

HABITAT RESTORATION OPTIONS

Canyon Creek Alluvial Fan Habitat Restoration

Prepared for

Whatcom County Public Works

October 2007



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Canyon Creek Alluvial Fan Habitat Restoration

Prepared for

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Introduction

Canyon Creek is a tributary of the North Fork Nooksack River, flowing into the river just upstream of the State Route (SR) 542 bridge (Warnick Bridge), at river mile (RM) 55.0, west of the town of Glacier in Whatcom County, Washington.

Whatcom County is interested in developing options for improving fish habitat conditions in the alluvial fan of Canyon Creek as part of its proposed lower Canyon Creek salmon habitat restoration project. The project reach for the Canyon Creek alluvial fan habitat restoration extends from river mile (RM) 0.0 to RM 0.9. Whatcom County received a grant from the Salmon Recovery Funding Board to improve fish passage and habitat within the project reach, particularly through the bedrock step cascades located at approximately RM 0.2 (Figure 1). As a result of previous actions by Whatcom County to relocate the channel after the 1989 and 1990 debris flood events, a partial fish barrier was created by the channelization and incision of lower Canyon Creek down to bedrock in the segment of Canyon Creek from RM 0.2 to RM 0.3.

Background Information

Canyon Creek has been subject to numerous debris floods that have degraded habitat used by multiple salmonid populations including three species listed as threatened under the federal Endangered Species Act. These debris floods also have posed a risk to both public infrastructure and private property along the project reach (the lower 0.9 miles of the creek) and across the alluvial fan itself. A *debris flood* is defined as a flow event with a volumetric concentration of sediment in the range of 15 to 35 percent. Three significant debris floods recently occurred within the watershed, destroying property and structures in the Glacier Springs subdivision (KWL 2003). One of the debris floods occurred in 1989 and the others in 1990. The magnitude of the 1989 event was estimated at approximately 16,100 cubic feet per second (cfs) at the mouth of Canyon Creek (KWL 2003). The magnitudes of the 1990 events are unknown but are assumed to be of smaller magnitude than the 1989 event based on geomorphic indicators such as remnant terraces. Although damaging, both events were relatively small in comparison to events identified in the geomorphic record (KWL 2003). As a corrective measure, in January 1990 (after the 1989 event), an approximately 800-foot bank armor was constructed by the Natural Resources Conservation Service (formerly the Soil Conservation Service [SCS]) along the right bank homes in the vicinity of Canyon View Drive to protect the Glacier Springs subdivision; and a bypass channel was constructed in an overflow path from the 1989 event at the left bank near the head of the alluvial fan to direct creek flood flows away from where the creek makes a sharp left turn before flowing down the alluvial fan and into the North Fork Nooksack River (Figure 1) (KWL 2003). The bank armor was subsequently destroyed by the 1990 debris floods. After these events, Whatcom County conducted engineering and geologic studies of the site to identify measures for alleviating flooding and erosion.

Under contract to the County, GeoEngineers completed a feasibility study for flood hazard management on the site and identified four options for addressing the debris flood damage

(GeoEngineers 1992). Option 4 was chosen for implementation by the County and other stakeholders. One element of Option 4 was a 2,400-foot armored (rock) levee along the right bank, which was constructed in 1994 (Figure 1). This levee was permitted as a temporary structure until a buyout project could be implemented under the shoreline permit issued by Whatcom County and approved by the Washington State Department of Ecology. In addition, an unarmored berm made of local alluvium was constructed at the downstream end of the armored levee to extend some protection downstream of previous flow paths that had adversely affected the Logs Resort. Five rock groins were also placed along the armored levee (right bank) in the upstream section where the creek turns sharply just downstream from the head of the alluvial fan. Since the construction of these measures, one high-flow event in 1995 damaged three groins, buried or removed fish habitat enhancement structures (logs cabled into the bank and groupings of boulders connected by cable loops and located in middle of the channel), and damaged the unarmored berm that extended downstream from the end of the levee. Since the 1995 event, the other two groins have failed and the channel is now behind the unarmored berm.

As observed during site visits in spring and summer 2006 by Herrera Environmental Consultants (Herrera) and Whatcom County, the 1994 levee is still intact along the right bank; however, channel incision appears to have exposed the toe of the levee in several locations. The most severe toe erosion occurs where the creek turns sharply to the left (south) at the apex of the alluvial fan (RM 0.7). Since the construction of this levee, the channel has incised approximately 6 feet at the bend (as evident during the summer 2006 field investigations by Herrera).

Another measure that was implemented in 1994 as part of Option 4 was the blasting of a bedrock outcrop between RM 0.2 and RM 0.3 (Figure 1) to create a “notch” in which the creek would be restricted to prevent its migration across the alluvial fan toward the Logs Resort. This notch is located where the levee constricts the floodplain and channel migration zone (CMZ). The placement of large (5-foot diameter) boulders on the floodplain between the levee and the bedrock notch further constrained the creek flows to the bedrock notch (reducing the effective width of the CMZ to less than 50 feet). This represents a decrease of approximately 66 percent (from 450 feet to 150 feet) in available channel width during flood flows. As evident by the channel alignments since 1994, the channel has not migrated from this notch, and there is an hour-glass constriction of the channel at this location (Figure 2).

Confinement of the creek to the bedrock notch has resulted in a barrier to fish passage. Fish passage in lower Canyon Creek is constrained when low-flow conditions limit the ability of fish to navigate a series of bedrock step cascades created by the bedrock blasting in 1994 (Seymour 2006). This notch is now often impassible to migrating chinook and pink salmon during flow conditions typical in August and September. During these late summer low flows, a 3- to 4-foot waterfall forms at the upper end of the bedrock notch. During high flows, velocities are extremely high (>15 feet/second), with little or no hydraulic refuge because all flow is concentrated within the notch. During late summer low-flow conditions, the upstream migration of salmon is either slowed or blocked, and the fish often congregate in a pool below the cascades where they are vulnerable to poaching and predation. This notch has been identified by the Washington Department of Fish and Wildlife (WDFW) as a fish passage barrier that limits fish

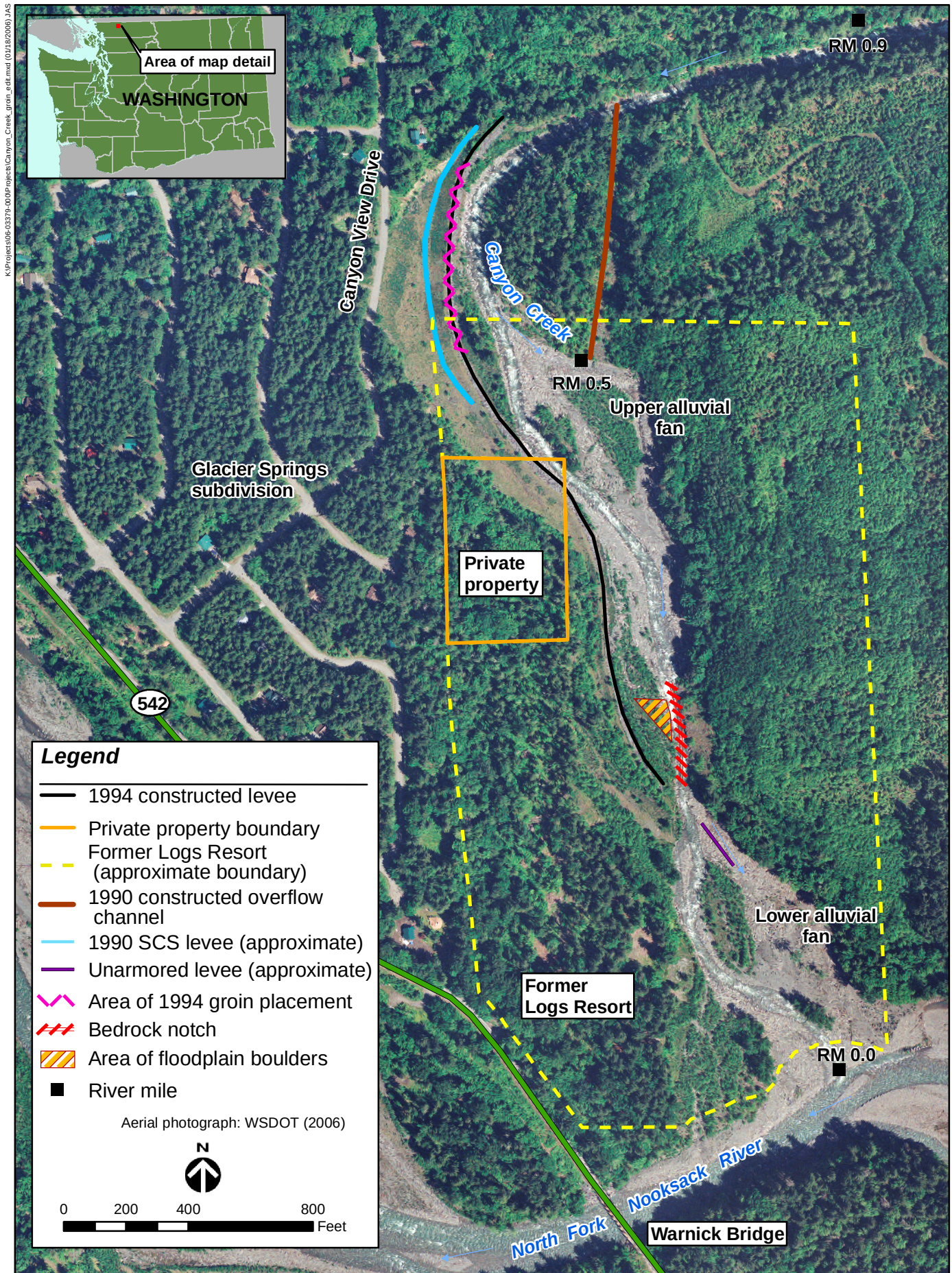


Figure 1. Vicinity and project reach for the Canyon Creek alluvial fan habitat restoration.

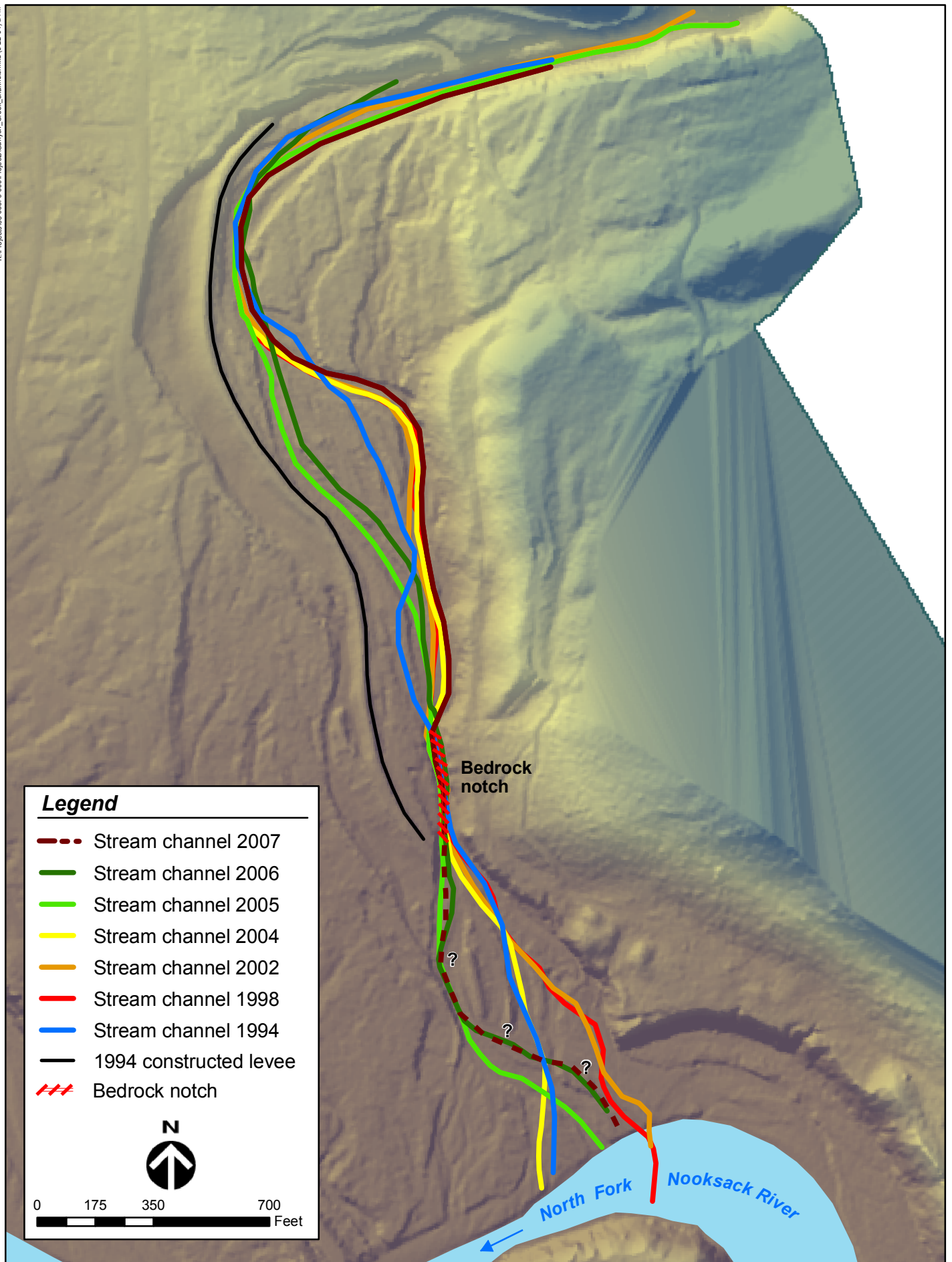


Figure 2. Channel alignments of lower Canyon Creek between 1994 and 2007.

access to the approximately 4 miles of historically available habitat. For these reasons, lower Canyon Creek has been indefinitely closed to fishing by WDFW since 2005. In the past, volunteer efforts led by the WDFW assessed barrier conditions annually and attempted to address the problem on an ad hoc basis by minor hand crew relocation of boulders and placement of sandbags to concentrate sufficient flow for the blocked fish to jump clear (Seymour 2006). To address the fish passage issues on the Canyon Creek alluvial fan, the County applied for and received a grant from the Salmon Recovery Funding Board to conduct an assessment and develop preliminary (30%) restoration designs.

The implementation of the Option 4 measures identified in the feasibility study (GeoEngineers 1992) did not fully address all the erosion and flood issues within the project reach nor was its focus to develop specific actions to restore salmon habitat. The habitat conditions in the creek were further degraded and damage occurred to the groins and the riprap revetment during the 1995 high-flow event. Therefore, additional studies were undertaken by the County to identify potential flood hazard management strategies for the continued alluvial fan erosion and flooding issues and provide the basis for the proposed restoration options.

Since the implementation of Option 4 in 1994, two major studies have been completed for the County to evaluate potential measures for restoring the site. One study was completed by Inter-Fluve, Inc. (2000), and the other was completed by Kerr Wood Leidal Associates, Ltd. (KWL 2003). Both reports were evaluated as part of Herrera's background review for the proposed alluvial fan habitat restoration. However, these reports focus primarily on the erosion and flood issues within the project reach, rather than salmon habitat enhancement or restoration and how geomorphic processes are linked to factors that limit salmon habitat function. Kerr Wood Leidal identified impact zones based on hydraulic modeling of debris floods (KWL 2003). Based on the recommendations in that report, the County purchased developed properties from voluntary sellers in the areas identified as highest risk for impacts due to debris flood events: the Logs Resort, three developed properties, and one undeveloped property in the Glacier Springs subdivision, totaling over 70 acres. The Whatcom Land Trust also purchased approximately 21 undeveloped lots (4.5 acres) to provide conservation and restoration opportunities. Ultimately, the County intends to transfer the lots under its ownership to the Whatcom Land Trust for long-term conservation, habitat restoration, and management.

Flooding on November 6 and 7, 2006, resulted in the delivery of a large amount of sediment that aggraded the streambed on the average approximately 6 feet, converting the channel from a step-pool morphology to a pool-riffle channel (Appendix A, photos 7 through 10). In addition, the channel has shifted to the left side of the alluvial fan (away from the 1994 levee) just above the bedrock notch between approximately RM 0.3 and RM 0.5. This change in channel alignment has exposed some additional bedrock "fins" or outcroppings in the steeply dipping sandstone just upstream of the fish passage constriction along the left bank. This newly exposed bedrock is likely contiguous along the left bank (looking downstream) with the bedrock that is exposed throughout the notch. However, since this flood event, the creek has re-incised through the recent debris flood deposits on the order of approximately 6 feet along much of its channel alignment in the upper fan area, and the channel bed elevation is similar or perhaps even lower than the pre-November 2006 levels (Thompson 2006).

Project Objective

The County's primary goal for the Canyon Creek alluvial fan habitat restoration is to "promote restoration of floodplain and in-channel habitat forming processes on a timescale that is meaningful to salmonid recovery while recognizing the hazards, risks, and limitations of working on an active alluvial fan" (Thompson 2006). The proposed restoration project will attempt to bring together the channel morphology, flood conditions, and habitat issues to develop potential solutions within the project reach with an emphasis on improving long-term passage at the bedrock notch and restoring fluvial processes conducive to habitat formation and maintenance.

Watershed Description

The Canyon Creek watershed covers approximately 31 square miles. Most of the watershed consists of land owned by the U.S. Forest Service; land in the lower portion of the watershed is either privately owned or state owned and is in commercial timber production with the exception of residential development in Glacier Springs. Canyon Creek has a history of debris floods originating from trigger sites upstream in the watershed. These floods have posed a risk to both infrastructure and property and to fish habitat quality along the project reach (lower 0.9 miles of the creek). Most recently were the debris floods of 1989 and 1990, which destroyed property in the Glacier Springs subdivision and required the implementation of measures to protect the Glacier Springs subdivision in 1994.

The Canyon Creek alluvial fan began forming when the glaciers retreated in the North Fork Nooksack River valley approximately 11,000 years ago (KWL 2003). The fan currently covers approximately 220 acres, with an elevation of approximately 865 feet at its apex (where the creek emerges from the upgradient bedrock canyon). The fan consists of fluvial and debris flood deposits (KWL 2003).

Hydrology

Continuous flow gauge data for Canyon Creek are not available. However, data are collected by the U.S. Geological Survey (USGS) on the North Fork Nooksack River near the town of Glacier (USGS gauge 12205000) located approximately 8 miles upstream of the confluence with Canyon Creek. This gauge has been in operation since 1937.

As part of a watershed analysis completed by the U.S. Forest Service in 1995, peak flows were determined using a number of methods available at the time to extrapolate peak flow data from data obtained from other gauges (USDA Forest Service 1995). The U.S. Forest Service used three methods to develop an estimated flood frequency for Canyon Creek. Further, Kerr Wood Leidal used these estimating methods to develop a flood frequency and magnitude for Canyon Creek to use in modeling efforts as part of its 2003 alluvial fan risk assessment (KWL 2003) (Table 1). A detailed discussion of these analyses and assumptions are provided in the Canyon Creek watershed analysis (USDA Forest Service 1995) and the alluvial fan risk assessment (KWL 2003).

The cumulative effect of timber harvesting and road construction, drainage, and maintenance changed the hydrology of the basin (Sprague and Nichols 1995) and exacerbated landslide initiation (Peak 1986; Thompson 2007). The extensive timber harvesting and related activities from the 1950s through the 1970s resulted in (1) a lack of large trees in the riparian corridor, limiting the recruitment of large trees to the stream channel, which provide sediment storage and channel form, (2) a loss of hydrologically mature forest canopy in the rain on snow zone (1,500 to 3,000 feet) and, (3) an extensive road drainage network in need of continual maintenance and repair. Timber harvest in the 1970s resulted in the loss of tree root strength in

the soil for 7 to 15 years after harvest and often occurred in areas that are naturally unstable and prone to mass wasting at the soil/bedrock interface where soil cohesion is a critical stability factor. In addition, early road construction techniques often employed side-cast construction methods that were prone to later mass failure and routing of large quantities of sediment to the creek. Mass wasting from roads most often can be tied back to improperly sized or constructed creek and drainage crossings (i.e., undersized culverts) or the combination of smaller drainages into a single larger drainage. Many road related landslides in Canyon Creek can be tied back to drainage structures which failed as the result of insufficient capacity to convey sediment and water. The combination of these management-related factors combined with naturally unstable landforms set the stage for the dramatic responses (i.e., landslides) to debris flooding events in 1984, 1989, and 1990 (Sprague and Nichols 2005).

Table 1. Estimates of flood frequency and magnitude in Canyon Creek.

Return Period (years)	Average Flood Flow (cubic feet per second)
2	2,705
5	3,555
10	4,010
25	4,835
50	5,340
100	5,970

Source: KWL (2003).

Note: The 2-year return period flood approximates the mean annual flood.

Debris Floods

Debris floods have occurred within Canyon Creek and will occur again within this watershed (KWL 2003). Significant debris floods occurred in 1989 and 1990, with extensive impacts on the project reach, including aggradation throughout the alluvial fan and damage to fish habitat and property located on the fan. In lower Canyon Creek, debris floods are likely initiated by temporary blockage of the channel due to a landslide upstream of the fan. If the blockage is high enough, it can act like a dam, with a lake developing on the upstream side of the dam. When the dam fails, it can result in an outburst flood, which consists of the mobilization of the dam-forming earth material, the water that was impounded by the dam, and additional material entrained as the outburst is routed downstream. Outburst floods have occurred in Canyon Creek, particularly because of its mostly narrow, confined channel, which is prone to landslide-induced blockages. The 1989 and 1990 debris floods were categorized as “dam outburst” floods (KWL 2003). Evidence collected by Whatcom County Public Works at the toes of the Jim Creek and Bald Mountain landslides in November 2006 indicate multiple landslide dams had formed and failed during the November 6 and 7, 2007 flood event. This is consistent with the multiple (more than four) debris flow layers identifiable in the deposits at the head of the alluvial fan that resulted from that debris flood event (Thompson 2007).

To determine the frequency of debris floods in Canyon Creek, an analysis of debris flood probability and magnitude was completed by Kerr Wood Leidal as part of the alluvial fan risk assessment (KWL 2003). Kerr Wood Leidal used four methods to date debris floods within the Canyon Creek basin to determine the probability of these events. These methods were the interpretation of aerial photographs, dendrochronology (study of the growth ring patterns of trees), eyewitness reports from local residents, and radio-carbon dating of trees. Based on a review of photographs taken in 1991, the 1989 or 1990 debris flood was the largest event in the last 60 years (period of the photographic record) (KWL 2003). These events significantly widened the channel downstream of Whistler Creek (left bank tributary at RM 8.6) as indicated in the aerial photographs. However, based on the other evaluation methods, Kerr Wood Leidal concluded that the 1989 event (with an estimated discharge of 16,100 cfs) was the largest event in the last 300 years, with a return period of 200 years (KWL 2003). According to the Kerr Wood Leidal analysis, other significant floods or debris floods likely occurred in 1937, 1962, 1984, and 1990 (KWL 2003). The Kerr Wood Leidal report concludes that high-magnitude debris floods occur in Canyon Creek with return periods of centuries (10 to 40 percent probability in 50 years).

1989 Debris Flood

The 1989 debris flood is attributed to the failure of a debris dam (“outburst flood”) upstream of Whistler Creek that failed during a large storm event (November 9 and 10) (Sprague and Nichols 2005). The estimated peak surge of the event was 16,100 cfs, three times the estimated 100-year event in Canyon Creek (Richardson, 1990 in Sprague and Nichols 2005). This estimate was determined from high water marks along the channel (observed in the spring after the event) and the slope-area (channel characteristics) method (KWL 2003). Twelve feet of sediment was deposited within the alluvial fan (Sprague and Nichols 2005). A local resident estimated that 20 to 25 feet of sediment was deposited in the area in front of his home in the Glacier Springs subdivision (GeoEngineers 1992). Trees along the right bank of the fan were buried. One house in the Glacier Springs subdivision was destroyed during this debris flood.

1990 Debris Flood

One year after the 1989 debris flood, two additional debris floods occurred in Canyon Creek. The size of these debris floods is unknown. Although field evidence and eyewitness accounts indicate that the peak surge of this debris flood was less than the 1989 event, the property damage was greater (KWL 2003). Based on an eyewitness account, approximately 5 feet of sediment was deposited in the downstream parts of the Glacier Springs subdivision, primarily within the Logs Resort. Three houses were destroyed during the flood, and another house was subsequently removed because it had been severely undercut by the flood (KWL 2003). Approximately 300 feet of Canyon View Drive was destroyed. In addition, the SCS bank armor that was constructed after the 1989 event was severely damaged.

Sediment

Sediment is delivered to Canyon Creek through natural surface erosion processes, including mass wasting events. These processes can be triggered naturally, or they can be initiated by a disturbance associated with anthropogenic activities such as logging, land clearing, and road building. In the case of Canyon Creek, the extensive logging and road construction throughout the basin in the 1960s and 1970s contributed large amounts of sediment to the system (KWL 2003; WRIA 1 SRB 2005a). Analyses of aerial photographs by KWL as part of the alluvial fan risk assessment indicated that approximately 100 debris avalanches and debris flows were triggered by clearcutting and sidecast failures on poorly constructed logging roads, and approximately half of these landslides entered Canyon Creek (KWL 2003). Slope instabilities related to timber harvest and forest roads have resulted in the delivery of 2.3 million cubic yards of excess sediment to the channel since 1940 (Peak Northwest 1986). In addition, because of the local glacial and bedrock geology, Canyon Creek is subject to debris slides, debris flows, and earthflows (KWL 2003).

Within the project reach of Canyon Creek, sediment is supplied to the system primarily from upstream sources during large flow events or debris floods such as those in 1989 and 1990. The 1989 event supplied approximately 12 feet of sediment to the alluvial fan (Sprague and Nichols 2005). In Canyon Creek immediately upstream of the project reach, the channel is mostly confined in a bedrock inner gorge landform, with little lateral channel migration. Sediment has been transported from the fan, as evident from the downcutting of the channel, since the last peak flow event in 1995.

