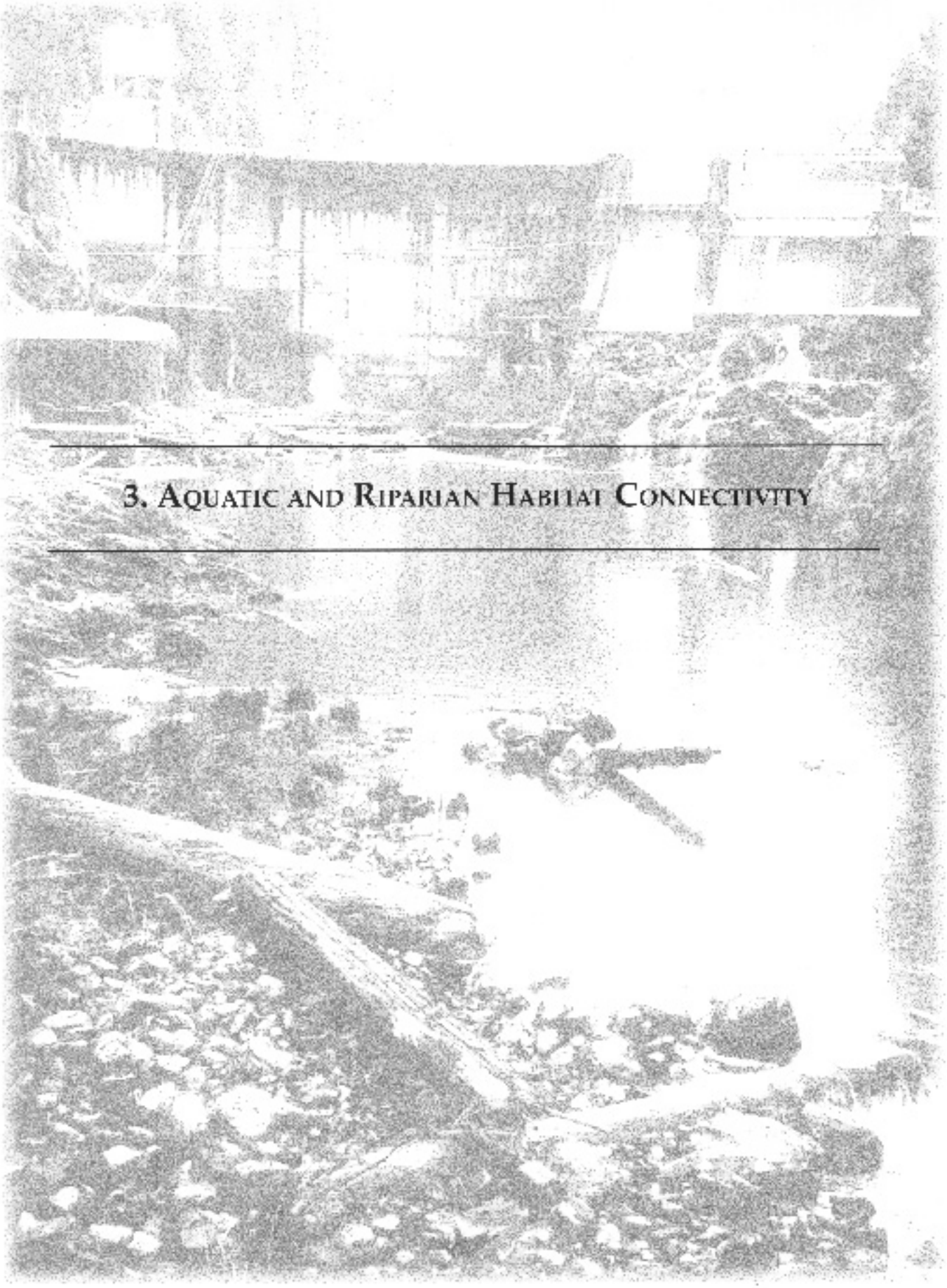


3. Aquatic and Riparian Habitat Connectivity

3. AQUATIC AND RIPARIAN HABITAT CONNECTIVITY

Habitat connectivity is important for maintaining healthy populations of species across the landscape. Habitat fragmentation—reduction in habitat area and isolation of habitat areas—reduces available habitat for species and isolates subpopulations from one another, which may increase the risk of extirpation or extinction for some species. The management goal associated with the issue of aquatic and riparian habitat connectivity is to maintain habitat in conditions sufficient to maintain ecological processes and interconnected and well-distributed populations of native species in the North Umpqua River watershed. This goal includes maintaining or restoring the Riparian Reserve function of providing habitat corridors across the landscape on lands under the jurisdiction of the Northwest Forest Plan.

Aquatic and riparian habitat connectivity is an integral part of the ecological integrity of the watershed as a whole and is addressed by the following objective of the Aquatic Conservation Strategy of the Northwest Forest Plan: "Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include floodplains, wetlands, upslope areas, headwater tributaries, and intact refugia. These linkages must provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian-dependent species" (USDA Forest Service and USDI Bureau of Land Management 1994, p. B-11).

The Northwest Forest Plan also provides guidance on Riparian Reserves and their function: "Riparian Reserves are areas along all streams, wetlands, ponds, lakes [including reservoirs], and unstable or potentially unstable areas where the conservation of aquatic and riparian-dependent terrestrial resources receives primary emphasis. The main purpose of the reserves is to protect the health of the aquatic system and its dependent species; the reserves also provide incidental benefits to upland species. These reserves will help maintain and restore riparian structures and functions, benefit fish and riparian-dependent non-fish species, enhance habitat conservation for organisms dependent on the transition zone between upslope and riparian areas, improve travel and dispersal corridors for terrestrial animals and plants, and provide for greater connectivity of late-successional forest habitat" (UDSA Forest Service and USDI Bureau of Land Management 1994, p. 7). For highly mobile species with large home ranges (for example, northern spotted owl, fisher), Riparian Reserves function as movement corridors between larger patches of suitable habitat. For smaller, less mobile, and/or sessile organisms (for example, red tree vole, mollusks, plants), Riparian Reserves help to maintain interconnectivity between populations of riparian or late-successional species by providing habitat suitable for successful completion of their entire life cycles. Thus, the function of Riparian Reserves is to provide both movement corridors and high quality riparian and late-successional habitat.

3.1 OVERVIEW OF RESULTS

Anthropogenic features and disturbances in the North Umpqua River watershed have reduced aquatic and riparian habitat connectivity compared to reference conditions. The most important disturbances potentially influencing the long-term persistence of populations of native species in the watershed are those that create year-round barriers to movement of aquatic and/or riparian species between sub-populations (although temporary barriers that recur during critical life history stages could have long-term effects because the reduction of dispersal may affect the maintenance of sub-populations, potentially increasing the risk of population extirpation). Year-round barriers include dams and reservoirs associated with the North Umpqua Hydroelectric Project, diversions and interceptions of tributaries into project waterways, waterways that are impassable to overland movement along Riparian Reserves, and impassible culverts. Such barriers reduce movement and genetic exchange between populations and limit opportunities for recolonizing sites where local populations have been extirpated.

Habitat degradation can also affect habitat connectivity for certain species by creating gaps in otherwise suitable habitat. Past timber harvest in Riparian Reserves has resulted in gaps between patches of suitable riparian habitat for late-successional species, but probably does not constitute a complete barrier to movement for most species; riparian conditions are expected to recover and re-establish habitat connectivity in the long term in most areas due to the guidelines contained within the Northwest Forest Plan. Roads in Riparian Reserves may have substantial local effects on the movements of some species such as mollusks or small mammals and many of these roads may remain in existence indefinitely; however, these roads are potentially passable on occasion by all but the weakest-dispersing species. Other factors potentially contributing to cumulative effects on aquatic and riparian habitat connectivity for some sensitive species in certain areas include inundation of stream reaches by reservoirs, water level fluctuations, and degradation of water quality.

3.2 ANALYTICAL METHODS

The assessment of aquatic and riparian habitat connectivity was performed based on literature review, a field survey of project features, and professional judgement regarding the likely effects of potential obstacles and barriers on the movement of species through aquatic and riparian habitats. Literature and personal communications describing project features, reference and existing conditions in the watershed, and the habitat requirements and behavior of analysis species were reviewed and summarized. Amphibian experts (Dr. Bruce Bury, Dr. Marc Hayes, and Mr. Larry Jones) who joined the Scientific Team provided input into the assessment of current conditions of and ecological impacts on amphibians. Dr. Terrence Frest, an expert on aquatic and riparian mollusks, provided valuable information about the distribution, habitat requirements, and potential impacts of management activities on these species. A field survey was conducted by members of the Terrestrial Subgroup to document the current condition of hydroelectric project features and culverts along PacifiCorp roads, characterize each feature in terms of its impact on habitat connectivity, and develop management alternatives to reduce impacts. In general, the

evaluation of ecological impacts and potential management alternatives relied heavily on the collective professional judgment of the Scientific Team.

3.3 REFERENCE CONDITIONS

The stream channel network in the North Umpqua River basin consists primarily of confined streams. Lower gradient unconfined reaches with associated floodplains are found in a few locations, but are generally much less common. Such reaches tend to be more ecologically diverse and productive compared to steeper confined reaches. Prior to the construction of the hydroelectric project, the only large lake in the basin was Diamond Lake. Movement of organisms between aquatic, riparian, floodplain, and upslope areas was unimpeded by anthropogenic features such as roads, dams, clear-cuts, or other obstacles.

Populations of aquatic and riparian species in the North Umpqua River basin have evolved under conditions of habitat connectivity influenced by such natural disturbances and catastrophic events as volcanic activity, glaciation, fires, flood events, landslides, and debris torrents. The effects of these disturbances vary both spatially and temporally and function to create a dynamic mosaic of habitat conditions across the landscape. Within such a landscape, populations of species often exist as metapopulations that are sustained by the regular dispersal of individuals between subpopulations residing in suitable habitat patches. Certain subpopulations ("source populations") characterized by a reproductive surplus act to sustain "sink" populations that would otherwise decline (Gilpin and Hanski 1991). Areas where catastrophic disturbance created unsuitable conditions for certain species would be recolonized from nearby undisturbed areas as they recovered. Habitat connectivity under reference conditions was also affected by smaller scale or seasonal habitat changes such as instream flow variation and changes to water quality. Such temporary obstacles to movement probably did not have a large influence on population dynamics under reference conditions. Natural barriers to the movement of aquatic species, such as waterfalls, may have acted to isolate subpopulations of aquatic species in both the long and/or short term.

In areas of the North Umpqua River watershed that are dominated by basaltic lithology, the numerous cascades and waterfalls effectively block anadromous salmonid access to large portions of the basin. Toketee Falls likely historically excluded fish from colonizing portions of the upper watershed affected by periods of glaciation and the most recent eruptions of Mt. Mazama. Natural falls also create barriers to dispersal between resident fish subpopulations in the basin, and may impede or block recolonization of stream reaches after their recovery from catastrophic events such as debris flows. Natural geologic processes following the colonization of streams by salmonid species have acted to create partial or complete separation between segments of salmonid populations exhibiting resident or anadromous life history strategies. Documented natural obstacles to anadromous salmonid migration downstream of Toketee Falls are listed in Attachment 3-1. (Note that obstacles to movement of resident fish are very numerous and therefore not listed; see PacifiCorp [1995], Volume 6, Section 8.)

On the mainstem North Umpqua River, Toketee Falls, which is located 7.7 km (4.8 miles) upstream of Soda Springs dam and 2.3 km (1.4 miles) upstream of Slide Creek dam, presents a complete natural barrier to all upstream fish migration. In Fish Creek, a complex of cascades, chutes, and falls ranging to 5 m (16 ft) high is located approximately 5.2 km (3.2 mi) upstream from its confluence with the mainstem North Umpqua River (Pacificorp 1995). This feature is currently presumed to function as a barrier to most anadromous salmonids, although it has not yet been conclusively determined whether or not this feature functions as a complete barrier to anadromous salmonids at high flows. An unsubstantiated account of a steelhead being caught 2 miles upstream of this obstacle, near Camas Creek, in the 1920s (J. Dose, pers. com. 1997) suggests that anadromous fish have been able to pass this obstacle on occasion. Hydrologic and/or geomorphic changes may have since altered the characteristics of this obstacle. This quarter-mile long complex is formed of large boulders and so may be relatively less permanent in a geological sense than those barriers represented by bedrock falls.

With regard to upstream movements of fish, natural waterfalls range in function from acting as complete barriers to all species, extreme obstacles passable by only certain species or individuals and/or only under certain flow conditions, to being obstacles passable by all but a few species. Certain obstacles may be passable only at certain instream flows; therefore, upstream passage by fish may vary according to seasonal and peak flow characteristics (Trush 1987). If burst speed is used as a measure of salmonid leaping ability, steelhead should be able to surmount the greatest obstacles (Orsborn and Powers 1985). Therefore, under reference conditions, steelhead likely occupied a greater portion of the watershed than other anadromous salmonid species. Pacific lamprey may be able to surmount many natural obstacles impassable to salmonids due to their ability to attach onto rocky substrate with their sucker disk and rest during upstream movements (Moyle 1976).

Under reference or undisturbed conditions in western Cascades streams, large woody debris (LWD) loading and the frequency of large debris jams is assumed to have occurred at much higher levels than under current conditions where human disturbance of riparian areas and LWD removal efforts have generally reduced LWD loading values. Naturally-formed debris jams (for example, those consisting of uncut trees and branches) under undisturbed conditions are believed to only rarely result in impassable barriers to anadromous salmonids, unlike those formed of logs remaining following timber harvest activities in a basin (J. Dose, pers. com. 1997). Large flood events, mass wasting, and debris flows may have occasionally functioned to create barriers to anadromous salmonid movement in the basin under reference conditions. It remains unknown what effects this may have had on anadromous salmonid populations.

Riparian habitats consisted of primary forests in a patchwork of ages and species created by fires, windthrow, landsliding, forest pathogens, insect outbreaks, and flooding. Disturbance maintained habitat structure and complexity (such as snags, downed wood) on which many organisms depend. Under reference conditions in the North Umpqua River basin, it is estimated that more than 70 percent of the total stream channel length was bordered by late-successional coniferous riparian forest (USDA Forest Service 1997b, USDI Bureau of Land Management 1996, USDA

Forest Service and USDI Bureau of Land Management 1995). Areas of early or mid-seral riparian vegetation likely occurred most frequently along smaller low-order stream channels where fire, mass wasting, or other processes disturbed riparian habitats more regularly (USBLM 1996). Unconfined stream reaches with associated floodplain vegetation are relatively rare in the North Umpqua River basin; early seral deciduous riparian vegetation such as alder, vine maple, willow, and cottonwood would be most commonly found in such habitats and thus would have had a patchy distribution under reference conditions. Deciduous riparian vegetation would have been characteristic of lower-gradient alluvial sections of the mainstem or tributary streams, and riparian areas recently disturbed by natural events. Riparian areas over much of the landscape likely consisted of old-growth coniferous forest with an abundance of downed woody debris and a relatively moist and cool microclimate. In confined channels and those bounded by rocky inner gorge areas, longitudinal connections between patches of riparian vegetation and lateral connections between stream channels and adjacent hillslopes are naturally limited.

3.4 CURRENT CONDITIONS

Anthropogenic activities affect aquatic and riparian habitat connectivity in ways that may be substantially different from the effects of natural disturbance mechanisms. Obstacles to connectivity arising from natural disturbances tend to be dynamic across the landscape and such disturbances generally allow the ecosystem to recover to conditions present prior to the disturbance. In contrast, many anthropogenic disturbances (such as timber harvesting, hydroelectric development) are static and may impede the recovery potential of the ecosystem (Reeves et al. 1995).

Habitat connectivity in the North Umpqua River watershed has been altered from reference conditions by the following: (1) dams and associated facilities; (2) reservoirs; (3) flows in bypass and full-flow reaches; (4) stream diversions and interceptions; (5) culverts and road/stream crossings; (6) roads in riparian areas; (7) disturbance of riparian vegetation; (8) changes to water quality; and (9) modifications of natural obstacles. The characteristics of these features or changes to reference conditions are described below. Maps showing current distributions of steelhead, coho salmon, and chinook salmon and barriers affecting these distributions are displayed in Attachment 3-2. Sea-run cutthroat trout distribution is not shown, because of the lack of information on their distribution as distinct from the resident cutthroat distribution.

3.4.1 Dams and Other Hydroelectric Project Facilities

Dams and other hydroelectric facilities can create obstacles or barriers to movement through streams and Riparian Reserves. Winchester dam is the most downstream dam on the North Umpqua River, located 11 km (7 mi) upstream from the river's confluence with the South Umpqua River. The dam is outfitted with a ladder that allows passage by fish. The North Umpqua Hydroelectric Project consists of five dams on the mainstem North Umpqua River (Soda Springs, Slide, Toketee, and Lemolo Nos. 1 and 2), one on Fish Creek, and two on Clearwater River. PacifiCorp (1995) provides the following information on each dam.

- Soda Springs dam is a 23.5-m (77-ft) high thin arch reinforced concrete dam.
- Slide Creek dam is a 9.1-m (30-ft) high concrete gravity structure.
- Toketee dam is an earthfill, center clay core structure dam 17.7 m (58 feet) in height.
- Lemolo No. 2 diversion dam is 7.6-m (25-ft) high and has a fish ladder that is not currently functioning well.
- Lemolo No. 1 dam is a rockfill structure with upstream concrete facing and a 32.3-m (106-ft) spillway.
- Fish Creek diversion dam is a 2-m (6.5-ft) high concrete gravity structure with free crest spillway with a fish ladder and sluiceway.
- Clearwater No. 2 diversion dam is a 5.5-m (18-ft) high concrete buttress on a concrete slab, with a free crest spillway.
- Clearwater No. 1 diversion dam is a 5.2-m (17-ft) high earthfill structure with upstream riprap face and free crest concrete spillway.

Other hydroelectric features located within Riparian Reserves includes waterways, penstocks, and powerhouses. There are 50.7 km (31.5 miles) of waterway and 9.3 km (5.8 miles) of penstock associated with the hydroelectric project. Where waterways cross streams, they can prevent movement of animals along the riparian area as well as instream transport of LWD and sediment. Where the waterway crosses a stream on an elevated flume trestle, movement of animals through the Riparian Reserve is less affected. Wildlife bridges also provide opportunities for some species, such as deer and elk, to cross waterways near streams, as discussed in Section 8 (Terrestrial Resources).

3.4.2 Reservoirs

The creation of reservoirs by dam construction results in the transformation of flowing stream reaches into stillwater or slower-velocity habitats, interrupting the longitudinal continuity of the stream habitat. PacifiCorp (1995) summarizes information on project reservoir and impoundment surface area at normal water surface elevations. There are three reservoirs on the mainstem of the North Umpqua River: Lemolo Lake (419 acres [170 hectares]), Toketee Lake (97 acres [39 hectares]), and Soda Springs reservoir (32 acres [13 hectares]). The Clearwater No. 1 diversion dam on the Clearwater River impounds the 12-acre (5 hectares) Stump Lake. There is no active water storage in the Fish Creek diversion impoundment at the normal water surface elevation. Smaller impoundments exist at the Lemolo No. 2 diversion dam (1.4 acres [.6 hectares]), Clearwater No. 2 diversion dam (1.2 acres [.5 hectares]), and Slide Creek diversion dam (2.0 acres [.8 hectares).

