Alternative Riparian Buffer Strategies for Matrix Lands of BLM Western Oregon Forests That Maintain Aquatic Ecosystem Values

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Executive Summary

An emerging issue in the management of forested lands administered by the Bureau of Land Management (BLM) in western Oregon is whether an increase in the land base for long-term timber production is compatible with the ecological and biodiversity goals for these forests. A major aspect of this issue relates to achievement of the goals of the Aquatic Conservation Strategy of the Northwest Forest Plan (NWFP) that was designed to maintain and improve habitat for Pacific salmon (*Oncorhynchus* spp.) and other aquatic and riparian-dependent organisms, along with water quality. This analysis develops and evaluates changes in the implementation of one part of the Aquatic Conservation Strategy (ACS)--the determination of stream buffers that are called "Riparian Reserves" in the plan. Interim buffers were set in 1994 when the NWFP was adopted, occupying approximately 40 percent of the landscape, with the expectation that they would be revised in the NWFP implementation. In general, that revision did not occur. Recently-developed science and analysis tools (NetMap) have opened the way to possible refinement of those buffer sizes. Applying these tools and science to streams in BLM Matrix, the land allocation that has long-term timber production as one of its goals, we conclude that alternatives exist to the current implementation of the ACS that reduce the area

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in buffers needed to meet the goals of the ACS. One alternative has fixed widths, and one has variable widths based on stream segment importance; the variable-width alternative could be better for both fish and timber harvest than the fixed-width alternative but is more challenging to apply. Both alternatives utilize "tree tipping" to ensure that thinning within buffers does not negatively affect wood falling into the stream. We simulated these alternatives in three watersheds in Western Oregon; these watersheds contain significant amounts of Moist Forests on BLM lands. Under the alternatives, we found that approximately 35-55% of the Riparian Reserves in the BLM Matrix under current implementation of the ACS is still devoted solely to achieving the ecological goals of the ACS, with the amount varying by watershed and alternative. The other portion of these Riparian Reserves contributes to ecological goals while providing opportunities for long-term timber production, with harvest limited to previously harvested acres (generally stands less than 80 years of age). In total, we estimate that this change would affect 10-13 percent of total BLM Moist Forest within two tree heights of fish-bearing streams and one tree height of non-fish bearing streams, when all land allocations are considered. Where that area is within one tree height of a stream, ecological forestry would guide activities. Analysis using NetMap makes it possible to identify the most important stream segments for aquatic ecosystem conservation across the watershed. Since many of these stream segments are on private lands, a single-minded focus on riparian buffers on federal lands will not be sufficient to recover fish populations. This analysis can be useful to public officials, Watershed Councils, and others in identifying where to allocate resources aimed at protection and restoration of aquatic ecosystems.

Introduction

Lands in western Oregon managed by the Bureau of Land Management (BLM) form a checkerboard pattern (Figure 1) that reflects their history as railroad and wagon-road grant lands that reverted to the federal government after the companies violated terms of the contract. The 1937 O&C Act, which calls for sustained timber production from those lands, guides their management, as do later laws such as the Endangered Species Act and Clean Water Act (Johnson and Franklin 2012).

These BLM Western Oregon Forests have recently been embroiled in political and social controversy. Historically, the lands supplied almost 10 percent of the timber harvest in Oregon, providing employment in local communities. In addition, revenue from timber sales went to counties where the lands were located. Under the Northwest Forest Plan (NWFP), timber harvest, mainly from thinning, has been lower than projected, reducing the potential employment that would be provided from logging and wood processing and payments to counties. Over the last decade, Congress provided funds to the counties through appropriations to compensate them for the loss of these payments, but that revenue stream is unlikely to continue. The southwest Oregon counties where most of the BLM lands are located continue to have high unemployment levels. Thus, political pressure has built for the BLM to increase timber harvest from its Western Oregon Forests.

Our purpose in writing this paper is to describe two alternatives to the current approach to Riparian Reserves under the NWFP that meet objectives of the Aquatic Conservation Strategy (ACS) of the NWFP (FEMAT 1993) and concerns related to ESA-listed fish while providing additional land for long-term timber production. The ACS was designed to halt further declines in watershed condition and to improve the ecological condition of watersheds in the NWFP area over a period of several years to decades (FEMAT 1993). It was premised on preserving key ecological processes, and recognized that periodic disturbances may result in less than optimal conditions for fish for short periods, but that these events are critical for maintaining long-term productivity of aquatic ecosystems. It recognized that significant results were not expected for several years to decades, because extensively degraded watersheds improve slowly (FEMAT 1993). The alternative strategies described here will maintain the ecological processes affecting aquatic ecosystems on Matrix lands managed by the BLM in western Oregon and thus meet the goals and objectives of the ACS.

Resources and Management of BLM Western Oregon

Streams on BLM Western Oregon Forests provide important habitat for a wide variety of salmon species (Figure 2): Coho Salmon (*Oncorhynchus kisutch*), fall Chinook Salmon (*O. tshawystscha*), spring Chinook Salmon, summer Steelhead (anadromous *O. mykiss*), and winter Steelhead. They also provide habitat for Coastal Cutthroat Trout (*O. clarkii clarkii*), and resident Rainbow Trout (non-anadromous *O. mykiss*). Coho Salmon on the Oregon Coast are listed as threatened under the Endangered Species Act and, as a result, many streams on these lands are designated as Critical Habitat (Dept. of Commerce 2008) (Figure 3).

We examined three watersheds in our analysis: 1) Myrtle Creek, 2) the Upper Coquille River, and 3) the Smith/Siuslaw Rivers (Figure 1). Two of the watersheds were chosen because they contain Secretarial Pilot Projects (see Johnson and Franklin 2012 for more discussion of these Pilots). The other (Smith/Siuslaw) was chosen because it had different geologic features and soil stability than the two Pilot watersheds. All three have importance as salmon habitat (Figures 2 and 3).

We use the classification of Franklin and Johnson (2012) that divides these lands into Moist and Dry Forests (Figure 4) for discussing management choices. Their division is a function of their average precipitation levels and resulting disturbance history (Franklin and Johnson 2012). Historically, Moist Forests generally experienced large, infrequent wildfires (intervals of one to several centuries), which included extensive areas where fire severity resulted in stand-replacement conditions. Dry Forest sites experienced predominantly low- and mixed-severity fire behaviors at more frequent intervals.

The Northwest Forest Plan established land designations on these lands to help conserve species associated with mature and old growth forests, including the Northern Spotted Owl (*Strix occidentalis caurina*) and the Marbled Murrelet (*Brachyramphus marmoratus*) (Thomas et al. 2007). Toward that end, Late-Successional Reserves (LSRs) were systematically placed throughout the range of the Northern Spotted Owl, with the goal of providing large areas of mature and old-growth forests (Figure 5). Currently the LSRs generally contain a mixture of young, mature, and old forest, with most of the young forest resulting from previous harvest. In some cases, such as the BLM forests in the Smith-Siuslaw watershed, the LSRs are composed mostly of young stands. Thinning is allowed in LSRs to advance late-successional ecosystem values, but LSRs are not designated for long-term timber production (US Forest Service & BLM 1994).

Matrix lands outside of the LSRs were designated for long-term timber production as one of their goals (Figure 5), with both thinning and regeneration harvest allowed[5]. They were intended to be the major source of projected timber harvest levels but rarely have achieved those levels due to protest and litigation

[5] Adaptive Management Areas, were also established, where innovative management practices were to be tried. Over the past 15 years, they have been managed in a similar fashion to Matrix and have been folded into that allocation in this discussion.

over attempts to harvest mature and old-growth forest and concerns by regulatory agencies about potential impacts on the habitat of ESA listed Coho Salmon.

In the NWFP, interim Riparian Reserves were established along streams in the Matrix, to conserve and restore aquatic ecosystem values as part of the Aquatic Conservation Strategy. Approximately 40 percent of Matrix falls within these reserves across the range of the Northern Spotted Owl, with a higher percentage in Moist Forests and a lower percentage in Dry Forests (Thomas et al. 2007). It was expected that the boundaries of the Riparian Reserves would be adjusted through site-specific analysis that used, in part, information developed in a watershed analysis (US Forest Service & BLM 1994). Thinning to advance aquatic ecosystem values is allowed within the Riparian Reserves, but they are not designated for long-term timber production.

Recently, the USFWS (2011) developed a new Recovery Plan for the Northern Spotted Owl with a number of recommendations that will affect the management of these BLM lands, including conservation of complex forest (such as mature and old-growth forest) wherever it is found. This recommendation will greatly limit further harvest of this type of forest. In addition, the USFWS (2012) specified Critical Habitat for the Northern Spotted Owl (Figure 6) that will limit timber harvest within the designated lands.

The Aquatic Conservation Strategy in the Northwest Forest Plan

Goals

The Aquatic Conservation Strategy is designed to maintain and improve habitat for Pacific salmon (*Oncorhynchus* spp.) and other aquatic and riparian-dependent organisms, along with water quality, on federal lands covered by the NWFP. The foundation of the ACS was a refinement of earlier strategies: "The

Gang of Four" (Johnson et al. 1991), PacFISH (USDA 1992), and the Scientific Assessment Team (Thomas et al. 1993). It was developed during the analysis that led to the Northwest Forest Plan (FEMAT 1993).

The ACS is a regional strategy applied to aquatic ecosystems across the area covered by the NWFP. It seeks to prevent further degradation of aquatic ecosystems and to restore and maintain habitat and the ecological processes responsible for creating habitat over broad landscapes of public lands administered by the U.S. Department of Agriculture Forest Service (USFS) and the BLM (US Forest Service & BLM 1994). In the short term (10–20 years), the ACS was designed to halt declines in watershed condition and to protect watersheds that currently had good-quality habitat and strong fish populations (FEMAT 1993). The long-term goal (100+ years) is to develop a network of functioning watersheds that supported populations of fish and other aquatic and riparian-dependent organisms across the NWFP area (US Forest Service & BLM 1994).

The ACS has five components to meet its goals and objectives: (1) watershed analysis, (2) riparian reserves, (3) key watersheds, (4) watershed restoration, and (5) standards and guidelines for management activities (US Forest Service & BLM 1994). Each component is essential for the success of the ACS (US Forest Service & BLM 1994) and any assessment must consider them in aggregate.

The key components considered in this analysis are watershed analysis and the riparian reserves. Watershed analysis is an analytical process that determines the ecological characteristics and processes of watersheds and identifies potential management actions to address watershed-specific problems and concerns, including possible adjustments to Riparian Reserve boundaries and management actions. Riparian Reserves were intended to define the outer boundaries of the riparian ecosystem and are portions of a watershed most tightly coupled with streams and rivers. They provide the ecological functions and processes necessary to create and maintain habitat for aquatic- and riparian-dependent organisms over time, dispersal corridors for a variety of terrestrial organisms, and connectivity of streams within watersheds (FEMAT 1993). The boundaries were intended to be interim, until a watershed analysis is completed, at which time they may be modified as suggested in the watershed analysis (US Forest Service & BLM 1994).

Selection of riparian buffer widths in the NWFP

The size of the Riparian Reserve in the NWFP varies with the presence or absence of fish. FEMAT scientists developed three buffer system choices (FEMAT 1993, page V-37) to serve as "interim" widths until watershed analysis could be completed. All required a buffer width on fish-bearing streams equal to two times the height of a site-potential tree (minimum of 300 feet), where a site-potential tree is defined as a tree that has attained the average maximum height possible given the conditions where it occurs (FEMAT 1993, page V-32). The buffer system choices varied in their requirements for non-fish bearing streams, ranging from a width equal to one-sixth of a site-potential tree height (minimum of 25 feet) to that of one site-potential tree height (FEMAT 1993, page V37). One of these riparian buffer choices was integrated into each of the 10 landscape alternatives developed by the scientists in FEMAT (FEMAT 1993).

The Secretaries of Interior and Agriculture choose Option 9 as their preferred alternative, which called for two site-potential tree heights on fish-bearing streams and one-half site-potential tree height on most non-fish bearing streams[6]. The boundaries of the Riparian Reserve were extended to a full site-potential tree height on all non-fish bearing streams between the draft and final Environmental Impact Statement (US Forest Service & BLM 1994) to increase the likelihood of success of the ACS, and to provide additional support for non-fish organisms that use the area near streams as habitat or migratory corridors (FEMAT 1993**)**. Therefore, in the NWFP, the interim buffer width is two site-potential tree heights on fish-bearing streams and one site-potential tree height on non-fish bearing streams (USDA Forest Service & BLM 1994).

Influence of the riparian buffer strategy on risk ratings for other species

Risk ratings were done for hundreds of species and species groups associated with late-successional forests for each landscape alternative in FEMAT. Those ratings, in general, were influenced by the amount of late-successional forest available for harvest and other considerations. The amount of this forest available for harvest would, in turn, be influenced by the riparian buffer system chosen, since late-successional forests generally could not be harvested in these buffers. Thus, the riparian buffer system chosen could influence the risk ratings for non-aquatic species in ways that are hard to fully identify.

Overall effect of ACS on watershed condition in the last 10-15 years

To date, the ACS has met the goal of improving the ecological condition of watersheds across the area to which it applies (Reeves et al. 2006; 15 year monitoring report). The ecological condition of 65 percent of the watersheds improved, 28 percent declined, and 7 percent remained unchanged after the first

[6] A site-potential tree height was designated on non-fish bearing streams within Key Watersheds.

ten years (Reeves 2006, Reeves et al. 2006). After 15 years, ecological conditions improved in 69 percent of the watersheds and declined in 18 percent (Lanigan et al. 2012). The primary factors responsible for this improvement were the increase in the number of large trees (>20 inches in diameter) in the Riparian Reserves and a reduction in the miles of roads in watersheds in the NWFP area. Watersheds in which conditions declined have recently experienced wildfires.

Limitations in implementation of the ACS

Interim boundaries of the Riparian Reserves have remained intact in the vast majority of watersheds to date following watershed analysis (Baker et al. 2006). One reason given for this outcome was that the burden of proof for adjusting the boundaries was too high. No explicit criteria for changing the boundaries were established by FEMAT (1993) or the Record of Decision (ROD) (USDA Forest Service & BLM 1994) other than to require that those proposing to undertake activities within the interim Riparian Reserves needed to demonstrate that the actions would not have negative effects. That demonstration proved difficult for specialists to make.

Management activities in riparian areas within one site-potential tree height on federal lands in western Oregon, and elsewhere, have also been limited recently because of concerns about consequences to habitat of fish listed under the Endangered Species Act. Options for actively managing Riparian Reserves along streams with listed fish on the Bureau of Land Management and other federal lands in western Oregon have been increasingly constrained because of concerns identified by NOAA Fisheries during project review and consultation procedures. These concerns focus on potential short-term risks to listed fish and their freshwater habitat, including possible reduction of stream shade or woody debris sources.

Alternative Riparian Buffers for Matrix Lands of BLM Western Oregon Forests----Underlying Principles and Concepts

Increasing the land base on the Matrix lands of BLM lands in western Oregon for long-term timber production while continuing to achieve the goals and objectives of the ACS requires maintaining and applying all components of the ACS. Boundaries of Riparian Reserves were expected to be changed as a result of watershed analysis (FEMAT 1993, p. V-35), and still meet the ACS objectives (FEMAT 1993, p. V-44). The interim widths were designed to ensure that ecological processes would be protected until watershed analyses were completed. Watershed analysis was expected to provide contextual information needed to define appropriate widths of the Riparian Reserve. Because of inherent variation in landscape features and in where ecological processes critical to aquatic habitat formation occurs, it was expected that site-specific characteristics, would result in Riparian Reserve boundaries different from the interim widths (FEMAT 1993, p. V-44).

Below, we describe two alternatives to the existing interim buffers that require less forest area while still achieving the goals of the ACS. In each case, we give the scientific rationale for the option. We put these options forward to advance the discussion about achieving the ecological goals of the NWFP while increasing the land available for long-term timber production.

We begin with two recent scientific advances that permeate both alternatives: 1) a recognition that aquatic ecosystems are dynamic in space and time, and 2) a recognition of the ecological importance of non-fish-bearing streams. Next, we discuss two forest-management strategies that we will utilize in the alternatives that were not covered in the Northwest Forest Plan: 1) ecological forestry (Franklin and Johnson 2012) as a guide to silviculture, and 2) "tree tipping" to compensate for potential loss in wood recruitment to streams.

Streams and associated aquatic ecosystems: dynamic in space and time

Assessing the potential ecological effects of management in riparian ecosystems is dependent on a number of factors. A primary one that is critical, but seldom recognized explicitly is the perspective of how streams and the associated aquatic ecosystems behave. One perspective holds that aquatic ecosystems tend to be in an equilibrium or steady state, and when disturbed they have been expected to return to pre-disturbance conditions relatively quickly (Resh et al. 1988, Swanson et al. 1988). Biological (Vannote et al. 1980) and physical conditions (Rosgen 1994) are presumed to be relatively constant through time and to be good (barring human interference) in all systems at the same time. Conditions in aquatic systems with little or no human influences, particularly those associated with old-growth forest, are understood to have the most favorable conditions for fish and other aquatic organisms and are most frequently used as references against which the condition of managed streams (e.g., Index of Biotic Integrity, Karr and Chu 1999) and impacts from management actions can be assessed.

There is an emerging understanding that views streams as being dynamic in space and time and experiencing a potential range of conditions, just as the terrestrial systems (Wimberly et al. 2000) in which they are embedded also do. Conditions in streams are variable through time (Naiman et al. 1992) depending on their location in the network, time since last disturbance, and the legacy of that disturbance (Reeves et al. 1995, Benda et al. 1998, Rieman et al. 2006, Wondzell et al. 2007). Larger streams and rivers in the lower portion of the network are less variable through time; those in the upper and middle portions are more dynamic (Naiman et al. 1992). Pristine, or less-disturbed, aquatic systems may actually exhibit a wider range of conditions than disturbed systems (Lisle 2002, Lisle et al. 2007). The range of conditions that aquatic ecosystems in different areas likely experience through time will differ depending on the natural disturbance regime, topographic setting, and geology. See Reeves (2006a) for a more detailed review.

Ecological importance of non-fish-bearing streams

The Riparian Reserves are a cornerstone of the ACS and include fish-bearing streams, which had been the focus of the management of aquatic ecosystems before FEMAT, as well as small, fishless headwater streams. The latter generally make up 70 percent or more of the stream network (Gomi et al. 2002). Before the ACS, these streams were not widely recognized as part of the aquatic ecosystem, but knowledge and recognition of the ecological importance of headwater streams has increased since then. They are sources of sediment (Benda and Dunne 1997a, b; Zimmerman and Church 2001) and wood (Reeves et al. 2003, May and Gresswell 2003, Bigelow et al. 2007) for fish-bearing streams, provide habitat for several species of native amphibians (Kelsey and West 1998) and macroinvertebrates (Meyer and Wallace 2001), including recently discovered species (Dieterich and Anderson 2000), and may be important sources of food for fish (Wipfli and Gregovich 2002). Small streams are also storage and processing sites of nutrients and organic matter, important components of the energy base for organisms used by fish as food (Kiffney et al. 2000, Wallace et al. 1995, Webster et al. 1999, Wipfli and Gregovich 2002).

Headwater streams are among the most dynamic portions of the aquatic ecosystems (Naiman et al. 1992). Tributary junctions between headwater streams and larger channels are important nodes for regulating material flows in a watershed (Benda et al. 2004, Gomi et al. 2002) and are the locations where site-scale effects from management activities are often observed. These locations have unique hydrologic, geomorphic, and biological attributes. The movement of sediment, wood, and other materials through these locations results in sites of high biodiversity (Johnson et al. 1995, Minshall et al. 1985). Habitat in these sites may also range from simple to complex, depending on time since the disturbance (such as landslides and debris flows) and the types and amount of materials delivered to the channel.

Large wood is an important element of stream and river ecosystems. It forms and influences the size and frequency of habitat units for fish and other organisms that depend on aquatic and riparian habitats (Bilby and Bisson 1998, Bilby and Ward 1989, Wallace et al. 1995). The size of pieces and amount of wood in the channel also influence the abundance, biomass, and movement of fish (Fausch and Northcote 1992, Harvey and Nakamoto 1998, Harvey et al. 1999, Murphy et al. 1985, Roni and Quinn 2001). Wood enters streams via chronic and episodic processes (Bisson et al. 1987). Chronic processes, such as tree mortality and bank undercutting (Bilby and Bisson 1998, Grette 1985, Murphy and Koski 1989), generally introduce single pieces or relatively small numbers of trees at frequent intervals. Episodic processes usually add large amounts of wood to streams in big but infrequent events, such as windthrow (Harmon et al. 1986), wildfire (Agee 1993), severe floods, landslides, and debris flows (Keller and Swanson 1979, Benda et al. 2003, May and Gresswell 2003, Reeves et al. 2003).

Pieces of large wood delivered from upslope areas are generally smaller than those originating from the riparian zones along fish-bearing streams. Reeves et al. (2003) found that the mean volume of a piece of large wood from upslope areas was one-third the mean size of pieces from stream-adjacent riparian areas in a coastal Oregon stream. Difference in mean size is likely attributable to fire history and other stand-resetting events. Hillslopes are more susceptible to fire and burn more frequently than streamside riparian zones (Agee 1993). Thus, trees in the streamside riparian zone may be disturbed less frequently and achieve larger sizes than upslope trees.

Geomorphic features of a watershed influence the potential contribution of upslope wood sources. Steeper, more highly dissected watersheds will likely have a greater proportion of wood coming from upslope sources than will watersheds with lower stream densities and gradients. Benda and Cundy (1990) identified the features of first- and second-order channels with the greatest potential to deliver sediment and wood to fish-bearing streams in the central Oregon coast. The primary features were gradients of 8 to 10 percent, with tributary junction angles <45°. A survey by the Oregon Department of Forestry (Robison et al. 1999) found that 95 percent of the streams in the central Oregon Coast that experienced landslides that reached fish-bearing streams had these features.

The presence of large wood from headwater streams influences the behavior of landslides and debris flows, and the response of the channel to such events. Large wood in debris flows and landslides influences the run-out length of these disturbance events (Lancaster et al. 2003). Debris flows without wood move faster and for longer distances than those with wood, and they are less likely to stop high in the stream network and to reach fish-bearing channels. A debris flow without wood is likely to be a concentrated slurry of sediments of varying sizes that can move at relatively high speeds over long distances, scouring substrate and wood from the affected channels. These types of flows are more likely to negatively affect fish-bearing channels rather than have potential favorable effects that result from the presence of wood. They can further delay or impede the development of favorable conditions for fish and other aquatic organisms.

Over time, headwater depressions and channels are filled with material from the surrounding hillslopes, including large wood that falls into these channels, forming obstructions behind which sediments accumulate (Benda and Cundy 1990, May and Gresswell 2004). These areas are evacuated following a landslide or debris flow. This cycle of filling and emptying results in a punctuated movement of sediment and wood to larger, fish-bearing streams (Benda et al. 1998), which is—at least in part—responsible for the long-term productivity of many aquatic ecosystems (Benda et al. 2003, Hogan et al. 1998, Reeves et al. 1995). The absence of wood to replenish the refilling process may result in a chronic movement of sediment to larger channels, which could lead to those channels developing different characteristics than those that occurred before forest management. Such conditions could be outside the range of watershed conditions to which native biota are adapted (Beschta et al. 2004).

Ecological forestry as a silvicultural guide

Within one-tree height of streams, our silvicultural proposals are based on "ecological forestry" concepts, which incorporate principles of natural forest development, including the role of natural disturbances in the initiation, development, and maintenance of stands and landscape mosaics (Seymour and Hunter 1999, Franklin et al. 2007, Franklin and Johnson 2012). Ecological forestry is based, therefore, on application of our best current ecological understanding of forest ecosystems and how they work in achieving integrated environmental, economic, and cultural management outcomes. In this way, ecological forestry contrasts with production forestry, which applies agronomic and economic models in the efficient production of wood products.

Key elements of ecological forestry (Franklin et al 2007, Franklin and

Johnson 2012) include: (1) retaining structural and compositional elements of the pre-harvest stand during regeneration harvests; (2) using natural stand development principles and processes in manipulating established stands to restore or maintain desired structure and composition; (3) using return intervals for silvicultural activities consistent with recovery of desired structures and processes; and (4) planning management activities at landscape scales, in accordance with knowledge of spatial pattern and ecological function in natural landscapes.

After a comparison of current and historical conditions in the Moist Forests of Western Oregon, Franklin and Johnson (2012) recommend an ecological forestry strategy for Moist Forests on BLM Western Oregon lands that would:

- Retain existing older stands and individual older trees found within younger stands proposed for management, using a selected threshold age;
- Accelerate development of structural complexity in younger stands (especially plantations), using diverse silvicultural approaches;
- Implement variable-retention regeneration harvests on *previously harvested* Moist Forest acres, retaining such structures as individual trees, snags, logs, and intact forest patches;
- Accommodate development of diverse early-seral ecosystems following harvest, by using less intense approaches to site preparation and tree regeneration; and
- Embed preceding objectives in a silvicultural system that includes creation and management of multi-aged, mixed-species stands on long rotations (e.g., 100-160 years).

As Franklin and Johnson (2012) note, the most potentially controversial element of their Moist Forest restoration strategy is resumption of regeneration harvesting in younger stands using variable-retention prescriptions. One specific objective of these harvests is to provide for continued creation of diverse early-seral ecosystems in Moist Forest landscapes as a part of a silvicultural system that includes management of mixed-age, mixed-species forests over long (e.g., 100- to 160-year) rotations. Very few regeneration harvests are currently planned in federal Moist Forests in the PNW, primarily because past proposed harvests in mature and old-growth stands have been successfully litigated. Existing timber harvests in Moist Forests are currently confined to thinning plantations (Thomas et al. 2007).

