A LANDSCAPE SYNTHESIS FRAMEWORK FOR THE CEDAR RIVER WATERSHED HABITAT CONSERVATION PLAN

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EXECUTIVE SUMMARY

This Synthesis Framework document provides a landscape-level approach to planning restoration under the Cedar River Watershed (CRW) Habitat Conservation Plan (HCP). It is designed to work in coordination with the three Restoration Strategic Plans (Aquatic, Riparian, and Upland Forest), the Transportation Strategic Asset Management Plan, the Watershed Characterization Strategic Plan, and the Monitoring and Research Strategic Plan to provide guidance for planning and implementing restoration, protection, and conservation projects over the 50-year term of the HCP.

Our overarching goal in the CRW is to use both restoration and protection to have a future watershed that produces high-quality drinking water; contains high-quality, well connected habitats for species of concern under the HCP; supports natural levels of biodiversity characteristic of healthy ecosystems; is resilient in the face of the changing nature of risks and threats in the regional environment; and is managed with improved knowledge and effectiveness over time through the practice of adaptive management.

The five specific goals of the Synthesis Framework are to 1) develop a landscape template to guide conservation and restoration of key ecosystems, communities, and species at all spatial and temporal scales; 2) define pathways to ensure the landscape template is incorporated into strategic plans; 3) design a method to gain synergistic benefit with interventions (i.e., ensure the greatest ecological benefit for the investment); 4) define a process to coordinate projects; and 5) inform design and evaluation of projects to improve performance over time.

The landscape template is not intended to be a static portrait of a future landscape, but rather uses ecological concepts along with a physical map to guide actions that will shape the future landscape and its functional capacity. The first component of the template specifies that four key, interdependent, ecological concepts (ecosystem resilience, natural processes that create and maintain habitat patches, natural biodiversity, and landscape habitat connectivity) be considered by strategic and project planning teams when selecting potential restoration sites. The second component articulates a set of desired, ideal conditions for specific elements in the watershed over the very long term to be used in development of site-specific desired future conditions.

The final component of the template is a set of GIS map layers that will be used to make an initial (coarse filter) selection of areas for restoration or other management activities. In addition to base map layers such as roads, streams, and topography, we created a *synergy layer* that combined three habitat elements: 1) key fish habitat, 2) habitat connectivity for amphibians and for species dependent on late-successional forest, and 3) areas adjacent to special ecosystem elements such as meadows and talus. Each habitat element was given a different weight based on the total number of species that utilize the habitat and the number that are considered at risk. We then created a model that emphasized overlaps between different habitat types and gave the greatest weight to fish habitat, areas adjacent to forests containing late-successional habitat, and corridors connecting existing late-successional forest patches and certain aquatic habitats.

We also created a number of *special consideration* map layers that address risks, threats, or other considerations (e.g., the probability of cultural resources, the road decommissioning plan, etc.)

Using all of these template components in combination allows strategic and restoration project teams to develop desired future conditions over the short and medium terms and to locate and prioritize restoration projects to gain the greatest synergistic benefit. The desired future conditions are addressed in the individual Restoration Strategic Plans, and final project site locations will be decided by project teams within the prioritization framework. Because all teams will be using this same coarse filter approach provided by the template, it will be easier for projects to be coordinated in space and time, when appropriate.

The asset management approach used by Seattle Public Utilities requires that we meet certain environmental service levels at the lowest life cycle cost. This concept meshes well with adaptive management, an approach we will use whenever there is significant uncertainty about the outcome of a restoration technique or action. Adaptive management is a scientific approach in which a clear description of expected outcomes (based on stated hypotheses) is articulated prior to project implementation, the project is monitored in a carefully constructed design to test the key hypotheses and determine outcomes, results are analyzed and evaluated, and actions are adjusted in the future, if appropriate, in response to monitoring results. Implementing adaptive management, along with an annual evaluation process, will help to ensure that future projects are designed to increase the chances of the best possible outcome.

1.0 PURPOSE AND ORGANIZATION OF SYNTHESIS FRAMEWORK

Consistent with commitments in the Cedar River Watershed (CRW) Habitat Conservation Plan (HCP), the intent of the Cedar River Watershed Restoration Synthesis Framework (Synthesis Framework) is to provide an overall, landscape-level approach to planning restoration in an integrated fashion to most efficiently and effectively achieve the goals of the HCP. The Synthesis Framework is intended to be used by Seattle Public Utilities (SPU) in conjunction with the Aquatic, Riparian, and Upland Forest Restoration strategic plans and the Transportation Strategic Asset Management Plan (covering roads) for planning restoration activities, and with the Strategic Monitoring and Research Plan for creating an intentional learning approach to restoration over time (Figure 1).

The specific goals of the Synthesis Framework are to:

1. Develop and articulate a *landscape template* (or vision) for the watershed to guide the conservation and restoration of key ecosystems, communities, and species at all scales, and to serve as a benchmark for planning and evaluation;

2. Define pathways to incorporate the elements of the landscape template into strategic plans and strategic planning, and to ensure that specific *desired future conditions* (DFCs) are established consistent with those elements;

3. Gain *synergistic benefit* among restoration strategies and projects (i.e., the greatest ecological benefits for the overall investment);

4. Define organizational processes for *coordination of projects* among restoration and management programs for best overall results, manageability, and cost effectiveness; and

5. Inform *design and evaluation* of restoration projects collectively to improve performance over time through implementation of appropriate research, monitoring, and adaptive management that addresses risks, threats, and uncertainties.

The Synthesis Framework specifies a process to effectively implement ecosystem restoration under the HCP that is linked to the restoration strategic plans for upland forests, riparian areas, and aquatic habitats, and to the strategic plan for research and monitoring. The remainder of this document describes:

? Goals of the HCP that are relevant to the Synthesis Framework (Section 2);

? An overall philosophy of restoration as practiced under the HCP (Section 3);

? Development of a three-part landscape template for how implementation of the HCP could change the watershed in pursuit of HCP goals for the watershed (Section 4);

? Use of the template for landscape level planning and linkages of the Synthesis Framework to other strategic plans (Section 5);

? Discussion of key concepts used in strategic planning (Section 6); and

? A periodic organizational process for evaluation and planning of the restoration program that will meet the goals of the Synthesis Framework and strategic plans by facilitating learning, producing short-term action plans, and providing feedback to strategic plans (Section 7).

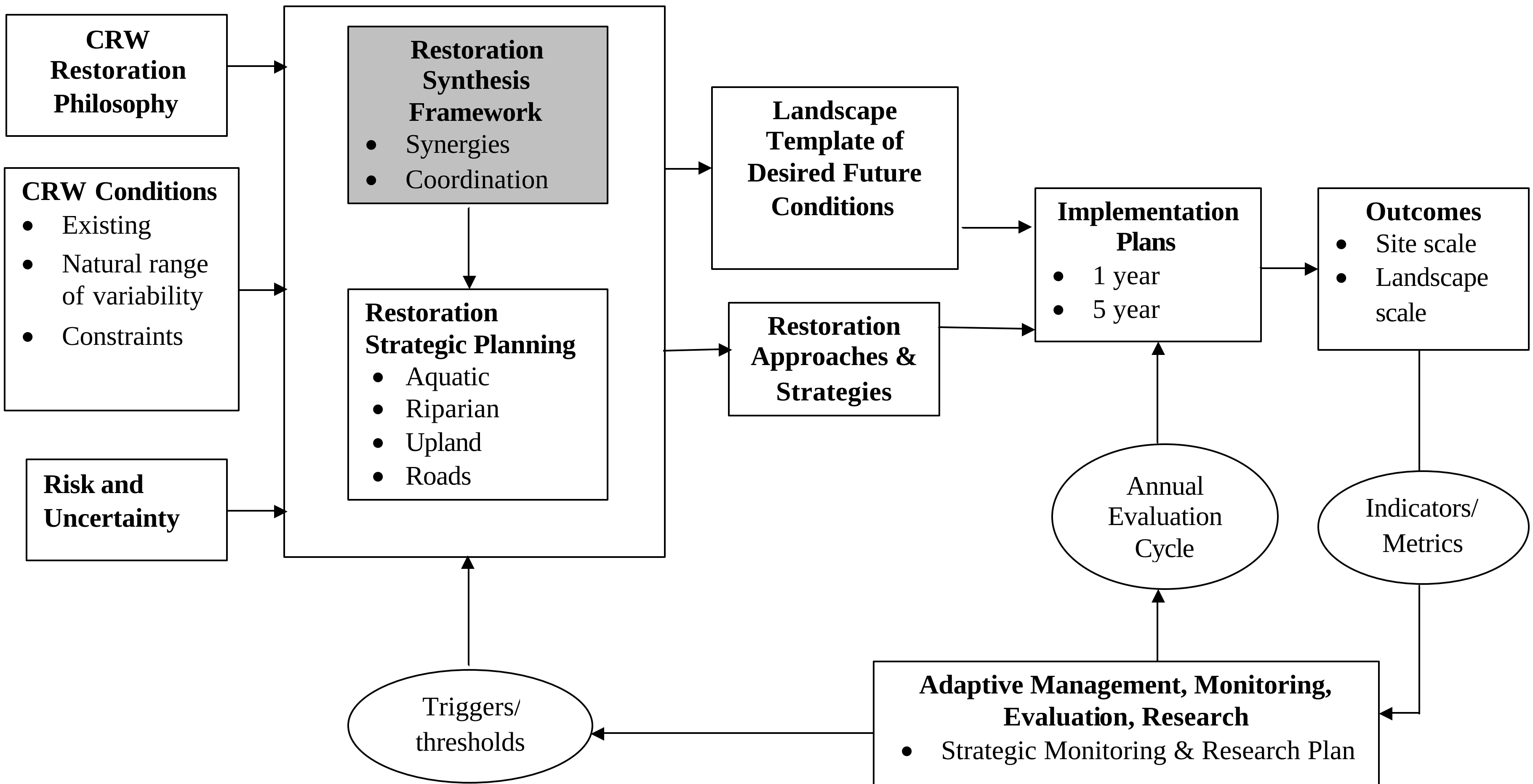

Figure 1. Flow diagram showing how Restoration Synthesis Framework is related to other components in implementing the CRW HCP.

2.0 RELEVANT GOALS OF THE HCP

The HCP provides a full discussion of goals for, and commitments to, various conservation measures, including different kinds of habitat restoration and adaptive management. More specific goals and objectives for different types of restoration can also be found in the respective strategic restoration plans for upland forests, riparian areas, and aquatic habitats. A high-level summary of goals in the HCP pertinent to the Synthesis Framework is given below.

2.1 Protecting and restoring ecosystems

- Protect and improve water quality
- Accelerate the development of old-growth forest habitat conditions and the natural functioning of riparian forests that have previously been logged, reduce sediment loading to streams from watershed roads, and restore natural habitat complexity in aquatic systems
- Improve landscape connectivity for and among aquatic, riparian, and upland habitats
- Manage to reduce the risk of catastrophic events such as forest fires that could jeopardize drinking water or habitats for at-risk species
- Develop strategies to protect and restore biodiversity, contribute to the maintenance of natural biodiversity in the region, protect special habitats and old-growth forest, and sustain natural processes and small- to moderate-scale disturbances that create and maintain habitats for at-risk species

2.2 Integrating restoration over space and time

- Prioritize, coordinate, phase, and integrate restoration projects over time to most effectively and cost-effectively achieve restoration objectives

2.3 Intentional learning

- Develop an overall strategy for monitoring and research at different scales of space and time that fosters the most effective use of resources to achieve HCP objectives, demonstrates the degree to which these objectives are being achieved, and facilitates learning and improvement in performance over time.

3.0 OVERALL PHILOSOPHY OF RESTORATION

The Cedar River Watershed Restoration Philosophy document (Chapin et al. 2005) provides a comprehensive discussion of the manner in which the term “restoration” is being used in implementing the HCP, describes elements of the philosophy, and includes specific recommendations related to watershed management. It defines ecosystem restoration and management in the CRW as

> *"…a strategy that attempts to repair the composition, structure, processes, and/or function of human-disturbed ecosystems. To the extent possible, we seek to maintain them as self-sustaining natural systems that are integrated with current ecological landscapes and land use and that eventually require minimal human intervention. In the short-term, we also seek to provide "bridging steps" – restoration actions that will provide ecosystem functions directly until natural processes become self-sustaining." (Chapin et al. 2005)*

This philosophy guides the Synthesis Framework, the restoration strategic plans, and the Strategic Monitoring and Research Plan. We are using the concept "restoration" very generally, as constrained by SPU's purpose and function to supply drinking water. Depending on the particular situation in the watershed, restoration may vary from trying to redevelop conditions similar to those prior to human disturbance (activities that are consistent with the strictest definition of the term) to trying only to redevelop some degree of the functional capacity of some components of ecosystems. In some cases, we may be substituting elements to achieve that functionality, such as providing drainage infrastructure that ameliorates the disrupting influences of roads on hydrology. Finally, restoration activities are being planned in recognition of threats and expected changes – including climate change; invasive, non-native plants; risks of catastrophic forest fires; and surrounding land use and development – that could influence the choice of desired future conditions or strategies to develop resilient, sustainable ecological communities in the future.

4.0 LANDSCAPE TEMPLATE FOR WATERSHED RESTORATION

The vision for the watershed derives from the goals expressed in Section 2. We are seeking to use the combined tools of restoration and protection to have a watershed in the future that produces high-quality drinking water; contains high-quality, well connected habitats for species of concern; supports natural levels of biodiversity characteristic of healthy ecosystems; is resilient in the face of the changing nature of risks and threats in the regional environment; and is managed with improved knowledge and effectiveness over time through the practices of adaptive management and intentional learning.

This vision is being pursued by the development of a three-part landscape template for watershed restoration and management that has two conceptual components and one map-based component. The three components of the landscape template are intended to provide guidance for long-term restoration planning and adaptive management at the watershed scale. The landscape template is not a static portrait of the exact components of a future landscape, but rather a conceptual and physical map to guide actions that will shape that future landscape by focusing on areas and approaches that are most likely to result in the achievement of the goals of the HCP. The three parts of the landscape template are:

1. Four *key, interdependent, ecological attributes of the watershed* most relevant to conditions that will support the HCP goals and protection of the region's primary water supply, include:

a. Ecosystem resilience;
b. The existence of regimes of natural disturbances and processes that create and maintain habitat for species of concern at different spatial and temporal scales;
c. Natural biodiversity and ecological sustainability; and
d. Landscape connectivity.

2. Statements regarding the *ideal condition of specific elements of the watershed* in the very long term that represent an optimistic view of the potential for restoration.

3. A set of *map layers representing a number of key themes*, with guidance for their use, that is used to make an initial (coarse filter) selection of areas for restoration or other management activities in a manner that focuses attention on areas of the watershed with the greatest potential for restoration and/or the greatest need for amelioration of risks and threats.

The three subsections below (4.1, 4.2, and 4.3) provide explanations of the above three parts of the landscape template.

4.1 Key Ecological Attributes at the Watershed Scale

Our template for watershed restoration in the CRW is necessarily framed by our conceptual understanding of how native ecosystems are structured and how they function with respect to anthropogenic and natural disturbances. Current ecological science recognizes the dynamic character of ecosystems, which makes any static picture of future conditions unrealistic (Buffington et al. 2003). This recognition is made even more important because the environment is changing, probably dramatically, in response to climate change (e.g., see Lovejoy and Hannah 2005); land development around the watershed will likely increase; and populations of invasive, alien species are likely to increase in numbers and kinds (Mooney et al. 2005). To incorporate current scientific understanding of ecological processes into the vision for the future for the CRW, we have identified four interdependent ecological attributes that provide a conceptual foundation for more explicit descriptions of DFCs:

4.1.1 Ecosystem resilience.

When key native species are lost, new species invade, or human-caused disturbances alter a system beyond its natural range of variability, ecosystems can change dramatically, no longer providing the same ecological services (e.g., late successional habitat) (Estes and Duggins 1995, Vitousek and Walker 1989). Ecosystem resilience is defined as the amount of disturbance a system can absorb and still remain within the same state (Holling 1973, 1996). The concept includes the ability of an ecosystem to reorganize and renew itself following change, thereby preventing dramatic shifts to undesirable states (Elmquist et al. 2003). Biological diversity and ecological redundancy (where numerous species or species groups fulfill the same function) play a substantial role in ecosystem resilience (Peterson et al. 1998). Given the context of the CRW in a developed and developing region and in a changing regional climate, ongoing and future impacts on the watershed's ecosystems will not be limited solely to those from natural disturbances experienced historically. Impacts will also include more subtle and/or unprecedented effects, likely including changing precipitation and temperature patterns; a loss of habitat connectivity and permeability between the watershed and some of its adjacent lands as a result of land use changes; increased risks of forest fire associated with increased development around the watershed and a warmer climate; and ongoing and novel threats from invasive alien species.

Our vision for the CRW includes ecosystems that are resilient in the face of the effects of a wide range of disturbance types – direct and indirect – resulting from human activities, both local and global. Given the unpredictability of many future disturbances and conditions, a management approach most likely to be successful will be one that focuses more on trajectories of ecosystem change, reestablishing the natural range of variability, and increasing species diversity than on specific conditions. Managing for resilience by maintaining and enhancing biodiversity and ecological redundancy is a recommended strategy to cope with uncertainty and surprise (Folke et al. 2002).

4.1.2. Natural disturbance regimes and processes.

A range of natural disturbances is inherent to all native ecosystems and is often necessary for creating and maintaining the structure, function, and processes characteristic of healthy ecosystems (Perera et al. 2004). Anthropogenic disturbances, on the other hand, are usually of different type, frequency, severity, and spatial pattern than natural disturbances and can either create a very homogeneous habitat or cause the characteristics of an ecosystem to exceed their natural ranges of variability. Although catastrophic disturbance, such as stand-replacing fire, is in conflict with the primary use of the CRW as a municipal water supply, retaining small- to mid-scale natural disturbances is an essential component of our vision for the watershed. Our operations and activities will be conducted in a manner that minimizes adverse ecological effects of anthropogenic disturbances and that complements, mimics, and supports those small- to mid-scale natural disturbances that are most important to ecological function and the development and maintenance of natural biodiversity (see also Section 6.2).

4.1.3. Natural biodiversity and sustainability.

Although we likely will never be able to recreate pre-settlement conditions in the CRW, even if that were desired, the previous complexity and diversity of native ecosystems in the watershed informs selection of the necessary elements for restoring overall ecosystem integrity and functionality, and for increasing the probability that the watershed will be resilient in the face of adverse changes in the regional environment. Our vision for the CRW includes ecosystem complexity, structural diversity, and biodiversity approaching – to the extent feasible – levels that existed prior to wide-scale human disturbance, but tempered by new knowledge of how regional changes in climate, land use, invasive species, and other factors are affecting and may affect ecological communities. The guiding hypothesis is that ecosystems with more natural levels of complexity and biodiversity are more likely to be sustainable in the long-term (Lovejoy and Hannah 2005), absent research that suggests a modification of that hypothesis.

4.1.4. Habitat connectivity.

As a result of fragmentation of late-successional and old-growth habitat caused by prior land-use activities and the construction of forest roads during those activities, restoring connectivity among patches of remaining, high quality habitat at appropriate scales is critical to maintaining and restoring viable populations of native organisms dependent on late-successional conditions (Lehmkuhl and Ruggiero 1991, Rochelle et al. 1999) and healthy conditions for aquatic habitats. Permeability through unsuitable or less suitable habitats is an important aspect of maintaining connectivity among patches of high quality habitat, as is consideration of adjacent land use and habitat conditions on that land. In addition, connectivity within aquatic systems has been compromised by artificial barriers within streams, and connections among aquatic, riparian, and upland forest habitat has been degraded by past management. Our vision for the CRW entails enhancing habitat connectivity and permeability for numerous species at a wide range of spatial and temporal scales in aquatic, riparian, and upland habitats.

4.2 Ideal Conditions of Specific Elements of the Watershed and its Management

We are attempting to engage in watershed restoration that will establish a direction of change that will lead, over the very long term (for example, over the next century), to an ideal set of conditions in the watershed. We see these conditions as including both the condition of the environment (physical and biological) and the state of our operational activities (i.e., the way we conduct business). When used in conjunction with an understanding of the key ecological attributes of the watershed (Section 4.1) and thematic map layers (Section 4.3), articulation of these ideal long-term conditions will enable us to develop an objective set of DFCs for the short term (0-10 years) and middle term (10-50 years) that can both guide our restoration work and allow us to measure our progress.