Lemolo, Toketee, and Stump lakes currently inundate a large portion of the relatively uncommon unconfined stream reaches found in the basin, transforming these areas to stillwater habitats and drawdown zones.

Resident trout reside in all project reservoirs. Brown trout, an introduced species capable of preying on fish and amphibians, are currently the dominant species of trout in Lemolo and Toketee lakes. Brown and rainbow trout also occur in Soda Springs reservoir, while brook and rainbow trout occur in Stump Lake. Amphibians are uncommon in project reservoirs (see Section 5, Reservoir and Forebay Management).

3.4.3 Flows in Bypass Reaches and Full-Flow Reaches

Flow fluctuations in bypass and full-flow reaches and reduced flows in bypass reaches may affect the habitat and movement of aquatic species in these reaches. Bypass reaches occur along the North Umpqua River, Clearwater River, and Fish Creek, in between each point of diversion and the associated powerhouse tailrace (see Attachment 3-3 for information on flows in bypass reaches). Full-flow reaches occur on the North Umpqua River at the following locations: (1) Lemolo No. 2 powerhouse to Toketee Lake; (2) Toketee powerhouse to the Slide Creek diversion; and (3) Slide Creek powerhouse to Medicine Creek Bridge.

3.4.4 Diverted and Intercepted Tributaries

Eight tributary streams are fully or partially diverted by small dam and diversion structures into waterways—Helen, Potter, Spotted Owl, Karen, Deer, Thorne, and Mill creeks into the Lemolo No. 2 waterway and White Mule Creek into the Lemolo No. 1 waterway (Map 3-1). Table 3-1 summarizes information on the diverted tributaries (see Attachment 3-4 for detailed information on each diversion). Only Deer Creek has minimum instream flow requirements, currently set at 1 cfs. In the other streams, water flows into the reach below the diversion only during high-flow periods when the flows in the tributaries exceed diversion capacity. Accretion flows downstream of the diversion contribute water to the channels during some periods of the year, but in many cases the channel downstream of the diversion is completely dewatered. Flows in a total of approximately 8.3 km (5.1 mi) of stream are eliminated or reduced by the diversions, in drainage areas totaling approximately 70.3 square kilometers (26.9 square miles). Deer Creek accounts for the great majority of the affected area (about 50 percent of the total drainage area affected by tributary diversions and 50 percent of the stream miles affected by tributary diversions). In Deer Creek, resident rainbow and brown trout occur downstream of the diversion and upstream to a barrier of about 9 m (30 ft) above the diversion. In Mill Creek, rainbow trout occur downstream of the diversion and to 1.53 km (0.95 mi) upstream. In Potter Creek, rainbow and brown trout occur downstream of the diversion and to 0.41 km (0.25 mi) upstream.

The diversion of tributaries affects the quality of Riparian Reserves as well as aquatic habitat. The waterways at Potter and White Mule creeks create barriers to movement of animals along the Riparian Reserve. Riparian vegetation downstream of diversion is assumed to have been affected by the reduction in available water. Downstream of the Potter Creek diversion, riparian vegetation is also chronically disturbed by severe erosion over a length of about 244 m (800 ft), and the road culvert needs improvement to restore aquatic and riparian habitat connectivity.

Table 3-1. Information on diverted tributary streams in the North Umpqua Hydroelectric Project area and changes to baseflows due to diversions.

Stream	Tributary To	Length of Reach Downstream of Diversion	Total Length of Reaches Upstream of Diversion	Drainage Area (to waterway)	Drainage Area (to North Umpqua River)	Quantity of Flow Diverted	Estimated Mean Summer Baseflow Above Diversion (cfs)	Estimated Summer Baseflow Below Diversion (cfs)
White Mule Creek	Lemolo No. 1 (North Umpqua River)	0.1 km (0.06 mi)	8.3 km (5.2 mi)	12.7 km^2 (4.9 mi^2)	12.7 km^2 (4.9 mi^2)	Up to 100 percent	0-0.7	0
Helen Creek	Lemolo No. 2 (North Umpqua River)	0.1 km (0.06 mi)	1.4 km (0.9 mi)	0.8 (0.3 mi^2)	0.9 km^2 (0.3 mi^2)	Up to 100 percent[a]	0.4	0
Potter Creek[b]	Lemolo No. 2 (North Umpqua River)	0.5 km (0.3 mi)	10.1 km (6.3 mi)	4.9 km^2 (1.9 mi^2)	5.0 km^2 (1.9 mi^2)	up to 100 percent	0.8-2.4	1.1[a]
Deer Creek	Lemolo No. 2 (North Umpqua River)	4.4 km (2.7 mi)	55.1 km (34.2 mi)	27.8 km^2 (10.7 mi^2)	39.8 km^2 (15.3 mi^2)	50 to 90 percent[a, c]	3-12	1 (required minimum)
Karen Creek	Lemolo No. 2 (Deer Creek)	0.07 km (0.04 mi)	3.9 km (2.4 mi)	2.3 km^2 (0.9 mi^2)	2.2 km^2 (0.8 mi^2) (to confluence with Deer Creek)	Up to 100 percent[a]	1.1	0
Spotted Owl Creek[e]	Lemolo No. 2 (Deer Creek)	0.3 km (0.2 mi)	5.7 km (3.5 mi)	4.7 km^2 (1.8 mi^2)	3.1 km^2 (1.2 mi^2) (to confluence with Deer Creek)	Up to 100 percent[a]	1.4	0
Thorn Creek	Lemolo No. 2 (Deer Creek)	0.9 km (0.6 mi)	4.6 km (2.9 mi)	2.3 km^2 (0.9 mi^2)	2.7 km^2 (1.0 mi^2)	Up to 100 percent[a]	1.0	0
Mill Creek	Lemolo No. 2 (North Umpqua River)	1.9 km (1.2 mi)	6.6 km (4.1 mi)	3.9 km^2 (1.5 mi^2)	9.2 km^2 (3.5 mi^2)	Up to 100 percent[a]	1.75	0.6–0.8[a]

a USDA Forest Service (1997a). b 100 percent of Potter Creek is diverted into the Lemolo No. 2 waterway during summer, creating an approximately 800' section of dry streambed downstream. A spring-fed tributary provides flow 500' above the confluence with the North Umpqua River (USDA Forest Service (1996b)). c McBain and Trush (1997). d Calculated using baseflow per unit area of 1.25 cfs/$mi^{2,}$ as derived from stream gage data. e This diversion is not currently operational.

In addition to the diverted tributaries, a total of 39 seeps and Class 3 and 4 (perennial non-fish-bearing and intermittent, respectively) streams are intercepted into project waterways (Map 3-2). Of these, 28 flow directly into sections of gunnite canal; 11 enter concrete flume sections either directly or via a pipe (see Attachment 3-4 for detailed information on each interception). Some of these are intermittent streams that would normally be dry during the summer and fall months and some are perennial streams or seeps that normally flow year-round. The amount of water contributed by these interceptions to the generation capacity of the project is unknown but is relatively minor. When the project was constructed, these small tributaries were probably directed into project waterways because it allowed a simpler engineering solution than constructing a mechanism to pass water under or over the waterway.

The downstream reaches of intercepted tributaries are completely dewatered. Whether these tributaries would have a well-defined channel that connects with downstream reaches if flows were present, and what types of riparian vegetation occur, is unknown and probably varies greatly between the intermittent seeps and streams and the perennial streams. Information on the length of dewatered stream reaches, total length of reaches upstream of the points of interception, and drainage areas affected by the interceptions cannot be calculated, because seeps and many of the intercepted stream channels are not in the geographic information systems (GIS) database due to their small size. Except in the few cases in which there is a wildlife bridge across the gunnite canal at or near an interception, animals are unable to move across the waterway. Therefore, the hydroelectric project eliminates aquatic habitat and reduces or eliminates riparian habitat in the downstream reaches of intercepted tributaries and causes the upstream seeps and stream reaches to be physically disconnected from downstream portions of the channel network.

3.4.5 Culverts and Road or Waterway/Stream Crossings

Relatively high road densities occur in many subbasins of the North Umpqua River watershed, resulting in a large number of culverts and other road/stream crossings that may affect habitat connectivity for fish, amphibians, mollusks, and other organisms. Based on data from the Forest Service and Bureau of Land Management, there are about 4,845 km (3,028 mi) of road within the boundaries of the North Umpqua watershed. About 320 km (200 mi), or six percent, of these roads are associated with the North Umpqua Hydroelectric Project. Of these 320 km (200 mi), approximately half are required exclusively for the project; the other half are used jointly by the Forest Service and PacifiCorp. A complete survey of culverts in the watershed and their potential effects on aquatic species has not been conducted. Table 3-2 lists some documented culvert obstacles to migration of fish in the basin.

Where project waterways cross streams, culverts are often used to convey the water underneath the waterway. There are 19 streams that pass under concrete flume sections of project waterways—18 through culverts and one through a low underpass supported by concrete footings (Map 3-3). Some of these streams are perennial, while others are typically intermittent. The underpass and two of the 18 culverts are large enough to contain substrate and to provide adequate aquatic habitat connectivity under nearly all flow conditions, but restrict animal movement through the Riparian Reserve to movement within the culverts. Of the remaining 16 culverts, 12 are too small to collect and retain substrate and these may provide upstream passage

for some species only when dry or under low flow conditions; these culverts also substantially restrict Riparian Reserve connectivity. The remaining four streams are diverted under flumes through vertical riser culverts that completely sever riparian and aquatic connectivity. Attachment 3-5 provides information on each of the streams passed under concrete flumes. Information on the length of stream reaches upstream and downstream of the culverts, and drainage areas affected by the diversions, cannot be calculated because many of the affected stream channels are not in the geographic information systems (GIS) database due to their small size. In cases where streams are passed under concrete flumes, effects on aquatic and riparian connectivity are varied. Some riparian-associated species could possibly move through many of the culverts, but several are too small to allow movement except at very low flows. The few vertical standpipes prevent all upstream or downstream movement.

Table 3-2. Potential culvert obstacles to upstream fish migration.

STREAM	COMMENTS
Alvin Creek	Culvert along Road 72 determined to be a fish barrier. However, no fish were observed in this stream. Site may be a barrier to other aquatic species (PacifiCorp 1995, vol. 26).
Thorn Creek (tributary to Deer Creek)	Culvert along Road 71 determined to be a fish barrier. However, no fish were observed in this stream. Site may be a barrier to other aquatic species (PacifiCorp 1995, vol. 26).
Slide Creek	Culvert on Road 010 approximately 200 m upstream from mouth is barrier, however, a >15-m falls 45 m above the culvert is a natural barrier and would limit benefits of providing fish passage at the site (PacifiCorp 1995).
Fugowee Creek (tributary to Steamboat Creek)	"Possible" culvert barrier on Road 3827 may restrict anadromous fish access. Two culverts upstream on Road 100 may pose additional passage problems (USDA Forest Service 1997b). USFS plans to correct.
Little Rock tributary "C" (Steamboat Creek drainage)	Culvert on Road 3827 is potential barrier to anadromous fish (USDA Forest Service 1997b). USFS plans to correct.
Unnamed tributary south of Wendy Creek in the Horse Horse Heaven drainage	Forest Road 3830 may impede anadromous fish access to these tributaries (USDA Forest Service 1997b)
Fairview Creek	Culvert barrier located near mouth on Highway 138 (D. Loomis, 1997, pers. comm.)
Miller Creek (tributary to Rock Creek)	An oval culvert under Road 78 may present partial barrier to fish migration; detailed data are not available (ODFW 1996 [Miller Creek stream survey])
McComas Creek (tributary to Rock Creek)	Culvert on Road 78 blocks access to 1.25 km (2 mi) of historically available coho and steelhead habitat (USBLM 1996)
Kelly Creek (tributary to Rock Creek)	Culvert on Road 78 blocks access to 1.5 mi of historic coho habitat (USBLM 1996)

There are 21 additional streams—1, 2, and 18 along the Clearwater No. 2, Fish Creek, and Lemolo No. 2 waterways, respectively—that flow under elevated flume trestles and then through culverts under adjacent roads (Map 3-4) (see Attachment 3-6 for information on these culverts). Table 3-3 summarizes information on the streams that pass underneath elevated flume trestles and through road culverts. In general, the streams and associated riparian habitat are relatively undisturbed by the elevated flume trestles. After flowing under the elevated trestles, however, all of the streams enter culverts to pass under roads adjacent and parallel to the waterway. The majority of these road culverts are overhanging at the downstream end and therefore prevent upstream movement by aquatic species; others appear to allow movement in both directions under most flows or under only low flows. In most cases, species that can move outside of the wetted

stream channel could move through the Riparian Reserve by crossing over the road. Project roads probably do not present an obstacle to most species, although they may impede movement by smaller and/or less mobile species with strict requirements for cover and moist microclimates. Some roads have a wide band of fill, creating a greater barren area for animals to cross.

3.4.6 Disturbances to Riparian Vegetation

Late-successional and old-growth riparian vegetation in the North Umpqua River basin has been fragmented by streamside logging, road construction, construction of the hydroelectric project, and other management-related disturbances. A thorough mapping and analysis of riparian vegetation has not yet been conducted on a watershed scale in the North Umpqua River. Available information on the distribution of forest seral stages in the basin does not have the resolution necessary to evaluate current riparian conditions. An analysis of riparian areas using historical and recent aerial photographs could increase understanding of reference conditions for riparian areas and current conditions. Areas where streamside logging and road construction have occurred are often characterized by reduced instream LWD and reduced amounts of downed LWD in adjacent riparian habitats, due to past removal efforts and to reduced recruitment following streamside logging and road construction. The lowermost portions of tributary streams were often those most affected by road construction, stream clean-out, and streamside logging.

Due to the confined nature of most stream channels in the basin and the naturally patchy distribution of deciduous riparian vegetation more characteristic of floodplain habitats, riparian habitat connectivity has been influenced primarily by removal of late-successional coniferous forests adjacent to streams. Streamside logging, valley bottom road construction, recreational facilities, road/stream crossings, and features associated with the hydroelectric project (such as dams, waterways, access roads and transmission line corridors) may interrupt the continuity of Riparian Reserves and impede the movement and dispersal of animals within and between subbasins. Increased frequency of debris flows and mass wasting resulting from logging or road construction on unstable hillslopes may also result in impacts to riparian habitat connectivity.

The construction and ongoing presence of the North Umpqua Hydroelectric Project have also fragmented riparian vegetation. Ongoing maintenance of waterways, roads, and transmission line corridors requires removal of vegetation, including that in riparian areas. In some cases, sidecast material resulting from road and waterway maintenance activities is deposited into Riparian Reserves, creating an ongoing disturbance that inhibits recovery of vegetation. Also, waterway spills and failures and the associated remediation efforts can disturb riparian vegetation.

Table 3-3. Information on tributary streams in the North Umpqua Hydroelectric Project area that pass under elevated flume trestles and associated road culverts.

Stream	Tributary to	Length of Reach Downstream of Culvert	Total Length of Reaches Upstream of Culvert	Drainage Area (to North Umpqua River)
Nancy Creek	North Umpqua River	0.096 km (0.059 mi)	0.020 km (0.012 mi)	1.04 km^2 (0.40 mi^2)
Beverly Creek	North Umpqua River	0.084 km (0.053 mi)	1.25 km (0.78 mi)	0.57 km^2 (0.22 mi^2)
Helen Creek[a]	North Umpqua River	0.11 km (0.068 mi)	1.40 km (0.87 mi)	0.86 km^2 (0.33 mi^2)
Norma Creek	North Umpqua River	0.077 km (0.048 mi)	1.64 km (1.02 mi)	0.84 km^2 (0.32 mi^2)
Dorothy Creek	North Umpqua River	0.097 km (0.06 mi)	2.92 km (1.81 mi)	1.37 km^2 (0.53 mi^2)
Sally Creek	North Umpqua River	0.12 km (0.074 mi)	0.56 km (0.35 mi)	0.50 km^2 (0.19 mi^2)
Sally Side Channel	Sally Creek	n/a[b]	n/a[b]	n/a[b]
Unnamed Creek-1	North Umpqua River	n/a[b]	n/a[b]	n/a[b]
Laura Creek	North Umpqua River	0.28 km (0.17 mi)	3.37 km (2.09 mi)	1.86 km^2 (0.72 mi^2)
Nurse Creek	North Umpqua River	0.28 km (0.17 mi)	5.31 km (3.30 mi)	2.15 km^2 (0.83 mi^2)
Barkenberger Creek	North Umpqua River	0.17 km (0.11 mi)	0.49 km (0.30 mi)	0.23 km^2 (0.09 mi^2)
Patricia Creek	North Umpqua River	0.53 km (0.33 mi)	4.28 km (2.66 mi)	1.97 km^2 (0.76 mi^2)
Unnamed Creek-2	North Umpqua River	0.22 km (0.14 mi)	0	0.093 km^2 (0.036 mi^2)
Alvin Creek	North Umpqua River	0.38 km (0.24 mi)	2.05 km (1.27 mi)	1.67 km^2 (0.64 mi^2)
Unnamed Creek-3	North Umpqua River	0.41 km (0.25 mi)	0.65 km (0.41mi)	0.28 km^2 (0.11 mi^2)
Spotted Owl Creek	Deer Creek	0.34 km (0.21 mi)	5.73 km (3.56 mi)	3.09 km^2 (1.19 mi^2)
Karen Creek[a]	Deer Creek	0.070 km (0.043 mi)	3.94 km (2.45 mi)	2.22 km^2 (0.86 mi^2)
Thorn Creek[a]	Deer Creek	0.86 km (0.54 mi)	4.62 km (2.87mi)	2.72 km^2 (1.05 mi^2)
No Tunnel Creek	Clearwater River	0.93 km (0.58 mi)	4.85 km (3.01 mi)	2.49 km^2 (0.96 mi^2)
No Name Creek-1	Fish Creek	0.46 km (0.29 mi)	6.79 km (4.22 mi)	6.44 km^2 (2.48 mi^2)

a = Area calculated from confluence with Deer Creek.
b = No stream network exists for analysis in DTM generated coverage.

3.4.7 Roads and Waterways in Riparian Areas

Streamside roads in the watershed may affect lateral habitat connectivity between aquatic, floodplain, riparian, and upslope habitats and/or may interrupt longitudinal connections between patches of riparian habitat. Where hydroelectric project waterways occur in riparian areas, they may have some of the same ecological effects as roads, such as interrupting connections and impeding or preventing animal movement.

