This document is part of a collection of Ecological Integrity Assessments addressing 67 of Washington's 99 Ecological Systems. These documents were prepared by the Washington Natural Heritage Program with funding provided by the Washington Department of Fish and Wildlife.

Ecological Integrity Assessment:
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland and Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland

Ecological Summary

The spruce – fir (*Picea engelmannii) - Abies lasiocarpa (*primarily *bifolia)* subalpine forest and woodlands of the Rocky Mountains and in northeast Cascade Mountains are composed of two ecological systems recognized at high-elevations. The Dry-Mesic Subalpine Spruce Fir and the Mesic-Wet Spruce Fir Forest and Woodland ecological systems usually co-occur on the landscape separated by aspect and topographic position. The Mesic-Wet system extends to lower elevations in cold air drainages or frost pockets and is more common in wetter, deeper snowpack climates. In Washington, the Mesic-Wet system is more common than the Dry-Mesic system which is more common in the Rocky Mountains. They are combined here for the EIA although differences will be emphasized when appropriate.

In Washington, these systems generally appear at mid-elevation to near upper treeline (4000 and 6500 feet) in northeastern Washington, east Cascades, Blue Mountains and in the high rain shadow in the northeast Olympic Mountains, Mount Baker and Mount Rainier in western Washington. These are in cold, moist environments with a snow-dominated, more continental climate. Winters are long and cold creating a short growing season. Snowpack depth (2-12 feet), late snow melting, and spring moisture are important to success of tree regeneration. Forests are closed to open and usually dominated by *Picea engelmannii* and/or *Abies lasiocarpa*. *Pinus contorta* is a common canopy member in Rocky Mountain and northeast Cascade occurrences. Large *Pinus contorta* var. *latifolia* stands are recognized as the Rocky Mountain Lodgepole Pine Forest system. A portion of the Mesic-Wet system includes *Tsuga mertensiana* in the Northern Rockies and in the drier portions of the Cascades (areas typically without *Abies amabilis* or *Cupressus nootkatensis).* The Mesic-Wet Subalpine Spruce Fir system is usually associated with Northern Rocky Mountain or East Cascades Montane Mesic systems. *Pseudotsuga menziesii, Pinus contorta,* or *Larix occidentalis* may persist in occurrences of the Dry-Mesic system for long periods without regeneration. Mixed conifer/*Populus tremuloides* stands may be encountered in the Dry-Mesic Subalpine Spruce Fir system.

Upper elevation examples may have more woodland physiognomy and *Pinus albicaulis* can be a seral component. The understory is variable where shrubs can be absent to dominant. The highest elevation sites that are in transition to subalpine parkland or woodland systems typically contain the short shrubs *Phyllodoce empetriformis* and *Empetrum nigrum* and the herbaceous species *Luzula glabrata* var. *hitchcockii* or *Lupinus arcticus* ssp. *subalpinus.* Mesic-Wet

Subalpine Spruce Fir system understory species includes taller shrubs *Menziesia ferruginea, Vaccinium membranaceum, Rhododendron albiflorum, Rubus parviflorus, Rubus pedatus Ledum glandulosum* and herbaceous species *Actaea rubra, Clintonia uniflora, Cornus canadensis, Gymnocarpium dryopteris, Tiarella trifoliata,* and *Valeriana sitchensis*. Species typically associated with the Dry-Mesic Subalpine Spruce Fir system include *Vaccinium scoparium, Shepherdia canadensis, Amelanchier alnifolia, Juniperus communis, Linnaea borealis, Mahonia repens* and herbaceous species *Arnica cordifolia, Calamagrostis canadensis* and *Carex geyeri*. More mesic shrub species, such as *Menziesia ferruginea, Rhododendron albiflorum*, and *Vaccinium membranaceum* may be present in the Dry-Mesic Subalpine Spruce Fir system as shorter stature less abundant members of the understory.

