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2.0 WATERSHED PROCESSES

2.1 PHYSIOGRAPHIC SETTING AND STREAM CHANNEL CLASSIFICATION (WTS 1)

2.1.1 Study Objectives

The objective of the study is to describe the general characteristics of the Lewis River watershed and to characterize study area streams.

2.1.2 Study Area

The study area includes the entire Lewis River watershed upstream of Eagle Island.

2.1.3 Methods

Existing information from previous reports and mapping completed by other parties (e.g., U.S. Forest Service, U.S. Geological Survey) was collected and summarized.

All streams were classified and coded into geographical information system (GIS) using the Rosgen system (Rosgen 1996) to Rosgen Level I (i.e., A, B, C) based on channel gradient and confinement displayed on USGS topographic maps. Streams of particular interest in the immediate study area were classified at Rosgen Level II (i.e., A2, B3) based on field surveys or previous survey data collected by other parties. Stream drainage areas for reaches of interest were calculated in GIS.

2.1.4 Key Questions

This report addresses the following key questions based on existing information:

- How has the eruption of Mount St. Helens affected fluvial geomorphic processes, channel morphology, and riparian areas?
- How has the eruption of Mount St. Helens affected sediment supply to the watershed and how might this change over time?

2.1.5 Results and Discussion

2.1.5.1 Physiographic Setting

Climate

The Lewis River basin, which extends from the western flanks of Mount Adams to the confluence with the Columbia River, has the predominantly temperate marine climate typical of the Pacific Northwest. It has a narrow range in temperature—a dry summer and a mild but rather rainy winter. Terrain and distance and direction from the Pacific Ocean influence the climate. The coastal mountains provide some protection from the brunt of more intense winter storms that move inland from the ocean, and the Cascade Range shields the region from the higher summer and lower winter temperatures of eastern Washington. Cold air in winter and the occasionally hot air in summer flowing west through the Columbia River Gorge influence the climate.

Late in spring and summer, large high-pressure centers over the north Pacific Ocean bring a prevailing flow of cool and comparatively dry air from a northwesterly direction. As the air moves inland, it becomes warmer and drier. As a result, a dry season begins late in spring and reaches a peak in mid-summer. During July and August, it is not unusual for 2 or 3 weeks to pass without measurable rainfall.

In fall and winter, low-pressure centers in the Gulf of Alaska intensify and high-pressure centers become smaller and move south. Circulation of air around these pressure centers in the north Pacific brings a prevailing flow of warm, moist air into this part of the state from a southwesterly direction. As a result, winter temperatures are mild, and the rainy season begins in fall, reaches a peak in mid-winter, and decreases in spring.

The average annual precipitation differs greatly from place to place. This difference is directly related to the effects of the 2 bordering mountain ranges. The average annual precipitation on much of the Coast Range and the Cascade Mountains exceeds 100 inches. Precipitation at lower elevations and toward the center of the basin between the 2 mountain ranges is much less. The annual precipitation at Vancouver, WA is about 37 inches; the precipitation reaches over 140 inches on nearby Mount Adams. During the growing season, however, the range in precipitation is small. For example, precipitation for July and August combined averages 1.4 inches at Vancouver, the driest station, in comparison with 2.77 inches at Cougar, the wettest station. The average annual snowfall at Vancouver is 8.4 inches, while it is estimated to exceed 200 inches at elevations of 3,000 feet and higher.

In the warmest summer months, afternoon temperatures range from the middle seventies to the lower eighties, with nighttime temperatures in the fifties. Maximum temperatures exceed 90ºF on 5 to 15 days each summer and reach 100º or slightly higher in 1 summer out of 3. Temperatures in the foothills and higher elevations are slightly lower than those recorded in the valleys. The hottest weather generally occurs when hot, dry, easterly winds reach the area. In this kind of weather, humidity is low and the risk of forest fires is high. Following 1 or 2 days of unusually warm weather, cooler air from the ocean moves inland and afternoon temperatures return to the seventies and eighties.

Topography

The Lewis River basin is located on the western slopes of the Cascade Mountains. Two volcanic peaks, Mount Adams (12,276 feet mean sea level [msl]) and the recently active Mount St. Helens (8,364 feet msl), are present in the watershed. Feeder streams from these peaks and the surrounding foothills drain into the Lewis River and its 3 reservoirs, the first of which is Swift Reservoir at 1,000 feet msl. From there the river flows to Yale Lake at 490 feet msl, and then to Lake Merwin at approximately 240 feet msl. The foothills surrounding these reservoirs are generally steep and mostly forested and range up to approximately 3,000 feet msl. The steep slopes in the area of these reservoirs result from the incision of numerous streams and rivers into the geologically young landscape. Downstream of Lake Merwin, the Lewis River enters a terrain of rolling hills that eventually transition to the essentially flat "Woodland Bottoms" near its confluence with the Columbia River.

