# CONCEPTUAL RESTORATION ALTERNATIVES ANALYSIS MEMORANDUM

## GOODELL CREEK ALLUVIAL FAN, TRIBUTARY TO THE SKAGIT RIVER, NEWHALEM, WASHINGTON

Prepared for
The Upper Skagit Indian Tribe

Prepared by
Herrera Environmental Consultants, Inc.

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**Note:**
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*The Upper Skagit Indian Tribe secured funding to lead the investigation into Goodell Creek alluvial fan and floodplain restoration opportunities. The Tribe, in conjunction with Project Team members from the National Park Service and Seattle City Light, selected Herrera Environmental Consultants, Inc. to complete a conceptual stage (also referred to as Phases 1 and 2) of restoration project planning. The objectives of this project stage were to characterize existing conditions, anticipate future geomorphic and hydraulic conditions under a No Action scenario, develop conceptual restoration opportunity potential, and provide recommendations to restore natural hydrogeomorphic processes supportive of salmonid population restoration and aquatic and terrestrial resources within the project area.*

*This final analysis memorandum was prepared by Herrera Environmental Consultants, Inc. in collaboration with the Project Team, and is intended to provide a concise summary of the first stage of developing and evaluating potential restoration opportunities for the Goodell Creek Alluvial Fan. It also documents the review and acceptance by the Project Team of the Existing Conditions Characterization (Phase 1), the Alternatives Analysis (Phase 2), and the Synopsis and Recommendations for Future Project Phases. Interpretation of the discussion presented herein might require the review of additional documents or data not currently included in this analysis memorandum.*

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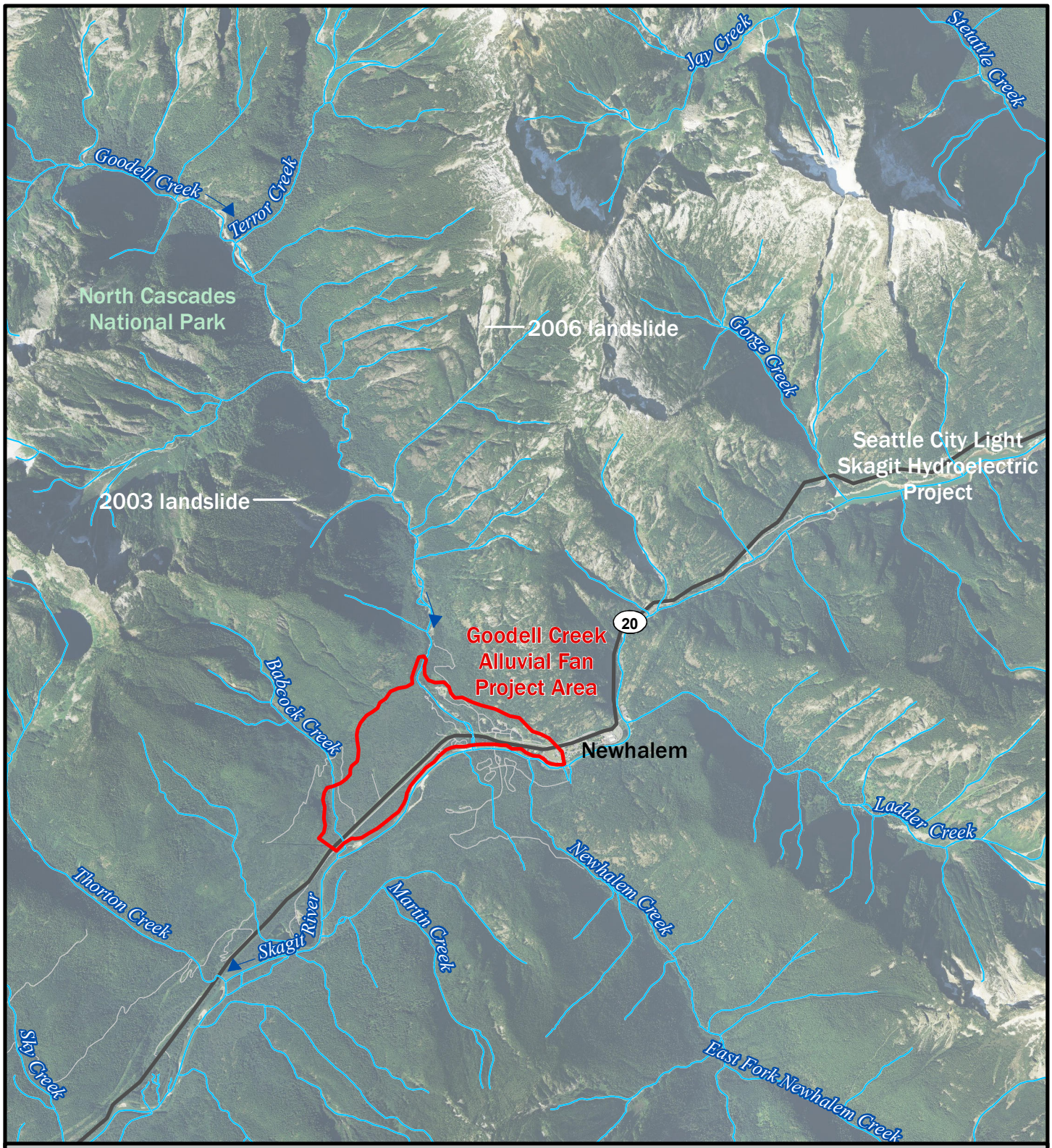
# INTRODUCTION

Goodell Creek flows into the Skagit River near Newhalem, Washington, and a historically dynamic alluvial fan is present at the mouth of Goodell Creek. Goodell Creek is known to support several salmonid species, including Steelhead, Chinook, Bull Trout, Coho, and Pink. However, the Goodell Creek alluvial fan area has been severely impacted by infrastructure during the last century and thus salmonid habitat utilization within the alluvial fan area has been restricted to the main stem channel. Facilities such as earthen levees, the North Cascades Highway (State Route (SR) 20), and campgrounds have fragmented aquatic and riparian habitats and restricted Goodell Creek from accessing its historic alluvial fan, side channels, and portions of the floodplain.

The Upper Skagit Indian Tribe (USIT), in partnership with National Park Service (NPS) and Seattle City Light (SCL), together, the "Project Team", have initiated a cooperative effort to develop a restoration plan for the Goodell Creek Alluvial Fan. Figure 1 depicts the Goodell Creek Alluvial Fan Project Area, also referred to in this document as the "Project Area". The primary goals of this plan are to maximize the ecological lift associated with the restoration of high quality salmonid habitat and natural hydrogeomorphic processes, while reducing hydraulic and geomorphic risks (e.g., from flooding, scour, sedimentation, channel avulsion) to infrastructure. The Project Team has identified four distinct priority areas for restoration efforts within the Project Area, consisting of 1) isolated floodplain and wetland areas on the left bank, 2) recently inundated floodplain areas along the right bank, 3) relic avulsion and side channel areas along the right bank initiating at the top/apex of the fan, and 4) the SR 20 bridge and cross culverts.

The restoration plan would be completed over several stages, including a conceptual planning stage and a future design and permitting stage. The alternatives analysis presented in this document describes the results of the first stage of conceptual project planning completed by Herrera, including a Phase 1 characterization of existing conditions, and a Phase 2 evaluation of restoration project alternatives.




## Legend

- Goodell Alluvial Fan Project Area
- Stream or River
- City limit
- Road
- Highway

**Figure 1.**
**Goodell Creek Alluvial Fan Project Vicinity Map.**

N

0 0.5 1 2 Miles

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USDA, Aerial (2013)

K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\vicinity_map.mxd (10/2/2014)

# PHASE 1 CHARACTERIZATION OF EXISTING CONDITIONS

This section summarizes Herrera's key findings from the Phase 1 characterization of existing conditions within the Project Area, which were based primarily on a review of historic documents and publicly available remote sensing data, field visits of the alluvial fan and 2003 landslide areas, and input from the Project Team. While a broad range of literature and data sources were reviewed, only information pertinent to alternative analysis is discussed in this section.

## Review of Historical Information

The Project Area is located within the Ross Lake National Recreational Area, which includes several campgrounds, administered by NPS. Additional NPS facilities in the vicinity of the Project Area include:

- Several administrative access roads
- A several acre shooting range that has recently been closed to public use but is still used for administrative purposes and is slated to undergo lead abatement
- A site for Recreational Vehicles (RV's) with water and power hookups
- A popular day use site and raft launch area along the Skagit River adjacent to the lower Goodell Campground

Although the Project Area is primarily forested today, its landscape reflects a diverse history of land use modifications. Appendix A provides an estimated timeline for several of these land use changes (NPS 2012). Prior to European settlement, the Goodell Creek alluvial fan and riparian area was used as a fishing area for the Upper Skagit tribes as evidenced by the presence of several archeologically sensitive areas within the area. This entire area is in very close proximity to the Upper Skagit village located at Newhalem. Starting from the early 1900s through 1968, when the Ross Lake National Recreational Area and North Cascades National Park were established, the alluvial fan and upper watershed were logged. The alluvial fan was host to a saw mill and gravel bar and pit mining operations, which likely supported the construction of SCL's Skagit River Hydroelectric Project, including Gorge, Diablo, and Ross dams, completed between 1924 and 1961. Levees were constructed along both banks to contain Goodell Creek sometime between the 1920s and 1940s and solid and industrial waste was buried within the upstream portion of the left bank levee during the 1980s (NPS 2012). The exact contents of this garbage dump site are unknown; however, it has been reported that this site is probably contaminated with arsenic and lead from sand blasting waste (NPS 2012). The Washington Department of Transportation has a right of way for the North Cascades Highway (SR 20), which traverses the Project Area. In addition, SCL manages power lines and power line tower infrastructure that are associated with the Skagit River Hydroelectric Project and which roughly parallel SR 20 through the Project Area.

The Goodell Creek alluvial fan has also been influenced by some comparatively recent hydrogeomorphic changes. Although landslides in the contributing watershed are common, a particularly large landslide occurred in 2003 that mobilized approximately 3.8 million cubic yards of very coarse ($D_{50}$ = 1.5m) landslide debris (Brummer 2006). Another landslide that occurred within the subbasin of a tributary to Goodell Creek in 2006 was also suspected of contributing large volumes of sediment to Goodell Creek (J. Riedel personal communication with C. Avolio during a site walk on April 3, 2014). Coincidentally, the NPS has observed increased aggradation in the main channel of Goodell Creek upstream of the SR 20 Bridge, including increased flooding of the Lower Goodell Creek group campground in recent years. These changes have resulted in the need to move camp sites 1 and 2, improve drainage with new cross-culverts under campground access roads, and develop a plan for potential re-routed access to the Lower Goodell Creek group campground from SR 20 (NPS 2007).

## Field Reconnaissance

Herrera conducted two field reconnaissance site visits to field verify existing geomorphic, hydrologic, and habitat conditions along with USIT and NPS staff. The first visit was conducted of the alluvial fan area on Thursday, April 3, 2014. The second site visit was conducted of the 2003 landslide area on Tuesday, April 8, 2014.

### *Alluvial Fan Observations*

Figure 2 depicts the locations of some of the key features assessed during the alluvial fan site reconnaissance, and selected representative photos are included in Appendix B. Appendix F includes a wildlife habitat checklist that Herrera developed and used as a field guide in order to note important wildlife habitat features during the site visit. A summary of the alluvial fan observations most important to the Phase 1 analysis are:

- Existing levees have cutoff side channels and disconnected floodplain areas (see Photos 19 and 30 in Appendix B). This has concentrated the sediment deposition within Goodell Creek's main stem (see Photos 6 and 14 in Appendix B), and has drastically affected alluvial fan dynamics and physical processes.
- Recent sediment aggradation was observed in the main stem of Goodell Creek upstream of SR 20 (see Photos 5, 6, and 14 in Appendix B) and active or recently active avulsion pathways and channels were observed alongside both the left and right bank levees (see Photos 15, 16, and 24 in Appendix B).
- There is a topographic break in the right bank levee (near campsite #2 of the Lower Goodell Group campground; see Photo 24 in Appendix B) that is allowing flow from Goodell Creek to back up westward and downstream from this levee break towards the campground access road and a culvert installed there in 2009.
- One of the left bank avulsion channels has engaged an existing levee, which contains buried anthropogenic materials including garbage (see Photos 13 and 17in Appendix B).
- Immature trees (less than 20 years old) and shrubs were observed along the main stem of Goodell Creek, mostly within the leveed areas (see Photo 16 in Appendix B).

