Fisheries Resources

1. **What is the condition of fish stocks in the analysis area?**
2. **What is the current condition of aquatic and riparian habitats and how has land management affected them?**

Hydrologic and Geomorphic Processes

1. **What are the current water quality conditions in the analysis area and how has land management affected them?**
2. **How are sediment and erosional processes affecting aquatic habitat and water quality in the watershed?**
3. **How are streamflow regimes influencing water quality and aquatic habitat within the watershed?**
4. **What are the dominant erosional processes within the watershed, where have they taken place and where are they likely to occur?**

Botanical Resources

1. **What is the status of rare, sensitive or listed botanical populations and habitats?**
2. **Are there noxious weed problem areas within the analysis area? If so, how should they be managed?**

The answers to these key questions are found throughout the following chapters in this document. Watershed analysis is an iterative process. The information laid out in this document is the result of six months of analysis which used the best available information at that time. The maps and information produced by this analysis, including the recommendations, may change in the future as new or better information becomes available.

The information from this analysis supplements the information previously assembled in the North Umpqua River Analysis (USDA/USDI 1999) and the North Umpqua Cooperative Watershed Analysis (Stillwater Sciences, Inc. 1998).

CHAPTER 3 – WATERSHED CHARACTERIZATION

GEOLOGY

The analysis area is situated within the Western Cascades physiographic sub-province and underlain by a crudely layered succession of variably altered lava flows, volcaniclastic[2] deposits and related volcanic and sedimentary deposits. These strata are classified as the Little Butte Group and are widespread throughout the southern Oregon Cascades (Table 2, Fig. 5). Their thickness approaches 15,000 feet along the North Umpqua River corridor between Rock Creek and Illahee Rock. In this vicinity, the strata dip slightly towards the east and are locally cut by northeast and northwest-trending faults with unknown offset (Peck et al. 1964; Sherrod and Smith 1989; and Walker and MacLeod 1991). Small isolated intrusive rock masses (e.g., primarily volcanic plugs) locally cut the volcanic strata (Peck et al. 1964; and Sherrod 1986).

Table 2. Map units of the Little Butte strata (Walker and MacLeod 1991) as portrayed on the 1:500,000 scale State Geologic Map.

UNIT	NAME	DESCRIPTION
Qls	Landslide-Earthflow Complex	Mass wasting deposits of rock and soil debris from ancient landslide or earthflow events.
Tib	Intrusive Basalt	Plugs and related 'feeder' dikes of basalt and basaltic andesite associated with eruptive centers (volcanic vents).
Tsv	Silicic Vent Complex	Dacite and rhyodacite lava flows and domes including flow breccia with associated near vent pyroclastic deposits including lapillii tuff, tuff-breccia and volcanic breccia
Tub	Undifferentiated Basaltic Lava Flows	Basalt and basaltic andesite and related flow-breccia with intervening near vent pyroclastic deposits including lapilli tuff, tuff-breccia and volcanic breccia
Tus	Undifferentiated Volcaniclastic & Sedimentary Rock	Volcaniclastic deposits include large mudflows (lahars) and debris avalanche flows formed by mass wasting processes; and related sedimentary rocks (tuffaceous siltstone, sandstone, and volcanic conglomerate) formed from fluvial 'reworking' of unconsolidated primary volcaniclastic material
Tut	Undifferentiated Volcanic Tuff	Near vent pyroclastic deposits including lapilli tuff, tuff-breccia and volcanic breccia, and medial to distal vent ash-flow variably welded tuff

[2] Volcaniclastic is a term that describes consolidated fragmental volcanic debris in whatever proportion and without regard to origin or depositional environment

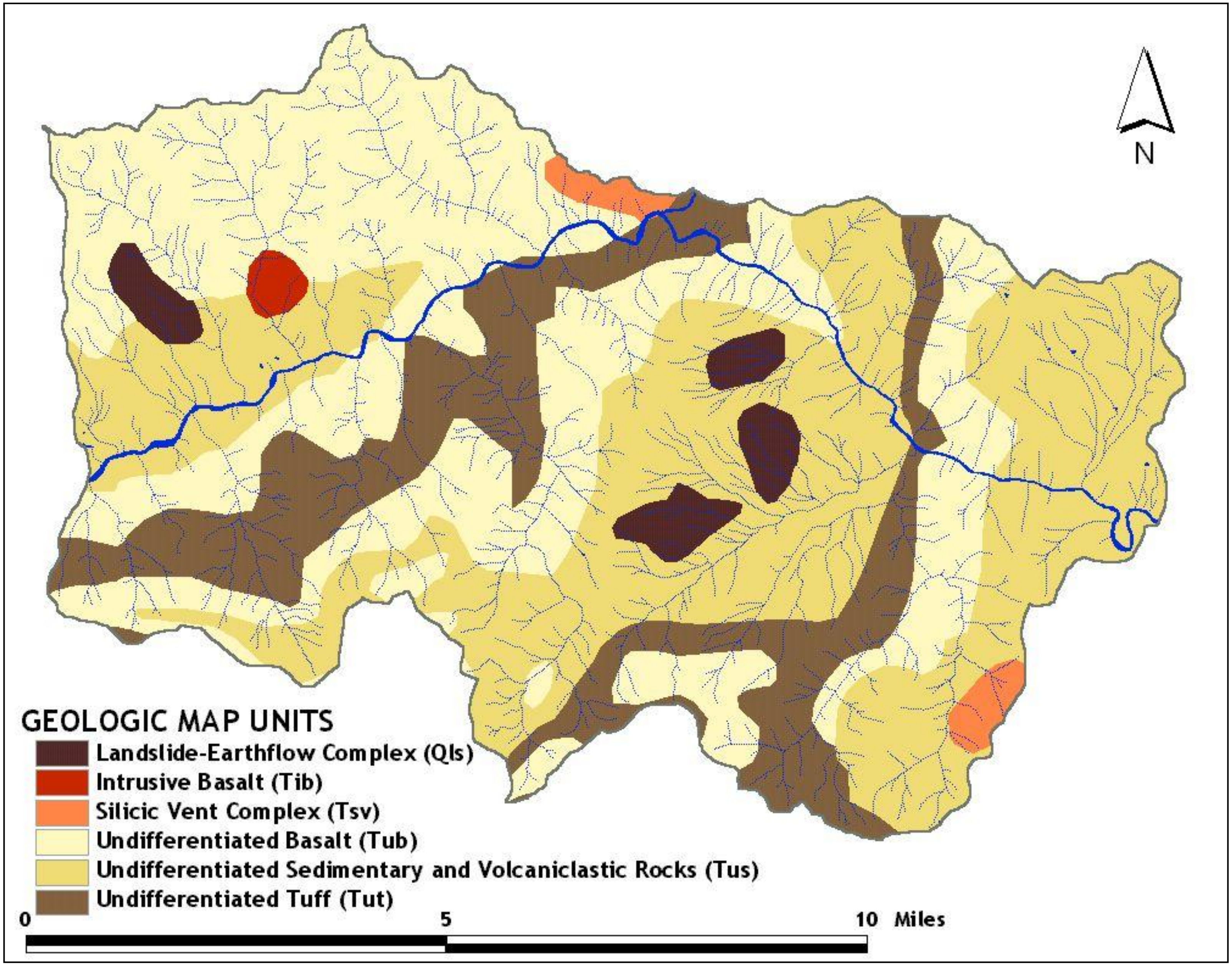


Figure 5. Geologic map units of the analysis area.

The strata were deposited between 35 and 17 million years ago (Sherrod 1996). The subsequent effects of burial metamorphism and hydrothermal activity altered the rock's chemistry. This is most pronounced in the porous and permeable tuffaceous strata, as evidenced by the abundance of clays, calcite, zeolites, and other secondary silica minerals (Paeth et al.1971). Swanson and Swanston (1977) indicate that the tuffaceous deposits within the Little Butte Group contain copious amounts of shrink-swell clay minerals making them susceptible to rapid chemical weathering and decomposition. Deep-seated landslides involving bedrock are noted to occur more frequently in areas underlain by altered tuffaceous rocks (Walker and MacLeod 1991). Slope instability is characterized by the widespread presence of ancient deep-seated bedrock failures and large massive earthflows.

Geomorphology

Widespread volcanism began in western Oregon roughly 42 million years ago and waned around 8-10 million years ago, shifting eastward and marking the early developmental stage of the High Cascades physiographic sub-province. The present day snow clad peaks of the High Cascades developed during the past 2 to 3 million years (Priest et al. 1983; Duncan and Kulm 1989, Sherrod 1986). Sometime between 3.3 to 6 million years ago the western flank of the Cascade Range began rising (the rate of uplift has steadily diminished since). This abrupt rise dramatically increased stream gradients resulting in considerably greater erosional power, thus creating the moderately to deeply incised landscape so pronounced along the western flanks of the Cascade Range today (Fig. 7). Regional fault patterns have influenced the development of drainage networks within parts of the analysis area, as evidenced by strong northwest and northeast alignments of stream systems (Kienle, et al. 1981). The analysis area is broadly stratified into five basic geomorphic landscape units as described below (Fig. 6).

STEEP SIDE SLOPES

These areas are identified by their abundance of 'V-shaped' canyons and sharp-crested ridges forming a steep dissected topography. Well-developed fan-shaped (dendritic) debris avalanche basins are generally found at the heads of the larger river tributaries. Streams have high-energy gradients that transport cobbles, boulders and large woody debris into higher order systems. The high stream power of the low order streams readily flushes finer-textured sediments into mid order streams where it is temporarily stored. Soils within this terrain are typically skeletal, coarse-textured and permeable. Rapid moving, shallow-seated landslides are common within this terrain.

INNER GORGE

These geomorphic features originated from rapid incision of major stream systems into the uplifted terrain over the past several million years. Typically bedrock, with chronic rockfall and ravel, they provide a continual source of coarse-textured sediment into adjacent stream channels. Inner gorges that have developed within landslide-earthflow deposits often pose a chronic source of sediment input into the aquatic environment. Ledges, crevices, and clefts associated with this terrain provide habitat for raptors and bats. Talus slopes beneath bluffs and pillars are favored habitat for reptiles and amphibians.

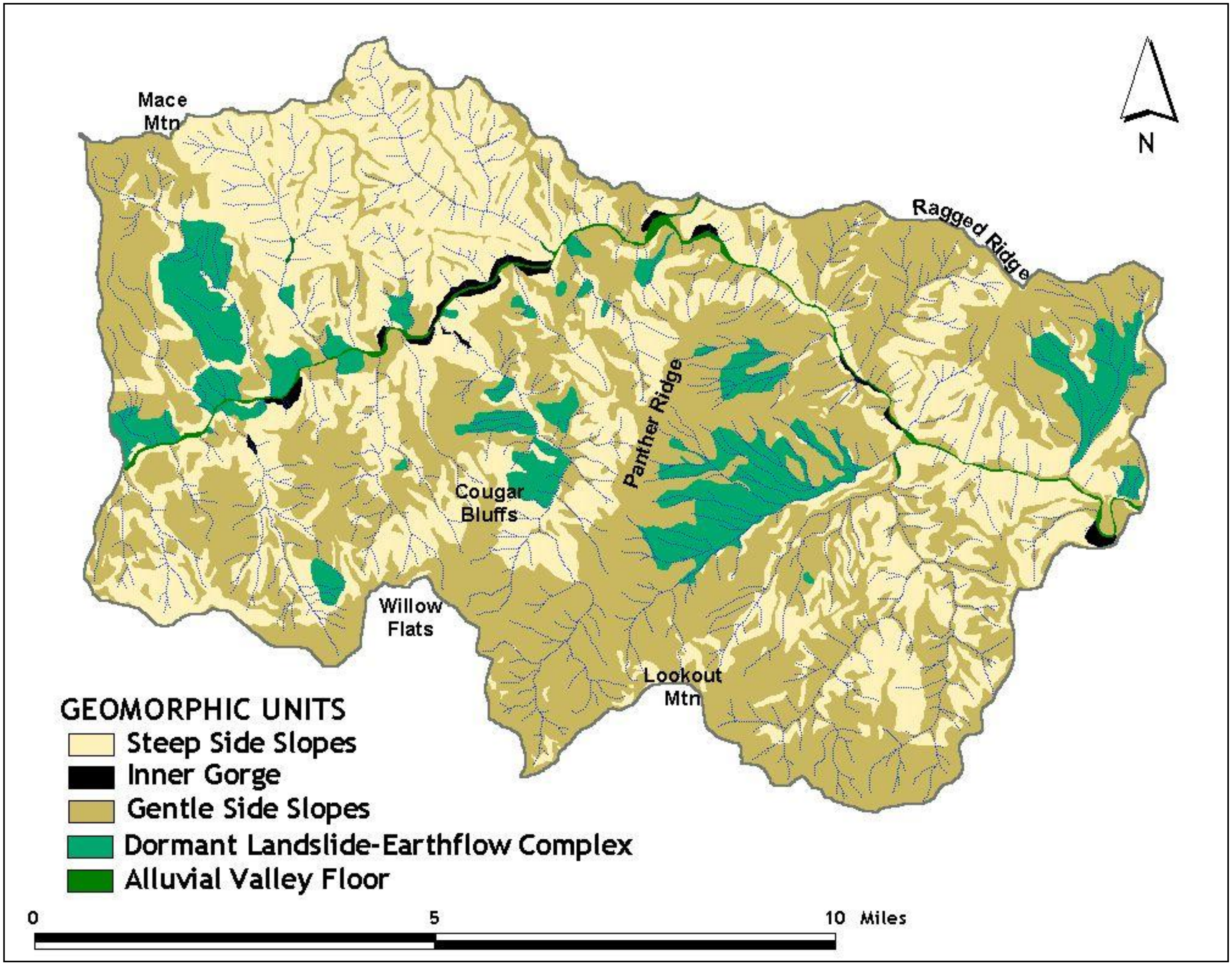
GENTLE TO MODERATE SIDE SLOPES

These geomorphic units are characterized by weakly dissected terrain with less than 65 percent in overall steepness. They encompass several landforms including broad ridge tops, rolling remnant and structurally controlled gently inclined dip slopes (e.g., Panther Ridge).