4.2.1 Ideal physical and biological conditions

Water Supply

- Maintain a reliable, high quality municipal water supply

Roads

- Maintain the minimal road system needed to support management and protection of the watershed, with minimal new roads constructed
- Eliminate existing roads in old-growth forest, wetlands, riparian corridors, areas with high mass wasting hazard potential, and in other sensitive habitats unless essential to watershed management, and construct no new roads within these habitats
- If new roads are required, build in less sensitive habitats with minimal adverse impact on forest soils and aquatic habitats
- Manage the road system to have minimal hydrologic connectivity of roads with the aquatic network resulting in minimal road-generated fine sediment delivering to the aquatic system
- Experience no road-associated (triggered) mass wasting events

Streams

- Have sediment, wood loading, and large woody debris (LWD) recruitment to all streams within the natural range of variation for late-successional riparian forests

- Have no human-made barrier to fish or peak storm flows in any stream except the Landsburg Diversion Dam, Masonry Dam, and Overflow Dike, and have minimal human-made barriers to passing sediment and organic debris in any stream

- Foster natural processes key to channel and floodplain formation and maintenance (e.g., flooding, sediment storage and sorting, bank and bed stability, floodplain connectivity, channel migration) within the natural range of variability

- Have natural flow paths and hydrologic regimes in all unregulated streams

- Have an assemblage of aquatic benthic invertebrates within the natural range of variability for undisturbed forested watersheds

- Have a natural fluvial disturbance regime influencing successional processes in riparian forests

Forests

- Have a forested landscape dominated by late-successional or old-growth conditions (absent large-scale natural disturbances), including natural diversity of forest structure and composition (including snags and down wood) supporting a full complement of plant, animal, and fungal species characteristic of late-seral forest in the watershed

- Have no areas of habitat that act as barriers to the movement of species of concern, either horizontally or with respect to elevation, other than those inherent to the habitat type

- Have minimal residual effects of past land use that are not related to current operations, including habitat permeability related to roads, unnatural forest edges, and unnatural species composition as a result of past logging

- Have a mix of conifer and deciduous trees across the landscape, within the natural range of variability, that best supports the species of concern in the HCP

- Have forest conditions that do not pose an unnaturally high risk of extensive forest fires, taking into account changes in fire risk as a function of climate change and the development of surrounding land

- Have minimal impact from watershed management activities on processes critical to the formation and maintenance of soil structure, biota, and biogeochemistry

- Have riparian forests consisting of deciduous, conifer, and mixed deciduous-conifer stands in proportions within the natural range of variability

Climate Change

- Have sufficient natural diversity of plant, animal, and fungal species, especially near existing ecotones, to enable shifts in distribution in response to climate change

4.2.2 Ideal operational conditions

- Have minimum impacts of operations on water quality
- Have minimal need for subsidies to habitat development, such as LWD placement, thinning, planting, snag creation, and down wood creation
- Have operational activities that minimize introduction, establishment, and spread of invasive, alien plants (or other alien organisms)
- Prevent introduction of new invasive plant species to the watershed and reduce existing invasive plant populations to levels that are ecologically insignificant and controllable in a cost-effective manner
- Within constraints of watershed management, have operational activities that minimize impacts to species of concern and disruption of ecosystem function (e.g., timing operations to avoid critical seasons, such as breeding, nesting, and rearing)
- Have operations conducted in a manner that minimizes soil compaction, anthropogenic mass-wasting events, erosion, sediment delivery to water bodies, and risk of forest fire
- Have transparent and effective stakeholder involvement programs, resulting in open communications and trust
- Have an effective program for evaluating effectiveness of restoration activities at different scales of space and time, using results of evaluation in planning and decisions, and communicating the results of evaluation to management and stakeholders
- Produce the best overall ecological result for the investment over the long term

4.2.3 Linkages

- Design and implement restoration, monitoring, and research programs that create synergies at both program and project levels where spatial and functional connectivity permits
- Conduct management in a manner that strategically addresses major risks, threats, and uncertainties, and that results in intentional learning and improvement over time.

4.3 Spatial Areas of Focus (Thematic Map Layers)

Ultimately, planning watershed restoration work and other management interventions requires the selection of specific areas for specific actions, and, conversely, the identification of other areas for which no intervention is likely appropriate. We have developed a three-tiered approach to selecting areas for management intervention:

1. An initial, coarse, landscape-scale selection of general areas of high synergy that is based solely on spatial position on the landscape;

2. The selection of an area for potential interventions within the broad high-synergy areas identified by the first step of site selection. This second step includes an evaluation of habitat conditions (i.e., the need for restoration or other action in particular areas as a result of degraded conditions) and the likelihood that interventions would produce a desired effect; and

3. The selection of a specific project site or sites with the area identified in the second step, along with specific strategies for management intervention at those sites.

The first step in this approach is encompassed by the Synthesis Framework, and is described below. The second step is described in the respective strategic restoration plans, which also provide guidance for development of specific projects (the third step). The linkages between the first and second steps are described below in Section 5 and in the respective strategic restoration plans. The third step is accomplished largely by interdisciplinary project teams, following guidance in the applicable strategic plans. It should be noted that management interventions may occur for the purpose of restoration or for the purpose of ameliorating risks and addressing threats, such as the potential for a large forest fire or spread of invasive, alien species.

To guide the initial selection of areas at the watershed scale (the first step in site selection) we developed a number of *thematic map layers*. Each thematic map layer represents a specific, high-priority theme that will guide initial selection of areas for specific kinds of intervention (e.g., forest or stream restoration, or reduction of forest fuels). The layers will also be used together to identify areas where synergies among types of intervention might be possible and most beneficial if planned in an integrated manner. For example, *ceteris paribus*, a thinning project that will benefit fish, amphibians, and upland species of concern would have greater overall benefit than one that would benefit only a few upland species.

We developed two sets of GIS maps. The first displays the thematic layers that guide restoration project site location. The second is a map of special considerations that contains additional information that may need to be considered during restoration project planning or that guide specific actions to address threats (e.g., risk of forest fire). The thematic layers combined with numerous base map layers will function as GIS tools for ID and project teams to utilize during both the project site selection and the planning process. The tools will not only focus projects in areas that will provide the greatest synergistic benefit, but also allow staff to select an area of potential interest and examine all of the variables that could influence project planning and implementation. The components of the GIS tools are described below.

4.3.1 Base map layers

The base map layers contain numerous GIS data that are useful for planning. They include topography (displayed using a LiDAR-derived hillshade representation), tree heights (a derived LiDAR product), distribution of deciduous and conifer trees (derived from the MASTER remote sensing dataset), locations of past forest thinning, all water bodies (i.e., lakes, ponds, rivers, streams, wetlands), and all existing and historical roads. The location and extent of the road system is important in general for planning restoration and specifically for identifying risks and threats to habitats. Roads have potential negative effects on habitats and species through fragmentation, creation of edges, creation of barriers to dispersal, and delivery of fine sediment to water bodies in excess of natural levels. Planning restoration work with spatial reference to the location and status of roads can help identify roads in most need of removal or improvement. In addition, it will aid in developing strategies for habitat restoration that encompass the existence of core roads that will remain in the landscape after the road decommissioning program is complete.

The base layers also include special ecosystem elements or special habitats (Appendix A). The landscape-level restoration strategy builds upon the existence in the landscape of areas either with high inherent biodiversity or with unique or important species (i.e., biodiversity hotspots). The basic ideas are that restoration should build upon this inherent framework of existing or potential biodiversity and that this approach will provide the greatest benefits to species of concern under the HCP. This existing framework includes two elements: areas with inherently high levels of natural biodiversity (alpha diversity), such as old-growth forest, wetlands, and other aquatic habitats, and areas that contribute to landscape-level biodiversity (beta diversity), such as special habitats listed in the HCP (talus and felsenmeer slopes, rock outcrops, cliffs, meadows, and persistent herb-shrub communities). Identifying habitats with high inherent biodiversity or that contribute to landscape-level biodiversity will ensure that they are considered and protected during project planning, as well as monitored for on-going threats (e.g., invasive species – see section 4.3.3). Planning restoration work in proximity to these areas should contribute to the goal of maintaining and enhancing natural biodiversity on a landscape basis by providing higher quality dispersal and other habitat for those species utilizing multiple habitat types (see section 4.3.2) (Hunter 1999).

4.3.2 Thematic map layers guiding intervention for restoration

Three themes were developed to guide the selection at a watershed scale of areas for potential restoration. See Appendix A for a complete description of each theme.

Fish Habitat

The *Fish Habitat* layer identifies habitat for a group of species of great importance to society and of concern under the HCP. We identified and mapped areas of current use by Chinook and coho salmon, steelhead trout, and bull trout (current habitat), as well as areas that could be used by those species if all artificial blockages were removed (potential habitat). Chinook salmon, steelhead trout, and bull trout are listed as Threatened under the Endangered Species Act (ESA) and, along with coho salmon, are identified as Species of Greatest Concern in the HCP. This layer delineates areas where aquatic restoration would have the most direct benefit for these species, should habitat conditions warrant intervention. Improving aquatic habitats for these species also generally dovetails with improving water quality for drinking. In addition, restoration of riparian areas adjacent to water bodies used by these fish species should benefit the fish in the longer term (e.g., by providing future recruitment of LWD, shade, and food inputs).

Habitat Connectivity
The *Habitat Connectivity* layers identify and map two types of habitat connectivity:

(1) Connecting patches of forest having late-successional or old-growth habitat conditions. The HCP identifies 23 wildlife species of concern directly associated with late-successional and old-growth forest communities that should directly benefit from connecting these habitat patches.

(2) Connecting complexes of aquatic, riparian, and upland areas most likely to be important for amphibians in the watershed. Fourteen species of amphibians are listed in the HCP as species of concern, many of which require a wide range of habitats to complete their life cycles. These species integrate several ecological processes and functions across habitat types, and many species may be at risk in portions of their range. As such, they are an ideal group of species to target for habitat improvement.

Habitat Adjacent to Special Ecosystem Elements
Finally, *Habitat Adjacent to Special Ecosystem Elements* targets habitat for numerous species that utilize not only the habitat within the biological hotspot, but also the adjacent forest. Increasing the complexity and diversity of habitat within forest adjacent to a biodiversity hotspot will benefit not only those species living within the forest, but also species that utilize a combination of habitats (e.g., meadows, wetlands, and forests). Examples include numerous small mammal, bird, bat, and carnivore species, 52 of which are listed as species of concern in the HCP and are in some way associated with late-successional upland or riparian forest habitat. Most restoration will emphasize linkages between biodiversity hotspots or between a hotspot and its neighboring habitat.

4.3.3 Development of the synergy map layer

Once all three themes were mapped, we created a synergy layer that combined all of the elements into a single GIS coverage (see Appendix A for a complete description of the procedure we used to develop this map layer). We developed and evaluated several synergy models based on the amount of overlap between the theme layers and a weighting applied to each contributing habitat element. The habitat elements used for each theme were:

- *Fish Habitat* – areas of streams with current and potential fish use, low gradient response reaches

- *Habitat Connectivity* – areas between depressional wetlands (amphibian connectivity) and between forest corridors (late-successional forest habitat connectivity)

- *Areas Adjacent to Special Ecosystem Elements* – areas near rock (talus, cliffs, rock outcrops), meadows, persistent herb-shrub communities, non-depressional wetlands, and late-successional forest habitat.

Each habitat element was given a different weight based on the total number of species that utilize the habitat and the number that are considered at risk. The various models evaluated contained different combinations of overlaps and habitat weighting.

We then chose the model that emphasized overlaps between different habitat types and gave the greatest weight to fish habitat, areas adjacent to forests containing late-successional habitat, and the corridors connecting existing late-successional forest patches. This model will be used by strategic and restoration teams to locate and prioritize areas for potential restoration projects.

4.3.4 Use of the synergy map layer to prioritize and coordinate restoration projects

The overlay of different theme layers in the synergy map provided a basis to identify “synergy areas”, which were the areas having the highest weighted scores of the three themes. Five such sites were identified (Map 1):

1. Upper Cedar River basin & north ridge
2. Lower Cedar River basin & lower Rex River basin above CML
3. Upper Rex River basin
4. Lost Creek & Taylor highlands
5. Lower Cedar River mainstem & tributaries

These areas and sites can be used as foci for prioritizing restoration projects from different restoration programs. In addition, the synergy areas can be used to coordinate with other programs (including road decommissioning), avoid conflicts among project types within a given area, and to guide the collection and analysis of information to better inform future coordination.

At this planning stage, the team considered it premature to identify and sequence specific projects or even project types. Instead, project types in each synergy area were given priority rankings based on our understanding of current conditions and habitat utilization as they relate to objectives for each project type (Table 1). For example, Stream/Riparian projects were given a high near-term priority ranking based on the current use and importance of habitat within these synergy areas for three species of concern (Chinook and coho salmon and bull trout). Long-term sequencing will be done as data become available. A framework for implementing the synergy layer and integrating it with the restoration strategic plans was also developed (Figure 2).

Table 1: Relative near-term priority for initiating project types within synergy areas.

Project Types	Synergy Area				
	Upper Cedar River Basin and North Ridge	***Lower Cedar and Rex River Basin above CML***	***Upper Rex River Basin***	***Lost Creek & Taylor Highlands***	***Lower Cedar River Mainstem and Tribs***
Stream/Riparian	M	H	L	L	H
Peak flow/fish passage	L	M	L_{Qpk}	L_{Qpk}	H
Wetland/riparian	H	L	H	H	M
Ecological Thinning	L	H	L	H	M
Restoration Thinning	H	L	M	H	L
Road Decom.	Variable	Variable	Variable	Variable	Variable

Priority code: H = High; M = Medium; L = Low. Road decommissioning work is considered variable since the prioritization of roads will be strongly influenced by restoration objectives associated with each project type.
Q_{pk} - Low ranking is associated with peak flow projects only. All fish passage projects are assumed high priority and ranked based on criteria developed in the Aquatic Restoration Strategic Plan.

The Implementation Framework includes both near-term restoration priorities and a longer-term approach to refining priorities. The elements of the implementation plan include:

(a) design/implementation of near-term restoration projects in known high priority areas;

(b) data collection and analysis; and

(c) fine-scale prioritization by project type for long-term restoration planning.

Since data are lacking (especially on upland forest conditions) in many high-synergy areas, it is not currently possible to sequence all restoration activities among program areas to achieve the best synergy. Consequently, long-term sequencing will be done as data become available.

Near-term priorities by project type in synergy areas

Near-term priorities for each project type were identified by the different restoration program ID teams. Where linkages are strong among restoration programs and/or project types, projects will be coordinated to achieve the highest synergy in the near-term. Where linkages are weaker among restoration programs and/or project types, restoration projects will be designed and implemented where they are most ecologically beneficial within the high synergy areas. Overlap of moderate to high priority restoration actions for different project types within an area shows where synergy is likely to be achieved, while also realizing relatively high ecological benefit. While opportunities for synergy among many project-types certainly exist within high-synergy areas, additional information on current conditions is necessary before prioritization among all project-types can be attempted.

Data collection in synergy areas to inform priorities

To prioritize restoration areas and treatments within high synergy areas, relatively detailed information is needed that is not currently available. Data collection and analysis for each program area and project type can be focused within the synergy areas to provide a much greater efficiency in these efforts.

The data collection, analysis, and prioritization efforts in high synergy areas will be guided by the Aquatic, Riparian, and Upland Restoration strategic plans. The level of detail should be appropriate to determine specific project locations, type of restoration work to be implemented, and opportunities for synergy with other restoration program/project types in those synergy areas. If the analyses have been conducted in the high synergy areas and the restoration opportunities are limited (and do not meet minimum HCP commitments), then analysis and prioritization of lower-ranked, non synergy areas will be necessary.

Information necessary for prioritizing roads for decommissioning and improvement is also important. Each restoration program can help to prioritize road segments for decommissioning based on relevant concerns (listed below). This information will be needed within the Transportation Strategic Asset Management Plan and will help ensure that resource objectives and needs are embedded in the road decision process.

- Stream issues from roads – Fine sediment delivery (sub-basin-scale and segment-specific)
- Wetland issues from roads – fragmentation, sediment delivery, and disruption of hydrology
- Riparian – encroachment, disturbance
- Late successional forest habitat fragmentation
- High priority roads needed for access to forest, riparian, and aquatic restoration areas, which will be based on application of criteria from restoration strategic plans.

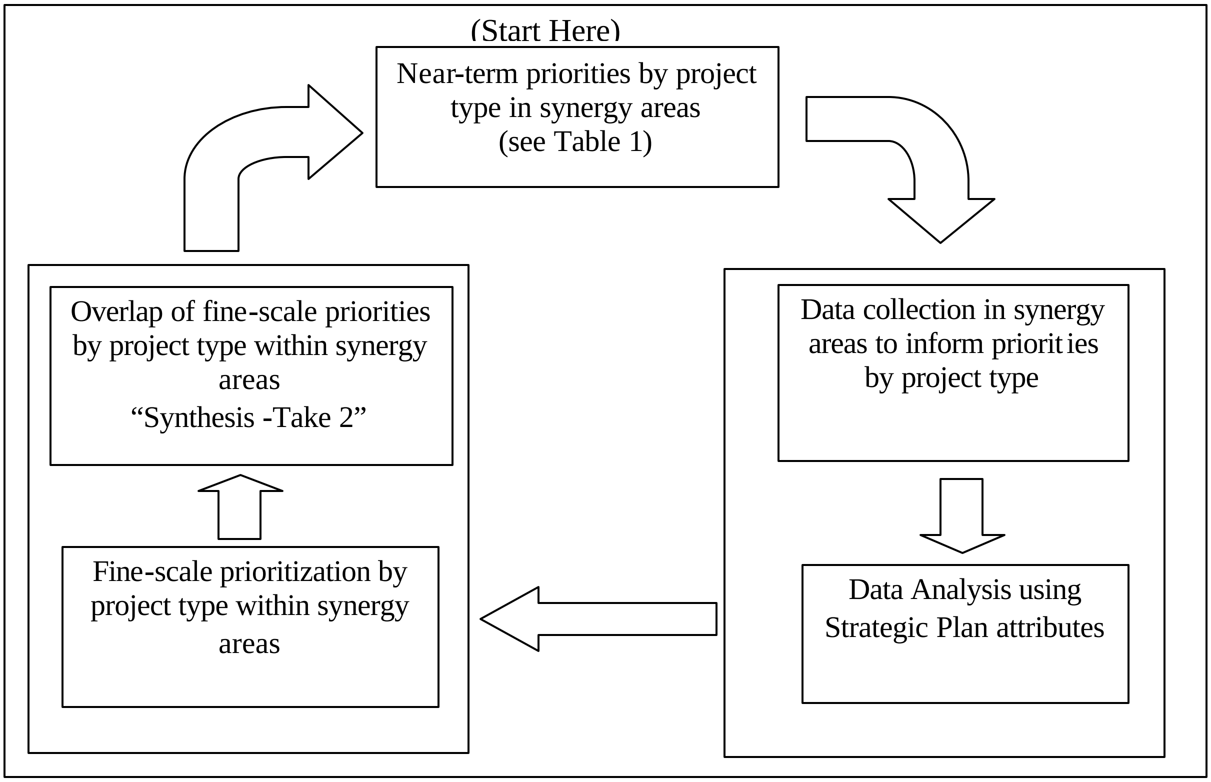

Figure 2. A framework for long-term implementation of the synergy layer for project prioritization.

Refined prioritization within high synergy areas
The data for different restoration program areas would then be used to prioritize restoration locations within synergy areas for different project types. These finer scale prioritizations would be compiled to produce the best synergy at the highest resolution in spatial scale. The compilation of the fine-scale priorities by restoration project type would occur in an interdisciplinary process, which might be called "Synthesis - Take 2."

4.3.5 Map layers addressing special considerations

A vulnerability assessment was conducted in response to a workshop focusing on the development of a watershed template held August 10, 2005, with Dr. David L. Peterson. The results of this workshop were used as a starting place to develop a list of special considerations – issues that project managers should take into account when planning specific projects. Table 2 describes the special considerations along with details about why they require special attention for the watershed. Once an individual project location is selected using the landscape template (including the synthesis layer), project planners should look to the special considerations table for specific concerns that they need to take into account when planning project details. We provide recommendations for intervention and strategies to ameliorate any threats associated with the special considerations. A thematic map layer was created for each of the areas of vulnerability (see map layers column in Table 2). These layers will be used in conjunction with one another to identify those areas on the landscape at greatest risk. Several of the key special considerations are discussed in more detail below.

Cultural Resources Probability

All ground disturbing projects must consider the probability of cultural resources occurring within the project area and be conducted consistent with the Cultural Resources Management Plan for the Cedar River Municipal Watershed (2008). If that probability is high, the project may be relocated to another site to avoid any risk of damaging cultural resources. If the proposed project site cannot feasibly be relocated, cultural resources surveys may be conducted by trained archaeologists to determine the extent of resources present on the site. If any cultural resources are found, those specific areas within the project site will then be avoided.

Road Decommissioning

A key factor that must be considered when planning projects is the road decommissioning schedule. While all road decommissioning and improvement work has been assessed and approved by work group leaders through the 2008 field season, it is important for project managers to also evaluate planned road work and coordinate projects with operations and other SPU staff. As work on the Transportation Strategic Asset Management Plan progresses, dialogue between road and ecosystem restoration ID teams will be critical to the early identification and resolution of potential conflicts between respective work plans.

In addition to identifying access conflicts, project teams might also develop additional road improvement strategies within specific project sites. These strategies would address potential road impacts that adversely affect key restoration objectives. Appendix D summarizes our assumptions about the extent to which current road conditions are contributing to degradation of vulnerable habitats. Some projects may be designed specifically to reduce the vulnerability of critical habitats (e.g., old-growth forest, wetlands, meadows, streams) to threats or risks. Examples include the risk of invasive species infesting special habitats and the effect of forest roads on sediment delivery into streams.

Table 2: Areas of special consideration, source of threat or risk, and strategy and rationale for interventions within the Cedar River Watershed.