Geology

The geology of the Lewis River watershed has a complex history, having undergone Tertiary volcanism, seismicity, glaciation, and deposition (Philips 1987a, Philips 1987b, Walsh et al. 1987). Folding, faulting, wind, and water have also influenced the shape of the land. Bedrock surrounding the reservoirs is predominantly comprised of Eocene-Oligocene basaltic-andesite lava flows, Oligocene volcaniclastic rocks, and Quaternary volcaniclastic deposits. Volcanic rocks have undergone regional compressional deformation; rock strata are folded by a major southeast plunging anticline and a southeast plunging syncline. The lower two-thirds of these Eocene-Oligocene lava flows, which are 19,000 feet thick, are comprised of mostly basaltic-andesitic pyroclastic debris in tuff breccia. The upper 6,000 feet of the formation include flow breccia with thin interbeds of siltstone, sandstone, conglomerate, and tuff. Volcanism in this area not only originated from the past eruptions of Mount Adams and Mount St. Helens but from various other volcanic centers, such as Indian Heaven and other nearby vents.

Glaciation has also shaped the landscape and helped to carve the Lewis River Valley. Alpine glacial deposits from glaciers originating on Mount Adams and Mount St. Helens overlay the older bedrock but underlay younger tephra deposits. The last 10-12,000 years have had a major effect on the landform of the Lewis River watershed. Seven to 8 tephra deposits (including the 1980 eruption) from Mount St. Helens have occurred over the past 10,000 years. Deposition patterns of tephra eruptions are wind dependent. Historical records show the prevailing winds 50 to 80 percent of the time are to the northeast, east, and southeast; therefore, deposits occur mostly in the Pine Creek/Muddy River watersheds. Glacial activity in this area created steep uplands and flatter lowlands, and deposition of tephra on these steep slopes has created areas where mass wasting is now very active.

Flows of volcanic rock and mud from Mount St. Helens have created the cave basalts in the northwestern part of the watershed and also numerous lahars, such as seen in the gorge forming Pine Creek in the northeastern part of the watershed. The southern half of the watershed (which lies south of Swift Reservoir) has been formed by older volcanic activity, along with the action of wind and water.

Soils

Soils in the Lewis River watershed have been mapped by the Soil Conservation Service (now called the Natural Resource Conservation Service [NRCS]) and are reported in soil surveys of Clark, Cowlitz, and Skamania counties (USDA 1972, 1974, and 1989, respectively).

Soils downstream of Merwin Dam on the Lewis River are primarily of basic igneous material or are formed on high terraces in old stream and lake sediments. Slopes in this region of the river are generally level and rolling. Some areas are hilly and very steep on terraces above the floodplains. Elevations in this part of the watershed range from 15 to

800 feet msl. Annual precipitation ranges from 40 to 60 inches. In general, the soils are deep, moderately well-drained, with some areas of poorly drained soils.

The soils north of the river in Cowlitz County fall under the Kelso-Minniece-Kalama association, were Kelso soils comprise 25 percent of the association, Minniece 15 percent, and Kalama 15 percent. Both Kelso and Kalama soils are moderately well-drained loam, and Minniece soils are somewhat poorly drained silt loam with silt clay subsoil.

To the south, in Clark County, the soil falls under the Hesson-Olequa association, with 50 percent Hesson soils and 10 percent Olequa. Hesson soils occur on terraces between 300 to 800 feet msl and are deep, well-drained clay loam. Olequa soils occur on terraces from about 150 feet msl and are generally deep, well-drained silt loam with silty clay loam subsoil. In places, poorly drained soils occur above the level of the river.

Soils generally upstream of Merwin Dam and around the 3 reservoirs are predominantly derived from volcanic ash to the north and basalt and andesite mixed with volcanic ash to the south. Slopes in this region range from nearly level to very steep, with grades from 0 to 90 percent. Precipitation ranges from 60 to 120 inches annually. In general, the soils are very deep and well-drained.

To the north of Lake Merwin and west of Yale Lake in Cowlitz County, the soils fall into the Cinebar association, of which 90 percent are Cinebar soils. Cinebar soils are deep, well drained silt loam that formed in wind-laid silts and volcanic rock and ash. In Skamania County and north of Swift Reservoir, the soils are classified as Cinnamon-Stabler-Chemawa with Cinnamon constituting 30 percent of the association, 15 percent Stabler, and 15 percent Chemawa. Cinnamon-Stabler-Chemawa soils are in general very deep, well-drained loam and sandy loam formed in pyroclastic flow of volcanic ash and pumice.

