and other policies. An adaptive management process that does not respect these realities is likely to be overly idealized and probably unrealistic. Some management adjustments in the OESF may be prompted by factors other than scientific findings. Examples include natural disturbances such as catastrophic winds or fire and economic factors such as changes in timber markets. If management adjustments are prompted solely by these factors, the changes are not considered part of the science-informed adaptive management process described in this chapter.

- Because of DNR's legal obligations under the HCP, most research and monitoring projects completed through the adaptive management process focus on **ecological lines of investigation,** particularly as related to implementation of the four habitat conservation strategies (northern spotted owl, riparian, marbled murrelet, and multispecies).

  Since ecological studies are conducted in response to DNR's management needs, they will benefit from **economic, social, and operational feasibility components** that support confidence that management strategies are viable business options and socially acceptable solutions. Stand-alone economic and social research are welcomed, although the expectation is that they will be conducted by external research partners. Operational trials, which will be described later in this chapter, are an important element of the OESF mission and are highly encouraged.

  Certain fundamental research studies, for example in the fields of taxonomy, evolutionary biology, and genetics, may be of high scientific interest, but inappropriate for adaptive management because they are not directly related to DNR's management needs. In other words, the information they produce likely will have relatively minor or indirect influence on management decisions. While valuable, such studies will not occur in the context of DNR's adaptive management process.

- Research and monitoring in the OESF are intended to have **broad implications for management of forested state trust lands**. To the appropriate extent, what is learned in the OESF, including paradigm

shifts, specific ecological knowledge, and improved management efficiencies, may be applied to management of other HCP planning units. For example, the OESF riparian conservation strategy described in the HCP was used in the development of the *Riparian Forest Restoration Strategy* for western Washington forested state trust lands (except the OESF) (Bigley and Deisenhofer 2006) and specifically in the guidance for thinning in riparian areas.

## Types of Adaptive Management Used in the OESF

DNR uses two types of adaptive management in the OESF: passive and active (Walters and Holing 1990).

- Under passive adaptive management, information comes from monitoring a single course of action, most often a best management practice. Uncertainties and hypotheses around expected outcomes are identified, but no alternative management approaches are compared. If the monitored approach is deemed ineffective, alternatives may not be readily available. An example of a project implemented in passive adaptive management context is the Status and Trends Monitoring of Riparian and Aquatic Habitat in the OESF project (refer to "Near-Term Priority Research and Monitoring Activities" later in this chapter).

- Under active adaptive management, alternative management approaches are developed to achieve specific goals, and these alternatives are implemented and monitored to determine which is the most effective. DNR recognizes that experimental manipulation provides the strongest inferences about cause-and-effect relationships, and therefore has the highest value as an information source for adaptive management. However, the high cost and logistical difficulties associated with field experiments limit their scale and number (Lindenmayer and Franklin 2002). An example of a project implemented in the active adaptive management context is the Long-term Ecosystem Productivity study, which compares the effects of different harvesting techniques, woody-debris retention levels, and plant species composition on tree and soil productivity (refer to "Near-Term Priority Research and Monitoring Activities" later in this chapter).

Both passive and active adaptive management approaches are accepted by the Federal Services as appropriate when developing a strategy to

address uncertainties in HCPs (USFWS and National Marine Fisheries Service [NMFS] 2000).

## Sources of Information for Adaptive Management

As adaptive management in the OESF is a science-informed process, most new information comes from research and monitoring, which are described in detail later in this chapter.

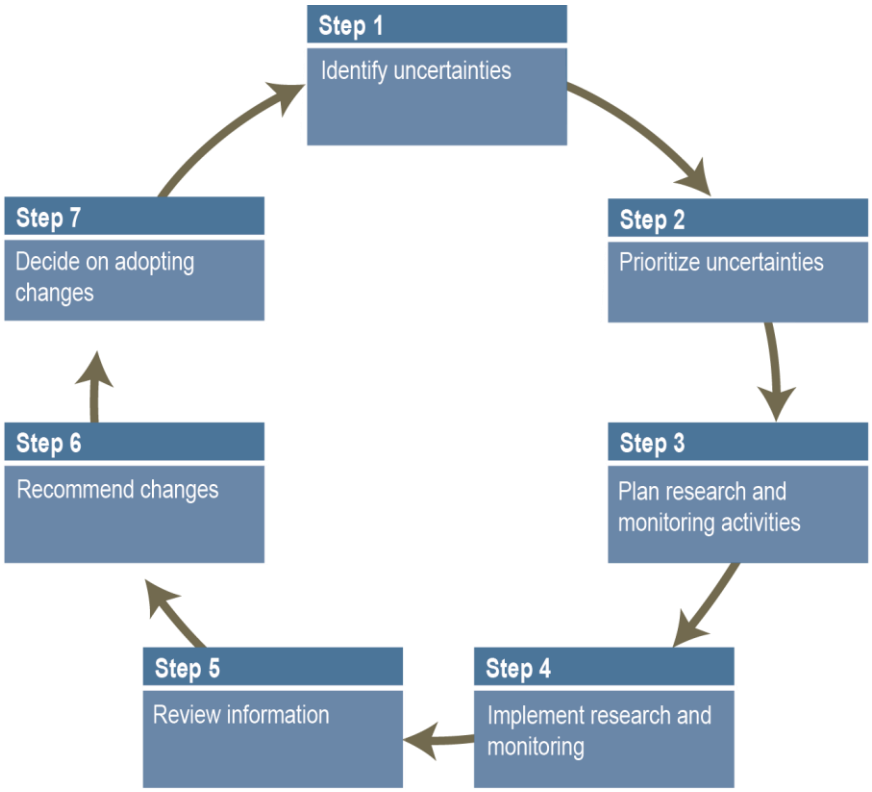
Along with Lindenmayer and Franklin (2002) and other authors, DNR supports the position that relevant knowledge for adaptive management also can be acquired from a variety of other sources, including modeling (for example, the OESF windthrow probability model described in Chapter 3) and operations. DNR views routine management operations and management experience as an important source of information for adaptive management. For many resource management problems, using management in an experimental, learning-oriented context is optimal for gaining the understanding needed to manage more effectively (Williams and others 2007). Under this holistic approach, recommendations for adaptive management are made after interpreting a range of information sources.