Area of special consideration	Source of Risk/Threat	Intervention Strategy and Rationale	Relevant Map Layers
Probability of cultural resources	Disturbance could damage or destroy cultural resources	Review cultural resources probability map layer and consult Public Programs manager prior to any ground disturbing activity. If project is proposed in a high probability location, conduct cultural resources surveys prior to initiating the project.	Map 2. Areas of Special Consideration: Cultural resources probability.
High priority roads based on assessment of adverse impact to Upland, Riparian and Aquatic Restoration Objectives.	Risk of delivery of road-generated fine sediment to vulnerable adjacent streams; traffic use on roads through old growth stands and roads which bisect special habitats (talus or wetlands); roads on unstable hillslopes and which encroach on riparian zones also potentially pose a risk.	Road decommissioning or improvements which address the direct delivery of road runoff to streams; reduce traffic on roads through vulnerable habitats; road realignment to allow for establishment of riparian vegetation within 200 feet of specific stream reaches; decommissioning or full bench construction of roads on unstable slopes; additional culverts to promote restoration of natural flow paths on roads within 600 feet of vulnerable wetlands.	Map 3. Areas of Special Consideration: Roads with Adverse Effects.
Old-growth forest edges	Risk of edge creep from wind damage where old-growth patches are adjacent to recent clear-cuts (small trees)	Silvicultural intervention near the edges of existing patches of old growth can increase the growth of adjacent trees, reduce the degree of wind exposure, and reduce edge creep.	Map 4. Areas of Special Consideration: Wind Vulnerability.

Area of special consideration	Source of Risk/Threat	Intervention Strategy and Rationale	Relevant Map Layers
Old-growth forest patches	Risk of fire spread from nearby young forests with high fuel loading	Silvicultural intervention and fuels reduction near the edges of existing patches of old growth can reduce the chance of a fire spreading into the patch from nearby young forests with high fuel loading	Map 5. Areas of Special Consideration: Fire Vulnerability: Primary Forest.
Forest edges near development	Risk of fire ignition by humans or spread of invasive plants from residential areas	Increased patrols, surveys for invasive plants, reduction of fuels near residential developments, and education of nearby residents can reduce the risk of fire ignition by humans and spread of invasive plants or fire into the watershed	Map 6. Areas of Special Consideration: Proximity to development
Special habitats (e.g., wetlands, meadows, and ponds)	Effects of forest roads on hydrology, sediment delivery, and species movement, and the risk of spread of invasive plants along roads	Selective thinning and planting will encourage development of appropriate species that can better maintain or restore natural functions of wetlands, meadows, and ponds where past land use poses a risk to key functions, such as hydrology and community development. Controlling invasive plant species along roads can prevent spread into special habitats, and removal of roads next to special habitats can reduce impacts of those roads.	Map 7. Areas of Special Consideration: Special habitats.
Ecotones between major forest zones and between forest and parkland zones	Lack of species diversity that could provide sources of propagules near ecotones that could shift in response to climate change	Thinning and planting to restore natural levels of biodiversity at ecotones between major forest zones and between forest and parkland zones – areas with marginal conditions for many species – will increase the likelihood that plant (and animal) communities can adapt	Map 8: Areas of Special Consideration: Ecotone edge.

Area of special consideration	Source of Risk/Threat	Intervention Strategy and Rationale	Relevant Map Layers
		to expected changes in climate and consequent elevation shifts in those ecotones by providing sources of propagules.	
Inner gorges above critical habitat for anadromous fish and bull trout	Risk of landslides from poor road drainage, over-steepened road fill, or reductions in root strength related to tree removal.	Appropriate silvicultural intervention and road management within inner gorges, areas of relatively high instability immediately adjacent to critical habitat, will reduce the risk likelihood that past and present management activities will trigger landslides which have a high likelihood of delivering to critical fish habitat.	Map 9: Areas of Special Consideration: Inner gorge.
Low gradient fish habitat strongly affected by inputs of sediment and large woody debris (Geomorphic Map Units 8-10, 12-16, as described in the Aquatic Strategic Restoration Plan)	Large inputs of fine and course sediment from roads or mass wasting events. Reductions in large woody debris as a result of historic timber harvest, current riparian stand conditions, or stream adjacent roads.	Reduce road generated (fine and coarse) sediment delivery via implementation of road BMPs or road decommissioning. Address immediate threats to habitat resulting from low levels of functioning LWD through LWD Replacement Projects. Where Riparian Recruitment processes are impaired, riparian underplanting, conifer thinning, road decommissioning, or road relocation may be considered.	Map 10. Areas of Special Consideration: Anadromous Fish Habitat.

Fire Hazard

A fire hazard assessment of the Cedar River Watershed was completed in January, 2007 (Johnson et al. 2007). The results showed that fire hazard varies across the landscape, but the majority of areas in the watershed would be expected to have one of the two classes of surface fire (CS and S in Fig 3), with a relatively small proportion of the watershed at risk of a crown fire (A and P in Fig. 3). We have chosen to not use fire hazard as one of the elements that guides where we locate restoration projects (see section 6.2.2 and Appendix C for a more complete discussion of the use of fire as a landscape template); instead, fire hazard will be one of the special considerations used for refining prescriptions and deciding where to do surface fuel treatment in accordance with a plan under development. It should be noted that, due to the proximity of the youngest forests to old growth, high fire hazard areas do tend to correspond to areas of high synergy, because adjacency to old-growth forest was one of the criteria used in developing the synergy layer (see section 4.3.3 and Appendix A). As a special consideration, fire hazard rank will guide surface fuel treatment. Surface fuel treatment should be prioritized in areas adjacent to old forest where the model predicts that fuel treatment will yield a reduction in fire hazard rank.

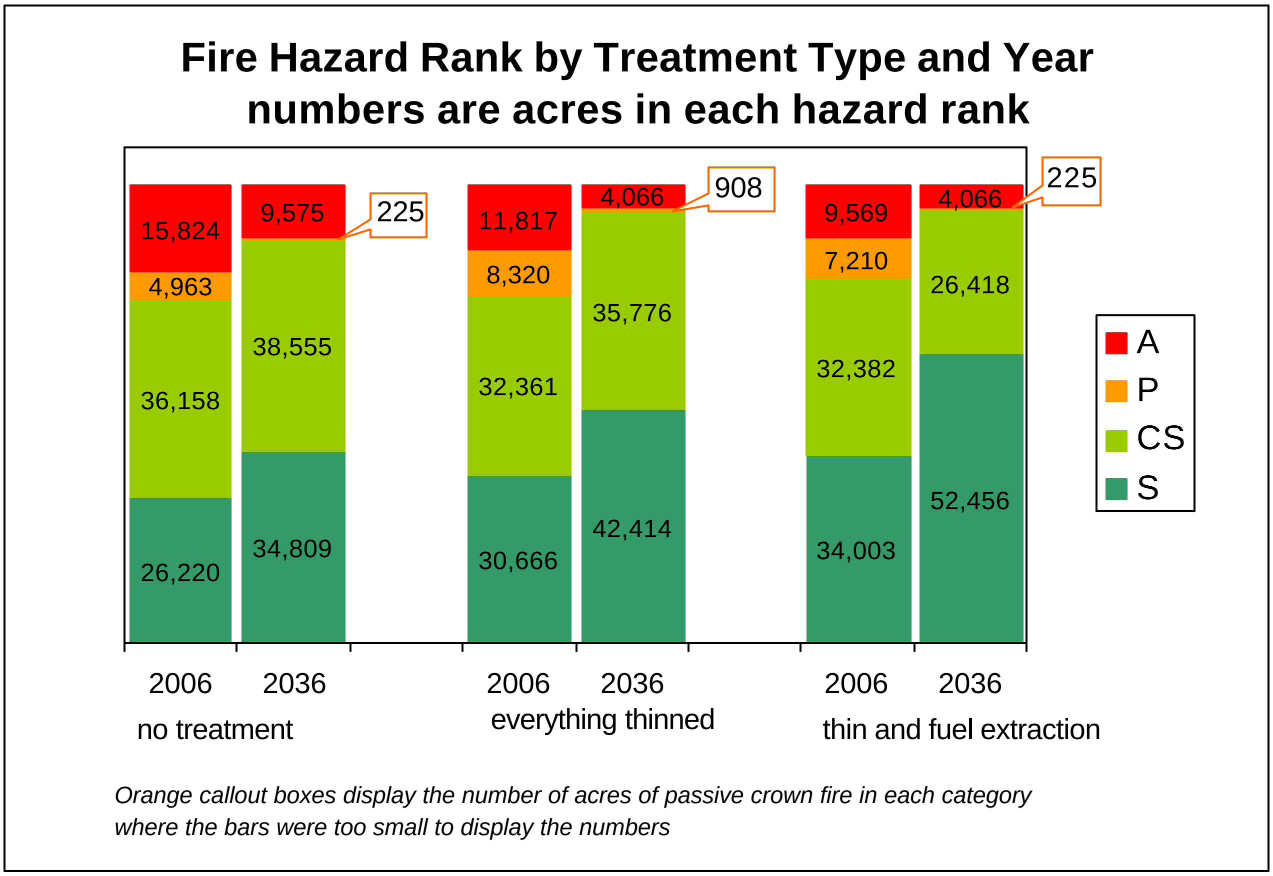

Figure 3: Acres of the watershed by fire hazard rank under different treatments and timeframes. A = Active crown fire, P = Passive crown fire, CS = Conditional surface fire, S = Surface fire

5.0 INTEGRATION OF THE LANDSCAPE TEMPLATE WITH STRATEGIC PLANS

As described above, we will follow a three-step process in selecting sites for management intervention (Figure 4), the first step of which is encompassed by the Synthesis Framework. The *first step* of the three-step process of site selection was accomplished by creation of a GIS tool that contains the different thematic GIS layers, including the synergy layer, described above in subsections 4.3.2 and 4.3.3. These GIS layers guide site selection for restoration and threat-reduction projects, to areas where intervention might achieve the highest level of synergistic benefit. The results of using this GIS tool to identify areas of focus for intervention serve as the starting point for step two in the process, as described below. At some time in the future, it may be necessary to repeat this first step to update the recommendations in response to new information, a change in assumptions, or other factors.

The key ecological attributes (Section 4.1) will serve as unifying concepts for overall planning and implementation of restoration, constituting a qualitative, conceptual screen for evaluating plans for, and outcomes of, restoration activities and management interventions to ameliorate risks and address threats. We intend that our management activities will be consistent with the statements regarding these ecological attributes, and the application of these four principles will be evaluated as part of the annual review process (Section 7).

The set of ideal conditions for specific watershed elements (Section 4.2) is being used largely to implement each of the three strategic restoration plans (aquatic, riparian, and upland) by facilitating the development of desired future conditions (DFCs) for different time frames from near-term to the end of the HCP (HCP year 50) that are consistent with expected responses to intervention, the schedule of activities, and resources available. These DFCs, based on the set of long-term ideal conditions, are described in the respective strategic restoration plans. The DFCs will serve as benchmarks to judge progress in achieving the goals of the HCP, the Synthesis Framework, and the strategic plans. A tabular matrix of how these ideal conditions will be handled in the restoration strategic plans is included in Appendix B.

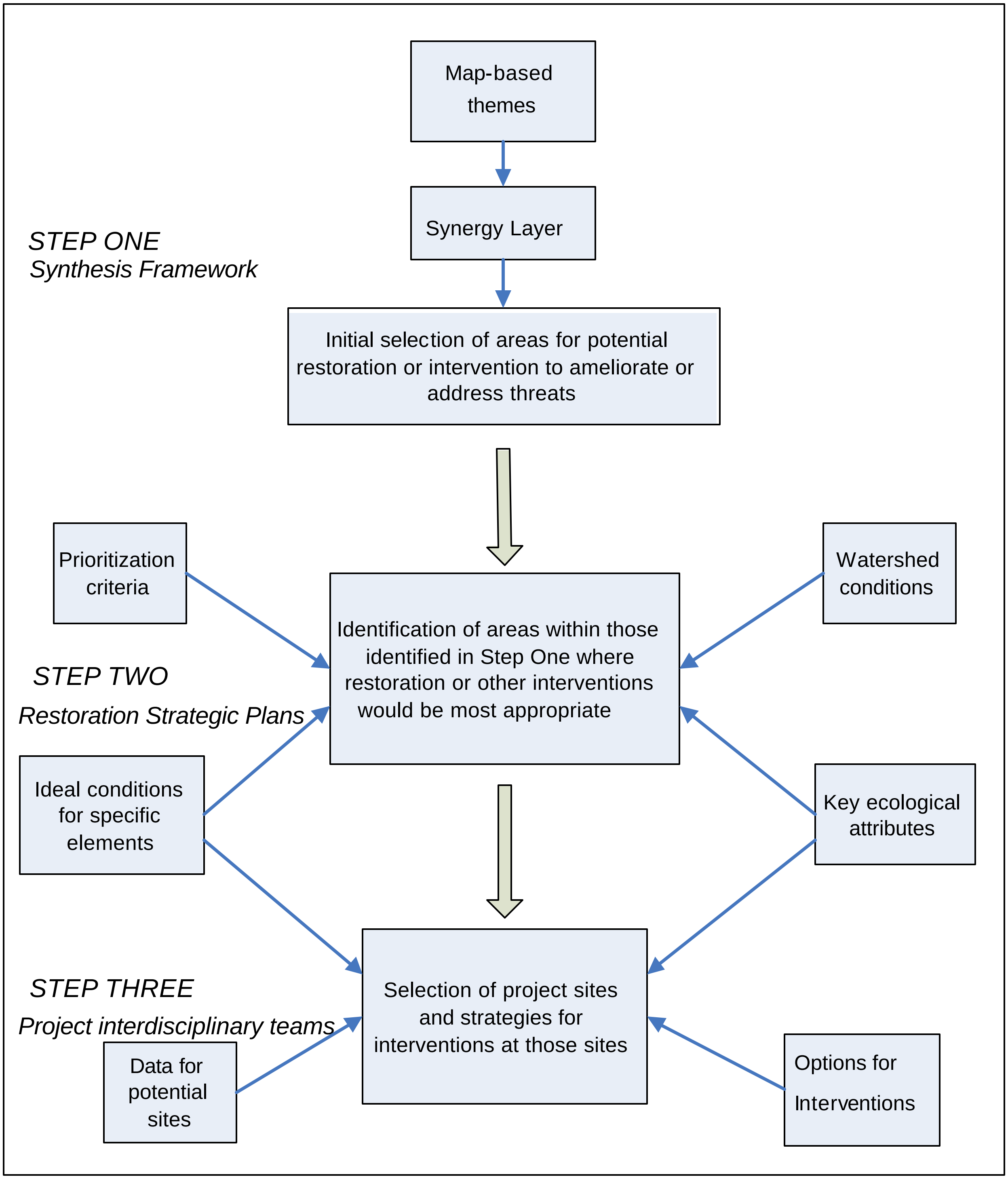

Figure 4. The three-step process for selection of sites for management intervention

The *second step* will be accomplished by applying the prioritization criteria from each strategic restoration plan (aquatic, riparian, and upland) to the areas selected in the first step using an assessment of watershed conditions relevant to that plan and additional analyses as prescribed in the strategic plans. The intent is to select specifc areas for potential restoration or other intervention that:

? Are in need of restoration (i.e., are in degraded condition) or other intervention (i.e., pose a significant threat);

? Will likely respond to restoration techniques, and

? Have spatial locations that would result in a significant benefit of restoration or intervention in terms of landscape-level ecological functions or threats.

The second step will be accomplished initially after the completion of the three restoration strategic plans, will be incorporated as an ongoing activity within the annual planning cycle, and will be revisited as more and better data are developed with regard to habitat conditions.

The *third step* will be accomplished by interdisciplinary project teams, who will choose specific sites and restoration or risk-management strategies for those sites from the areas identified in the second step. In some cases, single project sites may be identified, but in other cases a strategy may be designed that includes multiple, small-scale interventions at a variety of sites within the area identified in step two.

During planning, project sites may be identified that are not within areas identified in the first two steps described above. Restoration or other intervention on these sites will be done only if a strong case can be made that a greater overall benefit is likely to be produced. In other words, selection of project sites outside the three-step process will be done only if a convincing rationale can be developed for doing so. Any decisions of this kind will be documented in the Annual Evaluation and Learning Report (Section 7). A decision of this type will trigger an evaluation of the Synthesis Framework and appropriate restoration strategic plan, in order to determine whether the assumptions or rationales in the plans need to be revisited.

A number of other important features of our strategic planning approach that are not captured in the brief descriptions above are described in Section 6.

6.0 OTHER MAJOR FEATURES OF STRATEGIC PLANNING

In addition to the approach described above for selecting areas for restoration, our strategic planning approach includes a number of important concepts, which are briefly described below. These concepts include the commitment by SPU to principles of asset management; the need to address natural and anthropogenic disturbances and natural processes that occur at the watershed scale; evaluation and adaptive management; and information management. As described below, these concepts are addressed in the restoration strategic plans and the monitoring and research strategic plan, as appropriate.

6.1 Asset Management Framework Applied to Natural Resources

6.1.1. Asset management in SPU

As practiced by SPU, "Asset Management is the meeting of agreed customer and environmental service levels at the lowest life cycle costs." SPU has been systematically applying this new paradigm throughout the utility to the development, operation, maintenance, and replacement of its infrastructure. In our strategic planning under the HCP, we have tried to incorporate asset management principles into the overall restoration program, attempting to combine this systematic approach to managing assets with the most appropriate use of science (Table 3). To our knowledge, asset management has not been applied to natural resource management of this kind, and the conservation measures included in the HCP constitute a set of permit conditions for the Incidental Take Permit, thus circumscribing the decision space. In addition, natural assets differ from engineered infrastructure in that natural assets are often hard to define precisely; are typically continuously variable over space and time; do not require traditional, repetitive operations and maintenance; do require monitoring (and sometimes research) for effective management; do not have a replacement interval (or life cycle); and lack a systematic and well accepted body of knowledge of the system.

Table 3. Asset management principles as applied utility-wide and for watershed restoration

Key Principle	As Applied Generally to Infrastructure Within SPU	As Applied in Watershed Restoration
Benchmarking	The process of identifying, understanding and adapting outstanding practices and processes from organizations anywhere in the world to help your organization improve its performance	Comparison of practices with those of other agencies with similar missions, seeking best approaches to restoration, monitoring, and protection
Risk Management	Identification and mitigation of risks to the asset system	Identification and mitigation of risks (threats) to the watershed, including risks of management interventions failing to produce desired results, external threats (e.g., climate change and land development), and uncertainties associated with the underlying systems, species in the systems, and techniques of restoration and threat-mitigation
Service Levels	Agreed-upon levels of benefits to be produced by management of the asset	Conservation measures and other commitments in the HCP, requirements of applicable laws and regulations, and standards and goals from other guiding documents
Life Cycle Analysis	Taking a long-term view that encompasses asset decommissioning and replacement, as well as operating costs	Taking a long-term view of ecosystem development and functions that encompasses natural and anthropogenic disturbances and processes at various spatial and temporal scales (which can alter habitat conditions, either positively or negatively, with respect to overall goals for the ecosystem). Seeking to minimize the need for human subsidies over time through development of self-sustaining natural systems
Asset Profiles	Development of information on the asset system to facilitate informed decisions	Development and analysis of information on the condition of natural systems in the watershed, the distribution of species and/or their habitats, and the relative cost and effectiveness of various kinds of management intervention
Cost/Benefit Analysis	Comparison of options for development or renewal of an asset with respect to total costs of development and ownership	Comparison of options for approaches and techniques of restoration or intervention for mitigating risks and threats at both the landscape and project scales to determine which approaches and techniques might yield the greatest ecological benefit for a given investment
Triple Bottom Line	Delivery of services to produce environmental and social benefits at the lowest life cycle cost (cost-effectiveness).	Meeting HCP commitments in the most cost-effective manner, producing the greatest overall ecological benefit for the financial investment.

6.1.2 *Benchmarking*

The approach to benchmarking taken for the development of this synthesis and other strategic plans linked to the synthesis was to review the work of other agencies and organizations with similar goals. The underlying goal of the HCP is the conservation and restoration of biodiversity. Objectives written in the HCP that focus on the restoration of functional aquatic, riparian, and upland ecosystems are designed to support the key species of concern and all other biota dependent on the major ecosystems present in the CRW. This same focus has led numerous other organizations to develop a process for defining what is meant by 'biodiversity conservation' and for identifying measurable objectives against which to evaluate their progress (e.g. Kernohan and Haufler, 1999; Royal Society, 2003; Parrish et al, 2003; Levy et all, 2003).

The approaches used by all of these groups have converged upon one general process, although individual organizations have further developed specific components in more detail.

The six steps of the process are as follows:

1. Describe the biodiversity of concern in a tangible way (often termed 'targets')
2. Build conceptual models of the targets
3. Identify the desired future conditions (measurable outcomes) that define success for each target
4. Determine the threats or challenges that prevent these outcomes from occurring now
5. Identify strategies to abate these threats and achieve the desired outcomes
6. Assess whether the strategies employed have yielded the desired outcomes (adaptive management)

This process is incorporated into the restoration strategic plans and the monitoring and research strategic plan. In developing these strategic plans, we also consulted other agencies doing similar work and reviewed any plans or programs that they had developed. From these plans and programs, we incorporated or modified those ideas and approaches that were most appropriate for our situation. These reviews, and how they were used, are described in the respective strategic plans.

6.1.3 *Addressing risks, threats, and uncertainties*

Overall planning addresses uncertainties, threats, and risks, all of which could undermine strategies to achieve stated conservation goals or to reach DFCs. For the purpose of planning in the watershed, the following definitions are used:

- *Uncertainty*: An uncertainty exists where there is limited knowledge of an ecological system, restoration/management technique, or an environmental influence (e.g., some aspects of climate change) to the extent that restoration or other interventions cannot be conducted with a reasonable level of confidence regarding the outcome without improvement in understanding

- *Threat*: A threat exists where there is a known, expected, negative effect from tangible sources, including invasive plants, some aspects of climate change, and land development

- *Risk*: A risk exists when there is a reasonable chance for an undesirable outcome from a planned action or a lack of action (e.g., the risk of a restoration technique producing an adverse effect or the risk of forest fire as a result of failure to manage fuels).

