S. Skagit Highway Floodplain Restoration Project -

Preliminary Design Report

Prepared for:

Skagit River System Cooperative

March 31, 2015

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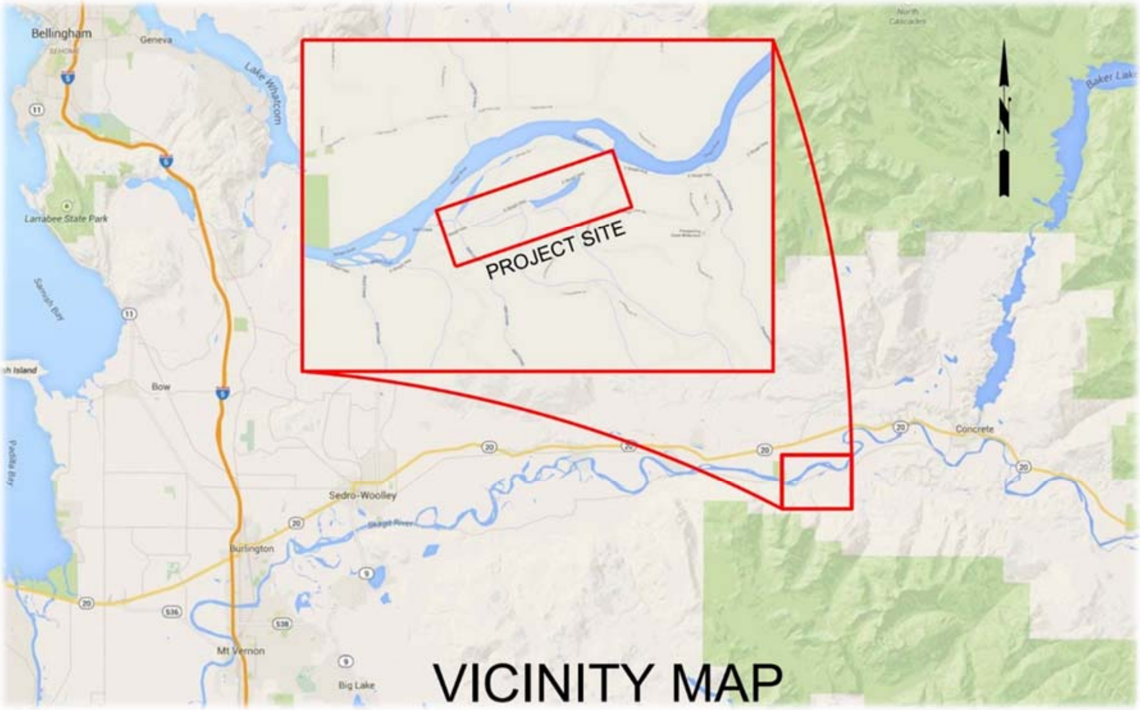
1. INTRODUCTION

Following obtaining federal funding from Washington State Salmon Recovery Funding Board (SRFB), The Skagit River System Cooperative (SRSC) desires floodplain restoration to occur along South Skagit Highway in the vicinity of Mill Creek and Savage Creek, realigning or modifying the existing highway and reconnection of the fragmented floodplain.

Although the project is administered by SRSC, the Skagit County Department of Public Works is a major stakeholder and partner in the Project and will be providing engineering peer review assistance during the course of the Project.

Project area extends from approximately milepost 17.8 to milepost 19.4 on South Skagit Highway, which is a two-lane paved highway owned and maintained by Skagit County. In this area the highway restricts connectivity between the Skagit River and approximately 62 acres of floodplain and completely isolates an additional 5.2 acres of wetlands. The highway also includes undersized crossing structures for two tributary streams, Mill Creek and Savage Creek, which result in habitat impacts for migratory fish species and significant challenges for highway maintenance. A Location Map is provided below.



The primary goal of the South Skagit Highway Floodplain Restoration Project is to identify and evaluate alternatives for restoring floodplain connectivity, improving habitat conditions, and reducing future maintenance costs for the highway and associated infrastructure.

In order to achieve these goals five alternatives are evaluated and are presented to the project's Steering Committee, composed of representatives from SRSC, Seattle City Light (SCL), Skagit County Public Works, Weyerhaeuser Corporation, and Merrill and Ring Corporation. These alternatives are the following;

Alt. 0 – Do nothing alternative or maintaining the existing alignment and conditions. This alternative will be referred to as existing conditions alternative.

Alt. 1 - Maintaining the existing highway alignment with enhancements to habitat and bridge hydraulics in the Mill Creek / Savage Creek crossing area only.

Alt. 1 A- Maintaining the existing highway alignment with greater enhancements to habitat and bridge hydraulics designing for wildlife crossing(s) and providing hydraulic and fish passage, with connectivity between ponded water bodies to the south of the highway and the Skagit River.

Alt. 2 - Realigning the highway out of the floodplain to a higher plateau developed by SRSC and Steering Committee, and providing hydraulic and fish passage.

Alt. 3 - Realigning the highway out of the floodplain to a higher plateau developed by the consultant design team with input from the Steering Committee, and providing hydraulic and fish passage.

The plan and profile of these alternatives are provided in Appendix 1.

In the following sections, these alternatives are investigated and preliminary cost estimates are developed.

2. DESIGN ANALYSIS

2.1 Surveying

Pre-design survey and base mapping deliverables for this project were provided by Pacific Surveying and Engineering (PSE) in June 2014. All survey information was provided on NAD 83/91 Horizontal and NAVD 88 Vertical control datum.

Boundary, right of way and ownership information were depicted on the base map from a combination of record survey maps, County Assessor property information, and GIS parcel lines available from Skagit County. The survey base map contains various AutoCAD line types and line weights to graphically depict and differentiate the origin of each feature on the map.

PSE provided minimal ground survey support for this phase of the project. Field surveying included location of primary cadastral and section corner monuments in the vicinity, and the establishment of GPS derived horizontal and vertical survey control at the project site. Ground survey areas were directed in the field by the project engineer, and were limited to proposed road intersections, water crossings, existing logging roads and ground truth shots along the proposed road corridor. Field data was compared against LiDAR derived digital terrain model three-dimensional surface, and differences between field survey data and LiDAR surface data were noted in a LiDAR accuracy report also prepared by PSE for the project.

PSE survey crews used a combination of Leica robotic/reflector less survey total stations and Topcon Hyperlite GPS equipment for this work. The CAD work product was produced using AutoCAD Civil 3D 2014 software.

2.2 GEOTECHNICAL

The geotechnical field investigation was completed by Aspect on September 25 and 26, 2014. Boring B-1 was drilled near the east bank of Mill Creek along the approximate Alternative 3 alignment, Boring B-2 was drilled along the Merrill & Ring logging road on the western portion of the project, and boring B-3 was drilled on Weyerhaeuser Pacific logging road on the eastern portion of the project.

The soils encountered are generally favorable for new road and bridge construction along an upland alignment. Preliminary geotechnical engineering conclusions include:

Bridge Foundations: The granular alluvium encountered in boring B-1 near Mill Creek has saturated zones that are susceptible to liquefaction during an extreme (design-level) earthquake. New bridge foundations will need to penetrate below liquefiable soils and extend a sufficient distance into the more dense/competent layers. Drill action at B-1 did not suggest a significant amount of oversize (cobble- or boulder-sized) material. Therefore, our preliminary conclusion is that heavy-walled open- or closed-ended steel pipe piles would be a potentially suitable deep foundation type for this project. For planning purposes, 24-inch diameter, ½-inch wall thickness, steel pipe piles, may be considered. Alternatively, 4-foot diameter, cast-in-place concrete drilled shafts, would also be suitable. Driven pile and drilled shaft foundation embedment depths of the order of 60 feet should be considered for preliminary purposes. More detailed geotechnical and structural engineering evaluations should be conducted.

Bridge Approaches: Depending on the crossing (Mill or Savage Creek) and location, approach embankments of varying thickness are anticipated. Where right of way restrictions require such fills to be retained, mechanically stabilized earth (MSE) approach embankments can be considered. Where permissible, sloped embankments should have permanent side slopes not steeper than 2H:1V.

Cut and Fill Retaining Walls: Depending on the upland alignment, permanent cut and fill retaining walls may be significant. For planning purposes, cut walls greater than about 10 feet in exposed height can be designed and constructed using soldier piles and lagging. Lower cut walls can be designed and constructed using cast-in-place concrete cantilever; gravity blocks; and MSE (if temporary excavations are allowed). Fill retaining walls can be designed and constructed using MSE systems. A variety of wall fascia options are suitable including sculpted shotcrete; pre-cast concrete panels/blocks; timber lagging;

and rock-filled wire gabions. Aesthetic or other non-geotechnical considerations may drive the required wall fascia.

General Earthwork Considerations: The upland alternative alignments will involve significant earthwork. In general much of the existing alluvium along the project alignment appears suitable for re-use as structural fill. Permanent cut and fill slopes should be planned at 2H:1V. Our Boring B-3 along the Weyerhaeuser logging road encountered an approximately 10-foot thick deposit of low-energy overbank alluvium consisting of soft to medium stiff sandy silt. Such zones are moderately compressible and therefore, in areas where new roadway embankment fill thickness is more than a few feet thick, settlement may be a considered. However, at the location of B-3, the potential/proposed new road would be at or near existing grade.

The Preliminary Geotechnical Memo by Aspect Consulting LLC, dated October 27, 2014, is presented in Appendix 2

2.3 HABITAT, HYDROLOGY & GEOMORPHIC CONDITIONS

Key questions addressed by hydraulic and geomorphic analyses of the Skagit River, Mill Creek, and Savage Creek are:

- What are Skagit River flood elevations that influence inundation of the highway, backwater up Mill and Savage Creeks, and connectivity with existing off-channel ponded and wetland areas that could potentially provide off-channel habitat for juvenile salmonids?
- What are optimum crossing locations for bridge relocation alternatives based on geomorphic considerations?
- What should the low chord elevation be for new bridges at each alternative crossing location?
- What is the minimum span length at each location based on flooding and geomorphic considerations?

Analysis are described in greater detail in Appendix 3. The analyses relied on the following primary information sources: (i) An existing US Army Corps of Engineers' (USACE) HEC-RAS model of the Skagit River extending from its mouth upstream to Concrete; (ii) USACE reports related to the Skagit River Flood Risk Management Study; (iii) 2014 Survey data; (iv) previous assessment of sedimentation processes performed for Skagit County in 2004; (v) 2006 LiDAR digital elevation model; and (vi) USGS StreamStats web-based program for estimating peak flood magnitudes. The following analysis products were developed from the information above:

- Flood hydrology (Table 1).
- A USACE Skagit River HECRAS model was modified and used to evaluate road flooding, backwatering up Mill Creek, and the approximate level at which ponds and wetlands located on either side of the existing highway would become connected to the river hydraulically.
- A HEC-RAS flood model was developed of Mill Creek from survey and LiDAR data. The model was run with no bridge present, thereby emulating a new bridge meeting a zero rise condition at the 100 year flood level.
- A HEC-RAS flood model was developed of Savage Creek using cross-section profiles that were cut from the LIDAR contour map. The model was run with no bridge present, similar to Mill Creek.
- Longitudinal (i.e., stream-wise) profiles were developed for Mill Creek of (i) thalweg elevation, (ii) grain size distribution changes, and (iii) hydraulic properties predicted by the HEC-RAS model. Graphs of the longitudinal

profiles were used to evaluate sediment deposition and transport trends in the project reach, knowledge of which was used to identify higher and lower risk locations for bridge placement. In addition, the LiDAR elevation contour map topography was used in concert with HEC-RAS model predictions to identify the zone outside which bridge abutments might be constructed without incurring a reasonable risk of interfering with channel migration and flood levels.

- Scour analyses were not performed at this time. Scour depths can be estimated once a bridge design is formulated based on the results of this analysis.

Table 1. Estimated Flood Hydrology for Project Area Rivers.

Recurrence Interval (Years)	Flow (cfs)		
	Skagit River at Concrete	Mill Creek	Savage Creek
2	77,300	231	78
10	127,700	422	142
25	165,300	524	176
50	189,100	620	208
100	225,400	698	235

Results are presented below for each of the key study issues.

SKAGIT RIVER HEC-RAS MODELING:

The modified USACE HEC-RAS model, of the Skagit River was used to predict water surface elevation (WSEs) for various flood levels at several survey control point locations along the South Skagit Highway for use in road design, and to estimate the flow approximately at which open water bodies and wetlands located south and north of the highway would be hydraulically connected (Figure 1). For the latter, it was assumed that WSEs surveyed in late July 2014 approximated the level at which flow from the river would engage them. The surveyed WSEs define the extent to which currently impounded relic side channels may be maintained with appropriate grade control, and what the approximate total head drop is for fish passage design scoping. The largest water body located south of the highway has the highest standing WSE, and would require fish passage structures to be designed in order to establish connectivity with the Skagit River at most flow levels. Alternatively, review of LiDAR data indicates that the water body WSE is below the WSE of Savage Creek where it exits the ravine onto a small alluvial fan. It may be feasible to re-unite Savage Creek through the ponds as an alternative to establishing connectivity under the highway.

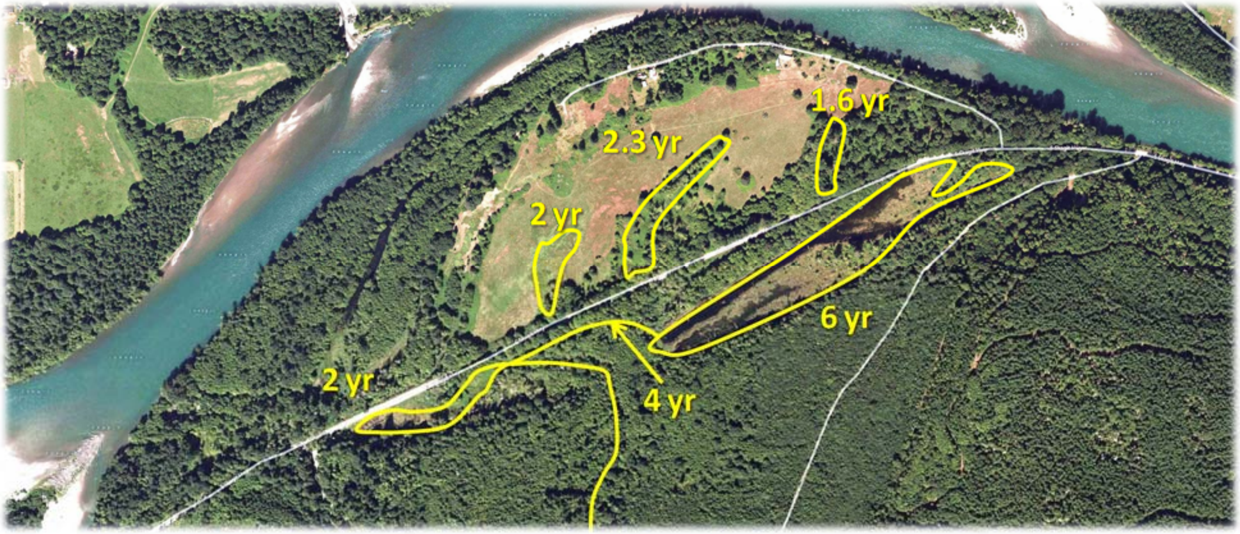


FIGURE 1. APPROXIMATE RECURRENCE INTERVALS OF SKAGIT RIVER FLOODS AT WHICH HYDRAULIC CONNECTIVITY IS PRESENTLY ESTABLISHED BETWEEN THE SKAGIT RIVER AND LOCATIONS OF SIGNIFICANT WATER BODIES AND WETLANDS SITUATED ADJACENT TO THE SOUTH SKAGIT HIGHWAY.

CROSSING DESIGN

Bridge/Road Layouts

Mill Creek: Alternatives 1 and 1A bridges could be constructed adjacent to the existing bridge on the upstream side. The long profiles of elevation indicated that the location of the bridge for Alternative 2 appears to be the best in a geomorphic process context because it is located above a prominent slope break located approximately 450-550 feet upstream of the existing highway location. However, this location has greatest risk of long term degradation scour.

The long profile was also used to guide the layout of the Alternative 3 route below the slope break based on HEC-RAS model predictions of top-width and hydraulic depth during the 100-year flood. Because this location is proximal to the larger scale slope break, however, additional measures would be required to promote deposition of coarsest bedload particles in the vicinity of the slope break and upstream.

Savage Creek: The precise locations of the crossing under Alternatives 2 and 3 are flexible given the slopes and valley widths in the vicinity of both are comparable. The stream flows through a relatively prismatic ravine, thus there does not appear to be any physical process basis for choosing one location over another.

Bridge Low Chord Elevation/Span Length

Recommended minimum low chord elevations and span lengths are summarized in Table 2. Design of the low chord elevation included consideration of (i) WAC 220-110-070 1(e) requirement that the bridge to pass the 100-year flood with sufficient clearance to pass debris, where WDFW specifies a minimum 3 feet clearance height, and (ii) historic debris flow aggradation trends, where the bed has been observed to rise as much as 5 feet temporarily. Design of bridge span length (and thus clearance between abutments) reflected the potential width of the floodplain channel migration zone as indicated by the LiDAR topography.

Table 2. Recommended Minimum Hydraulic Clearance Specifications

Stream	**Low Chord Elevation (ft. ; NAVD 88)**			**Span Length (ft. ; Range)**		
	Alt. 1, 1A	**Alt. 2**	**Alt. 3**	**Alt 1, 1A**	**Alt 2**	**Alt 3**
Mill Creek	133.0	160.5	145.1	300-325	350-380	225-250
Savage Creek	Similar to Mill Creek	7 Ft Above Floodplain		50 (Alt 1) 105 (Alt 1A)	125-150	150-170

A more comprehensive Habitat, Hydrology and Geomorphic Condition Technical Memorandum is provided in Appendix 3.

2.4 PERMITTING

Developing new or modifying existing roadway facilities in areas where water resources will be impacted (e.g., the Skagit River, Mill and Savage Creeks, and the wetlands bordering the South Skagit Highway) requires applying for and obtaining an array of federal, state, and local permits and approvals. In general, regulatory agencies at the federal, state, and local levels prefer to see projects that address environmental considerations at a watershed scale, and these types of projects are generally looked upon more favorably by regulatory agencies. Based on these general guidelines, high-level regulatory considerations for each of the five South Skagit Highway alternatives are provided. For the purposes of this comparison, it is assumed that all alternatives would have to meet current regulatory requirements associated with fish passage criteria, stormwater management, and compensatory mitigation.

ALT 0

Alternative 0 or the existing conditions obviously does not require any permitting activities.

ALT 1

Alternative 1 would generally be considered preferable to regulatory agencies over existing conditions because it would improve fish passage conditions and provides lower maintenance requirements. However, it would be a more difficult alternative to permit than the rest of the alternatives due to its lack of addressing the watershed level aspects of the project. The primary regulatory considerations for this alternative include the following:

- Floodplain connectivity: Alternative 1 minimizes the area available for migration of the alluvial fans associated with Mill Creek and Savage Creek.
- Wetland habitats, fish benefits, and wildlife benefits: Opportunities for restoring creek, alluvial fan, and wetland interconnects are minimized when compared to the Alternatives 1A, 2, and 3. Wildlife crossings is still hindered due to the lack adequate clearance from the ground to the soffit of the new bridge.
- Water quality benefits: Water quality would be expected to be improved because the new bridge structure would be required to meet current stormwater standards.
- Ongoing maintenance: It is expected that regulatory agencies would have more concerns about ongoing maintenance for this alternative than for the

other Alternatives 1A, 2 and 3 due to the historic sediment removal maintenance that has occurred.

ALT 1A

Alternative 1A is similar to Alternative 1 in terms of locations, except it provides further mainstem connectivity in the form of construction of three new 50 foot culverts on the east end of the project. This alternative also provides adequate clearance for wildlife (i.e., Elk) crossing by providing a higher bridge crossing at Mill Creek. This Alternative would generally be considered preferable to regulatory agencies over Alt 1 because it would improve fish passage conditions and lower maintenance requirements. The primary regulatory considerations for this alternative include the following:

- Floodplain connectivity: Alternative 1A improves the area available for migration of the alluvial fans associated with Mill Creek and Savage Creek with respect to Alt 1. Yet, it is still inferior to Alt 2 and 3 where one has the opportunity to take the full existing roadway prism out of the floodplain zones.
- Wetland habitats, fish benefits, and wildlife benefits: Opportunities for restoring creek, alluvial fan, and wetland interconnects are improved over Alt 1 but are inferior with respect to Alternatives 2 and 3. Wildlife crossings will be improved over existing conditions due to the larger span and height of the openings under the new bridge.
- Water quality benefits: Water quality would be expected to be improved because the new bridge structure would be required to meet current stormwater standards.
- Ongoing maintenance: It is expected that regulatory agencies would have more concerns about ongoing maintenance for this alternative than for the Alternatives 2 and 3 due to the historic sediment removal maintenance that has occurred.

ALT. 2

Alternative 2 would be considered preferable to regulatory agencies over Alternative 1 and 1 A because it addresses the project environmental objectives at a larger scale. The primary regulatory considerations for this alternative include the following:

- Floodplain connectivity: Under both Alternatives 2 and 3, structures would be generally located out of Mill Creek and Savage Creek floodplains and alluvial fans (support piers may be required to leave in the floodplain).

However, Alternative 2 has a longer span than Alternative 3 and could result in a greater area of piers being located in the floodplain.

- Wetland habitats, fish benefits, and wildlife benefits: When compared to Alternative 1 and 1A, Alternative 2 provides for a greater extent of wetland connectivity, assuming the current road alignment is abandoned and the area is restored (e.g. roadbed is removed and planted). This alternative also provides improved fish passage opportunities due to the location of the proposed bridge and roadway realignment, which could provide additional opportunities for designated wildlife crossing areas.
- Water quality benefits: Water quality would be expected to be improved over Alternative 1, and 1A because the new bridge structure and new roadways would be required to meet current stormwater standards.
- Ongoing maintenance: It is expected that regulatory agencies would have fewer concerns about ongoing maintenance for this alternative than for Alternative 1 and 1A.

ALT. 3

Alternative 3 would be considered preferable to regulatory agencies over Alternatives 1, 1A and 2 because it addresses the project environmental objectives at a larger scale and results in less overwater coverage and potentially less in-water structure. The primary regulatory considerations for this alternative include the following:

- Floodplain connectivity: Alternative 3 has a shorter span than Alternative 2 and could result in a smaller area of the support piers being located in the floodplain.
- Wetland habitats, fish benefits, and wildlife benefits: Alternative 3 provides for a level of wetland connectivity that is similar to Alternative 2. This alternative may result in fewer piers and could provide for more fish passage connectivity than Alternative 2. Alternative 3 provides similar wildlife passage benefits to Alternative 2.
- Water quality benefits: Water quality improvements would be similar to Alternative 2.
- Ongoing maintenance: Will be similar to Alt 2 and an enhancement over Alt 1 and 1A.