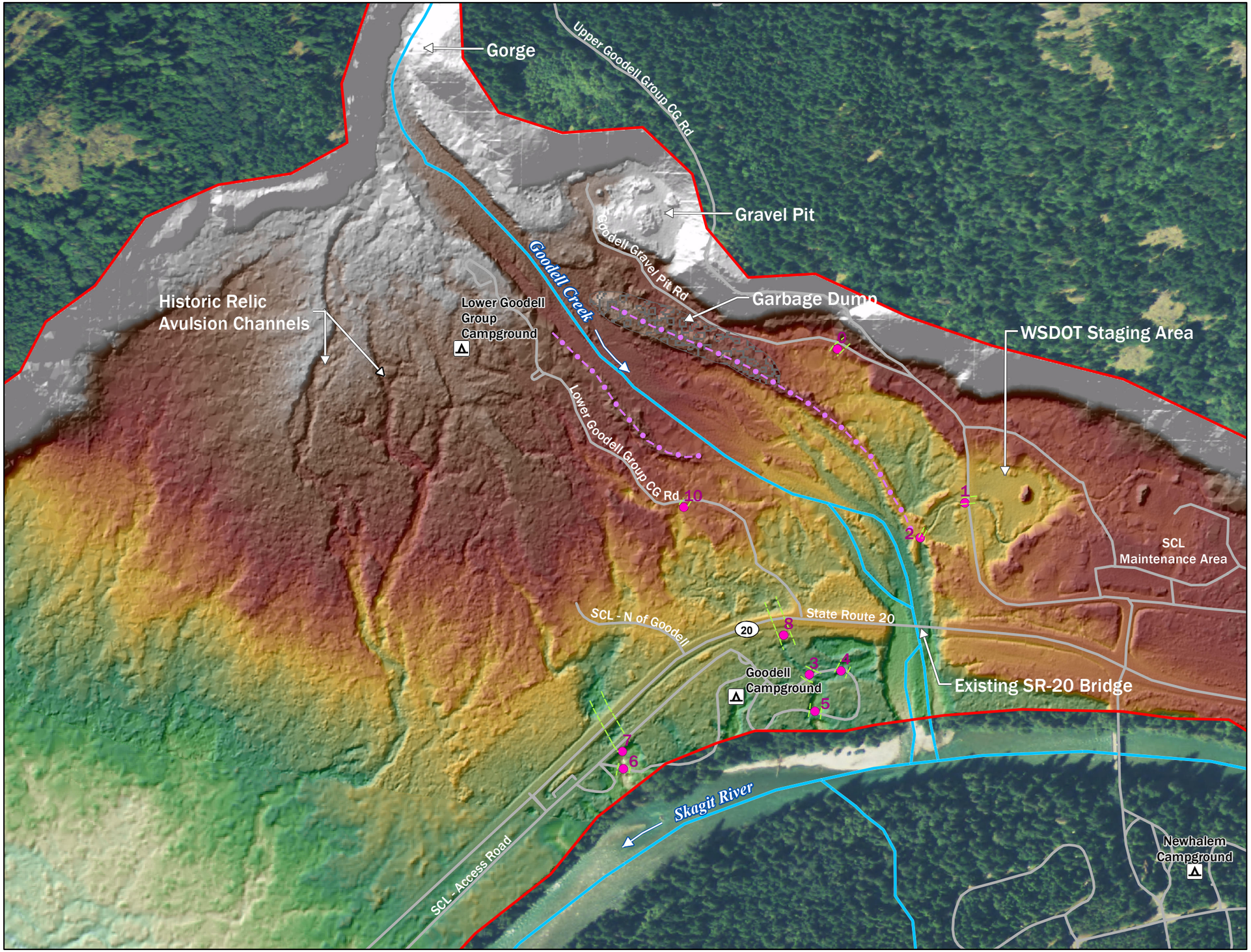


Figure 2.
Existing Conditions at the Goodell Creek Alluvial Fan Project Area and Key Geographic Features of the Alternative 1 - No Action Alternative.

**Legend**

- Goodell Alluvial Fan Project Area
- Culvert GPS point
- Existing culvert pipe
- Approximate extent of existing levee
- Garbage dump
- Campground
- Stream or River
- Flow direction
- Road

Merged 2009 & 2006 Lidar - Elevation (ft)
High : 540
Low : 460

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

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Project: K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\existing_conditions.mxd (12/9/2014)

- The vegetation alongside and within the active or recently active avulsion pathways and channels was dominated by immature deciduous and coniferous tree species, while many shrubs have washed away or died (see Photo 16 in Appendix B).
- Mature trees are mostly lacking from the top of the left-bank levee and from the WSDOT staging area and SCL maintenance facilities (see Photo 18 in Appendix B).
- No emergent wetlands were readily observed (although a more comprehensive investigation would be necessary to definitively confirm whether site soil, vegetation, and hydrologic conditions were suitable to support wetland habitats): ponded water located behind levees appeared likely to be caused by cutoff side channels and surface runoff. One dead juvenile char fish (bull trout or Dolly Varden) was found within a ponded water area located within the Goodell Campground, behind the right bank levee downstream of SR 20 (Photo 31 in Appendix B).
- Little to no existing surface expressions of hyporheic connectivity was observed between the existing channel and the historic relic channels and tributaries, although gravel/cobble layers were observed just a few inches below the forest duff surface within the historic relic channels (see Photos 27 and 28 in Appendix B).
- Mature, functioning forested terrestrial habitats are present in the broader fan area, mostly composed of a mosaic of big leaf maple and cottonwood patches, and larger areas of conifer species (see Photos 9, 27, and 28 in Appendix B). No sensitive species (Appendix F) or nests of sensitive species were observed during the site visit.
- At the SR 20 Bridge, sand deposition was observed just a few feet below the bottom chord of the bridge deck (see Photo 3 in Appendix B).
- At the SR 20 Bridge, the Goodell Creek main channel flow is concentrating between the middle and right bank abutments and sediment is accumulating in between the middle and left bank abutments (see Photos 1, 2, and 3 in Appendix B).
- At the SR 20 Bridge, the middle pier is at increasing risk from scour (see Photos 1 and 2 in Appendix B).

## *Landslide Observations*

Figure 3 depicts the locations of some of the key features from the landside site reconnaissance and photos are included in Appendix B. The 2003 slide (see Photo 36 in Appendix B) was accessed via the Goodell Creek climber's trail and the forested slope below the trail just upstream from the left bank tributary (see Photo 37 in Appendix B) that experienced a landslide and debris flow in 2006. This tributary enters Goodell Creek across from the middle of the 2003 slide. From the trail access point, Herrera observed the 2006 debris flow deposits within the tributary down to the snout upstream of the confluence with Goodell Creek (Appendix B). Due to thick vegetation and uneven topography, only the upstream end of the 2003 slide, along with the remnants of the landslide-dammed lake, was observed directly (see Photos 38 through 44 in Appendix B). However, Herrera collected some topographic information to define the extents of bedload and sand deposition within the lake and tied the survey into geographic features that were consistent and easily observable from aerial photographs and the 2009 NPS lidar dataset. Following the landslide visit, additional

reconnaissance of the right bank floodplain on the alluvial fan was undertaken from the SR 20 Bridge to the fan apex where Goodell Creek outlets the bedrock confined gorge reach. A summary of the landslide observations most important to the Phase 1 analysis are as follows:

- Aerial photographs just after the 2003 landslide and measurements by Brummer (2006) indicate there was a pulse of debris initially mobilized, but the majority of the mobile bedload from the landside is just now reaching the Alluvial Fan Project Area.
- Debris flow deposits from the 2006 landslide are still locked up within the left bank tributary drainage upstream of the confluence with Goodell Creek (see Photo 37 in Appendix B).
- The lake created in Goodell Creek upstream of the 2003 landslide is estimated to be approximately half-full and still capturing bedload and some suspended load from the upper watershed (see Photos 43 and 44 in Appendix B).
- The 2003 landslide has significantly armored Goodell Creek and locked the channel profile in place for now (see Photos 38 and 39 in Appendix B).
- Although there is a significant volume of wood in the lake (see Photos 40 and 41 in Appendix B), no evidence of debris flood deposits or large debris dams capable of sequestering large volumes of flood water were observed.
- No significant change has occurred at the landslide since 2006, aside from deposition of a coarse deltaic feature at the upstream end of the lake and sand deposited in the bottom of the lake (see Photos 41 through 44 in Appendix B).
- Recent sand deposits (deposited in the last year) were found downstream of the 2003 landslide dam along the channel periphery in the armored slide reach.
- Bank erosion into historic landslide deposits (some greater than 10 meters thick) downstream of the 2003 landslide provide another significant sediment source to Goodell Creek downstream of the landslide dam.
- There are large volumes of remobilized coarse landslide debris within gravel bars located downstream of the slide (see Photo 34 in Appendix B), but upstream of the gorge that could be susceptible to erosion and delivery to the fan in the future.

## *Project Area Topography*

Herrera combined topographic information available from two sources of lidar data, including a 6-foot 2006 Puget Sound Lidar Consortium (PSLC) dataset (PSLC 2006) and a 1-meter 2009 dataset of the Goodell and Newhalem Creek watersheds provided by NPS (NPS 2009). Table 1 compares each of these lidar datasets. During the alluvial fan site visit, Herrera flagged specific locations (including cross-sections near the SR 20 Bridge and levees, and selected spot elevations within the floodplain) within the Project Area for a surveyor to provide additional topographic detail to help validate the lidar accuracy. A copy of the survey is included in Appendix C. Herrera performed a direct comparison of the survey and the lidar topography (see comparison cross-section plots in Appendix C). The direct comparison indicated that the 2009 lidar was fairly accurate for the cross-section survey points located above the water surface at the time the lidar was flown. Cross-section survey points collected

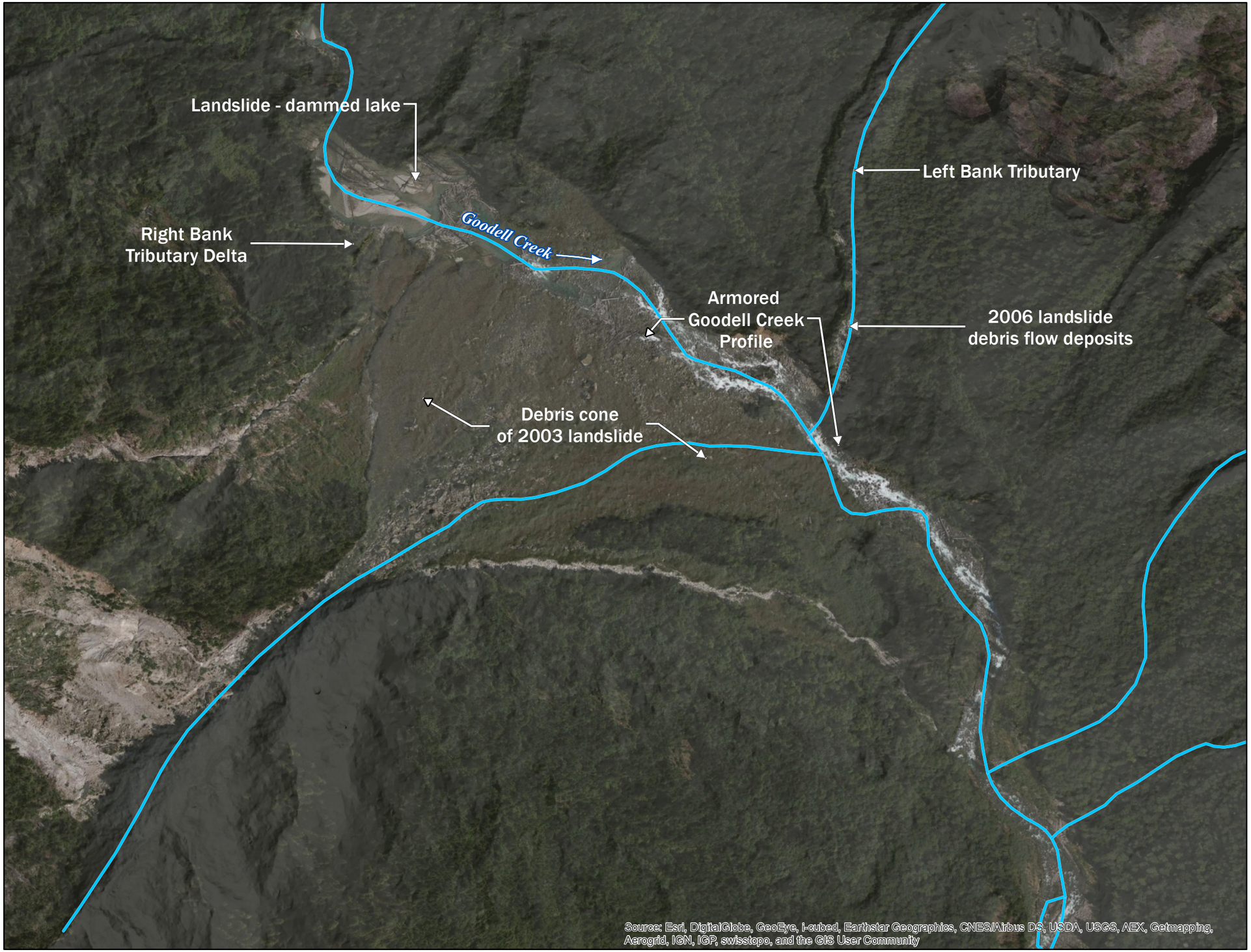


Figure 3.
Geographic Features Important
to the Landslide Reconnaissance.

Legend

Stream or River

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

ESRI, Aerial (2010)

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Project: K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\landslide_area.mxd (10/2/2014)

from the channel bottom were used to guide the adjustment of the model topographic surface for in-channel areas.