DORMANT LANDSLIDE-EARTHFLOW COMPLEX

These areas typically are weakly dissected with gently sloping topography characterized by the presence of deep, fine-textured soils. The earthflow complex tends to be poorly drained due to variable clay content and contains high amounts of surface water and groundwater. Failure processes involve chronic soil creep, and deeper-seated slump-earthflows. Ground movement seems to be most active within concave slope forms where water pathways converge (Swanson and Swanston 1977 and Swanson et al. 1987). Characteristics include headwall and lateral scarps, tension cracks, pressure ridges and levees, 'jackstrawed' and leaning trees, benchy or hummocky topography, and highly disrupted drainage networks. These ancient complexes are essentially dormant in today's climate, and are thought to have formed during the Ice Ages when climatic conditions were substantially wetter than today. Earthquakes are believed to have triggered movements of these deep-seated landslides.

Stream channels that cut through this terrain have a natural deficiency of channel armoring materials (e.g., bedrock and boulders). Large wood often provides the primary element of channel roughness. Seasonal peak flows can be expected to carry considerable amounts of sediments. Abundant wetlands associated with landslide-earthflow landforms provide habitat for pond breeding amphibians. The deep and highly weathered clay-rich soils are favorable for timber growth due to their high nutrient capacity and water retentive properties.


Mace Mtn
Ragged Ridge
N
Panther Ridge
Cougar Bluffs
Willow Flats
Lookout Mtn
GEOMORPHIC UNITS
Steep Side Slopes
Inner Gorge
Gentle Side Slopes
Dormant Landslide-Earthflow Complex
Alluvial Valley Floor
0
5
10 Miles

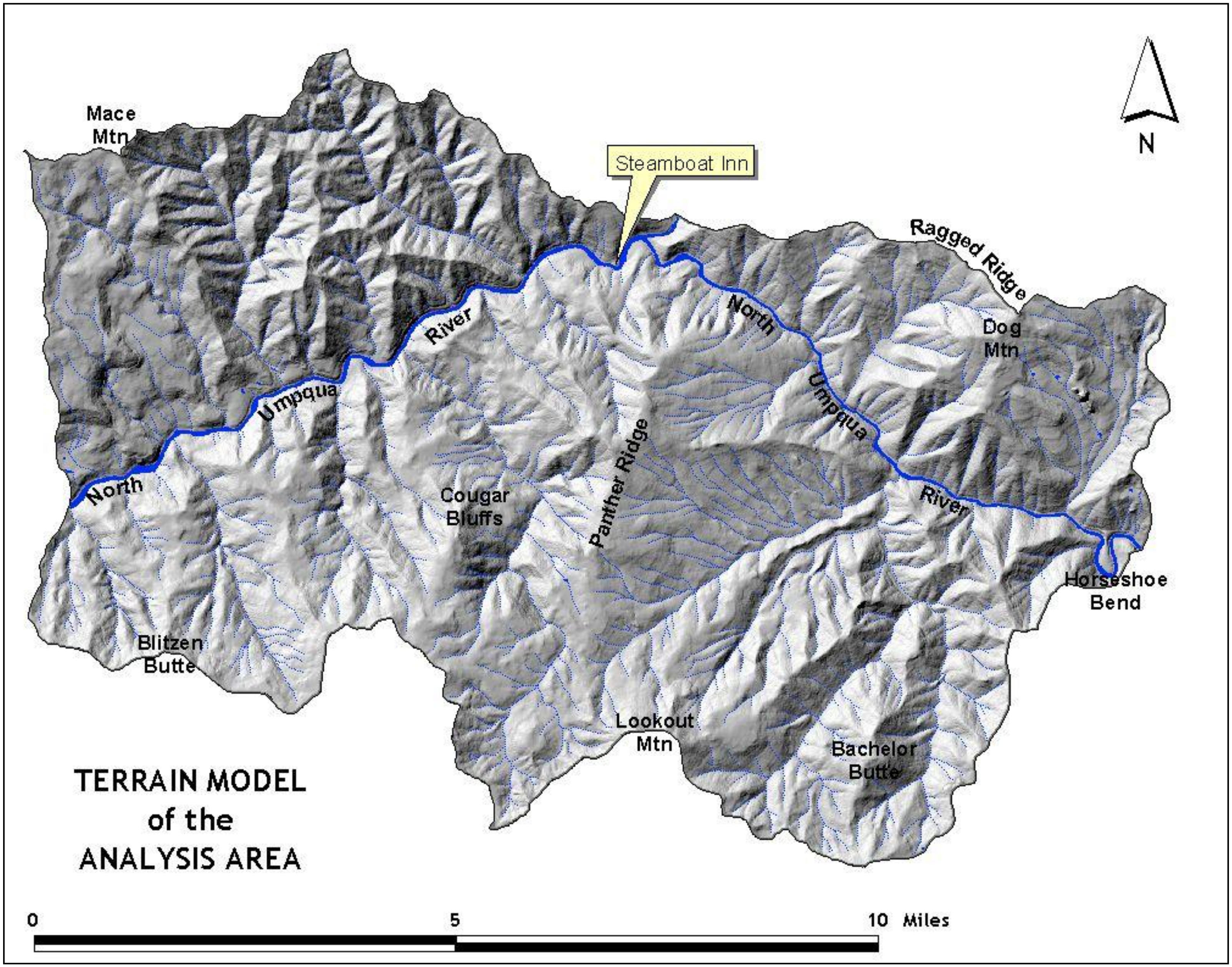


Figure 7. Terrain model of the analysis area generated with 10 meter resolution USGS digital elevation data (DEMs).

ALLUVIAL VALLEY FLOOR

This landform includes present-day floodplains and terraces formed exclusively by fluvial processes. Alluvial valley floor landforms are highly desirable locations for many recreational uses because of their smooth flat surfaces and proximity to water. Terraces often buffer the direct influx of sediment caused by rapid-shallow landslides from adjacent valley side slopes. Unconfined stream channels may be present within the alluvial valley floor and are typically sensitive to natural disturbance events and intensive management practices (Rosgen 1994 & 1996). Slope stability concerns are primarily limited to stream bank undercutting, sloughing, and chronic ravel.

BROAD ENVIRONMENTAL GRADIENTS

Broad environmental gradients were mapped within the watershed ranging from steep-dry to gentle-moist (Fig. 8). This mapping provides the landscape-scale context in which to characterize the variation in physiography, vegetation patterns and fire regimes across the watershed (Table 3). It is useful in designing management treatments at a larger scale, such as prescribed fire and treatment of thinning units to restore large blocks of habitat. Later in this document these gradients are used to delineate "landscape areas" for future land management (Fig. 60, Page 117).

Table 3. Attributes of the environmental gradients within the analysis area.

ATTRIBUTE	GENTLE/MOIST	STEEP/DRY
Physiography	• Minimal topographic relief • Landslide-earthflow terrain • Linear/parallel drainage pattern • Broad ridge tops or table lands	• Highly incised 'V-shaped' canyons • Valley inner gorge • Sharp-crested drainage divides • Dendritic drainage pattern
Hydrology	• High density of wetlands • Discontinuous channels • Deep soils • Cold water temperatures (springs) • Higher summer base flows • Lower channel density	• Few wetlands – more confined to channels • Shallower soils • Lower base flows • Flashy response to storms • Higher channel density
Fire	• Less frequent stand replacement fires • Large, intense fires usually associated with extreme weather • Stand-replacement fires tend to be larger but occur less frequently	• More frequent stand replacement fires • Patches tend to be smaller but occur more frequently
Forest Types	• Dominated by contiguous old forest • Western hemlock in the lower elevations and silver fir in higher elevations	• More patchiness • More Douglas-fir forest types in the lower elevations and white fir in the upper elevations
Unique Habitats	• Mostly wetlands and deep-soiled meadows	• Mostly rocky openings and dry meadows • Cliffs, caves and crevices

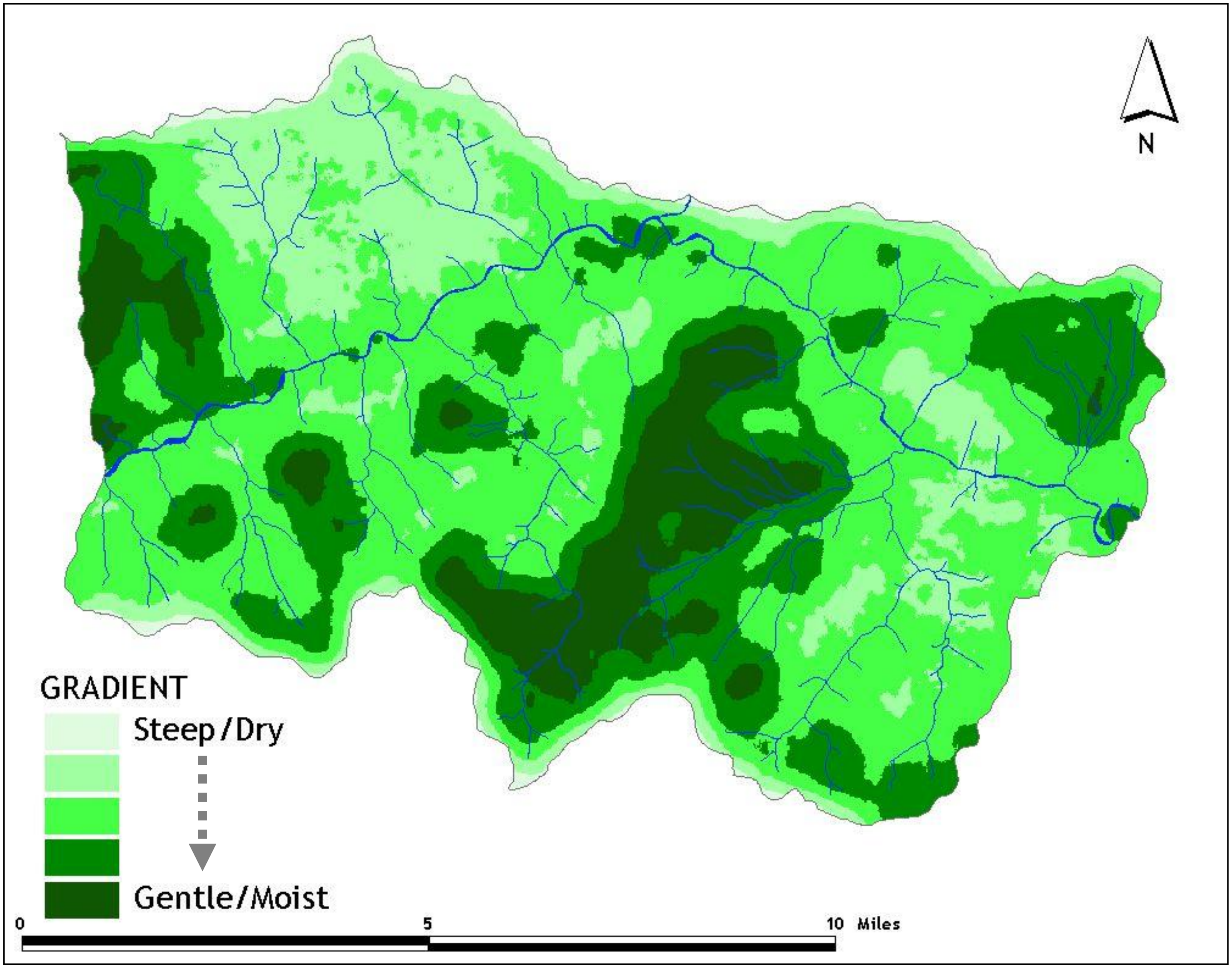


Figure 8. Topographic model of the broad environmental gradients within the watershed.

Natural Disturbances

Natural disturbance is an important forest ecosystem process. It alters the forest at the stand and landscape scale by killing trees, changing amounts of coarse woody debris, and changing forest patch sizes and shapes (Morrison and Swanson 1990). These terrestrial changes usually influence changes in the aquatic ecosystems. Examples of natural disturbances include wildfire, wind, insect and diseases.

