6 Riparian and Wetlands

The purpose of this section is to provide an assessment of the current conditions for the riparian and wetland areas within the Wilson River watershed and to establish a range of potential future conditions (~50-100 year timeframe) for use in management direction. This section presents findings following a series of Critical Questions from the OWEB watershed assessment manual (WPN 1999) and a suite of ODF Key Supplemental Questions to address specific management needs and to enhance the understanding and knowledgebase of the watershed. While the entire Wilson analysis area will be considered, the majority of the available data and management focus will be placed on ODF lands.

This section presents the following:

- Riparian Composition and Structure,
- Riparian Restoration and Enhancement Opportunities, including the development of the Desired Future Condition (DFC),
- Large Wood Recruitment,
- Wood Budget,
- Wetlands, Ponds and Lakes Conditions,
- Noxious and Non-native Weed Species, and
- Recreational Impacts on Riparian Vegetation.

6.1 Riparian Composition and Structure

6.1.1 Riparian Management Areas

The Riparian Management Area(s) (RMA) can be coarsely divided into four zones, each contributing unique ecological values to the stream system at progressively increasing distances from the stream channel. The four zones are:

Aquatic Zone: This zone contains the stream channel, the Channel Migration Zone[35], side channels, in-stream wetland components, and features such as beaver ponds. Vegetation components are present, though many riparian functions are served immediately outside of this zone.

[35] The Channel Migration Zone is the area adjacent to an unconfined stream channel, where channel migration is likely to occur during high flow events. Often, these areas are associated with side channels, stream-associated wetlands, and low terraces.

Stream Bank Zone: This area is interactive with the stream channel, originating at the stream banks to approximately 25 feet from the stream channel. This area serves many ecological functions to the stream channel, including direct influence on stream shading, coarse particulate organic matter (CPOM) inputs such as tree/shrub litterfall, large wood, bank stability, and in-stream habitat features such as submerged branches and root wads.

Inner Riparian Zone: This zone is immediately adjacent to the Stream Bank Zone, originating at approximately 25 feet and extending to ~100 feet from the stream channel. This area highly contributes to riparian ecological functions, including stream shading (both vegetative and topographic influences), large wood delivery, and associated coarse particulate organic matter inputs. The majority of ecological functions (and the magnitude of how they function) occur within this zone. As such, the Inner Riparian Zone is a *high priority* zone for implementation constraints as they relate to management actions.

Outer Riparian Zone: This area extends outside of the ~100 feet outer stream buffer to ~170 feet, and is usually dominated by upland vegetation. The primary ecological function for this zone is to provide a buffer to protect microclimates within the inner and stream bank zones (e.g., windthrow). Other functions may be contributed to the riparian ecosystem (vegetative/topographic shade and LW), though to a lesser extent than the inner and stream bank zones.

Though the entire riparian zone will be considered in this watershed analysis, the focus of the analysis and available data occur on ODF lands, with quantitative emphasis on the Stream Bank Zone and the Inner Riparian Zone.

6.1.2 Vegetation Classifications

All fish-bearing (Type F) and perennial streams in the Wilson River watershed were selected for a riparian vegetation classification mapping effort in 2006[36]. Stream segments were buffered to a 100 foot width on both sides of the stream to approximate the combined widths of the Stream Bank Zones and Inner Riparian Zones which constitute the key RMAs within the watershed. We determined that 13,037 acres of riparian management area (RMA) exist along fish-bearing streams (Type F streams). Of this, 124 acres are lost due to road prism width (for a more detailed discussion of roads and road widths, refer to Chapter 7 Sediment Sources, section 7.4 Road-Related Issues).

Color stereo-pair aerial photographs (taken in 2006; 1:12,000 scale) and digital orthoquad imagery were used to delineate and interpret the 100 foot buffer areas

[36] Conducted by Duck Creek Associates in 2006.

for the entire watershed. Delineations were made in a GIS on the basis of homogenous vegetation structure (tree size and densities) and major species dominance (e.g., conifer, hardwood, mixed). The hierarchical classification scheme followed the coding system that is compatible with the Forest Projection and Planning System (FPS)[37] vegetation labels used in stand compilation and growth modeling. This system involved a four-digit code that describes the species, size and relative density of forested polygons, and provided a suite of non-forest classifications (water, shrub, administrative, etc.). The classification hierarchy is presented in Table 80 in Appendix E – Detailed Methodologies.

Following classifications of the 100 foot riparian buffers, the riparian vegetation coverage was analyzed for the entire watershed with greater intensity on lands under ODF management (see section 6.1.3, Field Reconnaissance, below).

The size classifications following the FPS codes (1-5) were further classified to denote stands of *Early Structure* (ES; sizes 1 and 2), *Intermediate Structure* (IS; size 3) and *Advanced Structure* (AS; sizes 4 and 5). These size classifications were used to group the current and potential future distribution of stand types in categorical classes that follow the Elliot State Forest Habitat Conservation Plan (refer to Appendix J – Desired Future Conditions). These structural classifications were also used to determine the desired future condition, assuming a range of structural types (see Potential Future Conditions, section 6.2).

6.1.3 Field Reconnaissance

While the aerial photo classifications provide qualitative groupings based on major species, size and density, the interpretive classifications did not provide adequate stand metrics to meet the supplemental questions for this analysis. In efforts to meet these goals, a field reconnaissance of the riparian zones was conducted on ODF-managed lands with the objective to collect stand-level inventory data (species, size, height) within the most dominant riparian classifications in the watershed.

Of the 45 different vegetation codes found on ODF lands, approximately 92% of the riparian area was represented by 10 forested vegetation codes. The field sampling protocol was designed to capture a proportional number of acres of each type (representing between 8 and 10%) to better describe the major vegetation types currently on the landscape. A total of 71 stands[38] in 775 riparian acres were selected within the 6 major mixed forest types, 2 pure conifer types, and 2 pure hardwood types (Table 14). Stands were selected from a GIS to

[37] Forest Projection and Planning System (FPS). 2006. Version 6.50. Forest Biometrics Research Institute, Corvallis, Oregon.
[38] 68 stands in the Stream Bank Zone.

maximize field efficiencies and were selected in groups to avoid excessive access times between individually sampled stands.

Each selected riparian stand was subdivided into two zones to approximate the stream bank zone (0 – 35 ft) and the inner riparian zone (~50 ft). In each of these areas of each stand, a variable radius plot was established and sampled, in the stream bank zone, every 5-10 acres[39]. The variable radius plot was conducted in a semi-circle away from the stream and plot counts were doubled. The field sampling protocol followed the standard ODF Stand Level Inventory (SLI) protocol for upland inventories[40] for trees ≥5 inches DBH. Empirical data collected included tree species, diameter, and a sample of tree heights. Species, size and density values for trees 0-5 inches DBH (including seedlings) was obtained from existing SLI plot data, where plots fell within the measured riparian stands.

In addition to the SLI protocol, conifer stumps were tallied in a 1/10th acre circular plot (37.5 ft radius). The purpose of these data were to identify a sub-sample of stands in the watershed that have been altered by human disturbance – the primary goal was to determine the proportion of hardwood mixed or dominated stands that may have been converted from an historically conifer dominance.

Stream connectivity metrics were also collected, including visual bankfull width estimates, vertical elevation at the stream edge (stream bank zone plots), vertical elevation at the stream bank/ inner riparian zone interface, and the horizontal and vertical distance to plot center from the stream edge. These data provide a spatial context of landform and connectivity to the stream channel for measured plots.

Following data collection, the riparian SLI data were incorporated into an FPS database, with the FPS code classification as the basis for the expansion. Stands were compiled and weighted averages for stand metrics were calculated. Stands with like FPS codes (vegetation classes) were expanded with the weighted average stand metrics. Stands were populated to provide a stand table summary and a summary by species and DBH class. No stand metric data were assigned to unsampled FPS codes (Ranks 11-45, or ~8% of the ODF riparian area).

Using FPS, the expanded riparian SLI dataset was modeled for future conditions assuming no future management. The datasets for the stream bank zone and inner riparian zone were treated separately in the future growth modeling. Data were modeled in five 20-year increments to provide *midpoint* stand metrics for

[39] 1-4 plots were installed in the stream bank zone and the inner riparian zone for each stand.
[40] Reference SLI Protocol, ODF.

2006 (current growth year), 2016, 2036, 2056, 2076 and 2096. Hence, the values represent each of the 20-year time periods: 2006-2026, 2026-2046, 2046-2066, 2066-2086 and 2086-2106 (100 year timeframe).

Table 14. Riparian Vegetation Sampling Intensity. The sampling intensity of the ten-most represented FPS Vegetation classes on ODF lands.

Major Type	FPS Code	Rank[41]	Sampled Stands	Sampled Acres	Total Stands	Total Acres	% Acres Sampled
Conifer	1D2H	5	5	64	165	628	10%
Conifer	1D3H	7	4	34	122	370	9%
Hardwood	1H2H	2	10	165	364	1,773	9%
Hardwood	1H3H	8	4	45	82	321	14%
Mixed	HX2H	1	10	159	428	2,101	8%
Mixed	DX2H	3	14	144	398	1,675	9%
Mixed	DX3H	4	12	75	254	863	9%
Mixed	HX3H	6	4	44	127	517	8%
Mixed	HX2M	9	3	23	65	240	10%
Mixed	DX2M	10	3	22	52	235	10%
	Totals		**69**	**775**	**2,057**	**8,722**	**9%**

Though the streambank zone is defined as 0-25 feet from the stream channel, the variable plot sampling used as part of this analysis incorporated approximately 0-35 feet of the near-stream riparian zone (a legacy of the variable plot sampling). At the 50 ft point away from the stream channel, the inner riparian zone was sampled to capture the 25 – 100 ft buffer areas. Though not exactly in line with the riparian zone management area designations, the data reflect a sampling of these two zones.

6.1.4 Field Validation and Final Classification Scheme

Photo-interpreted data were analyzed and evaluated for appropriate use in further analyses by determining the extent of statistical differences between the it and the FPS classification data. Structural data were compiled and analyzed based upon a range of compositional, structural, and spatial classifications. Classifications were made as variations upon the FPS codes originally described, and the physical location of the installed plots in both the inner riparian zone and stream bank zone) to capture a range of classification complexity (i.e. simple to complex). The following hierarchical classifications ("Classification Factors")

[41] Rank refers to the highest to lowest (1-45) of forested classifications by acre found on ODF lands. Mixed hardwood/conifer type HX2H was the most common on ODF lands, representing 2,101 acres.

were made to evaluate sensitivities in the structural data, in increasing order of complexity:

- **Riparian Zone Classification:** Streambank zone and inner riparian zone, pooled for all measured FPS codes. This category offers the lowest level of classification resolution and complexity (spatial distribution only).

- **Major Vegetation Types:** Pooled FPS Codes for Conifer, Hardwood and Mixed dominance, also pooled for inner and stream bank zone (compositional distribution only)

- **FPS Codes:** Pooled for inner riparian zone and stream bank zone (composition and structure).

- **Major Vegetation Type and Riparian Zone:** Combined classifications of Conifer, Hardwood and Mixed Dominance, separated by inner and stream bank zone (compositional and spatial considerations).

- **Combined FPS Code and Riparian Zone:** Combined classifications of FPS Codes, separated by inner riparian zone and stream bank zone. This category offers the highest level of classification, and was the resolution sampled in the field (compositional, structural and spatial considerations).

Measured structural stand data were compiled and analyzed at the stand level. Large trees (≥20 inches DBH) were calculated as separate variables to describe absolute trees per acre and basal area (ft^2 per acre) and relative densities (i.e., the percentage of large trees compared to total trees per acre and basal area). Other attributes included total stems per acre, total basal area, and quadratic mean diameter (QMD). Table 11 displays the Analysis of Variance (ANOVA) results for determining differences of structural attributes among Classification Factors.

Overall, no robust statistical differences that provided for clear delineations among increasing levels of classification hierarchies were detected. The proportion and nominal values of large trees (≥20 inches DBH) served as statistically significant and strong indicators for determining differences between conifer and hardwood types (mixed types were not significantly different). The measured trends suggest that hardwoods had approximately one-half of the large trees (by density and basal area size) of conifer stands (Table 16).

Perhaps the strongest observation was the difference in stand structure relative to the proximity to the stream channel. Mixed- and hardwood-dominated types within the stream bank zone had higher total basal areas (average 212 and 231

ft^2/ac) than the same types in the inner riparian zone (167 and 141 ft^2/ac). This was mostly due to the higher prevalence for large-diameter trees (i.e., higher basal area and relative densities) near the stream bank.

Table 15. Classification Significance Matrix. Significant differences detected of structural attributes among grouping factors of FPS codes, riparian zones sampled, and both factors. Values are probability values (P) with an alpha value of 0.05, measured by ANOVA. * Statistically Significant (P< 0.05) and ‡ Strong biological significance (P<0.10).

	Classification Factor				
	Lowest Complexity			Highest Complexity →	
Structural Attribute	**Riparian Zone Class**	**Major Vegetation Type**	**FPS Code**	**Major Veg. Type & Riparian Zone**	**FPS Code & Riparian Zone**
Large Tree TPA	0.16	0.01*	0.06‡	0.05‡	0.28
Large Tree RD (TPA%)	0.83	0.11	0.08‡	0.47	0.06‡
Large Tree BA	0.30	0.01*	0.02*	0.08‡	0.27
Large Tree RD (BA%)	0.91	0.04*	0.05‡	0.26	0.16
Total Stems	0.06	0.50	0.62	0.33	0.41
Total BA	<0.01*	0.82	0.56	0.03*	0.24
QMD	0.87	0.07‡	0.16	0.39	0.23
Total Score[42]	**1**	**3**	**2.5**	**2**	**0.5**

A "Total Significance Score" was developed to rate the associations of the stand metrics with each Classification Factor. This simply identifies the number of statistically and potentially biologically significant relationships with increasing classification complexity. The intent is to provide a basis for balancing important and discrete stand metrics with ecological functions in an appropriate classification scheme.

While the FPS codes by themselves demonstrated reasonable differentiation in stand metrics, the pooling of FPS codes into Major Vegetation Types (conifer, hardwood and mixed) provided the highest levels of differentiation for classification purposes. However, considering the ecological importance of

[42] Total Significance Score was determined by a score of 1 point for each statistically significant relationship and a score of 0.5 points for relationships of strong biological significance (i.e. P<0.10).

stream proximity to riparian functions, and considering the strong relationships in large tree basal area between the stream bank and the inner riparian zone, a hybridized classification scheme involving Major Vegetation Types and Riparian Zones is considered for this analysis. A summary of stand metrics and sampled sites is presented in Table 16.

Table 16. Stand Metrics by Major Type and Riparian Zone. The average stand metrics for sampled stands using the most robust classification scheme (Riparian Zone and Major Vegetation Type).

Riparian Zone	Major Type	Large Trees (TPA)	Large Trees (% TPA)	Large Trees (BA, ft^2/ac)	Large Trees (% BA)	Stem Density (TPA)	Basal Area (ft^2/ac)	QMD
Inner RMZ	Conifer	28	23%	74	40%	151	199	16.1
Inner RMZ	Hardwood	10	9%	29	23%	158	141	13.9
Inner RMZ	Mixed	20	22%	65	38%	134	167	16.4
Stream Bank Zone	Conifer	29	27%	85	44%	155	194	16.5
Stream Bank Zone	Hardwood	19	11%	47	23%	220	231	14.4
Stream Bank Zone	Mixed	23	22%	70	37%	172	212	16.3

It is important to note that the field sampling was biased toward the current conditions (i.e., intent was to capture the most abundant FPS codes, Table 14), and the majority of the land area is within FPS size class codes of "2" and "3" (≥8 – 20 inches in diameter). As a result, the measured stands reflected this condition, with average QMDs between ~14 and 16 inches in diameter (Table 16). To capture future conditions and a range of size classes within the sampling regime, current stands were compiled by riparian zone and FPS code, and stand metric data were expanded to the larger population. These data were modeled for growth and structure in 10-year increments using the Forest Vegetation Simulator (FVS; assuming normal mortality patterns) and no management from 2006 until 2106. Diameter classes from the FPS codes (1-5) were assigned to the modeled FVS stand metric data for ease with interpretation.

Two analytical scales and datasets are used for the riparian portion of this watershed analysis. For local scales where stand metrics are important factors in evaluating ecosystem functioning (stream shade modeling, large wood recruitment, etc.), riparian stands will be evaluated on the basis of location (inner and stream bank zone) and major vegetation type (conifer, hardwood and mixed species); diameter measures were summarized as diameter classes that have been derived from the FVS modeled database. At landscape scales, the original FVS

codes are presented throughout this report using a consolidated system of major vegetation type, size class and density[43].

6.1.5 Riparian Vegetation Current Conditions

6.1.5.1 Distribution of Riparian Zones

Riparian zones typically do not constitute a large percentage of land area, though they perform many key ecological functions for the landscape. In the ~123,000 acre analysis area, approximately 11% of the land area is represented by the combined stream bank and inner riparian zones (0 - 100 ft) riparian zones (Table 17), which is at the upper end of a range that is typical for other watersheds of this size, and underscores the importance of riparian zone management in the dynamics of the Wilson River system.

The distribution of the riparian zones under ODF management is similar to that of the watershed as a whole, with the exceptions of the Little North Fork Wilson River, Lower Wilson River and Devils Lake Fork subwatersheds. These areas have higher proportions of lower gradient stream systems, which contribute to higher proportions of riparian area on non-ODF managed lands (Table 17 and Map 23).

Table 17. Riparian Land Area Summary. The distribution of key riparian zones (100 ft buffer area) by subwatershed (6th field HUC) and the watershed as a whole for ODF management and all riparian zones.

	ODF Lands		Watershed-Level		Subwatershed Acres	
Subwatershed Name	Acres	% Riparian Zone	Acres	% Riparian Zone	Acres	% of Watershed
NF Wilson River	1,146	7%	1,625	9%	17,297	14%
Upper Wilson/ Cedar Creek	1,314	9%	1,527	11%	14,307	12%
SF Wilson River	1,283	13%	1,284	13%	10,217	8%
Little NF Wilson River	1,155	9%	1,457	12%	12,621	10%
M Wilson River	999	7%	1,138	8%	13,487	11%
Jordan Creek	1,010	6%	1,224	8%	16,201	13%
L Wilson River	796	5%	2,236	13%	16,893	14%
Devils Lake Fork	2,002	9%	2,547	12%	22,106	18%
Totals	**9,704**	**8%**	**13,037**	**11%**	**123,128**	**100%**

[43] For a complete list of the major vegetation classifications used for the landscape-level vegetation analysis, see Appendix U.

6.1.5.2 Major Vegetation Types

The distribution of major species dominance (conifer, hardwood, mixed and non-forest), as measured from photo-interpretation (FPS codes) is notably similar in proportion between ODF-managed lands and the watershed as a whole (Table 18, Map 23). Approximately two-thirds of the watershed riparian zones are dominated by mixed conifer-hardwood species. This "Mixed" forest type is characterized as a stand having ≤80% of the observed basal area in a single species, and is typified by the Douglas-fir and red alder community type in shifting proportions of co-dominance.

It is important to note that "dominance" from aerial photo interpretation is less reliable than stand-level data, especially for the mixed types. Stand samples (see Appendix K) indicate that mixed types could contain higher than 80% of basal area or trees per acre in a single-type. Aerial photo interpretation involves the estimate of canopy cover, not basal area, and hence the canopy-level view may suggest a mixed type when the inventory data suggest dominance by a single type. Despite these shortcomings, the major dominance types are useful for a landscape-level view of major vegetation types in the watershed.

Hardwood-dominated sites occur throughout the watershed, representing ~22% of all riparian acres, and 24% of ODF riparian zones. Conifer-dominated stands were less prevalent, representing only 13% of the riparian land area in the watershed.

Table 18. Coarse Riparian Vegetation Types. The distribution of the major vegetation types within ODF managed areas and the watershed as a whole.

Forested	Forest Type	ODF Acres	% of ODF Lands	Total Acres	% of Watershed
Forested	Conifer	1,157	12%	1,697	13%
Forested	Hardwood	2,339	24%	2,833	22%
Forested	Mixed	5,967	61%	7,637	59%
Non Forest	Other	241	2%	871	7%
	Totals	**9,704**		**13,037**	

At the subwatershed scale (Figure 9 and Table 19), the distribution of ODF-managed riparian zones is highly biased toward mixed conifer/ hardwood types; mixed types ranged between ~48% and 73% of each subwatershed riparian areas. Hardwood dominated types were abundant (~20 – 49%) in all subwatersheds except Devils Lake Fork (7%) and the SF Wilson (16%) subwatersheds, where conifers were more prevalent (28 and 22% conifers, respectively).