**Table 1. Summary of Lidar Datasets Used in Developing Project Area Topography.**

| | 2009 NPS Goodell Creek Watershed Lidar | 2006 PSLC Lidar |
|---|---|---|
| **Source** | NPS, Watershed Sciences (North Cascades Mountain Range) | USGS North Puget Sound Lidar survey |
| **Date Flown** | Sept 2009 | Spring, Summer 2006 |
| **Projection** | UTM Zone 10 (meters) | State Plane North NAD83 (feet) |
| **Vertical Datum** | NADV83/NAVD88 (Geoid 03) | NAVD1988 |
| **Cell Size** | 1, 1 (meter) | 6, 6 (feet) |
| **Source** | NPS, Watershed Sciences (North Cascades Mountain Range) | USGS; USGS North Puget Sound Lidar survey |
| **Date** | Sept 2009 | Spring, Summer 2006 |

## Geomorphic Analysis of Existing Conditions

Based upon the site reconnaissance, it is clear that the Goodell Creek basin is still in the process of responding to the extremely large 2003 landslide event. Brummer (2006) reports that the volume of this event was approximately 3.8 million cubic yards. Of this, only about one million cubic yards of material was delivered to the creek valley. The rest of the slide volume resides on the hillslope above the creek. Brummer (2006) documents that of the 1 million cubic yards delivered to the channel, 150,000 cubic yards had been eroded out at the time of his survey in 2006. As predicted by Brummer (2006), the site reconnaissance indicates that the slide surface has been largely unchanged since then. Most of the response since 2006 has been the continued sequestration of approximately 250,000 cubic yards of sediment in the landslide-dammed lake upstream from the slide deposit (Figure 3). The remaining sediment storage above the slide deposit is estimated to be 120,000 cubic yards. Assuming upper basin sediment inputs remain close to either their historical value or estimated annual average yields from a Syvitski et al. (2005) analysis (Appendix D), the lake will remain a blockage to upper basin bedload (gravel and coarser material) for another 5 to 7 years.

Of the 150,000 cubic yards of sediment that eroded out shortly following the 2003 landslide, most of this volume has been temporarily sequestered in between the slide and the bedrock gorge upstream of the fan. As evidenced by a comparison between the 2009 and 2006 lidar datasets (Appendix D), approximately 16,000 cubic yards formed a sediment wave and reached a location currently functioning as the fan apex (due to the levees and other hydromodifications) well downstream of the gorge, sometime between 2006 and 2009. However, there remains a large volume of unconsolidated material above the fan, but below the slide. Since upstream bedload supply will remain cutoff until the landslide-dammed lake fills, bank erosion of the remobilized slide material above the gorge is expected to be the dominant sediment supply to the fan over approximately the next 10 years. Beyond that time,

the fan will be supplied by the upper basin supply again, possibly supplemented by erosion of the remaining material between the slide and the gorge. That is, unless there is another large landslide below the existing large landslide, in which case, the characteristics of that slide may overwhelm these processes.

The fan itself, which has until the arrival of the sediment wave between 2006 and 2009 only been marginally affected by the 2003 landslide, has historically been dominated by the construction SR 20 Bridge and the confinement of the channel by a series of levees and other infrastructure and fill. These collective actions have effectively relocated the fan apex to its current location about 2,000 feet upstream of the SR 20 Bridge. The bridge has had a profound adverse effect on the creek, heightening sediment deposition from it upstream to the fan apex. This has caused the channel between the confining levees to fill, initiating overbank flows during floods, which are now common.

The most pronounced deposition has been at and just upstream of the bridge, including forming a large, now vegetated (with mostly immature deciduous trees) mid-channel island and filling in nearly the entire east half of the bridge crossing. Downstream of the bridge, the channel is somewhat incised (at least with respect to a creek on an alluvial fan) and fixed in place down to its confluence with the Skagit River.

The channel aggradation observed during the site visits is having dramatic consequences on the existing physical aquatic and riparian habitat. Because of the dynamic nature of alluvial fans, vegetation within (on bars) and immediately adjacent to the main stem is typically disturbed by sediment deposition and the creation of new avulsion pathways and distributary channels. Consequently, it is not uncommon to find mostly immature vegetation on recently disturbed areas. As the fan expands and the main channel shifts location, the disturbance frequency decreases allowing vegetation to mature and become more resilient. Over time, the main creek flow may return to previous channel locations, where the now mature vegetation can better handle sediment deposition and flood flows. However, when the fan is constricted and the floodplain is disconnected from the main stem by levees as has taken place in Goodell Creek, the frequency of vegetation disturbance within the leveed areas increases and the less resilient vegetation is removed, rendering channel areas devoid of vegetation.

## Estimation of Existing Hydrologic Conditions

Four flows were developed, including two peak recurrence interval flood flows, one habitat significant flow, and one extreme flood (Bulked 100-year) to provide the hydrologic inputs for the hydraulic modeling. Because Goodell Creek is ungauged, Herrera relied on available existing model analyses, streamflow gauge data from the USGS gauge #12179900 at Bacon Creek (adjacent basin approximately 10 miles to the west of Goodell), and the USGS regression equations for ungauged streams (Sumioka et al. 1998; Curran et al. 2012) to develop these four hydrographs. Table 2 summarizes the final hydrologic inputs used for the modeling analysis and their supporting references are presented in Appendix E.

Given its steep upper watershed and plentiful supply of coarse sediment transported as bedload and debris flows, the Project Area was initially evaluated for susceptibility to debris dam formations and debris floods. However, based on a review of the field evidence and

other historic documentation, running a debris flood or flood wave was eliminated from the analysis. Instead, and given the need to evaluate an extreme event due to the infrastructure present in the project area (WSDOT highway, SCL towers), a bulked 100-year event was developed assuming a sediment entrainment volume of 20 percent that can be transported in these types of large flood events (compared to 30 to 50 percent hyperconcentrated sediment entrainment for a debris flow/mudflow). A 20 percent sediment entrainment bulking factor results in a flow multiplication factor of 1.25 times the USGS 100-year flow. This multiplication factor of 1.25 times is also within the range of a typical factor for estimating the 500-year clear flow from the 100-year hydrologic clear flow for Pacific Northwest basins. As such, the estimated bulked flow used in the hydraulic analysis provides a good representation of an extreme event that could occur within the design life of the downstream infrastructure.

**Table 2. Summary of Goodell Creek Hydrologic Inputs for Hydraulic Modeling.**

| Recurrence Interval/ Event (year) | Flow (cfs) | Skagit River Boundary Condition Flow (cfs) |
|---|---|---|
| Habitat Flow / Low Flow | 250 | 10,000 |
| 2 | 2,935 | 10,000 |
| *10* [1] | *5,413* [a] | *30,000* [a] |
| *10* [1] | *5,413* [a] | *10,000* [a] |
| 100 | 9,024 | 10,000 |
| Extreme/ Sediment Transporting Event (Bulked 100-year = 1.25 X 100-year Q) | 11,281 | 10,000 |

cfs = cubic feet per second

[a] *Analyzed for sensitivity and backwater effects analyses only*

The hydrologic characteristics and flood timing for the Skagit River (large regulated basin) and Goodell Creek (small and steep basin) are very different, and the probability of two extreme peak flows occurring at the same time is very low. A flow of 10,000 cfs was selected as the flow rate to use as the Skagit River boundary condition flow for the various Goodell Creek flood flows approximated in the hydraulic model. This flow rate is approximately a 1-year peak event in the Skagit River at Newhalem (Gauge # 12178000). Ross Dam passes through most flows smaller in magnitude than a 2-year event. The USGS flow gauge results for the Skagit River at Newhalem indicates 10,000 cfs was exceeded 6 times in the last 7 years. A sensitivity analysis was conducted in order to evaluate the influence of the selected Skagit River boundary condition flow on the Project Area. The 10,000 cfs was eventually selected as it represented a frequent peak but was not so large as to dwarf the hydraulic effects (e.g., peak velocities and shear stress) of Goodell Creek at the existing SR 20 Bridge, nor blur a comparison of the hydraulic differences across alternatives described later in this memorandum. To assess the potential backwater effects for large flows in both the Skagit River and Goodell Creek, a 10 year flow in Goodell Creek was coupled with approximately a 10 percent exceedance event (10-year flood flow) in the Skagit River (30,000 cfs).

## Desktop Review and Remote Sensing Analysis of Existing Fish and Wildlife Habitat Conditions

Herrera conducted a remote-sensing desktop data review of publicly available information (aerial photographs, Lidar) and the habitat information provided during the proposal process (NPS habitat reports, WDFW off-channel habitat inventories) to supplement field observations and generate a preliminary understanding of floodplain and instream habitat conditions present within the Project Area.

Several species of fish that have been listed with some degree of protection status utilize the Goodell Creek watershed at various points in their life histories. Three species of fish are listed under the federal Endangered Species Act in the Skagit System: Chinook salmon, steelhead trout, and bull trout. Coho salmon are a federal species of concern, and Chinook and bull trout are also listed as Washington State species of concern. Upper Skagit summer Chinook spawn in the Skagit main stem and its tributaries upstream of the Sauk River, primarily from September through early October (NPS 2012). The wide distribution of Chinook spawning indicates that upper Skagit summer Chinook are seeding all the habitat available to them (SRCS and WDFW 2005). Goodell Creek also supports bull trout that exhibit anadromous, fluvial, and resident life history patterns (NPS 2012).

One other federally listed species that utilizes the Goodell Creek watershed is the spotted owl (WDFW 2014). Given the prevalence of fairly mature coniferous vegetation within the Alluvial Fan Project Area, a good portion of the Project Area has the potential to be spotted owl habitat (WDFW 2014), even though there are no mapped nests and no nests were located during the alluvial fan site visit. Other sensitive species with the potential to be in or near the Project Area include gray wolf, grizzly bear, wolverine, Canada lynx, northern spotted owl, marbled murrelet, bald eagle, peregrine falcon, harlequin duck, pileated woodpecker, osprey, and northern goshawk. There are also potentially several bat species that are either Washington State candidates or Federal species of concern including: Townsend's Big-eared, Western long-eared, Long-legged myotis, Fringed myotis, Western small-footed, and Yuma myotis (R. Christophersen, NPS Wildlife Biologist email to R. Hartson, USIT Aquatic Scientist on April 8, 2014, Appendix F).

The Goodell Creek alluvial fan is composed of rich but fragmented aquatic, riparian, and floodplain habitats, and its confluence with the Skagit River has been identified as “rare habitat” (Beamer et al. 2010). Although perhaps partially through natural alluvial fan processes, the Goodell Creek floodplain is highly disconnected due to anthropogenic modifications primarily associated with roads and levees. These roads and levees have cut off side channels and prevented seasonal inundation of floodplain areas. There is a ponded area behind the left bank levee just upstream from the SR 20 Bridge that drains through the levee via a culvert. Barkdull et al. (2012) met to explore possibilities for improving fish passage into the pond but noted that although there were no monitoring piezometers installed, the pond has been observed drying up in the summertime.

The fact that Goodell Creek’s floodplain areas have been disconnected is likely having significant effects on the survival and productivity of this system’s salmonids and wildlife species. For example, juvenile rearing salmon are not likely using the floodplain areas for

rearing, overwintering, or flood refugia, as seasonal access to those areas is prevented by the levees. Seasonal flooding of the floodplain is a key hydrological process influencing fluvial ecosystems. For example, the flood pulse concept (Junk et al. 1989) establishes that annual high-water pulses are the main force in determining existence, productivity, and interactions of major biota in river–floodplain systems. This is consistent with the general principles used to analyze and predict fish habitat suitability and availability (Simenstad and Cordell 2000). These principles consider access opportunity, habitat capacity, and realized function when evaluating juvenile salmon habitat suitability. The flood pulse concept (Junk et al. 1989) suggests that areas affected by flood pulses have higher productivity than areas that maintain continuous flow. This concept recognizes the key contributions of off-channel habitat, including important zones of high production from floodplains. In fact, findings from recent research performed in the Methow River indicate that seasonally disconnected floodplain side channels contain high densities of young-of-year steelhead, Chinook salmon, and coho salmon (Martens et al. 2014). Therefore, it is highly likely that the productivity of salmonid populations within Goodell Creek is being affected by the existing anthropogenic modifications. The same is also likely the case for wildlife species that depend on, or use Goodell Creek's floodplain areas.

## Hydraulic Analysis of Existing Conditions and the No-Action Alternative

The Goodell Creek hydraulic analysis was performed using the two dimensional finite volume RiverFlow2D Plus hydrodynamic model. The required model inputs included a topographic surface, boundary conditions, and Manning's n roughness values. Details of the model development, inputs assumptions, and results are provided in Appendix G. The model was evaluated for an existing conditions and No-Action Alternative, briefly described below.

A No-Action Alternative was developed to represent potential alluvial fan geomorphic and hydraulic conditions at a point in time approximately 5 to 15 years in the future. The No-Action Alternative model was developed under the assumption that aggradation would continue at roughly the same rates and locations of observed deposition between the recent lidar flights (2006 and 2009, Appendix D). Deposition in this area occurs because it is where the flow begins to spread out, as is typical at the apex of an alluvial fan. The location of the apex is set by existing infrastructure (i.e., the levees and the SR 20 Bridge, see geomorphic analysis above). Provided that existing infrastructure remains in place (i.e., SR 20 is not damaged or washed out), normal alluvial processes will persist to ensure that this continues into the near future (within the next 10 to 20 years).

For existing conditions, discharges less than the 2-year flood event are primarily confined to the main channel due to the presence of left and right bank levees. Flow is noted to breach the mid to lower half of the right bank levee for the 2-year flow in a location consistent with field observations. Right bank overflow cannot flow back into Goodell Creek and crosses SR 20 via a 48-inch diameter culvert (that can become a fish trap or barrier, Barkdull et al. 2012). For higher flows, this culvert is overwhelmed and flow overtops SR 20. Velocities over SR 20 exceed 6 feet per second (fps) for the 100-year flow. More importantly, under the No-Action Alternative 2-year scenario, flow overtops SR 20 for flows as low as the 2-year flood, with velocities exceeding 5 fps. In general, aggradation in the main channel (No-Action) significantly increases the right bank flow and risk to SR 20.

Herrera first provided the initial Existing Conditions and No-Action Alternative results to the Project Team at the second conference call, held on April 21, 2014. Screen shots from the hydraulic model of the No-Action Alternative results are included in Appendix G.