FIRE REGIME

Prior to fire suppression and intensive timber harvesting, wildfire was the major disturbance shaping forests of the western Oregon Cascades (Agee 1993, Morrison and Swanson 1990, Teensma 1987). The role wildfire plays in an ecosystem is described in terms of a fire regime. Fire regimes are classified at various scales often encompassing specific mountain ranges or similar climatic areas. They are a function of the frequency of fire occurrence and fire intensity (Irving 1971). They are often based in terms of fire severity. As such, high-severity fire regimes are defined as having infrequent high-intensity fires (greater than 100 years between fires) that often kill most trees in a forest stand (Agee 1990). Moderate-severity fire regimes have infrequent fires (25-100 years) that are often partial stand-replacement fires and include areas of high and low-intensity.

In general, forests in this part of the Cascades have moderate-severity fire regimes (Agee 1993). Such is the case for the Steamboat Creek and Little River 5th field watersheds that border the analysis area to the north and south, respectively. However, analysis of historic fires patterns and the topographic character of the analysis area indicate that it normally experiences high-severity fires. Burn patterns reveal a significant amount of stand replacement events within the watershed, far exceeding percentages of adjacent 5th field watersheds. The percentage of high-severity fires over the last 150 years has been approximately 49% of the area (Fig. 9), as opposed to 25% within adjacent watersheds.

The frequency, extent and effects appear to be concentrated in areas of the watershed. The western half of the watershed has been subjected to numerous large, high-severity fires over the last 150 years. The steep terrain of that area combined with the affects of canyon winds from both Steamboat Creek and the river above the Steamboat Creek may support more stand-replacement fires. The eastern half of the watershed has fire patterns more typical of a moderate-severity fire regime. The largest continuous area that supported intact late-successional type stands was located on the eastern part of the watershed in the Panther Creek sixth field sub-watershed.

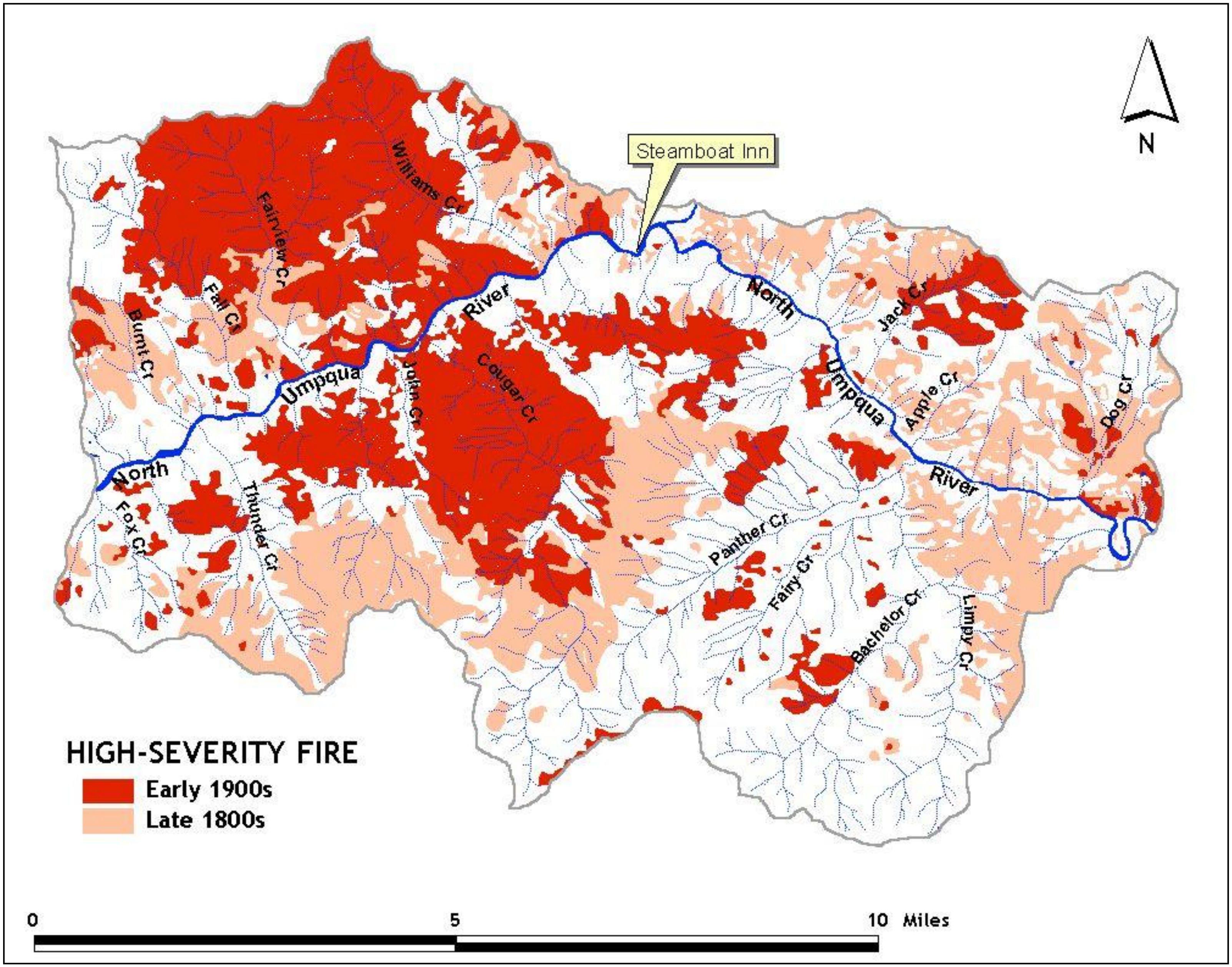


Figure 9. A map of high-severity fires, which occurred within the analysis area over the last 150 years and prior to 1946.

The analysis area contains unique characteristics that provide optimum conditions for frequent high-severity fires. For instance, the proportion of moderate to steep and dry, dissected terrain is higher in the analysis area than in adjacent watersheds. In addition, the North Umpqua River canyon experiences diurnal winds that typically flow up-canyon during the daytime and down-canyon at night. When a high-pressure system sets up on the east side of the Cascades with a low-pressure system along the Pacific coast, conditions exist for a strong east wind (Foehn wind) event. The river canyon, especially below the confluence of Steamboat Creek, provides a funnel for wind flow (Fig. 10), which dries fuels and creates extreme fire behavior.

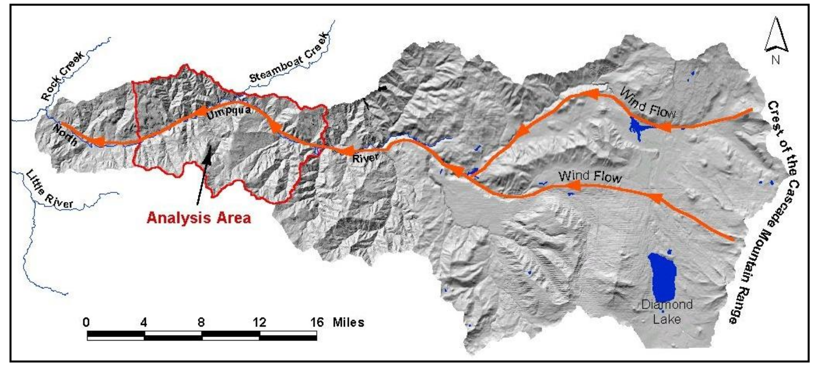


Figure 10. This terrain model shows how Foehn winds are concentrated along the river canyon within the analysis area.

Historically, some of the largest wildfires in Oregon and Washington were caused by strong east winds that fanned wildfires. The most critical period for Foehn winds occurs in late summer and early fall when high pressure systems moving southeast out of British Columbia can actually intensify as they reach the northern Rocky Mountains. In these cases, east to west pressure gradients actually increase across Western Washington and Oregon over a period of several days. When pressure gradients across the Cascades reach 8 millibars or more, east winds of 40-60 mph can be expected in east to west, wind prone drainages or through terrain gaps in the Cascades (NOAA).

The terrain within the analysis area is also ideal for the development of mid-slope thermal belts during the fire season. These thermal belts sustain higher temperatures through the night than the ridge tops and valley bottoms. This keeps mid-slope fire active throughout the night, allowing fuels to preheat so that when increased temperatures and winds arrive the following day, these fuels burn with high intensity. This allows for severe fire runs as noted by Paul Solarz, Fire Behavior Analysis on the 1987 Apple Fire complex.

The extent of low to moderate-severity fire during the reference period is hard to determine from interpretation of the old 1946 aerial photographs, as the fire's effect on forested stands is easily missed. However, estimates based on fire intensity mapping of the Apple Creek (1987) and Spring Fire (1996) indicate that approximately 76-83% of the area burned at low to moderate-severity, respectively. However, it is important to realize these fires were actively suppressed. Much of the area in Figure 9 (outside of the high-severity patches) likely burned at low to moderate-severity over the last 100-150 years.

FIRE OCCURRENCE

The analysis area has experienced large stand replacement fires throughout history. These fires were rarely limited to less than 100 acres in size. Several fires or one conflagration occurred early in the 20th century within the watershed on both sides of the North Umpqua River. The 1946 aerial photos are the most apparent evidence of this, showing several thousands of acres having been severely burned. Based on stand exam information, the fire that occurred in the Mace Mountain and Fairview Creek area occurred between 1908-1938. Another fire or part of the same fire burned in the area of Winslow Cabin Springs and Fisher Creek. This fire occurred between 1910 and 1940. Based on fire history data collected in the analysis area, the mean fire return interval is estimated to be 30 years. Time between stand-replacement fires is estimated to be between 30-80 years.

Fire frequency is based on fire occurrence records from 1970 thru 1996. In that time period, there were 103 fires recorded (average of 3.8 fires/yr) within or adjacent to the analysis area (Table 4). This was 19% of the District's fires for that period. Based on these numbers, the fire occurrence rate (FOR) for the analysis area is 0.7 fires per 1,000 acres per year. In other words, there is a 7% chance of a fire occurring on any given 1,000 parcel for any given year (this FOR is similar to the District's FOR). Over the next fourteen years, it can be expected that a fire could occur within each 1,000-acre block within the watershed. The probability of one or more of these fires reaching 100 acres in size is 79 percent. There is a 32% chance that at least one of these fires will burn between 100-1000 acres.

Table 4. Summary of fires within the analysis area between 1970-1996.

FIRE CAUSE	NUMBER OF FIRES	PERCENT OF TOTAL FIRES	TOTAL ACRES BURNED
Lightning	68	66%	2,584
Campfire	7	7%	1
Slash Burning	5	5%	10.5
Smoking	4	4%	0.5
Equipment Use	4	4%	27
Arson	3	3%	0.5
Unknown Human-Caused	12	11%	154

Over this 27-year time period, 34% of all fires were human-caused. The analysis area receives heavy recreation use and human-caused fires are the highest here compared to the rest of the District.

WIND

Wind provides both small and large-scale changes to forest structure. In Oregon, the majority of strong surface winds are from the southwest and associated with storms moving onto the coast from the Pacific Ocean. When winds are from the west, they are often stronger on the coast than in the interior valleys due to the north-south orientation of the Coast and Cascade Mountain Ranges, which obstruct and slow down the westerly surface winds. The most potentially damaging winds are those that blow from the south, parallel to the major mountain ranges. The Columbus Day Storm of 1962 was a classic example of a south windstorm. There have been a dozen major windstorms since 1880, occurring on the average every 10 years. All 12 of these storms occurred during the winter, with most occurring between October and January. The last large windstorm within the analysis area occurred in December of 1996.

Windstorms can cause stem breakage and windthrow, which increases stem decay in wounded trees and leads to bark beetle buildups in wind-thrown trees (Campbell et al. 1996). The amount of windthrow that occurs today is influenced by the amount of forest edge. Past clearcut harvesting and road building have created several hundreds of miles of high contrast edges (about twice as much as occurred historically). It is common to see blowdown along these man-made edges.

INSECTS AND DISEASE

Historically, insects and disease played a small, but important role in the forest. Insects like the mountain pine beetle and the Douglas-fir beetle are endemic within the analysis area. Incidences of significant outbreaks were rare except following infrequent large storm fronts, which created significant areas of blowdown. Similarly, root disease was endemic with small pockets of laminated and black stain root rot the most prevalent. Available evidence suggests that root disease centers probably maintained populations of Douglas-fir bark beetles between outbreak years. Finally, dwarf mistletoe affected small pockets of Douglas-fir and hemlock by creating characteristic “brooms”.

Wildfire helped control disease and insect activity and kept the forest healthy. An increase in hemlock dwarf mistletoe and pine health problems are believed to be caused by a lack of low intensity fire. The winter storm of 1996 created the most measurable amount of blowdown in any single event since 1962. As a result, an increase in bark beetle activity was apparent in 1998 and 1999. Small pockets of beetle-killed trees are scattered throughout the watershed in groups of 3-12 trees. Past timber management practices have also helped increase root disease areas and black stain root rot, which has expanded in association with road system development.

Landscape Patterns

Landscape patterns were divided into four broad classifications, which are roughly equivalent to seral (or successional) stages (Fig. 14). The landscape within the watershed (as seen from above) was naturally dynamic. Historically, changes were mainly influenced by the climate and natural disturbances, with wildfire as the main mechanism of change. Lightning was the main cause of wildfires but humans have caused many fires throughout the centuries. These fires created a shifting mosaic pattern of forest patches of varying shapes and sizes through time. Figure 11 and Figure 12 show how landscape patterns within the watershed have changed in the last 50 years.