South of Lake Merwin and east of Yale Lake in Clark County, the soils fall under the Cinebar-Yacolt association. Cinebar accounts for 60 percent of the association and Yacolt 30 percent. Cinebar soils are deep, well-drained silt loam derived from volcanic ash, and Yacolt soils are deep, well-drained loam with gravelly loam subsoil formed in glacial alluvium that consists largely of pumice, basalt, and volcanic ash. The soil association south of Swift Reservoir, in Skamania County, is classified as Zygore-Aschoff-Swift. Zygore soils are 25 percent, Aschoff soils are 20 percent, and Swift soils are 20 percent of the association. Zygore and Aschoff soils are both very deep, well-drained gravelly loam formed in colluvium derived dominantly from basalt and andesite mixed with volcanic ash. Swift soils are also very deep and well-drained but are cindery sandy loam formed in colluvium. It is derived from basalt and andesite mixed with volcanic ash and basic igneous rock with a mantle of volcanic ash and cinder. Soils along the south shore of Swift Reservoir, around the mouth of Range Creek, are composed of Cinnamon-Stabler-Chemawa.

2.1.5.2 Large-scale Geomorphic Processes

The Lewis River watershed is geologically active, and several large-scale geomorphic processes active during the Holocene (past 10,000 years) have shaped, and continue to shape, the watershed (USFS 1995, 1996, 1997, 1998). The most obvious of these processes is the active volcanism from Mount St. Helens, Mount Adams, and the Indian Heaven volcanic field, located mid-way between the 2 mountains. There are 3 main types of volcanic activity that have had a major effect on the watershed: lava flows, debris avalanche/lahars, and tephra (ash) falls (Figures 2.1-1 and 2.1-2; Scott et al. 1995). Lava flows are probably the least common of the 3 and have most often affected smaller, localized areas near the volcanic vents. Some past lava flows in the Indian Hills and on the southern flanks of Mount St. Helens have resulted in underground lava tubes or other features that disrupt normal streamflow patterns and result in “lost” streams that disappear as they flow underground.