Two significant and large earthflows, the Jim Creek and Bald Mountain earthflows, are located upstream of the project reach at RM 3.4. These two slides are classified as translational/rotational slides (Peak Northwest 1986; Hale and Nichols 1994). These earthflows are located directly opposite each other and provide a continual supply of sediment to the creek from gravitational creep, fluvial erosion at the toe of the slide, and occasional mass failure of oversteepened areas of the landslide toe. They are the result of natural mass movement processes that may have been affected by forest management and continue to provide a significant proportion of the naturally derived sediment delivered to Canyon Creek (KWL 2003). The site of these two earthflows is also a potential site for the formation of very large landslide dams that could result in catastrophic outburst floods. As stated previously, the November 2006 landslide dams produced a significant response on the alluvial fan, yet were relatively minor events compared to the geologic record. These earthflows likely date back to the deglaciation of the area 11,000 years ago (KWL 2003). As the glaciers retreated, they left steep, unstable slopes and deposited recessional gravels along the upper slopes in an area underlain by fault contacts and disconformities between geologic units. Massive deep-seated failures of these steep slopes likely resulted in both the Jim Creek slide and the Bald Mountain slide.

North Fork Nooksack River

The Canyon Creek alluvial fan formed at a hanging valley where Canyon Creek enters the North Fork Nooksack River valley. The alluvial fan was created as the creek shifted its location in

response to the alignment of the North Fork Nooksack River, resulting in sediment deposition over the extent of the fan area. Canyon Creek adjusts its vertical channel slope and topographic channel alignment in response to the location of the North Fork Nooksack River at any given time. This shifting has allowed the development of the alluvial fan over time and continual deposition and incision cycles within the fan.

The Church Mountain landslide, which occurred approximately 2,300 years ago, dammed the North Fork Nooksack River channel near its confluence with Canyon Creek. Since the slide, the North Fork Nooksack River has cut through the slide deposits and concurrently lowered the base level of Canyon Creek. The location and elevation of the North Fork Nooksack River is a controlling factor of Canyon Creek's slope and depth through segment 1 (from the mouth upstream to the bedrock notch). Canyon Creek has aligned itself along the left (east) side of its fan, probably since the Church Mountain slide. As the North Fork Nooksack River migrates to the north and cuts into the alluvial fan or, vice versa, as the river moves to the south away from the alluvial fan, Canyon Creek adjusts its slope to account for the change in alignment of the North Fork Nooksack River. Therefore, the position of the North Fork Nooksack River influences the channel characteristics (alignment, slope, and length) of lower Canyon Creek.

In its existing alignment within the alluvial fan, Canyon Creek is generally flowing along the left (easterly) edge of the entire fan area. The central portion and right side of the fan are currently occupied by the Glacier Springs subdivision. However, during the development of the fan after the glaciers retreated, the creek flowed throughout the entire area of the fan (including the area of the Glacier Springs subdivision and the former Logs Resort) as it was being built up from fluvial processes including debris floods. The Church Mountain slide has affected the location of the North Fork Nooksack River, pinching the river against the Canyon Creek alluvial fan (at their confluence). This shift of the North Fork Nooksack River to the north changed the length and slope of Canyon Creek. Initially, the channel length was shortened, resulting in conditions of increased slope through the alluvial fan to its confluence with the North Fork Nooksack River. The Church Mountain slide and its effect of pinning the North Fork Nooksack River channel against the Canyon Creek fan has kept the alignment of Canyon Creek primarily along the left side of its fan by creating a shorter and steeper channel.

Fish Habitat

Several species of salmonids are known or believed to use the lower approximately 4 miles of Canyon Creek for adult and juvenile migration, spawning and rearing (WDFW 1998, 2002; WRIA 1 SRB, 2005a). These include three species currently listed as threatened under the Endangered Species Act: early-run chinook salmon (the North Fork/Middle Fork Nooksack spring chinook stock), bull trout (the Canyon Creek stock), and the Mainstem/North Fork Nooksack River stock of steelhead, part of the Puget Sound distinct population segment of steelhead. Early chinook spawn from early August through the end of September. Pink salmon also enter the system to spawn in August and September. North Fork Nooksack River chum salmon may spawn in lower Canyon Creek but are believed to largely restrict themselves to the

main stem of the North Fork Nooksack River. Canyon Creek also supports migratory and resident cutthroat trout. The North Fork/Middle Fork chinook stock, currently rated in critical status by the WDFW, is of particular concern because recent return rates of natural origin spawners have been critically low (WDFW 2002; WRIA 1 SRB 2005a). This implies a severe limitation in survival for the spawn through outmigration lifestages of this chinook population.

Degradation of channel conditions in Canyon Creek caused by debris floods and subsequent floodplain management actions in the project reach near the Nooksack River confluence has resulted in a channel morphology that is inconsistent with natural regime conditions. The channel bed has been degraded to bedrock or become heavily armored in some areas and become overly wide and shallow in others. Shade-forming mature riparian vegetation is largely nonexistent due to frequent “clearing the deck” during flood events. These combined factors have resulted in degraded habitat conditions that are detrimental to the long-term conservation and eventual recovery of depleted salmonid populations.

Several key habitat-limiting factors have been identified in the Canyon Creek system as part of the recovery planning process (WRIA 1 SRB 2005a). Habitat restoration actions targeting these limiting factors have been prioritized for funding by the WRIA 1 Salmon Recovery Board in terms of the benefits provided to federally listed chinook salmon and bull trout (WRIA 1 SRB 2005b). The habitat-limiting factors and WRIA 1 SRB relative priority of those limiting factors are summarized in Table 2.

The most significant limiting factors prevalent in the project reach of Canyon Creek are channel stability, fish passage, and habitat diversity. Restoring passage in the project reach is considered a high priority action as a whole because of the certainty regarding the benefits of restoration and the direct effects of fish passage on the productivity, distribution, and abundance of chinook salmon and bull trout within the Nooksack River basin. While not prioritized in the local salmon recovery plan, ensuring passage for ESA listed steelhead is also necessary. As stated earlier, fish passage in lower Canyon Creek is constrained when low-flow conditions limit the ability of fish to navigate a series of bedrock step cascades created by bedrock blasting that was conducted as part of corrective measures implemented at the site in 1994 for flood control purposes (Seymour 2006). This confinement has also “fixed” the channel into the bedrock notch further exacerbating fish passage. This notch is currently a partial barrier to migrating chinook and pink salmon with passability determined by flow conditions and the species and lifestage of fish present. Passage during August and September is especially critical for the early chinook and pink salmon. This notch has been identified by WDFW as a fish passage barrier that limits fish access to historic upstream habitat areas and is considered a priority barrier project in the WRIA 1 Salmonid Recovery Plan.

Although of lesser concern than the physical barriers in the project reach, water temperatures are also a concern. Lower Canyon Creek has been placed on the state 303(d) list because of summer water temperatures in excess of 16 degrees Celsius (16°C) (Ecology 1998). The limited amount of temperature data available for Canyon Creek suggest that summer water temperatures in excess of 15°C could occur regularly into late August during low water periods (Utah State University 2002). This suggests the potential for a thermal barrier to migration during this

Table 2. Habitat limiting factor and Salmon Recovery Funding Board restoration priority rankings for the Canyon Creek watershed.

Factor	Limiting Factor Priority Ranking ^a			Relative Importance of Limiting Factor for SRFB Ranking ^b	
	Magnitude of Impact	Certainty of Impact	Causal Mechanisms/ Contributing Factors	NF/MF Early Chinook	Bull Trout
Passage Barriers	Moderate	High	Channel management activities	2	1
Channel Stability	High	Moderate	Lack of-in channel wood, forest management practices	1	1
Habitat Diversity	High	Moderate	Excess sedimentation from debris flows	3	2
Temperature	Moderate	High	Lack of shade due to degraded riparian conditions caused by debris flows	3	3
Sediment Load	Moderate	Moderate	Forest management practices	4	4
Key Habitat Quantity	Moderate	Moderate	Forest management practices, habitat degradation caused by debris flows	4	Not evaluated
Streamflows	Moderate	Low	Forest management practices, floodplain confinement, loss of channel structure, sedimentation	4	Not evaluated

^a Magnitude and certainty of impact ratings derived from the assessment of limiting factors on North Fork/Middle Fork Nooksack Early Chinook and Nooksack Bull Trout in Canyon Creek (WRIA 1 SRB [2005a], Sections 4.1.3 and 4.1.4).

^b Limiting factor scoring criteria rating for Salmon Recovery Funding Board (SRFB) project funding consideration (WRIA 1 SRBb, Tables C-3 and C-4).

period for bull trout, which are intolerant of water temperatures above 15°C without adequate thermal refugia. Recent studies of coastal bull trout populations (Brenkman and Corbett 2005) indicate that bull trout spawning migrations in river basins on the Olympic Peninsula occur from May through September. Little is known about the migratory timing of the Canyon Creek bull trout stock (WDFW 1998). However, if it can be assumed that migratory timing is similar in the Nooksack River sub-basin, migration through lower Canyon Creek is probably at least partially restricted. On balance, however, temperature conditions are not viewed to be a significant passage issue in Canyon Creek (Seymour 2006). Moreover, because shade-forming riparian vegetation is lacking for a considerable distance upstream, it will be difficult to significantly improve temperature conditions in lower Canyon Creek with localized actions.

Canyon Creek Alluvial Fan

For purposes of evaluating possible habitat restoration alternatives, the project reach has been divided into three separate segments.

- Segment 1: lower alluvial fan (RM 0.0 to RM 0.21)
- Segment 2: bedrock notch (RM 0.21 to 0.29)
- Segment 3: upper alluvial fan (RM 0.29 to 0.9).

These segment boundaries are based on the geomorphology and channel characteristics of the alluvial fan area and were defined using available information from aerial photographs, light detection and ranging (LiDAR) data, and onsite field investigations. These segment boundaries provide the basis for developing options for improving the habitat conditions throughout the project reach (RM 0.0 to RM 0.9). The purpose of this report is to identify habitat restoration options for each of the three segments.

The project reach extends from RM 0.0 to RM 0.9. At the head (upstream end) of the alluvial fan, Canyon Creek emerges from an incised, bedrock canyon consisting of Chuckanut sandstone. The upstream bedrock canyon is narrow and deep and constricts the stream flow. The bedrock also provides a geomorphic upstream channel bed control point. During high-flow events, flows are concentrated within this canyon (with no floodplain or off-channel areas to dissipate flood flow volumes or flood flow energy), resulting in high-volume and high-velocity flows that emerge at the head of the alluvial fan. Segment 3 extends from the downstream end of this canyon (approximately RM 0.9) where the creek flows along a sharp bend (to the left) and is aligned with a levee that was built in 1994 as part of the measures to protect the Glacier Springs subdivision downstream to the bedrock notch at RM 0.29. Segment 2 consists of the bedrock notch. This segment has remained static both in its channel alignment and position, with little to no lateral channel migration since 1994 (Figure 2). Segment 1 consists of the lower part of the alluvial fan between the bedrock notch and the confluence with the North Fork Nooksack River. The average slope of the project reach is approximately 3.0 percent (based on the 2005 LiDAR data).

Based on Canyon Creek hydrology and channel geometry, the flows (shown in Table 3) in Canyon Creek are supercritical throughout the length of the project reach. Supercritical flows are characterized by high velocities and occur when flow velocities are greater than the wave velocities (at a particular location or reach). Supercritical flow occurs when the Froude number (a dimensionless number) is greater than 1, whereas subcritical flow occurs when the Froude number is less than 1. In addition, stream power (a dimensionless number) is the energy available to move sediment within a river or stream. The greater the stream power, the greater the ability to move sediment. The highest Froude number and stream power are within segment 2 of the project reach, where the bedrock notch constricts stream flows, thereby increasing velocities over a decreased width and restricting fish passage throughout the segment. The high stream power values indicate most sediment is transported through this reach where it is then deposited downstream in segment 1.

Table 3. Froude numbers and stream power in the project reach of Canyon Creek, under existing conditions based on HEC-RAS modeling (2-year flood results).

Cross-Section River Mile (Cross-Section ID)	Channel Width in Feet (meters)	Froude Number (dimensionless)	Stream Power (dimensionless)
0.5 (822)	137 (42)	1.51	0.055
0.39 (646)	142 (43)	1.22	0.054
0.34 (569)	130 (40)	1.67	0.058
0.29 (488)	157 (48)	1.20	0.049
0.24 (437)	40 (12)	1.93	0.174
0.19 (327)	131 (40)	2.2	0.058
0.06 (131)	373 (114)	1.62	0.020

2-year model results are uncalibrated; the numbers are presented for discussion purposes only.

Froude number = $V / \sqrt{gd}$ where V is velocity, g is specific weight of water, and d is depth.

Stream power = $g * Q * S$, where g is the specific weight of water, Q is flow, and S is energy slope.

Segment 1: Lower Alluvial Fan (RM 0.00 to RM 0.21)

Segment 1 (the lower alluvial fan) extends from just below the bedrock outcrop to the mouth of Canyon Creek at its confluence with the North Fork Nooksack River. The average active channel width is approximately 400 feet, with a channel slope of 3.1 percent (based on 2005 LiDAR data) (Figure 3) (Appendix A, photos 2 and 3). The channel alignment within this segment switches in response to flow conditions, sediment load and transport, and the alignment of the North Fork Nooksack River. The North Fork Nooksack River is currently aligned along its left bank opposite the mouth of Canyon Creek, at the base of a steep bluff (remnant of the Church Mountain slide) just upstream of the Warnick Bridge. According to the photographic record and LiDAR data, the North Fork Nooksack River has shifted its channel location at the foot of the Canyon Creek alluvial fan. These shifts are often in response to large debris flood events issuing from Canyon Creek wherein the fan progrades into the North Fork Nooksack River forcing the river towards its left bank. As sediment production wanes from Canyon Creek in subsequent years, the North Fork is able to transport this fan material downstream and migrate laterally toward Canyon Creek. The LiDAR data indicate one historical meander of the North Fork Nooksack River along the right bank, where it cut into the lower alluvial fan.

Segment 2: Bedrock Notch (RM 0.21 to RM 0.29)

Segment 2 extends through the bedrock step cascades that constitute a partial barrier to fish passage through the alluvial fan (Appendix A, photos 4 and 5). Throughout this constricted segment, the creek is confined within its channel by the bedrock notch. These bedrock step cascades present a partial fish barrier blocking access to approximately 4 river miles of previously accessible (prior to 1994 corrective measures) habitat for early chinook, sockeye,

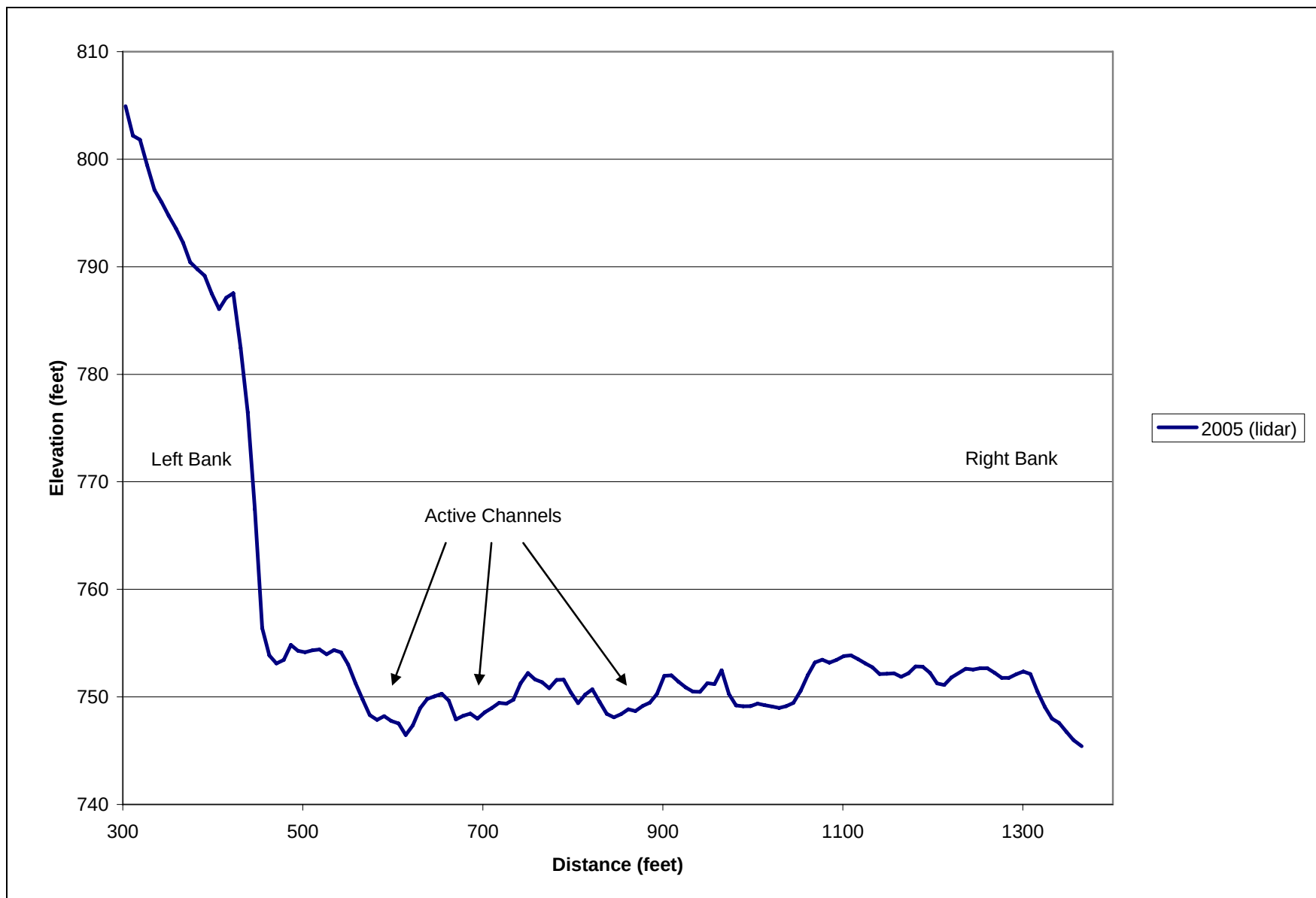


Figure 3. Cross-section of segment 1 of the project reach in lower Canyon Creek at river mile 0.09.

pinks, steelhead, and bull trout when low-flow conditions limit the ability of fish to navigate the falls or when velocities are too high during large discharge events. These 3- to 4-foot cascades were created after the channel incised following relocation of the stream channel by Whatcom County for flood control purposes in 1994 following the debris floods in 1989 and 1990. The bedrock steps have become a chronic challenge to migrating chinook and typically block pink salmon preceding and during spawning in August and September. When barrier conditions occur, salmon become either slowed or blocked and congregate in a pool below the cascades, where they are vulnerable to poaching and predation.

The width of the channel through this segment is narrow (approximately 40 feet), with a 3.0 percent slope and a fairly defined step-pool morphology (based on 2005 LiDAR data) (Figure 4). The notch now acts as a nickpoint at a hydraulic jump and fish passage barrier. Flows are constricted through this segment during high-flow events, with no overbank capacity to dissipate flows and slow velocities or reduce stream power during most high-flow events. This segment would be the ideal location to increase the overbank capacity for maximum benefit to the entire Canyon Creek system in terms of fish passage. This nickpoint has created an hour-glass effect on the creek, where flows must funnel through the constriction at the bedrock during most flow regimes. The bedrock notch is demonstrated to constitute the most significant constraint on habitat forming processes in the project reach. Hence, the restoration options presented later in this report focus on reducing the adverse effects of this bedrock notch and increasing the CMZ and overbank capacity.

Segment 3: Upper Alluvial Fan (RM 0.29 to RM 0.9)

At the head of the alluvial fan, Canyon Creek turns sharply to the left. Currently, the alignment of the creek through this bend is maintained by the 1994 levee (and buried toe) (Appendix A, photo 6). Historically, Canyon Creek built up the surface of the alluvial fan as the channel “switched” positions throughout the entire expanse of the fan, depositing sediment. Therefore, historically the creek channel has occupied all areas of the fan, including the entire area of the Glacier Springs subdivision. Usually, creek channels in this type of system are prone to braiding and changing location frequently.

Because of the sharp left turn due to the location of the levee, the creek has remained constricted within a single-thread channel that has been incising since the construction of the levee in 1994 along the upper part of this segment. This incision was evident during field investigations by Herrera in 2006 and 2007. The creek has incised below the floodplain constructed in 1994, and the toe of this levee appears to be exposed along the right bank. However, the November 2006 event deposited a large amount of sediment within this segment, resulting in a change in the channel position to the left side of the unvegetated channel (Figure 2). The channel through this segment is classified as having mostly a step-pool morphology (Figure 5). The slope of the channel in this segment is 2.7 percent (based on 2005 LiDAR data).

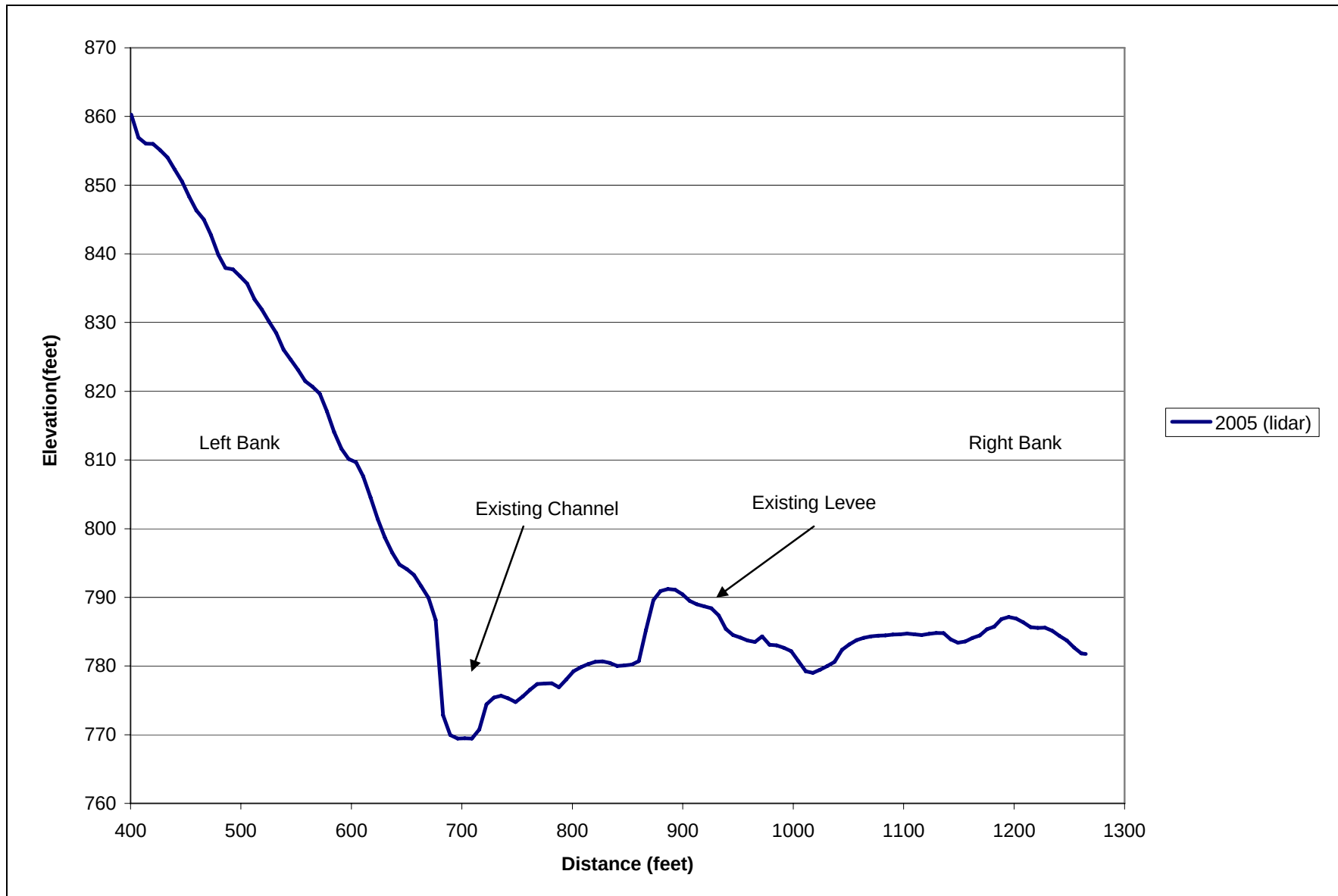


Figure 4. Cross-section of segment 2 of the project reach in lower Canyon Creek at river mile 0.25.