A high-severity/low frequency fire regime typically characterizes spruce-fir forests (Agee, 1993). This results from the subalpine environment that influences flammability and fire spread and in combination with weather limits fires occurrences to only a few weeks in late summer (Jenkins et al 2008). Fire frequency in spruce-fir forests consequently is low. Trees with dense crowns and low branches are often covered with lichens and typically have a sparse understory with compact litter. This reduces low-intensity surface fires and creates conditions for crown fire (Jenkins et al 2008). Landfire (2007) lists fire regime III for both Wet-Mesic and Dry-Mesic subalpine spruce-fir systems that include 35-100+ year frequency of mixed severity and 35-400+ year frequency of high severity fires. Lightning strikes are frequent, but will often result in small, patchy spot fires. Other natural disturbances include occasional windthrow and insect outbreaks (30-50 years) that create canopy gaps. Actions of defoliator and bark beetles can influence stand development, species composition and stand density. Large scale insect infestations may create large patches of early seral conditions and/or create conditions that lead to large, stand-replacement fires.

The historic range of variability of these systems is highly variable. Because of fire sensitivity of both *Picea engelmannii* and *Abies lasiocarpa* fire return interval is important in initial stand conditions. In general, infrequent fires often lead to dominance of *Picea engelmannii* and/or *Abies lasiocarpa* with little or no *Pinus contorta, Larix occidentalis*, or *Pseudotsuga menziesii* because of severe site conditions. When very severe fires occur, shrubland or grassland areas can persist for long periods. These are often part of the Mesic-Wet Subalpine Spruce Fir system with high severity fire regimes. Persistent treeless areas may better be classified the Northern Rocky Mountain Subalpine Deciduous Shrubland or Northern Rocky Mountain Subalpine-Upper Montane Grassland systems. Tree establishment is slow and stands remain open even into old-growth (Agee 1989). These aging mixed conifer stands become more susceptible to spruce beetle, to root diseases (*Phellinus, Armillaria*), and to windthrow with time. Stands with over 65% *Picea engelmannii* over 15 in (40 cm) dbh are most susceptible to spruce beetle attack. The patchy nature of these forests is similar to forests with a mixed severity fire regime although the stands are primarily uneven age. The Dry-Mesic Subalpine Spruce Fir system typically has mixed conifer forests with more fire-adapted tree species, *Pinus contorta, Larix occidentalis* or *Pseudotsuga menziesii* with *Picea engelmannii* and/or *Abies lasiocarpa* present than in the Mesic-Wet system. These may include small even-aged stands of a single species. Bark beetle infestations of *Pinus contorta* can create gaps and move these stands to high severity regimes dominated by *Picea engelmannii* and/or *Abies lasiocarpa.* Quigley and others (1997) estimate that, historically, late-seral patches occupied approximately 25%, mid-seral 52%, and early-seral

23% in the east Cascades of Washington. Landfire (2007) modeled 30-35% of these systems (BpS) as late seral (25% open), 50-60% mid-seral (40% closed) and 5-20% early seral.

Stressors

The stressors described below are those primarily associated with the loss of extent and degradation of the ecological integrity of existing occurrences. The stressors are the cause of the system shifting away from its natural range of variability. In other words, type, intensity, and duration of these stressors is what moves a system's ecological integrity rank away from the expected, natural condition (e.g. A rank) toward degraded integrity ranks (i.e. B, C, or D).

Since European settlement, timber harvest, introduced diseases, such as balsam woolly adelgids (*Adelges piceae*) on subalpine fir, road building, development, and tree plantations have all impacted natural disturbance regimes, forest structure, composition, landscape patch diversity, and tree regeneration. Fire exclusion generally has had little to no effect on fuels or forest structure in forests characterized by high-severity fire regimes (Noss et al 2006). Road development has fragmented many forests creating fire breaks. Quigley and others (1997) estimate that mid-seral forest structure is currently 10% more abundant than historically, late-seral forests are diminished by 75% and early-seral forest abundance is 57% more than historically in the east Cascades of Washington.

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with this system are presented in Figure 1.