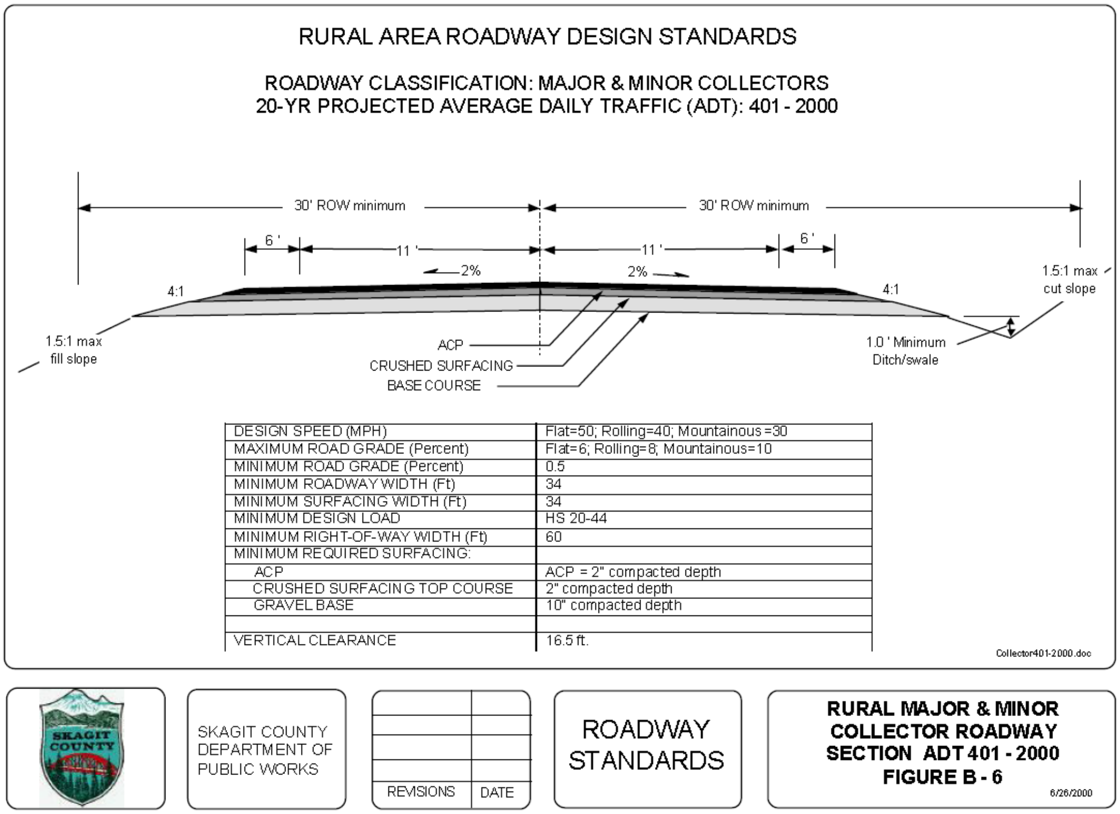
It is to be noted that other parameters associated with the On-going Maintenance attribute of a transportation facility like; additional roadway length, additional walls / bridges, additional bridge inspections utilizing Under Bridge Inspection Truck (UBIT), may be studied and considered for a more thorough assessment of this attribute. This study was beyond the scope of the current contract.

2.5 ROADWAY/ DRAINAGE

Roadway

The current County road facility is one-lane each way. The facility currently gets carried over the Mill Creek via a one-span bridge. The bridge was constructed in 1969 and is 41' long and has a curb-to-curb width of 28 feet. The new proposed bridge(s) will meet current Skagit County Public Works roadway design requirements. Please refer to the Figure 2 below.

Figure 2– Skagit County Standard Roadway Section



RURAL AREA ROADWAY DESIGN STANDARDS

ROADWAY CLASSIFICATION: MAJOR & MINOR COLLECTORS
20-YR PROJECTED AVERAGE DAILY TRAFFIC (ADT): 401 - 2000

DESIGN SPEED (MPH)	Flat=50; Rolling=40; Mountainous =30
MAXIMUM ROAD GRADE (Percent)	Flat=6; Rolling=8; Mountainous=10
MINIMUM ROAD GRADE (Percent)	0.5
MINIMUM ROADWAY WIDTH (Ft)	34
MINIMUM SURFACING WIDTH (Ft)	34
MINIMUM DESIGN LOAD	HS 20-44
MINIMUM RIGHT-OF-WAY WIDTH (Ft)	60
MINIMUM REQUIRED SURFACING:	
ACP	ACP = 2" compacted depth
CRUSHED SURFACING TOP COURSE	2" compacted depth
GRAVEL BASE	10" compacted depth
VERTICAL CLEARANCE	16.5 ft.

Collector401-2000.doc

SKAGIT COUNTY
DEPARTMENT OF
PUBLIC WORKS

REVISIONS | DATE

ROADWAY
STANDARDS

RURAL MAJOR & MINOR
COLLECTOR ROADWAY
SECTION ADT 401 - 2000
FIGURE B - 6
6/26/2000

Alternatives for evaluation that are investigated as part of this project include the following:

- Upgrading the existing roadway with new crossing structures adequate to restore floodplain connectivity. At a minimum this would require consideration of the Mill Creek channel and alluvial fan, multiple Savage Creek channels, and at least three separate wetlands (Two studied Alternatives of Alt 1 and Alt 1A belong to this concept).

- Realigning approximately 1.5 miles of South Skagit Highway out of the Skagit River floodplain. A conceptual alignment is proposed by Skagit River System Cooperative (SRSC) dated January 13, 2014. (i.e. ALT 2)
- One additional alternative developed by the consultant team in consultation with the Project Steering Committee. This also is an upland alignment developed with input from R2 with regards to optimum bridge locations to incorporate channel migration considerations. (i.e. ALT 3)

The aforementioned alternatives were studied with respect to various transportation engineering parameters; Table 3 below provides the values for the studied parameters.

Table 3 – Transportation Engineering Parameters for the Proposed Alternatives

	Alt 0	**Alt 1**	**Alt 1A**	**ALT 2**	**ALT 3**
Design Speed	60	60	60	35	60
Posted Speed	50	50	50	30	50
Horizontal Curve	2960	2960	2960	500	1200
Vertical Grade	0%	2.09%	2.09%	3.50%	2.82%
K- Value (CREST) Stopping Sight Distance (151 min.)	Very Large	230	230	200	317
K- Value (SAG) Headlight Sight Distance (136 min.)	Very Large	251	251	199	270
Elk Crossing Clearance (12')	No	No	Yes	Yes	Yes
Change of length from Existing	0	0	0	350	390
Shutdown potential due to Mill Creek flooding	High	Low	Low	Low	Low
Shutdown potential due to Skagit River flooding	High	High	High	Low	Low
Right of Way (AC.)	0	2	2	21.1	22.1
Long Term Maintenance	High	Medium	Medium	Medium	Medium
Mill Creek Bridge	40	300	300	380	250
Savage Creek Bridge	0	50	105	125	185

The preliminary plan and profile of these alternatives are provided in Appendix 1.

Drainage

Application of stormwater management techniques is highly varied from project to project. The following assessment summary outlines our rational and analysis for the alternatives assessed.

Design Criteria

The 2012 DOE SWMMWW (here-in-after referred to as the “DOE Manual”) will be used for assessing all stormwater management impacts of the project is concert with the County’s Storm Drainage Ordinance (SDO). In conjunction with the DOE Manual, the 2012 Western Washington Hydrology Manual (WWHM) will be used in developing facility water quality and quantity sizes. Stormwater conveyance sizing will be in accordance with SDO section 14.32.080(9).

Stormwater Management Methodology

The proposed stormwater management methodology applies across all project alternatives as they generally include components of the following. This methodology is general in nature as at this time wetlands, wetland buffers, OHWM, stream buffers, and full topographic survey data has not yet been collected. Even so the following methodologies are expected to hold true once complete data has been collected based upon what we understand at this time.

A. Erosion and Sediment Control

In accordance with SDO Section 14.32.060(4), the project is required to prepare a formal Erosion and Sediment Control Plan for approval and per Section 14.32.060(5), the project must meet the appropriate Large Development Erosion and Sedimentation Control Plan Minimum Requirements.

B. Stormwater Quality Methodology

In aggregate, we propose managing water quality through the use of “Type 1 Media Filter Drains”, as described in the WSDOT Highway Runoff Manual (HRM). This is a very low maintenance system used frequently by WSDOT in rural areas at relatively low cost.

As an alternative treatment approach in areas near and adjacent to wetlands, we would propose the use of constructed stormwater wetlands. Here coordination with the permitting Agencies will be necessary to evaluate whether repurposing of Class III wetlands for stormwater management will be acceptable.

For upland areas associated with Alternatives #2 & #3, we propose using “Continuous Inflow Bio-Retention Swale as described in WSDOT’s HRM. Here too this is an effective low maintenance, low cost solution for managing water quality.

C. Stormwater Quantity Methodology

Flow Control is not required for projects that discharge directly to, or indirectly to a water listed in DOE's Appendix I-E - Flow Control-Exempt Receiving Waters which includes the Skagit River.

For Alternative #1, and 1A, we would propose exercising the clause in the DOE Manual to petition the permitting agencies to exempt this alternative is selected given its location relative to area wetlands and the Skagit River.

For Alternatives #2 and #3 we propose relying upon the perceived high soil permeability rate to employ a full dispersion of runoff through the Continuous Bio-Retention Swales

D. Stormwater Conveyance Piping

As our primary proposed modes of conveyance are sheet flow and then to either infiltration through dispersion or discharge to adjacent wetlands or other water bodies, we do not anticipate a significant amount of upland conveyance piping with the exception of driveways or access crossings for logging roads.

In summary, existing site conditions support a range of alternatives that are low in cost both initially and for long term maintenance. As portions of all alternatives are being proposed within the Floodway as defined by FEMA, a Letter of Map Revision (LOMR) will be required and submitted to FEMA for approval. The duration and complexity of this approval process is unknown at this time. Lastly, it has been made clear to us by multiple Skagit County staff that maintenance of future facilities must be minimized, even to the extent of constructing a more expensive solution initially to avoid additional on-going maintenance costs. We believe the proposed solutions meet the needs of the County to minimize these costs.

2.6 STRUCTURAL

The proposed roadway alternatives that were described in the previous sections require different levels of bridge and structural wall infrastructure to support the roadway facility. Following our studies and consultations with the project's Steering Committee on topics like flood, hydrology, channel migration zones, and maintenance, the design team has identified required bridge locations, lengths, and vertical clearances.

For bridge span arrangements, our approach was to optimize bridge span(s) with stream channel related migrations and minimize potential upstream channel aggradations.

Figure 3 depicts the bridge span layout relative to reach – scale geomorphic stream channel characteristics

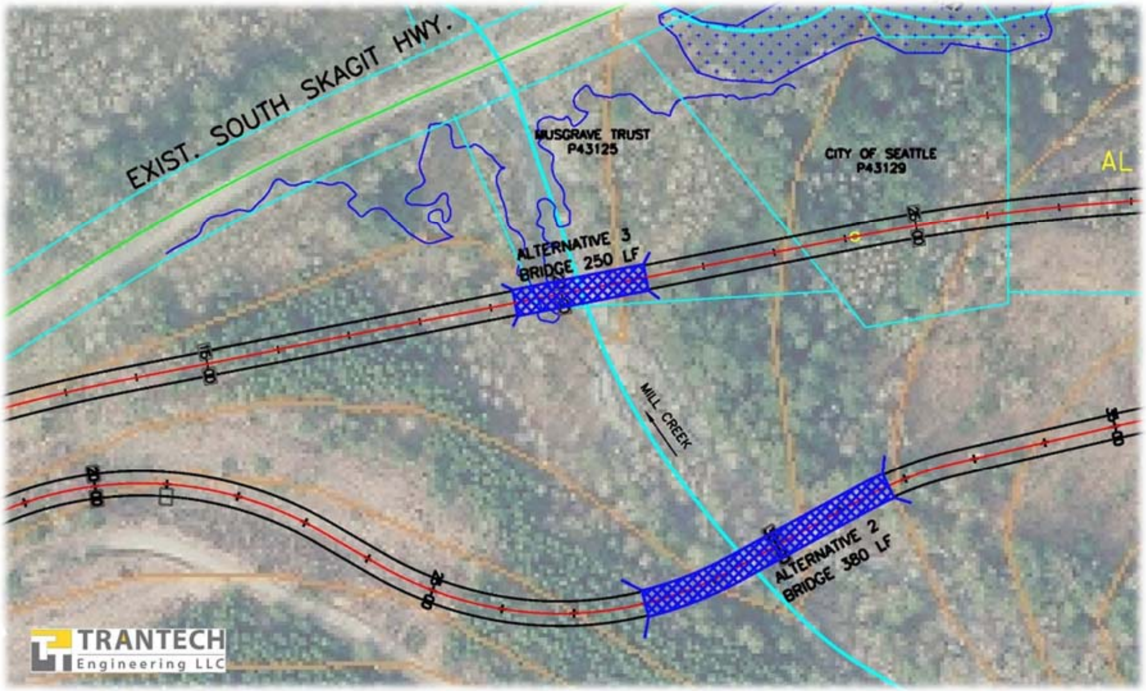


FIGURE 3. BRIDGE SIZE AND LOCATIONS FOR ALTERNATIVES 2 AND 3

For bridge superstructure alternatives, we have looked at transportable precast girders and steel girders to incorporate constructability aspects, especially for the upland alternatives (i.e., Alternatives 2 and 3).

For bridge substructure alternatives, we have looked at both precast solutions and cast-in-place concrete piers founded on driven piles, per our team's geotechnical engineer recommendations.

It shall be noted that except for Alt 1, all of the proposed bridge alternatives will provide enhanced clearance for wildlife passage, with Alternatives 2 and 3 providing the most (i.e., minimum of 12 feet).

In the following, the bridge lengths required for each of the proposed alternatives is summarized:

Alternative 1: Savage Creek Crossing – 1-box culvert 50'; Mill Creek Crossing – 3-span 300'.

Alternative 1A: Savage Creek Crossing – 1-span 105'; Mill Creek Crossing – 3-span 300'.

Alternative 2: Savage Creek Crossing – 1-span 125'; Mill Creek Crossing – 2-span 380'.

Alternative 3: Savage Creek Crossing – 1-span 170'; Mill Creek Crossing – 2-span 250'.

Appendix 4 provides the plan and elevation view of the bridge crossings associated with Alternative 3. These conceptual plans are applicable to all of the studied alternatives.

Regarding structural walls, each alternative has different amounts of required cut and fill walls, with Alternative 2 requiring the least amount. To the extent feasible, the walls will be composed of free draining Structural Earth (SE) walls.

These walls are not only cost-effective but they also blend into the environment by allowing vegetation to cover the walls.

2.7 ALTERNATIVE COMPARATIVE ANALYSIS

The design team studied a variety of analytical methods to be used for comparative study amongst the aforementioned alternatives.

For the sake of providing a simpler and broader level of comparative study that is appropriate for the current level of design, we have compared the aforementioned alternatives from environmental benefits, transportation attributes, and cost perspectives as described below.

2.7.1 – Environmental benefits

Benefits to fish can be quantified and compared approximately in terms of miles of accessible stream habitat for coho salmon and steelhead trout in Mill and Savage creeks, and total area of ponded waterbody currently isolated by the South Skagit Highway that would become more accessible to juvenile salmon and steelhead for a given alternative. Benefits to wetlands are less readily quantified because of uncertainty in areas classified as wetland and in predicting changes in areas that might become wetlands in response to the project; benefits to wetlands are thus discussed in a relative, qualitative sense.

2.7.1.1 Stream Habitat Benefits: The amount of potential steelhead and coho salmon stream habitat available in Mill Creek is indicated by WDFW’s SalmonScape web mapping utility to extend ~1.3 miles upstream of the confluence with the Skagit River. All alternatives are associated with the same level of accessibility to this habitat. The Mill Creek crossing presently affects sediment transport and flooding processes, but not upstream fish passage.

Conversely, the existing Savage Creek crossing does not adversely affect sediment transport, but it may affect flooding over the road prism and upstream fish passage. There is some confusion in available maps of the course of Savage Creek, which complicates estimation of the length of stream that might provide spawning and rearing habitat for salmon, steelhead, and possibly bull trout. The USGS 7.5 minute topographic map shows a channel that drains to the east of where Savage Creek drains onto the floodplain, whereas the stream network map on WDFW’s SalmonScape mapping utility shows two channels that combine and split higher up on the mountain, including the actual location of Savage Creek. The LiDAR data do not indicate the presence of the eastern branch channel that is indicated on the USGS map, and aerial photography on Google Earth indicates the western branch is the only main channel with branching tributaries upslope, consistent with the LiDAR topography. Following the course of the channel apparent in the aerial photography and summing up stream lengths mapped in SalmonScape as potentially supporting coho and steelhead leads to an estimated 2.5 miles of stream channel that could be made more accessible. The same amount could be made readily accessible under all studied alternatives.

Of the two streams, Savage Creek contains substantially higher quality fish habitat than found in Mill Creek.

2.7.1.2 Ponded Habitat Benefits: The isolated pond waterbodies located to the south of the highway amount to a little over 9.2 acres of potential rearing habitat, assuming water quality and access conditions are suitable. The water level in this habitat is a few feet lower than the water surface elevation in Savage Creek where it exits the ravine and drains onto a small alluvial fan that is evident in the LiDAR and aerial photography. Hence, providing access to Savage Creek could also be associated with providing access to the presently isolated pond water bodies for juveniles originating in or migrating into the stream under all but the ‘do-nothing’ and Alt 1 alternatives. There would likely be some loss of ponded area in Savage Creek proper above the highway culvert, amounting to approximately - 2.5 acres if water levels are dropped from EL 124’ down to EL 122’ as a result of culvert replacement, so the net potential gain in ponded rearing area would be about 6.7 acres under all action alternatives, assuming connectivity can be established with Savage Creek under Alternative 1.

The isolated pond waterbodies are ~6-8 feet higher than mapped wetlands on the north side of the highway, thus any of the action alternatives would require constructing some form of upstream passage feature to make this habitat more accessible for juveniles coming directly from the Skagit river upstream (as opposed to from Savage Creek). Amongst studied alternatives, Alternatives 1A, 2 and 3 provide the most benefit in this arena while Alternative 1 does not.

2.7.1.3 Wetlands: The total area of wetlands to the north of the highway would likely increase over existing conditions under Alternatives 1A, 2 and 3 if greater hydraulic connectivity is created such that water from the hillslopes and Savage Creek can seep or overflow into those areas more readily. At the same time, increased hydraulic connectivity could lead to a reduction in wetland area to the south of the highway. If no additional connectivity is provided under Alternative 1, the wetland areas would be expected to remain unchanged by the project.

2.7.1.4 Wildlife Crossings: Alternatives 1A, 2, and 3 would all be associated with approved and safer conditions for wildlife movement across the current location of the highway.

2.7.1.5 Floodplain Connectivity:

The degree of floodplain connectivity varies with alternative in terms of two mechanisms:

- **Hydraulic Connectivity:** Where the floodplain and/or river banks are affected by constructed structures that interrupt channel migration, but flood waters can still access the entire floodplain area. Under this scenario, flood waters of the Skagit River can inundate the floodplain to the south of the existing highway via conveyance pathways constructed through the road prism. Increased hydraulic connectivity can be accordingly achieved by adding culverts and bridges. An analogue is the case when a levee is partially breached so that flood waters can access the floodplain behind it more quickly and extensively.

- **Full Floodplain Connectivity:** Where the river is also free to migrate and flow uninterrupted over the floodplain by anthropogenic structures such as a road prism. In this case, full or nearly full removal of the road prism is required so that the floodplain vegetation community and off-channel habitats reflect a natural frequency and duration of inundation by high water. In single channel systems such as the affected reach of the Skagit River, the channel migrates primarily through a meandering process, leaving behind initially active side channels and ultimately relic off-channel habitats that provide rearing opportunities for fish and habitat for amphibians, waterfowl, and wildlife. Occasionally, the river may create a side channel through avulsion (i.e., cutting of a short-cut channel across the inside of a bend) that eventually may become captured as the main river channel, a possibility that exists here since the ponded waterbodies provide a potential avulsion pathway.

All alternative cost estimates were developed under the premise that hydraulic connectivity would be provided in one form or another for Alternatives 1A, 2, and 3 via relatively small conveyance pathways across the existing South Skagit Highway location. Skagit River floodwaters can flow through these pathways during high flows, but full floodplain connectivity potential is not achieved. In so doing, the ponded waterbodies located to the south of the highway would be hydraulically connected under Alternatives 2 and 3, but in order to keep costs down for all alternatives given the developing cost estimates, the analysis assumed that three breaches of the road prism would occur under Alternatives 1A (via large culverts), 2 and 3 (via cuts in the prism). Alternative 1A would also provide additional hydraulic connectivity via the widened Mill Creek and Savage Creek crossings.

In order to achieve full floodplain connectivity, Alternatives 2 and 3 would each require removing all or most of the road prism between the Savage Road turnoff and Mill Creek. In addition, the paving and subgrade of Savage Road would also need to be removed. Alternative 1A could conceivably achieve a more modest degree of floodplain connectivity benefits by removing a larger portion of the roadway prisms in the vicinity of the ponded water bodies, but the design and construction cost will likely increase accordingly. Alternative 1 is inferior to the others in this respect because hydraulic connectivity would not be established between the Skagit River and the ponded waterbodies to the south of the highway.

2.7.2 Cost Analysis

The preliminary cost data associated with all 4 floodplain improvement alternatives are presented in Appendix 5. As seen, the costliest alternative is Alternative 2 at $18M, while Alternative 3's cost is $17.4M and Alternatives 1A and 1 cost $12.9M and $8.6M respectively. In case full floodplain connectivity is desired, in which roadway prisms associated with S. Skagit Highway and Savage Road need to be fully removed, then $1M needs to be added to project costs associated with Alternatives 2 and 3.

Of particular interest is the cost differences between Alternative 1 and 1A. Alternative 1 can be looked upon as the least cost permittable alternative that alleviates the hydraulic conveyance issues at the roadway's Mill Creek crossing and its vicinity. This alternative also provides enhanced fish habitat in the aforementioned area. Yet, Alternative 1A can be looked upon as Alternative 1 with more environmental benefits like more mainstem habitat connectivity, wildlife crossing clearances, etc.