Threats at the landscape scale, as well as some risks (of no action), are being addressed in the vulnerabilities analysis and thematic map layer described above (Section 4.3). A discussion of strategies to address uncertainty and risks is presented below in Section 6. 4. Other threats, risks, and uncertainties are being addressed in the respective strategic restoration plans and in the Strategic Monitoring and Research Plan.

6.1.4 Getting the best overall result for the cost

Many decisions regarding natural resource management entail some levels of risk or uncertainty. For many activities, there is no accepted, off-the-shelf best approach. The widely accepted best approach to achieve the best results for investments in the management of natural resources in the long term is *adaptive management* (discussed in section 6.5). This approach entails not just the selection of the restoration approaches best grounded in science but also an intentional learning goal with restoration. This may mean employing several techniques in order to compare their effectiveness, and designing projects to test the hypotheses underlying the different approaches. It also means that the restoration program needs to be tightly integrated with the programs for monitoring and research at both project and landscape scales.

6.2 Natural Processes and Scale

6.2.1 Emulating natural processes or their outcomes

The strategic restoration plans include discussions of the key natural disturbances and processes relevant to that arena of restoration, as well as how those processes and disturbances are being incorporated into restoration planning for at least three spatial scales (watershed, sub-basin to reach, and site), and at smaller scales if relevant. An explanation is given in each strategic restoration plan for how restoration activities are being used to influence or emulate these processes or the outcomes of these processes.

For example, large woody debris (LWD) addition to a stream emulates the physical and biological outcomes of natural wood recruitment, improving stream habitat for fish. Forest thinning may stimulate tree growth (a key process) and emulate some of the outcomes of competition and disturbance mortality (i.e., tree death and change in tree spacing patterns). Basin- or watershed-scale processes may include both natural disturbances and other phenomena, such as dispersal of propagules and organisms. The approaches to these processes and disturbances are presented in the strategic restoration plans as a set of conceptual models intended to guide restoration.

We considered which processes and disturbances would be most important at the scale of the entire watershed (Table 4). Processes of dispersal and connectivity were addressed, in part, in the three-step process through the connectivity map layers incorporated into the synergy layer (Section 4.3). These processes are also addressed in the restoration strategic plans. Our approach to wildfire as a landscape process is described in Section 6.2.2 below.

Table 4. How key natural disturbances and processes are being addressed in strategic and project planning for restoration and other management intervention.

	SCALE		
Natural Disturbance or Process	**Watershed***	**Sub-basin/reach***	**Site***
Disturbances			
Wildfire	**SF****		**PPs**
Wind	**UFSRP**	**UF, R, & ASRPs**	**PPs**
Pathogens & some insects		**UFSRP**	**PPs**
Invasive plants	**SF****	**UF, R, & ASRPs**	**PPs**
Mass Wasting	**SF, ARSP, & TSAMP**		**PPs**
Processes			
Dispersal of organisms	**SF (vertebrates)**	**UFSRP**	
Forest structural development		**UFSRP & RSRP**	**PPs**
Forest understory development		**UFSRP & RSRP**	**PPs**
Forest canopy differentiation			**PPs**
Vertebrate habitat use	**SF**	**UF, R, & ASRPs**	**PPs**
Sediment delivery from roads	**TSAMP & ASRP**	**TSAMP & ASRP**	**PPs**
Riparian inputs		**R & ASRPs**	**PPs**

* Abbreviations:
SF: Synthesis Framework
UFSRP: Upland Forest Strategic Restoration Plan
RSRP: Riparian Strategic Restoration Plan
ASRP: Aquatic Strategic Restoration Plan
TSAMP: Transportation Strategic Asset Management Plan
PPs: Project Plans
** Vulnerabilities: see text

In planning restoration in the context of natural and anthropogenic disturbances, we have attempted to:

- Identify the most important (key) types of disturbance and process to consider;

? Develop an understanding of, or set of hypotheses concerning, the relationship between key disturbance types and biodiversity (as well as species of concern);

? Develop an understanding of spatial and temporal patterns of these key natural disturbances and processes;

? Develop models of expected disturbances based on our scientific understanding of those disturbances and knowledge of spatial patterns within the watershed, addressing both expected ranges and uncertainty in our understanding;

? Incorporate an expectation for the occurrence and nature of disturbances without intervention, and expectations of system responses with different kinds of intervention;

? Develop a strategy for planned intervention within the context of natural disturbances, working *with* key natural processes and letting natural processes "do the work" where appropriate, and aimed at goals related to biodiversity and sustainable management;

? Develop a strategy for restoration that addresses disturbances at all relevant scales, from a single tree to the entire watershed; and

? Make provisions for regular evaluation and reassessment of the occurrence of natural disturbances, and readjustments of plans as needed.

6.2.2 An evaluation of using forest fire as a landscape template

Landscape templates are regularly created for managing large areas of land that are based on a wide variety of societal values. Forest managers have used a variety of landscape patterns as templates to guide the restoration of natural processes and patterns, ranging from the use of past disturbances to the use of simulation modeling (Perera et al. 2004). At the watershed scale, we evaluated the potential use of forest fire (wildfire) as a landscape template, possibly mimicking some or all of the outcomes of fire across the landscape (see Appendix C for a complete discussion).

With two major exceptions (described below), we made a decision not to use forest fire as a landscape template given:

- The lack of applications or models of approaches to emulating forest fires in the episodic, long-return-interval, high-severity/stand-replacing fire regime in which the CRW exists (Agee 1993; Perera et al. 2004; Arno and Fiedler 2004);

? The inadvisability of using past conditions as a reference in a changing world (Hughes et al. 2005);

? The lack of good information on past conditions in the watershed and our inability to pick a relevant time frame under ongoing regional climate change;

? The focus of the HCP on particular species of concern, suggesting that a habitat-based approach for these species would be more appropriate;

? The preclusion under the HCP of timber harvest other than thinning; and

? The risk to the water supply of using intentional burning as a restoration tool.

The first exception to this decision is that we included the risk of forest fire in a vulnerability assessment and are developing associated strategies to ameliorate that risk (Section 4.3) at the recommendation of Dr. David L. Peterson, who oversaw a landscape assessment of fire risk in the CRW. The second exception is that, within the constraints of the HCP, we are emulating some of the effects of fire on smaller scales by using silvicultural techniques (see the Upland Forest Strategic Restoration Plan) – in particular by creating coarse woody debris (snags and logs).

6.3 Climate Change

At the time the HCP was being developed in the 1990s, the reality of directional global climate change and its potential effects were matters of considerable debate. In response to the lack of agreement among scientists at that time, climate change was considered under the HCP to be an "unforeseen circumstance," an event that was "not predictable as to occurrence or severity" in the context of the HCP (4.5-63). Consequently, no strategies for addressing climate change were included in the HCP.

Consensus is now emerging among scientists that the climate of the earth is changing in a systematic fashion, with an expectation of profound effects on biodiversity (Lovejoy and Hannah 2005. Research is documenting changes in the ranges and phenology of plant and animal species across the globe (Lovejoy and Hannah 2005), and questions are being asked about the potential effects at particular locations. Models linking global climate changes to regional changes in Washington are predicting future changes in regional air temperature, precipitation patterns, snow pack, stream flows, water supply, and vegetation, all factors of importance to watershed management and restoration (see http://cses.washington.edu/cig/).

Changes in the local climate could affect the growth, well being, and survival of plants and animals targeted under the HCP, and the functions of ecosystems on which they depend. For example, some currently common plant species could experience increased mortality or shifts in elevational range as a result of changes in the distribution of diseases or the physical environment. Patterns of water storage in snowpack and runoff could change, affecting water supply and seasonal stream flows. Also, the frequency and intensity of disturbances, such as forest fires or disease outbreaks, could change.

A goal of the HCP is to manage the watershed in a sustainable manner CRW HCP 4.2-135). A consideration of climate change is important in planning ecosystem restoration in order to have a reasonable probability of accomplishing the goal of sustainability. Restoration necessarily is focused on what future conditions are desired. Simply trying to recreate plant communities that were present several centuries ago may, in some cases, be a poor choice. Failing to recognize that changes in vegetation may occur could lead to developing target conditions that cannot be achieved or sustained, or could result in undesired outcomes. Under climate change, we should expect a moving target with respect to what species may be viable, and we can expect our understanding of risks and strategies to change over time. Currently, we may not know what species could be at risk, but we can begin to examine the vulnerability of species based on what we now know about those species in the context of a range of scenarios regarding how we expect the environment to change.

With respect to planning in a landscape context, consideration of climate change perhaps links less to prioritizing areas for restoration than to the nature of that restoration. An example can illustrate how concern about climate change might influence decisions regarding restoration. The younger forest stands in the watershed are primarily at higher elevation, and largely consist of Pacific silver fir that as "advanced regeneration" (i.e., existing understory trees that were not cut) was released when the original old-growth forest was clear-cut logged several decades ago. The starting conditions for these stands – dense, similar-aged, monotypic stands of young silver fir – are quite different from starting conditions that might have occurred after a large forest fire, the most common natural, large-scale disturbance in this region. In the latter case, regeneration would likely have been by seedling establishment, would have occurred over a number of years (possibly decades), and would have been characterized by at least some shade intolerant species. As silver fir appears to do poorly at low elevations now, a reasonable argument can be made that it may not be tolerant of regional warming. If silver fir is vulnerable to climate change, simply thinning these areas could result in loss of the primary cohort of trees, resetting of succession, and, ultimately, a longer period of time until late-successional conditions might be achieved. Instead, coordinating thinning with planting potentially tolerant native species and a diversity of species could be a better strategy to more quickly achieve old-growth conditions.

Considering climate change in the watershed restoration program will, in part, entail:

? Identifying and evaluating vulnerabilities and risks associated with climate change, including uncertainties in the range and intensity of changes that could occur;

? Identifying and evaluating strategies for ameliorating or adapting to those risks, including strategies to deal with uncertainty; and

? Regularly updating our understanding of the implication of climate change and the latest research results, and incorporating those updates as adjustments to restoration strategies.

6.4 Use of Reference Conditions

Many authors have recommended the use of reference conditions in developing DFCs for restoration. For reasons discussed in Sections 6.2 and 6.3 above, we have concluded that such use must be tempered by recognition that changes in climate and land use, both past and future, can both render the use of past conditions as a reference of questionable appropriateness and make the achievement of such conditions impossible.

When available, however, we have identified and used data on reference conditions to establish both intermediate and long-range DFC's for key indicators. Within the Aquatic Restoration Strategic Plan, we have exploited recent research within unmanaged watersheds located throughout the western cascades to establish a desired range of conditions for streams based on channel dimensions (Fox 2003).

Establishing DFC's for Upland and Riparian areas has been more problematic, however, and the combination of pervasive land development and intensive timber harvest has made the task of locating appropriate reference sites that were produced by natural disturbances infeasible for most habitats at low-to middle-elevations in the Puget Sound region. Additional complexity for the task of finding reference sites comes with the recognition that forests can develop by multiple pathways at a given site (Edmonds et al. 2000). We do have some existing old-growth forest at higher elevations, however, that can provide information used in developing DFCs, and we are completing a historic analysis of watershed forest cover using GLO surveyors' notes from the late 1800s and a 1911 timber cruise that covered most of the watershed. We have also established 37 permanent sample plots in old-growth stands in the CRW, primarily in the Pacific Silver Fir Zone, that are being used to establish expectations regarding stand development for previously harvested sites of similar nature. Greater detail on how DFC's for the aquatic, riparian, and upland ecosystems have been established can be found in the respective strategic plans.

6.5 Adaptive Management and Research: Addressing Uncertainty and Risk

The environmental outcome of projects typically entails some uncertainty about the results of a restoration technique and potentially the risk of an adverse effect. The uncertainty can often be large, particularly in the arena of ecosystem restoration. Accurate information is key to several strategies for making informed management decisions in the face of environmental uncertainties, risks, and threats over time. Information (or knowledge) can be valuable in managing risks in both the short and long terms.

6.5.1 Managing uncertainty and risk in the short term with information

Greater knowledge generally increases the chance of designing a project that meets its objectives (shown conceptually in Figure 5, below). Likelihood of success is low when little information is available for planning actions, but at some point the incremental increase in the chance of success begins to diminish with an increase in knowledge. Because acquiring knowledge has a real cost, there is, in concept, an optimum range of investments of time and resources that yields an acceptable likelihood of success at a reasonable cost (shown conceptually as the "Desired Zone" in Figure 5). Efforts to provide knowledge can take a variety of forms, including literature review, consultation with experts, field surveys, and scientific research into one or more important and relevant phenomena.

The three restoration strategic plans address the key questions and uncertainties about restoration in each program area. We have begun to address many of the short-term questions and uncertainties in order to reduce the risk of an undesirable outcome from restoration projects. In some cases, we are conducting collaborative research experiments to provide short-term information; in other cases, we are consulting experts or the literature and designing projects based on the most current data.

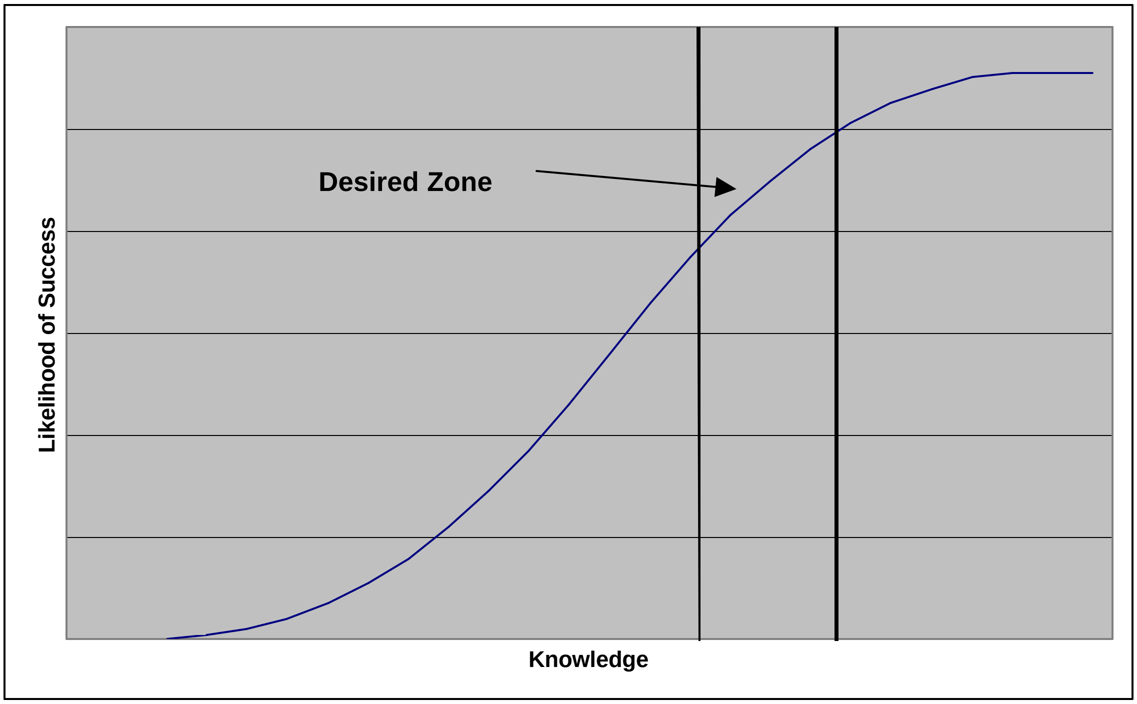

Figure 5. Likelihood of success of environmental intervention as a function of knowledge that can be used in planning actions.

6.5.2 Managing uncertainty and risk in the long term with information

When uncertainty cannot be reduced to an acceptable or desired level, but the potential ecological benefit of the project is substantial, risks can be managed over the long term through *adaptive management* (Holling 1978). An adaptive management approach enables us to implement management actions intended to benefit species or habitats when faced with some uncertainty regarding the outcome, while not requiring the statistical rigor of a traditional ecological research experiment (Murray et al. 2000). Adaptive management is a scientific approach in which a clear description of expected outcomes (based on stated hypotheses) is articulated prior to project implementation, the project is monitored in a carefully constructed design to test the key hypotheses and determine outcomes, results are monitored and analyzed, and actions are adjusted in the future, if appropriate, in response to monitoring results (Marmorek 2003). As a primary means of managing uncertainty and risk, adaptive management has the disadvantage of potentially requiring many years, even decades, to yield results that can inform decisions, particularly in forest ecosystems where trees grow very slowly. Where similar actions are repeated over long periods and time is available for monitoring the results of those actions, adaptive management is likely an appropriate strategy to inform future decisions.

There are two types of adaptive management: passive and active (Walters and Holling 1990, Marmorek 2003). In passive adaptive management, available historical data are used to construct a single "best estimate" or model for the expected ecological response. The decision to implement a restoration treatment assumes that this single model is correct and there is little uncertainty about the outcome. In active adaptive management, much more uncertainty about the ecological outcome of the treatment is assumed. As a result, a range of alternative response models is constructed and multiple treatments (including controls) are conducted at replicate sites of the same character and conditions. Active adaptive management is most appropriate where uncertainty is greatest, similar actions will be repeated over long time frames, intervention is costly, and/or the risk of adverse outcomes is significant. As described in the Strategic Monitoring and Research Plan and the three restoration strategic plans, the monitoring and adaptive management program is keyed to indicators of key ecological attributes that are related to the DFCs for restoration and intervention.

6.6 Information Management

An effective learning organization requires the meticulous and efficient management of information, i.e., curation of the intellectual capital developed in an organization over time in the form of databases, protocols, models, analyses and projections, planning documents, documentation of projects and their outcomes, and other key information needed for management of natural resources. We recognize the value of well designed and managed information management systems, and are developing systems that will integrate the asset information and environmental science data needed to support decisions.

Our approaches to the acquisition, management, analysis, and storage of information used in strategic planning are described in the Watershed Characterization Plan. Section 7 below describes the organizational structures and processes needed to ensure that what we learn over time is articulated, evaluated, documented, and used for planning.

7.0 PERIODIC EVALUATION AND PLANNING

A process of annual evaluation and planning will be implemented as part of the intentional learning and adaptive management paradigm (Figure 1).

7.1 Annual Evaluation Process

Each year, the Watershed Ecosystems Section will conduct an annual review and evaluation. The purposes of the annual evaluation process will be to:

- ? Identify what planned work was or was not accomplished, and differences between what was done and what was planned;

- ? Ensure that projects are documented as completed (i.e., that "as-builts" are created);

- ? Compile and analyze data on compliance, effectiveness, validation, and trend monitoring, including information on the distribution and abundance of invasive species;

- ? Identify any new and relevant research findings from SPU-sponsored work or work of outside scientists that is relevant to our management (particularly about climate change, control of invasive plants, new techniques or approaches in restoration, or local land use and development);

- ? Check that monitoring data are entered and documented and that appropriate updates are made to the Science Information Management System (SIMS), the Transportation Information Management System (TIMS), and/or other information management systems as appropriate;

- ? Identify any carryover of work for the next year (or later);

- ? Identify any lessons learned or new information relevant to planning near-term work (in the 1-5 year time frame) or to revising strategic plans; and

- Ensure that what we learned is incorporate into management decisions and planning.

We will document what was learned in an Annual Evaluation and Learning Report, focusing on those things learned that have the most important implications for planning future work.

7.2 Annual Planning Process

Each year, following the annual evaluation process, the Watershed Management Division will produce 1-year and update 5-year plans for restoration, monitoring, and research that reflect what we have accomplished and learned in the past year. This will likely occur in February, and may be initiated in January or earlier.

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APPENDIX A. DEVELOPMENT OF THE SYNERGY MAP LAYER

1.0 INTRODUCTION

In order to prioritize and coordinate the wide array of upland, riparian and aquatic restoration projects within the CRW such that efforts are synergistic and address the most critical and potentially responsive habitat elements first, three central themes were identified:

1. *Fish Habitat*, which consists of current and potential habitat used by bull trout, coho salmon, and Chinook salmon. This element focuses watershed restoration activities in areas that are strongly linked to processes critical to the restoration and maintenance of current and potential future habitat for these ESA-listed species.
2. *Habitat Connectivity*, which has two major components:
   - Connecting existing old-growth forest habitat with appropriate corridors of forest containing late-successional habitat conditions, and
   - Creating and maintaining corridors of complex forest habitat between breeding ponds and upland forest to provide a range of habitat types needed by amphibians during their life cycle.
3. *Habitat Adjacent to Biodiversity Hotspots* or special ecosystem elements. These areas focus watershed restoration activities with spatial reference to areas characterized by habitat heterogeneity and the associated diversity of biota and ecosystem processes.

Collectively, these three themes target habitat crucial for most of the species listed in the HCP. Each theme is described in more detail below in the Sections 2, 3 and 4. These themes were then combined into a single synergy map layer that will be used to focus restoration efforts in areas of the landscape that will provide the greatest benefits to the largest numbers of species. Development of the synergy map layer is described in Section 5.