Roads that parallel streams in the watershed exist along mainstem reaches, major tributaries, and headwater streams. The mainstem of the North Umpqua River is paralleled along much of its length by a paved highway (Highway 138) that may affect the movement of animals between

aquatic and terrestrial habitats and that fragments riparian vegetation. Examples of riparian roads in the Steamboat Creek basin include a large streamside road running along nearly the entire length of the mainstem of Steamboat Creek which encroaches into the riparian zone in many areas (USDA Forest Service 1997b). Much of the lower 8.9 km (5.5 mi) of Canton Creek contains roads within 61 m (200 ft) of the stream. Approximately 9.2 km (5.7 mi) of gravel surface road within Cedar Creek basin is situated within 61 m (200 ft) of the fish-bearing sections of the stream. Streamside roads also occur in the lower reaches of Calf, Panther, Limpy, Fairy creeks as well as along mainstem and tributary reaches of the Rock Creek and Little River basins. In the Little River watershed, for example, 23 percent of all roads (354 km [217 mi]) are adjacent to stream channels. Rock Creek mainstem reaches and larger tributaries are bordered by roads located within the riparian zone in many areas, according to ODFW stream survey data (ODFW 1996).

3.4.8 Changes to Water Quality

Changes to water quality characteristics resulting from dams, reservoirs, diversions, streamside logging, or other anthropogenic disturbances may impede movements of aquatic species through stream reaches or create gaps in suitable habitats. Reference and current conditions for water quality in the North Umpqua River basin are discussed in Section 6. Water quality impacts caused or exacerbated by the hydroelectric project that may adversely affect aquatic habitat connectivity include pH swings in the Lemolo No. 2 full-flow reach; relatively large changes in temperature over short distances of stream during the summer in the lower reaches of the Lemolo No. 2 and Clearwater No. 2 bypass reaches (due to the combined effect of reduced baseflows and substantial input of cold groundwater in these areas); increased water temperatures at the confluence of Fish Creek and the North Umpqua River; high TDGs in Lemolo Nos. 1 and No. 2 tailraces; and increased algal growth downstream of some reservoirs and tailraces.

Certain tributaries to the North Umpqua River, such as Steamboat Creek and Little River, appear to have summer stream temperatures that have increased from reference conditions due to streamside logging. Such increases appear to be diminishing as riparian areas recover from past disturbances. Ongoing forest management practices on non-federal land that allow logging in riparian areas on low-order streams may continue to impact water temperatures in some areas. Large daily fluctuations in pH and dissolved oxygen levels have been observed in Steamboat Creek and other North Umpqua River tributaries (Powell 1997). These fluctuations appear to represent a change in water quality characteristics from reference conditions, based on data from other relatively undisturbed streams in the western Cascades.

3.4.9 Modifications of Natural Obstacles

Modifications of obstacles to expand the range of anadromous fish have been undertaken at natural waterfalls and cascades within the North Umpqua River basin. Table 3-4 lists those modifications that have been documented.

Table 3-4. Changes made to natural obstacles to facilitate fish passage within the North Umpqua river watershed.

STREAM	COMMENTS
Copeland Creek	A 5.3-m (17-ft) cascade located 2.3 km (1.4 mi) upstream from the mouth may have historically restricted anadromous salmonid access (Eggers 1980). Modification to the falls in the early 1980s facilitated steelhead passage (T. Roelofs, 1997, pers. comm..)
Panther, Fairy, Limpy, and Bachelor creeks	Barrier modifications "several decades ago" may have increased anadromous salmonid distribution in Panther, Fairy, Limpy, and Bachelor creeks. Specific sites include: (1) confluence of Limpy and Panther creeks, (2) Panther Creek approximately 1 km upstream from confluence, (3) confluence of Limpy and Fairy creeks (Lightcap 1994).
Steamboat Falls	A fish ladder installed in 1959 may have increased steelhead and cutthroat access to the upper Steamboat Creek basin. The falls apparently remains a barrier to chinook and coho salmon (Dambacher 1991; USDA Forest Service 1997b)
Little River	A qualitative survey by the Oregon Game Commission in 1962 identified potential barriers to anadromous fish migration. Many of the barriers identified were altered or removed. One of the largest barriers, Poore Creek Falls, had a concrete passageway installed in 1989 (USDA Forest Service and USDI Bureau of Land Management 1995)

3.5 ECOLOGICAL IMPACTS

3.5.1 Potential Effects of Dams and Other Hydroelectric Project Facilities on Habitat Connectivity

Dams act as obstacles or barriers to the movement of aquatic species. Fish ladders may increase habitat connectivity for some fish, but may be ineffective for other native resident fish species and other aquatic organisms such as amphibians, aquatic macroinvertebrates, and freshwater mollusks. The condition of lands surrounding a dam may also affect habitat connectivity for species that require cover in Riparian Reserves. Animals such as small mammals and amphibians may be vulnerable to predation if they move across barren or sparsely vegetated landscapes. Changes to riparian microclimates caused by the existence of hydroelectric facilities may affect habitat suitability for amphibians, riparian-associated invertebrates such as land snails or slugs, and possibly small mammals that feed on fungi.

Winchester dam was a complete barrier to anadromous fish migration on the North Umpqua River during periods of low flows earlier in the century, although a modified spillway allowed passage at higher flows (FCO and OSGC 1946). A fish ladder allowing passage and the counting of upstream migrating fish has been in operation since 1946 at the dam. Currently, the fish ladder is believed to be passable by anadromous and resident fish.

Soda Springs and Slide Creek dams are downstream of Toketee Falls, which was the most upstream natural barrier to anadromous fish on the North Umpqua River under reference conditions. Neither of these dams has a fish ladder and both therefore block upstream migration of anadromous fish to historically accessible habitat. Soda Springs dam blocks access to at least 10.6 km (6.6 miles) of habitat for anadromous fish, including 3.4 miles in the North Umpqua River and 5.2 km (3.2 miles) in Fish Creek. Slide Creek dam blocks access to an additional 2.3 km (1.4 miles) in the North Umpqua River. The Anadromous Fish Passage and Offsite Mitigation section (Section 7) discusses this subject in more detail.

The Fish Creek dam fish ladder appears to allow unimpeded upstream movement by resident fish. The fish ladder at Lemolo No. 2 is currently operable; however, the entrance is not easily located by upstream migrating trout because most of the water flowing over the dam spills into the stilling basin. Fish may be attracted upstream into the stilling basin where they do not have access to the fish ladder entrance. Accessibility could be improved by connecting the fish ladder to the spillway stilling basin (PacifiCorp 1995, Volume 26). In most cases, dams create a complete barrier to upstream movement of species that are restricted to traveling within the wetted stream channel, such as fish, larval amphibians, and freshwater mollusks.

The project dams vary in the degree to which they block downstream movement of aquatic species (see Attachment 3-7 for a description of the ways in which each project feature affects aquatic and riparian habitat connectivity). In general, downstream movement at dams can occur three ways: through entrainment into project waterways; over spillways; and through instream flow release outlets. Aquatic organisms that are entrained into project waterways at diversion dams are shunted either into forebays or directly into powerhouses, where turbine mortality can result. Predators may be attracted to tailraces, where they may feed on injured or stunned fish and other aquatic species that are entrained into powerhouses. Most of the dams allow downstream movement of aquatic species over the spillways when flows are high. Instream flow release outlets may allow downstream movement of aquatic species at some diversion dams, but this route may be ineffective for many species because most of these valves are located where aquatic organisms would not generally use them (either deep in the water column or along the side of the waterway).

Species associated with riparian areas are able to move around project dams in some cases but not in others (see Attachment 3-7 for a description of the riparian connectivity around each dam). In some cases, wildlife could move around the dam on one side only. Some of the dams (particularly Lemolo No. 1) are so high that only the most mobile species could move around them, but others (such as Toketee and Clearwater No. 1) are relatively low and have suitable cover on the banks, such that they appear to be relatively easy for even smaller, less mobile species to circumnavigate. In some cases, concrete wing walls and junctions between the dam and waterway are barriers to movement of animals through the Riparian Reserve.

Penstocks and waterways also present obstacles to movement of some species in some areas of Riparian Reserve. Where penstocks and waterways are elevated, animals can pass underneath, and where wildlife bridges have been installed, some species such as deer and elk have crossing opportunities, although movement is much more restricted than would be possible in an undisturbed area. Some sections of the waterway are elevated enough that small to medium-sized animals could pass underneath it, but larger mammals could not. Existing wildlife bridges have been in place since the 1980s and provide opportunities for larger animals such as deer and elk to cross.

3.5.2 Potential Effects of Reservoirs on Habitat Connectivity

The creation of reservoirs by dam construction results in the transformation of flowing stream reaches into stillwater or slower-velocity habitats. Such habitat may not be suitable for some aquatic species because of changes to physical characteristics such as loss or reduction in directional flow, water temperatures, turbidity or chemical characteristics such as dissolved oxygen or pH levels. They may also be colonized by or stocked with introduced species, some of which may prey on native species that are moving through these habitats. If a species is especially vulnerable to predation, the presence of predators could function as an obstacle to movement through some reservoirs. Water level fluctuations in the reservoirs, particularly Lemolo Lake, inhibit the growth of shoreline vegetation and therefore reduce cover in the Riparian Reserves along the reservoirs. In addition, the shoreline of Lemolo Lake, situated upslope of the where the natural riparian zone was prior to inundation, is now located in well-drained soils that limit the growth of riparian vegetation.

Because of its relatively large size, Lemolo Lake in particular may affect dispersal of headwater stream amphibians such as tailed frogs; the lack of riparian vegetation along its shoreline may also affect habitat suitability for and movements of stillwater-associated amphibians. Reservoirs may constitute a complete barrier to the dispersal of mollusks such as freshwater snails and some unionid mussels if they cannot exist in reservoir habitats, since they cannot disperse overland. The creation of fish passage at dams could allow interchange between populations of unionid mussels upstream and downstream of reservoirs to occur because the larval stage of these species lives within a host fish. Reservoirs probably do not constitute complete barriers to most species of amphibians because the adult stage is capable of overland dispersal. Although exchange between upstream and downstream segments of the population may be more limited than under reference conditions, the successful exchange of only a few individuals between populations may be sufficient to maintain genetic diversity; however, a very low level of dispersal might slow or prevent re-colonization of areas of habitat in which a local sub-population has been extirpated, so that the goal of maintaining well-distributed populations across the landscape might not be completely met.

3.5.3 Potential Effects of Flow Changes in Bypass and Full-Flow Reaches on Habitat Connectivity

As described in the section on instream flows (Section 4), reductions and rapid fluctuations in instream flows in project-affected reaches can affect habitat quality and quantity and/or cause direct mortality of aquatic species. Diversion of larger mainstem stream reaches (North Umpqua River, Clearwater River, Fish Creek) reduces habitat availability and/or suitability for some species in bypass reaches. Reductions in stream flows may reduce the ability of some animals to use stream channels as migration corridors due to inadequate depth and/or changes in water temperatures (water temperature effects are discussed in Section 3.5.8, below).

Full-flow reaches are affected by daily ramping of flows due to power generation. Bypass reaches are subject to project-induced ramping only during annual maintenance activities and unplanned outages, but the magnitude of such changes in flows is much greater than in the full-flow reaches.

Ramping can cause mortality of fish, larval amphibians, and invertebrates by displacing eggs, larval, and adult forms to unsuitable sites downstream or by increasing vulnerability of disoriented individuals to predation; drowning of non-aquatic species; and stranding when the flows subside (see Section 4, Instream Flows, for a more detailed discussion on the magnitude, timing, and effects of flow fluctuations in project-affected reaches). These changes to instream flows likely reduce habitat suitability and movement of many aquatic species between stream reaches but do not completely eliminate the potential for movement through affected reaches. It is possible that flow fluctuations may make some reaches unsuitable for larval amphibians and some types of invertebrates, thereby fragmenting habitat. Flow fluctuations may also affect the habitat of the margined black knotmoss (*Scouleria marginata*), a sensitive moss species that lives in the splash zone along streams. This moss is a Survey and Manage species under the Northwest Forest Plan (USDA and USDI 1994, Table C-3). It has recently been identified along the North Umpqua River near the confluence with Steamboat Creek (C. Barkhurst, pers. com. 1997); information on its distribution in the watershed and its biology is limited.

3.5.4 Potential Effects of Diversions and Interceptions of Tributaries

Dewatered stream channels downstream of diversions and interceptions of streams by project waterways may isolate populations of aquatic species such as resident fish, mollusks, aquatic macroinvertebrates, and other aquatic invertebrates. Species that may have naturally disjunct populations, such as seep salamanders, may be particularly vulnerable to isolation of headwater streams and seeps (note, however, that the seep salamanders have not been documented in the hydroelectric project area, though they may occur). Aquatic species can be entrained into project waterways at tributary diversions and interceptions. In addition, nutrient cycling processes are disrupted by discontinuity in the longitudinal movement of nutrients and organic matter downstream. The downstream transport of LWD and sediment are also disrupted by stream diversion and interception. Interceptions and diversions also affect Riparian Reserve functions because animals are not able to move along the reserve across the waterway. In some cases, however, a wildlife bridge is located within the Riparian Reserve, allowing movement across the waterway by some species; these bridges provide movement opportunities but do not provide for full Riparian Reserve function, as intended by the Northwest Forest Plan. In summary, diversion and interception of tributaries reduces or eliminates aquatic and riparian habitat in the downstream reaches and results in upstream reaches being physically and biologically disconnected from the rest of the channel network.

3.5.5 Potential Effects of Culverts and Road or Waterway/Stream Crossings on Habitat Connectivity

Culverts often create obstacles or barriers to fish movement and migration. Such features may block upstream migration of anadromous fish and may affect movements of resident fish. Upstream movements of larval amphibians and mollusks may be blocked by culverts that have their outlets projecting over the stream channel. Culverts vary in their ability to provide passage; those that retain substrate and have low flow velocities, large diameters, and gentle gradients are believed to provide better conditions.

Culverts that act as complete barriers to movement may effectively isolate subpopulations of resident fish, amphibians, or other aquatic species and make them vulnerable to extirpation from catastrophic events. Determining which culverts form barriers requires site-specific data that are often lacking for many of the concerned basins. Many culverts are only passable over a narrow range of flows and may therefore be species-specific in their effects, depending on the timing of migration events. Such obstacles may have important effects on fish movements as well. For example, during an isolated storm event, a fish may begin its upstream migration on the rising limb of the hydrograph. At this flow, a culvert leading to spawning and rearing habitat within a tributary basin may allow fish passage. However, because the tributary flows peak sooner than those in the mainstem, the receding flows re-establish the culvert as a barrier before the migrating fish can reach the site. For a more detailed description of factors influencing fish passage at culverts refer to Powers and Orsborn (1985).

3.5.6 Potential Effects of Disturbances to Riparian Vegetation on Habitat Connectivity

Changes to streamside canopy cover, microclimate, downed woody debris, and vegetative communities may reduce habitat quantity and quality for fish, amphibians, small mammals, birds, macroinvertebrates, fungi, lichens, bryophytes, and other plant species in riparian areas. Streamside logging, hydroelectric project features (such as dams, waterways, transmission line corridors), roads, and recreational facilities have removed important cover within Riparian Reserves for small mammals and amphibians, potentially making them more vulnerable to predation. Reductions in instream flows may increase development of deciduous riparian habitat along some channels through encroachment of willows and other early seral vegetation or may decrease deciduous vegetation, depending on local hydrologic conditions.

Riparian zones are often important movement corridors for animals both between and within watersheds and are also potentially important for plant dispersal (Gregory et al. 1991). Extensive logging along North Umpqua River basin streams has likely reduced habitat connectivity for riparian-associated species that are weak dispersers, such as amphibians, land snails and slugs, and some small mammals. The protection of riparian vegetation in Riparian Reserves on federal land should restore habitat connectivity for these species in the long term, except where continuing impacts from project operations and other management-related disturbances and the ongoing presence of powerhouses, dams, roads, and other structures impede recovery of vegetation. However, riparian habitat connectivity may continue to be reduced on state or private lands in lower portions of the basin, especially along headwater streams that may be critical for dispersal of animals between subbasins.

3.5.7 Potential Effects of Roads and Waterways in Riparian Areas on Habitat Connectivity

Roads and trails that parallel streams, lakes, or wetlands, and project waterways that occur in riparian areas, may reduce interactions between the aquatic systems and adjacent riparian, floodplain, and upslope habitats. The presence of roads, trails and waterways reduces recruitment of LWD to stream channels because they directly reduce the amount of area covered by riparian forest and because they may function to interrupt the transport of wood from adjacent hillslopes

to stream channels. Roads, waterways, and rights-of-way that occupy riparian areas represent an ongoing loss of habitat. Riparian areas often serve as important foraging and denning habitat or cover for terrestrial species due to their structural complexity and species richness. Changes to riparian microclimates caused by the existence of roads and waterways in riparian areas may affect habitat suitability for amphibians, riparian-associated invertebrates such as land snails or slugs, and possibly small mammals that feed on fungi.

Species most likely to be negatively affected by roads in riparian areas include small mammals, amphibians, and mollusks that may be vulnerable to predation or those that hesitate to cross open areas lacking cover. For such species, roads paralleling stream channels may reduce habitat connectivity on a local scale, and may thus reduce rates of exchange between individuals of different sub-populations. However, habitat connectivity is probably sufficient to allow movement between sub-populations of most species that need to move between aquatic, floodplain, riparian, and upslope habitats. Roads, trails, or other developments that completely encircle wetlands or lakes may hinder movements of species to and from these habitats, reducing dispersal rates and genetic exchange with other populations and making these populations more susceptible to extirpation by catastrophic events. Function of Riparian Reserves can be compromised in areas of high road densities.

3.5.8 Potential Effects of Changes to Water Quality on Habitat Connectivity

Changes to water quality may affect aquatic habitat connectivity by reducing survival of aquatic organisms within certain stream reaches due to high water temperatures or other water quality problems. Certain stream reaches or reservoirs may be unsuitable for some aquatic species year-round or only during certain seasons or under certain conditions. Water quality is not likely to be a complete barrier to the movement of most fish species in the North Umpqua River basin because most changes to water quality involve seasonal changes in temperature, dissolved oxygen, turbidity, and pH and changes from reference conditions are probably not substantial enough to completely block passage for most of the year.

Changes to water quality may result in habitat fragmentation for relatively less mobile organisms such as larval amphibians, freshwater mollusks, and macroinvertebrates. Wide swings in pH, as have been documented in the Steamboat Creek drainage, may be harmful to the survival of freshwater mussels such as *Anodonta* spp. (Pynnonen and Huebner 1995, Fuller 1974). Reductions in water quality due the hydroelectric project or land use impacts, including increased algal growth, altered water temperatures, and changes in pH, may also locally affect habitat suitability and connectivity, particularly for aquatic species with poor dispersal capabilities such as macroinvertebrates or mollusks or those that have narrow seasonal windows for successful dispersal. Potential impacts of changes to these water quality parameters are discussed further in Section 6, although inadequate information is available with which to specifically evaluate the magnitude or relevance of these impacts to the issue of habitat connectivity. Reservoirs or stream reaches with habitat unsuitable for certain species do not necessarily result in impacts to dispersal between sub-populations because many of these species may naturally occur in patchy distributions.

