WHITE PAPER

USDA Forest Service Pacific Northwest Region Umatilla National Forest

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A Stage Is A Stage Is A Stage…Or Is It? Successional Stages, Structural Stages, Seral Stages

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INTRODUCTION

A landmark book called "Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington" was published in 1979 (Thomas 1979). This book examined the effects of management activities on wildlife habitat, particularly the impact of timber management practices on large, free-ranging ungulates (e.g., deer and elk).

Among other things, the Blue Mountains book also attempted to correlate wildlife habitat with vegetation seral status by using a successional stage classification system. As a result of the book's popularity with natural resource managers, use of its successional stage classification became common in the Blue Mountains (fig. 1).

Shortly after publication of the *Wildlife Habitats* book, the Umatilla National Forest initiated a planning process in response to the National Forest Management Act of 1976. The planning process consumed an entire decade and culminated with publication of a Land and Resource Management Plan (e.g., Forest Plan) in 1990 (USDA Forest Service 1990).

The Land and Resource Management Plan (Forest Plan) for the Umatilla National Forest (USDA Forest Service 1990) established specific standards related to seral (successional) stages for three management allocation areas (A10, C4, and E2). The seral stage system used in the Forest Plan is the same as the successional stage system described in the *Wildlife Habitats* book (Thomas 1979).

In response to a petition from the Natural Resources Defense Council to halt timber harvest in old-growth forests of eastern Oregon and eastern Washington (March 1993), and after an Eastside Forest Ecosystem Health Assessment was released in draft form (April 1993), the Pacific Northwest Region of the U.S. Forest Service issued interim planning direction known as the Eastside Screens in August of 1993 (USDA Forest Service 1994a, USDA Forest Service 1995).

Figure 1 – Successional stages for coniferous forest ecosystems (adapted from Thomas et al. 1979). After a stand-initiating disturbance event, it was assumed that a new forest develops by passing through successive and predictable stages. This figure shows a six-stage chronosequence, beginning with a grass-forb stage and culminating in a late-seral, old-growth stage. These successional stages have the following interpretation:

Grass-forb: dominant vegetation is herbaceous (grasses and forbs); downed logs are present but not decayed.

Shrub-seedling: dominant vegetation is woody shrubs and/or seedlings; downed logs are present but not decayed.

Pole-sapling: dominated by trees usually less than 40 years old; self thinning not yet occurring; even-height canopy; logs on ground are beginning to decay.

Young: dominated by trees usually less than 80 years old; self thinning beginning; downed logs are moderately decayed; understory vegetation is beginning to reappear.

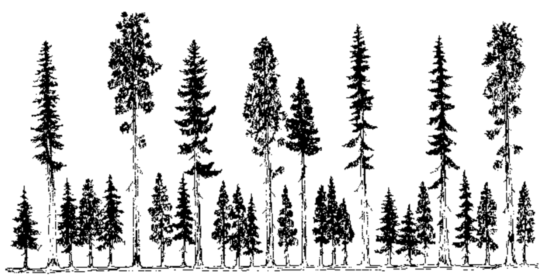
Mature: dominated by trees generally less than 140 years old; self thinning occurring; both decayed and undecayed logs are on the ground; some snags are present; understory vegetation is well established.

Old-growth: dominated by trees generally greater than 140 years old; understory vegetation well established; snags present; heart rot and other signs of decadence present; all tree ages and heights represented; abundant decayed and undecayed logs on the ground.

The Eastside Screens require that proposed timber sales be evaluated using three screens, one of which is the "ecosystem standard." This ecosystem screen requires a landscape-level assessment of the historical range of variability (HRV) for structural stages (table 1), including a determination of how existing structural stage amounts compare to their historical ranges.

As managers began working with the Eastside Screens, points of confusion soon arose. Are the Screens' entities called structural stages related to the successional stages from Thomas (1979) and as used in the Umatilla Forest Plan? And do successional stages and structural stages have any relationship to the seral stages (fig. 2) of forest vegetation (Hall et al. 1995)? Finally, are these various stages related to potential vegetation, existing vegetation, or both?

Table 1: Description of forest structural stages.