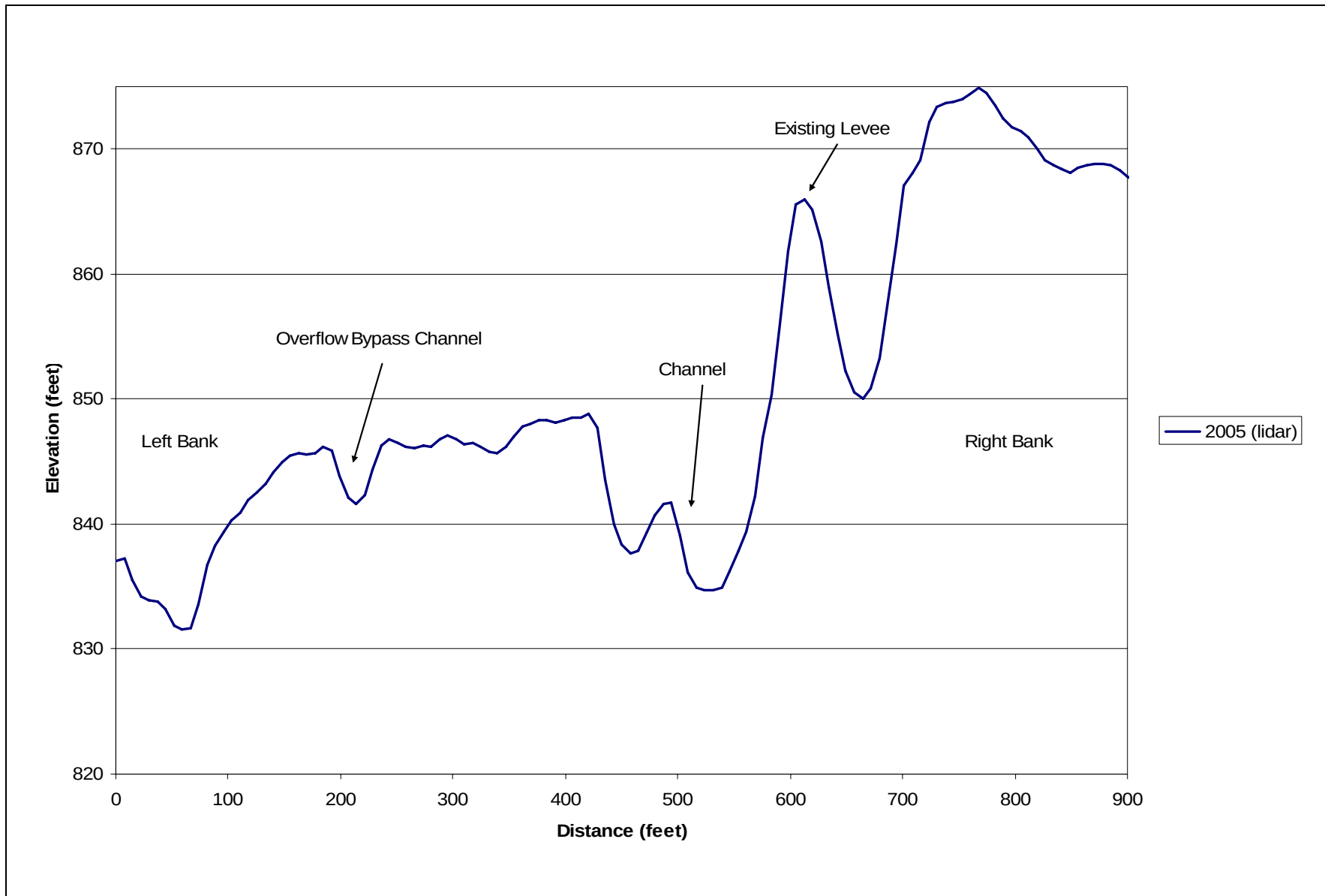


Figure 5. Cross-section of segment 3 of the project reach in lower Canyon Creek at river mile 0.62.

Immediately downstream of the “bend,” the un-vegetated channel immediately widens. This widening has resulted in a braided channel, where the lower creek velocities (in the wider channel) have resulted in the deposition of the sediment transported from upstream areas. Characteristic of braided segments, the channel has changed alignments throughout this segment. Between 2004 and 2006, the channel alignment changed from the left bank to the right bank and back to the left bank after the November 2006 flood event. The frequent channel shifts have inhibited maturation of riparian trees to a size that will effectively provide shading or functional large woody debris in the future.

Habitat Restoration Design Considerations

As part of past investigations of the Canyon Creek alluvial fan, alternatives for providing flood protection to the Glacier Springs subdivision and other properties have been explored by Whatcom County. Two reports have presented options for flood control (Inter-Fluve 2000; KWL 2003). However, these studies did not focus on habitat improvements in the alluvial fan; therefore, they are only briefly summarized below.

Previous Analyses of the Alluvial Fan

As part of the studies by Inter-Fluve and Kerr Wood Leidal, recommendations were made for the project reach of Canyon Creek to address the flooding issues related to Canyon Creek high-flow events (Inter-Fluve 2000; KWL 2003). The measures recommended as a result of these studies are summarized in Appendix B. Most of the measures involve repair, modification, or partial removal of the existing 2,400-foot levee constructed as part of the 1994 corrective measures. Purchase and removal of structures on properties in high hazard areas was also recommended to protect human life and safety in light of the findings that the levee design was unlikely to withstand an event on par with the 1989 debris flood. The levee constricts the channel along the stream's right bank, extending from the upstream bend to the bedrock notch. The levee pinches the channel against the bedrock outcrop at RM 0.21, effectively creating an hour-glass configuration of the current channel. The levee confines the channel in the upper segment of the fan, particularly around the bend of the fan.

Infrastructure and Land Use on the Alluvial Fan

Land use on the Canyon Creek alluvial fan consists mostly of single-family residences constructed on the lower alluvial fan (Table 4). Most of these residences are located in the Glacier Springs subdivision. The concentrated development on and around the alluvial fan and land use within the project reach are elements that were considered during the development and design of potential habitat restoration options. In addition to the Glacier Springs subdivision, SR 542 and the Warnick Bridge are located on the alluvial fan. The Glacier Springs subdivision is a residential community with both seasonal and year-around residences. Approximately 100 lots are located within the subdivision. Of these, approximately 70 percent have been developed.

One objective of the proposed project is to keep the creek within the vicinity of its current channel alignment and not increase the likelihood of avulsion across the alluvial fan through the occupied portions of the Glacier Springs subdivision or other unacquired private property within high hazard zones on the alluvial fan. SR 542 is located along the top of a very high (80 foot), steep right bank (Warnick Bluff) over the North Fork Nooksack River. The project is not expected to increase erosion of the left or right abutments of the Warnick Bridge by actions of North Fork Nooksack River. The project is also not expected to increase erosion of the right (west) abutment by Canyon Creek flood flow across the alluvial fan and the concentration of

Table 4. Physical constraints: existing conditions of infrastructure on and near the Canyon Creek alluvial fan.

Feature	Existing Hazard	Potential Project Limitations
1994 levee (RM 0.2 to RM 0.8), a 2,400-foot levee constructed in 1994 as part of the GeoEngineers (1992) Option 4 selected for the site (after the 1989 and 1990 debris floods)	Erosion. The levee was constructed with a 10-foot-deep buried toe. Because of creek incision and channel migration, it appears the toe of this levee is now exposed in places at its upstream bend. As the levee unravels, large boulders could fall into the creek and compromise the integrity of the structure.	Levee (and toe) likely will continue to erode at the upstream bend. The proposed project should not increase the rate or risk of failure of this levee at its toe. In addition, the location of the levee constricts the lateral migration of the channel and pinches the channel into a narrow constriction point at the bedrock steps at RM 0.21.
Glacier Springs subdivision and associated homes and roads (including the privately-owned property [5-acre parcel])	Flooding and erosion.	Limits restoration options because the development is built on an existing alluvial fan. Previous County buy-out did not include all properties on the alluvial fan, only the properties at highest risk near the right bank. Buy-out (to date) has not included the acquisition of the private 5 acre in-holding within the previously acquired former Logs Resort property.
Canyon View Drive	Erosion of road prism.	Potential for erosion would remain if the upstream portion of the levee were to breach and erode laterally or overtop Canyon View Drive at the existing swale.
SR 542	Erosion and flooding.	The proposed project should keep the creek within the vicinity of its current channel alignment and not increase the likelihood of its avulsing across the alluvial fan through the occupied portions of the Glacier Springs subdivision or other unacquired private property on the alluvial fan. SR 542 is located along the top of a very high (80 foot) steep right bank (Warnick Bluff) bluff over the North Fork Nooksack River.
SR 542 bridge (Warnick Bridge)	Erosion of the left or right abutments of the Warnick Bridge by actions of North Fork Nooksack River. Erosion of the right (west) abutment by Canyon Creek flood flow across the alluvial fan and concentration of flow along the SR 542 right-of-way entering the North Fork Nooksack River at the right abutment.	Proposed project should not directly influence the location of North Fork Nooksack River channel. Bridge footings may be compromised if the North Fork Nooksack River erodes along the left bank at the bridge crossing. Even with no action, Canyon Creek has a history of flowing across its alluvial fan, resulting in southerly prograding of the fan, which forces the North Fork Nooksack River against its left bank upstream of the Warnick Bridge. These actions have resulted in erosion of the left bank of the North Fork Nooksack River and minor landslides.

flow along the SR 542 right-of-way entering the North Fork Nooksack River at the right abutment. The project is not expected to directly influence the location of North Fork Nooksack River channel. The bridge footings may be compromised if the North Fork Nooksack River erodes along the left bank at the bridge crossing. Even with no action, Canyon Creek has a history of flowing across its alluvial fan, resulting in southerly prograding of the fan, which forces the North Fork Nooksack River against its left bank upstream of the Warnick Bridge. These actions have resulted in erosion of the left bank of the Nooksack River and minor landslides.

Habitat Restoration Options

The options for habitat restoration primarily focus on increasing the available CMZ and eliminating the bedrock notch in segment 2 (RM 0.21 to RM 0.29). Four habitat restoration options are presented in this report: Options A through D. These four options are proposed for implementation during Phase I. Option D represents a no-action alternative. Options A through C vary in terms of the extent of increase in the CMZ and available channel area, while not increasing flood and erosion risk for the Glacier Springs subdivision and SR 542.

The County's primary goal for this project is to address the fish passage barrier caused by the constriction in segment 2 (as described previously). The removal of the levee in segment 2 would increase the available CMZ. An increase in the available CMZ will allow more channel area during flood events, will reduce stream power and associated sediment transport, and may result in the movement of the creek away from the bedrock notch and the development of a new channel alignment within the CMZ (without further alteration to the channel or bedrock). This would allow the creek an opportunity to self correct the fish passage barrier in a passive or indirect manner.

Because of the extremely dynamic nature of alluvial fans and the ability of a stream channel to shift location frequently, placement of a habitat structure on the fan (i.e., a wood structure such as an engineered logjam [ELJ]) may not guarantee the structure will be engaged by creek flows, or the structure may be buried by sediment during a single large flood event or debris flood. Therefore, the implementation of such features may not be practical or feasible for long-term salmon habitat improvements. Effective implementation of these types of features could be challenging upstream and downstream of the bedrock notch, where the channel changes location frequently due to the dynamic nature of the fan. Therefore, the options presented in this section focus on increasing the available CMZ area and the available channel area for the creek to improve habitat conditions. The hydraulic modeling completed for this assessment indicated that removing the bedrock notch alone would not maximize the habitat benefits in the system. To address the high flow and velocity issues associated with higher flow and flood events, segment 2 (the bedrock notch) should be widened by removing the levee and previously placed floodplain boulders throughout this segment as well.

The County proposes to implement the habitat restoration using a two-phased approach. The Phase I habitat restoration options would focus on increasing the CMZ and decreasing the channel constriction at the bedrock notch to improve channel conditions in the lower alluvial fan. Reducing the constriction at the bedrock notch would allow the creek to restore its historical dynamic processes within this constricted segment (i.e., remove the hour-glass effect on the channel and CMZ), which may indirectly address the fish passage barrier at the bedrock notch. In addition, if the bedrock fish passage barrier is not directly or indirectly eliminated through the Phase I actions, then Phase II measures could specifically address the bedrock notch (see the discussion of Phase II habitat restoration options below). Phase II options (if implemented) could address more specific habitat areas within the project reach after the historical processes have been restored to maximize the benefits to habitat.

Elements of the Phase I Habitat Restoration Options

The proposed project would improve habitat conditions in the Canyon Creek alluvial fan by removing a portion of the existing levee and creating a larger CMZ and overbank channel area. The Phase I habitat restoration options (Options A through C) include one or more of the elements described in the following subsections. Details of each of the proposed options are provided in a separate section, “Phase I Habitat Restoration Options.” Engineering design sheets in support of these options are included in Appendix C.

Levee Removal

The proposed habitat restoration options include the removal of portions of the existing levee built as part of the 1994 protection measures. The proposed options include the removal of two different lengths. Based on available information in the GeoEngineers (1992) design, the levee is estimated to be buried approximately 10 feet deep with a 5-foot toe. The levee consists of mostly six-man rock that is approximately 5 feet in diameter. For purposes of this analysis and cost estimating, it is assumed (based on best available information) that the riprap material in this levee is 70 percent salvageable. All of the rock salvaged during the levee removal would be used in the construction of various components of the proposed options or stockpiled for other project elements that may be implemented by other stakeholders or for future project phases.

Toe-Slope Protection

If restoration measures in Canyon Creek involve the removal of the lower portion of the levee, the rock could be made available for use in an engineered toe-slope protection along the eastern side of the SR 542 embankment along a flow path occupied during the 1989 or 1990 flood events. Ideally, the protection would extend westerly from the Warnick Bridge for approximately 800 feet.

The extent of this protection is based on the results of FLO-2D modeling performed by Kerr Wood Leidal as part of its risk analysis (KWL 2003). FLO-2D is an unsteady state two-dimensional finite difference flood routing model used to predict flow depth and velocity for riverine, floodplain, alluvial, and debris flow environments. The velocities and depths for an event of the same magnitude as the 1989 event (approximately 16,000 cfs) were used to size the riprap and determine the extent of treatment necessary (Figures 6 and 7, respectively) (Pittman 2007). As a worst-case scenario, a breach of the existing levee was modeled. Under this scenario, the remaining levee deflects the overflow away from the channel towards the highway. The depth and velocities generated by FLO-2D were used for sizing the potential riprap. Based on preliminary sizing equations, the necessary median diameter (D_{50}) of the rock would range from 3.2 to 4.1 feet (Table 5). KWL Flo-2D modeling results indicate a flow magnitude similar to the 200-year event (16,000 cfs) would largely be contained within the historic active channel area of Canyon Creek with the levee in place (Figure 8).

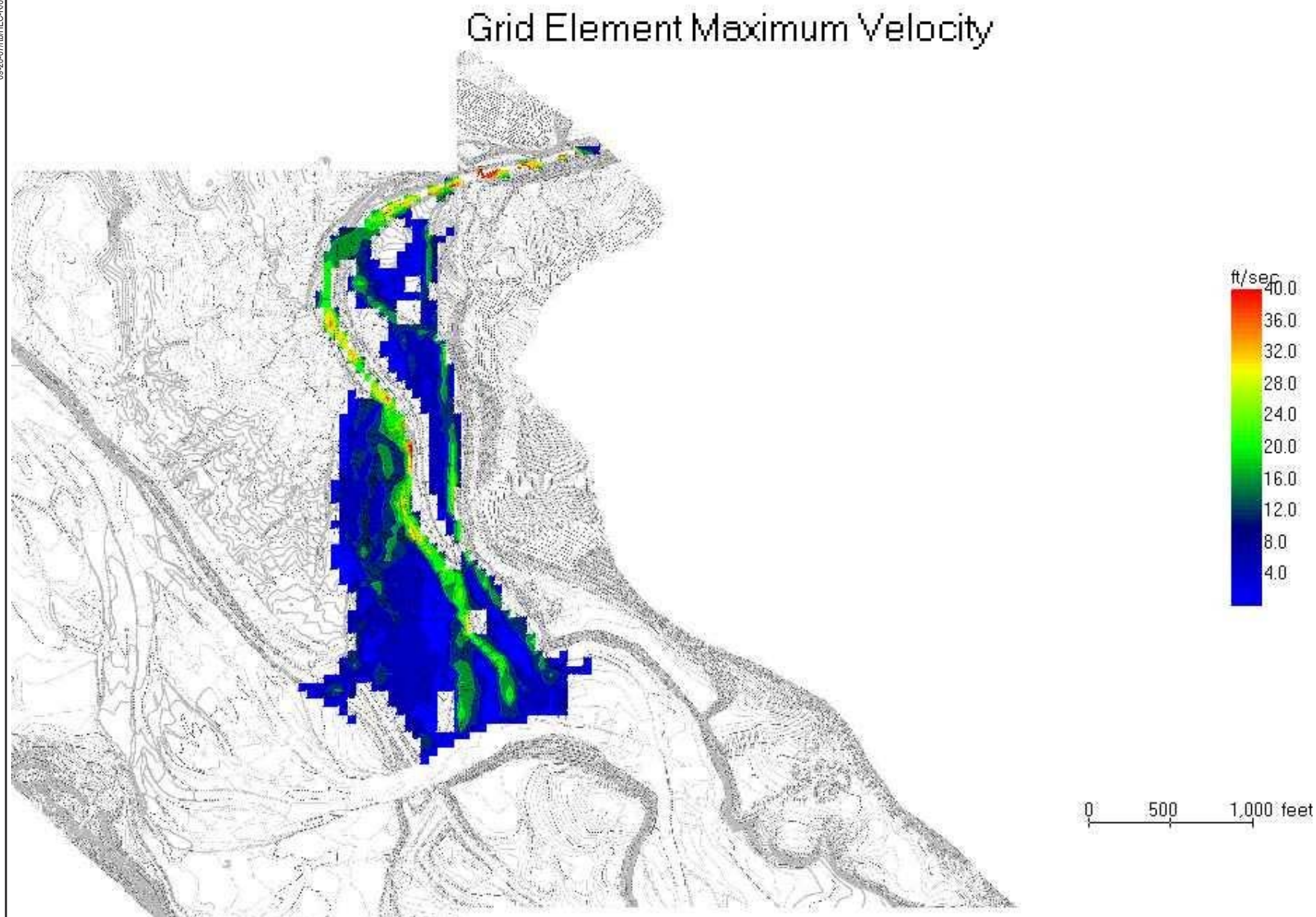


Figure 6. FLO-2D velocity modeling results for lower Canyon Creek at a debris flood magnitude similar to the 1989 event (16,000 cfs) with a breach in the existing levee.

Grid Element Maximum Flow Depth

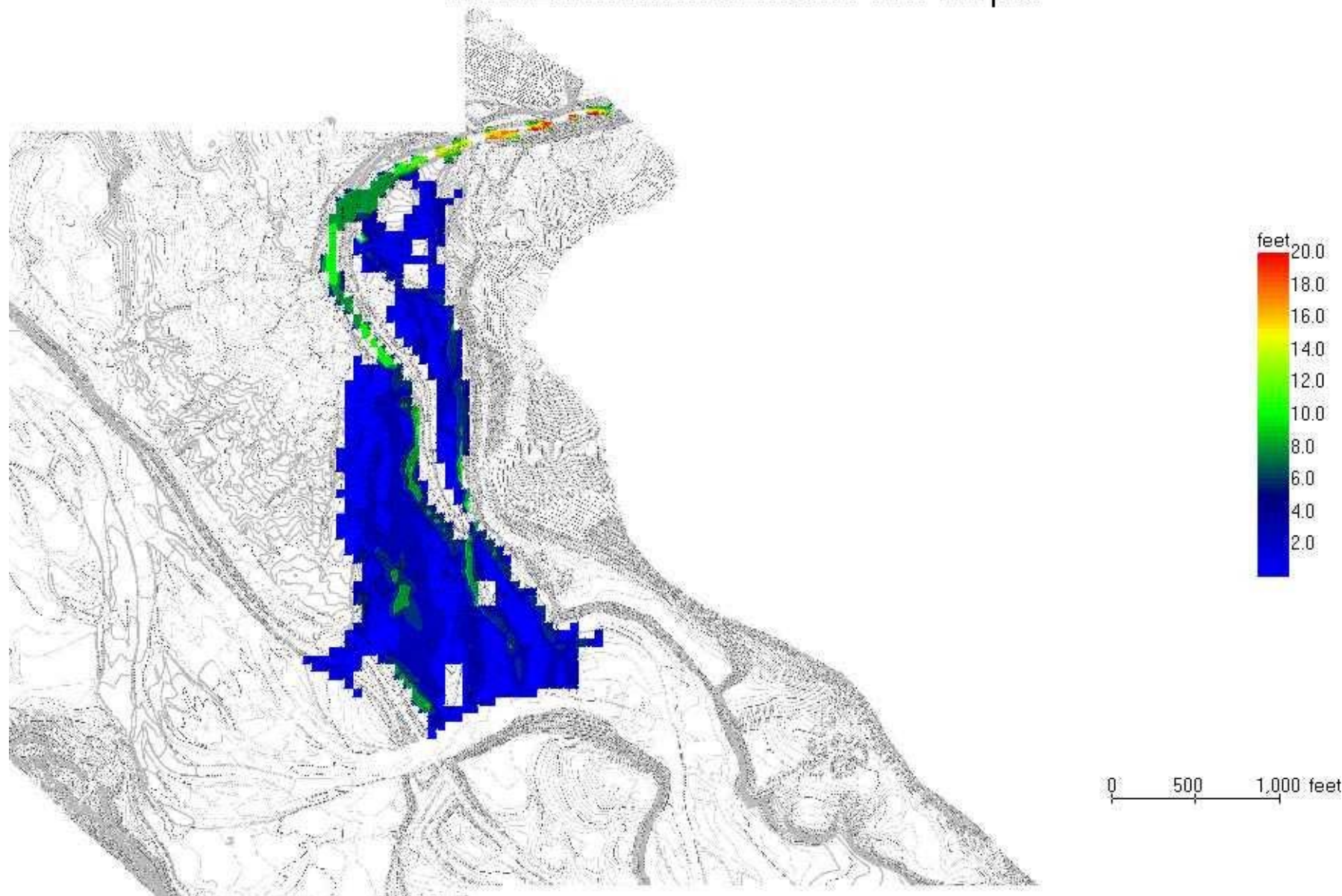


Figure 7. FLO-2D depth modeling results for lower Canyon Creek at a debris flood magnitude similar to the 1989 event (16,000 cfs) with a breach in the existing levee.

Grid Element Maximum Flow Depth

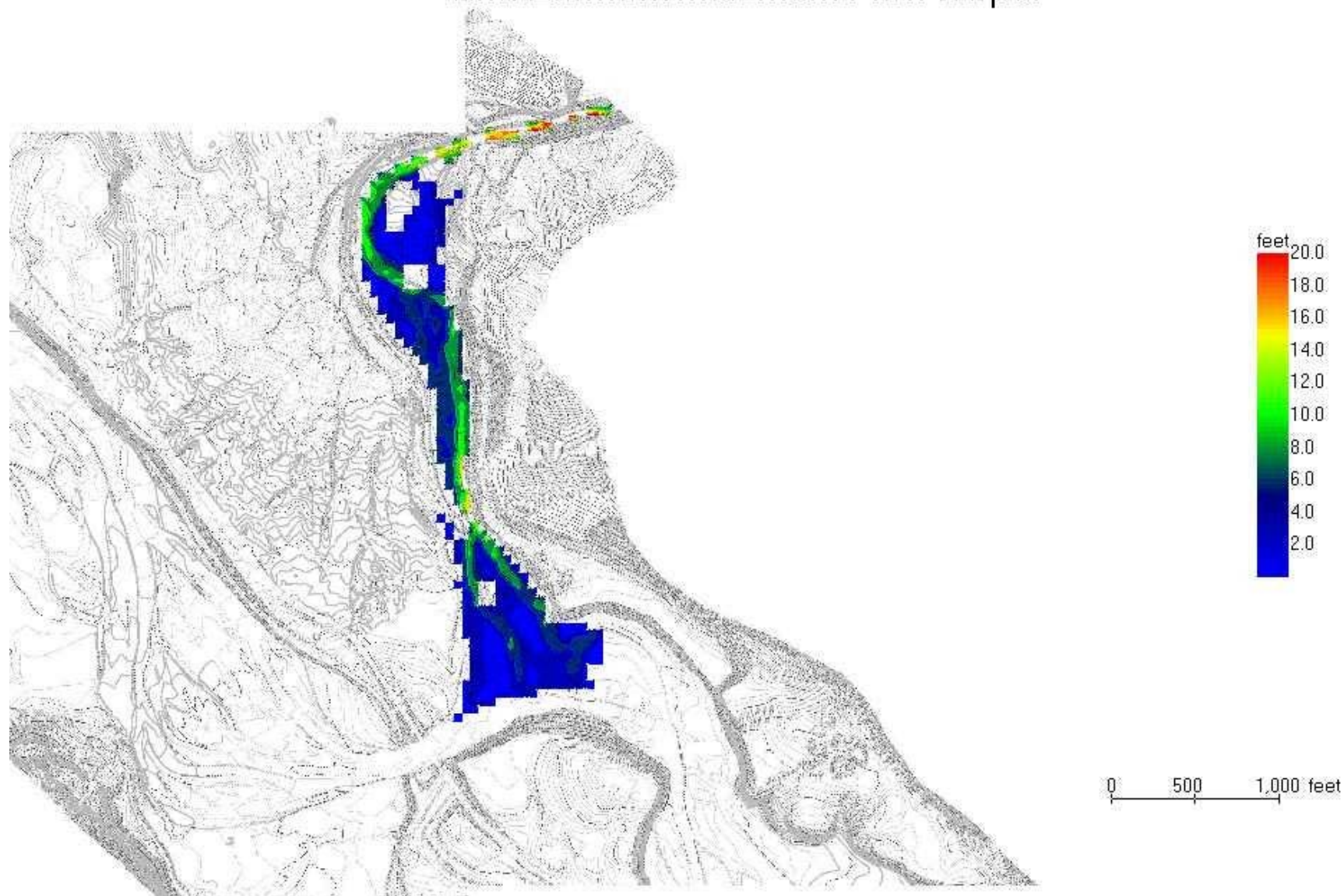


Figure 8. FLO-2D depth modeling results for lower Canyon Creek at a debris flood magnitude similar to the 1989 event (16,000 cfs) with the existing levee alignment.

Table 5. Range of potential D₅₀ riprap size necessary for the toe-slope protection along SR 542.

Method of Calculation	Velocity (feet/second) ^a	Depth (feet) ^a	Riprap Calculated (D ₅₀) (feet)
USACE EM 1110-2-1601 (1994)	8	14	3.2
Caltrans rock slope protection (2000)	8	14	3.2
FHWA HEC 11 (1989)	8	14	4.1

^a Depth and velocity from FLO-2D modeling results for lower Canyon Creek based on a levee breach with a flood flow rate similar to that of the 1989 event (16,000 cfs) (KWL 2003).

For a design event of the magnitude of the 1989 debris flood, the toe-slope protection structure would be approximately 800 feet in length and would be excavated to a maximum depth of 20 feet. The face of the protection would have a 1.5:1 horizontal face slope and would follow a 3 percent slope up from the North Fork Nooksack River. The depth of the toe-slope protection excavation for rock placement would be set at the elevation of the North Fork Nooksack River (at southern/easterly extent). The depth of excavation would follow an approximately grade of 3 percent up-gradient along SR 542 for the extent of this protection. This is the gradient of Canyon Creek through the alluvial fan and is assumed (for design purposes) as the potential scour depth along the toe-slope protection. To account for some scour, the elevation of the protection is set 5 feet below the 3 percent slope elevation up from the North Fork Nooksack River with a 5-foot water depth. Also, this protection is designed with a self-launching toe in the event that it is subject to additional scour.