Because very little is known about the life histories, habitat requirements, and environmental tolerances of most of the species that may be particularly sensitive to water quality problems, and because little to no information is available regarding historical and current distributions of these organisms, it is difficult to draw conclusions about the potential effects of existing barriers and obstacles to movement on the long-term health of these species' populations. Many of these species may have rather narrow habitat requirements and may be naturally patchy in distribution, while others may be tolerant of a fairly wide range of habitat conditions are may be more ubiquitous in the watershed. Barriers to dispersal of organisms between sub-populations in the watershed may contribute to cumulative effects that may increase the risk of extirpation of sub-populations and/or reduce the viability of some species' populations in the watershed.

High water temperatures may seasonally function as a dispersal barrier to organisms with narrow temperature tolerances, such as tailed frogs and seep salamanders. These two species spend several years in the larval stage, so reaches with high water temperatures for only a portion of the year would be unsuitable. Project-induced elevation of summer water temperatures in the North Umpqua River between Lemolo No. 2 dam and the confluence with Loafer Creek and in the Clearwater River between Clearwater No. 1 dam and the confluence of Watson Creek may create gaps in suitable habitat for tailed frogs and seep salamanders. Temperatures in Fish Creek under both unimpaired and current diverted conditions are probably too high to support populations of these species.

3.5.9 Potential Effects of Modifications of Natural Obstacles on Habitat Connectivity

Modification of natural obstacles to anadromous salmonid migration has been proposed as a measure to increase habitat area for spawning and rearing of salmonids. However, natural obstacles may have important effects on the distribution and persistence of aquatic species within a watershed. Barriers to fish distribution may be critical in some areas to the long-term persistence of amphibian and aquatic invertebrate populations that are vulnerable to fish predation. Some species may exist only where fish predation is reduced or nonexistent. It is believed that the stocking of rainbow trout into lakes and streams which were previously fishless may be at least partially responsible for amphibian declines in some regions (Hecnar and McCloskey 1997). Areas where fish predation pressure is relaxed or nonexistent may be important source areas for recolonization of habitats where amphibian populations have been extirpated due to natural or anthropogenic disturbances.

Modification of natural barriers may have unforeseen negative impacts on otherwise isolated populations of amphibian or invertebrate species. Such modification may compromise the ability of certain populations to persist or may result in extirpation from some areas and further isolation of sub-populations, especially in headwater areas that may have been impacted by other anthropogenic disturbances such as streamside logging. Modifications to natural obstacles in the North Umpqua River watershed have potentially allowed or increased anadromous salmonid (especially steelhead) access to several areas where they did not historically occur or may have changed the window during which passage over these natural obstacles is possible. However, many of these stream reaches were probably already occupied by resident salmonids and so the effects on native amphibians or invertebrates were probably less substantial than if fish were not

present above the obstacles. Numerous natural obstacles still exist on streams in the watershed due to its underlying geology. Therefore, it is not likely that modifications that have occurred to date have had substantial negative effects on native species.

3.5.10 Potential Impacts of Changes to Aquatic and Riparian Habitat Connectivity on Analysis Species

Salmonids

Landscape features that may act as obstacles to salmonid movements include dams, culverts, diverted reaches of stream, and high water temperatures or other water quality problems. Although anadromous salmonids have received the most attention with regard to migration barriers because of their extensive movements, native resident trout may also be negatively impacted by habitat fragmentation. Anadromous fish may be affected by changes to aquatic and riparian habitat connectivity in several ways. Features which block or impede upstream migration of adult anadromous salmonids reduce the amount of habitat available to them for spawning and rearing and eliminate an important nutrient source from being delivered to upstream reaches in the form of spawned out carcasses. Transformation of stream reaches into lentic reservoir habitats or changes to stream flows in bypass or diverted reaches may reduce the quality of habitat within salmonid migration corridors and increase mortality during migration by reducing instream flows used as directional cues, or by increasing exposure to predation or water quality problems (although predation and competition by non-native salmonids such as brown trout may also reduce habitat suitability and habitat connectivity in some stream reaches as well). Whether or not such changes to habitat connectivity result in reduced abundance of anadromous fish depends on the limiting factors controlling populations within the basin. Section 7 (Anadromous Fish Passage and Offsite Mitigation) discusses potential limiting factors that may be controlling anadromous salmonid populations in the basin and the relative benefit of providing passage to areas upstream of Soda Springs and Slide Creek dams. Barriers may also reduce genetic exchange between anadromous and resident portions of the population and/or reduce the potential for recruitment of anadromous individuals from resident populations (for example, cutthroat and rainbow trout).

Sub-populations of resident trout are currently isolated by obstacles and barriers to movement between the upstream and downstream portions of the mainstem North Umpqua River and Fish Creek or between small subwatersheds where streams are diverted into waterways. Isolation of resident salmonid sub-populations may reduce genetic integrity of these isolated populations by blocking immigration and reduce opportunities for natural recolonization of areas that are affected by catastrophic events such as debris flows. Whether or not the isolation of resident trout populations by the hydroelectric project has resulted in negative effects on genetic integrity or the health of native trout populations is unknown.

Pacific lamprey

Pacific lamprey distribution and dispersal in the North Umpqua River watershed is potentially affected by dams, reservoirs, culverts and road/stream crossings, and possibly stream reaches where water quality has changed from reference conditions. Natural features such as falls and cascades are probably less of an obstacle to Pacific lamprey than to salmonids due to their ability to secure themselves to the rocks. Moyle (1976) quotes Kimsey and Fisk (1964, p. 6) on the ability of Pacific lamprey to surmount obstacles: "Great wriggling masses of lampreys are often seen ascending barriers and fish ladders on coastal streams in the early spring...In many cases the flow is too great for the fish to move across the barrier in one attempt. They solve the problem by swimming until tired, then attaching themselves to the bottom and sides and resting for a while. When recovered, they make another attempt and move upstream several more feet. In this manner, by successive spurts and resting period, they move over various obstructions until they reach their spawning grounds." It is not known to what extent changes to habitat connectivity affect Pacific lamprey populations in the North Umpqua River watershed, although their populations have experienced substantial declines in the basin. The loss of habitat resulting from impassable barriers such as Soda Springs dam could potentially be contributing to depressed populations, particularly if the species would be able to use habitat upstream of the cascade obstacle in Fish Creek or upstream of other natural barriers in tributaries upstream of Soda Springs dam. However, Pacific lamprey declines appear to have been most severe in the 1970s, and therefore do not appear related to the erection of barriers by the hydroelectric project. (Section 7, Anadromous Fish Passage and Offsite Mitigation, includes more detailed discussion of Pacific lamprey population trends and possible causes for their decline.) Flow fluctuations downstream of Soda Springs dam have caused stranding of ammocoetes, reducing habitat suitability but probably not affecting habitat connectivity for this highly mobile species.

Amphibians

The amphibian species that are believed to be the most sensitive to impacts caused by the hydroelectric project and other anthropogenic disturbances in the watershed are those associated with headwater streams and seeps (tailed frog and seep salamander). Headwater streams are often important as amphibian habitat because predation pressure from fish is generally relaxed or nonexistent in these small streams. Because of their lack of fish, however, these streams have generally received less stringent protection with regard to streamside logging and road/stream crossings, as well as during the original construction of the hydroelectric project.

While most of the habitat in headwater streams in the basin is unaffected by the hydroelectric project, the diversion and interception of tributary streams may make habitat unsuitable in the reaches of these streams situated downstream of the waterways, potentially creating gaps between populations. The inundation of low gradient mainstem reaches by reservoirs in the North Umpqua River watershed reduced habitat primarily for species associated with wetlands and slow-moving water; however, it is possible that inundation removed some suitable habitat for species such as tailed frogs and seep salamanders in the lower reaches of tributary streams at Lemolo Lake.

Little is known regarding the movements of amphibians in the North Umpqua River basin. It is unknown whether headwater-associated species use shorelines along reservoirs as travel corridors to move between headwater streams. The diversion and interception of headwater streams by hydroelectric project waterways may act to isolate populations of aquatic amphibians that do not generally disperse overland. Such isolation may make these sub-populations vulnerable to extirpation by natural or human-induced disturbances such as logging, debris flows, landslides, or flood events. Tailed frogs and seep salamanders, whose populations tend to be patchily distributed even under natural conditions, are the species in the basin most likely to be sensitive to this type of impact, although seep salamanders have not been documented in the project area. While these species have been observed to travel across terrestrial habitat during wet conditions and may disperse between drainages in this manner, impacts to riparian and terrestrial habitats may reduce the success of such overland movements.

Connectivity of amphibians populations may be affected by entrainment of individuals into project waterways at tributary diversions and interceptions. Entrained individuals would be shunted to project forebays or powerhouses, where survival is expected to be low. See Section 5 (Reservoir and Forebay Management) for a discussion of factors influencing survival of amphibians in forebays.

The use of culverts at stream crossings rather than bridges in low-order stream channels potentially affects amphibian movements by replacing the natural stream channel substrate that animals would be traveling over with an artificial substrate that may be more difficult to traverse. Culverts that are installed with the outlet projecting over the stream channel ("shotgun" culverts) are common in the watershed and likely create total barriers to upstream movement for life stages that are restricted to the wetted stream channel (such as larval tailed frogs and seeps salamanders, and neotenic Pacific giant salamanders). Survival of downstream migrating individuals may be reduced at these sites as well. The formation of a scour pool at the outlet can create a barrier similar to the shotgun configuration. The other types of culvert problems discussed above in Section 3.5.5 likely also affect amphibian movements.

Habitat connectivity for aquatic species or life history stages of amphibians may be affected by changes to water quality in the basin. For example, high summer water temperatures may make certain reaches uninhabitable by species sensitive to water temperature, as discussed above in Section 3.5.8. This may not constitute a complete barrier to the dispersal of some species since the habitat may be suitable during other portions of the year; for species such as tailed frog and seep salamanders that spend over a year in the larval stage, severe water quality problems could create gaps in otherwise suitable habitat. Post-metamorphic forms may be able to live in or disperse through more disturbed aquatic habitats than egg and larval forms, and can travel overland outside of the wetted stream channel.

Amphibian species that use both terrestrial and aquatic habitats may be affected by changes that affect lateral habitat connectivity between stream channel, riparian, floodplain, and upslope areas. Species that use aquatic habitats for egg and larval stages but are terrestrial as adults (for example, northwestern salamander, Cascades and red-legged frogs, western toad) may be impeded in their movements between habitats by waterways, clear-cuts, or roads in riparian areas.

Disturbance to vegetation in Riparian Reserves can reduce habitat suitability for amphibians by reducing cover, shade, and LWD recruitment, all of which may affect microclimate.

Riparian-nesting birds

Birds that nest in deciduous riparian vegetation (for example, willows, vine maples, alders, cottonwoods) may be affected by disturbances to or removal of such vegetation through logging operations, changes to instream flows that affect growth and development of riparian vegetation, construction of roads in riparian areas that affect floodplain characteristics and functions, or changes to disturbance regimes that may affect development of riparian vegetation. Species in the North Umpqua River watershed that may use early-seral riparian areas for nesting include yellow warbler and willow flycatcher. Birds are less prone than other species to isolation of sub-populations on a watershed scale because of their dispersal capabilities. Therefore, it is likely that their populations would be more affected by direct loss of suitable habitat rather than by habitat fragmentation. Deciduous riparian vegetation in the North Umpqua River is naturally patchy in distribution due to the generally confined nature of much of the stream channel network. While willow and/or cottonwood habitat has perhaps never been common because of channel characteristics, alder habitat may have increased due to streamside logging and debris flows that occurred in the last 50 years. For this reason and because of the generally superior ability of birds to disperse, it is doubtful that habitat connectivity is an important factor affecting riparian-nesting bird populations in the watershed.

Mollusks

Mollusks may be the species most at risk in the basin for extirpation or extinction resulting from habitat fragmentation. Changes to aquatic habitat connectivity may affect the dispersal of freshwater mollusks and thus isolate sub-populations within the watershed. The isolation of sub-populations in tributaries, stream reaches, or reservoirs may increase potential for their extinction during catastrophic natural or anthropogenic disturbances, reduce genetic exchange with other sub-populations, and reduce the potential for long-term viability of populations within the watershed. Freshwater mussel populations appear to have been substantially reduced by alterations to river systems in the United States and many species have become extinct (Bogan 1993, Williams and Neves 1995). “Decline, local extirpation and the final extinction of freshwater bivalve species is directly tied to the degradation and loss of essential habitat” (Bogan 1993, p. 600). Population trends and current distributions of freshwater and riparian-associated mollusks in the Umpqua River are largely unknown, but the status of many species is considered extremely sensitive due to their apparent vulnerability to extirpation and extinction. The Riparian Reserve strategy on federal lands is expected to benefit riparian-associated mollusk species (USDA Forest Service and USDI Bureau of Land Management 1994, p. 38). However, land snails and slugs appear vulnerable to relatively minor disturbances and some species may suffer severe impacts even in Late-Successional Reserves from such relatively minor disturbances as thinning and burning (USDA Forest Service and USDI Bureau of Land Management 1994, p. 40). In addition, management activities on nonfederal lands may be substantial enough that a high risk of extinction would remain even with appropriate protection on federal lands (USDA Forest Service and USDI Bureau of Land Management 1994, p. 42).

Populations of freshwater mollusks expected to be most vulnerable to habitat fragmentation include those that are endemic to the basin or to smaller areas within the basin and those that have an annual life cycle, including the Umpqua pebblesnail (*Fluminicola* new species 12) and rotund lanx (*Lanx subrotunda*) (T. Frest, pers. com. 1997). Endemic species are most common in the *Lanx*, *Fluminicola*, and *Juga* genera, some species being confined to only one or a few intermittent streams, springs, or seeps (Holthausen et al. 1994). Within the area encompassed by the Northwest Forest Plan, the highest concentration of endemism in freshwater mollusks occurs in southern Oregon and northern California (USDA Forest Service and USDI Bureau of Land Management 1994). The risk of extinction may be very high for these species if their habitat is disturbed by timber harvest, road construction, grazing, stream flow diversion, or changes in water quality. Freshwater mollusks adapted to life in flowing water habitats are unlikely to survive in reservoirs, which results in the isolation of sub-populations within the watershed. Existing impoundments in the North Umpqua River basin are believed to have had negative impacts on *Fluminicola* populations as these organisms do not appear to survive in reservoir environments (Holthausen et al. 1994; T. Frest, pers. com. 1997). *Lanx subrotunda* are unlikely to exist in North Umpqua River reservoirs because of the species' preference for stream habitats with fairly swift currents and high dissolved oxygen levels (Holthausen et al. 1994; Weismar 1997; T. Frest, pers. com. 1997). Habitat for freshwater mollusks that require flowing water habitats and high levels of dissolved oxygen has likely been fragmented in the basin by the reservoirs.

Freshwater mussels in the North Umpqua River (such as *Margaritifera falcata* and *Anodonta* spp.) tend to be characterized by species that are not endemic to the basin and that have longer life spans than freshwater snails (Taylor 1981). Many species of freshwater mussels, including those occurring in or closely related to those in the basin, appear to be sensitive to watershed disturbances. *Anodonta californiensis* has become extinct in several states where it was formerly widespread, while *A. wahlametensis* has been extirpated from large portions of river and lake systems where formerly it was abundant (Holthausen et al. 1994). *M. falcata* appears to prefer high velocity stream habitat and thus is unlikely to survive in impoundments. Of the *Anodonta* species, *A. oregonensis* appears to be better adapted than other unionid mussels to reservoir conditions (Fuller 1974); however, its status appears to be tenuous in many reservoir-laden systems such as the North Umpqua River (T. Frest, pers. com. 1997). *A. californiensis* does not survive well in reservoirs and therefore populations of this species are likely fragmented in the basin (T. Frest, pers. com. 1997). Eutrophication in aquatic habitat also appears to be harmful to freshwater mussels because of reductions to pH and available dissolved oxygen levels (Fuller 1974). In addition to reservoirs and dams, stream reaches impacted by changes to water quality (temperature, pH, and dissolved oxygen) and/or sedimentation may also act as obstacles or barriers to the dispersal of freshwater mollusks.

Unionid mussels require host fish for completion of their life cycle. Therefore, their populations are vulnerable to disturbances affecting host fish populations as well as changes to their juvenile and adult habitat (Bogan 1993, Holthausen et al. 1994). Changes to aquatic habitat connectivity that block the movements and migration of anadromous fish populations within the North Umpqua River basin may also have reduced the dispersal capabilities and distribution of unionid populations.

Land snails and slugs that are associated with riparian and late-successional forest habitats are vulnerable to habitat disturbance and fragmentation in the North Umpqua River basin because of the group's propensity toward rarity and localized distributions. Most species are found in moist forest environments and around springs and other freshwater habitat (Holthausen et al. 1994). In the Pacific Northwest, many of the over 150 species of land snails and slugs are endemic and over 100 species have been identified as being associated with late-successional forests (Holthausen et al. 1994). Areas where populations have been extirpated are rarely recolonized because land snails are weak dispersers, not moving far from their natal sites (Holthausen et al. 1994). Examples of taxa that may be associated with undisturbed riparian areas in the North Umpqua River basin include *Monadenia* species (sideband snails) and *Prophysaon* species (tail-dropper slugs). Because many areas of the North Umpqua River basin have experienced streamside logging, habitat for these species may currently be fragmented, especially in low-order streams or springs where less stringent protection measures have been implemented. Even with buffer zones along stream channels, clear-cuts adjacent to riparian areas likely result in edge effects such as changes to microclimate and vegetative communities and increases in predation. Such effects may substantially reduce habitat quality for weak dispersers and endemic species such as land snails and slugs. Protection of riparian areas on private lands are probably inadequate for the long-term persistence of riparian-associated mollusks; therefore, protection of such habitat on federal lands is of primary importance for these species. Substantial risk of extirpation and extinction is still believed to exist on federal lands within the area covered by the Northwest Forest Plan because of the vulnerability of these species (Holthausen et al. 1994).

Aquatic macroinvertebrates

Many aquatic macroinvertebrate species are vulnerable to habitat fragmentation resulting from management disturbances to riverine ecosystems because of their relative immobility, extended stream residency, and the intolerance of many species to habitat changes. Hydroelectric facilities and operations likely affect habitat suitability for and dispersal of aquatic macroinvertebrates adapted to lotic (flowing water) conditions. Reservoirs are unsuitable habitat for most of these species, and changes to substrate characteristics, water quality, or instream flow regimes in bypass and full-flow reaches may also cause some stream reaches to be unsuitable for some species of aquatic macroinvertebrates. Increased sedimentation resulting from forest management practices or roads may make certain stream reaches unsuitable for species which live in the interstitial spaces between substrate, such as net-spinning caddisflies. Changes to the frequency, magnitude, or timing of high flows in bypass reaches may make habitat unsuitable for taxa that are intolerant of heavy scour and frequent mobilization of sediment. Changes to water temperature, increases in filamentous algae, and/or reduced capacity for retention of organic material may also make some stream reaches unsuitable for certain species.