Changes in landscape patterns were analyzed by comparing the current patterns with historic patterns of the 1940s. Landscape patterns for the current conditions were developed through interpretation of aerial photos taken in 1997. Patterns for the historic (or reference) period were obtained from historical vegetation mapping done in 1914, 1932 and 1946 and through interpretation of aerial photos taken in 1946.

Over the last few centuries and up until the last few decades of the 20^{th} century, the watershed was mainly covered by late-successional forests with scattered patches of early to mid-successional forests resulting from stand replacement fires (Fig. 11). The patch pattern within the eastern half of the watershed consisted of many smaller patches in the upper slopes. Riparian forest patterns were well defined in this portion of the watershed. The western portion of the watershed was characterized by larger patches, indicative of higher severity fires, and showed large sections of riparian forests having been burned over. Overall, contiguous late-successional forest covered the majority of the watershed through time and seemed to be concentrated around the gentler, moister terrains.

Fire suppression since the early 1920s has significantly altered how fire affects the landscape within the watershed by greatly diminishing the occurrence of high-severity, stand replacement fires. In addition, highway and road construction, development of human infrastructures, residences and timber harvesting over the last five decades have caused major changes to the watershed's landscape patterns causing landscape patterns to deviate from their natural range (Fig. 12).

Historic patterns on the landscape were relics of large stand-replacement fires. Today's landscape patterns are primarily created through clearcut timber harvesting and road construction. When compared to the historic (reference) patterns, today's patterns are more fragmented with smaller patch size and less connectivity.

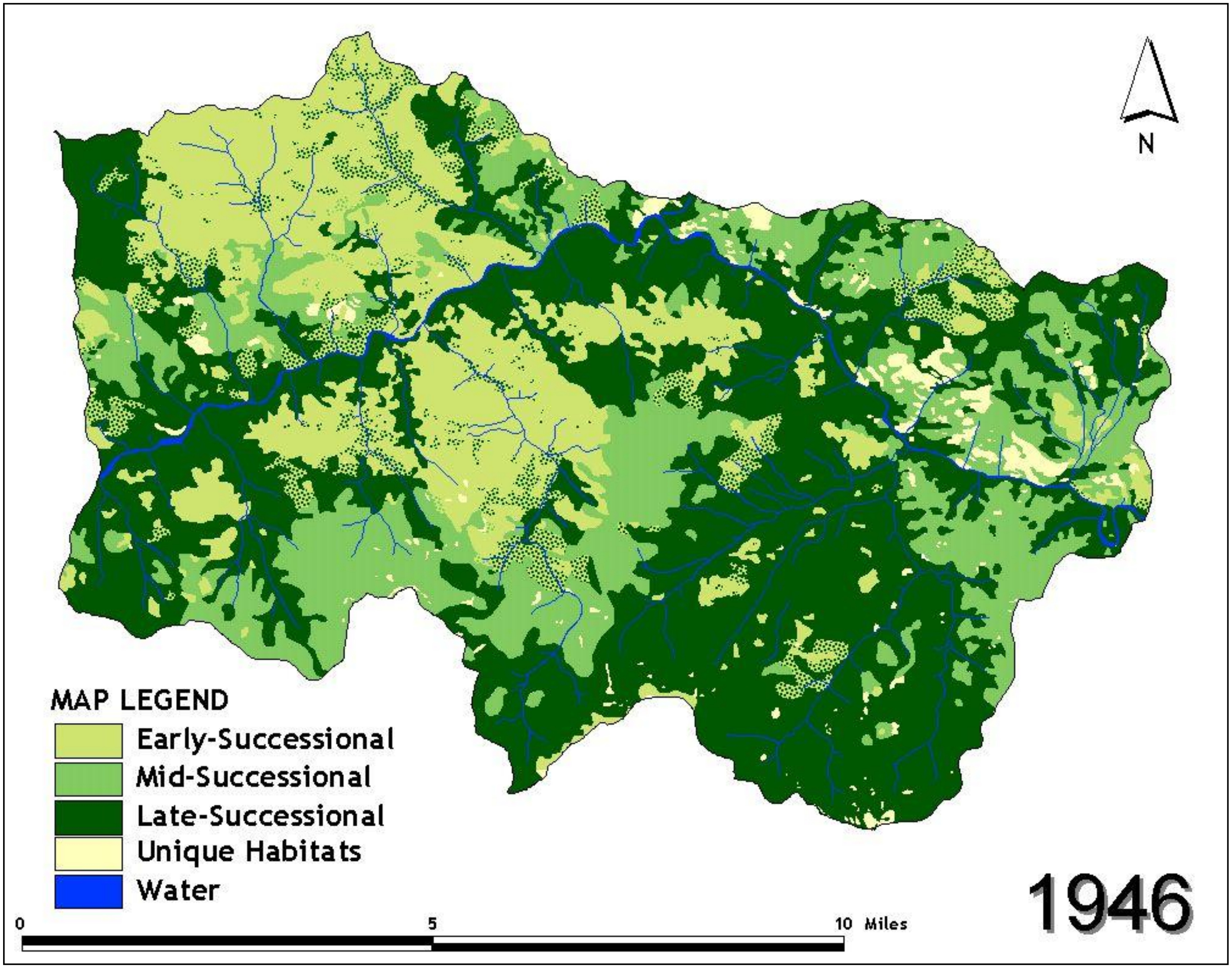


Figure 11. Reference landscape patterns in the analysis area.

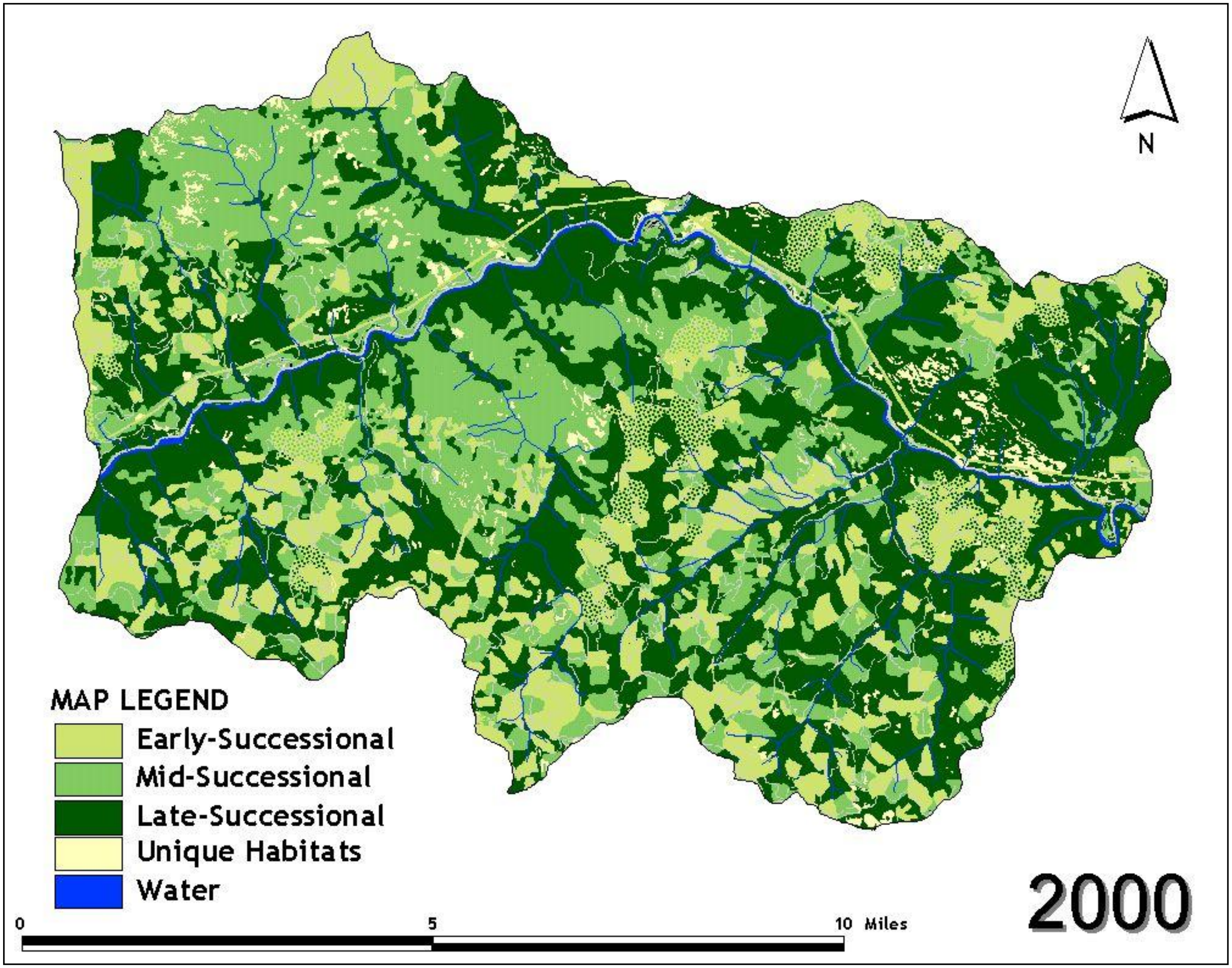


Figure 12. Current landscape patterns in the analysis area.

Forest Zones

The distribution of forest zones (a.k.a., forest types, plant series or plant association groups) throughout the watershed is quite complex. There are five forest zones that occur within the watershed (Fig. 13). They are described below.

DOUGLAS-FIR ZONE

This zone occurs on the upper slopes and ridges usually with steep gradients and southerly aspects. The diversity of plant associations is relatively low. Most of the plants that occur are adapted to drier conditions. Douglas-fir dominates the stands. Common associates are incense-cedar, sugar pine and less commonly white fir. Western hemlock and western redcedar are uncommon and mostly absent. Madrone and chinquapin are the dominant hardwood species. Other hardwoods found in this zone include canyon live oak, pockets of Oregon white oak and occasionally bigleaf maple. The shrub layer is usually sparse. Soils are generally shallow with low moisture availability. The convex landforms characteristic of this zone maintain "young" and relatively unproductive soils through erosion. Because of harsher growing conditions, these areas are slow to revegetate after disturbances, exposing the soil to more erosion through time. The result is a zone that produces less biomass and smaller diameter trees. Based on a summary of old-growth characteristics, the average old-growth stand in this zone is two-storied and about 200 years in age, with approximately 8-10 trees/acre ranging in diameter from 24-37 inches. High quality late-successional habitat characteristics can be achieved in this zone, similar to those found in moister forest zones; however, they are usually achieved more slowly by as much as 50 years.

DRY WESTERN HEMLOCK ZONE

This forest zone is the most common zone within the planning area. Douglas-fir is the dominant tree species with scattered incense-cedar, sugar pine, western white pine, Pacific yew and western redcedar. Western hemlock dominate the understory tree layers and is the climax tree species. However, due to the presence of fire and other disturbances, mature stands are often dominated by large, old Douglas-fir that can persist for centuries. Thus, overstory dominance is sometimes shared between Douglas-fir and western hemlock. This zone has the highest plant diversity, exhibiting hardwood species seen in both the Douglas-fir and moist western hemlock zones. Based on a summary of old-growth characteristics from site class 3-5 western hemlock plots, the average stand is two-storied and about 200 years in age, with approximately eight trees/acre ranging in diameter from 21-31 inches.

MOIST WESTERN HEMLOCK ZONE

This zone encompasses the moister, low elevation environments. There is a strong association with riparian influences and earth flow terrain. The topography is mostly gentle, with northerly aspects and undulating to concave in form. In this zone, western hemlock is expected to become the dominant tree species, given the opportunity to achieve a long-term stable state. The major conifer species in this zone are Douglas-fir, western hemlock and western redcedar. Minor conifer species include Pacific yew, white fir and sugar pine. Hardwoods include the bigleaf maple and red alder. The shrub and herbaceous layers are diverse with species such as vine maple, willow, dogwood, rushes, sedges and grasses. This zone is highly productive and produces a considerable amount of biomass, including large diameter trees. Based on a summary of old-growth characteristics from high site class (1-2) western hemlock plots, the average stand is multi-storied and about 200 years in age with approximately eight trees/acre ranging in diameter from 35-42 inches.

