Skokomish River RM 1.5

Preliminary Design Report

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1. INTRODUCTION

The Mason Conservation District (Mason CD) is working with project partners throughout the Skokomish River watershed to restore habitat and help the community adapt to ongoing changes in the river. Mason CD is working extensively throughout the Lower Skokomish River to implement projects that meet multiple objectives for flooding, potential channel migration, ongoing sediment aggradation, and habitat improvements. Habitat improvements include the placement of large wood to replace lost ecological functions and provide complexity in a system that provides documented spawning habitat for coho (*Oncorhynchus kisutch*), fall chinook (*Oncorhynchus tshawytscha*), pink (*Oncorhynchus gorbuscha*), fall chum (*Oncorhynchus keta*), and winter steelhead (*Oncorhynchus m. indeus*) and has rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), summer steelhead, coastal cutthroat (*Oncorhynchus clarkii*), and sockeye presence (*Oncorhynchus nerka*) (WDFW 2021).

Natural Systems Design, Inc. (NSD) is supporting the Mason CD to develop and analyze restoration approaches and conceptual designs for habitat improvement projects between RM 3.4 and RM 1.5 of the Skokomish River, see Figure 1. The project reach extends from the distributary split near RM 1.4 to approximately RM 3.2. The project area is shown in more detail in Figure 2.

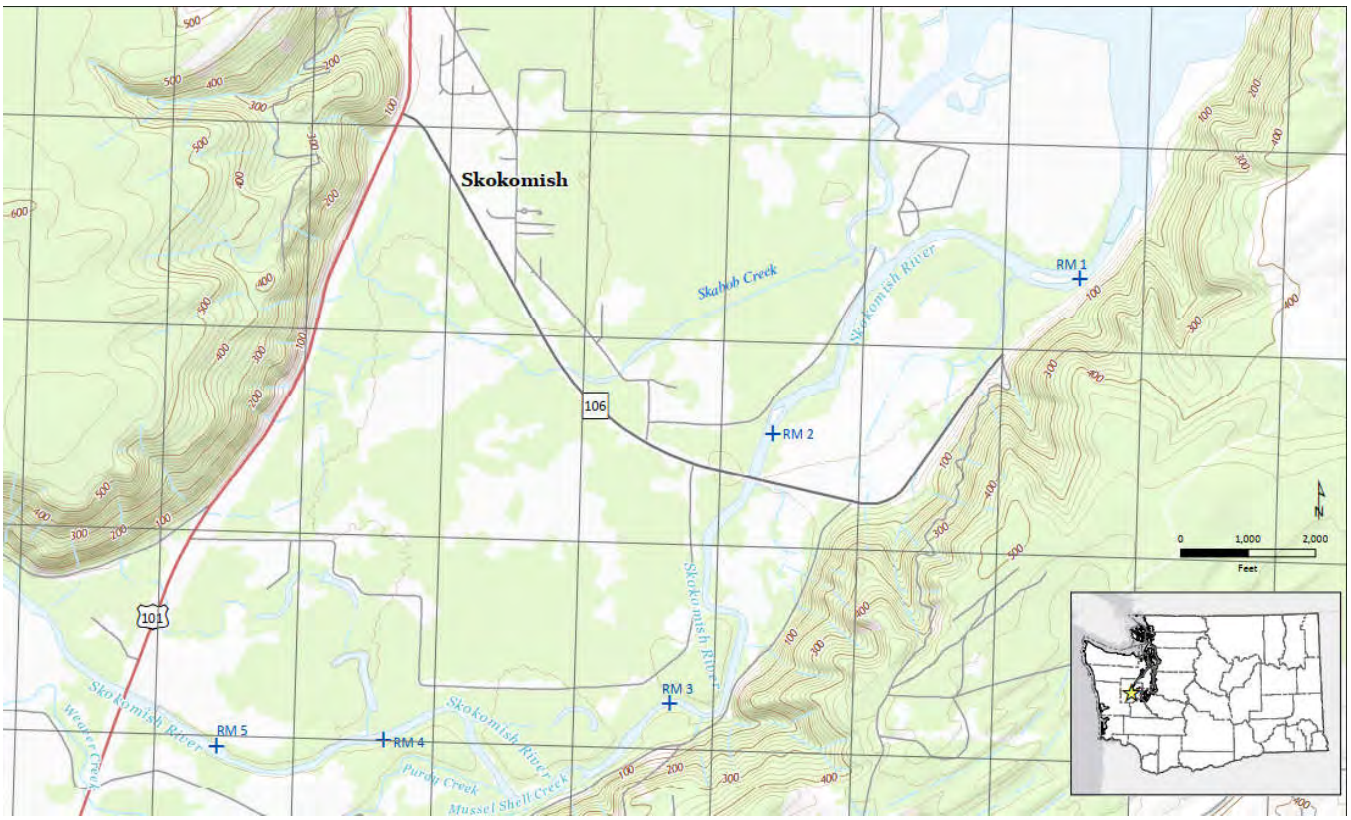

Figure 1. Vicinity Map for Skokomish RM 1.5

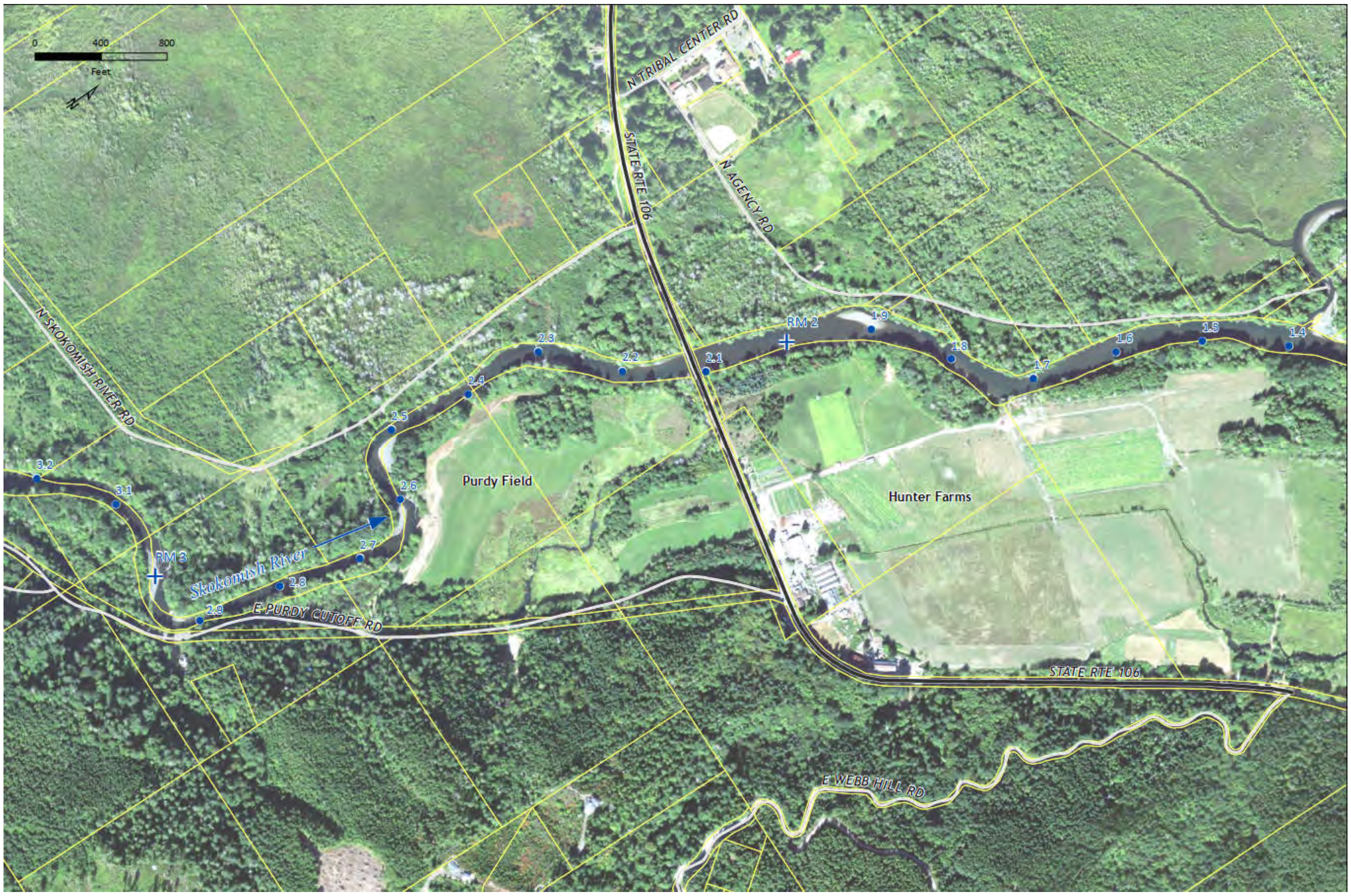

Figure 2. Project Reach for Skokomish RM 1.5 project

Any eventual project within the project reach will involve close coordination with the Skokomish Tribe, private landowners, and the Washington State Department of Transportation (WSDOT).

This report is organized to:

- Present an overview of the geomorphology of the Lower Skokomish River including results from our geomorphic, sediment, and hydraulic analyses
- Present and discuss preliminary design alternatives for the project reach

Graphics supporting this document include Figures included in-line in the text, a series of Maps included in Attachment A, and Preliminary Design Alternatives Sheets include in Attachment B.

1.1 Project Goals

Goals of this project include increasing habitat complexity through placement of large wood in the channel to increase pool depth and frequency, avoiding increases in flood risk from a range of flow conditions, and riparian planting. Restoration actions also considered how they would influence water quality in the estuary by reducing topsoil and fertilizer runoff from inundation of agricultural lands.

Large wood installations will also influence local hydraulics, increasing rates of local bed scour and possibly increasing sediment transport that could decrease aggradation of the mainstem and potentially increase transport through this reach. Another goal of this project is to better understand the relationship between flow and stream power in this reach and how that relationship affects sediment transport within the mainstem and the sustainability of off-channel features.

2. EXISTING CONDITIONS

2.1 Previous Studies

The geomorphology and sediment transport characteristics of the Skokomish River have been widely studied for decades as ongoing channel bed aggradation resulted in increased frequency and duration of overbank flooding and increased groundwater elevations. Studies include the US Army Corps of Engineers (USACE) Environmental Impact Statement (EIS) for the Skokomish River Ecosystem Restoration Project (USACE 2015) and other focused research efforts (e.g. Collins et al 2019; Grossman et al 2015; Arcos 2012). These studies have focused on attempting to identify causal mechanisms for the aggradational state of the river system and project the future trajectory for the channel. These studies have been summarized elsewhere (see for example Bountry et al 2009 and Booth 2019), so this report does not include an exhaustive summary of the literature. Key take-aways from past work include:

- Ongoing aggradation has been tracked at cross-sections at HWY 101 showing as much as 7.5 feet (2.3 meters) of aggradation from 1965 to 2015.
- The rate of aggradation has slowed in the last ~20 years, and recent Mason CD survey found only subtle aggradation between 2015 and 2019.
- Using sediment volumes from the watershed reported in Collins et al 2019 and observed aggradational patterns, it appears that approximately 90% of that volume is currently being passed through the lower reaches to the estuary (Booth 2019).
- There is general agreement that the pre-European contact condition of the river was anastomosing, with multiple perennially inundated channels separated by forested islands (Stage 0 in Cluer and Thorne, 2014).
- Channel narrowing with vegetation encroachment has occurred, but primarily in the reach above HWY 101.
- Channel meandering is occurring in the upstream-most section at the Purdy Creek confluence.

NSD's work builds on these previous studies to examine the potential effects of large wood placement, side channel creation, and floodplain reconnection on habitat value, sediment transport, and flooding within the project reach.

2.2 Valley Context

The Skokomish watershed drains three major tributary basins, the North Fork (118 square miles), the South Fork (76 square miles) and Vance Creek (29 square miles). The river collects flow from these steep, mountainous basins and drains into a flat, alluvial plain approximately ¾ to 1½ miles wide known as the Skokomish Valley. Richert Springs, Hunter, Weaver, and Purdy Creeks are predominantly spring fed tributaries that flow through agricultural lands in the southern portion of the Skokomish Valley floodplain before entering the mainstem Skokomish River. The Skokomish River mainstem flows through the Skokomish Valley to the Skokomish estuary. The Skokomish River empties into Annas Bay at the southern end of Hood Canal (USACE 2015).

2.2.1 Geologic History

The lower Skokomish River flows along the eastern edge of the Skokomish Valley, near the valley wall, a position it has held with only minor lateral channel migration for the last 1,000 years. Upstream of the Highway 101 bridge, the river channel has migrated as much as 170 meters since 1938 (Arcos 2012), and the entire valley bottom exhibits abandoned channels. Downstream of the Highway 101 bridge, no more than 20 meters of natural channel migration has taken place since mapping and aerials are available, and abandoned meanders are limited to the eastern side of the delta. Furthermore, based on river slope relative to delta slope, upstream of the Highway 101 bridge, the Skokomish River has a high avulsion potential, while downstream of the bridge the river has low avulsion potential (GeoEngineers 2006 in Arcos 2012).

This long-term channel stability of the channel position is ascribed to geologic uplift and tilting of valley by the Saddle Mountain fault zone. Additionally, a large ridge (potentially a fault line or an uplifted and tilted former beach berm) runs across the valley perpendicular to the river, which may be restricting channel mobility (Arcos 2012). State Route 106 runs along the top of this ridge. This ridge spans the entire valley and the floodplain, with only two openings: the Skokomish River on the eastern side of the valley and a much smaller opening for Skabob Creek near the center of the valley.

2.2.2 Channel Morphology

Today, the Skokomish River is a single thread channel with a bankfull width that ranges from 105 to 260 feet through the project area. The longitudinal profile of the mainstem is overall low slope with two reaches. From HWY 101 to just above HWY 106, the typical bed slope is 0.15%, reducing to 0.05% below HWY 101.

Figure 3 shows the mainstem and distributary profiles from the Highway 101 bridge to the estuary using LiDAR collected in 2015 and 2016. The western distributary is a shorter flow path to the bay and slightly steeper than the mainstem in the lower reach with an average slope of 0.07%.

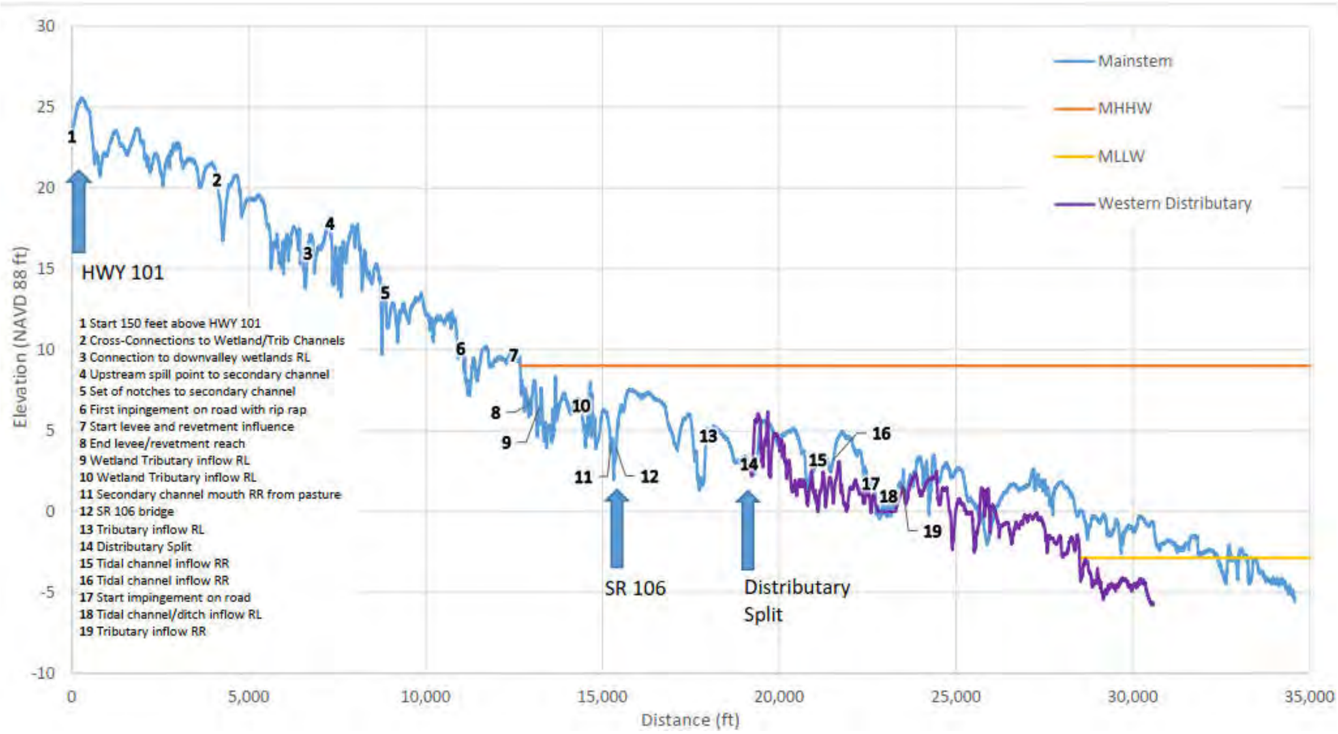

Figure 3. Skokomish River longitudinal bed profile using 2015/6 Blue-Green LiDAR

2.2.3 Overbank Topography

In the project area, the channel is very close to the eastern valley wall from RM 2.8 to RM 3.4. Purdy Cutoff Road follows the valley wall, with the river impinged against the road toe near RMs 3.4 and 2.9, see Figure 2. On the left (north) bank, the river is paralleled by low levees, likely a combination of natural depositional features and historical farming practices, which separate the river from an extensive, marshy floodplain between HWY 101 and SR 106. The only infrastructure in this floodplain is North Skokomish River Road, a low-lying, mostly unpaved road utilized by the Skokomish Tribe.