Diverse early-seral ecosystems on Moist Forest sites are highly diverse, trophic- and function-rich ecosystems that occur after a severe disturbance but before the re-establishment of a closed forest canopy (Swanson et al. 2011). Many Moist Forest landscapes currently lack sufficient representation of high-quality early-seral ecosystems due to harvest, reforestation, and fire suppression policies on both private and public lands (Swanson et al. 2011, Spies et al. 2007). Functional early-seral habitat can be created using regeneration harvest prescriptions that retain biological legacies and use less intensive approaches to re-establishment of closed forest canopies (Franklin and Johnson 2012).

Franklin and Johnson (2012) expect the call for resumption of regeneration harvests on federal lands to be controversial, even if focused on previously harvested forests, because stakeholders usually equate it with the unpopular practice of clearcutting (Bliss 2000). However, Franklin and Johnson (2012) propose using variable-retention harvesting and not clearcutting; these are very different approaches. Unlike conventional clearcuts, variable-retention harvests incorporate significant elements of the pre-harvest stand through the next rotation, including undisturbed forest patches and individual live and dead trees to enrich the biodiversity, ecological processes, and structural diversity of the post-harvest stand (Gustafsson et al. 2012, Lindenmayer et al. 2012).

Franklin and Johnson (2012) call for Moist Forest regeneration harvest that retains approximately 30 percent of the pre-harvest stand as patches, plus some additional retention (typically of green trees that are intended to become snags and logs) on harvested portions of the units. With these biological legacies and the significant open areas created by the harvesting, they note that variable-retention harvests provide optimal conditions for: (1) development of diverse early-seral ecosystems needed by significant elements of regional biodiversity; (2) regenerating new cohorts of desirable shade-intolerant tree species; and (3) providing substantial flows of wood products.

Further, *they view younger, previously harvested acres as the obvious candidates for these regeneration harvests,* given that current levels of older forests are far below historic levels and that scientific review (Forsman et al. 2011) and new policy direction calls for retention of mature and old forest (complex forest) as NSO habitat (US Fish and Wildlife Service 2011). Also, watersheds with forests 80-140 years old in the Oregon Coast are the most productive for salmon (Reeves et al. 1995).

After a similar analysis of Dry Forests, Franklin and Johnson (2012) recommend an ecological forestry strategy for Dry Forests on BLM Western Oregon lands that would:

- Retain and improve survivability of older conifers by reducing adjacent fuels and competing vegetation—old trees can respond positively (e.g., McDowell et al. 2003);
- Retain and protect other important structures such as large hardwoods, snags, and logs; some protective cover may be needed for cavity-bearing structures that are currently being used;

- Reduce overall stand densities by thinning so as to: (1) reduce basal areas to desired levels, (2) increase mean stand diameter, (3) shift composition toward fire- and drought-tolerant species, and (4) provide candidates for replacement old trees;
- Restore spatial heterogeneity by varying the treatment of the stand, such as by leaving untreated patches, creating openings, and providing for widely spaced single trees and tree clumps;
- Establish new tree cohorts of shade-intolerant species in openings;
- Treat activity fuels and begin restoring historic levels of ground fuels and understory vegetation using prescribed fire; and
- Plan and implement activities at landscape levels, incorporating spatial heterogeneity (e.g., provision for denser forest patches) and restoration needs in non-forest ecosystems (e.g., meadows and riparian habitats).

Elements of this Dry Forest restoration strategy, including stand-level treatments and retention of dense forest habitat patches at the landscape level have been, or are currently being, incorporated into projects on federal lands (e.g., Ager et al. 2007, Gaines et al. 2010). Projects using these Dry Forest principles are underway on BLM lands in southwestern Oregon, where the Northern Spotted Owl is featured (Franklin and Johnson 2012). Retaining and nurturing older trees and other significant structural elements of Dry Forest stands is the starting point for this restoration strategy. Currently, both remaining old trees and the forest in which they are embedded are at risk from intense wildfires, epidemics of defoliating insects, and competition, the latter resulting in accelerated mortality due to bark beetles (Franklin and Johnson 2012). Selection of the threshold age for older trees is particularly important for Dry Forests, since it is applied to all Dry Forest stands.

Retaining some denser forest areas in an untreated or lightly treated condition is a challenging landscape-level planning component of the Dry Forest restoration strategy. Most Dry Forest landscapes include species and processes that require denser forest as habitat, such as preferred nesting, roosting, and foraging habitat for Northern Spotted Owls (US Fish and Wildlife Service 2011). Maintaining approximately one-third of a Dry Forest landscape in denser patches of multi-layered forest has been proposed for the Northern Spotted Owl (Courtney et al. 2008); in general, landscape amounts and distributions will be a function of topographic and vegetative factors along with wildlife goals. Losses of denser forest patches are inevitable, but—since the surrounding restored matrix still is populated with older, larger trees—suitable dense replacement habitat can be re-grown within a few decades.

Franklin and Johnson (2012) propose that this Dry Forest strategy be applied across the landscape including both Matrix and Late-Successional Reserves. *It is important to note that in this paper the discussion of using ecological forestry in streamside areas of both Moist Forests and Dry Forests applies only to the BLM Matrix.*

Tree tipping to compensate for potential reduction in wood recruitment

Mitigation for the potential reduction of wood recruited to a stream as a result of management activites can be achieved by felling or pulling over trees directly into the channel during management activities. Such actions would immediately increase the amount of wood in the channel, which should provide benefits to fish and other aquatic organisms. We explored this management option by modeling the amount of in-stream wood that would result from directionally falling or pulling over trees from the stand and compared this to the amount of wood that would be expected to be found in the stream without management activities (Table 1). The volume of wood in the channel increased above the "no thin" level immediately after the entry in all of the options of wood additions. However, the cumulative total volume of wood expected in the stream over 100 years relative to the unmanaged stand varied depending on the amount of wood delivered (Table 1). When ≥15% of the volume of harvested trees were tipped at each entry, the total amount of dead wood in the channel exceeded the unmanaged scenario over time.

In addition, it is possible to mitigate for potential reduction in wood recruitment from reducing the size of the Riparian Reserve on non-fish bearing streams to one-half of site-potential tree height as described above. The deficit could vary from 5 to 15 percent of the total amount of wood that could be delivered from a distance of one site-potential tree. Wood from the outer half of the Riparian Reserves can be directionally felled or moved into the channel during harvest operations. We estimate that it would take 10-15 percent of the total volume that would be harvested in the outer half (Figure 7).

Alternative Riparian Buffers for Matrix Lands of BLM Western Oregon Forests----Design and Scientific Rationale

We present two alternatives to the current approach to the size of, and activities conducted in, riparian buffers in Matrix under the NWFP that could meet ACS objectives and concerns related to ESA-listed fish while increasing the land available for long-term timber production. We first discuss the logic behind the alternatives and then simulate the implications for riparian buffers in Matrix on BLM forests. Most of our discussion below relates to Moist Forests, since they occupy most of the three watersheds being studied.

For comparison, we simulate the buffers associated with current policy on BLM forests, and private forest buffers under the Oregon forest practice rules on private lands within the study watersheds. Finally, we estimate the extent of buffers if buffers mandated for private lands in Oregon are applied to BLM lands.

We also provide a summary of the prescriptions on Moist Forests that could be applied to the buffers on BLM lands under each alternative (Table 2). We emphasize Moist Forest prescriptions in this discussion for two reasons: 1) more than 90 percent of the total acreage in our study watersheds is in Moist Forests, and 2) the ecological forestry prescriptions for Moist Forests are more controversial than those for Dry Forests because they create openings as part of regeneration harvest.

In general, regeneration harvest in the buffers is most appropriate for previously harvested acres[7] (generally less than 80 years of age) following the recommendations of the JOINT FS, NOAA, EPA, FWS GROUP (2012), Franklin and Johnson (2012),the Spotted Owl Recovery Plan (2011) and discussion in the recent Critical Habitat Rule (2012). In addition, watersheds with forests 80-140 years old in the Oregon Coast are the most productive for salmon (Reeves et al. 1995). Thus, we limit regeneration harvest within the buffers to previously harvested acres (Table 2).

[7] In this paper, "previously harvested acres" describe acres on which a regeneration harvest previously occurred. Most of those acres were previously clearcut and planted, many have since been pre-commercially thinned, and some have been commercially thinned. While most stands on these acres are less than 80 years of age, some are 85-100 years old. It should be noted that not all of the previously harvested stands would be available. Some include a remnant overstory of older trees that could make them function as an older stand from a biodiversity standpoint; their availability for long-term timber production may be limited. We attempted to adjust for this complication in the acreage numbers reported later. For more detail, see Johnson and Franklin (2013).

Alternative A

Alternative A reduces stream buffers in the BLM Matrix lands to one site-potential tree height on fish-bearing streams and retains the current one site-potential tree height on non-fish-bearing streams. The stream buffer on fish-bearing streams and the inner half of the buffer on non-fish-bearing streams would be managed for aquatic ecosystem goals in a manner similar to that of current policy for Riparian Reserves in the Northwest Forest Plan. The outer one-half of the buffer on non-fish-bearing streams would be managed for both aquatic ecosystem goals and timber production, utilizing ecological forestry as described above (See Table 2 for the Moist Forest prescriptions that could be considered within the outer half of the stream buffer on non-fish streams).

Rationale for reducing the buffer width along fish-bearing streams

Key ecological processes that maintain the long-term productivity of the aquatic ecosystem occur within the first site-potential tree height (US Forest Service & BLM 1994), including the beneficial effects of root strength for bank stability, litter fall, shading, and delivery of coarse wood to streams (Figure 8a). Also, the first tree height is more than enough distance to provide the moderating effects of buffers on erosion delivery to streams during upland activities (Castelle et al. 1994).

A primary purpose for the extension of the boundary of the Riparian Reserve from one site-potential tree height to two on fish-bearing streams was to protect and enhance the microclimate of the riparian ecosystem within the first tree height, (US Forest Service & BLM 1994). Research on the effects of clearcutting on microclimatic conditions (Chen et al. 1993) in upland forest stands found that the influence extended into adjacent unharvested stands. The distance from cut edge to which microclimate alterations could be detected within the forest interior varied from yards (e.g., soil moisture) to hundreds of yards (e.g., wind velocity). It was hypothesized from the initial works of Chen et al. (1993) that a second tree height could provide significant benefits to Riparian Reserves in terms of relative humidity and other microclimatic effects in the Riparian Reserve along fish-bearing streams (Figure 9a).

A number of research efforts have examined the effects of forest management on microclimate in riparian areas since the ACS and the associated ecological function curves were originally formulated. The vast majority of this work has been on small, headwater streams; little has been done along larger streams (see review by Moore et al. 2005). The magnitude of harvest-related changes in microclimate in riparian areas is generally inversely related to the width of the riparian buffer, and generally effects did not extend beyond a distance equal to one tree height. As a result, it has been suggested that a one tree-height buffer on fish streams should reduce potential impacts of harvesting in areas on the edge of the buffer on riparian microclimate and water temperature (Brosofske et al. 1997, Moore et al. 2005) (Figure 9b). While these results come from studies of smaller streams, we argue that they also apply to larger streams and justify reducing the interim Riparian Reserve boundary from two site-potential trees to one.

Rationale for the buffer strategy along non-fish-bearing streams

As described above, Alternative A retains a one site-potential tree height on non-fish-bearing streams, with the inner half of the buffer managed for aquatic ecosystem goals in a manner similar to that of current policy for Riparian Reserves in the Northwest Forest Plan and the outer-half managed for both aquatic ecosystem goals and timber production. Key considerations in this approach are effects on microclimate, water temperature, amphibian habitat, and wood recruitment.

Effect on microclimate and water temperature

One of the more comprehensive studies on the effect of vegetation manipulation within riparian areas of varying sizes was conducted by Anderson et al. (2007), who monitored microclimatic conditions in riparian areas on headwater streams in western Oregon that had varying widths (<49 ft (14.9 m) – 492 ft (150 m)) and moderate levels of thinning (reducing trees from 250-432 trees/acre (500 – 865 trees/hectare) to 99 trees/acres (198 trees/hectare)). They determined changes in microclimate above the stream channel and in the adjacent riparian zone relative to unthinned stands. This is different from studies cited previously that examined the effects of harvesting on the outer edge of the riparian area on the microclimate within the buffer. With buffers of 49 ft or greater width, daily maximum air temperature above stream center was less than 1°C greater, and daily minimum relative humidity was less than 5 percent lower than for unthinned stands.

The portion of the buffer managed solely for ecological goals,, one half the height of a site potential tree (minimum distance of 75 ft (22.9 m) in the Northwest Forest Plan area), is considerably more than 49 ft. If concerns still exist about the application of ecological forestry to the area beyond one-half tree height on some non-fish-bearing streams in the Matrix of Moist Forests, strategic placement of aggregate retention patches during regeneration harvest could help ameliorate them. Positioning the 30 percent retention that is part of the Moist Forest prescription along the half-tree-height boundary would raise the effective buffer distance to at least 100 ft.

Allowing ecological forestry in the outer half of the tree-height buffer on non-fish bearing streams could raise potential concerns about water temperatures in those streams. These streams tend to be narrow channels in steeper constrained valleys (Gomi et al. 2002, Moore et al. 2005). Near-stream vegetation and topographic features often shade the entire channel in such settings (Janisch et al. 2012). The curve for the shade in the FEMAT ecological curves (Figure 8a) is most applicable to larger streams and cannot be applied to smaller streams, where the zone of influence is much smaller. Additionally, water temperatures in headwater streams are strongly influenced by in-channel substrate (Johnson 2004, Janisch et al. 2012). The influence of factors other than vegetation helps explain the variation in results of studies that have examined the influence of buffer width on water temperatures in these streams (Janisch et al. 2012). In sum, adopting Alternative A for non-fish-bearing streams is unlikely to increase water temperatures in these streams.

Effect on amphibians

Olson et al. (2007) reviewed studies of the effects of timber harvest activities, inside and outside of riparian buffers, on microclimatic conditions and amphibians. They concluded that relatively narrow buffers (compared to those of the Northwest Forest Plan) can be effective in maintaining microclimates 33-66 ft (10-20 m) from the stream center. Potential concerns about microclimate that could arise from reducing the size of riparian buffers can be reduced further by minimizing clearcutting along the outer boundary (Moore et al. 2005, Anderson et al. 2007, Kluber et al. 2008). As mentioned previously, clearcutting is not part of the silvicultural strategy under ecological forestry—strategically placing aggregated retention patches during harvest should help ameliorate concerns here. Limiting activity in the inner half of the riparian reserve (minimum distance of 75 ft (22.9 m)) along non-fish-bearing streams and utilizing ecological forestry in the outer half should be sufficient to maintain ecological integrity for amphibians.

Headwater streams may also serve as connection corridors within and between watersheds (Olson and Burnett 2009). Recent research by D. Olson, PNW Research Station, (unpublished) found that most amphibians moved along the stream within 45 ft (13.6 m) of the channel. Maintaining a one tree height buffer on non-fish bearing streams, with the inner half (at least 75 ft in width) devoted to ecological goals and the outer half managed with ecological forestry, should provide movement corridors for amphibians and other organisms within and between watersheds. In addition, providing for down wood on the forest floor, in the outer half of the riparian buffer where ecological forestry will be allowed, will further reduce potential impacts on terrestrial salamanders (Rundio and Olson 2007).

Effect on wood recruitment

Allowing ecological forestry in the outer half of the riparian buffers along non-fish-bearing streams is also unlikely to affect wood recruitment. The graph of the relationship between the cumulative effectiveness of an ecological process and the distance (expressed as the height of a site-potential tree) for wood recruitment suggests that about 80 percent of wood recruitment function occurs within one-half a tree height (Figure 8a). This graph was based on a limited number of studies (McDade et al. 1990, Van Sickle and Gregory 1990) and the professional judgment of scientists involved with FEMAT. Since FEMAT, studies on wood sources (McDade et al. 1990, Van Sickle and Gregory 1990) and new information in Gregory et al. (2003) show that about 95 percent of the total instream wood inputs from the adjacent riparian area in these studies came from distances that ranged between 82 to 148 feet (25 and 45 m) from the stream in the Cascade Range of western Oregon. Given that the height of a site-potential tree in that area is approximately 180 feet (personal communication from Cheryl Friesen, Science Liaison, Willamette National Forest), this suggests that 95 percent of the wood comes from a distance equal to 0.46 to 0.82 of a site-potential tree (Figure 8b). This scientific finding compares to the hypotheses expressed in the FEMAT curve (Figure 8a) showing that 95 percent of the wood recruitment function occurs within a distance equal to about 0.95 of the height of site-potential tree. Thus, managing the outer half of the riparian buffer with ecological forestry maintains a larger proportion of the wood recruitment process in non-fish-bearing streams than originally hypothesized in FEMAT (1993).

It is possible to mitigate for potential reduction in wood recruitment using tree tipping. The estimated deficit could vary from 5-15 percent of the total amount of wood that could be delivered from a distance of one site-potential tree. Wood from the outer half of the Riparian Reserves can be felled or moved into the channel during harvest operations. We estimate that it would take 10-15 percent of the total volume that would be harvested in the outer half of the buffer (Figure 7). This amount is likely to be sufficient in most cases, but site-specific analyses can be used to estimate the amount needed for a given setting. Implementing directional felling and placement of wood in the channel from the outer half of the Riparian Reserve can present operational challenges. Methods and procedures will need to be developed and tested to ensure that this can be done successfully and the goal for wood loading is met.

Summary

In sum, changing the boundaries of the Riparian Reserves as described above for Alternative A will have minimal, if any, impacts on the ecological processes along these streams. Some would argue that assessing the consequences of such changes in the Riparian Reserve component on BLM managed lands would require consideration of changes in BLM management, in the context of existing policies for FS and other lands of the area of the Northwest Forest Plan. For all the reasons described above, we expect the ecological consequences of the option for aquatic ecosystems should be minimal. As a result, we expect that the ACS would not be compromised or its effectiveness reduced with the implementation of this option.

Alternative B

The second alternative uses ecological context to partition a watershed into areas of different importance in achieving aquatic ecosystem values. The current emphasis in the scientific literature is on recognizing variation in the productive capacity and the strength of ecological processes among and within aquatic ecosystems, and crafting management approaches that recognize and accommodate this variation. This concept was not well developed or recognized at the time of the development of the ACS in the NWFP.

Rationale and concepts for variable-width buffers

Management of riparian areas has almost exclusively used the approach of fixed-width buffers, with variation depending on the size or type of stream (Richardson et al. 2012). This approach is easy to administer and apply. Also, the cost of developing site-specific recommendations tends to be higher, in part, because of the analysis required. The combination of these factors and uncertainty about results has limited the development and application of a variable approach to riparian management.

There has been movement towards allowing discretion in setting site-specific activities and guidelines (Lee et al. 2004). This approach recognizes variation among, and within, aquatic ecosystems and that management approaches should accommodate this variation. Olson et al. (2007) suggest there could be a mix of approaches to riparian management, ecologically focused and production focused, if done at large scales and with consideration is given to the distribution of populations of concern and connectivity. There have been few attempts to design and implement such an approach because available guidelines are vague (Richardson et al. 2012). The best example is Cissell et al. (1999) for Blue River, Oregon. This plan was based on the variation in the disturbance (in this case, wildfire) patterns in the watershed and suggested that some older trees would be harvested. The latter resulted in threats of litigation and the plan was never implemented.

Management of Riparian Reserves could vary depending on the context of the particular location. The management of a particular location depends on the "context" of that specific area (Montgomery 2004, Kondolf et al. 2003). Many restoration efforts fail (Kondolf et al. 2003) and management options (Naiman et al. 2012) are constrained because of the reliance on "off-the-shelf" and one-size-fits-all concepts and designs, rather than on an understanding of specific features and capabilities of the location of interest. Management prescriptions of Riparian Reserves should be tailored to the specific features and characteristics of the location of interest. There is variation in the potential of streams and stream reaches to provide habitat for different fish species based on the geomorphic setting of the stream or reach. This variation depends on the channel gradient and size, and the ratio of the valley width relative to the size of the active channel. Intrinsic potential (IP) is a measure of the capability of a given stream or stream segment to potentially provide suitable habitat for a given fish species

(Burnett et al. 2007). For Coho Salmon in western Oregon, medium-sized, low-gradient streams in wide valleys are the most productive; productivity declines as gradient increases and valley width declines.

The source of wood also varies within and among watersheds. Small, headwater streams can be important sources of wood in streams in the Oregon Coast Range (Reeves et al. 2003), which can be a key component of fish habitat in fish-bearing streams (Bigelow et al. 2007). The potential of a given stream to contribute wood varies widely, however (Benda and Dunne 1997a,b; Benda et al. 2004). The program NetMap (Benda et al. 2007) is capable of identifying the streams that are the most likely to provide sources of wood.

Modification of riparian vegetation can potentially influence water temperature as well as wood recruitment. However, other factors such as the orientation of the stream relative to the sun's path and topographic shading may also influence the potential for a stream to warm. These factors should be considered when assessing the potential management options for riparian areas on changes in stream temperature.

A key component of the ACS was watershed analysis (FEMAT 1993). This analysis was supposed to provide the context of a given location (Kondolf et al. 2003, Montgomery 2004) to justify adjustments of the boundaries and to provide for allowing activities within the Riparian Reserves. However, the original intent of watershed analysis was never realized because of a number of factors, including costs and the need to consider a multitude of species and their ecological requirements (Reeves et al. 2006).

Implementing a variable buffer approach

This approach recognizes the inherent variation in where ecological processes critical to aquatic habitats occur within a watershed, and in the inherent capacity of streams to provide habitat for selected fish species. A one tree-height buffer was maintained on all streams, but the type and extent of activities allowed within that boundary depends on the ecological context of the area. Site features include intrinsic potential (Burnett et al. 2007) for Coho Salmon and Steelhead, thermal loading potential, erosion potential, and the location of headwater streams relative to their potential to deliver wood to the location of interest. The most ecologically important or sensitive areas along fish-bearing streams in our analysis have Intrinsic Potential values >0.5 or are susceptible to warming or to erosion or have a high potential to deliver wood to fish-bearing streams. Less sensitive areas lacked all of these criteria. The most ecologically important or sensitive areas along non-fish-bearing streams have a high potential to deliver wood to fish-bearing streams. Partitioning the watershed into these categories with the particular value for each parameter along with the modified buffers and tree tipping requirements should ensure that ecological goals of the ACS are met on BLM lands.

NetMap (Benda et al. 2007) is an analysis platform that integrates a suite of numerical models and analysis tools to provide insights about the context of locations in a timely and cost-efficient manner, the way that watershed analysis was originally intended to be. It uses models that are available in the published scientific literature to identify selected watershed features, such as channel gradient, valley configuration, channel orientation, and landslide susceptibility, which can be used to establish the context of a location of interest. The focus is on understanding environmental variability, including ecological processes, in order to help diversify management options for the spatial scale of interest.

We used NetMap to identify and help evaluate these key features:

1) *Intrinsic potential* was determined by ranking a set of watershed attributes with a linear weighting scheme ranging from 0 to 1. Mean annual flow,

channel gradient, and floodplain width/channel width were assigned values for each stream segment. Intrinsic potential was derived from the geometric mean of the combination of the three attributes into a final ranking from 0 to 1 (Burnett et al. 2007). Stream reaches with an IP value of >0.5 were considered the most ecologically important. A value of 0.5-0.7 represents a moderate capacity for production and >0.7 is considered a high capacity. Because of the heightened concern about fish and fish habitat on BLM and other lands, we include reaches with high and moderate capacities to minimize potential adverse consequences.

2) *Susceptibility to erosion or debris flows* was based on four topographic attributes: 1) channel slope, 2) valley width or confinement, 3) angles of tributary junctions, and 4) cumulative length of scour and deposition. Values derived indicate the relative potential for debris flow movement through a reach. This model lacks a temporal component; therefore, values are relative to each individual watershed. For the purposes of this analysis, these values can be used to predict the relative susceptibility for direct debris flow impacts on the downstream fish habitat in each watershed. The upper quartile of all values for each watershed was used to estimate a high level of debris flow susceptibility; they were considered the most ecologically important. These particular streams are especially important as potential sources of wood for fish bearing streams during landslides and debris flows.

3) *Thermal loading potential* was used as the best proxy to calculate stream temperatures at the watershed scale. Parameters used within the NetMap model to determine direct beam and diffuse solar radiation include 1) topographic shading, 2) channel width, 3) aspect, 4) latitude, and 5) streamside vegetation height and density. In concert with ArcMap's solar radiation model, incoming diffuse, direct, and total radiation for every vertex in a stream network was calculated based on hourly intervals on July 20th (typically the hottest day of the

year). Thermal energy (watts/m^2) was calculated as the sum of all vertices for each reach for an entire day. Values were calculated for full canopy cover and vegetation density and compared to thermal values associated with regeneration harvests (i.e., clearcutting to the stream edge). Stream reach values were converted to a thermal percent change. Thermal loading potential was considered high if percent change values were above 10 percent. This estimate of the change in thermal loading is likely to be greater than what will occur with the implementation of either alternative because small streams still have no-harvest buffers along them. Therefore, it is a conservative estimate of stream segments that are susceptible to warming.

We evaluated each stream segment against these criteria; we placed fish-bearing stream segments into higher or lower importance categories and made a similar division on non-fish-bearing streams (Table 3). All stream segments receive a one tree-height buffer. Stream segments of higher importance continue the current prescription of the Northwest Forest Plan, with management focused solely on aquatic ecosystem goals. Lower importance stream segments have an inner buffer, which continues the prescriptions of the NWFP to achieve aquatic ecosystem goals, and an outer buffer which allows long-term timber production using ecological forestry principles (Table 2).

An inner buffer of 100 ft (30.5 m) was chosen for lower priority fish-bearing streams and 50 ft for lower priority non-fish-bearing streams. These choices were based on research of P. Anderson, PNW Research Station, showing that this distance reduces potential effects of harvest on water temperatures in small streams as discussed under Alternative A and also the recent work, mentioned above, that most amphibian use is within 50 ft of the stream.