TRUE FIR ZONES (WHITE FIR & SILVER FIR)

These zones occur above 4,000 feet. White fir seems to be more common in the cooler, drier areas. Under a natural fire disturbance regime, Douglas-fir will usually dominate the overstory, however with the lack of fire, white fir will become the climax species. The major conifer species in this zone are Douglas-fir and white fir (especially in the understory). Minor conifer species include western hemlock, incense-cedar, western white pine, Pacific silver fir, Shasta red fir and mountain hemlock. Hardwoods include golden chinquapin in the drier areas, with alder and bigleaf maple in the moister sites. Based on a summary of old-growth characteristics from white fir plots taken in Central Oregon, the average old-growth stand is two-storied and about 150 years in age, with approximately 10-20 trees/acre averaging 21 inches in diameter. In the more humid areas with moderate temperatures, short growing seasons and late summer dry seasons; the dominant climax tree species is Pacific silver fir. It commonly shares dominance with western hemlock, mountain hemlock, Shasta red fir and white fir. It can produce pure stands in moister localities. Other associates include western white pine, Douglas-fir, incense-cedar and western redcedar. The true fir zone is generally a very diverse zone for tree species. Snow accumulation is high in this zone and provides moisture well in to the dry season. The zone is characterized by a high occurrence of lightning started fires that commonly burn as low intensity ground fires. Infrequent higher intensity fires can occur in this zone during extended hot and dry climatic conditions. Based on a summary of old-growth characteristics from Pacific silver fir plots, the average old-growth stand is two-storied and about 190 years in age, with approximately 6-7 trees/acre averaging 25 inches in diameter.

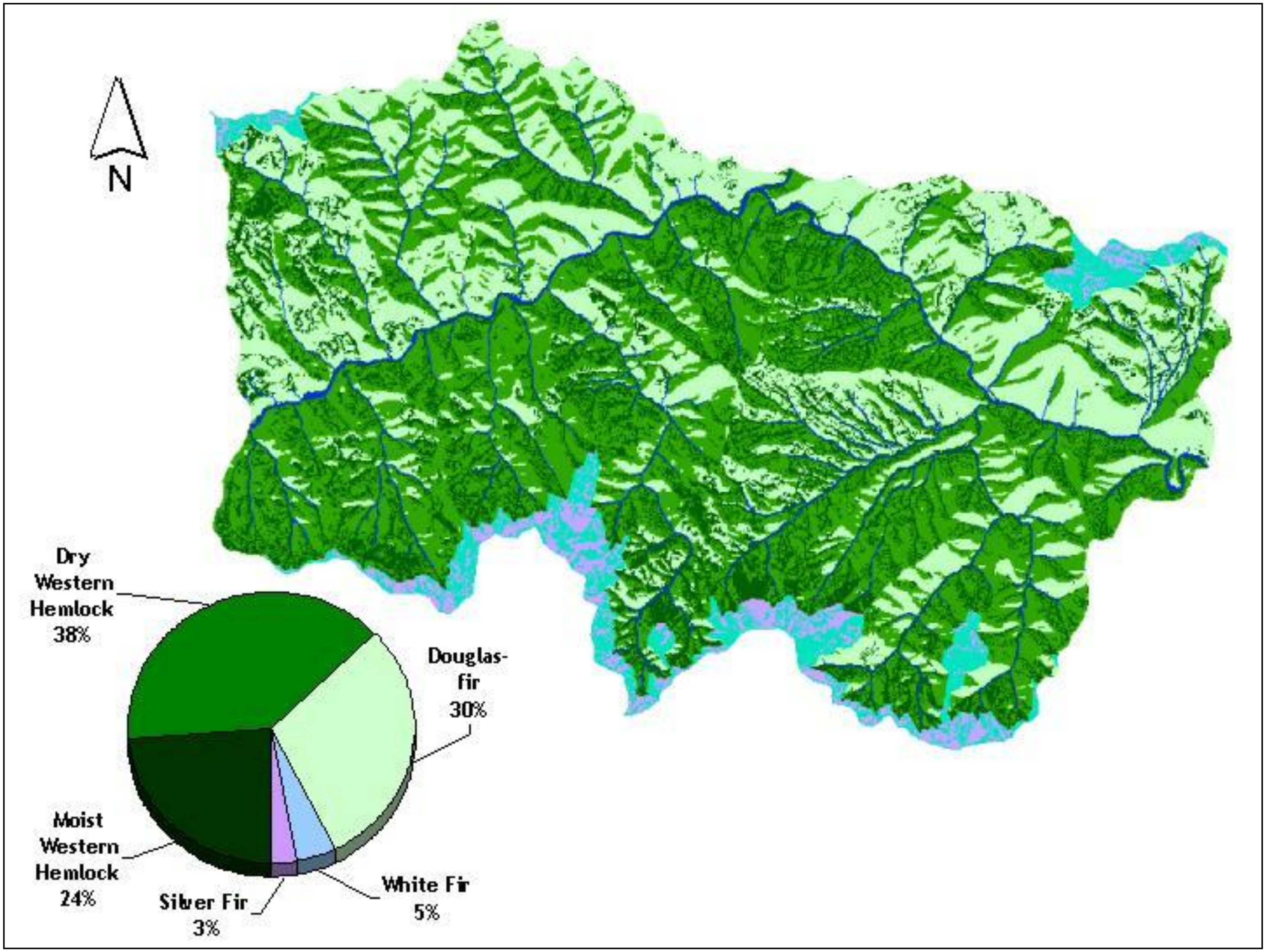
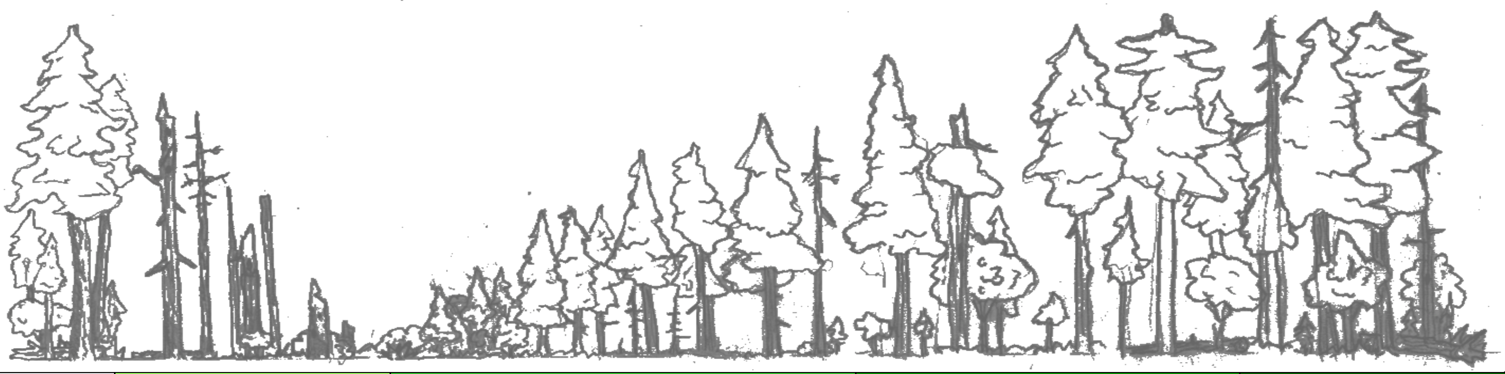


Figure 13. Forest zones of the analysis area (the white fir and silver fir zones are sometimes referred to as the true fir zone).

Forest Structure

Forests usually follow a typical progression of stand structures over time (Fig. 14) until the next disturbance, which can happen at any time during its development, alters its structure and sets it along another course or back to "time zero". Because of the moderate climate and fire regime, most forest stands in southwestern Oregon are more complex and diverse than their northern counterparts. They contain more tree species with more variations in size, age, and density than in the typical northern temperate forest stand. These more complex stand structures are primarily a result of frequent low to moderate-intensity fires that mostly under-burn and occasionally kill groups of trees creating a mosaic of stand structures.

The following definitions represent four basic stand structure conditions along the continuum of forest succession. Each description is an "idealized" picture of a stand condition at one point in time. Forest stands will eventually reach a point where they fit that stand structure definition. As they grow away from that condition and toward another, many stands will be in a transition area where they do not quite fit either description.



TIMELINE (YRS)	0-30	30-80	80-120	120+
Successional Stage	Early	Mid	Late	
Forest Stand Structure	Stand Initiation	Stem Exclusion	Understory Reinitiation	Old Forest

Figure 14. Timeline and cross-reference schematic for natural forest succession and stand structure stages.

STAND INITIATION

In this stage, conifer and hardwood seedlings/saplings, grasses, herbs, and/or shrubs dominate the stand (Fig. 15). Normally, components from the previous stand (snags, down wood and remnant larger green trees) would occur. These components are usually absent in old clearcut timber harvest units or where burned areas were salvage logged.

Competition has not yet resulted in widespread loss of grass, herb and shrub layers. Growth is vigorous. This continues for up to 30-35 years before crown closure shades the lower layers sufficiently so that the grasses, herbs and shrubs begin to lose vigor and die.

Figure 15. Stand initiation structure resulting from the 1987 Apple Fire.

STEM EXCLUSION

During the stem exclusion stage, conifers fully occupy the stand forming a single canopy layer (Fig. 16). There is little to no understory development. Forest floor vegetation is sparse and consists of shade-tolerant species such as Oregongrape, swordfern and salal. Understory trees, if any, provide minimal layering and are in “survival” mode. Death of some understory trees may be evident.

Early in this stage, most trees have large crowns and are growing rapidly. A lack of disturbance and high stocking densities over an extended period of time slows tree growth and crowns recede. Stands can remain in this condition for decades. Eventually, disturbance (e.g., disease, wind or fire) may thin out the stand, encouraging understory reinitiation.

Figure 16. Stem exclusion structure in a Douglas-fir plantation on Panther Ridge.

UNDERSTORY REINITIATION

These stands contain more diverse herb and shrub layers and tree canopies ranging from single-species/single-layered to multiple-species stands (Fig. 17). However, significant layering of tree crowns has not yet developed. Adequate light enters the stand allowing both shade tolerant and intolerant herb and shrub species to develop and flourish.

Understory trees are vigorous and beginning to diversify. Vertical layering is beginning. In southwestern Oregon the understory reinitiation process is very important. Many stands may have recycled through this process several times through their life history, in successive fire events, to develop older forest structures.

Figure 17. Understory Reintitiation structure in a stand on Panther Ridge.

OLD FOREST

In old forests, the vertical structure and species composition is more complex than in the understory reinitiation stage (Fig. 18). Shrub and herb layers and multiple tree canopies are present. At the more ecologically complex end of this stand condition are stands that have a mixture of tree cohorts of shade-tolerant and intolerant tree species as well as shrub and herb species.

Tree crowns are arranged in a variety of configurations with significant layering of tree crowns. Substantial amounts of dead trees (snags) and recently fallen trees are usually a common structural feature and may occur in high amounts depending on various factors, including site productivity and disturbance history.

Figure 18. Old forest (old-growth) structure within the watershed.

HYDROLOGY

The North Umpqua River is noted for its outstanding water quality and quantity (USDA/USDI 1992). Most of the water flowing through the analysis area's streams and its portion of the river occurs during the winter rains and snowfall (Table 5). However, sustained summer base flows and cold water are a particular outstanding quality of the River.

BASE FLOWS AND ANNUAL YIELDS

Summer base flows largely depend on snowmelt and groundwater input. Seasonal snowmelt from the large, high elevation snow packs of the High Cascades provides streamflow throughout the summer. This is enhanced by a lattice of interconnecting fractures in the unaltered lava flows of the High Cascades, which provides a high storage capacity for groundwater and regulates its flow uniformly over time. In addition, a widespread blanket of highly permeable pumice ash derived from the eruption of Mt. Mazama some 7,600 years ago serves as a highly porous "sponge" that absorbs water during intense rainfall, directing it downward into the fractured "water-storing" bedrock below. As a result, approximately 42% of the river's annual water yield above the analysis area occurs in the summer (Table 5).

TABLE 5. Gauging station information along the North Umpqua River.

Station #	Station Location	Drainage Area (mi^2)	Period of Record	Average Annual Streamflow (cfs)			% Flow (Nov 1-April 30)	% Flow (May 1-Oct 31)
				Min	Max	Mean		
14316500	North Umpqua River above Copeland Creek	475	1949 - 2000	897	2,080	1,487	58	42
14316700	Mouth of Steamboat Creek	227	1956 -2000	239	1,253	744	85	15
14317500	North Umpqua River above Rock Creek	886	1924 -1945	1390	3,960	2,260	70	30

In contrast, snowmelt within the steep, moderately dissected terrain of the analysis area occurs much earlier in the season, causing streams within it to have diminished summer base flows and warmer temperatures. The shallow soils and deeply weathered Western Cascades volcanic substrates within the analysis area have minimal water-holding capacity; therefore runoff during intense rainfall is very rapid, resulting in "flashy" flows (Ingebritsen et al. 1994 and Sherrod 1995, writt. comm.).

The tributaries within the analysis area have streamflows that are primarily dependent upon rainfall patterns and upland vegetation. Evapotranspiration and interception from vegetation affect water yield, largely determining the proportion of precipitation that ultimately ends up as streamflow. Steamboat Creek (hydrologically representative of the tributaries within this area) records only 15% of its annual flow from May through October (Table 5). A survey of the relative contribution of base flow to the North Umpqua River by tributaries within the analysis area was completed in August 2000 (Table 6). Results of this field data show that the contribution of these tributaries to the summer base flow of the North Umpqua River is minimal.

TABLE 6. Discharge data for tributaries within the analysis area (collected in August 2000).