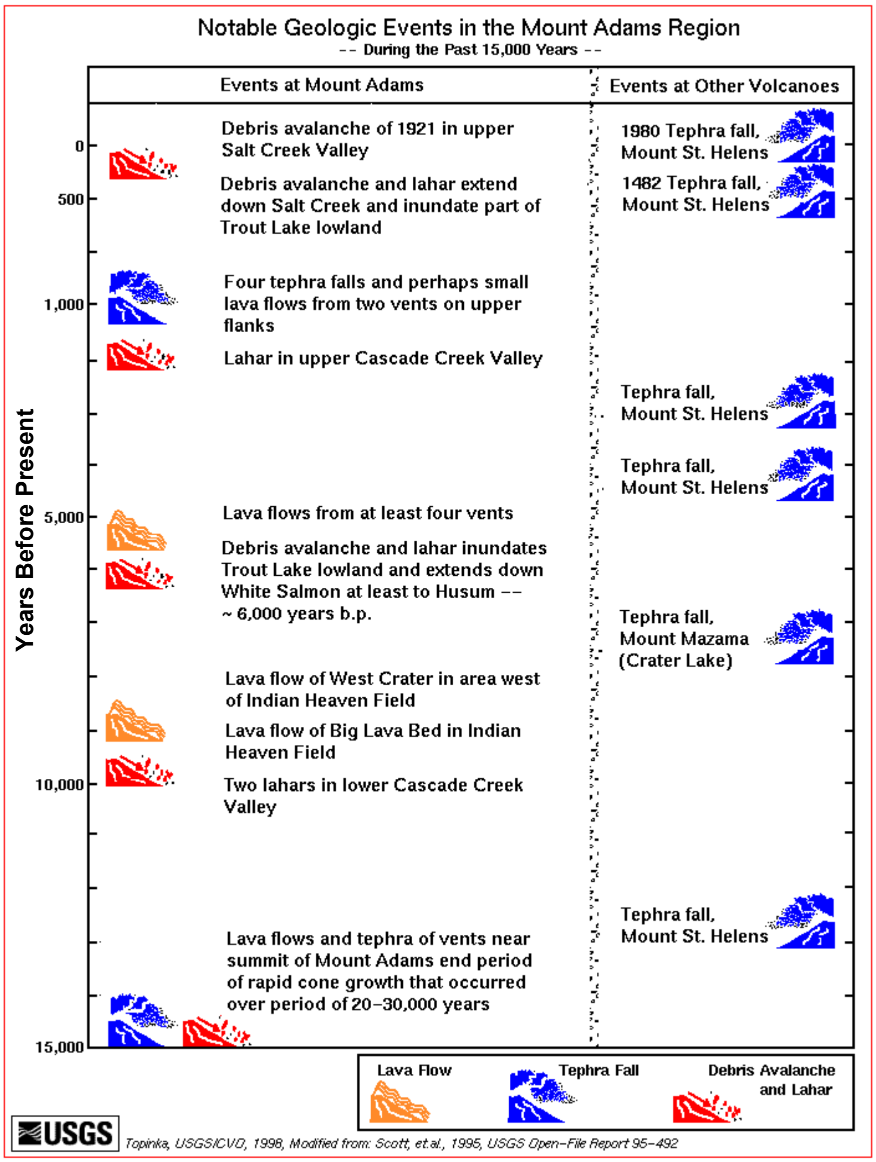

Figure 2.1-1. Notable volcanic events in the Mount Adams region during the past 15,000 years (from Scott et al. 1995).

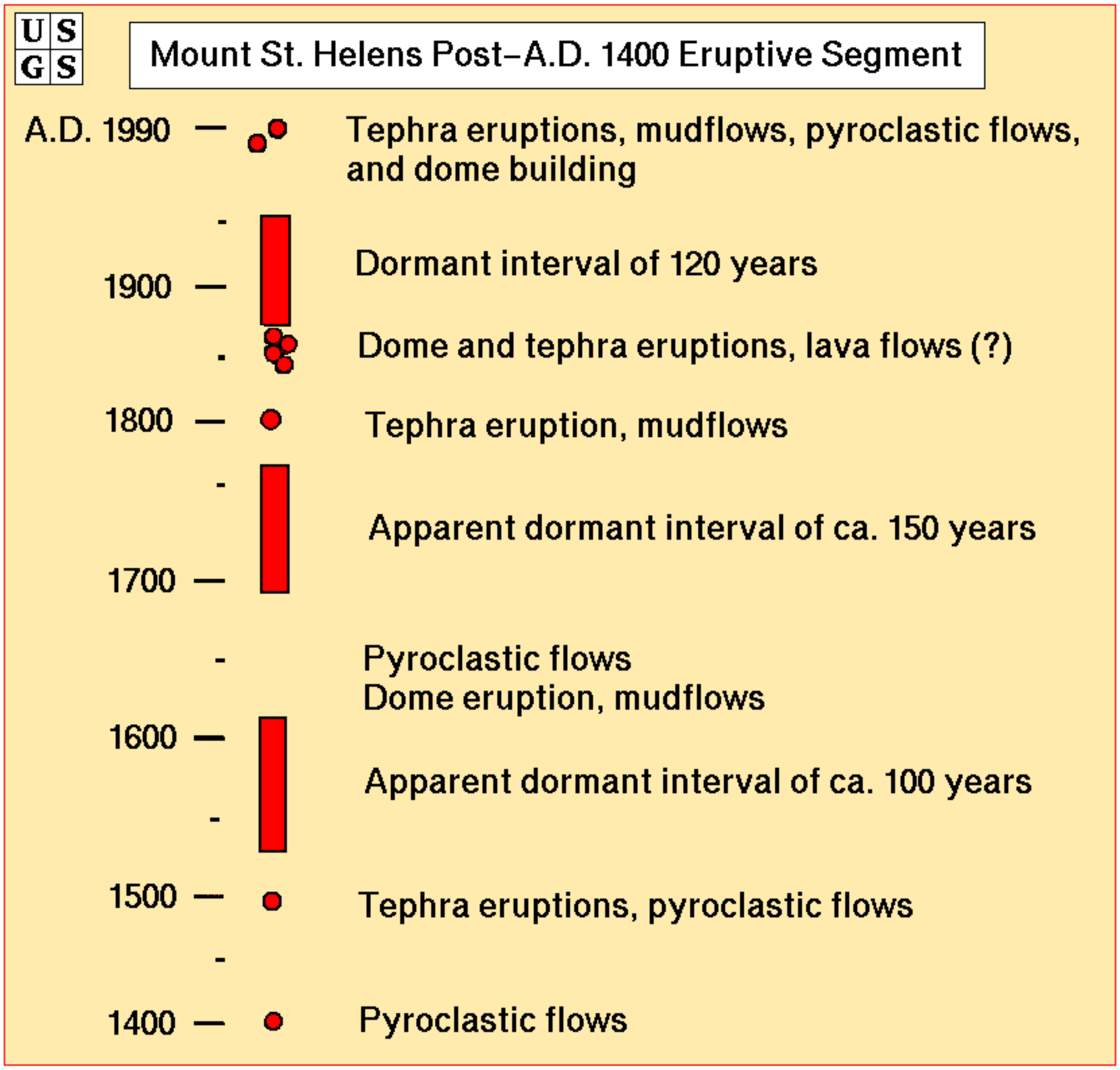

Figure 2.1-2. Volcanic events at Mount St. Helens since 1400 A.D. (from Tilling et al. 1990).