DNR uses not only information generated through DNR-sponsored and/or-led monitoring and research, but also new knowledge acquired by other organizations and research partners. The HCP recognizes that "other organizations may sponsor work that will generate the knowledge needed" and that DNR needs "to stay in touch with other Pacific Northwest research programs and assimilate information that can be used to meet HCP information needs" (DNR 1997, p. V.9).

# The Adaptive Management Process

The adaptive management process in the OESF is illustrated in Figure 4-2. DNR implements this process through PR 14-004-530, *Adaptive Management in the OESF HCP Planning Unit*, found in the forestry handbook on DNR's intranet.

**Figure 4-2. Adaptive Management Process in the OESF**




Some steps in the adaptive management process are carried out by the Adaptive Management Advisory Group, Science Advisory Group, or DNR decision makers.

- The **Adaptive Management Advisory Group** includes Forest Resources assistant division managers, the Olympic Region state lands assistant and Coast District manager, and the OESF research and monitoring manager.
- Membership in the **Science Advisory Group** is not permanent; participating experts are carefully selected for each project based on their professional credentials in a particular subject area. Members include three scientific experts on the subject being reviewed and the OESF research and monitoring manager or a DNR scientist leading the study being discussed.

- **Decision makers** vary depending on the type and magnitude of the proposed changes to management and may include the Board of Natural Resources, members of DNR's executive management team, the Forest Resources Division Manager, and the Olympic Region Manager.

The roles and responsibilities of these groups will be explained briefly in the following steps. For a more complete explanation, refer to PR 14-004-530.

## ►Step 1, Identify Key Uncertainties


During development of this forest land plan and its environmental analysis, DNR compiled an initial list of key uncertainties about management of natural resources in the OESF and specifically about integration of revenue production and ecological values. Some uncertainties are broad in focus and date back to the HCP (DNR 1997); for example, the effectiveness of interior-core buffers to provide for riparian functions or the adequacy of northern spotted owl habitat thresholds in each landscape. Other uncertainties are more specific, for example the rate of tree regeneration in the small forest openings with high edge density created through variable retention harvest and variable density thinnings.

The list of key uncertainties, their relevance to DNR management objectives, and examples of research questions that are raised to help reduce key uncertainties can be found in the OESF Living Library on DNR's intranet. DNR expects the list to change over time as new knowledge is acquired or new uncertainties are identified. For example, uncertainties related to management of marbled murrelet habitat will be identified during development of the long-term marbled murrelet habitat conservation strategy. Going forward, updating key uncertainties will be the responsibility of the Adaptive Management Advisory Group.

The list of uncertainties is used in the prioritization process (Step 2 of the adaptive management process). DNR also provides the list to potential research partners and collaborators to guide the development of project-specific research questions and testable hypotheses.

Given the complexity of natural resource management in general and the experimental nature of the OESF management strategies in particular, the list of uncertainties can be very long. DNR restricted the list per the scope of adaptive management (described earlier in this chapter) and the geographic area (state trust lands in the OESF). The resulting key uncertainties are organized by 10 ecological themes (Table 4-1) which are inter-dependent.

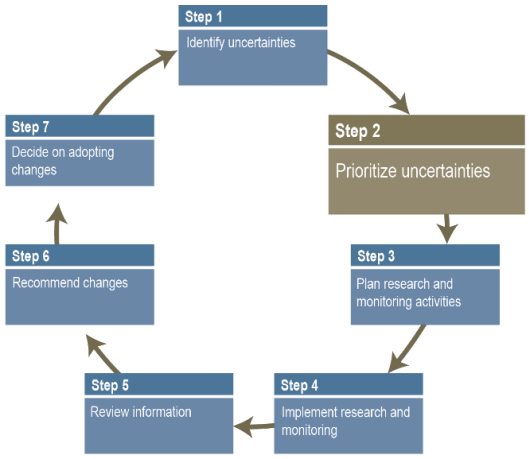
**Table 4-1. Themes Used to Organize Uncertainties**

