7.0 Human Influence on Geomorphic Processes

The Snoqualmie watershed has been subject to pervasive, albeit comparatively low-intensity, human modification. Despite this low-intensity land use, it is clear that human activities, taken as a whole, constitute the most substantial geomorphic perturbation in the Snoqualmie watershed since glaciation. The following is a description of some of the most geomorphically significant human activities in this watershed:

7.1. Logging

Logging has cumulatively affected more area in the Snoqualmie River watershed than any other land use activity (Photo 22). Logging began in the Snoqualmie watershed in the late 1800s and it has continued without interruption since that time. Many areas of the watershed have been logged twice and are now growing a third rotation of timber.

Logging can have a myriad of impacts on the fluvial network. Logging typically increases sediment delivery through a variety of mechanisms. Logging roads have been identified as the largest source of sediment associated with logging (Waters, 1995). Reid and Dunne (1984) demonstrated that fine sediment, forced through the gravel surfacing by truck traffic and washed into roadside drainage, can be the largest source of fine sediment in a watershed undergoing timber harvest. Interception of shallow groundwater by roadside ditches, creation of impervious road surfaces, and concentration of surface flow in roadway cross culverts can all contribute to increased peak flows. In the small steep channels, common to those portions of the watershed in forest production, this increased flow can cause channel erosion or initiate debris flows.

Independent of road influences, logged slopes are often more prone to landsliding than forested slopes (Sidle et al., 1985). When trees are cut, their roots decay over a period of years. Loss of tree-root reinforcement in the soil increases landsliding on steep slopes. Dramatic bank erosion and channel widening have been documented on the Tolt River as a result of historic logging of the riparian zone to the river's edge (Kennard, 2004).

In addition to increasing sediment discharge, logging in the Snoqualmie watershed (outside of the wilderness area) has largely eliminated old-growth trees from the standing stock available for LWD recruitment.

Although logging has a history and a continuing potential to cause significant adverse impacts to fluvial systems in the Snoqualmie watershed, many such impacts can be effectively mitigated by application of the controls mandated by the Washington State Forest Practices Act. Even in areas where logging has been conducted without such controls, this logged-off land probably has more potential to return to natural character and function, compared with areas used for agriculture, residential or commercial development, or any of the more intense and permanent land uses present in this watershed.

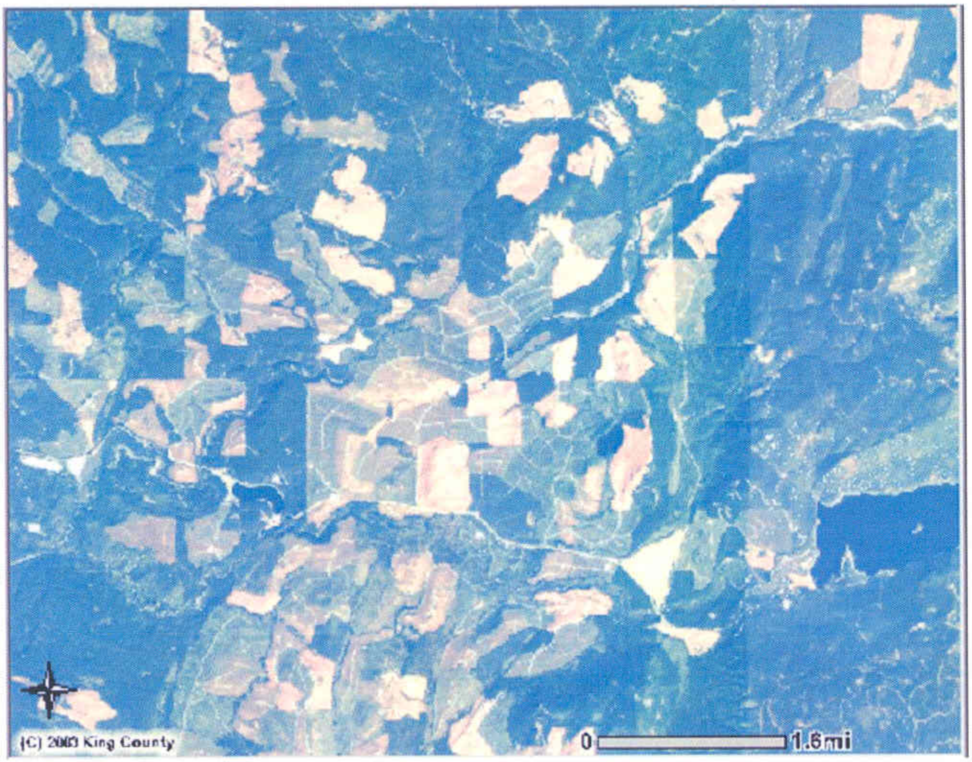

Photo 22: Logging clearcuts near the confluence of the North and South Forks, Tolt River.