# PHASE 2 ALTERNATIVES ANALYSIS

Phase 2 of the Goodell Creek Alluvial Fan Restoration involved close collaboration with the Project Team to develop conceptual project alternatives and to evaluate associated impacts and ecological lift to physical and ecological processes so that habitat restoration potential could be anticipated. In general, the alternative analysis considered the process-based principles identified by Beechie et al. (2010). Process-based restoration principles are intended to reestablish physical, chemical, and biological processes that create and sustain river and floodplain ecosystems.

## Workshop

Herrera hosted a workshop with the Project Team on Friday, May 30, in which the preliminary No-Action Alternative assumptions and results, including potential infrastructure risks and lost habitat opportunities, were clearly identified and discussed. This discussion of the No-Action Alternative provided the Project Team with a common foundation for comparing potential project alternative actions. The workshop also succeeded in identifying the specific alternative project components to be evaluated as well as proposed alternative evaluation criteria to be used during the evaluation. Herrera then proceeded to develop the hydraulic and geomorphic analysis for the identified project alternatives using the models and information developed in the Phase 1 portions of existing conditions characterization. Once preliminary model results were available, the evaluation criteria were also refined, as outlined in the following sections.

### *Alternative Project Identification*

The alternatives selected for the Phase 2 analysis addressed the four priority areas identified in the original project RFP, the physical and ecological constraints of the project site documented during the Phase 1 analysis, and the concerns of the stakeholders identified during the workshop. Herrera advocated taking a step-wise approach to potential alternative project implementation so that the Project Team could better adapt eventual project implementation in future project stages to available funding and resources for final design and construction. The final alternatives identified and their specific project components are listed in Table H-1 of Appendix H and graphically depicted on Figures 4 through 7.

### *Alternative Evaluation Criteria*

The Alternatives Evaluation analysis compared the Existing Conditions/No-Action Alternative against the alternative concepts using these guiding principles and objectives identified during the project RFP and reiterated during the workshop:

- To address one or more of the four priority areas consisting of 1) isolated floodplain and wetland areas on the left bank, 2) recently inundated floodplain areas along the right bank, 3) relic avulsion and side channel areas along the right bank initiating at the top/apex of the fan, and 4) the SR 20 Bridge and cross culverts

- To develop potentially feasible project alternatives given some identified project constraints
- To restore natural hydrogeomorphic processes and functions
- To increase the area and/or quality of functional habitat including rearing and spawning habitat for ESA listed species and riparian/terrestrial habitat for other wildlife
- To promote fish passage for both juvenile (laterally, to the floodplain habitats) and adult fish species (upstream, to spawning grounds)
- To protect and enhance water quality and aquatic habitat
- To protect cultural resources
- To maintain existing levels of access to recreational uses (camping, boating, hiking)
- To promote public education
- To reduce/limit/manage hazards and risks to existing infrastructure and land uses

Table H-2 of Appendix H summarizes the final evaluation criteria as they were applied during the alternatives evaluation analysis.

## Hydraulic and Geomorphic Analysis of Alternatives

The hydraulic models developed for the Phase 1 characterization of existing conditions were modified to reflect the project alternative geometries and conditions depicted in Figures 4 through 7. The existing conditions topographic surface was copied and modified for each alternative in one or more of the following ways, depending on the specific alternative:

- Removing the levees to match adjacent floodplain elevations
- Removing bank material and grading-in channels to match the new bridge locations and expanded openings
- Grading in new low-flow channel conveyance pathways
- Adding wider, fish-passable culverts and connecting channel conveyance pathways
- Adding flow blockages to represent wood roughening structures or engineered log jams (ELJs)

The existing conditions Manning's n roughness layer was also modified for each alternative to represent approximate changes from either proposed project elements or geomorphic changes over time.

Given the likelihood of increased aggradation within the Alluvial Fan area, the alternative model geometries were also modified, similarly to the No-Action Alternative, to reflect possible future aggradation conditions at a point in time potentially 5 to 15 years in the future. Alternative 2 assumes that, in addition to deposition in the main channel (Appendix D),

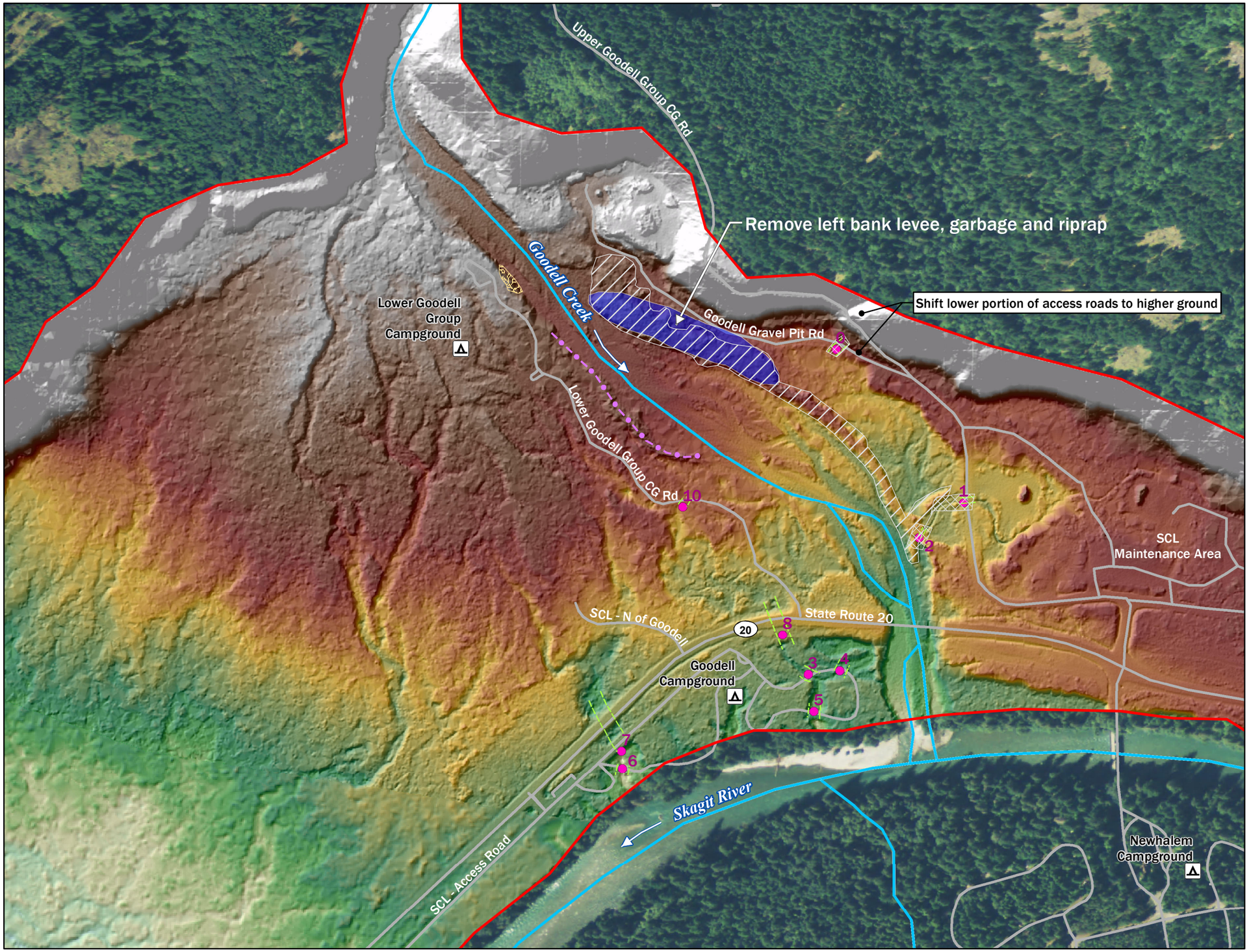


Figure 4.
Key Project Components of Alternative 2 - Left Bank Floodplain.

## Legend

- Goodell Alluvial Fan Project Area
- Culvert GPS point
- Excavation
- Concrete removal
- Removal of existing culvert pipe
- Existing culvert pipe
- Approximate extent of existing levee
- Levee, garbage, and riprap removal
- Campground
- Stream or River
- Flow direction
- Road

Merged 2009 & 2006 Lidar - Elevation (ft)
High : 540
Low : 460

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

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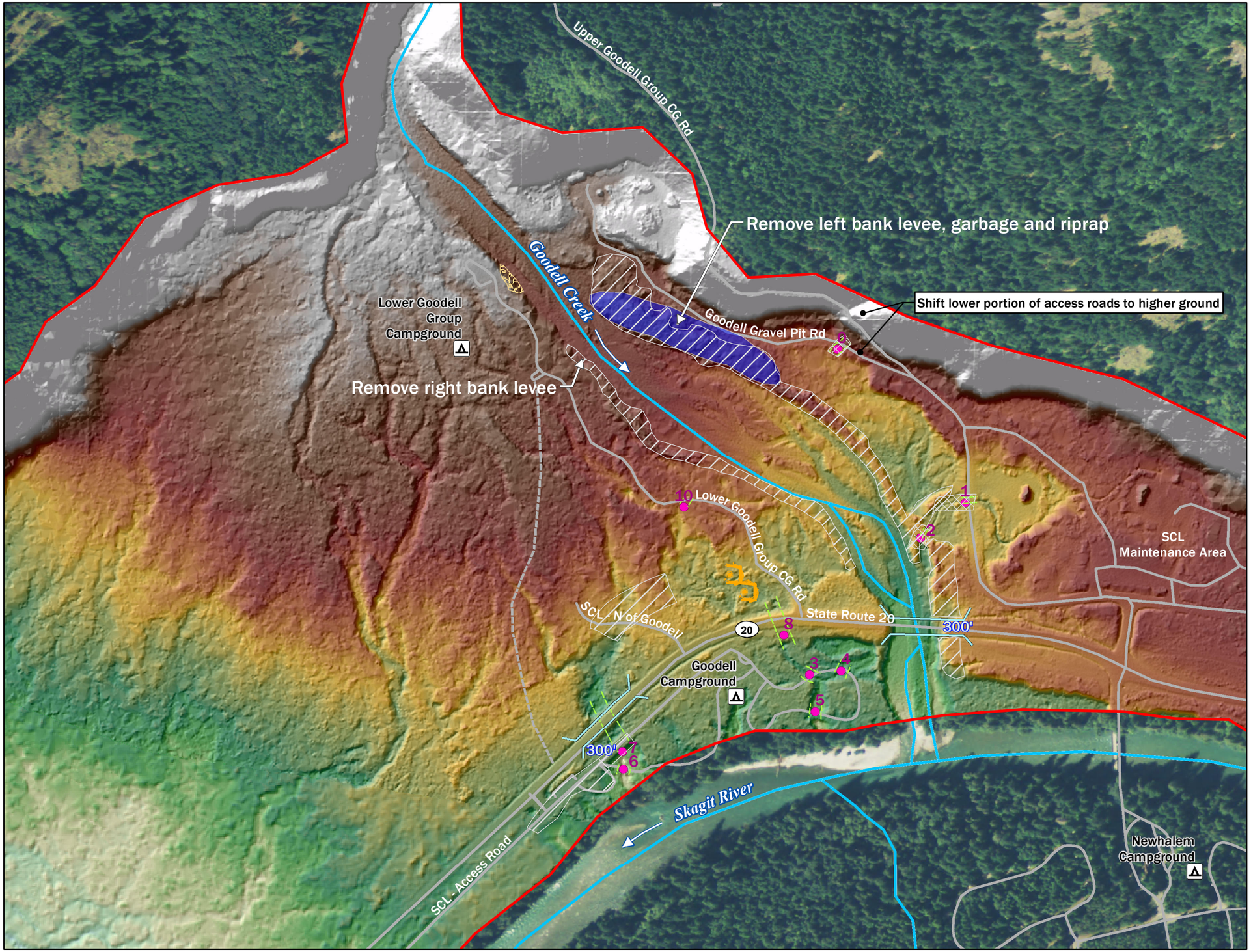


Figure 5.
Key Project Components of Alternative 3 - Left Bank and Right Bank Floodplain Reconnection and two new 300ft Crossings at SR-20.