A design to protect for the 100-year clearwater was not prepared for two reasons. First, a flood of this magnitude, with or without the levee, in not modeled to produce flow through the former Logs Resort property. Hence flow through the swale adjacent to the highway would be negligible or non-existent and threat to the highway would be minimal. Second, based on the County's conversations with WSDOT staff, it seemed prudent to design to a known flood event of larger magnitude that was documented to have put flow into the swale along the highway.

Topographic Low Fill

A topographic low that extends for approximately 400 feet along the western edge of the former Logs Resort would be filled with spoils (alluvium composing the levee prism) salvaged during the levee removal (under Options A and B only). After completion, this filled area would be revegetated with native vegetation. This area would be filled so that it would not serve as a preferential flow pathway during a peak flood event.

Floodplain Boulders

Approximately 21 boulders were placed along the right bank area at the head of the bedrock notch as part of the 1994 actions by Whatcom County (Appendix A, photo 11). These large boulders were initially placed with the intent of helping funnel flows into the head of the bedrock

notch. Removal of these boulders is proposed under Options A through C to reduce the constriction they pose. These boulders could be placed either in the channel upstream to encourage minor channel movement away from the bedrock notch, randomly downstream of the bedrock notch to provide floodplain roughness, or they could be removed from the channel altogether and placed with the levee rock in the highway toe-slope protection or stockpiled. The final placement of these boulders would be determined onsite during implementation of the selected option by Whatcom County's site engineer and geomorphologist and in consultation with permitting agencies, or stockpiled for later placement. If placed in-channel, care would be taken to ensure that flow towards the subdivision is not encouraged or where they would not impede fish passage.

Phase I Habitat Restoration Options

Implementation of the Phase I habitat restoration options would focus on increasing the CMZ and available channel area through the bedrock notch during all flow scenarios by allowing the channel to resume its historical channel alignments within the lower alluvial fan. The four Phase I options (Options A through D) are described in detail in the following subsections. As discussed above, if further habitat enhancement options are warranted after the implementation of Phase I, they may be implemented as part of a next phase (Phase II) to improve the channel conditions at the bedrock notch or the habitat conditions resulting from the implementation of Phase I and other natural processes.

Description of Phase I Restoration Options

Option A

Option A would involve removing the lower 520 feet of the existing Canyon Creek levee and removing the floodplain boulders that have been placed along the right bank (Figure 8). The levee would be removed to the downstream boundary of the 5-acre private in-holding. What remains of the cabled log revetments would be removed along the right bank, downstream of the bedrock notch (RM 0.21) so that lateral channel migration (to the west) would not be impeded. The removal of the lower part of the levee and the log revetments would increase the available CMZ by approximately 18.4 acres (Figure 9), encouraging the creek to move away from the bedrock notch and develop a new channel alignment within segment 2 (without further manmade alteration to the channel or bedrock). This new channel alignment would allow the creek an opportunity to self correct the fish passage barrier in a passive or indirect manner. The correction would likely occur during a higher flow event, when overbank channel flow conditions are occurring upstream of the bedrock notch. Such conditions would allow water to flow along the right side of the channel in the area of the existing levee and floodplain, which would be available for the creek after the removal action.

After the removal of the lower section of the levee, the riprap could be used to construct toe-slope protection along SR 542 to further protect the highway from Canyon Creek up to at least the 100-year clearwater flood. Ideally, this highway protection would be 800 feet long, extending northwest from the Warnick Bridge along the east side of the bridge. This toe-slope

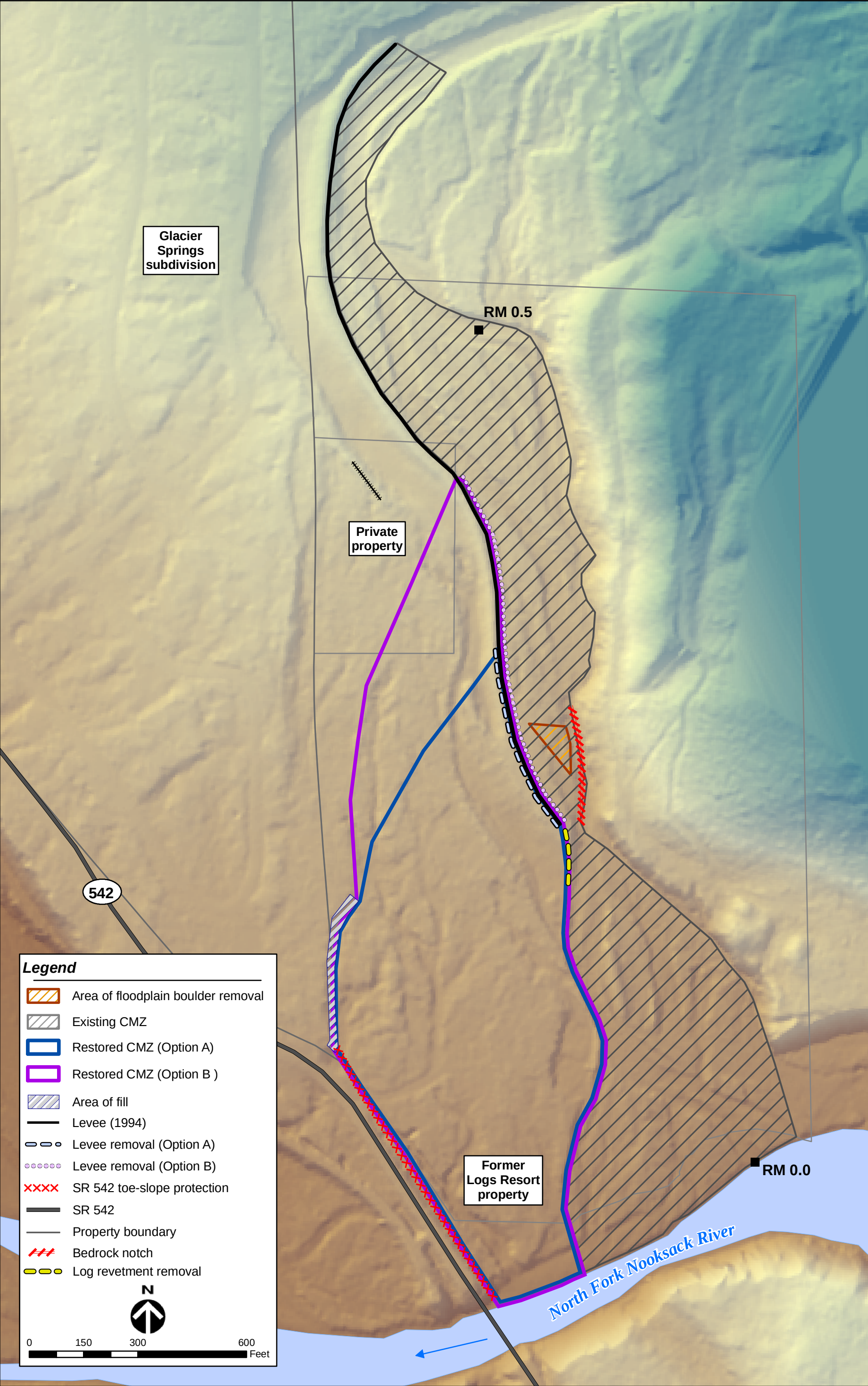


Figure 9. Proposed Phase I Option A and Option B for the Canyon Creek alluvial fan habitat restoration.

protection would protect the highway from potential flows from Canyon Creek that may cross the lower part of the alluvial fan in the area of the former Logs Resort. In addition, the low swale (approximately 400 feet long) along the western edge of the former Logs Resort would be filled with alluvium excavated during the levee removal. Whatcom County is in ongoing discussions with WSDOT to determine their level of participation in this component of the project.

Option B

Option B would involve removing the lower 1,025 feet of the existing Canyon Creek levee and removing the floodplain boulders that have been placed along the right bank (Figure 9). What remains of the cabled log revetments would be removed along the right bank downstream of the bedrock notch (RM 0.21). The removal of the lower part of the levee and the log revetments would increase the available CMZ by approximately 22.8 acres.

Similar to Option A, toe-slope protection could be constructed along SR 542 for a distance of 800 feet from the Warnick Bridge, along the east and north side of the highway. In addition, the low swale along the western edge of the former Logs Resort would be filled with alluvium excavated during the levee removal to prevent this area from becoming a flow path during a flood event.

Option C

There are two variations of Option C referred to as Option C-1 and Option C-2. Option C-1 would involve removing 520 feet of the existing Canyon Creek levee (the length to be removed under Option A) (Figure 10). Option C-2 would involve removing 1,025 feet of the levee (the length to be removed under Option B). This option would increase the available CMZ either by 18.4 acres (Option C-1) or 22.8 acres (Option C-2). Similar to Options A and B, toe-slope protection could be constructed along SR 542 after the levee removal. Option C would not include filling in the low-lying swale area that extends along a portion of the east side of the Glacier Springs subdivision.

Option D

Under Option D (no action), the existing Canyon Creek levee would remain in place and conditions at the bedrock notch that have resulted in channel constriction would not be improved. Erosion of the bedrock notch would likely continue, resulting in larger steps that would further impede fish passage through this segment of the project reach. In addition, further exposure of the bedrock fans just upstream of the bedrock notch may continue. No toe-slope protection would be constructed along SR 542.

Comparison of Phase I Restoration Options

The implementation of Options A through C would help to improve habitat conditions within the Canyon Creek alluvial fan (downstream of RM 0.5).

Improvements in Habitat Conditions

Options A through C would approximately double the existing amount of CMZ available to the creek (Table 6) by the removal of the levee and floodplain boulders that currently limit channel migration and fish passage. The rationale for these options is that expanding the CMZ in the constricted area of segment 2 (RM 0.21 to RM 0.29) will encourage the channel to shift away from the existing bedrock notch, improving fish passage conditions. However, as a first step, the levee must be removed throughout segment 2 so that the available channel width and capacity are increased to allow the channel to move away from the bedrock notch. Similar to the other parts of the alluvial fan, the creek uses most of the available channel area (Figure 2). If the creek migrates away from the bedrock notch, the channel would no longer be constricted in a narrow bedrock channel, which should result in a decrease in flow velocities and stream power as the channel width increases over the wider available channel area. Options A through C would allow the opportunity for the channel to naturally shift away from the bedrock notch and improve fish passage. The more of the levee that is removed, the more available CMZ and habitat area would be available. This change in channel alignment may not occur until the wet season, when high-flow conditions occur in the channel. Therefore, improvements in fish passage through the bedrock notch may not occur immediately after levee removal.

Table 6. Summary of habitat restoration options for the Canyon Creek alluvial fan.

Option Attribute	Option A	Option B	Option C-1	Option C-2	Option D
Existing levee removal (linear feet)	520	1,025	520	1,025	0
Increase in available CMZ (acres)	18.4	22.8	18.4	22.8	0
Salvaged riprap (cubic yards)	2,940	5,880	2,940	5,880	0
Imported riprap (cubic yards)	3,460	520	3,460	520	0
Number of floodplain boulders removed	21	21	21	21	0
SR 542 toe-slope protection (linear feet)	800	800	800	800	0
Filled topographic low (linear feet)	400	400	0	0	0
Toe-Slope Protection Cost ^a	\$543,799	\$466,722	\$543,799	\$466,722	\$0
Estimated total cost (2007 dollars) ^b	\$1,151,385	\$1,286,744	\$1,158,447	\$1,286,170	\$0

^a Toe-slope protection cost shown does not include tax, bonding, insurance and 30% contingency.

^b Total cost includes tax, bonding, insurance and 30% contingency.

The difference between Option A and Option B in terms of increase in available CMZ would be approximately 4.3 acres, 18.4 acres under Option A and 22.8 acres under Option B (Table 6). Option C would allow for approximately the same increase in available CMZ, depending on the amount of the existing levee that is removed (520 linear feet under Option C-1 or 1,025 linear feet under Option C-2). The Phase I habitat restoration options would allow passive measures to improve conditions resulting from the manmade bedrock notch, by encouraging the channel to naturally shift away from the bedrock notch. However, there is a possibility that the levee removal would not result in channel migration away from the bedrock notch and no improvement in fish passage would occur in segment 2. If this is the case, the County or another WRIA 1 restoration partner would address the bedrock notch as part of Phase II restoration actions.

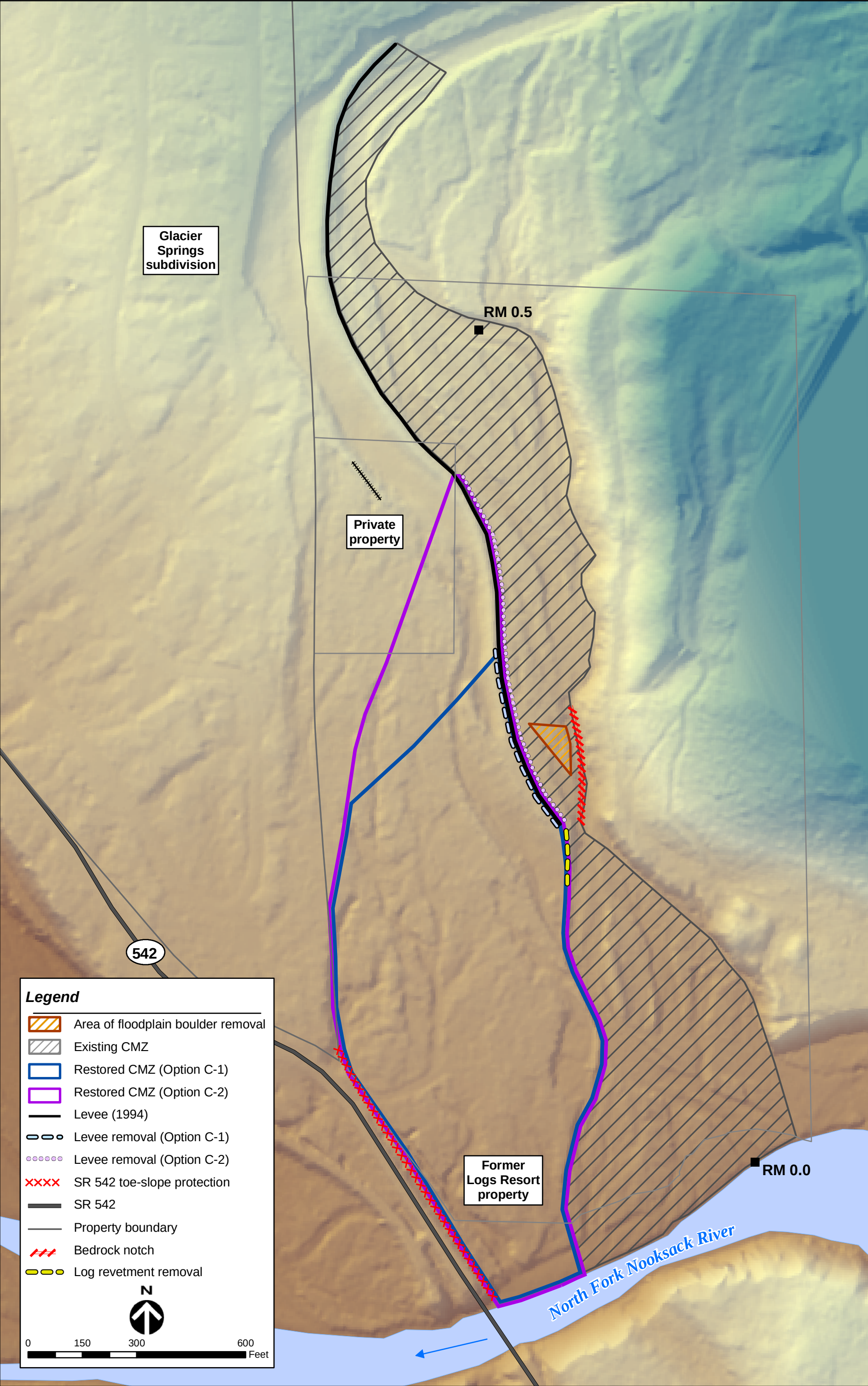


Figure 10. Proposed Phase I Option C for the Canyon Creek alluvial fan habitat restoration.

Estimated Costs

Restoration costs (in 2007 dollars) were developed for the proposed restoration options (A through C) (Table 6). There would be no restoration costs associated with Option D (no action). The estimated costs for implementing the options range from \$1,151,385 (Option A) to \$1,286,744 (Option B). Complete cost sheets for all restoration options are included in Appendix D.

Potential Effects of Restoration Options on the Levee

If as a result of the restoration, the channel shifts away from the bedrock notch, adjustments to the existing channel grade would occur. These adjustments may affect the elevation of the channel bed upstream of the bedrock notch as the channel bed equilibrates to the new grade. Initially the channel would likely undergo some incision immediately upstream of the bedrock notch as it adjusts to this grade change. If during this adjustment period, the creek is aligned adjacent to the remaining levee, there is a possibility that the toe of the remaining levee could become exposed. The toe may become exposed along the extent of the levee just upstream of the bedrock notch; however, no effects would be expected farther upstream in the area where the levee bends at the upper limit of the project reach. The channel would eventually adjust to its new slope and reach a dynamic equilibrium. More of the levee (at base) may be exposed from this adjustment. However, if the shorter levee removal option is selected (Option A or C-1) then this bed adjustment would likely not extend as far to the north (upstream) because the adjustment would start farther downstream with the shorter removal option. Therefore, a greater distance to private property would be adjacent to where this bed adjustment may occur than with Option B or C-2 (longer levee removal) where levee removal would extend farther to the north and in closer proximity to private property.

Phase II Habitat Restoration Options

The Phase II habitat restoration options would build upon the new habitat area resulting from implementation of the selected Phase I restoration option. All of the options included in Phase I would almost double the amount of available CMZ downstream of RM 0.3. Increasing the CMZ would allow the stream more migration area and help to attenuate flood flow velocities. The Phase II habitat restoration options are presented below by segment. The Phase II objectives include the following:

- Remove or modify the bedrock notch (if there is still a fish passage issue after the implementation of the Phase I option)
- Improve riparian habitat conditions
- Increase the potential for recruitment of large woody debris
- Improve habitat and channel complexity
- Remove more of the levee.

Segment 1: Lower Alluvial Fan (RM 0.0 to RM 0.21)

Segment 1 of the project reach is characterized by a partially braided channel. The channel is extremely dynamic throughout this segment, shifting its location frequently (as evident by the photographic record). The unvegetated channel is wide and approaches 400 feet. The wetted channel occupies a much smaller area within this unvegetated segment. However, overall the frequently shifting channel remains unvegetated because the moving water wipes out any vegetation before it can become established, thereby limiting the development of new riparian buffer or forested islands. Riparian cover is very limited within this segment and the recruitment of large woody debris is low because of a lack of forested riparian areas that are adjacent to the active channel.

Potential Phase II habitat restoration options for segment 1 include the following:

- **Creation of channel hard points.** Channel hard points could be created by constructing logjam structures (Figure 11). The intent of these logjams is to develop areas with the potential for establishing and sustaining a mature riparian forest, which could provide the following benefits:
 - Increase large woody debris in the system
 - Increase the potential for future recruitment of large woody debris
 - Improve riparian habitat conditions
 - Increase habitat diversity by increasing channel length, pools, and complexity.

Log jam construction costs, depending on design complexity and size, may range from \$80,000 to \$120,000 per structure.

- **Establishment of mature riparian buffer.** Strategically placed bank ELJs or similar wood revetment structures would likely be sustainable and promote the development of a mature riparian vegetated buffer. Riparian buffer construction costs may range between \$60,000 to \$80,000 per acre.

Segment 2: Bedrock Notch (RM 0.21 to RM 0.29)

If the channel does not migrate away from the bedrock notch naturally after implementation of the Phase I option, fish passage would remain a problem in segment 2. The problem could potentially become worse as further erosion of the bedrock increases the height of the bedrock steps that pose a barrier to fish passage. In addition, the exposure of more bedrock (from stream erosion) just upstream of the constriction along the left bank could increase the fish passage problem by increasing the length of this constricted segment.

If the Phase I restoration option does not improve fish passage, further corrective action may be necessary. Additional measures would involve altering the bedrock in segment 2 or filling the bedrock notch (Figure 12) so that the channel can expand and migrate throughout the segment.

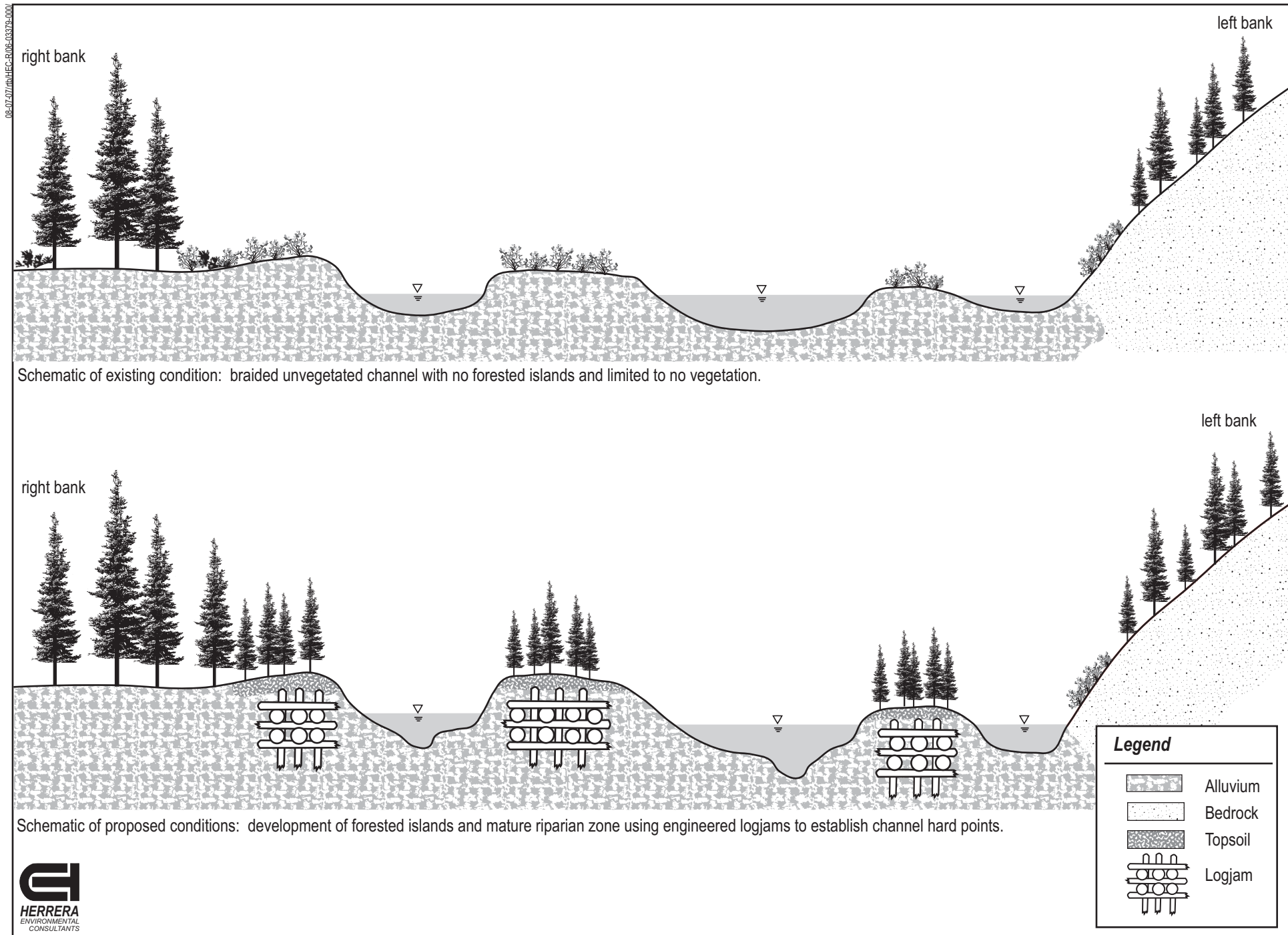
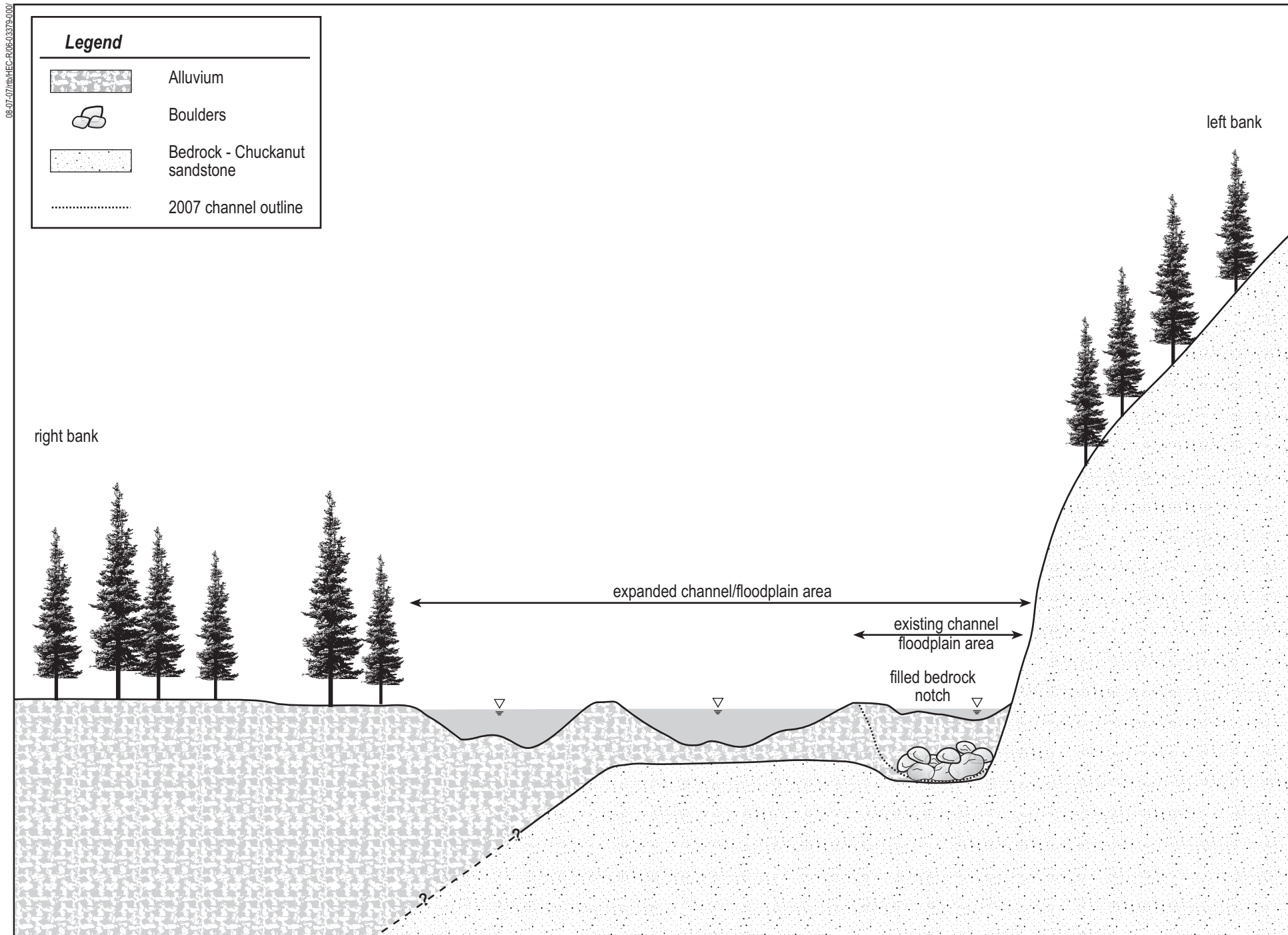


Figure 11. Potential Phase II restoration option in sement 1 of the Canyon Creek project reach (after levee removal as part of Phase I), showing existing and proposed conditions.