Small floodplain channels join the mainstem on river left near RMs 2.3 and 2.5. On river right (south), the floodplain is much narrower than on river left and is in active agricultural production. These lands are largely leveed off from the river, although these levees have eroded and failed in some locations, particularly at Purdy Field near RM 2.6.

2.2.1 Regulatory Floodplain

The current regulatory floodplain extends essentially from valley wall to valley wall through the project reach (Figure 4).

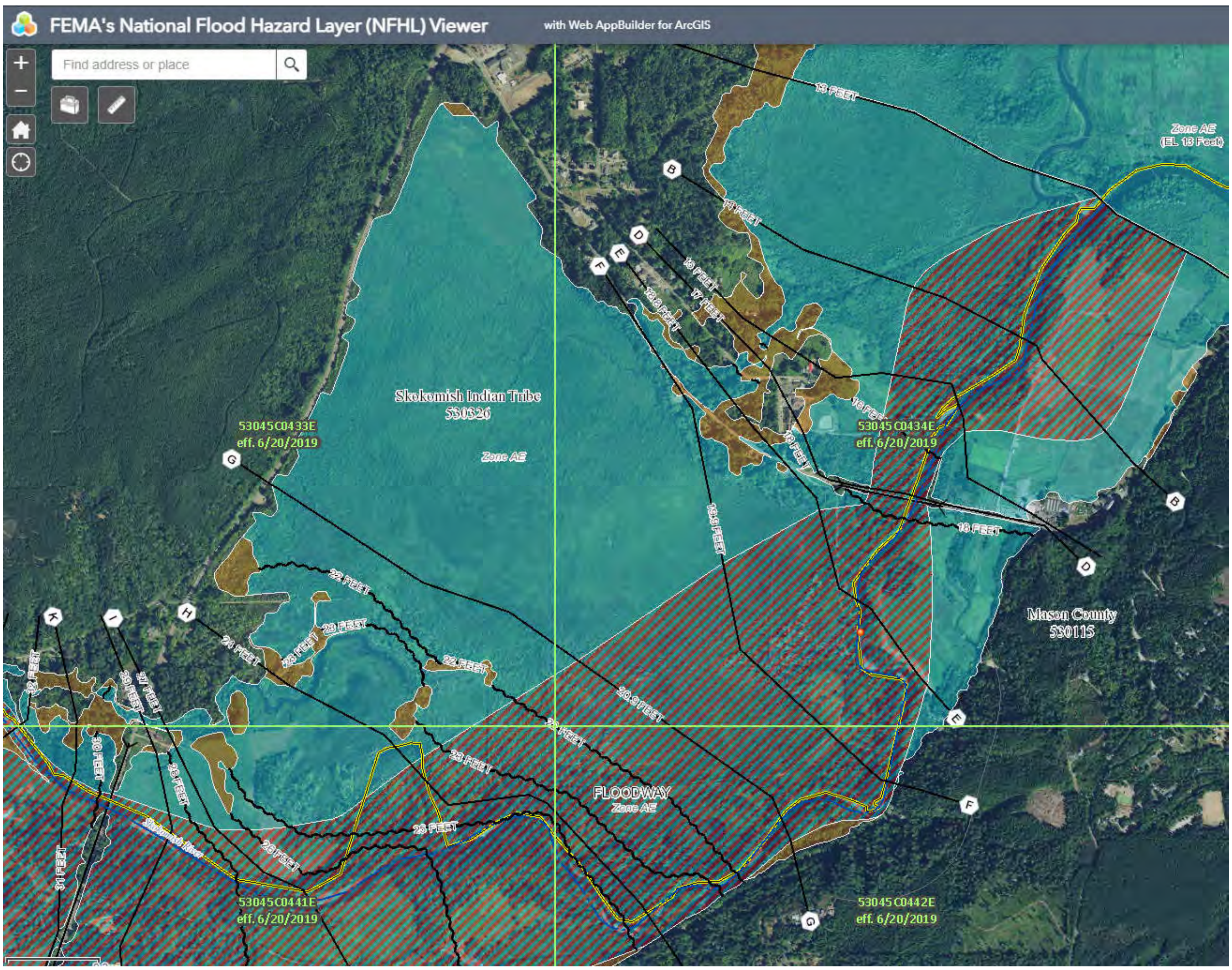

Figure 4. FEMA floodplain mapping for the project area. Zone AE is shown in the blue hatch, and the diagonal hatch indicates the floodway within the overall regulatory floodplain. Image generated by FEMA National Flood Hazard layer Viewer.

Mason County's floodplain code (14.22.200) treats the entire Skokomish River floodplain as a Special Flood Risk Zone that treats the entire floodplain as a floodway and an avulsion risk area. In general, any increases in flood heights at the Base Flood (the 1 percent annual chance event, often referred to as the 100 year flow) are not allowed.

2.3 Hydrology

The Skokomish River drains a watershed of approximately 230 square miles with a mean annual precipitation of 128 inches (USGS 2019). The Skokomish basin is low-lying at the southern end of the Olympic Mountains and is precipitation-driven, displaying typical rainfall driven peak flows throughout the wet season from October to March. The complex topography at the southern end of the Olympic Mountains also means that individual precipitation events, including atmospheric rivers that deliver the most focused precipitation, can vary between the sub-watersheds.

The North Fork Skokomish is part of Tacoma Power's hydropower system with a dam below Lake Cushman. The hydropower system includes an out-of-basin transfer where flow from the North Fork is conveyed directly to Hood Canal, reducing overall flow within the Skokomish River. Flows from the North Fork to the Skokomish are maintained by Tacoma Power under a set of operating rules to maintain low flows and meter water downstream during high inflow events (Tacoma Power 2009)

2.3.1 River Flows

For the analysis of their upstream project, USACE used the following flows selected as representative high and low flow conditions.

RECURRANCE INTERVAL	FLOW (CFS)	EVENT
Winter Low Flow	1,200	Synthetic
1-YR	11,900	February 14-16, 2017
1.4-YR	15,810	November 21-22, 2017
2-YR	19,530	November 21-22, 2017 (scaled)
10-YR	29,420	December 3, 2007 (scaled)
100-YR	38,000	March 18-19, 1997 (scaled)

Table 1. USACE Analysis Flows (USACE 2015, as updated)

FEMA has developed the following flows and recurrence intervals for the Skokomish River at Hood Canal as part of the 2019 update to the Mason County flood insurance study (FEMA 2019).

RECURRENCE INTERVAL	FLOW (CFS)
10-YR	26,900
50-YR	33,500
100-YR	36,000
500-YR	41,000

Table 2. FEMA Peak Flow Recurrence Intervals (FEMA 2019)

2.3.2 Tidal Influence

The lower Skokomish River is tidally influenced in portions of the project reach. The nearest tidal gauge that records measured water elevations is 9447130 Seattle, although there is also a predictive gauge 9445478 at Union, Hood Canal, approximate 1.5 miles from the river mouth (NOAA 2021). The MHHW elevation (9.6 feet NAVD 88) extends to approximately 3000 feet upstream of the SR 106 bridge. To evaluate tidal effects in the river, Mason CD installed a series of water level loggers through the project reach from November 2019 to January 2021. This period captures a full year of data and allows for examination of tidal effects at both high and low river flows.

Figure 5 shows the diminishing effect of the tides from the estuary to the HWY 101 bridge. At HWY 101, the hydrograph is driven by rain events with no tidal influence readily apparent (USGS 2021). (Note that the USGS gauge in this location experiences outages at high flows, which is why the data series appears to be missing some of the peak observed downstream.) Downstream of SR 106 (including the SR 106 data logger, which was placed approximately 50 feet below the bridge) tidal effects are very evident, with the effects being stronger at lower river flows and less pronounced during storm events (MCD 2021). During the summer, water surface elevations at these three gauges fluctuate by 1 to 4.5 feet with the tidal cycle, with the degree of fluctuation depending on river mile and the magnitude of the tide. The further downstream gauges show stronger tidal effects, but even just below the SR 106 bridge, the tidal flux is still up to 3 feet. At Purdy field, approximately ½ mile above the SR 106 bridge, very little tidal influence is observed during winter peak flows, but up to 0.5 feet of tidal influence is observed as river flows drop going into the summer months. Data for this data logger do not continue for the full monitoring period due to technical issues.

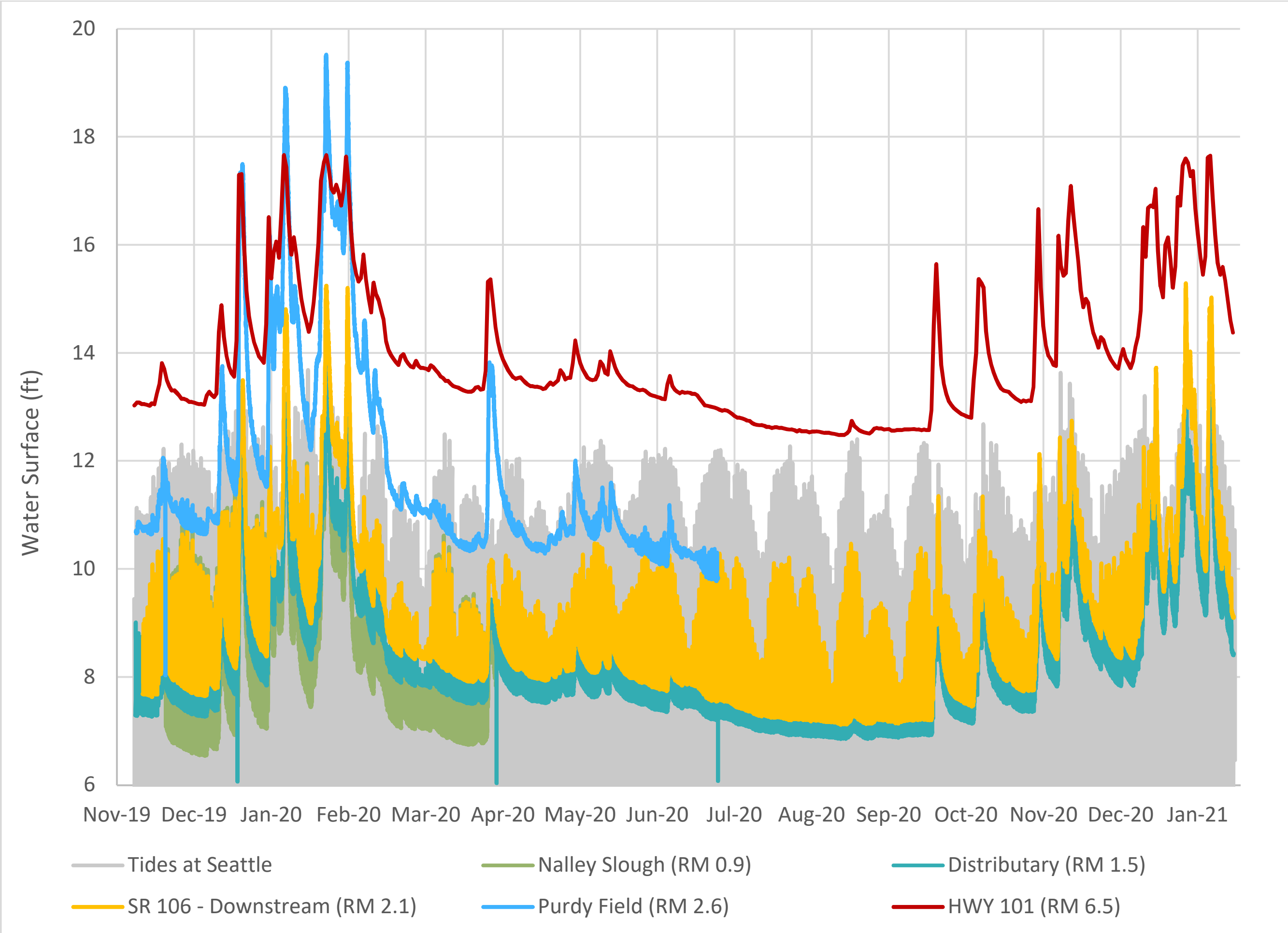

Figure 5. Mason CD Water level monitoring data from November 2019 to January 2021 showing levels from the mouth upstream to HWY 101

(Data Sources: Tides – NOAA 2021; HWY 101 gauge – USGS 2021; All other data – Mason CD 2021)

At low tides, water surface elevations are controlled by the stage in the river, which is why the base flow level at all the loggers so closely parallels the upstream watershed contribution-driven stage.

2.4 Hydraulics

2.4.1 Model Setup

NSD adapted the USACE 2D HEC-RAS model for the Skokomish River Basin for this study. The USACE model was developed for the Skokomish River Ecosystem Restoration Project and included development of topographic and bathymetric surfaces for the basin, as well as updated hydrology (USACE 2015). NSD's modifications for this project were to refine and update the bathymetry in several areas of interest using survey data collected by Mason CD (MCD 2019) and to refine the mesh through the study area to enable more detailed hydraulic outputs. This refinement was particularly important for examining the hydraulic effects of the engineered log jam (ELJ) structures, which have strongly localized effects.

For our analysis, NSD developed a synthetic hydrology that ramps gradually from 200 cfs to 10,000 cfs to observe how flows transition from in-channel to overbank and to analyze how our proposed restoration elements function through these key transitions. This hydrology was used as a supplement to the high flows provided in the USACE model.

2.4.2 Overbank Flow Patterns

As noted above, the USGS gauge at HWY 101 does not produce usable flow data above approximately 5,000 cfs, so the HEC-RAS model was used to investigate overbank flow patterns through the project reach. Under existing conditions, water first begins to spill out into the overbank through the floodplain channels near RMs 2.3 and 2.5 at approximately 1,050 cfs. Next, the small, right overbank floodplain and floodplain channel between RM 3.0 and RM 3.2 engages at approximately 1,500 cfs. By 2,000 cfs, the left overbank upstream of SR 106 is extensively engaged through multiple routes including flows coming down valley from upstream overflow points (particularly overflows from the large slough near HWY 101). Also at 2,000 cfs, floodwater begins to enter Purdy Field on the right overbank both through the berm breach and as backwater from the existing slough outlet. At 3,000 cfs, the alternative flood route through Skabob Creek is fully engaged and water is spilling onto the left bank floodplain downstream of SR 106.

Table 3 lists how flow is divided between the mainstem and the overbanks for different flow increments based on the USACE existing conditions modeling. This table represents conditions at RM 2.35, approximately 1,200 feet upstream of SR 106. Purdy Field is on the right overbank. The left overbank carries most of the flow at larger magnitude events with flows in the channel increasing at a much slower rate than overbank flows.

FLOW (CFS)	LEFT OVERBANK (CFS)	CHANNEL (CFS)	RIGHT OVERBANK (CFS)	SKOKOMISH / SKABOB SPLIT (%)
1,000	0	1,000	0	100 / 0
2,000	160	1,840	< 1	94 / 6
3,000	500	2,380	120	94 / 6
4,000	880	2,600	520	94 / 6
5,000	1,310	2,770	920	95 / 5
7,500	2,500	3,100	1,900	95 / 5
10,000	3,660	3,415	2,925	95 / 5
15,000	6,300	3,850	4,850	92 / 8
20,000	8,950	4,200	6,850	92 / 8
25,000	11,900	4,550	8,500	89 / 11
30,000	15,000	5,000	10,000	84 / 16
37,500	19,900	5,250	12,350	81 / 19

Table 3. Overbank Flow Division

As previously mentioned, a large ridge spans the valley at SR 106 (RM 2.1). All overbank floodwaters are funneled into one of the two openings in this ridge, with flows in the right overbank funneling to the Skokomish River and flows in the left overbank dividing between the Skokomish River and Skabob Creek. Table 3 also lists the percentage split between these two flow routes. For flows greater than approximately 18,600 cfs, the ridge begins to overtop at various locations in the left overbank. These overtopping flows are counted towards the Skabob Creek flood route because they remain in the left overbank.