Many aquatic macroinvertebrates commonly disperse and recolonize habitat patches through the mechanism of passive or active downstream drift. This dispersal mechanism may be impeded or blocked by the existence of dams, reservoirs, diverted or intercepted streams, or changes to habitat conditions in bypass reaches. Some species may disperse upstream in the adult winged stage, and therefore may be less likely than others to become extirpated upstream of the obstacles.

Species most at risk of extirpation due to habitat fragmentation are those associated with headwater reaches, seeps, or springs; species that are long-lived; and those that are relatively intolerant of habitat degradation. Five species of caddisfly have been documented as occurring in the Umpqua National Forest and are on its list of sensitive species: Cascades apatanian caddisfly (*Apatania tavala*), Mt. Hood primitive caddisfly (*Eobrachycentrus gelidae*), Tombstone Prairie farulan caddisfly (*Farula reaperi*), Fort Dick limnephilus caddisfly (*Limnephilus atercus*), and one-spot rhyacophilan caddisfly (*Rhyacophila unipunctata*). Four others documented as occurring in Douglas County are listed by the Oregon Natural Heritage Program or by The Nature Conservancy as species of concern (ONHP 1995): Vertree's ceraclean caddisfly (*Ceraclea* [= *Athripsodes*] *vertreesi*), Sagehen Creek goeracean caddisfly (*Goeracea oregona*), Alsea ochrotrichian micro caddisfly (*Ochrotrichia alsea*), and Vertree's ochrotrichian micro caddisfly (*Ochrotrichia vertreesi*).

Water shrew

Longitudinal habitat connectivity for water shrews and other small mammals may be reduced where riparian habitats have been affected by disturbance of vegetation and where obstacles to movement have been introduced. Such areas may include dams, reservoirs, road/stream crossings, and areas where streamside logging has occurred. Loss of downed woody debris or dense riparian vegetative cover may increase predation on small mammals such as water shrews and thus reduce survival of individuals using stream corridors for dispersal. Very little is known regarding water shrew dispersal; however, because they are relatively mobile, it is not likely that complete barriers to dispersal exist in many areas of the North Umpqua River watershed.

Other species associated with late-successional forest

One of the goals of Riparian Reserves is to provide habitat and movement corridors for species associated with late-successional forests. Features in Riparian Reserves such as waterways, dams, roads, and impassible culverts reduce the effectiveness of the reserves to serve as movement corridors. Also, where past or ongoing disturbances related to the hydroelectric project, roads, logging, or recreation result in changes to late-successional forest habitat, populations of poorly dispersing species may become fragmented from each other.

3.6 MANAGEMENT OPTIONS

3.6.1 Dams

Options for improving aquatic habitat connectivity at the project dams are described below. The following evaluations of these management options should be considered preliminary and would require more detailed engineering and ecological analysis prior to implementation. The costs of construction and lost hydroelectric power generation associated with these options have not yet been estimated.

General types of options for addressing aquatic connectivity at project dams

Actions that would address both upstream and downstream movements at dams include:

- removing dams;
- modifying dams, which could entail creation of a V-notch in dams, lowering dams, and/or constructing an engineered channel below the dams that allows passage; and
- developing a “passive riparian route” that semi-aquatic and terrestrial species could use to move around the dams.

Actions that would address only upstream movements, and would require evaluation to document success, include:

- installing fish ladders where they are currently lacking or improving existing fish ladders; and
- trapping and hauling fish around the dams.

Actions that would address only downstream movements, and would require evaluation to document success, include:

- spilling flows over dams;
- installing instream flow release outlets at the surface of the water column;
- installing screens at diversion intake structures to reduce entrainment, or installing screens in waterways and provide a bypass escape route directing fish into natural channels downstream of the dams; and
- modifying turbines to reduce mortality of organisms passing through them (although this may reduce mortality, it would not be considered an effective way to provide passage).

Of the above options, dam removal would provide the greatest improvement in aquatic and riparian habitat connectivity, as well as the largest loss of hydroelectric power generation. Management of the stored sediment that has accumulated in project reservoirs would be necessary prior to the removal of any dam. To address this problem, sediment could be dredged out of the reservoirs, as has been proposed for other reasons (PacifiCorp 1995). Dredged sediment could be placed back into the river over a period of time to augment sediment supplies downstream where depletion has occurred due to the dam’s capture of sediment. (See Section 2, Geomorphic Processes, for a discussion of project effects on sediment regimes and potential management options to address these changes.)

Modifying the dams might be the second best method for improving habitat connectivity. One option would be to construct an engineered structure on the downstream side of the dam face that mimics a boulder-dominated stream channel at a gradient of less than ten percent (which might be considered an "A2" channel under Rosgen’s [1994] classification system). This option would require lowering of the highest dams (for example, Soda Springs and Lemolo No. 1) in order to be effective, but could potentially be implemented at dams such as Slide Creek without lowering of the dam. Another modification option would be to create a V-notch in the dams.

Constructing engineered structures on the downstream side of dam faces, lowering the dams, or creating V-notches in dams might allow increased upstream and downstream passage of many aquatic organisms, particularly if spills were released over the top of the dam and/or if instream flows were increased. Modified dams could also possibly be designed to provide for increased downstream transport of bedload and LWD (currently, all dams except Lemolo No. 1 and Clearwater No. 1 have "trash gates" that allow project operators to pass LWD. Sediment currently stored in reservoirs, however, might be retained behind the dam, possibly eliminating the ecological need for dredging. Engineering constraints could limit the feasibility of dam modifications.

Providing a “passive riparian route” to allow semi-aquatic and terrestrial species such as amphibians and mammals to move around dams would improve riparian habitat connectivity and Riparian Reserve function at dams that currently block or impede movement along riparian corridors. Relocation, closure, or obliteration of roads or restoration of disturbed riparian habitats near dams could be done in association with this option.

The remaining options listed above would improve habitat connectivity to a somewhat lesser degree. Providing a fish ladder to allow upstream movement is considered preferable to trapping and hauling of fish around dams. Neither of these options would improve passage over dams for aquatic organisms other than fish. To improve opportunities for downstream movements, shutting down the powerhouse and spilling water at certain times of the year may provide some benefit~~s~~, and might improve passage of LWD, although it would not increase transport of sediment nor improve habitat connectivity for a number of aquatic and riparian species. Installing instream flow release outlets closer to or at the water’s surface, screening waterways and providing bypass escape routes, and possibly modifying turbine designs could also facilitate downstream movements of aquatic organisms. The feasibility and potential benefits of modifying turbines based on new technology are largely unknown.

Site-specific evaluations

Based on an initial review by the Scientific Team, priorities for improvement of habitat connectivity at project dams are (from highest to lowest priority): (1) Soda Springs; (2) Toketee; (3) Slide Creek; (4) Fish Creek; (5) Clearwater No. 1; (6) Clearwater No. 2; (7) Lemolo No. 2; and (8) Lemolo No. 1. Each of these sites is discussed briefly below. A table displaying the notes from the Scientific Team discussion of relative priorities at dams is given in Attachment 3-7.

Soda Springs dam

Improving aquatic connectivity at this dam would result in the highest potential benefits to anadromous fish and other aquatic organisms in the mainstem reaches of the watershed. Providing passage for anadromous fish would allow access to at least 10.6 km (6.6 mi) of potential habitat, including 5.4 km (3.4 mi) in the North Umpqua River and 5.2 km (3.2 mi) in Fish Creek. Improving aquatic habitat connectivity at Soda Springs dam would enhance longitudinal connections between the Wild and Scenic River reach downstream of Soda Springs dam and upstream portions of the watershed, including Fish Creek, which is a major tributary

upstream of the dam (see Section 7, Anadromous Fish Passage and Offsite Mitigation, for a discussion of the potential benefits of providing fish passage at Soda Springs or Soda Springs and Slide Creek dams).

Modifying or removing Soda Springs dam would reduce or eliminate its ability to function as a re-regulation facility to reduce the magnitude of flow fluctuations caused by operating the hydroelectric facilities located upstream to meet load requirements Re-regulating flows at Soda Springs dam currently dampens project-related flow fluctuations in the Wild and Scenic River reach downstream. Removal of Soda Springs dam would limit load factoring operation of the project or require using Toketee Lake as a re-regulation facility in order to prevent or reduce project-induced flow fluctuations in the Wild and Scenic River reach. A table displaying the notes from the Science Team discussion of relative priorities at Soda Springs dam is given in Attachment 3-8.

Toketee dam

Improving habitat connectivity at Toketee could provide opportunities for dispersal of amphibians and other aquatic species between reaches located upstream and downstream of the dam and may improve habitat conditions for aquatic species in general. Management options that improve passage of LWD and allow sediment transport could improve longitudinal connections for such fluvial processes between the Clearwater and the North Umpqua rivers. In recent years, the natural channel of the Clearwater River has divided, creating a new channel that flows around Toketee dam and directly into the Toketee bypass reach of the North Umpqua River. Maintaining flows through this channel might provide the easiest and most ecologically beneficial option for improving aquatic and riparian habitat connectivity between the Clearwater River drainage and the North Umpqua River reaches below Toketee dam.

Providing fish passage at Toketee dam would not benefit anadromous fish, as their upstream movements are blocked by Toketee Falls, located downstream. Due to the presence of substantial numbers of introduced brown and brook trout in Toketee Lake and the Clearwater River, as well as the number of natural barriers to fish passage in the Clearwater drainage, improving habitat connectivity for resident trout is a relatively low priority at this site. Ongoing recruitment of brown trout from Toketee Lake to downstream areas, which occurs via entrainment through the Toketee waterway and powerhouse, may reduce habitat quality for native species in these downstream areas. Options for reducing the downstream dispersal of introduced trout species include installation of devices to either reduce entrainment or survival of entrained fish.

Slide Creek dam

Providing anadromous fish passage at Slide Creek dam should be considered only if passage at Soda Springs dam is to be provided as well, because Soda Springs dam constitutes a barrier to anadromous fish downstream of Slide Creek. Passage at Slide Creek dam would allow access to an additional 2.3 km (1.4 mi) of stream habitat in the North Umpqua River. Because there are no significant tributary streams that enter the North Umpqua River upstream of Slide Creek dam and downstream of Toketee Falls, altering Slide Creek dam to allow passage of sediment would be a relatively low priority at this dam.

The highest estimated annual entrainment of both brown trout and amphibians during the relicensing studies (PacifiCorp 1995) occurred at the Slide Creek diversion. Organisms entrained at the Slide Creek diversion are delivered directly to the Slide Creek penstock and turbines, where turbine mortality is estimated at 30 percent. Since the movement of brown trout downstream into the Slide Creek bypass reach would likely increase if the dam were modified, potential adverse ecological consequences of increasing opportunity for downstream dispersal of this species would need to be assessed. Because the Slide Creek dam is relatively low (9 m [30 ft]), the construction of an engineered channel on the downstream side of the dam face may be possible without modification of the existing dam structure.

Fish Creek dam

Fish Creek dam is a low-head dam with a functioning fish ladder that currently provides adequate passage for resident fish. Altering the dam would be unlikely to improve conditions for anadromous fish, because a fish ladder is already in place and because a natural barrier located downstream likely blocks movement of most anadromous fish. However, modifying the dam could enhance or restore physical processes such as sediment and LWD transport, improving longitudinal connections between the headwaters and lower reaches of the Fish Creek basin. Some amphibians and aquatic invertebrates might benefit from such modifications, although water temperatures in Fish Creek, even under undiverted conditions, appear to be too high for certain species such as the tailed frog and seep salamander (see Section 6, Water Quality, includes a more detailed discussion of water temperature effects on aquatic species).

Clearwater No. 1 dam

The Clearwater No. 1 dam created Stump Lake by inundating what was formerly a wetland. Stump Lake continues to provide wetland habitat for some species, although it is much deeper than under reference conditions. Modifying Clearwater No. 1 dam to improve aquatic habitat connectivity would increase ecological connections between the headwaters of the Clearwater River, Stump Lake/wetlands, and downstream portions of the watershed. Modifications that re-connect Bear Creek (a tributary to Stump Lake) with the Clearwater River would potentially improve both aquatic habitat connectivity and habitat conditions in downstream reaches since Bear Creek was the main source of sediment to the Clearwater River under reference conditions. A table displaying the notes from the Science Team discussion of relative priorities at Clearwater No. 1 dam is given in Attachment 3-9.

Clearwater No. 2 dam

Alteration of Clearwater No. 2 diversion dam could ecologically re-connect Mowich Creek, a relatively large tributary, to the rest of the Clearwater River basin. Amphibians and other aquatic species would be expected to benefit from such modification, and physical processes such as transport of sediment and LWD between Mowich Creek and the Clearwater River could be enhanced or recovered.

Lemolo No. 2 dam

Upstream movements of resident fish could be improved at this dam by modifying the existing fish ladder. Modifying the dam to improve or restore ecological connections between Warm Springs Creek and the North Umpqua River would improve habitat connectivity for amphibians and other

aquatic organisms and increase transport of sediment and LWD from Warm Springs Creek to the North Umpqua River.

Lemolo No. 1 dam

Restoring aquatic habitat connectivity at Lemolo No. 1 dam would require substantial alterations due to its height (32.3 m [106 ft]). Lowering of the dam might partially address concerns about water quality and eutrophication in Lemolo Lake and its potential effects on aquatic habitats downstream. Restoration or enhancement of sediment and LWD transport at this dam would increase ecological connections between the upper North Umpqua River basin and downstream reaches. Installation of fish screens at the diversion intake would address the problem of entrainment of aquatic species into the Lemolo No. 1 waterway. Entrained individuals are currently delivered directly to the Lemolo No. 1 penstock and turbine, where mortality is high. If the proposed Lemolo No. 1 forebay (see PacifiCorp 1995) is designed to provide suitable aquatic habitat that entrained organisms could live in or disperse from, such mortality would be reduced, but habitat connectivity would not be improved.

3.6.2 Reservoirs

Predation by native and non-native resident trout in reservoirs may be a factor limiting the movement or occurrence of some species (especially amphibians) in reservoirs. Studies would be necessary to determine the effects of reservoir predators on populations of native aquatic species. If predation is determined to be a limiting factor, control of trout populations could potentially increase habitat connectivity for species vulnerable to such predation. Methods that are sometimes employed in the control of exotic fish include lethal methods such as poisoning, relaxation of harvest regulations, or bounties; however, these efforts must be continued indefinitely in order to be effective and may cause incidental mortality of native species. Addition of physical structure to reservoir habitats could possibly reduce predation, but this action could also increase predator populations or their success. In general, populations of introduced fishes are difficult or impossible to eradicate once established, often support popular recreational fisheries, and may be intentionally reestablished by the public. Because of these issues, control or removal of trout populations in reservoir habitats in the North Umpqua River watershed may not be a viable management option.

Alteration of reservoir habitats to restore habitat connectivity for mollusks or other aquatic species that depend on stream channels to disperse upstream or downstream through the channel network would involve substantial modification of the structure and/or operation of the hydroelectric project. An alternative that would limit reservoir fluctuations could restore connectivity of flowing water habitat and associated populations.

3.6.3 Flows in Bypass and Full-Flow Reaches

Management options for bypass and full-flow reaches of the North Umpqua River mainstem are described and evaluated in Section 4 (Instream Flows). These options include management of baseflows (minimum instream flows), high flows, and flow fluctuations associated with power

generation, annual maintenance activities, and unplanned project shut-downs. Options that have fewer ecological impacts are the most likely to best maintain habitat connectivity.

3.6.4 Diverted and Intercepted Tributaries

In addition to the "no action" option, 12 specific management options—eight single actions and four combinations—were evaluated for addressing habitat connectivity for aquatic and riparian-associated species. Each of these 13 management options is discussed in this section. Table 3-5 lists these management options and summarizes the benefits and costs associated with each, along with preliminary rankings by the Terrestrial Subgroup of the ability of each option to meet the defined management goal. See Attachment 3-10 for detailed information on cost estimates. The costs associated with each option represent extremely rough estimates and are presented primarily for comparison purposes. More accurate cost estimates will be prepared for the Resource Team as needed to facilitate decision-making. At the end of this section a comparative discussion of the costs and benefits is presented.

Monitoring efforts associated with these options would include implementation monitoring, such as periodic field inspection to ensure that the actions specified in the management option (for example, restoration of flows, maintenance of culverts to pass flood flows and retain bedload) are correctly implemented and maintained over time. In addition, effectiveness and validation monitoring may be needed in some cases to ensure that the biological objectives of the management options (for example, animals are able to move through the Riparian Reserve across project waterways) are also being met.

Other combinations of options than those presented in this report may be developed in order to achieve management goals. Likewise, the monitoring plans for a given option can be made less or more intensive based on the desired degree of certainty that the implemented options will be successful. The Resource Team, in consultation with the Scientific Team, will determine the combination of measures and level of intensity of monitoring efforts to best address management goals for aquatic and riparian habitat connectivity.

Table 3-5. Comparison of benefits and costs of management options for restoring aquatic and riparian habitat connectivity at tributary streams. (Note: Costs are very rough estimates and should be used for comparative purposes only).