Debris avalanches, mudflows, and lahars are more common than lava flows on Mount St. Helens and Mt. Adams. They are rapidly moving slurries of water, rock, soil, and debris and can be triggered by: (1) eruptions or steam explosions that rapidly melt accumulated glacial ice; (2) earthquakes that shake loose weak, hydrothermally altered rock; or (3) large-scale eruptions of hot pyroclastic material mixing with water and melted ice (this occurred during the 1980s eruptions of Mount St. Helens). Mudflows swept down Swift Creek, Pine Creek, and Muddy River during the May 18, 1980 eruption of Mount St. Helens, emptying nearly 18 million cubic yards of water, mud, and debris into Swift Reservoir (Figure 2.1-3; Tilling et al. 1990). These types of features have the ability to alter the streambed and valley characteristics of affected drainages in a matter of hours, and have long-term effects of very high sediment load and resulting channel characteristics. It is estimated that Clearwater Creek transported 1.5 million tons of sediment between

1983-1989; Muddy River carried 12.8 million tons between 1982 and 1990 (Dinehart 1997). Pine Creek also had a high sediment load during this period, but the measurement station was destroyed and not replaced so quantities are unknown. These channels are continuing to process the sediment and woody debris supplied to them by the mudflows, and have substantially changed from narrow channels into wide, braided, unstable channels with high sediment and wood loads. Riparian vegetation along these channels was wiped out, and is slowly recovering as sediment loads decrease with time. The majority of sediment, wood, and debris supplied by Mount St. Helens mudflows was trapped in Swift Reservoir. As a result, mainstem reaches downstream of Swift Reservoir were not subjected to the high wood and sediment loads and associated channel changes.