Tributary Name	Drainage Area (mi^2)	Streamflow (cfs)
Dog Creek	3.9	0.7
Panther Creek	6.6	2.2
Steamboat Creek	163	59
Cougar Creek	9.3	1.0
Wright Creek	3.5	0.6
Thunder Creek	3.9	1.3
Williams Creek	4.5	0.2
Fairview Creek	4.3	0.4

PEAK FLOWS

Peak flows (flood events) are a part of the natural disturbance regime that is vital to a properly functioning ecosystem. When they occur, they can reduce stream stability, modify channel complexity and remove riparian vegetation. Removal of vegetation, in turn can increase the occurrence of peak flows.

In addition to vegetation removal, ground compaction caused by tractor harvest and road construction, interception of ground water at road-cut slopes, and extensions of the channel network due to road ditch lines and relief culverts, have all been shown to increase peak flows by altering the timing of water delivery to the stream network. Compaction increases peak flows by reducing infiltration of water into the ground thus increasing surface runoff. Road-cuts and banks may cut the toe of a slope causing interception of subsurface water. Subsurface flow may be partially intercepted along road cuts and transferred to more rapid runoff via ditch lines. Ditch lines that feed directly into streams act as extensions of stream networks. Such ditch lines may deliver fine sediment, as well as intercepted ground and surface water directly into stream channels (Wemple 1994). Stream network extension is typically expressed as a percent of the length of ditch line feeding directly into streams compared to the total length of the stream network. A survey in the adjacent Steamboat Creek watershed (with similar road densities) found channel extension of 8-23%.

Failed stream crossings and potential stream channel diversion pose the greatest risk for severe sedimentation and mass wasting (Furniss et al. 1991). A diverted stream channel can destabilize soil or road fills, and trigger sudden, massive slope failures. Such failures may propagate into channel scouring debris flows.

Stream flow data collected since 1955 at the Steamboat Gage Station (No.14316700) provides some insight into the severity of flood events that have affected the analysis area (Wellman et al. 1993). Annual peak flow summaries indicate that the analysis area experienced only three flood events that exceeded a 10-year recurrence interval between 1955 and 1997 (Table 7).

Table 7. Instantaneous peak flow discharge of 10-year or greater magnitude in Steamboat basin

DATE	PEAK FLOW (CFS)	RECURRENCE INTERVAL
December 22, 1955	26,900	10
December 22, 1964	51,000	100+
November 18, 1996	31,400	20-25

HYDROLOGIC IMPORTANCE OF THE FOREST CANOPY

The condition of the forest canopy has many influences on an area's hydrology. Within the analysis area, many of the drainages have experienced large changes to their canopies, especially through timber harvesting over the last few decades (Fig. 19). Drainages that have been clearcut harvested on greater than forty percent of their area (within the last 50 years) include Bachelor, Panther, Fairy, Wright and Thunder Creeks. There are no long-term streamflow records for these tributaries; however, these drainages have likely experienced an increase in annual yield. Although summer base flows in these tributaries are relatively low, research suggests base flows have likely increased temporarily due to lower evapotranspiration rates of recently harvested areas.

Stand structure also influences snow accumulation and the rate at which it melts. More snow can accumulate in openings than under forest canopies due to wind eddies in the openings (Brooks et al. 1991). Rapid melt occurs in forested areas because snow caught in the canopy has a greater surface area exposed to convection and condensation processes than on a snow-packed surface in an opening. When rain occurs, snow packs melt rapidly. Some of the most severe floods are attributed to rain-on-snow events. Areas where the air temperature frequently hovers around 32^{o}F during the winter frequently have "rain-on-snow" events. These areas, collectively, are called the "transient snow zone". On the Umpqua National Forest, the transient snow zone occurs within the 2,000-5,000 feet elevation band.

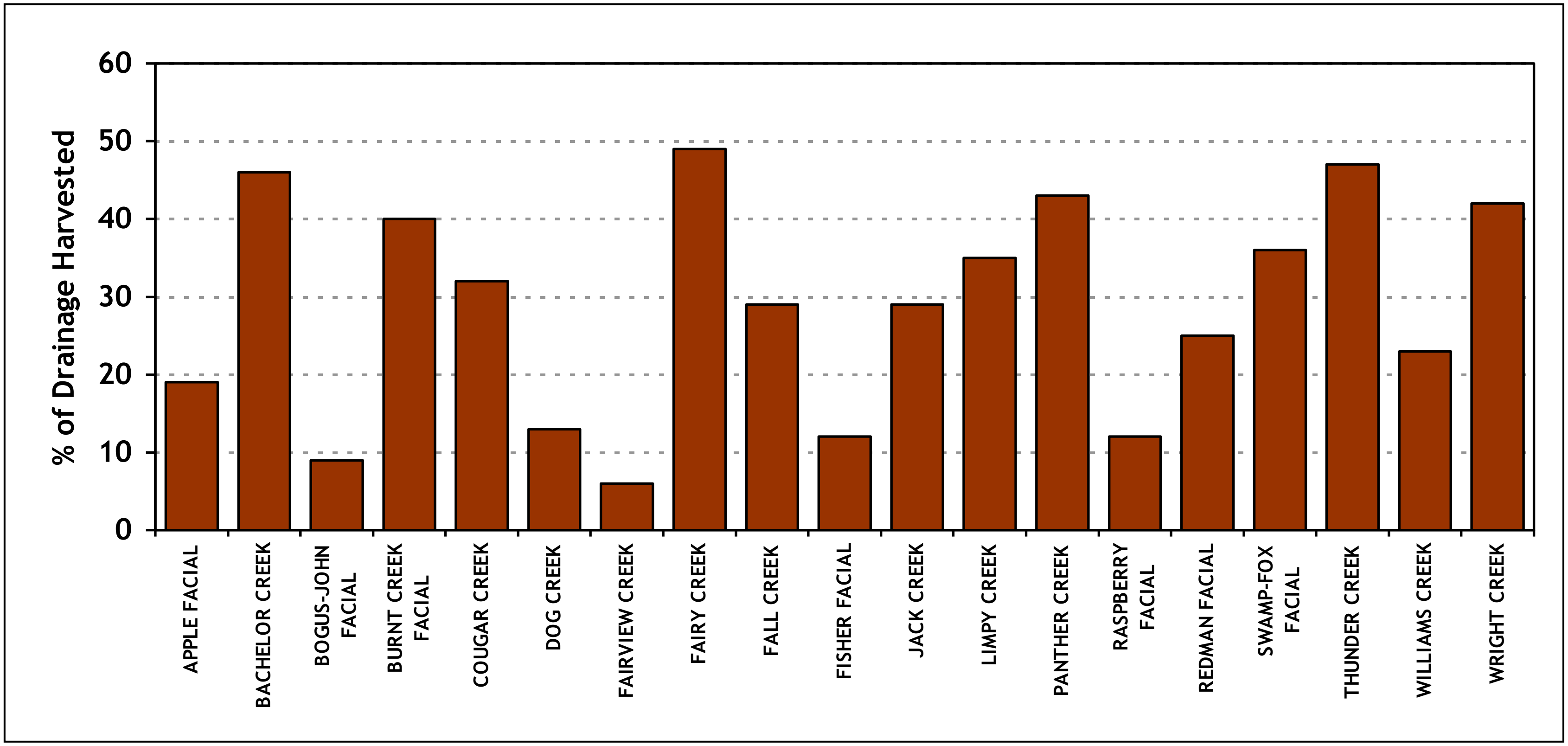


Figure 19. Cumulative clearcut timber harvest within the drainages of the watershed analysis area.

Cumulatively, twenty-nine percent of the analysis area has been previously clearcut harvested, creating openings that, for a period of time, are susceptible to rain-on-snow events. To estimate peak flow response to rain-on-snow events caused by forest canopy removal, the Umpqua National Forest currently utilizes the Hydrologic Recovery Procedure (HRP) model. According to this model, hydrologic recovery is minimal until the stand reaches an age of 10-15 years. Stands are considered to be fully recovered at approximately 30-39 years of age (depending on the tree growth rate within the unit). HRP modeling results indicate that all of the subwatersheds within the analysis area are more than 83% recovered from the effects of timber harvest (Table 8).

Table 8. Hydrologic Recovery Model (HRP) values for the subwatersheds and drainages of the analysis area.

SUBWATERSHED	DRAINAGE	DRAINAGE AREA (ACRES)	CURRENT HRP (% RECOVERED)
Apple Creek Facial	Dog Creek	2,517	98
	Apple Facial	3,737	95
	Jack Creek	1,557	94
	Redman Facial	4,019	95
Panther	Bachelor Creek	2,723	88
	Fairy Creek	2,055	87
	Limpy Creek	3,134	85
	Panther Creek	4,255	87
Williams Facial	Williams Creek	2,891	86
	Fisher Facial	3,540	97
Blitzen Facial	Bogus-John Facial	1,621	97
	Cougar Creek	5,976	89
	Wright Creek	2,255	86
	Fall Creek	2,059	93
	Raspberry Facial	1,122	97
	Fairview Creek	2,781	99
	Thunder Creek	2,484	84
	Burnt Creek Facial	1,497	89
	Swamp-Fox Facial	2,747	92

In addition to the harvest-related canopy openings, it is also important to consider the affect that wildfire had on creating openings in the forest's canopy. Reference streamflow conditions as described above, would have experienced natural fluctuations due to periodic episodes of high-severity wildfires. Fire patterns visible in the 1946 aerial photos show that 27% of the forest stands within the analysis area were less than forty years of age at that time. Today, fire suppression has reduced the occurrence of large fires within the analysis area and the presence of large forest openings. The effects of clearcut harvesting have compensated for this but have spread the openings over a wider area of the watershed than what occurred naturally.

RAMPING

A ramping event occurs when the river's water flow suddenly increases or decreases, and the water level rises or falls. The hydroelectric project upriver of the analysis area affects the hydrology of the river downstream by increasing flows during peak electric usage and reducing flows (by refilling reservoirs and fore bays) during non-peak hours. Occasionally, emergency shutdowns also cause ramping, such as the emergency fire shutdown in August of 1996, which caused a decrease in the river's water level of 0.5 ft/hr. In August and September of 1999, daily water flow fluctuations of more than 6% were recorded in the river above Copeland Creek resulting from actions taken by the hydropower project in order to meet power demands (USGS 1998). Again, between late June and early July of 2000, daily fluctuations in the river's water flow above Copeland Creek ranged from 400-700 cfs. Daily changes of this magnitude during the seasonal base flow period are extremely unlikely to occur under a natural flow regime and are detrimental to channel morphology and the aquatic ecosystem. Even smaller ramping fluctuations that routinely occur during low flows have likely reduced habitat quality.

Increases in flow (up-ramping) have resulted in displacement of fish eggs, as well as juveniles and adult fish. The subsequent decrease in flow (down-ramping) has stranded eggs and juvenile fish within side channels and pocket pools which were previously isolated from the river's channel. Ramping can also reduce benthic (river bottom) species diversity, density and biomass by eliminating species less tolerant of flow fluctuations. Flow fluctuations can also affect water quality parameters like water temperature, dissolved oxygen concentrations, turbidity and sediment.

Hydroelectric operations also influence the frequency, magnitude, timing and the rate of natural ramping events, which occur during storms. At the river's gauging station above Copeland Creek, a storm caused up-ramping of 0.7ft/hr and down-ramping of 0.5 ft/hr. Flood frequencies and magnitudes appear to have changed slightly with the most dramatic change in floods with return intervals of at least five years. The magnitude of the five-year flood at the downstream gauging station, North Umpqua River at Winchester, increased from 60,000cfs to 73,000cfs in the period after regulation. This increase is likely caused by climatic changes (Pacificorp 1998).

WATER QUALITY

Water quality is considered to be one of the outstanding features of the North Umpqua River. This analysis looks at the river and its tributary's temperature regime, chemistry and sediment regime in the following discussions.

Stream Temperature

Stream temperature is a critical factor affecting the quality of aquatic habitat. Early studies of small steams in western Oregon found that solar radiation is the primary source of energy causing water temperature increases when streamside vegetation is removed. The processes of convection, conduction and evaporation are of minor importance to changes in stream temperatures (Brown 1969). The Clean Water Act of 1972 requires States to identify waters that exceed their water quality standards. In Oregon, the temperature standard for the protection of salmonid and resident fisheries during the summer rearing period is a seven day average of daily maximum temperatures not to exceed 64°F.

Table 9. Stream temperature parameters during the warmest 7-day periods of 1999 and 2000*.

Tributary Name	1999 Temperatures (°F)		2000 Temperatures (°F)	
	7-day Max. Avg.	Daily Change	7-day Max. Avg.	Daily Change
Dog Creek at Mouth	63.6	2.1	63.5	3.0
Panther Creek at Mouth	64.7	4.0	67.2	6.5
Bachelor Creek at Mouth	62.7	2.3	63.3	3.8
Limpy Creek above Bachelor Creek	63.1	2.9	-	-
Limpy Creek above Panther Creek	-	-	68.1	7.4
Fairy Creek at Mouth	63.4	3.3	63.7	4.2
Panther above Limpy Creek	63.9	4.4	-	-
Cougar Creek at Mouth	62.4	5.9	63.6	3.5
North Umpqua above Panther Creek	-	-	62.8	-
North Umpqua above Steamboat Creek	-	-	63.1	-
North Umpqua above Wright Creek	-	-	65.3	-
Wright Creek at Mouth	61.6	2.2	-	-
Thunder Creek at Mouth	61.6	2.2	62.2	3.7
Williams Creek at Mouth	61.5	2.0	62.6	2.9
Fairview Creek at Mouth	61.6	2.2	61.8	1.9

* Values are not directly comparable due to climatic variation between years.