| | Theme | Relevance to Management Improvement |
|---|---|---|
| 1 | Use of silviculture to integrate revenue production and ecological values | DNR uses silviculture to create and maintain a biologically diverse working forest to support revenue production and ecological values, including habitat for native species. Many aspects of DNR's planned silvicultural activities are untested. DNR could benefit from more information on how the forest may respond to these activities. |
| 2 | Use of remote sensing for inventory and environmental monitoring | New remote-sensing techniques (for example, light detection and ranging [LiDAR]) have been developed to assess site and forest conditions for planning, inventory, and monitoring purposes more completely and at a lower cost than traditional methods. DNR could benefit from increased understanding about the feasibility and best practices for these techniques, and the types of metrics that can be applied to the data collected. |
| 3 | Ecological effects of forest roads | Projects completed under road maintenance and abandonment plans, new road construction per the forest practices rules and the Forest Practices Board Manual, and other management practices are expected to minimize the delivery of fine sediment to streams. DNR will benefit from increased understanding of the ecological and cost effectiveness of these practices. |
| 4 | Ecological effects of endemic winds | Wind is major natural disturbance factor in the OESF. DNR will benefit from better understanding the influence of forest management on wind firmness, the threshold for severe endemic windthrow risk used in the OESF windthrow probability model, and how best to account for windthrow in tactical model projections. |

| | Theme | Relevance to Management Improvement |
|---|---|---|
| 5 | Management of unstable slopes and headwater streams | DNR defers potentially unstable slopes or landforms in its tactical model and makes decisions on whether or not to harvest in these areas on a case-by-case basis consistent with the forest practices rules. DNR will benefit from both improving the effectiveness of its screening tools to identify these areas, and investigating the possibility of managing these areas without increasing the frequency and severity of landslides. DNR also will benefit from a better understanding of how forest management affects headwater streams on stable ground, on which DNR does not apply an interior-core or exterior wind buffer, and of how management activities affect soils susceptible to compaction, displacement and erosion in these and other areas. |
| 6 | Measurable thresholds for ecological values | A key concept that underlies DNR's riparian conservation strategy is to "conserve habitat complexity as afforded by natural disturbance regimes on the western Olympic Peninsula." Under the northern spotted owl conservation strategy, DNR restores and maintains threshold proportions of Old and Young Forest Habitat in each landscape. Quantifying habitat complexity (for the former) and improving the habitat definition of Old Forest (for the latter) will improve DNR's ability to monitor these areas and ultimately attain conservation objectives. |
| 7 | Ecological processes in a working forest | A better understanding of ecological processes, such as the decay of snags and down wood, and ecological relationships such as fish and wildlife species habitat associations will allow DNR to better plan, model, and monitor forest management activities and practices for attainment of revenue and ecological objectives. |
| 8 | Fish and wildlife species' response to forest management | Assessing the response of fish and wildlife to forest management is the ultimate validation of the HCP conservation strategies and the assumption "if we build it they will come." |

| | Theme | Relevance to Management Improvement |
|---|---|---|
| 9 | Planning from a landscape perspective | Uncertainties exist around the landscape distribution of habitat (for example, the optimal spatial configuration of northern spotted owl habitat) and the economic feasibility of the spatial distribution of management activities (for example, effects of road costs on harvest scheduling). Increasing DNR's understanding of both could lead to more efficient and effective attainment of revenue and ecological objectives. |
| 10 | Climate change and carbon budget | The specific effect of climate change on forest growth, species composition, resiliency, and distribution are largely unknown but may impact the agency's ability to meets its revenue and ecological goals. A better understanding of these potential effects could help DNR prepare for climate change. |

## ►Step 2, Prioritize Uncertainties




The Adaptive Management Advisory Group prioritizes uncertainties for reduction per DNR's most relevant, pressing management needs using the prioritization criteria in Text Box 4-3. Prioritization helps DNR determine where to put efforts and resources first, and ensure an objective and transparent selection process. The prioritization process itself is described in the adaptive management procedure (PR 14-004-530, found in the forestry handbook). As uncertainties are prioritized, some may be dropped from consideration.

**Text Box 4-3. Prioritization Criteria**

1. **Linkage to future decisions**

   DNR will explore whether research and monitoring information gathered to reduce an uncertainty is likely to influence management decisions. Uncertainties that increase DNR's knowledge but have little or no relevance to management needs will be prioritized lower than those that are more relevant.

2. **Level of impact to revenue and conservation objectives**

   For this criterion, DNR will review the level of impact to revenue and ecological objectives associated with each uncertainty. The level of impact is a function of how severe the impact may be and how likely it is to occur. The level of impact can be quantified through sensitivity analyses of proposed management actions.

3. **The degree of uncertainty**

   DNR will evaluate the nature and degree of uncertainty about the ecological system in question through a combination of research synthesis and expert opinion. DNR also will consider the relevance of each uncertainty to the information needs specified in the monitoring and research sections of the HCP (p. V.1 through V.8) and the adaptive management section of the HCP Implementation Agreement (p. B.10 through B.11).