Potential Phase II habitat restoration options for improving fish passage in segment 2 include the following:

- Filling of the bedrock notch channel with large rock and alluvium
- Relocation of the active channel away from the bedrock notch
- Mechanical removal of the right bank of the notch creating additional smaller passable steps in the notch throughout the segment.

Segment 3: Upper Alluvial Fan (RM 0.29 to RM 0.9)

Phase I habitat restoration options are not proposed for Segment 3. Phase I would not impact the 1994 levee along the right bank of the creek through this segment. The Glacier Springs subdivision is located immediately west of the creek channel, which limits the potential for restoring the historical CMZ. Potential Phase II habitat restoration options in Segment 3 include the following:

- **Construction of engineered logjams.** ELJs could be constructed along the banks or in the channel to improve fish habitat. In addition, ELJ structures could be built behind the right bank levee along Canyon View Drive (Figure 13). These structures would provide habitat enhancement along the right bank in the upper alluvial fan. Given the exposure of the current revetment toe, this would provide significant habitat should the levee fail, and minimize the potential for public demand of a new riprap structure. In addition, placement of these structures would have to be supported by hydraulic modeling to ensure that backwater effects from the ELJs does not increase the flood risk to the Glacier Springs subdivision. Because of the proximity to the Glacier Springs subdivision, these structures would be designed to meet “factor of safety” requirements to limit risk to property. The greater the factor of safety requirements, the greater these structures would cost to build. Log jam construction costs, depending on design complexity and size, may range from \$80,000 to \$120,000 per structure.
- **Development of riparian buffer.** A mature riparian buffer could be developed between Canyon View Drive and the unvegetated channel. This area would help to improve the habitat conditions in the channel and the potential for recruitment of large woody debris, as well as providing additional protection for the highway and the Glacier Springs subdivision. The development of a new riparian buffer may range from \$60,000 to \$80,000 per acre.
- **Additional levee removal.** If only the shorter levee length is removed during Phase I (under Option A or Option C-1), further removal of the levee upstream of RM 0.30 could occur. Based on levee removal costs

developed for the restoration options presented in this report (see Appendix D), the cost to haul and locally dispose of levee material is approximately \$10 per cubic yard, based on County quote.

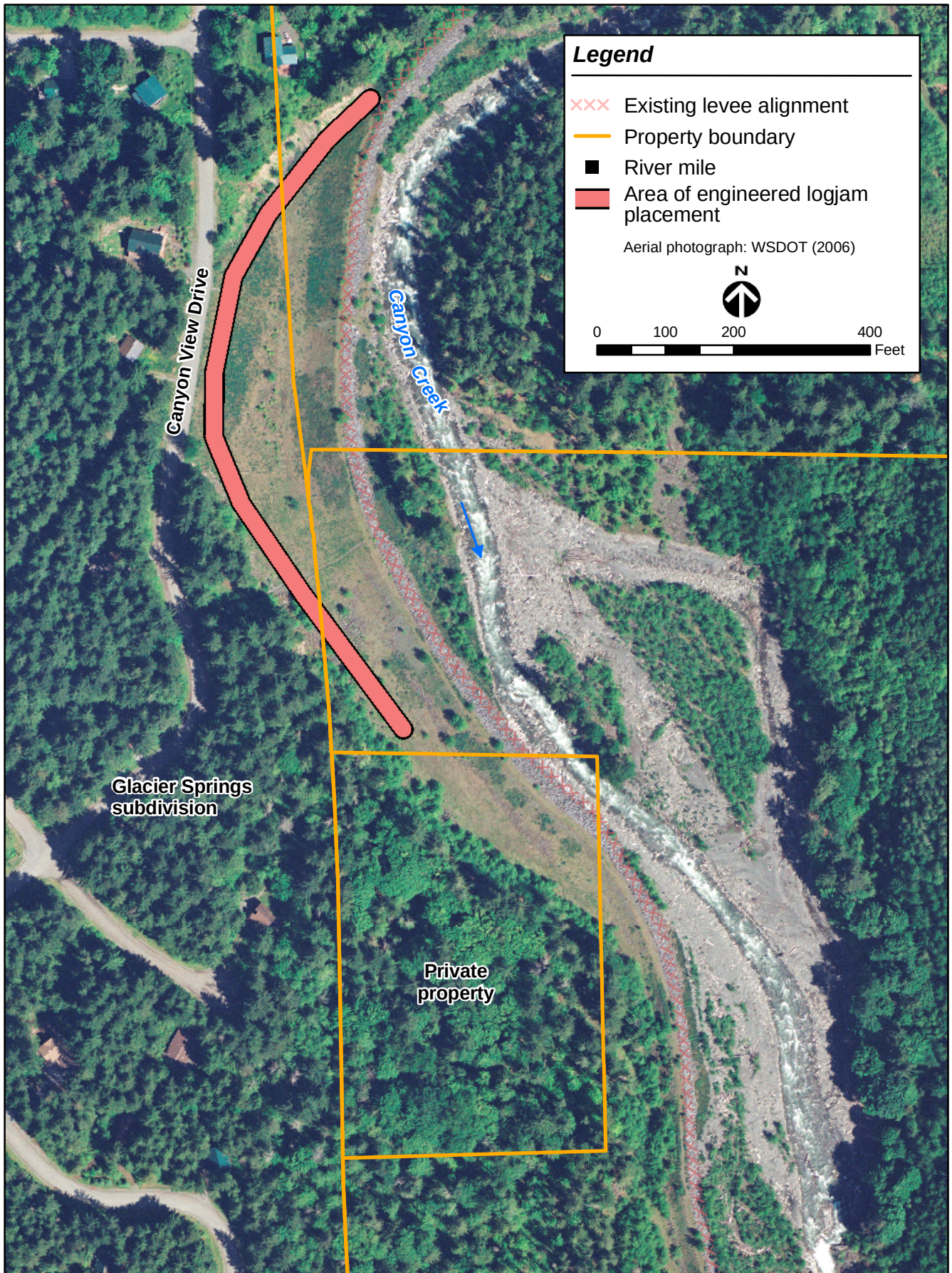


Figure 13. Potential Phase II restoration option in segment 3 of the Canyon Creek project reach.

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APPENDIX A

Photographs of the Project Reach for the Canyon Creek Alluvial Fan Habitat Restoration



**Photo 1. View looking downstream along the Canyon Creek 1994 levee, March 2007.
Photo by Herrera.**



Photo 2. Segment 1 of Canyon Creek project reach, looking downstream from lower extent of the 1994 levee along the right bank, March 2007. Photo by Herrera.

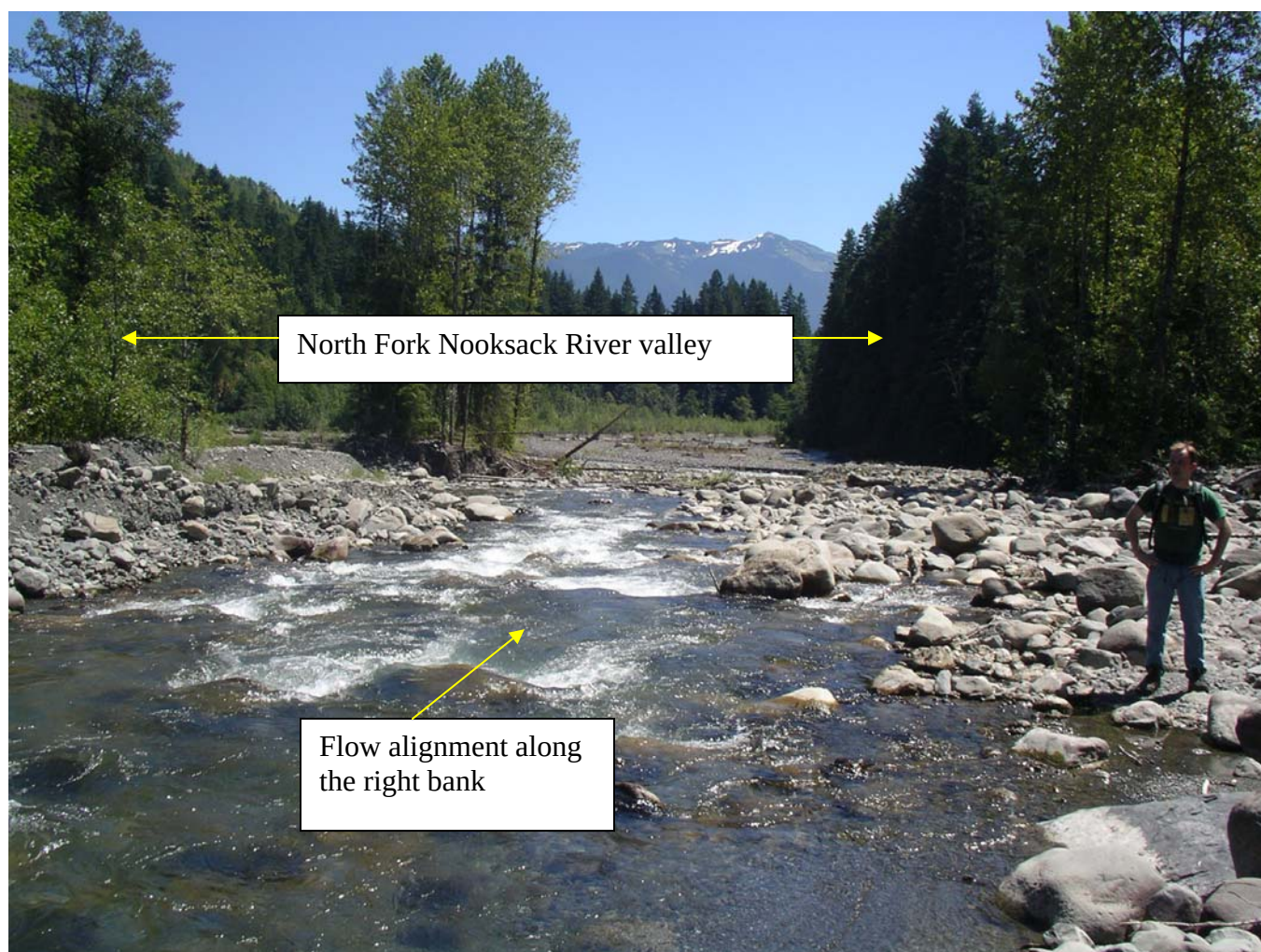


Photo 3. Segment 1 (lower alluvial fan) of Canyon Creek project reach, looking downstream at the confluence with the North Fork Nooksack River, July 2006. Photo by Herrera.



Photo 4. Segment 2 (bedrock notch) of Canyon Creek project reach, looking downstream from the right bank, March 2007. Photo by Herrera.



Photo 5. Segment 2 of Canyon Creek project reach, looking upstream from the right bank, February 2007. Photo by Whatcom County.

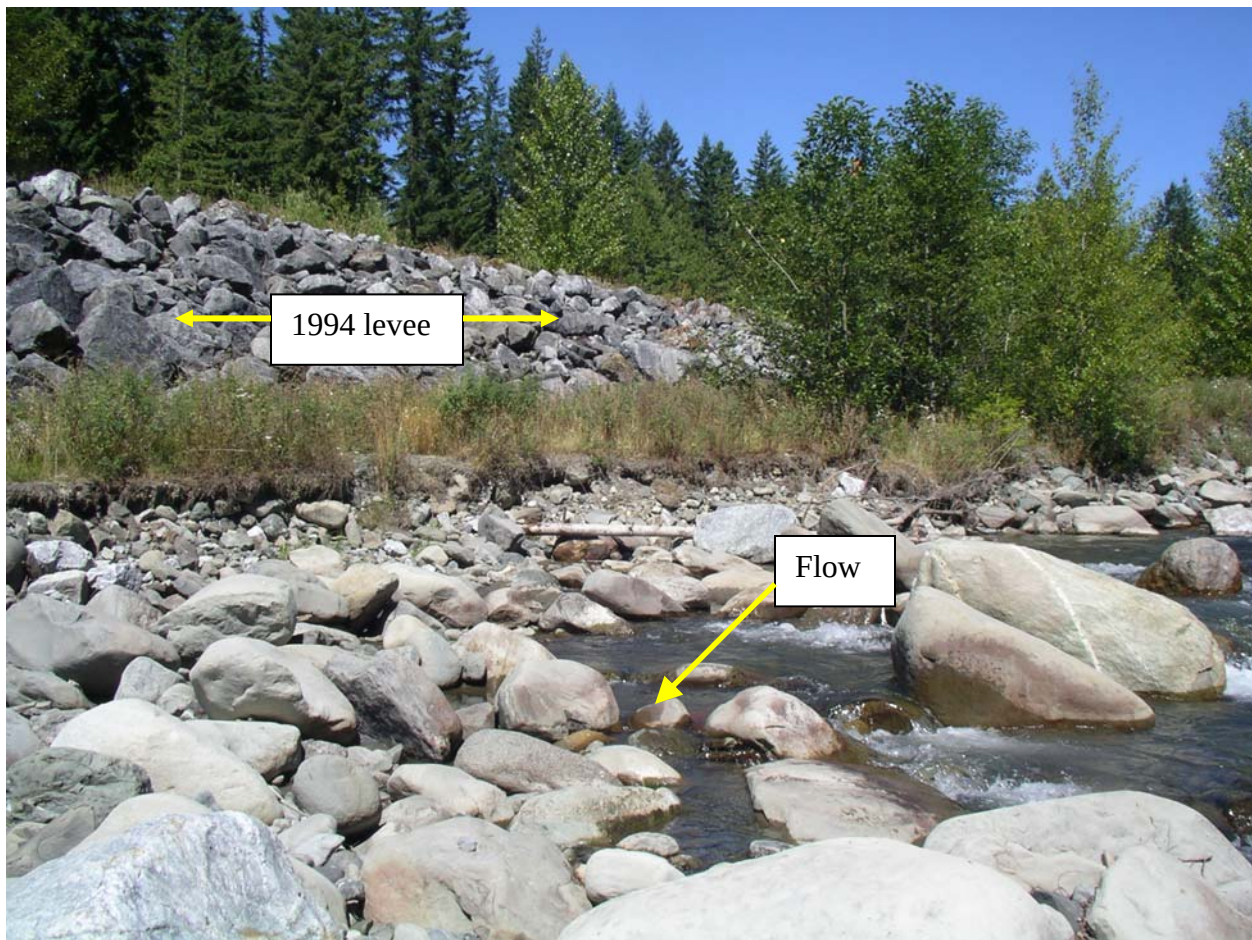


Photo 6. Levee and creek channel in segment 3 (upper alluvial fan) of Canyon Creek project reach, looking upstream along the right bank, July 1996. Photo by Herrera.

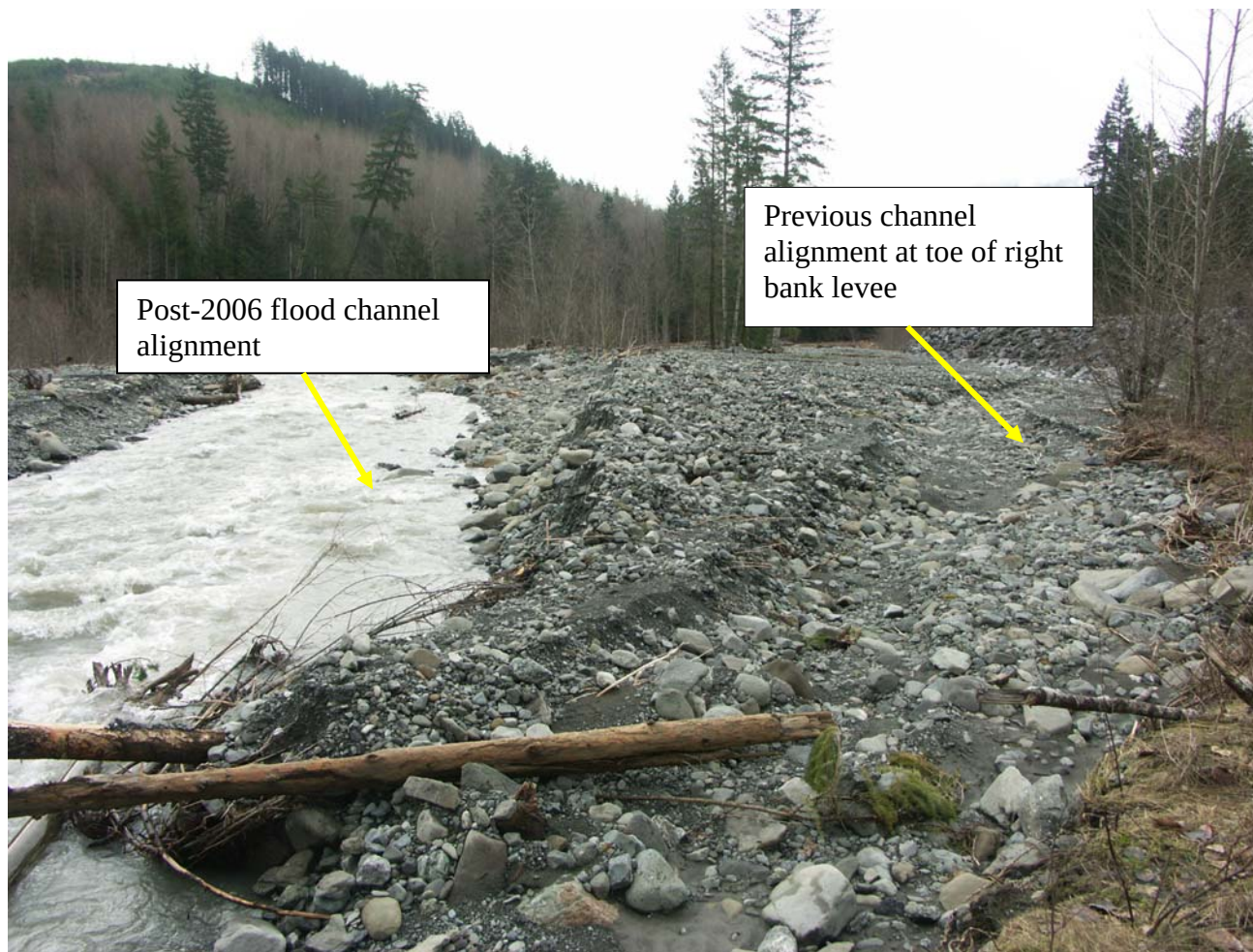


Photo 7. View looking downstream of Canyon Creek new channel alignment after November 2006 flood event, February 2007. Photo by Whatcom County.

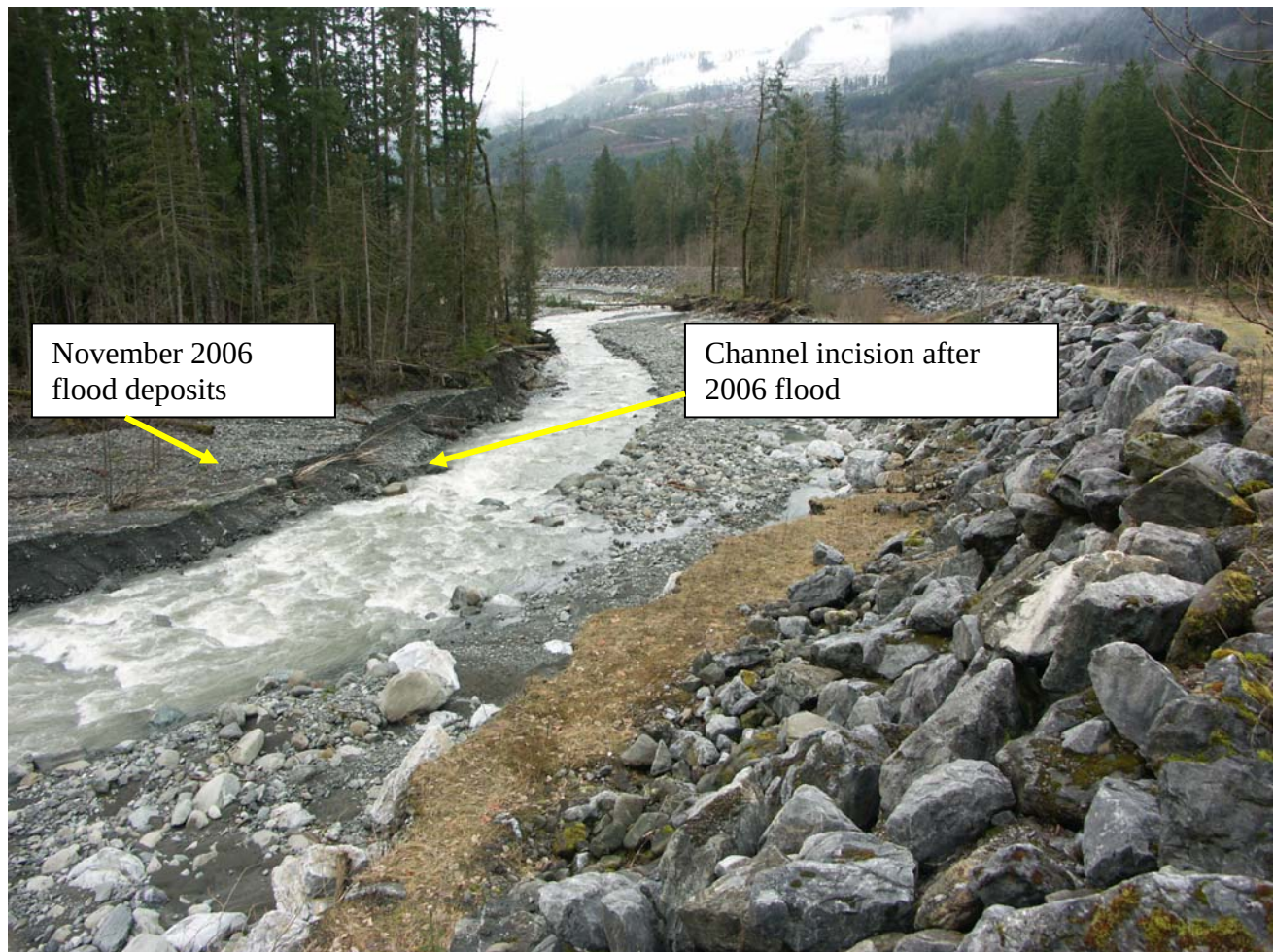


Photo 8. View looking downstream along the 1994 levee (right bank) showing post-November 2006 flood channel incision, February 2007. Photo by Whatcom County.

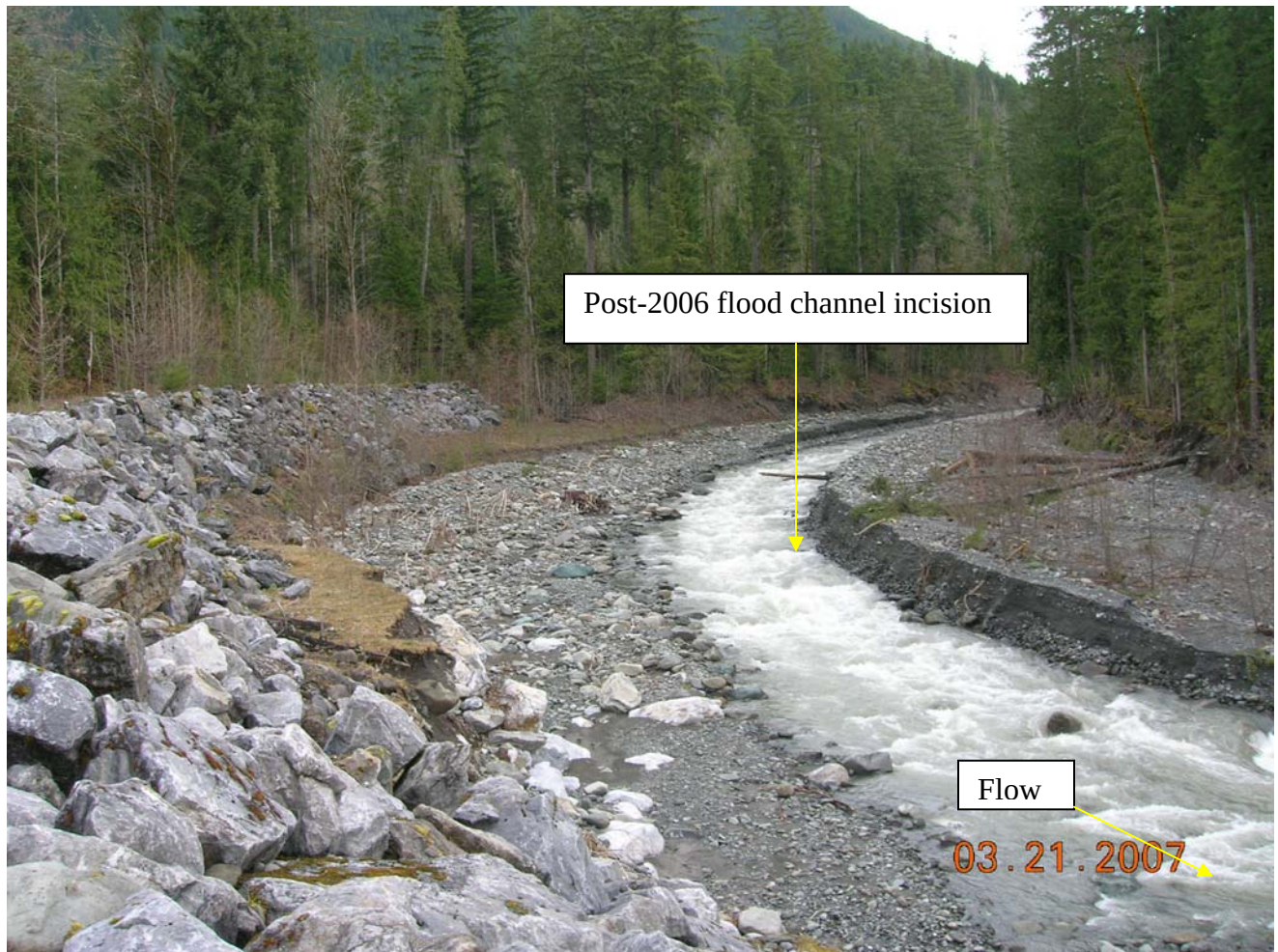


Photo 9. Segment 3 of Canyon Creek project reach, looking upstream from the right bank levee, March 2007. Photo by Herrera.