Overbank flow depths increase with increasing flow. In the left overbank, depths reach their maximum of 7 feet deep adjacent to the channel at the 100-year flow event, tapering off to 1 foot deep at the floodplain margins. In Purdy Field, flows are a fairly uniform 6 feet deep for the same event with some variation due to local topography.

2.4.3 Velocity and Shear Stress

Velocities in the Skokomish River channel are relatively low and exceptionally stable, remaining between 2 to 5 fps in most locations at flow levels ranging from 1,000 to 37,750 cfs, Figure 6 and Map 1. Below 1,000 cfs, velocities drop to 1 to 2 fps for most locations downstream of SR 106 and near the Purdy Field berm breach. Velocities generally increase (within the range of 2 to 5 fps) with increasing river flow, with the notable exception of RM 2.55 at the Purdy Field berm breach where velocity is directed into the right overbank as flows increase, and velocities in the adjacent mainstem drop below 1 fps. Velocity hot spots in this reach at all flow levels, with velocities of 4 to 5 fps, are: where the river impinges on the valley wall and Purdy Cutoff Road near RM 2.9, at the meander bend near the Hunter revetment at RM 1.7, and just upstream of the western distributary near RM 1.5. The SR 106 bridge also becomes a hot spot, with velocities up to 7.5 fps, at higher flows as flood flows contract back into the narrowed cross section. Velocities in Skabob Creek reach 3.5 fps at the same flow events. In the left overbank, velocity generally remains below 2.5 fps and decreases with increasing distance from the channel. In the right overbank, velocities at the Purdy Field berm breach reach 3.5 fps adjacent to the channel, but rapidly drop off to 1 to 2 fps as flow enters the field.

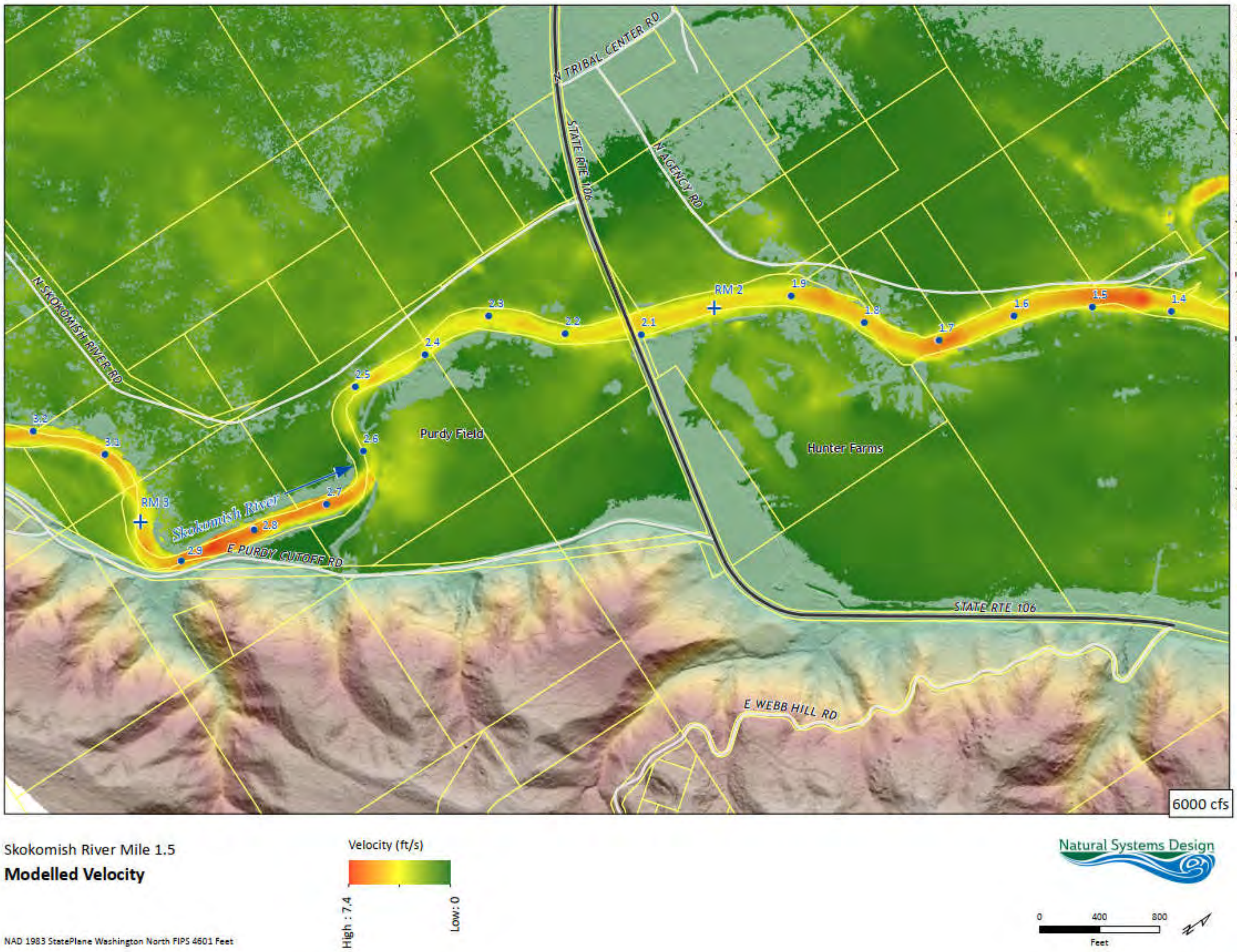

Figure 6. Existing Conditions modelled velocities at 6,000 CFS through the project reach

Higher velocities outside eddy lines formed by flow obstructions were observed during the May 18, 2021 site visit at meander at Purdy field meander (RM 2.65). The vortex "street" associated with these eddy lines are associated with deeper water as a result of vortex flow impinging on the river bed (Figure 7). Two-dimensional hydraulic modeling does not predict vortex flow and thus under-estimates shear stress in areas affected by vortices.

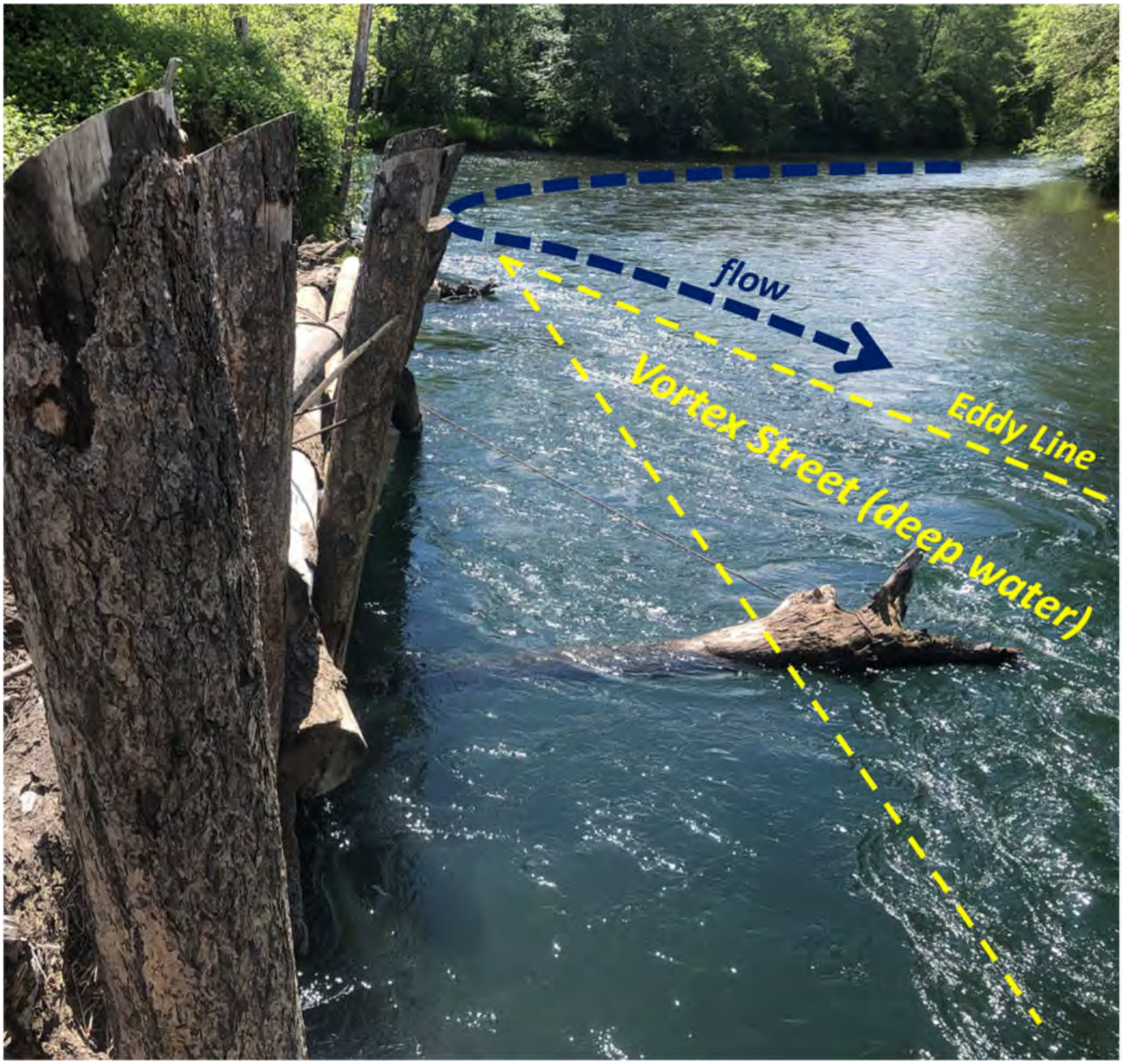

Figure 7. Example of vortex flow along timber revetment at RM 2.65, upstream of Purdy field. View is looking upstream along right bank. May 18, 2021.

Shear stress, which is a function of depth and slope, follows similar patterns as velocity. In-channel shear ranges from 0.05 to 0.20 lbs/ft^2 with higher values near the outsides of meander bends (Map 2). Higher shear values, near 0.4 lbs/ft^2 occur on the stream banks. This is a function of the model equation using the local maximum slope to calculate shear rather than the overall reach slope. Since flow is travelling horizontally along the channel slope rather than vertically down the banks, these local bank values are likely overestimated. RM 2.9, where the river impinges on the valley wall and Purdy Cutoff Road, is the only notable and consistent hotspot. Shear stress is often slightly higher in the overbank area adjacent to the channel than in the channel itself, which may be promising for the creation and propagation of side channels. Shear also increases with increasing flows.

At 1,000 cfs, the average reach shear is less than 0.10 lbs/ft^2 while at 10,000 cfs it has increased to 0.10 to 0.15 lbs/ft^2 and by 37,750 cfs it is closer to 0.15 to 0.20 lbs/ft^2.

2.4.4 Tidal Hydraulics

The USACE model of the Skokomish River uses a constant downstream tidal boundary condition at the MHHW elevation (9.1 feet NAVD 88). This is a reasonable approach for assessing flooding impacts as the maximum tidal elevations will correspond to the maximum flood extents. However, to assess changes to stream power and shear, variable tidal elevations will more accurately capture the peak shear and velocity conditions. To better assess the potential real-world effects of the project, we modeled a variable downstream tidal boundary and a constant inflow for the winter low flow (1,200 cfs), a small flood (6,000 cfs), and the 100-year flood (38,000 cfs) scenarios.

At low flow conditions, model runs show clear changes in velocity and depth with the tides extending from the bay to at least 500 feet above the SR 106 Bridge, with the greatest effects occurring the furthest downstream. At the 100-year flow effect, river effects dominate, and tidal forces are no longer visible above the estuary. Within the project area, velocities shift by up to 1 to 2 fps with the tides, with the high velocity point near the SR 106 Bridge shifting from a maximum of 4.7 fps at flood tide to 5.1 fps at ebb tide. These are still relatively low overall velocities, but this does illustrate an effect on the system that is not captured with a constant tidal boundary. Map 3 shows the difference in velocity and water depth between flood and ebb tides at a constant low flow of 1,200 cfs. Map 4 shows the much smaller differences in velocity and water depth between flood and ebb tides for a constant high flow of 38,000 cfs (100-year flow event).

2.5 Sediment

The Skokomish River is estimated to have an annual sediment load of 144,000 metric tons per year (Downing 1983 in Arcos 2012). The mainstem Skokomish River system has been depositional since approximately the mid-1960s, with recent average deposition rates estimated at 0.03 meters (1.2 inches) per year (Stover & Montgomery 2001). This deposition has several contributing causes including timber harvest, upstream bank erosion, channel modification, and reductions in stream power due to upstream water diversion at Cushman Dam (Collins et al 2019). Consequences of this deposition have included increases in flood frequency, loss of pool habitat, and blocked access to off-channel refugia (USACE 2015). In addition, historical channel confinement disconnected the river from floodplain areas that would have captured and stored sediment thereby reducing total load moving downstream. Historical channel anabranches would have been effective at distributing flow and sediments across floodplain.

2.5.1 Channel Bed Sediments

Mason CD conducted Wolman pebble counts at seven point bars in the project area, as well as sieving to characterize subsurface materials at two of the sites. Materials were very similar at six out of the seven sites, with an average D_{50} of 12 mm and D_{90} of 29 mm, while sediment at Site 7 was notably finer. Initial existing conditions modeling confirms that Site 7 is a lower velocity area, and field observations noted potential wetland conditions and active vegetation growth at this site, which was not observed on the other coarser, more active gravel bars. Figure 8 and Figure 9 show surface and subsurface characteristic of sediment in this reach. Sampling locations are shown on Map 5.