7.2. Levee and Revetment Construction

There has been extensive construction of levees and revetments along the Snoqualmie River and its major tributaries (Figure 19). Constructed levees are continuous raised berms constructed along the riverbank and intended to contain floodwaters and prevent inundation of the natural floodplain. Revetments are sections of bank armoring (usually riprap) intended to prevent lateral migration of the river channel. These structures were largely built during a period of time when engineering control of river flooding, channel migration, and river alignment were widely seen as economic and life-safety enhancements, and little attention was paid to possible environmental impacts. Subsequent experience has shown that the protection provided by such projects is sometimes unreliable, the cost of maintenance can be high compared to the economic benefit, and such projects can have serious adverse environmental consequences (King County, 1993). Such projects have sometimes created an unrealistic sense of protection for adjacent properties, encouraging relatively high value land development in areas still at significant risk from riverine processes.

Many of the problems associated with levees and revetments occur because of the ways these structures alter natural geomorphic processes. Constructed levees confine floodwaters, raise flood elevations within the levees, and eliminate floodwater storage on the floodplain outside of the levees. These effects can worsen flooding and erosion in areas upstream and downstream or opposite the leveed section. Levees and revetments constrain a river to a fixed alignment, often imposing a simple channel geometry. An actively meandering river on the other hand typically develops a complex channel form with multiple sloughs and side channels. These complex forms provide a broad, complex riparian zone with multiple ecological niches for plant and animal species.

7.3. Dams

Dams with large reservoirs trap all of the suspended load, bedload, and LWD transported. The channel downstream may be sediment-starved and deficient in LWD. Lack of sediment supply can cause the channel downstream of the dam to incise the streambed texture to coarser. The only dam with a large reservoir in the Snoqualmie watershed is the South Fork Tolt River water supply dam. The elevated water surface in the reservoir behind a dam causes a corresponding elevation of the groundwater table in the area surrounding the reservoir. Given suitable topography, the resulting increase in pore water pressure can initiate landsliding. This mechanism activated a large landslide approximately 0.6 mile (1.0 km) downstream of the South Fork Tolt River dam during initial reservoir filling. This mechanism was also responsible for the 1918 “Boxley burst,” an approximately 1,000,000-cubic-yard (750,000-cubic-meter) landslide in Boxley Creek (a Snoqualmie River tributary) during filling of a water supply reservoir immediately south on the Cedar River.

7.4. Floodplain Clearing and Drainage

Floodplains along the lower Snoqualmie River offer flat topography and fertile soils. These areas were cleared for agriculture early in the non-native settlement of this area. Removal of the naturally occurring riparian forests reduces the source for LWD recruitment.

Prior to European settlement, much of the floor of the lower Snoqualmie Valley was wetland (Collins and Sheikh, 2002). Early settlers recognized the agricultural potential of the valley floor, and began clearing and constructing ditches in order to make the floodplain cultivatable. The best record of early agricultural land conversion comes from aerial photographs taken in 1936. This record shows that virtually all of the area in the lower Snoqualmie Valley, ultimately destined for agricultural production, had already been cleared and drained by that time.

Conversion and continued use of the lower Snoqualmie floodplain for agriculture has several significant ramifications for the geomorphic processes in this area. One obvious consequence of agricultural land use is the removal of most of the riparian forest that would otherwise be available to supply LWD to the mainstem.