Photo 10. Segment 3 of Canyon Creek project reach, looking downstream from the right bank levee, March 2007. Photo by Herrera.



Photo 11. Floodplain boulders within the Canyon Creek floodplain (segment 2), March 2007. Photo by Herrera.

APPENDIX B

Habitat Restoration Options
Recommended by Inter-Fluve, Inc.,
and Kerr Wood Leidal Associates, Ltd.

Table B-1. Canyon Creek Habitat Restoration Options identified by Inter-Fluve, Inc.

Option	Habitat Benefit	Costs Listed in 2000 Report (Approximate)
1a. Maintain existing dike. Repair and maintenance of the existing armored dike upstream of Logs Resort.	Same as existing condition.	\$90,000
1b. Maintain existing dike. Repair and maintenance of the armored dike and purchase of Logs Resort.	Same as existing condition.	\$630,000
2. Repair, maintain, and extend (downstream) existing channel dike by 650 feet. ^a	Same as existing condition.	\$410,000
3. Propose dike set back (and extension). ^b	Increases the amount of available habitat. Doesn't necessarily address the issues at the rock step constriction.	\$1,000,000
4. Purchase property.	Same as existing condition. However, the potential now exists for more available habitat.	County has completed the transaction to buy the Logs Resort.
5. No action. Assumes no action by the county.	Same as existing condition. Likely to worsen with time because the stream remains constricted at the bedrock nick point.	No cost.

Source: Inter-Fluve (2000).

^a The cost of Option 2 is based on 1994 construction costs of \$313/foot for the dike. For the set back, the cost is based on the assumption that 2/3 of the existing rock is salvaged at \$200/foot.

^b The cost of Option 3 assumes 2/3 of the rock on the existing dike is salvaged for the set back at \$200/foot.

Table B-2. Canyon Creek Habitat Restoration Options identified by Kerr Wood Leidal Associates, Ltd.

Category	Option	Costs (Estimate)	Habitat Benefit
Debris flood mitigation structures	Debris basin	\$1,000,000	None
	Debris barrier	\$1,200,000	None
Deflection berm	Berm removal (lower 2/3) and armoring of right bank adjacent to Canyon View Drive	\$300,000	Potential increase in habitat area from increasing potential channel width.
	Mt. Baker Highway deflection berm	\$500,000	None. Feature would not affect Canyon Creek.

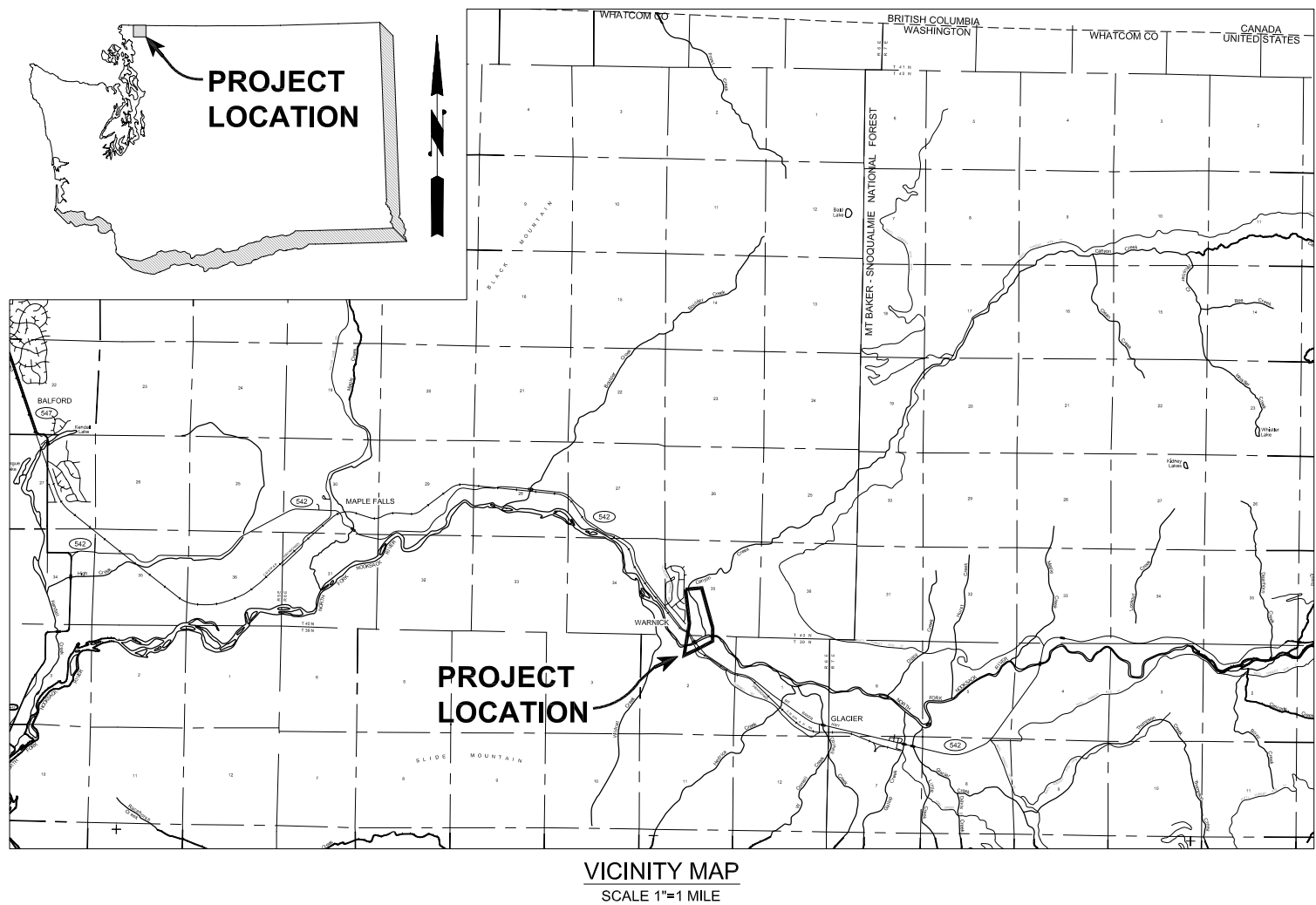
Source: KWL (2003).

Note: The report presents four main categories of mitigation measures for Canyon Creek: land use planning, warning systems, watershed management actions, and debris flood mitigation structures. This table summarizes the debris flood mitigation structures.

APPENDIX C

Design Sheets (30%) for the Canyon Creek Alluvial Fan Habitat Restoration

CANYON CREEK RESTORATION PLAN WHATCOM COUNTY, WASHINGTON



SHEET INDEX		
SHT NO.	DWG NO.	SHEET TITLE
1	G-1	TITLE SHEET
2	C-1	SITE PLAN
3	C-2	TOE SLOPE PROTECTION PLAN
4	C-3	TOE SLOPE PROTECTION SECTIONS
5	C-4	TOPOGRAPHIC LOW SECTIONS
6	C-5	LEVEE REMOVAL PLAN AND SECTIONS
7	ESC-1	TESC DETAILS

② ← KEY NOTE NUMBER

① ← DETAIL REFERENCE NUMBER
C-1 ← DRAWING ON WHICH DETAIL IS SHOWN

DETAIL
SCALE: NTS

① ← DETAIL REFERENCE NUMBER
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▲ ← SECTION REFERENCE LETTER
C-2 ← DRAWING ON WHICH SECTION IS SHOWN

SECTION
SCALE: NTS

▲ ← SECTION REFERENCE LETTER
C-2 ← DRAWING FROM WHICH SECTION WAS TAKEN

"-" INDICATES THAT THE DETAIL/SECTION IS SHOWN ON THE SAME SHEET

"TYP" INDICATES THAT THE DETAIL/SECTION IS UNIFORMLY TYPICAL THROUGHOUT PROJECT EXCEPT WHERE OTHERWISE NOTED

NOTE AND DETAIL/SECTION REFERENCING

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Printer: Adobe PDF

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2200 Sixth Avenue
Suite 1100
Seattle, Washington
98121-1820
206-441-9080
206-441-9108 FAX
<http://www.herrerainc.com>



DESIGNED: G. KAYS	DRAWN: T. GRIGA
DESIGNED: -	DRAWN: T. PRESCOTT
DESIGNED: -	CHECKED: J. GOLDSMITH
SCALE: AS NOTED	APPROVED: M. SPILLANE

**CANYON CREEK
RESTORATION PLAN**

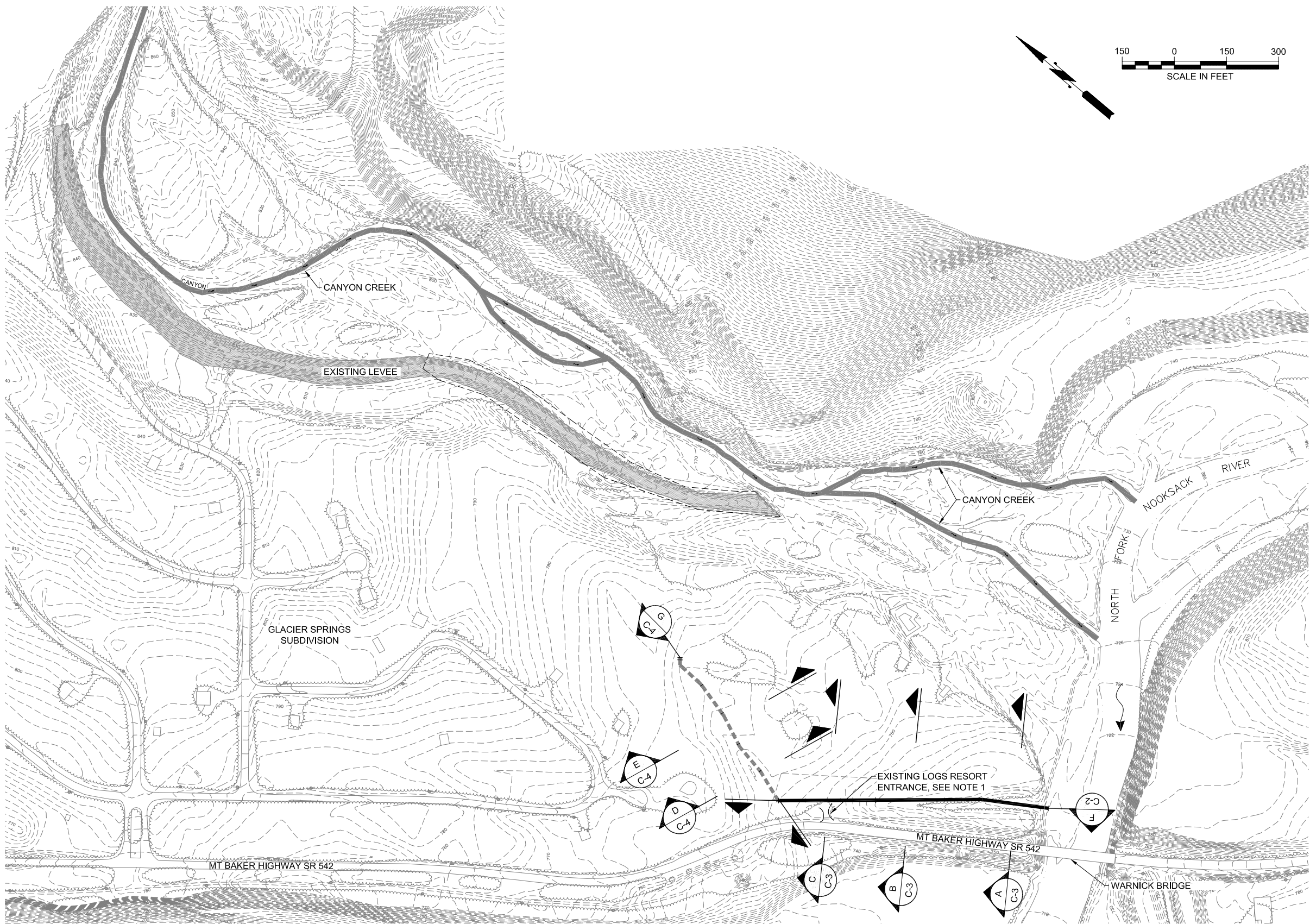
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PROJECT NO: 06-03379-000
DRAWING NO: G-1
SHEET NO: 1 OF 7

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INCH SCALE ACCORDINGLY

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- NOTES:**
1. EXISTING ENTRANCE TO SITE SHALL BE MODIFIED AND MAINTAINED AS A CONSTRUCTION ENTRANCE. SEE DETAIL SHEET ESC-1.

LEGEND:

- CANYON CREEK
- TOPOGRAPHIC LOW FILL ALIGNMENT
- TOE SLOPE PROTECTION ALIGNMENT
- EXISTING LEVEE
- EXISTING VEGETATION

30% DESIGN (NOT FOR CONSTRUCTION)

No.	REVISION	BY	APP'D	DATE



2200 Sixth Avenue
Suite 1100
Seattle, Washington
98121-1820
206-441-9080
206-441-9108 FAX
<http://www.herrerainc.com>



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DESIGNED: -	DRAWN: T. PRESCOTT
DESIGNED: -	CHECKED: J. GOLDSMITH
SCALE: AS NOTED	APPROVED: M. SPILLANE

**CANYON CREEK
RESTORATION PLAN**

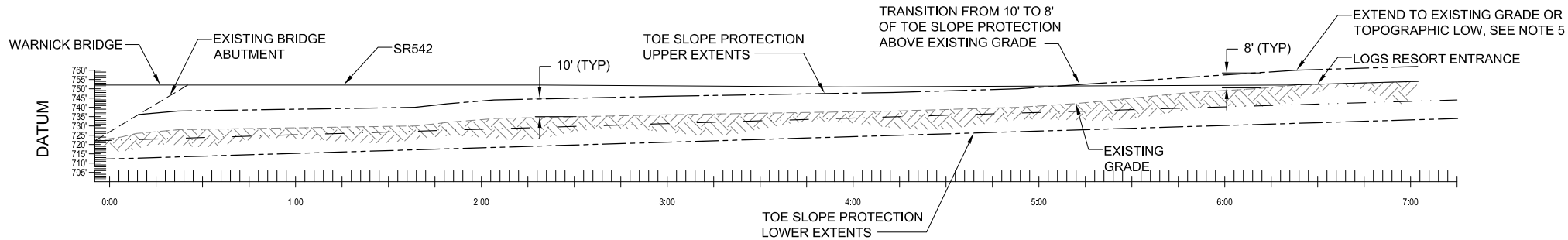
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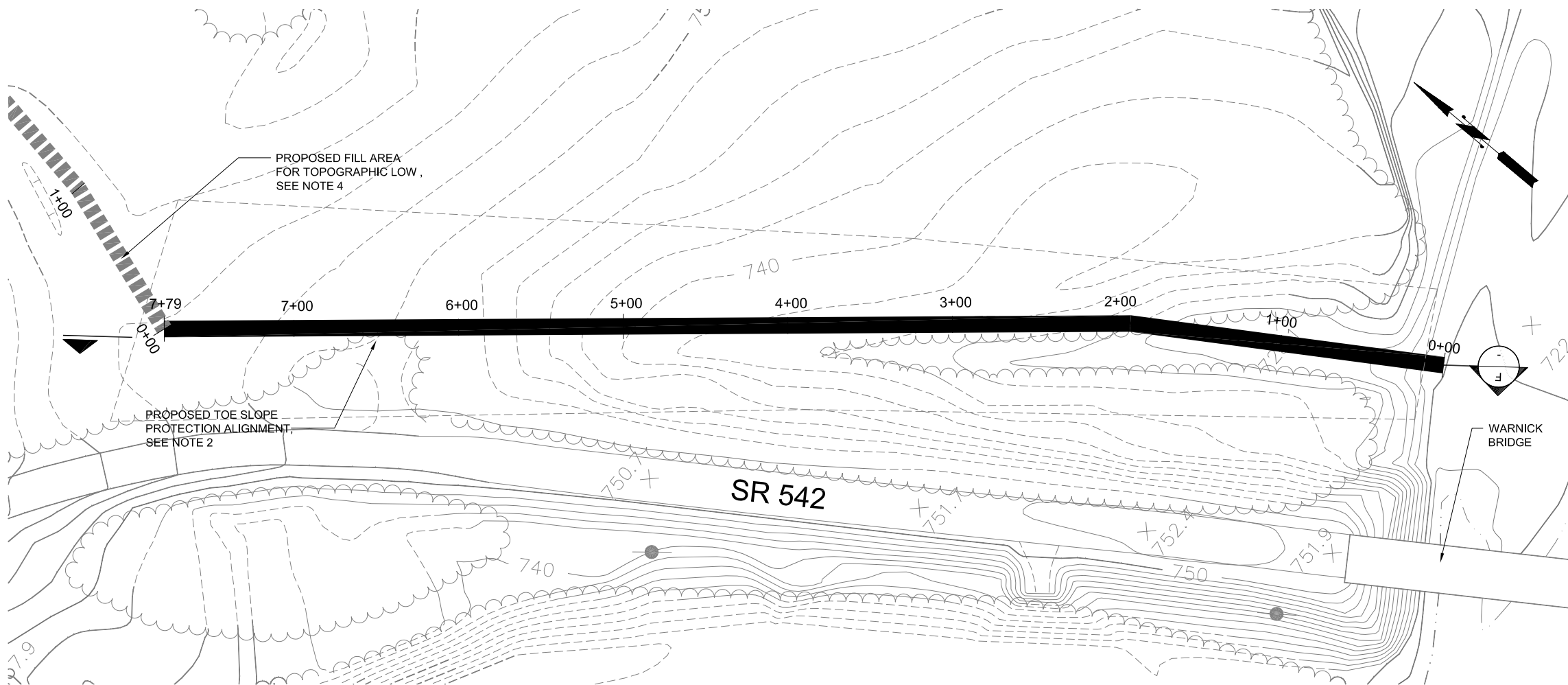
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TOE SLOPE PROTECTION PROFILE
SCALE: NTS



TOE SLOPE PROTECTION PLAN
SCALE: 1"=40'



NOTES:

- 8' TO 10' OF RIP RAP BANK PROTECTION PLACED ABOVE GRADE TO PREVENT OVER TOPPING OR BACK SCOURING DURING POTENTIAL FLOODING AS INDICATED IN "KWL, CANYON CREEK ALLUVIAL FAN RISK ASSESSMENT, 2003" REPORT
- ALIGNMENT FOLLOWS EXISTING TOPOGRAPHIC LOW ADJACENT TO SR 542
- ELEVATION SET 5' BELOW UNIFORM 3% SLOPE FROM THE 2004 SURVEY OF NORTH FORK NOOKSACK RIVER WATER SURFACE ELEVATION TO ACCOUNT FOR POSSIBLE HEAD CUTTING
- OPTION C-1 AND C-2 DO NOT INCLUDE FILLING THE TOPOGRAPHIC LOW
- MAINTAIN A MINIMUM ELEVATION OF 762' TO MEET EXISTING GRADE OR TOPOGRAPHIC LOW.

LEGEND:

	EXISTING GROUND
	3% GRADE FROM N.F. NOOKSACK
	EXISTING GRADE
	TOE SLOPE PROTECTION EXTENTS
	TOE SLOPE ALIGNMENT
	TOPOGRAPHIC LOW FILL ALIGNMENT

RIPRAP SPECIFICATIONS:

% OF TOTAL FRAGMENTS	RANGE OF WEIGHTS (LBS)
50% - 90%	3000 - 8000
30% - 50%	800 - 3000
10% - 30%	800 or LESS

NOTE:

SPECIFICATION FROM WHATCOM COUNTY BID#98-145
MINIMUM SPECIFICATIONS RIPRAP ROCK, PAGE 2



30% DESIGN (NOT FOR CONSTRUCTION)

No.	REVISION	BY	APP'D	DATE



2200 Sixth Avenue
Suite 1100
Seattle, Washington
98121-1820
206-441-9080
206-441-9108 FAX
<http://www.herrerainc.com>



DESIGNED: G. KAYS	DRAWN: T. GRIGA
DESIGNED: -	DRAWN: T. PRESCOTT
DESIGNED: -	CHECKED: J. GOLDSMITH
SCALE: AS NOTED	APPROVED: M. SPILLANE

CANYON CREEK
RESTORATION PLAN

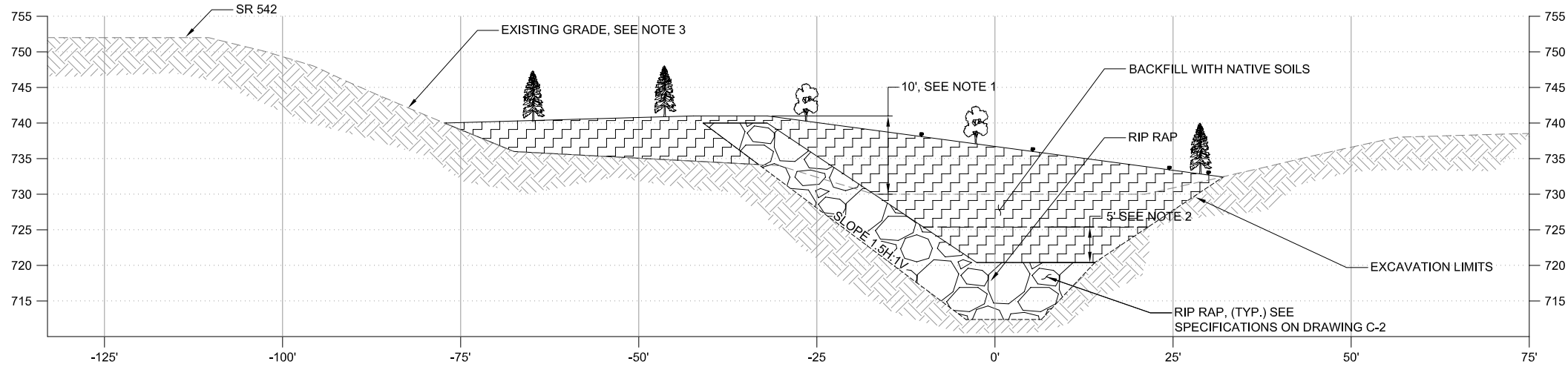
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SHEET NO:	3	OF 7

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AT FULL SIZE, IF NOT ONE
INCH SCALE ACCORDINGLY

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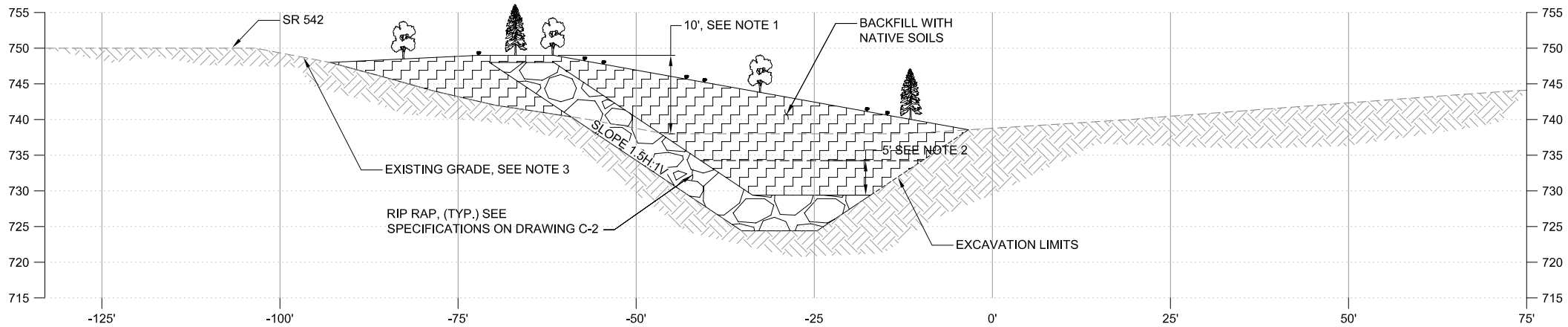
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Caid User: Todd Prescott
Printer: Adobe PDF



TOE SLOPE PROTECTION SECTION

SCALE: 1" = 10'

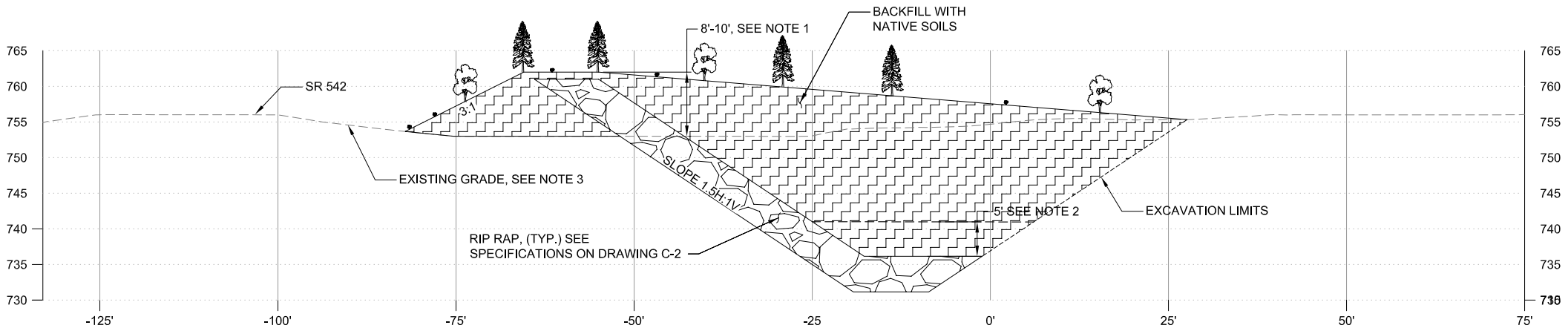
A
C-1



TOE SLOPE PROTECTION SECTION

SCALE: 1" = 10'

B
C-1



TOE SLOPE PROTECTION SECTION

SCALE: 1" = 10'

C
C-1

NOTES:

- 8'-10' OF RIP RAP BANK PROTECTION PLACED ABOVE GRADE TO PREVENT OVER TOPPING OR BACK SCOURING DURING POTENTIAL FLOODING AS INDICATED IN "KWL, CANYON CREEK ALLUVIAL FAN RISK ASSESSMENT, 2003" REPORT
- ELEVATION SET 5' BELOW UNIFORM 3% SLOPE FROM NORTH FORK NOOKSACK RIVER WATER SURFACE ELEVATION TO ACCOUNT FOR POSSIBLE HEAD CUTTING
- TOE SLOPE PROTECTION SECTION C-C WAS CREATED USING CONTOURS DEVELOPED USING LIDAR. TRUE ELEVATION SHOULD BE VERIFIED WITH A MORE ACCURATE SURVEY.