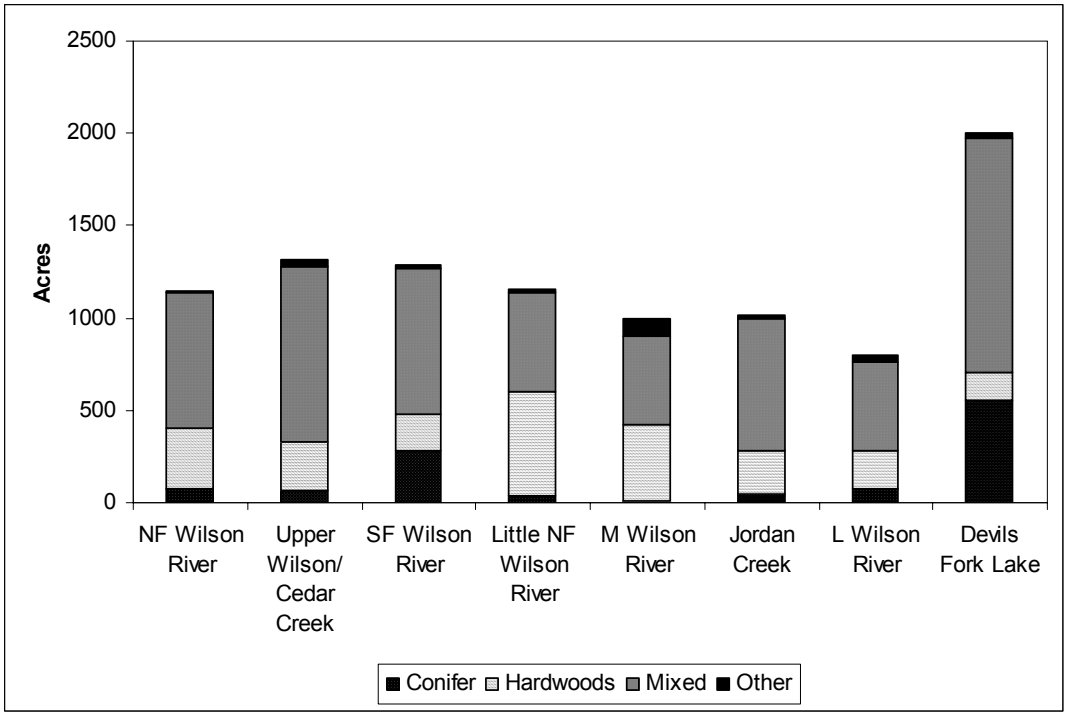

Figure 9. Major Vegetation Types (ODF Lands). The distribution of forest dominance for the 9,704 acres under ODF management.

The dominance of hardwood and mixed conifer/hardwood types in context with the fire and management history suggests that the majority of ODF lands have undergone a near-complete conversion from historic vegetative patterns to, at a minimum, a current condition of early- and mid-seral vegetative structures.

Compositionally, the stump presence data collected as part of the field campaign suggest that, while stumps were found in 52 of the 72 measured stands, without exception the stumps appeared to be formed soon after the fire and salvage logging events of the 1950s. Given the apparent widespread homogeneity of stand ages due to fire and intensive salvage logging, and the relative uniformity of stand metrics among types measured (Table 16), the data strongly suggest the current condition of the forested riparian zones represents a uniformly-aged stand structure, with divergence in species compositional dominance throughout ODF lands.

Table 19. Major species classes by subwatershed. The distribution of major species on ODF lands. Note hardwood and mixed types represent ~85% of ODF lands.

	Conifer		Hardwood		Mixed		Other		
Subwatershed Name	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Totals**
N. Fk. Wilson River	73	6%	328	29%	741	65%	4	<1%	**1,147**
Upper Wilson/ Cedar Creek	70	5%	257	20%	955	73%	33	3%	**1,315**
S. Fk. Wilson River	282	22%	200	16%	789	62%	12	1%	**1,284**
Little N. Fk. Wilson River	39	3%	564	49%	532	46%	19	2%	**1,156**
Middle Wilson River	10	1%	410	41%	481	48%	97	10%	**1,000**
Jordan Creek	47	5%	235	23%	718	71%	11	1%	**1,011**
Lower Wilson River	79	10%	203	26%	478	60%	36	4%	**797**
Devils Lake Fork	557	28%	143	7%	1,272	64%	29	1%	**2,003**
Totals	**1,157**	**12%**	**2,339**	**24%**	**5,967**	**61%**	**241**	**2%**	**9,705**

6.1.6 Vegetation Type Descriptions

This section describes the dominant conifer, hardwood and mixed forest types (including the riparian characteristics), connectivity with the stream channel, and forest health concerns for ODF lands. In addition, the subsequent sections report the current mean, range and distributions of species, size and density values collected during the field reconnaissance.

A stand-level summary of all measured stands is presented in Table 20. A full species table is included in Appendix K – Riparian Stand Information. A distribution of the conifer, hardwood and mixed stands as well as size classifications is displayed on Map 24.

6.1.6.1 Conifer Dominated Stands

Conifer-dominated stands were the least common forested riparian type and comprise 1,157 acres of ODF riparian zones, or 12% of the ownership in the Wilson watershed (Table 19); approximately one-half of the land area in conifer-dominated types is within the South Fork and Devils Lake Fork subwatersheds. A total of 9 sampled stands (out of 139) were conifer dominated; five stands were in size class 2 (8-14 inch L40 DBH) and four stands in size class 3 (14-20 inch L40 DBH) (Table 20).

As was the case with all stands measured, the stand table information is highly variable among sites (see Appendix K – Riparian Stand Information), though these stands averaged 67-92% of the basal area and ranged between 36% and 90% of the stem density in Douglas-fir dominance in both the inner riparian zone and the stream bank zone. Most of these sites had regenerating western hemlock in the understory, with occasional pockets of red alder in the mid-story strata (range 8-14 inches DBH). Approximately 14-18% of the stems and 29-40% of the basal area were in large trees (≥20 inches), almost exclusively in Douglas-fir, with a very minor contingent (1%) in western hemlock. A typical image of these conifer stands is displayed in Photographic Plate 3.

Conifer stands represent an early to intermediate stage of succession; the presence of western hemlock in the seedling and small tree categories indicates a gradual shift to shade-tolerant establishment. These zones are relegated to the upper reaches of the stream systems transitioning to hardwood co-dominance fairly rapidly with progression downstream.

Table 20. Summary of Field Data. The stand-level mean and range for basal area, stem density and quadratic mean diameter (QMD) for the71 stands sampled within the Inner Riparian Zone (IRZ) and the 68 stands sampled within the Stream Bank Zone.

Riparian Zone	Major Type	Major Class	FPS Code	N of Stands	Mean BA (ft^2/ac)	Min BA (ft^2/ac)	Max BA (ft^2/ac)	Mean Density (TPA)	Min Density (TPA)	Max Density (TPA)	Mean QMD (Inches)	Min QMD (Inches)	Max QMD (Inches)
IRZ	Conifer	FC2H	1D2H	5	203	126	286	172	62	277	15.5	12.9	19.3
IRZ	Conifer	FC3H	1D3H	4	193	151	235	125	91	169	16.9	16.0	17.4
IRZ	Hardwood	FH2H	1H2H	10	140	80	218	153	79	334	13.3	11.0	15.2
IRZ	Hardwood	FH3H	1H3H	4	135	60	201	200	30	305	12.8	10.1	19.2
IRZ	Mixed	FM2H	DX2H	14	176	120	302	142	31	276	16.6	10.4	28.0
IRZ	Mixed	FM2H	HX2H	11	145	38	226	156	35	370	13.7	10.6	18.3
IRZ	Mixed	FM2M	DX2M	3	164	88	235	73	46	89	20.0	18.6	22.7
IRZ	Mixed	FM2M	HX2M	3	108	50	138	90	59	151	15.3	12.5	20.4
IRZ	Mixed	FM3H	DX3H	12	199	101	336	182	38	473	16.0	10.8	22.2
IRZ	Mixed	FM3H	HX3H	5	105	25	160	105	14	208	15.3	11.1	18.8
SBZ	Conifer	FC2H	1D2H	5	190	151	226	117	57	182	18.1	15.1	23.3
SBZ	Conifer	FC3H	1D3H	4	208	126	302	209	112	386	14.1	12.0	16.4
SBZ	Hardwood	FH2H	1H2H	10	230	80	347	339	149	565	11.5	8.5	15.5
SBZ	Hardwood	FH3H	1H3H	4	188	80	269	247	48	595	13.9	8.8	17.4
SBZ	Mixed	FM2H	DX2H	14	206	101	440	172	49	371	15.6	11.5	19.5
SBZ	Mixed	FM2H	HX2H	9	185	120	218	192	73	395	14.5	8.4	20.6
SBZ	Mixed	FM2M	DX2M	3	218	151	269	153	53	265	18.1	12.8	22.8
SBZ	Mixed	FM2M	HX2M	3	190	67	252	208	23	341	16.0	11.6	23.0
SBZ	Mixed	FM3H	DX3H	12	226	101	520	202	46	486	15.4	11.3	19.9
SBZ	Mixed	FM3H	HX3H	4	218	100	280	302	86	765	13.7	8.2	16.6

6.1.6.2 Hardwood Dominated Stands

Hardwood dominated stands were the second-most dominant stand type for ODF riparian zones (2,339 acres, 24% of all ODF riparian zones, Table 19), though these types were co-dominant with mixed hardwood/conifer types in the Little NF Wilson River and Middle Wilson River subwatersheds (~49 and 41%, respectively). To capture the dominant structural classes on the landscape (L$) sizes 2 and 3), fourteen stands were field sampled in both the inner and stream bank zones.

In all measured cases, red alder was the dominant tree species, contributing >92% of the basal area and stems in the stream bank zone, with the balance found in bigleaf maple. Red alder ranged between 83-96% of the basal area and stem density in the inner riparian zone, with contributing components of bigleaf maple (3-7%) and midstory Douglas-fir. The size class distribution for both "size 3" and "size 4" stands showed an even distribution of basal area in trees 8-14 and 14-20 inches in DBH; ~40% of the basal area were in each of these size classes. Trees ≥20 inches were present throughout, mostly red alder and bigleaf maple, with minor components of Douglas-fir (inner zone only). A typical image of these stand types is presented in Photographic Plate 4.

As is the case elsewhere, these stands are in a relatively early stage of succession. Few regenerating conifers were found in this stand type, though some evidence of legacy conifers were found in the stream bank portions of the stands (Photographic Plate 5), suggesting some minor historic conifer co-dominance in some areas. Of the hardwood-dominated stands, 7 of the 14 sampled stands had ranged between 1 and 3 total legacy conifer stumps per acre for all plots sampled. Hence, legacy conifers were present, though their overstory dominance appeared to have been intermittent in this vegetation type.

One potential large-structured hardwood stand was found as part of the aerial photo interpretation (L40 size class 4). This stand was found on non-ODF lands at the confluence of Tillson Creek, on the right bank of the Wilson River. Though this stand appeared to have large-diameter trees, it is within a large strip of managed areas, pastures, and other disturbed features. Hence, the stand had large-diameter trees, but not old-growth structure. Though the photo-typed "mature" levels corresponded to the diameter classes, the majority of the watershed contained elements of mature hardwoods, where successional dynamics appeared to show regenerating cohorts of hardwoods with older (~50 year old) hardwood overstories. Though these may be considered "mature hardwood stands", the likelihood is this is a legacy of the extreme stand-replacement fire activity from the Tillamook Burns. Hence, the current structure

of hardwoods is possibly transient, though in later sections, the "transient" nature may exceed 100 years before conifer establishment may increase the conifer/ hardwood mix. For practical purposes, the current status of the majority of the hardwood stands is in an element of stem exclusion status, where older hardwoods are (or soon will) undergo self-thinning and regeneration. This status is probably not the "mature" status considered for hardwoods, though it is indicative that the near-term trend will favor a hardwood-dominated environment for the majority of the watershed. The hardwood dominated stands are found throughout all gradients and are associated with the range of stream sizes and types.

6.1.6.3 Mixed Dominance Stands (Hardwood and Conifer)

The most abundant stand type on ODF lands (and the watershed as a whole) is found in the "mixed" type, containing at least 20% conifer or hardwood. Two mixed forest types are identified in the FPS coding system: Hardwood-Conifer and Conifer-Hardwood (HX and DX, Table 14). These stands are best described as highly diverse in composition and structure; abrupt changes in topography or aspect favors one species group over the other (conifer vs. hardwood). Field data and walk-through exams suggest the FPS code system at the photo-interpreted scale (~1,500 ft stream lengths) does not provide sufficient detail to distinguish subtle and patch mosaic differences in co-dominance. Photographic Plate 6 provides an example of similarly coded stands with markedly different patch compositions and structures.

The heterogeneity among (and within) mixed types favors a diverse mix of species from black cottonwood to western hemlock. The hardwood to conifer ratio in trees per acre and basal area were highly variable; generally stands that were indicated to have more conifer cover than hardwood did have average higher relative densities than stands indicated to have hardwoods more dominant, though trends were not strong enough to support discrete stand classes.

Douglas-fir, red alder and bigleaf maple were the principle species for these stands, with few stands having regenerating western hemlock and western red cedar (steeper draws). Large trees were common among all sites; stand types had ~10 to 40% of the trees per acre in trees ≥20 inches DBH (~20% total basal area) and up to 5% of the trees per acre in trees ≥30 inches DBH (~5% total basal area).

The diversity of these stands provides important features for the stream system. As with other stands in the watershed, the Mixed stand types are in an early stage of development, with lower gradient communities transitioning to hardwood dominance (red alder, bigleaf maple and black cottonwood, Photographic Plate 7) and upslope riparian communities—both in the inner and the stream bank zones

in steep gradient systems – differentiating away from hardwood co-dominance to include regenerating shade-tolerant species (western hemlock and western red cedar, following Photographic Plate 6, left image). These vegetation types offer the best opportunities for restoration and enhancement, discussed in greater detail in section 6.3 Riparian Enhancement Opportunities.

6.2 Potential Future Conditions

6.2.1 Riparian Vegetation Dynamics: "No Management" Scenario

Estimates of stand successional dynamics and the potential for instream large wood recruitment from riparian vegetation was generated from the riparian dataset with expanded stand metrics (ODF lands only). The expanded dataset was modeled for growth and tree mortality using the Pacific Coast variant of the Forest Vegetation Simulator (FVS). Species, size and density projections were modeled in 10-year increments, from 2006 (growth year of field measurement) to 2106. Regeneration and 0-5 inch size class components were obtained from SLI plot data in measured and expanded stands. Regeneration components were considered in different ways, and the model results presented here involve the growth model to "force" seedling establishment every other time step (20 years)[44].

The primary purpose of this analysis is to quantify and describe the expected ranges of principle riparian functions and attributes (e.g., large wood recruitment, stream shading, and compositional dynamics) under the assumptions of no management and no disturbances. This is important, as this analysis does not include stochastic factors that often influence stand structure and composition (e.g. landslides, debris torrents, gap mortality, etc.) – some of these factors are described elsewhere in this analysis and typically are beyond the normal range of forest management options or the capacity of the model utility. Ultimately, this analysis serves to evaluate if projected ranges meet the desired ranges of conditions without active management. In addition, this tool provides a basis to determine the range of limiting factors that may be present, by which active management options could be considered. As a modeling tool, the no-management option provides the basis to compare the effects of potential vegetation treatments on the benchmarked ranges (see section 6.3 Riparian Enhancement Opportunities).

It is of critical importance to note that the collected data and base riparian vegetation map have utility at the subwatershed scale and larger. The limiting

[44] Further discussion and model evaluations are presented in Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

factors affecting the resolution of the data are primarily the coarse-level vegetation codes (FPS codes) and the unit delineation size for riparian stands (~1,500 ft). At the subwatershed scale, these data provide insight as to the fundamental patterns in species composition, tree growth and mortality. Site-level prescriptions based on these data are not advised, as the data do not have the resolution needed to prescribe a practical or valid active management scenario. The reason for these limitations and pathways for solutions are described in detail below (refer to section 6.3 Riparian Enhancement Opportunities).

This section describing the non-managed scenario is arranged to quantify the successional dynamics of the following riparian ecosystem aspects for the 100-year time period[45]:

- Species composition, specifically the ratios of conifers and hardwoods contributing to total tree densities,
- Stand structural characteristics, including trees per acre by size class, rate of recruitment of trees to the forest canopy, and quadratic mean diameter changes,
- Species compositional dynamics of the forest strata, or the distribution of conifer and hardwood species in context of forest structure and succession, and
- Canopy tree mortality, and the number and rate of hardwoods and conifers that die within each time period.

Following this section, further discussion associated with riparian forest dynamics is explored with stream temperature modeling (vegetative shade effects) and estimating the fate and interaction of dying trees with the stream channel. Potentials for management options and utility and confidence of this dataset are also explained. A "general" silvicultural prescription and an Action Plan Pathway are presented to provide guidance for increasing the utility and management design of a riparian base map using LiDAR available in early 2008.

6.2.1.1 Species Composition: Shifts in Conifer Abundance

Riparian tree species were grouped on the basis of their conifer or hardwood classification and the relative abundance of conifers was calculated as a

[45] For additional information on how assumptions change these characteristics, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

percentage of stand-level trees per acre for all modeled years. This value provided an evenly scaled system to evaluate the relative abundance of conifers within the riparian zones, despite stand-to-stand and year-over-year changes in trees per acre. Specifically, this attempts to describe the relative shifts in species dominance between conifers and hardwoods through time. Stand-level relative abundances were weighted on the basis of acres, and reported at the subwatershed scale (Figure 10).

A caveat associated with this particular analysis is that standardized growth models have difficulty in quantifying the shifts in species composition through time, especially in longer time periods. Species shifts are often controlled by microclimate, opportunity (seed dispersal and germination), disturbance patterns, and other factors at play at the site level that are difficult to measure and predict. The deterministic growth models are designed to provide opportunity for cohort advancement on the basis of model thresholds (stand density indices, canopy cover, percent survival, etc.). As such, the compositional changes observed are a function, in part, of the model input assumptions and thresholds, showing how trees respond to the mortality thresholds set in the models.

With a full understanding of this potential limitation, the model is useful in generalizing trends in species composition at the landscape-level to evaluate the establishment and abundances of potential seed trees, and to quantify the dynamics of recruitment into the different levels of the forest strata. Conifer and hardwood abundances are examined here to evaluate the ranges of co-dominance, and to predict if any marked or notable changes are predicted to occur under a non-managed/ no disturbance scenario at the sub-watershed scales for the 100-year time period.

The model run shows a clear increase in conifer proportions through time, with a shift from hardwood dominance in the first 50 years to a reversal by the end of the model run (Figure 10). Two major factors contribute to the observed trend. The first is the presence of the 0-5 inch cohort, which contained an element of conifers that are allowed to compete and eventually recruit or persist to later periods of the model run (i.e. when hardwood abundances decline beyond ~50 years). The second and most significant factor is the regeneration component, and the use of this component during the model run. As stated and explained elsewhere in this document[46], the regeneration feature in the FVS model utilized "forced" natural regeneration, meaning time steps and not stand density thresholds dictated when seedlings were to be established. This is evidenced by the "stair-step" curves in Figure 10, where establishment of seedlings occurred

[46] For a discussion of different model runs and assumptions, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

and were subsequently adjusted by mortality triggers relating to stem density, shading, etc. As such, the most persistent species will be projected to survive, favoring conifer species over hardwoods (e.g. hemlock, cedar). Hence, the projection of conifer dominance is mostly dependant upon the assumptions made in regeneration and stand density indices for mortality, and this becomes more important at later periods in the time series. Disturbance events (which are not modeled here) are more significant contributors to compositional dynamics.

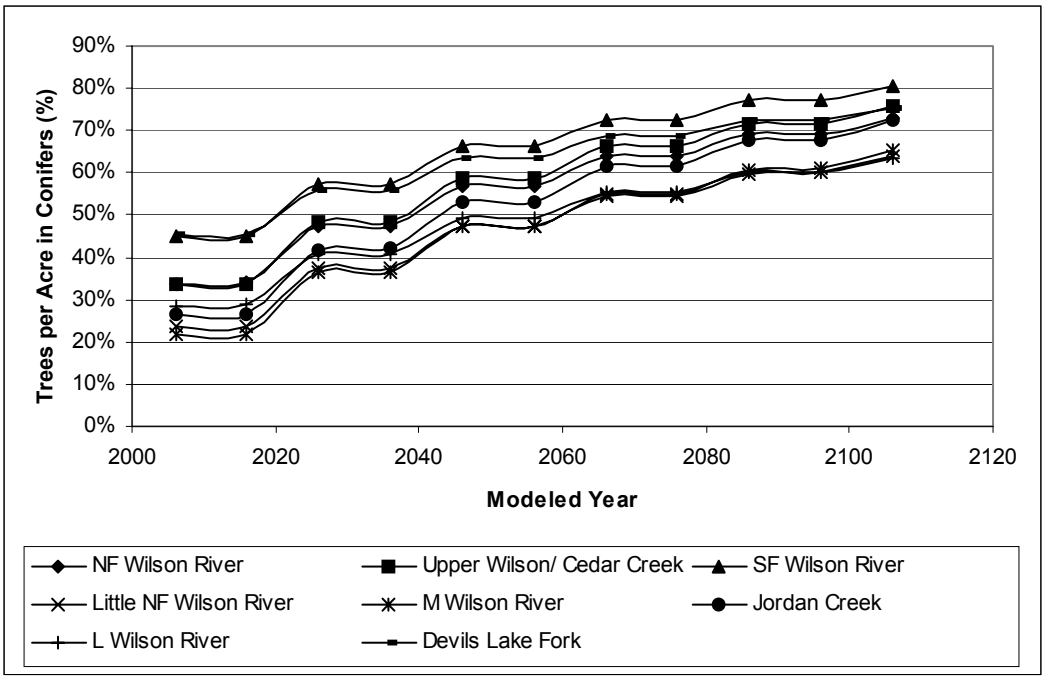

Figure 10. Relative Abundance of Conifers. Stand-level averages of conifer proportions of trees per acre, weighted at the subwatershed scale.