	**Stand Initiation.** Following stand-replacing disturbance, growing space is occupied rapidly by vegetation that either survives the disturbance or colonizes the area. Survivors survive the disturbance above ground, or initiate new growth from underground organs or seeds present onsite. Colonizers disperse seed into disturbed areas, it germinates, and new seedlings establish. One stratum of tree seedlings and saplings is present in this stage.
	**Stem Exclusion.** Trees initially grow fast and occupy their growing space, competing strongly for sunlight and moisture. Because trees are tall and reduce light, understory plants are shaded and grow slowly. Species needing sunlight usually die; shrubs and herbs may go dormant. In this stage, establishment of new trees is precluded by a lack of sunlight (stem exclusion closed canopy) or by a lack of moisture (stem exclusion open canopy).
	**Understory Reinitiation.** A new tree cohort eventually gets established after overstory trees begin to die or because they no longer fully occupy their growing space. This period of overstory crown shyness occurs when tall trees abrade each other in the wind (Putz et al. 1984). Regrowth of understory vegetation occurs, trees begin stratifying into vertical layers, and a moderately dense overstory with small trees beneath is eventually produced.
	**Young Forest Multi Strata**. In this stage, three or more tree layers have become established as a result of minor disturbances (including tree harvest) that cause progressive but partial mortality of overstory trees, thereby perpetuating a multi-layer, multi-cohort structure. This stage consists of a broken overstory layer with a mix of sizes present (large trees are scarce); it provides high vertical and horizontal diversity (O'Hara et al. 1996).
	**Old Forest.** Many age classes and tree layers mark this stage featuring large, old trees. Snags and fallen trees may also be present, leaving a discontinuous overstory canopy. The drawing shows single-layer ponderosa pine created by frequent surface fire on dry sites (old forest single stratum). Cold or moist sites, however, generally have multi-layer stands with large trees in the uppermost stratum (old forest multi strata).

Sources/Notes: Based on O'Hara et al. (1996), Oliver and Larson (1996), and Spies (1997). Other ecologists described process-based stages by using slightly different names (see appendix 1).