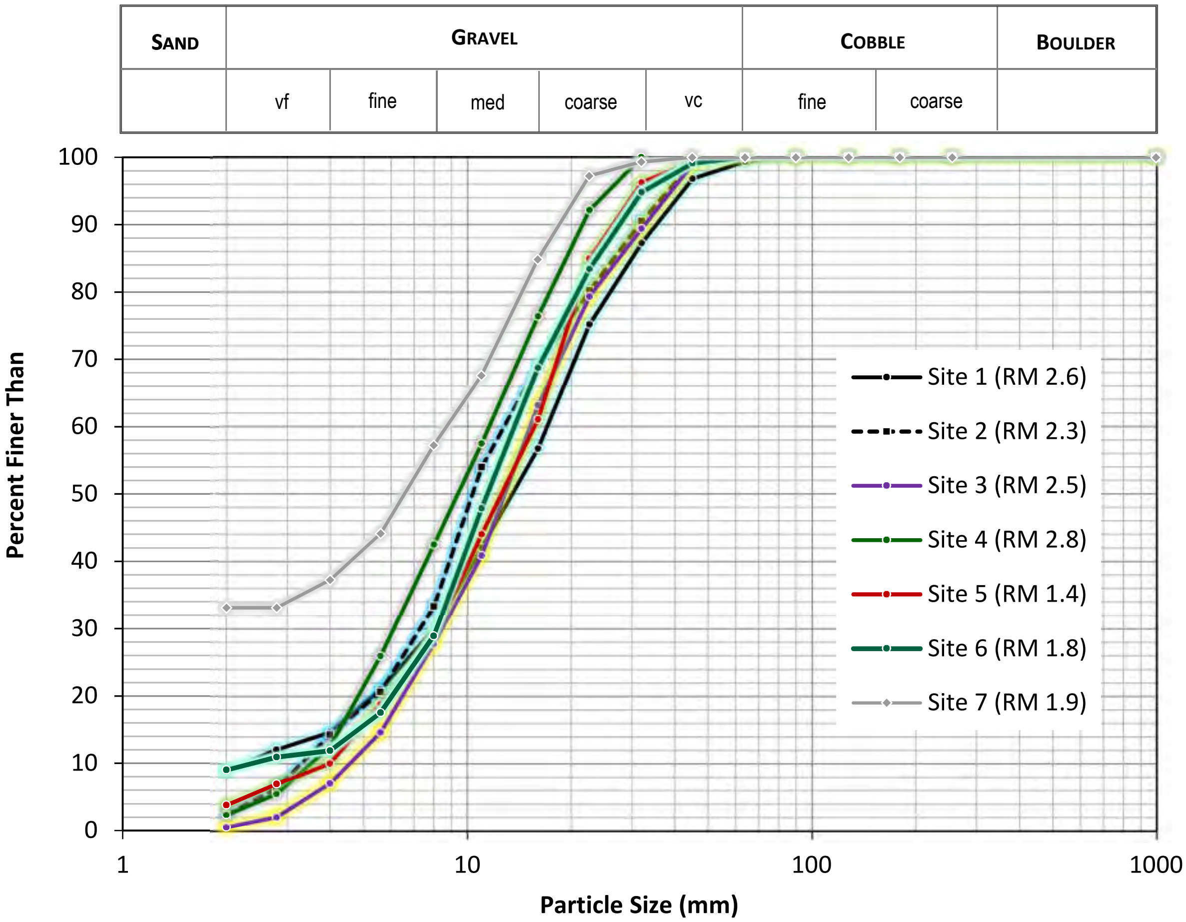

Figure 8. Mason CD provided surface particle size distributions

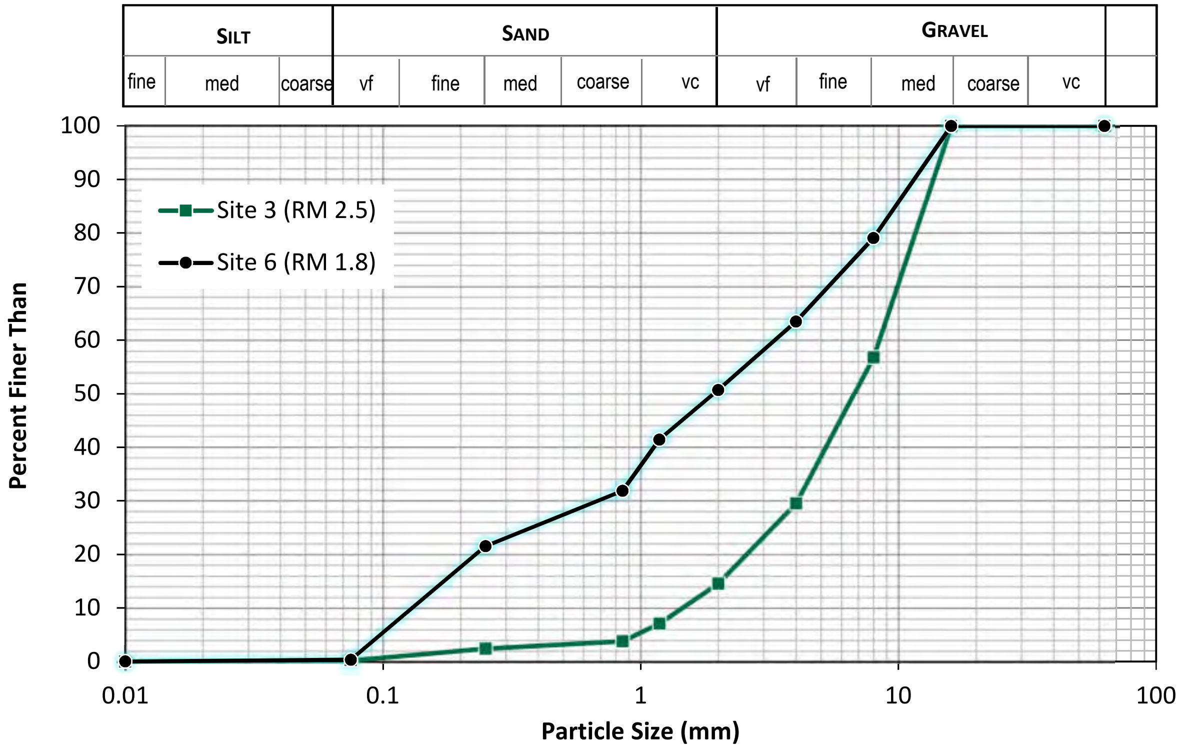

Figure 9. Mason CD provided subsurface (sieve) particle size distributions

2.5.2 Stable Particle Analysis

The Shields equation predicts that material of the average size observed on the bar surface in this reach of the Skokomish becomes mobile at shear stresses between 0.2 lbs/ft^2 (8.7 Pa) for the D_{50} and 0.4 lbs/ft^2 (21.1 Pa) for the D_{90}. Initial hydraulic model results for shear stress indicate that the D_{50} is mobile at the bankfull flow in most locations through the project reach, Map 2, resulting in the active gravel bars observed throughout the reach. If the D_{50} was not mobile, we would expect to see vegetation forming on these bars.

2.5.3 Topographic Comparison

In 2019, Mason CD resurveyed seven cross sections between RM 1.5 and the Highway 106 bridge, including one in the western distributary. These sections were previously surveyed by USACE in 2010. We compared the 2019 and 2010 survey results to quantify bed elevation changes in the reach over the past 10 years. The six mainstem sections are plotted in Maps 6 and 7. The overall erosion and deposition patterns in the resurveyed sections showed some evidence of lateral channel migration, with 1 to 5 feet of erosion on the inside bend and comparable deposition on the outside bend. There was also deposition on bars and a mix of scour and deposition at other locations. In general, changes were non-uniform across each section, with areas of both aggradation and degradation. At some sections, pools filled in, while in others they scoured out.

For our analysis we divided the net change bed elevation by the bankfull width of each section to derive an average change in bed elevation. All the mainstem sections have aggraded since the 2010 survey, while the distributary section had incised slightly. The average aggradation over all the mainstem sections was 3.6 inches of that 9 year period (0.4 inches/yr), with individual section aggradation ranging from 0.01 inches (at a glide immediately upstream of the distributary) to 8.5 inches (at a meander bar). The distributary channel section degraded by an average of 6.8 inches. The distributary was recently reconnected to the mainstem and represents a shorter, steeper route for flows to reach the bay, which may explain the incision.

2.6 Aquatic Habitat

Historically, the Skokomish River system produced the largest runs of salmon and steelhead in Hood Canal (Correa 2003 in USACE 2015). The US Army Corps of Engineer (USACE) study of the basin identified the following key stressors on salmon recovery (USACE 2015):

- Removal of LWD leading to loss of pool habitat and cover.
- Removal of the riparian forest has increased river temperatures through loss of shading, interrupted key links between the terrestrial and aquatic food chains, and destabilized banks, leading to increased erosion and sediment supply.
- Bank armoring has reduced natural channel migration.
- Cushman Dam has changed flow magnitudes and timing.
- The U.S. Highway 101 and State Route 106 road embankments disrupt overbank flood flows and reduce habitat connectivity. (Note that the high ground at SR 106 is a naturally occurring geologic feature.)

The lower Skokomish River is documented habitat for the following fish species (WDFW 2021):

SPECIES	USE TYPE	ENDANGERED SPECIES ACT STATUS
Coho Salmon	Spawning	
Fall Chinook	Spawning	Endangered
Pink Salmon	Spawning	
Summer Chum (Hood Canal ESU)	Unmapped but within ESU mapping	Threatened
Winter Steelhead	Spawning	Threatened
Rainbow Trout	Presence	
Bull Trout	Presence	Threatened
Summer Steelhead	Presence	Threatened
Coastal Cutthroat	Presence	
Sockeye	Presence	

Table 4. ESA listed species in the lower Skokomish River

2.7 Geomorphic Analysis

There is general agreement that the pre-European contact condition of the river was anastomosing. Conversion of the floodplain to farmland converted the Skokomish to a single thread river. Reductions in inflows due to Cushman Dam diversion significantly changed the overall flow magnitudes. This raises the question of what the natural channel form for the Skokomish is under existing conditions. To investigate how the channel is changing and may change in the future, we reviewed hydraulic model results and field information to assess the current trajectory and refine our understanding of how restoration actions may influence that trajectory.

2.7.1 Channel Planform

We used the concepts set forth in Eaton et al. (2010) to estimate the natural channel form of the Skokomish River in this reach, given the existing changes. Plotting the slope against the formative dimensionless discharge (a function of the channel forming discharge and the sediment D_{50}) indicates that this reach in on the threshold between being a naturally single thread stream and being an anabranching system (multi-channel separated by vegetated islands). Sampling sites upstream of SR 106 trended towards anabranching, while sites lower in the system trended more towards single thread.

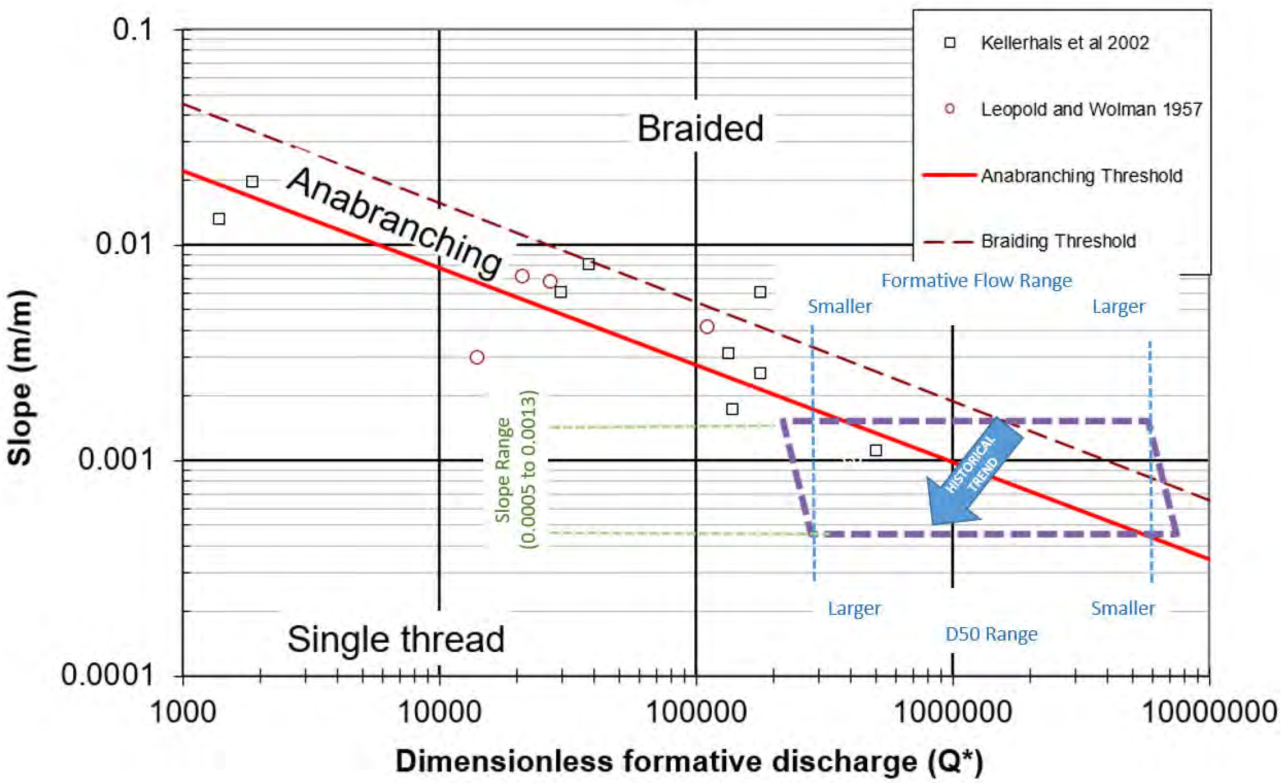

Figure 10. Trends in Lower Skokomish plan form using anabranching threshold based on Eaton et al (2010)

We selected 3,000 cfs as a representative channel forming flow for this analysis and applied the reach-scale slopes of 0.13% upstream of the SR 106 Bridge and 0.05% downstream of the SR 106 Bridge. This is a subjective choice, as the channel forming discharge is not readily apparent in this reach, given both changes in flow regime and the hydraulic result that shear stress and velocity are not particularly sensitive to flow. The channel forming discharge is most likely somewhere between the bankfull flow (approximately 1,100 cfs) and 1.1 year recurrence interval flow (approximately 11,900 cfs). The historical trend is likely for a reduction in the formative flow over time with aggradation in the channel.

Conducting a sensitivity analysis on these results by reducing our estimate of the channel forming discharge to 1,100 cfs pushes all the sampling sites except RM 2.5 and 3.0 down into the single thread category. Sites 2.5 and 3.0 remain anabranching. Increasing the channel forming discharge to 11,900 cfs pushes all the sites except RM 1.5 up into the anabranching or braided categories. The dashed, gray box shows the bounds of uncertainty. Overall, higher estimates of the channel forming discharge or a smaller D_{50} push results to the right, closer to the anabranching / braided threshold while a smaller channel forming discharge or a larger D_{50} will push results to the left, more into the single thread category. Changes in the estimated river slope move results up and down, with more steeply sloped reaches likelier to be anabranching or braided.

Based on this analysis, it appears that there is a possibility that multiple channels could occur, but changes in flow regime, particularly reductions in discharge and channel capacity are pushing the system towards the single thread morphology. If the river were to transition to anabranching in the project reach, we would expect each of the channels to be narrower than current mainstem, such that the overall cross-sectional area and conveyance capacity remains roughly constant. In a previous assessment Booth (2019) also suggests that reductions in flow and channel capacity means that the present-day channel network does not have the ability to support multiple threads. Booth does not provide the specific analysis in the technical memo. Booth did not consider the influence of logjams in splitting flow into smaller channels. These logjams would also increase vortex flow along the eddy lines downstream of the jams (Figure 5).

2.7.2 Sediment Transport Potential with Narrowed Channel

Large wood structures have the potential to locally mobilize sediment by constricting flow, reducing conveyance areas initiating vortex flow, and increasing water depth and velocity. These effects are the most pronounced at flows below the bankfull event. Once flood water surface elevations exceed the bank height, large wood structures become less effective at changing sediment dynamics because they can no longer affect water depths – the water spreads out more than up – and their relative effect on the conveyance area diminished as the total area in flow increases. One of the challenges of the Skokomish River is that the channel is quite shallow, and water spills out of bank at relatively low flow events before it has much opportunity to develop scouring velocities in the channel. The key mechanism of bed scour by wood is vortex flow (Abbe and Montgomery 1996).

To analyze the potential for large wood structures to increase stream power and sediment transport in the project reach through channel constriction, NSD conducted a thought experiment where we modeled an artificially constricted channel reach from Hwy 101 to SR 106 to demonstrate the theoretical maximums of using large wood to affect instream hydraulics. The constricted channel has the same thalweg and bank elevations as the existing channel and a uniform width at toe of bank of 25 feet with 1:1 side slopes (Figure 11).

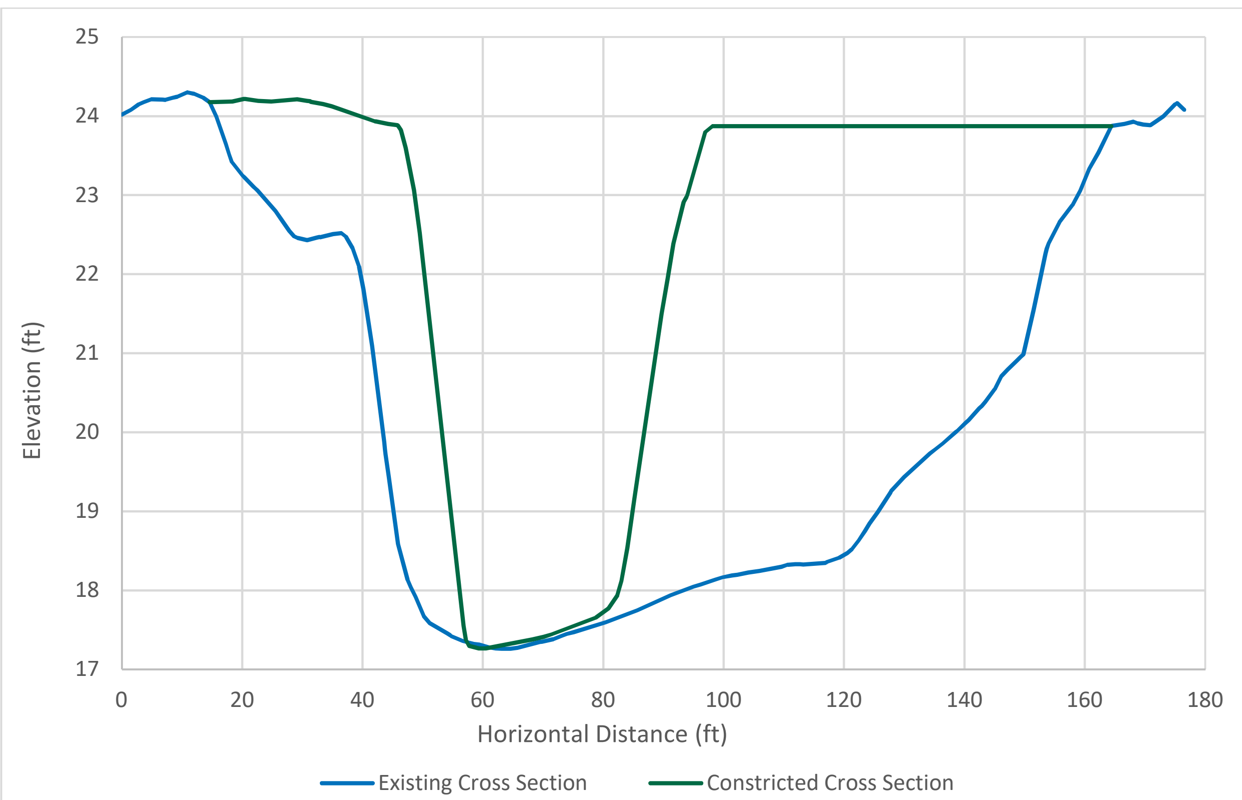

Figure 11. Typical Constricted Channel Cross Section

We ran both the existing conditions model and the constricted channel model for a slowly ramping range of flows from 150 cfs to 10,000 cfs to capture the transition from in-bank to overbank flows. Map 8 shows the differences in shear stress between the regular and the constricted channel at a flow of 5,000 cfs. Overall, very little changed. In fact, there is a slight reduction in shear stress though most of the mainstem with the narrower configuration, likely because the channel is carrying less total flow. However, our hydraulic model cannot capture the potential effects of scour increasing total channel depth, so it is possible that this scenario underestimates the benefits of constricting the channel.