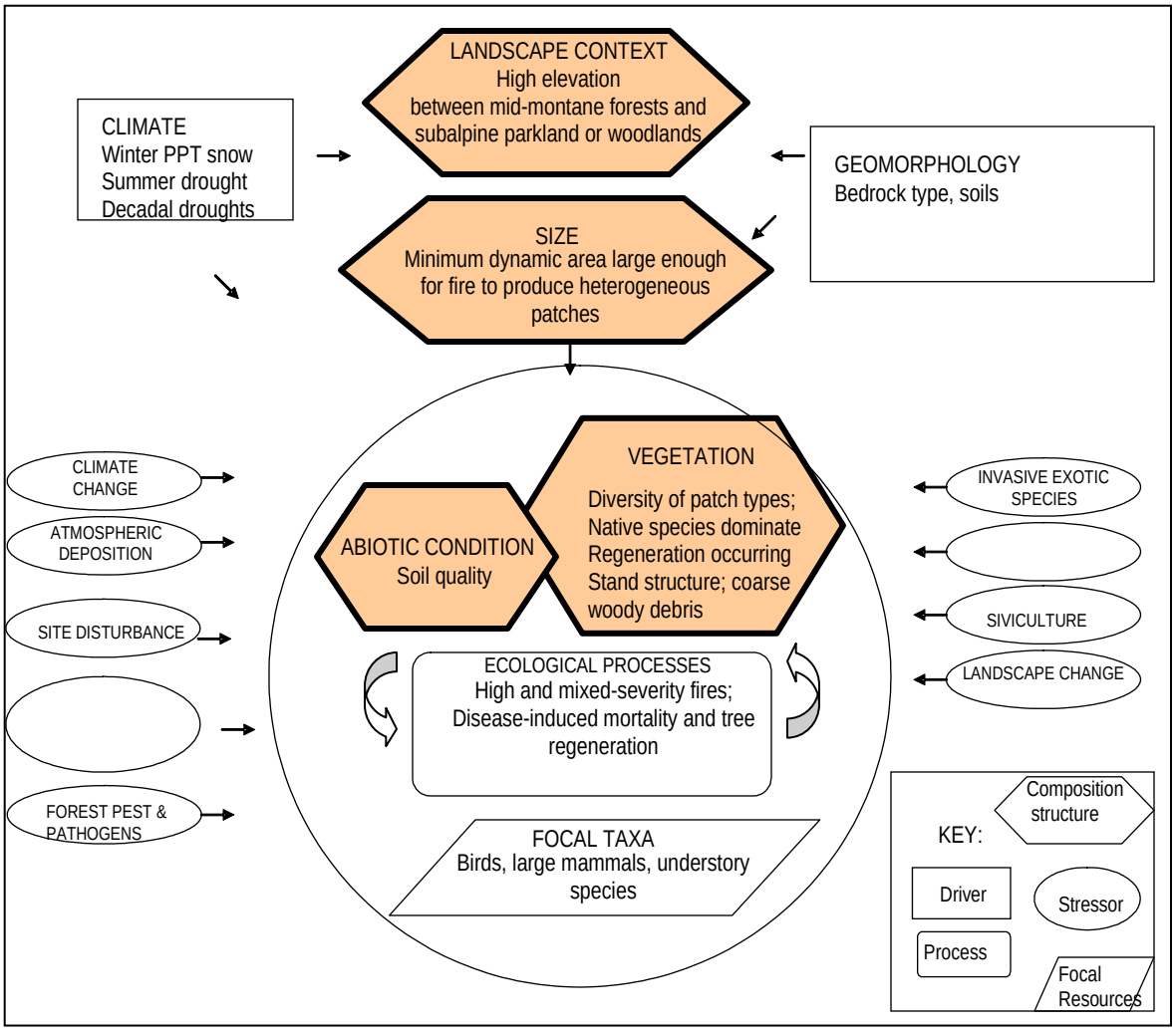

Figure 1. Conceptual Ecological Model for Rocky Mountain Subalpine Dry-Mesic and Mesic-Wet Spruce-Fir Forest and Woodland Systems.