To further highlight the cost differences amongst these two alternatives, Appendix 5 provides a side-by-side cost comparison sheet that sheds further light on the optional benefits of Alternative 1A.

A higher contingency factor has been used for Alternatives 2 and 3, due to the uncertainty and the risks associated with the pioneering roadway with undermined amounts of cuts and fills required for these alternatives. Alternatives 1 and 1A contingencies have been reduced to 15% from 25% associated with the Alt 2 and Alt 3, due to minimal cuts and mostly fills with engineered walls.

In the spirit of value engineering, the optional environmental benefits and their associated cost increases over Alternative 1 are summarized in Table 4:

Table 4 – Alt 1 and Alt 1A Cost Difference Summary

Environmental Options	Affected Bid Items	Increase Cost Over Alt 1
Providing a higher profile for animal crossing (i.e., Elk)	Walls; Borrow; Embankment;	$700K
105-foot bridge crossing at Savage Creek, as opposed to a 50-foot culvert, for further fish habitat and conveyance enhancement	Savage Creek Structure	$1,000K
More mainstem connectivity at east side of Mill Creek zone	3 connectivity culverts; further traffic control	$1,500K

2.7.3 – Transportation attributes

Section 2.5 provided the transportation attributes associated with each alternative. As discussed, all alternatives meet the County’s roadway desired attributes except for Alternative 2 as it fails on the desired Design Speed attribute for the highway.

In the following, we have summarized all the studied attributes associated with aforementioned alternatives in one table for comparison convenience:

Table 5 – Alternative Attributes Comparison Summary

	Alt 0	Alt 1	Alt 1A	ALT 2	ALT 3
ENVIRONMENTAL					
Fish passage into Savage Creek	Partial	Full	Full	Full	Full
Fish passage into Mill Creek	Full	Full	Full	Full	Full
Increased Wetland Area	NO	NO	NO	YES	YES
Safer Wildlife Passage	NO	NO	YES	YES	YES
Reduced Sediment Transport Impacts /More Natural Fan Processes	NO	YES	YES	YES	YES
Increased Floodplain Connectivity Potential	NO	NO	NO	YES[1]	YES[1]
Increased Hydraulic Connectivity with Floodplain	NO	NO	YES	YES	YES
COST					
Construction Estimate	0	$8.6M	$12.9M	$18M	$17.4M
Roadway Prism Removal	NO	NO	NO	$1M	$1M
ROADWAY DESIGN					
Design Speed (MPH)	60	60	60	35	60
Posted Speed (MPH)	50	50	50	30	50
Horizontal Curve (FT)	2950	2960	2960	500	1200
Vertical Grade	0%	2.09%	2.09%	3.50%	2.82%
K- Value (CREST) Stopping Sight Distance (151 min.)	Very Large	230	230	200	317
K- Value (SAG) Headlight Sight Distance (136 min.)	Very Large	251	251	199	270
Change of length from Existing	0	0	0	350	390
Shutdown potential due to flooding	High	High	High	Low	Low
Right of Way (AC.)	0	2	2	21.1	22.1
Long Term Maintenance	High	Medium	Medium	Medium	Medium
Mill Creek Bridge (FT)	40	300	300	380	250
Savage Creek Bridge (FT)	0	50	105	125	185

1 - Floodplain Connectivity requires removal of roadway prisms of Savage Road and Skagit Highway

3. CONCLUDING REMARKS AND RECOMMENDATIONS

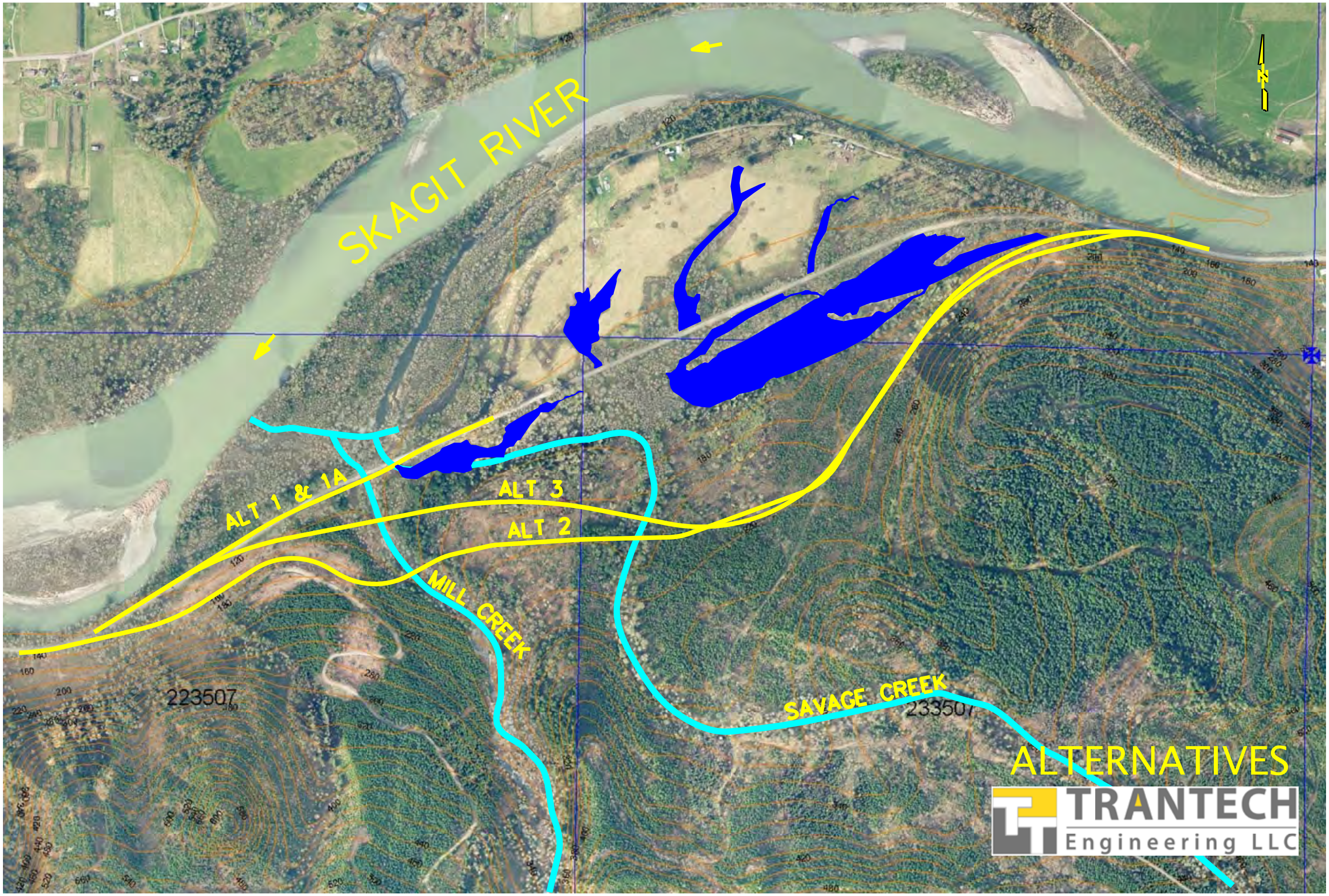
All the alternatives, except Alt 0 or Do Nothing alternative, will provide sufficient flow capacity (i.e., hydraulic connectivity) to alleviate overtopping issues in the vicinity of the Mill Creek bridges. Reduction of shutdown days within the limits of this project due to flooding resulting from the water level rise in Skagit River will favor Alternative 2 and 3, since it relocates the road to a higher elevation.

Moreover, Alternatives 2 and 3 provide the opportunity for full floodplain connectivity by fully removing roadway prisms associated with S. Skagit Highway and Savage Road within the project limits.

Following the design team’s presentation of the studied alternatives to the Steering Committee, the Committee has recommended to drop Alternative 2 from further consideration due to its non-compliance to the corridor’s Design Speed requirements and to keep Alternatives 1, 1A and 3 as viable alternatives for further investigations.

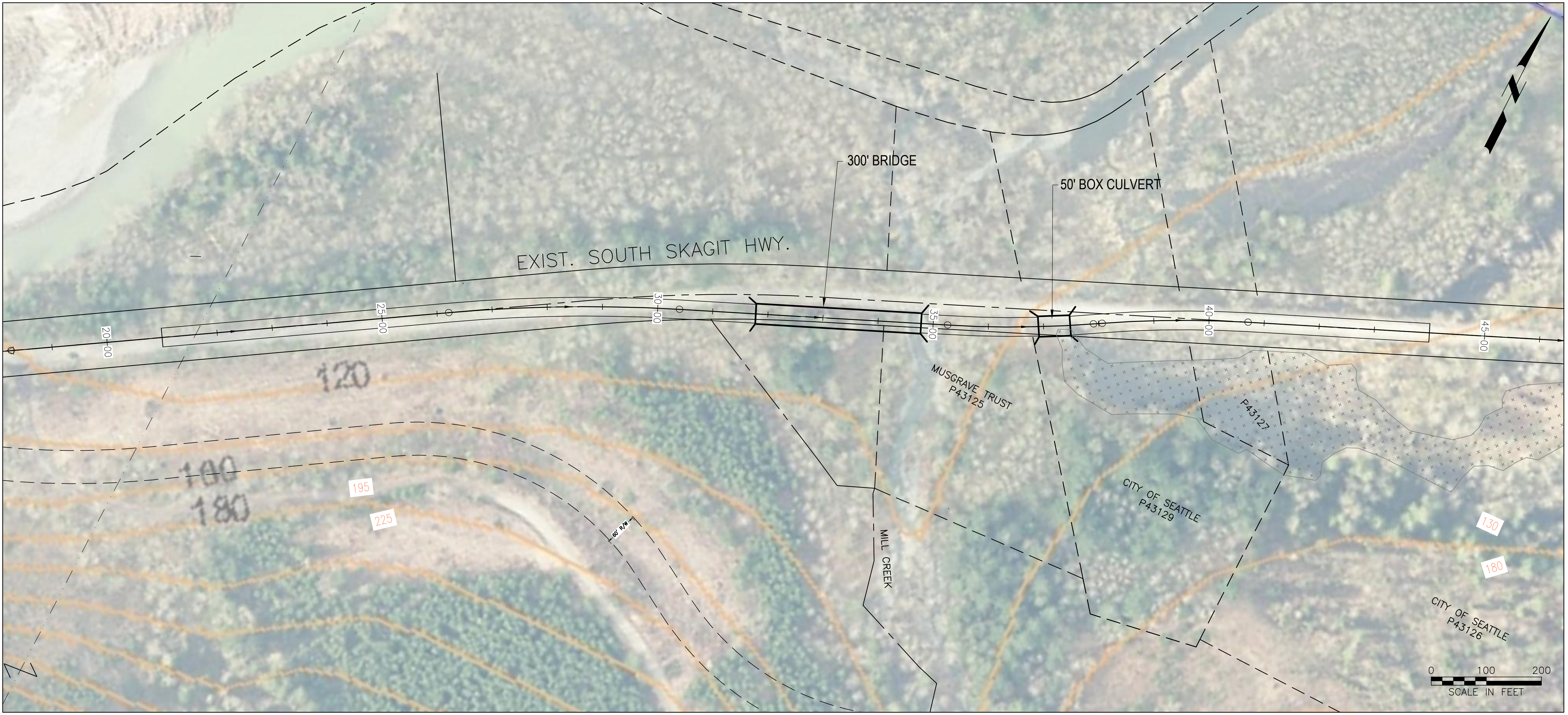
Lastly, as one of the primary benefits of this project is fish passage within Savage Creek, it is recommended that the Steering Committee also considers optimization of the Savage Creek channel enhancement as a standalone or first-phase project. This project will also have potential implications to alleviate the overtopping frequencies at Mill Creek Bridge crossing.

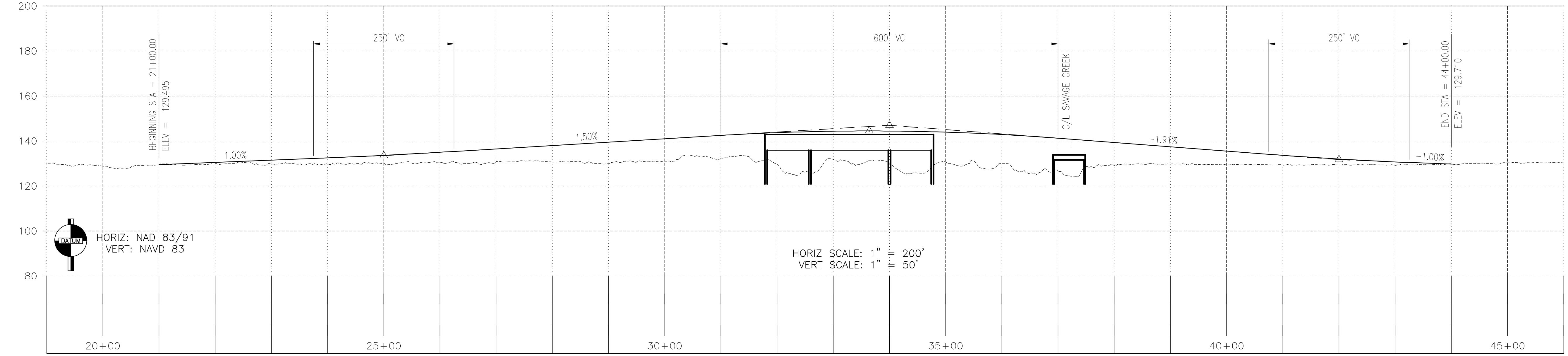
A1 Alternatives’ Plan and Profiles



ALTERNATIVES

TRANTECH Engineering LLC





TRANTECH
Engineering LLC
12011 NE 1st STREET, STE 305
BELLEVUE, WA 98005
MAIN: 425-453-5545 / FAX: 425-453-6779

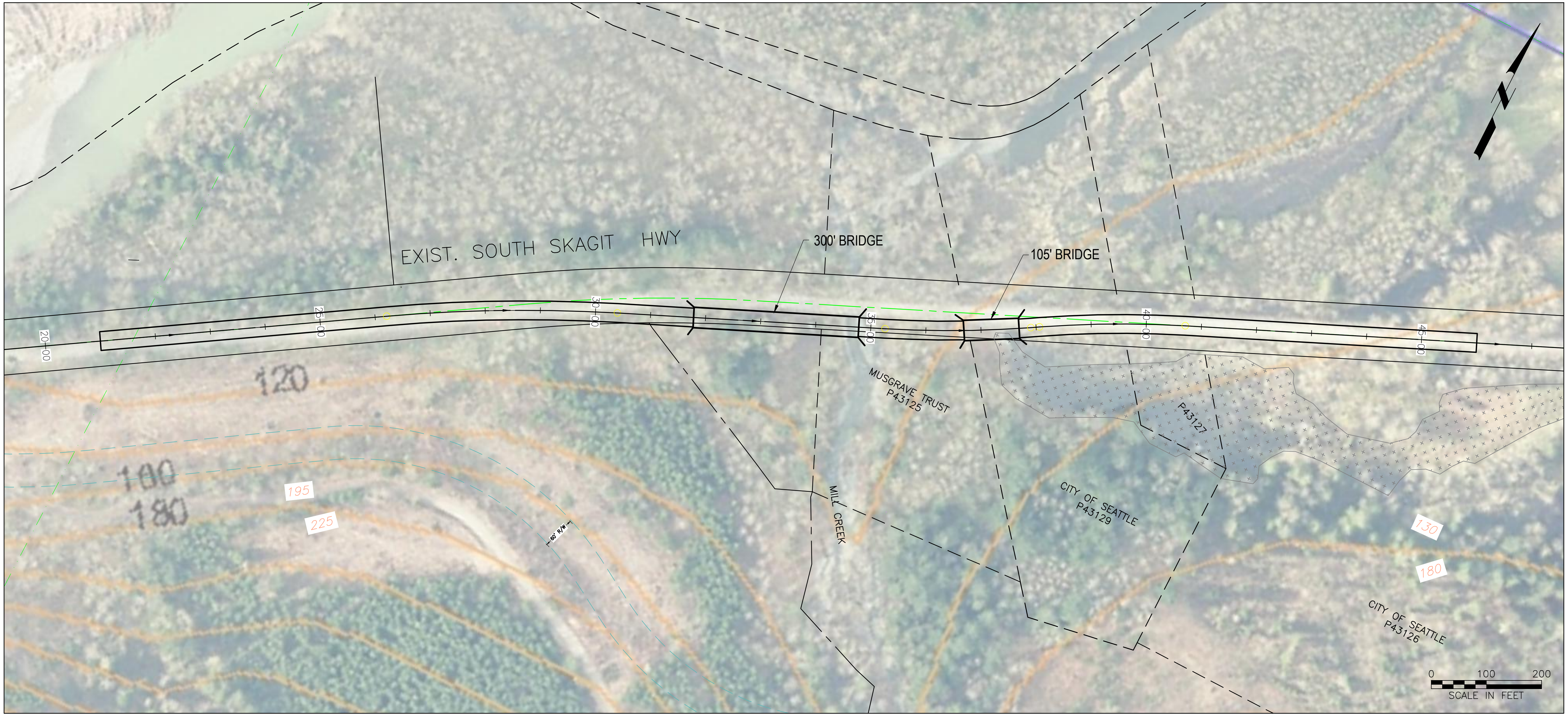
NO.	REVISIONS	DATE

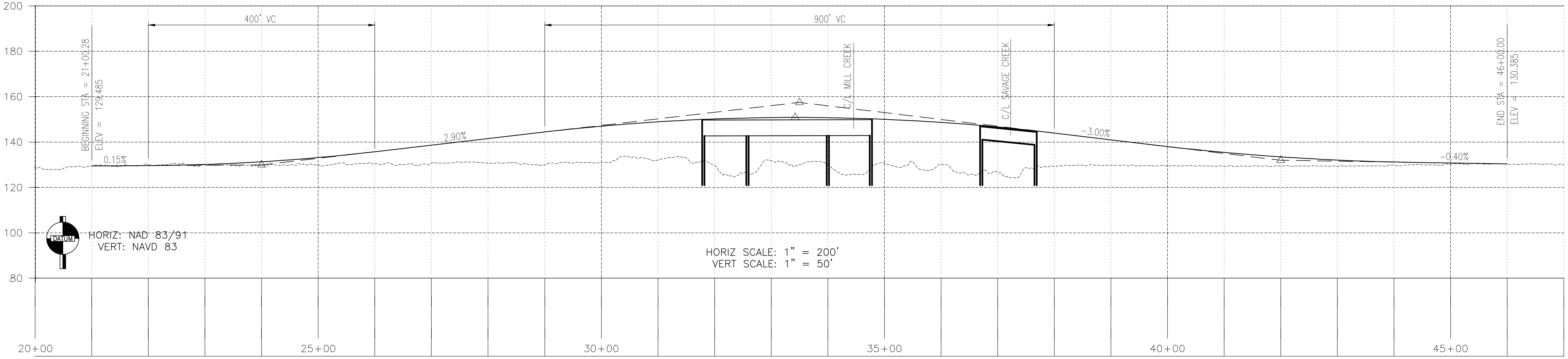
PROJECT NO.: 2014-013
FED.AID NO.
DESIGED BY: SR
DRAWN BY: GTR
CHECKED BY: SR
APPROVED BY:
PROJECT LOCATED NEAR:
MP 17.8 - 19.4

SOUTH SKAGIT HIGHWAY
ALTERNATIVE-1

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: 01
1 OF 6





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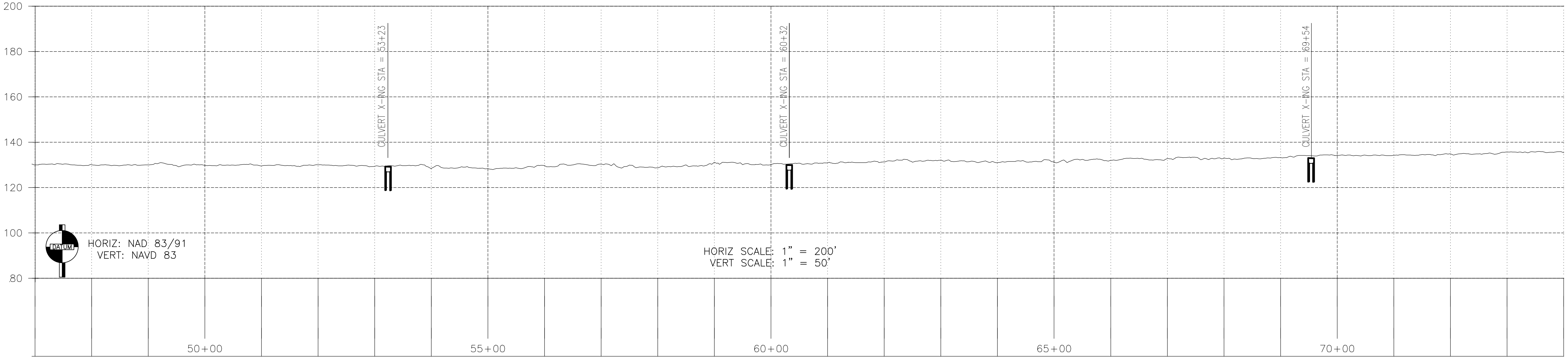
SOUTH SKAGIT HIGHWAY
ALTERNATIVE-1A