The river within the analysis area exceeds this standard below its confluence with Steamboat Creek. The Panther Creek tributary system, to its headwaters, is listed by the Oregon Department of Environmental Quality for exceeding this temperature standard. There is also a state temperature standard from mid-September to mid-May for the seven day average of daily maximum temperature not to exceed 55°F in waters that support salmon spawning, egg incubation and fry emergence. This standard is exceeded in the North Umpqua River, below Copeland Creek.

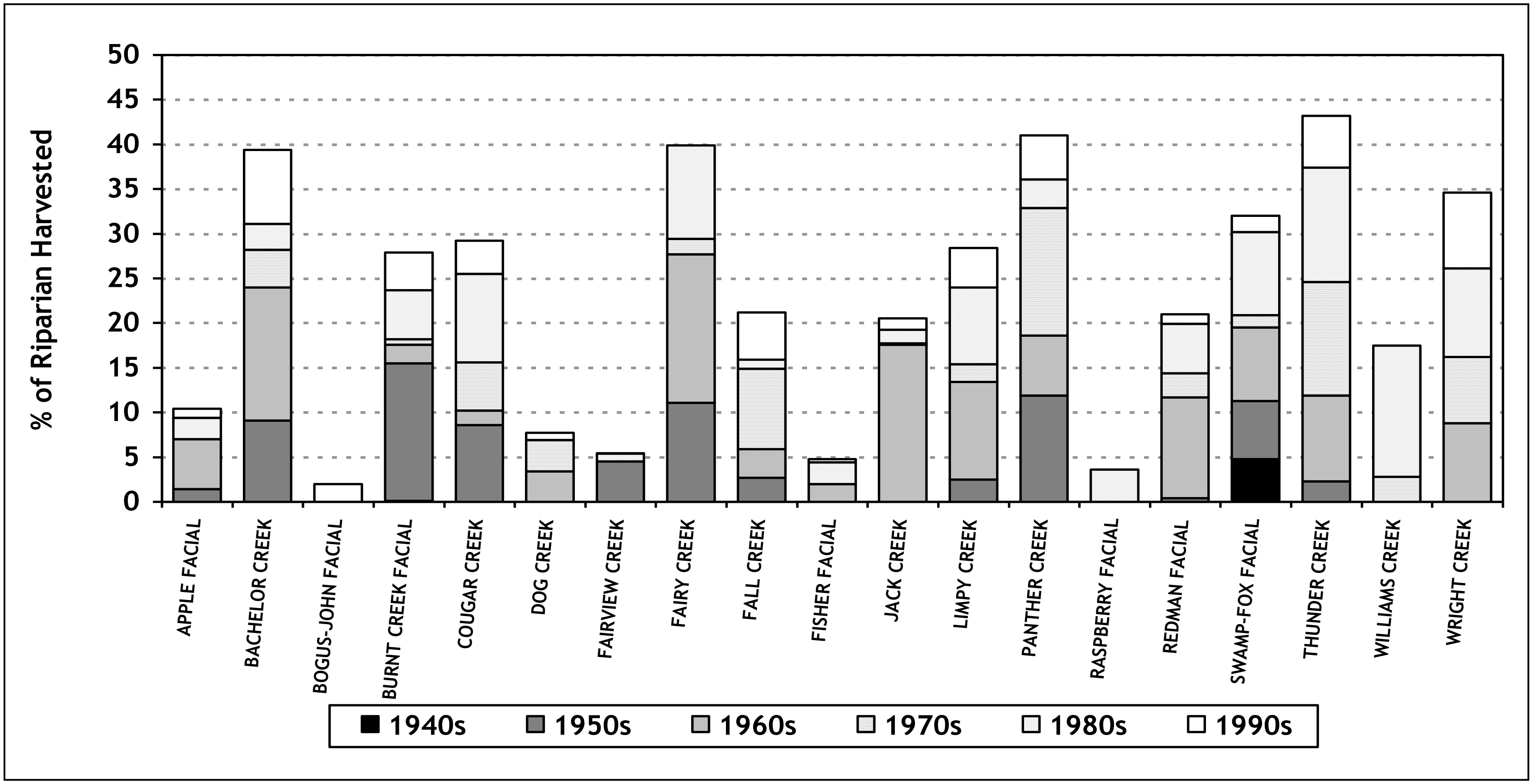


Figure 20. Cumulative riparian (now Riparian Reserve) timber harvesting (by decade) within the drainages of the analysis area.

The cumulative effects of timber harvesting, on a watershed scale, has been identified as one of the primary causes for high water temperatures in the river below its confluence with Steamboat Creek. The large daily temperature changes (fluctuations) seen in Table 9 are likely due to reduced vegetative shading and/or channel widening which allows more solar radiation to reach streams. Removal of streamside vegetation during timber harvesting was a common practice throughout the analysis area from the 1940s until the late 1990s. Some significant riparian tree removal has occurred in several of the drainages over the last few decades (Fig. 20).

The effect of the hydropower system, above the analysis area, on water temperature is difficult to determine. Warmer surface waters in reservoirs and impoundments may cause increases in the river water temperatures, but this increase may be offset by mixing with the colder water at the bottom of reservoirs. While cumulative temperature changes due to the upstream hydropower project cannot be determined, there is little daily fluctuation in the river's water temperature because releases from the Soda Springs Dam and Reservoir dominate its flow (USGS 1998).

The predominate north-south orientation of many of the tributaries within the analysis area, coupled with low base flows may also be contributing to the high water temperatures during the summer. Current management activities within the watershed are not believed to pose an impact to stream temperatures given stringent standards to provide for adequate streamside shading. The temperature regime is in a state of recovery from past timber management activities.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations are controlled by temperature, photosynthesis, respiration and aeration. Increasing water temperatures and respiration by aquatic organisms can reduce DO concentrations whereas; photosynthesis in algae can increase levels (usually highest in the afternoon with good exposure to the sun). Dissolved oxygen can also be added to water through the turbulence created by rapids and falls as it aerates the water.

With the exception of a sampling site in the river near Mott Bridge (outside on upriver of the analysis area), samples taken in July of 1995, show that DO concentrations did not increase during the afternoon, which could have indicated high primary production. They did show a decrease indicating a response to increasing water temperatures. None of the samples were below the 95% minimum saturation benchmark set by the Oregon Department of Environmental Quality (DEQ) for protection of water quality during salmonid rearing. High primary production[3] within the river may be occurring, but the effects may not be as strong as reaeration from the numerous rapids and falls along the river, deaeration, and water temperature in controlling DO levels (USGS 1998).

[3] Primary production refers to the production of algae or other aquatic organic material created by photosynthesis.

pH

Many chemical and biological processes in rivers and streams are both affected by and affect pH. The Oregon Department of Environmental Quality established a pH range of 6.5-8.5 as being optimum for aquatic organisms in the North Umpqua River basin. When the water's pH goes outside this range it can reduce aquatic biodiversity because it stresses the physiological systems of most organisms and can reduce reproduction. A low pH can also permit toxic elements and compounds to become available for uptake by aquatic plants and animals. Algal metabolism can alter pH levels in the early morning and late afternoon. The North Umpqua River has a low to moderate buffering capacity (USGS 1998). Reduction of the limited CO_2 (or bicarbonate HCO_3) in the water due to algal photosynthesis during the afternoon can increase pH significantly.

The 8.5 standard was not exceeded within the analysis area in 1995. Although none of the river sampling sites in the analysis area exceeded the State's pH standard of 8.5, there were increases in afternoon pH levels, therefore pH appears to be responding to primary productivity. Although the pH standard was not exceeded within the analysis area, a pH of 8.5 was recorded below the analysis area on the North Umpqua River below Little River (USGS 1998).

Major Ions

Sampling of major ions and trace elements within the analysis area was performed by USGS from 1993-1995. Concentrations of both cations and anions were found to be low. Total dissolved solids (TDS) ranged from 39-60 mg/L. Calcium and sodium were the primary cations, 20 and 40 percent, respectively. Magnesium comprised approximately 80% of the cations found. Approximately 80% of the anions present were bicarbonate with chloride and sulfate accounting for about 10%.

Trace Elements

Arsenic, barium, manganese, and aluminum were detected during low flow sampling. During high flow sampling additional trace elements - copper and nickel were detected. Zinc was found in two samples but this may have been due to contamination of the sample (Table 10).

Table 10. Trace elements found within the river flowing through the analysis area.

Trace Element in Water Column	Low Flow Concentrations (µg/L)	High Flow Concentrations (µg/L)
Aluminum	4-9	153-167
Arsenic	1	< 1
Barium	3	4-5
Copper	< 1	2
Manganese	2	2
Nickel	< 1	1

Table 11. Trace elements found within the riverbed's sediment.

Trace Element in Bed Sediment	Lowest Effect Level Guidelines * (mg/Kg)	High Flow Concentrations (mg/Kg)
Arsenic	6	8.6
Chromium	26	61
Copper	16	24
Manganese	460	835
Nickel	16	44

* Lowest Effect Levels adopted by New York State Dept. of Environmental Conservation (1994) and the Ontario Ministry of the Environment (Persaud et al. 1993).

Detection of arsenic is probably the most significant finding. Its concentration in the North Umpqua River is one-half the EPA's Risk Specific Health Advisory of 2 μg/L for drinking water. At this concentration, there is a cancer risk of 1:5,000 to 1:20,000 for people who, over their lifetime, consistently drink water and eat fish from the polluted source. The source of arsenic in the river is unknown, but may come from the volcanic geology of the North Umpqua River basin. Concentrations of several trace elements in the riverbed sediment exceeded available reference levels for potential adverse effects to benthic organisms (Table 11).

Pesticides

Water samples were tested for 87 pesticides during high-flow sampling during December 1993 at sampling sites located on the North Umpqua River above Wright Creek and Rock Creek. No pesticides were found in the water.

Nutrients

High concentrations of phosphorus were found in the riverbed sediment. This may be due to the volcanic geology of the basin. Organic and inorganic nitrogen within the water were only detected in minute amounts in only a few samples. Nitrogen was rarely detected in the mainstem and tributaries, in spite of sometimes-abundant algal growth. Inputs of nitrogen are more likely to be taken up by the algae immediately upon entry into the stream rather than to remain in the water column. Therefore, water column measurements may not accurately portray nitrogen concentrations. Phosphorus concentrations were higher than nitrogen levels and showed a slight but steady decrease from Soda Springs downstream to Glide, perhaps indicating that aquatic organisms take up the available phosphorus.

Erosion from management-related landslides, roads, harvest units and slash burning may be increasing nutrient loading above background levels. Fertilizer was routinely used to promote tree growth but use was curtailed (except for some hand applications outside riparian areas) after 1993 because of budget declines and water quality concerns. Indirect effects of forestry on algal growth may include increased solar availability from reduced riparian shade; changes in sediment delivery; changes in the flow regime or loss of instream large wood resulting in channel scour.

Sediment and Erosional Processes

Random and episodic disturbance patterns of wildfire, wind storms, rain-on-snow events, and strong seismic jolts are considered to be among the primary forces for erosional processes that drive sediment flux in the Western Cascade Range (Swanston 1991). Erosion and sediment flux appear to have a wide range of natural variability over time frames that encompass tens to hundreds of years. Intensive management practices conducted over the past 50 years are believed to have resulted in the delivery of chronic levels of sediment into the aquatic habitat outside of the natural range of variability.

There are essentially three mechanisms of sediment delivery to the aquatic ecosystem. These are:

1. **Mass Wasting** - Mass wasting is defined as landslides that, in a natural system, contribute to proper ecosystem functioning by delivering sediment and large woody debris to higher order stream channels. Large wood is an essential component in the landslide mass and provides roughness within stream channels to dissipate flow energy, store and route sediment and create channel complexity for diversified aquatic habitat (Naiman et al.1992 and Fetherston et al. 1995).

2. **Fluvial erosion** - Fluvial erosion occurs as streamside bank failures and channel incision caused by the flow of water. This type of erosion is considered to be a major contributing source of sediment flux and cause of alteration to stream channel morphology (Reid and Dunne 1996). The high flow and flashy nature of stream systems in the Western Cascades causes significant lateral or downcutting erosion and transport of sediment in stream channels devoid of channel roughness such as that created by large wood.

3. **Surface erosion** – Surface erosion is caused by rain splash and sheet wash. It occurs more vigorously in areas where vegetation is not well established or absent (Swanston 1991). Surface erosion typically generates fine-textured sediment flux that may be delivered directly to stream channels.

These mechanisms of erosion contribute varying degrees to the overall sediment budget of the North Umpqua River. Stillwater Sciences (2000) identified four sources of sediment flux for the sediment budget of the lower reach of the North Umpqua River basin (Table 8). Deviation from the reference condition is noted by measurable changes in both the volume of flux and particle size distribution of the bedload material (Stillwater Sciences 2000).