4. **Feasibility of getting answers in a reasonable time and at a reasonable cost**

   Whether an answer can be obtained in a reasonable time and at a reasonable cost depends on both the complexity of the ecological system and how long it may take that system to respond. Appropriate questions when applying this criterion are as follows: *Can cost-effective research and monitoring techniques be developed to reduce the uncertainty?* W*hat degree of rigor of research and monitoring is needed to influence future decisions, and can this rigor be achieved?*

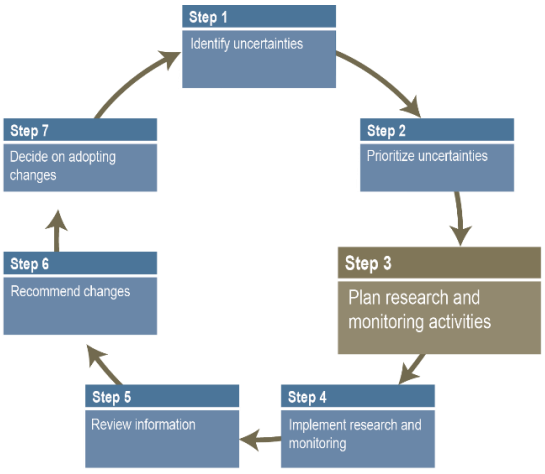
   Similar to Criteria 3 (degree of uncertainty), feasibility is best evaluated through expert opinion. Whether judgments are made qualitatively or quantitatively is less important than having those judgments explicitly stated (Failing and others 2004).

5. **Can research and monitoring conducted by different agencies and other sources be tapped?**

   Often, it is more efficient and cost-effective to gather information in collaboration with other researchers. If others are already addressing an uncertainty, it may become a priority for DNR. By working with others, DNR will have an opportunity to obtain the necessary information at lower cost, in a shorter time, or both. If others are already addressing a key uncertainty and reduction of that uncertainty can contribute to DNR's management needs, the priority rank of this uncertainty may be elevated. For example, DNR participates in a number of regional research cooperatives that address specific uncertainties related to tree spacing and growth rates, the climatic and edaphic controls on productivity, long-term sustainability, vegetative competition effects, and other topics that may contribute to reducing the uncertainties described for the OESF.

At this step, the Adaptive Management Advisory Group also discusses potential ways to reduce priority uncertainties; appropriate research and monitoring questions, similar to the examples in the key uncertainties list in the living library; key hypotheses to be tested; study approaches; and other issues. Scoping papers that outline the studies or brief project proposals may be submitted for consideration at this step.

## ►Step 3, Plan Research and Monitoring Activities

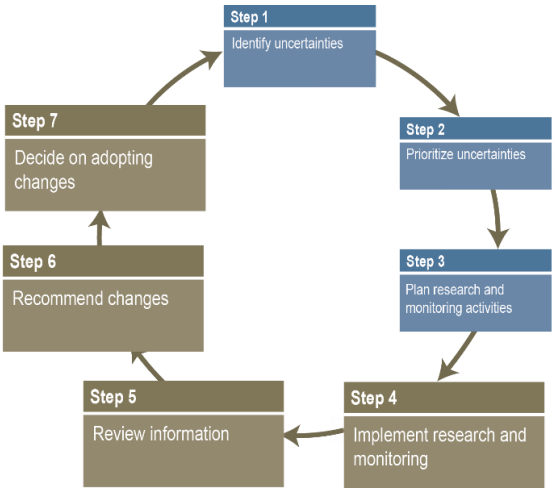



In this step, DNR develops specific research and monitoring projects to reduce the uncertainties prioritized in Step 2. Project planning starts with formulating specific research questions and developing a project proposal or scoping paper. Once DNR support for the project proposal is secured from decision makers, the principal investigator(s) develops a study plan which includes objectives, refined research questions, testable hypotheses, study design, field protocols, and analytical methods. The study plan also describes how results may inform future management

decisions. Selection of field sites requires involvement of managers at various levels depending on the size, location, and type of proposed treatments. As part of this step, DNR may consider the potential for external funding (through grants and research partnerships) and the opportunity for collaborative monitoring and data sharing.

DNR's Science Advisory Group(s) meets as needed to peer-review, and in some cases develop study plans.

## ►Step 4, Implement Research and Monitoring




In Step 4, DNR implements the research and monitoring projects developed in Step 3 or conducts those projects through research partnerships and other forms of collaboration. In most cases, research and monitoring projects and consideration of results by decision makers span more than one adaptive management cycle. This is especially true for ecological systems such as forests that change very slowly.

## ►Step 5, Review New Information

In Step 5, the Adaptive Management Advisory Group reviews and interprets research and monitoring findings from Step 4, as well as other scientifically-credible information from outside sources.

The Science Advisory Group(s) often peer-reviews externally-produced information and reports from DNR projects. Members of this group may be asked to explain results to the Adaptive Management Advisory Group.

At this step, external organizations may request a change in land management. The Adaptive Management Advisory Group considers these requests and may seek scientific review on them.

## ►Step 6, Recommend Adaptive Management Changes to Decision Makers

In Step 6, the Adaptive Management Advisory Group formulates adaptive management recommendations for DNR decision makers. The group bases their recommendations on the findings from Step 5 but also considers the economic and social consequences and operational feasibility of potential changes.

## ►Step 7, Make Decisions on Adaptive Management Changes and Implement

In this final step, decision makers decide whether to adopt proposed adaptive management changes. They may direct a specific management change to be implemented (which may be a modification of the recommended change), make an informed decision not to change current management practices, or request more information. Potential changes may include an update or amendment to a policy or planning document (for example, the HCP or the OESF forest land plan, respectively), new or updated procedures (such as those found in the Forestry Handbook), change in operational guidelines, new or updated training in natural resource management, or organizational changes. Some of these changes may require SEPA review, for example if a proposed change falls outside the range of alternatives analyzed in the environmental impact statement for this forest land plan. If management changes are adopted, DNR decision makers ensure DNR has the financial means and organizational structure to implement them.