2.8 Implications for Restoration

Based on our geomorphic analysis, the following findings informed the development of restoration actions described in the next section:

- Despite low overall velocities within the mainstem, existing channel bed sediments are mobile with existing flows, and convey the majority of sediment delivered to the reach.
- Building on existing transport dynamics and local roughness elements such as large wood will be effective at influencing local bed morphology to create more, deeper, pools.
- Encouraging additional overbank flow, either on the floodplain or in new side channels is unlikely to increase or reduce overall sediment conveyance in the mainstem.
- Channel avulsion into side channels is possible, as they provide a marginally more hydraulically efficient path, but overall potential remains low.
- Maximize development of vortex flow by introducing flow obstructions (engineered logjams) and increasing channel sinuosity.
- There is significant uncertainty regarding the sustainability of multiple thread channels under current flow conditions in the Skokomish River, but the reduction in channel formative flows suggest that single thread is a more likely form.
- Constructing engineered logjams in the bank full channel will creating vegetated islands and local anabranching (as well as increasing vortex flow to scour channel).
- There are no ‘low hanging fruit’ for floodplain side channel creation. Any new side channels will require significant excavation and have low likelihood of self-maintenance. However, they can allow for an overall higher slope so may provide more sediment transport potential and will provide additional sediment storage.

3. PRELIMINARY DESIGN ALTERNATIVES

NSD considered the overall project objectives and the geomorphic context of the reach of the Skokomish River from the bifurcation of distributary at RM 1.4 to approximately RM 3.5 to develop a suite of potential project actions. We developed alternatives focused on three areas and approaches:

- Mainstem Wood Placement (RM 1.4 to 3.1)
- Purdy Field (near RM 2.5)
- Side Channel Creation (Left Bank from Approximately RM 2.4 to 3.0)

The following sections discuss potential project elements and alternatives for this reach.

3.1 Overall Design Opportunities and Constraints

These action areas were selected as a combination of opportunity areas - areas where landowner interest could allow for work in the floodplain - and areas of hydraulic significance where actions might have the potential to both immediately enhance existing habitats and change the evolutionary trajectory of the stream.

Primary design considerations included:

1. Influence on flooding. There is a balance to be struck between restorative actions that are large enough to have a substantive influence on instream habitat and sediment transport and actions while avoiding increases in water surface elevations during flood events.
    a. Avoiding increases to both the 1 percent annual chance flood elevation and nuisance flooding is the primary project constraint. This condition limits the extent of instream work that can be accomplished
    b. We analyzed alternative to determine if instream actions result in an increase in the 1% annual chance water surface elevation. We used the Corps 2D HEC RAS hydraulic model as the baseline.
    c. We also reviewed instream actions to assess if they would result in increased “nuisance” flooding – defined here as the duration of overbank flows between 6,000 and 10,000 cfs that occur nearly every year.
2. Bank erosion of less than half the channel width is allowable adjacent to log structures.
3. Wood placements will not increase velocities or otherwise increase risks to HWY 106 nor Purdy Cutoff Road.
4. Construction access to, and into, the mainstem river will be allowable during appropriate work windows.

3.2 Mainstem Wood Placement

Large wood in rivers has many benefits for juvenile salmon including increasing habitat complexity and number of pools, providing instream cover and predation refugia, and serves as a substrate for aquatic invertebrates that salmon rely on as a food source (Quinn 2005 in USACE 2015). USACE identified a goal of achieving approximately 64 logs, two to three feet in diameter and 15 to 30 feet long, per river mile for the reach from RM 0 to RM 9, based on recommendations found in Fox and Bolton 2007 (USACE 2015).

We used the hydraulic and geomorphic investigations described above to develop a range of large wood placement approaches for the mainstem. All approaches focus on installing Engineered Log Jams (ELJs) as a way of using available logs to form stable log jams to influence flows and improve aquatic habitat by increasing instream complexity and cover. Each ELJ is also expected to create a scour pool and encourage sediment deposition immediately downstream of the structure.

The two alternatives vary with the density of structures placed within the mainstem. Alternative MS1 provides a dense installation intended to have a nearly continuous influence on flowpaths, particularly at lower flows. Alternative MS2 focuses on installing ELJs at the head of existing bars to emphasize existing flowpaths and focus on areas where sediment deposition is most likely. These alternatives can work with either of the other two sets of alternatives with the left and right overbanks but would need subtle modifications to align with the off-channel features included in those options.

3.2.1 Mainstem ELJ Alternative 1 – Full Array (MS1)

For alternative MS1, NSD has developed a conceptual layout of 25 Apex-type ELJ structures and 6 deflector-type ELJ structures. The Apex structures are distributed approximately from RM 1.4 to 3.1. The ELJs are positioned fully within the mainstem channel, typically skewed towards the bank or at the head of existing gravel bars. Each structure is approximately 25 feet wide by 35 feet long and occupies approximately 20% of the channel width. They alternate between the left bank and right bank to push flow back and forth to develop a complex low flow path within the existing active channel.

The six deflector structures are positioned near RM 2.9, at the outside of a large meander bend where the river flows directly along Purdy Cutoff Road. In reviewing historical aerials, channel migration in this location has proceeded towards the road. There is currently discontinuous informal riprap along the toe of slope that provides some protection for the road but is unlikely to fully prevent erosion over time. In addition to adding cover and habitat complexity in the pools in that location, the deflectors will help to push the river away from the road toe and back towards the vegetated floodplain on the left bank.

Hydraulic modeling of this alternative indicates that each structure splits flow, dividing the velocity vectors around the structure and creating a downstream lee of lower velocities. In the reaches that are straight under existing conditions, the velocity path becomes visibly sinuous with the addition of the ELJs, see Sheet 4 in Attachment B. The ELJs do not substantively increase overall velocities within the mainstem, but they do change how velocity is distributed in the channel.

Because our model is unable to capture potential changes in channel depths with scouring flows, it is difficult to assess how this alternative might affect shear stress (a product of depth and slope) and sediment transport. This alternative presents the best likelihood of reach scale increase in sediment transport rates through a combination of channel narrowing and integrative hydraulic effects of log jams. Hydraulic investigations suggest limited velocity changes so there is a high degree of uncertainty regarding long term sediment trend (Map 9

As currently shown, MS1 raises water surface elevations by approximately 0.1 to 0.5 feet at the 1 percent annual chance flow event, so either the density or the cross-sectional area blockage (or both) would need to be reduced to meet the flood stage goals described above. We included this alternative to indicate that there is a limit to how much channel blockage can occur without influencing flood flows, but this is the most likely alternative to achieve the sediment transport goals.

3.2.2 Mainstem ELJ Alternative 2 – Focused Bar Placement (MS2)

Alternative MS2 (Sheet 10 in Attachment B) involves a simplified placement of Apex-type ELJ structures at the head of existing gravel bars to stabilize the bar and encourage additional deposition and the establishment of colonizing riparian vegetation, such as willows to effectively narrow the channel. This concept would include 8 ELJs distributed approximately from RM 1.4 to 3.1. In addition to increasing instream habitat complexity, stabilizing the bars would provide temporary storage for a portion of the mobile fraction of bedload. This alternative was not modeled separately but is expected to have similar localized effects at each ELJ and a smaller overall effect on the system.

No changes to the 1 percent annual chance flood event are anticipated for alternative MS2

3.3 Purdy Field

The Purdy Field is located at the southwestern corner of the intersection of SR 106 and Purdy Cutoff Road (see Map 2 and Sheet 3). The field is currently privately owned and is in agricultural use. Based on modeling results, the field is currently frequently flooded both as overbank flow from upstream at RM 2.6 and via backwater from a slough channel downstream at RM 2.1 just upstream from SR 106. Lateral channel migration has occurred at the upstream bend, eroding a streamside berm that used to extend from Purdy Cutoff Road to the main channel. The eroding bend is currently protected with a log revetment. Continued erosion, particularly at the downstream end of the revetment, is occurring. There are also recent sediment deposits on the floodplain behind the revetment, suggesting that portions of the log revetment may float at high water stage, allowing concentrated flow to access the floodplain.

Project objectives for this site include:

- Increase agricultural viability by reducing flooding of crop areas.
- Improve downstream water quality by reducing wash-off of fertilizers and topsoil.
- Retain more stream power in the mainstem by redirecting flows that are currently scouring the bank.
- Restore riparian habitat.
- Expand aquatic habitat area through side channel creation.

Three alternatives were developed for the field, two of which consider continued agricultural, while the third considers acquisition or an easement that would allow full restoration of the parcel. All three are compatible with in-channel wood replacement, although the ELJ layout would be adjusted locally to maximize its interactions with the field restoration elements.

Map 10 shows the pattern of inundation in the field area under existing conditions, which is the baseline that all other scenarios were compared to assess changes in flooding and velocity.

3.3.1 Purdy Field Alternative 1 – Log Revetment (PF1)

Alternative PF1 (Sheet 11) only focuses on preventing lateral channel migration and involves replacing the existing log structure with a longer complex wood revetment near RM 2.6 to reduce scour and to reduce flow velocities where flows leave the river. This approach could retain more stream power in the mainstem. This structure would:

- Provide cover and habitat in the scour hole adjacent to the right bank.
- Protect agriculture by reducing scour and erosion along the channel bend.
- Potentially improve water quality by reducing overland flow velocities and scour on agricultural soils.

Flood frequency and conditions with the revetment were very similar to the existing conditions scenario. Hydraulic modeling of this alternative indicates that the revetment results in little to no change in inundation frequencies or water depths on the field. Flow velocity across the field does reduce slightly as inundation is dominated by backwater rather than overwash from upstream. While a well-designed log revetment could be effective at reducing erosion along the meander corner, it would not provide significant habitat or flood protection benefits.

3.3.2 Purdy Field Alternative 2 – Offset Berm and Side Channel (PF2)

Alternative PF2 (Sheet 12) involves excavating an 1,110-linear foot right bank side channel starting near the downstream end of the existing log revetment (RM 2.65). The spoils from side channel excavation (12,250 CY) would be used to construct an offset berm to protect the field (replacing an existing berm which has eroded away and failed). The alternative also includes approximately 5 acres of riparian planting in the current agricultural land between the new berm and the existing riparian buffer. This alternative would:

- Expand aquatic habitat area by 1.4 acres through side channel creation.
- Retain more stream power in the mainstem by redirecting flows scouring the bank.
- Increase area of riparian cover by 5 acres.
- Potentially improve water quality by reducing overland flow velocities and scour on the exposed agricultural soils.

Map 11 shows the pattern of inundation with the offset berm and side channel. Under existing conditions, the field appears to flood in roughly equal parts due to backwater through the existing slough near SR 106 and overbank flows through the existing berm breach. The proposed offset berm does not have significant effects on the frequency or duration of flooding for the property because it does not address backwater from downstream.

The side channel results in reduced water surface elevations and maintains higher velocities in the mainstem at the upstream end of Purdy Field. The new side channel increases conveyance in this location and appears to be as or more effective as the berm in reducing floodwaters entering the field from upstream. The berm is not engaged until flows reach 3,000 cfs, when much of the field is already inundated. This suggests that a much smaller, more focused berm across the lowest point could be equally effective at reducing flooding from upstream, though with little change overall due to the backwater from downstream.

3.3.3 Purdy Field Alternative 3 – Full Restoration (PF3)

Alternative PF3 (Sheet 13) would require property acquisition and would involve creating a new, 1,500-linear foot side channel that would connect to and expand the existing swale through the center of the property. This alternative would require approximately 12,000 CY of excavation and would reuse some of this material to reroute the existing swale away from the toe of the SR 106. This alternative could also include 30 to 50 acres of riparian planting. The alternative would:

- Improve downstream water quality by eliminating wash-off of fertilizers and soil from this property.
- Dedicate more space to the river.
- Restore 30 to 50 acres of riparian habitat.
- Expand aquatic habitat area by 2.2 acres through side channel creation.

Hydraulic modeling indicates that the PF3 connects Purdy Field to the river at lower flows than in existing conditions (Map 12). The proposed channel is connected to the river at all flows and begins to spill onto the field at 1,000 cfs. It is possible that these effects are overstated because the LiDAR does not capture the low point of the existing swale, but it is safe to assume that this alternative would significantly increase connectivity between the river and the right overbank. At flows of 10,000 cfs, velocities in the new channel are close to 4 fps near the channel mouth where the river is currently attacking the bank, then decrease to less than 2 fps for the rest of the channel length, so it is possible that the channel will scour and widen over time. However, as noted above, it is not clear at this time if the Skokomish can maintain multiple perennial channels.

It is possible that with an easement, the field could remain in production for hay and grazing, but the landowner would need to be compensated for increased frequency and duration of flooding. A vehicle crossing – likely a bridge, would be necessary to provide access to the area west of the new side channel.

3.3.4 Purdy Field – Evaluating Alternatives

None of the three Purdy Field alternatives were able to increase agricultural viability by reducing flooding of agricultural areas. The water quality benefits of alternatives PF1 and PF2 are questionable. The revetment and the berm do reduce the velocity of flows across the field, but the initial velocity was only 1 fps, reducing to 0.3 fps with the berm. None of the alternatives presented effectively prevent flooding, and only PF3 prevents the potential downstream transport of soils and fertilizer if the land is removed from agricultural production and revegetated with native riparian species.

3.4 Side Channel Creation

We investigated the feasibility of two opportunities to engage off-channel habitats via creating new side channels. Both locations are on the left (facing downstream) overbank. The shorter alignment, SC1, leaves the mainstem near RM 3.05 and returns near RM 2.55, while the longer route, SC2, leaves the mainstem near RM 3.2 and returns near RM 2.5.

For both alignments, the proposed side channel was assumed to be approximately 30 to 40 feet wide at top of bank, roughly half the width of the adjacent mainstem. The side channel thalweg would be at the same elevation as the mainstem thalweg to promote perennial engagement. In either alignment, the new side channel would be shorter than the existing flow path with a steeper slope, which could promote increased velocities and sediment transport. It could also serve as a sediment sink, providing more area for sediment to deposit without raising the bed elevation of the mainstem.

In addition to creating aquatic habitat and providing a potentially more efficient route for transporting sediment, the new side channel could help to take some pressure off the adjacent portion of Purdy Cutoff Road. Any side channel creation would need to consider both protection of existing infrastructure and potential impacts to established tribal fishing locations. The area proposed for side channel construction has challenging access, which should be considered when evaluating the feasibility of these alternatives.

Please note that the Purdy Field side channel (PF 2) could also be included on this list, but is only discussed in the section above.

3.4.1 Side Channel Alternative 1 – Short Route (SC1)

Alternative SC1 (Sheet 14) considers creating a new side channel on river left between approximately RM 3.05 and 2.55. The channel is 1,675 feet long and would require significant excavation, as the floodplain is approximately 6 to 10 feet higher than the mainstem thalweg. Initial volume estimates indicate that approximately 10,000 CY of excavation would be required, but that volume may be overestimated if LiDAR did not accurately capture bed elevation of existing low spots that may be holding water. With site survey it may also be possible to connect localized low points to avoid tree removal and minimize excavation.