Ecological forestry, including thinning and regeneration harvest, would be allowed in the outer buffer, and these acres could be part of the land base for long-term timber production. As noted earlier, regeneration harvest would be limited to previously harvested acres. If concerns still exist about the application of ecological forestry to the area beyond the 50 ft buffer on lower priority non-fish bearing stream segments in the Matrix of Moist Forests, strategic placement of aggregate retention patches during regeneration harvest could help ameliorate them. Positioning the 30 percent retention that is part of the Moist Forest prescription along the half-tree-height boundary would raise the effective buffer distance to at least 75 ft on those lower-priority stream segments.

Relative to maintain wood delivery processes, the non-fish bearing streams in the upper quartile of debris flow susceptibility will remain solely devoted to ecological goals. The other non-fish bearing streams will utilize a combination of an inner buffer, of at least 50 ft, devoted to ecological goals and an outer buffer managed under ecological forestry combined with tree tipping. Overall, this approach should ensure maintenance of wood delivery processes.

As discussed above under Alternative A, headwater streams may also serve as connection corridors within and between watersheds (Olson and Burnett 2009). Recent research by D. Olson, PNW Research Station, (unpublished) found that most amphibians moved along the stream within 45 ft (13.6 m) of the channel. Maintaining a one tree height buffer on non-fish bearing streams, with those in the upper quartile of debris flow susceptibility managed for ecological goals and the other non-fish bearing streams having an inner buffer of 50′ devoted to ecological goals and the outer buffer managed with ecological forestry using aggregate retention, should provide movement corridors for amphibians and other organisms within and between watersheds. In addition, providing for down wood on the forest floor, in the outer portion of the riparian buffer where ecological forestry will be allowed, can further reduce potential impacts on terrestrial salamanders (Rundio and Olson 2007).

In sum, changing the boundaries of the Riparian Reserves as described above for Alternative B will have minimal impacts on the ecological processes along these streams. Some would argue that assessing the consequences of such changes in the Riparian Reserve component on BLM managed lands would require consideration of changes in BLM management in the context of existing policies for FS and other lands of the area of the Northwest Forest Plan. For all the reasons described above, we expect the ecological consequences of this alternative for aquatic ecosystems should be minimal. As a result, we expect that the ACS would not be compromised or its effectiveness reduced with the implementation of this alternative.

Study Areas

We chose three watersheds to demonstrate these ideas: 1) Myrtle Creek, 2) Coquille, and 3) Smith-Siuslaw (Figures 1-6). As mentioned above, two of the watersheds were chosen because they contain Secretarial Pilot Projects (see Johnson and Franklin 2012 for more discussion of these pilots). The other (Smith/Siuslaw) was chosen because it had different geologic features and soil stability from the two Pilot watersheds. All three have importance as salmon habitat (Figures 2 and 3). Coquille and Smith/Siuslaw are located in Moist Forests, while Myrtle Creek has Moist Forests in upper portions and Dry Forests in the lower portion (Figure 4). In terms of land allocations, Coquille and Myrtle Creek are mostly in Matrix while Smith/Siuslaw has mostly Late-Successional Reserves (Figure 5). Not surprisingly, the pattern of Critical Habitat closely follows that of the Late-Successional Reserves in these watersheds, except that the top of Myrtle Creek Matrix (where the Secretarial Pilot projects are located) is now in Critical Habitat (Figure 6).

Simulating Alternative Riparian Buffers in the Study Watersheds

We did five analyses for each of our three study watersheds to create the two alternatives: 1) delineate the fish and non-fish bearing streams; 2) map current riparian policy on federal and private lands; 3) map Alternative A (assign fixed width buffers); 4) classify stream segments based on aquatic ecosystem importance; and 5) map Alternative B (assign buffers based on the stream classification). We describe the analyses below and illustrate them with the Myrtle Creek case study. We also provide a summary set of maps for the Coquille watershed and Smith/Siuslaw watershed in the main text, and maps reflecting the five analyses for these watersheds in Appendix A.

Analysis 1: Delineate the stream network and divide the streams into fish-bearing and non-fish-bearing

NetMap delineates the streams in the watershed using a "catchment basin" approach. In this case, the initiation size for a stream varied with slope (steeper areas required less area and a shorter stream length than less steep areas) and planform curvature (L. Benda, Earth Systems Institute, Mt. Shasta, CA., pers. communication). Based on our initial validation assessment (Appendix B), we believe that we somewhat underestimate the initiation points of headwater streams (they originate higher in the watershed than we indicate). This result would cause us to slightly underestimate the extent of the stream systems, largely in the non-fish-bearing streams.

Determination of fish-bearing and non-fish-bearing streams marks the beginning of the alternative buffer strategy analyses. We used a 10-meter Digital Elevation Model (DEM) to assess the stream network gradient for each study watershed. The fish-bearing stream network was calculated by using a channel gradient threshold. For this analysis, Steelhead and Coho Salmon were the key aquatic species of interest. We assigned a gradient threshold of 10 percent, which is the upper limit for the anadromous species and includes resident fish. Based on the gradient threshold assigned and the watershed DEM, we used NetMap to delineate both the fish- and non-fish-bearing portions of the stream network. Many watersheds contain artificial barriers such as dams; when fish distributions were known to be present above a fish blockage, the fish-bearing network was corrected to reflect this. Fish-bearing network determinations by NetMap were compared with BLM (Roseburg) *in situ* data and the datasets were found to differ by less than 1 percent. See Appendix A for a more detailed discussion of fish-bearing stream delineation validation work. See Figure 10a for stream delineation and our fish/no fish determination for Myrtle Creek and Appendix A for the same determination for Coquille and Smith/Siuslaw. Also, see Figures 11, 12, and 13 for zoomed-in views of the stream system on federal lands in a selected area of each watershed.

Analysis 2: Simulate current riparian policy

The NWFP calls for "interim" buffers of two site-potential trees along each side of fish-bearing streams and one site-potential tree along each side of non-fish-bearing streams, with a minimum width of 300 feet (91.4 m) on each side of fish-bearing streams and 150 feet (45.7 m) on each side of non-fish-bearing streams. On BLM Moist Forests in our study, a site-potential tree height varies from 160 to 220 feet (48.7 – 67.1 m). Thus, buffers vary from 320-440 feet (97.5 – 134.2 m) on each side of a fish stream and 160-220 (48.7 – 67.1 m) feet on each side of a non-fish stream (Table 4).

For perspective, we simulate buffer widths under the Oregon Forest Practice rules for private lands. Those rules specify different maximum sizes of buffers based on rate of streamflow[8] and whether a stream potentially has fish (Table 5). Within that maximum buffer width for a particular stream type, a specified level of tree basal area must be achieved before trees can be removed. If that target basal area can be achieved in less area than the maximum width, the buffer can be reduced to a minimum of 20 feet (6.1 m) from the stream. On private lands in our study watersheds, we found approximately 6 percent of the forest within the maximum buffer widths, on average. This result is similar to that found in the Oregon Coast Range in other studies (Johnson, et al. 2007). Over the last 15 years, the Oregon Forest Practice Rules have come under criticism relative to their potential to protect aquatic ecosystems and habitat, in part because of the lack of tree buffers on non-fish-bearing streams of the Oregon Coast and the Western Cascades (Botkin et al. 1995, IMST 1999) and inadequate temperature control (State of Oregon Department of Forestry 2011). However, they help to provide a policy context for our discussions. See Figure 10b for our simulation of current riparian policy for federal and private lands for Myrtle Creek, and Appendix A for the same simulation for Coquille and Smith/Siuslaw. Also, see Figures 11, 12, and 13 for zoomed-in views of current riparian policy on federal lands in a selected area of each watershed.

Analysis 3: Simulate Alternative A—One tree-height buffers on fish-bearing and non-fish-bearing streams

[8] NetMap calculates the mean annual flow based on a combination of landscape specific PRISM climate data and watershed-specific regression equations. For Oregon Coast specific watershed regression equations see Clarke et al. 2008.

As described above, Alternative A reduces stream buffers in the BLM Matrix lands to one site-potential tree height on fish bearing streams and retains the full one tree-height buffer on non-fish-bearing streams. The stream buffer on fish-bearing streams and the inner half of the buffer on non-fish-bearing streams would be managed for aquatic ecosystem goals in a manner similar to the existing strategy for Riparian Reserves in the Northwest Forest Plan. The outer buffer on non-fish-bearing streams would be managed for both aquatic ecosystem goals and timber production using ecological forestry as described above (See Table 2 for the Moist Forest prescriptions that could be considered within the outer half of the stream buffer on non-fish-bearing streams).

See Figure 10c for application of Alternative A to Myrtle Creek, and Appendix A for the same simulation for Coquille and Smith/Siuslaw. Also, see Figures 11, 12, and 13 for zoomed-in views of Alternative A on federal lands in a selected area of each watershed.

Analysis 4: Identify the aquatic importance of each fish- and non-fish-bearing stream segment for Alternative B.

The criteria for identifying the management class for each steam segment (Table 3) were applied in each sample watershed by classifying each segment into one of four categories based on whether they were a fish-bearing or non-fish-bearing stream segment, and their ecological importance. See Figure 10d for this stream segment delineation for Myrtle Creek, and Appendix A for the same delineation for Coquille and Smith/Siuslaw.

Analysis 5: Simulate Alternative B—Apply variable-width buffers to stream segments based on aquatic ecosystem importance

The size of stream buffers for all streams was a full tree height, but area devoted solely to achieving ecological goals varied with ecological importance. Higher-priority stream segments in fish- and non-fish-bearing streams continue the current approach of the Northwest Forest Plan, which focuses solely on aquatic ecosystem goals in the entire Riparian Reserve. Lower-priority stream segments have an inner buffer, which continues the current approach of the Northwest Forest Plan to achieve aquatic ecosystem goals, and an outer buffer that allows long-term timber production, using ecological forestry principles as its goals. An inner buffer of 100 ft (30.5 m) was used for lower-priority fish-bearing streams and 50 ft (15.2 m) for lower-priority non-fish-bearing streams. (See Alternative B of Table 2 for more details for Moist Forests).

See Figure 10e for the buffer delineation for Alternative B to Myrtle Creek, and Appendix A for the same delineation for Coquille and Smith/Siuslaw. Also, see Figures 11, 12, and 13 for zoomed-in views of Alternative B on federal lands in a selected area of each watershed.

Proportion of the Matrix in Stream Buffers

Both of the alternatives we modeled reduce the amount of area in stream buffers in Matrix; the actual amount varies by watershed (Figure 14). Total area in Matrix buffers is 18 to 23 percent lower under Alternatives A and B, depending on watershed, as compared to current policy. That reduction is the consequence of reducing the size of the Riparian Reserves from two site-potential tree heights to one on fish-bearing streams.

Under both alternatives, the forest in this second tree height in BLM Matrix is no longer in the riparian buffer, and management would default to the terrestrial prescription. On the BLM Moist Forests Matrix allocations under the

Northwest Forest Plan (the focus here), rotations of 80 to 100 years would be likely. At regeneration harvest, distributed retention of 10 to 20 percent would be employed depending on location (US FS and US BLM 1994). Given the recommendations in the new Northern Spotted Owl Recovery Plan (US FWS 2011) and other considerations, it is unlikely that much mature and old growth will be harvested in these areas, i.e., harvest would most likely be restricted, in general, to previously harvested acres as we recommend in the ecological forestry prescriptions (Table 2).

Alternatives A and B have a one-tree height buffer on all streams in Matrix, with that buffer divided between an inner buffer devoted solely to achieving aquatic ecosystem goals and an outer buffer that has both aquatic ecosystem goals and timber production goals. Regarding the outer buffer in Alternatives A and B that would serve both aquatic ecosystems goals and timber production goals(Figure 14), two points should be made: 1) most of this area in the outer buffer is along non-fish-bearing steams (division between fish/non-fish bearing streams in gold portion of Figure 14) and 2) timber production goals are recognized only in Matrix stands on previously harvested acres of this outer buffer. We also simulated the maximum area in stream buffers assuming that Oregon forest practice rules were applied to the Matrix in each watershed (Figure 14). Due to the higher proportion of non-fish streams on federal land as compared to private lands, the percentage of the Matrix in these buffers is less than that found on private lands. In all cases, the area allocated solely to aquatic ecosystem goals under Alternatives A and B is at least four times the maximum size of requirements in the Oregon forest practice rules, and the total area in buffers under Alternatives A and B is at least seven times the maximum size required by those rules.

The Distribution of Stream Category and Stream Importance by Landowner

The distribution of stream segments between higher and lower priority for both fish-bearing and non-fish-bearing streams for different landowners (Figures 15-17) illustrates the importance of location in the watershed for stream category and stream priority. Where private landowners control the lower elevations, such as Myrtle Creek (Figure 15), they tend to have higher proportions of their streams in the higher priorities and a higher proportion of fish-bearing streams than do federal lands that are located at higher elevations. On the other hand, when federal and private lands are more intermingled, as in Coquille and Smith-Siuslaw (Figures 16 and 17), the differences between land owners are not as great.

The results suggest that many miles of higher-priority fish-bearing and non-fish-bearing streams occur on private lands. This argues strongly for a "whole watershed" or "all lands" approach to aquatic ecosystem conservation.

These results are associated, in part, with a specific set of parameter values for our classification variables (See Table 3). Also, only one variable needs to be in the higher priority classification for the stream segment to be considered high priority. We justified our threshold values earlier in this paper, but initial sensitivity analysis does suggest that the choice of other threshold values can affect, somewhat, the segments classified as high priority. Also, policy makers may wish to set the thresholds differently on federal land as compared to private land. We recommend that more research be undertaken to refine the results shown here. However, we do not expect that this sensitivity analysis will fundamentally change the conclusions reached in this paper.

Finally, it must be noted that our goal in this paper is to illustrate the implications of Alternatives A and B for management of the BLM Matrix. We show BLM LSR, Forest Service Matrix and LSR, and private land stream-priority distributions (Figures 15-17) for completeness.

Magnitude of These Potential Changes[9]

How extensive would the changes be in stream buffers if these alternatives were adopted for the BLM Matrix forests in western Oregon? In this discussion, we will focus on Moist Forests where the ideas discussed in this paper would probably be most controversial. Approximately 45 percent of the 1.4 million acres of BLM Moist Forests in western Oregon (or 630,000 acres) lies within two tree heights of fish-bearing streams and one tree height of non-fish-bearing streams, considering all land allocations. We estimate that slightly more than 100,000 of those acres (perhaps 130,000 acres) are currently in Riparian Reserves in Matrix outside of Critical Habitat and other restrictions in previously harvested acres—the focus of discussions here about increasing the land base for long-term timber production. Based on our analysis reported above (Figure 14), 45 to 65 percent of those acres (60,000-85,000 acres), could be shifted into that land base, depending on the alternative chosen and the watershed being considered. These acres would serve both ecological goals and wood production goals. This represents approximately 10 to 13 percent of the forest within two tree heights of fish-bearing streams and one tree height of non-fish-bearing streams on BLM Moist Forests in western Oregon, with that acreage coming from the outer portions of the current buffers (Figure 18).

How much of this forest might be harvested in ways that would create openings through regeneration harvest during the "normal" life of a forest plan (about 10 years)? Sustained yield plans for the BLM generally have rotation ages

[9] BLM acreage estimates discussed here come from Johnson and Franklin (2013). National forest estimates come from Johnson and Franklin (2009).

of 70 to 80 years based on the growth-maximizing rotation age that helps maximize the sustained yield level. The ecological forestry prescriptions of Franklin and Johnson (2012) described above call for rotation ages of 100 to 160 years. Assuming an average rotation of 100 years, an average of one percent of the land base would be harvested per year or one-tenth over the first decade. Thus, implementing this plan for a *decade* could result in openings being created on approximately one percent of BLM Moist Forest in western Oregon within two tree heights of a fish-bearing stream or one tree height of a non-fish-bearing stream. Even with somewhat higher rates of regeneration harvest, not more than two percent of this forest would have openings created in the first decade. With the inclusion of an effective monitoring and adaptive management plan, any adjustments needed could be made during the next planning cycle.

BLM manages approximately 25 percent of the Moist Forest on federal lands in western Oregon, with the Forest Service managing the rest. Considering Moist Forest within two tree heights of fish-bearing streams and one-tree height of non-fish-bearing streams on all federal forests in western Oregon, adoption of Alternative A or B for the BLM Matrix would affect management of approximately 2-3 percent of that area. If these alternatives were also adopted for previously harvested acres in the Matrix on the national forests in western Oregon, we expect that they could affect the management of approximately 10 to 13 percent of the total area within two tree heights of a fish-bearing stream and one tree height of a non-fish-bearing stream.

Potential Impacts on Terrestrial Wildlife

Many terrestrial species use the area near streams for at least part of their lives, as acknowledged in FEMAT (1993) and the documents associated with the Northwest Forest Plan (USFS and USBLM 1994). These documents discuss the "size" of the riparian reserves as being important for some mammals and amphibians, and the FEMAT summary (p. II-31) describes Riparian Reserves serving as dispersal habitat for the Northern Spotted Owl. There is also reference to riparian reserves being important for connecting LSR for organisms with limited dispersal capabilities (e.g., fungi, plants, flightless insects, amphibians, mollusks) (p. IV-187) and a paragraph in the aquatic section (p. V-34) that describes the importance of Riparian Reserves as travel and dispersal corridors for terrestrial animals and plants. Thus, potential changes to riparian policy need to consider the effect on these organisms. Again, we focus on Moist Forests and associated regeneration harvest under Alternatives A or B.

We argue that, generally, the effects of adopting either Alternative A or Alternative B will be minimal for five reasons:

1. Much of the evaluation of effects of different management options on species in development of the Northwest Plan centered on harvest of mature and old-growth stands (FEMAT 1993). For a number of reasons, including the recommendations in the new Northern Spotted Owl recovery plan and the prescriptions associated with ecological forestry, it is unlikely that harvest of these stands would occur to any significant degree.
2. A sizeable majority of forest within two site-potential trees of fish-bearing streams or one site-potential tree of non-fish-bearing streams would be unaffected by adoption of Alternative A or B (Figure 18).
3. The use of ecological forestry within one tree height of both fish-bearing streams and non-fish-bearing streams under Alternatives A and B includes aggregate retention patches that can be placed to aid dispersal of organisms with low dispersal capabilities.

4. The recent Northern Spotted Owl Recovery Plan and Critical Habitat analysis and rule did not single out these stream buffers in Matrix for spotted owl habitat. Rather, those plans, analyses, and rules focused more on retention of mature and old forest wherever it occurs and also some young forest near historic spotted owl nests.
5. While the forest near streams on federal land has been highlighted as potential wildlife corridors for some species, the fragmented (often checkerboard) nature of the BLM Western Oregon Forests makes it difficult to maintain continuous stream-side forest across the landscape no matter what management policies are chosen for these lands.

In sum, the adoption of Alternatives A or B should have minimal impacts on wildlife conservation and dispersal.

Discussion and Conclusions

A number of summary points and conclusions emerge from this analysis: Alternatives exist to the current implementation of the ACS, relative to stream buffer size and placement, which reduce area in buffers needed to meet the goals of the ACS. This is an important conclusion for the ongoing search for ways to increase timber harvest and associated revenue from these lands.

- One alternative has fixed buffer widths and one has variable widths based on stream segment importance; the variable-width buffer is better for both fish and timber harvest because it enables managers to target where buffers will do the most good for fish while increasing the proportion of the buffer that also has timber production goals. However, the variable-width buffer approach will require more analysis to be successful.

- Both alternatives utilize "tree tipping" to ensure that thinning within buffers does not negatively affect the amount of wood falling into the stream. This emergence of this tool can increase the compatibility of timber harvest and aquatic goals throughout the area of the Northwest Forest Plan.

- Under the alternatives, approximately 35-55 percent of the area in Riparian Reserves under current implementation of the ACS would still be devoted solely to achieving the ecological goals of the ACS. The other portion of the Riparian Reserves contributes to ecological goals while providing opportunities for long-term timber production, with harvest generally limited to previously harvested acres (generally stands less than 80 years of age) under current law, regulation, and policy.

- The models in NetMap make it possible to identify the most important stream segments for aquatic ecosystem conservation. Since many of these stream segments are on private lands (Figures 15-17), a single-minded focus on riparian buffers on federal lands will not be sufficient to recover ESA listed fish populations. Careful consideration of higher-importance stream segments on private lands will also be needed.

- This analysis can potentially be useful to Watershed Councils and others in identifying where to put resources aimed at protection and restoration of aquatic ecosystems. The NetMap analysis can also help systematize land exchanges between private landowners and the BLM that contribute to watershed conservation.

- It would be relatively inexpensive to expand this type of analysis to all forested watersheds in western Oregon and western Washington.

- We intend this paper to assist in development and analysis of policy alternatives. If used in on-the-ground management, our classification of higher and lower steam segments would need field validation.

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Tables

Table 1. Percent difference in the volume of in-channel wood between an unmanaged stand and one in which varying percentages of trees were directionally felled or tipped into the stream channel. The width of the modeled stand was equal to the **height of one site-potential tree**. The stand was thinned from 400 to 90 trees/acre (162 to 36 trees/hectare), and there were two entries (year 2015 and year 2045). Wood input was predicted from only one bank over a hundred years. (from: S. Litshert, Earth Systems Institute, Mt. Shasta, CA.)

Percent of trees felled or tripped into the stream	Time period (simulation year) when wood volume production curves for treated and untreated trajectories cross.	Percent difference in total volume of instream wood produced relative to the unmanaged stand
Manage, no tip	N/A	-43
5	2055-60	-17
10	2065-70	-4
15	2070-75	7
20	2075-80	14
25	2080-85	18

Table 2. Summary of forest management prescriptions for Moist Forest riparian buffer alternatives consistent with the Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan.

	Fish-bearing streams		Non-fish-bearing streams	
Strategy	**Buffer width**	**Prescriptions considered for buffer**	**Buffer width**	**Prescriptions considered for stream buffer**
Current policy	Two site-potential tree heights	Thinning in stands less than 80 years of age to advance ACS	One site-potential tree height	Thinning in stands less than 80 years of age to advance ACS
Alt. A	One site-potential tree height	Thinning in stands less than 80 years of age to advance ACS, including directionally felling part of the harvest toward the stream channel	One site-potential tree height	*Inner buffer of ½ site-potential tree height*: Thinning in stands less than 80 years of age to advance ACS, including directionally felling part of the harvest toward the stream channel *Outer buffer: From inner buffer to one site-potential tree height:* Prescription depends on the terrestrial land allocation: In LSRs, prescription is unchanged. In Matrix, thinning and regeneration harvest allowed *on previously-harvested acres* using ecological forestry principles as a component of long-term timber production, with part of the harvest directionally felled toward the stream channel.
Alt. B: Higher priority stream segments	One site potential tree height	Thinning in stands less than 80 years of age to advance ACS, including directionally felling part of the harvest toward the stream channel	One site potential tree height	Thinning in stands less than 80 years of age to advance ACS, including directionally felling part of the harvest toward the stream channel
Alt. B: Lower priority	One site potential tree	*Inner buffer of 100 ft*: Thinning in stands less than 80 years of age to	One site potential tree	*Inner buffer of 50 ft*: Thinning in stands less than 80 years of age to advance ACS,

stream segments	height	advance ACS, including directionally felling part of the harvest toward the stream channel *Outer buffer from 100 ft to site-potential tree height:* prescription depends on the terrestrial land allocation: In LSRs, thinning is allowed following the LSR prescriptions in the NWFP. In Matrix thinning and regeneration harvest allowed using ecological forestry principles as a component of long-term timber production.	height	including directionally felling part of the harvest toward the stream channel *Outer buffer from 50 ft to site-potential tree height:* Prescription depends on the terrestrial land allocation: In LSRs, prescription is unchanged. In Matrix, thinning and regeneration harvest allowed *on previously harvested acres* using ecological forestry principles as a component of long-term timber production, with part of the harvest directionally felled toward the stream channel.

Table 3. Criteria for identifying management class for each stream segment based on aquatic ecosystem importance (Management classes 1 and 3 = higher priority; Management classes 2 and 4 = lower priority)

Management Class	Ecological Context Areas	Priority
	Fish-bearing streams	
1	Intrinsic potential for any species >0.5 OR >10% increase in thermal loading potential OR High potential of wood delivery from streamside riparian zone OR Med-high erosion potential from adjacent upslope areas	higher
2	IP (<0.5) for all species OR <10% increase in thermal loading potential OR Low-med wood delivery potential from streamside riparian zone OR Low erosion potential	lower
	Non-fish-bearing streams	
3	Med-high probability of delivering to a med-high reach OR a reach immediately adjacent to	higher

	a med-high IP reach	
4	Low probability of delivering to a fish-bearing stream	lower

Management Class	Ecological Context Areas Fish-bearing Streams
1	Intrinsic potential for any species >0.5 OR >10% increase in thermal loading potential OR High potential of wood delivery from streamside riparian zone OR Med-high erosion potential from adjacent upslope areas
2	IP (<0.5) for all species OR <10% increase in thermal loading potential OR Low-med wood delivery potential from streamside riparian zone OR Low erosion potential

	Non-fish-bearing Streams
3	Med-High probability of delivering to a med-high reach OR a reach immediately adjacent to a med-high IP reach
4	Low probability of delivering to a fish-bearing stream

Table 4. Site-potential tree heights and Riparian Reserve widths in study watersheds

Watershed	Site-potential tree height (ft)	Width of Riparian Reserve each side of stream (ft)	
		fish-bearing	non-fish-bearing
Myrtle Creek	160	320	160
Coquille	210	420	210
Smith-Siuslaw	220	440	220

Table 5. Stream buffer maximum widths on private lands under the Oregon Forest Practice Rules for the Oregon Coast and western Cascades. Minimum width is 20′ on large streams. Actual width depends on width needed to meet targets for conifer retention.