LEGEND:

	EXISTING GROUND
	RIPRAP
	BACKFILL
	PROPOSED PLANTINGS
	3% GRADE FROM N.F. NOOKSACK
	EXISTING GRADE
	TOE SLOPE PROTECTION EXTENTS
	EXCAVATION LIMITS

30% DESIGN (NOT FOR CONSTRUCTION)

No.	REVISION	BY	APP'D	DATE



2200 Sixth Avenue
Suite 1100
Seattle, Washington
98121-1820
206-441-9080
206-441-9108 FAX
<http://www.herrerainc.com>



DESIGNED: G. KAYS	DRAWN: T. GRIGA
DESIGNED: -	DRAWN: T. PRESCOTT
DESIGNED: -	CHECKED: J. GOLDSMITH
SCALE: AS NOTED	APPROVED: M. SPILLANE

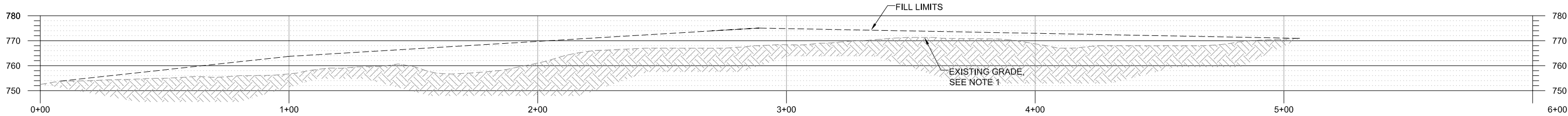
CANYON CREEK
RESTORATION PLAN

TOE SLOPE PROTECTION SECTIONS

DATE: JULY 2007
PROJECT NO: 06-03379-000
DRAWING NO: C-3
SHEET NO: 4
OF 7

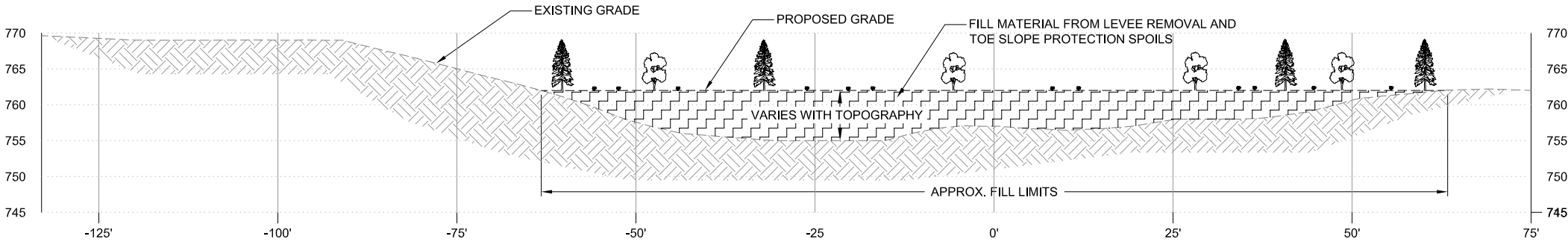
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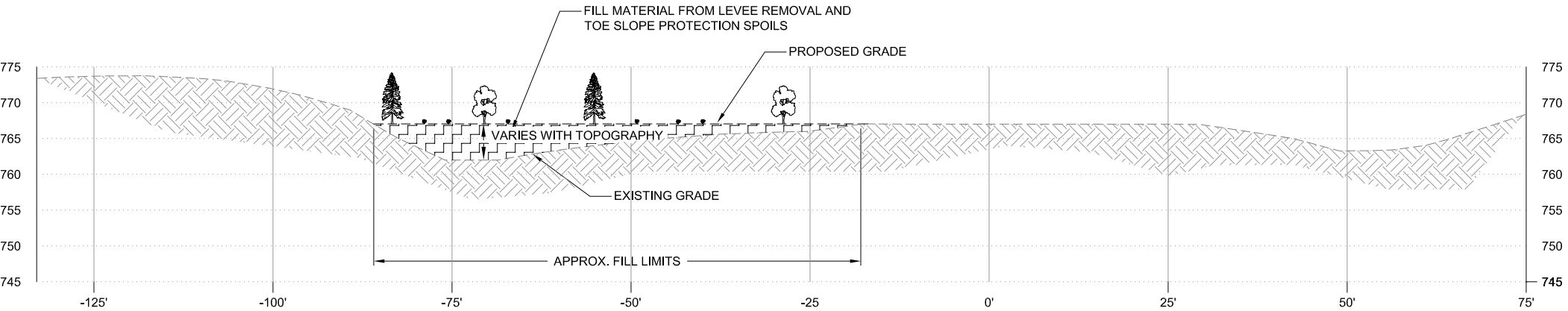
TOPOGRAPHIC LOW PROFILE
SCALE: 1" = 20'

G
C-1



TOPOGRAPHIC LOW SECTION
SCALE: 1" = 10'

D
C-1



TOPOGRAPHIC LOW SECTION
SCALE: 1" = 10'

E
C-1

- NOTES:
- TOPOGRAPHIC LOW PROFILES CREATED USING CONTOURS DEVELOPED FROM LIDAR. TRUE ELEVATIONS SHOULD BE VERIFIED WITH MORE ACCURATE SURVEY PRIOR TO FINAL DESIGN AND CONSTRUCTION.

LEGEND:

	EXISTING GROUND
	BACKFILL
	PROPOSED PLANTINGS
	FILL LIMITS
	EXISTING GRADE

30% DESIGN (NOT FOR CONSTRUCTION)

No.	REVISION	BY	APP'D	DATE



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Suite 1100
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98121-1820
206-441-9080
206-441-9108 FAX
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DESIGNED: -	DRAWN: T. PRESCOTT
DESIGNED: -	CHECKED: J. GOLDSMITH
SCALE: AS NOTED	APPROVED: M. SPILLANE

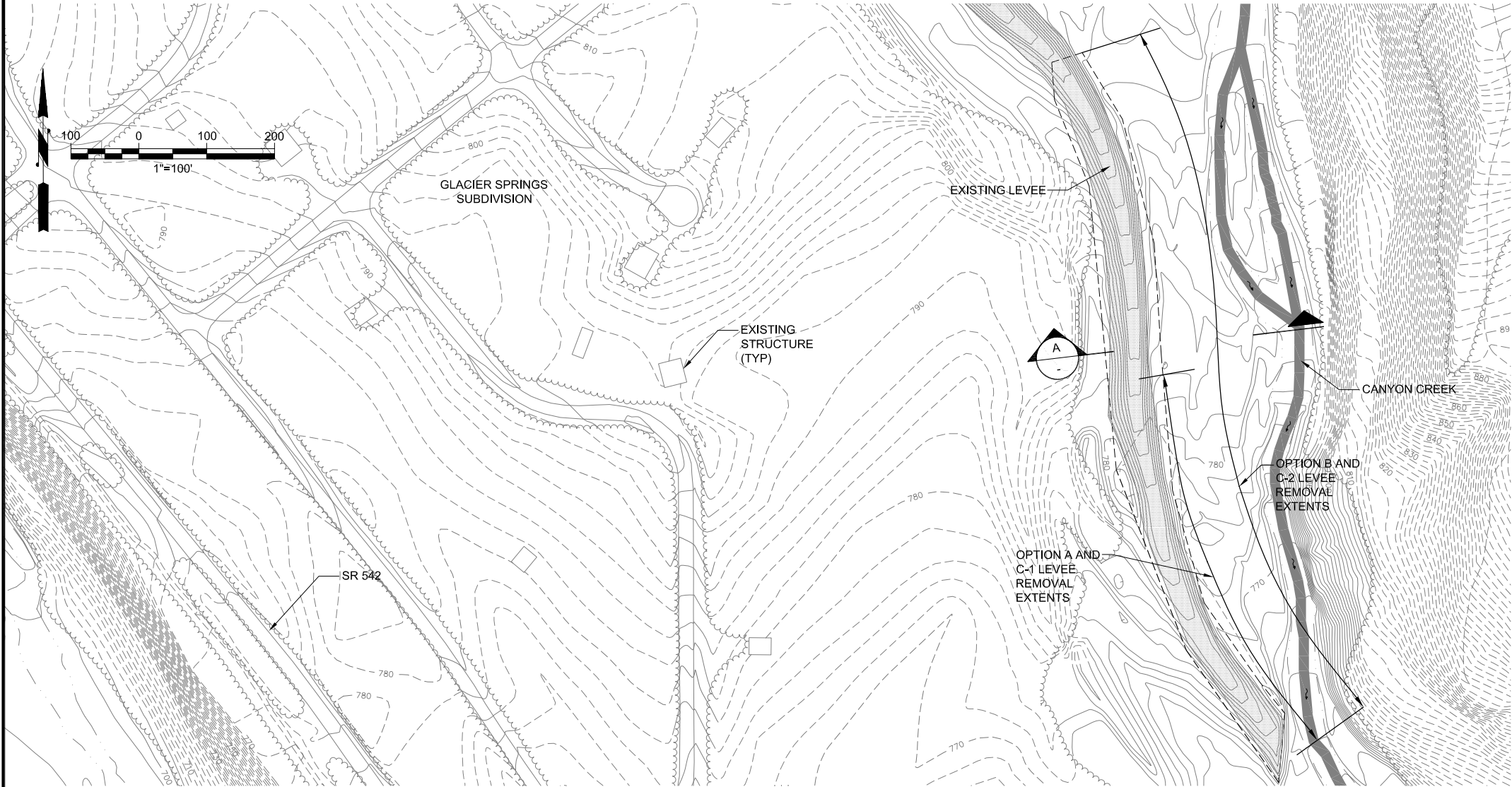
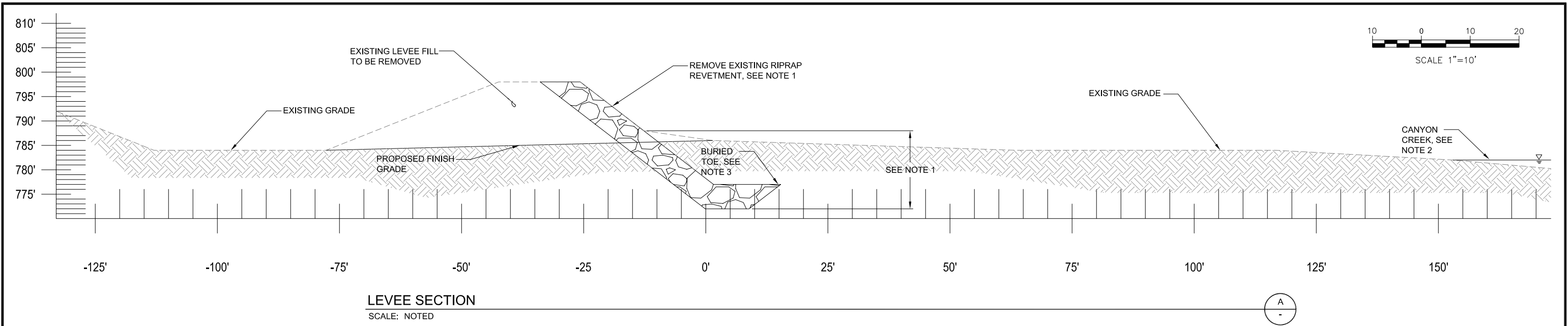
CANYON CREEK
RESTORATION PLAN

TOPOGRAPHIC LOW SECTIONS

DATE: JULY 2007
PROJECT NO: 06-03379-000
DRAWING NO: C-4
SHEET NO: 5 OF 7

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- NOTES:**
- EXTENTS OF RIPRAP WITHIN EXISTING LEVEE APPROXIMATED FROM GEO-ENGINEERS' REPORT "GEOTECHNICAL SERVICES FOR EVALUATIONS OF CANYON CREEK FLOOD DAMAGE REPAIRS" (1997)
 - CANYON CREEK WATER ELEVATION AND ALIGNMENT SHOWN ARE APPROXIMATE AND REFLECT CONDITIONS AT TIME OF SURVEY (2004) AND ARE SUBJECT TO CHANGE
 - RIPRAP SALVAGE FROM BURIED REVETMENT TOE MAY NOT BE ECONOMICAL DUE TO TOE EMBEDMENT DEPTHS AND PROXIMITY TO CANYON CREEK

LEGEND:

	CANYON CREEK
	LEVEE EXTENTS
	EXISTING GRADE
	EXISTING LEVEE
	EXISTING GROUND
	RIPRAP
	FINISH GRADE

30% DESIGN (NOT FOR CONSTRUCTION)

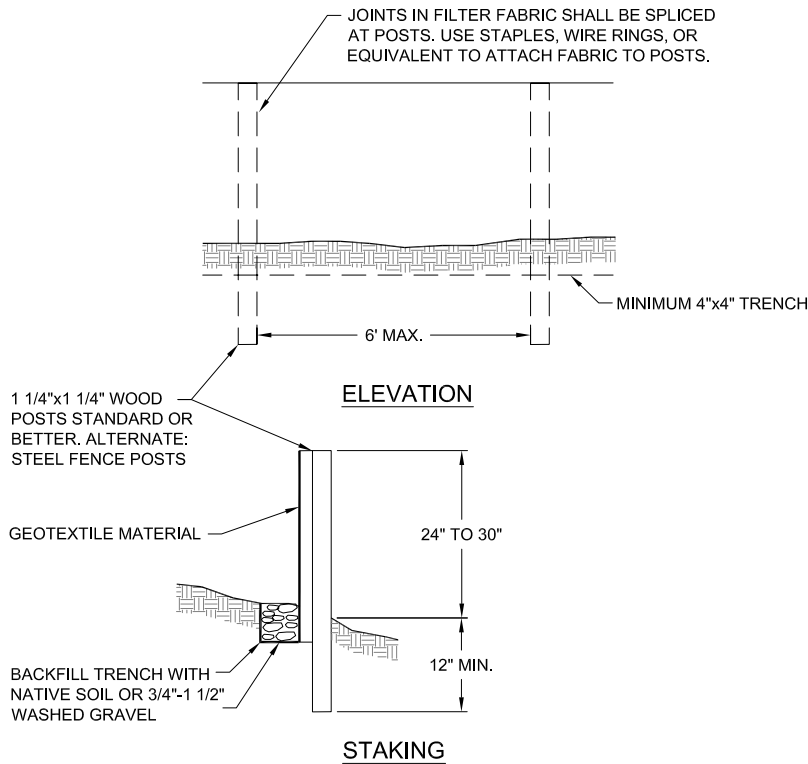
HERRERA ENVIRONMENTAL CONSULTANTS				2200 Sixth Avenue Suite 1100 Seattle, Washington 98121-1820 206-441-9080 206-441-9108 FAX http://www.herrerainc.com		DESIGNED: G. KAYS DESIGNED: - DESIGNED: - SCALE: AS NOTED DRAWN: T. GRIGA DRAWN: T. PRESCOTT CHECKED: J. GOLDSMITH APPROVED: M. SPILLANE		CANYON CREEK RESTORATION PLAN LEVEE REMOVAL PLAN AND SECTIONS		DATE: JULY 2007 PROJECT NO: 06-03379-000 DRAWING NO: C-5 SHEET NO: 6 OF 7	
No.	REVISION	BY	APP'D	DATE							

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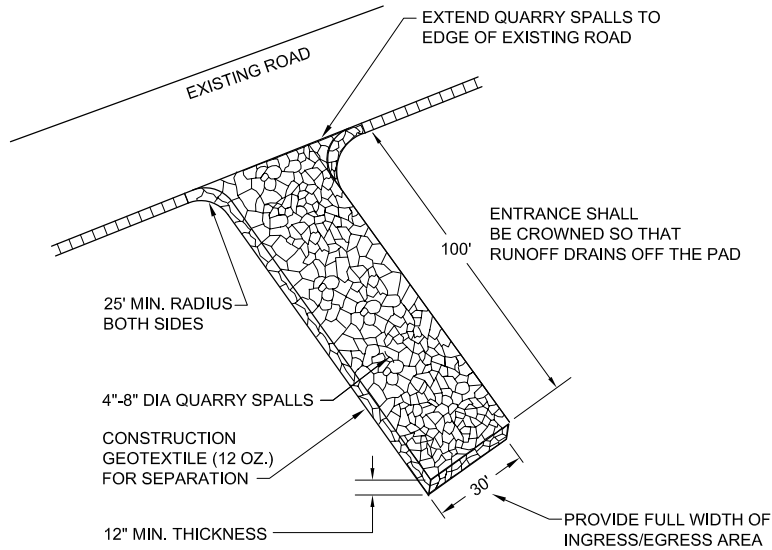
DETAIL: SILT FENCE

SCALE: NTS



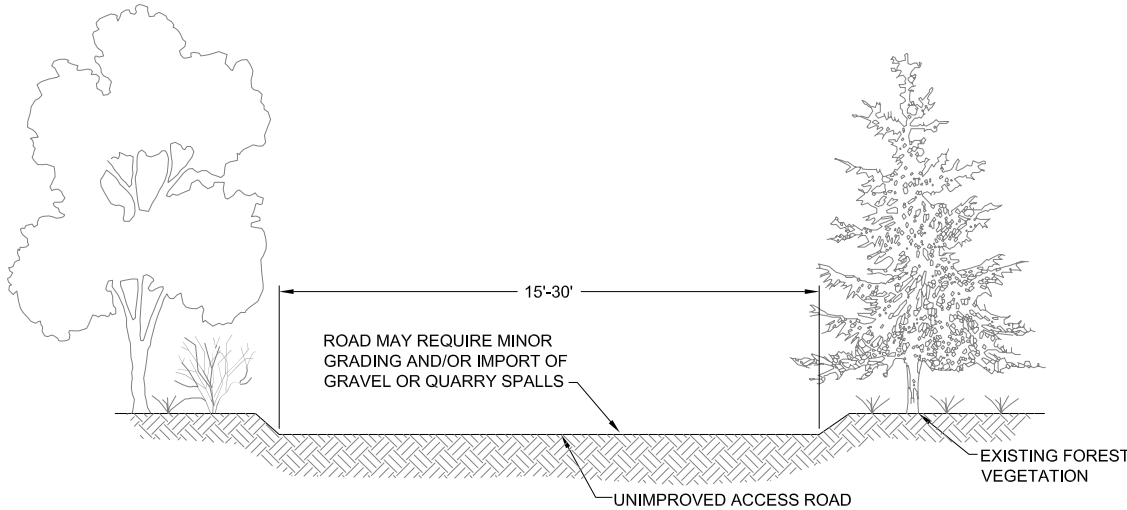
SILT FENCE NOTES:

1. THE FILTER FABRIC (CONSTRUCTION GEOTEXTILE FOR TEMPORARY SILT FENCE) SHALL BE PURCHASED IN A CONTINUOUS ROLL, 5FT WIDE, CUT TO THE LENGTH OF THE BARRIER TO AVOID USE OF JOINTS. WHEN JOINTS ARE NECESSARY, THE FILTER FABRIC SHALL BE SPICED TOGETHER ONLY AT A SUPPORT POST, WITH A MINIMUM 6 INCH OVERLAP, AND SECURELY FASTENED TO THE POST.
2. THE FENCE POSTS SHALL BE SPACED A MAXIMUM OF 6 FEET APART AND DRIVEN SECURELY INTO THE GROUND A MINIMUM OF 12 INCHES.
3. A TRENCH SHALL BE EXCAVATED A MINIMUM OF 4 INCHES WIDE BY 4 INCHES DEEP, UPSLOPE AND ADJACENT TO THE POST TO ALLOW THE FILTER FABRIC TO BE BURIED.
4. THE FILTER FABRIC SHALL BE STAPLED OR WIRED TO THE POSTS, AND 6-12 INCHES OF THE FABRIC SHALL BE EXTENDED INTO THE TRENCH. THE FABRIC SHALL NOT EXTEND MORE THAN 30 INCHES ABOVE THE ORIGINAL GROUND SURFACE. FILTER FABRIC SHALL NOT BE STAPLED TO TREES.
5. THE TRENCH SHALL BE BACKFILLED WITH NATIVE SOIL OR WITH 3/4"-1 1/2" WASHED GRAVEL.
6. SILT FENCES SHALL BE REMOVED AT DIRECTION OF ENGINEER, BUT NOT BEFORE THE UPSLOPE AREA HAS BEEN PERMANENTLY STABILIZED.
7. SILT FENCES SHALL BE INSPECTED IMMEDIATELY AFTER EACH RAINFALL EVENT AND AT LEAST DAILY DURING PROLONGED RAINFALL. ANY REQUIRED REPAIRS SHALL BE MADE IMMEDIATELY.
8. SILT FENCE PERFORMANCE SHALL BE EVALUATED AND SILT FENCE LOCATIONS SHALL BE EVALUATED AND ADJUSTED AS DIRECTED OR APPROVED BY THE ENGINEER AND THE PERMITTING AUTHORITY.
9. SILT FENCE SHALL BE INSTALLED AS SHOWN ON DRAWINGS.
10. ANY DEVIATION OR CHANGE TO SILT FENCE DETAILS MUST BE APPROVED BY THE OWNERS REPRESENTATIVE.
11. THE CONTRACTOR SHALL MAINTAIN A COPY OF THE MANUFACTURER'S SPECIFICATIONS FOR FILTER FABRIC ON SITE.
12. MAINTENANCE STANDARDS:
 - A. ANY DAMAGE SHALL BE REPAIRED IMMEDIATELY.
 - B. IF CONCENTRATED FLOWS ARE EVIDENT UPHILL OF THE SILT FENCE, THEY MUST BE INTERCEPTED AND CONVEYED TO A SEDIMENT TRAP OR POND, OR OTHERWISE DIVERTED TO A LOCATION THAT DOES NOT RESULT IN TURBID DISCHARGES TO SURFACE WATERS.
 - C. THE UPHILL SIDE OF THE SILT FENCE SHALL BE CHECKED FOR SIGNS OF THE SILT FENCE CLOGGING, ACTING AS A BARRIER TO FLOW, AND CAUSING CHANNELIZATION OF FLOWS PARALLEL TO THE FENCE. IF SUCH CHANNELIZATION OCCURS, THE CONTRACTOR SHALL REPLACE THE FENCE OR REMOVE THE TRAPPED SEDIMENT.
 - D. SEDIMENT SHALL BE REMOVED AND PROPERLY DISPOSED OF WHEN THE SEDIMENT IS 6 INCHES HIGH.
 - E. IF THE FILTER FABRIC HAS DETERIORATED DUE TO ULTRAVIOLET BREAKDOWN, IT SHALL BE REPLACED.



DETAIL: STABILIZED CONSTRUCTION ENTRANCE

SCALE: NTS



DETAIL: TEMPORARY CLEARED ACCESS ROAD

SCALE: NTS



ACCESS ROAD NOTES:

1. THE FILTER FABRIC (CONSTRUCTION GEOTEXTILE FOR TEMPORARY SILT FENCE) SHALL BE PURCHASED IN A CONTINUOUS ROLL, 5FT WIDE, CUT TO THE LENGTH OF THE BARRIER TO AVOID USE OF JOINTS. WHEN JOINTS ARE NECESSARY, THE FILTER FABRIC SHALL BE SPICED TOGETHER ONLY AT A SUPPORT POST, WITH A MINIMUM 6 INCH OVERLAP, AND SECURELY FASTENED TO THE POST.
2. AT COMPLETION OF CONSTRUCTION, CONTRACTOR SHALL BACKBLADE TO MATCH EXISTING GRADE AND REPAIR SOFT SPOTS BY REPLACING SUITABLE NATIVE MATERIAL.