Velocities in the proposed channel are close to 4 fps near the channel mouth at the outside of meander bend, then decrease to less than 2 fps for the rest of the channel length, see Map 13, so it is possible that the channel will scour and widen over time. Over the range of flows analyzed (500 cfs to 10,000 cfs) the side channel does not appreciably change floodplain connectivity on the left overbank. That area is already very wet and inundates through multiple flow paths. The side channel increase flow velocities and the volume of flow passing through the area but does not change inundation extents.

3.4.2 Side Channel Alternative 2 – Long Route (SC2)

Alternative SC2 (Sheet 15) explored a longer side channel route, 2,925 linear feet. The alignment for SC2 took advantage of existing low areas along the bank and apparent overbank flow paths to reduce required excavation. Initial volume estimates indicate that this route would require approximately 7,100 CY of excavation, so nearly doubling the length of channel with less excavation. The excavation volume is almost certainly overestimated as the LiDAR would not accurately capture the bed elevation of the existing, wetted drainage. This alternative route is on Skokomish Tribe land and extends north of old Skokomish River Road with the potential need for two new crossing structures to retain road access.

It also traverses a large wetland complex, which would make equipment access extremely challenging and increase permitting complexity. Full excavation of a channel along this alignment may be infeasible, due primarily to equipment access and constructability issues.

The longer side channel SC2 route is more hydraulically effective than the SC1 route, with velocities close to 4 fps near the channel mouth and near or above 3 fps for much of the rest of the channel length, see Map 14. The longer proposed side channel alignment reduces inundation slightly in the left overbank by providing a more effective conveyance route. It also reduces velocities slightly in the mainstem. Overall, this alternative appears to be the more viable of the two for producing a potentially self-sustaining side channel. The greater length also maximizes the potential habitat benefits.

3.4.3 Side Channel Alternative 3 – Excavate Channel Openings Only (SC3)

To reduce excavation costs and impacts, Alternative SC3 was developed to only excavate the ends of the potential side channel path to connect existing side drainages or low spots to the river and then allow flows into these areas to potentially carve and widen the side channel into an alternative flow route, similar to the existing multi-thread channel at the Purdy Creek confluence or the upstream side channel / avulsion near RM 9.5. This could be attempted for either side channel route but might be more successful for Alternative 2 since most of the proposed path already exists as a well-defined flow route and modeled forces are higher. If flows do not carve and widen the channel, then the excavated areas serve as alcoves, providing high flow refugia and off-channel habitat.

The primary disadvantage of this “Ends Only” approach is that we do not have strong evidence to suggest that the channels will develop with low velocities in the densely vegetated overbank. This reach of the Skokomish River is depositional, and changes in channel morphology and flow regime reduce the chances of cutting a new channel. If floodwaters leave the mainstem through the new opening, but do not cut a new channel or follow the anticipated route to return to the river, this might increase flooding frequency and inundation depth in the left overbank. If the “Ends Only” approach does work and sufficient energy is available to cut a new channel in this reach, it will produce a significant amount of sediment which would be transported to downstream reaches and may increase sediment deposition and aggradation issues in those areas.

3.5 Revegetation

All the alternatives discussed above, except the instream ELJ installations, would include plantings of native riparian species. New side channels would all include a 50- to 150-foot-wide buffer zone of native plantings on each bank, and the offset berm would similarly be fully vegetated. Bank structures such as the ELJ – Alternative 2 deflectors or the Purdy Field – Alternative 1 log revetment would be backfilled with native soils and alluvium and planted with willow live stakes to encourage vegetative establishment. Vegetating instream structures, such as the apex ELJs, may not be feasible, but in sufficient material racks on the structure, willows or other flood tolerant species may recruit and vegetate naturally. Access roads and staging areas will be restored to pre-construction conditions or better, as agreed to by landowners.

3.6 Alternatives Summary

Each of the alternatives was reviewed against criteria for:

- Primary Habitat Benefits
- Influence on flood heights and inundation duration
- Influence on sediment transport
- Influence on adjacent properties
- Constructability considerations
- Cost Considerations

Alternatives are summarized in the matrix on the following pages.

Asdf

Alternative Group	Alternative	Description	Primary Habitat Benefits	Influence on flood heights and inundation duration	Influence on sediment transport	Influence on adjacent properties	Constructability considerations	Cost considerations
Mainstem Large Wood	MS 1	Dense installation of apex and deflector ELJs to develop a more complex flow path within the mainstem and increase the potential for increased net sediment transport.	Increase in pool density and cover quality scaled to number of ELJs (31 total).	current alternative shown increases 1% AC flood stage. Can be designed to avoid flood impacts but may limit effectiveness for sediment transport and pool creation	Local increases of transport with increases in channel storage on bars. Best likelihood of reach scale increase in sediment transport rates through a combination of channel narrowing and integrative hydraulic effects of log jams. Hydraulic investigations suggest limited velocity changes so there is a high degree of uncertainty regarding long term sediment trend.	No changes to overbank flow patterns for inundation frequency, direction, or duration. Deflectors provide increased protection for Purdy Cutoff Road.	Will require instream work to install, including temporary access and dewatering. Vehicle access from right bank may be challenging due to extensive wetland areas.	Most costly of the mainstem options due to number of ELJs and difficult access
	MS 2	Installation of apex ELJs aligned to existing gravel bars.	Increase in pool density and cover quality scaled to number of ELJs (8 total).	Can be designed to avoid flood impacts.	Local increases of transport with increases in channel storage on bars. Less likely to produce reach scale changes in sediment transport.	No changes to overbank flow patterns for inundation frequency, direction, or duration.	Will require instream work to install, including temporary access and dewatering. Vehicle access from right bank challenging due to extensive wetland areas.	Least costly of the mainstem options due to reduced number of ELJs avoiding the most difficult access

Alternative Group	Alternative	Description	Primary Habitat Benefits	Influence on flood heights and inundation duration	Influence on sediment transport	Influence on adjacent properties	Constructability considerations	Cost considerations
Purdy Field	PF 1	Replace existing log revetment with longer complex wood revetment.	Localized pool formation and improved cover at the revetment location.	Minimal flood changes; slight reduction in overbank flow velocity.	Minimal change.	No change to existing property use (excluding temporary construction impacts).	Requires localized dewatering of mainstem.	High cost to install 400 feet of robust revetment.
	PF 2	Set back low berm and excavate new side channel to form forested island. Native riparian restoration within the setback area.	Increased perennially inundated side channel habitat (1.4 ac). Increased riparian cover (5 acres).	Minimal flood changes: new side channel is effective at lowering flood stage at the upstream side of the Purdy Field, but not on the downstream. No changes for 1% AC flow.	Increased conveyance in the main and proposed channel slightly increases velocity in both channels, suggesting that PF2 would not increase aggradation and could subtly increase sediment conveyance at RM 2.5.	Reduction of 5 acres of current agricultural field for new channel and setback.	Relatively straightforward construction, primarily in uplands with up and downstream connections to the mainstem. ~12,250 CY of cut and placement.	Moderate to low construction costs based on excavation, local haul and transport of materials, and native revegetation.
	PF3	Full restoration of Purdy Field with connection of new side channel and native riparian revegetation.	Increased perennially inundated side channel habitat (2.2 ac). Increased riparian cover (30 to 50 acres). Removal of agricultural land use in the floodplain (13.5 acres).	Purdy Field begins to flood at lower flows than under existing conditions, but there is reduced flood risk due to land use conversion. No changes for 1% AC flow.	New side channel provides temporary sediment storage in the channel and on the floodplain.	Land use conversion on Purdy Field. Reduction in risk for SR 106 with re-routing side channel away from road bed. Design would avoid typical erosion along the driveway at Purdy Cutoff Road	Straightforward construction with good access. Would require haul of ~12,000 CY of material to avoid floodplain impacts.	Moderate initial construction costs due to longer side channel and greater area of riparian vegetation. Potentially lower long-term costs as the site would be returned to the river.

Alternative Group	Alternative	Description	Primary Habitat Benefits	Influence on flood heights and inundation duration	Influence on sediment transport	Influence on adjacent properties	Constructability considerations	Cost considerations
New Side Channels	SC1	Excavation of 1,675 linear feet of new side channel on left overbank from RM 3.05 to 2.55.	Increased perennially inundated side channel habitat (1.6 ac). Could reduce flow and habitat in existing mainstem. Routes flow through shaded riparian area.	Minimal flood changes with no increase in 1% AC stage.	New side channel provides temporary sediment storage in the channel and on the floodplain. New side channel would reduce flowpath length and marginally increase slope, which could capture the mainstem and increase sediment transport efficiency.	No property impacts based on current uses. Potential to reduce the amount of flow in the existing mainstem, which could change habitat and tribal fishing locations.	Difficult construction access. Would require haul of ~10,000 CY of material to avoid wetland impacts.	High unit cost for excavation and haul, given access constraints.
	SC2	Excavation of 2,925 linear feet of new side channel on left overbank from RM 3.2 to 2.5.	Increased perennially inundated side channel habitat (1.9 ac). Could reduce flow and habitat in existing mainstem. Routes flow through shaded riparian area. Follows, expands, and connects existing floodplain drainages.	Minimal flood changes with no increase in 1% AC stage.	New side channel provides temporary sediment storage in the channel and on the floodplain. New side channel would slightly reduce flowpath length and marginally increase slope which could capture the mainstem and increase sediment transport efficiency.	Potential change for Skokomish Tribe by removing portion of Skokomish River Road or installing water crossing structures. Potential to reduce the amount of flow in the existing mainstem, which could change habitat and tribal fishing locations.	Difficult construction access and would require haul of ~7,100 CY of material to avoid wetland impacts.	High unit cost for excavation and haul given access constraints but would be less overall excavation than SC1 and would provide a longer flowpath.
	SC3	Excavate channel openings only.	Limited initial habitat benefit consisting of off-channel alcoves along mainstem. May evolve into longer perennial side channel.	Minimal changes with no increase in 1% AC stage. Overbank velocities are higher at the excavation points, suggesting some potential for continued channel evolution, but overall velocities are low, so channel development and maintenance is highly uncertain.	No immediate changes but could evolve into side channel with changes as described for SC1 and SC2.	No property impacts based on current uses but could evolve into an issue if Skokomish River Road is fully washed out. Potential to reduce the amount of flow in the existing mainstem, which could change habitat and tribal fishing locations.	Difficult construction access, but limited excavation volume.	High unit cost for excavation and haul given access constraints.

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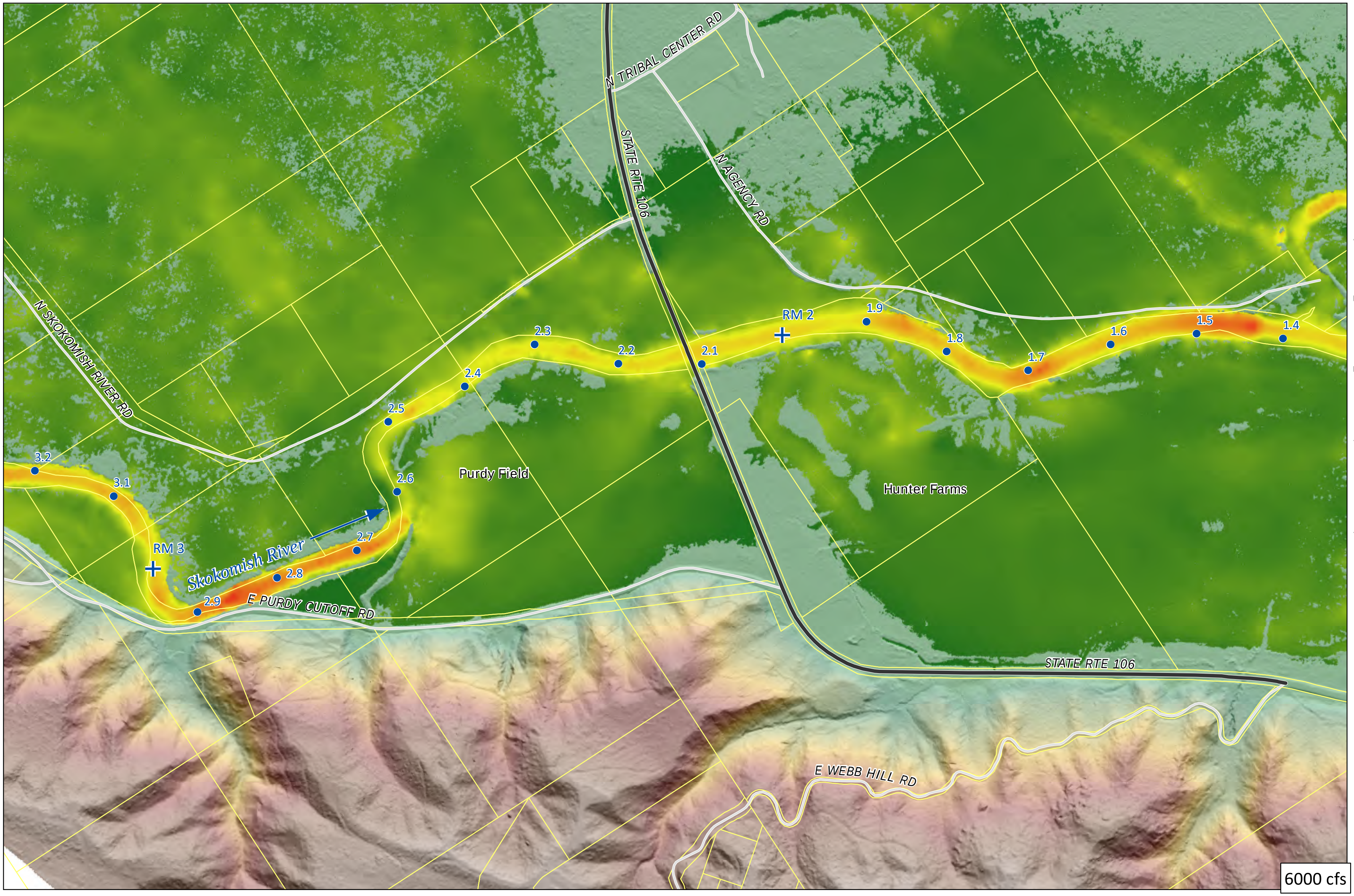
Attachment A

Supporting Maps

Natural Systems Design



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Skokomish River Mile 1.5

Map 1

Modelled Velocity

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Velocity (ft/s)

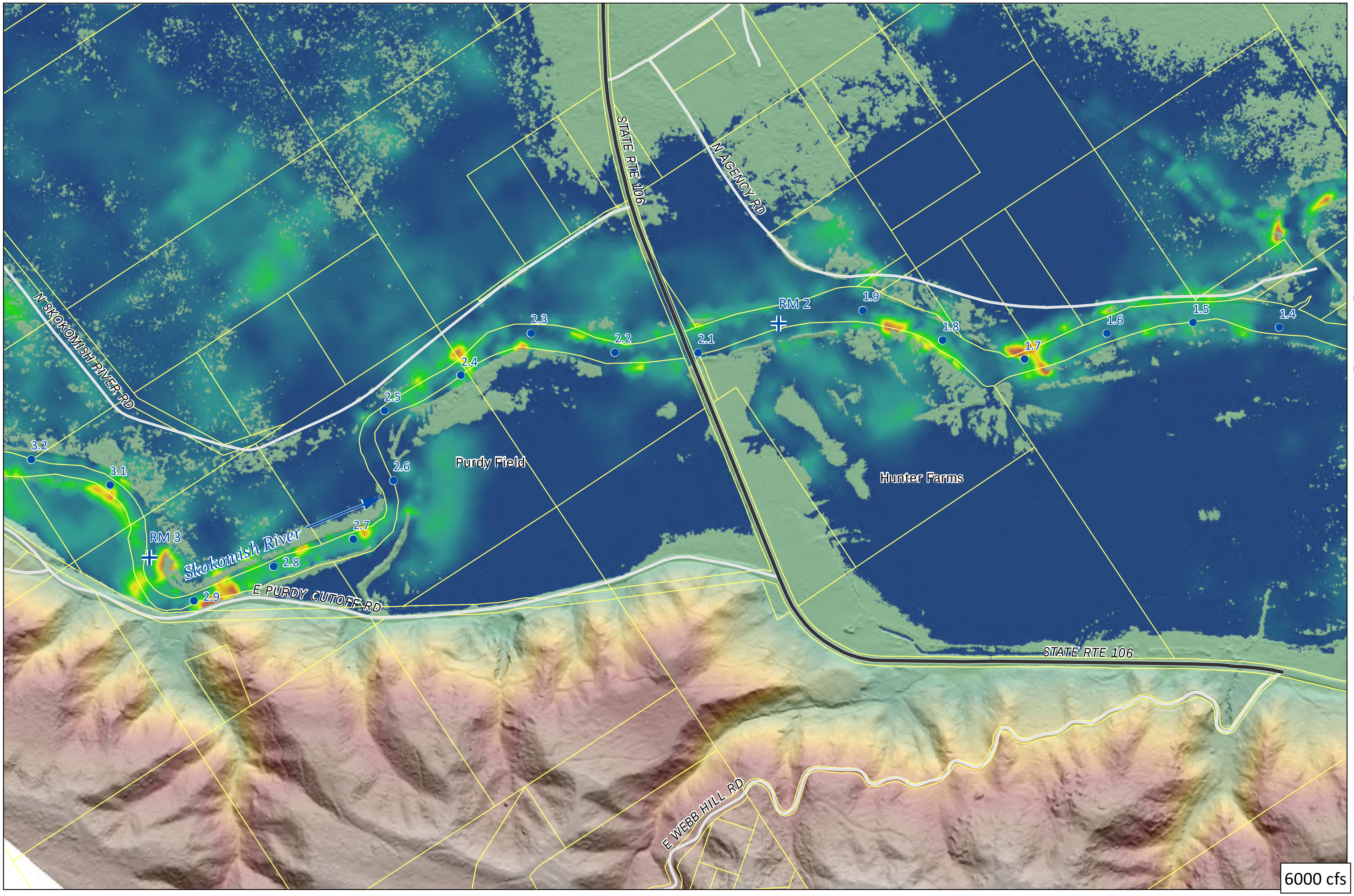
High : 7.4

Low: 0

Natural Systems Design

0 400 800

Feet



Skokomish River Mile 1.5

Map 2

Modelled Shear Stress

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Shear Stress (lb/ft^2)