**Legend**

- Goodell Alluvial Fan Project Area
- Culvert GPS point
- Excavation
- Concrete removal
- Removal of existing culvert pipe
- New 300-ft clear-span bridge
- New road
- Existing culvert pipe
- Levee, garbage, and riprap removal
- Large wood structures around powerline towers
- Campground
- Stream or River
- Flow direction
- Road

Merged 2009 & 2006 Lidar - Elevation (ft)
High : 540
Low : 460

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

Produced By: GIS
Project: K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\key_proj_components_Alt3.mxd (12/9/2014)

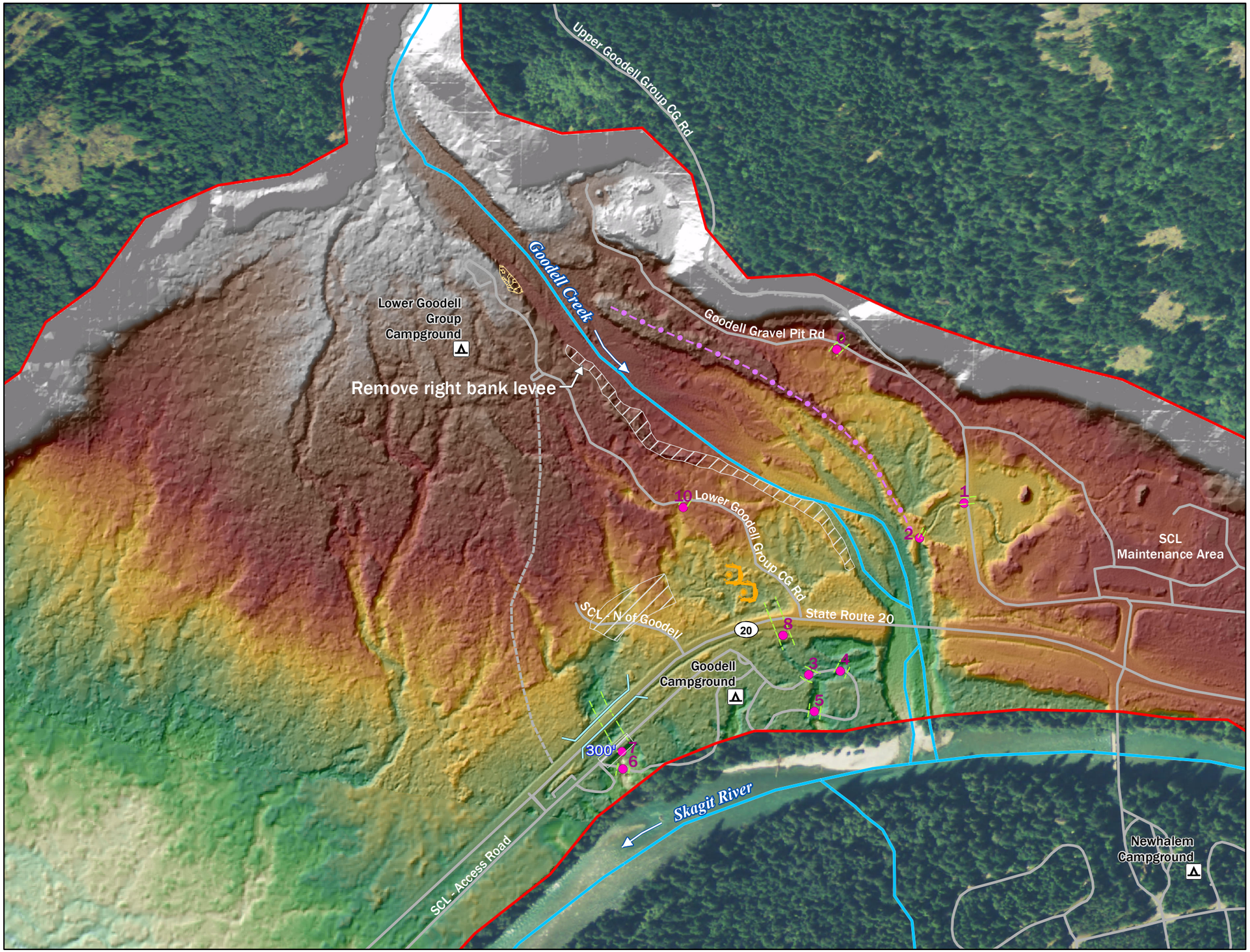


Figure 6.
Key Project Components of Alternative 4 - Right Bank Floodplain Reconnection, Leave Existing SR-20 Bridge and add 1 new 300ft-span Crossing at SR-20.

## Legend

- Goodell Alluvial Fan Project Area
- Culvert GPS point
- Excavation
- Concrete removal
- New 300-ft clear-span bridge
- New road
- Existing culvert pipe
- Approximate extent of existing levee
- Large wood structures around powerline towers
- Campground
- Stream or River
- Flow direction
- Road

Merged 2009 & 2006 Lidar - Elevation (ft)
- High : 540
- Low : 460

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

Produced By: GIS
Project: K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\key_proj_components_Alt4.mxd (12/9/2014)

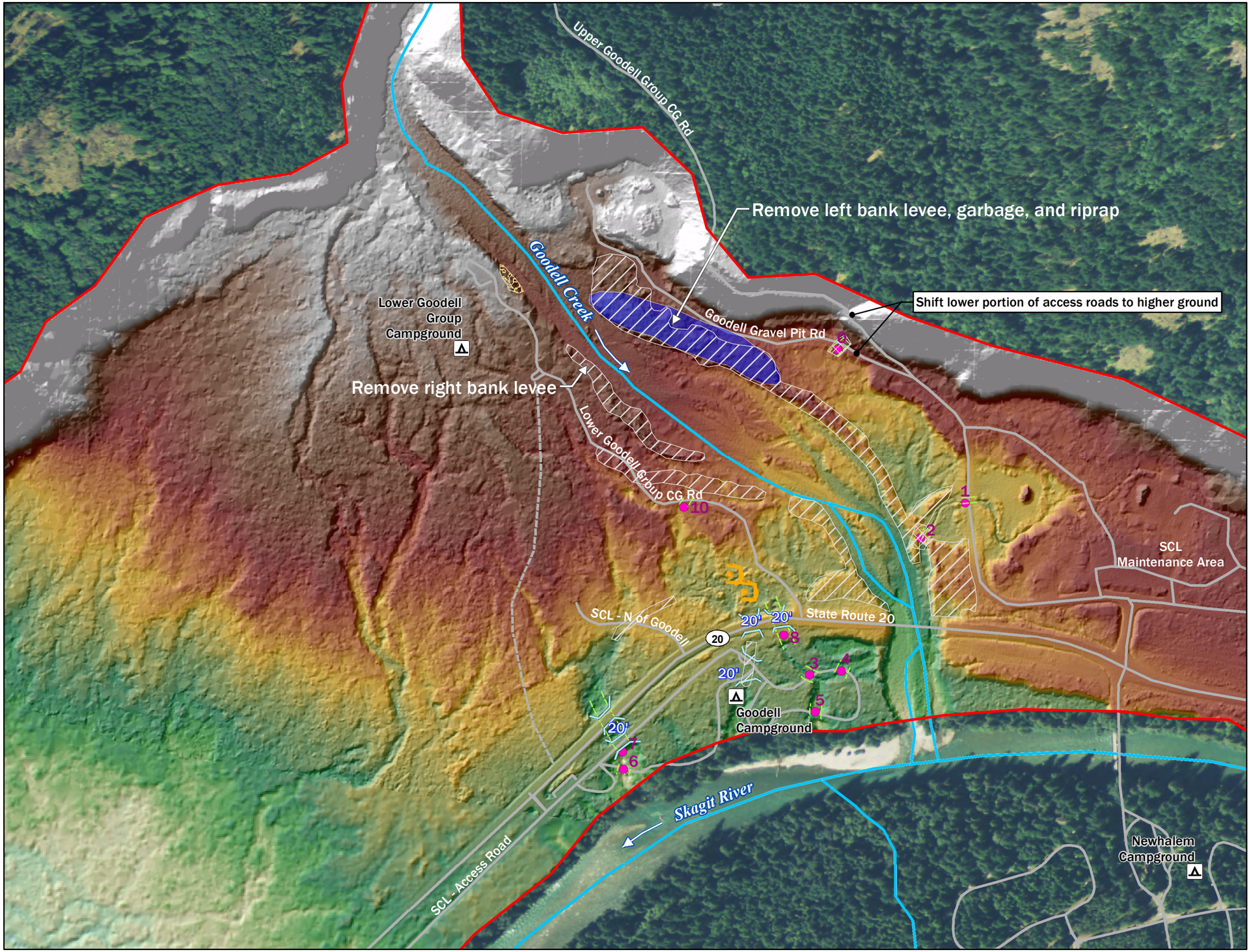


Figure 7.
Key Project Components of Alternative 5 - Left Bank and Right Bank Floodplain Reconnection.

## Legend

- Goodell Alluvial Fan Project Area
- Culvert GPS point
- Excavation
- Concrete removal
- Removal of existing culvert pipe
- New 20-ft span culvert
- New road
- Existing culvert pipe
- Levee, garbage, and riprap removal
- Large wood structures around powerline towers
- Campground
- Stream or River
- Flow direction
- Road

Merged 2009 & 2006 Lidar - Elevation (ft)
High : 540
Low : 460

N

0 200 400 800 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

Produced By: GIS
Project: K:\Projects\Y2014\14-05759-000\Project\Alternatives_Memo\key_proj_components_Alt5.mxd (12/9/2014)

an additional 2 feet of sediment will be sequestered in the newly opened left bank floodplain. It is unclear whether the additional flood storage provided by the levee removal will lessen sediment deposition in the main channel or increase it, since there will likely be competing effects of flow and sediment diversion (e.g., siphoning flow into floodplain side channels may adjust the depositional environment in the main stem, causing a greater fraction of the suspended load to deposit there, although well-positioned log structures at side channel inlets can help to maintain flow and sediment conveyance into the floodplain). Therefore, it is assumed that main channel deposition will not change due to the project. The same approach was taken with Alternatives 3 through 5. Here sediment was assumed to fill slower backwater areas in the right bank that would then engaged from a geomorphic perspective, in addition to the left bank, where it is also opened up. Since there will likely be competing effects of flow and sediment diversion, and existing modeling cannot confirm the magnitude of either of these effects, it was assumed that these effects would cancel out.

Channels were also not placed in any of the overbank splay deposits because it is unclear without further modeling whether they will form and, if so, where. As a result, in the modeling there is significant spreading of flow that is not likely to occur once channels incise into the overbank splay deposits. Similarly, modeling of the restoration alternatives illustrate a conservative picture of habitat conditions. It is likely, even probable, that many side channels will form once the levees are removed and geomorphic change is allowed to occur in a more undisturbed fashion.

In general, the results for Alternative 2 do not significantly vary compared to existing conditions for both the time zero as-built existing conditions and the No-Action geomorphic response scenario. Significant inundation of the left bank will likely take some time and it is unlikely that immediate inundation and habitat benefits would occur unless small notched channels were cut into the floodplain. Even then, inundation would likely be periodic until the main channel starts to aggrade over time. The removal of the left bank and the increase in inundation into the left bank does very little in alleviating the right bank overflow and flow rates and velocities over SR 20.

The hydraulic model results for Alternative 3 suggests that floodplain inundation (available habitat area) increases in comparison to existing conditions and aggradation scenarios. The results indicate that the immediate habitat gains and long term geomorphic response and creation of habitat is more prominent for Alternative 3 than any of the other Alternatives. Inundation and velocities over SR 20 are also eliminated for the 2-year flow and at time zero for the 100-year flow. Results show that flow breaches SR 20 for the 100-year aggradation scenario, but the velocities are greatly reduced as compared to the No-Action aggradation scenario. Alternative 3 also demonstrates the least differences as far as floodplain inundation and velocity between time zero and the geomorphic changes (aggradation) over time. This suggests that Alternative 3 demonstrates a higher level of resiliency to change over time.

The hydraulic model results for Alternative 4 are very similar to Alternative 3 because the dominant hydraulic gradient is to the south over the right bank floodplain. As such, the removal of the right bank levee appears to dictate the hydraulic response of the Goodell alluvial fan. Comparison of the Alternative 4 results with the Alternative 3 results indicate that the breaching over SR 20 would likely occur more frequently (i.e., triggered by smaller

peak flood events), but the results suggest the difference between the two alternatives is minor. In the same way, these results also suggest that replacement of the existing SR 20 Bridge crossing has minor hydraulic differences (Alternative 4 compared to Alternative 3) when compared to the placement of a new bridge west of the existing bridge. Replacing the existing bridge would support natural geomorphic responses and address the existing scour risk, yet at high flows the overall conveyance benefits are marginal given that the long term preferential floodplain flow path is to the south and southwest.

The hydraulic model results for Alternative 5 are very similar to Alternative 3 and show benefits for flooding and erosion risks to SR 20, but only for smaller magnitude events or for the short-term. The aggradation results are very different for Alternative 5 compared to both Alternative 3 and No-Action (Alternative 1). The combination of a right bank levee, a lack of conveyance under SR 20, and increased right bank floodplain flow over time due to aggradation in the main channel, results in significantly more inundation and higher velocities over SR 20. In summary, the Alternative 5 results suggest that there are likely big habitat gains due to floodplain inundation and short-term flood and risk benefits, but over time, the risk to SR 20 and the SCL facilities are greater than the "do nothing" No-Action Alternative. Considerably more analysis and hydraulic optimization of the culvert(s) and floodplain flow deflectors would be required to reduce the risk to SR 20 and it is uncertain whether the hazards associated with Alternative 5 could feasibly be alleviated compared to the No-Action Alternative without significantly large culverts.

## Floodplain and Habitat Connectivity Analysis

As previously stated, existing infrastructure has reduced or eliminated connectivity to the floodplain and degraded main-channel habitat, likely impacting salmonid productivity. For juvenile salmonid species, habitat productivity is a function of three critical metrics: opportunity, habitat's capacity, and realized function to enhance survivability. In Goodell Creek, access opportunity is the most critical metric, because the fan contains highly functioning rearing habitats, but on disconnected areas of the floodplain. These disconnected floodplain habitat areas have varying degrees of capacity to support natal juvenile rearing and provide flood refugia; therefore possibilities of reconnecting these areas present exciting habitat restoration opportunities for the project.