2.0 FISH HABITAT THEME

While achieving the broad restoration goals for the entire watershed is likely to result in successful conservation of bull trout, coho salmon, steelhead trout, and Chinook salmon, we have opted to not rely exclusively on this assumption given their identification as Species of Greatest Concern under the HCP. As such, we have identified those watershed processes critical to the maintenance of key habitat elements, as well the linkages between these processes and our management and restoration activities.

2.1 Definition of Habitat Conservation for Bull Trout, Coho and Chinook

In order to achieve the broad objective of restoring and maintaining natural processes that maintain key habitats associated with coho, Chinook, steelhead, and bull trout within the CRW, efforts will need to be coordinated at a variety of scales (from reach to watershed) to be effective. Degraded habitat resulting from past (and current) land use activities which have altered riparian composition and dynamics, natural sediment supplies, flow regimes, connectivity (access), and water quality will be addressed based on resource sensitivity, uniqueness, and likelihood of success. For details on the distribution and critical habitat elements for these species in the CRW as well as a discussion of the important linkages between management and restoration activities on these elements, see the Aquatic Restoration Strategic Plan (ARSP).

2.2 Implications for restoration planning

The steps appropriate to using current and potential future bull trout, Chinook and coho salmon habitat as a filter for site/project selection include:

1. Identifying the spatial extent of current and potential fish habitat for the species of concern. For these species, there are fairly strong connections between potential habitat and specific channel types or Geomorphic Map Units (GMUs). For bull trout, these consist largely of the Upper Cedar and Rex Rivers, Chester Morse Lake, and several tributaries to the lake. For Chinook salmon, habitat is generally limited to the mainstem Cedar River between Landsburg Dam and the Powerhouse. Coho habitat is more dispersed, including extended reaches within Williams, Rock, and Webster Creeks as well as the mainstem Cedar River.

2. Defining and making explicit our understanding of (or hypotheses about) the critical habitat elements for each species and relationships between these and surrounding habitats. A discussion of these habitat elements and the critical watershed processes controlling them can be found in the ARSP.

3. Identifying important linkages between past and present management and restoration activities and key habitat elements for each species. A discussion of these linkages and the assumptions used to identify them are also in the ARSP.

4. Prioritizing aquatic, riparian, and upland restoration projects based on the likelihood of achieving the greatest overall ecological benefit will require focused discussions about the attributes and processes unique to specific areas. It will also require an assessment of the strength in linkages between key processes and habitat elements likely altered by various restoration efforts in order to gauge the extent to which integrating projects achieves the intended synergies and greatest net benefit.

3.0 HABITAT CONNECTIVITY THEME

3.1 Late-Successional Forest Habitat Connectivity

The connectivity of late-seral forest habitat in the Pacific Northwest has become a major concern in the conservation of many wildlife species. In the last century, the loss and fragmentation of habitat resulting from timber harvest and land cover conversion has confined species dependent on late-seral forest to remnant parcels of habitat primarily found on public lands and at higher elevations. Populations of these species are reliant on the overall amount of habitat available, the size of remnant parcels, and the proximity of habitat parcels to one another. Habitat parcels need to be large enough to provide for viable subpopulations, and/or the juxtaposition or connectivity of parcels must allow for inter-parcel migration to preserve the genetic integrity of the metapopulation and provide for the recovery from localized extinctions.

The CRW ranges from the high-elevation mountain crest on its eastern boundary to lowland foothills to the west. As such, it provides vital links not only between the north and south western Cascades, but also from low to high elevations. Currently, there are roughly 14,000 acres of forest habitat that have not been subject to past timber harvest (e.g. greater than 200 years of age). These areas are generally confined to higher elevations that were previously managed by the US Forest Service (USFS). Because the USFS ownership was in a checkerboard pattern with private ownership (e.g. every other section), the remaining mid- to late-seral habitat is fragmented into distinct islands of varying sizes.

The HCP identifies 23 wildlife species directly associated with late-seral and old-growth forest communities. Connectivity of late-successional habitat for these species, as well as numerous other native species, is one of the major factors being considered when selecting locations for restoration. In order to include these corridors in the synergy map layer, several staff biologists mapped areas connecting all remaining fragments of old-growth forest.

The process was to first map all areas of forest that were never harvested (termed old-growth). Then areas of second-growth forest that are developing late-successional habitat characteristics were delineated. Identification of these areas was based on tree height, appearance of the canopy from aerial photographs, amount of conifer and deciduous vegetation, and site visits. The entire watershed was then analyzed for areas of connectivity between these patches of high quality forest habitat. Forest corridors were drawn based on the shortest distance between patches, using streams and other topographic features as travel routes. Four phases of connectivity were mapped, as we envisioned how restoration projects might accelerate late-successional forest habitat connectivity through time. The first phase identified relatively narrow corridors linking all the patches, although wider corridors were drawn to create a large old-growth forest patch in the upper watershed and to link forest habitat in the upper and lower watershed. This first phase also contains north-south linkages as well as corridors from major water sources to ridge tops. Subsequent phases provide larger and larger patch sizes. The first phase was used for development of the synergy layer (see section 5 of this appendix).

3.2 Amphibians and Habitat Connectivity

Wetlands support high species diversity and provide critical habitat to a variety of species, including amphibians. Amphibians require a wide range of habitats to complete their life cycle, ranging from breeding ponds and intact riparian habitat to suitable upland forest for overwintering, as well as connectivity between these habitats (Walls et al. 1992, deMaynadier and Hunter 1999). Many habitat features found in late-successional forest, such as large amounts of woody debris and stable microclimatic temperatures, influence abundance of amphibians. Higher densities of salamanders were documented in older forests with these habitat features on Vancouver Island, British Columbia (Dupuis et al. 1995). Focusing restoration goals to create and maintain corridors of complex forest habitat between breeding ponds and upland forest provides a range of habitat types needed by amphibians during their life cycle while simultaneously benefiting other species found in these habitats (Houlahan and Findlay 2003).

Depressional wetlands, characterized by a topographical low point on the landscape, usually hold water for a portion of the year. These wetlands provide the best breeding habitat available to amphibians and typically lack fish species (potential amphibian predators). Many of the depressional wetlands in the CRW support breeding populations of one or more amphibian species (SPU unpub. data). The adults make an annual migration to and from breeding ponds and young disperse through riparian forests into upland forests after metamorphosing. Depressional wetlands are scattered throughout the CRW at all elevations and occur in close proximity to all forest types.

Habitat surrounding depressional wetlands is used by many amphibian species during large portions of their life cycle, as well as for dispersal. A distance of one kilometer, while greater than many salamander species migrate, is a typical distance for several frog species (pers. com Mark Hayes, WDFW, Hayes et al. 2001, Muths 2003). Habitat restoration efforts designed to improve amphibian habitat and connect depressional wetland habitat to upland forests would be most beneficial to amphibians within the one kilometer migration circle surrounding breeding ponds. In some cases, migration circles overlap, creating a larger block on the landscape. These areas may serve to increase genetic exchange between breeding ponds and would be a high priority for restoration projects designed to benefit amphibians.

4.0 SPECIAL ECOSYSTEM ELEMENTS THEME

One general conservation objective of the CRW HCP is to "develop strategies to restore and sustain the natural processes that foster biological diversity" (CRW HCP 4.2-10). Our restoration work focuses on restoring these natural processes, while protecting and maintaining existing biodiversity. Certain landscape features are known to support relatively high or unique concentrations of biodiversity, or to feature unique or important ecosystems processes (e.g., water filtering and infiltration, groundwater connections, or flood regulation. These areas have environmental characteristics (e.g., wetness, shade, old trees, or unique substrates) that create more abundant niches, rarer niches, or more advanced niche complexity than other areas.

4.1 Definition

The HCP effectively places reserve status on some of these special ecosystem elements (termed Special Habitats in the HCP), which span upland, aquatic, and riparian environments. The Special Habitats include talus and felsenmeer slopes, all rock formations, cliffs and caves, all natural upland grass-forb meadows, and persistent shrub communities. These habitats were deemed of importance in the HCP because they support a unique set of species, thus contributing to beta diversity (i.e., diversity between ecosystems; habitat patchiness). In this definition of special ecosystem elements, we are using the HCP's Special Habitats and adding other habitats or ecosystem elements that are known to support high levels of alpha diversity (i.e., diversity within an ecosystem; species richness). These areas include ponds, lakes, and wetlands, along with their associated riparian areas; old-growth forest and areas of second-growth forest that are structurally complex or have high plant species diversity; and natural slide chutes. Collectively, these Special Ecosystem Elements can be considered "biological hotspots" with regard to alpha and/or beta diversity.

4.2 Applicability to Cedar River Municipal Watershed

Conservation science has long focused on the identification and protection of "biodiversity hotspots" as a way to conserve global biological diversity. While conservation in the broad sense may not be well-served by focusing too exclusively on biodiversity to the detriment of ecosystem functionality and other measures of ecological importance, the use of biodiversity (or one of its proxies, heterogeneity) as one of our criteria for locating or prioritizing restoration activity across a local landscape has promise. The specific relationships between a Special Ecosystem Element and its surrounding habitats will help guide project planning by providing specific restoration objectives.

In general, habitats adjacent to Special Ecosystem Elements will be targets for restoration work rather than the Ecosystem Element itself, with some special exceptions (e.g., wetlands that were impacted by past logging or road construction; meadows or wetlands that have been infested by non-native invasive species). Special Ecosystem Elements may be preserved, enhanced, or linked through restoration efforts. Most of our work will emphasize linkages between biodiversity hotspots (e.g., between patches of old growth forest) or between a hotspot and its neighboring habitat. For example, some organisms are dependent both on wetland habitats and the neighboring forest (e.g., amphibians in a pond ecosystem). By including amphibian habitat objectives in upland forest restoration planning we may be able to better support amphibian populations. Restoration work also enhances links for species dispersal. Special Ecosystem Elements may provide seed source or inocula (such as mycorrhizas) to neighboring areas in which restoration treatments are implemented. Restoration treatments can be planned to provide expanded or enhanced habitat for biota existing in Special Ecosystem Elements, allowing them to expand into neighboring habitats if restoration is planned with that expansion in mind.

The conservation of biodiversity can thus be more effective if restoration treatments are planned with spatial reference to Special Ecosystem Elements. In this way, Special Ecosystem Elements become important foci for both locating and designing restoration work.

4.3 Implications for restoration planning

The steps appropriate to using Special Ecosystem Elements as a filter for site/project selection include:

- Determining the suite of Special Ecosystem Elements (e.g., HCP Special Habitats, areas with high alpha diversity);
- Locating and mapping Special Ecosystem Elements;
- Defining and making explicit our understanding of (or hypotheses about) the relationships between Ecosystem Elements and surrounding habitats (and relationships with species of concern);
- Describing how restoration can enhance linkages between Special Ecosystem Elements and their surrounding habitats or the Ecosystem Elements themselves; and
- Prioritizing Special Ecosystem Elements in terms of importance for restoration to incorporate into our approach for restoration project site selection.

5.0 DEVELOPMENT OF THE SYNERGY MAP LAYER

Once all three themes were developed and mapped, we created a synergy layer that combined the habitat elements from all of the themes. To create this layer we first mapped all layers described above. These included current and potential fish habitat, stream segments with plane-bed response reaches (the most responsive reaches to restoration treatments such as large wood inputs; additionally they represent areas of greatest potential synergy between aquatic and riparian restoration projects), old-growth forest patches, patches of forest with developing late-successional habitat conditions, forest corridors, depressional wetlands, non-depressional wetlands, all rocky habitats (including talus slopes, cliffs and rock outcrops), meadows, and persistent shrub-herb communities. Each habitat patch was evaluated and if it was within 500 feet of another patch of the same type, they were combined into a complex. For example, two ponds that are 300 feet apart were combined into one depressional wetland complex.

We then mapped an area surrounding each habitat patch or habitat complex. The distance mapped varied by habitat type (Table A1) and, unless otherwise noted, was determined from wildlife species likely to use the habitat. Next we assigned a weight to each habitat type (Table A1). Weights were determined using total number of species, number of species listed in the HCP and number of species federally listed as threatened or endangered that use the habitat type (Table A2).

Table A1. Summary of distances mapped around each habitat type and weight used in final model

Habitat Type	Distance Mapped (ft)	Model Weight	Notes
Current and potential fish habitat	200	7	This distance was chosen not to represent an actual riparian area, but simply to highlight the appropriate stream segments with an area that could be viewed at a landscape scale
Plane-bed response reaches	200	5	Same as fish habitat
Rocky habitats	1,000	1	Represent species such as bats that utilize forested areas with late-successional characteristics that are close to edges of openings used for foraging (Johnson and O'Neil 2001)
Meadows, shrub-herb communities, non-depressional wetlands	1,000	3	Represent species such as bats that utilize forested areas with late-successional characteristics that are close to edges of openings used for foraging (Johnson and O'Neil 2001)
Depressional wetlands	3,280	3	The best amphibian breeding habitat in the CRMW. 3,280 ft is the average dispersal distance for frogs (pers. com Mark Hayes, WDFW, Hayes et al. 2001, Muths 2003)
Depressional wetlands	1,640	5	The core area near the ponds most likely to be used during terrestrial life stages of most amphibians
Old-growth forest, high quality second-growth forest	1,320	7	The home range size of an olive-sided flycatcher, an HCP-listed species that uses old-growth forests.
Forest corridors	Variable	7	Width and length of the corridor varied depending on the size and juxtaposition of the forest patches it was connecting, the size of the river valley it followed, and the location on the landscape

Table A2. Number of species estimated to use the different habitat types, used in assigning weights during model development

Habitat Type	**Species Use and Other Reasons for Importance**	**# Total Species**	**# Species in HCP**	**# Federally Listed***
Rock	Some insects over rock; some foraging opportunity for bats, birds. Little niche diversification. Limited amphibian use of rock and surrounding forest.	38	25	6
Meadows/ Shrub-Herb/ Non-depressional wetlands	Good insect breeding; Good forage areas for bats, birds. Numerous small mammals, small carnivores, birds will use both forest and these habitats (cover, nesting in forest, forage in meadows, wetlands).	47	32	12
Depressional wetlands	Open water important for insect breeding; Good forage areas for bats, birds. Numerous small mammals, small carnivores, birds will use both forest and ponds. Several pond-breeding amphibians use surrounding forest and are considered at risk. Amphibians are key functional integrators between aquatic/riparian/upland. Area closest to depressional wetlands likely more heavily used by both amphibians and other species.	29	21	10
Old-growth and high quality second-growth forest/ Corridors linking old-growth and good second-growth forest	Federally listed species (spotted owl, marbled murrelet). Old-growth forest has high biodiversity.	108	52	20
Fish-bearing streams/ Plane-bed response reaches	Federally listed species (bull trout, Chinook salmon). High political interest in listed fish. Good habitat includes high biodiversity. High invertebrate populations can form base of food chain for species using surrounding forest.	87	28	14

* Species listed as concern or threatened. This number only includes those species likely to occur in CRMW - excludes grizzly bear, wolf, lynx

Each area was then assigned a score, which was determined by combining the number of overlaps between different habitat types and the weight of each habitat type. Six models that varied the weights and number of overlaps were created and evaluated. The final model selected used the weights shown in Table A1, and emphasized overlaps between (rather than within) habitat types. The greatest weight was given to fish habitat, areas adjacent to late successional forest habitat, and corridors connecting these patches of old forest because of the larger total number of species and number of listed species using these habitats.

The final model used was**:**
[rock_score] + ([SUM_meadow_score] * 3) + ([SUM_herb_score] * 3) + ([SUM_wet_score] * 3) + ([SUM_amphib_score] * 3) + ([SUM_amp_half_score] * 2) + ([fish] * 7) + ([old_forest] * 7) + ([ripzone] * 5) + ([corridor] * 7)

Finally the total potential area was calculated, which included all areas with a score of at least 1. This pool was then divided into five categories, each representing as close to 20% of the total potential area as possible (Table A3). These categories were then displayed as a map layer with blue representing the greatest synergy and white the least.

Table A3. Comparison of category ranges and scores for final model[1]

Category	Score Range	Number Acres	Percent of Total Available Acres
#1 Blue[2]	16-35	11,003	16.9
#2 Purple	11-15	14,424	22.1
#3 Red	7-10	16,54.	25.4
#4 Yellow	4-6	11,011	16.9
#5 White[3]	1-3	12,210	18.7

[1]Total acres categorized = 65,188
[2] Greatest synergy
[3] Least synergy

We also displayed the final inclusive model results without using categories (i.e., each score of 1 to 35 was displayed separately as a different color). For the both the category and inclusive displays of the model, the components that led to its score are included for each polygon. Finally, we displayed the same model using a moving window technique to calculate a mean value for each pixel based on the neighboring model scores. To create this display, we converted all model scores into a raster display of 10 meter pixels. Then a radial distance of 100 meters was used to calculate the average score, which was then assigned to the pixel. This display eliminates the sharp boundaries that are artificially imposed on the landscape by the other displays. However, it has the disadvantage of not having the model components tied to the display.

The areas with the highest scores should provide the greatest synergistic benefit to the most species, and will be the highest priority for investigation as potential restoration sites (if degraded conditions exist).

APPENDIX B. LINKING SYNTHESIS DOCUMENT TO STRATEGIC PLANS

Draft Framework Linkage to Strategic Plans		
	Vision element	**Relevant Strategic Plan(s): Potential Indicators**
Road Characteristics	The minimal road system needed to support management and protection of the watershed, with minimal or no new roads constructed	***Roads:*** Length of existing roads (excluding those formally decommissioned)
	Eliminate existing roads in old-growth forest, wetlands, riparian corridors, areas with high mass wasting hazard potential, or in other sensitive habitats unless essential to watershed management, and construct no new roads within these habitats	***Roads:*** Length of existing roads within sensitive habitats. GIS screen of sensitive habitats to be developed by **Aquatic, Riparian, and Upland ID Teams.**
	If new roads are required, build in less sensitive habitats with minimal adverse impact on forest soils	***Roads:*** Length of new road within sensitive habitats
	Minimal hydrologic connectivity of roads with the aquatic network resulting in minimal road-generated fine sediment delivering to the aquatic system	***Roads:*** Drainage network extension (miles of drain with direct connectivity to streams); WARSEM model prediction ***Aquatic:*** Fine sediment deposition from the road network
	No road-associated (triggered) mass wasting events	***Roads:*** Length of roads within High MW Potential areas ***Aquatic:*** Frequency of road-generated landslides
Aquatic and Riparian Characteristics	Sediment, wood loading, and LWD recruitment to all streams within natural range of variation for late-successional riparian forests	***Aquatic:*** Indicators already identified in plan ***Riparian:*** LWD recruitment (to be addressed via riparian characterization project)
	No human-made barrier to fish or peak storm flows in any stream except Landsburg Diversion Dam, Masonry Dam, and Overflow Dike, and minimal human-made barriers to passing sediment and organic debris in any stream	***Aquatic:*** Evaluate indicators already identified in plan ***Roads:*** Number of undersized culverts; Number of culverts with chronic sedimentation (from culvert tracking database)
	Natural processes key to channel and floodplain formation and maintenance (e.g., flooding, sediment storage and sorting, bank and bed stability, floodplain connectivity, channel migration) within natural range of variability	***Aquatic***: Evaluate indicators already identified in plan ***Riparian:*** Distribution of riparian cover types
	Natural flow paths and hydrologic regimes in all unregulated streams	***Roads:*** Drainage network extension; Miles of midslope roads ***Aquatic:*** Miles of road on active floodplains
	Assemblage of aquatic benthic invertebrates within natural range of variability for undisturbed forested watersheds	***Aquatic:*** Ongoing work with USGS
	Natural fluvial disturbance regime influencing successional processes in riparian forests	***Aquatic:*** Review indicators associated with sediment input, LWD function and recruitment processes. ***Riparian:*** Change in composition of riparian cover types
	Riparian forests consisting of hardwood, conifer, and mixed hardwood-conifer stands in proportions within the natural range of variability	***Riparian:*** Distribution of riparian cover types by GMU
Forest Characteristics	Long-term goal of a forested landscape dominated by late-successional or old-growth conditions (absent large-scale disturbances), including natural diversity of forest structure and composition (including snags and down wood) supporting a full complement of plant, animal, and fungal species characteristic of late-seral forest	***Upland:*** Proportion of CRW dominated by Late-successional and old-growth forest

	No areas of habitat that act as barriers to the movement of species of concern, either horizontally or with respect to elevation, other than those inherent to the habitat type	***Upland:*** Amount and juxtaposition of habitat with appropriate conditions for species of concern.
	Minimal residual effects of past land use that are not related to current operations, including habitat permeability related to roads, unnatural forest edges, and unnatural species composition as a result of past logging	***Upland:*** Amount, location, and species composition of edge habitat. ***Roads:*** Length of road in sensitive habitat
	Mix of conifer and deciduous trees across the landscape, within the natural range of variability, that best supports the species of concern in the HCP	***Upland:*** Distribution and amount of forest types
	Forest conditions that do not pose an unnaturally high risk of extensive forest fires; probability of large-scale catastrophic disturbance from fire within natural range of variability (recognizing the effects of climate change on fire risk)	***Upland: (to be developed***) Future wildfire risk assessment lower than current
	Minimal impact from watershed management activities to processes critical to the formation and maintenance of soil structure, biota, and biogeochemistry	***Upland/Monitoring:*** Changes in soil compaction associated with restoration projects
Climate Change	Sufficient natural diversity of plant, animal, and fungal species to enable shifts in response to global climate change	***Upland: S***pecies richness, evenness, diversity, with focus on keystone and at-risk species
Operational Conditions	Minimum impacts of operations on water quality	***Monitoring:*** Ongoing turbidity monitoring at Landsburg. Stream turbidity in association with road projects, when appropriate. Turbidity, pathogen, temperature at locations in basins or subbasins that integrate upstream projects and processes.
	Minimal need for subsidies to habitat development, such as LWD placement, thinning, planting, snag creation, and down wood creation	***Monitoring:*** Achieving or moving towards relevant interim DFC's. ***Aquatics:*** LWD recruitment ***Upland:*** Less area in need of thinning and planting; greater overall abundance and size of down wood and snags
	Operational activities that minimize introduction, establishment, and spread of invasive plants (or other organisms).	*All*: BMP's to be developed in all strategic plans. ***Monitoring:*** Track species, density, location of invasive plants in relation to operational activities (gravel pits, road work, etc)
	No new invasive plant species introduced to the watershed and reduction of existing invasive plant populations to insignificant levels.	***Monitoring:*** Number of invasive species; number and amount of existing invasive plant species below some threshold
	Within constraints of watershed management, operational activities that minimize impacts to species of concern and disruption of ecosystem function (e.g., timing operations to avoid critical seasons, such as breeding, nesting, and rearing)	*All*: BMP's to be developed in all strategic plans.
	Operations conducted in a manner that minimizes soil compaction, anthropogenic mass-wasting events, erosion, sediment delivery to water bodies, and risk of forest fire	***Monitoring:*** Compliance with current and evolving BMP's and project plans.
	Transparent and effective stakeholder involvement program, resulting in open communications and trust	Measures of effective and transparent stakeholder involvement
	An effective program for evaluating effectiveness of restoration activities at different scales of space and time, using results of evaluation in planning and decisions, and communicating the results of evaluation to stakeholders	*All:* Programmatic implementation of strategic plans
Linkages	Restoration, monitoring, and research programs that create synergies at both program and project levels where spatial and functional connectivity permits (e.g., areas utilized by species such as amphibians that use aquatic, riparian, and upland habitats)	Implementation of synthesis framework (and following identified paths for integration). Commitment to annual review and planning process.