Stream size (average annual flow)	Maximum width of stream buffer (feet)	
	Fish-bearing	Non-fish-bearing
Small (0-2 cfs)	50	None
Medium (2-10 cfs)	70	50
Large (>10 cfs)	100	70

Appendix A

Simulation maps for Coquille and Smith Siuslaw (see Figures)

Appendix B

NetMap Validation

In an attempt to validate the accuracy of NetMap modeled stream networks, we compared our results to BLM field observations and current Oregon Department of Forestry (ODF) stream layers. Jonas Parker, a BLM hydrologist, recently created two small datasets of field-verified stream networks within the Siuslaw/Smith and Myrtle Creek watersheds. While small in area, these two datasets were completely validated by field observations. Additionally, the ODF surveys portions of stream networks when permitting activities to occur adjacent to streams. They maintain a working dataset of the stream reaches surveyed. Taken together, these datasets provide an opportunity to compare NetMap stream networks with recent field observations to determine the strengths and weaknesses of the current model.

The BLM's original stream layer was derived from a previous version of NetMap provided to the agency by Earth Systems Institute (Mt. Shasta, California). Upon comparison of the updated field network, the original corporate BLM layer initially provided models too many small streams and portrays stream initiation points higher up the channel than the surveyed data. Comparatively, the current NetMap model typically has its stream initiation points lower in the channel than the surveyed stream reaches. At times, the current NetMap models stream segments that were shown not to exist in surveys; conversely, in other portions of the network, NetMap stream networks failed to model some small streams found during the field verification. Due to inconsistencies between NetMap and the field-verified stream datasets, it is difficult to ascertain a quantitative metric that is unbiased. Therefore it is unclear whether the current NetMap is under- or overestimating the miles of field-verified streams. We submit, upon visual inspection, that, in aggregate, the current NetMap is slightly underestimating total miles of small streams in this comparison. Furthermore, we compared the fish-bearing determinations between the current NetMap and field-verified data. Fish-bearing portions of the network were determined to be highly consistent between datasets. While a small amount of variation exists between the two, in general, NetMap's modeling is very accurate at predicting larger, mainstem stream reaches and determining the theoretical presence of fish.

Current NetMap stream networks were also compared to ODF stream data. Similar to the BLM, the ODF uses the same, somewhat outdated, stream network provided by Earth Systems Institute. The ODF is primarily concerned with fish-bearing portions of the network only, therefore, if a field technician determines a stream reach to be non-fish-bearing, the ODF assumes that there is no fish presence in the stream network above the surveyed point. ODF considers only game fish (anadromous and resident) and does not survey stream reaches beyond their initial no-fish determination. Field technicians were given instructions to identify barriers or obstacles within the stream network and assume no fish presence above that point. Often, resident fish have been found to occupy areas upstream of barriers or obstacles.

Most of the field verification work done by the ODF was completed prior to 2007, as significant budget constraints drastically reduced field verifications the following year. Prior to 2007, the ODF evaluated stream networks based on actual fish presence and made their fish/no fish stream determinations based on electroshocking results. Beginning in 2008, the ODF altered their criteria for determining fish networks to a potential presence and moved modeling methods similar to those used in the current NetMap due to their constraints on sending technicians into the field for verification.

Given the inaccuracies demonstrated between the corporate layer and the BLM field-verification work on small, non-fish-bearing streams, comparing these reaches between our current model and ODF is unrealistic. Thus, we have limited our comparisons to fish-bearing portions of the stream network. In general, our current NetMap model was found to overestimate fish-bearing portions of the network. Within the ODF verified fish streams, the two datasets were found to be roughly 90 percent in congruence, but our model includes many reaches determined as fish-bearing that ODF designates as non-fish-bearing in their stream network.

Generally, our validation work has demonstrated that the current NetMap stream networks are highly accurate in the fish-bearing portions of the stream network. Where some variation exists is typically higher in the watershed when evaluating small streams. Delineation of stream networks has been proven to be highly variable among national and state agencies, primarily due to inconsistencies with original base data. Currently, digital elevation models are the standard for modeling stream networks, and there much variation exists among digital orthoquads. That being said, we contend that our current model is the best representation of stream networks in our study areas, given the status of current computation abilities.

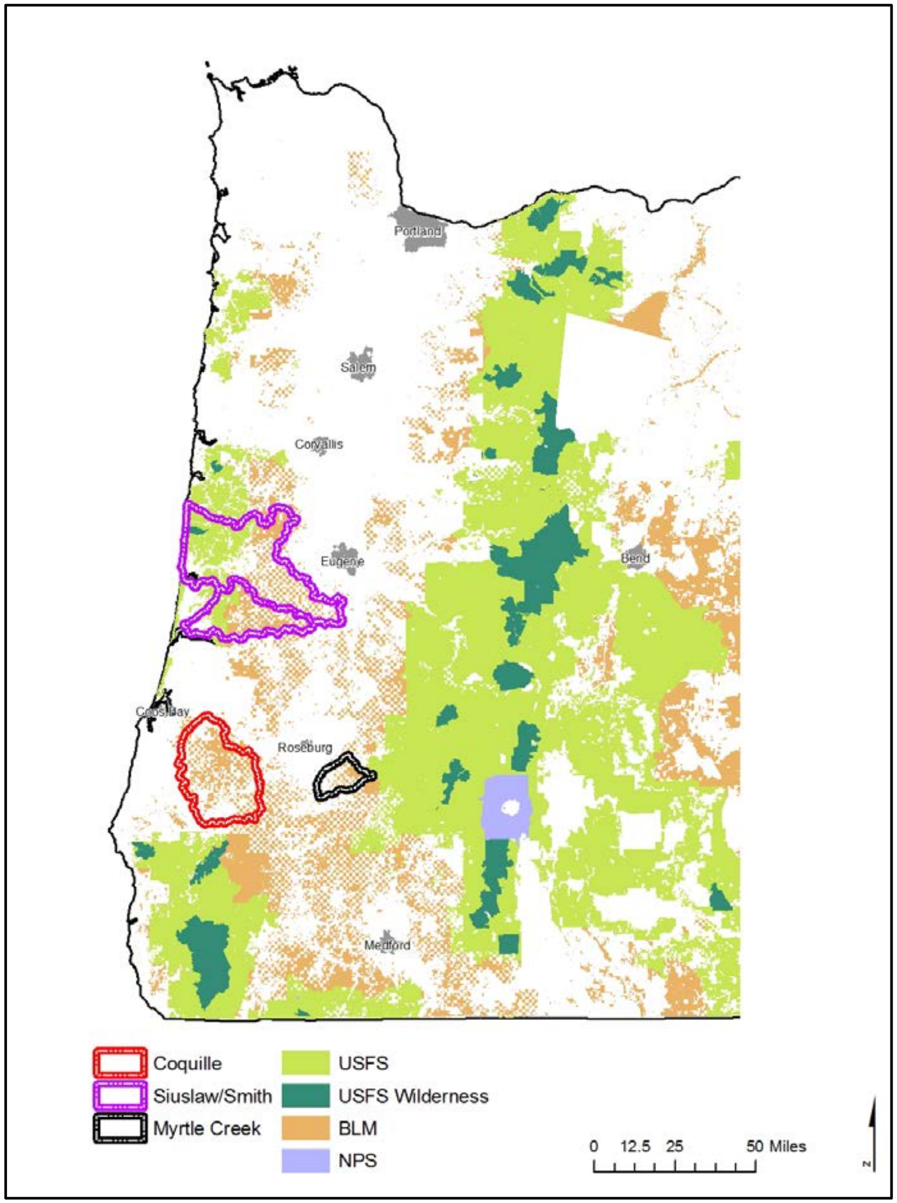


Figure 1. Land ownership with three study watersheds highlighted.

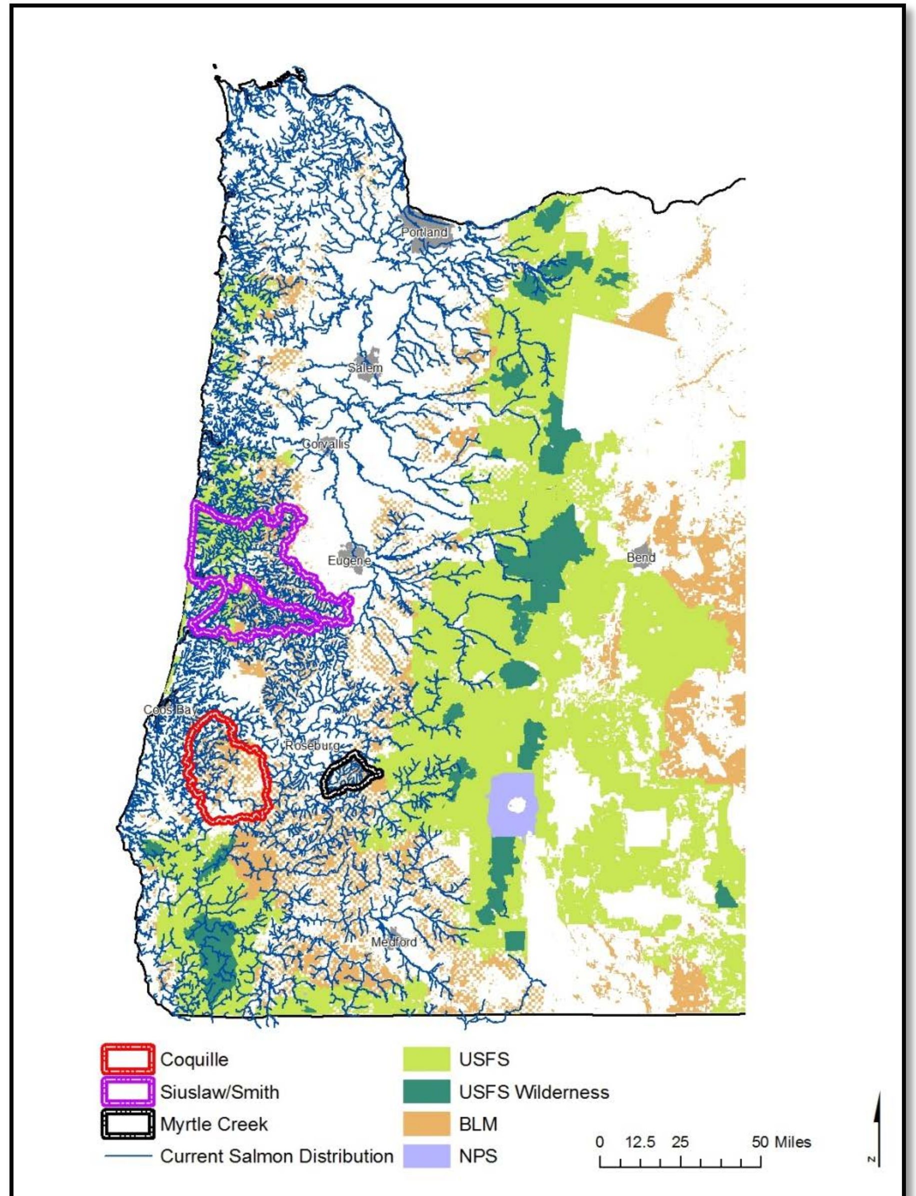


Figure 2. Current salmon distribution in western Oregon shown over land ownership with three study watersheds highlighted. Source: TNC and WSC (2012)

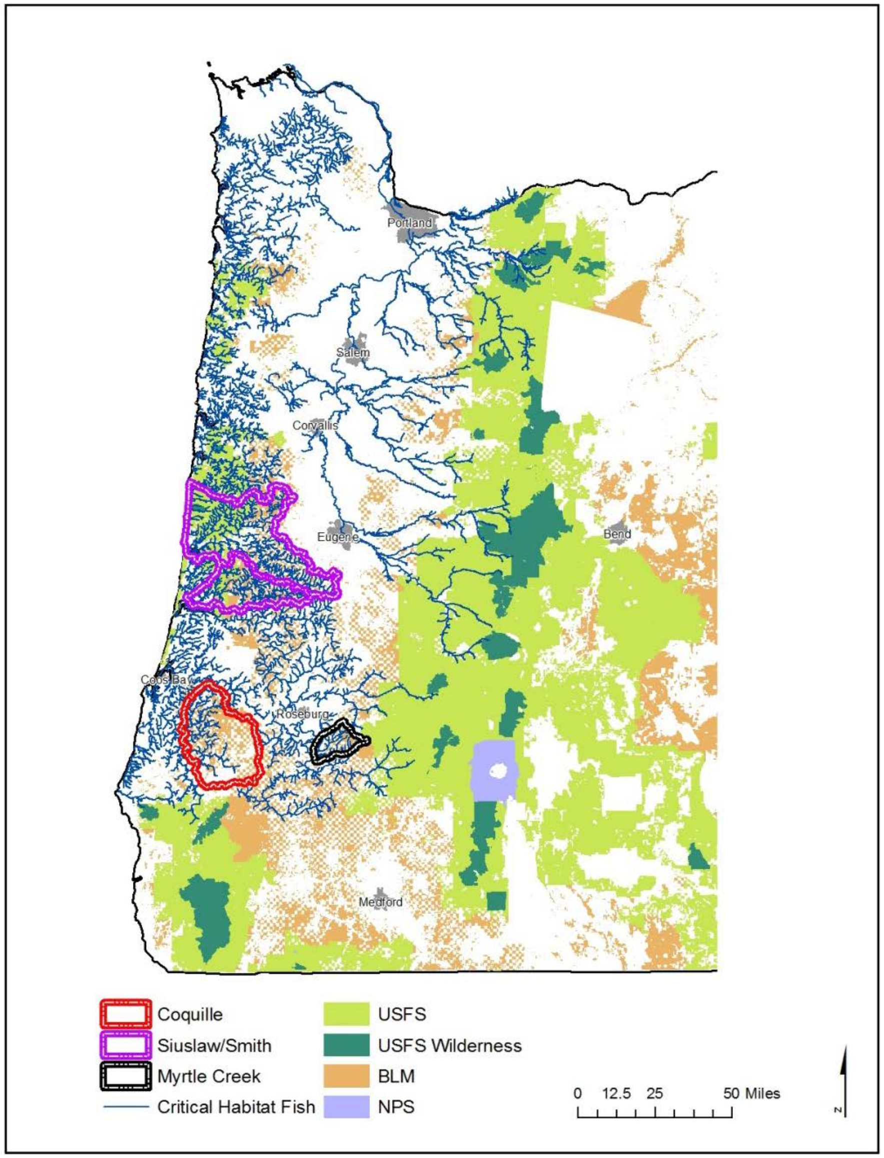


Figure 3. Critical habitat for the western Oregon Coast Coho Evolutionary Significant Unit (ESU) with three watersheds highlighted. Critical habitat for coho salmon in southwest Oregon is in a different ESU and not shown.

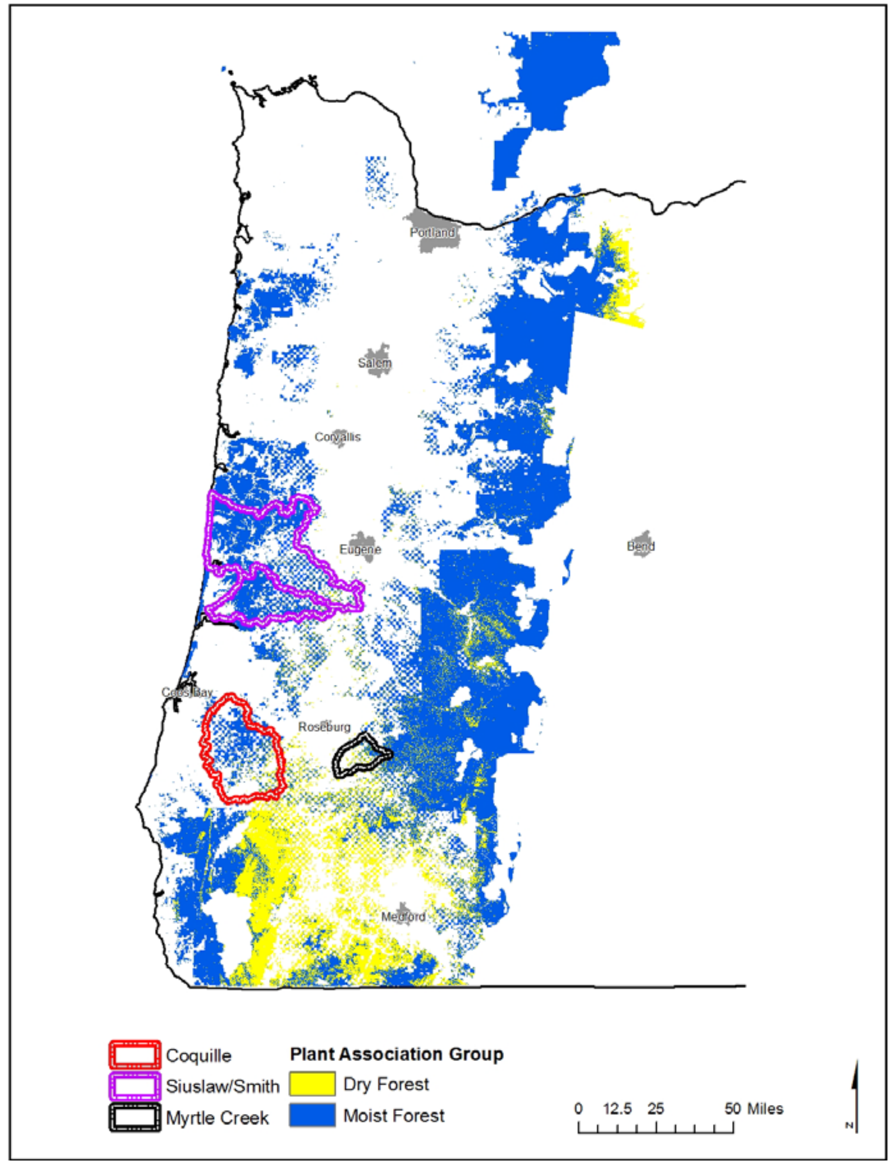


Figure 4. Moist and Dry Forests (Franklin and Johnson 2012) with three watersheds highlighted.

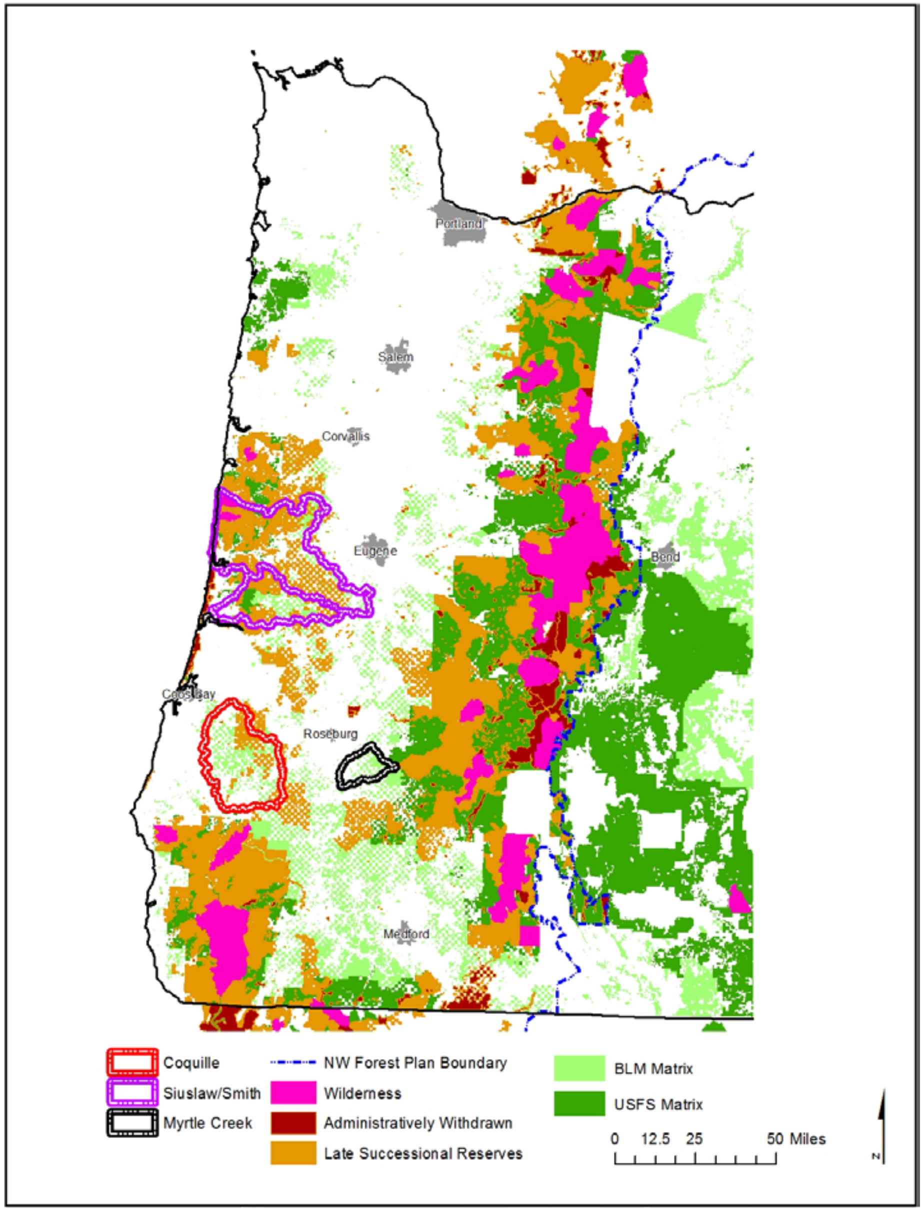


Figure 5. NWFP land allocations with the three study watersheds highlighted for Oregon.

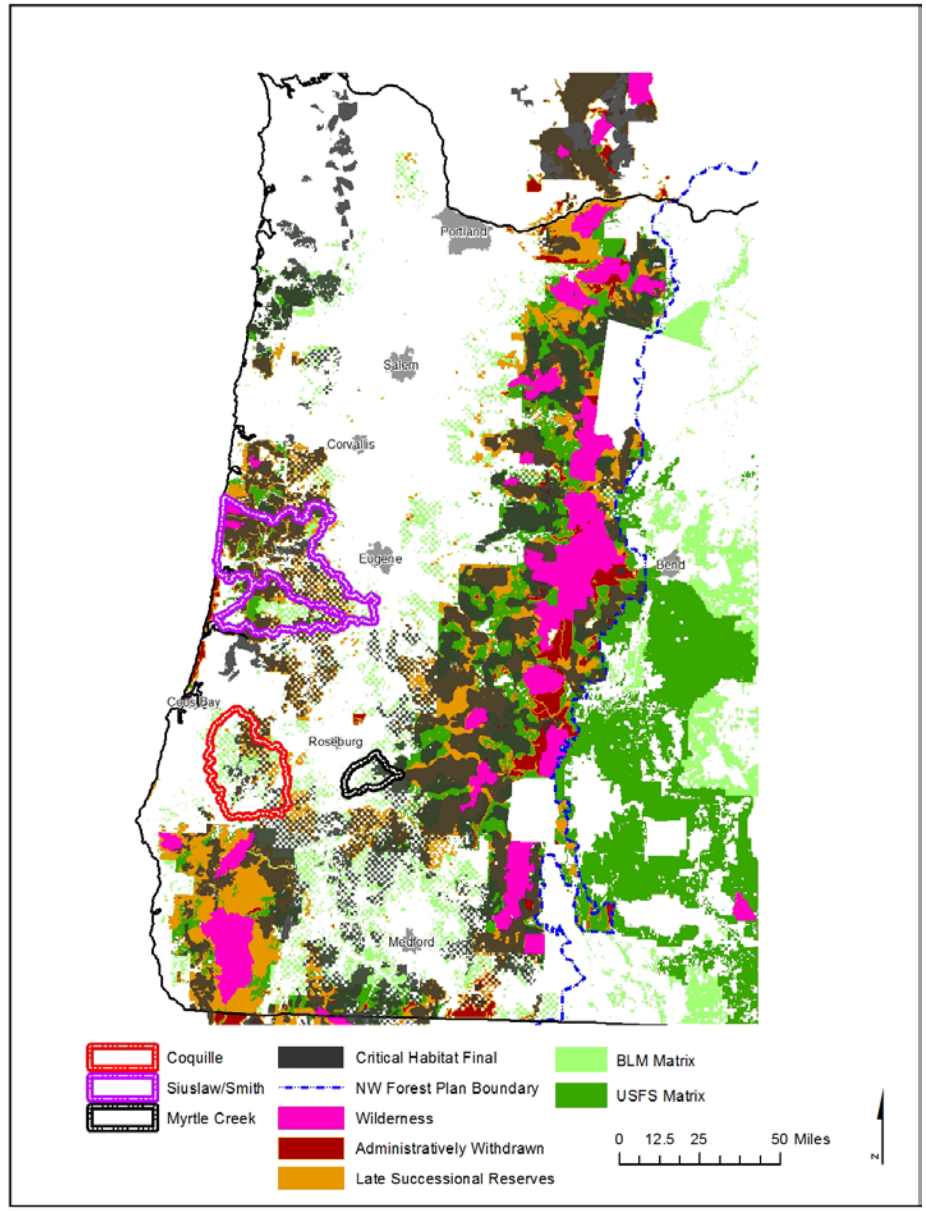


Figure 6. Northern Spotted Owl Critical Habitat for Oregon over NWFP land allocations with three watersheds highlighted. Source: USFWS (2012)