With the understanding of the caveats associated with modeling compositional dynamics, the landscape-level view shows the potential for conifer establishment in these stands (from a relative abundance standpoint), though as described in subsequent sections, the conifer component is very slow in gaining dominance in the overstory component of the system (≥14 inches DBH). In addition, and tough not directly measured, the age of these riparian zones is approximately 55 – 60 years old, with very low observed densities of conifer seed trees at the current year (2006) in most subwatersheds. Assuming the model captures the future profile of conifer and hardwood proportions, it can be concluded that the Wilson River watershed is hardwood dominated, and hardwoods (particularly red alder) will remain a significant proportion of the forested riparian landscape

affecting vegetative shade, wood inputs, and nutrient inputs to the stream system for a long period of time (see subsequent analysis for overstory components).

6.2.1.2 Stand Structural Changes in Mid- and Over-story Canopy

Mid- and overstory canopy components were selected through the 100-year time series to illustrate the shifts in abundances for the dominant and co-dominant trees in the canopy strata. Tree sizes ≥14 inches DBH were considered to be "mid and overstory" components, as these size classes contain the majority of the basal area, or are most influential on basal area and stand-level structure within a given stand. Absolute abundances (trees per acre) for all tree species were considered, and stand-level averages were weighted on the basis of acre contribution to each subwatershed.

For the 100-year time series, the overall canopy tree abundances increase from a range of ~50 – 70 trees per acre in 2006 to a maximum range of ~75 – 95 in 2056. By the end of the time series (100 years), overall trees in the dominant and co-dominant canopy strata decrease to ~50 – 65 trees per acre, representing the approximate density under the current conditions (2006) (Figure 11).

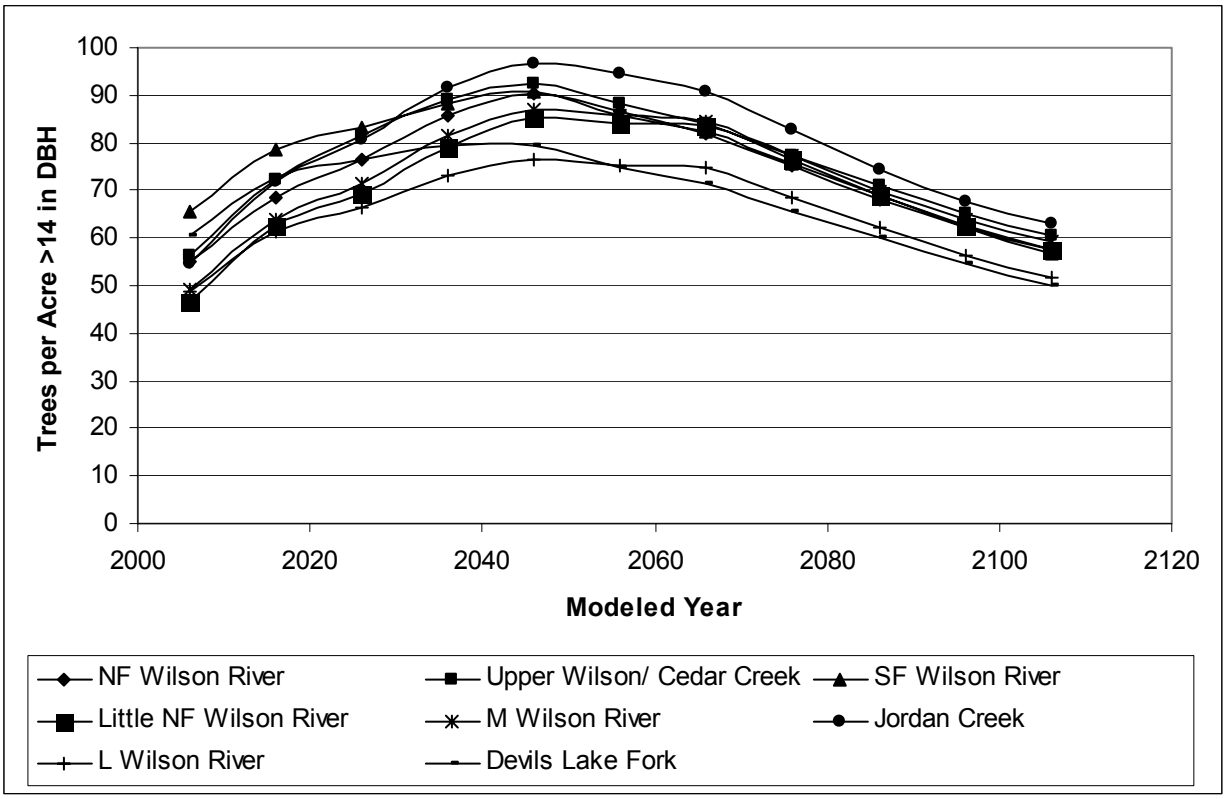

Figure 11. Projected Live Canopy Tree Densities. 100-year modeled weighted average standing trees per acre for conifers and hardwoods combined ≥14 inches DBH, reported by subwatershed.

Rates of "canopy recruitment", or the percentage increase (or loss) of trees entering the ≥14 inch DBH size class in a 10-year period, show increased rates of recruitment in the next ~30 years, followed by a gradual decline to the end of the first 50 year period. In the 50-100 year time steps, canopy tree recruitment rates decline steadily and level off at a steady decline of 10% loss in densities per model step for the final 30-50 years of the time series. This indicates the potential for growth stagnation and lack of recruitment of younger trees into the canopy size class.

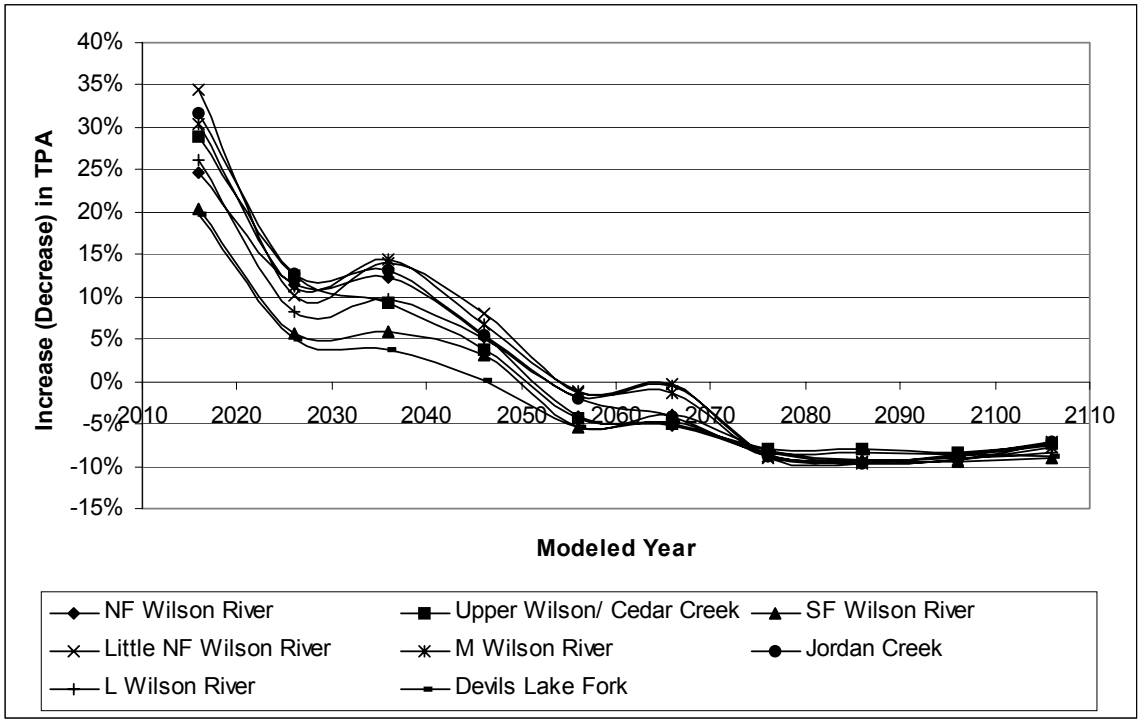

Figure 12. Projected Rates of Live Canopy Tree Recruitment. The percent increase or decrease in TPA for trees ≥14 inches DBH through time. Note negative values show declines in recruitment rates to this size class.

Modeled quadratic mean diameter (QMD) for canopy species increases steadily through the time series (Figure 13). Projected QMD increases steadily from the current ~22 inch diameter range to a range of 25 – 30 inches through time for the ≥14 inch size class. The smooth lines observed are probably legacies of the FVS model itself, though the combined increases in QMD with flux in the canopy-level TPA and rate of recruitment underscores evidence that there is a relative lag in mid-sized trees following the 50-year time period.

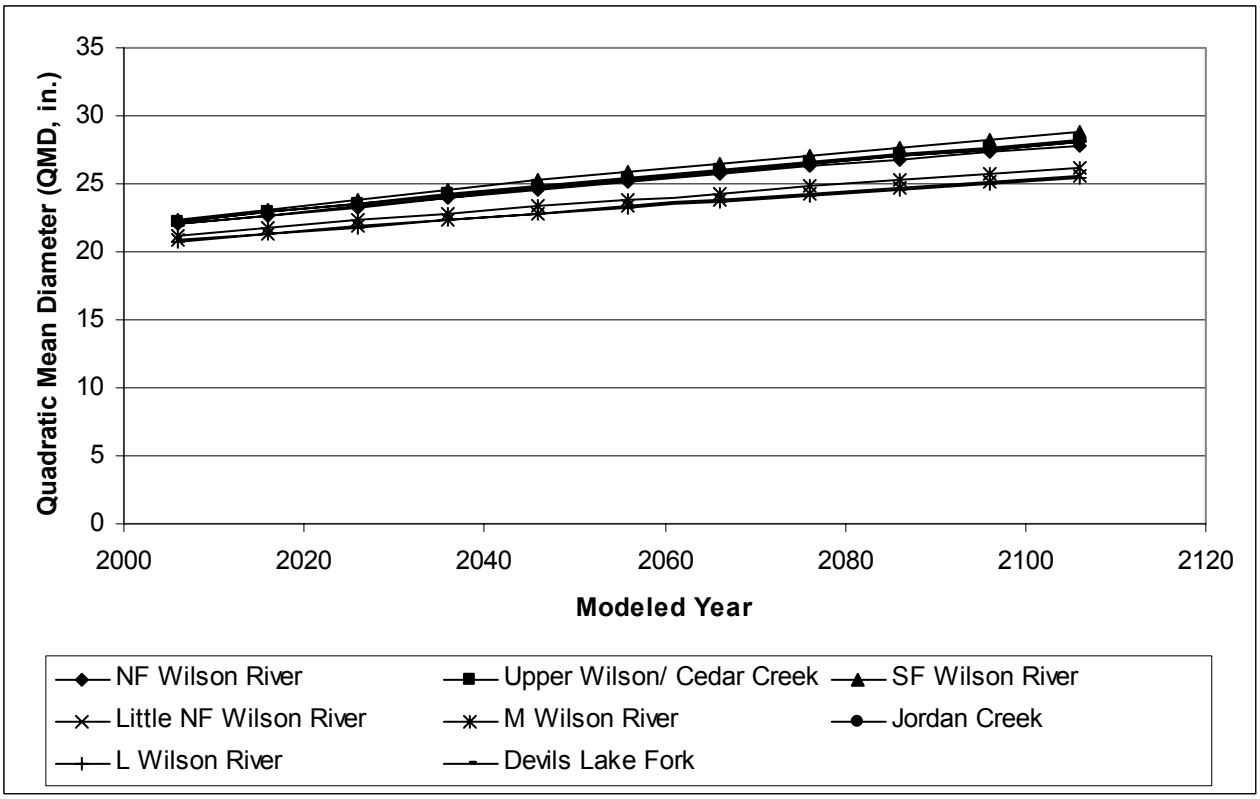

Figure 13. Projected Live Tree Quadratic Mean Diameter (Canopy strata). The 100-year projection of quadratic mean diameter for stand-level live trees ≥14 inches DBH, weighted for acre contribution by subwatershed.

The models and field observation suggest the canopy dynamics are currently entering in a 'stem exclusion' phase, where the overstory canopy is represented by smaller diameter trees that will experience a period of growth stagnation from competing canopy pressures. The long-term outlook suggests a decline in the number of trees entering the canopy strata through time, and more importantly, the *rate* by which trees will enter the canopy strata. The latter is of particular importance as it indicates a long-term trend of current trees getting larger in diameter (an ODF priority), but less replacement of those larger trees from the younger size classes of today. Hence, as the fewer, larger trees die, there does not appear to be a replacement cohort for those large-diameter trees in the future. These combined observations strongly suggest the trajectory of the riparian zones in all subwatersheds will not meet the definitions of "mature forest conditions" within the projected 100 year timeframe (refer to Appendix J – Desired Future Conditions).

6.2.1.3 Forest Structure and Compositional Dynamics

Following the similar methods presented in the previous section, canopy structure was evaluated on the basis of major species type (conifer and hardwood) to investigate the recruitment of these species types to the canopy.

The projected densities for live conifer (Figure 14) recruitment to the canopy (≥14 inches DBH) illustrates a slight increase in conifer recruitment within the next 10 years, followed by a steady decline over the remainder of the time period. Beginning approximately in 2040, the conifer density in the canopy declines to approximately that found in the current conditions for all subwatersheds, resulting in a net loss of canopy-sized conifers by the end of the time period. Both SF Wilson and Devils Lake Fork, the richest in conifer abundances, are projected to have the largest nominal decline, ending the model run at a density lower than the highs of the conifer poor areas. Stand-level mean diameters for conifers in this class are highly variable and range between 17-30 inches DBH and increase to 20 – 40 inches by the end of the model run, achieving a component of >35 inch conifers in most of the subwatersheds.

The majority of the recruitment to the canopy is in hardwoods (Figure 15), with a doubling of trees per acre in the upper strata of the forest structure by the 50 year time step. Following this time, the decline ends in a net gain by Year 100 of approximately 30% more hardwoods in the canopy strata as compared with the current conditions. The stand-level mean diameters of the canopy class, as with conifers, are highly variable, but do appear to increase in size from 15 – 22 inches DBH in the first 50 years, to ~18 – 25 inches DBH by year 100.

Similar to the canopy structural dynamics described above, understory structures and recruitment (defined as trees <14 inches DBH) were evaluated as subsets of conifers and hardwoods. Perhaps the clearest observation in this component is the effect of the modeled regeneration assumptions, evidenced by a "stair-step" increase and decline in abundances of persistent conifers (Figure 16) that corresponds to the forcing of regeneration feature of the model run. This pattern is attributed to the projection model reaching stand density thresholds to promote self-thinning. The magnitude of the conifer curve in combination with the canopy recruitment models presented above suggests that this size class distribution probably (a) contains sufficient stocking to not be limited for potential canopy recruitment but is (b) probably limited in stand density indices driving growth and mortality thresholds. This suggests the model will inherently favor the most shade-tolerant conifer species (e.g. hemlock).

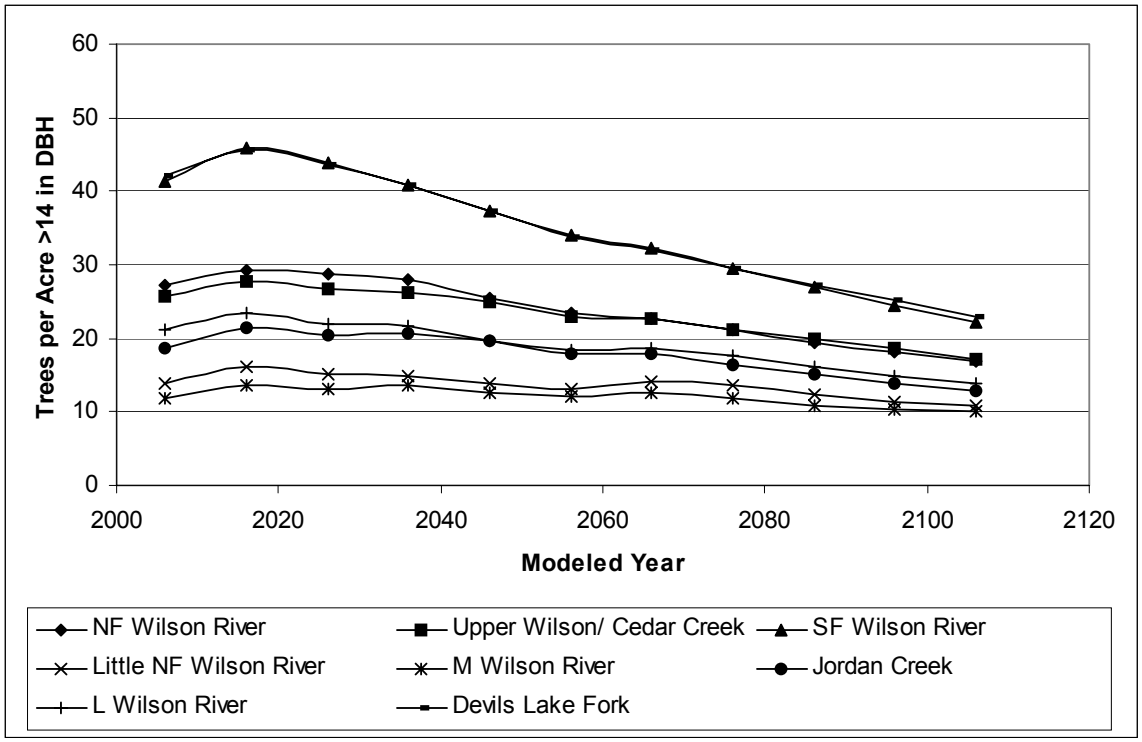

Figure 14. Projected Conifer Recruitment to the Canopy (>14 inches DBH). 100-year modeled weighted average live conifer trees per acre for riparian zones on ODF lands.

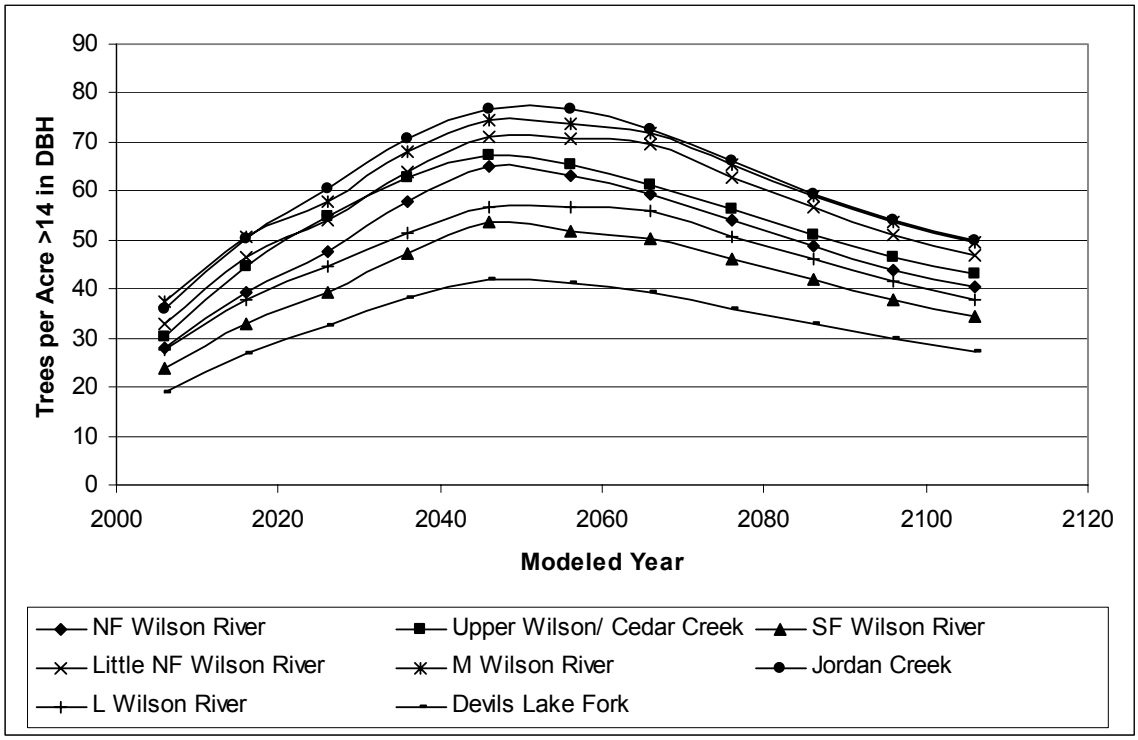

Figure 15. Projected Hardwood Recruitment to the Canopy (>14 inches DBH). 100-year modeled weighted average live hardwood trees per acre for riparian zones on ODF lands.