APPENDIX C. THE USE OF FIRE AS A LANDSCAPE TEMPLATE

Scientists have recognized three fire regimes in the region based on typical fire return intervals and behavior (Agee 1993, Edmonds et al. 2000, Keane et al. 2004, Arno and Fiedler 2005):

1. low severity/understory only/frequent (<30/40 year return intervals),
2. moderate severity/mixed severity/moderate frequency (30/40-100 year return intervals), and
3. high severity/stand replacing/infrequent (> 100 year return intervals).

The CRW is within the stand-replacing (or high severity and infrequent) fire regime, in which fires are episodic, rather than periodic, and have return intervals measured in hundreds of years (Agee 1993; Perera et al. 2004; Arno and Fiedler 2005).

The approach of emulating fire or its effects has been used by various landowners (Arno and Fiedler 2005), but apparently only for ecosystems with periodic fires and return intervals of a few to 100 years (Perera et al. 2004; Arno and Fiedler 2005). These are the fire regimes for which fire suppression activities have led to substantial fuel buildup, shifting the areas so managed to the high severity type fire regime (e.g., see Arno and Fiedler 2005). We found no examples of the use of the approach of emulating fire regimes in areas within the natural stand replacing/high severity fire regime.

As explained below, we concluded that use of forest wildfire as a landscape template would not be appropriate in the CRW in a general sense, but could inform restoration in several ways. Fire could, in theory, be used to guide management in prescribed burning, using timber harvest to emulate large-scale patterns of fire on the landscape (e.g., creating mosaics of seral stages), using silviculture to emulate some of the effects of fire (e.g., creating coarse woody debris), or using a fire risk assessment to address vulnerabilities to wildfire. We reviewed some of the pertinent literature and consulted two regional experts in addressing the appropriateness of using forest wildfire in some way as a landscape template or management tool.

When asked, national fire ecology expert Dr. James K. Agee recommended against using prescribed burns in the Cedar River Watershed, largely because of the risk that such a fire might easily evolve into a catastrophic event (James K. Agee, personal communication). When asked during a workshop on developing a watershed template (see Section 4.3), Dr. David L. Peterson, an expert on forest fires and climate change, stated that he did not believe using fire as a landscape template would be appropriate for the watershed (David L. Peterson, personal communication, August 10, 2005).

Apart from the direct use of wildfire itself, approaches to using fire as a template typically use timber harvest of some kind to emulate the effects of fire (Perera et al. 2004, Arno and Fiedler 2005), often trying to recreate historic conditions prior to modern human influence. MacRae et al. (2001), however, caution that timber harvest differs substantially from natural wildfire in its effects on ecosystems, and this difference would be substantial under the severe fire regime.

Furthermore, Hughes et al. (2005) have argued, for riverine ecosystems, that using historical reference condition is not appropriate for planning restoration because (1) there are often no appropriate reference systems to use, (2) many catchment parameters have changed since the times of chosen historic reference systems, (3) climate change has been continuous throughout the Holocene, (4) projected climate change is of uncertain magnitude, (5) alien species cannot be avoided, and (6) landscape context changes through time.

Many of these observations apply to some degree to the CRW: (1) no appropriate reference watersheds are available that lack substantial human influence, (2) current conditions in the watershed were produced largely by clear-cut logging, rather than by fire, (3) climate has varied over past millennia in the region, (4) regional climate is expected to change more, but there is substantially uncertainty with respect to the details of that change in any small area, (5) invasive, alien species are present in and near the watershed, and (6) land use around the watershed (landscape context) has changed substantially over time, and can be expected to change more. Consequently, we decided that fire is an inappropriate tool to use as a landscape template. We will, however, attempt during restoration to simulate some of its effects (i.e., creation of snags and logs), and have considered the risk and consequences of fire during our vulnerabilities analysis.

APPENDIX D. VULNERABILITY OF SENSITIVE AND CRITICAL AREAS TO ROADS

The extensive road network with the Cedar River Watershed is both a blessing and a curse. This network provides access to numerous unique and ecologically significant resources and enables us to both monitor and consider for restoration many remote areas. Parts of this road network are also critical to the daily operation and maintenance of key infrastructure. This same network, however, threatens a wide array of natural resources and key processes in complex ways. To assess these interactions and support an integrated strategy for future road decommissioning and improvement work, the following approach was developed to rank and prioritize road segments which are consistent with restoration objectives identified in the strategic plans and the Synthesis Framework document.

Each restoration group (Upland, Aquatic, and Riparian) identified specific restoration goals which are potentially affected by road-related activities (Table D1, below). For each goal, which addressed a unique resource or process, criteria were developed to differentiate between resource areas based on their likely sensitivity to road impacts. In many instances, proximity of the road to the sensitive resource determined the relative sensitivity, such as where roads entered riparian zones adjacent to low gradient streams. Conversely, where the restoration goal addressed natural connectivity within old growth forests, for example, road-related sensitivity was a function of patch size with larger forest stands having greater relative sensitivity to roads than smaller stands.

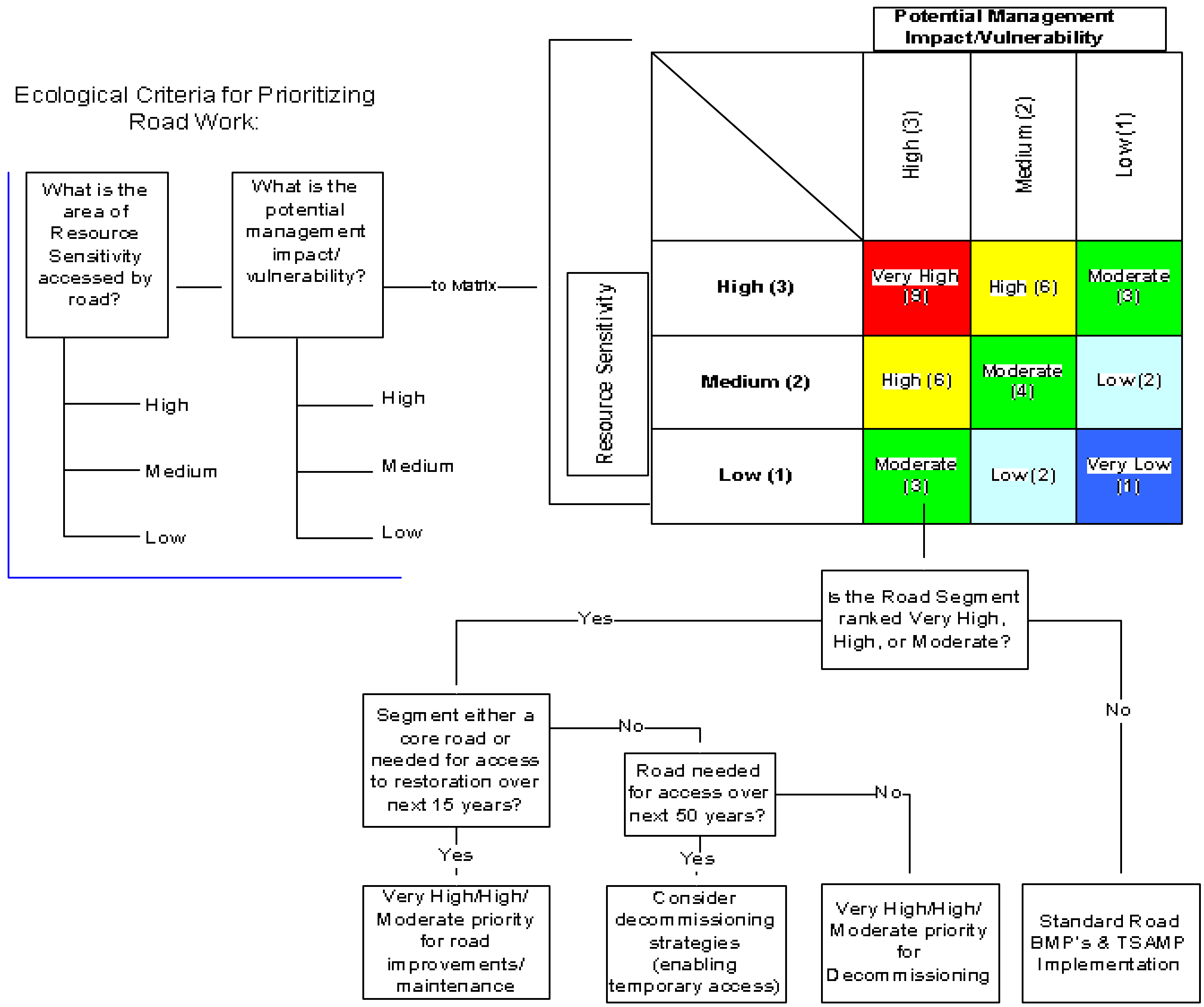
In addition to an assessment of resource sensitivity, the likely impact to the resource or road-related process was assessed based on current road use and conditions (Table D1). Road use, road location relative to the resource, and road attributes affecting surface flow interception and sediment delivery are all examples of road-related impacts used to assess current road impacts.

Table D1: Ecosystem-based road prioritization criteria

Restoration Type	Restoration Goal	Resource Sensitivity	Potential Management Impact/Vulnerability
Upland	Natural connectivity within and/or between forest patches that are old growth or high quality 2nd growth	**High**: Old Forest Patch Size >250 acres or good spotted owl nesting habitat (“STOC_best”=1) **Moderate:** Old Forest Patch Size 100-250 acres and good foraging habitat (STOC_best”=2) Data at F:\projects\old_forest\ classification.mdb (og forest table)	**High**: Roads usage equivalent to Light, Moderate, or Moderately Heavy usage as assessed using WARSEM traffic factors **Moderate**: Road use equal to Occasional or None
	Natural connectivity within special habitats (e.g., talus, open meadows, etc.)	**High:** Special habitat patches greater than 15 ac in size **Moderate:** Special habitat patches 10 – 15 ac in size	**High:** Road length crossing habitat patch > 800 ft **Moderate:** Road length crossing habitat patch 500 - 800 ft
Riparian/ Aquatic	Maintain natural LWD recruitment processes within response reaches	**High**: GMUs 8-16, 18 **Moderate:** GMUs 5-7, 11,17	**High:** Roads within 100 feet of stream **Moderate:** Roads within 200ft
	Reduce fine sediment delivery from roads	**High:** GMUs 8-18 streams (adjacent to or less than 3,000 ft downstream of road	**High:** Segments contributing more than 5.8 tons/year **Moderate:** 1-5.8 tons/year

Restoration Type	Restoration Goal	Resource Sensitivity	Potential Management Impact/Vulnerability
		Moderate: All other stream crossings	
	Maintain amphibian habitat connectivity between wetlands and adjacent forests	**High:** Open and Closed Depressional Wetlands **Moderate:** Riverine, Lacustrine, and Slope-connected wetlands	**High:** Roads within 1640 feet (0.5 km) of wetland **Moderate:** Roads within 3280 ft (1 km) of wetland
	No landslides triggered by roads	**High**: GMUs 8-18 streams (adjacent to and within 3,000 ft) **Moderate:** All other stream crossings	**High:** Roads within High Mass Wasting Potential Hazard Areas (and Inner Gorges if not included) **Moderate:** Roads within Moderate Mass Wasting Potential Hazard Areas
	Maintain natural hydrologic flow paths	**High:** Wetlands within 300 feet of road **Moderate:** Wetlands within 600 feet of road	**High:** Ratio of culverts to road segment length : <1/400ft **Moderate:** Ratio of culverts to road segment length : Between 1/400 and 1/200ft

Using the criteria defined above, a prioritization matrix (Figure D1) was used to link our understanding about areas of particular resource sensitivity with our understanding of road-related impacts to these areas and relevant critical processes. Using this approach, individual road segments were assigned a prioritization rating which reflects the extent to which current road conditions are contributing to habitat degradation as it relates to each restoration goal.


Ecological Criteria for Prioritizing Road Work:
What is the area of Resource Sensitivity accessed by road?
High
Medium
Low
What is the potential management impact/ vulnerability?
High
Medium
Low
to Matrix
Potential Management Impact/Vulnerability
High (3)
Medium (2)
Low(1)
Resource Sensitivity
High (3)
Very High (9)
High (6)
Moderate (3)
Medium (2)
High (6)
Moderate (4)
Low(2)
Low (1)
Moderate (3)
Low(2)
Very Low (1)
Is the Road Segment ranked Very High, High, or Moderate?
Yes
No
Segment either a core road or needed for access to restoration over next 15 years?
Yes
No
Road needed for access over next 50 years?
Yes
No
Very High/High/ Moderate priority for road improvements/ maintenance
Consider decommissioning strategies (enabling temporary access)
Very High/High/ Moderate priority for Decommissioning
Standard Road BMP's & TSAMP Implementation

2 * 1 = 2 Low
1 * 1 = 1 Very Low

Using this ranking scheme, the majority of road segments representing variable road lengths ranging from 100 feet to 1 mile) fall into the very low to moderate priority category (Table D2 and Figure D2 below). Based on this scheme, the extent of restoration goal most likely to be significantly adversely affected by current road conditions relates to alteration of natural flow paths due to insufficient culverts adjacent to critical wetlands, where 19% of all road segments are assumed to have a high to very high priority. Conversely, this analysis also suggests that roads do not currently pose a significant threat to most special habitats such as talus and meadow systems.

Table D2: Number of road segments (and percent of total) in each Restoration Goal Rank

Restoration Priority	Old Forest Connectivity	Spec. Habitat Connectivity	Impairment of LWD Recruitment	Fine Sediment Delivery	Amphibian Habitat Connectivity	Mass Wasting Disturbance	Natural Flow Paths
Very Low (1)	4296 (94%)	4560 (99%)	4103 (90%)	3530 (77%)	573 (13%)	2146 (47%)	671 (15%)
Low (2)	0	11(<1%)	0	704 (15%)	1493 (33%)	1491 (32%)	1071 (23%)
Moderate (3-4)	73 (2%)	6 (<1%)	111 (2%)	294 (6%)	2430 (53%)	538 (12%)	1984 (43%)
High (6)	213 (4%)	2 (<1%)	252 (5%)	50 (1%)	39 (<1%)	407 (9%))	471 (10%)
Very High (9)	0	3 (<1%)	116 (3%)	4 (<1%)	47 (1%)	0	385 (9%)

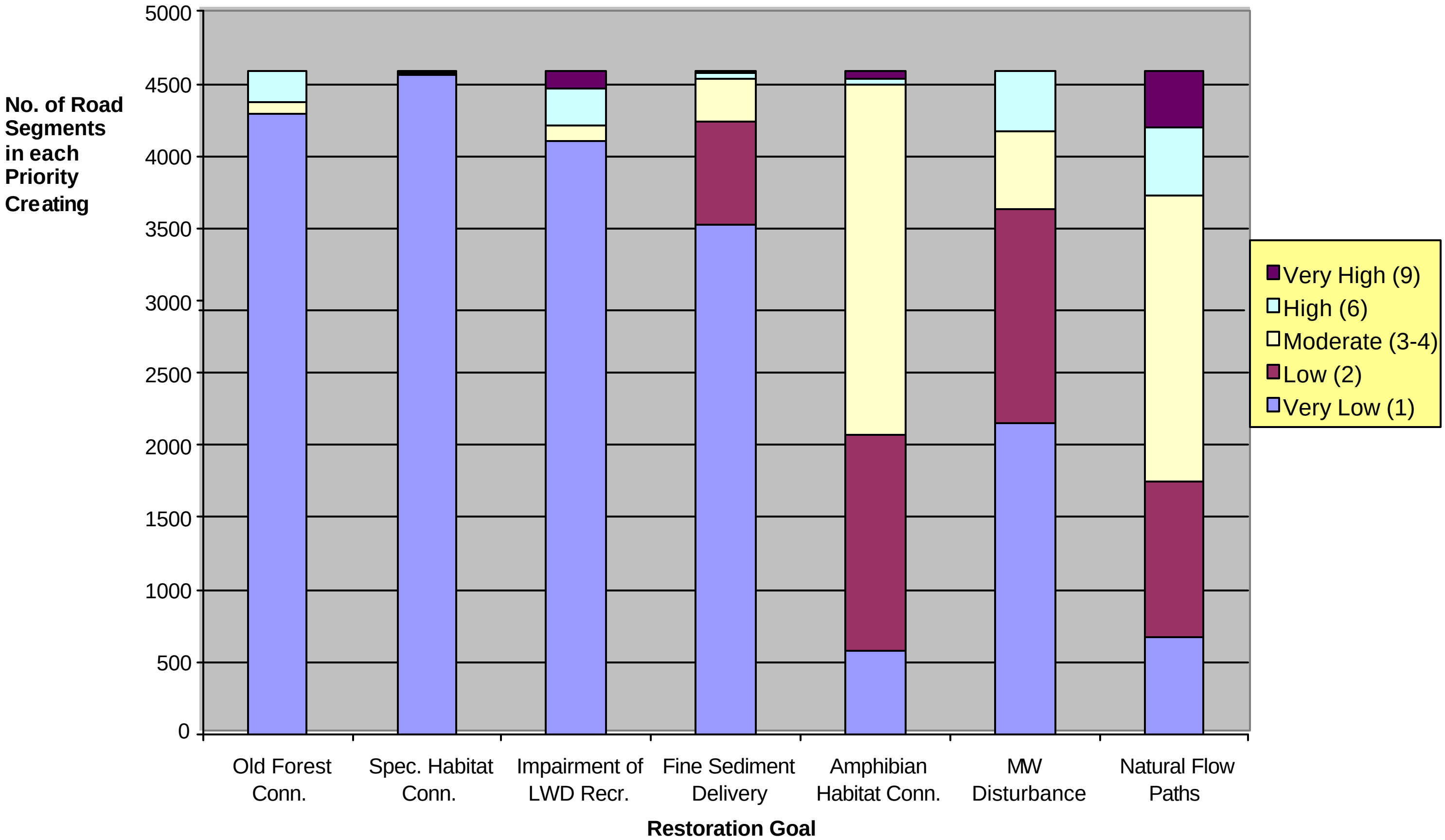


Figure D2: Summary of Ecosystem-based road segment ranking

<u>Overall Ecosystem Prioritization Ranking:</u>
To come up with an overall ranking which integrates all of the restoration goals, road segment values for each restoration goal were summed and divided by 7. Overall rank values, ranging from 1 to 5.2, were partitioned into one of five prioritization categories as defined below:
1.0 - 1.5 Very Low
1.6 - 2.1 Low
2.2 - 2.6 Moderate
2.7 - 3.3 High
3.4 - 5.0 Very High

Based on this ranking system, 63 road segments have been identified as very high priority and an additional 368 segments as high priority (Figures D3 and D4). The extent to which the ecological impacts from these segments could be addressed via decommissioning versus other management strategies depends on the unique combination of impacts posed by a given road. In light of this analysis, one approach to tackling this issue might be for each restoration work group to critically evaluate all of the high and very high priority road segments and develop some project-specific solutions which would reduce the adverse impacts from these road segments as they relate to there respective restoration goals.

<u>Relationship of this work to the Transportation Strategic Asset Management Plan (TSAMP):</u>
The ranking system discussed above provides an important piece of information used by the TSAMP in its ongoing effort prioritize all road work within the CRW while meeting the varied and complex needs of SPU and SCL. To understand how this information was integrated into the TSAMP, please see the draft TSAMP.