Information is documented during all steps of the adaptive management process through meeting notes, recommendation reports, or other documents as needed. These documents will be stored in the OESF Living library.

# Research and Monitoring

A science-informed adaptive management process relies primarily on research and monitoring to provide new, relevant, and reliable information for increasing confidence in current management or developing new management options. The Federal Services identify research and monitoring as one of the key components of a meaningful adaptive management process (USFWS and NMFS 2000):

> [Key components include] careful planning through identification of uncertainty, incorporating a range of alternatives, implementing a sufficient monitoring program to determine success of the alternatives, and a feedback loop from the results of the monitoring program that allows for change in the management strategies.

If an HCP has an adaptive management provision, as it is the case with DNR's HCP, the Federal Services consider integrating the monitoring program into adaptive management as "crucial in order to guide any necessary changes in management" (USFWS and NMFS 2000).

## *Types of Monitoring*

Research and monitoring are both scientific activities that answer questions through systematic, objective, empirical testing of hypotheses. The difference between them lies in their goals:

- The primary goal of research is to acquire fundamental knowledge about natural phenomena and to develop innovative management practices.
- The primary goal of monitoring is to provide information about management operations (Wilhere and Bigley 2001).

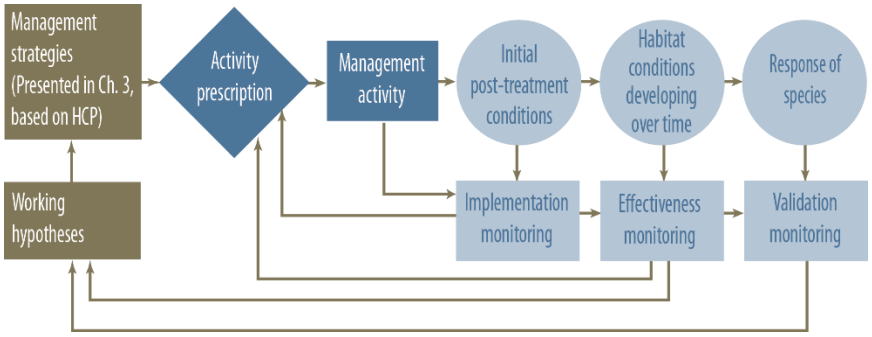
The HCP described three types of monitoring to be conducted in the OESF (DNR 1997, p. V. 3-5):

- **Implementation monitoring**, used to determine whether the HCP conservation strategies are implemented as written;
- **Effectiveness monitoring**, used to determine whether implementation of the conservation strategies results in anticipated habitat conditions; and
- **Validation monitoring,** used to evaluate cause-and-effect relationships between habitat conditions resulting from implementation of conservation strategies and the salmonid and northern spotted owl populations these strategies are intended to benefit.

Different types of monitoring involve different levels of complexity, and all three types are essential elements of an adaptive management program (Lindenmayer and Franklin 2002). Inferences made at a higher, more complex level (for example, effectiveness monitoring) depend on results at a lower level (implementation monitoring).

Figure 4-2 shows the relationship between the three types of monitoring and their effects on forest management.

**Figure 4-2. Relationship between Implementation, Effectiveness, and Validation Monitoring and Forest Management**
Modified From Wilhere and Bigley 2001




**Activity prescriptions** are written for **management activities** such as silvicultural treatments. Those prescriptions are based on management strategies (refer to Chapter 3), which are based on the conservation strategies in the HCP.

After a **management activity** has been conducted, DNR evaluates it through **implementation monitoring**. DNR determines whether or not the activity is implemented as described in the prescription, and whether the **initial post-treatment conditions** are in compliance with the requirements of the HCP. For example, DNR documents the number of leave trees remaining after harvest and the threshold proportions of northern spotted owl habitat remaining in the landscape.

Through **effectiveness monitoring**, DNR evaluates **habitat conditions developing over time** after a management activity or series of activities. For example, DNR monitors the rate at which stands treated with variable density thinning develop structural diversity. The results from both implementation and effectiveness monitoring are expected to inform the development of future management prescriptions.

Through **validation monitoring**, DNR evaluates the **response of species** to a management activity. For example, DNR may evaluate the change in species composition and survival of salmonids in response to variable retention harvests across a watershed. In this step, DNR utilizes information about habitat conditions collected through effectiveness

monitoring and information about species habitat needs. The results from validation monitoring support or reject DNR's **working hypotheses** and therefore also would inform the **management strategies** based on those hypotheses.

Categorizing monitoring by types helps to illustrate the scope and purpose of monitoring. However, these categories are not discrete; they can overlap. For example, the HCP does not distinguish status and trends monitoring as a separate category. Since the ultimate goal of tracking and evaluating long-term changes in habitat is to link such changes to the implemented management strategies, status and trends monitoring falls under the broader category of effectiveness monitoring.

## Near-Term Priority Research and Monitoring Projects

As of September 2016, DNR has identified the following research and monitoring projects and programs as high priorities in the near term (within the next five years). Topics are not listed in order of priority.