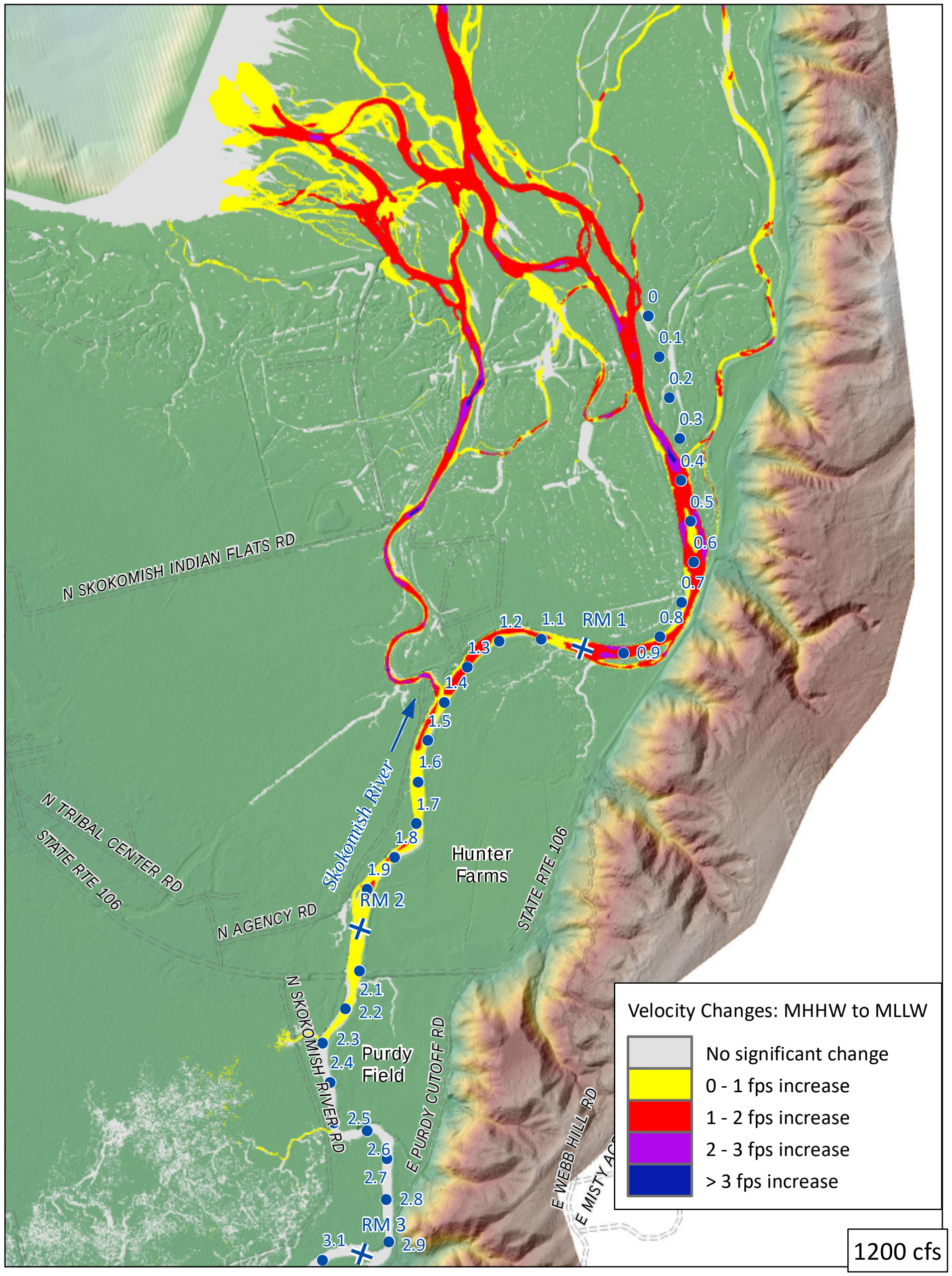
High : 1.7

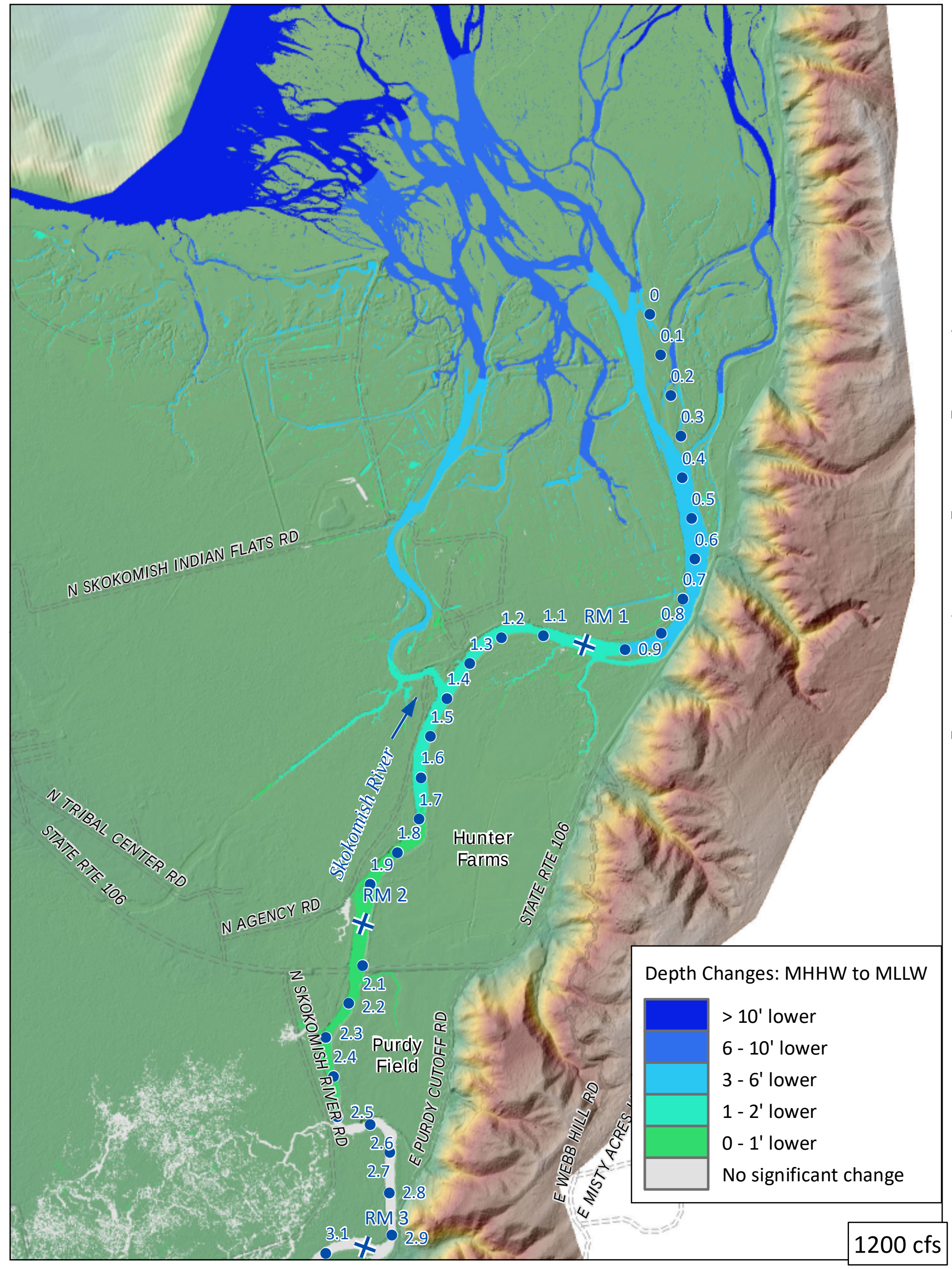
Low : 0

Natural Systems Design

0 400 800

Feet





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Skokomish River Mile 1.5

Map 3

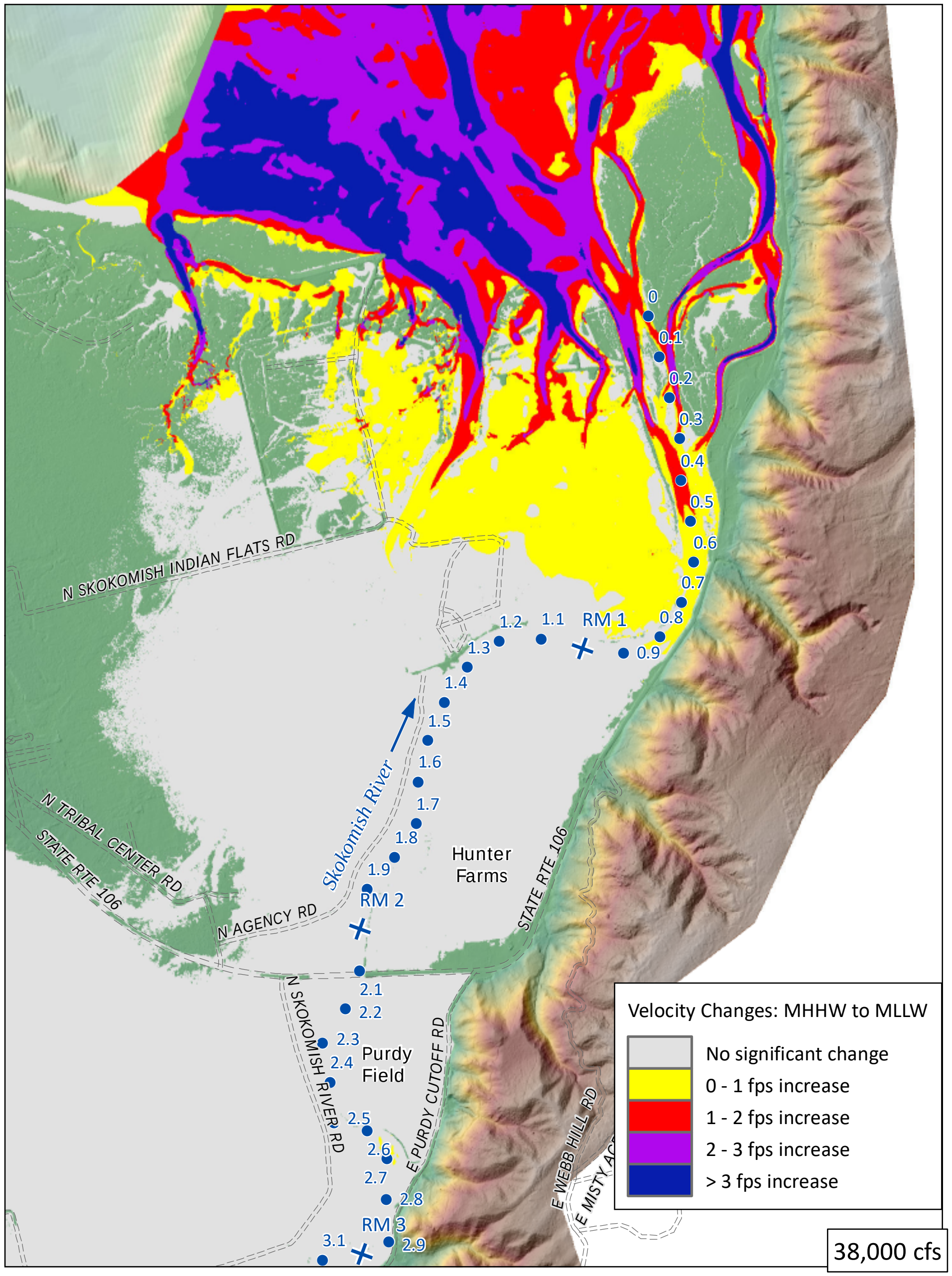
Tidal Influence at Low Flow

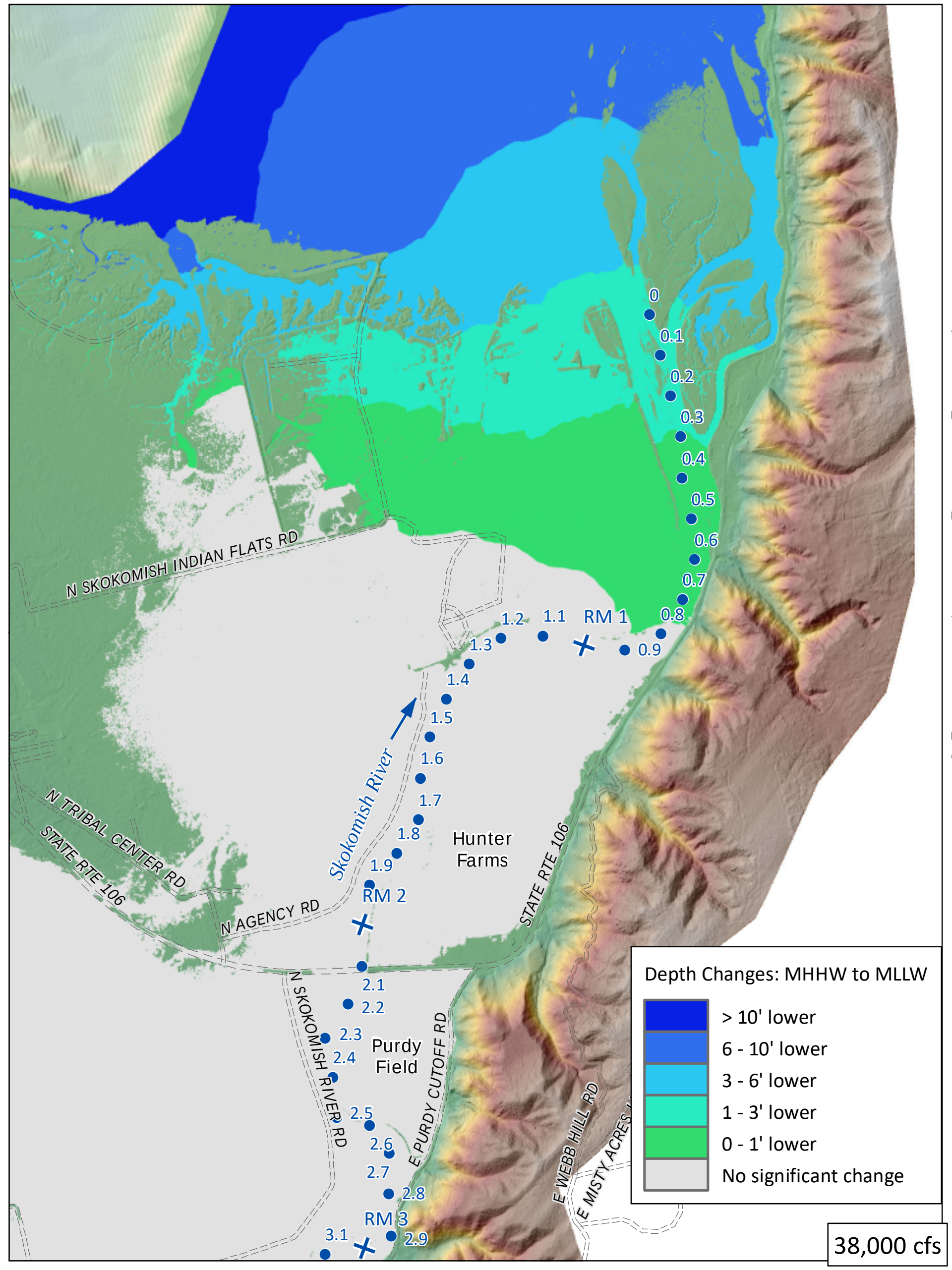
Variability in hydraulic conditions on the Skokomish River between MHHW and MLLW under low flow (1200 cfs) conditions. Values represent differences in velocity and depth at low tide relative to high tide.