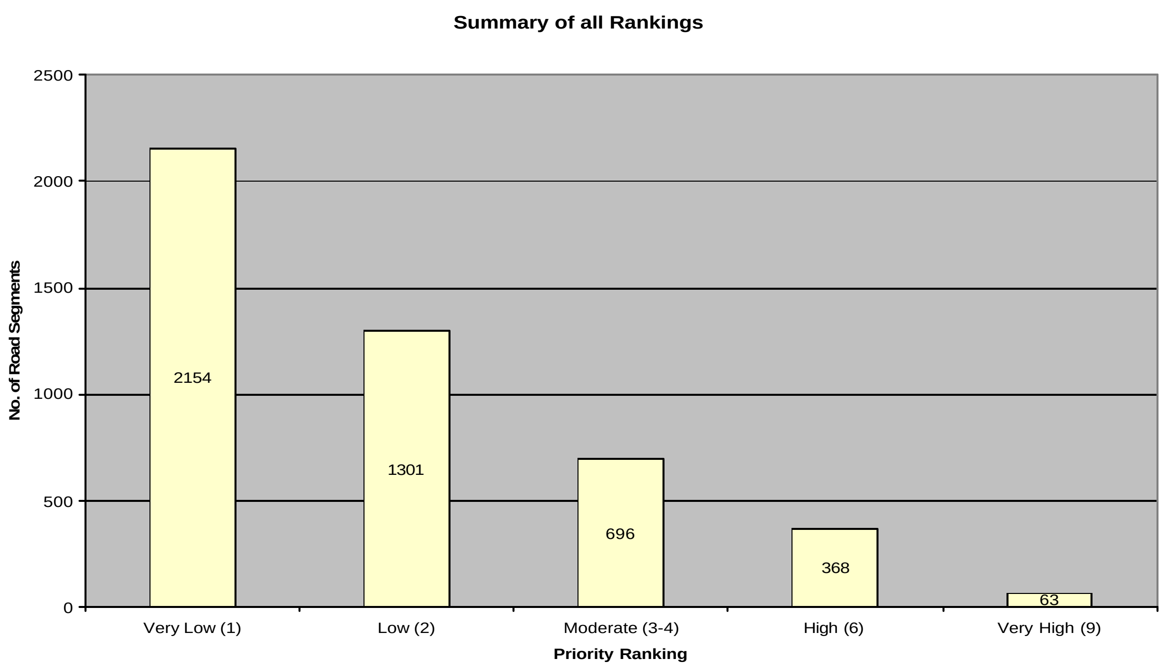


Figure D3: Summary of All Rankings

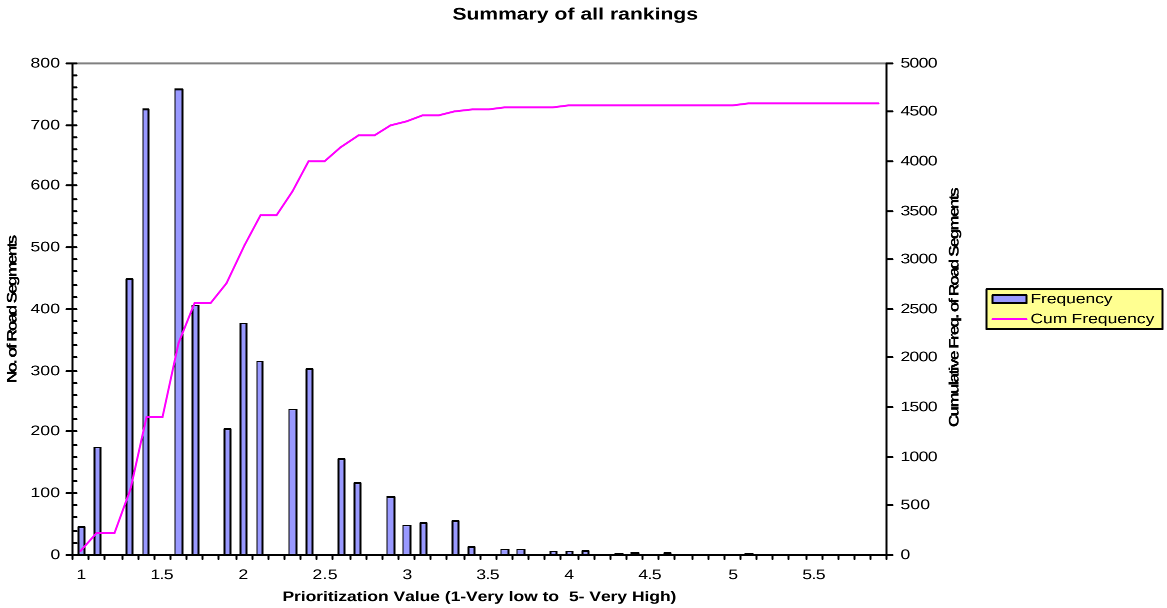
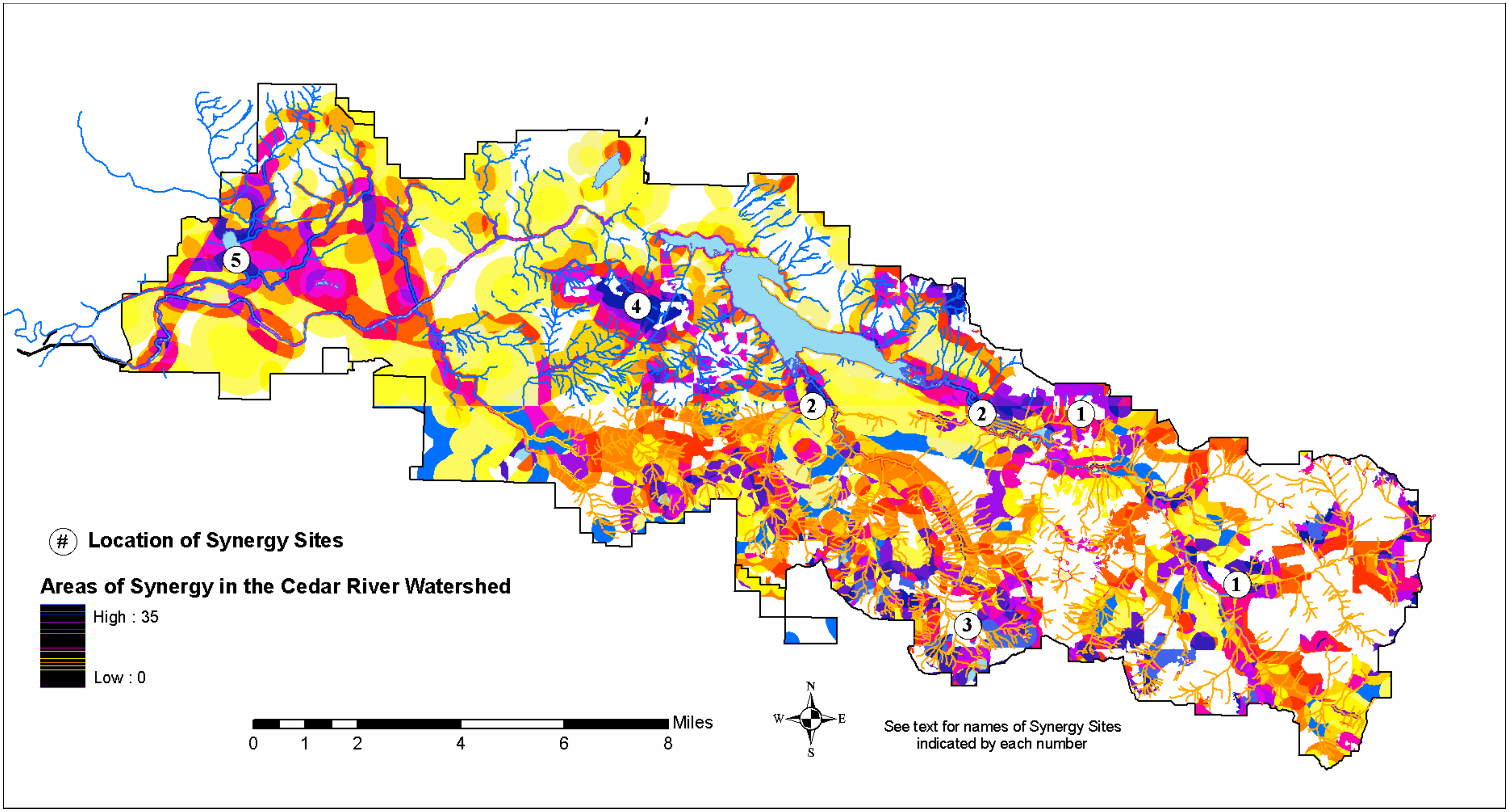
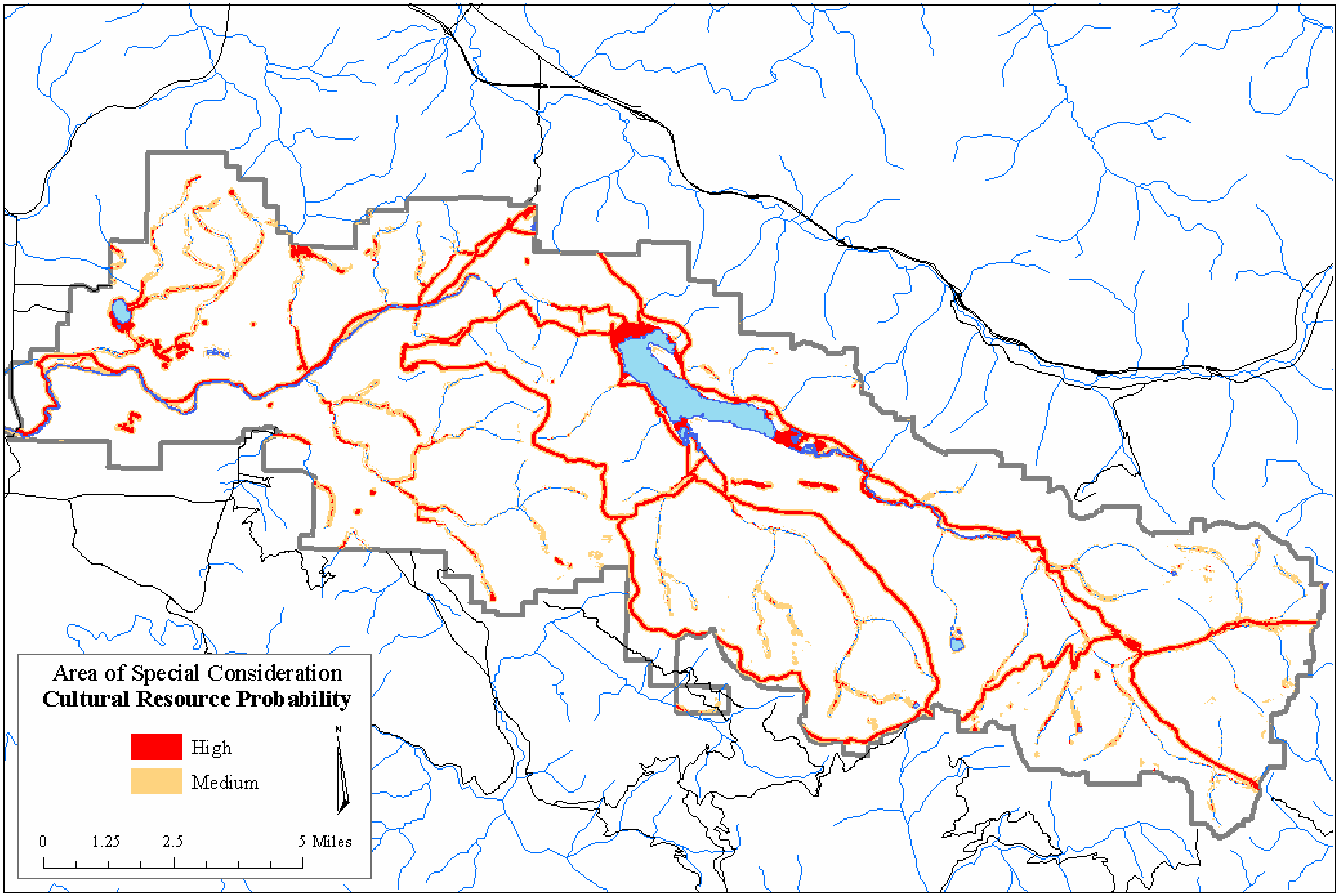


Figure D4: Cumulative frequency of all ecosystem-based road segment ranks

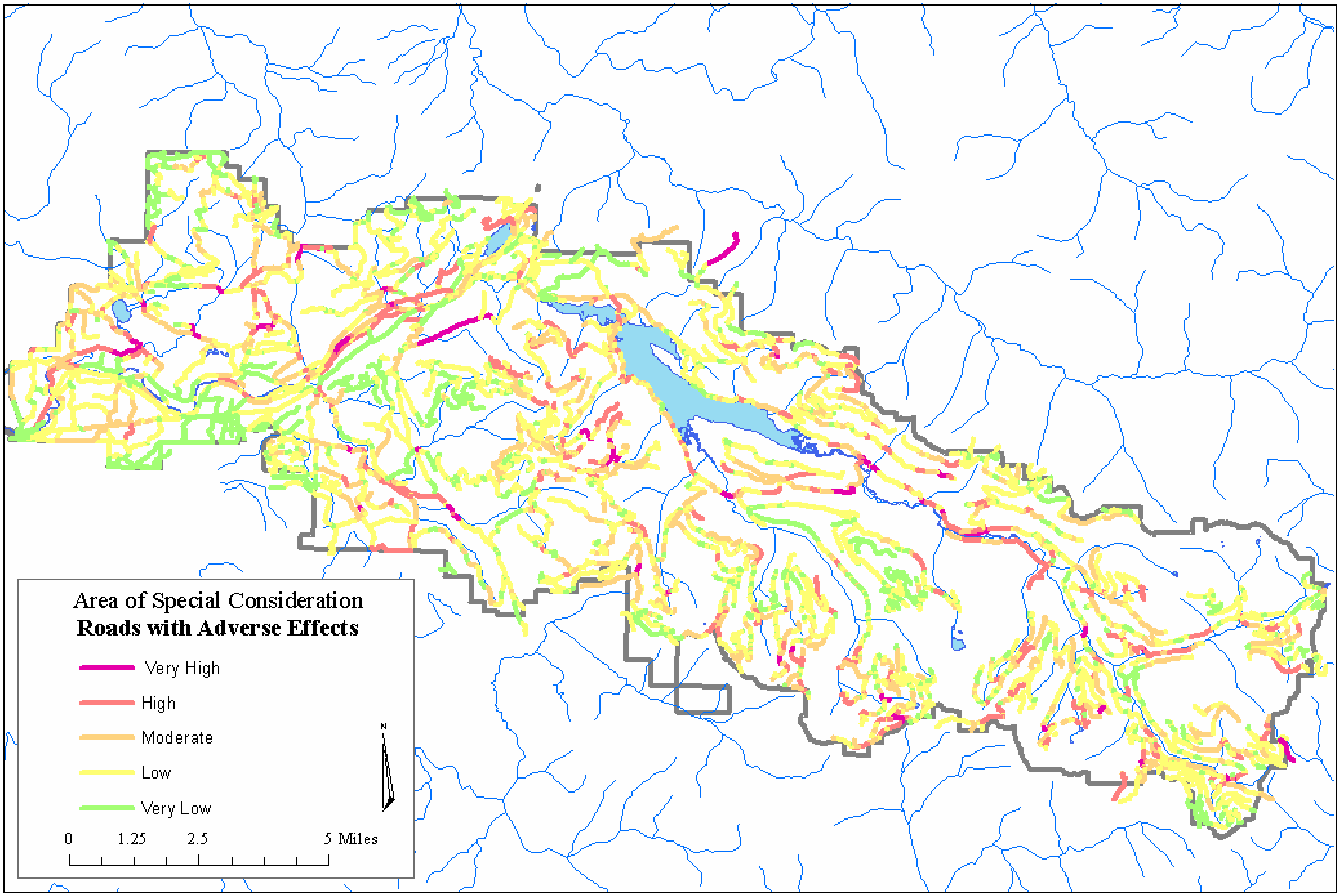
APPENDIX E: MAPS



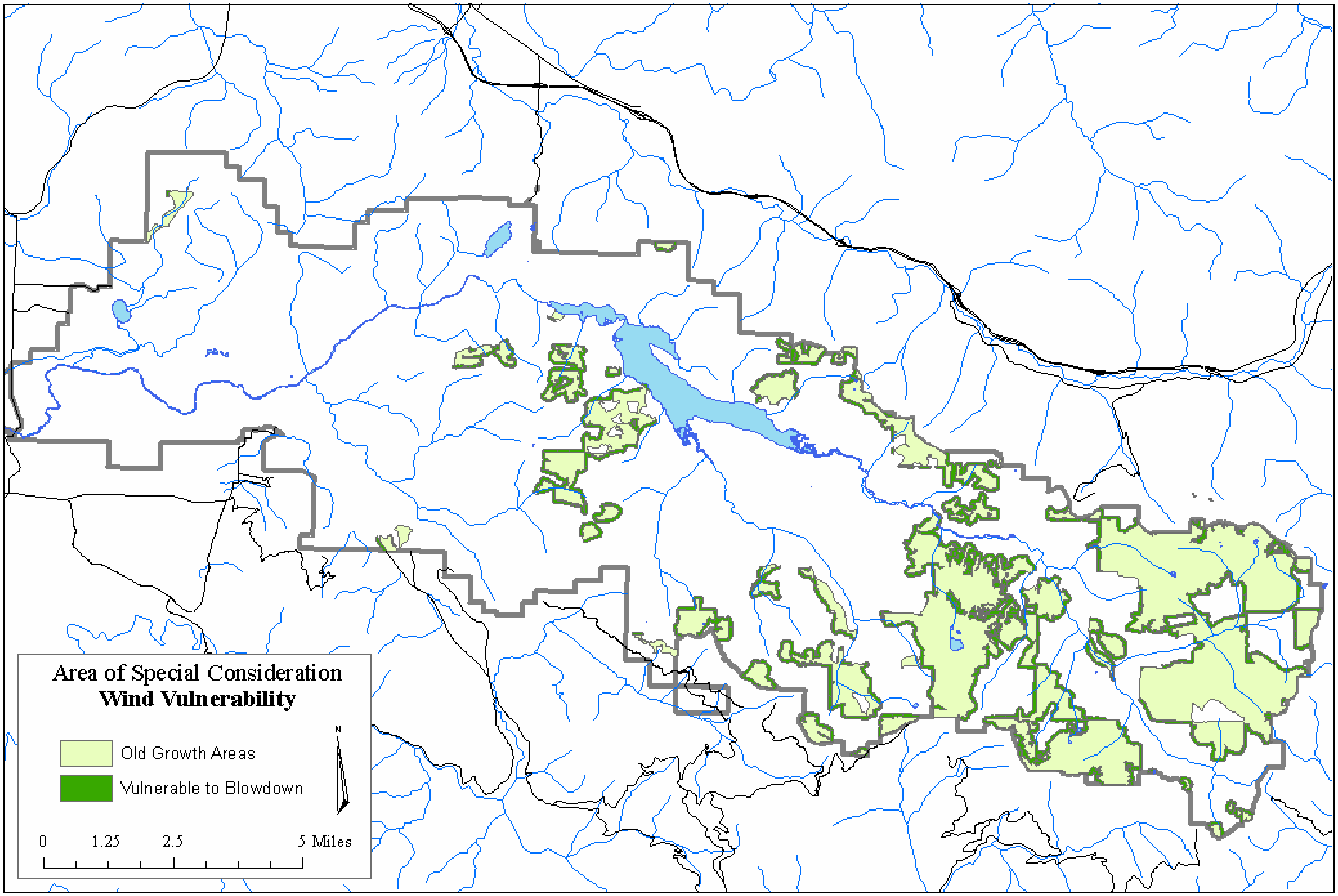
Map 1. Synergy Areas.