	MANAGEMENT OPTION	Number of Streams with Restored Flows	Number of Miles of Stream with Restored Flows (mi)	Number of Streams with Restored Riparian Connectivity	Construction and Installation Costs ($)	Lost Power Generation Costs ($ per year)	Relative Rank	Confidence That Option Will Achieve Management Goals
1	NO ACTION	0	0	0	0	0	1	1
	SINGLE ACTION OPTIONS							
2	Increase summer minimum flows in Deer Creek from 1 to 2 cfs	0	0	0	0	cost of lost power generation from minimum flows	2	3
3	Restore reference flows to fish bearing tributaries diverted into the Lemolo No. 2 waterway (Deer, Mill, and Potter creeks)	3	4.2	0	4,000	78,000–234,000	4	15
4	Restore reference flows to the 8 tributaries diverted into Lemolo Nos. 1 and 2 waterways	8	5.1	0	29,000	127,000–382,000	7	25
5	Restore flows to the 8 tributaries diverted into Lemolo Nos. 1 and 2 waterways and reestablish aquatic and riparian connectivity to Potter and White Mule Creeks	8	5.1	2	2,000,000	127,000–382,000	8	35
6	Restore riparian habitat connectivity at 7 tributaries associated with elevated flume trestles	0	0	7	38,000	0	3	10
7	Restore reference flows and riparian habitat connectivity at 12 tributaries intercepted by waterways	12	3.4[a]	12	146,000	negligible	6	20
8	Restore riparian habitat connectivity at 12 tributaries that pass under concrete flumes through culverts	0	0	12	159,000	0	5	15
9	Restore aquatic and riparian habitat connectivity at tributaries intercepted by project waterways (39) or that pass under concrete flumes through culverts (approximately 16)	39	9.4[a]	55	1,152,000–24,000,000	negligible	9	50

	MANAGEMENT OPTION	Number of Streams with Restored Flows	Number of Miles of Stream with Restored Flows (mi)	Number of Streams with Restored Riparian Connectivity	Construction and Installation Costs ($)	Lost Power Generation Costs ($ per year)	Relative Rank	Confidence That Option Will Achieve Management Goals
	COMBINATION OPTIONS							
10	OPTIONS 4, 6, 7, 8: • Restore reference flows to the 8 tributaries diverted into Lemolo Nos. 1 and 2 waterways • Restore riparian habitat connectivity at 7 tributaries associated with elevated flume trestles • Restore reference flows and riparian habitat connectivity to 12 tributaries intercepted by waterways • Restore riparian habitat connectivity at 12 tributaries that pass under concrete flumes through culverts	20	8.5[a]	31	372,000	127,000–382,000	10	60
11	OPTIONS 5, 6, 7, 8: • Restore reference flows to the 8 tributaries diverted into Lemolo Nos. 1 and 2 waterways • Reestablish aquatic and riparian habitat connectivity to White Mule and Potter creeks • Restore riparian habitat connectivity at 7 tributaries associated with elevated flume trestles • Restore reference flows and riparian habitat connectivity at 12 tributaries intercepted by waterways • Restore riparian habitat connectivity at 12 tributaries that pass under concrete flumes through culverts	20	8.5[a]	33	2,850,000	127,000–382,000	11	80
12	• Restore reference flows to all diverted tributaries (8) • Reestablish aquatic and riparian habitat connectivity to White Mule and Potter creeks • Restore reference flows and riparian connectivity to all intercepted tributaries (39) • Restore riparian habitat connectivity at tributaries that pass under concrete flumes through culverts, where appropriate (approximately 16) • Restore riparian habitat connectivity at all tributaries associated with elevated flume trestles (21)	47	14.5[a]	78	3,307,000	127,000–382,000	12	90

MANAGEMENT OPTION		Number of Streams with Restored Flows	Number of Miles of Stream with Restored Flows (mi)	Number of Streams with Restored Riparian Connectivity	Construction and Installation Costs ($)	Lost Power Generation Costs ($ per year)	Relative Rank	Confidence That Option Will Achieve Management Goals
13	• Restore reference flows to all diverted tributaries (8) • Reestablish aquatic and riparian habitat connectivity to White Mule and Potter creeks • Re-establish reference flows and natural stream corridors, to the extent possible, at all tributaries intercepted by the project (39) • Re-establish natural stream corridors, to the extent possible, at all tributaries that pass under concrete flumes through culverts (approximately 16) • Restore riparian habitat connectivity at all tributaries associated with elevated flume trestles (21)	47	14.5[a]	78	5,772,000–28,620,000	127,000–382,000	13	95

a numbers are estimates, because many intercepted stream reaches are not mapped

Management Option 1: No Action

Under the "no action" option, no specific measures to improve aquatic and riparian habitat connectivity would be implemented.

Physical description
The existing diversion structures would remain on the eight streams that are currently diverted into the Lemolo Nos. 1 and 2 waterways. Similarly, project waterways would continue to intercept 39 streams. Culverts under roads and flumes would remain but some may be replaced over the life of the project with larger structures, as required to meet standards for erosion control and flood flow passage.

Achievement of management goal
The "no action" option would not likely meet the watershed goals of maintaining aquatic and riparian habitat connectivity and landscape linkages for fish and wildlife species in the watershed as a whole, although there would be site-specific improvements in the project vicinity based on planned improvements to culverts. Water would continue to be diverted from eight tributary streams along the Lemolo Nos. 1 and 2 developments, affecting associated riparian habitat and resulting in stream channels that are dry for much of the summer and fall months. In addition, project waterways would continue to intercept 39 streams and completely dewater the associated downstream channels. It is likely that the "no action" option would result in improved riparian connectivity for some of streams that currently pass through culverts under concrete flumes or roads. PacifiCorp currently plans to replace a number of existing culverts with larger structures to meet standards for erosion control and flood flow passage (see the Erosion Control Plan in PacifiCorp [1995]). These new larger culverts would be designed to carry bedload material as well as high flows, thus improving riparian connectivity for some streams. PacifiCorp engineers and biologists would work cooperatively to ensure that new culverts would improve riparian connectivity as well as flood flow passage.

Cost
There would be no cost associated with Option 1 (except those costs associated with culvert upgrades already planned).

SINGLE ACTION OPTIONS

Management Option 2: Increase summer minimum flows in deer creek from 0.028 to 0.057 cms (1 to 2 cfs)

Management Option 2 would involve increasing the summer minimum instream flow in Deer Creek from the current 1 cfs to 2 cfs, as proposed in PacifiCorp's license application for the North Umpqua Project (PacifiCorp 1995). Winter minimum instream flows would be increased from 0.057 to 0.113 cms (2 to 4 cfs).

Physical Description
As proposed in the license application, the minimum flow downstream of the Deer Creek diversion would be increased from 1 to 2 cfs in the summer and 2 to 4 cfs in the winter by diverting less water into the Lemolo No. 2 waterway.

Achievement of management goal
Management Option 2 would not likely make substantial progress towards meeting the management goal for restoring aquatic and riparian habitat connectivity in the watershed as a whole. This option would increase flows primarily during the summer and fall months in Deer Creek, which is a fish-bearing stream and one of the larger tributaries to the North Umpqua River upstream of the confluence of the Clearwater River. Increased flows would be expected to benefit fish, stream-dwelling amphibians, and riparian vegetation along the 6.4 km (4 mi) of Deer Creek below the diversion. However, because summer base flows in Deer Creek average from 0.085 cms to 0.340 cms (3 to 12 cfs), benefits under Option 2 would be less than if reference flows were restored. In addition, this option would do nothing to restore or improve aquatic and riparian connectivity to other streams in the project vicinity that are currently diverted, intercepted, or affected by culverts that are too small to adequately pass flows under roads or concrete flumes.

Costs
The total cost of Management Option 2 would primarily be the cost of power associated with the generation capacity lost from implementation of higher minimum flows.

Management Option 3: Restore reference flows to fish-bearing tributaries diverted into the Lemolo No. 2 waterway

Management Option 3 would restore reference flows to three tributaries that are currently diverted into the Lemolo No. 2 waterway but support fish upstream of the diversion structures—Potter, Deer and Mill creeks.

Physical description
Restoration of reference flows to Potter, Deer, and Mill creeks would involve breaching diversion dams and/or removing stop logs to allow water to flow down the stream channel instead of into a diversion pipe. Option 3 assumes that erosion control measures currently planned for Potter Creek would be implemented and would allow reference flows to be restored without exacerbating erosion in the lower portion of this drainage. This option does not include the design changes and structural modifications needed at the Potter Creek diversion to restore aquatic and riparian connectivity; connectivity is unaffected by diversion structures on Deer and Mill creeks.

Achievement of management goal
Management Option 3 would only partially meet the management goal of restoring aquatic and riparian habitat connectivity, but would come closer to meeting this goal than Option 2. Under this option, reference flows would be restored to 6.8 km (4.2 mi) of stream channel along three of the eight tributaries diverted into project waterways. Of the eight diverted tributaries, Deer,

Potter, and Mill creeks have large drainage areas, representing about 54 km^2 (20.7 mi^2) out of 70.3 km^2 (26.9 mi^2) affected by tributary diversions (calculated as the drainage area above the North Umpqua River), and are the only streams that support fish upstream of the diversions. In addition, Potter and Mill creeks currently have no required minimum instream flows; their channels are therefore dry below the diversion when flows are equal to or less than the diversion capacity.

Option 3 would be expected to benefit fish, stream-dwelling amphibians, and riparian habitat in the lower reaches of Deer, Potter, and Mill creeks. It would not, however, reconnect aquatic or riparian habitat along Potter Creek; the configuration of the waterway and diversion structures in this drainage would continue to represent a barrier to most aquatic and riparian-dependent species, even with restoration of reference flows. In addition, Option 3 would not improve riparian habitat or aquatic connectivity in the five other tributaries diverted into the Lemolo Nos. 1 and 2 waterways, nor would it benefit streams intercepted by project waterways, or affected by culverts under concrete flumes or roads.

Costs

The total cost of Management Option 3 is estimated at $4,000 plus the cost of lost power generation, ($78,000 to $234,000 per year). The cost of erosion control measures at Potter Creek are not included in this option.

Management Option 4: Restore reference flows to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways

Management Option 4 would restore reference flows to White Mule, Helen, Potter, Spotted Owl, Karen, Deer, Thorne, and Mill creeks, which are currently diverted into the Lemolo Nos. 1 and 2 waterways.

Physical description

Restoration of reference flows to the eight tributary streams diverted into the Lemolo Nos. 1 and 2 waterways would involve breaching diversion dams and/or removing stop logs to allow water to flow down the stream channel instead of a diversion pipe. Restoring reference flows to White Mule Creek would also require some modifications to the downstream channel (for example, riprap) to prevent erosion and a pipe would need to be installed to carry the water over the Lemolo No. 1 waterway and into the original channel. Option 4 assumes that the erosion control measures currently planned for Potter Creek would be implemented and would allow restoration of reference flows without exacerbating erosion in the lower portion of this drainage. This option does not include the design changes and structural modifications needed at the diversions on Potter and White Mule creeks and adjacent waterway sections to restore aquatic and riparian connectivity. Aquatic and riparian connectivity are unaffected by the diversion structures at the other six diverted tributaries.

Achievement of management goal

Management Option 4 would partially meet the management goal to restore aquatic and riparian habitat and would come closer to meeting this goal than Options 2 or 3. Under Option 4,

reference flows would be restored to approximately 8.3 km (5.1 mi) of stream channel along the eight tributaries diverted into project waterways. With the exception of Deer Creek, none of these tributaries currently have minimum instream flow requirements; their channels are therefore dry below the diversions when flows are equal to or less than the diversion capacity. Consequently, Option 4 would be expected to benefit fish, stream-dwelling amphibians, other aquatic organisms such as invertebrates, and riparian vegetation in the lower reaches of these tributaries.

Option 4 would completely restore aquatic connectivity to all of the diverted tributaries. It would not, however, restore aquatic and riparian connectivity to Potter and White Mule creeks. The configuration of the waterway and diversion structures at these two creeks make upstream movement by fish or other aquatic species, and both upstream and downstream movement by riparian-associated wildlife, virtually impossible even with restoration of reference flows. In addition, Option 4 would not improve riparian or aquatic connectivity for small streams intercepted by project waterways, or affected by culverts under concrete flumes or roads.

Costs

The total cost of Management Option 4 is estimated at $29,000 plus the cost of lost power generation ($127,000 to $382,000 per year). The cost of erosion control measures at Potter Creek are not included in this option.

Management Option 5: Restore reference flows to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways and reestablish aquatic and riparian connectivity to Potter and White Mule creeks

Management Option 5 would restore reference flows to the eight tributary streams that are currently diverted into the Lemolo Nos. 1 and 2 waterways and would reestablish riparian connectivity to Potter and White Mule creeks. This option differs form Option 4 in that it includes restoration of aquatic and riparian connectivity to both Potter and White Mule creeks.

Physical description

Restoration of reference flows to White Mule, Helen, Potter, Spotted Owl, Karen, Deer, Thorne, and Mill creeks would involve breaching diversion dams and/or removing stop logs to allow water to flow down the stream channel instead of a diversion pipe. This option would also include removal of diversion structures and the redesign and modification of waterway sections at White Mule and Potter creeks to restore aquatic and riparian connectivity.

Achievement of management goal

Management Option 5 would partially meet the management goal to restore aquatic and riparian connectivity and would come closer to meeting this goal than Options 2 through 4. Like Option 4, Option 5 would restore reference flows to approximately 8.3 km (5.1 mi) of stream channel along the eight tributaries diverted into project waterways and would be expected to benefit fish, stream-dwelling amphibians, and riparian vegetation in the lower reaches of these streams. In addition, Option 5 would also restore riparian habitat connectivity to Potter and White Mule creeks, allowing fish, other aquatic species, and riparian-dependent wildlife can move upstream

and downstream. However, Option 5 would not improve riparian or aquatic connectivity for small streams intercepted by project waterways or affected by culverts under concrete flumes or roads.

Costs

The total cost of Management Option 5 is estimated at $2,507,000 plus the cost of lost power generation ($127,000 to $382,000 per year). The cost of restoring aquatic and riparian habitat connectivity at Potter Creek, estimated at about $2,000,000, is very uncertain at this time. PacifiCorp is developing conceptual engineering designs and better cost estimates as part of an erosion control plan.

Management Option 6: Restore riparian connectivity to seven streams associated with elevated flume trestles

Management Option 6 would restore riparian connectivity to seven streams that flow under elevated flume trestles and then through culverts under adjacent roads. Six of these streams are located along the Lemolo No. 2 waterway and one is along the Fish Creek waterway.

Physical description

There are 21 streams—1, 2, and 18 along the Clearwater No. 2, Fish Creek, and Lemolo No. 2 waterways, respectively—that flow under elevated flume trestles and then through culverts under adjacent roads. In general, the streams and associated riparian habitat underneath the elevated flumes are believed to provide riparian function. After flowing under the elevated trestles, however, all of the streams then enter culverts to pass under adjacent parallel roads. The roads interrupt the riparian corridor and most of the culverts are too small to carry flood flows or bedload material. Riparian-dependent wildlife may be able to move through these culverts during low flows but the lack of substrate and confined space results in an inhospitable environment. For most streams, vegetation, rock, and debris between the culvert and the roadbed provide adequate cover for the majority of wildlife traveling through the riparian corridor to bypass small culverts by moving up the bank and crossing the road. In several cases, however, the area between the road and the culvert consists of a steep bank of loose fill material with little or no vegetation and is not conducive for wildlife movement, particularly by small mammals or amphibians. In addition, 15 of the 21 culverts have outlets that are above grade, or "shotgun", that result in a waterfall effect. These culverts allow fish and aquatic organisms to move down- but not upstream.

Option 6 would involve replacing the road culverts associated with seven streams under elevated stream trestles. All seven of these culverts have shotgun outlets and five are associated with steep fill banks that do not have adequate vegetation or other cover suitable for wildlife to move through the riparian corridor and cross the road. Based on a preliminary analysis, the Terrestrial Subgroup judged these seven culverts as the highest priorities for replacement. Under Option 6 these culverts would be replaced with larger arch culverts that would carry bedload as well as high flows. Culvert outlets would also be redesigned to eliminate the waterfall effect and allow both upstream and downstream movement.

Achievement of management goal
Management Option 6 would partially meet the management goal for aquatic and riparian connectivity. The combination of larger culverts that might retain substrate (improving cover for wildlife passage through culverts) and the elimination of shotgun outlets would greatly improve riparian habitat connectivity along seven streams in the project vicinity. However, Option 6 would not restore flows in the 8 streams diverted into and the 39 streams intercepted by project waterways. Furthermore, it would not improve riparian connectivity for the streams that pass under concrete flumes or the 14 other streams that flow through road culverts after passing under elevated flume trestles. Although these 14 streams are of lower priority than the seven covered under Option 6, many have culvert with shotgun outlets and would benefit from improvements.

Costs
The total cost of Management Option 6 is estimated at $38,000.

Management Option 7: Restore reference flows and riparian connectivity to 12 tributaries intercepted by project waterways

Management Option 7 would restore reference flows and riparian connectivity to 12 seeps and Class 3 and 4 streams that are currently intercepted by project waterways. Of these, one is intercepted by the Fish Creek waterway, two each by the Clearwater Nos. 1 and 2 waterways, and seven by the Lemolo No. 2 waterway.

Physical description
There are a total of 39 seeps and Class 3 and 4 streams that are currently intercepted by project waterways. Of these, 28 flow directly into sections of gunite canal; 11 enter concrete flume sections either directly or via a pipe. Some are typically dry during the summer and fall months and some flow year-round; the amount of water contributed to the overall project capacity by these interceptions is unknown. The downstream reaches of these tributaries have been completely dewatered and therefore aquatic and riparian habitat connectivity has been substantially reduced or eliminated. Based on a preliminary field analysis, C. Barkhurst (Umpqua National Forest biologist) identified 12 intercepted tributaries where reestablishing aquatic connectivity was considered a high priority. High priority was determined on the basis of one or more of the following parameters: (1) a larger drainage area (based on field observations); (2) presence of a wetland either upstream or downstream; (3) stream class; and (4) the presence of a well-defined channel both upstream and downstream. Further field assessment would be needed prior to implementation of this option and may result in identification of the same or different intercepted streams for restoration.

Management Option 7 would restore reference flows to the 12 intercepted tributaries considered the highest priority for restoration of aquatic connectivity. Of these, 11 are intercepted by gunite sections of waterway and one by a double-walled flume. Measures to restore flows would vary depending on the tributary, but would most likely involve installation of structures to carry water over the top of, or under, the waterway. Pipes or concrete slabs could be used to convey water over the waterways and would probably work best for streams intercepted by gunite canal. Culverts under the waterway or underpasses may be most suitable for streams that currently flow

into concrete flumes. Appropriately-sized culverts would also be installed to pass the stream under the road adjacent to the waterway and vegetation may need to be restored at some sites.

Achievement of management goal

Management Option 7 would partially meet the management goal for aquatic and riparian habitat connectivity. Under this option, reference flows and riparian habitat connectivity would be restored to 5.4 km (3.4 miles) along 12 tributaries that are currently intercepted by project waterways, with benefits to fish, amphibians, and other aquatic organisms. Although Option 7 would restore riparian habitat connectivity to these streams, it would not necessarily result in natural stream channels and corridors. The degree to which "natural conditions" for riparian habitat connectivity would be achieved would depend on the measure selected to reestablish reference flows. For example, a large arch culvert under a concrete flume would probably result in a more natural riparian corridor than a pipe culvert and its associated support bridge over a gunite canal section. Option 7 would not restore reference flows in the eight streams diverted into project waterways or the 27 other intercepted tributaries. Furthermore, it would not improve riparian connectivity for the tributaries affected by culverts under concrete flumes or roads.

Costs

The total cost of Management Option 7 is estimated at $146,000; the cost of lost generation from the contribution of the 12 intercepted tributaries is unknown.

Management Option 8: Restore riparian connectivity to 12 tributaries that pass under concrete flumes through culverts

Management Option 8 would restore riparian connectivity to 12 tributary streams that currently pass under sections of concrete flume. Of these, one is associated with the Lemolo No. 1 waterway, one with the Fish Creek waterway, two with the Clearwater No. 2 waterway, and eight with the Lemolo No. 2 waterway.

Physical description

There are 19 streams that pass under concrete flume sections of project waterways, 18 through culverts and one through a low underpass supported by concrete footings. Some of these streams are perennial; others are typically dry during the summer and fall. The underpass and two of the 18 culverts are large enough to contain substrate and provide adequate upstream and downstream connectivity under nearly all flow conditions. Of the remaining 16 culverts, 12 are too small to collect and retain substrate or provide upstream passage except when dry or under low flow conditions; four are drained under flumes by vertical culverts that completely sever riparian and aquatic connectivity. The Terrestrial Resources Team considered the four seeps that drain into vertical stand pipes of lower priority for replacement because they drain very small areas and have poorly defined channels.