The hardwood understory component (Figure 17) follows a general decline for the duration of the model run, following model thresholds for stem density and shading affecting mortality triggers. Of important note, the current conditions show twice to three times the abundances of hardwoods to conifers; a trend that reverses by year 50. This is a legacy of the model run, where conifers are selected to persist on the basis of mortality thresholds. This also underscores how model assumptions affect projections during longer time periods. The question for monitoring purposes is to evaluate the true persistence of conifer species in the understory to ensure adequate "front end loading" of conifer species to ultimately recruit to the overstory canopy.

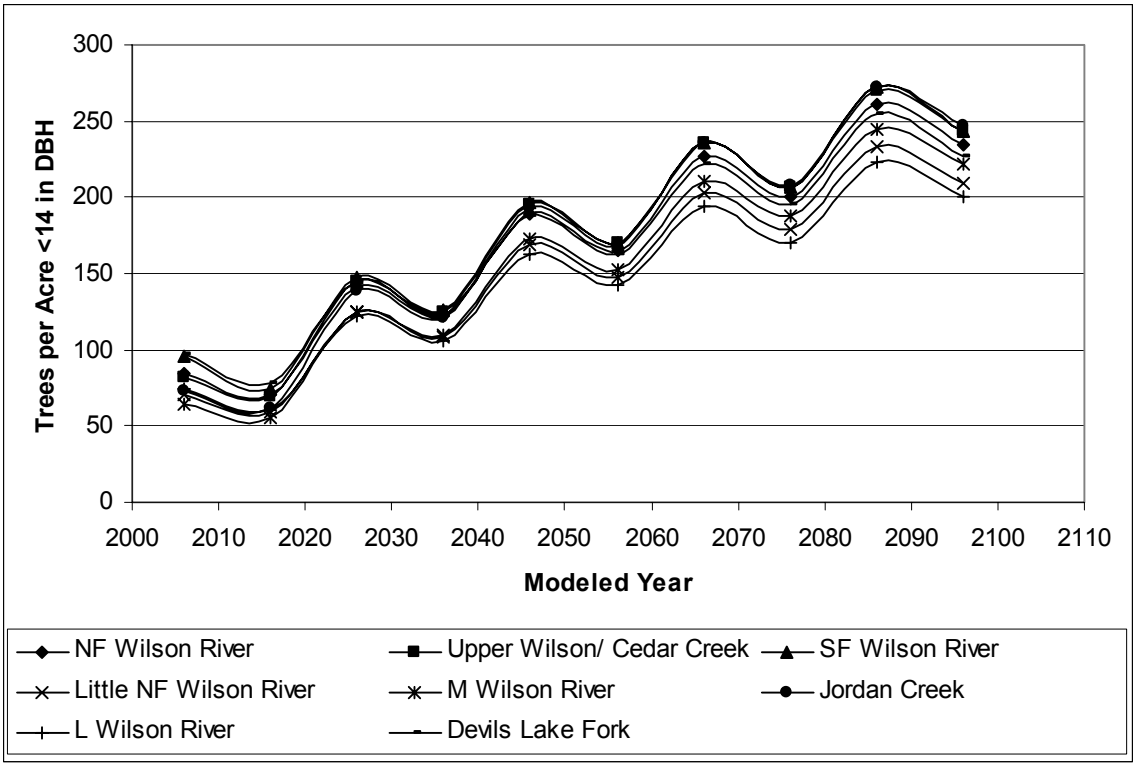

Figure 16. Projected Conifer Regeneration. The 100-year projected density of conifer trees per acre in size classes <14 inches DBH. Mean values are weighted for acreage contribution by subwatershed.

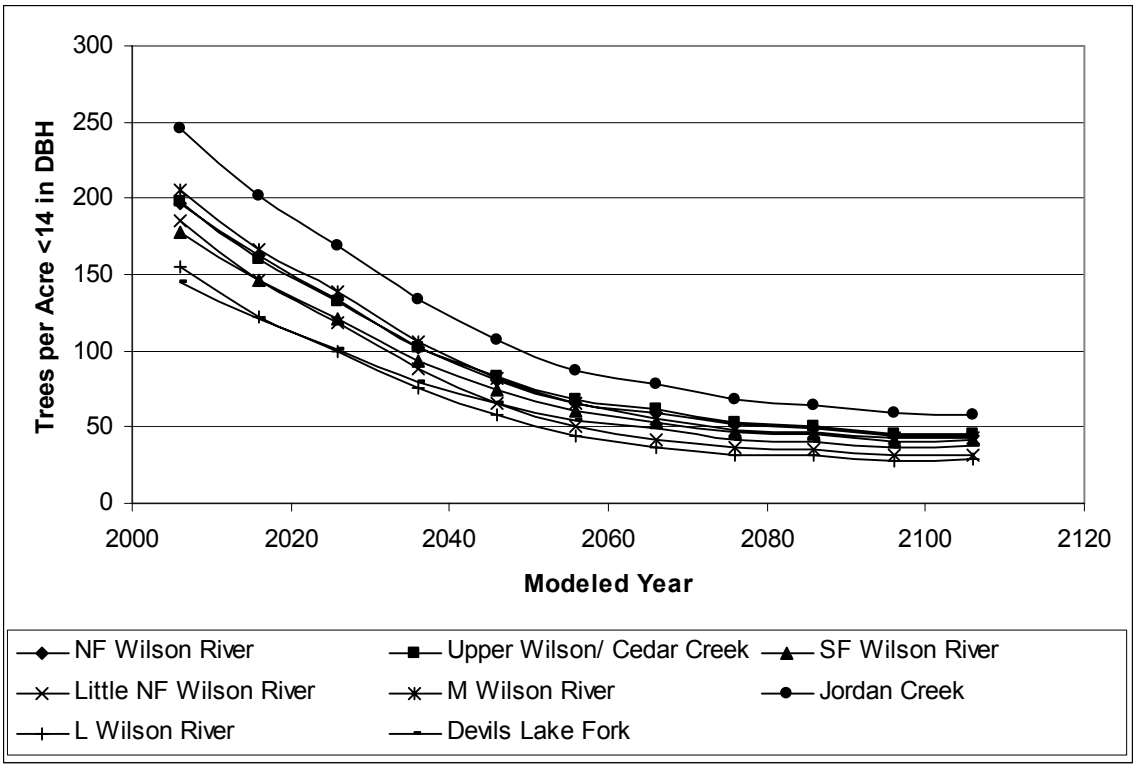

Figure 17. Projected Hardwood Regeneration. The 100-year projected density of hardwood trees per acre in size classes <14 inches DBH. Mean values are weighted for acreage contribution by subwatershed.

6.2.1.4 Stand Mortality and Creation of Downed Wood

Mortality rates, expressed as trees per acre, were calculated for the 100-year time period. The mortality rates expressed are through modeled mortality due to stem exclusion, competitive pressures, and other successional probabilities for mortality. As explained in earlier sections, these estimates do not include stochastic events such as landslides, debris torrents, flooding, insects or disease, animal pressures, or fire. In addition, human-caused damages are not a factor, including harvest, compaction, recreational impacts, road damage, etc.

The data presented in this section describes the potential mortality, of which a subset is potentially interactive with the stream channel. The data also provide important information for stand-level downed large wood, providing habitat components, large wood for nurse logs and overland sediment mediation, and for nutrient cycling. Further information about probabilities of stream channel interactivity are presented in a later section (refer to section 6.2.3 Stand Modeling of Large Wood Recruitment, below).

For the canopy strata (trees ≥14 inches DBH), there is an observed increase in the number of downed trees in the next ~40 years (Figure 18). Following this peak, there is a general decline in available downed trees ≥14 inches DBH for all areas, resulting in a net loss of available trees as compared with the current condition (approximately 30% fewer dead trees per 10 year period). Of particular note is the rate of change in downed wood creation, especially after ~2036 (Figure 19). Following two consecutive time periods with increases in medium-large downed wood, there is a marked decline in the mortality rates, with all subwatersheds continuing to have declining rates, excepting Jordan Creek, Little North Fork and Middle Fork Wilson River until 2056. Mortality rates continue in a steady decline at a rate of 10% to 20% per decade until the end of the period.

The "lag period" begins in approximately 2036 can be attributed to the beginning of the decline in conifer mortality (Figure 20) and the period of time before 2056, when hardwood mortality begins to reach its peak (Figure 21). This lag period has particular implications on available wood for riparian recruitment to the stream. Considering the relatively low *density* of conifers in the canopy on the landscape, the apparent slow *recruitment* of conifers to the canopy, coupled with the declines in *mortality* suggest this lag period may extend beyond 100 years for conifers, assuming the modeled scenario.

The influx of large wood in the next 30 years, followed by an extended lag period of tree mortality appears to follow a 'stem exclusion' pathway, where smaller-diameter trees in the canopy will compete and experience a minor "pulse" of mortality, allowing for the residual trees to compensate and grow to larger diameters and heights. However, there is concern for the available trees that will follow this pulse, with an apparent limited recruitment into the mid-story and upper stories throughout the time series – primarily found in slow-growing persistent conifers and declining hardwood abundances. In addition, the larger-diameter trees (especially conifers) do not appear to die during the latter portions of the time series – further underscoring the lack of instream large wood, especially durable conifer wood, during this time. While these patterns are not unusual for non-managed, ~60 year old mixed forests, and large trees appear to grow larger (but less plentiful), there is a limitation in the available large wood and stream shading (see sections below) in the mid- and later periods of the timescale.

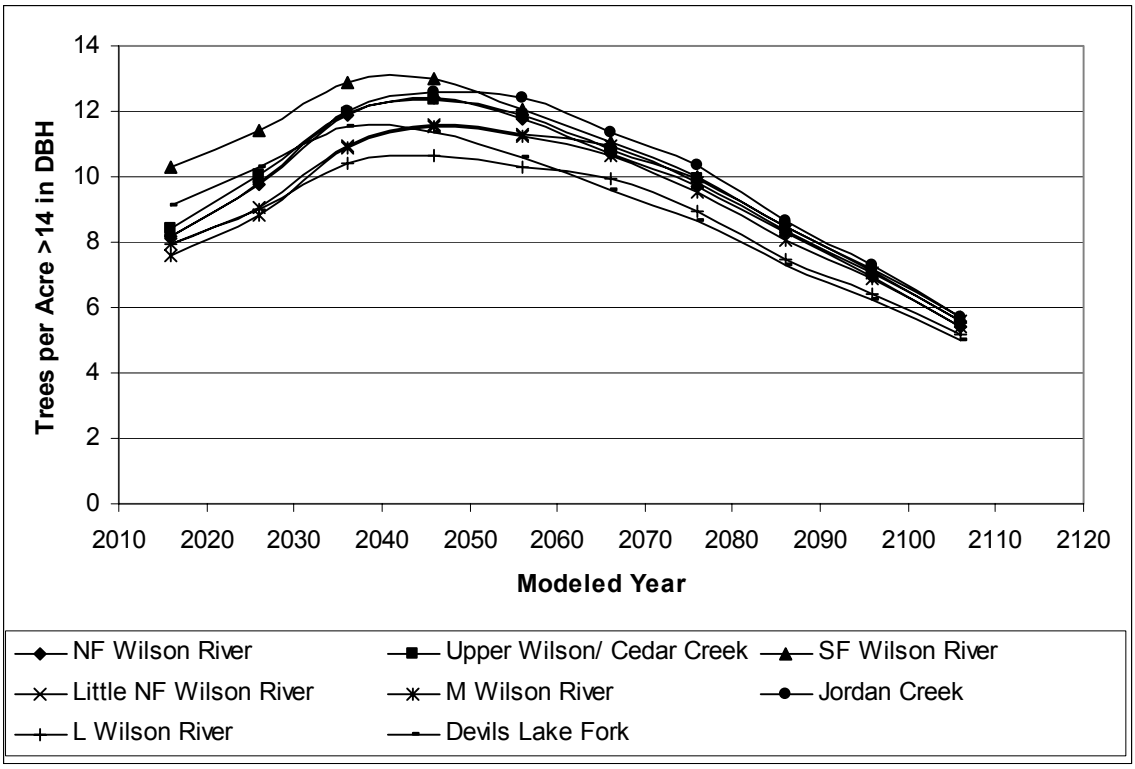

Figure 18. Projected Canopy Strata Mortality. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, presented by subwatershed.

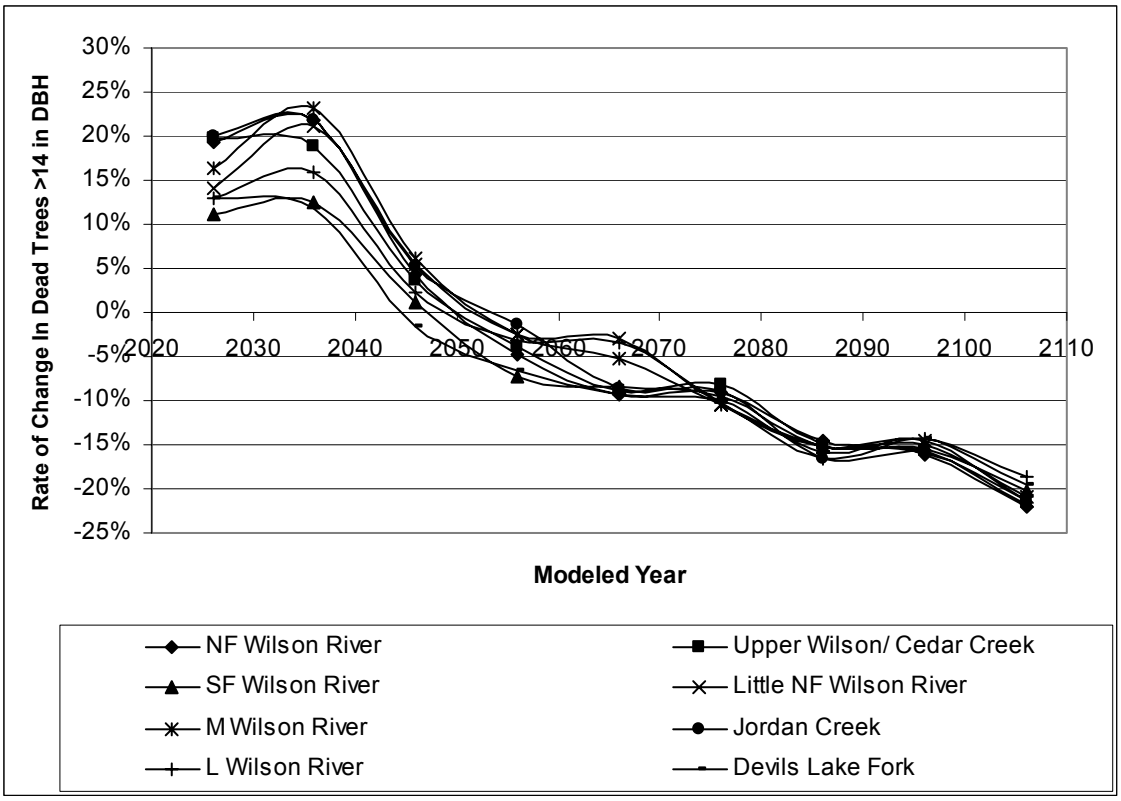

Figure 19. Rate of Change in Canopy Tree Mortality. Percent increase or decrease in tree mortality ≥14 inches DBH, presented as weighted averages by subwatershed.

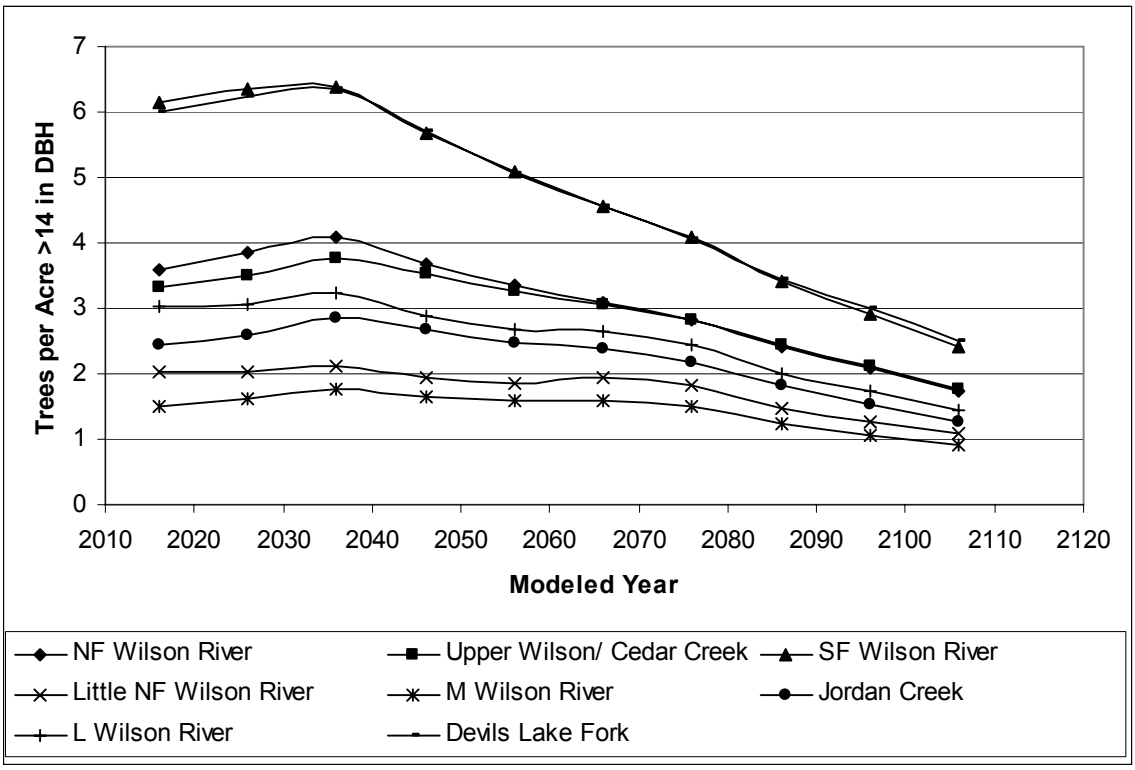

Figure 20. Projected Canopy Mortality of Conifers. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, by subwatershed.

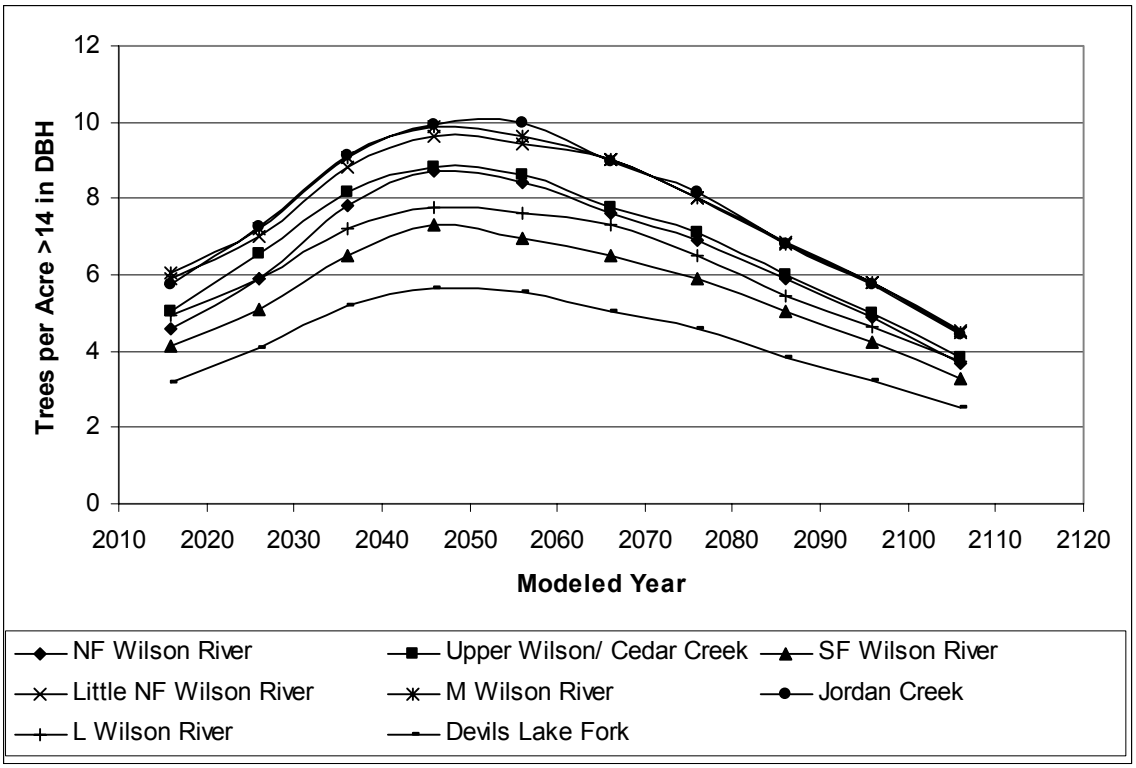

Figure 21. Projected Canopy Mortality of Hardwoods. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, presented by subwatershed.