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: **02**
2 OF **6**



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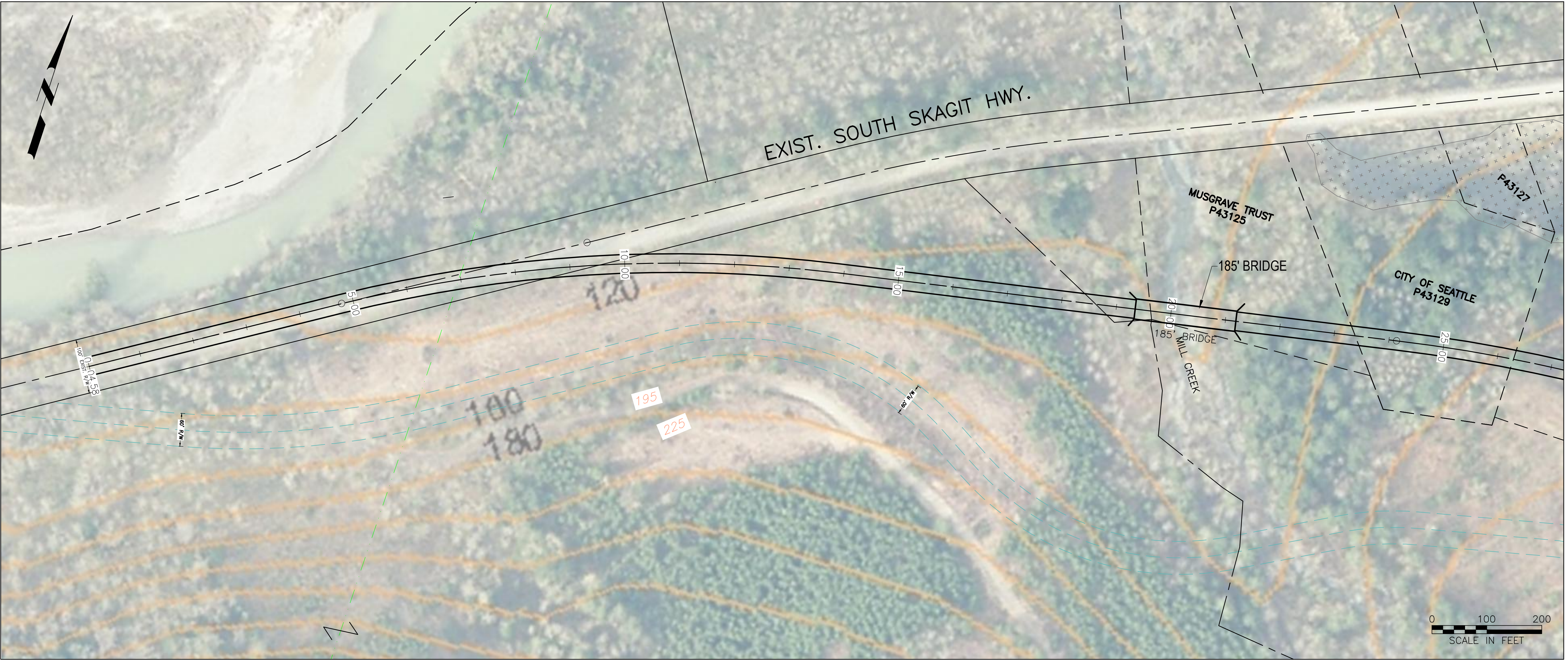
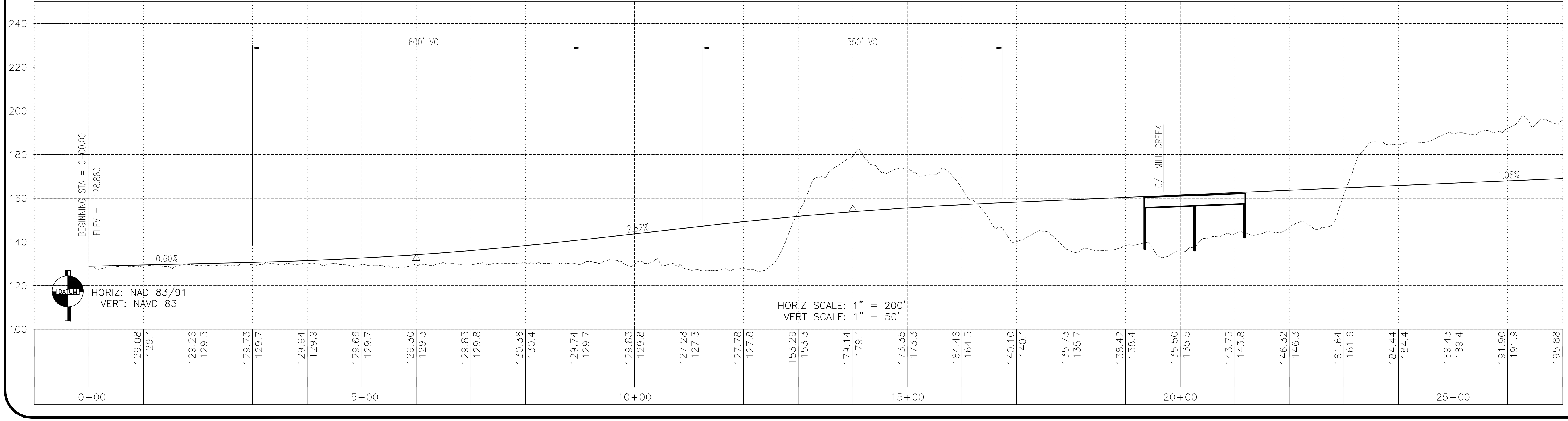
SOUTH SKAGIT HIGHWAY
ALTERNATIVE-1A

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: 03
3 OF 6





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DESIGED BY: SR
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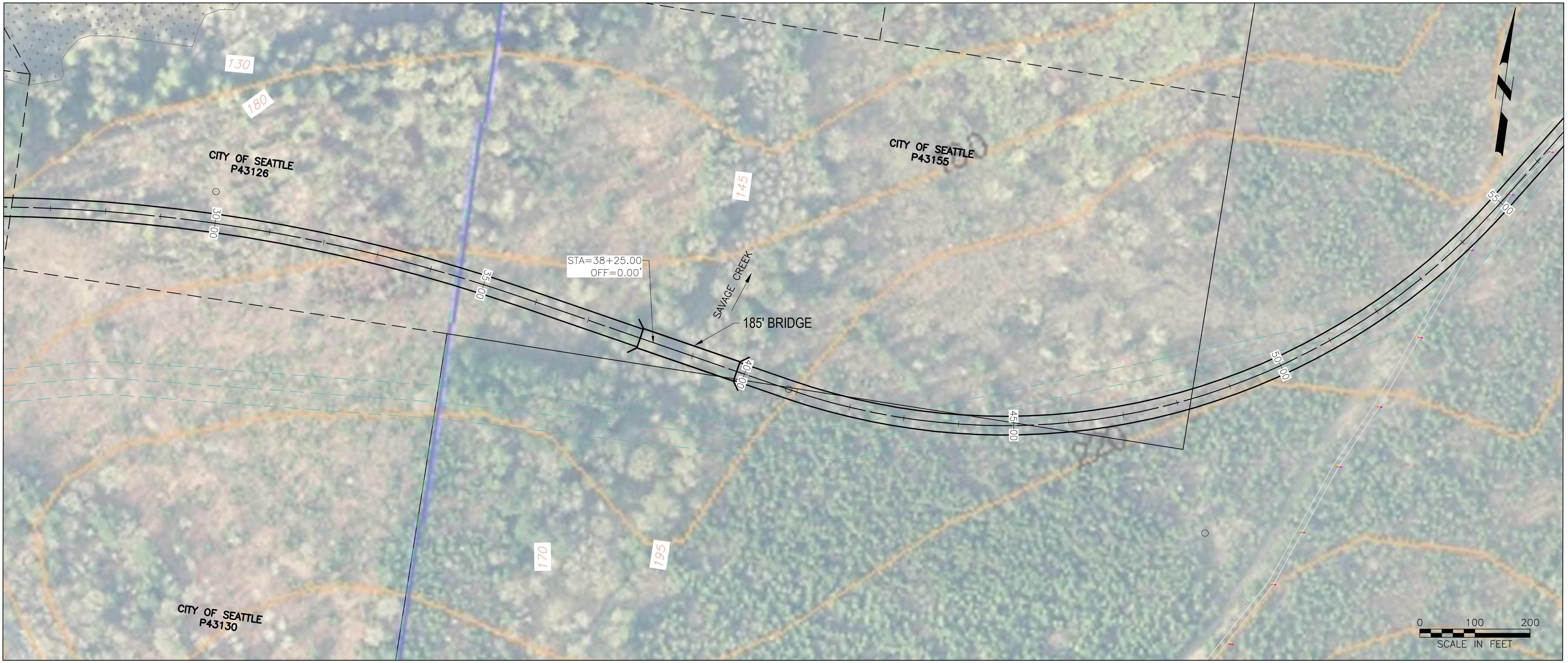
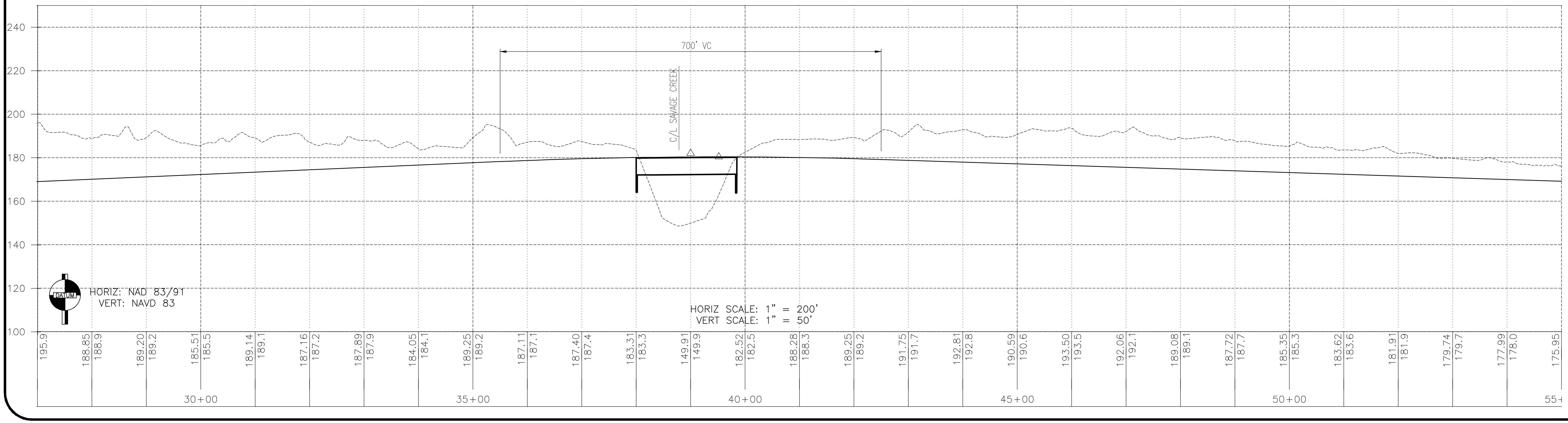
APPROVED BY:
PROJECT LOCATED NEAR:
MP 17.8 - 19.4

SOUTH SKAGIT HIGHWAY
ALTERNATIVE-3

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: 04
4 OF 6





DATUM
HORIZ: NAD 83/91
VERT: NAVD 83

HORIZ SCALE: 1" = 200'
VERT SCALE: 1" = 50'

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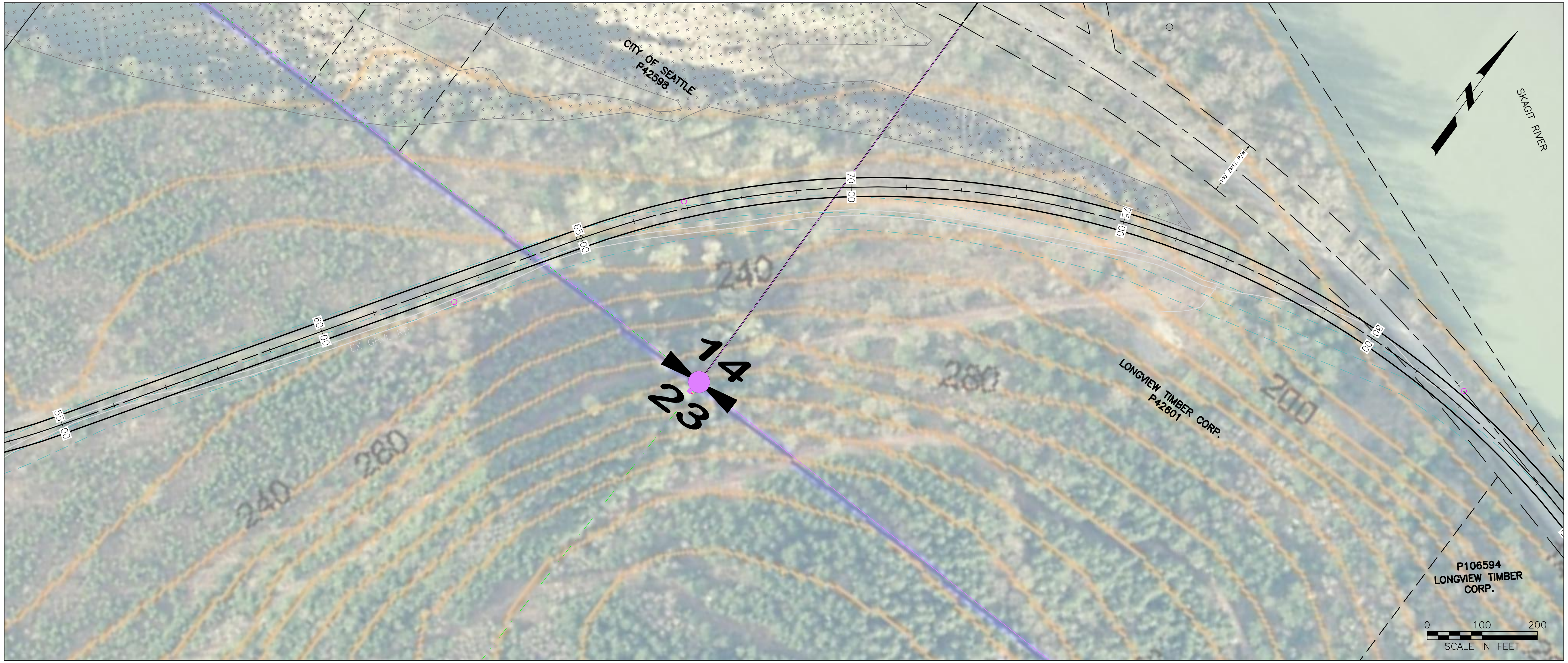
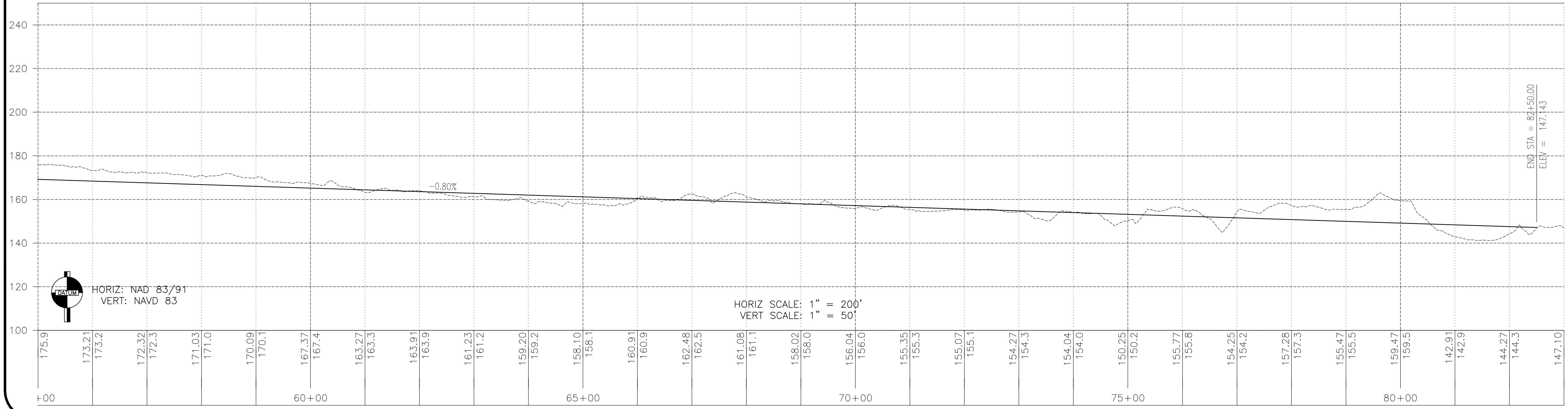
APPROVED BY:
PROJECT LOCATED NEAR:
MP 17.8 - 19.4

SOUTH SKAGIT HIGHWAY
ALTERNATIVE-3

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: **05**
5 OF **6**





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SOUTH SKAGIT HIGHWAY
ALTERNATIVE-3

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

SHEET: **06**
6 OF **6**

A2 Geotechnical Report

Aspect
CONSULTING

April 3, 2015

Mr. Khashayar Nikzad, P.E., PhD.
TranTech Engineering LLC
12011 NE First St, Suite 305
Bellevue, WA 98005

Re: South Skagit Highway Floodplain Restoration Project
Preliminary Geotechnical Recommendations
Project No. 140034-001

Dear Kash:

This memorandum summarizes findings and recommendations results from Aspect Consulting's geotechnical field exploration program in support of the preliminary engineering evaluation of the South Skagit Highway Relocation and Floodplain Restoration Project (Project).

Project Description

An approximately 1½ mile long stretch of the South Skagit Highway extends across the lower Mill Creek and Savage Creek drainages near their former confluences with the Skagit River. The elevated roadway grade with small culverts and narrow bridge has impacted flow from these creeks to historic wetlands on the Skagit River floodplain, resulting in degradation of the floodplain and aggradation of the creek beds and flooding-related impacts. The objective of this Project is to restore the function of wetland along the Skagit River floodplain along this section of the South Skagit Highway, and reduce long-term flooding and associated maintenance requirements.

At present, two alternative upland highway re-alignments are being considered (Alternatives 2 and 3) in addition to the Maintain Existing Alignment (Alternative 1). Figure 1 is a Site Plan showing the site and existing alternative alignments.

Site Geology

In the Project area, hillsides rising above the floodplain of the Skagit River are composed of recessional glacial outwash that forms a broad and undulating terrace generally to the south of most of the alignment. Post glacial (Holocene) incision and meander of the Skagit River and its tributary drainages have eroded this glacial outwash terrace and created a series of successively lower terraces of recent alluvium that step down to the north into the modern river channel. Meander of the Skagit River also created a number of now abandoned incised flood channels, many of which are now the wetlands adjacent to the highway.

Most of the upland alignments (Alternatives 2 and 3) will traverse areas of second-growth forest with little understory vegetation. Based on our observations of deposits exposed at the site, regional geologic mapping, and preliminary analysis of subsurface conditions encountered in the borings, we anticipate that deposits at the Site will generally consist (from generally older to younger) of the following:

- **Recessional Glacial Outwash** – Chiefly medium dense sand and gravel with variable silt content. Expected to have low compressibility, moderate shear strength, and high permeability. This unit contains cobbles and boulders.

- **Alluvium** – Alluvium occurs in two settings at the Site – in the older terraces deposited by the Skagit River (that now lie well above modern river level), and within the modern drainage channels of Mill and Savage Creeks where these creeks have eroded through these older Skagit River terraces. Within these two settings, alluvium is divided into two principal types: channel deposits and overbank floodplain deposits. Overbank floodplain sediments were deposited in low-energy backwater environments and consist of soft/loose silt and fine sand. Channel alluvium was deposited high-energy environments in the Skagit River and modern channels of Mill and Savage Creeks. Channel bed alluvium consists of loose grading to medium dense to dense sand and gravel with cobbles and boulders.

  The channel deposits are anticipated to have low compressibility and possess moderate to high shear strength. The overbank floodplain deposits are anticipated to be moderately compressible, possess low to moderate shear strength, and may contain interbeds of weak silt and clay and potentially highly compressible organic rich soils. Buried logs and wood debris may be present in both channel and overbank deposits.

- **Wetland Deposits** – Wetlands in the vicinity of the highway may contain deposits with high fines and organics content. These soils are expected to be compressible, possess low to very low shear strength, and low permeability.

- **Topsoil** – Topsoil is present in most forested areas of the site. Topsoil thickness is estimated to be on the order of up to several feet deep. Topsoil is compressible and weak.

- **Landslide Deposits** - Although not indicated on the regional geologic map, a series of deep-seated landslides were observed near the eastern end of the site alignment, above the Weyerhaeuser Columbia road entrance and gate. These landslide deposits consist of unsorted sand and gravel deposits with variable silt content that has slid from the steep slope of the glacial outwash terrace. Landslide deposits are anticipated to be loose and possess low shear strength.

Geotechnical Explorations

The geotechnical field investigation was completed on September 25 and 26, 2014. Three borings were drilled and sampled at the approximate locations shown on Figure 1. Boring B-1 was drilled near the east bank of Mill Creek along the approximate Alternative 3 alignment, boring B-2 was drilled along the Merrill & Ring logging road on the western portion of the Project, and boring B-3 was drilled on the Weyerhaeuser Pacific logging road on the eastern portion of the Project. Borings B-2 and B-3 were each drilled to 21.5 feet below ground surface using hollow stem auger. Boring B-1 (next to Mill Creek) was drilled using hollow stem auger for the first 25 feet and then it was completed to 51.5 feet using rotary wash methods. Disturbed samples were obtained from all three borings at 5-foot intervals in each of the borings using non-standard penetration test (NSPT) methods.

Subsurface Conditions

The three borings encountered topsoil, and alluvium which can be subdivided into two units: coarse-grained channel deposits; and fine-grained floodplain overbank deposits. Boring B-1 located on the east side of Mill Creek encountered alluvium extending to the bottom of the boring at a depth of 51.5 feet below ground surface (BGS). Alluvium in B-1 was interpreted as a channel bed deposit. It included sandy gravel (GW and GP), slightly silty gravelly sand (SM-SW), slightly silty sandy gravel (GM-GP), and silty sandy gravel (GM). Broken coarse gravel in the sampler indicate that cobbles were present in this deposit. Groundwater was encountered in B-1 at about 10 feet BGS, which corresponds to approximately the level of surface water in nearby Mill Creek. Soil densities ranged from very loose in the upper approximately 5 feet, grading medium dense to the bottom of the borehole, with interbeds of dense to very dense strata.

Boring B-2, located on an alluvial terrace near the western end of the alignment, encountered alluvial channel bed deposits from the ground surface to the bottom of the borehole at 21.5 feet BGS. Soils in this borehole consisted of medium dense, slightly silty sand gravel (GM-GW). A several-inch-thick bed of clayey silt was encountered at the 6-foot depth. Groundwater was not encountered.

Boring B-3, located on an alluvial terrace near the eastern end of the alignment, encountered recent alluvium consisting of interbedded channel bed deposits and floodplain overbank deposits. The upper approximately eight feet was interpreted to be channel bed alluvium and consisted of medium dense, slightly moist, slightly silty gravelly sand (SM-SW). Broken coarse gravel suggests that cobbles were present in this deposit. From about 8 to 18 feet BGS, a bed of floodplain overbank deposits was encountered. This was composed of soft grading to medium stiff, moist slightly sandy silt (ML). Below 18 feet, channel deposits resumed with a layer of medium dense, moist sand (SP). Groundwater was not encountered in this boring.

Boulders and cobbles were not directly observed in the channel bed samples, but our observations of site conditions and understanding of the site setting suggests that they may be present in these deposits. Logs and wood and organic deposits may also be present, particularly in the floodplain deposits.

Preliminary Engineering Conclusions

The soils encountered in our borings are generally favorable for new road and bridge construction along an upland alignment. General and preliminary geotechnical engineering conclusions for foundations, approaches, walls, and site earthwork, are presented in the following paragraphs.