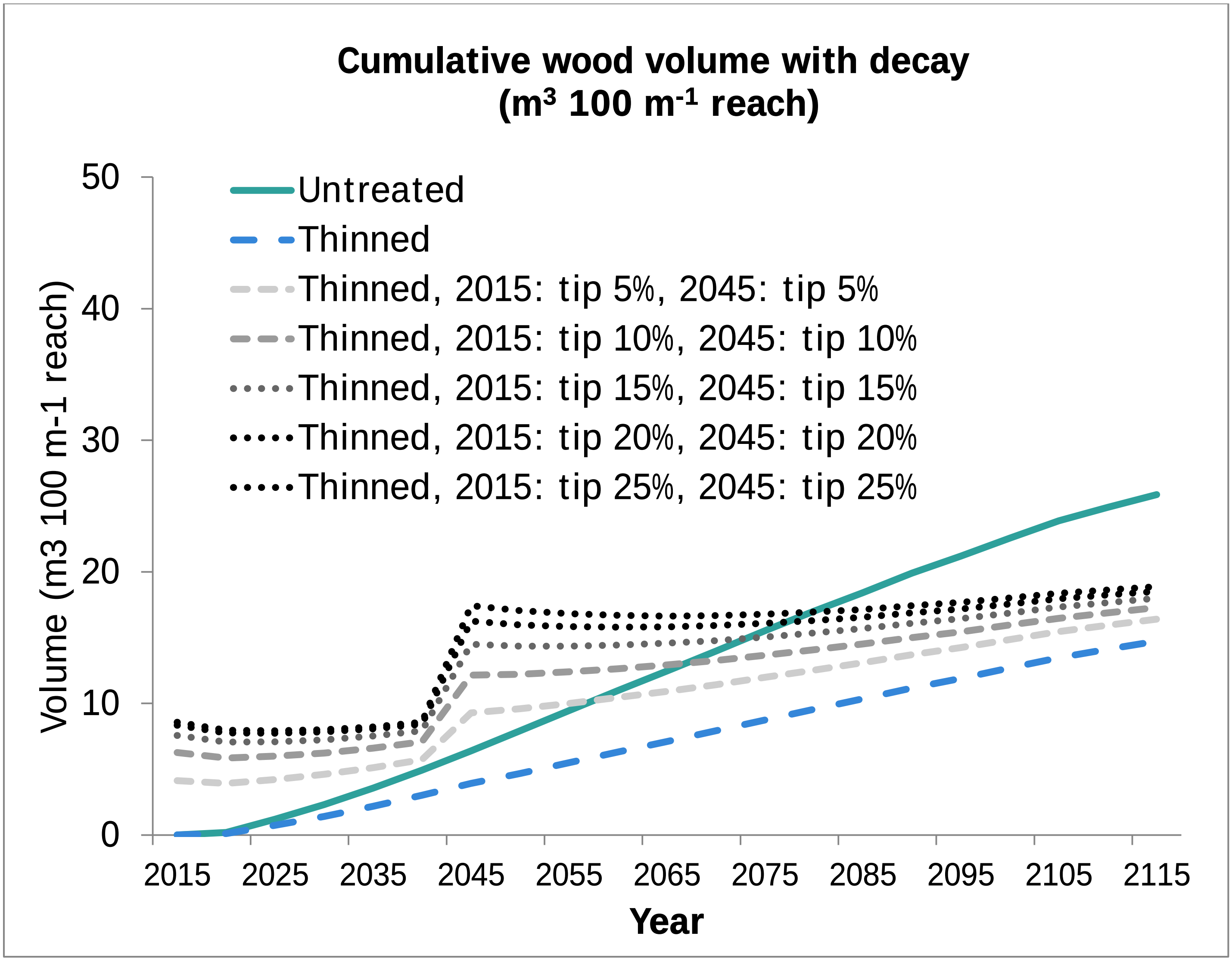


Figure 7.Estimated volume of wood (area under curve) that would be delivered to a stream from riparian stands that were thinned from 400 to 90 trees/acre with two entries (year 2015 and year 2045) with varying percentages of the removed volume being felled or placed in the stream. Wood input was predicted from only one bank over a hundred years. (from: S. Litshert, Earth Systems Institute, Mt. Shasta, CA)

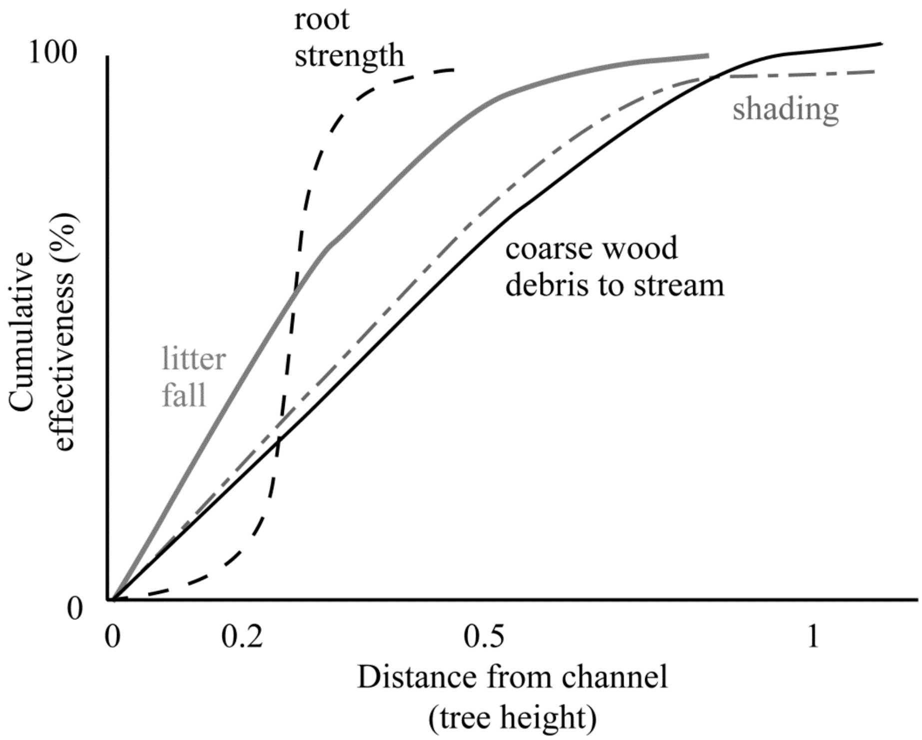


Figure 8a. Relation of distance from stream channel to cumulative effectiveness of riparian ecological functions. (from: FEMAT 1993, V-27)

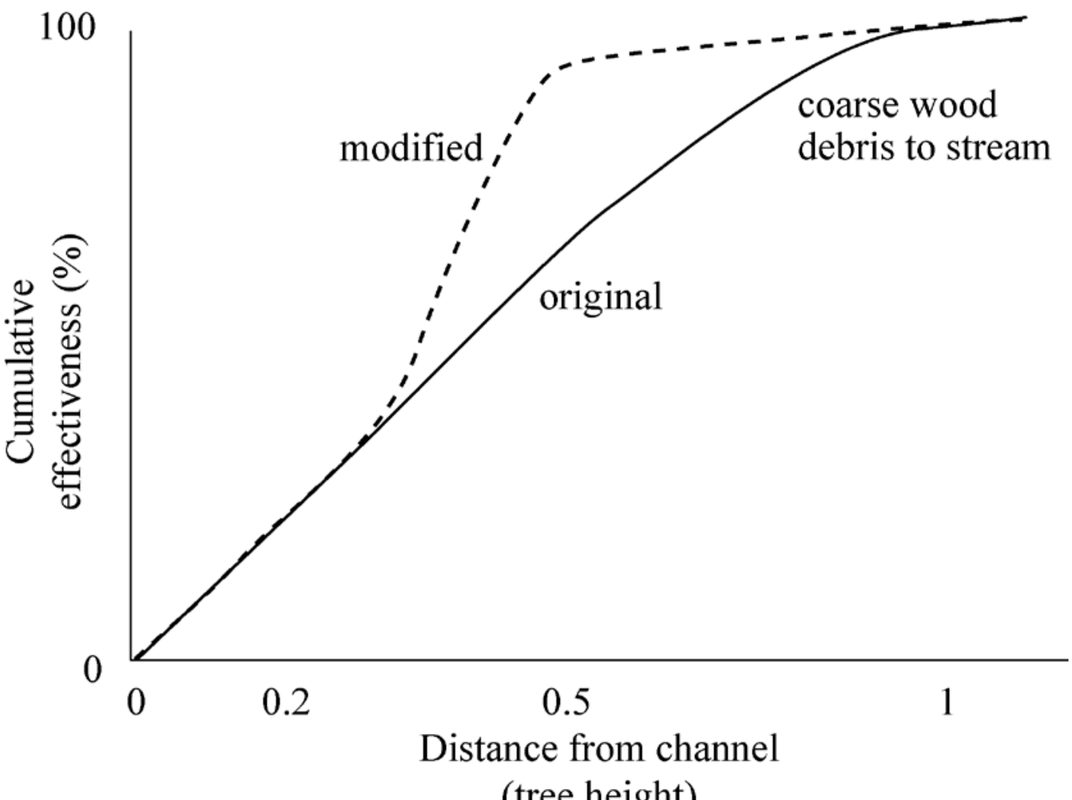


Figure 8b. Modified effectiveness curve for wood delivery to streams as a function of distance from the stream channel. The curve was changed based on scientific literature developed since the curve was originally portrayed in FEMAT (1993).

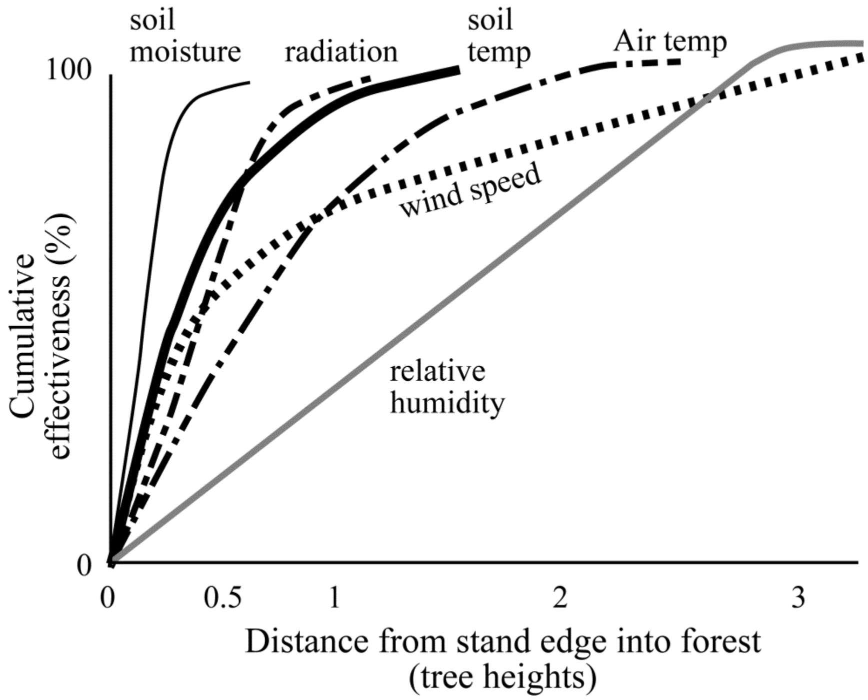


Figure 9a. Relation of distance from stream channel to cumulative effectiveness of factors influencing microclimate in riparian ecosystems. (from: FEMAT 1993, v-27)

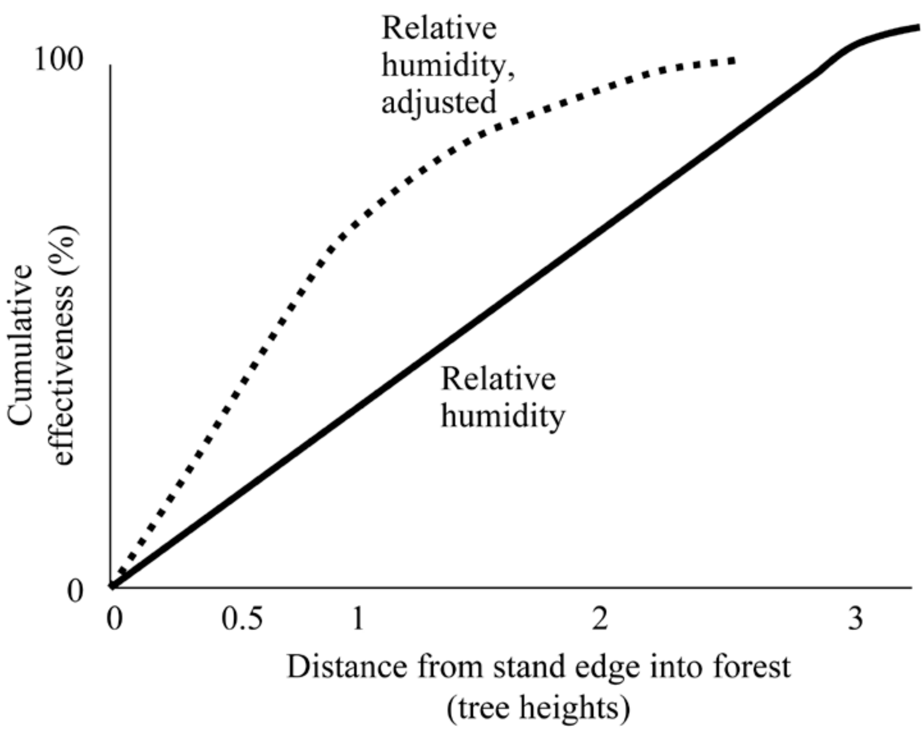


Figure 9b. Modified effectiveness curve for relative humidity as a function of distance from the stream channel. The curve was changed based on scientific literature developed since the curve was originally portrayed in FEMAT (1993).

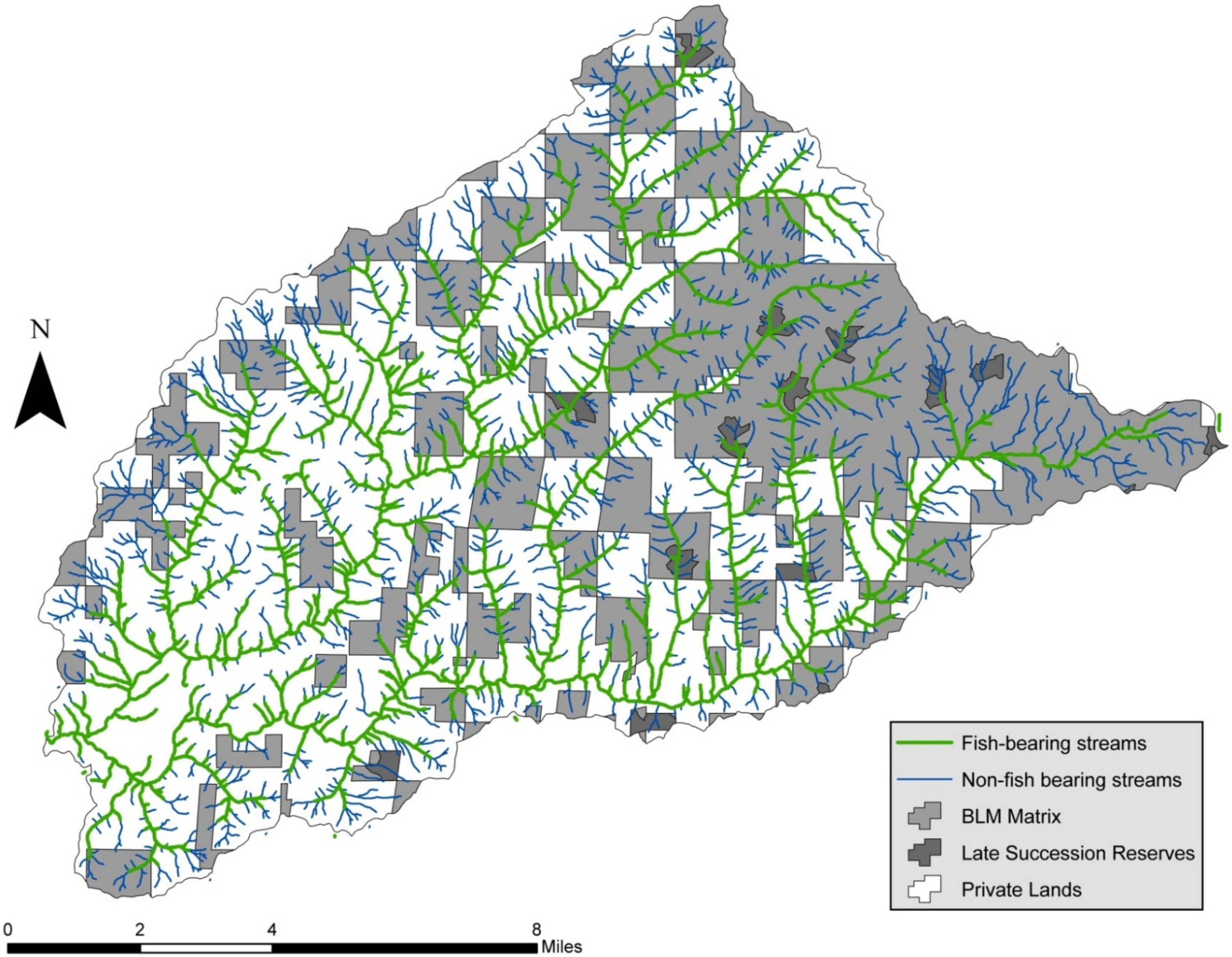


Figure 10a. The fish and non-fish bearing portions of the stream network in the Myrtle Creek watershed developed using NetMap (Benda et al. 2007).

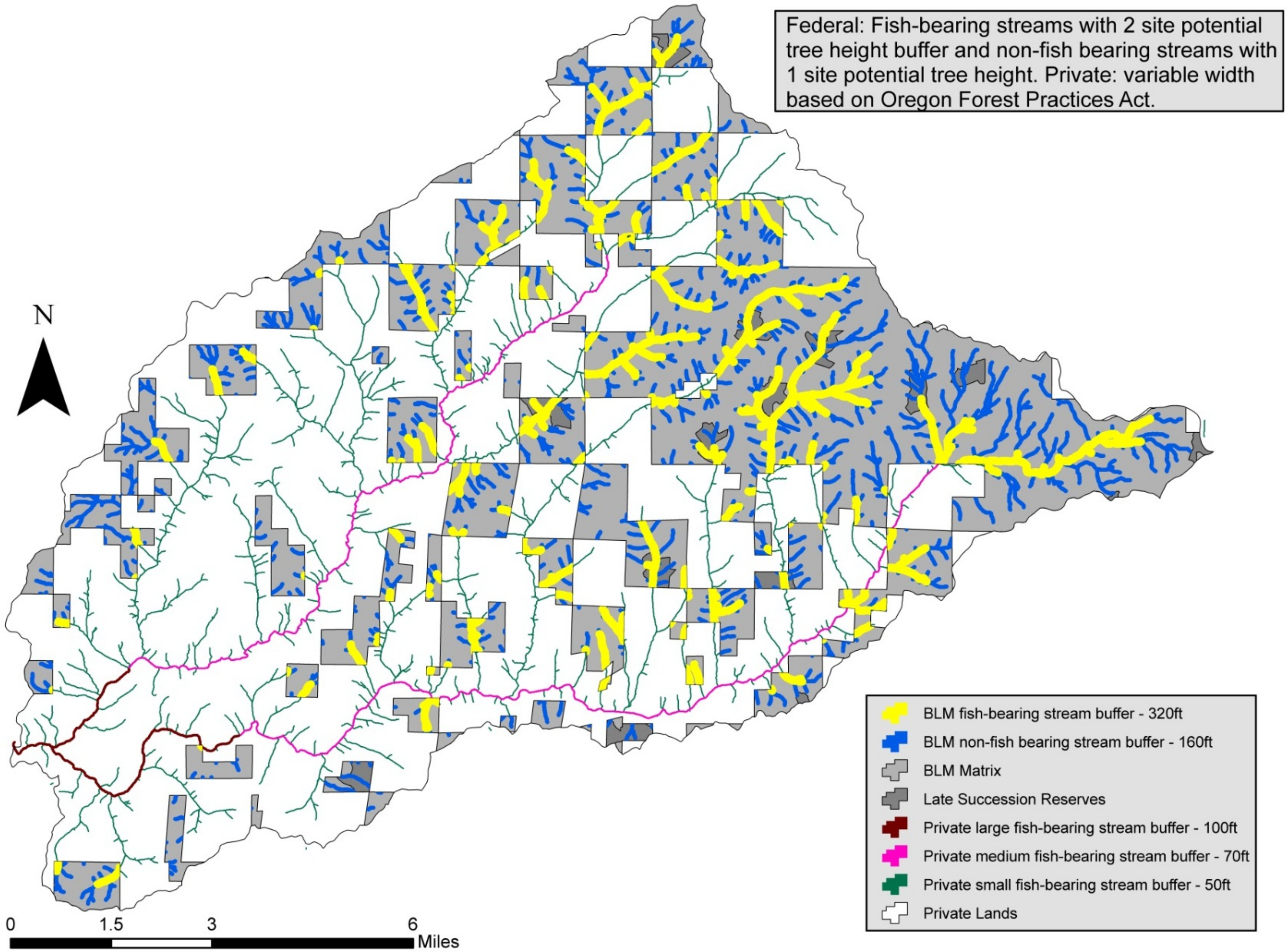


Figure 10b. Current riparian buffers on BLM lands (Northwest Forest Plan) and private lands (Oregon Forest Practice Rules) in the Myrtle Creek watershed.

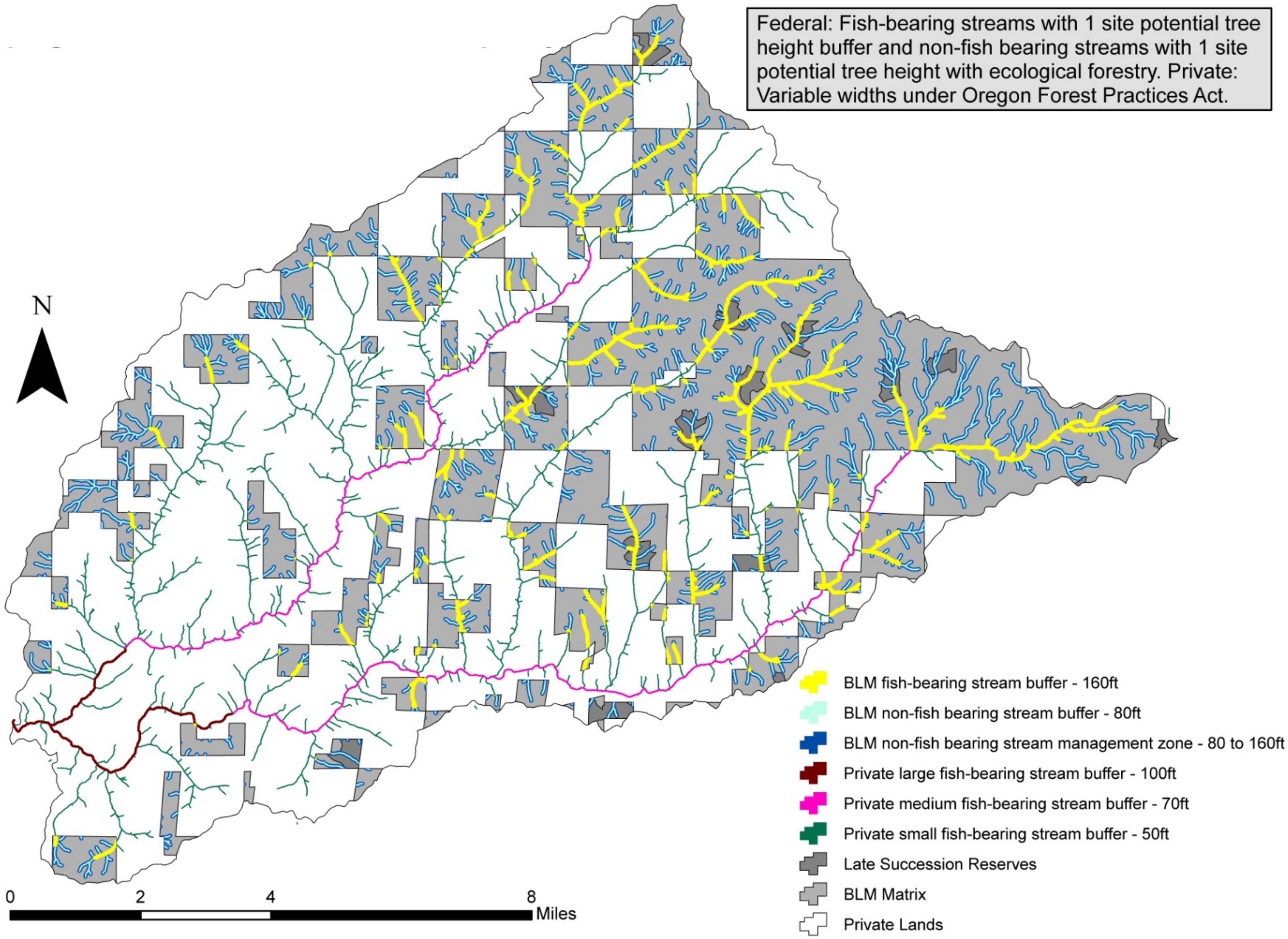


Figure 10c. Riparian buffers on BLM lands (Northwest Forest Plan) under Alternative A (see text for details) and private lands (Oregon Forest Practice Rules) in the Myrtle Creek watershed.