Management Option 8 would involve replacing the small culverts on 12 streams under concrete flumes with larger structures, possibly arch culverts or underpasses, that can contain substrate and provide upstream passage under most flow conditions. Associated road culverts would probably also need to be replaced as well.

Achievement of management goal
Management Option 8 would partially meet the management goal for aquatic and riparian connectivity. Larger culverts or underpasses that would be able to retain some substrate would greatly improve riparian habitat connectivity along 12 streams in the project vicinity. However, Option 8 would not restore flows in the 8 streams diverted into and the 39 streams intercepted by project waterways. It also would not improve riparian connectivity for the four seeps that pass under concrete flumes in vertical stand pipes or the 21 streams that flow through road culverts after passing under elevated flume trestles.

Costs
The total cost of Management Option 8 is estimated at $159,000. Costs were based on installation of culverts; underpasses are likely to cost more.

Management Option 9: Restore aquatic and riparian connectivity to tributaries that are either intercepted by project waterways or pass under concrete flumes through culverts

Management Option 9 would restore reference flows and riparian connectivity to all 39 tributaries that are intercepted by project waterways and the 16 streams that currently pass under sections of concrete flume in culverts that are too small or otherwise inappropriate.

Physical description
Option 9 would involve burying or elevation sections of waterway to restore reference flows and riparian connectivity to tributary streams that are currently either intercepted by waterways or that pass under waterways in culverts. Depending on the location and adjacent topography, sections of waterway could either be elevated as short flumes or replaced with pipe that would then be buried. Both alternatives would allow restoration of the stream channel and riparian corridor. In addition, roads adjacent to the buried sections of waterway would be modified to allow connectivity. Modifications would include installation of culverts large enough to carry flood flows and bedload under the road or "dips" to pass flows and bedload over the road.

Achievement of management goal
Management Option 9 would partially meet the management goal for aquatic and riparian connectivity. Under this option, reference flows and riparian habitat connectivity would be restored to all 39 tributaries that are currently intercepted by project waterways. Riparian connectivity would also be reestablished along all 16 of the streams that pass under sections of concrete flume in culverts that are too small or otherwise inappropriate. In addition, this option attempts to recreate natural stream channels and associated riparian corridors, to the extent possible, by elevating or burying section of waterway as well as modifying adjacent roads. Presumably such natural channels and corridors would be more conducive to wildlife or aquatic organisms that travel along these areas. Option 9 would not, however, restore flows in the eight streams that are currently diverted into project waterways, nor would it improve riparian connectivity for the 21 streams that flow through road culverts after passing under elevated flume trestles.

Costs
The total cost of Management Option 9 will depend on various engineering, design, and construction challenges presented at each of the 55 sites with streams that are currently intercepted into project waterways or pass underneath in culverts. A minimum cost was estimated by assuming that the waterway would be replaced with 15.2-meters (50-foot) sections of pipe at all 55 sites and was estimated to be about $1,152,000. The maximum was assumed to be the cost of replacing the entire gunite portion of the waterway with pipe, an estimated $24,000,000 (see Option 6 for Terrestrial Habitat Connectivity in Section 8). At some sites the cost of putting the waterway into a pipe or flume may be prohibitive.

COMBINATION OPTIONS

Management Option 10: Restore reference flows to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways; restore reference flows and riparian connectivity to 12 tributaries intercepted by project waterways; and restore riparian habitat connectivity to seven streams associated with elevated flume trestles and to 12 tributaries that pass under concrete flumes through culverts

Management Option 10 combines Options 4, 6, 7, and 8.

Physical description
Management Option 10 consists of the following five components: (1) breaching diversion dams and/or removing stop logs in White Mule, Helen, Potter, Spotted Owl, Karen, Deer, Thorne, and Mill creeks; (2) installing structures, such as pipes or culverts, to carry water over the top of or under waterways from the White Mule Creek and the 12 intercepted tributaries considered the highest priority by the Forest Service for restoration of aquatic and riparian connectivity; (3) installing appropriately-sized culverts to pass the 12 streams under the roads adjacent to the waterways; (4) replacing the road culverts associated with seven streams under elevated stream trestles; and (5) replacing the small culverts on 12 streams under concrete flumes and associated roads with larger structures, possibly arch culverts or underpasses, that can retain substrate and provide upstream passage under most flow conditions.

Achievement of management goal
Management Option 10 would better meet the management goal for aquatic and riparian habitat connectivity than Options 4, 6, 7, and 8 separately. Under this option, reference flows would be restored to the eight diverted tributaries and 12 streams that are currently intercepted by project waterways. The riparian corridor would also be reestablished along the 12 intercepted streams, although natural stream channels and corridors may not necessarily be restored. In addition, Option 10 would improve riparian connectivity for streams affected by culverts under 12 concrete flumes and associated roads and seven roads adjacent to flume trestles. It would not, however, restore reference flows to 27 other streams that are currently intercepted by project waterways nor would it reestablish aquatic or riparian connectivity along White Mule or Potter creeks.

Costs
The total cost of Management Option 10 is estimated as the combined costs of Options 4 ($29,000 + cost of lost power generation), 6 ($38,000), 7 ($146,000), and 8 ($159,000) plus the cost of lost power generation. The total cost of Management Option 10 is therefore estimated to be $372,000 plus $127,000 $ to $382,000 per year in lost generation.

Management Option 11: Restore reference flows to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways; reestablish aquatic and riparian habitat connectivity to potter and white mule creeks and 12 tributaries intercepted by project waterways; and restore riparian habitat connectivity to seven streams associated with elevated flume trestles and to ten tributaries that pass under concrete flumes through culverts.

Management Option 11 combines Options 5, 6, 7, and 8.

Physical description
Management Option 11 consists of the following six components: (1) breaching diversion dams and/or removing stop logs in Helen, Spotted Owl, Karen, Deer, Thorne, and Mill creeks; (2) removing diversion structures and re-engineering and/or substantially altering facilities at White Mule and Potter creeks; (3) replacing the road culverts associated with seven streams under elevated stream trestles; (4) installing structures, such as pipes or culverts, to carry water over the top of or under waterways from the 12 intercepted tributaries considered the highest priority by the Forest Service for restoration of aquatic connectivity; (5) installing appropriately-sized culverts to pass the 12 streams under the road adjacent to the waterway; and (6) replacing the small culverts on 12 streams under concrete flumes and associated roads with larger structures, possibly arch culverts, that can retain substrate and provide upstream passage under most flow conditions.

Achievement of management goal
Management Option 11 would better meet the management goal for aquatic and riparian habitat connectivity than Options 5, 6, 7, and 8 separately. Under this option, reference flows would be restored to the eight diverted tributaries and 12 streams that are currently intercepted by project waterways. The riparian corridor would also be reestablished along the 22 intercepted streams, although natural stream channels and corridors may not necessarily result. In addition, Option 11 would improve riparian connectivity for streams affected by culverts under 12 concrete flumes and associated roads and seven roads adjacent to flume trestles. It would not, however, restore reference flows in 27 other streams that are currently intercepted by project waterways.

Costs
The total cost of Management Option 11 is estimated as the combined costs of Options 5 ($2,507,000 + cost of lost power generation), 6 ($38,000), 7 ($146,000), and 8 ($159,000) plus the cost of lost power generation. The total cost of Management Option 11 is therefore estimated to be $2,850,000 plus $127,000 plus $ to $382,000 per year in lost generation.

Management Option 12: Restore reference flows to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways; reestablish aquatic and riparian connectivity to Potter

and White Mule creeks and all tributaries that are intercepted (39) by project waterways; and restore riparian connectivity to all streams that pass under concrete flumes through culverts (16) and to all streams associated with elevated flume trestles (21)

Management Option 12 would restore reference flows and riparian connectivity to all streams affected by project waterways and associated roads, to the extent possible without burying the portions of concrete flume or gunite canal.

Physical description

Option 12 consists of the following six components: (1) breaching diversion dams and/or removing stop logs in Helen, Spotted Owl, Karen, Deer, Thorne, and Mill creeks; (2) removing diversion structures and re-engineering and/or substantially altering facilities at White Mule and Potter creeks; (3) replacing the road culverts associated with the 21 streams under elevated stream trestles; (4) installing structures, such as pipes or culverts, to carry water over the top of or under waterways from the 39 intercepted tributaries; (5) installing appropriately-sized culverts to pass the 39 streams under the road adjacent to the waterway; and (6) replacing the small culverts on 16 streams under concrete flumes and associated roads with larger structures, possibly arch culverts, that can contain substrate and provide upstream passage under most flow conditions.

Achievement of management goal

Management Option 12 would better meet the management goal for aquatic and riparian habitat connectivity than any single action option and was considered by the Terrestrial Subgroup to be second only to Option 13. Under this option, reference flows would be restored to the eight diverted tributaries and all 39 streams that are currently intercepted by project waterways. The riparian corridor would also be reestablished along the 22 intercepted streams, although natural stream channels and corridors may not necessarily result. In addition, Option 12 would improve riparian connectivity for streams affected by culverts under 16 concrete flumes and associated roads and 21 roads adjacent to flume trestles. The only measure among those considered by the Scientific Team that Option 12 does not include is burying sections of the waterway to ensure the restoration of natural stream channels and corridors along the 39 tributaries that are currently intercepted by project waterways.

Costs

The total cost of Management Option 12 is estimated as the combined costs of implementing measures to restore reference flows and riparian connectivity, to the extent possible, on all streams affected by project waterways. Costs are estimated as the cost of Option 5 ($2,507,000 + cost of lost power generation) plus the costs of Options 6, 7, and 8, extrapolated to cover all affected streams. These extrapolations are as follows (results are rounded): Option 6 ($38,000/7*21 = $113,000); Option 7 ($146,000/12*39 = $475,000); Option 8 ($159,000/12*16 = $213,000). The total cost of Option 12 would therefore be $3,307,000 plus $127,000 plus $ to $382,000 per in year in lost power generation.

Management Option 13: Restore reference flows and riparian connectivity to the eight tributaries diverted into the Lemolo Nos. 1 and 2 waterways; reestablish aquatic and

riparian connectivity to Potter and White Mule creeks; restore natural stream channels to streams that are intercepted by project waterways or that pass under concrete flumes through culverts; and restore riparian connectivity to seven streams associated with elevated flume trestles

Management Option 13 would restore reference flows and riparian connectivity to all streams affected by project waterways and associated roads, and would, to the extent possible, restore natural stream and riparian corridors to tributaries that are intercepted by or pass under concrete flume. It represents a combination of Options 5 and 9 with the addition of restoring riparian habitat connectivity to the 21 streams associated with flume trestles.

Physical description

Option 13 consists of the following five components: (1) breaching diversion dams and/or removing stop logs in White Mule, Helen, Potter, Spotted Owl, Karen, Deer, Thorne, and Mill creeks; (2) removing diversion structures and re-engineering and/or substantially altering facilities at White Mule and Potter creeks; (3) replacing the road culverts associated with 21 streams under elevated stream trestles; (4) elevating or burying sections of waterway to restore reference flows and riparian connectivity to the 39 streams that are currently intercepted by waterways and the 16 tributaries that pass under waterways in culverts that are too small; and (5) installing culverts or "dips" in roads adjacent to the buried or elevated sections of waterway.

Achievement of management goal

Management Option 13 comes closest to meeting the watershed management goal for aquatic and riparian habitat connectivity than any other management option. Under this option, reference flows and riparian habitat connectivity would be restored to the eight diverted tributaries and all 39 streams that are currently intercepted by project waterways. To the extent possible, Option 13 would also restore natural stream corridors and channels for the 39 currently intercepted stream and to all 16 of the tributaries that pass under waterways in culverts. In addition, this option would restore riparian connectivity to all 21 streams affected by culverts under roads adjacent to flume trestles.

Costs

The total cost of Management Option 13 is estimated as the combined costs of Options 5 ($2,507,000 + cost of lost power generation) and 9 ($1,152,000 to $24,000,000) plus the cost of Options 6 extrapolated to cover all 21 of the affected streams ($38,000/7*21 = $113,000). The total capital cost of Option 13 would therefore range from $3,772,000 to $25,620,000; lost generation would result in an additional $127,000 to $382,000 per year.

Cost-Benefit summary

The costs and benefits of the 13 management options are summarized above in Table 3-5. These cost figures are very rough estimates and likely represent minimums for each management option, because they do not include the costs of any adaptive management actions that could result from data obtained from testing or monitoring. Several of the management options summarized in this table represent certain combinations of actions; additional options can be developed based on

different combinations of actions. Of course, the associated costs would change if the options are tailored to increase or decrease the magnitude or complexity of the management actions. The intensity of the monitoring and/or testing programs described for each of the management options would determine the associated costs.

The Terrestrial Subgroup ranked each of the management options using one set of criteria and two different ranking methods. Criteria were as follows: (1) the number of tributaries for which the option improves aquatic and riparian habitat connectivity; and (2) confidence that the measures included in the option would accomplish the goals for restoring connectivity. The first ranking method involved comparing the management options in terms of their ability to improve aquatic and riparian habitat connectivity relative to current conditions. The option believed to represent the most improvement over current conditions was given the highest rank; conversely, the option believed to improve aquatic and riparian habitat connectivity the least was assigned a rank of 1 (Table 3-5). The second ranking method involved an assessment of the relative ability of each option to meet the management goal and the objectives of the Aquatic Conservation Strategy and Riparian Reserves allocations, as described in the Northwest Forest Plan. The option that came closest to restoring aquatic and riparian habitat connectivity in the project vicinity, to the greatest extent possible, was determined to best meet the watershed goal and was assigned a rank of 95 (Table 3-5). No option was assigned a rank of 100 because the Terrestrial Subgroup believed that none could ensure that the watershed goals and standards and guidelines of the Northwest Forest Plan Options would be completely met, due to the factors in the watershed that would continue to fragment aquatic and riparian habitat. Options that partially meet the watershed goal were assigned ranks from 1 to 90.

3.6.5 Culverts and Road or Waterway/Stream Crossings

Road/stream crossings that act as obstacles or barriers to upstream or downstream movement of aquatic species may restrict access to important habitat year-round or at certain flows. Aquatic and riparian habitat connectivity can be restored by replacing culverts with road/stream crossings that can effectively transport sediment and woody debris downstream and allow upstream and downstream passage by aquatic species. Modification of culverts or construction of bridges may achieve these goals while simultaneously serving to storm-proof road systems. Road/stream crossings that block or reduce access to suitable spawning and rearing habitats for anadromous fish species are considered a high priority for early restoration efforts due to the importance of anadromous fish in the ecosystem and the depressed status of several species; subsequent restoration of obstacles to other species would also address important ecological disturbances. A number of barriers to fish movement have been identified in the Rock Creek and Steamboat Creek basins (see Table 3-2).

Providing fish and other aquatic species passage at culverts requires detailed site surveys. Options for providing fish passage must be carefully evaluated. Designs that maintain the continuity of the stream bed under the road are most desirable, especially for species that are not as mobile as salmonids. A bridge is often the best solution, but can be design intensive and prohibitively expensive. Listed below are other options for improving fish passage at culverts and road/stream crossings and notes regarding the limitations of each technique.

- **Install roughness elements within culvert.** This measure facilitates upstream movement of aquatic species, especially during high flows. However, baffles within the culvert reduce hydraulic capacity and thus increase the risk of debris plugging the culvert during flood flows.

- **Construct backwater structure at overhanging or "shotgun" culverts.** Construction of backwater structures to raise the water surface elevation of the downstream area to meet the culvert's mouth can re-establish connectivity by allowing upstream movement of aquatic species. However, structures to raise the water surface elevation at the outlet often wash out or become ineffective after flood flows. Constructing backwater structures can be complex and expensive, particularly for larger stream channels and those on steep slopes. For overhanging culverts with a relatively short drop (less than 2 ft), building up rocks at the outlet could reduce erosion and create a stair step effect that amphibians and other aquatic organisms might be able to use to gain upstream access into the culvert.

- **Replace culverts that are too small or too steep in gradient.** Many culverts in the watershed have diameters that are too small to allow passage by many species, or are set at an angle that may inhibit or prevent upstream movement. However, installing new culverts at more suitable slopes is expensive because it involves excavation. Culvert diameter must be carefully chosen to provide adequate water depths for migrating fish as well as adequate hydraulic capacity. This may conflict with passage for other species where shallow depths or moist perimeter environments are preferred. Ideally, the culvert should not increase velocities above those in the channel and should be backwatered to eliminate the need for an animal to jump or climb to gain access into the culvert.

- **Install bottomless pipe arches.** The design of bottomless culverts reduces disturbance to the stream channel and comes closest to simulating natural streambed conditions. Designs that allow continuity of the natural stream bed under the road are the most desirable; however, the footings used with bottomless pipe arches are prone to settling, and may lead to partial collapse of the structure.

- **Install pipe arch culverts.** These maintain the natural channel cross section better than circular pipes and yet do not suffer from susceptibility to settling as do the bottomless arches. However, placement of the pipe at a grade appropriate for retaining streambed connectivity is difficult.

- **Replace capped or uncapped vertical (riser) culverts.** This type of culvert prevents all upstream and downstream movement by aquatic and riparian species. Replacement of these culverts with circular or arched culverts would restore aquatic habitat connectivity to some degree. However, site-specific constraints may limit options for replacing these structures.

- **Replace culverts with bridge crossings.** Bridges are preferable to culverts at road/stream crossings because they result in much less disturbance to natural streambed and fluvial

processes and maintain a continuous streambed. Because of their greater expense, they are less practical to construct on forest roads that receive infrequent use (Meehan 1991).

- **Replace culverts with dips (low-water fords).** Dips can be more effective than culverts at passing high flows and sediment and they present less of an obstacle to movement.

- **Decommission and/or obliterate roads and their associated crossings.**

Options for improving connectivity at culverts associated with tributary streams are discussed above in Section 3.6.3. Site-specific evaluations of culverts under project waterways or PacifiCorp roads, including options for their improvement, are given in Attachments 4 through 6.

3.6.6 Disturbances to Riparian Vegetation

Habitat elements and characteristics associated with late-successional riparian forests that may be important for maintaining habitat connectivity for riparian-associated species include an abundance of large downed wood and a moist cool microclimate. Both of these characteristics may be important for riparian-associated amphibians, small mammals, mollusks, and other invertebrates. Riparian communities are adapted to frequent disturbance and are thus believed to have a relatively high capacity to recover following the termination of anthropogenic disturbances (Kauffman et al. 1997). Therefore, the most effective type of restoration effort may be to halt those human activities that are causing degradation of riparian habitats or preventing their recovery and allow the system to recover without further manipulation ("passive" or "natural" restoration) (Kauffman et al. 1997).