6.2.1.5 Key Findings at the Subwatershed Scale

The following are key points regarding the riparian successional dynamics under the 100-year non-managed scenario:

- **Conifers Dominance is Dependant Upon Assumptions and Opportunity.** The model suggests the proportion (relative density) of conifers and hardwoods in the system begins to reverse by year 50, with hardwood abundances declining to below that of conifers in the second half of the model run. The primary assumption of this finding is that disturbances and management are not present to create gaps to allow for micro-site establishment opportunities by either species type. As such, trees most adapted to shade tolerance will persist (e.g. hemlock). Because these trees are a relatively small component of the seedling pool, their modeled dominance is primarily dependant upon modeled mortality of shade intolerant species.

- **Conifer recruitment to the canopy declines through time.** Rates of conifer tree recruitment to the ≥14 inch size class decline through time

for the 100 year time period, especially following 2036. This trend appears to be attributed to few conifers available for recruitment, and mortality triggers that constrain the recruitment pool to slow growth, shade tolerant species. This trend is causing an apparent lag in conifer recruitment to the canopy, which is likely to extend beyond 100 years, until conversion to multi-structured forest types (e.g. shade tolerant hemlock dominant) becomes dominant. The projected time beyond 100 years for this conversion is unknown.

- **Trees are growing.** There is evidence that trees in the canopy strata are attaining larger mean diameters in both hardwoods and conifers. Stands are becoming multi-layered, though apparent recruitment to the canopy classes generally declines. This trend appears to peak at 50 years, where the completion of the stem-exclusion phase allows for additional cohort differentiation between hardwoods and conifers <14 inches DBH.

- **Lower mortality rates and fewer downed trees per acre.** Sharp declines in mortality of the ≥14 inch size class begin after 2036. These declines persist for the remainder of the model run, and the current rates suggest they will continue to decline for more than 100 years at a rate of ~20% fewer trees per 10 year period. In addition, fewer conifers are contributing to the mortality pool. This has direct implications for large wood recruitment to the stream channel.

The model results summarized above strongly indicate the current riparian stands in the Wilson River watershed are reaching the point of 'stem exclusion', where growth stagnation and competition for light will cause a pulse in mortality through self-thinning, followed by growth of a simplified, multi-layered (two or three layers) canopy, consisting of larger-diameter trees that increase in size over time. Though the Forest Management Plan (FMP; specifically, Appendix J of the FMP) recommends the growth of large-diameter conifer trees in the riparian zone as the 'desired future condition', the data suggest that this condition will likely not exist for 100 years and potentially longer, and there are limiting factors that will inhibit how the riparian zones function for streams within all subwatersheds during the modeled time period.

One limiting factor to the FMP strategies is the observation that conifer dominance and recruitment to the canopy is a very slow process, and does not appear to have an effect on canopy dynamics during the 100 year time frame (i.e. hardwood dominance persists)[47]. Understanding the model is limited in

[47] For further growth model discussions, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

quantifying these successional dynamics on the basis of the primary assumptions, the dominance of hardwoods observed through the models and in the field suggests there are limited opportunities for conifer establishment, recruitment to the canopy, and (ultimately) recruitment to the stream channel as instream large wood for at least 100 years assuming no management or disturbance. Hence, one management option would be to attempt to shift the species composition to favor conifer growth though time to enhance conifer establishment and increases in co-dominance percentages at earlier time periods, especially within the canopy strata.

The recruitment to the mid-story canopy by both hardwoods and conifers is also limiting. Following the stem exclusion mortality pulse, there does not appear to be good recruitment success to the lower and mid-canopy strata in the latter 50 years of the time series. This is especially true for conifer trees, though there are notable declines in canopy recruitment for hardwoods as well. Coupled with this shortfall in canopy establishment is the corresponding decline in tree mortality (for both hardwoods and conifers), which has direct implications on in-stream large wood recruitment to the stream channel in the last 50 years. Large trees, especially large conifers, are observed in the latter periods of the model runs, though the concern is a lag period in trees to ultimately replace the largest size classes (in 75 – 150 years), and to provide interim inputs of large wood. Management options to increase the diversity in size classes are recommended (see Pathways to Action Plan below), with the ultimate goal to sustain mid-term (~50 year) recruitment to the canopy and subsequent shade and large wood inputs during the 50-100 year period (and beyond).

It is not known if the canopy recruitment and species dynamics will change their current trajectories in time frames exceeding 100 years. Included with the inherent assumptions that form growth and yield models (such as FVS) are uncertainties associated with the disturbance patters on the landscape. Climate change, alterations in fire frequency and severity, stochastic factors, land uses, and shifts in the hydrologic regime are all factors that can (and do) change the species and structural dynamics of a given system. In fact, these factors ultimately stimulate structural and compositional diversity on the landscape, and promote conditions found in 'first growth' forests. Under this modeled scenario of no management in a managed system, and extrapolating the trends observed, the limitation and lag of young trees recruiting the canopy suggest a situation beyond 100 years that may provide less shade and wood inputs to the system than it will be projected to within the next 30-50 years.

Further discussion on management options that follow the FMP (specifically, Appendix J of the FMP) and recommended pathways for an action plan using current ODF resources are described in more detail below.

6.2.2 Large Wood Recruitment[48]

Estimates of large wood recruitment to the stream channel was evaluated in two different ways:

- Evaluation of standing wood through time, specifically targeting benchmark ranges for *conifer* trees in the riparian zone, based upon a range of reference stream reaches in the Coast Range (Kavanagh et al. 2005). This method provides "pass/no pass" criteria for *categorical* evaluation for the watershed as a whole.

- A time-series of tree growth and mortality, with modeled probabilities for large wood inputs (all species and sizes) to engage the stream channel. This method is specific to the Wilson watershed, and provides a range of expected conditions through time, expressed as nominal values. This method is *adaptive* for evaluating effects of potential treatments on large wood recruitment.

6.2.2.1 Methods: Categorical Evaluation of Standing Trees

Estimates of large wood recruitment to the stream zone was generated from the riparian dataset with expanded stand metrics (ODF lands only). Considerations of large wood inputs were made for conifer species at ≥20 and >35 inches DBH per 1,000 feet of stream length (by 100 ft buffer strip, ~30 m). Low and High values obtained from reference reaches in the Coast Range (ODFW unpublished) represent the 25th and 75th percentiles of the data:

Diameter Minimum	Stream Length (feet)	Low Range	High Range
>20 inches DBH	1,000 ft	<22 trees/ 1,000 ft	>153 trees/ 1,000 ft
>35 inches DBH	1,000 ft	0 trees/ 1,000 ft	>79 trees/ 1,000 ft

6.2.2.2 Results: Categorical Evaluation of Standing Trees

Figure 22 presents an overview of the potential future standing conifer stocks ≥20 inches DBH for each of the subwatersheds, assuming a no-management scenario (see Riparian Stand Dynamics section for further discussion). While Little North Fork and the Middle Fork Wilson River do achieve the minimum of the low range of conditions in the first time step, the overall modeled data

[48] For a detailed wood recruitment *budget* for the Wilson River watershed, refer to Appendix L.

indicate most subwatersheds have standing stocks of conifers that are within the lowest quartile of the desired range between 2016 and the end of the model run. However, declines in conifer stocks and losses of conifer mortality and canopy recruitment are of concern in the later years of the model (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above).

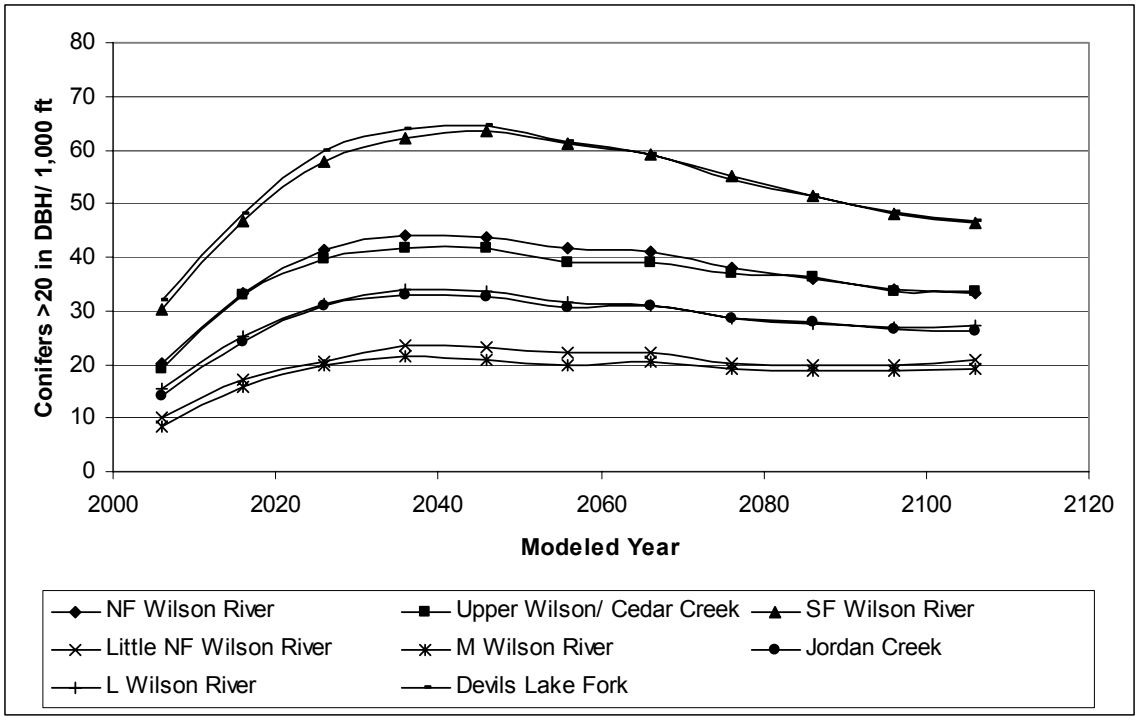

Figure 22. Standing Large Conifers (≥20 in DBH) per 1,000 ft of stream. The 100-year modeled scenarios of large conifers, presented as weighted averages for each subwatershed.

While recruitment of conifers to the canopy layer is slowed throughout the time series, conifer sizes do increase through time and provide a range of ~13 – 33 conifers >35 inches in DBH as standing trees in the riparian zones (Figure 23). These values are within the lower half of the desired range determined from reference reaches, though it is important note the recruitment of *new* conifers after the model period is likely very low. Without continued recruitment of large conifers to the upper canopy layers, the eventual mortality of these large trees will create a "lag point" where annualized standing conifer stocks will decline.

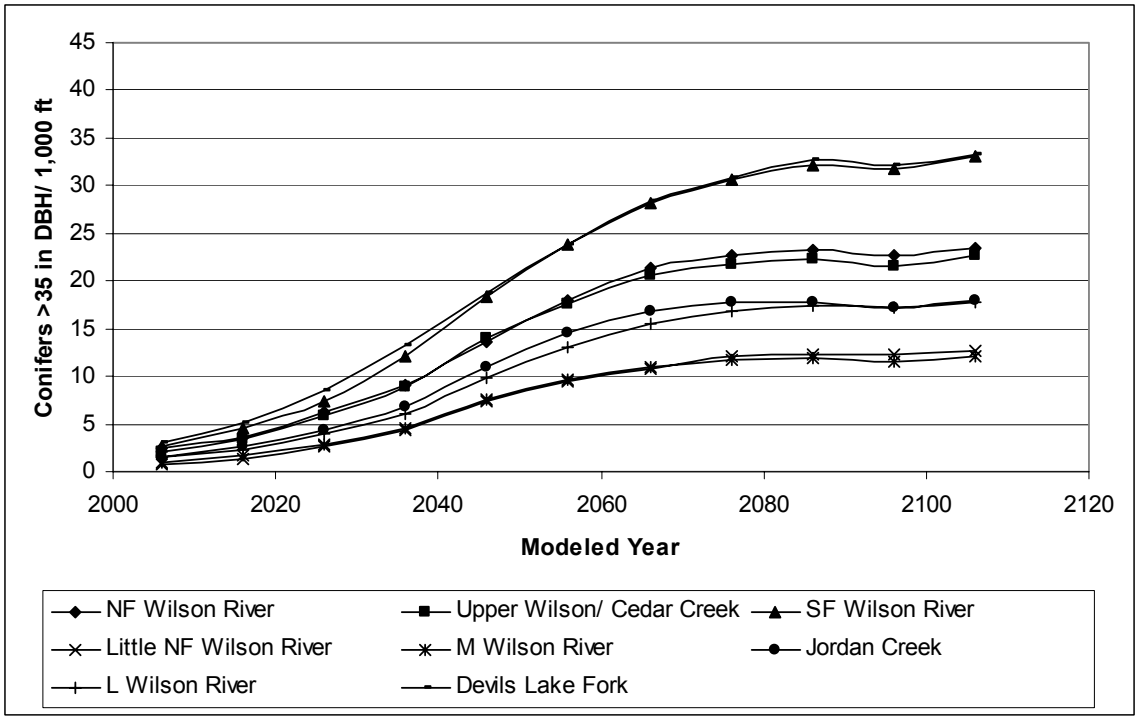

Figure 23. Standing Large Conifers (>35 in DBH) per 1,000 feet of stream. The 100-year modeled scenarios of large conifers, presented as weighted averages for each subwatershed.

Table 21. Standing stocks of conifers >35 and ≥20 inches DBH per 1,000 feet of stream channel. 100 year profile for conifers, in 10 year increments, averaged on a weighted acre basis and summarized by subwatershed.

Subwatershed	2006		2016		2026		2036		2046		2056		2066		2076		2086		2096		2106	
	>35”	>20”	>35”	>20”	>35”	>20”	>35”	>20	>35	>20	>35	>20	>35	>20	>35	>20	>35	>20	>35	>20	>35	>20
NF Wilson River	2	20	4	33	6	41	9	44	14	44	18	42	21	41	23	38	23	36	23	34	23	33
Upper Wilson/ Cedar Creek	2	19	3	33	6	40	9	42	14	42	18	39	21	39	22	37	22	36	22	34	23	34
SF Wilson River	3	30	4	47	7	58	12	62	18	63	24	61	28	59	31	55	32	52	32	48	33	46
Little NF Wilson River	1	10	1	17	3	21	4	23	7	23	9	22	11	22	12	20	12	20	12	20	13	21
Middle Wilson River	1	8	2	16	3	20	4	21	8	21	10	20	11	21	12	19	12	19	11	19	12	19
Jordan Creek	2	14	3	24	4	31	7	33	11	33	15	31	17	31	18	29	18	28	17	26	18	26
Lower Wilson River	1	15	2	25	4	31	6	34	10	33	13	32	15	31	17	29	17	28	17	27	18	27
Devils Lake Fork	3	32	5	48	9	60	13	64	19	65	24	61	28	59	31	55	33	51	32	49	33	47

6.2.2.3 Stand Modeling of Large Wood Recruitment

In-stream wood arrives via several potential routes: riparian trees die or are blown over and fall into streams, bank erosion undermines trees that topple into streams, overbank flooding carries wood to streams, and landslides and debris flows carry wood to streams. Of these processes, recruitment rates from the first three vary directly with the size, species, and age distribution of trees in the riparian zone; hence our focus on characterization of riparian stands and the use of reference size and species densities for evaluating the potential for wood recruitment from these stands.

However, the benefits for aquatic habitat provided by recruited wood vary both with wood-piece and channel size. To incorporate these factors into our evaluation of current and future wood recruitment from riparian stands, we use a spatially distributed wood recruitment model. The model estimates the number, diameter, and species type (conifer versus hardwood) of wood pieces entering each stream reach from modeled riparian tree mortality (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). The recruitment model is spatially referenced to the 10-m DEMs. It uses preferential tree fall directions dependent on hillslope gradient and on tree location relative to all channel edges. Annual wood sources from every DEM cell and annual wood inputs to every channel reach are calculated for every year using tree mortality for riparian stands obtained from FVS (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). Pieces are lost from the system by decay or fluvial transport. We assign a constant species-dependent depletion rate to approximate wood lost to these processes and then integrate recruitment and depletion rates over time to estimate future nominal in-stream wood abundance (pieces per unit length) from riparian tree fall by piece-size class for all delineated stream reaches in the fish-bearing channel network. The reported results are for an unmanaged scenario. To account for channel size, these results are compared to the minimum piece diameter required for pool formation to obtain the number of potential pool-forming (functional) pieces accumulated in each reach, calculated each year over a 100-year period. These values indicate the degree to which riparian stands can serve as functional wood sources, provide predictions that can be compared to field measurements, and help to identify reaches where riparian wood sources may be inadequate for production and maintenance of high-quality aquatic habitat.

Effects of debris flows on wood recruitment and consequences for aquatic habitat must also be considered. For type F channels, we view debris-flow effects both from the potential for debris flows to carry sediment and wood to these streams and from the potential for debris flows to trigger debris-laden floods that can remove accumulated wood from these streams. Both of these processes are

addressed in Chapter 7 of this document. Channels subject to debris flow inputs are identified in Map 25; debris flow source areas to these channels can be identified from Maps 26 and 27; channels most susceptible to debris-laden floods are identified in Map 28. The debris-flow-prone Type F reaches shown in Map 25 identify areas where debris flow inputs of wood serve important ecological functions. At any time, some subset of these reaches may have high wood loading values, and other effects, due to inputs from recent debris flows. The abundance of reaches with high debris-flow-derived wood will vary over time, depending on the temporal sequence of large storms. The size of wood carried by a debris flow depends on the size of the trees present along the debris flow path and the size of buried wood scoured from steep Type N channels traversed by the debris flow. In general, upland stands in the Wilson basin do not currently provide opportunities for recruitment of key (>60cm) wood pieces (although such pieces may be present in steep type N channels that have not been traversed by a debris flow in the past century or so). However, potential for debris-flow recruitment of key pieces can increase over time as upland stands grow. Maps 26 and 35 identify source areas for these pieces.

6.2.2.1.1 Methods

Modeled tree mortality for un-managed riparian stands was calculated using FVS at 10-year increments (refer to section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). Dead trees were assumed to fall over a 10-year interval. Trees were divided into five size classes, with a mean stem density and height reported for each class, and divided between conifer and hardwood species. Every tree within a tree height of a channel edge can potentially fall into the channel; the probability that it does was calculated using an empirical distribution of fall angles for the Pacific Northwest reported by Sobota et al. (2006). The size of the piece entering the channel was calculated as a function of tree distance from the channel and tree height, using taper equations for conifer and hardwood. Wood inputs were tracked over 10 piece size classes. This provided an average annual input rate for each reach that varied over time in response to changing riparian stand conditions.

To estimate the number of pieces accumulating in each reach, the annual input rate was integrated over time. This gives the number of pieces likely to have fallen into each reach from the starting year (2006). To account for decay and fluvial export, pieces were removed using a constant depletion rate (Beechie, Pess et al. 2000). This assumes that fluvial inputs equal fluvial outputs. An annual depletion rate of 3% was used for conifers and 4% for hardwoods, based on values reported by Hyatt and Naiman (2001) and Bilby et al. (1999).

To estimate the minimum diameter of pieces large enough to persist in a reach (i.e., resist fluvial transport out of the reach) and likely to form pools, we used an

equation reported by Beechie et al. (2000), based on data from Beechie and Sibley (1997):

$$D_{pf} = 0.025W \quad (1)$$

where D_{pf} is the pool-forming minimum piece diameter and W is channel width, both in meters. Channel widths were calculated for each reach from NetMap using equations reported in Clarke et al. (in press). Equation (1) provides a rough guide for the minimum diameter of wood to serve as a habitat-forming element. Not all pieces of this size (or greater) will be stable or form pools, these aspects of piece function depend on many site and event-specific factors, but we expect that pieces smaller than this will generally not serve as persistent habitat-forming elements.