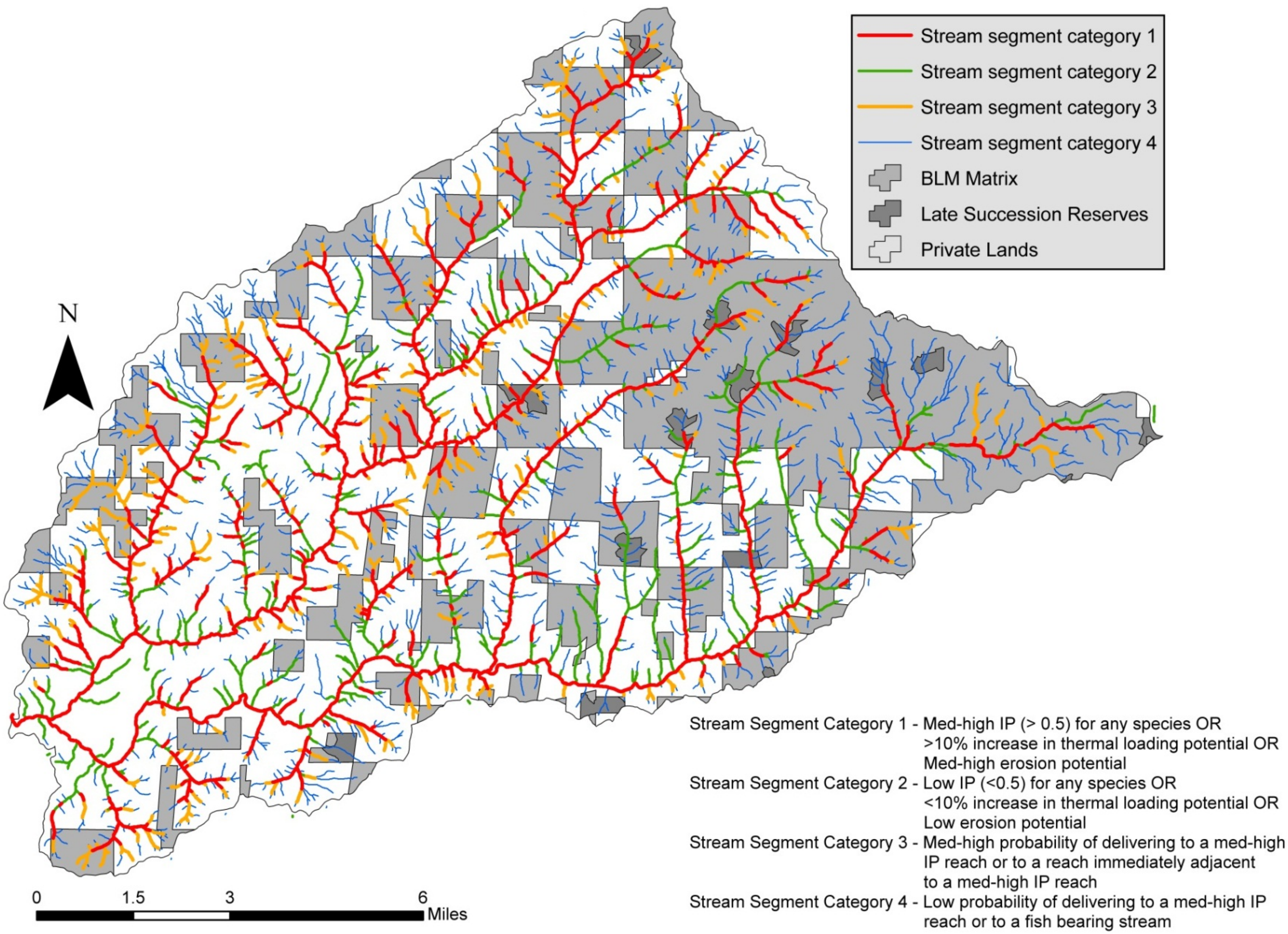


Figure 10d. Stream segments classified by aquatic ecosystem importance on BLM and private lands in the Mrytle Creek watershed. (Fish-bearing streams: red= higher, green=lower; Non-fish bearing streams: orange = higher, blue = lower)

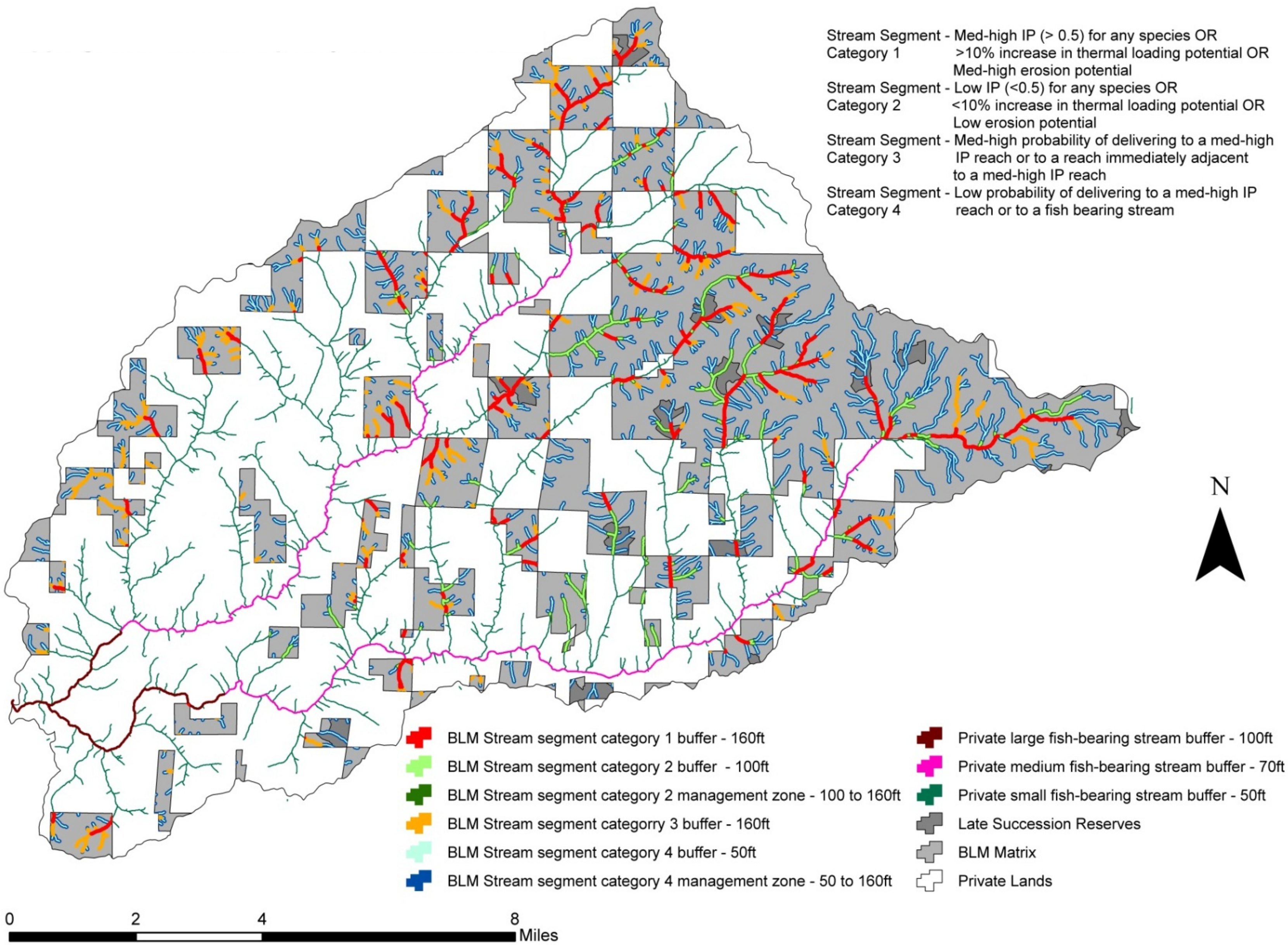


Figure 10e. Stream buffers (see text for details) of Alternative B on BLM lands and current buffers on private lands (Oregon Forest Practice Rules) in the Myrtle Creek watershed.

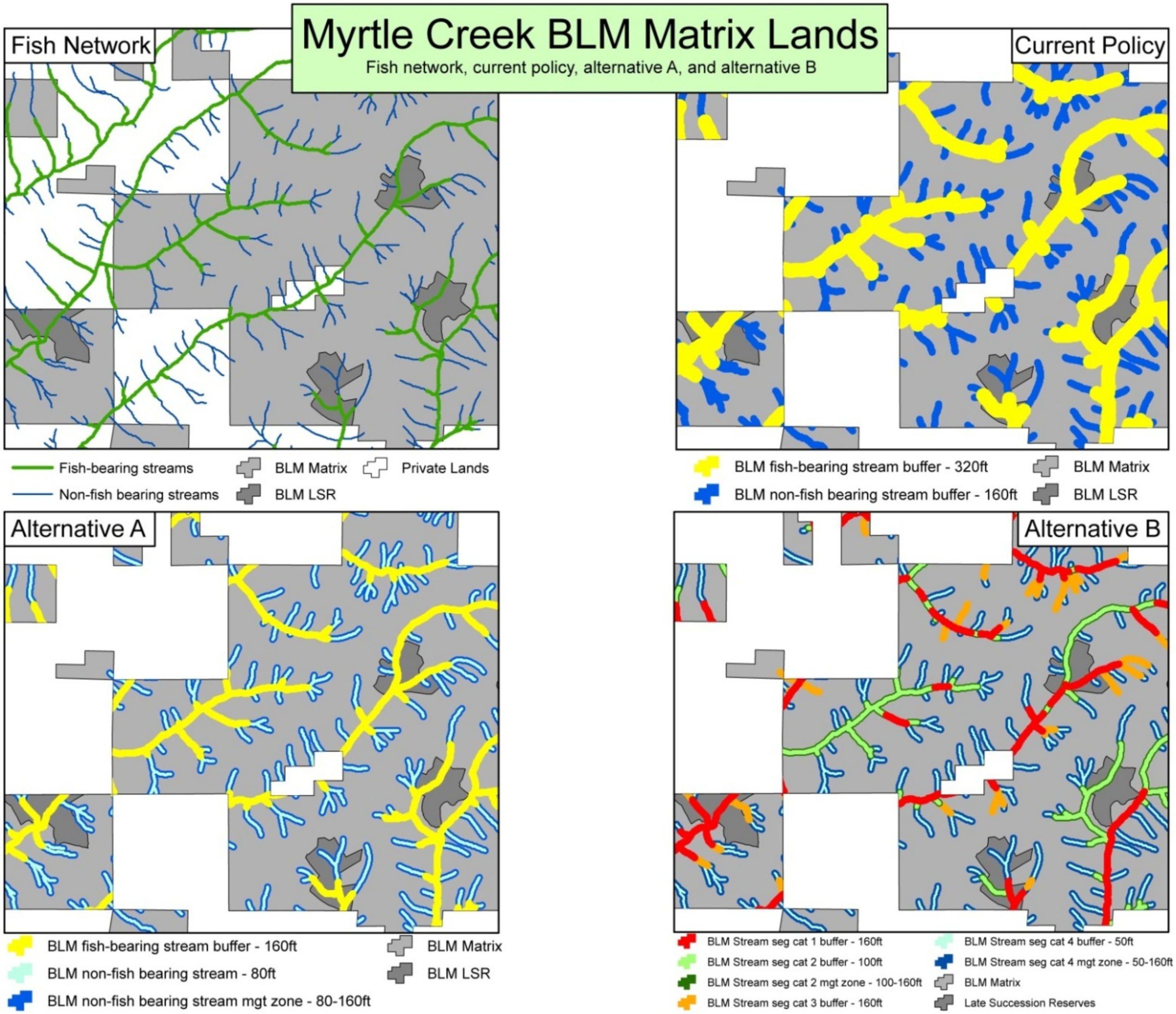


Figure 11. Modeled fish-bearing and non-fish bearing streams (upper left), and riparian buffers on BLM lands under current policy (upper right), Alternative A (lower left), and Alternative B (lower right) on a selected part of BLM lands in the Myrtle Creek watershed. See text for specifics for the size of and prescriptions for the riparian buffers.

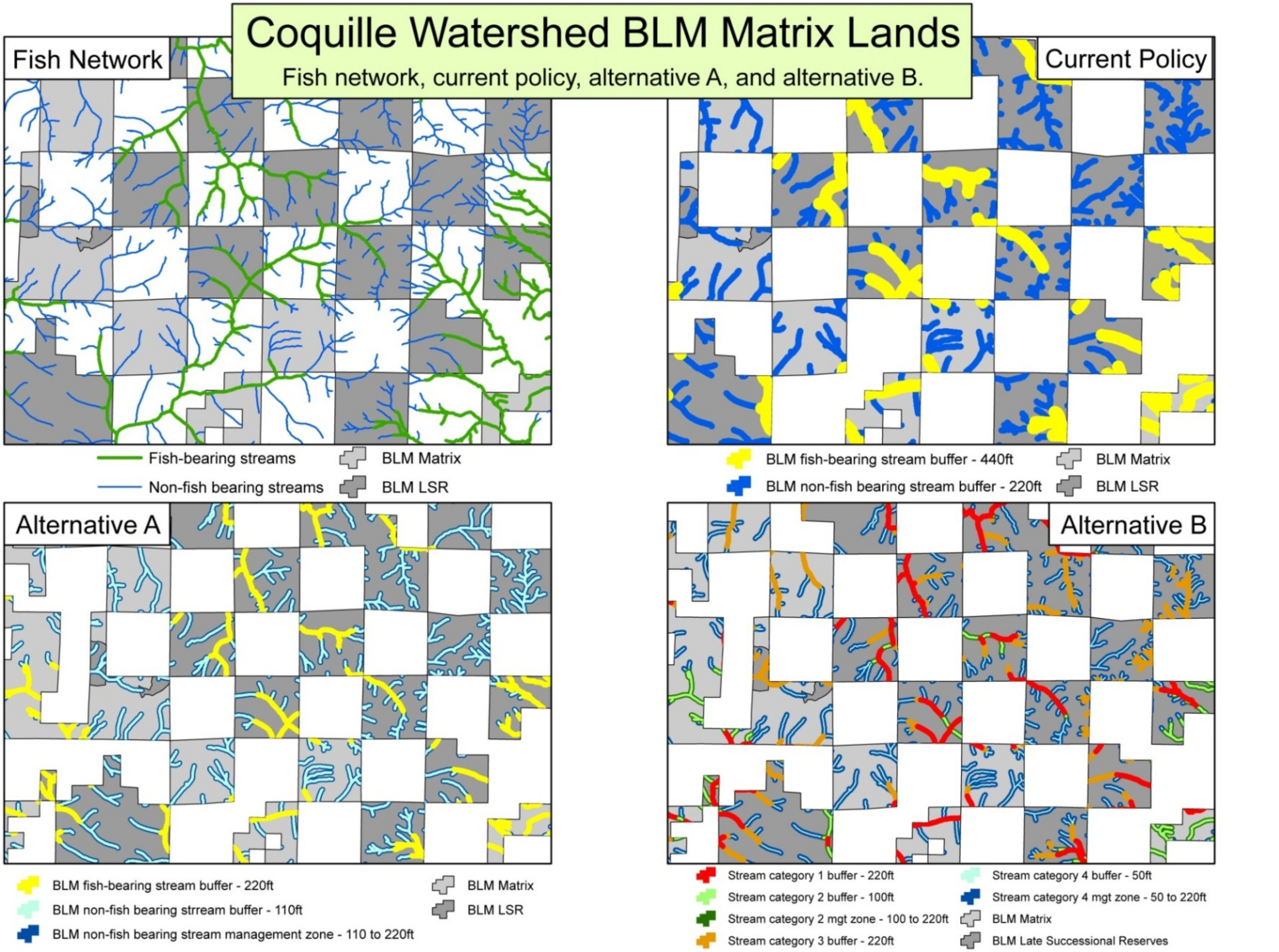


Figure 12. Modeled fish-bearing and non-fish bearing streams (upper left), and riparian buffers on BLM lands under current policy (upper right), Alternative A (lower left), and Alternative B (lower right) on a selected part of BLM lands in the Coquille watershed. See text for specifics for the size of and prescriptions for the riparian buffers.

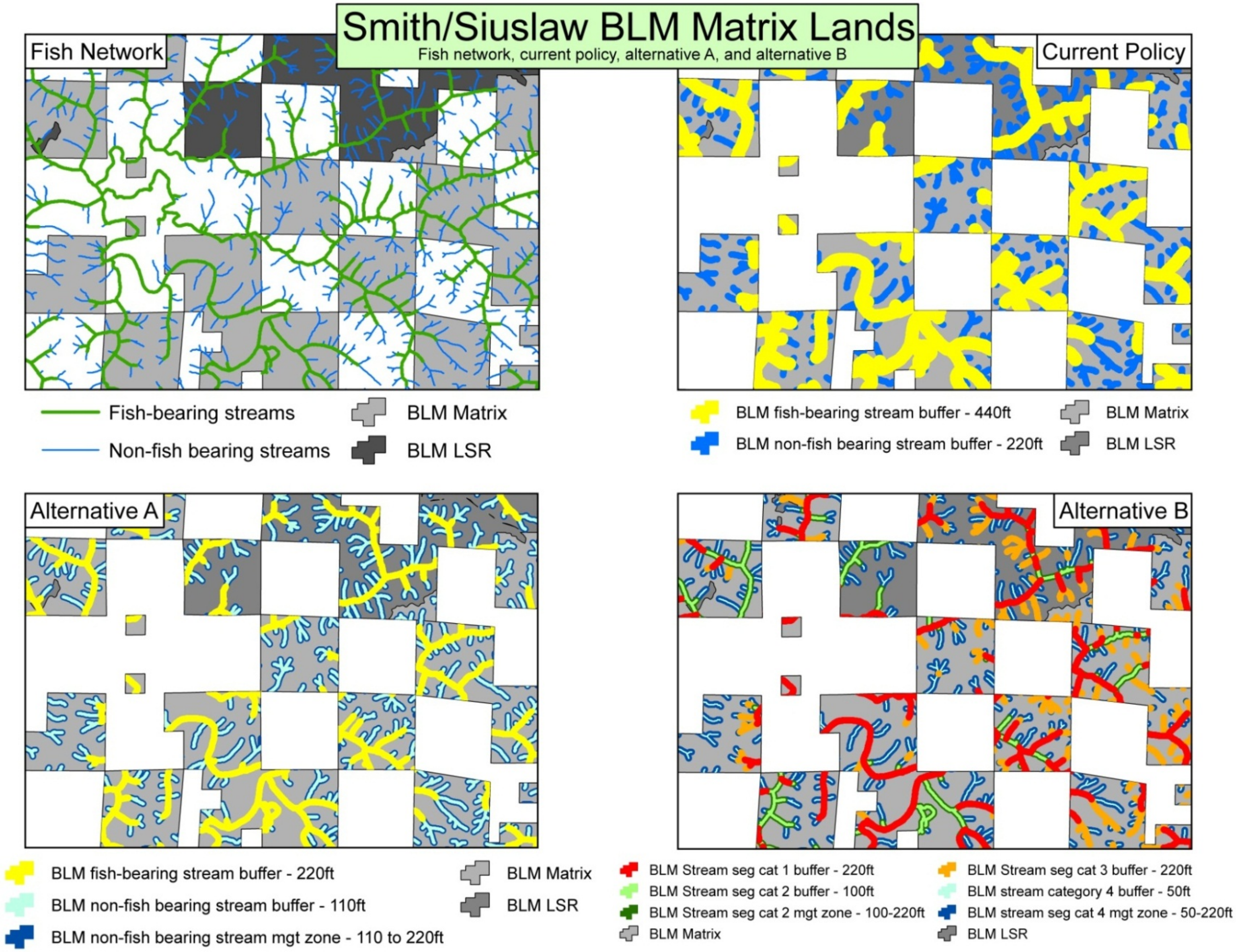


Figure 13. Modeled fish-bearing and non-fish bearing streams (upper left), and riparian buffers on BLM lands under current policy (upper right), Alternative A (lower left), and Alternative B (lower right) on a selected part of BLM lands in the Smith Siuslaw watershed. See text for specifics for the size of and prescriptions for the riparian buffers.

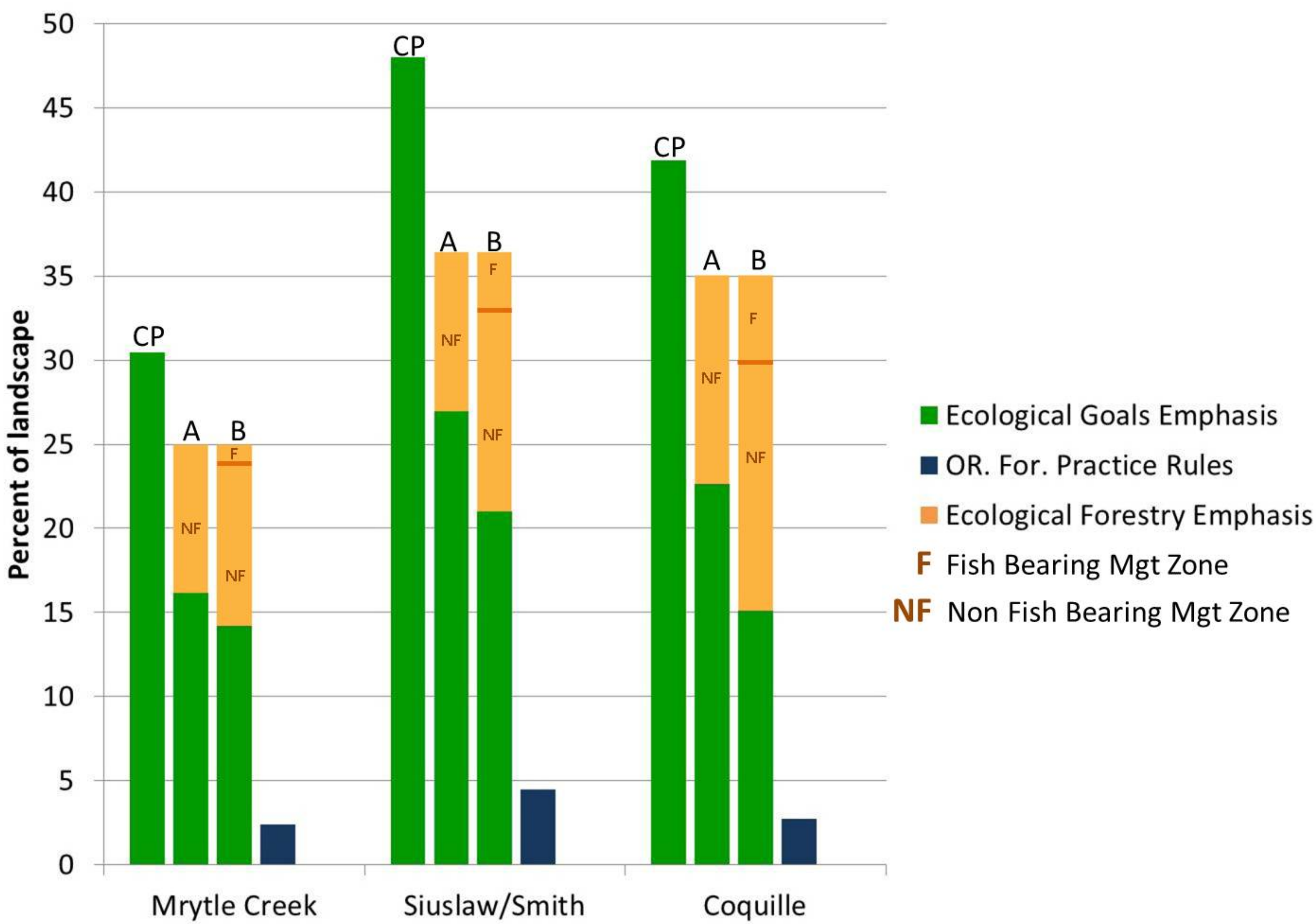


Figure 14. Percent of forest in stream buffers under three different alternatives for BLM Matrix (Current Policy (CP), Alternative A, and Alternative B) and percent of forest in stream buffers in BLM Matrix if managed under the Oregon Forest Practice Rules. Under Current Policy, the entire buffer is managed for ecological values. Under Alternatives A and B, a portion of the buffer is managed solely for ecological values and a portion is managed for both ecological values and timber production using ecological forestry. See text for further explanation.

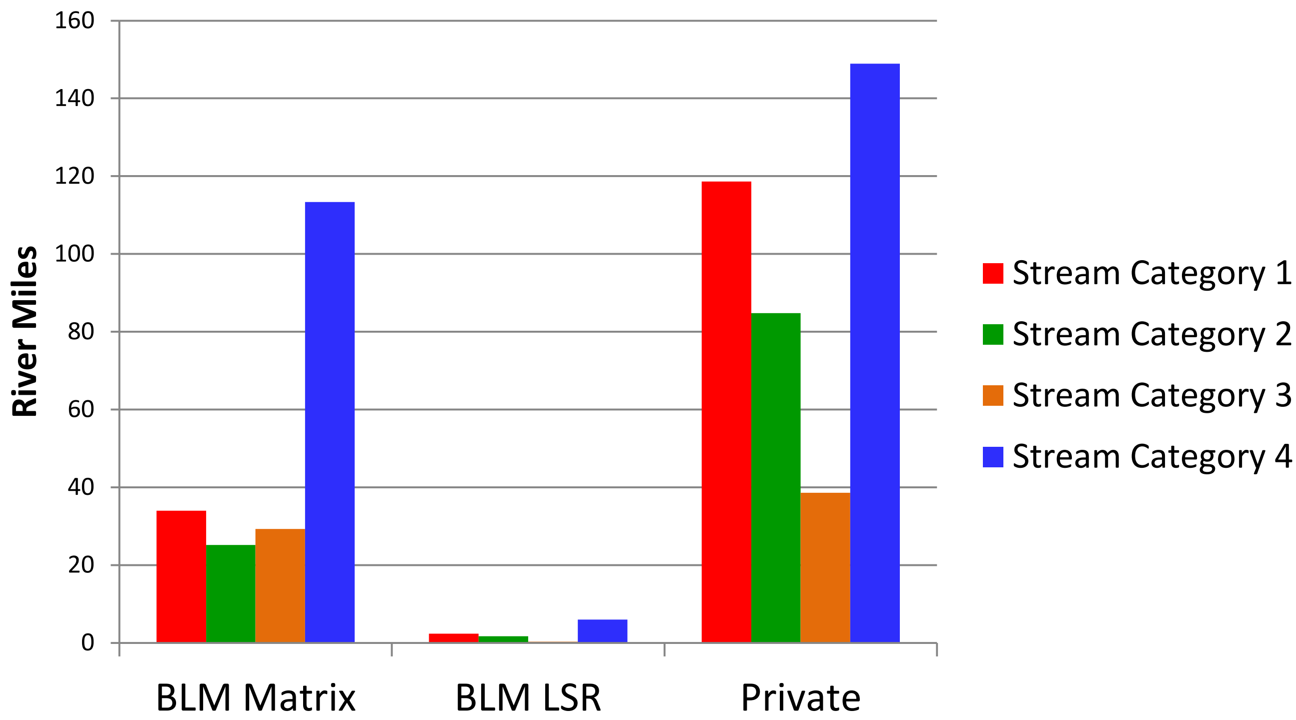


Figure 15. River miles in stream categories of different aquatic ecosystem importance on BLM and private lands in the Myrtle Creek watershed. (Fish-bearing streams: red = higher, green = lower; Non-fish bearing streams: orange = higher, blue = lower). “LSR” is Late Successional Reserves of the Northwest Forest Plan.