If riparian areas are sufficiently degraded such that their natural capacity to recover has been lost, more active restoration efforts may be desirable. Restoration of mature conifers in riparian areas is critical to the recovery of LWD recruitment to both instream and riparian areas. Silvicultural techniques may be used to speed the recovery of late-successional coniferous forest characteristics in riparian areas through re-establishing and/or increasing growth of coniferous species where they are currently lacking or where growth has been suppressed by shading of faster-growing hardwoods such as alders, which are characteristic of disturbed riparian habitats (Sedell and Beschta 1991, J.P. Hayes et al. 1996). Manipulations should be conducted in a patchy and irregular manner to mimic the effects of natural disturbances and late-successional forest stand structure (Kauffman et al. 1997). Although the use of silvicultural treatments in riparian areas are designed to accelerate re-establishment of late-seral characteristics compared to natural rates, the time frame required for such measures to become effective is relatively lengthy (50–100+ years). Relative benefits of various riparian silvicultural measures are discussed in Section 7 (Anadromous Fish Passage and Offsite Mitigation).

For the protection of riparian-associated land snails and slugs which may exhibit extremely small and localized distributions, the identification of areas where species are currently located, based on field surveys, is of high priority. The establishment of small reserves may be used to protect small populations of land snails and slugs (areas as small as tens of acres may be all that is

required to provide protection for some colonies). Protection of riparian areas along headwater streams, seeps, and springs is also of high priority for these species.

While the Northwest Forest Plan has increased riparian protection on federal lands, measures such as conservation easements, land acquisition, or legislation could increase protection of riparian areas on state and private lands and increase habitat connectivity between riparian habitats in the watershed. Education of private landowners about the importance of riparian areas and their role in the watershed's overall health and encouraging landowners to voluntarily protect these areas may have potential benefits. The use of some type of program for rewarding or compensating landowners who protect riparian areas on their land could be investigated. Section 7 (Anadromous Fish Passage and Offsite Mitigation) discusses the potential benefits of these strategies for protection of riverine habitat in the watershed.

3.6.7 Roads in Riparian Areas

Reducing future impacts of roads on habitat connectivity may include enhancement measures as storm-proofing, decommissioning, and obliteration of roads. An inventory of road/stream crossings and road conditions and analysis of the relative risks they present to fish habitat would be a prerequisite for this type of habitat restoration. Section 7 (Anadromous Fish Passage and Offsite Mitigation) includes a discussion of potential road enhancement measures.

3.6.8 Changes to Water Quality

Management options for maintaining and restoring water quality are addressed in the Section 6 (Water Quality).

3.6.9 Modifications to Natural Obstacles

The modification of natural obstacles to anadromous salmonid migration has occasionally been employed for the purposes of increasing available area for production (see Section 7). Removal of natural obstacles may reduce ecological integrity and may have unforeseen impacts to other native species such as amphibians, whose regional declines may be due in part to the introduction of fish to areas where they previously did not exist. Areas that currently do not support native or introduced fish populations may be critical for the long-term persistence of amphibian populations in the watershed. Enhancement measures that modify channel features that have been formed through natural processes is not recommended by the Science Team.

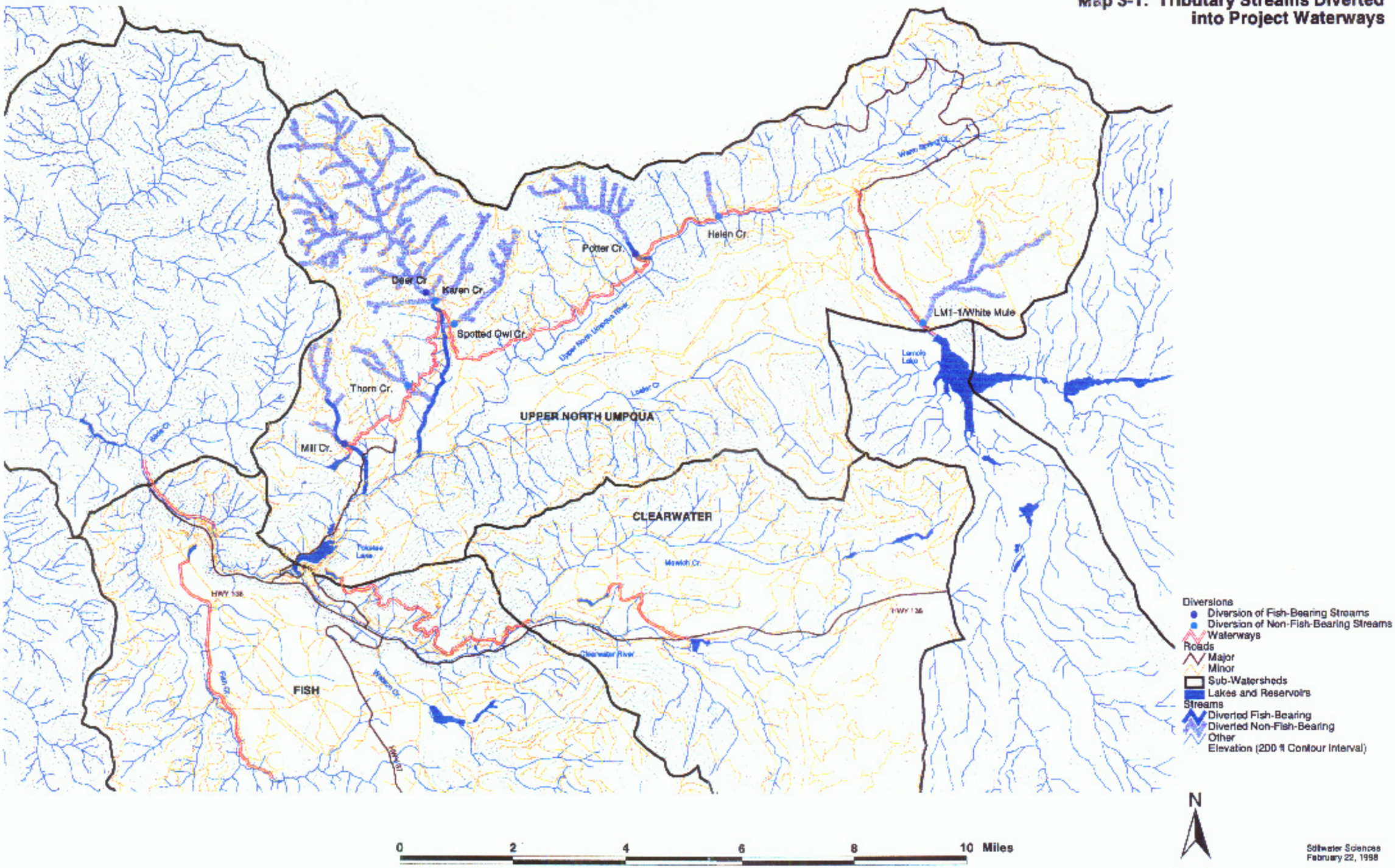
3.7 OVERLAPPING ISSUES

The issue of aquatic and riparian habitat connectivity is related to terrestrial habitat connectivity (see Section 8) in that both address the ability of individuals to move across the landscape and of populations to interact and interbreed. Issues of instream flows (see Section 4) and water quality (see Section 6) affect aquatic habitat connectivity. Individuals moving downstream in intercepted tributaries become entrained into project waterways and probably experience the same problems

as wildlife that becomes entrapped (described in Section 8). Potential impacts of aquatic barriers on anadromous fish and related management options are described in more detail in Section 7.

NORTH UMPQUA COOPERATIVE WATERSHED ANALYSIS

Aquatic and Riparian Habitat Connectivity
Map 3-1: Tributary Streams Diverted into Project Waterways



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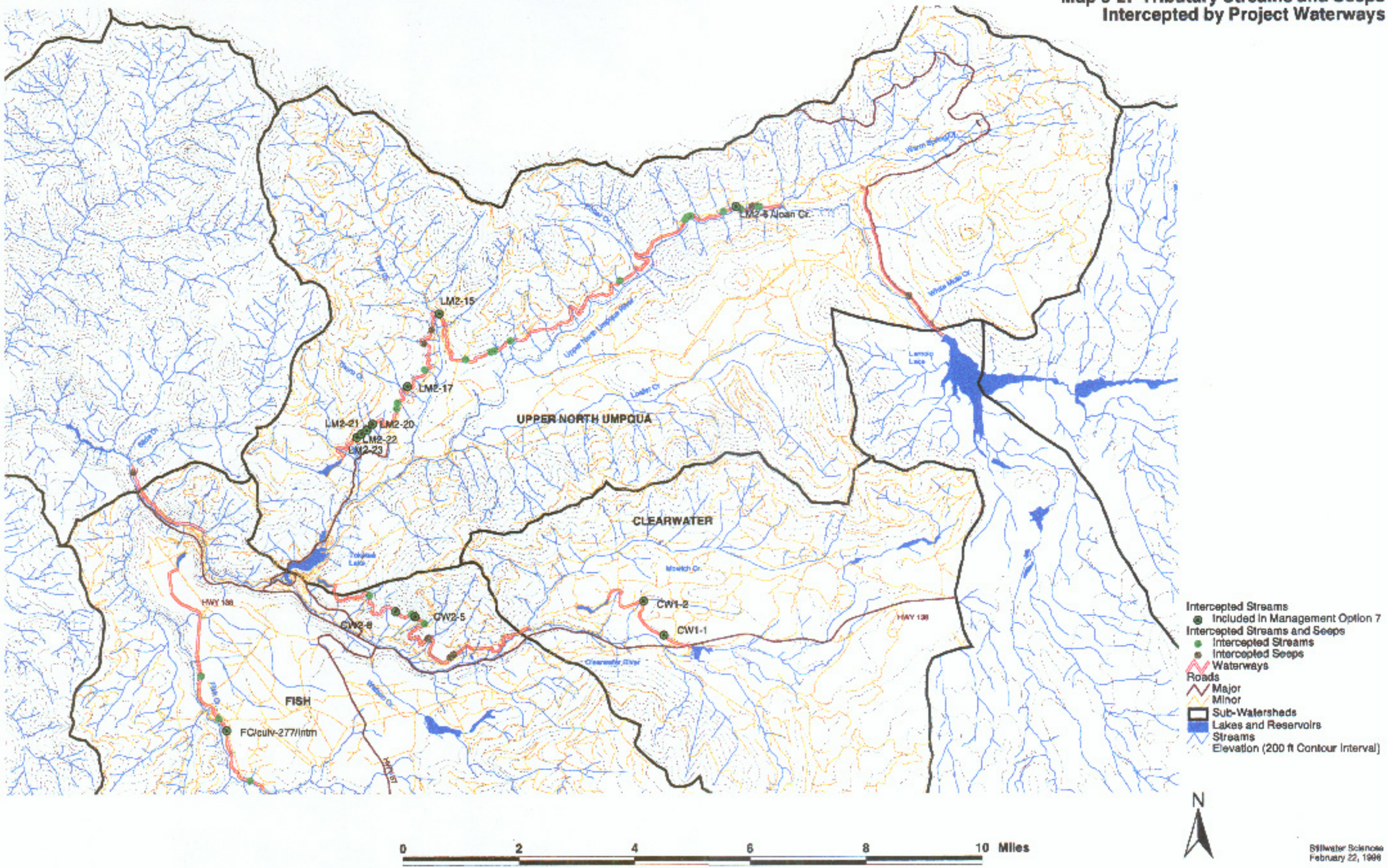
Aquatic and Riparian Habitat Connectivity
Map 3-2: Tributary Streams and Seeps Intercepted by Project Waterways



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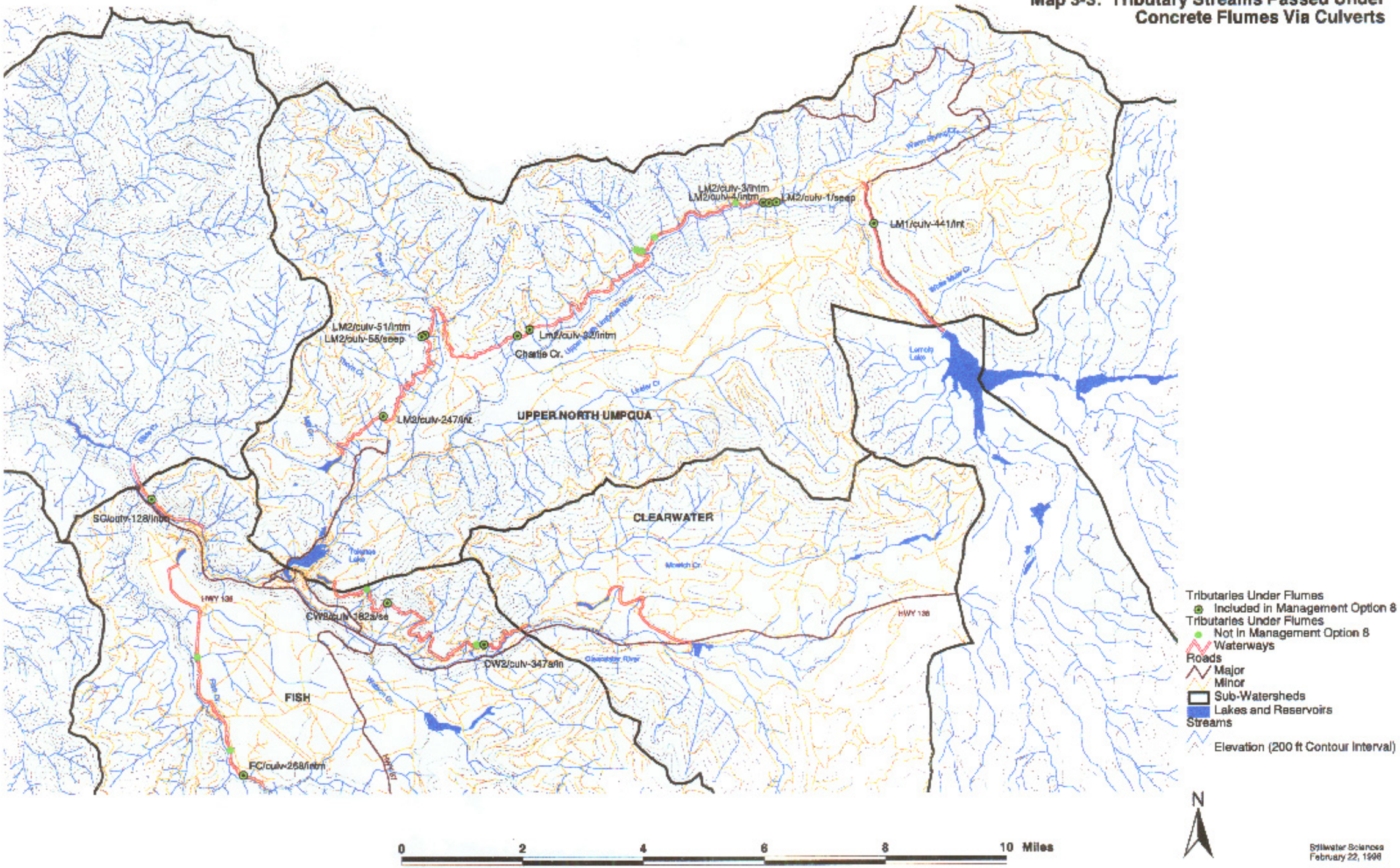
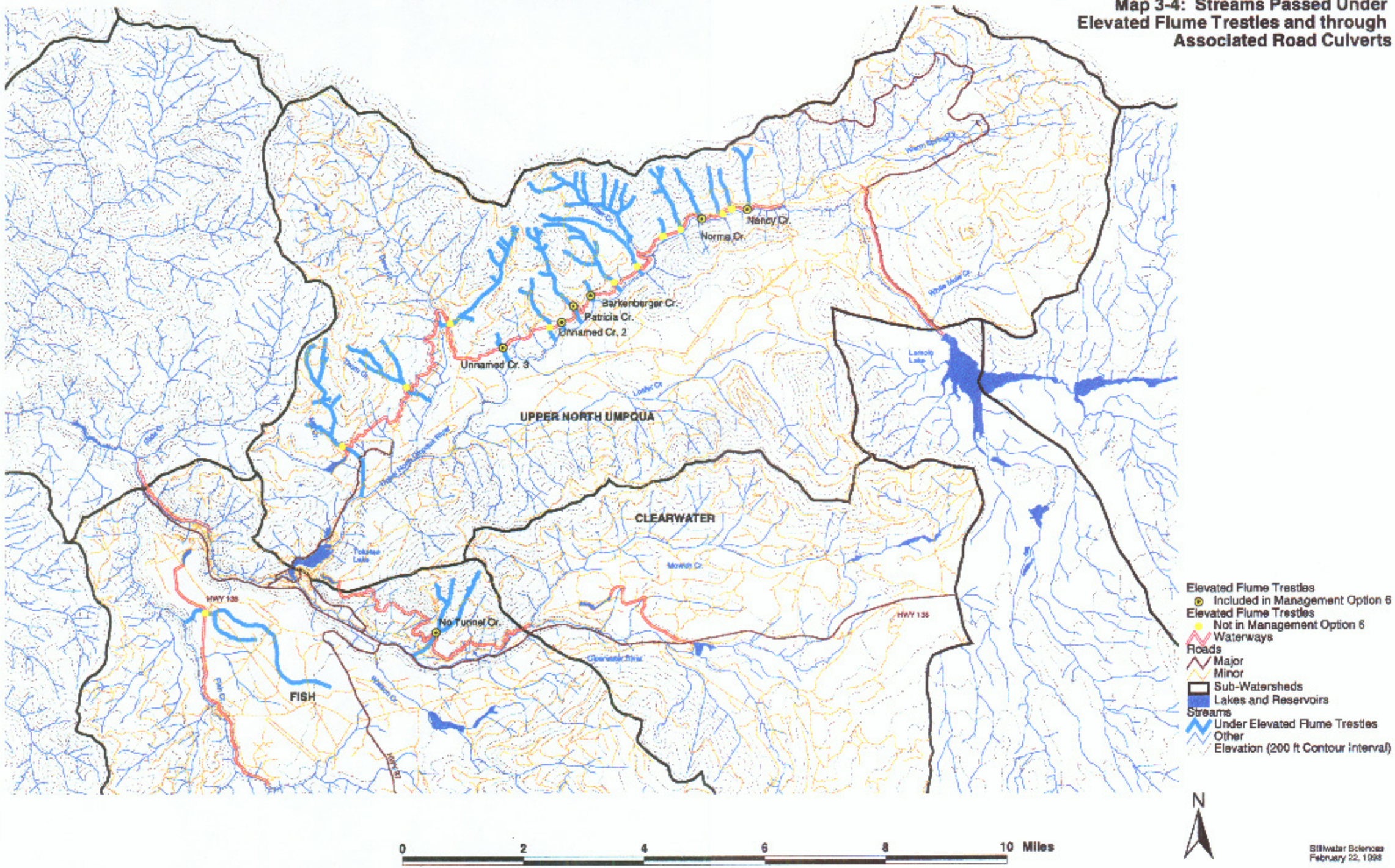
Aquatic and Riparian Habitat Connectivity
Map 3-3: Tributary Streams Passed Under Concrete Flumes Via Culverts



NORTH UMPQUA COOPERATIVE WATERSHED ANALYSIS

Aquatic and Riparian Habitat Connectivity
Map 3-4: Streams Passed Under Elevated Flume Trestles and through Associated Road Culverts



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