Consequently, Herrera developed an ArcGIS model to quantitatively evaluate, where possible, the metrics for aquatic habitat and fish passage outlined in Table H-2 (Appendix H) for each set of alternative hydraulic model output in the Goodell Project Area. These data were input to the model in GIS grid format and a series of calculations were run using Spatial Analyst map algebra functions to determine whether the grids met each set of suitability criteria. This analysis was run at the pixel scale and each grid cell was assigned a value of 1 if it met the criteria or a value of 0 if it didn't. Areas could then be calculated based on the grid cells that met the criteria. To supplement the conditions referenced for evaluating the alternatives (Table H-2), the following assumptions were made in guiding the GIS analysis approach and in using the analysis output to score the alternatives:

- **Channel Habitat Area (wetted)**: Wetted channel habitat area was defined as including all grid cells associated with a water depth greater than zero and where those grid

cells were also connected to the main stem Skagit River or Goodell Creek by other grid cells meeting this same minimum surface water depth criterion. This metric referenced the hydraulic model results for low-flow time-zero (no future aggradation) conditions. This was based on field observations, which substantiate the assumption that the low flow (250 cfs) represents a minimum flow that is likely to be present at all times, and thus a minimum area that can be utilized for juvenile salmonid rearing habitat. As the GIS analysis required adjacent elements to meet the minimum depth criterion, it eliminated areas that might show water inundation but be disconnected from main channel areas (e.g., ponded, cutoff side channels areas behind levees).

- **2-Year Floodplain Inundation Area**: This metric includes all areas where the hydraulic model showed some level of flow inundation under the 2-year flow (2,935 cfs) at time zero (no future aggradation). No additional connectivity criteria were added to this metric because most inundated areas (distributary channels) are suitable for juvenile salmon rearing under existing conditions. Of the hydrologic inputs used in this analysis, the 2-year flow represents a peak flow with a more regular recurrence (e.g., when compared to the 100-year peak flow, with a less regular recurrence). Therefore, the 2-year flow presents an opportunity to compare the alternatives for areas that might be available to salmonids for flood refuge or rearing habitat under a more frequent peak flow. This metric does not assess the suitability of these habitat areas however, but rather reports the total area.

- **Floodplain Habitat**: Floodplain habitat is also an area associated with hydraulic model floodplain inundation and was calculated by taking the difference in the inundation areas associated with the 100-year flow (9,024 cfs) and the areas defined as channel habitat (described above). The 100-year event was selected as the outer boundary for floodplain areas due to its regulatory significance (Federal Emergency Management Agency (FEMA) base flood) and common association with floodplains. The channel habitat area was subtracted out in order to differentiate between different channel and floodplain habitat types. Thus, this floodplain habitat metric does include side channels that might not be inundated under low flow conditions but which are inundated under 100-year flow conditions. Also, floodplain inundation is seen here as an analog of floodplain connectivity. It provides a measure of floodplain habitat access for juvenile salmon regardless of whether those areas are suitable, for juvenile rearing or to provide flood refugia. Note that not all inundated areas (sheet flow areas) are suitable for juvenile rearing under existing conditions.

- **Adult Fish/Passage Connectivity**: The adult fish passage metric was defined as including all grid cells with a water depth of at least 1 foot that were also connected to the main stem Skagit River or Goodell Creek by other grid cells meeting the same depth criterion. This metric referenced the hydraulic model results for the 2-year (2,935 cfs) time-zero (no future aggradation) conditions based on the assumption that the 2-year flow once again represents a peak flow with a more regular recurrence. The 1 foot minimum depth criterion, although more commonly used for culverts (Bates et al. 2003), was selected as a widely accepted minimum depth to support passage by many different adult salmonid species present in Goodell Creek. Velocity criteria for fish passage were considered but dropped from the analysis after discussing the

likelihood that that the model output would be incapable of capturing the localized hydraulic conditions (e.g., spaces between boulders and logs) that adult fish can use to navigate passage. Using velocity criteria based primarily on maximum swimming speeds would eliminate too much of the aquatic habitat areas that were known to be passable by many adult salmonids (email from Ed Connor to Christina Avolio on September 3, 2014). As the GIS analysis required adjacent elements to meet the minimum depth criterion, it eliminated areas that might show water inundation but be disconnected from main channel areas (e.g., ponded areas behind levees) and thus present either inaccessible or stranding areas to adult salmonids. The result is a metric that focuses on main stem, side channels, and distributary channel areas within the floodplain.

- **Juvenile Fish/Passage Connectivity**: The juvenile fish passage metric was defined as including all grid cells with a surface connection to the main stem Skagit River or Goodell Creek by adjacent grid cells with a depth of at least 0.1 foot. Of these hydrologically connected areas, only those cells with velocities less than 2 ft/s were considered. This metric referenced the hydraulic model results for the 2-year (2,935 cfs) time-zero (no future aggradation) conditions based on the assumption that the 2-year flow once again represents a peak flow with a more regular recurrence. Initial exploratory data analysis was based on edge habitat criteria (i.e., >0.66 deep and <1.5 fps); however, it later incorporated the full range of depths and water surface velocities described by Beamer et al. (2005; Figures 8 and 9) and Beechie et al. (2005). This included edge habitat velocities classified as high (>1.5 fps), medium (0.5-1.5 fps), and low (<0.5 fps) (Beechie et al. 2005). The goal was to avoid excluding habitat areas known to be suitable, but experiencing a modeled range of water depths and water surface velocities outside the edge habitat criteria. As the GIS analysis required adjacent elements to meet the minimum depth criterion, it eliminated areas that might show water inundation but be disconnected from main channel areas (e.g., ponded areas behind levees) and thus present either inaccessible or stranding areas to juvenile salmonids. This metric focuses on juvenile salmon access to the floodplain through lateral movement. However, it does not consider uncertainties associated with floodplain inundation duration and the loosing nature (hydrologically speaking) of the floodplain/alluvial fan with high accumulation of unconsolidated material.

- **Reduced Stranding Potential**: The reduced stranding potential metric is actually a qualitative metric but referenced output from the GIS analysis to support the scoring. The quantitative calculation was based on the difference in the area for the 2-*year floodplain inundation area* metric and the *adult fish passage connectivity area* metric. Both of these reference metrics were based on the 2-year time-zero hydraulic model results and thus the difference between them represents areas that are inundated at some depth during the 2-year peak flow but which are not connected to Goodell Creek or the Skagit River. As a result, these areas can be considered “disconnected” areas or potential stranding areas within the floodplain. The alternative with a greater disconnected area, or stranding potential, would receive a lower score as lower scores correspond to poor conditions. This metric focuses on juvenile fish within floodplain

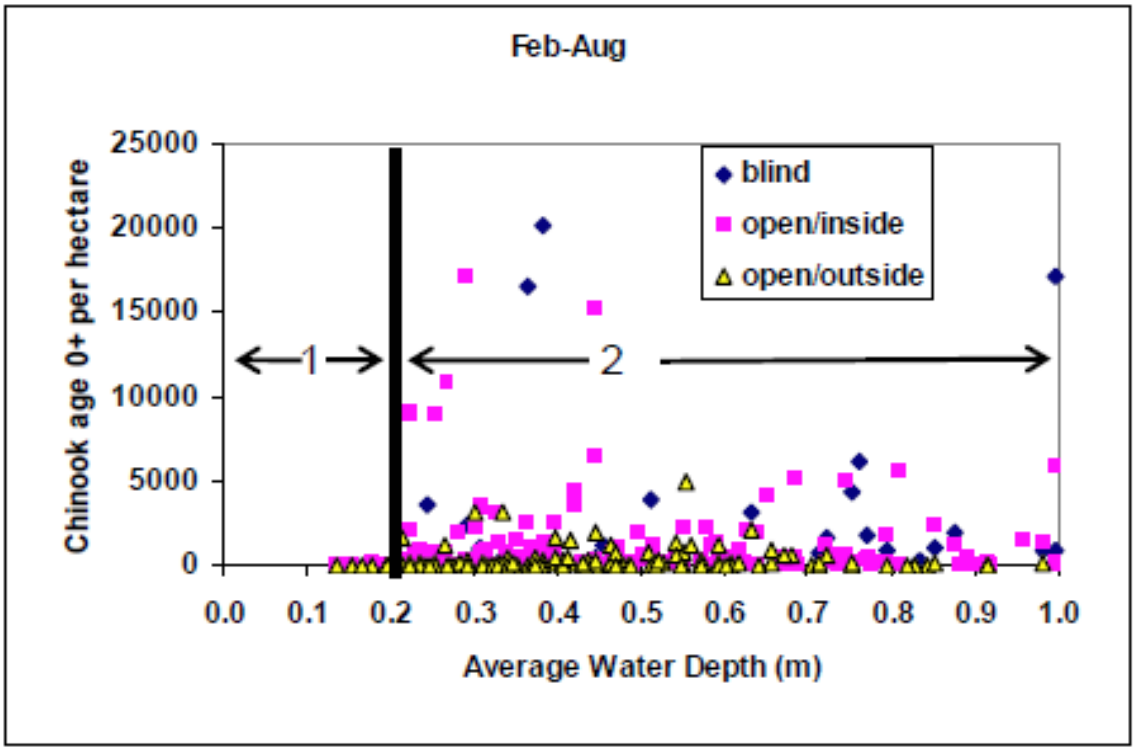


**Figure 8. Relationship between Juvenile Chinook Salmon Density and Water Depth in Tidal Delta Channel Habitat (Beamer et al. 2005).**

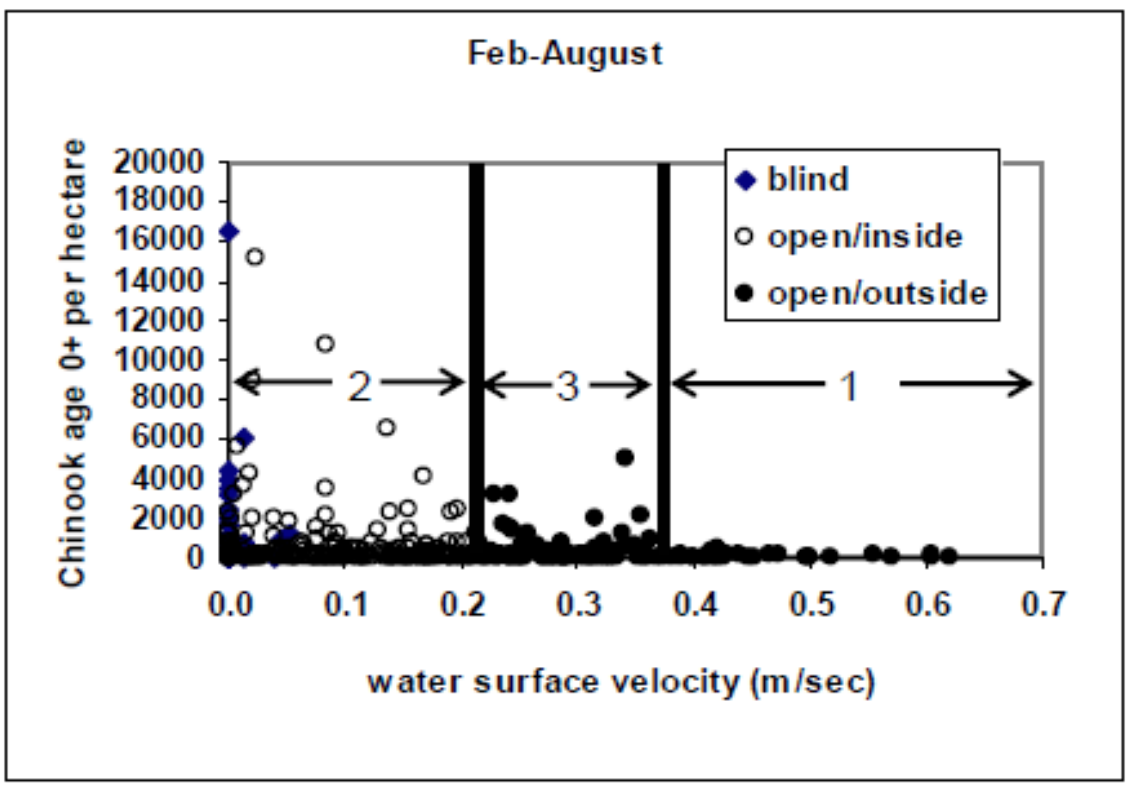


**Figure 9. Relationship between Juvenile Chinook Salmon Density and Surface Water Velocity in Tidal Delta Channel Habitat (Beamer et al. 2005).**

areas, considers uncertainties associated with floodplain inundation duration and the losing nature (hydrologically speaking) of the floodplain/alluvial fan with high accumulation of unconsolidated material, and also considers the degree to which side channels and distributary channels inlets/outlets may stay open given the dynamic nature of the system and expected sediment deposition. Because alluvial fans are naturally characterized by distributary channels that may or may not have surface connectivity to downstream wetted channels, it should be acknowledged that the alternatives that best restore alluvial fan hydrogeomorphic processes might be expected to score the worst for reduced stranding potential. This is in part due to the high degree of uncertainty given that groundwater monitoring data are not available for those areas. It is also due to the loosing nature (hydrologically speaking) of distributary channels within alluvial fans. However, during the preliminary analysis, members of the Project Team with extensive field experience and familiarity with the project site did not feel that this metric, as calculated with the GIS analysis and evaluated here, adequately captured existing conditions. As a result, the final scoring for the reduced stranding potential metric relied heavily on field observations from NPS, SCL, and USIT staff and a qualitative comparison of model results for the low flow (250 cfs) and 2-year flow (2,935 cfs) at both the time-zero (no future aggradation) and the 5 to 15 years in the future time frame (with future aggradation).