- Implementation monitoring
- Status and Trends Monitoring of Riparian and Aquatic Habitat in the OESF
- Silvicultural experimentation to develop structurally complex forests
- Cooperative silvicultural research
- Validation monitoring of the HCP riparian conservation strategy
- Long-Term Ecosystem Productivity Study
- Large-Scale Integrated Management Experiment

As DNR engages in a formal adaptive management process, the priority status of these projects will be evaluated annually and new projects likely will be added to the list.

Several of the projects described in this section, namely the Status and Trends Monitoring of Riparian and Aquatic Habitat project, silvicultural experimentation, and the Large Scale Integrated Management Experiment, help DNR meet its HCP commitment for effectiveness monitoring. DNR may consider other projects, for example the effectiveness of thinning to create or accelerate development of northern spotted owl habitat, as future priorities for effectiveness monitoring.

Following is a brief description of each project. Details and project documents are available on DNR's external website at

http://www.dnr.wa.gov/programs-and-services/forest-resources/olympic-experimental-forest/ongoing-research-and-monitoring.

## ►Implementation Monitoring

DNR conducts implementation monitoring on a sample of its forest management activities across state trust lands every year. The majority of this monitoring is done to satisfy the requirements of the HCP (DNR 1997, p. V.1-9). The focus of HCP implementation monitoring is primarily on timber harvest and road management activities. However, other forest and non-timber management activities that may affect the outcome of the conservation strategies also are subject to implementation monitoring. Examples include silvicultural activities such as site preparation, vegetation management, and pre-commercial thinning.

In addition to demonstrating compliance with the HCP, data from OESF implementation monitoring is needed for the following:

- **HCP effectiveness and validation monitoring and research.** Information on completed activities and the assessment of immediately resulting habitat conditions is used to characterize baseline ecological conditions and to conduct retrospective studies such as the effectiveness of exterior wind buffers.
- **Adaptive management.** Findings of non-compliance and their causes is used to continuously improve management.
- **Reruns of the tactical model.** Updates on completed activities and resulting ecological conditions will improve model input data.
- **Communication with DNR stakeholders and research partners.**
- **Other DNR programs such as forest certification.**

Past implementation monitoring projects (starting in 2001) have included northern spotted owl habitat maintenance treatments, management activities in wetlands and wetland management zones, riparian restoration treatments, and retention of large, structurally unique trees and snags (implementation monitoring reports are available on DNR's website at http://www.dnr.wa.gov/programs-and-services/forest-resources/habitat-conservation/monitoring-and-reporting).

Future implementation monitoring projects in the OESF likely will revisit previously monitored strategies, since past strategy compliance does not assure future compliance. Future implementation monitoring projects may include new management strategies because

implementation risk is elevated if staff are implementing something for the first time.

In the future, DNR may increase its use of remote sensing data (for example, LiDAR-derived datasets) and other datasets for office audits. More information on the implementation monitoring approach in the OESF and its organization and funding is provided in the OESF Living Library.

## ►Status and Trends Monitoring of Riparian and Aquatic Habitat in the OESF

Through this project, DNR documents how riparian and aquatic habitat conditions change across OESF over time as this forest land plan is implemented. In its environmental analysis for this forest land plan, DNR projected gradual improvement in riparian and aquatic conditions (DNR 2016). Monitoring allows DNR to test this projection with empirical data and help reduce key uncertainties about ecological relationships between in-stream, riparian, and upland areas. DNR uses monitoring data to characterize baseline habitat conditions and habitat variability, both of which are used in riparian validation monitoring (monitoring fish response in managed landscapes; refer to "Validation Monitoring for the HCP Riparian Conservation Strategy" later in this section). In addition to gathering data on the status and changes over time of multiple habitat indicators, DNR makes inferences about management effects on riparian and aquatic habitat across the OESF through an analytical approach called "model-based inference" (Burnham and Anderson 2002).

Following the 2012 study plan (Minkova and others 2012), long-term (at least 10 years) monitoring sites were established in 50 Type-3 watersheds representative of riparian conditions across the OESF. DNR is sampling seven aquatic habitat indicators (channel morphology, channel substrate, stream temperature, shade, discharge, in-stream large wood and habitat units such as pools or riffles) and two riparian habitat indicators (microclimate and riparian vegetation) at the outlet of each watershed. DNR is providing the majority of the funding and logistical support for the study. The USFS Pacific Northwest Research Station, a key collaborator on this project, is providing scientific expertise, field support, and additional funding.

## ►Silvicultural Experimentation to Develop Structurally Complex Forest

A major impetus for designating the OESF was to experiment with silvicultural techniques for integrating revenue production and ecological values. For example, DNR uses variable density thinning to create gaps in the forest canopy to increase structural diversity, and also uses pre-commercial thinning to bypass the structurally simple, "competitive exclusion" stand development stage and set the stand on a trajectory to develop elements of structural complexity such as more than one canopy layer (refer to Chapter 2 for more information). Both of these activities were meant to create and maintain a biologically diverse working forest that provides quality timber for harvest as well as habitat for native species, as described in Chapter 2.