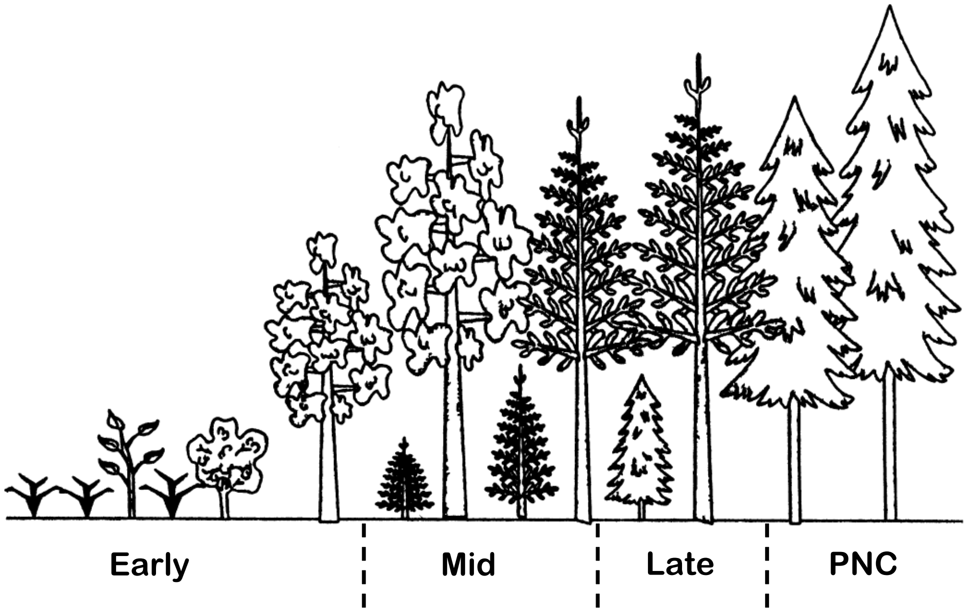


Figure 2 – Seral stages for a grand fir plant association in the Blue Mountains (figure adapted from USDA Forest Service 1994b). The series of stages shown in this diagram is called a sere. After a stand-initiating disturbance event such as crown fire or regeneration cutting, the plant community transitions from a simpler, somewhat disorganized state (early-seral stage) to a relatively complex, highly organized state (the potential natural community or PNC). The early-seral stage is initially dominated by grasses, forbs, and shrubs (some ecologists refer to this non-tree phase as a very-early stage), but shade-intolerant tree species also get established in the early-seral stage. The mid-seral stage has a mix of species, with early-seral species (ponderosa pine above) and mid-seral species (Douglas-fir above) present in almost equal amounts. Late-seral stands have both mid-seral and late-seral tree species present (grand fir is the late-seral species above). Although PNC stands are uncommon in the Blue Mountains, they feature a composition where early- or mid-seral species are scarce or absent altogether (Hall et al. 1995).

Table 2 shows the successional stages from Thomas (1979), the structural stages on which the Eastside Screens were based (O'Hara et al. 1996, Oliver and Larson 1996), and a seral status framework (Hall et al. 1995).

In table 2, there is a vertical line separating the successional stage column from the structural stage and seral stage columns – the line was included because it is not appropriate to assume a one-to-one relationship between the three stages (successional, structural, and seral).

Bottom-line: Although there are some similarities between successional stage, structural stage, and seral stage, these classification systems are not identical and should not be considered interchangeable.

Table 2: Are successional stages related to structural stages and seral stages?

Successional stage		Structural stage?		Seral stage?
Grass–Forb	➔	Stand Initiation	➔	Early
Shrub–Seedling	➔	Stand Initiation	➔	Early
Sapling–Pole	➔	Stem Exclusion	➔	Early/Mid
Young	➔	Young Forest	➔	Mid
Mature	➔	Understory Reinitiation	➔	Mid/Late
Old Growth	➔	Old Forest	➔	Late/PNC

Sources: Successional stages are from Thomas (1979); structural stages are from O'Hara et al. (1996) and Oliver and Larson (1996); seral stages are from Hall et al. (1995). The glossary provides definitions for each of these classification systems.

If successional stages, structural stages, and seral stages are not synonymous, how are they similar or different? Briefly, here are some of the similarities and differences:

- **A structural stage does not indicate seral status**. Seral stage is determined using the species composition of a stand and our understanding of its ecological role. To illustrate this concept further, consider the following two examples.

  a. Example 1: A forest stand on the grand fir/elk sedge plant association has large-diameter ponderosa pines in the overstory, and small-diameter Douglas-firs and grand firs in the understory. The overstory pines have about the same canopy cover as the understory firs and Douglas-firs combined.

  From the information provided, we know these things about this stand:

  √ Since the stand is established on a grand fir plant association, grand fir is the climatic climax tree species, and it will predominate in a potential natural community resulting from long-term forest succession in the absence of disturbance (Hall et al. 1995);

  √ Another shade-tolerant tree species (interior Douglas-fir) will also be present in late-seral stands because it is functioning as a mid-seral species on this plant association; and

  √ Ponderosa pine is functioning as an early-seral tree species on this plant association, so it cannot maintain its overstory dominance if disturbance is excluded from the site (the Douglas-fir and ponderosa pine seral status implications are derived from Clausnitzer 1993, and Johnson and Clausnitzer 1992).

  We can conclude from these existing conditions that this stand currently has a mid-seral status because late-seral species are approaching equal proportions with early- and mid-seral species (see Hall et al. 1995, and the 'seral status' section of the glossary, for more information about how this seral-status determination was made).

The structural stage of this 2-layered stand would be *old forest multi-strata* if the ponderosa pines are over 21" DBH, or *understory reinitiation* if the overstory pines are less than 21" DBH (table 3 shows how these existing conditions would be assigned to a structural stage).

b. Example 2: Now let's suppose that a windstorm, or bark beetles, or another type of top-down disturbance process kills most or all of the large ponderosa pines, leaving behind a mix of small grand fir and Douglas-fir trees.

Since the composition now consists entirely of late-seral and climax tree species, this stand would classify as a late-seral or potential natural community (PNC) forest, even though it no longer contains any large-diameter trees.

The structural stage would be stand initiation or stem exclusion, depending on the size and density of the new overstory layer (see table 3).