## Alternative Scoring

Each alternative was scored according to the alternative criteria and metrics described in Table H-2 of Appendix H, including the habitat and connectivity metrics defined above in addition to other metrics. These criteria were generally grouped according to the following categories:

- **Implementation opportunities or constraints**, including:
  - Construction Complexity
  - Water Quality
  - Phasing Potential
- **Habitat and ecological significance**, including:
  - Channel habitat area (wetted)
  - 2-year floodplain inundation area
  - Floodplain habitat
  - Adult fish passage / connectivity
  - Juvenile fish passage / connectivity
  - Reduced stranding potential
  - Physical habitat quality and diversity
  - Side channel reconnection potential

- Terrestrial and riparian habitat quality and diversity
- Ecological resiliency
- Sustainable hydrogeomorphic processes restored

- **Infrastructure and land use impacts,** including
  - Flooding and geomorphic hazard/risk to WSDOT highway
  - Flooding and geomorphic hazard/risk to campgrounds and recreational areas
  - Flooding and geomorphic hazard/risk to SCL infrastructure
  - Flooding and geomorphic hazard/risk to Gravel pit and access road
  - Flooding and geomorphic hazard/risk to WSDOT staging area and house

Flooding and geomorphic risks to cultural resources was identified as its own separate category. Given the sensitive nature of historic and archaeological sites, this category was not scored in the matrix but evaluated separately by the Upper Skagit Indian Tribe.

Table H-2 of Appendix H describes how each of the alternatives were evaluated using each evaluation criterion. It describes the metric used, whether the metric was based on quantitative or qualitative information, if the metric was quantitative what the unit of analysis was, and which specific model results, GIS analyses, or figures were used in generating the results for each metric. Regardless of the category grouping, each metric was scored from 1 (red color) to 5 (green color) with a 5 being the best score and a 1 being the worst score. Table H-2 also describes whether the score is related to relative sorting of the results (i.e., the alternative with the highest metric result compared to the alternative with the lowest metric result) or based on an absolute result where more than one alternative could obtain the same score (e.g., construction complexity). In cases where quantitative metrics produced alternatives with equivalent results, two alternatives could also receive the same score. The overall score for each alternative was then calculated by simply taking the arithmetic mean of all the scores for each metric, without using any weighting. The results of the alternative analysis scoring are presented in Table 3, including overall scores and scores for each category, as well as an explanation of the scoring results.

# Synopsis and Recommendations for Future Project Phases

## Synopsis

All alternative projects scored better than the Alternative 1/No-Action Alternative, which scores low for the habitat and ecological significance criteria and, due to the aggradation that is expected to continue in the future, poses significant flooding and geomorphic channel avulsion risk to almost all infrastructure in the Alluvial Fan Project Area.

The Alternative with the overall best score was Alternative 3, strengthened by its superior performance under the habitat and ecological significance criteria and relatively better performance under the infrastructure and land use impacts criteria. Alternative 3 maximizes habitat potential by improving connectivity to both the left bank and right bank portions of the floodplain. Alternative 3 also does the most to compensate for potentially increased hydraulic and geomorphic impacts of levee removal by providing for adequate hydraulic conveyance as well as channel pathways for aquatic habitat connectivity.

Alternatives 2, 4, and 5 score fairly closely overall but for various reasons. Alternative 2 is the most straightforward to implement with no new culverts or bridges being required. Alternative 5 assumes that replacing existing culverts that are documented to be fish barriers with wider culverts will be much more straightforward than the bridges included in Alternatives 3 and 4. Alternative 4 scores fairly high for the impacts category because the installation of a new SR 20 Bridge to the west of the existing SR 20 Bridge does the most for improved flow and sediment conveyance as well as for anticipating an avulsion channel pathway to the west where the overall hydraulic gradient of the fan appears to be. Alternative 3's addition of the improved SR 20 Bridge crossing at the existing location improves flow and sediment conveyance at that location but alone does not seem to exert a pronounced influence on inhibiting flood flows and potential avulsion pathways toward the west.

The results clearly suggest that by removing the right bank levee, additional conveyance (i.e., a new downstream bridge crossing) would be necessary to prevent significant impacts to the highway. All alternatives show flood impacts to the SCL towers in the lower west corner of the Project Area; however, these towers have been designed to withstand flooding and the greater concern is preventing an unanticipated channel avulsion from intercepting the towers (Ed Connor personal communication to the Project Team and Herrera during the May 30, 2014, workshop). Alternatives 3 and 4 provide both log structures to reduce the likelihood that the main flow of new side channels would avulse into the SCL towers as well as the additional conveyance to handle increased flows and potential avulsion channel flow that is likely to result from the removal of the right bank levee.

## Recommendations for Future Project Phases

The current situation at the Goodell Creek alluvial fan is one of degraded in-channel and floodplain habitat conditions, with the potential for further degradation in the coming years. Restoration of the alluvial fan would return natural processes that create and maintain critical habitat for federally threatened Chinook salmon, steelhead trout and bull trout as well as habitat for riparian and wetland dependent species. Levees along both banks of the current stream channel severely limit interactions between the main channel and the floodplain. Overtopping of most sections of the levees and inundation of the floodplain would require a massive flow event. As such, potential side channels and floodplain habitats are reduced in quantity and quality. Increased floodplain activation would provide benefits to water quality (e.g., temperature and nutrient cycling) and a variety of species (e.g., salmonids, amphibians, and waterfowl). A minimal amount of off-channel activation currently occurs in locations where levees have been degraded. In these areas there is limited flow pathway through the floodplain and poor routing of flows back to the channel. The result is fish stranding and missed opportunities to create natural off-channel aquatic and riparian habitats. Moreover, the Project Team is concerned the stream may be trending toward a braided plan form with unstable, shallow channels. A braided Goodell Creek channel would offer limited rearing opportunity for juvenile salmonids. Additionally, during base flow the creek could become overly hyporheic (subsurface) and run risk of cutting off connectivity to habitats above the alluvial fan, thus impacting upstream migration of adult Chinook and bull trout. In contrast, a restored Goodell Creek with a stable anabranched channel plan form and vegetated islands would better maintain connectivity to upstream habitats and provide high quality year-round rearing for juvenile steelhead and spring Chinook. This is particularly important for a high elevation, cold water system such as Goodell Creek because such streams will become increasingly important as climate change causes increased water temperature and reduced summer base flow.

Future actions for the Goodell Creek alluvial fan project must consider the uncertainty and risk associated with the No Action alternative. Working in and predicting outcomes in alluvial fan settings is inherently challenging; these geomorphic features are dynamic by nature. It is difficult and costly to contain alluvial fan dynamics over decadal time scales with levees and undersized bridges, as is currently the approach in the Goodell Creek alluvial fan. Similarly, it is difficult to anticipate alluvial fan behavior under restoration alternatives. Despite such challenges, the combination of an existing undersized bridge span at SR 20, locally high rates of sedimentation from recent upstream landslides, and failing levees along the channel banks presents an unacceptably high risk of flood damage if no action is taken to restore natural geomorphic function. As the fan is today, there is a high risk of flooding to the west of the current channel, which, in the absence of defined flow paths and conveyance under SR 20, has the potential to cause considerable damage to vital infrastructure (i.e., SR 20 road prism, SCL power line towers and National Park Service campgrounds). Furthermore, if sediment delivery and aggradation above the SR 20 Bridge continue as anticipated, there is a strong likelihood of more intense flood damage and flooding during smaller, more frequent events as well.

A long-term sustainable and cost-efficient approach to the current situation at the Goodell alluvial fan must address natural geomorphic functions. Such an approach would promote high

quality instream and floodplain habitat and reduce risk to infrastructure. The analysis presented herein indicates that to reduce risk in a long-term sustainable way, alternative components such as levee removal and floodplain widening upstream of SR 20, alone, will not be adequate. Rather, levee removal in combination with bridge expansions and construction of adequate channel conveyance pathways, offer longer-term and more cost-effective approaches. Such actions could reduce costly maintenance and flood fighting efforts in the coming decades by allowing natural process to maintain channel form and sediment conveyance through the fan, while also providing maximum benefits to in- and off-channel habitat and threatened species.

The Project Team has agreed to a multi-benefit conceptual proposal for the Goodell Creek alluvial fan that would reduce infrastructure risk and long-term maintenance costs, and simultaneously restore important habitat types for threatened and other species. An important next step is to engage WSDOT, as their support and partnership will be necessary to continue developing the project. The Project Team intends to begin discussions with WSDOT before seeking funding for the next phase of this project.

The scoring matrix indicated clear support for Alternative 3, which includes 1) levee setbacks on both banks, 2) an expanded bridge for the current SR 20 crossing 3) and construction of a new channel and bridge for SR 20 west of the current channel. If the Project is successfully advanced into subsequent design phases, Alternative 3 offers a general starting point, but certain components may be abandoned or altered depending upon further discussion and analysis. The following describes the next steps and project components and design approach that The Project Team currently proposes:

## Next Steps:

- Project Team to engage WSDOT and determine WSDOT's role
- Secure WSDOT as a project partner for Design Phases 2 and 3, as described below, to move forward
- After meeting with WSDOT, Project Team to discuss timeline and funding strategy for implementation of future project components

### *Proposed Further Analysis:*

- Left bank levee contamination testing
- Installation and monitoring of a flow gauge near the SR 20 crossing
- Groundwater well and soil testing to evaluate hyporheic connectivity and potential for losing (hydrologically speaking) stream segments
- Cultural survey
- Additional Stakeholder outreach
- NEPA analysis
- Additional modeling and analysis of geomorphic channel formation, evolution, in addition to anticipated sediment deposition patterns associated with proposed design

components. It is assumed that hydraulic modeling and geomorphic evaluation will be refined throughout the design process.

## *Proposed Project design Components and potential construction phasing:*

### *Design and Construction Phase 1:*

- Relocation of upper Goodell group campground access road and gravel pit access road
- Complete contaminants testing and assess their potential removal
- Remove left bank levee
- Restore and reconnect wetland habitat (if conditions supportive of wetland habitat exist) and side channel habitat

Phase 1 would neither reduce nor increase long-term risk of flooding and infrastructure damage on right bank floodplain and current bridge crossing. Phase 1 may create short-term relief for right bank flooding by storing sediment.

### *Design and Construction Phase 2:*

- Relocation of camp ground access roads (including the Lower Goodell group campground access road)
- Excavate and stabilize a new channel on the right bank floodplain and construct a new bridge under SR 20 to the west of the existing bridge
- Remove right bank levee
- Remove riprap and concrete debris from the right bank levee near the Lower Goodell group campground
- Channel and bridge specs to be determined during the design phase

Phase 2 would be expected to provide conveyance for all or a large portion of the total Goodell Creek flow, given the potential for a full or partial avulsion toward the Phase 2 channel. Phase 2 will not restore full alluvial fan function, but will utilize soft engineering techniques to maintain flow in stable, defined channels. It will also provide adequate conveyance for these stable channels to connect back to Goodell Creek or the Skagit River main stem.

### *Design and Construction Phase 3:*

- Assess need to replace/expand the current SR 20 Bridge and conduct restoration in current channel
- Assess response following Phase 2 construction to determine needed Phase 3 components
- Over decadal time scales and sediment pulses, full or near-full flow may return to the current channel