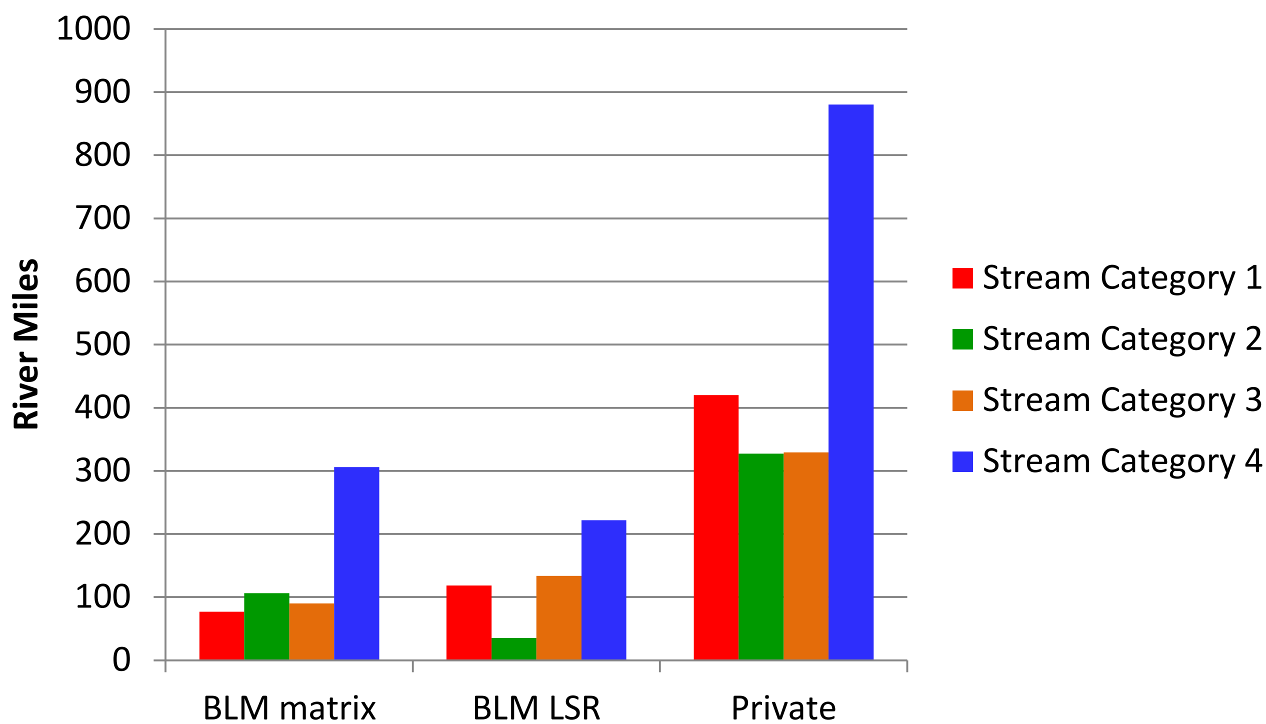


Figure 16. River miles in stream categories of different aquatic ecosystem importance on BLM and private lands in the Coquille watershed. (Fish-bearing streams: red = higher, green = lower; Non-fish bearing streams: orange = higher, blue = lower). “LSR” is Late Successional Reserves of the Northwest Forest Plan.

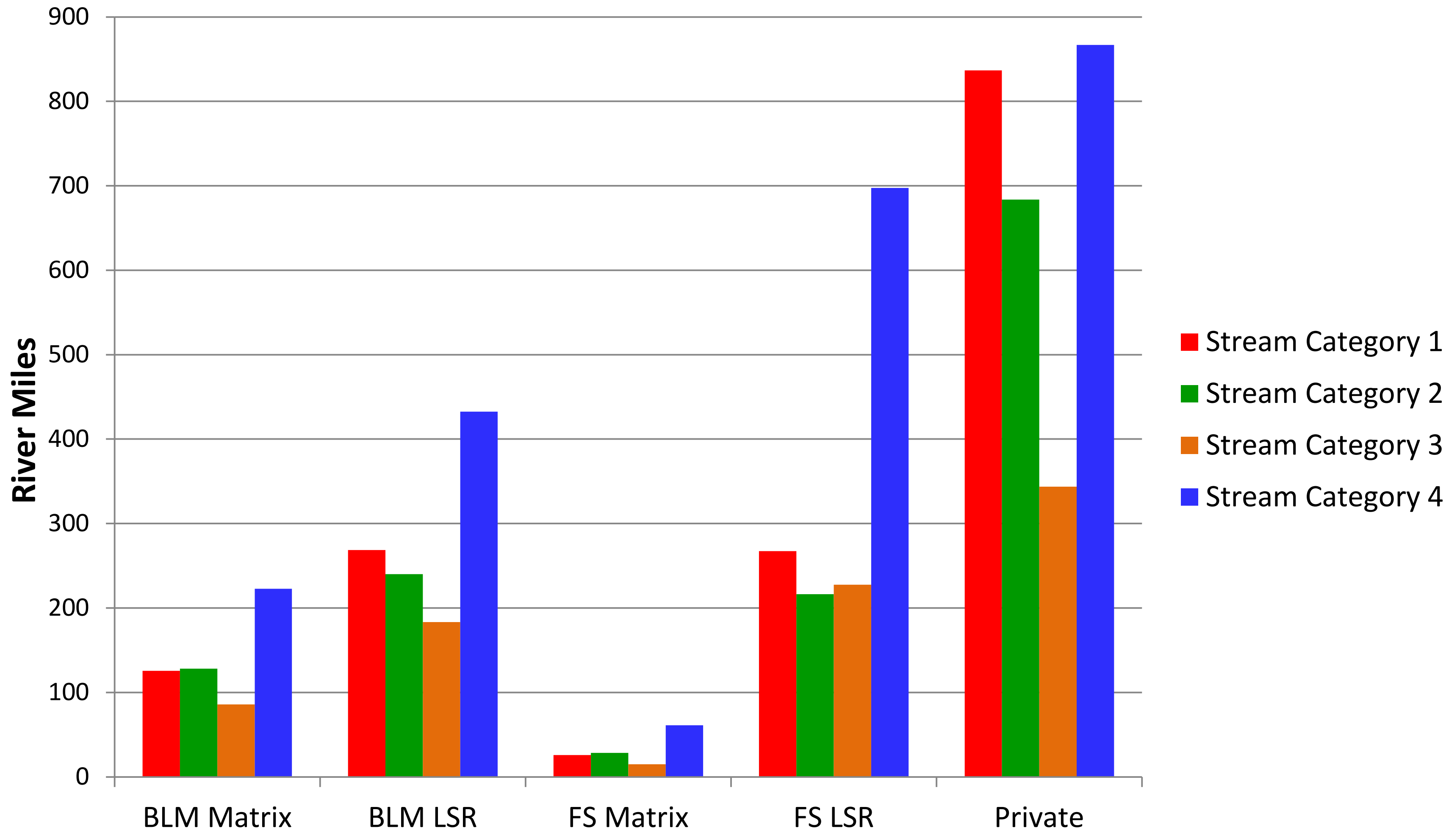


Figure 17. River miles in stream categories of different aquatic ecosystem importance on BLM, Forest Service, and private lands in the Siuslaw-Smith watershed. (Fish-bearing streams: red = higher, green = lower; Non-fish bearing streams: orange = higher, blue = lower). “LSR” is Late Successional Reserves of the Northwest Forest Plan

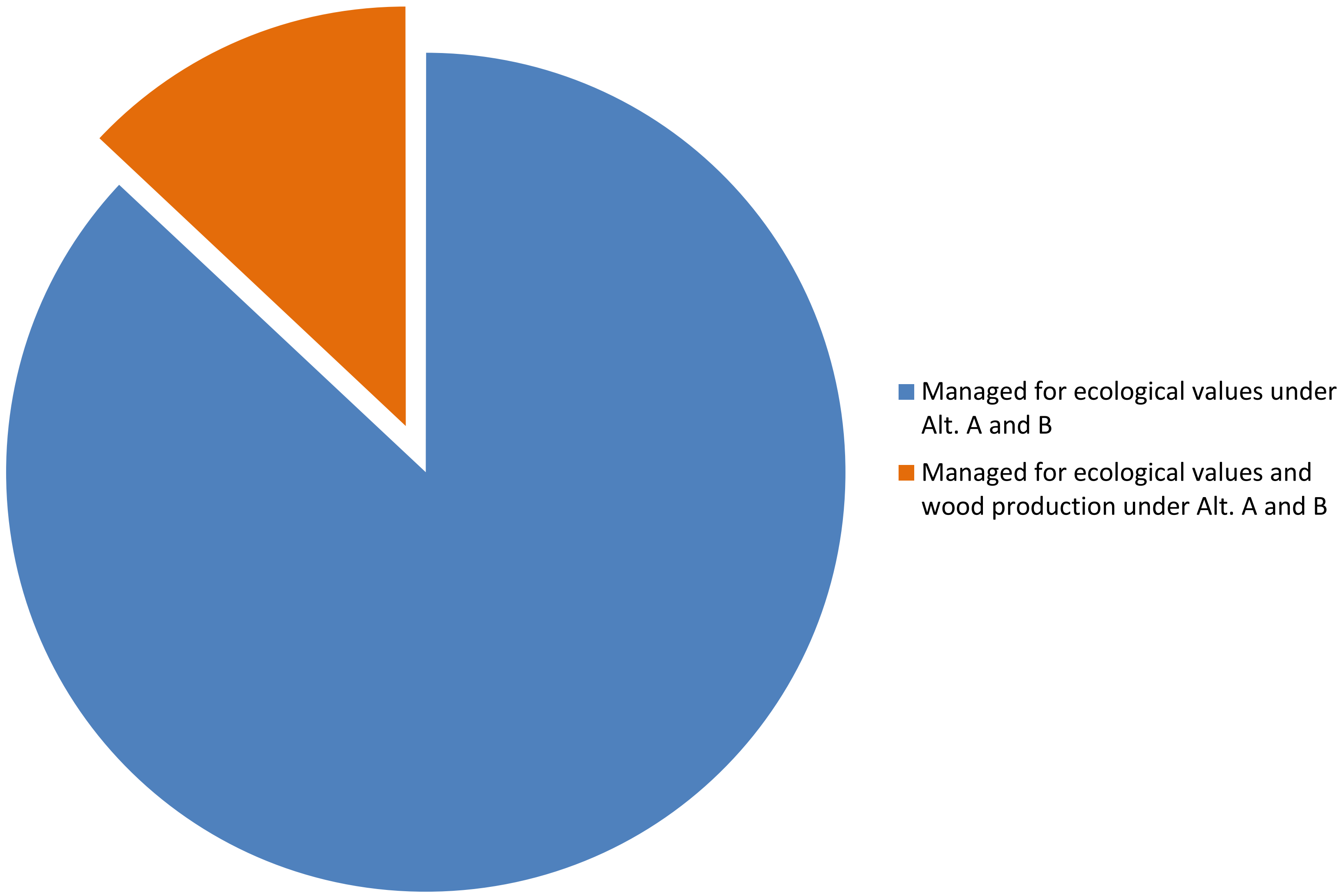
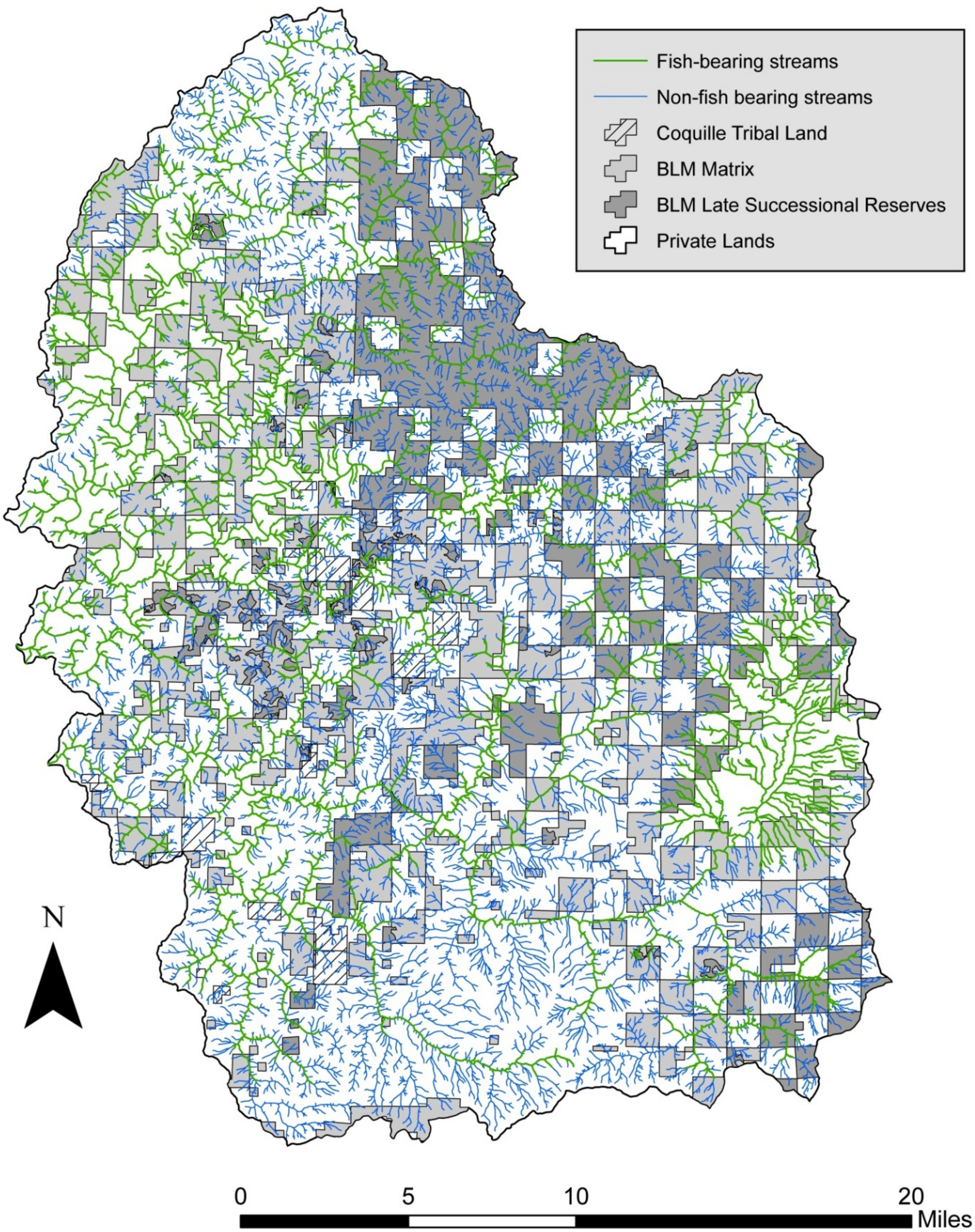
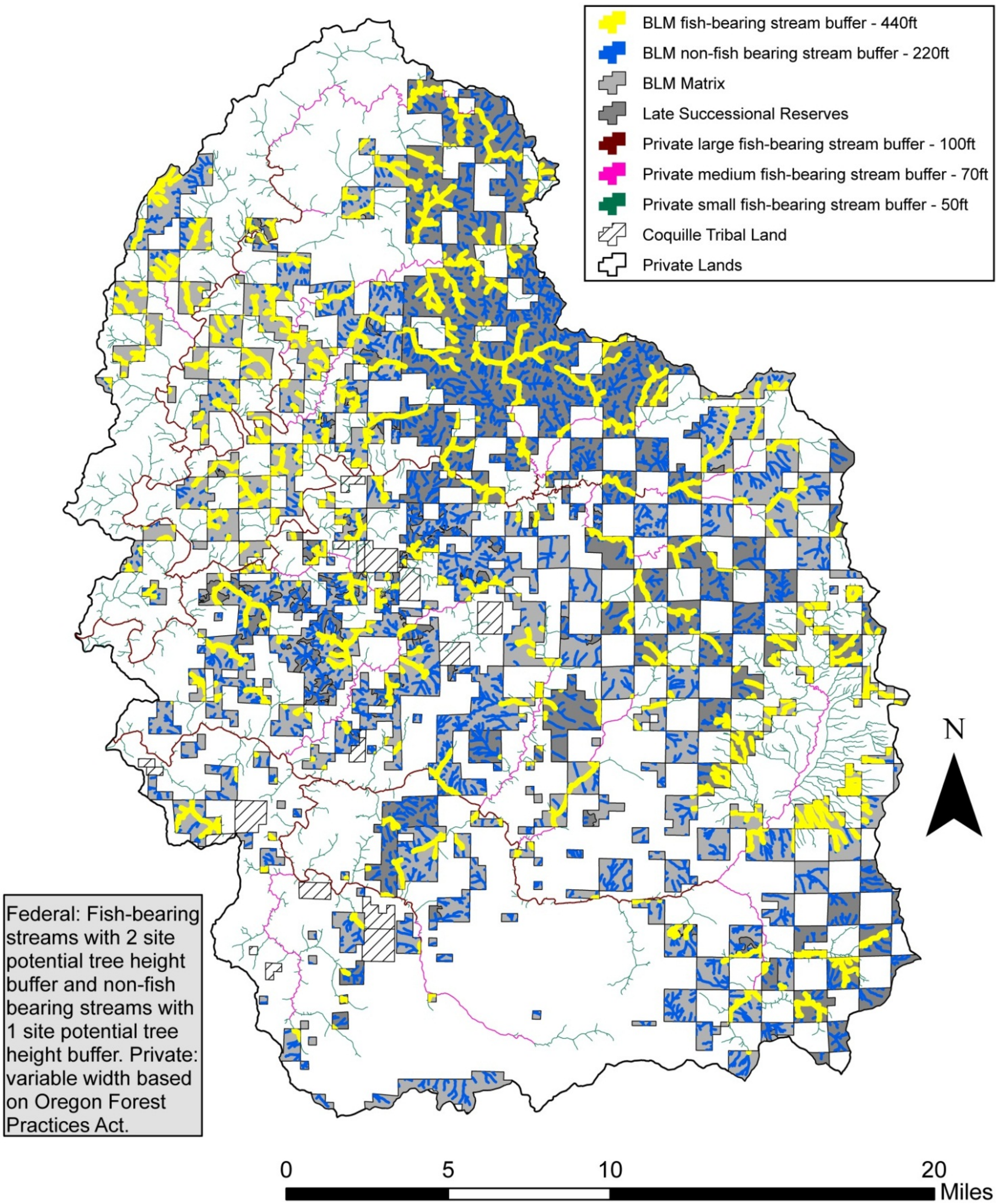


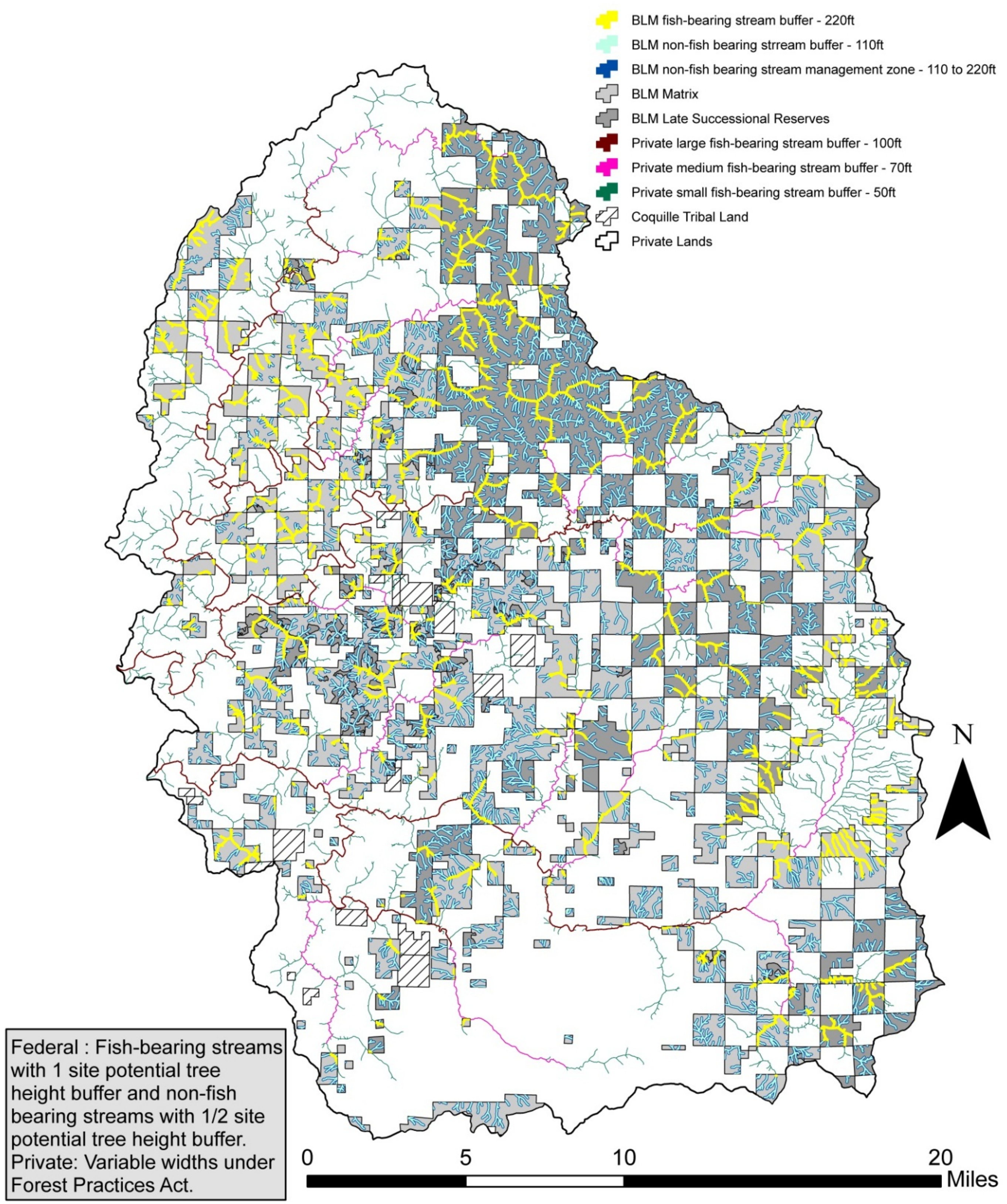
Figure 18. Moist Forest within two tree heights of fish-bearing streams and one tree height of non-fish bearing streams on BLM Western Oregon forests.



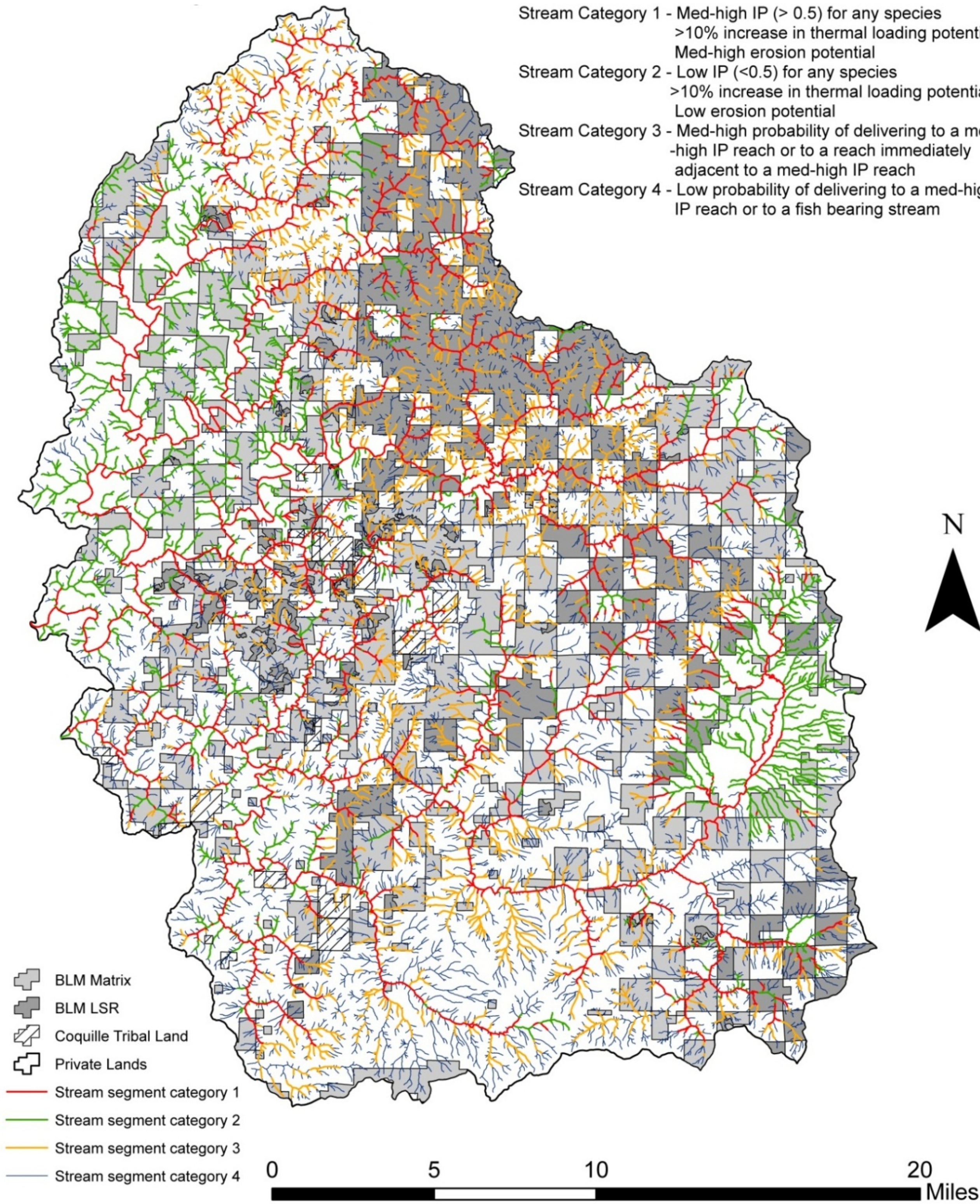
Appendix A. Figure 1a. The fish and non-fish bearing portions of the stream network in the Coquille watershed developed using NetMap (Benda et al. 2007).