GENERAL EROSION AND SEDIMENT CONTROL NOTES:

1. THE IMPLEMENTATION OF EROSION AND SEDIMENT CONTROL (ESC) PLANS AND THE CONSTRUCTION, MAINTENANCE, REPLACEMENT, AND UPGRADING OF ESC FACILITIES IS THE RESPONSIBILITY OF THE CONTRACTOR UNTIL ALL CONSTRUCTION IS APPROVED.
2. THE ESC FACILITIES SHOWN ON THIS PLAN MUST BE CONSTRUCTED PRIOR TO OR IN CONJUNCTION WITH ALL CLEARING AND GRADING SO AS TO ENSURE THAT THE TRANSPORT OF SEDIMENT TO SURFACE WATERS, DRAINAGE SYSTEMS, AND ADJACENT PROPERTIES IS MINIMIZED.
3. THE ESC FACILITIES SHOWN ON THIS PLAN ARE THE MINIMUM REQUIREMENTS FOR ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, THESE ESC FACILITIES SHALL BE UPGRADED AS NEEDED FOR UNEXPECTED STORM EVENTS AND MODIFIED TO ACCOUNT FOR CHANGING SITE CONDITIONS.
4. THE ESC FACILITIES SHALL BE INSPECTED DAILY BY THE CONTRACTOR'S ESC SUPERVISOR AND MAINTAINED TO ENSURE CONTINUED PROPER FUNCTIONING. WRITTEN RECORDS SHALL BE KEPT OF WEEKLY REVIEWS OF THE ESC FACILITIES.
5. ANY AREAS OF EXPOSED SOILS, INCLUDING ROADWAY EMBANKMENTS, THAT WILL NOT BE DISTURBED FOR SEVEN DAYS SHALL BE IMMEDIATELY STABILIZED WITH THE APPROVED ESC METHODS (E.G., SEEDING, MULCHING, PLASTIC COVERING, ETC.).
6. ANY AREA NEEDING ESC MEASURES THAT DO NOT REQUIRE IMMEDIATE ATTENTION SHALL BE ADDRESSED WITHIN SEVEN (7) DAYS.
7. THE ESC FACILITIES ON INACTIVE SITES SHALL BE INSPECTED AND MAINTAINED OR WITHIN TWENTY FOUR (24) HOURS FOLLOWING A STORM EVENT.
8. STABILIZED CONSTRUCTION ENTRANCES AND ROADS SHALL BE INSTALLED AT THE BEGINNING OF CONSTRUCTION AND MAINTAINED FOR THE DURATION OF THE PROJECT. ADDITIONAL MEASURES, SUCH AS WASH PADS, MAY BE REQUIRED TO ENSURE THAT ALL PAVED AREAS ARE KEPT CLEAN FOR THE DURATION OF THE PROJECT.
9. WHERE STRAW MULCH FOR TEMPORARY EROSION CONTROL IS REQUIRED, IT SHALL BE APPLIED AT A MINIMUM THICKNESS OF 2 TO 3 INCHES.

30% DESIGN (NOT FOR CONSTRUCTION)

					 2200 Sixth Avenue Suite 1100 Seattle, Washington 98121-1820 206-441-9080 206-441-9108 FAX http://www.herreralnc.com		DESIGNED: G. KAYS		DRAWN: T. GRIGA		CANYON CREEK RESTORATION PLAN TESC DETAILS	DATE: JULY 2007
								DESIGNED: -	DRAWN: T. PRESCOTT			PROJECT NO: 06-03379-000
								DESIGNED: -	CHECKED: J. GOLDSMITH			DRAWING NO: ESC-1
								SCALE: AS NOTED	APPROVED: M. SPILLANE			SHEET NO: 7 OF 7
No.	REVISION	BY	APP'D	DATE								

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APPENDIX D

Detailed Construction Cost Estimates for the Canyon Creek Alluvial Fan Habitat Restoration

Draft Engineering Estimate of Probable Construction Cost

Project: Canyon Creek
Project #: 06-03379-000
Client: Canyon Creek

OPTION A
"Short Levee Removal and Fill Topo Low"

Prepared by: GK
Edit Date: 8/8/07
Reviewed by: MMS
Reviewed Date:4/9/07

Excavate and Place Large Diameter (4' minus Riprap) in excavation along SR 542 (approximately 800') and remove approximately 520' of the existing levee and fill topo low that runs north from the SR 542 embankment structure nearest to the housing development

Assumptions

- 1. Not all riprap remains for salvage from original levee as built. Not all riprap is cost effective for salvage.
- 2. Some excess spoils from levee removal will be used on site for filling Toe Slope Protection (TSP) and remainder disposed.
- 3. Assumes toe slope protection would incorporate any existing riprap along the right bank N.F. Nooksack Rier at approach to Warnick Bridge.
- 4. Based on 30% Design Drawings.

Levee Segment Geometry Inputs

Assumed Percent RipRap that is salvageable = 70%

Item	Quantity	Units				Notes
Length	530	FT				
Total Existing Riprap Volume	4,200	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"
Total Removed soils	9200	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"

Toe Slope Protection Geometry

Item	Quantity	Units				Notes
Length	800	FT				

Topographic Low Geometry

Item	Quantity	Units				Notes
Volume	2,668	CY				

Number	Item	Quantity	Units	Unit Cost	Unit Amount	Amount	Notes
1	Mobilization	1	LS	\$71,825.57		\$71,826	%10 of all other costs
2	Construction Entrance	1	Ea	\$1,250.00		\$1,250	
3	Silt fence	2,000	LF	\$1.25		\$2,500	
4	Straw mulch	5,000	Sqyd	\$0.25		\$1,250	
5	TESC Management	8	Wk	\$700.00		\$5,600	
6	Grade Access Road	4,000	Sqyd	\$2.00		\$8,000	Minimal improvements to existing network of roads
	a. crushed rock	300	TN	\$20.00		\$6,000	Minimal improvements to existing network of roads
	b. removal	300	TN	\$5.00		\$1,500	assumes access road gravel removed and placed in TSP
7	Toe Slope Protection (TSP)	1	EA	\$543,799.01		\$543,799	
	a.Prep/Grub	2	AC	\$5,600.00	\$10,927		WSDOT unit bid analysis state average
	b. Excavate embankment	13,000	Cyd	\$5.00	\$65,000		Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT). the Guide 2006 for common excavation, assuming spoils stockpiled near excavation
	c. Riprap Placement	6,400	Cyd	\$10.00	\$64,000		Volume From Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT), Cost is Estimate assuming placed individually for 3 point bearing
	d. Riprap Purchase	3,460	Cyd	\$47.50	\$164,350		Cost from average of quotes obtained by James Lee (Whatcom County Eng.) of \$37/yd and \$58/yd
	e. Riprap Salvage From Levee Removal	2,940	Cyd	\$25.00	\$73,500		Estimate, includes haul to embankment
	f. Shape embankment	9,444	Sqyd	\$2.00	\$18,889		Assumed 70' wide
	g. Revetment Back Fill and Compaction	13,000	Cyd	\$5.00	\$65,000		Assumed spoils will be reused onsite to backfill embankment so no off sight hauling
	h. Place Grubbed Surface Soil	3150	CY	\$5.00	\$15,750		Assumes 85,000sqft (Embankment) and 12" deep
	i. Finish Grade	9440	SY	\$2.00	\$18,880		Assumes 85,000sqft (Embankment) and 12" deep
	j. Hydroseed	2.0	AC	\$2,000.00	\$3,903		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	k. Plantings/Shrubs	9440	SY	\$2.50	\$23,600		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	l. Plantings/Trees	200	EA	\$100.00	\$20,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
8	Levee Removal	1	EA	\$127,611.98		\$127,612	
	a. Prep/Grub	0.8	AC	\$5,600.00	\$4,500		WSDOT unit bid analysis state average
	b. Excavate and Haul Levee	9,200	Cyd	\$10.00	\$92,000		assumed \$10/Cyd to haul and dispose/grade out (quote from Whatcom County), Reasonable assuming double the Guide 2006 for common excavation \$5 to account for sorting of rock and haul to topo low, TSP for fill (TSP may accommodate up to 6500cy from levee as shown on plans)
	c. Place Grubbed Surface Soil	1300	CY	\$5.00	\$6,500		Assumes 35,000sqft (levee removal)12" deep
	d. Finish Grade	3890	SY	\$2.00	\$7,780		Assumes 35,000sqft (levee removal)12" deep
	e. Hydroseed	0.8	AC	\$2,000.00	\$1,607		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	f. Plantings/Shrubs	3890	SY	\$2.50	\$9,725		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	g. Plantings/Trees	100	EA	\$100.00	\$10,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
8	Backfill Topographic Low	1	EA	\$13,594.72		\$13,595	
	a. Prep/Grub	0.23	AC	\$5,600.00	\$1,286		WSDOT unit bid analysis state average
	b. Shape Fill	1,111	Sqyd	\$2.00	\$2,222		From Gis Calculation
	c. Place Grubbed Surface Soil	370	CY	\$5.00	\$1,850		Assumes 10,000sqft (topo low) 12" deep
	d. Hydroseed	0.2	AC	\$2,000.00	\$459		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	e. Plantings/Shrubs	1111	SY	\$2.50	\$2,778		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	f. Plantings/Trees	50	EA	\$100.00	\$5,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
Floodplain Rock Removal							
9	Removal and Haul Rocks	21	EA	\$83.33		\$1,750	Assumes Class 400 excavator (\$250/hr) working for 10 minutes per rock and one Truck Hauling (\$125/hr) for 20 minutes to TSP
Log Embankment Removal							
10	Remove and haul logs	45	EA	\$120.00		\$5,400	assumes cut cable and haul logs to floodplain for habitat

Construction Subtotal		\$790,081
Contingency +30%	30.00%	\$237,024
Subtotal		\$1,027,106
Tax Bonding Insurance	8.60%	\$88,331
	2.00%	\$20,542
	1.50%	\$15,407
Total		\$1,151,385

Draft Engineering Estimate of Probable Construction Cost

Project: Canyon Creek
Project #: 06-03379-000
Client: Canyon Creek

OPTION B
"Long Levee Removal and Fill Topo Low"

Prepared by: GK
Edit Date: 8/8/07
Reviewed by: MMS
Reviewed Date:4/9/07

Excavate and Place Large Diameter (4' minus Riprap) in excavation along SR 542 (approximately 800ft) and remove approximately 1025' of the existing levee and fill topo low that runs north from the SR 542 embankment structure nearest to the housing development

Assumptions

- 1. Not all riprap remains for salvage from original levee as built. Not all riprap is cost effective for salvage.
- 2. Some excess spoils from levee removal will be used on site for filling Toe Slope Protection (TSP) and remainder disposed.
- 3. Assumes toe slope protection would incorporate any existing riprap along the right bank N.F. Nooksack Rier at approach to Warnick Bridge.
- 4. Based on 30% Design Drawings.

Levee Segment Geometry Inputs

Assumed Percent RipRap that is salvageable = 70%

Item	Quantity	Units				Notes
Length	1030	FT				
Total Existing Riprap Volume	8,400	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"
Total Removed soils	16700	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"

Toe Slope Protection Geometry

Item	Quantity	Units				Notes
Length	800	FT				

Topographic Low Geometry

Item	Quantity	Units				Notes
Volume	2,668	CY				

Number	Item	Quantity	Units	Unit Cost	Unit Amount	Amount	Notes
1	Mobilization	1	LS	\$80,269.51		\$80,270	%10 if all other costs
2	Construction Entrance	1	Ea	\$1,250.00		\$1,250	
3	Silt fence	2,000	LF	\$1.25		\$2,500	
4	Straw mulch	5,000	Sgyd	\$0.25		\$1,250	
5	TESC Management	8	Wk	\$700.00		\$5,600	
6	Grade Access Road	4,000	Sgyd	\$2.00		\$8,000	Minimal improvements to existing network of roads
	a. crushed rock	300	TN	\$20.00		\$6,000	Minimal improvements to existing network of roads
	b. removal	300	TN	\$5.00		\$1,500	assumes access road gravel removed and placed in TSP
7	Toe Slope Protection (TSP)	1	EA	\$466,721.55		\$466,722	
	a. Prep/Grub	2.0	AC	\$5,600.00	\$10,927		WSDOT unit bid analysis state average
	b. Excavate Embankment	13,000	Cyd	\$5.00	\$65,000		Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT). the Guide 2006 for common excavation, assuming spoils stockpiled near excavation
	c. Riprap Placement	6,400	Cyd	\$10.00	\$64,000		Volume From Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT), Cost is Estimate assuming placed individually for 3 point bearing
	d. Riprap Purchase	520	Cyd	\$47.50	\$24,700		Cost from average of quotes obtained by James Lee (Whatcom County Eng.) of \$37/yd and \$58/yd
	e. Riprap Salvage From Levee Removal	5,880	Cyd	\$25.00	\$147,000		Estimate
	f. Revetment Back Fill and Compaction	13,000	Cyd	\$5.00	\$65,000		Assumed spoils will be reused onsite to backfill Embankment so no off sight hauling
	g. Shape Embankment Backfill	9,444	Sgyd	\$2.00	\$18,889		Assumed 30' wide
	h. Place Grubbed Surface Soil	3150	CY	\$5.00	\$15,750		Assumes 85,000sqft (Embankment) and 12" deep
	i. Finish Grade	9440	SY	\$2.00	\$18,880		Assumes 85,000sqft (Embankment) and 12" deep
	j. Hydroseed	2.0	AC	\$2,000.00	\$3,903		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	k. Plantings/Shrubs	9440	SY	\$2.50	\$23,600		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	l. Plantings/Trees	200	EA	\$100.00	\$20,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
8	Levee Removal	1	EA	\$289,128.80		\$289,129	
	a. Prep/Grub	1.7	AC	\$5,600.00	\$9,642		WSDOT unit bid analysis state average
	b. Excavate and Haul Levee	16,700	Cyd	\$10.00	\$167,000		assumed \$10/Cyd to haul and dispose/grade out (quote from Whatcom County), Reasonable assuming double the Guide 2006 for common excavation \$5 to account for sorting of rock and haul to topo low, TSP for fill, or Disposal(TSP may accommodate up to 6500cy from levee as shown on plans)
	c. Dispose of excess Spoils	7,532	Cyd	\$5.00	\$37,658		Guide 2006 (assumes topo low fill and 6500cy to TSP)
	d. Place Grubbed Surface Soil	2780	CY	\$5.00	\$13,900		Assumes 75,000sqft (levee removal) and 12" deep
	f. Finish Grade	8330	SY	\$2.00	\$16,660		Assumes 75,000sqft (levee removal) and 12" deep
	g. Hydroseed	1.7	AC	\$2,000.00	\$3,444		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	h. Plantings/Shrubs	8330	SY	\$2.50	\$20,825		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	i. Plantings/Trees	200	EA	\$100.00	\$20,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
9	Backfill Topographic Low	1	EA	\$13,594.72		\$13,595	
	a. Prep/Grub	0.23	AC	\$5,600.00	\$1,286		WSDOT unit bid analysis state average
	b. Shape Fill	1,111	Sgyd	\$2.00	\$2,222		From Gis Calculation
	c. Place Grubbed Surface Soil	370	CY	\$5.00	\$1,850		Assumes 10,000sqft (topo low) 12" deep
	d. Hydroseed	0.2	AC	\$2,000.00	\$459		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	e. Plantings/Shrubs	1111	SY	\$2.50	\$2,778		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	f. Plantings/Trees	50	EA	\$100.00	\$5,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
Floodplain Rock Removal							
1	Removal and Haul Rocks	21	EA	\$83.33		\$1,750	Assumes Class 400 excavator (\$250/hr) working for 10 minutes per rock and one Truck Hauling (\$125/hr) for 20 minutes to TSP
Log Embankment Removal							
2	Remove and haul logs	45	EA	\$120.00		\$5,400	assumes cut cable and haul logs to floodplain for habitat

Construction Subtotal		\$882,965
Contingency +30%	30.00%	\$264,889
Subtotal		\$1,147,854
Tax	8.60%	\$98,715
Bonding	2.00%	\$22,957
Insurance	1.50%	\$17,218
Total		\$1,286,744

Draft Engineering Estimate of Probable Construction Cost

Project: Canyon Creek
Project #: 06-03379-000
Client: Canyon Creek

OPTION C-1
"Short Levee Removal and no Topo Low Fill"

Prepared by: GK
Edit Date: 8/8/07
Reviewed by: MMS
Reviewed Date:4/9/07

Excavate and Place Large Diameter (4' minus Riprap) in excavation along SR 542 (approximately 800') and remove approximately 520' of the existing levee

Assumptions

- 1. Not all riprap remains for salvage from original levee as built. Not all riprap is cost effective for salvage.
- 2. Some excess spoils from levee removal will be used on site for filling Toe Slope Protection (TSP) and remainder disposed.
- 3. Assumes toe slope protection would incorporate any existing riprap along the right bank N.F. Nooksack Rier at approach to Warnick Bridge.
- 4. Based on 30% Design Drawings.

Levee Segment Geometry Inputs

Assumed Percent RipRap that is salvageable = 70%

Item	Quantity	Units				Notes
Length	530	FT				
Total Existing Riprap Volume	4,200	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"
Total Removed soils	9200	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"

Toe Slope Protection Geometry

Item	Quantity	Units				Notes
Length	800	FT				

Number	Item	Quantity	Units	Unit Cost	Unit Amount	Amount	Notes
1	Mobilization	1	LS	\$72,266.05		\$72,266	%10 if all other costs
2	Construction Entrance	1	Ea	\$1,250.00		\$1,250	
3	Silt fence	2,000	LF	\$1.25		\$2,500	
4	Straw mulch	5,000	Sqyd	\$0.25		\$1,250	
5	TESC Management	8	Wk	\$700.00		\$5,600	
6	Grade Access Road	4,000	Sqyd	\$2.00		\$8,000	Minimal improvements to existing network of roads
	a. crushed rock	300	TN	\$20.00		\$6,000	Minimal improvements to existing network of roads
	b. removal	300	TN	\$5.00		\$1,500	assumes access road gravel removed and placed in TSP
7	Toe Slope Protection (TSP)	1	EA	\$543,799		\$543,799	
	a. Prep/Grub	2.0	AC	\$5,600.00	\$10,927		WSDOT unit bid analysis state average
	b. Excavate Embankment	13,000	Cyd	\$5.00	\$65,000		Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT). the Guide 2006 for common excavation, assuming spoils stockpiled near excavation
	c. Riprap Placement	6,400	Cyd	\$10.00	\$64,000		Volume From Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT), Cost is Estimate assuming placed individually for 3 point bearing
	d. Riprap Purchase	3,460	Cyd	\$47.50	\$164,350		Cost from average of quotes obtained by James Lee (Whatcom County Eng.) of \$37/yd and \$58/yd
	e. Riprap Salvage From Levee Remov	2,940	Cyd	\$25.00	\$73,500		Estimate, includes haul to Embankment
	f. Shape Embankment	9,444	Sqyd	\$2.00	\$18,889		Assumed 70' wide
	g. Revetment Back Fill and Compactio	13,000	Cyd	\$5.00	\$65,000		Assumed spoils will be reused onsite to backfill Embankment so no off sight hauling
	h. Place Grubbed Surface Soil	3150	CY	\$5.00	\$15,750		Assumes 85,000sqft (Embankment) and 12" deep
	i. Finish Grade	9440	SY	\$2.00	\$18,880		Assumes 85,000sqft (Embankment)
	j. Hydroseed	2.0	AC	\$2,000.00	\$3,903		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	k. Plantings/Shrubs	9440	SY	\$2.50	\$23,600		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	l. Plantings/Trees	200	EA	\$100.00	\$20,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
Levee Removal		1	EA	\$145,611.52		\$145,612	
8	a. Prep/Grub	0.8	AC	\$5,600.00	\$4,500		WSDOT unit bid analysis state average
	b. Excavate and Haul Levee	9,200	Cyd	\$10.00	\$92,000		assumed \$10/Cyd to haul and dispose/grade out (quote from Whatcom County), Reasonable assuming double the Guide 2006 for common excavation \$5 to account for sorting of rock and short haul to TSP for fill (TSP may accommodate up to 6500cy from levee as shown on plans)
	c. Dispose of excess Spoils	2,700	Cyd	\$5.00	\$13,500		Guide 2006 (assumes no topo low fill and 6500cy to TSP)
	d. Place Grubbed Surface Soil	1300	CY	\$5.00	\$6,500		Assumes 35,000sqft (levee removal)+85,000sqft (Embankment) and 12" deep
	f. Finish Grade	3890	SY	\$2.00	\$7,780		Assumes 35,000sqft (levee removal)+85,000sqft (Embankment)
	g. Hydroseed	0.8	AC	\$2,000.00	\$1,607		Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	h. Plantings/Shrubs	3890	SY	\$2.50	\$9,725		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	i. Plantings/Trees	100	EA	\$100.00	\$10,000		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
Floodplain Rock Removal							Assumes Class 400 excavator (\$250/hr) working for 10 minutes per rock and one Truck Hauling (\$125/hr) for 20 minutes to TSP
9	Removal and Haul Rocks	21	EA	\$83.33		\$1,750	
Log Embankment Removal							
10	Remove and haul logs	45	EA	\$120.00		\$5,400	assumes cut cable and haul logs to floodplain for habitat

Construction Subtotal		\$794,927
Contingency +30%		30.00% \$238,478
Subtotal		\$1,033,405
Tax		8.60% \$88,873
Bonding		2.00% \$20,668
Insurance		1.50% \$15,501
Total		\$1,158,447

Draft Engineering Estimate of Probable Construction Cost

Project: Canyon Creek
Project #: 06-03379-000
Client: Canyon Creek

OPTION C-2
"Long Levee Removal and no Topo Low Fill"

Prepared by: GK
Edit Date: 8/8/07
Reviewed by: MMS
Reviewed Date:4/9/07

Excavate and Place Large Diameter (4' minus Riprap) in excavation along SR 542 (approximately 800ft) and remove approximately 1025' of the existing levee

Assumptions

- 1. Not all riprap remains for salvage from original levee as built. Not all riprap is cost effective for salvage.
- 2. Some excess spoils from levee removal will be used on site for filling Toe Slope Protection (TSP) and remainder disposed.
- 3. Assumes toe slope protection would incorporate any existing riprap along the right bank N.F. Nooksack Rier at approach to Warnick Bridge.
- 4. Based on 30% Design Drawings.

Levee Segment Geometry Inputs

Assumed Percent RipRap that is salvageable = 70%

Item	Quantity	Units				Notes
Length	1030	FT				
Total Existing Riprap Volume	8,400	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"
Total Removed soils	16700	CY				Total Volume from AutoCad file "800FT EMB XSECT.dwg"

Toe Slope Protection Geometry

Item	Quantity	Units				Notes
Length	800	FT				

Number	Item	Quantity	Units	Unit Cost	Unit Amount	Amount	Notes
1	Mobilization	1	LS	\$80,233.70		\$80,234	%10 of all other costs
2	Construction Entrance	1	Ea	\$1,250.00		\$1,250	
3	Silt fence	2,000	LF	\$1.25		\$2,500	
4	Straw mulch	5,000	Sqyd	\$0.25		\$1,250	
5	TESC Management	8	Wk	\$700.00		\$5,600	
6	Access Road Improvements						
	a. grade	4,000	Sqyd	\$2.00		\$8,000	Minimal improvements to existing network of roads
	b. crushed rock	300	TN	\$20.00		\$6,000	Minimal improvements to existing network of roads
	c. removal	300	TN	\$5.00		\$1,500	assumes access road gravel removed and placed in TSP
7	Toe Slope Protection (TSP)	1	EA	\$466,722		\$466,722	
	a. Prep/Grub	2	AC	\$5,600.00	\$10,927		WSDOT unit bid analysis state average
							Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT). the Guide 2006 for common excavation, assuming spoils stockpiled near excavation
	b. Excavate Embankment	13,000	Cyd	\$5.00	\$65,000		Volume From Ave. End Area method with area of xsect from Autocad file (800FT EMB XSECT), Cost is Estimate assuming placed individually for 3 point bearing
	c. Riprap Placement	6,400	Cyd	\$10.00	\$64,000		Cost from average of quotes obtained by James Lee (Whatcom County Eng.) of \$37/yd and \$58/yd
	d. Riprap Purchase	520	Cyd	\$47.50	\$24,700		Estimate
	e. Riprap Salvage From Levee Removal	5,880	Cyd	\$25.00	\$147,000		Assumed spoils will be reused onsite to backfill Embankment so no off sight hauling
	f. Revetment Back Fill and Compaction	13,000	Cyd	\$5.00	\$65,000		Assumed 30' wide
	g. Shape Embankment Backfill	9,444	Sqyd	\$2.00	\$18,889		Assumes 85,000sqft (Embankment) and 12" deep
	h. Place Grubbed Surface Soil	3150	CY	\$5.00	\$15,750		Assumes 85,000sqft (Embankment)
	i. Finish Grade	9440	SY	\$2.00	\$18,880		
							Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	j. Hydroseed	2.0	AC	\$2,000.00	\$3,903		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	k. Plantings/Shrubs	9440	SY	\$2.50	\$23,600		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
	l. Plantings/Trees	200	EA	\$100.00	\$20,000		
8	Levee Removal	1	EA	\$302,365.40		\$302,365	
	a. Prep/Grub	1.7	AC	\$5,600.00	\$9,642		WSDOT unit bid analysis state average
							assumed \$10/Cyd to haul and dispose/grade out (quote from Whatcom County), Reasonable assuming double the Guide 2006 for common excavation \$5 to account for sorting of rock and short haul to TSP for fill (TSP may accommodate up to 6500cy from levee as shown on plans)
	b. Excavate and Haul Levee	16,700	Cyd	\$10.00	\$167,000		Guide 2006 (assumes topo low fill and 6500cy to TSP)
	c. Dispose of excess Spoils	10,179	Cyd	\$5.00	\$50,895		Assumes 75,000sqft (levee removal) and 12" deep
	d. Place Grubbed Surface Soil	2780	CY	\$5.00	\$13,900		Assumes 75,000sqft (levee removal)
	e. Finish Grade	8330	SY	\$2.00	\$16,660		
							Premium seed mix w/mulch & tackifier applied at 1800lbs/acre. North West Erosion Control quote (\$1200/acre for hydro and compost additional \$42/yd blown in)
	f. Hydroseed	1.7	AC	\$2,000.00	\$3,444		Estimate from Guide 2006 (assuming \$5/1gal shrub planting per every 2 yards)
	g. Plantings/Shrubs	8330	SY	\$2.50	\$20,825		Estimate from Guide 2006 (assuming \$100/6' tree spaced 10' apart)
	h. Plantings/Trees	200	EA	\$100.00	\$20,000		
9	Floodplain Rock Removal	21	EA	\$83.33		\$1,750	minutes per rock and one Truck Hauling (\$125/hr) for 20 minutes to TSP
10	Log Embankment Removal	45	EA	\$120.00		\$5,400	assumes cut cable and haul logs to floodplain for habitat

Construction Subtotal		\$882,571
Contingency +30%	30.00%	\$264,771
Subtotal		\$1,147,342
Tax	8.60%	\$98,671
Bonding	2.00%	\$22,947
Insurance	1.50%	\$17,210
Total		\$1,286,170