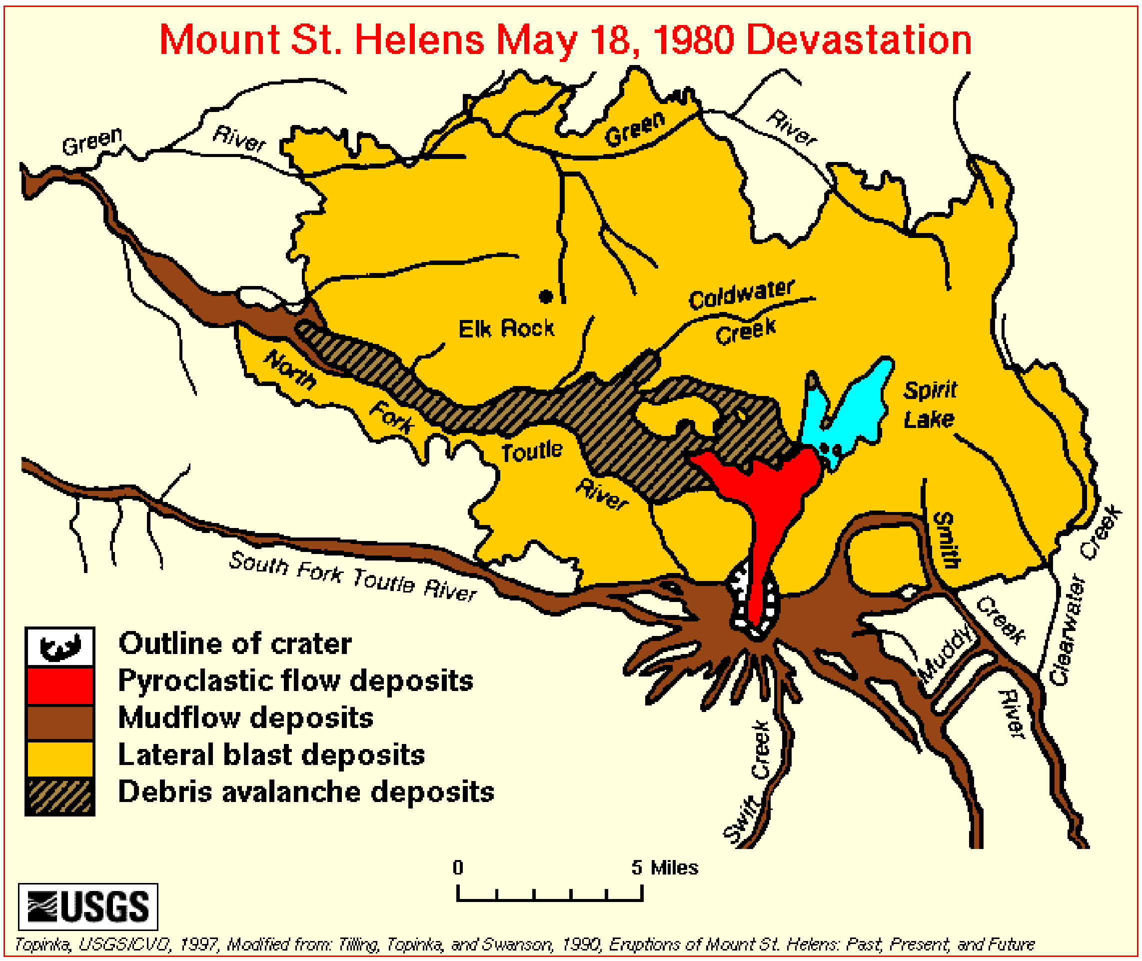

Figure 2.1-3. Volcanic deposits associated with the May 18, 1980 eruption of Mount St. Helens (from Tilling et al. 1990).

Tephra, ash, and/or pumice falls are the most common and widespread volcanic activity originating from Mount St. Helens and Mount Adams. Thick deposits of tephra can reduce infiltration rates and increase erosion rates for up to several years following deposition, as was noted in the upper part of the Clearwater Creek basin (upper Lewis River watershed) following the 1980 eruption of Mount St. Helens (Dinehart 1997). The probability of a thick (10 cm) tephra accumulation in the watershed in any one year is shown in Figure 2.1-4.

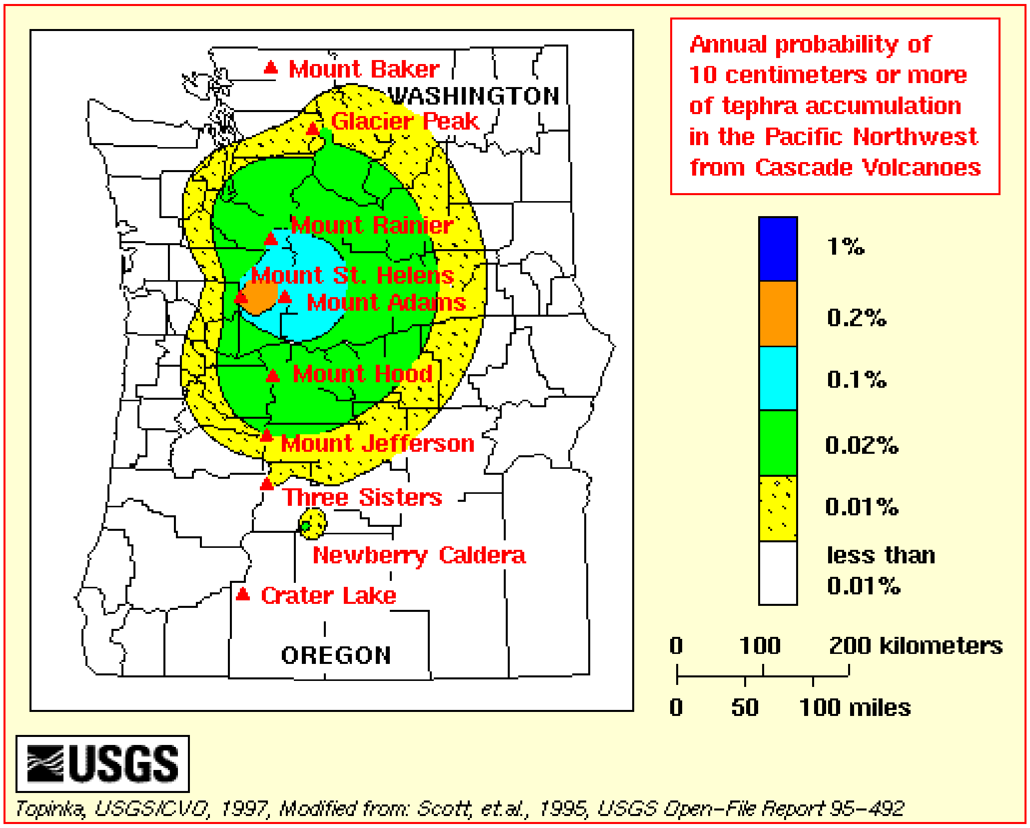

Figure 2.1-4. Annual probability of 10 cm or more of tephra accumulation (from Scott et al. 1995).