Ecological Integrity Assessments

The assessment of ecological integrity can be done at three levels of intensity depending on the purpose and design of the data collection effort. The three-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy. The three-level approach also allows users to choose their assessment based in part on the level of classification that is available or targeted. If classification is limited to the level of forests vs. wetlands vs. grasslands, the use of remote sensing metrics may be sufficient. If very specific, fine-scale forest, wetland, and grassland types are the classification target then one has the flexibility to decide to use any of the three levels, depending on the need of the assessment. In other words, there is no presumption that a fine-level of classification requires a fine-level of ecological integrity assessment.

Because the purpose is the same for all three levels of assessment (to measure the status of ecological integrity of a site) it is important that the Level 1 assessment use the same kinds of metrics and major attributes as used at Levels 2 and 3. Level 1 assessments rely almost entirely

on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed. Level 2 assessments use relatively rapid field-based metrics that are a combination of qualitative and narrative-based rating with quantitative or semi-quantitative ratings. Field observations are required for many metrics, and observations will typically require professional expertise and judgment. Level 3 assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences. They often use quantitative, plot-based protocols coupled with a sampling design to provide data for detailed metrics.

Although the three levels can be integrated into a monitoring framework, each level is developed as a stand-alone method for assessing ecological integrity. **When conducting an ecological integrity assessment, one need only complete a single level that is appropriate to the study at hand.** Typically only one level may be needed, desirable, or cost effective. But for this reason it is very important that each level provide a comparable approach to assessing integrity, else the ratings and ranks will not achieve comparable information if multiple levels are used.

Level 1 EIA

A generalized Level 1 EIA is provided in Rocchio and Crawford (2009). Please refer to that document for the list of metrics applicable to this ecological system.

Level 2 EIA

The following tables display the metrics chosen to measure most of the key ecological attributes in the conceptual ecological model above. The EIA is used to assess the ecological condition of an assessment area, which may be the same as the element occurrence or a subset of that occurrence based on abrupt changes in condition or on artificial boundaries such as management areas**. Unless otherwise noted, metric ratings apply to both Level 2 and Level 3 EIAs. The difference between the two is that a Level 3 EIA will use more intensive and precise methods to determine metric ratings.** To calculate ranks, each metric is ranked in the field according the ranking categories listed below. Then, the rank and point total for each metric is entered into the EIA Scorecard and multiplied by the weight factor associated with each metric resulting in a metric 'score'. Metric scores within a key ecological attribute are then summed to arrive at a score (or rank). These are then tallied in the same way to arrive at an overall ecological integrity score.

Table 1. Rocky Mountain Subalpine Dry-Mesic and Mesic-Wet Spruce-Fir Forest and Woodland Level 2 EIA

Metric	Justification	Rank			
		A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Edge Effects*					
Edge Length	The intactness of the edge can be important to biotic and abiotic aspects of the site.	75 – 100% of edge is bordered by natural communities	50 – 74% of edge is bordered by natural communities	25 – 49% of edge is bordered by natural communities	< 25% of edge is bordered by natural communities
Edge Width		Average width of edge is at least 100 m.	Average width of edge is at least 75-100 m.	Average width of edge is at least 25-75 m.	Average width of edge is at least <25 m.
Edge Condition		>95% cover native vegetation, <5% cover of non-native plants, intact soils	75–95% cover of native vegetation, 5–25% cover of non-native plants, intact or moderately disrupted soils	25–50% cover of non-native plants, moderate or extensive soil disruption	>50% cover of non-native plants, barren ground, highly compacted or otherwise disrupted soils
Key Ecological Attribute: *Landscape Structure*					
Connectivity	Intact areas have a continuous corridor of natural or semi-natural vegetation	Intact: Embedded in 90-100% natural habitat; connectivity is expected to be high.	Variegated: Embedded in 60-90% natural or semi-habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification;	Fragmented: Embedded in 20-60% natural or semi-natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	Relictual: Embedded in < 20% natural or semi-natural habitat; connectivity is essentially absent