- **Bridge Foundations** - The saturated sandy gravel alluvium in B-1 has medium dense zones above 25 feet BGS that are susceptible to liquefaction during an extreme (design-level) earthquake. New bridge foundations will need to penetrate liquefiable soils and extend a sufficient distance into the underlying more competent and non-liquefiable alluvium. We conclude that heavy-walled open- or closed-ended steel pipe piles are a potentially suitable deep foundation type. For planning purposes, 24-inch diameter, ½-inch wall thickness, steel pipe piles, may be considered. Alternatively, 4-foot diameter, cast-in-place concrete drilled shafts, would be suitable. Driven pile and drilled shaft foundation embedment depths of the order of 60 feet should be considered for preliminary purposes. More detailed geotechnical and structural engineering evaluations should be conducted.

- **Bridge Approaches** - Depending on the crossing (Mill or Savage Creek) and location, approach embankments of varying thickness are anticipated. Where right of way restrictions require such fills to be retained, mechanically stabilized earth (MSE) approach embankments can be considered. Where permissible, sloped embankments should have permanent side slopes not steeper than 2H:1V.

- **Cut and Fill Retaining Walls** - Depending on the upland alignment, permanent cut and fill retaining walls may be significant. For planning purposes, cut walls greater than about 10 feet in exposed height can be designed and constructed using soldier piles and lagging. Lower cut walls can be designed and constructed using cast-in-place concrete cantilever, gravity blocks, and MSE (if temporary excavations are allowed). Fill retaining walls can be designed and constructed using MSE systems. A variety of wall fascia options are suitable including sculpted shotcrete, pre-cast concrete panels/blocks, timber lagging, and rock-filled wire gabions. Aesthetic or other non-geotechnical considerations may drive the required wall fascia.

- **General Earthwork Considerations** - The upland alternative alignments will involve significant earthwork. In general much of the existing alluvium along the Project alignment appears suitable for re-use as structural fill. Permanent cut and fill slopes should be planned at 2H:1V. Boring B-3 encountered an approximately 10-foot thick deposit of low-energy floodplain overbank soil consisting of soft to medium stiff sandy silt. Such zones are moderately compressible. In areas where new roadway embankment fill thickness is more than a few feet thick, settlement may be a consideration. However, at the location of B-3, the potential/proposed new road will be at or near existing grade.

Limitations

Work for this project was performed for TranTech and the Skagit River System Cooperative (Client), and this letter was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This letter does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Sincerely,

Aspect consulting, LLC

Engineering Geologist
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David H. McCormack

4-3-2015

Erik O. Andersen
36466

April 3, 2015

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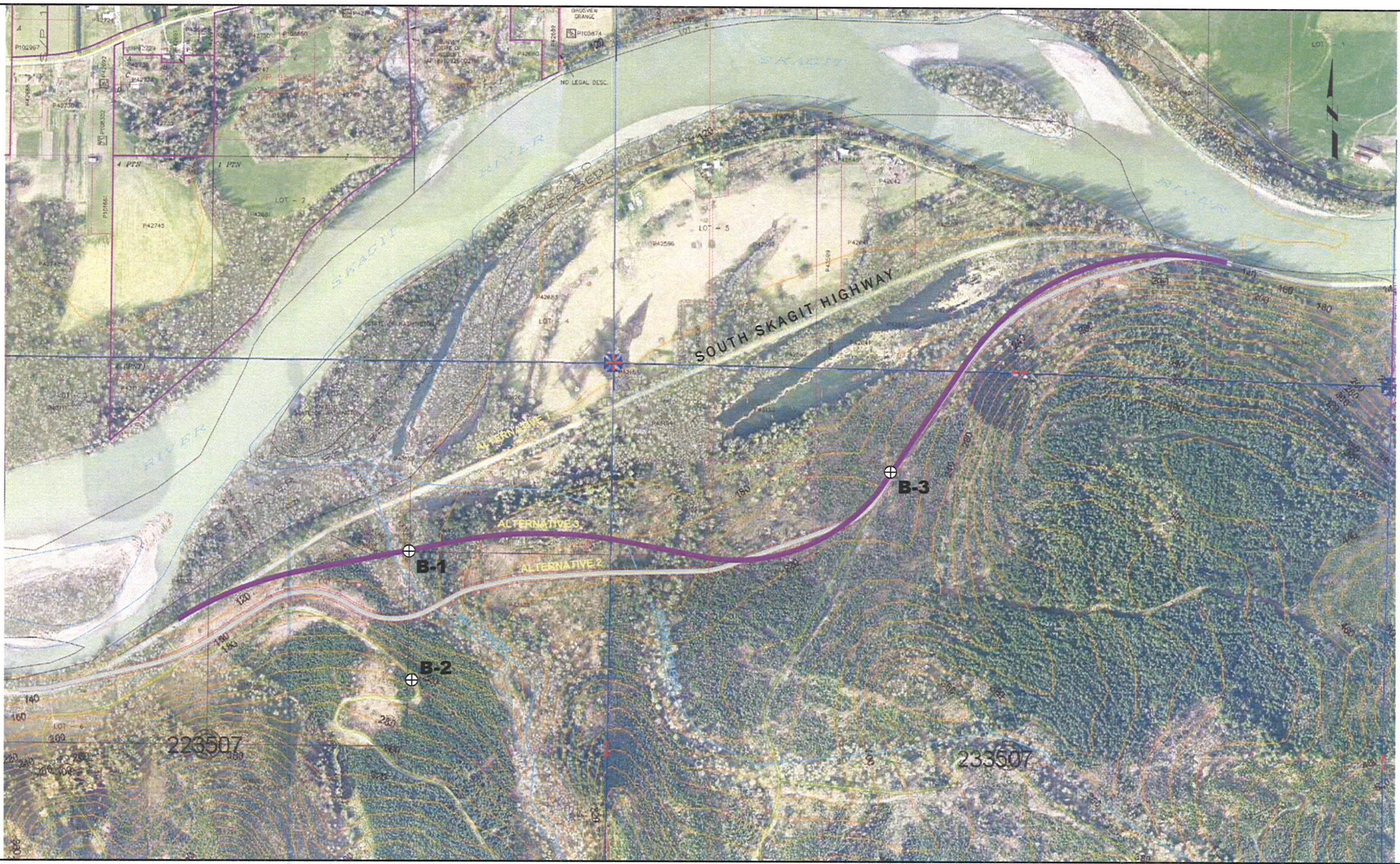
eandersen@aspectconsulting.com

Attachments:

Figure 1.	Site and Exploration Plan
Figure 2.	Exploration Log Key
Figures 3 - 5.	Logs of Borings B-1 through B-3

W:_GEOTECH\140034 S Skagit Hwy Re-alignment\Deliverables\Geotechnical Recommendations Memo\Final\Preliminary Geotechnical Memo Final April 2015.docx



Source: Base map provided
by Trantech Engineering, LLC,
Bellevue, Washington.

Legend

⊕ Boring Location

Note: Boring locations were determined by pacing from existing site features and should be considered approximate.

Approximate Scale

Site and Exploration Plan

South Skagit Highway Re-alignment
Skagit County, Washington

Aspect CONSULTING

OCT-2014

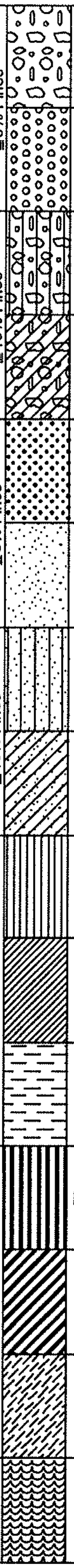
PROJECT NO. 140034

BY: EA/SCC

REVISED BY: -

FIGURE NO. 1

CAD Path: Q:_GeoTech\140034 Skagit River System Cooperative\2014-10 South Skagit Highway Re-alignment\140034-02.dwg 11x17 Landscape || Date Saved: Oct 27, 2014 11:34am || User: scudd



Coarse-Grained Soils - More than 50% (1) Retained on No. 200 Sieve	Gravels - More than 50% (1) of Coarse Fraction Retained on No. 4 Sieve	≤5% Fines (5)	**GW**	Well-graded gravel and gravel with sand, little to no fines
			GP	Poorly-graded gravel and gravel with sand, little to no fines
		≥15% Fines (5)	**GM**	Silty gravel and silty gravel with sand
			GC	Clayey gravel and clayey gravel with sand
	Sands - 50% (1) or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines (5)	**SW**	Well-graded sand and sand with gravel, little to no fines
			SP	Poorly-graded sand and sand with gravel, little to no fines
		≥15% Fines (5)	**SM**	Silty sand and silty sand with gravel
			SC	Clayey sand and clayey sand with gravel
Fine-Grained Soils - 50% (1) or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50		**ML**	Silt, sandy silt, gravelly silt, silt with sand or gravel
			CL	Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			OL	Organic clay or silt of low plasticity
	Silts and Clays Liquid Limit 50 or More		**MH**	Elastic silt, clayey silt, silt with micaceous or diatomaceous fine sand or silt
			CH	Clay of high plasticity, sandy or gravelly clay, fat clay with sand or gravel
			OH	Organic clay or silt of medium to high plasticity
Highly Organic Soils			**PT**	Peat, muck and other highly organic soils

Terms Describing Relative Density and Consistency

	Density	SPT (2) blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50

	Consistency	SPT (2) blows/foot
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

FC = Fines Content
G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Consolidation
DD = Dry Density
K = Permeability
Str = Shear Strength
Env = Environmental
PiD = Photoionization Detector

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

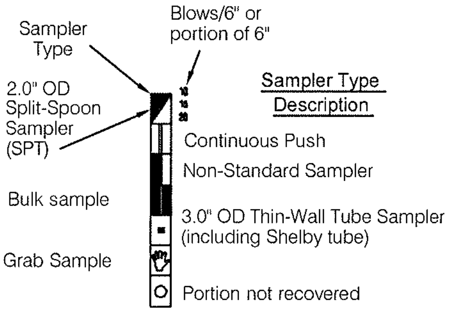
(3) Estimated Percentage

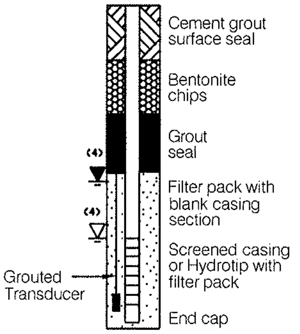
Percentage by Weight	Modifier
<5	Trace
5 to 15	Slightly (sandy, silty, clayey, gravelly)
15 to 30	Sandy, silty, clayey, gravelly)
30 to 49	Very (sandy, silty, clayey, gravelly)

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch
Slightly Moist - Perceptible moisture
Moist - Damp but no visible water
Very Moist - Water visible but not free draining
Wet - Visible free water, usually from below water table

Symbols





(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of groundwater
∇ ATD = At time of drilling
▼ Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 15% as estimated in General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
BGS = below ground surface

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

Aspect CONSULTING

Exploration Log Key
South Skagit Highway Realignment

DATE OCT-2014
DESIGNED BY Aspect
DRAWN BY Aspect
REVISED BY MML
PROJECT NO. 140034
FIGURE NO. 2

Q:_ACAD Standards\Standard Details\Exploration Log Key A1.dwg

Aspect CONSULTING

Boring Log

Project Number	Boring Number	Sheet
140034	B-1	1 of 2

Project Name: South Skagit Highway Realignment

Location: Mile Post 18, S Skagit Hwy, WA

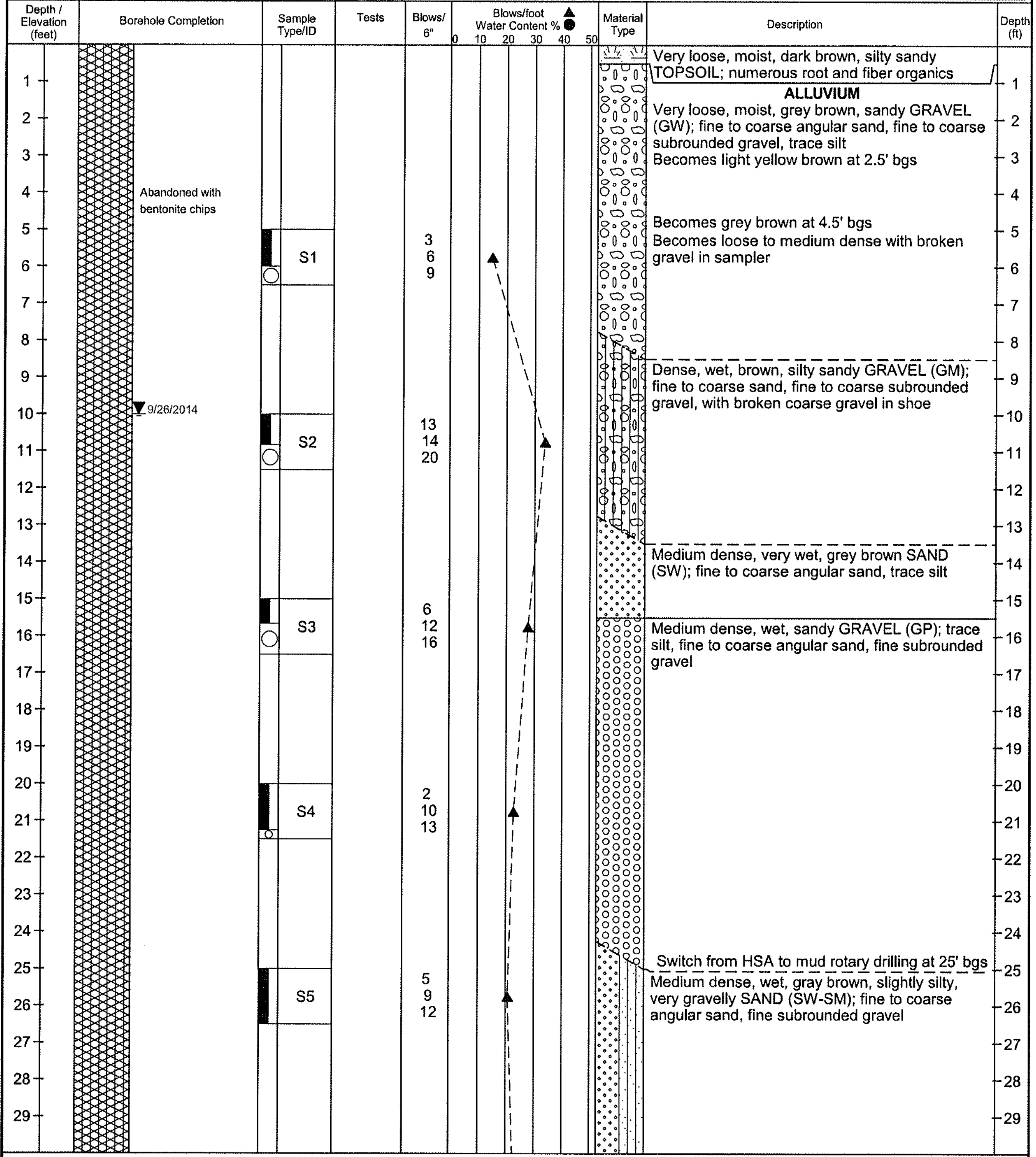
Driller/Equipment: Gregory Drilling / CME 850 X Track Mounted Rig

Drilling Method/Hammer: HSA/Mud Rotary / 300 lbs / 30" drop

Ground Surface Elev 145 ft (from Google Earth)

Depth to Water (ft BGS) 10

Start/Finish Date 9/25/2014 - 9/26/2014



Sample Type/ID	Blows/ 6"
S1	3 6 9
S2	13 14 20
S3	6 12 16
S4	2 10 13
S5	5 9 12

Very loose, moist, dark brown, silty sandy TOPSOIL; numerous root and fiber organics

ALLUVIUM

Very loose, moist, grey brown, sandy GRAVEL (GW); fine to coarse angular sand, fine to coarse subrounded gravel, trace silt
Becomes light yellow brown at 2.5' bgs

Becomes grey brown at 4.5' bgs
Becomes loose to medium dense with broken gravel in sampler

Dense, wet, brown, silty sandy GRAVEL (GM); fine to coarse sand, fine to coarse subrounded gravel, with broken coarse gravel in shoe

Medium dense, very wet, grey brown SAND (SW); fine to coarse angular sand, trace silt

Medium dense, wet, sandy GRAVEL (GP); trace silt, fine to coarse angular sand, fine subrounded gravel

Switch from HSA to mud rotary drilling at 25' bgs

Medium dense, wet, gray brown, slightly silty, very gravelly SAND (SW-SM); fine to coarse angular sand, fine subrounded gravel

Sampler Type:
- ○ No Recovery
- ▮ 3.25" OD D&M Split-Spoon Ring Sampler
- ▯ California, modified split spoon sampler

Drilling Method:

HSA: Hollow Stem Auger

MR: Mud Rotary

Logged by: MML

Approved by: EOA

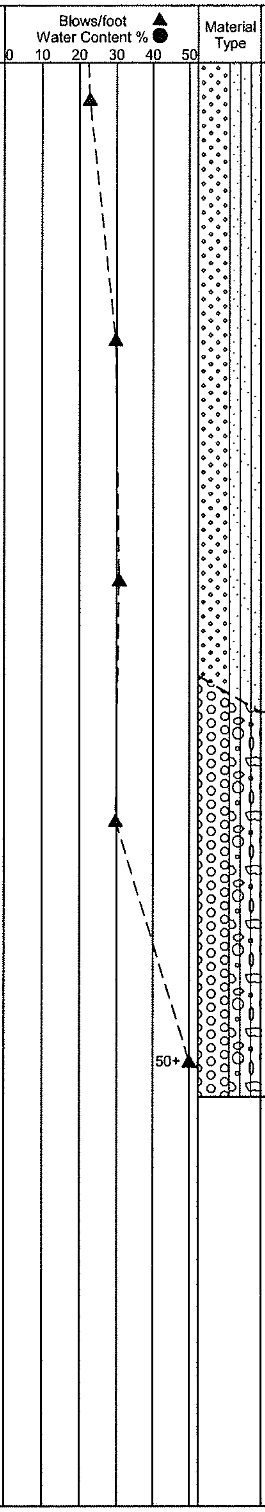
Figure No. 3

Aspect CONSULTING

Boring Log

Project Number	Boring Number	Sheet
140034	B-1	2 of 2

Project Name: South Skagit Highway Realignment
Ground Surface Elev 145 ft (from Google Earth)
Location: Mile Post 18, S Skagit Hwy, WA
Driller/Equipment: Gregory Drilling / CME 850 X Track Mounted Rig
Depth to Water (ft BGS) 10
Drilling Method/Hammer: HSA/Mud Rotary / 300 lbs / 30" drop
Start/Finish Date 9/25/2014 - 9/26/2014



Depth / Elevation (feet)	Sample Type/ID	Tests	Blows/ 6"	Description	Depth (ft)
31	▥ ○ S6		3 11 12	Medium dense, wet, gray brown, slightly silty, very gravelly SAND (SW-SM); fine to coarse angular sand, fine subrounded gravel Poor sample recovery, fines washed out of sample	31
36	▥ ○ S7		5 15 15	Fine to coarse subrounded gravel	36
41	▥ ○ S8		4 15 16		41
44				Medium dense, wet, gray brown, slightly silty, sandy GRAVEL (GP-GM); fine to coarse angular sand, fine subrounded gravel	44
46	▥ ○ S9		7 13 17		46
51	▥ ○ S10		7 26 27	Grades very dense	51
52				Boring terminated at 51.5 ft bgs, groundwater encountered at 10' bgs (static) on 9/26/2014 with steel casing to 25' bgs	52

Sampler Type:
- ○ No Recovery
- ▮ 3.25" OD D&M Split-Spoon Ring Sampler
- ▥ California, modified split spoon sampler

Drilling Method:
HSA: Hollow Stem Auger
MR: Mud Rotary

Logged by: MML
Approved by: EOA
Figure No. 3

Aspect CONSULTING

Boring Log

Project Number	Boring Number	Sheet
140034	B-2	1 of 1

Project Name: South Skagit Highway Realignment

Location: Mile Post 18, S Skagit Hwy, WA

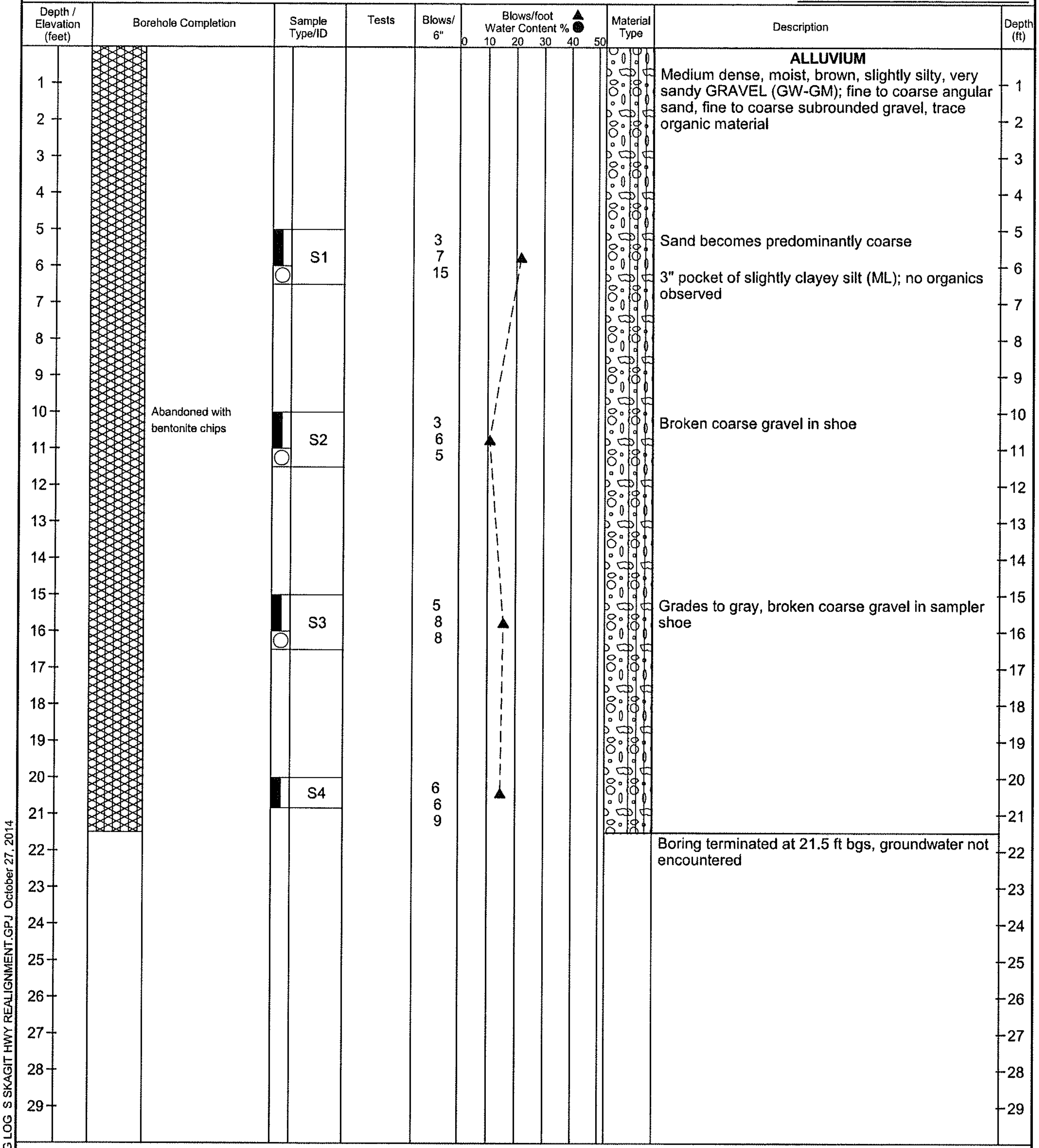
Driller/Equipment: Gregory Drilling / CME 850 X Track Mounted Rig