6.2.2.1.2 Results

6.2.2.3.2.1 Wood Abundance

For any reach, the predicted wood abundance varies over time. Predicted values for all wood pieces > 15 cm (6 in) in channels between 2 and 20 m (6.6 – 65 ft) wide on ODF lands, using the unmanaged stand-growth scenario, are shown in Figure 24. This size range represents channels typically included in habitat surveys. Because we start with a wood loading of zero, piece numbers initially increase. The number lost each year increases as total wood load increases, until after about 25-30 years, around simulation year 2030 – 2040, the number depleted is of the same magnitude as the number recruited. Changes from this point on reflect changing riparian stand conditions. Simulated basin-wide wood abundance reaches a peak around 2050, corresponding to the peak in modeled mortality around 2036. Total wood abundance decreases over the remainder of the simulation. Throughout the simulation period, the proportion of accumulated pieces from hardwood species remains near 70%, decreasing very slightly over time. The median value obtained from channel surveys in the basin is 20 pieces per 100 m (Appendix P – Summary of Aquatic Habitat Conditions, Table 1). These surveys include wood from mass wasting, bank erosion, and legacy wood predating the current riparian stands, none of which were included in modeled wood abundances.

The predicted abundance of key wood pieces, those over 60cm (24 in) in diameter, follows a different pattern (Figure 25). Initially there are almost no riparian stands providing trees of this size, so modeled abundances are low and gradually increase over time as trees grow and larger trees become available for recruitment to the channel. A smaller proportion of these key pieces are derived from hardwood species, which don't grow as large as conifers, but this proportion

increases over the course of the simulation as many of the now 30 to 40-year-old hardwoods in the riparian stands reach the end of their lifespan.

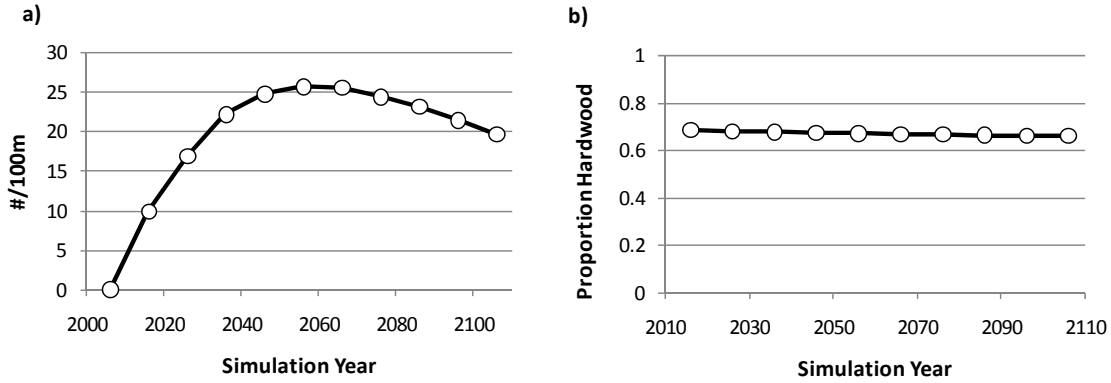

Figure 24. Temporal sequence of simulated wood abundance for all pieces >15 cm (6 in) in diameter by a) number per unit stream length and b) proportion of hardwood for all streams between 2m (6.6ft) and 20m (66ft) wide on state lands.

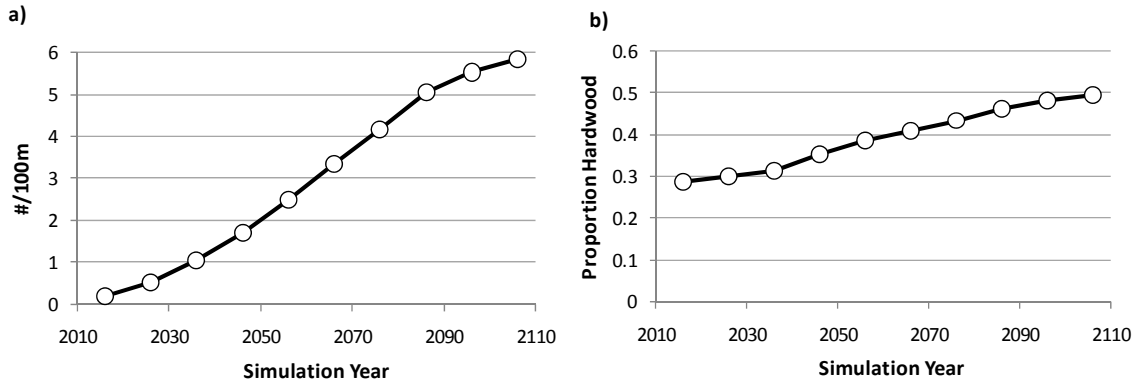

Figure 25. Temporal sequence of simulated wood abundance for key pieces, those > 60 cm (24 in) diameter by a) number per unit stream length and b) proportion of hardwood.

6.2.2.3.2.2 Functional wood

Map 30 shows how the minimum diameter for wood sufficiently large to resist fluvial transport and to significantly affect channel morphology (e.g., form pools), based on Equation 1 above, varies across the Wilson River channel network. Because larger channels require larger wood, the ability of riparian stands to provide functional wood varies in time and space across the channel network, as shown in Figure 26 and Maps 31-33. Because riparian stands in the Wilson River basin are of a relatively uniform age, with most post dating the

large fires and extensive salvage logging of the mid century, the ability of riparian stands to provide functional wood is primarily a function of channel size. For small channels, less than about 10 meters (~33 ft) in width, there is abundant supply of functional wood,. Once past the 25-30 year lag time to account for the zero-wood starting condition (see above), modeled abundances exceed levels considered high – 20 pieces per 100 meters – with declining peak abundance after year 2050. For larger channels, the abundance of functional wood is persistently low, but increasing over time (Figure 26).

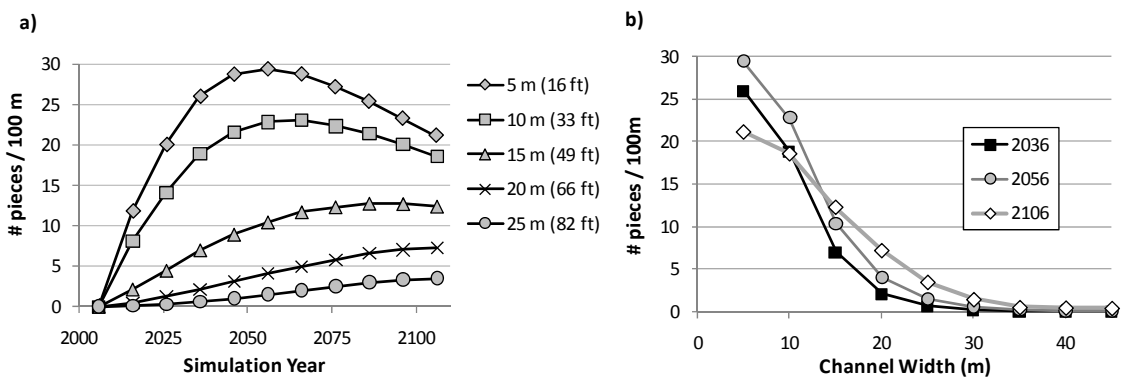

Figure 26. Simulated abundance of functional size (a) and dependence on channel size (b).

6.2.2.3.2.3 Debris Flows

Channel reaches susceptible to debris flow inputs of sediment and wood are identified in Map 34 (see also section 7.2 – Debris Flow-Prone Channels and section 7.3 – Deep-seated Landslides). Lack of riparian wood recruitment can increase the sensitivity of these reaches to debris-flow effects; reaches having both moderate to high debris-flow susceptibility and low anticipated riparian recruitment of functionally sized wood (<2 pieces /100m) are shown in Map 35. The fate of debris-flow deposited material and the consequences for in-channel habitat vary with the size of the debris-flow relative to the size and steepness of the receiving channel (Benda, Andras et al. 2004). Reaches most likely to be affected by debris-flow inputs include those classified in Chapter 7 (Sediment Sources) as morphologically significant and those having the potential of forming scouring debris-laden floods, shown here in Map 28. For both types, the negative impacts of debris flows are exacerbated by lack of large (i.e., functionally sized) wood. Reaches that are both particularly sensitive to debris flow inputs and that have low anticipated riparian recruitment of functionally sized wood are identified in Map 35. These are sites where upland sources of wood, identified with the landslide plus delivery susceptibility (refer to Maps 26 and 27 and

Chapter 7 – Sediment Sources), can have great influence on future channel conditions.

6.2.2.3.2.4 Upslope Wood Sources

Identification of upslope areas and headwater channels likely to provide the greatest benefit to fish involves overlay of results from three analyses: 1) identification and prioritization of reaches currently or potentially used by fish (section 9.14 Priority Streams), 2) evaluation of riparian wood sources (this section) for those reaches, and 3) identification of steep slopes and headwater channels that can provide wood and ranking of these source areas by the potential for delivery to those reaches (section 7.2.2 Results). Two factors aid in generalization of these results. First, the nearly uniform and relatively young age of riparian stands throughout the basin allows us to characterize riparian wood recruitment potential in terms of channel size; channels greater than 15m (~50 ft) in (estimated) width have widespread and persistent low abundances of functionally sized wood. Second, the widespread presence of fish, particularly steelhead, renders nearly all streams greater than 15m width of high importance for fish in this basin. Hence, delineation of slopes and headwater channels draining to these streams and overlay of estimated landslide and delivery potential within these areas serves to identify those upslope areas and headwater streams most likely to provide large wood that will benefit fish.

For example, Map 37 shows the fish-bearing portion of the channel network for channels less than and greater than 15m wide. (Note that these estimates of channel width are based on regional regressions to drainage area and mean annual precipitation. They serve as a reference of average stream size, verified by field visits within the basin (Appendix S – Field Validation of Some NetMap Parameters), but actual width varies dependent on reach-specific conditions. Our interest here is in average channel size). Overlain on these are reaches identified as high priority for fish because they have current high fish abundances or high habitat intrinsic potential (see section 9.14 Priority Streams). High-priority reaches falling within HU-code 6th-field basins designated as Salmon Anchor Habitat are also delineated. The potential for debris-flow delivery to all high-priority reaches was calculated using the methods described in Section 7 and Appendix T – Slope Stability Assessment. These were used with the calibrated landslide susceptibility model to determine the areas encompassing a given proportion of the expected landslide sites that might deliver sediment and wood to these high-priority reaches. The delineated areas are shown in Map 38. These results were also used to identify the headwater channels most likely to be traversed by debris flows that travel to the high-priority reaches. These headwater channels are shown in Map 39, in terms of the channels expected to contain specified proportions of debris flow events. The upslope areas that can

potentially provide debris flows to these high-priority reaches are extensive, as indicated by the broad expanse of (low) hazard area in Map 38. This low-hazard zone primarily involves source areas for long-runout debris flows, which have a low (but greater than zero) probability of reaching a high-priority stream. The areas most susceptible to triggering landslides and debris flows that travel to a high-priority reach are concentrated on channel-adjacent slopes. Likewise, because debris flows from upslope are routed into headwater channels, the lower portions of these channels have the highest potential to be traversed by a debris flow from upslope source areas.

Nearly all debris flows that reach fish-bearing streams must traverse these headwater channels. Headwater channels form long-term storage sites for instream large wood, accumulating wood and sediment over decades to centuries, until the next debris flow scours the accumulated material and carries it downstream (May and Gresswell 2003). Riparian management zones along these headwater channels and extending into landslide source areas can help maintain sources of large wood, including trees that fall or are carried by small landslides into headwater channels, stored until scoured by a debris flow, and standing trees that get incorporated into landslide and debris-flow material.

Management goals for these source areas should include buffers to maintain live trees, and may include thinning to maximize the size of these trees. The fish-bearing streams that may someday receive these trees in debris-flow deposits are currently lacking key, jam-forming pieces (> 24 in diameter); the larger the trees available for debris-flow recruitment, the more likely it is that the recruited wood will provide stable channel structures.

6.2.3 Future Vegetative Conditions

Detailed discussions pertaining to future vegetation conditions, assuming a “no management (harvest)” scenario, can be found in section 5.4 – DHSVM Future Modeling.

6.3 Riparian Enhancement Opportunities

6.3.1 Potential Management Following Forest Management Plan Standards

Given that the majority of the riparian zones exhibit high proportions of hardwood species, and that the successional changes predicted in the 100-year time frame do not indicate any substantial shifts in species composition through time, the riparian zones are likely to remain predominantly hardwood dominated for the foreseeable future. At the subwatershed scale, the current trajectories indicate a period of a tree mortality pulse, followed by a lag period where

mortality declines and mid-sized trees are not recruited to the canopy. This lag period trajectory appears to extend beyond the 100-year timeframe, assuming a no-management scenario. This has direct implications that limit the potential for large recruitment and stream shading.

As stated in previous sections, the structure and composition and apparent lag period in canopy recruitment is primarily due to the overall age of the stands. The stand-replacement fires, salvage logging, roads, and in-stream log drives have dramatically altered the riparian vegetation, and have effectively "reset" the successional age diversity of the system. Through a long timeframe (~250 – 300 years) with native disturbance patterns in place and limited land-use interaction, there may be a conversion to a multi-strata forest with old-growth conifer characteristics without considerations for active management. At present the area is within a potential ODF management zone, and priorities for active management can be shifted to evaluate whether active management can alter the composition and structure to favor multi-strata conifer co-dominance.

Though the current available data are not suitable for prescribing valid or practical site- and time-specific silvicultural treatments, it is possible to apply a qualitative approach to evaluate the Forest Management Plan (refer to Appendix J in the FMP) objectives to the riparian zones as a whole. The Forest Management Plan states for the Inner RMZ zone that the zone is to be managed for a "mature forest condition", following a range of other best management practices. This "mature forest condition" is further described as the following:

> "*Desired mature forest condition consists of a stand dominated by large conifer trees, or where hardwood-dominated conditions are expected the natural plant community, a mature hardwood/shrub community. For conifer stands, this equates to a basal area of 220 square feet or more per acre, inclusive of all conifers over 11 inches DBH. At a mature age (80-100 years or greater), this equals 40-45 conifer trees 32 inches in DBH per acre.*" (refer to Appendix J in the FMP).

Considering the prevalence of hardwoods, the apparent lack of conifer seed trees currently established in the riparian zones and neighboring uplands and the canopy dynamics favoring hardwoods through time (with slow-to-establish understory conifers), it is sensible to assume the foreseeable (100 year) projections will favor a hardwood-dominated system for the watershed as a whole. The Forest Management Plan describes specific management targets for conifer stands; these stand types represent the fewest acres (12%) of the riparian zones in the watershed. Although site-specific prescriptions based on the current data are not advised, it is possible to evaluate all stand types on the basis of their

potential for obtaining a mature forest condition, on the basis of large conifer densities.

The Forest Management Plan describes the mature age at 80 – 100 years, which is equivalent to stand ages at ~2036 – 2056 model years. The 100 year Forest Vegetation Simulator model run was examined for conifer densities and basal area for the 10 representative *expansion stands*, or the weighted stand averages for the 10 major FPS codes sampled that represent the stand metrics for unsampled stands of like codes. The purpose of this analysis is to evaluate the Forest Management Plan standard for meeting mature age metrics for conifers. Acres were not considered, as the stand resolution (slope, patch size, etc) is not fine enough to follow other best management practices defined in the Forest Management Plan (SDI retention at the patch level, slope criteria, etc.). However, this analysis provides the "best case scenario" to evaluate if stand types will achieve the mature conditions (expressed as conifer density) through time. All stand types were considered in this analysis.

Figure 27 and Figure 28 below display scatterplots of the basal area and stem density of conifer trees >32 inches DBH for the 100 year timeframe. With the assumption that 'mature conditions' are reached at 80-100 years, data points after year ~2060 could be considered eligible for mature stand ages. Of particular note in the figures below is the divergence in both BA and TPA for these large conifers beginning in Year 2066, with a relatively flat level of growth for approximately one half of the stand types. These stand types are the mixed hardwood and pure hardwood stands that dominate the land area (1H and some HX types); other representative mixed types (DX and other HX) show moderate increases in large conifer basal area and density, ranging between 150 and 200 ft^2 per acre by the end of the model run. Lastly, the mostly pure conifer types (the least represented on the landscape) show increases in basal area between 158 and 230 ft^2 in 20-24 trees per acre in the second half of the model run.

Although there are observed increases in numbers and basal area of conifers for most vegetation types through time, the nominal values are far below the Forest Management Plan standard defining maturity (e.g.,40-45 trees per acre of conifers >32 inches DBH to meet the basal area targets), excepting near attainment in Jordan Creek. The fundamental limitations and retention numbers described for mature stages in the Forest Management Plan do not appear to be met for the major vegetation types, which indicates that management would likely not be allowable in the majority of the land area. Treatment options that promote even-aged patches of conifers (particularly on terraces and other near-stream environments) are potentials for increasing the density of large conifers, and meeting the Forest Management Plan objectives over time (see section 6.3.2 Pathways for Management Action, below).

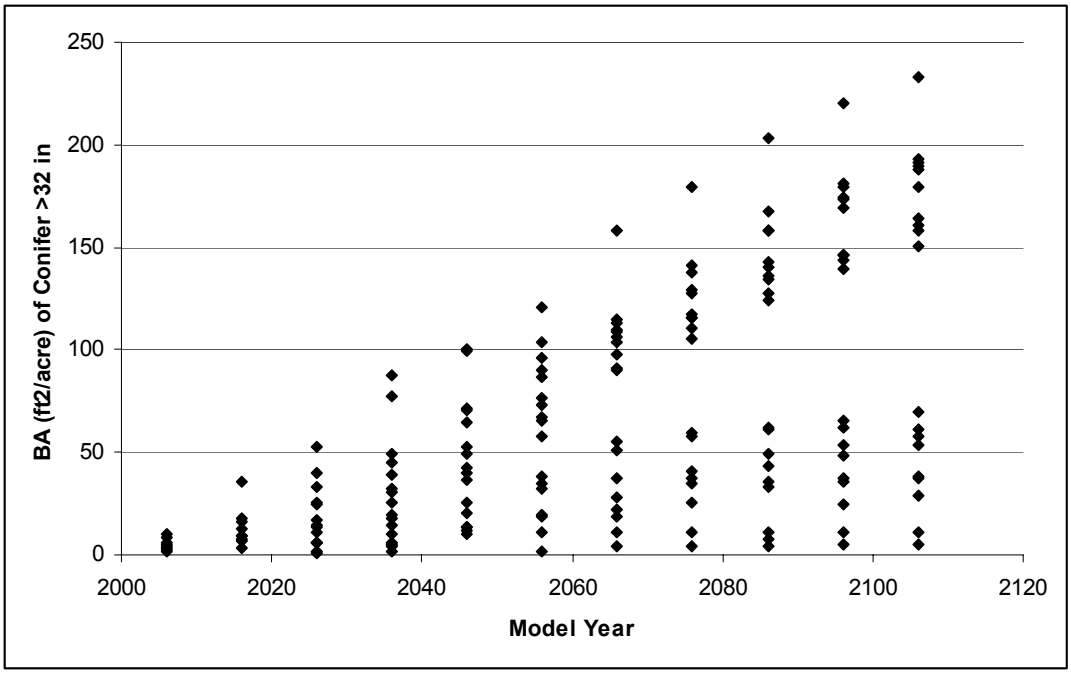

Figure 27. Basal Area of Conifers > 32 inches DBH -- All Measured Vegetation Types. The projected basal area (ft^2/ac) of available conifers for sampled stands within the 10 expanded vegetation types within the Wilson River watershed.

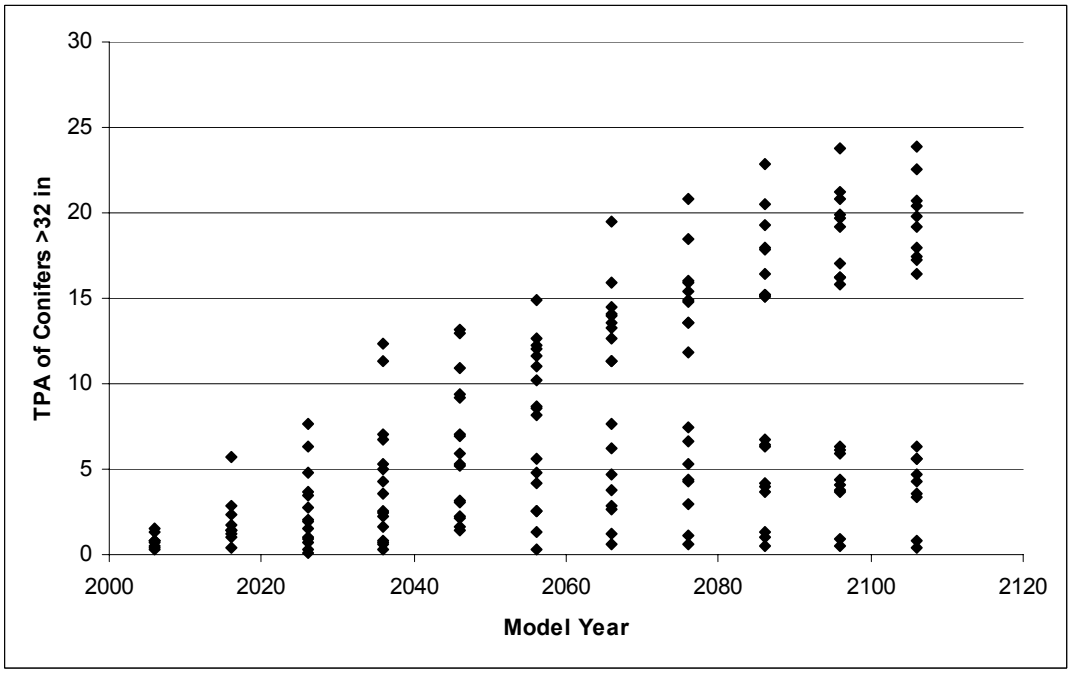

Figure 28. Trees Per Acre of Conifers > 32 inches DBH -- All Measured Vegetation Types. The projected TPA of available conifers for sampled stands within the 10 expanded vegetation types within the Wilson River watershed.