Landscape Condition Model Index	The intensity and types of land uses in the surrounding landscape can affect ecological integrity.	Landscape Condition Model Index > 0.8		Landscape Condition Model Index 0.79 – 0.65	Landscape Condition Model Index < 0.65
Fire Condition Class	Mixed to high severity fire is vital to maintaining ecological integrity. (Fire Regime Condition Class) 2008)	FRCC 1 No departure from historic fire regime.	FRCC 2 Slight-moderate departure from historic fire regime.		FRCC 3 Severe departure from historic fire regime. Fire suppression is evident; Fuel laddering is severe and throughout much of stand.
Rank Factor: CONDITION					
Key Ecological Attribute: *Vegetation Composition*					
Relative Cover Native Understory Plant Species	Native species dominate the understory; non-natives increase with human impacts.	Relative cover of native plants = 95-100%.	Relative cover of native plants 80-95%.	Relative cover of native plants 50 to 79%.	Cover of native plants <50%.
Species Composition Once developed the Floristic Quality Assessment Index can replace this metric (FQA measures percentage of conservative native species)	The overall composition of native species can shift when exposed to stressors.	Composed of appropriate species and proportions. Native species sensitive to degradation are present, functional groups indicative of degradation (e.g., pioneer or early successional trees) are absent to minor, full range of diagnostic/indicator species are present.	Functional groups indicative of degradation are present but low in abundance. Some indicator/diagnostic species may be absent.	Native species characteristic of the type remain present but weedy (pioneer, early successional) native species that develop after clearcutting or clearing are dominant. Many indicator/diagnostic species may be absent.	Severely altered from reference condition. Most or all indicator/diagnostic species are absent. Native species consist mostly of weedy species.
Key Ecological Attribute: *Vegetation Structure*					
Late Seral Patches	Late seral patches are closed to open, typically multilayered of shade tolerant trees or mixed with shade intolerant trees.	Vast majority of the old trees have not been harvested, i.e. there are only a few if any large stumps; Large trees >150 yr. old; >10 old trees/ac (>15”dbh)	Some (10-30%) of the old trees may have been harvested. 4-10 old trees/ac (10-20/ha) (>15”dbh)	Many (over 50%) of the old trees may have been harvested. 2-4 old trees/ac (5-10/ha) (>15”)	Most, if not all, old trees have been harvested. <2 old trees/ac (<5/ha) (>15”)
Coarse Woody Debris	With a disturbance regime of relatively infrequent, mixed to high severity fire there should be considerable CWD both resulting from infrequent fire events and accumulation between fire events.	Considering the natural stand development stage, a wide size-class diversity of downed coarse woody debris (logs), with several large logs and logs in various stages of decay.	Considering the natural stand development stage, a moderately wide size-class diversity of downed coarse woody debris (logs), with a few large logs and logs in various stages of decay.		Considering the natural stand development stage, a low size-class diversity of downed coarse woody debris (logs) with large logs and logs in mostly early stages of decay (if present).
Key Ecological Attribute: *Natural Disturbance Regimes*					