Table 8. Estimated rates of sediment flux in the lower basin reach of the North Umpqua River (Stillwater 2000)

SEDIMENT SUPPLY MECHANISM	REFERENCE CONDITION (PRE-1946) (TONNES/KM^2/YR)	CURRENT CONDITION (POST 1946) (TONNES/KM^2/YR)
Landslides (mass wasting) [a]	60 ± 30[b]	280 ± 140[c]
Soil creep (mass wasting)	25 ± 12	25 ± 12
Surface erosion	5 ± 3[d]	Unknown
Stream bank (fluvial) erosion	Unknown	Unknown
TOTALS	**(90 ± 45)**	**(305 ± 150)**

a. Landslide sediment inputs includes rapid-shallow slope failures (including debris flows) that originate in colluvial hollows, as well as from slumps, and active toe zones of earthflows.
b. This value is the average of sediment delivery rates based on landslides inventories in the Upper Steamboat and Little River watershed analyses areas from the 1946 photos.
c. This value is the average of sediment delivery rates based on landslides inventories in the Upper Steamboat and Little River watershed analyses areas from the post 1946 photos.
d. This value is from studies conducted by Swanson et al., (1982) in the H.J. Andrews Experimental Forest, Oregon in western Cascades lithology.

Construction of the Soda Springs Dam in 1952, combined with extensive road construction and clearcutting over the last 5 decades, has altered the sediment regime of the North Umpqua River. Road construction and timber harvest in tributary watersheds have increased average sediment yield rates to slightly more than 3 times that of the reference condition (Stillwater Sciences 2000). This increase is conjectured to offset the loss of sediment transport below the Soda Springs Dam due to impoundment in the reservoir. Stillwater Sciences (1998) estimated that bedload delivery along the river between the dam and Boulder Creek has been reduced by at least 95 percent and decreased from 70 to 15 percent from Boulder Creek to Steamboat Creek. The presumption that tributaries will continue to furnish elevated rates of bedload into the river over the long-term may not be plausible. As upland recovery occurs over the next several decades, a gradually diminishing sediment supply into the river can be anticipated. The long-term prognosis, assuming Soda Springs Dam remains, is that the river directly below the Soda Springs Dam will become more sediment limited. Fluvial erosion may be significant.

LANDSLIDE INVENTORY

According to the sediment budget analysis prepared by Stillwater Sciences, Inc. (2000), rapid-shallow landslides are considered to be the primary driver for sediment flux in both the reference condition and current condition. They account for 67% of the overall sediment budget in the reference condition and 93% in the current condition. A broad time-sequential inventory was prepared for the analysis area through review of aerial photographs encompassing the 1946, 1966, and 1997 flight years. The 1946 photographs were considered to have limited usefulness in detecting landslides. Due to their scale and poor resolution, only very large landslides (several acre-size) could be detected on them. Comparing landslides detected on the 1946 aerial photos with those detected in subsequent aerial photo flight years (higher resolution) may result in a significant bias.

There appears to be a trend of increasing management-related landslides over time (Fig. 21). For the 30-year period from 1967-1997, roughly 122 management-related landslides were detected for a rate of 4.1 landslides per year. The 20-year period encompassing 1947-1966 shows roughly 51 management-related landslides for a rate of 2.6 landslides per year. The majority of the management-related landslides for the period of 1947-1966 are believed to be the result of the 1955 and 1964 flood events. The 1964 flood event was considered to be the storm of record (100+ year recurrence interval) within the lower North Umpqua River basin. Poor road location, design, and construction practices (excessive fills, slash in fills and inadequate drainage structures) during the period prior to the 1980s resulted in a higher incidence of road-related failures. Many of the landslide occurrences detected on the 1997 aerial photographs likely reflect a series of closely spaced storm events that took place between November 18, 1996 and January 31, 1997. The initial November 18, 1996 storm was considered to be a 20-25-year flood event in the lower North Umpqua River basin.

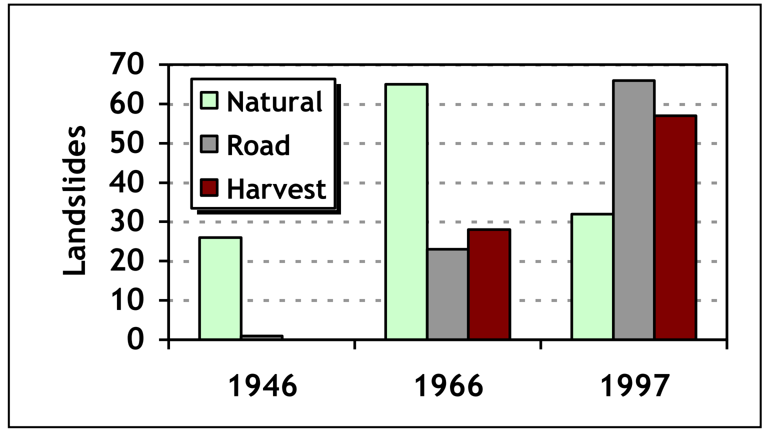


Figure 21. Landslides inventoried within the analysis area for the 1946-1997 time period.

LANDSLIDE FREQUENCY

Based on this landslide inventory (Fig. 22), harvest-related landslide frequencies are approximately two times higher than that of natural-occurring landslides by area. Similarly, road-related landslide frequency appears to be roughly nine times more frequent. With respect to the geomorphic landscape units discussed earlier in this chapter (Fig. 6, Page 16), landslides seem to be most frequent in the inner gorge terrain. The steep side slope terrain and the dormant landslide-earthflow complexes seem to experience landslides about three times more frequently than on the weakly dissected gentle to moderate side slope terrain. Landslides are non-existent in the alluvial valley floors, which are formed by fluvial (stream related) erosion and usually serve as the end point for many landslides and debris flows in the surrounding terrain.

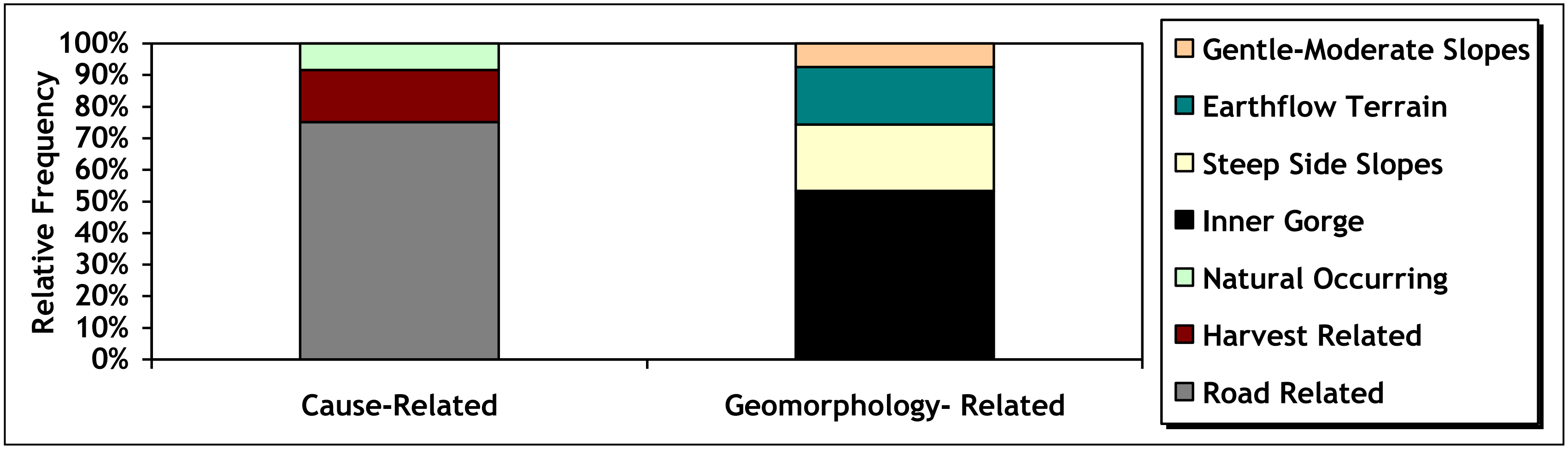


Figure 22. Landslide frequency by probable cause and geomorphic unit (as normalized to unit area) for the period 1947-1997.

LANDSLIDE RISK ASSESSMENT

A model (SHALSTAB) developed by Bill Dietrich (Geomorphologist at the University of California at Berkeley) was used to assess landslide risk within the analysis area. This model predicts the spatial distribution of rapid, shallow-seated landslide risks in a forested landscape (Fig. 23). In general, high-risk areas denote steep, convergent topography.

This model does not delineate topography that is at risk of deeper-seated, slow-moving landslides (e.g., slumps and earthflows). In addition, the model does not assess risk of road-related mass-wasting attributed to failure of cut and fill slopes. Road failures and runoff-induced failures may cause landslides in sites classified as having low risk. In terrain rated as high risk, road systems may be impacted by debris flows at stream crossing intersections. The model is limited by the resolution of the data used. Model inaccuracies (landslides occurring at places predicted to have low risk) typically occur when the digital elevation data does not accurately record the actual topography. Streamside inner gorges (areas of high mass-wasting and sediment delivery potential) may be relatively common, but may occur at a scale that is not adequately captured by USGS digital elevation data.

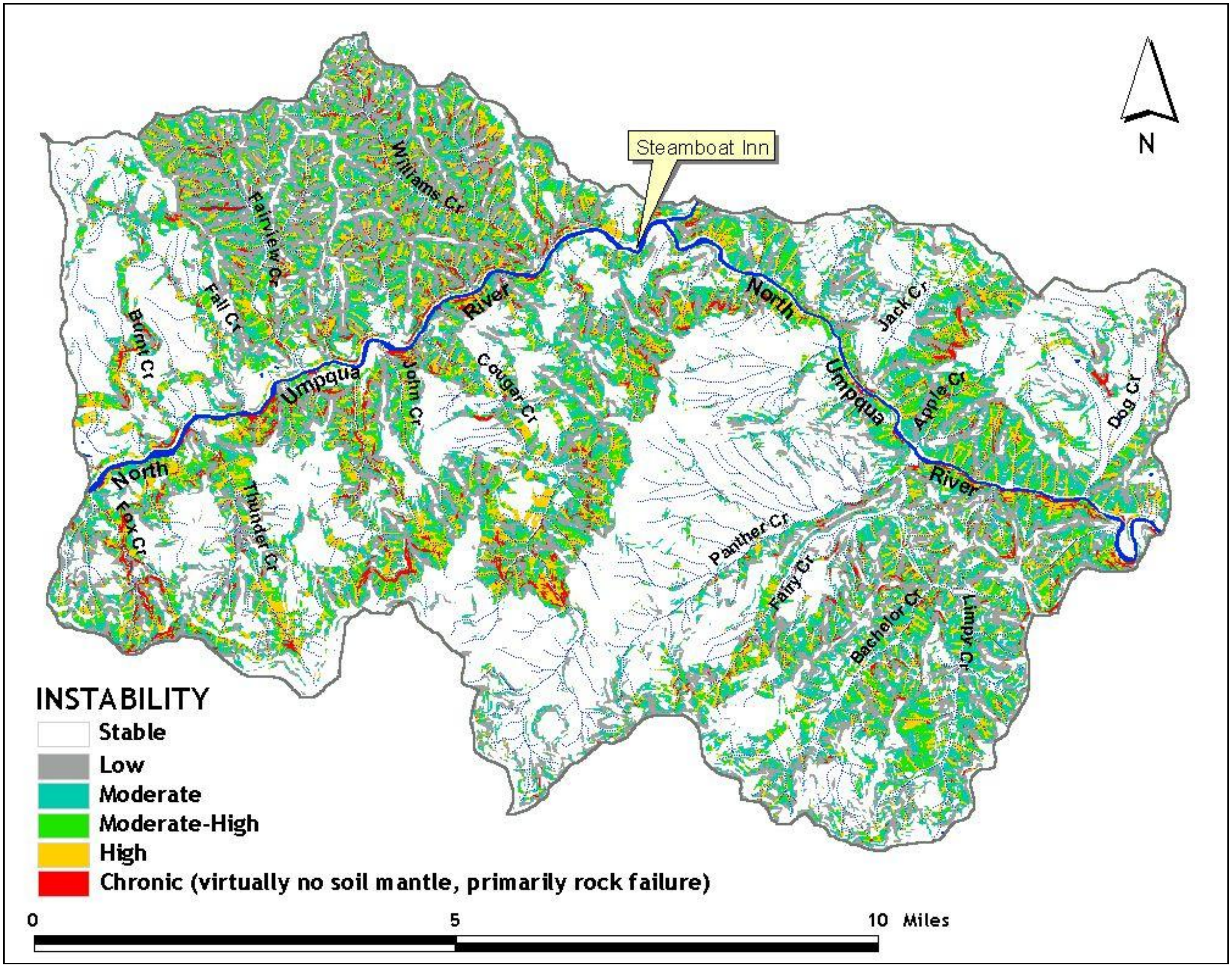


Figure 23. Rapid, shallow-seated landslide risk probability map (SHALSTAB).