Another consequence of agricultural use of the Snoqualmie River floodplain has been the extensive ditching required to drain the former wetlands to allow cultivation. This has dramatically altered the character of numerous, mostly small tributaries that cross these agricultural areas. These tributaries have typically been relocated through a rectilinear system of deep narrow ditches with little or no native riparian buffers (Figure 25). Many of these tributaries originate in or flow through steep ravines on the valley walls before reaching the floodplain. Under pre-developed conditions, these channels often formed alluvial fans at the break in slope between the ravine and the floodplain. The constructed ditch system does not accommodate the inevitable sediment accumulation formerly spread over the alluvial fan. As a result, the ditches require regular dredging in order to maintain their conveyance capacity. Examples of creeks now conveyed through agricultural ditches include Tuck Creek, Cherry Creek, and Peoples Creek.

7.5. Land Development

Land development as discussed here refers primarily to conversion of land from a largely forested condition to a landscape devoted to single- and multi-family residences, commercial structures, farms, and their associated infrastructure. Such conversions have a broad range of impacts to many natural systems. From the perspective of geomorphic processes, the most significant impacts result from changes in the hydrologic regime, especially dramatic increases in peak discharges in streams draining headwater areas (Booth, 1991). Erosion and channel incision as a result of development-related hydrologic changes have been well-documented in the Snoqualmie watershed (Photo 23) (Stoker, 1988). The direct impact of land development to stream channels tends to decrease with increasing contributing area. Despite dramatic impacts to a number of small tributaries, it is not clear that any such hydrologic impact can be documented for the mainstem Snoqualmie River.