Forest Pathogens	Forest pathogens are sources of natural tree mortality that influence fire effects and forest structure	Pathogens are all native species and are within the natural range of variability (NRV).	Native pathogen are significantly effecting forest structure beyond NRV	Exotic and native pathogen are significantly effecting forest structure beyond NRV	Exotic and native pathogen are significantly effecting forest structure beyond NRV
Key Ecological Attribute: *Physicochemical*					
Soil Surface Condition	Soil disturbance can result in compaction, erosion thereby negatively affecting many ecological processes (Napper et al 2009)	**Soil-disturbance Class 0** Undisturbed • No evidence of past equipment. • No depressions or wheel tracks. • Forest-floor layers are present and intact. • No soil displacement evident. • No management-generated soil erosion. • No management-created soil compaction. • No management-created platy soils.	**Soil-Disturbance Class 1** • Wheel tracks or depressions evident, but faint and shallow. • Forest-floor layers are present and intact. • Surface soil has not been displaced. • Soil burn severity from prescribed fires is low (slight charring of vegetation,discontinuous). • Soil compaction is shallow (0 to 4 inches). • Soil structure is changed from undisturbed conditions to platy or massive albeit discontinuous.	**Soil Disturbance Class 2** • Wheel tracks or depressions are evident and moderately deep. • Forest-floor layers are partially missing. • Surface soil partially intact and maybe mixed with subsoil. • Soil burn severity from prescribed fires is moderate (black ash evident and water repellency may be increased compared to preburn condition). • Soil compaction is moderately deep (up to 12 inches). • Soil structure is changed from undisturbed conditions and may be platy or massive.	**Soil Disturbance Class 3** • Wheel tracks or depressions are evident and deep. • Forest-floor layers are missing. • Surface soil is removed through gouging or piling. • Surface soil is displaced. • Soil burn severity from prescribed fires is high (white or reddish ash, all litter completely consumed, and soil structureless). • Soil compaction is persistent and deep (greater than 12inches). • Soil structure is changed from undisturbed and is platy or massive throughout.
Rank Factor: SIZE					
Key Ecological Attribute: *Size*					
Relative Size	Indicates the proportion lost due to stressors.	Site is at or minimally reduced from natural extent (>95% remains)	Occurrence is only modestly reduced from its original natural extent (80-95% remains)	Occurrence is substantially reduced from its original natural extent (50-80% remains)	Occurrence is severely reduced from its original natural extent (<50% remains)
Absolute Size	Absolute size may be important for buffering impacts originating in the surrounding landscape	>10,000 ha	1000-10,000 ha	100-1000 ha	<100 ha

Level 3 EIA
Level 3 metrics would include more quantitative measures of the metrics listed above. In addition, further consideration might be given to:

- Stand structure and composition measurements (Franklin et al. 2002)
- Impact of introduced forest pathogens, particularly white pine blister rust on *Pinus albicaulis* and adelgid aphid on forest structure
- Weighted Old Growth Habitat Index (Franklin, Spies and Van Pelt 2005)
- Fire Regime Condition Class standard landscape worksheet method (FRCC 2010)

Triggers or Management Assessment Points
Ecological triggers or conditions under which management activities need to be reassessed are shown in the table below. Since the Ecological Integrity rankings are based on hypothesized thresholds, they are used to indicate where triggers might occur. Specific details about how these triggers translate for each metric can be found by referencing the values or descriptions for the appropriate rank provided in the Table above.

Table 2. Triggers for Level 2 & 3 EIA

Key Ecological Attribute or Metric	Trigger	Action
Any metric (except Connectivity)	▪ C rank ▪ Shift from A to B rank ▪ negative trend within the B rating (Level 3)	Level 2 triggers: conduct Level 3 assessment; make appropriate short-term management changes to ensure no further degradation Level 3 triggers: make appropriate management adjustments to ensure no additional degradation occurs. Continue monitoring using Level 3.
Any Key Ecological Attribute	▪ any metric has a C rank ▪ > ½ of all metrics are ranked B ▪ negative trend within the B rating (Level 3)	Level 2 triggers: conduct Level 3 assessment; make appropriate short-term management changes to ensure no further degradation Level 3 triggers: make appropriate management adjustments to ensure no additional degradation occurs. Continue monitoring using Level 3.

Protocol for Integrating Metric Ranks
If desired, the user may wish to integrate the ratings of the individual metrics and produce an overall score for the three rank factor categories: (1) Landscape Context; (2) Condition; and (3) Size. These rank factor rankings can then be combined into an Overall Ecological Integrity Rank. This enables one to report scores or ranks from the various hierarchical scales of the assessment

depending on which best meets the user's objectives. Please see Table 5 in Rocchio and Crawford (2009) for specifics about the protocol for integrating or 'rolling-up' metric ratings.

Supporting documents for the EIAs can be found at:
http://www1.dnr.wa.gov/nhp/refdesk/communities/eia.html

Documentation about Ecological Systems can be found at:
http://www1.dnr.wa.gov/nhp/refdesk/communities/ecol_systems.html

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