Drilling Method/Hammer: HSA / 300 lbs / 30" drop

Ground Surface Elev 260 ft (from Google Earth)

Depth to Water (ft BGS) Not Encountered

Start/Finish Date 9/25/2014



Depth (ft)	Sample Type/ID	Blows/6"	Description
0			**ALLUVIUM** Medium dense, moist, brown, slightly silty, very sandy GRAVEL (GW-GM); fine to coarse angular sand, fine to coarse subrounded gravel, trace organic material
5	S1	3 7 15	Sand becomes predominantly coarse 3" pocket of slightly clayey silt (ML); no organics observed
10	S2	3 6 5	Broken coarse gravel in shoe
15	S3	5 8 8	Grades to gray, broken coarse gravel in sampler shoe
20	S4	6 6 9	
21.5			Boring terminated at 21.5 ft bgs, groundwater not encountered

Sampler Type:

○ No Recovery

▮ 3.25" OD D&M Split-Spoon Ring Sampler

Drilling Method:

HSA: Hollow Stem Auger

MR: Mud Rotary

Logged by: MML

Approved by: EOA

Figure No. 4

Aspect CONSULTING

Boring Log

Project Number	Boring Number	Sheet
140034	B-3	1 of 1

Project Name: South Skagit Highway Realignment

Ground Surface Elev 180 ft (from Google Earth)

Location: Mile Post 18, S Skagit Hwy, WA

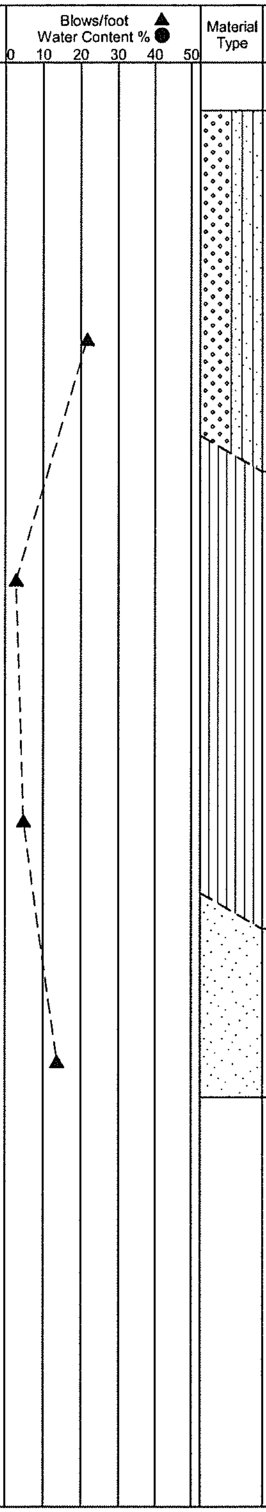
Driller/Equipment: Gregory Drilling / CME 850 X Track Mounted Rig

Depth to Water (ft BGS) Not Encountered

Drilling Method/Hammer: HSA / 300 lbs / 30" drop

Start/Finish Date 9/26/2014

Depth / Elevation (feet)	Borehole Completion	Sample Type/ID	Tests	Blows/ 6"	Description	Depth (ft)
	Filled with 0.75" crushed gravel at surface				Road surface, compacted sand and gravel fill	
1					**ALLUVIUM** Medium dense, slightly moist, gray, slightly silty, gravelly SAND (SW-SM); fine to coarse angular sand, fine subrounded gravel	1
5		S1		8 13 9	Broken coarse gravel in sampler	5
9					**OVERBANK DEPOSITS** Soft, moist, gray brown, slightly sandy SILT (ML); low plasticity, non dilatant silt, fine to medium sand in frequent laminae, trace clay, rare organics, micaceous with bioturbated fabric	9
10	Abandoned with bentonite chips	S2		1 2 1		10
15		S3		2 2 3	Grades to medium stiff	15
18					**ALLUVIUM** Medium dense, moist, brown, SAND (SP); fine to medium angular sand, trace silt, trace fine subrounded gravel	18
20		S4		5 6 8		20
22					Boring terminated at 21.5 ft bgs, groundwater not encountered	22



Sampler Type:

○ No Recovery

▥ California, modified split spoon sampler

Drilling Method:

HSA: Hollow Stem Auger

MR: Mud Rotary

Logged by: MML

Approved by: EOA

Figure No. 5

A3 Habitat, Hydrology and Geomorphic Conditions Tech Memo

R2 Resource
Consultants, Inc.

15250 NE 95th Street
Redmond, WA 98052-2518
Phone: (425) 556-1288
Fax: (425) 556-1290
e-mail: mail@R2usa.com

Technical Memorandum – DRAFT

Date: October 28, 2014 Project Number: 2056.01/MM101

To: Khashayar Nikzad, TranTech, Inc.

From: Paul DeVries, Ph.D., P.E.

Subject: Assessment of Hydraulic and Geomorphic Conditions Influencing Design of South Skagit Highway Modification and Relocation Alternatives in the Vicinity of Mill and Savage Creeks

---

1.0 BACKGROUND

R2 Resource Consultants, Inc. (R2) was tasked to perform hydraulic and geomorphic analyses of the Skagit River, Mill Creek, and Savage Creek to assist TranTech, Inc. (TT) with the design of alternative layouts of the South Skagit Highway. The work is being performed under contract to the Skagit River System Cooperative (SRSC). Key issues addressed by the analyses are:

- What are Skagit River flood elevations that influence inundation of the highway, backwater up Mill and Savage Creeks, and connectivity with existing off-channel ponded and wetland areas that could potentially provide off-channel habitat for juvenile salmonids?
- What are optimum crossing locations for bridge relocation alternatives based on geomorphic considerations?
- What should the low chord elevation be for new bridges at each alternative crossing location?
- What is the minimum span length at each location based on flooding and geomorphic considerations?

Three alternatives were evaluated accordingly:

1. Keep existing highway alignment, replace existing bridge at Mill Creek
2. Move highway upslope to follow alignment proposed by Andy Blachly (Weyerhaeuser)
3. Move highway upslope with crossings at locations between Alternatives 1 and 2

This technical memorandum summarizes the analyses performed and makes recommendations for each alternative based on the results.

2.0 METHODS

The analyses relied on the following primary information sources:

- An existing U.S. Army Corps of Engineers' (USACE) HEC-RAS model of the Skagit River extending from its mouth upstream to Concrete, provided to R2 by Northwest Hydraulic Consultants previously for work performed downriver for the Skagit Fisheries Enhancement Group (SFEG).
- USACE reports related to the Skagit River Flood Risk Management Study
- Survey data collected for the project by Pacific Surveying and Engineering in May 2014
- Survey and pebble count data collected for the project by SRSC and R2 in July 2014
- A previous assessment of sedimentation processes performed for Skagit County in 2004
- A 2006 LiDAR digital elevation model provided by SRSC with 2 ft elevation contour intervals
- USGS StreamStats web-based program for estimating peak flood magnitudes; previous analyses by R2 indicate that the mean regional regression estimates predicted by StreamStats are reasonable for use in design.

The LiDAR data were compared with ground-truth survey data collected by PSE and SRSC. Overall, the survey data indicated that the LiDAR elevation contour map was reasonably accurate on average, with some deviations occurring (Figure 1).

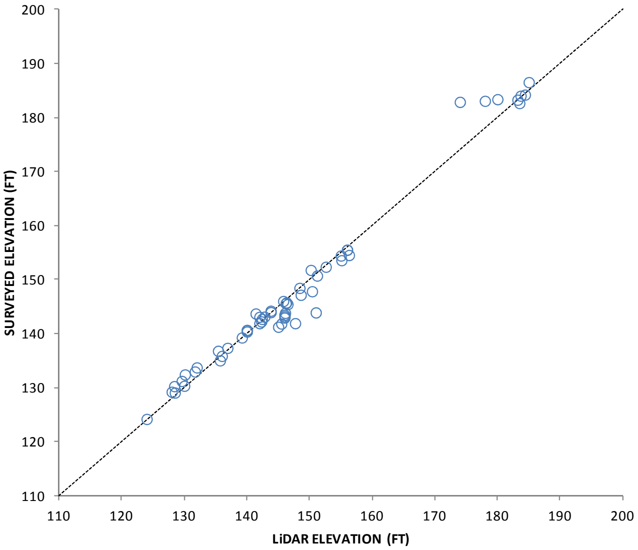


Figure 1. Comparison of LiDAR elevations with survey data.

The following analysis products were developed from the information above:

- A contracted version of the USACE Skagit River HECRAS model (Figure 2), where the lower river below RM 24 was deleted from the model so that it could be run as a steady flow model for evaluating various flood recurrence intervals. The project site is located between model RM 45-46. The lower segments of the USACE model involved numerous defined storage features that would have required creating an unsteady flow file for a 100 year flood event; the model is hydraulically simpler above RM 24. Flood flow magnitudes were taken for difference recurrence intervals as the current condition estimates presented in the USACE's Flood Risk Management study (Table 1; see Table 4-4 in USACE 2014); the values are higher than predicted for future conditions and are thus more conservative for bridge design purposes. In addition, a range of flow magnitudes were modeled to identify the approximate level at which ponds and wetland located on either side of the existing highway would become connected to the river hydraulically. The contracted model predictions for the 25 year flood generally approximated the values reported for the October 2003 flood (Table 8 in USACE 2011), and also predicted reasonably well the flow level at the Concrete gage at which a side channel inlet ~ 8 miles downriver began to be engaged according to visual observations made by the SFEG. These consistent results gave confidence that the model as created could be used reasonably for predicting river water levels for use in this project's evaluation and design.
- A HEC-RAS flood model was developed of Mill Creek from the survey and LiDAR data, extending from below the existing highway crossing to upstream of the Alternative 2 crossing location (Figure 2). The survey data were used to define the profiles of most cross-sections and were blended on either end by profiles cut from the LiDAR contour map. Manning's n roughness coefficients were estimated by comparing the stream slope and estimate of the 2 year flood from StreamStats (Table 1) with empirical data presented in Hicks and Mason (1998); the corresponding values of roughness coefficients for channel and vegetation were set accordingly at n=0.08 and 0.12, respectively. The model was run with no bridge present, thereby emulating a new bridge meeting a zero rise condition. Various flood flow magnitudes were run through the model (Table 1).
- A HEC-RAS flood model was developed of Savage Creek using cross-section profiles that were cut from the LIDAR contour map and ignored the conveyance of the low flow channel, which was observed in the field to be relatively small in cross-section area. The floodplain is relatively prismatic and well contained by ravine walls such that ignoring the conveyance of the low flow channel when modeling the 100 year flood level results in water level predictions that are expected to be conservative (i.e., over-estimates) for bridge design purposes. The model was run with no bridge present, thereby emulating a new bridge meeting a zero rise condition. Flood flow estimates from StreamStats are summarized in Table 1.

- Longitudinal (i.e., stream-wise) profiles were plotted for Mill Creek of (i) thalweg elevation from the LiDAR and survey data, (ii) grain size distribution changes from the pebble count data, and (iii) hydraulic properties predicted by the HEC-RAS model. The graphs were used to evaluate sediment deposition and transport trends in the project reach, knowledge of which was used to identify higher and lower risk locations for bridge placement. In addition, the LiDAR elevation contour map topography was used in concert with HEC-RAS model predictions to identify the zone outside which bridge abutments might be constructed without incurring a reasonable risk of interfering with channel migration and flood levels.

Scour analyses were not performed at this time. Scour depths can estimated once a bridge design is formulated based on the results of this analysis.

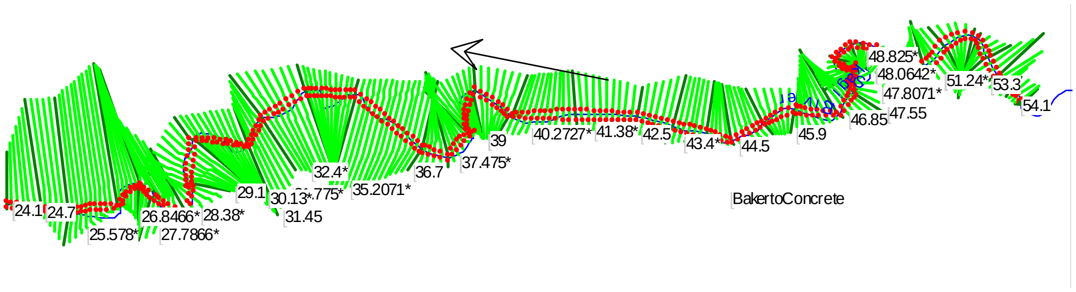


Figure 2. Skagit River HEC-RAS model cross-section locations used in this analysis. The U.S. Geological Survey streamflow gage near Concrete is located at the upstream end of the model. Mill Creek is located near cross-section RM 45.2. Flow is from right to left. Light green lines depict interpolated cross-sections.

Table 1. Estimated flood hydrology for project area rivers.

	Flow (cfs)		
Recurrence Interval (Years)	**Skagit River at Concrete**	**Mill Creek**	**Savage Creek**
2	77,300	231	78
10	127,700	422	142
25	165,300	524	176
50	189,100	620	208
100	225,400	698	235

3.0 RESULTS

Results are presented below for each of the key study issues.

3.1 SKAGIT RIVER HEC-RAS MODELING

The modified USACE HEC-RAS model was used to predict water surface elevation (WSEs) for various flood levels at several survey control point locations along the South Skagit Highway for use in road design (Table 2), and to estimate the flow approximately at which open water bodies and wetlands located south and north of the highway would be hydraulically connected (Figure 3). For the latter, it was assumed that WSEs surveyed in late July 2014 approximated the level at which flow from the river would engage them. The surveyed WSEs define the extent to which currently impounded relic side channels may be maintained with appropriate grade control, and what the approximate total head drop is for fish passage design scoping. The largest water body located south of the highway has the highest standing WSE, and would require fish passage structures to be designed in order to establish connectivity at most river flow levels.

The SRSC has collected summer water temperature and dissolved oxygen grab samples to assess the quality of the habitat for fish in each ponded location. That information should be evaluated along with the water level data above to prioritize off-channel habitats for which upstream passage design would be required. In addition, the designs would need to consider the influence of beaver.

Table 2. Predicted water surface elevations (WSE) at PSE survey control points for floods with various recurrence intervals.

PSE Survey Control Point				HECRAS Transect ID	2yr WSE	10yr WSE	100yr WSE
ID	**Easting (ft)**	**Northing (ft)**	**Elevation (ft; NAVD88)**				
20	1391738.92	555167.10	140.86	46.4937*	127.67	132.70	139.12
50	1390272.82	555150.91	135.86	46.375*	127.22	132.21	138.56
61	1387859.18	554098.72	129.07	45.6666*	123.62	128.82	135.79
60	1386834.64	553638.64	129.22	45.3166*	121.68	127.05	134.09
70	1386311.16	553369.09	131.07	45.2	120.91	126.51	133.86
71	1386206.01	553333.32	130.33	45.2	120.91	126.51	133.86

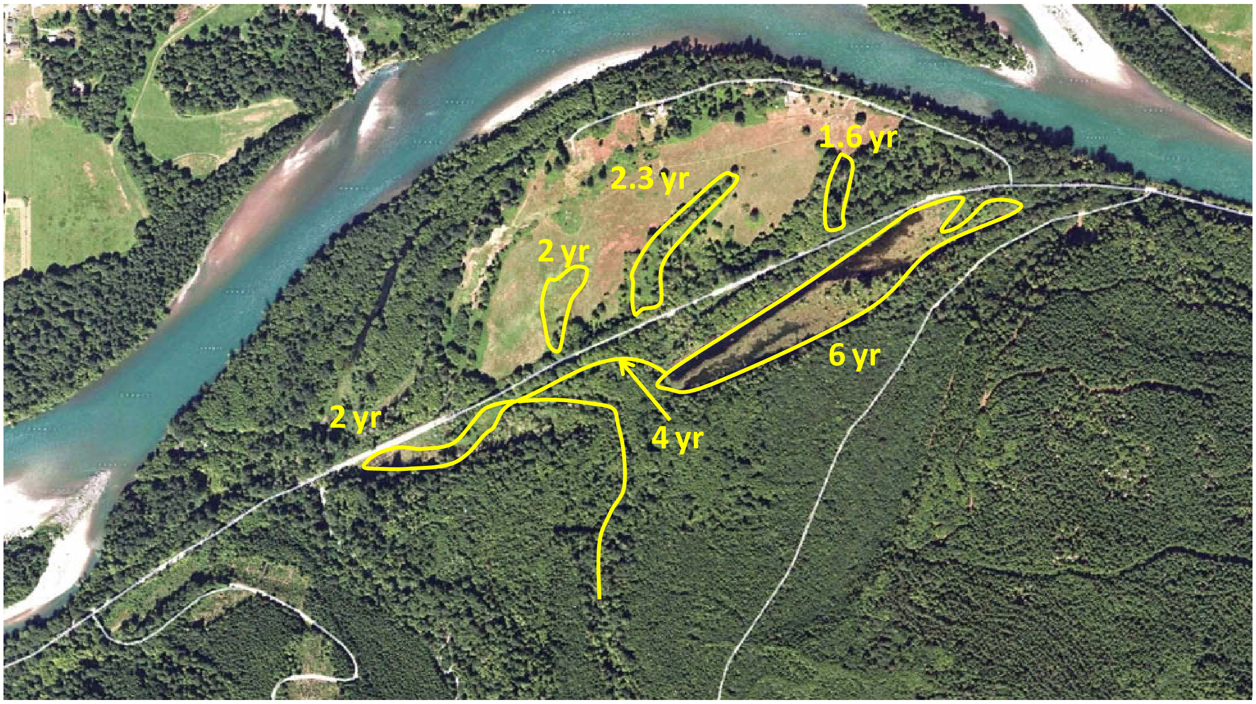


Figure 3. Approximate recurrence intervals of river levels at which hydraulic connectivity is presently established between the Skagit River and locations of significant water bodies and wetlands situated adjacent to the South Skagit Highway.

3.2 MILL CREEK CROSSING DESIGN

3.2.1 Bridge/Road Layout

The long profiles of elevation indicate the presence of a prominent slope break located approximately 450-550 ft upstream of the existing highway location (Figure 4). The grain size distributions are generally consistent with this feature, where they are smallest and comparable at the PC-1 and PC-2 locations, largest and comparable at the PC-4 and PC-5 locations, and intermediate in size at the PC-3 location (Figure 5). The hydraulic predictions of the Mill Creek HEC-RAS model indicate that the backwater influence of the Skagit River extends up to approximately 300 ft upstream of the existing South Skagit Highway. Upstream of that, the predictions indicate greatest top-width and shallowest hydraulic depth in the vicinity of transect 11 of the model, and conversely smallest top width and greatest depth in the vicinity of transects 8 and 15 of the model.

Noting that the slope break depicted in Figure 4 is in the vicinity of transect 10 of the model, the location of the bridge for alternative 2 appears to be the best in a geomorphic process context because it is located above the slope break and the active channel is narrower and deeper than downstream (Figure 6), thereby facilitating greatest through-transport of coarse bedload to deposit farther downstream. However, speed safety constraints on the design of the road arc favor a more desirable location downstream of Alternative 2. In addition, this location has greatest risk of long term degradation scour (see discussion of low chord elevation design below).

Accordingly, the next best location for a bridge is in the vicinity of transect 8 of the HEC-RAS model where the transport capacity is highest between the slope break and the current highway location. Because this location is proximal to the larger scale slope break, however, additional measures would be required to promote deposition of coarsest bedload particles in the vicinity of the slope break and upstream. Fortunately, the 100-year floodplain channel is widest just above the slope break, and was observed in the field to be associated with extensive deposition of large cobbles and small boulders across transect 11. With appropriate design of bedload detention/storage structures that promote floodplain deposition and channel wandering/braiding in this sub-reach, it should be feasible to construct a bridge in the vicinity of transect 8 where smaller cobbles, gravel and sand can be more readily transported through to deposit even farther downstream.

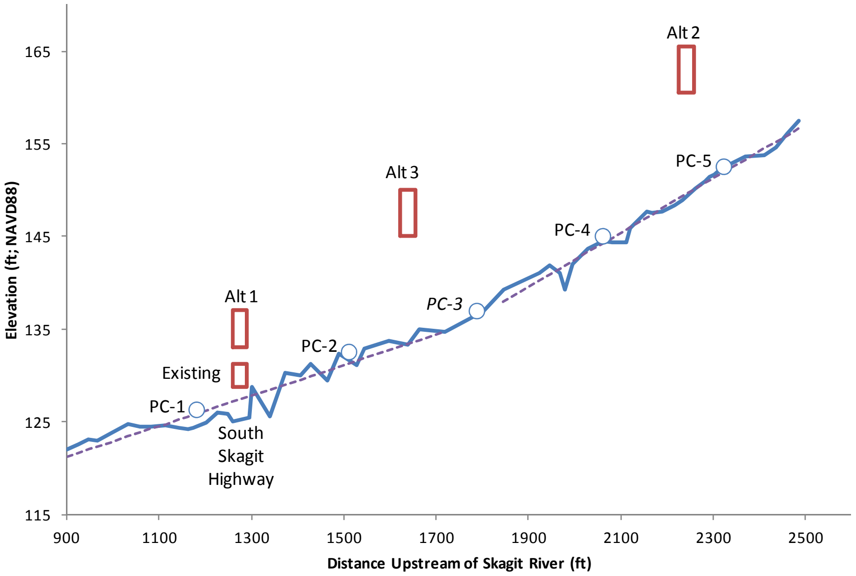


Figure 4. Long profile of thalweg elevation of Mill Creek above and below the South Skagit Highway. Also depicted are (i) approximate bridge profiles of the existing bridge and the three alternatives (Alt 1 to Alt 3), (ii) pebble count locations (circles; PC-1 to PC-5), and (iii) bed profile regression lines (dashed) for above (slope = 0.029) and below (slope = 0.016) a clear slope break located near PC-3.