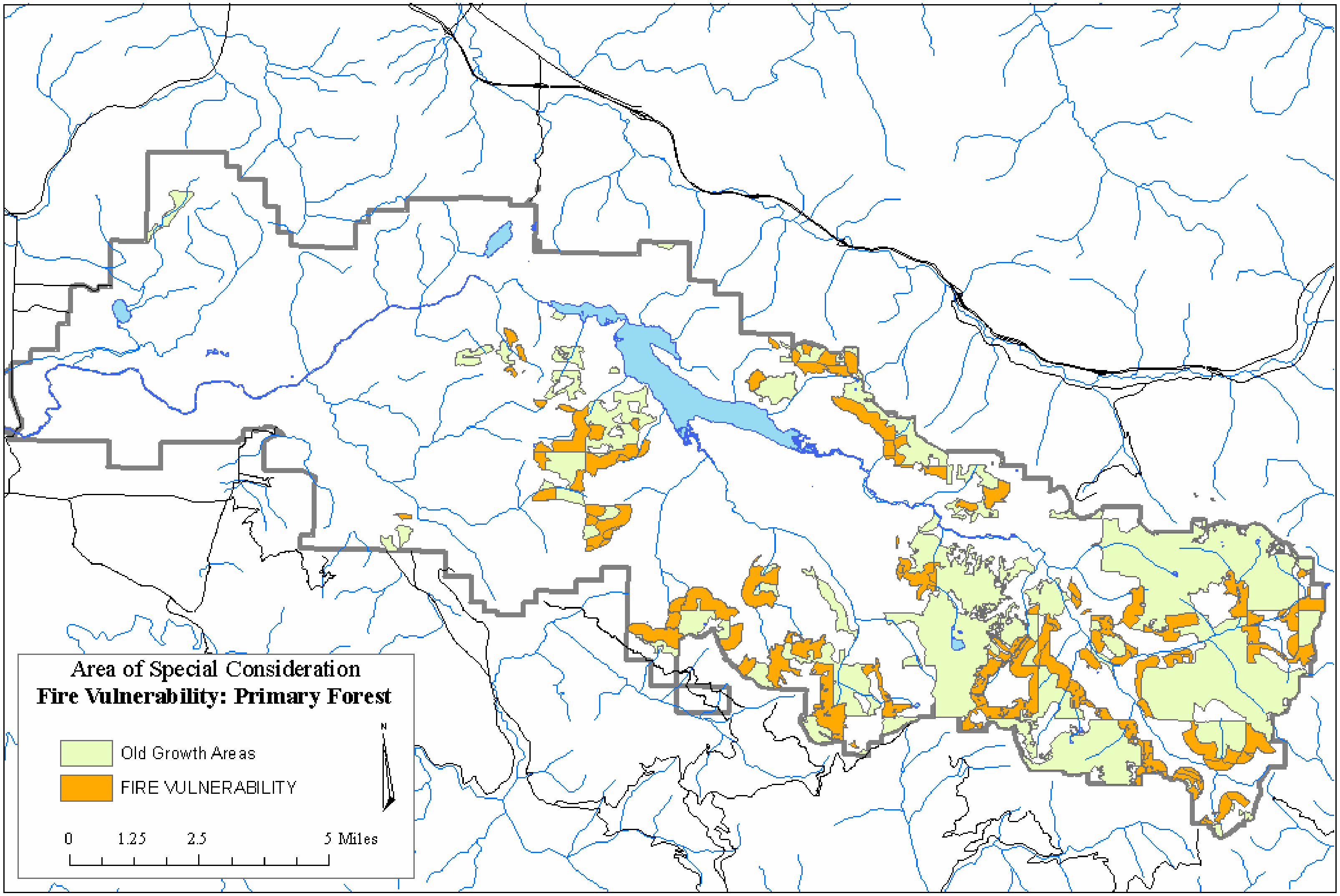
Map 2. Areas of Special Consideration: Cultural Resource Probability.



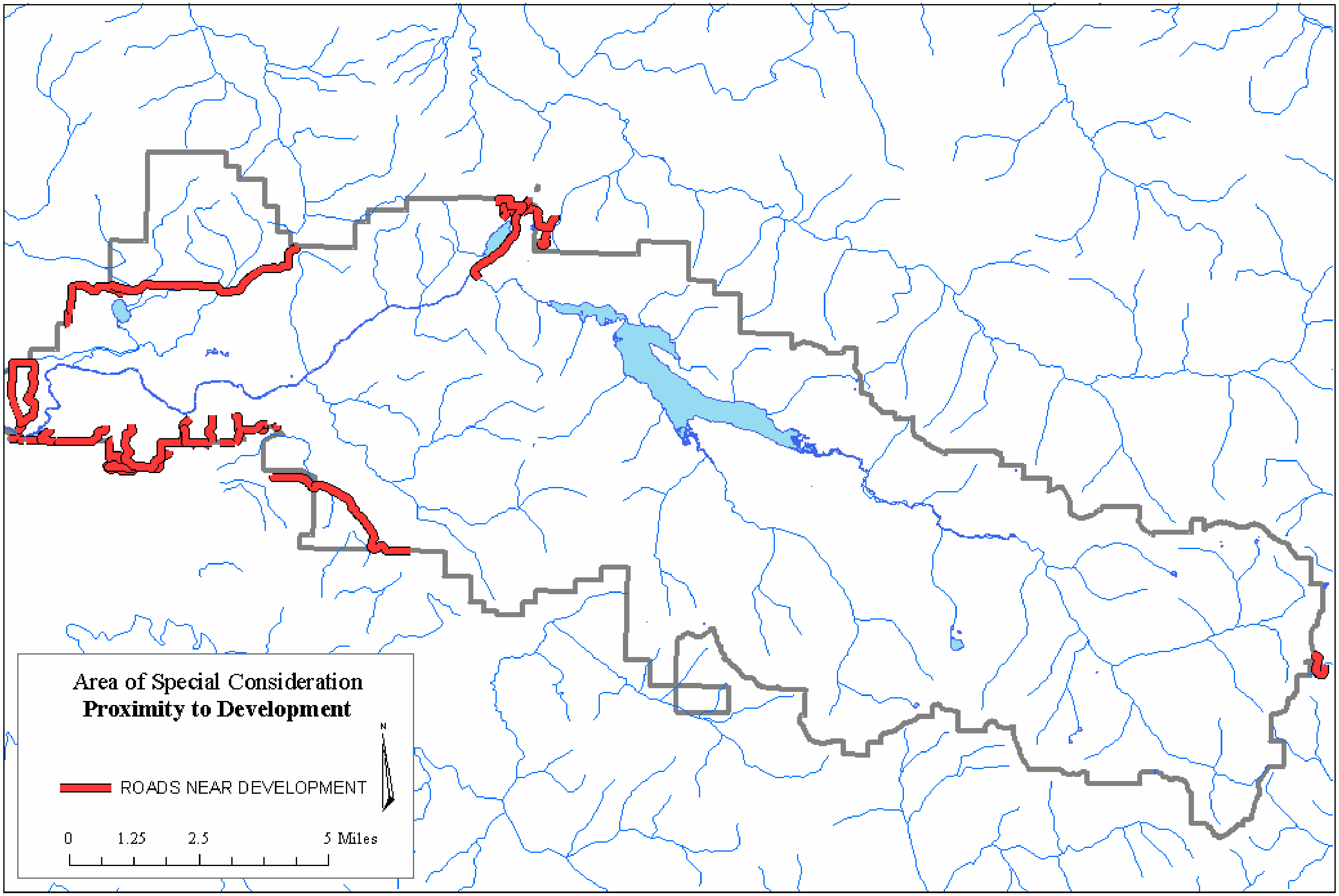
Map 3. Areas of Special Consideration: Roads with Adverse Effects.



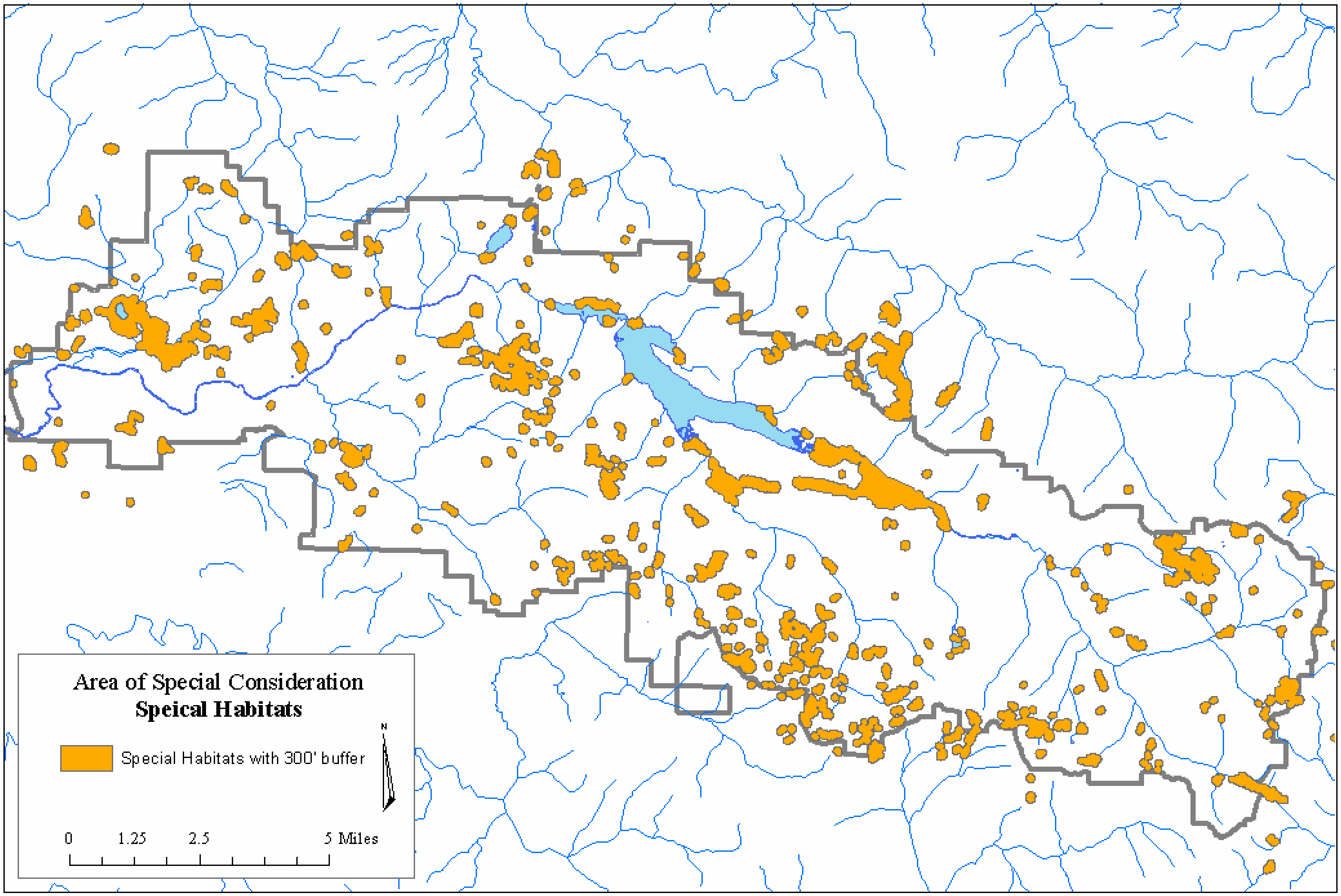
Map 4. Areas of Special Consideration: Wind Vulnerability.



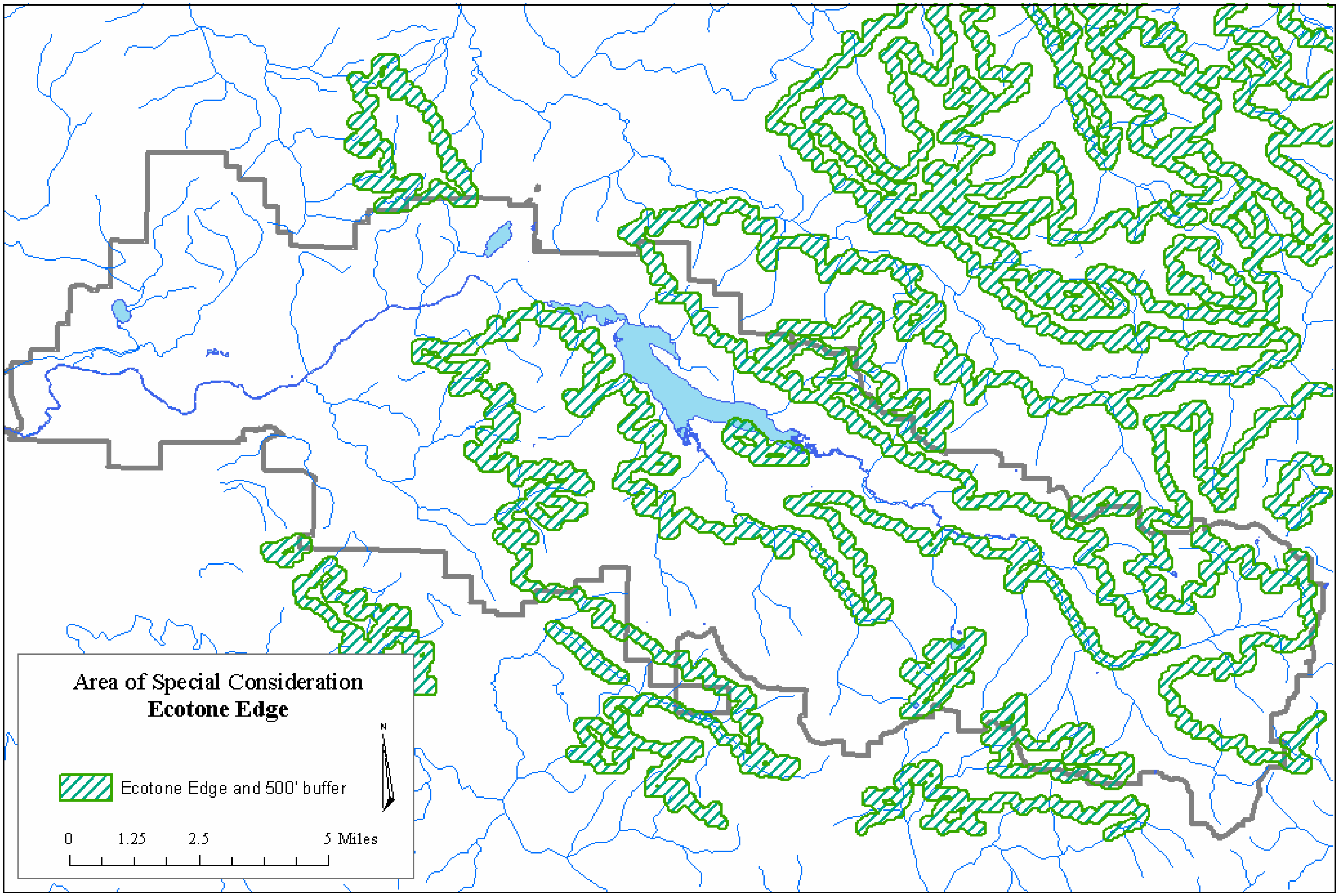
Map 5. Areas of Special Consideration: Fire Vulnerability: Primary Forest.



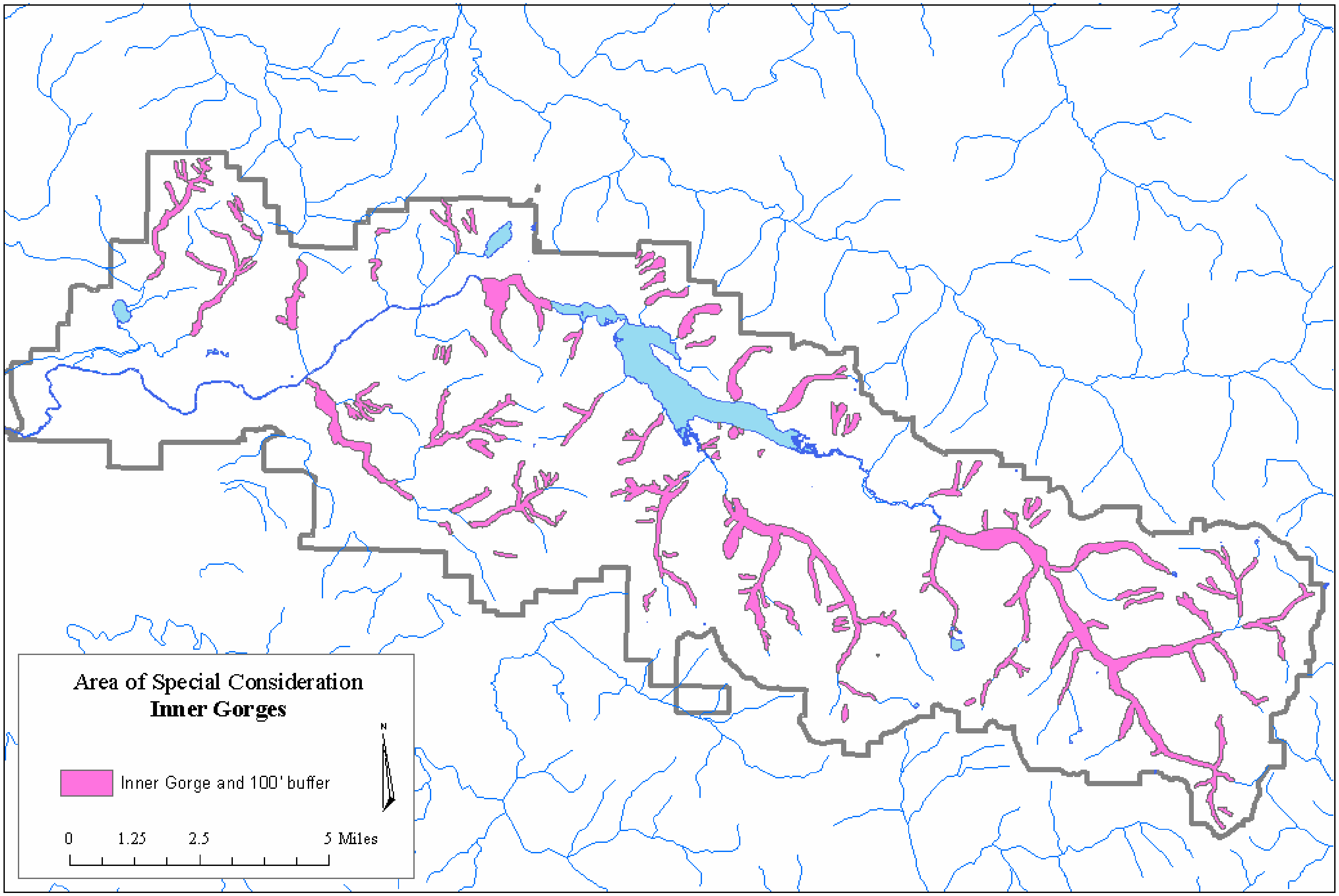
Map 6. Areas of Special Consideration: Proximity to Development.



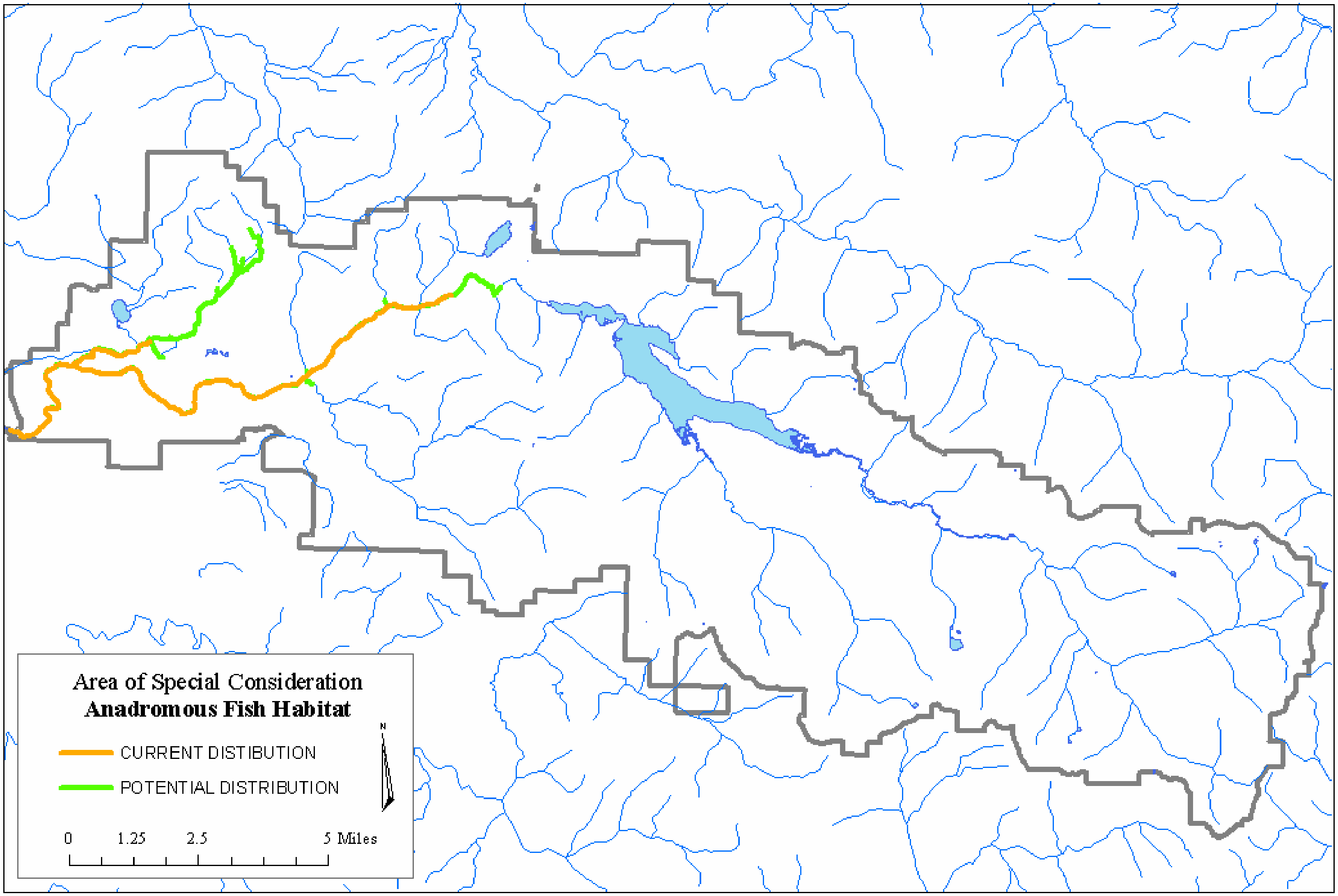
Map 7. Areas of Special Consideration: Special Habitats.



Map 8. Areas of Special Consideration: Ecotone Edge.



Map 9. Areas of Special Consideration: Inner Gorges.



Map 10. Areas of Special Consideration: Anadromous Fish Habitat.