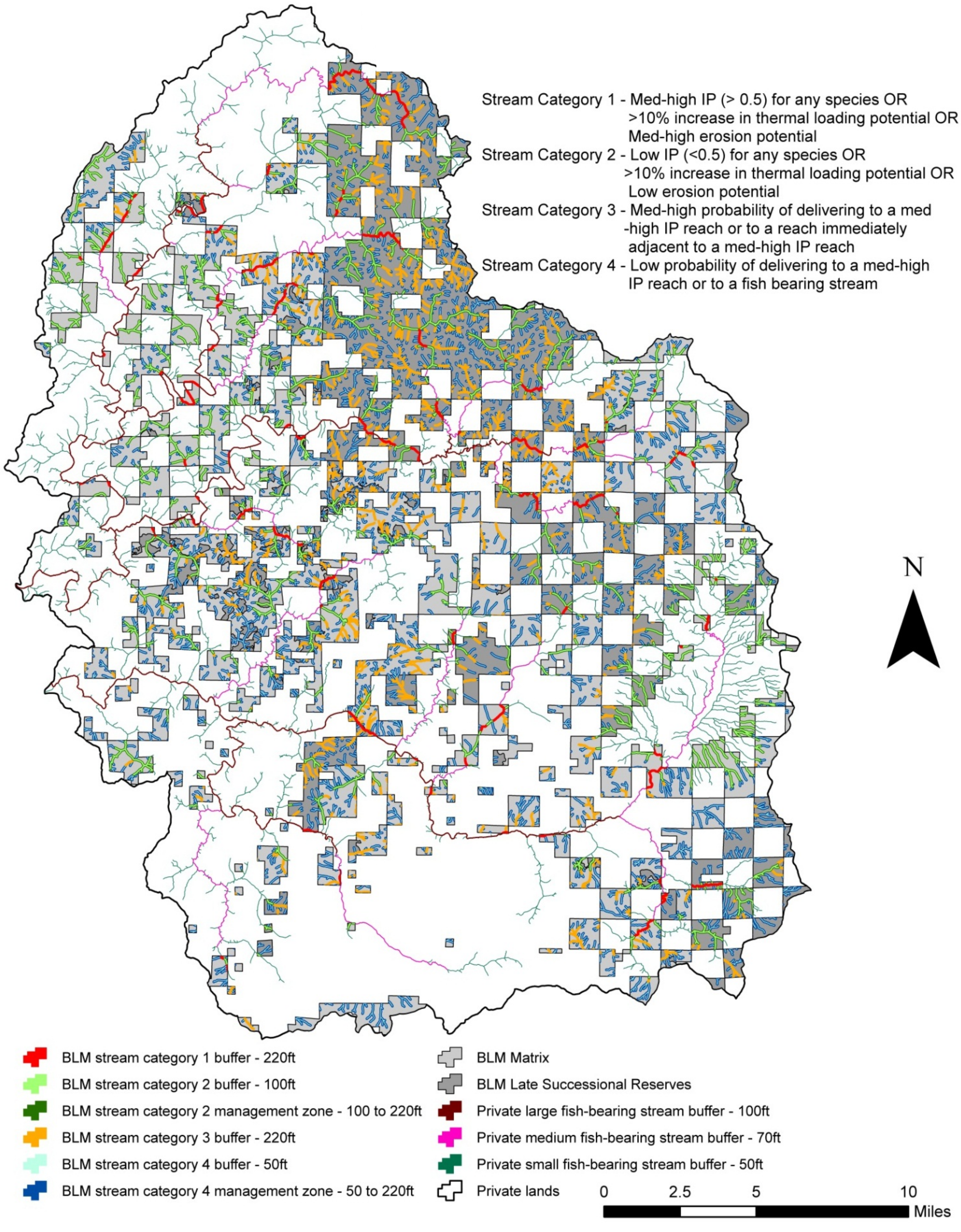
Appendix A. Figure 1b. Current riparian buffers on BLM lands (Northwest Forest Plan) and private lands (Oregon Forest Practice Rules) in the Coquille watershed.



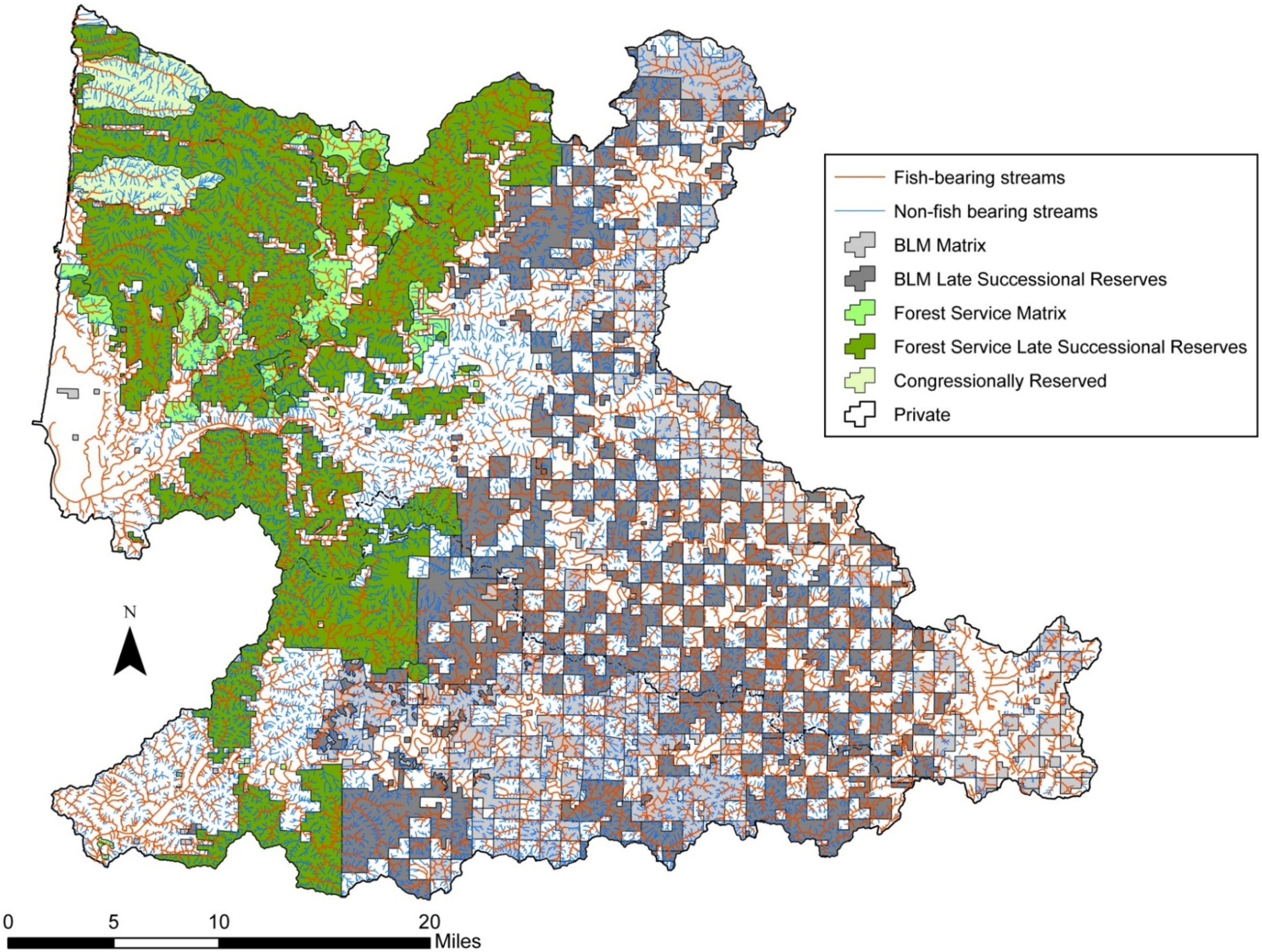
Appendix A. Figure 1c. Riparian buffers on BLM lands under Alternative A (see text for details) and private lands (Oregon Forest Practice Rules) in the Coquille watershed.



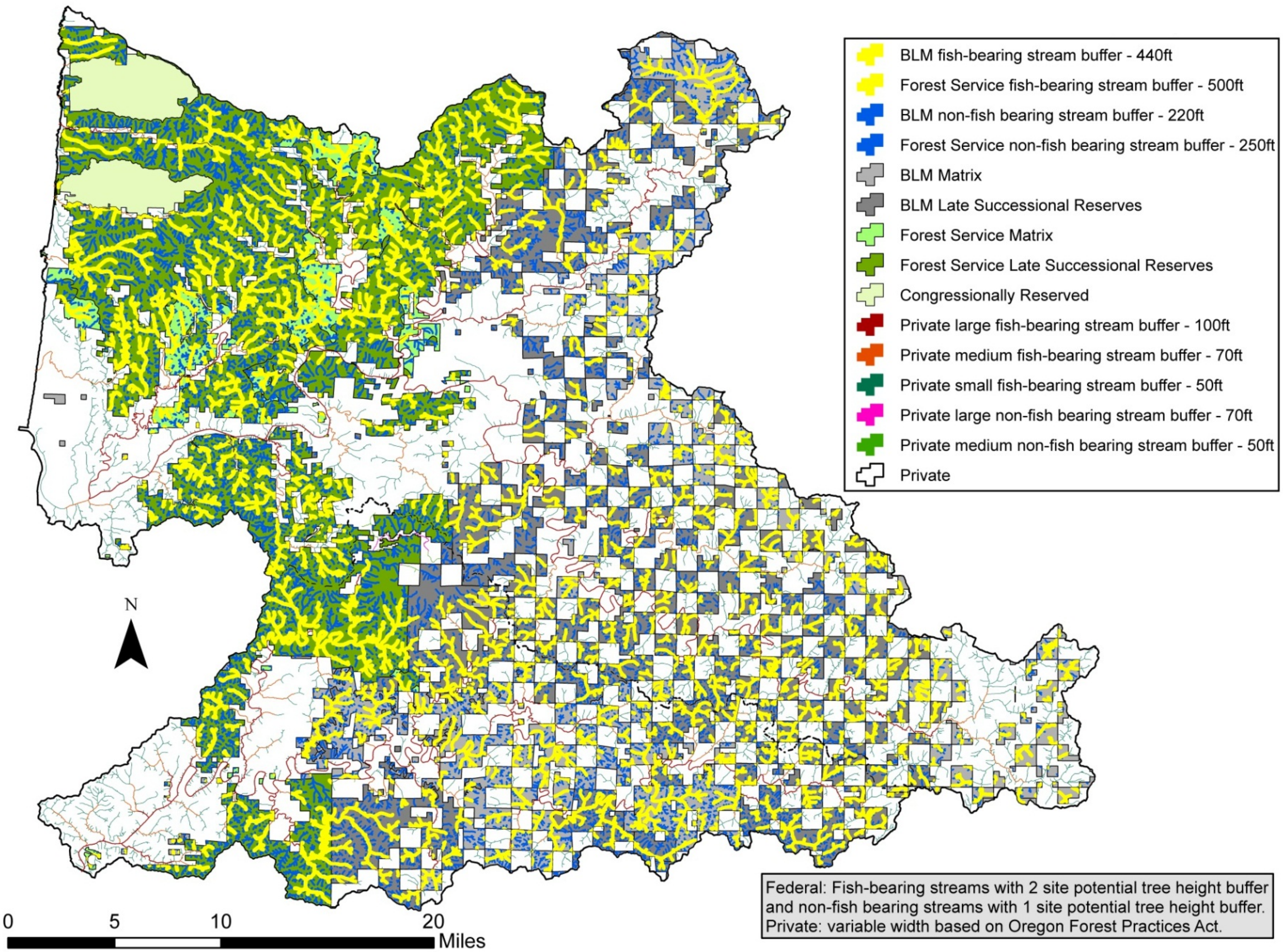
Appendix A. Figure 1d. Stream segments classified by aquatic ecosystem importance on BLM and private lands in the Coquille watershed. (Fish-bearing streams: red = higher, green = lower; non-fish bearing: orange = higher, blue = lower)



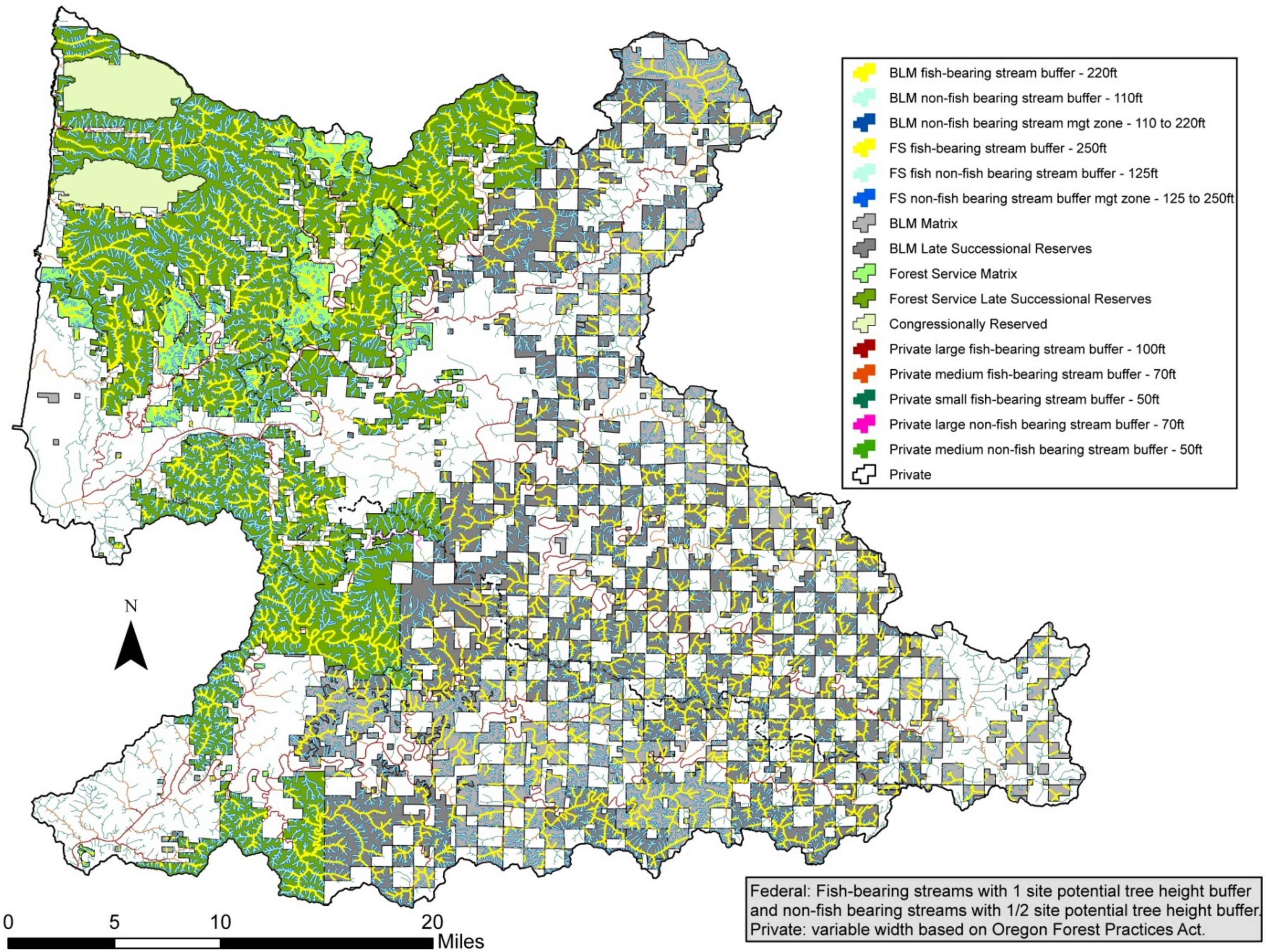
Appendix A. Figure 1e. Stream buffers (see text for details) of Alternative B on BLM lands and current buffers on private lands (Oregon Forest Practice Rules) in the Coquille watershed.



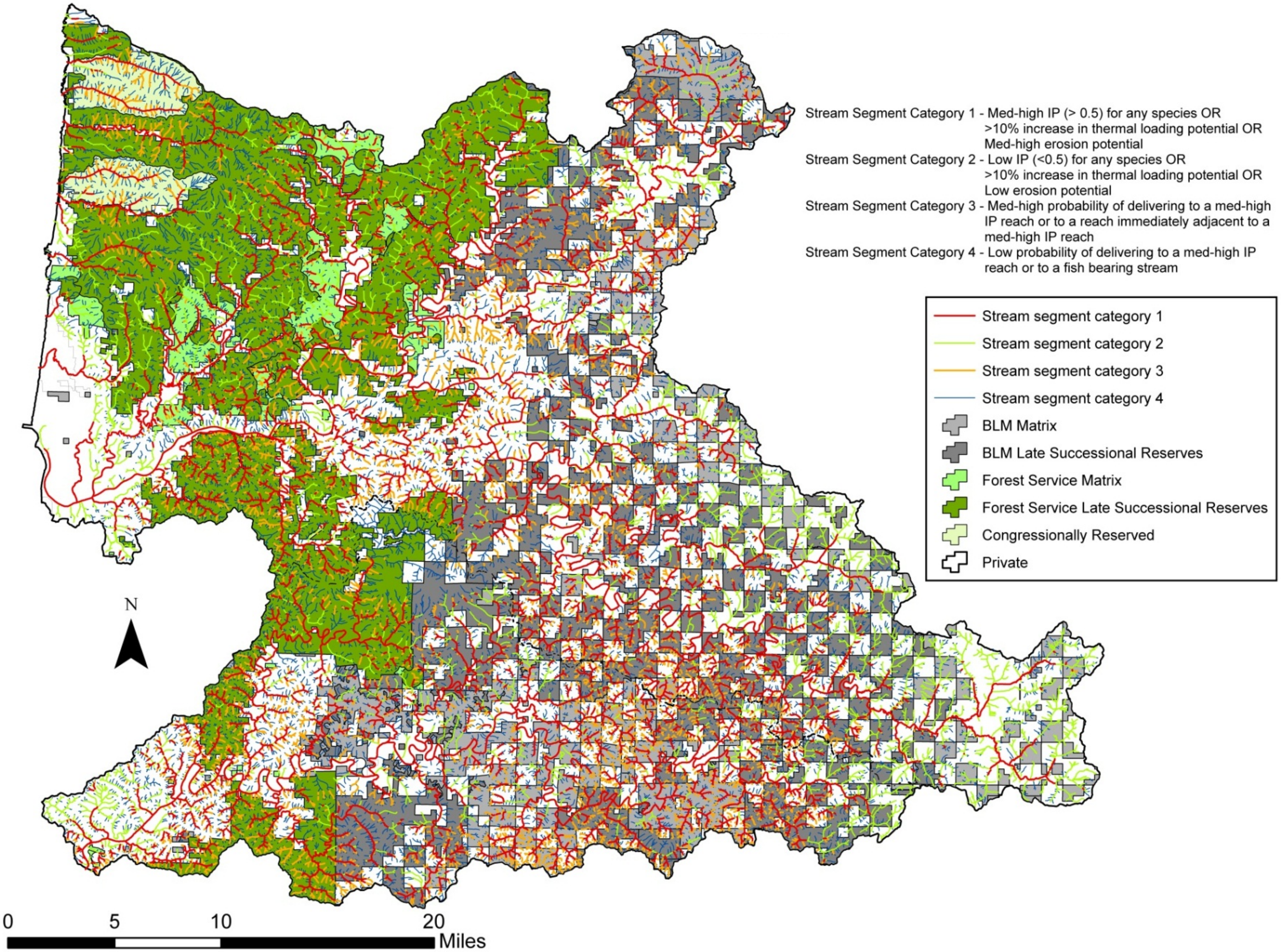
Appendix A. Figure 2a. The fish and non-fish bearing portions of the stream network in the Siuslaw-Smith watershed developed using NetMap (Benda et al. 2007).



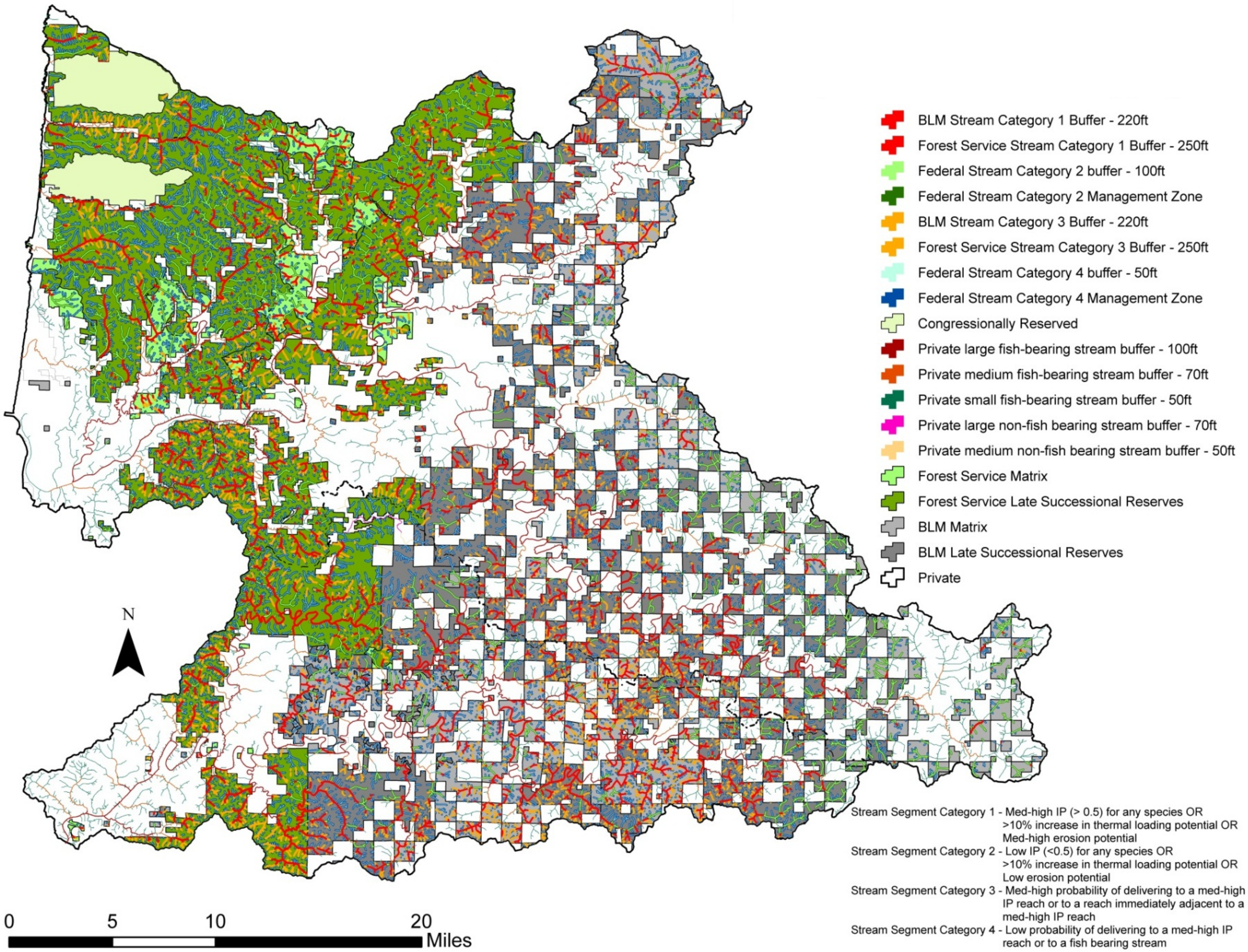
Appendix A. Figure 2b. Current riparian buffers on BLM lands (Northwest Forest Plan), Forest Service managed lands, and private lands (Oregon Forest Practice Rules) in the Siuslaw-Smith watershed.



Appendix A. Figure 2c. Riparian buffers on BLM and Forest Service lands under Alternative A (see text for details) and private lands (Oregon Forest Practice Rules) in the Siuslaw-Smith watershed.



Appendix A. Figure 2d. Stream segments classified by aquatic ecosystem importance on BLM, Forest Service, and private lands in the Siuslaw-Smith watershed. (Fish-bearing: red = higher, green = lower; non-fish bearing: orange = higher, blue = lower)



Appendix A. Figure 2e. Stream buffers (see text for details) of Alternative B on BLM and Forest Service lands and current buffers on private lands (Oregon Forest Practice Rules) in the Siuslaw-Smith watershed.