**Score color code:**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Worst | Bad | Med | Good | Best |

**Table 3. Alternatives Analysis Score Results.**

| Evaluation Criteria | Channel habitat area (wetted) | 2-year floodplain inundation area | Floodplain Habitat | Adult Fish Passage/Connectivity | Juvenile Fish Passage/Connectivity | Reduced Stranding Potential | Physical Aquatic Habitat Quality and Diversity | Side Channel reconnection potential | Terrestrial and Riparian Habitat Quality | Ecological Resiliency | Sustainable Hydrogeomorphic Processes Restored |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative** | **Habitat and Ecological Significance** | | | | | | | | | | |
| **1 - Existing Conditions / No Action** | 3<br>Moderate channel habitat area, 13.58 acres | 1<br>Least 2-year floodplain inundation area, 23.39 acres | 2<br>Little floodplain habitat area, 36.85 acres | 1<br>Smallest area adult fish passage/ connectivity, 15.8 acres | 1<br>Smallest area juvenile fish passage/ connectivity, 6.12 acres | 1<br>Greatest stranding potential: Model Results indicate 7.59 acres of disconnected 2-year floodplain; modeling results do not adequately capture existing conditions. Field visits made by NPS staff have found Coho and other salmonids isolated on the North side of Hwy 20. Additionally, high flow events under existing conditions are causing overbank flow that forces fish into ponded areas on the left and right banks that become isolated and dewater. | 1<br>Least physical habitat quality and diversity, lacks diverse range of high quality, connected high and low velocity and depth areas within the floodplain that can support multiple aquatic species and life histories | 1<br>Least side channel reconnection potential: historic side channels and potential wetland areas remain isolated from main channel behind levees. | 3<br>Comparable Terrestrial and Riparian Habitat Quality between alternatives, 370 acres of mature forested alluvial fan area not inundated by 100-year | Not able to detect differences at scale required for comparison | 1<br>No potential to restore hydrogeomorphic processes, Goodell Creek remains confined by levees and disconnected from its fan and floodplain |
| **2 - Left Bank Floodplain Reconnection** | 3<br>Moderate channel habitat area, 13.58 acres | 2<br>Little 2-year floodplain inundation area, 26.59 acres | 5<br>Greatest floodplain habitat area, 43.71 acres | 3<br>Moderate area adult fish passage/ connectivity, tied at 17.1 acres | 2<br>Small area juvenile fish passage/ connectivity, 9.35 acres | 2<br>High stranding potential: Model results indicate 9.49 acres of disconnected 2-year floodplain; this alternative does not remedy the existing stranding issues along SR 20, as described for Alt 1. | 2<br>Some physical habitat quality and diversity, relatively smaller extent of reconnected left bank floodplain increases habitat diversity but does not have as wide a range of high and low velocity and depth areas that would support diverse physical habitat types as would the other alternatives | 3<br>Some side channel reconnection potential: potential to reconnect historic side channels and potential wetland areas along the left bank portion of floodplain. Right bank areas remain isolated from main channel behind levees. | 3<br>Comparable Terrestrial and Riparian Habitat Quality between alternatives, 370 acres of mature forested alluvial fan area not inundated by 100-year | Not able to detect differences at scale required for comparison | 2<br>Some restoration of hydrogeomorphic processes, levee removal along left bank reconnects a portion of the alluvial fan and floodplain but the natural preferential flow path toward the right bank remains disconnected by the levee and the existing SR 20 crossing does not support sustainable hydrogeomorphic processes |
| **3 - Left Bank and Right Bank Floodplain Reconnection and two new 300ft Crossings at SR 20** | 4<br>Good channel habitat area, 15.88 acres | 5<br>Greatest 2-year floodplain inundation area, 36.63 acres | 4<br>Good floodplain habitat area, 40.93 acres | 5<br>Largest area adult fish passage/ connectivity, 19.28 acres | 5<br>Largest area juvenile fish passage/ connectivity, 18.69 acres | 4<br>Model results indicate 17.35 acres of disconnected 2-year floodplain; however, based on field experience NPS staff expect this alternative to improve conditions where stranding currently occurs, as well as improved hydrologic connectivity allowing fish to "escape" as flows drop. Since this alternative has the highest likelihood of restoring natural processes it was scored higher, assuming that flow and water level will drop gradually enough to allow most fish to find mainstem connected habitats. | 5<br>Greatest physical habitat quality and diversity, Large extent of reconnected floodplain has a diverse range of high and low velocity and depth areas likely to support diverse physical habitat types, and alternative also has adequately sized downstream conveyance to support overall habitat connectivity | 5<br>Greatest side channel reconnection potential: potential to reconnect historic side channels and potential wetland areas along both the left bank and right bank portions of floodplain, while providing significantly improved conveyance to support sustainable connectivity. | 3<br>Comparable Terrestrial and Riparian Habitat Quality between alternatives, 370 acres of mature forested alluvial fan area not inundated by 100-year | Not able to detect differences at scale required for comparison | 5<br>Greatest potential to restore hydrogeomorphic processes, complete levee removal and adequately sized conveyance to support self-sustaining hydrogeomorophic processes over the long-term |
| **4 - Right Bank Floodplain Reconnection, leave existing bridge and add 1 new 300ft-span Crossing at SR 20** | 4<br>Good channel habitat area, 15.9 acres | 3<br>Moderate 2-year floodplain inundation area, 32.58 acres | 1<br>Least floodplain habitat area, 32.19 acres | 4<br>Good area adult fish passage/ connectivity, 17.97 acres | 3<br>Moderate area juvenile fish passage/ connectivity, 14.68 acres | 3<br>Moderate stranding potential, 14.61 acres of disconnected 2-year floodplain | 4<br>Good physical habitat quality and diversity, good extent of reconnected right bank floodplain has a diverse range of high and low velocity and depth areas likely to support diverse physical habitat types, and alternative also has adequately sized downstream conveyance to support overall habitat connectivity and functioning habitat within the crossing | 4<br>Good side channel reconnection potential: potential to reconnect historic side channels and potential wetland areas along the right bank portion of floodplain, while providing some improved conveyance to support sustainable connectivity. | 3<br>Comparable Terrestrial and Riparian Habitat Quality between alternatives, 370 acres of mature forested alluvial fan area not inundated by 100-year | Not able to detect differences at scale required for comparison | 4<br>Good potential to restore hydrogeomorphic processes, levee removal along right bank reconnects a large portion of the alluvial fan and floodplain along the natural preferential flow path toward the right bank, adequately sized conveyance for the right bank floodplain better supports self-sustaining hydrogeomorophic processes over the long-term, although the existing SR 20 bridge may continue to disrupt hydrogeomorphic processes |
| **5 - Left Bank and Right Bank Floodplain Reconnection** | 4<br>Good channel habitat area, 15.75 acres | 4<br>Good 2-year floodplain inundation area, 33.64 acres | 3<br>Moderate floodplain habitat area, 37.89 acres | 3<br>Moderate area adult fish passage/ connectivity, tied at 17.3 acres | 4<br>Good area juvenile fish passage/ connectivity, 15.27 acres | 2<br>High stranding potential, 16.34 acres of disconnected 2-year floodplain | 3<br>Moderate physical habitat quality and diversity, Large extent of reconnected floodplain has a diverse range of high and low velocity and depth areas likely to support diverse physical habitat types, alternative has downstream conveyance to support overall habitat connectivity but quality of habitats within the culverts are less than that below the bridges | 4<br>Good side channel reconnection potential: potential to reconnect historic side channels and potential wetland areas along both the left bank and right bank portions of the floodplain, while providing some improved conveyance to support hydrologic connectivity. | 3<br>Comparable Terrestrial and Riparian Habitat Quality between alternatives, 370 acres of mature forested alluvial fan area not inundated by 100-year | Not able to detect differences at scale required for comparison | 3<br>Moderate potential to restore hydrogeomorphic processes, complete levee removal reconnects a large portion of both right and left bank floodplains but alternative does not include downstream conveyance that is adequately sized to support self-sustaining hydrogeomorophic processes over the long-term, maintenance and adaptive management will likely be necessary |

**Table 3. Alternatives Analysis Score Results.**

| Evaluation Criteria | Construction Complexity | Water Quality | Phasing Potential | Flooding and Geomorphic hazard/ risk to WSDOT Highway | Flooding and Geomorphic hazard/ risk Campgrounds and recreational uses | Flooding and Geomorphic hazard/ risk to SCL Infrastructure | Flooding and Geomorphic hazard/ risk to Gravel pit access Road | Flooding and Geomorphic hazard/ risk to WSDOT staging area and house | | Overall Score | Habitat Category Score | Implementation Category Score | Impacts Category Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative** | **Implementation Opportunity/Constraint** | | | **Infrastructure and Land Use Impacts** | | | | | | | | | |
| **1 - Existing Conditions / No Action** | 5<br>Not complex, no construction required | 2<br>Bad conditions, existing potential for degraded water quality as river will continue to entrain along left bank levee and expose buried waste, because alternative opens up right bank floodplain it draws some flow away from the left bank levee | Not applicable, no project components to phase | 2<br>Great flood and avulsion risk to SR20, existing scour/sediment situation at existing bridge and large extents of flood inundation over SR20 | 2<br>Great flood and avulsion risk to campgrounds and access, largest extents of flood inundation across recreational areas, especially the lower Goodell campground and main Goodell campground and access | 1<br>Greatest flood and avulsion risk to SCL towers, future aggradation scenarios indicate flood depths and velocities will increase risks over time if no actions taken, additional towers to west also vulnerable | 2<br>Great flood risk to Gravel pit access road, flow inundation cuts off access and inundates over half of access path | 2<br>Great flood risk to WSDOT staging area, flow inundation across entire area | Alt 1 | 1.8 | 1.5 | 3.5 | 1.8 |
| **2 - Left Bank Floodplain Reconnection** | 3<br>Fairly complex, only removing one levee, all work on NPS property, no new crossings under SR20, potential complications from hazardous waste removal | 5<br>Best conditions, greatest potential for improved water quality as waste buried within the left bank levee is removed and the area cleaned up when levee is removed | 4<br>Good phasing potential, entire alternative can be completed in phases or incorporated as a phase of another alternative | 3<br>Moderate flood and avulsion risk to SR20, removal of left bank levee provides some flood and sediment storage but doesn't address scour/sediment situation at existing bridge and, large extents of flood inundation over SR20 | 2<br>Great flood and avulsion risk to campgrounds and access, extents of flood inundation across recreational areas, especially the lower Goodell campground and main Goodell campground and access, are comparable to Alternative 1 | 2<br>Great flood and avulsion risk to SCL towers, removal of left bank levee provides some flood and sedimentation relief, but model results indicate inundation areas near SCL towers are slightly less but very similar to no-action results | 3<br>Moderate flood risk to Gravel pit access road, flow inundation cuts off access and inundates over half of access path, alternative includes new realigned access route to high ground further east | 3<br>Moderate flood risk to WSDOT staging area, flow inundation across almost entire area | Alt 2 | 2.9 | 2.7 | 4.0 | 2.6 |
| **3 - Left Bank and Right Bank Floodplain Reconnection and two new 300ft Crossings at SR 20** | 1<br>Extremely complex, removes both levees requiring elongated construction schedule, involves multiple crossings under SR 20, project construction affects multiple land uses (NPS campgrounds, WSDOT ROW, SCL easements), new bridge spans will require expensive construction equipment and traffic control | 5<br>Best conditions, greatest potential for improved water quality as waste buried within the left bank levee is removed and the area cleaned up when levee is removed | 3<br>Moderate phasing potential, left floodplain work can be easily phased, but right floodplain work would require downstream conveyance improvements and associated WSDOT coordination, schedule for phasing two WSDOT crossings may be driven by WSDOT phasing requirements | 5<br>Greatest reduction in flood and avulsion risk to SR20, new bridges reduce risks of scour and sedimentation at crossings, wider span openings provide conveyance for a right bank avulsion channel | 2<br>Moderate flood and avulsion risk to campgrounds and access, slightly lesser extents of flood inundation across recreational areas, especially the lower Goodell campground and main Goodell campground and access; however campgrounds will be lost to construct a new channel and bridge. | 3<br>Moderate flood and avulsion risk to SCL towers, complete levee removal provides overall flood and sedimentation relief but also increases SCL towers (within project area and also to west) to flow inundation and sedimentation, new bridges improve conveyance so inundation around towers can drain quickly, log structures protect towers from erosive flows | 4<br>Slightly reduced flood risk to Gravel pit access road when compared to existing conditions, shorter length of road is inundated, alternative includes new realigned access route to high ground further east | 4<br>Slightly reduced flood risk to WSDOT staging area when compared to existing conditions, smaller area of inundation influenced by increased floodplain storage capacity with reconnected right bank floodplain area | Alt 3 | 4.0 | 4.5 | 3.0 | 3.6 |
| **4 - Right Bank Floodplain Reconnection, leave existing bridge and add 1 new 300ft-span Crossing at SR 20** | 2<br>Complex, removes one levee, requires one new crossing under SR 20, project construction affects multiple land uses (NPS campgrounds, WSDOT ROW, SCL easements), new bridge span will require expensive construction equipment and traffic control | 2<br>Bad conditions, existing potential for degraded water quality as river will continue to entrain along left bank levee and expose buried waste, because alternative opens up right bank floodplain it draws some flow away from the left bank levee | 3<br>Moderate phasing potential, can construct new bridge prior to right floodplain work, but right floodplain work could not be constructed prior to new bridge, schedule for phasing construction may be driven by WSDOT phasing requirements | 4<br>Some reduction in flood and avulsion risk to SR20, new wide bridge to west provides conveyance for a right bank avulsion channel beneath SR20, existing SR20 bridge still vulnerable to scour and sedimentation problems | 2<br>Moderate flood and avulsion risk to campgrounds and access, slightly lesser extents of flood inundation across recreational areas, especially the lower Goodell campground and main Goodell campground and access; however campgrounds will be lost to construct a new channel and bridge. | 2<br>Great flood and avulsion risk to SCL towers, removal of right bank levee provides some flood and sedimentation relief, but model results indicate inundation areas near SCL towers are slightly less but very similar to no-action results | 2<br>Great flood risk to Gravel pit access road, flow inundation cuts off access and inundates over half of access path, alternative does not address left bank floodplain improvements | 3<br>Moderate flood risk to WSDOT staging area, flow inundation across almost entire area | Alt 4 | 2.9 | 3.3 | 2.3 | 2.6 |
| **5 - Left Bank and Right Bank Floodplain Reconnection** | 3<br>Moderately complex, removes both levees requiring elongated construction schedule, involves multiple crossings under SR 20, project construction affects multiple land uses (NPS campgrounds, WSDOT ROW, SCL easements) | 5<br>Best conditions, greatest potential for improved water quality as waste buried within the left bank levee is removed and the area cleaned up when levee is removed | 4<br>Good phasing potential, left floodplain work can be easily phased, can construct new culverts prior to right floodplain work, but right floodplain work could not be constructed prior to new culverts, schedule for phasing construction may be driven by WSDOT phasing requirements, but culverts are anticipated to be easier to add to the WSDOT construction schedule than a new bridge | 1<br>Greatest flood and avulsion risk to SR 20, removal of right bank levee increases risk of full avulsion toward the right bank, alternative with greatest length and area of inundation along and over WSDOT highway | 1<br>Greatest flood and avulsion risk to campgrounds and access, removal of right bank levee increases risk of full avulsion toward the right bank, second largest extent of flood inundation across recreational areas, especially the lower Goodell campground and main Goodell campground and access | 1<br>Greatest flood and avulsion risk to SCL towers, complete levee removal provides overall flood and sedimentation relief but also increases exposure of SCL towers (within project area and also to west) to flow inundation and sedimentation; right bank levee removal increases risk of full avulsion toward the right bank, log structures will help direct primary channel pathways around the SCL towers, alternative model results indicate the greatest flood inundation alongside the WSDOT ROW | 3<br>Moderate flood risk to Gravel pit access road, flow inundation cuts off access and inundates over half of access path, alternative includes new realigned access route to high ground further east | 4<br>Slightly reduced flood risk to WSDOT staging area when compared to existing conditions, smaller area of inundation influenced by increased floodplain storage capacity with reconnected right bank floodplain area | Alt 5 | 3.1 | 3.3 | 4.0 | 2.0 |

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