Alpine glacial activity is another active geomorphic process affecting the Lewis River watershed. The current extent of active glaciers is limited to the tops of Mount Adams and Mount St. Helens. The Pinnacle Glacier on Mount Adams flows into the headwaters of the Lewis River, and the Nelson, Ape, Shoestring, and Dryer glaciers on the flanks of Mount St. Helens are at the headwaters of Smith, Pine, and Swift creeks. Active glaciers produce large quantities of water and sediment during the glacial melt season in late summer. Streams with a large percent of flow from glacial melt carry heavy loads of both fine-grained sediment and bedload, resulting in high summer turbidities and braided, shifting channels. These characteristics become less dominant downstream as clear, non-glacial inflows dilute the sediment load. Past alpine glacial activity has shaped the upper valleys of these same creeks into U-shaped troughs with steep sidewalls.

Landslides are a third active large-scale geomorphic process in the Lewis River watershed. Small, shallow-rapid or rotational landslides occur most often in areas with steep slopes and unstable soils. Thick deposits of ash and unconsolidated mudflows are often unstable and prone to slides. In addition to smaller features, there are many large, deep-seated and ancient landslides mapped within the watershed (Walsh et al. 1987). These features either move very slowly or are dormant and no longer active.

2.1.5.3 Stream Channel Classification and Drainage Areas

All streams within the study area were classified using the Rosgen stream classification system (Rosgen 1996). This system groups streams by channel slope, width/depth ratio, sinuosity, entrenchment ratio, and dominant substrate. Most of the small, headwater streams in the area fall into the A or A/B stream type–steep, entrenched, cascading, step/pool channels (Table 2.1-1; Figure 2.1-5). Streams upstream from Merwin Dam are dominantly A or B channel types. Channels affected by the large sediment loads from Mount St. Helens are D type (braided) channels. The larger mainstem channels are dominantly B or C channel types.

Table 2.1-1. Miles of streams classified by Rosgen stream type in the Lewis River basin.

	Rosgen Stream Type						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Slope range	**4-10%**	**2-4%**	**<2%**	**<4%**	**<2%**	**<2%**	**2-4%**
Description	**Steep, entrenched step/pool**	**Moderately entrenched riffle/pool**	**Low gradient meandering**	**Braided channel**	**Low gradient stable meanders**	**Entrenched meanders**	**Entrenched gullies**
Upstream of Swift Dam	193	32	8	5	6	1.5	1
Yale Dam to Swift Dam	46	5	0	0	0	4	0
Merwin Dam to Swift Dam	45	8	1.4	0	0.9	5	0
Eagle Island to Merwin Dam	28	6	12	0	0	4	0

The Swift bypass reach, lower Speelyai Creek, and the Lewis River between Merwin Dam and Eagle Island were further characterized based on substrate observations made during field work. Lower Speelyai Creek is characterized as a C3 channel (cobble-bedded, low gradient riffle/pool channel). The Lewis River in the Swift bypass reach is characterized as an F3 channel (cobble-bedded, entrenched riffle/pool channel with high width:depth ratio). The Lewis River between Merwin Dam and the Lewis River Hatchery is characterized as an F3 (cobble-bedded entrenched riffle-pool channel); and between the hatchery and Eagle Island it is characterized as a C3c- to C4c- (cobble to gravel bedded low gradient meandering alluvial channel).

Watershed areas for selected sub-basins in the Lewis River basin were computed from the GIS database (Table 2.1-2).

Table 2.1-2. Sub-basin areas for selected stream reaches.

Sub-basin	Sub-basin Area (acres)
Swift bypass reach (total reach)	**6,128**
Lewis River from Swift Dam – Rain Creek	649
Rain Creek	1,529
Ole Creek	3,221
Lewis River from Rain Creek – Yale Lake	729
Speelyai Creek (total)	**11,132**
Upper Speelyai (upstream of upper diversion)	8,540
Lower Speelyai (upper diversion to Merwin Lake)	2,592
Lewis River from Merwin Dam to Eagle Island	**55,562**
Lewis River from Merwin Dam to Eagle Island (without Cedar Creek)	20,365
Cedar Creek	35,197

2.1.6 Schedule

This study is complete.