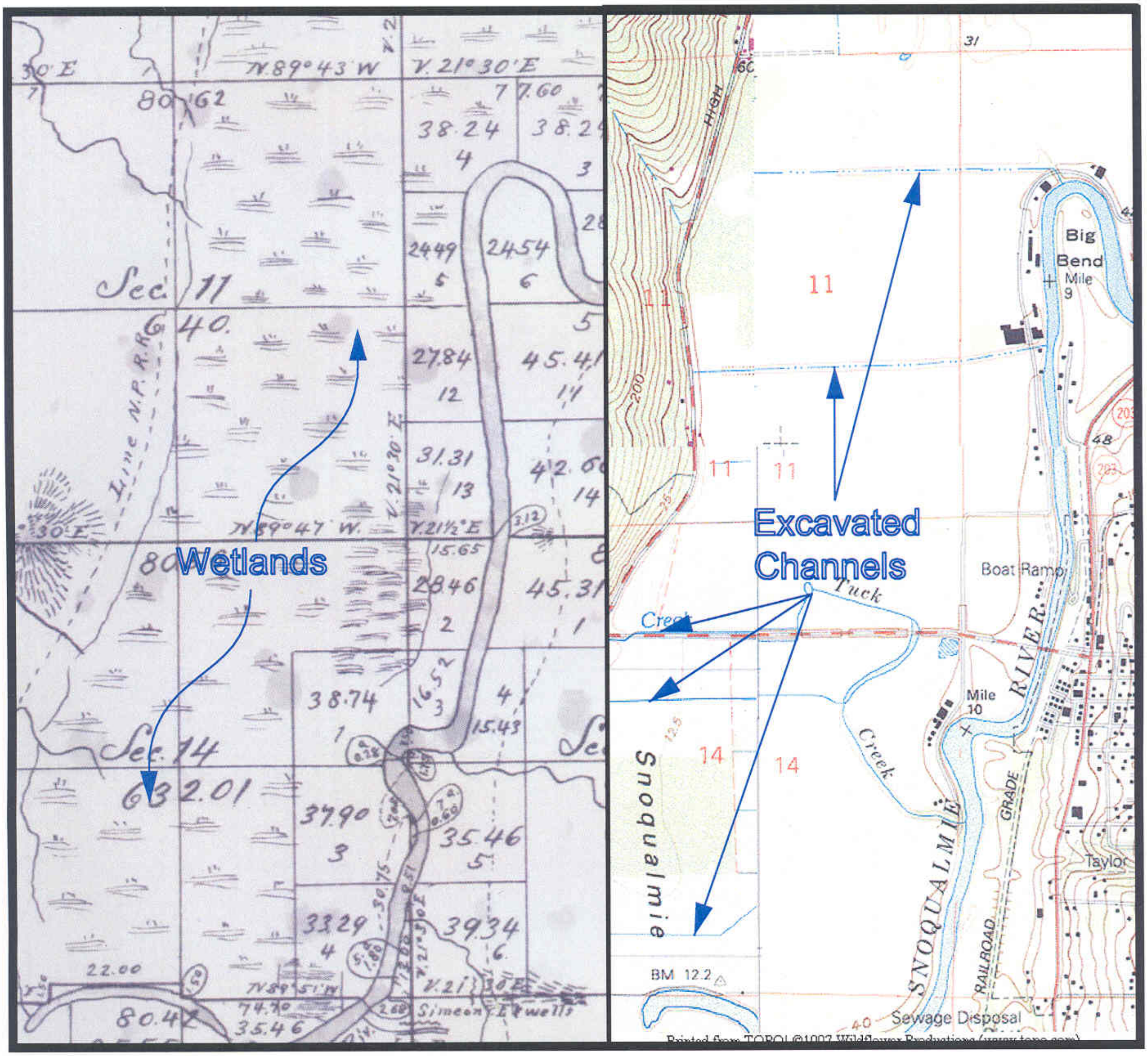

Figure 25: A Portion of the 1873 Govenment Land Office map (on the left) showing extensive wetlands on the Snoqualmie River Floodplain. Compare to recent USGS mapping of the same area (on the right) showing multiple excavated drainage channels and no wetlands

Photo 23: Severe erosion along a small, intermittent stream channel on the west wall of the Snoqualmie Valley in the vicinity of Carnation. This erosion is a result of increased peak flows resulting from upstream development. The geologic unit exposed in this canyon is Vashon advance outwash (Qva). This unit is especially subject to erosion by flowing water. Photo courtesy of Derek Booth.

8.0 Suggested Further Investigations

In the continuing effort to restore instream and riparian habitat, and to minimize risks to human life and property, it is critical to understand the physical processes that shape fluvial landscape features. During preparation of this report, several lines of investigation presented themselves.

- Some of the most heavily modified and frequently disturbed fluvial features in the Snoqualmie watershed are low-gradient channels that carry tributaries across the Snoqualmie floodplain to the mainstem channel. Such channels are common on the lower valley floodplain from Fall City all the way to the mouth. Many such channels have been straightened, shortened, disconnected from adjacent wetlands, and denuded of riparian forests. Because of their location downstream of steep ravines, and because of their low gradient, sediment accumulation in such channels is inevitable. An investigation of the biology and geomorphology of such channels would provide a valuable basis for working in cooperation with agricultural landowners to develop new management strategies for these systems.
- An extensive system of levees and revetments has been constructed along portions of the mainstem Snoqualmie River and on many of its tributaries. In large part, these facilities were intended to limit lateral movement of these channels. Several such facilities have been proposed for removal, but the removal has been delayed or abandoned because of concerns about the lateral or downstream impacts of the removal. The proposed removal of these facilities was predicated on the premise that a channel which is free to migrate across its floodplain is likely to sustain higher quality aquatic and riparian habitat as compared with a channel that is stabilized. It would be useful to investigate:
    - The likely extent and timing of increased channel mobility resulting from removal of bank protection and flood control structures, given the generally stable character of the river even before revetments were constructed.
    - The character and magnitude of habitat benefit associated with allowing a previous constrained channel the freedom to migrate.

9.0 Conclusion

The modern physical landscape in the Snoqualmie River watershed is a product of the geologic and geomorphic history of this area. The character of this landscape exerts a controlling influence on both the ecological regime and human habitation in the watershed. Landscape evolution is still very much a work in progress in this basin, however, and the processes of sediment erosion, transport, and deposition that sculpted the present topography remain active. These active processes play a critical role in creating modern habitat. For example, regular bedload movement in gravel-bed channels is critical for maintaining high-quality spawning habitat in these channels.

Many of these geomorphic processes, including large floods, landslides, channel migration, channel aggradation on alluvial fans, and LWD jam development, may appear catastrophic and even unnatural from the perspective of a human timeframe, but they are orderly, predictable, and inevitable when viewed on a geologic timescale. It is often the case that human activities that do not account for such processes entail unexpected risks and incur unexpected costs. Examples include houses built in active floodplains, communities located on actively aggrading alluvial fans, or roads built in areas of active channel migration. Recognition and characterization of and accounting for such geomorphic processes is a critical step both to implement effective habitat enhancement and conduct appropriate land-use planning in the Snoqualmie River watershed.