These examples demonstrate that it may be difficult to make consistent interpretations from phrases such as *late and old structural stages* (this phrase comes from the Eastside Screens; it refers to structural conditions where trees over 21 inches in diameter are common). *Late* traditionally refers to vegetation seral status in a classification system such as Hall et al. (1995), and yet *seral status conveys no explicit information about tree size or diameter*.

In example 1 above, the early-seral species (ponderosa pine) has the largest tree diameter and the late-seral species (grand fir and interior Douglas-fir) the smallest. In example 2, late-seral species dominate the stand composition, and yet no trees of large diameter are present.

- **Successional stages are not the same as structural stages**. Thomas (1979) defined successional stages using two criteria: tree size and stand age. His criteria included no explicit consideration of vertical stand structure (e.g., the number of stand layers).

  A forest stand classified as Thomas' young successional stage (poles and small trees between 40 and 79 years old; see glossary) could be assigned to several structural stages depending on how many canopy layers it contains. If it has 2 layers, it would be the *understory reinitiation* structural stage; if it has 3 or more layers, it would be an example of the *young forest multi strata* structural stage (see table 3).

- **Successional stages do not relate directly to seral status**. Since successional stages are classified using tree size (sapling, pole, etc.) and stand age, there is no direct consideration of the ecological roles of the tree species in this classification system.

  If a stand is in the pole-sapling successional stage, we have no way of knowing what proportion of the saplings and poles are early-seral tree species. We could assume they are early-seral species, in which case the pole-sapling successional stage has early-seral status. But what if they are actually late-seral species as described in example 2 above? In the example 2 situation, a pole-sapling successional stage would have late-seral status.

Table 3: Matrix for assigning structural stages based on number of canopy strata and tree size.

Number of Canopy Strata (Layers)	SIZE CLASS OF UPPERMOST STRATUM (LAYER)		
	Seedlings/Saplings (< 5" DBH)	Poles and Small Trees (5 to 20.9" DBH)	Medium Trees (> 21" DBH)
1	Stand Initiation	Stem Exclusion	Old Forest Single Stratum
2	Not Applicable	Understory Reinitiation	Old Forest Multi Strata
3 or more	Not Applicable	Young Forest Multi Strata	Old Forest Multi Strata

Source: Adapted from Stage et al. (1995).

GLOSSARY

Historical range of variability. A characterization of fluctuations in ecosystem conditions or processes over time; an analytical technique used to define the bounds of ecosystem behavior remaining relatively consistent through time (Morgan and others 1994).

Seral stage (status): a stage of secondary successional development (secondary succession refers to an ecological process of progressive changes in a plant community after stand-initiating disturbance). Four seral stages are recognized: potential natural community, late seral, mid seral, and early seral (Hall et al. 1995).

Early Seral: clear dominance of seral species (western larch, ponderosa pine, lodgepole pine, etc.); PNC species are absent or present in very low numbers.

Mid Seral: PNC species are increasing in the forest composition as a result of their active colonization of the site; PNC species are approaching equal proportions with the seral species.

Late Seral: PNC species are now dominant, although long-lived, early-seral tree species (ponderosa pine, western larch, etc.) may still persist in the plant community.

Potential Natural Community (PNC): the biotic community that one presumes would be established and maintained over time under present environmental conditions; early- or mid-seral species are scarce or absent in the plant composition.

Structural stage (class). A stage or recognizable condition relating to the physical orientation and arrangement of vegetation; the size and arrangement (both vertical and horizontal) of trees and tree parts. The following structural stages have been described (O'Hara et al. 1996, Oliver and Larson 1996):

Stand initiation: one canopy stratum of seedlings and saplings is present; grasses, forbs, and shrubs typically coexist with the trees.

Stem exclusion: one canopy stratum comprised mostly of pole-sized trees (5-8.9" DBH) is present. The canopy layer may be open (**stem exclusion open canopy**) on sites where moisture is limiting, or closed (**stem exclusion closed canopy**) on sites where light is a limiting resource.

Young forest multi strata: three or more canopy layers are present; the size class of the uppermost stratum is typically small trees (9-20.9" DBH). Large trees may be absent or scarce.

Understory reinitiation: two canopy strata are present; a second tree layer is established under an older overstory. Overstory mortality created growing space for the establishment of understory trees.