2.1.7 References

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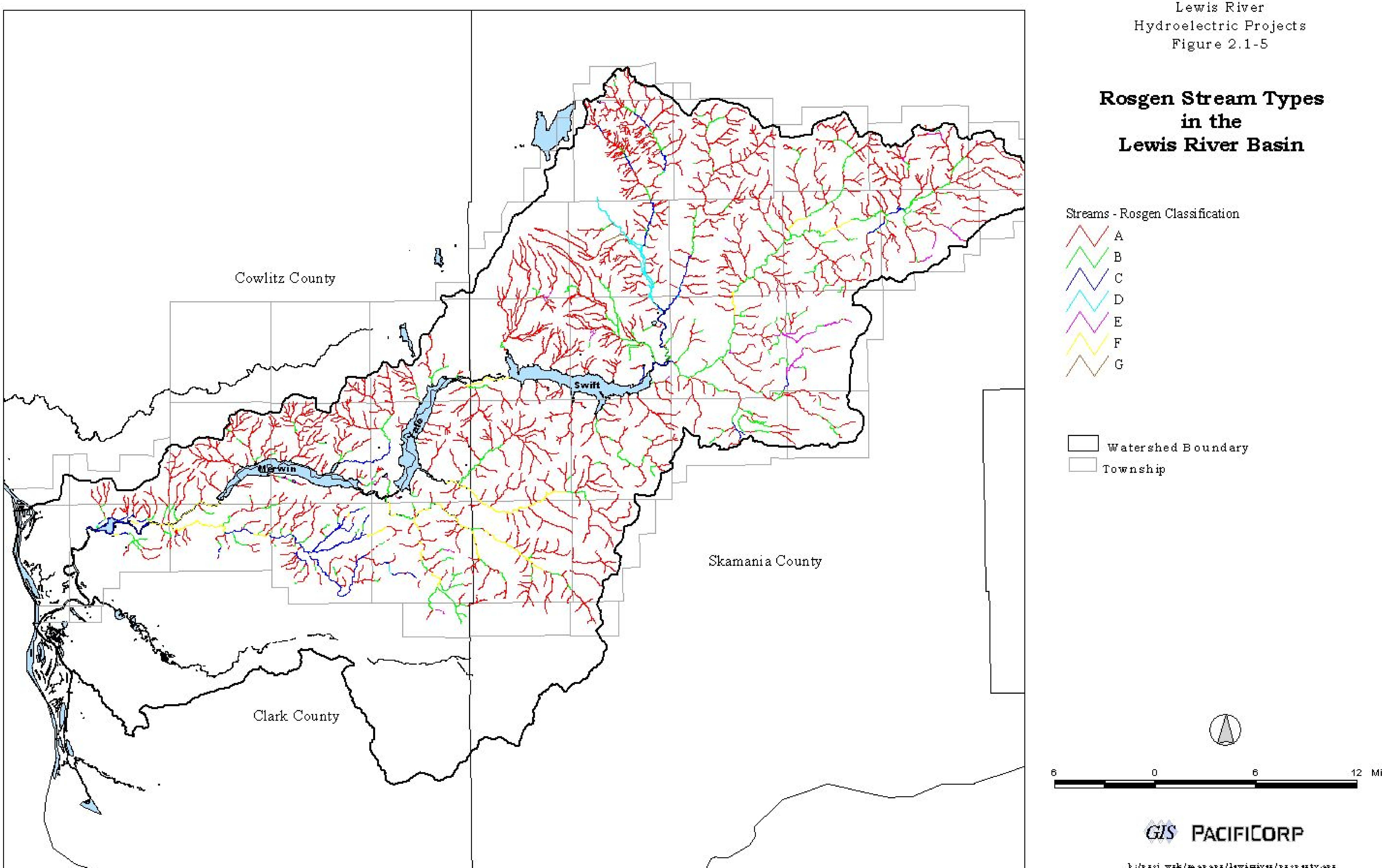
Lewis River
Hydroelectric Projects
Figure 2.1-5

Rosgen Stream Types in the Lewis River Basin



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This report was prepared by:

2.1.8 Comments and Responses on Draft Report

This section presents stakeholder comments provided on the draft report, followed by the Licensees' responses. The final column presents any follow-up comment offered by the stakeholder and in some cases, in italics, a response from the Licensees.

Commenter	Volume	Page/ Para	Statement	Comment	Response	Response to Responses
WDFW - KAREN KLOEMPKEN	1	WTS 01-7 Fig. 2.1-3	Volcanic deposits.	For black and white printing more patterns or more gradation in colors should be used so distinguishing between deposits is possible.	The figure was taken from an outside source, so it is not possible to alter colors.	