6.3.2 Pathways for Management Action

6.3.2.1 Current Data Sources and Limitations

This watershed analysis produced several key findings involving the riparian zone and the *ecosystem service* dynamics expected through time. The majority of these findings were based upon a map and subsequent ground-truth sampling based on aerial photography, coarse vegetation types, and relatively large stands. Stand sizes averaged 4.1 acres in size (range: ~1 – 93 acres) to a 100 foot buffer from the stream channel, and were designed to average ~1,500 feet in length (actual average: 1,786 feet). A total of 10 major vegetation types were sampled, and data were expanded to like FPS vegetation codes.

It is important to note that the current riparian vegetation map served as a very refined effort to ascertain the watershed and subwatershed level trends in species composition, structure, large wood recruitment, stream shading, and other intrinsic characteristics of the system. At the stage where Watershed Analysis enters the need for an Active Management Plan, however, the data do not provide enough resolution to assign site-specific silvicultural treatments, nor are they sufficient to evaluate the potential effects of those treatments on large wood, shade, and other ecosystem services to the stream system. That said, 1) the data were sufficient for developing "*general*" silvicultural prescriptions based upon the current and projected stand conditions (presented below) and 2) the acquisition and use of high resolution LiDAR data (Light Detection and Ranging; also called ALSM, Airborne Laser Swath Mapping) may help resource managers develop "site-specific" silvicultural treatments (and ODF is in process of obtaining LiDAR data for some districts).

LiDAR data have enormous utility in improving our understanding of elevation changes, including stream initiation, stream channel widths, site topography, landslides, etc. For riparian zones, LiDAR provides unique opportunities to characterize, type, and target specific locations for riparian enhancement.

The Forest Management Plan (Appendix J in the FMP) management standards, considerations for adverse effects on the stream system, and practical forestry all dictate that the potential management of riparian zones involves "patch management". Specifically, patch management is defined here as locating areas where specific silvicultural targets and operations can be applied on the ground, excluding areas that are outside of operational practicality, regulatory constraints, or may cause unnecessary damage to the stream system.

For purposes of illustration, a small portion of processed LiDAR data was obtained from the Nehalem River watershed (~1,000 acre segment), containing a reach of the mainstem Quartz Creek (~1.76 mi), a tributary to the Nehalem River (Hawksworth & Nile, pers. comm.). The data include a "bare earth" (BE) view and an "above ground" (AG) view, both at a 3-foot resolution (Watershed Sciences, 2007). Specific to the utility of mapping riparian zones, both of these sources in combination with the color aerial imagery (2006) are elegant tools to identify riparian features and highlight "manageable units" to evaluate potential management options.

6.3.2.2 Pathways for Riparian Management and Mapping

6.3.2.1.1 Recommended (General) Silvicultural Treatments

The inherent high variability of riparian stands hinders the collection of high quality stand inventory information from which silvicultural prescriptions are traditionally based. Remotely sensed information (e.g., aerial photograph interpretation) may provide coarse estimates of riparian stand conditions, but the inherent variability of riparian areas prevents fine-scaled interpretation of stand conditions. Despite this, the combined field-collected and photo-interpreted stand data provide a basis for identifying candidate stands for silvicultural treatments that produce large wood. The best resource for assessing any given stand for both large-wood potential and the best silvicultural approach is the field forester. We have identified areas that appear to have a high potential (at the coarse scale) for developing large wood (Maps 63-67; see below). These areas can be considered a "list" of potential sites that require evaluation by a professional forester.

We also assumed that the overall objective of treatments is the production of large-diameter trees (primarily conifers) that will eventually be recruited into streams as large wood. We considered a number of criteria (see below) that may make a given stand a good choice for silvicultural treatments that encourage in-stream large wood recruitment. Some of these criteria may appear at odds with each other, and again, the judgment of a field forester is necessary to determine if and how treatment should occur.

Table 22 shows the stand and geomorphic disturbance criteria used to arrive at 3 levels of candidacy for visitation and evaluation by a field forester for subsequent treatment. Maps were derived from overlay analyses using GIS layers representing relative landslide risk (Maps 25-29, 34-36, and 38-39; see Appendix T – Slope Stability Assessment), channel disturbance risk (Map 11 and section 3.4.4 – Simulation Models and NetMap Analyses), and classified riparian stands (Map 23-24 and sections 6.1 – Riparian Composition and Structure and 6.2 –

Potential Future Conditions). The resulting maps (63-67; see below) show the locations of stands identified by the criteria in Table 22.

Table 22. Matrix of treatment candidacy for various stand and disturbance conditions.

Disturbance Frequency	Stand Conditions		
	Conifer-dominated with no large diameter trees	Conifer-dominated with large diameter trees (>20 in DBH)	Mixed hardwood-conifer
Low landslide or flood disturbance frequency	High	Moderate	Low/Moderate
High landslide or flood disturbance frequency	Moderate	Low	None

6.3.2.2.1.1 Disturbance

Given our treatment objective, we focused our identification of candidate stands on those areas where short return-interval disturbance (e.g., landsliding and flooding[49]) is at a minimum and existing vegetation conditions are likely to respond. Treating stands in areas prone to frequent disturbance may not result in large diameter trees if a disturbance(s) returns before large tree growth is realized. This precluded many of the lower-elevation, wide stream channel areas with hardwood dominated, flood deposited terraces since most of these sites are intrinsically persistent hardwood-dominated stands and not suitable for encouraging large diameter conifers. Similarly, steep, higher-elevation sites that have high landsliding risks (refer to Chapter 7 – Sediment Sources, sections 7.1, 7.2, and 7.3) may also be poor candidates for treatment. It is worth noting, however, that landslides and debris flows are important processes for the movement of large wood into streams. Thus, some treatment in these stands may facilitate the recruitment of large wood into streams in an accelerated manner. Treating such stands, however, will require an evaluation of costs versus benefits of treatment given the possibility of a premature disturbance at the site. Treatment of such stands may also be opportunistic and incorporated while

[49] Because the fire return interval in the Wilson (and surrounding areas) is relatively long (e.g., 300-700 years), we did not incorporate fire disturbance.

harvesting in adjacent areas. Nevertheless, we feel it reasonable to dedicate some portion of wood recruitment treatment efforts in these stands.

6.3.2.2.1.2 Stand Vegetation Conditions

Of the 2,364 identified riparian stands in the Wilson River watershed, 947 (40%) were identified as conifer dominated and densely stocked with smaller diameter trees. Release by thinning is a very effective treatment that may be applied in such stands to encourage rapid growth among the remaining trees. To maximize retention of large-diameter trees in these stands, we recommend thinning from below (e.g., thin the smallest diameter classes first). Specifically, we recommend that conifer-dominated stands containing large-diameter "legacy" trees occurring on high landslide-risk sites be passively managed since these large trees may already be of target size for in-stream large wood recruitment (Map 63). Likewise, conifer-dominated stands containing large-diameter trees occurring on low landslide-risk sites may be moderate candidates for active management because the densely-stocked younger cohort may respond to density control treatment (Map 63). Additionally, conifer-dominated stands *without* large-diameter trees on both high and low landslide-risk sites present good candidates for active treatment to encourage growth of large-diameter trees that will be delivered to streams via landslide-debris flows or direct treefall (Map 63).

6.3.2.2.1.3 Hardwood Conversion

It may be desirable to integrate hardwood conversion and large wood recruitment management objectives. Since riparian hardwood stands in the Coast Range are often perpetuated by relatively frequent disturbance (e.g., flooding), we considered hardwood stands identified in this assessment to be *intrinsically* hardwood stands that would not respond well to treatments designed to encourage conifer dominance. This does not mean that all pure hardwood stands are intrinsically hardwood but we have insufficient information to distinguish between stands with varying histories. Therefore, we identified mixed stands (e.g., hardwood and conifer) occurring on sites with low landslide/flood disturbance risk as potentially suitable sites for conifer-dominated stands. Map 63 shows stands that may be candidates for hardwood conversion treatments that also encourage large in-stream wood.

6.3.2.1.2 Riparian Mapping using LiDAR

Examples from Quartz Creek LiDAR were examined in the GIS to compare and contrast methodologies to improve a riparian base map and examine available data components to address potential management options. While this example is limited and does not provide specific examples for the Wilson River

watershed, the available data components presented here will become available for many ODF lands in 2008.

The principle components to a riparian management map follow those presented that currently exist for the Wilson River. These components include the stream layer, riparian buffer widths, delineation criteria, and a ground-truth sampling plan. With the LiDAR data, there are several additional factors that can be considered that will influence the sensitivity and utility of the riparian vegetation map. These factors include topography, canopy characteristics, and other features that can be modeled and mapped in the GIS.

6.3.2.2.2.1 Stream Layer and Buffer Zone Comparisons

A quality stream coverage layer can be developed with added precision, using a combination of GIS tools and ground truth analysis to delineate and map current channels. In addition, it may be possible to identify points where streams initiate, or where a defined channel begins, to further understand the extent of the stream network. An accurate and comprehensive stream layer provides the foundation for a functional map for a variety of purposes, including riparian vegetation management.

Using the example from the Nehalem River watershed, a section of Quartz Creek, a low-gradient system with a wide floodplain, was examined with LiDAR. A simple stream line coverage was delineated following the LiDAR 3 foot DEM image. This example coverage was compared with the existing ODF stream coverage (sourced from 1:24,000 USGS quads from the State of Oregon Geospatial website).

A total of 1.74 mi of stream was captured from the ODF stream layer for the example area. The LiDAR stream coverage included three additional, unmapped streams for a total of 3.46 mi. Excluding the previously unmapped streams, the short section of the mainstem Quartz Creek showed 1.81 mi from LiDAR, contrasting with the 1.63 mi using the prior ODF coverage, demonstrating 11% more *sinuosity* that was captured by LiDAR over the existing stream coverage.

In addition to total stream length and sinuosity, the *accuracy* of the stream placement on the landscape has direct implications for riparian management (refer to Photographic Plate 25). Using the 100 foot buffer zone recommendations for both the stream bank and inner riparian zones, the stream segments of the mainstem Quartz Creek were compared in terms of riparian buffer areas. While both the buffer areas created from LiDAR and from the ODF coverage were similar in area (43.4 and 40.3 acres, respectively), the *placement* of the ODF riparian zone on the landscape had only 35.7 acres in common with that generated by the LiDAR, or ~82% spatial accuracy. For the Wilson River

watershed, where 9,704 acres of riparian zones were identified on ODF lands using the ODF coverage, this could potentially result in an increase of ~2,100 acres of land area that could be considered under riparian management. In addition, it is possible to capture previously unmapped streams (and their associated riparian buffer zones), and/ or to invalidate current streams mapped on the ODF layer. Naturally, the simple increased detection of streams may not serve to better manage aquatic resources (i.e. streams are intermittent or simple gullies), but the detection limits of LiDAR provides managers with a decision to determine a new level of mapping standard.

6.3.2.2.2.2 Buffer Zone Utility and Modifications

The obvious implication with finer-scale mapping of stream areas is the increased areas in buffer zones, assuming a uniform buffer area (e.g. 100 feet). The Quartz Creek example found three additional tributaries to the mainstem, effectively doubling the stream area (and riparian buffer area) from the current ODF coverage. While this can be a potentially very significant change in management area and objectives, the important and underlying management question remains as to the *utility* of the buffer area for enhancing and promoting the *ecosystem services* to the stream system (large wood, shade, sediment buffering, etc.).

One pathway to refining the standardized buffer areas involves referencing the slope and elevation relative to the stream channel, and prioritizing these areas into different sub-management units. For example, in the mainstem Quartz Creek system, the riparian buffer area can be easily divided along terraces, steeper slopes, and floodplain. Each of these components provide different functions to the stream channel, and can have different management objectives, with possibilities for different treatment opportunities to enhance, restore, or otherwise utilize the available resources.

An unmapped tributary having a higher gradient and representative of the upper reaches of the Wilson watershed was identified using LiDAR, and its 100 foot buffer zone was examined. Polygons were delineated on the basis of slope only, capturing areas of homogenous slope, or delineating on abrupt changes in slope. For the small section of unnamed tributary (<0.5 mi), approximately 8.1 acres were within the 100 foot buffer zone of the stream channel. Of these acres, 2.6 acres (32%) were located in areas that would be considered to be outside of or have limited influence on the riparian shade and instream large wood inputs[50]. Hence, a management pathway to first identify and buffer, then later evaluate, or

[50] Large wood inputs in this case does not refer to stochastic events (debris torrents, landslides, etc.), rather the simple project of an immediate interaction from falling trees into the stream channel through natural mortality processes.

prioritize the utility of those buffer areas to the desired *ecosystem services* is recommended.

Other environmental attributes can be considered in addition to slope (lateral gradient) for a buffer prioritization process, including channel width, perennial/ intermittent channels, longitudinal stream gradient, soils, etc. These, in addition to slope, are pathways by which a 'first cut' can be made at large scales (GIS and ground truth) to refine the buffer system for a given watershed and set of watershed priorities (refer to Photographic Plate 26 and Photographic Plate 27).

6.3.2.2.2.3 Vegetation Typing

Following the development of an accurate stream map and utility prioritizations within buffer zones, the vegetation component can be classified on the landscape. The primary objective to vegetation typing is to develop a standardized, simplified, and representative system that serves an ultimate goal to minimize field sampling efforts for expansion. To be effective, this system should be adaptable for changing management needs and should be relatively inexpensive to modify and improve through time.

The current system (Wilson River) has used FPS codes, which are 4-digit classifications to designate forest type (conifer, mixed, hardwood), size class, and density values. A system such as this serves well, if (1) there are enough categories to describe subtle, but significant difference, and (2) the polygons are delineated to a scale that fits the classification well. In the case of the Wilson River, the system of FPS codes did not provide the resolution necessary for vegetation types, nor did the polygon delineation requirements provide enough resolution to sample and manage with high confidence at the stand-level. The classification served well at larger scales (subwatershed) and identified key needs, patterns and trends on the landscape.

In addition to the bare earth view of the LiDAR, there is a coverage that includes the 'above ground' elevation value, or the highest value at the 3 foot scale of resolution. This above ground coverage can be compared with the bare earth coverage to obtain canopy height and a classification for a categorical stand structure designation. To illustrate this coverage as a potential pathway for riparian mapping and management, canopy height was calculated for the Quartz Creek example. The level of resolution, in this case, can present its own problems, as the "characteristically patchy" nature of riparian zones is evidenced by the wide array of tree heights. However, simplifying the output to highlight different heights of the overstory strata (e.g., 50 foot increments) provides refinement in describing the stand structure.

For purposes of illustration, the Quartz Creek and tributary example area were delineated on the basis of canopy output only, based upon maximum size classes and like differences in patch size. Patches were identified as having tree heights of 0-25 feet (gap), 25 – 50 feet, and at 50 foot increments to the maximum observed height (<250 feet). Polygons were delineated on the homogeneity of size class and the evenness of spread of different size classes (i.e. gaps interspersed with larger trees, etc.).

Following this illustrative method, delineations occurred at a very fine scale, averaging 0.7 acres for the 26 polygons (average 0.7 acres, range 0.25 – 1.6 acres) in the 17.4 acre riparian buffer area. While this is clearly delineated at a scale far below common upland forest practices, these stands resemble and appear (with the use of aerial imagery) to represent the patch mosaic of the riparian zones, and may be of the appropriate size to attempt management activities to promote conifer growth for the long term (refer to Photographic Plate 28). Considerations for minimum size, stratification of size classes, and incorporating elements of automation in the GIS process may provide a cost-effective pathway for achieving a 'first cut' of stand structure at landscape scales using available LiDAR tools.

Stand composition can likewise be reviewed at large scales. The availability of Infrared imagery is a useful tool in determining differences between conifer and hardwood canopies; these, in combination with use of crown modeling from the above ground LiDAR (Nile, pers. comm.) can provide algorithms to estimate basic stand compositional differences between hardwoods and conifers. Specifically, crown areas can be modeled to predict mean diameter ranges of the canopy, thus giving a range of density classes expressed as trees per acre.

Ultimately, the delineation criteria for vegetation typing should include elements of stand structure, composition, and stand density. Combinations of canopy height patch analysis (structure), assessing species using infra-red (IR) or photo interpretation (composition), and crown characteristics (density) are useful elements of an accurate and fine-scale vegetation typing design that can be attributed at the landscape scale for use at local scales.

6.3.2.2.2.4 Uses in Management

The use of fine-scale mapping is an important and necessary component to developing site-level or "type-level" prescriptions in meeting management objectives. The current vegetation types for the Wilson River watershed are at a scale that contain a range of physical and compositional conditions (slope, aspect, stream type, species composition, etc.), and their size and delineations are at a scale that contain many "manageable units" as well as "non-manageable units." Hence, within each different type – especially the mixed types HX and

DX – a range of treatments can be considered for riparian enhancement (see section 6.3.2.1.1 – Recommended (General) Silvicultural Treatments, above). Generally speaking, however, these treatment ranges are discussed below, and (at the scale of the current vegetation typing), treatment objectives can be applied according to on-the-ground professional judgment. Additionally, another approach would be to use a LiDAR classification scheme (as described above) to better target the range of manageable units within the larger vegetation types.

Following a classification scheme that incorporates buffer utility and vegetation components, it is possible to gear ground-truth sampling toward the major types that would be considered "manageable units" within the buffer zone. This is of critical importance, as sampling will focus on the major vegetation types in areas where management will be possible, and prescriptions can be evaluated at the same time to meet management objectives. Management objectives specific to the Wilson River involve:

1. **Promote conifer recruitment to overstory, ≥14 inches DBH (40-80 years).** Using small, manageable patches, treatments can be applied to promote even-aged mosaics of conifers in areas that have high potentials for interaction with the stream channel, and where operations will have the lowest impact to stream function. Depending on the topography and methods used, the 25 foot designation for "no harvest" within the streambank zone may or may not be appropriate. Serious evaluation of the prescribed buffer zones (refer to Appendix J in the FMP) is recommended following the implementation and use of LiDAR mapping.

2. **Limit "lag period" in large wood recruitment (30-50 years).** The competition pressures associated with the apparently ubiquitous stem exclusion phase will create a short-term pulse in large wood (particularly hardwoods), but a lag in mortality is projected in conifers (30 years) and hardwoods (~50 years). This lag is expected to last beyond the 100 year time series. Management priorities include promoting a conifer overstory *and* time treatments to add wood through selective thinning during lag periods.

3. **Monitor reach-level responses to instream large wood and stream shading (5-10 year increments).** Treated areas will likely be smaller in size (~0.7 acres), and treatments should be applied at reach-level scales. Effectiveness monitoring (and validation of modeling) should be conducted to evaluate treatment effects at scales large enough to measure signals (reach-level or larger).

4. **Refine the desired future condition in the Forest Management Plan.** A review of the Forest Management Plan (refer to Appendix J in the

FMP) is strongly recommended to define goals that are more specific to the ecosystem services of the riparian zone (instream large wood, shade targets, sediment buffers, etc.). The current plan provides retention targets for conifer trees—these do not directly address large wood recruitment or stream shade.

6.4 Wetlands, Ponds and Lakes – Condition and Location

This section is intended to update the original 2001 assessment of the Wilson River watershed (E&S Environmental Chemistry), with emphasis on ODF lands.

Wetland, pond, and lake locations were gathered from the SLI upland vegetation layer (ODF), the National Wetland Inventory (NWI)[51] and a survey of the aerial photographs and USGS quads (this study). All wetland or potential wetland types were assigned a wetland classification type (Cowardin et al. 1979) and assigned a calculated acreage value from a GIS (Map 40).

Digital NWI data locations were available for the lower reaches of the Wilson River watershed only (Lower Wilson River subwatershed); the majority of this coverage was located on non-ODF lands (~564 acres, Table 23). A summary review of the ODF SLI vegetation mapping dataset[52] coupled with aerial photo review using USGS maps and ground truth analysis yielded few acres but several potential wetland sites.

The major wetland types on ODF lands included freshwater forested and emergent wetland types. These were primarily seeps or draws, and areas influenced by beaver activity (Photographic Plate 8). Wetland areas created by beaver are especially important for enhancing fisheries habitats, as they are connected with the stream system, slow water flow, create highly interactive areas with the floodplain, and provide visual isolation for fish species (to provide more habitat per length of stream).