Old forest: a predominance of large trees (> 21" DBH) is present in a stand with one or more canopy strata. On warm dry sites with frequent, low-intensity fires, a single stratum may be present (**old forest single stratum**). On cool moist sites without recurring underburns, multi-layer stands with large trees in the uppermost stratum may be present (**old forest multi strata**).

Successional stage: a stage or recognizable condition of a plant community occurring during its development from bare ground to climax. In the Blue Mountains, successional stage has been determined using two primary criteria: tree size class, and stand age. Coniferous forests progress through six recognized stages, as defined below (Thomas 1979).

Grass-forb: dominant vegetation is herbaceous (grasses, grass-like plants, and forbs); stand age: less than 10 years; downed logs are present but not decayed.

Shrub-seedling: dominant vegetation is woody shrubs and/or tree seedlings; stand age: less than 10 years; downed logs are present but not decayed.

Pole-sapling: dominated by trees in the sapling size class, pole size class, or both; stand age: 11-39 years; even-height canopy; logs on ground are beginning to decay.

Young: dominated by trees that are no longer poles, but have not yet reached maturity; stand age: 40-79 years; self-thinning beginning; downed logs are moderately decayed; understory vegetation is starting to reappear.

Mature: domination or predominance of mature, vigorous trees; stand age: 80-159 years; self-thinning occurring; both decayed and undecayed logs are on the ground; some snags are present; understory vegetation is well established.

Old Growth: a stand that is past full maturity and showing decadence – the last stage in forest succession; stand age: 160 years and greater; understory vegetation is well established; snags are present; heart rot and other signs of decadence are common; all tree sizes and ages represented to some extent; abundant decayed and undecayed logs on the ground.

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Appendix 1: Alternative approaches for describing forest development phases (structural stages).

INCREASING TIME SINCE DISTURBANCE ↓	**Watt 1947**	**Daubenmire & Daubenmire 1968**	**Bormann and Likens 1979**	**McCune and Allen 1985**	**Peet and Christensen 1987**	**Oliver and Larson 1996**	**O'Hara et al. 1996**	**Spies 1997**
	Pioneer	Invasion	Reorganization	Establishment	Establishment	Stand Initiation	Stand Initiation	Establishment
	Building	Stagnation	Aggradation	Canopy Development	Thinning	Stem Exclusion	Stem Exclusion	Thinning
	Mature	Resumption of Regeneration	Transition	Canopy Breakup	Transition	Understory Reinitiation	Understory Reinitiation	Transition
	Degenerate		Steady State	Climax Recognition	Steady State	Old Growth	Young Forest Multi Strata	Shifting Mosaic
							Old Forest	

APPENDIX 2: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continually evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases,

techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of dry forests in the Blue Mountains: silvicultural considerations
5	Site productivity estimates for upland forest plant associations of the Blue and Ochoco Mountains
6	Fire regimes of the Blue Mountains
7	Active management of moist forests in the Blue Mountains: silvicultural considerations
8	Keys for identifying forest series and plant associations of the Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created openings: direction from the Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: a process paper
16	Douglas-fir tussock moth: a briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of the Blue and Wallowa Mountains
21	Historical fires in the headwaters portion of the Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree

Paper #	Title
25	Important insects and diseases of the Blue Mountains
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: some ecosystem management considerations
28	Common plants of the south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of the Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of the "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – forest vegetation
33	Silviculture facts
34	Silvicultural activities: description and terminology
35	Site potential tree height estimates for the Pomeroy and Walla Walla ranger districts
36	Tree density protocol for mid-scale assessments
37	Tree density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: forestry direction
39	Updates of maximum stand density index and site index for the Blue Mountains variant of the Forest Vegetation Simulator
40	Competing vegetation analysis for the southern portion of the Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for the Umatilla National Forest
42	Life history traits for common conifer trees of the Blue Mountains
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: vegetation management considerations
46	The Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in the northern Blue Mountains: regeneration ecology and silvicultural considerations
48	The Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for the Umatilla National Forest: a range of variation analysis
51	Restoration opportunities for upland forest environments of the Umatilla National Forest

REVISION HISTORY

November 2012: minor formatting and editing changes were made; appendix 2 was added describing the silviculture white paper system, including a list of available white papers.