Two ongoing research projects address uncertainties related to silviculture:

- **Mind the Gap: Developing Ecologically Based Guidelines for Creating Gaps in Forest Thinning on the Olympic Peninsula**: This study combines remote sensing and field data to better link silvicultural gap treatments with the late-successional forests they aim to emulate. The study is conducted in three phases: 1) a retrospective study of gaps created over 10 years ago, to understand ecosystem response; 2) an observational study of natural gap structures in primary mature and old-growth forests (primary forests are forests that developed after natural disturbance and have never been logged), to establish critical reference information; and 3) a replicated silvicultural experiment to test novel gap treatments (informed by the structures found in primary forests) within a variable density thinning treatment. Response variables include tree recruitment, understory vegetation response, branching and crown responses, decadence (dead wood) creation around edges, and post-treatment dynamics of gap contraction and expansion (for example, windthrow). Funding is provided by DNR.

- **Influence of Repeated Alternative Biodiversity Thinning Treatments on Coastal Forests:** This study evaluates the effects of repeated thinning on wood production and wildlife habitat. The stands included in the experiment was first thinned in 1999. Funding is provided by DNR.

## ►Cooperative Silvicultural Research

Two long-term studies conducted through DNR's participation in silvicultural research cooperatives (co-ops) have installations in the OESF. These two studies are replicated regionally and have broad management implications but also provide information relevant to specific OESF management questions. (For a description of research co-ops, refer to "Research Partnerships" later in this chapter.)

In the first study, the Stand Management Co-op (based at University of Washington) is investigating the performance of Douglas-fir in relation to a wide range of tree spacing and density levels. In relation to HCP objectives, the study is investigating crown and branch development, tree stability, and growth and yield in relation to tree spacing. Large treatment blocks in the OESF were planted at various spacings in the mid-1990s and study plots are re-measured every five years. This installation in the OESF is one of 47 installations, comprising over 550 permanent plots, scattered across the Pacific Northwest.

In the second study, the Hardwood Silviculture Co-op (based at Oregon State University) is investigating red alder establishment and growth in relation to spacing, thinning, and pruning at two locations. This study provides DNR with insights into managing stands for a diversity of tree species as an alternative to even-aged conifer stands. A diversity of tree species is expected to contribute to biodiversity in the OESF. The data from this study has been used to develop the first growth and yield model of plantation red alder and techniques for planting and managing red alder successfully. Study plots were installed in 1991 and 1996 and are re-measured at three to five year intervals. The study has been replicated at 26 locations on multiple ownerships across the Pacific Northwest.

Measurement responsibility for these two studies is shared between DNR and Co-op staff, while analysis is largely conducted by Co-op staff at their respective universities. Results are shared with DNR and often published in peer-reviewed literature (refer to "Research Partnerships" for more information on co-ops).

## ►Validation Monitoring for the HCP Riparian Conservation Strategy

Riparian validation monitoring, which is to occur only in the OESF, is an HCP commitment. Incomplete knowledge about the habitat needs of riparian and aquatic species, and specifically salmonid species, as well as their response to management, have been identified as key uncertainties.

Two riparian validation monitoring approaches (observational and experimental) are described in DNR's draft study plan (Martens in prep). Under the observational approach, management effects, habitat, and

salmonid conditions (for example, the abundance, biomass, species composition, age structure, and (or) number of spawning redds) are assessed over time within the 50 Type-3 watersheds selected for Status and Trends Monitoring of Riparian and Aquatic Habitat (described earlier in this section). The observational approach explores a potential range of management effects over much of the OESF, recognizing that salmonid conditions may be influenced by multiple factors (for example, ocean and freshwater harvest, climate change, and natural disturbances) that may confound the results. Under the experimental approach, treatment (management actions) and control sites are installed in a paired-basin design to evaluate the habitat and salmonid response to specific management actions over a limited area. Implementation of individual experimental studies depends on information gathered under the observational approach; the collected observational data is evaluated on a 6-year rotation.

DNR conducted a pilot fish survey in the 50 Type-3 watersheds used in the Status and Trends Monitoring of Riparian and Aquatic Habitat project in 2015 and started to implement the observational monitoring approach in 2016. Funding is provided by DNR. USFS Pacific Northwest Research Station, NOAA Fisheries, and the United States Geological Survey (USGS) are providing scientific expertise.

## ►Long-Term Ecosystem Productivity Study

The OESF is host to one of four replicates of the Long-Term Ecosystem Productivity Study (the other 3 are in Oregon), which is led by the USFS Pacific Northwest Research Station. This study evaluates the effects of different silvicultural treatments on long-term ecosystem productivity, including carbon dynamics, by measuring vegetation response and conducting soil analysis.

The OESF installation was established and treatments were implemented in 1996. Silvicultural treatments included clearcutting; leaving woody debris; thinning to accelerate late-seral stage forest development, favoring early-successional species; and planting monocultures of Douglas-fir. Post-treatment measurements and later re-measurements of the plots, included vegetation and soil sampling are ongoing. Funding is provided by DNR, USFS Pacific Northwest Research Station, and University of Washington.

### ►Large-Scale Integrated Management Experiment

DNR and the University of Washington's Olympic Natural Resources Center are developing a proposal to implement a long-term, landscape-level management experiment in the OESF to evaluate the ecological and economic feasibility of the integrated management approach. Researchers will compare a no-action control and integrated management applied at three different intensities across a selection of Type-3 watersheds: 1) Integrated management as represented by this forest land plan; 2) Integrated management that is less conservative (higher risk but potentially higher return) than represented in this forest land plan, with more intensive silvicultural activities in more managed areas within the watersheds selected for experimentation; and 3) Integrated management that is more conservative (lower risk with potentially lower return) than represented in this forest land plan, with more areas restricted from harvest within the watersheds selected for experimentation.