The overall condition of the wetlands and ponds within ODF lands is generally good; road influence may cause increased siltation in some areas, though there appears to be relatively intact riparian buffers available to slow sediment delivery. In areas where management has occurred near wetland areas, standing tree buffer areas appear to be present on ODF lands.

[51] http://wetlandsfws.er.usgs.gov/NWI/download.html
[52] Upland FPS code classifications, "Vegpoly.shp". Duck Creek Associates, 2006.

Table 23. Wetlands, Lakes and Ponds. Wetland composite from National Wetland Inventory (NWI), vegetation mapping (ODF), aerial interpretation/ review and ground-truth analysis (this study).

Subwatershed	Wetland Type (NWI Code)	ODF Acres	Non-ODF Acres
NF Wilson River	Freshwater Emergent Wetland	0.6	
NF Wilson River	Freshwater Forested/Shrub Wetland	0.3	
NF Wilson River	Freshwater Pond	1.2	3.2
SF Wilson River	Freshwater Forested/Shrub Wetland	3.4	
SF Wilson River	Freshwater Pond	1.9	
Little NF Wilson River	Riverine		4.2
Jordan Creek	Freshwater Emergent Wetland		0.6
Jordan Creek	Freshwater Forested/Shrub Wetland	1.5	
Lower Wilson River	Freshwater Emergent Wetland		185.2
Lower Wilson River	Freshwater Forested/Shrub Wetland	0.9	192.5
Lower Wilson River	Freshwater Pond		2.2
Lower Wilson River	Lake		<1.0
Lower Wilson River	Riverine	1.2	183.8
Devils Lake Fork	Freshwater Emergent Wetland	20.4	3.0
Devils Lake Fork	Freshwater Forested/Shrub Wetland	56.6	
Devils Lake Fork	Freshwater Pond	0.8	
	Totals	**88.8**	**574.8**

Data describing the recreational impacts of OHV use to wetlands have not been directly quantified, though it represents an important consideration with the development of Best Management Practices (BMPs) for recreational uses on the forest. Examples of buffer area enhancement could be the placement of large logs or other obstructions in the near-wetland zone, and relocation of campsites within 100 feet of a wetland area. This would serve to minimize impacts associated OHV use in the near-wetland and riparian environment, and would decrease sedimentation from up-gradient sources near existing trails or roads.

In addition, as part of the BMPs, it is important to evaluate areas of potential emergent wetland environments and provide mechanisms of buffer enhancement to increase the success of wetland establishment. This is especially true for lower gradient systems where beaver activity is observed. Accommodation of natural disturbance processes, such as beaver activity, provides the mechanisms necessary to create patch diversity of wetland communities. Minimizing recreational and other land-use impacts in these areas would increase the potential for wetland diversity in the watershed.

6.5 Noxious and Non-native Weed Species

The Wilson River, because of its proximity to other areas of known infestations, is a prime location for establishment of noxious weeds. Though the Wilson

River watershed may have been slow to establish weed species compared with nearby drainages, the presence of Scotch broom (*Cytisus scoparius*), garlic mustard (*Alliaria petiolata*) and Japanese knotweed (*Polygonium cuspidatum*), are of growing concern to the watershed. Invasion vectors for these species include recreation, equipment use, roads, and imported material from infested areas (e.g., road fill). Flood events, and post-flood restoration efforts provide particular vectors for disbursement and establishment.

The 2005 and 2006 Tillamook Rapid Biological Assessments[53] (Bio-Surveys, LLC) indicated the presence of knotweed in 30 locations in the Wilson River, 8 locations in the Little North Fork Wilson and its tributaries and 5 locations in Devils Lake Fork (Map 41). Knotweed infestations in the Wilson River were in small, scattered and isolated patches (i.e., new establishments), with several large and continuous (600 x 40 ft) patches throughout. The majority of these populations were encountered at the mouth to the confluence of the Little North Fork, outside of the majority portions of ODF land. Other populations are somewhat smaller and extend up the Wilson River to the Jones Creek Bridge. In the Little North Fork Wilson, a continuous patch begins at the confluence with the Wilson River and extends ~8,800 feet to an unnamed tributary stream that is mostly on private lands, though has some overlap with a strip under ODF management. The proximity of these patches to ODF lands suggests that collaborative restoration efforts between ODF and private landowners would help to minimize potential risk to ODF lands.

Devils Lake Fork had 5 encounters (all on ODF lands) of knotweed that were all relatively small in size, but are high-risk colonies because of the mid-channel position and the up-gradient location in the watershed (potential source for downstream spread). The knotweed distribution effectively stops at the Idiot Creek Bridge (RM ~2.5 of Devils Lake Fork), suggesting the road fill for the bridge may be the likely source. These sightings were new sightings in 2006; the 2005 survey did not detect these colonies. A *high priority* for enhancement in this area is to curtail the knotweed spread to minimize spread downstream. Surveys and evaluations of potential source quarries or materials outlets for knotweed prior to organizing restoration work (e.g. road fills) would help to minimize importation into the watershed. Other invasive species observed were Himalayan blackberry (*Rubus armeniacus*)[54] throughout ODF riparian zones. Garlic mustard is a relatively new invasive weed concern in the watershed and has been found in the Gales Creek sub-basin on public and private land. Known

[53] GIS data available for the 2005 assessment only.
[54] Originally from Armenia, *Rubus armeniacus* has long been incorrectly described as *R. procerus* or *R. discolor* in North America.

vectors include OHVs, pets, livestock, wildlife and humans (foot traffic) as well as floods.

6.6 Key Findings and Recommendations

- Develop a riparian management action plan focuses on 1) improved canopy recruitment, 2) areas that have high potentials for interaction with the stream channel, 3) selecting variable-sized treatment patches to better typify natural variability, 4) pairing treatments with similarly functioning reference reaches, and 5) monitoring and evaluation of treatment trajectories with reference trajectories.

- Given the variability in the stand-level vegetation data and the predicted large wood (LW) recruitment, shade, and other ecosystem trends, developing additional focused field and mapping efforts should help to refine subwatershed-scale estimates to the stand-level.

- Riparian areas that could be considered likely candidates for treatment (harvest) occur throughout the Wilson River watershed. The highest candidacy stands for treatment (e.g., mixed species stands and densely stocked conifer stands without large legacy trees and occurring on low-moderate landslide risk sites) are concentrated in the Devils Lake Fork and South Fork Wilson River subwatersheds.

- Refinement of the riparian base map, using LiDAR tools, will identify "management patches" on terrain that is the most interactive with the stream channel (shade and LW recruitment), while minimizing the effects of potential harvest management. One example includes terraces and areas of appropriate size (~0.7 acres) to allow for patch harvests and replanting of conifer species. Using this fine scale map, the patch dynamics and successional trends at the reach- and subwatershed scales can be evaluated to allow managers means to better predict how stand treatments could enhance or detract from LW recruitment, shade, peak flows, weeds, etc.

- Include current road issues when selecting potential riparian management sites.

- In areas where the road infrastructure permits, allow beaver to persist as their activities will likely result in increased wetland areas, improved water storage capacity and improved fisheries habitats.

- Restrict recreational uses (primarily OHV use) in the near-wetland environment (within ~100 feet) to limit potential negative effect on wetlands.
- Several invasive noxious weed locations were identified in the Wilson River watershed. ODF should, when developing future Best Management Practices (BMPs), probably include management of OHV use in riparian zones and the incorporation of wash stations at trailheads.
- Careful consideration should be given to the type of seeds utilized for bank stability control reseeding projects.
- Collaborate with other agencies and landowners for weed eradication.
- Initiate noxious weed outreach programs targeting recreation groups.

6.7 Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects

Recreation trends, activity use levels and intensities in Tillamook State Forest indicate a greater risk to watershed health from recreation than would normally be expected. Contributing environmental factors are climate, topography, soil type and vegetation sensitivity. Contributing human factors are use intensity, lack of defined site boundaries, lack of regulation and maintenance.

OHV management takes up a considerable amount of recreation and other staff time in dealing with permitting, supervising and post event restoration. In the last five years 102 OHV events were held (133 event days, with 7,128 participants). That is an event average of 20 per year.

Forest wide issues related to the site conditions, staff capacities and recreation demand have been documented in a recent report by David Reed and Associates and provide staff with a comprehensive status report and set of recommendations.[55] This assessment and analysis focused solely on the Wilson River watershed primarily utilizing results from field data.

Recreational activities that disturb, destroy or remove vegetation are a concern to watershed health. To determine the extent and intensity of impacts requires a framework of standards and thresholds by which impacts can be monitored. These do not yet exist for the Wilson River watershed but recommendations have

[55] Reed, David. 2007. David Reed & Associates. Recreation management Assessment for the Oregon Department of Forestry NW Oregon State Forests. Draft Final Report. April 16.

been included below. Current recreational impacts to riparian vegetation can be characterized by the following descriptions:

Camping: Both designated and dispersed camping activity is widespread across the watershed but impacts are more acute along streams and river edges because that is where people prefer to camp and where facilities have been developed or allowed to continue. Designated campgrounds attract users that prefer the convenience of defined parking, toilets, trash collection, firewood supplies and a management presence. There is still considerable riparian vegetation impact through vandalism, firewood cutting, trampling, trash dumping (fire pit waste) and human waste.

Use levels at the established campgrounds continue to climb. According to ODF staff, campgrounds are at or over capacity during most weekends of the event season. Warm weather and holidays exacerbate the pressures sending overflow campers into the forest to find alternate sites. In addition, overflow comes from other parts of the region due to the high cost of alternatives along the coast and the scarcity of campgrounds on other public land.

Dispersed campsites absorb overflow and attract those seeking more rustic, secluded camping sites that have no fees. However, such sites exhibit the most impacts because use is unrestrained and unregulated. Spot checking of dispersed campsites in the watershed during the 2007 Memorial Day weekend provided evidence that people were camped or occupying most of the sites along the main stem of the Wilson and tributaries. A significant number of people were well established and stated intentions to camp for 4-10 days. Severe impacts are common where OHV use is focused on social trails in and around campsite areas, especially those in riparian zones, and several photographic examples have been provided in Photographic Plate 9.

The challenge for this assessment is to put these impacts into a framework that is used to measure impact and human disturbance. In the case of campsite-related impacts, the literature offers methodology developed for wilderness settings that typically exhibit much smaller scale environmental damage (Cole, 1989).[56] The type of use that is most prevalent in the Wilson River watershed is car camping, OHV use or a combination of the two. While this is not a wilderness setting, the methodologies are sufficient to determine the intensity and extent of campsite impacts in the watershed.

[56] Wilderness Campsite Monitoring Methods: A Sourcebook, Cole, David N., GTR-INT-259, April 1989.

6.7.1 Methods

Recreational impacts on riparian vegetation were assessed using two different methods, the first based on ODF's dispersed campsite inventory data (existing); the second based on a field sample of ODF dispersed campsites from the existing inventory data (new). To evaluate the direct and indirect effects to the riparian vegetation, the first method utilized data from ODF's dispersed camping inventory database. The second assessment required field-measurement of vegetation loss, tree damage and soil exposure in a sub sample of 10% of the ODF dispersed camping site inventory (shown on Map 31) Both assessments are presented below.

Small disturbances associated with near-stream campsites create disruptions in the continuity of stream shade, increased mortality to the overstory, and inhibition of vegetation regeneration and recruitment. At larger scales and at increasing sizes of campsites and camp use, the patch-level disturbances increase sediment flow to the stream channel, offer increasing potentials for firewood cutting, and minimize the potentials for other *ecosystem services*, including LW recruitment, stream shading and sediment retention. At small scales with managed uses (i.e., minimize OHV use in the riparian zone), dispersed campsites offer a balance of human appreciation and use while retaining quality riparian functions.

6.7.1.1 Dispersed Campsite Inventory Data

For the dispersed campsite impacts, ODF provided a database of site survey records and hardcopies of inventory datasheets (FG District, only). The ODF inventory datasheet included a list of parameters related to site location, use type, impacts, size and site characteristics. These data provided important baseline data against which future monitoring efforts could be compared but offered few metrics beyond presence/absence of indicators.

6.7.1.2 Field Sample of Dispersed Campsites

To better quantitatively assess dispersed camp impacts, a sample was drawn from ODF's dispersed campsite inventory to represent hydrologically connected sites within the upper tributaries, the mainstem Wilson River, and the lower tributaries. A total of 18 sites (~10%) were assessed using the Minimum Recreation Site Monitoring Protocol[57]. The condition class ratings are applied to ground cover, tree damage and soil disturbance area on a numerical scale (Table 24) of 1-10. We recommend that a tree density metric be added to future

[57] Recreation Site Monitoring Procedures and Protocols: David Cole, Aldo Leopold Wilderness Research Institute

monitoring protocols to indicate a percentage degree of damage. A count would have to be made of *all trees/severely damaged trees* within the disturbed area assessed for condition class. To ensure consistency and accuracy, boundary trees may need to be marked for future re-measurement. This is addressed in greater detail in sections 7.5.11 (Future Inventory and Monitoring) and 7.5.12 (Effectiveness of Recent (post-1994) Recreation Site Upgrades).

Table 24. Recreation Site Monitoring and Frissell Condition Classes. The monitoring criteria and condition classes associated with dispersed campsite evaluations. Scores for FGI, TD and DA are summed and presented as a scale of 1-10.

Criteria	Condition Class				
Frissell Groundcover Impact **(FGI)**	1 – Ground vegetation flattened but not permanently injured	2 - Ground vegetation worn away in activity center	3 – Ground vegetation lost on most of the site	4 – Bare mineral soil widespread, exposed roots	5 – Soil erosion obvious, trees reduced in vigor or dead
Tree Damage **(TD)**	0 – No more than 3 severely damaged trees.	1 – 4 to 10 severely damaged trees.		2 – More than 10 severely damaged trees.	
Disturbed Area **(DA)**	0 – No more than 25 m^2 (0-250 ft^2).	1 – 26 to 100 m^2 (251 – 1,000 ft^2).	2 – 100 m^2 to 1,000 m^2 (1,000 to 10,000 ft^2).	3 – More than 1,000 m^2 (more than 10,000 ft^2).	

6.7.2 Results

6.7.2.1 Dispersed Campsite Inventory Data

Results based on ODF's dispersed campsite database indicate that OHV impacts and unrestricted use of riparian have significant impacts on riparian vegetation. Table 25 summarizes the data collected by ODF. The two most frequently reported impacts were tree damage and soil compaction – both of which have direct and indirect impacts on riparian vegetation health. Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates 9-13.

Table 25. ODF Dispersed campsite inventory provides a baseline record of conditions found during the field survey of 2006.

ODF Dispersed Campsite Inventory Observation (n=184)	Number of Sites	Percentage of Sites
Road Damage	34	18.5
Tree Damage	93	50.5

ODF Dispersed Campsite Inventory Observation (n=184)	Number of Sites	Percentage of Sites
Vehicle Damage	41	22.3
Streamside Damage	19	10.3
Soil Compaction	121	65.8
Erosion*	NA	-
Water Quality*	NA	-
Distance from water <25 feet**	33	17.8
Overall Impact Rating		
Very High	28	15.1
High	34	18.4
Moderate	52	28.1
Low	70	37.8
Disturbance Area (sq ft)		
<250	128	69.6
250-1000	48	26.1
Larger than 1000	8	4.3
Number with Site Improvements	***43***	***23.4***
Rated effective	19	44.0
Rated partially effective	16	37.0
Rated ineffective	8	18.0

** Field data missing from the database.*
*** Simplified by ODF to +/- 25 feet during data entry; from field record of actual distance (in feet) from camp edge to water.*

Of the 184 dispersed campsites inventoried by ODF, those sites within the Stream Bank Zone and the Inner Riparian Zone were most relevant to this study. Unfortunately, the ODF data entry protocol for "water access distance" only called for an entry distance of +/- 25 feet from water. Therefore, we can only say that 33 sites (or 17.8%) are in the Stream Bank Zone but are not able to say how many sites are in the Inner Riparian Zone[58]. The data entry process also excluded the number of sites exhibiting erosion, although the Forest Grove District hard copies show 50% of site forms were marked as having visible erosion and 64% were within 100 feet of water. As most of the observed high impacts conditions were within the Inner Riparian Zone, the loss of this data is unfortunate.

Overall impact ratings were applied by ODF recreation staff as a subjective judgment of observed impacts to the sites and results show over 62% of the sites were found to have moderate, high or very high impacts (See Map 31). Site

[58] This could, however, be extracted from the original field forms.

dimension was used as an indicator of erosion severity and of the 184 sites, three-quarters of them were less than 250 sq ft, a quarter were 250-1,000 sq ft of bare ground, and 8 sites were larger than 1,000 sq ft. However, two of these were 15,000 and 22,000 sq ft respectively. Total area of all site dimensions combined was 82,760 sq feet.

Combined recreation impacts (soil exposure, tree damage) can inhibit reproduction of tree species (Bratton et al. 1982) much more than any one impact type. Wilson River dispersed campsites exhibit very heavy combined impacts, particularly OHV damage, indicating that buffering the Inner Riparian Zone from dispersed campsite use would be more effective than specific regulations targeting one or two impact types (Reid and Marion, 2005).

Data gaps: There appears to be some important information lost in the data entry phase which limits an assessment of the severity of erosion from ODF data. Field forms had human impact categories that were inconsistently entered, including the "Erosion" category mentioned above.

6.7.2.2 Field Sample of Dispersed Campsites

Field assessment work of the dispersed campsites is summarized in Table 26 below. Of the 18 sites visited, 13 were within 10 feet of the high water mark of a stream, 3 were within 20-50 feet, and 2 sites were within 100 feet (i.e., 100% were within the Inner and Stream Bank riparian zones; Map 31). Overall, the majority of the sites had bare soils with widespread and exposed root systems, or with trees showing visible signs of reduced vigor or mortality (average FGI = 4.25, average tree damage = 1.3). Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates 9-13.

Disturbance areas were generally ~1,000 ft^2 in size, though 4 sites with extensive OHV use had disturbance areas of more than 0.25 acres. The total condition class (i.e., all factors considered) ranged between 2 and 10 (low impact to severe impacts), and averaged 7.4. OHV damage was prevalent on 72% of the sites. Human impact observations included direct erosion to the stream channel or wetlands, site-level tree mortality, severe compaction, and multiple user-defined trails to the stream channel. Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates, numbers 9-13.

Table 26. Dispersed Campsite Condition Classes. Groundcover impacts, tree damage, disturbed areas, and total condition class score for the 18 campsites reviewed. See Table 24 for score definitions and classification scheme.

Site I.D.	ODF Sitecode[1]	FGI class	TD class	DA class	Total Score	Distance to drainage (ft) [59]	Notes
1	FG053	5	1	2	9	<100	extensive OHV damage
2	TL012	2	1	1	4	<50	low OHV damage, erosion direct to creek
3	TL016	5	2	2	9	<10	high OHV in streams and road drainage
4	TL017	4	2	3	9	<10	high OHV use in streams
5	TL077	5	2	2	9	<10	Mod OHV use in stream
6	TL019	5	1	1	7	<10	Mod OHV use
7	FG059	4	1	1	6	<10	Mod OHV use
8	FG091	2	0	0	2	<100	Mod OHV use
9	FG094	4	1	1	6	<10	Erosion over cliff direct into Wilson River
10	FG103	4	1	1	6	<10	Large pool overflows towards river
11	FG076	5	1	2	8	<10	Direct mud flow to drainage and creek
12	FG066	4	1	2	7	<10	Edge of wetland
13	FG067	5	1	1	7	<20	Edge of wetland, OHV use, blocked culvert
14	FG029b	5	2	2	9	<10	Erosion to stream and culvert
15	FG029d	5	1	3	9	<10	OHV use extensive
16	FG029a	5	2	3	10	<50	OHV use extensive
17	TL129	5	2	3	10	<10	OHV use
18	FG104	4	1	2	7	<10	OHV use

[1] As identified in ODF's dispersed campsite inventory database.

6.7.3 Recommendations

In general, recreation impacts can be addressed by specific management actions on-site, but targeting the disturbing agent is likely to be most effective in minimizing impact levels (Marion and Cole, 1996). Marion (2003) describes management responses to three distinct types of recreation impacts:

[59] Edge of main activity area to high water mark.

- impacts from visitors knowingly engaging in illegal actions require a law enforcement response.
- Careless, unskilled or uninformed actions are often most appropriately addressed through visitor contacts and educational responses.
- Unavoidable impacts are commonly reduced by relocating visitation to resistant surfaces or by limiting use.

One critical factor in campsite impact management is location, and in this case, proximity to water is the key variable. The ODF has a recreation management guideline that requires campsites be kept at least 25 feet from high water. Backcountry camping research gives the most common distance as 100 feet (Cole, Petersen, and Lucas; 1987). Practical concerns about tree damage, soil erosion and human waste indicate the latter be a better minimum distance. Long term implications for protecting future LW recruitment into the streams would also dictate at least one tree length be a prudent minimum distance to apply.

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