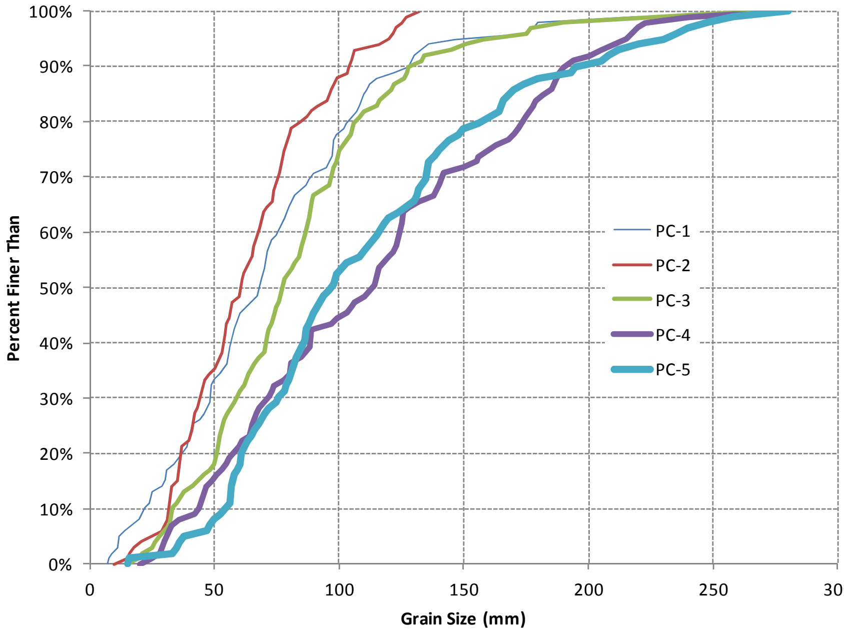
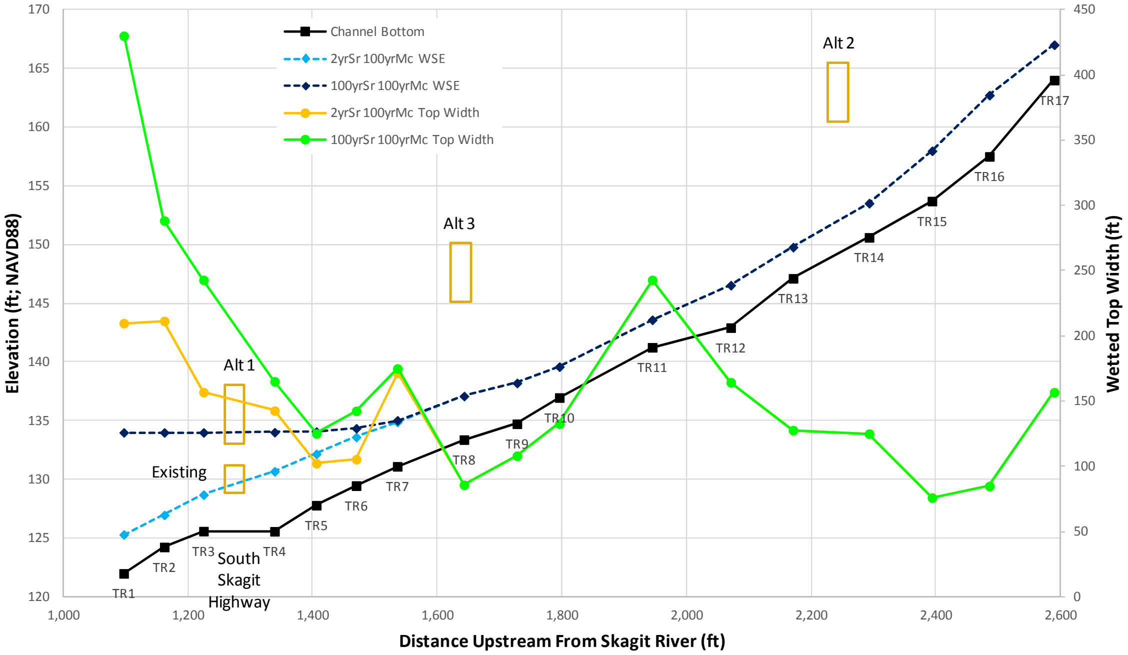


Figure 5. Grain size distributions determined at the five pebble count locations depicted in Figure 4.



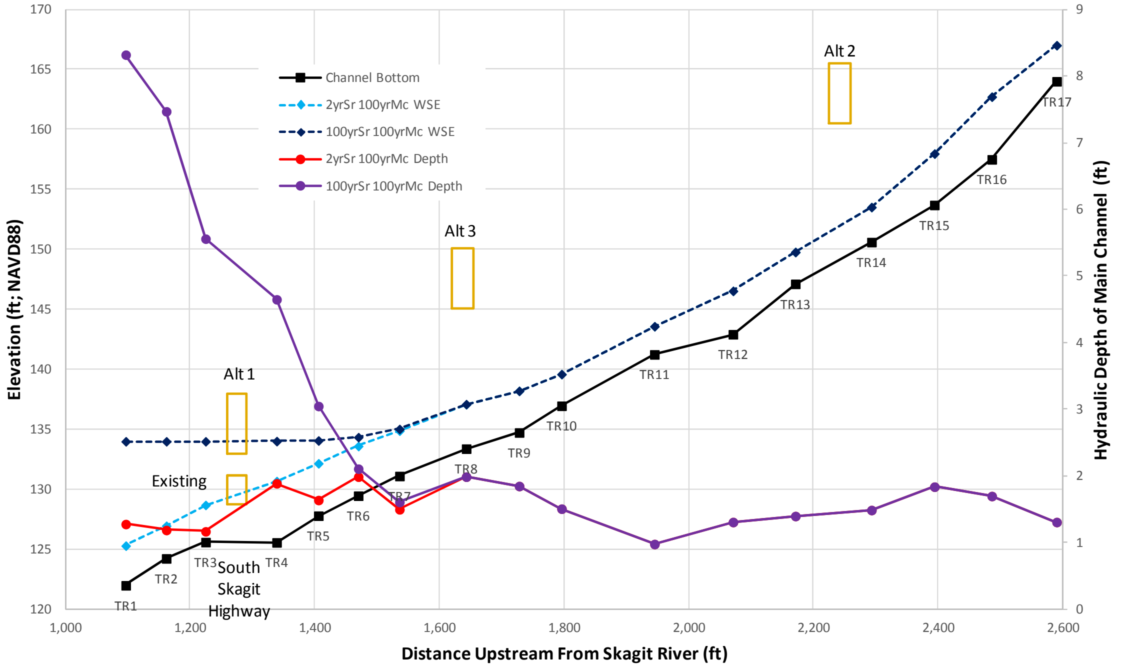


Figure 6. Hydraulic predictions of water surface elevations (WSE) in Mill Creek for the 100 year flood in Mill Creek (‘100yrMc’ in legend) with downstream boundary condition WSE set as either the 2 year or 100-year flood in the Skagit River (‘2yrSr’ and ‘100yrSr’, respectively). Top graph also depicts predicted wetted top width for both Skagit River scenarios; bottom graph depicts predicted hydraulic depth of channel for both scenarios. Approximate bridge locations are depicted following Figure 4.

3.2.2 Bridge Low Chord Elevation/Span Length

Two sources of information were found to have bearing on design of the low chord elevation:

- The HEC-RAS model predictions of the 100 year flood level are depicted on Figure 6, and can be used to specify a minimum low chord elevation at any location along the stream corridor. WAC 220-110-070 1(e) requires the bridge to pass the 100 year flood with sufficient clearance to pass debris. WDFW (Barnard et al. 2013) specifies a minimum 3 ft clearance height. Therefore, the minimum low chord elevation of the bridge should be 3 ft above the predicted 100 year flood level, assuming no long term change in bed elevation.
- Aggradation problems at the Mill Creek crossing have been evaluated previously in response to a large scale debris flow that occurred in 2002 (NHC 2004). That assessment relied on county bridge maintenance records and a landslide and bank erosion survey and analysis performed previously after the 2002 floods by Jeff Grizzel of Washington Department of Natural Resources. The net conclusion of the assessment was that the stream transports a substantial amount of sediment annually, and the streambed has continued to rise in elevation since the 1970s at least. NHC estimated that approximately 18,000 CY of material deposited in the vicinity of the bridge between 1972 and 2002. Comparison of longitudinal elevation profiles of the stream bottom derived from the 2006 LiDAR with the 2014 survey data, however, suggests that the stream bottom has down-cut upstream of the slope break location, and stayed closer to the same downstream (Figure 7). Assuming the 2002 debris flow to be a worst case condition, the 2006 profile suggests that future events could raise the bed in the vicinity of the slope break and upstream by approximately 5 ft.

These observations lead to recommending a low chord elevation for alternatives 2 and 3 that is 8 ft above the current predicted 100 year flood elevation. This corresponds to a low chord elevation of 145.1 ft and 160.5 ft (NAVD88) at the alternative 3 and 2 locations, respectively.

The existing bridge location is clearly the worst of the three alternatives for accommodating geomorphic processes. As seen in Figure 6, the location can be under a backwater effect from the Skagit River. Moreover, the bridge sits at the transition to a floodplain fan, which is characteristically a strongly aggradational setting. An 8 ft high clearance above the current 100 year flood level for Mill Creek would require extensive fill to raise the road prism. At this location, it appears that greater design emphasis should be placed on the width of the span as opposed to the height, where a wider span effectively precludes significant effects and interactions of the bridge with natural sediment transport and deposition processes, allowing natural fan processes to resume to a greater extent than can occur presently. Given the general correspondence of the 2006 LiDAR and 2014 survey profiles, it appears that given sufficient width, the rate of vertical aggradation should be relatively small such that a 3 ft clearance above the current 100 year flood would be sufficient. This corresponds to a low chord elevation of 133.0 ft (NAVD88). This elevation would be associated with a road elevation that is above the 100 year flood elevation of the Skagit River (Figure 6).

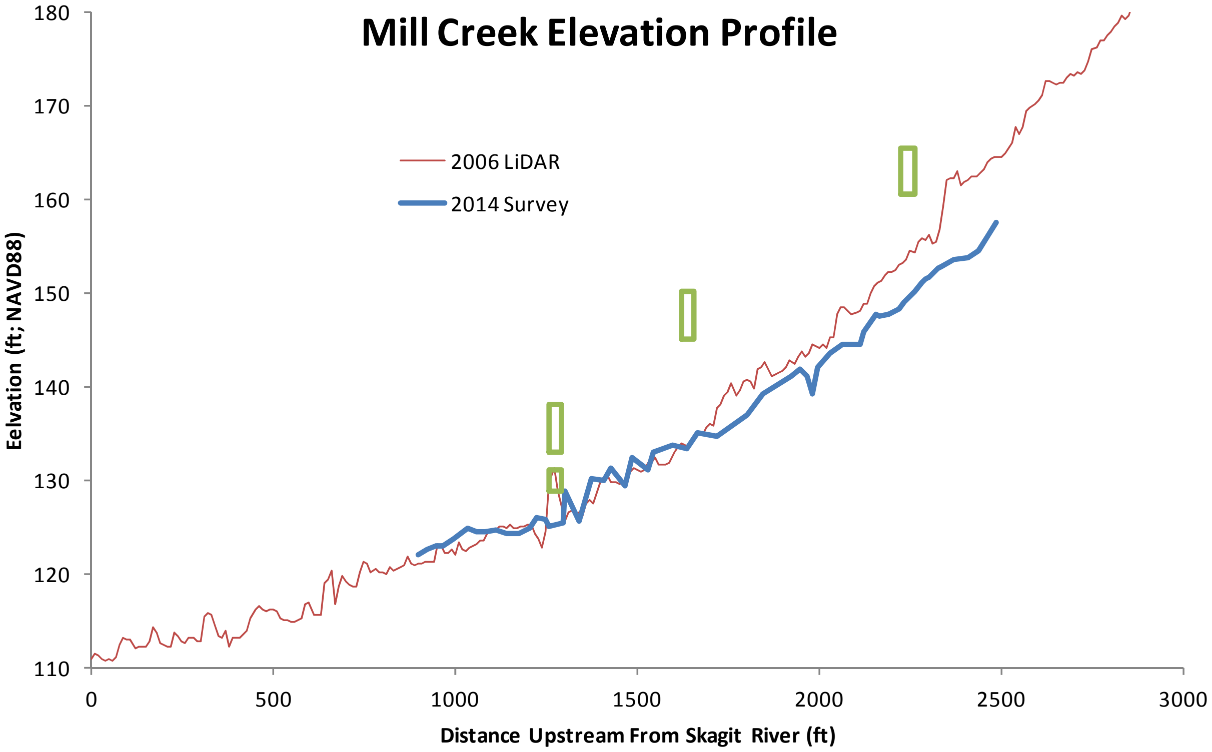


Figure 7. Comparison of long profile of thalweg elevation surveyed in 2014 vs. 2006 LiDAR profile. Bridge locations are depicted following Figure 4. The two datasets are generally consistent below the slope break depicted in Figure 4, and diverge upstream suggesting erosion has occurred since 2006.

WAC 220-10-070 1(h) requires abutments and piers to be aligned to cause the least effect on the hydraulics of the watercourse. When the channel is well confined and there is little risk of channel migration, the 100-year flood extent is a suitable approximate indicator of the minimum required span length, with abutments situated landwards of the ground level equal to the predicted flood water surface elevation. Figure 6 indicates a minimum bridge low chord span length of 90 ft and 125 ft for alternatives 3 and 2, respectively, for this case. However, the LiDAR topography indicates the existence of an active floodplain that the channel has the potential to migrate across, and thus a longer span will be required. The potential floodplain channel migration zone is approximately 180-200 ft wide at the alternative 3 crossing location, and 250-280 ft wide at the alternative 2 location. Span lengths on this order of magnitude should be sufficient for accommodating future lateral channel movement at these two potential new road crossing locations. If one or more piers are required structurally for these alternatives, the present topography appears to be compatible with placing them at locations that are presently not in the active channel, and that the stream would be free to migrate past in the future without significantly impeding flood flows. Ideally, the topography would favor placing one central pier at each alternative location.

Determination of a suitable minimum span length at the existing bridge location (Alternative 1) is less clear. The existing alignment crosses Mill Creek over a relatively wide portion of an alluvial fan deposit formed from sediments transported by Mill Creek. The 134 ft elevation contour, which coincides with the WSE of the 100 year flood in the Skagit River and the general elevation of the toe of the adjacent hillside, indicates a fan width of approximately 400 ft at the location of the South Skagit Highway. A bridge span of 400 ft therefore appears to be the largest required for allowing unrestricted migration of Mill Creek across its fan. A smaller span of 300 ft may also be potentially acceptable from a geomorphic perspective, in that it approximates the maximum width of the channel migration zone upstream.

3.3 SAVAGE CREEK CROSSING DESIGN

3.3.1 Bridge/Road Layout

The precise locations of the crossing under alternatives 2 and 3 are flexible given the slopes and valley widths in the vicinity of both are comparable. The stream flows through a relatively prismatic ravine, thus there does not appear to be any physical process basis for choosing one location over another.

3.3.2 Bridge Low Chord Elevation/Span Length

The Savage Creek HEC-RAS model indicates that the 100 year flood depth is around 3-3.5 ft above the floodplain throughout the vicinity of the proposed alternative 2 and 3 bridge crossings (Figure 8). Combined with a minimum clearance of 3 ft for debris, a general rule of thumb specification is inferred that the low chord of the bridge should be a minimum of 7 ft above the floodplain at any of the locations under consideration. Given that the floodplain elevation is about 30 ft below the top of the ravine, cut and fill volume considerations as part of road layout design are expected to lead to a bridge that is higher than this.

The model predicted a wetted top width of around 70-80 ft in the vicinity of the proposed crossing locations of alternatives 2 and 3 (Figure 8). Placing the abutments landward of the 100-year flood extent would establish an equivalent minimum low chord span length that would accordingly be associated with no net rise in the 100 year flood.

For alternative 1, a separate 100 ft span should accommodate flow from Savage creek about 100 feet to the east given that that stream first flows into an expansive wetland pond complex before flowing under the road such that aggradation at that crossing is not anticipated to be an issue in the future.

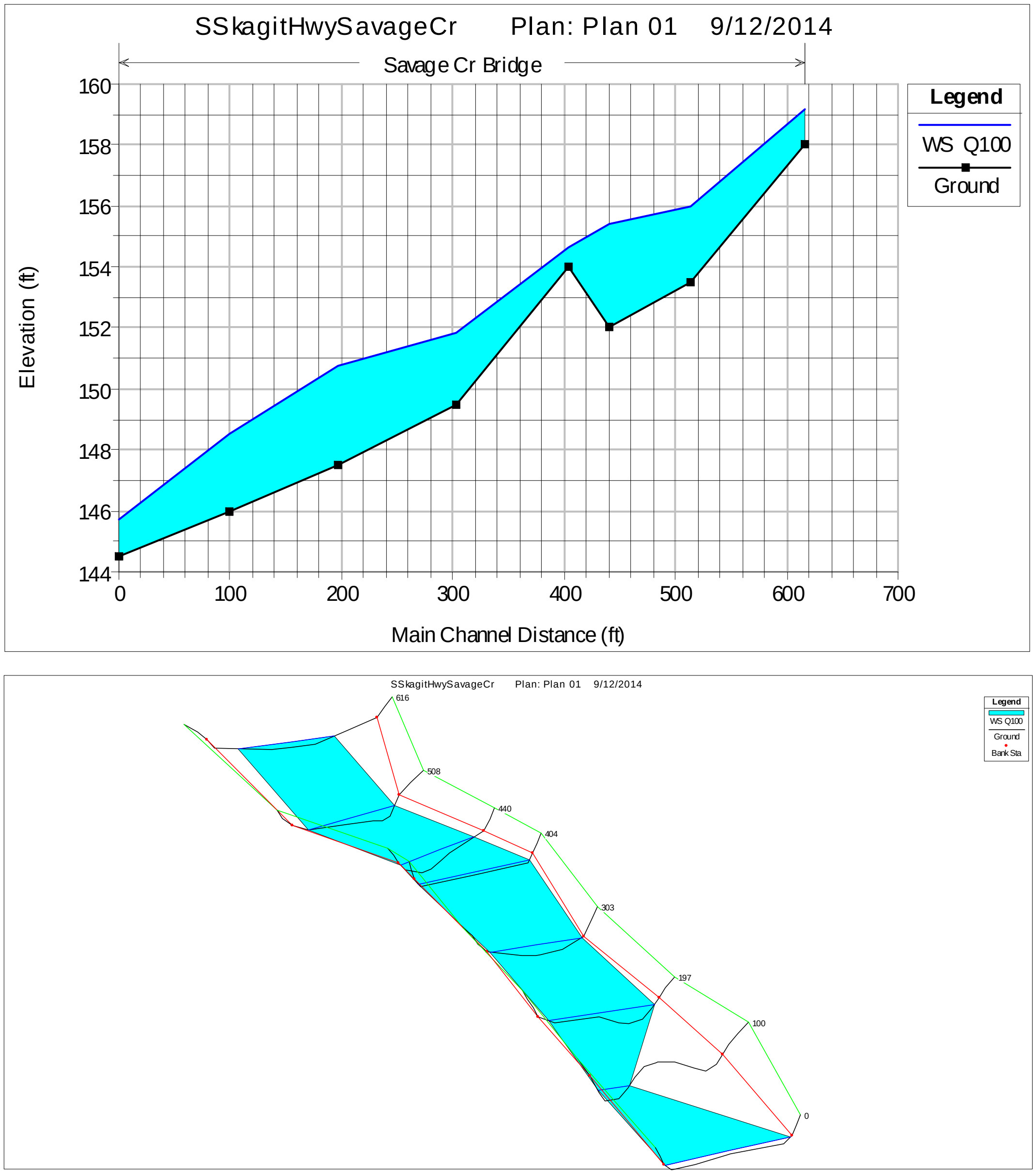


Figure 8. HEC-RAS model results for the 100 year flood in Savage Creek; crossing locations for alternatives 3 and 2 are in the vicinity of cross-sections 404 and 508, respectively. Top: Long profile showing range of flood depths above the floodplain. Bottom: perspective plot showing general similarity in wetted top widths at most locations in the reach. These results were used to establish general rules of thumb for specifying minimum bridge low chord height and span length.