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11.0 Glossary

Adverse gradient: A section of stream channel that slopes uphill in the direction of stream flow. Channel reaches with adverse gradient, depending on their length, form in-channel pools, wetlands, and lakes.

Alluvial fan: A deposit of generally coarse sediment that accumulates in an area where a stream's gradient, and therefore its ability to carry sediment, decreases rapidly.

Andesite: A volcanic rock common in the Cascade Mountains. Fresh (unweathered) andesite consists of a dark gray matrix inset with scattered light and dark colored crystals.

Base flow: The amount of flow in a stream during an extended dry period, when there is no perceptible contribution from preceding storms. See Peak Flow.

Bedload: The coarser portion of a stream's sediment load that is transported by rolling or sliding along the streambed. See Suspended Load.

Cirque: A bowl-like feature at the head of an alpine valley, scoured out by glaciers that occupied the valley. Many lakes in alpine settings occupy cirques.

Clast: A single (generally coarse) sedimentary particle; for example, a single piece of gravel.

Cross-bedding: A distinctive depositional pattern, often seen in sandy gravelly sediments that indicate that the sediment was deposited in flowing water.

d_{50}: This denotes the diameter of the average grain size in a sediment sample. For example, for sediment with a d_{50} of 2 mm, half (by weight) of the grains are smaller than 2 mm in diameter and half are larger.

Delta: A delta is a sediment deposit that occurs where a stream enters a body of standing water like a lake or ocean.

Fluvial: Related to rivers and streams.

Gabbro: A dark colored plutonic rock (see below) composed of coarse dark crystals and rich in iron and magnesium.

Geomorphology: The study of the geologic processes that shape the earth's surface, and of the features that result from those processes.

Granitic: Granitic refers to a group of plutonic rocks (see below) that are rich in silica and aluminum, and have the characteristic speckled appearance of granite. Common granitic rocks in the Cascade Mountains include granodiorite and tonalite.

Impervious surface: Any type of land surface that does not allow precipitation to soak into the ground. Generally, impervious surfaces are created by development activities; for example, paved roads or rooftops. A few natural surfaces are impervious; for example, bare exposed rock.

Lacustrine: Related to freshwater lakes.

Mass wasting: Any geomorphic process in which soil or rock, not being carried by another medium (wind or water, for example) moves downhill. Landslides and rock fall are examples of mass wasting.

Peak flow: A large stream flow of short duration that results from a large storm. See base flow.

Plutonic: This refers to rock that was formed when molten rock cools and hardens deep under the earth's surface. Granite is a familiar plutonic rock.

Sinuosity: A measure of how straight or winding a river channel is. Sinuosity is found by dividing the channel distance between two points by the straight-line distance between the same points. For example, if the distance between two points along a winding channel is three kilometers, but the points are only two kilometers apart along a straight line, then that reach of channel has a sinuosity of one and a half.

Sorting: This is a measure of how much variation there is in the size of particles in a deposit. If all the particles are nearly the same size, as in clean sand, for example, the sediment is well sorted. If it contains particles of a wide range of sizes, for example, a mixture of sand, gravel, and cobbles, the sediment is poorly sorted.

Stade: During a glacial epic (commonly known as an ice age), there are typically multiple episodes of glacial advance. Such individual advances and retreats are termed stades.

Stratigraphic: Stratigraphic comes from stratigraphy, the study of layering in geologic deposits. Stratigraphy can reveal information about age, depositional environment, and post-depositional deformation of a geologic deposit.

Suspended load: The finer portion of a stream's sediment load that is transported suspended in the streamflow. See bed load.

Talus: A slope covered by angular rock fragments. Taluses are generally located below cliffs and are the accumulation of the rocks that fall off of the cliff.

Tectonic: Related to large-scale movement of the earth's crust. For example, vertical movement of the crust that creates mountain ranges or horizontal movement of crustal plates.

Texture: The texture of a granular geologic material refers to size and distribution of its constituent grains.

Underfit stream: A relatively small modern stream that flows through a large valley carved by much larger flows in the geologic past.

Valley confinement: The extent to which a stream channel is directly confined by its valley walls. For example, a stream flowing in a steep-sided gully is highly confined by the gully walls on either side. In contrast, the channel of a large stream flowing through a broad floodplain is free to move across its floodplain, seldom if ever encroaching on the valley walls. Such a stream would have low confinement.