Response variables are derived from consideration of past and potential future management decisions and include ecological effects, economic returns, and assessment of operational feasibility. DNR and the University of Washington's Olympic Natural Resources Center envision participation of stakeholders at all stages of the study and multiple research partnerships. A detailed study plan will be developed and peer-reviewed after support for this proposal is secured.

## *Research Partnerships*

Because DNR has limited resources to dedicate to research and monitoring, successful implementation of its research and monitoring program relies on partnerships with other research institutions, organizations, and individuals who have relevant areas of expertise. Strong partnerships between DNR and other research institutions are expected to increase the visibility of OESF, attract external funding, and effectively implement research and monitoring studies that meet DNR's management needs and fulfill HCP commitments.

DNR has used different partnership models over the years ranging from contracts on specific projects to long-term cooperatives. Following is a description of two of these partnerships.

## ►Silvicultural Research Co-ops

DNR participates in several long-term, regional silvicultural research studies investigating forest stand development and dynamics with silvicultural research co-ops.

Co-ops are university-based organizations with a tenure-track professor hired as the director. They are funded through dues paid by the membership which typically represents most of the larger organizations managing forest land in the Pacific Northwest, including agency, industrial, and private owners. In most cases, field studies are installed on member lands. They are replicated on-site and regionally, thus providing a robust statistical design that spans a wide range of environmental conditions. Measurement responsibility is generally shared between members and co-op staff, while analysis is largely conducted by co-op staff at their respective universities. Results are shared with members and often published in peer-reviewed literature.

Co-op studies improve DNR's understanding of the fundamental growth dynamics of trees in relation to growing space and other considerations. Such knowledge will better enable DNR to devise new silvicultural approaches, for example ways to create the complex stand structures that define northern spotted owl habitat. Furthermore, the growth models developed in these types of studies better enable DNR to forecast future stand development, a necessary part of planning.

## ►National Experimental Forest and Range Network

In 2009, the OESF joined the Experimental Forest and Range Network. This national network includes 70 experimental forests and ranges, and is coordinated by USFS to encourage data-sharing and to promote collaborative research. Participation in the network provides DNR the opportunity to increase visibility for the OESF within the nationwide research community, access scientific expertise and science leadership provided by the Pacific Northwest Research Station, participate in other research and data-sharing networks, and benefit from the technology transfer being done in the network.

# Operational Trials Program

With adoption of this forest land plan, DNR implemented a new program of operational trials in the OESF. Operational trials are ideas proposed by DNR staff that explore new operational techniques or methods within the context of current management strategies. For example, these trials may involve new yarding techniques, new logging methods, or new ways to meet typical logging contract requirements such as avoiding damage to leave trees. Some trials may explore ways to make restoration thinnings, such as those proposed to create or accelerate northern spotted owl habitat development, more operationally and economically feasible. Ideas for operational trials could be sparked by experience, trade shows, conferences of professional organizations, articles, or other interactions and opportunities.

Operational trails are meant to be agile, implemented in a short time frame and typically small in scale (such as an individual timber sale). They are meant to provide DNR staff the opportunity and space to innovate and are well suited to DNR's mission of intentional learning. Outputs from this program may include basic white papers or other simple reports that are distributed throughout DNR.

Operational trials are linked to the research and monitoring program in the following ways:

- All operational trials are included in DNR's research and monitoring database, which is available through the OESF Living Library on DNR's intranet.
- Depending on the geographic scale and/or potential impacts of the proposed operational trial, it may be elevated to a formal research project with a study plan, in which case it would be implemented through the research and monitoring program, not as an operational trial.
- A completed operational trial may result in findings that warrant more formal scientific exploration, in which case the operational trial may be elevated to a formal research study with a study plan.

# Communication and Outreach and Information Management

Communication and outreach and information management are critical components of the research and monitoring program in the OESF and affect the overall success of the adaptive management process. The HCP considered them as key processes for implementing integrated management (DNR 1997 p. IV. 85). These topics are covered in Chapter 2 of this forest land plan.

# Planning for Success

While developing the adaptive management process, the adaptive management procedure, and the structure of the OESF research and monitoring program, DNR drew upon lessons learned from past efforts, the successes and challenges faced by other regional land managers, and review of the best available science on adaptive management of natural resources. In 2015, DNR organized an adaptive management workshop and invited practitioners from state, federal, and private organizations in the Pacific Northwest to share their experience in implementing adaptive management and promoting practices for successful implementation. The results of these efforts are summarized in two white papers available in the OESF Living Library on DNR's intranet.

What has emerged from this assessment is a clear understanding of both the challenges DNR is likely to face in implementing the OESF adaptive management process and the ways to meet those challenges: a robust research and monitoring program with clearly defined and prioritized uncertainties linked to land management needs, a well-established administrative structure, and an institutionalized, step-by-step adaptive management process. DNR's recent accomplishments in these areas build confidence in the future of adaptive management in the OESF.

[1] When an activity raises threats of harm to the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context, the proponent of an activity, rather than the public, should bear the burden of proof (Science and Environmental Health Network 2000).