4.0 REFERENCES

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, D.C. Ponder, P.D. Smith, and P.D. Powers. 2013. Water Crossings Design Guidelines, Washington Department of Fish and Wildlife, Olympia, Washington. http://wdfw.wa.gov/hab/ahg/culverts.htm

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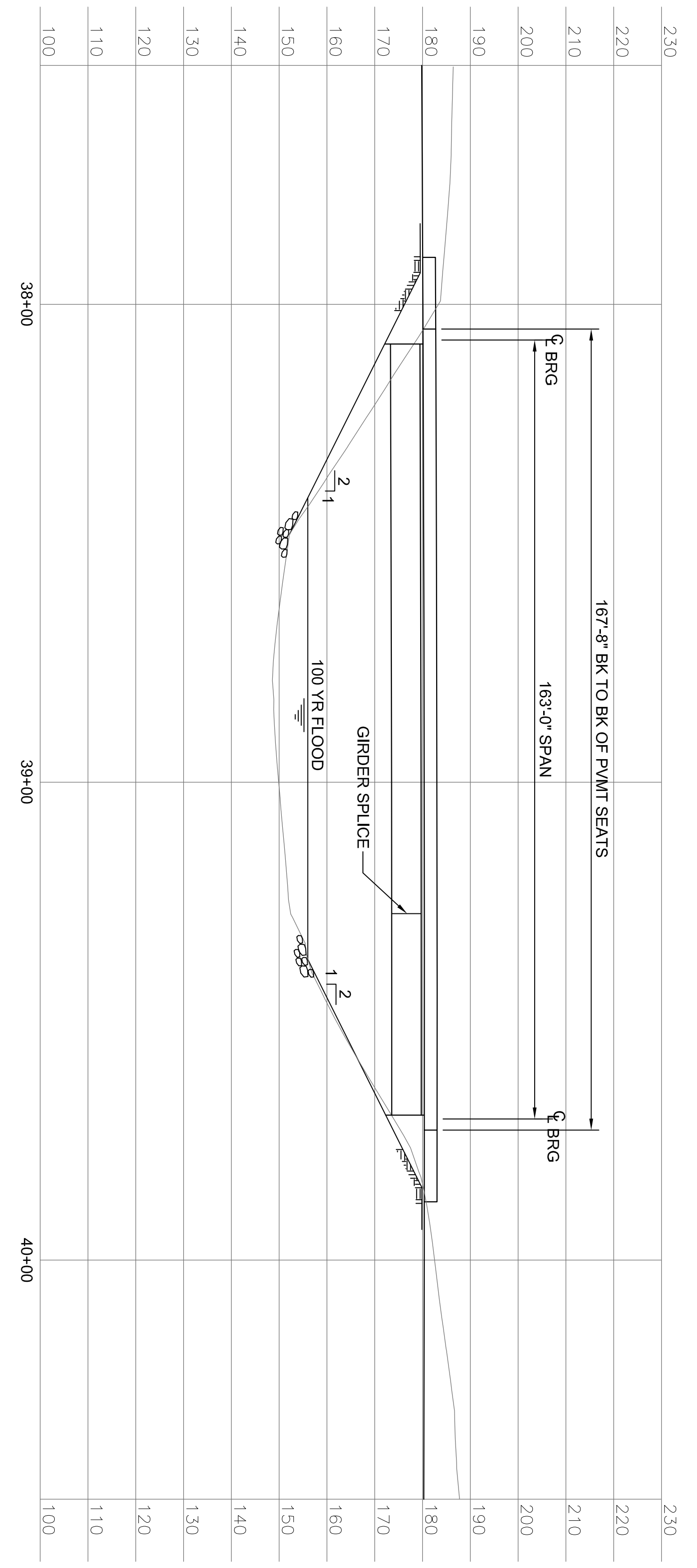
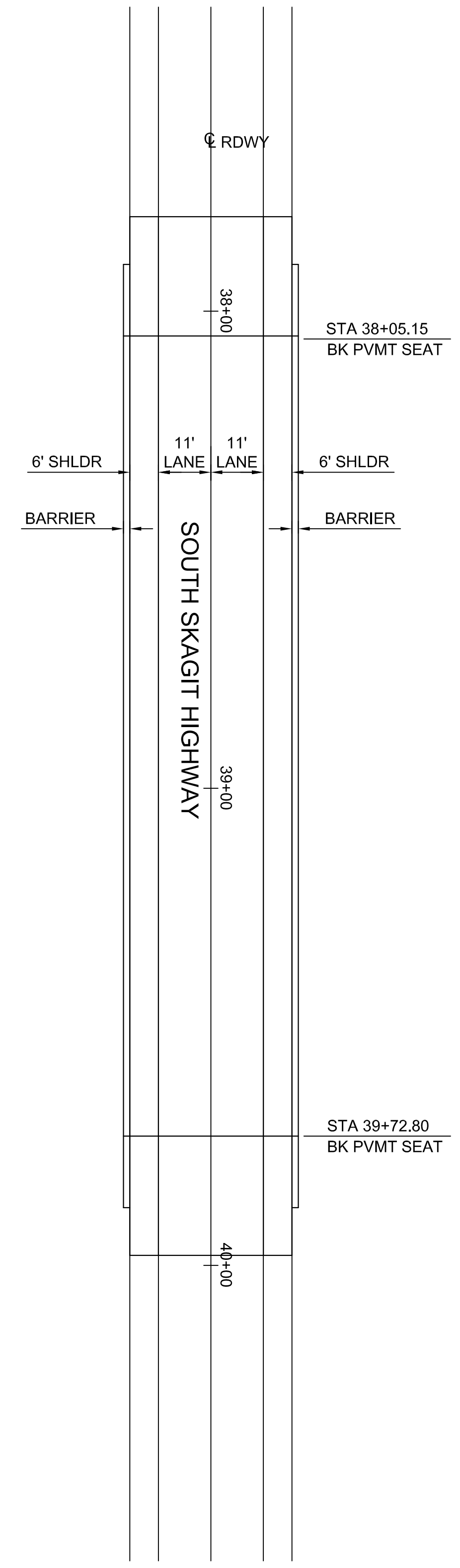
A4 Structural Plans for Alternative 3

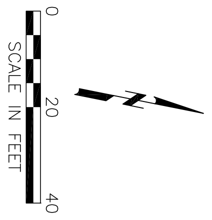
DJENSEN - October 7, 2014 - 1:58 PM - P:\2014\2014-013 S. SKAGIT HIGHWAY IMPROVEMENTS\000 CAD\ALT 3 BRIDGE PLAN & ELEV.DWG

SAVAGE CREEK BRIDGE ELEVATION



SAVAGE CREEK BRIDGE PLAN





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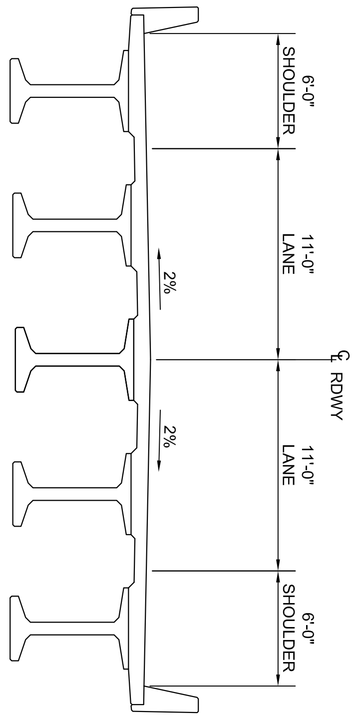

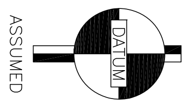

SCALE:
1" = 20' HOR
1" = 20' VER

SHEET
OF

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

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PROJECT NO.: ####
FED. AID NO.: ####
DESIGNED BY: #### DRAWN BY: ####
CHECKED BY: #### APPROVED BY: ####

PROJECT LOCATED NEAR:
####
####

NO.	REVISIONS	DATE

SKAGIT COUNTY
PUBLIC WORKS
1800 CONTINENTAL PLACE
MOUNT VERNON, WA 98273-5625
(360) 336-9400 FAX (360) 336 9478

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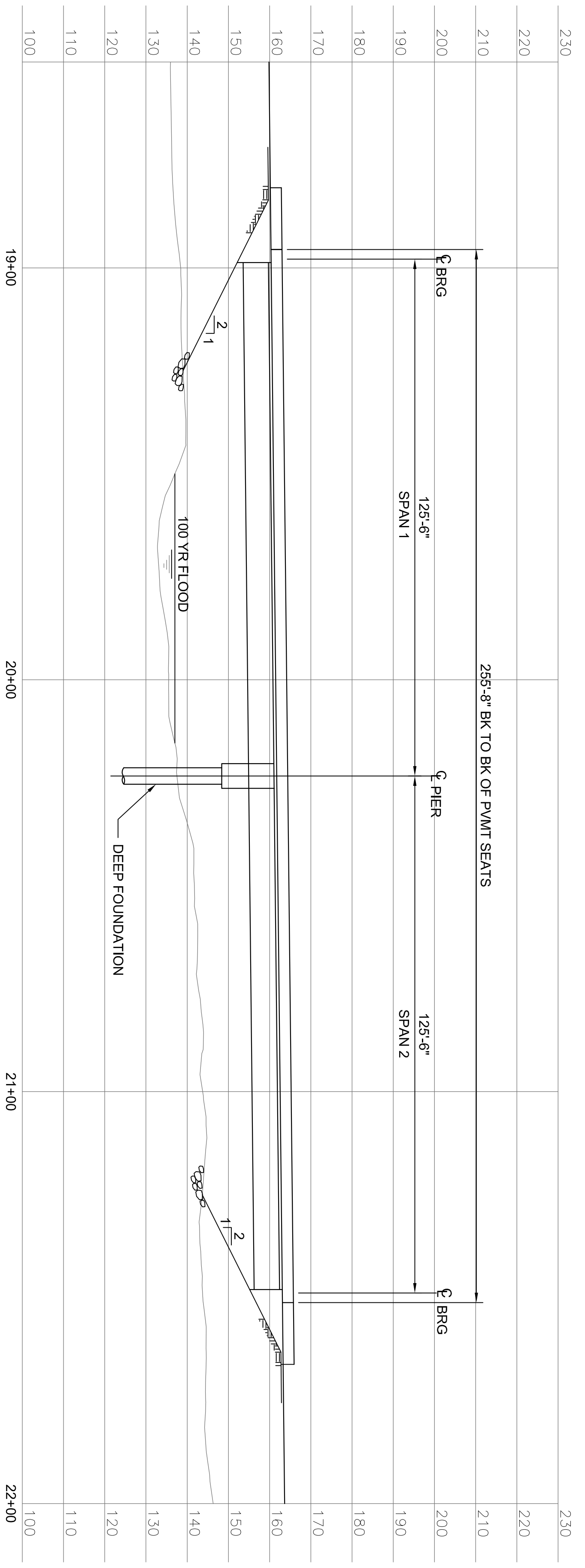
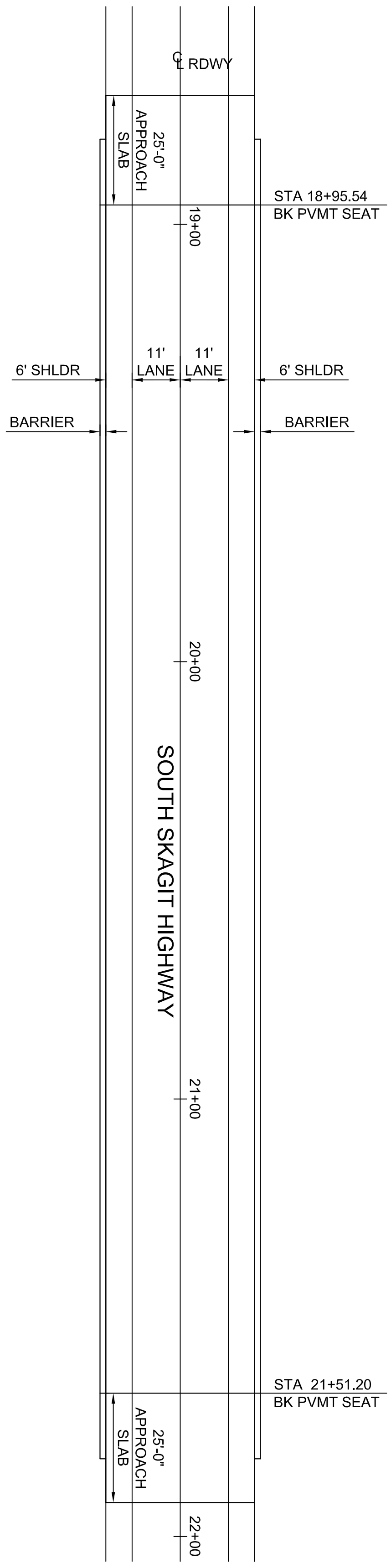
MILL CREEK BRIDGE ELEVATION



MILL CREEK BRIDGE PLAN



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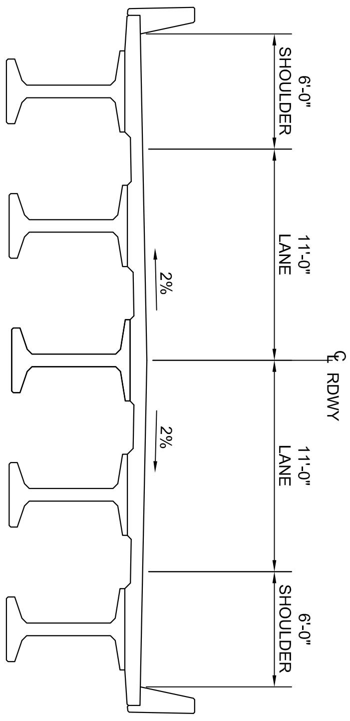

SCALE:
1" = 20' HOR
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SCALE IN FEET

SHEET
OF

1 INCH SCALE BAR
ADJUST SCALE ACCORDINGLY

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PROJECT NO.: ####
FED. AID NO.: ####
DESIGNED BY: #### DRAWN BY: ####
CHECKED BY: #### APPROVED BY: ####

PROJECT LOCATED NEAR:
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NO.	REVISIONS	DATE

SKAGIT COUNTY PUBLIC WORKS
1800 CONTINENTAL PLACE
MOUNT VERNON, WA 98273-5625
(360) 336-9400 FAX (360) 336 9478

A5 Alternative Cost Estimations

S Skagit Highway Floodplain Resotration - Alternative 1

Engineer's Preliminary Opinion of Cost

General Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
1	1	L.S.	Mobilization	$700,000	$700,000
2	1	L.S.	Type B Progress Schedule	$2,500	$2,500
3	1	L.S.	Licensed Surveying	$50,000	$50,000
				SUBTOTAL	**$752,500**

Roadway-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
4	1	L.S.	Temporary Erosion and Sediment Control	$30,000	$30,000
5	1	L.S.	Removal of Structure	$100,000	$100,000
6	5900	S.Y.	Removal of Existing Road Surface	$4	$23,600
7	5900	C.Y.	Removal of Existing Road Base	$10	$59,000
8	0	C.Y.	Roadway Excavation Incl. Haul	$10	$0
9	10100	S.F.	Retaining Wall	$40	$404,000
10	10700	C.Y.	Embankment Compaction Incl. Haul	$30	$321,000
11	19640	TN.	Gravel Borrow Incl. Haul	$10	$196,400
12	4510	TN.	Crushed Surfacing Base Course	$20	$90,200
13	705	TN.	Crushed Surfacing Top Course	$30	$21,150
14	750	TN.	HMA, CL B, PG 58-22	$75	$56,250
15	1	EA.	Stormwater Treatment	$50,000	$50,000
16	1	L.S.	Detour Complete Incl. Traffic Control	$250,000	$250,000
17	1	L.S.	Misc. @ 10% Civil Items	$150,000	$150,000
				SUBTOTAL	**$1,751,600**

Structure-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
18	1850	S.F.	Savage Creek (~105')	$300	$555,000
19	11100	S.F.	Mill Creek (~300')	$400	$4,440,000
20	0	S.F.	Connectivity Culverts	$300	$0
				SUBTOTAL	**$4,995,000**

Total	**$7,499,100**
Contingency @15%	**$1,124,865**
Total Construction Cost	**$8,623,965**

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S Skagit Highway Floodplain Resotration - Alternative 1A

Engineer's Preliminary Opinion of Cost

General Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
1	1	L.S.	Mobilization	$1,100,000	$1,100,000
2	1	L.S.	Type B Progress Schedule	$2,500	$2,500
3	1	L.S.	Licensed Surveying	$50,000	$50,000
				SUBTOTAL	**$1,152,500**

Roadway-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
4	1	L.S.	Temporary Erosion and Sediment Control	$30,000	$30,000
5	1	L.S.	Removal of Structure	$100,000	$100,000
6	6500	S.Y.	Removal of Existing Road Surface	$4	$26,000
7	6500	C.Y.	Removal of Existing Road Base	$10	$65,000
8	0	C.Y.	Roadway Excavation Incl. Haul	$10	$0
9	16700	S.F.	Retaining Wall	$40	$668,000
10	19400	C.Y.	Embankment Compaction Incl. Haul	$30	$582,000
11	35745	TN.	Gravel Borrow Incl. Haul	$10	$357,450
12	4985	TN.	Crushed Surfacing Base Course	$20	$99,700
13	780	TN.	Crushed Surfacing Top Course	$30	$23,400
14	830	TN.	HMA, CL B, PG 58-22	$75	$62,250
15	1	EA.	Stormwater Treatment	$50,000	$50,000
16	1	L.S.	Detour Complete Incl. Traffic Control	$1,000,000	$1,000,000
17	1	L.S.	Misc. @ 10% Civil Items	$270,000	$270,000
				SUBTOTAL	**$3,333,800**

Structure-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
18	3885	S.F.	Savage Creek (~105')	$400	$1,554,000
19	11100	S.F.	Mill Creek (~300')	$400	$4,440,000
20	2400	S.F.	Connectivity Culverts (50' EA)	$300	$720,000
				SUBTOTAL	**$6,714,000**

Total	**$11,200,300**
Contingency @15%	**$1,680,045**
Total Construction Cost	**$12,880,345**

S Skagit Highway Floodplain Resotration - Alternative 2

Engineer's Preliminary Opinion of Cost

General Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
1	1	L.S.	Mobilization	$1,400,000	$1,400,000
2	1	L.S.	Type B Progress Schedule	$2,500	$2,500
3	1	L.S.	Licensed Surveying	$50,000	$50,000
				SUBTOTAL	**$1,452,500**

Roadway-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
4	1	L.S.	Temporary Erosion and Sediment Control	$30,000	$30,000
5	1	L.S.	Removal of Structure	$100,000	$100,000
6	4000	S.Y.	Removal of Existing Road Surface	$4	$16,000
7	10000	C.Y.	Removal of Existing Road Base	$10	$100,000
8	135000	C.Y.	Roadway Excavation Incl. Haul	$10	$1,350,000
9	5000	S.F.	Retaining Wall	$40	$200,000
10	65000	C.Y.	Embankment Compaction Incl. Haul	$30	$1,950,000
11	1000	TN.	Gravel Borrow Incl. Haul	$10	$10,000
12	20800	TN.	Crushed Surfacing Base Course	$20	$416,000
13	3250	TN.	Crushed Surfacing Top Course	$30	$97,500
14	3120	TN.	HMA, CL B, PG 58-22	$75	$233,999
15	1	EA.	Stormwater Treatment	$280,000	$280,000
16	1	L.S.	Detour Complete Incl. Traffic Control	$100,000	$100,000
17	1	L.S.	Misc. @ 10% Civil Items	$500,000	$500,000
				SUBTOTAL	**$5,383,499**

Structure-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
18	4625	S.F.	Savage Creek (~105')	$400	$1,850,000
19	14060	S.F.	Mill Creek (~380')	$400	$5,624,000
20	2400	S.F.	Connectivity Culverts	$50	$120,000
				SUBTOTAL	**$7,594,000**

Total	**$14,429,999**
Contingency @25%	**$3,607,500**
Total Construction Cost	**$18,037,499**

S Skagit Highway Floodplain Resotration - Alternative 3

Engineer's Preliminary Opinion of Cost

General Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
1	1	L.S.	Mobilization	$1,300,000	$1,300,000
2	1	L.S.	Type B Progress Schedule	$2,500	$2,500
3	1	L.S.	Licensed Surveying	$50,000	$50,000
				SUBTOTAL	**$1,352,500**

Roadway-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
4	1	L.S.	Temporary Erosion and Sediment Control	$30,000	$30,000
5	1	L.S.	Removal of Structure	$100,000	$100,000
6	4000	S.Y.	Removal of Existing Road Surface	$4	$16,000
7	10000	C.Y.	Removal of Existing Road Base	$10	$100,000
8	180000	C.Y.	Roadway Excavation Incl. Haul	$10	$1,800,000
9	25000	S.F.	Retaining Wall	$40	$1,000,000
10	45000	C.Y.	Embankment Compaction Incl. Haul	$30	$1,350,000
11	1000	TN.	Gravel Borrow Incl. Haul	$10	$10,000
12	18200	TN.	Crushed Surfacing Base Course	$20	$364,000
13	2900	TN.	Crushed Surfacing Top Course	$30	$87,000
14	2750	TN.	HMA, CL B, PG 58-22	$75	$206,250
15	1	EA.	Stormwater Treatment	$280,000	$280,000
16	1	L.S.	Detour Complete Incl. Traffic Control	$100,000	$100,000
17	1	L.S.	Misc. @10% Civil Items	$540,000	$540,000
				SUBTOTAL	**$5,983,250**

Structure-Related Items

Item No.	Quantity	Unit	Item	Unit Price In Figures	Extended Price in Figures
18	6845	S.F.	Savage Creek (~105')	$400	$2,738,000
19	9250	S.F.	Mill Creek (~250')	$400	$3,700,000
20	2400	S.F.	Connectivity Culverts	$50	$120,000
				SUBTOTAL	**$6,558,000**

Total	**$13,893,750**
Contingency @25%	**$3,473,438**
Total Construction Cost	**$17,367,188**

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S Skagit Highway Floodplain Resotration

Engineer's Preliminary Opinion of Cost Comparison

General Items

Item No.	Unit	Item	ALT 1 Extended Price in Figures	ALT 1A Extended Price in Figures	Cost Difference	Percent Difference
1	L.S.	Mobilization	$700,000	$1,100,000	$400,000	36%
2	L.S.	Type B Progress Schedule	$2,500	$2,500		
3	L.S.	Licensed Surveying	$50,000	$50,000		
			$752,500	**$1,152,500**	**$400,000**	**35%**

Roadway-Related Items

Item No.	Unit	Item	Extended Price in Figures	Extended Price in Figures		
4	L.S.	Temporary Erosion and Sediment Control	$30,000	$30,000		
5	L.S.	Removal of Structure	$100,000	$100,000		
6	S.Y.	Removal of Existing Road Surface	$23,600	$26,000	$2,400	9%
7	C.Y.	Removal of Existing Road Base	$59,000	$65,000	$6,000	9%
8	C.Y.	Roadway Excavation Incl. Haul	$0	$0		
9	S.F.	Retaining Wall	$404,000	$668,000	$264,000	40%
10	C.Y.	Embankment Compaction Incl. Haul	$321,000	$582,000	$261,000	45%
11	TN.	Gravel Borrow Incl. Haul	$196,400	$357,450	$161,050	45%
12	TN.	Crushed Surfacing Base Course	$90,200	$99,700	$9,500	10%
13	TN.	Crushed Surfacing Top Course	$21,150	$23,400	$2,250	10%
14	TN.	HMA, CL B, PG 58-22	$56,250	$62,250	$6,000	10%
15	EA.	Stormwater Treatment	$50,000	$50,000	$0	0%
16	L.S.	Detour Complete Incl. Traffic Control	$250,000	$1,000,000	$750,000	75%
17	L.S.	Misc. @ 10% Civil Items	$150,000	$270,000	$120,000	44%
			$1,751,600	**$3,333,800**	**$1,582,200**	**47%**

Structure-Related Items

Item No.	Unit	Item	Extended Price in Figures	Extended Price in Figures		
18	S.F.	Savage Creek (~105')	$555,000	$1,554,000	$999,000	64%
19	S.F.	Mill Creek (~300')	$4,440,000	$4,440,000		
20	S.F.	Connectivity Culverts (50' EA)	$0	$720,000	$720,000	100%
			$4,995,000	**$6,714,000**	**$1,719,000**	**26%**

Total	**$7,499,100**	**$11,200,300**	**$3,701,200**	**33%**
Contingency @15%	**$1,124,865**	**$1,680,045**	**$555,180**	**33%**
Total Construction Cost	**$8,623,965**	**$12,880,345**	**$4,256,380**	**33%**