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Natural Systems Design

0 1,000 2,000 Feet





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Skokomish River Mile 1.5

Map 4

Tidal Influence at High Flow

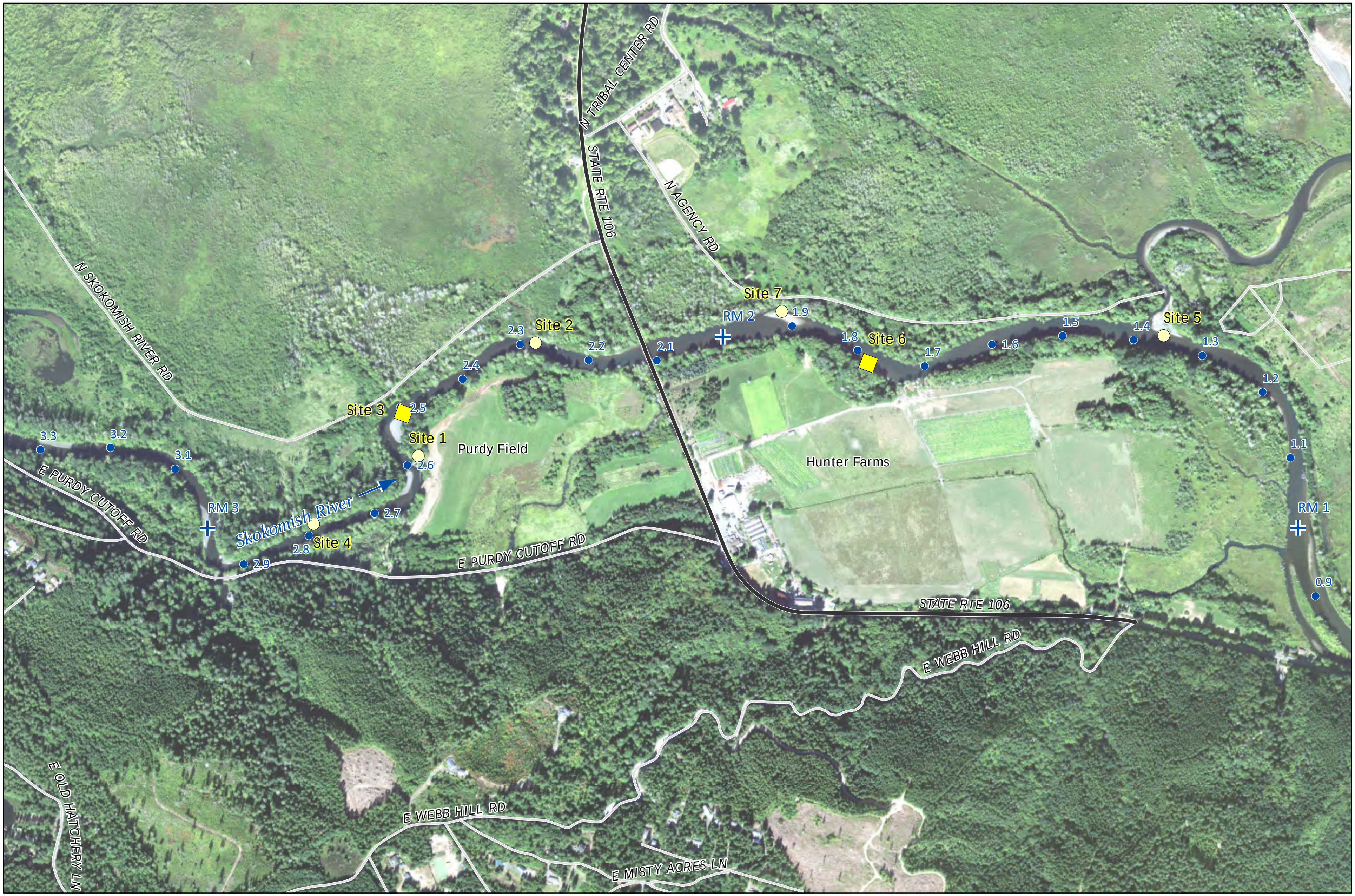
Variability in hydraulic conditions on the Skokomish River between MHHW and MLLW under 100-year flood (38,000 cfs) conditions. Values represent differences in velocity and depth at low tide relative to high tide.

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Natural Systems Design

0 1,000 2,000

Feet



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Skokomish River Mile 1.5

Map 5

Gravel Count and Sieving Sites

NAD 1983 StatePlane Washington North FIPS 4601 Feet

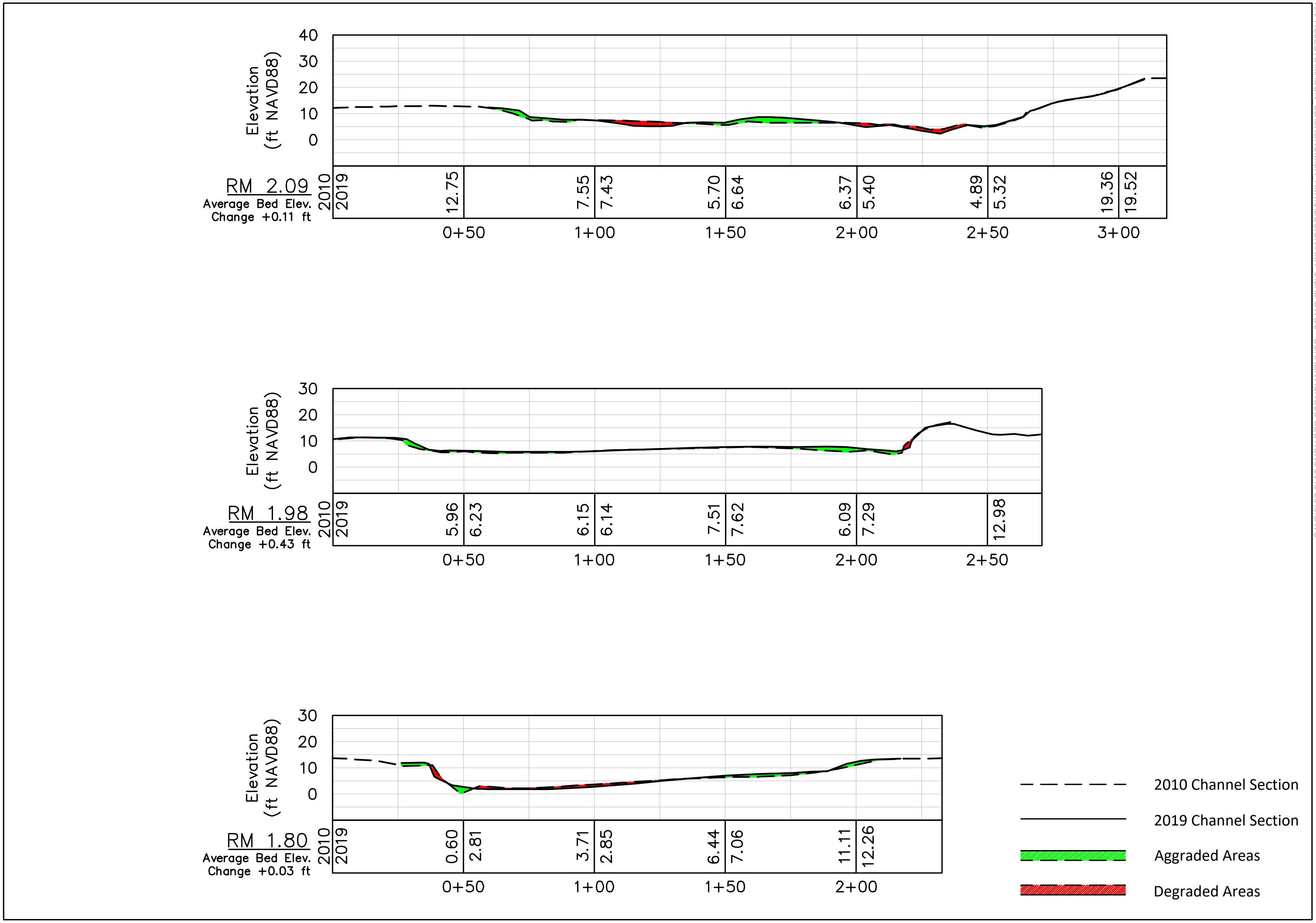
Sediment Sample Sites

- Gravel Count
- Gravel Count and Sieving Site

Natural Systems Design

0 500 1,000

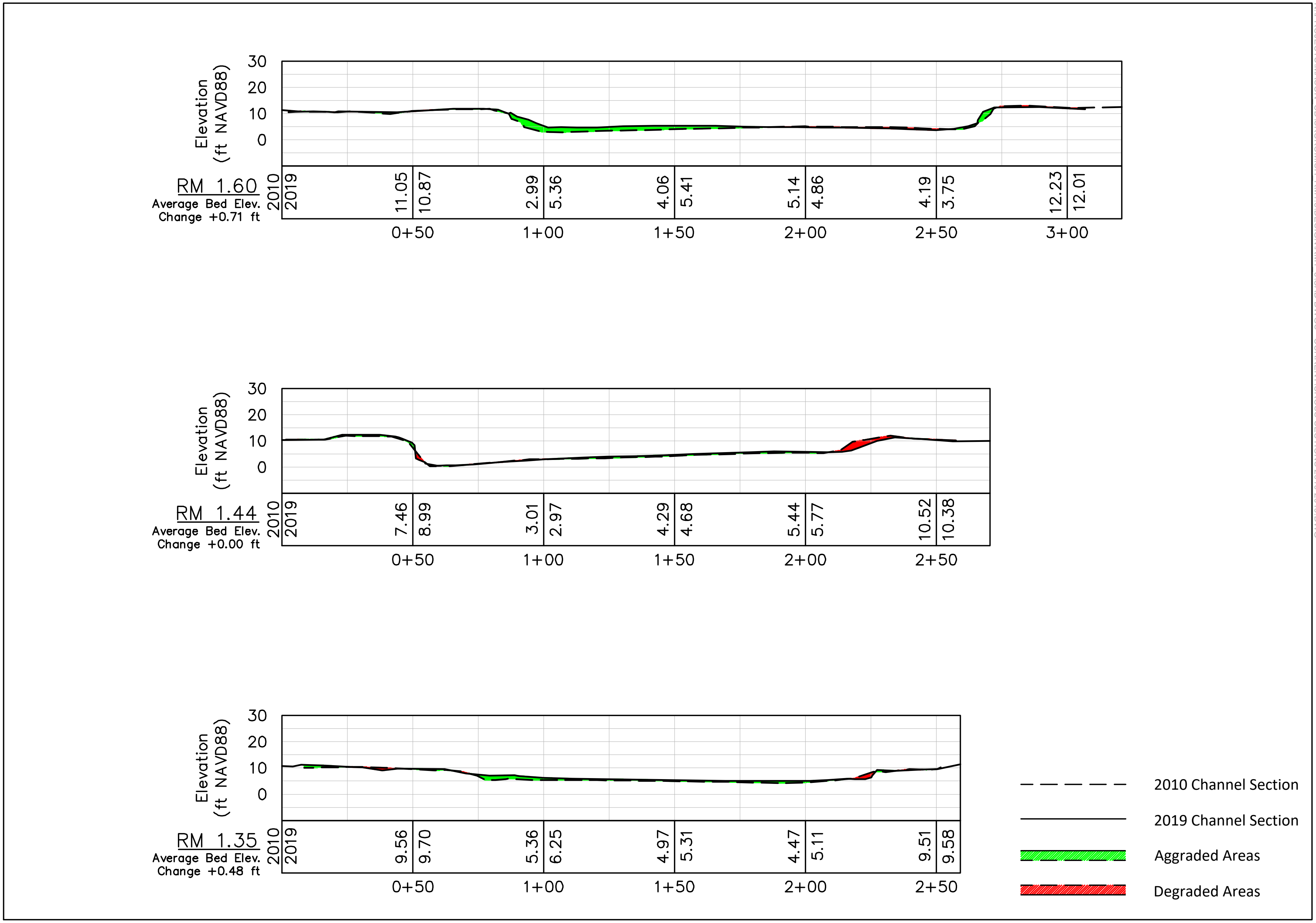
Feet



Skokomish RM 1.5

Mainstem Cross Section Comparison

Map 6

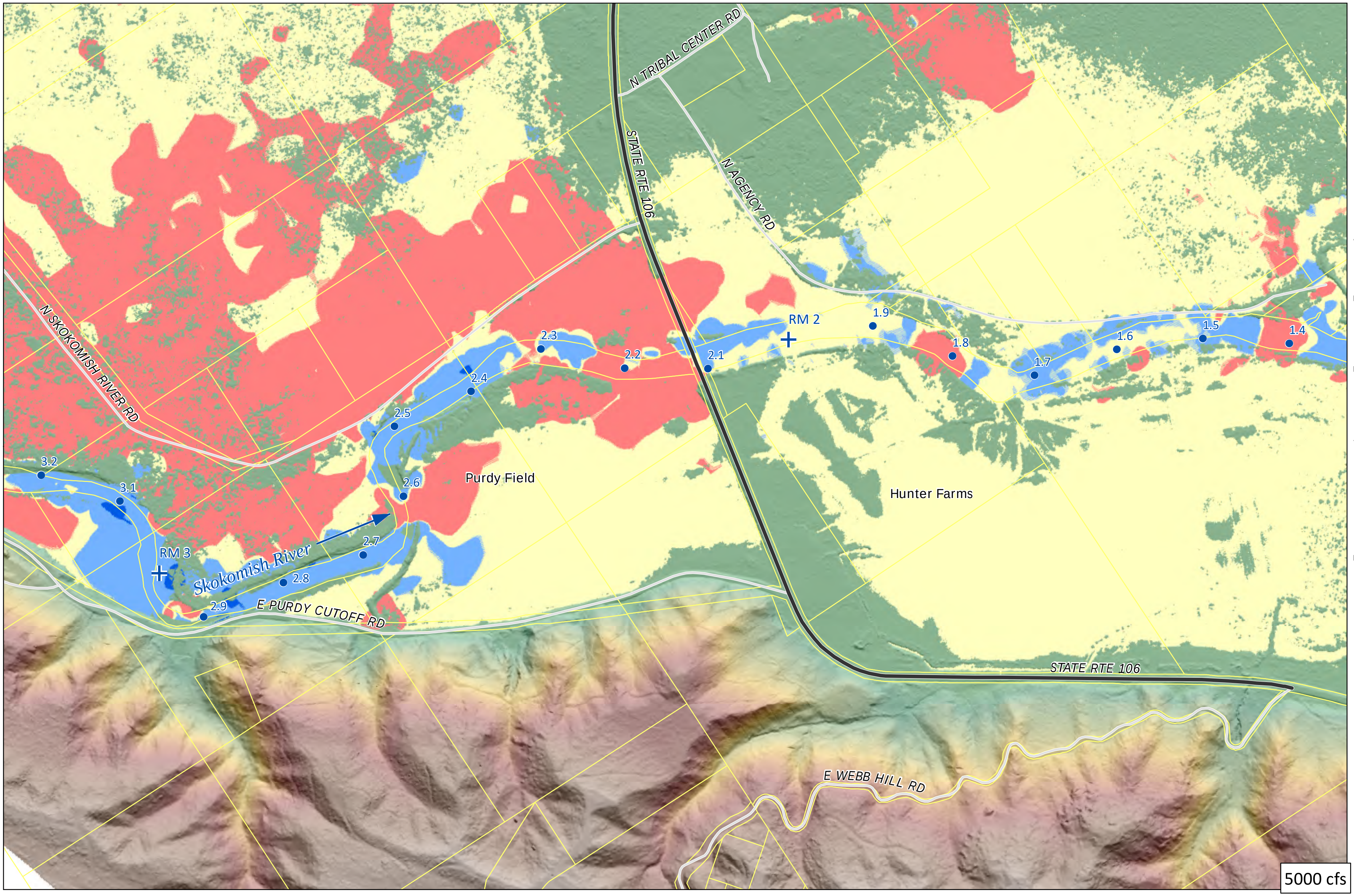


Skokomish RM 1.5

Mainstem Cross Section Comparison

Map 7

Natural Systems Design



Skokomish River Mile 1.5

Map 8

Changes in Shear Stress with Channel Constriction

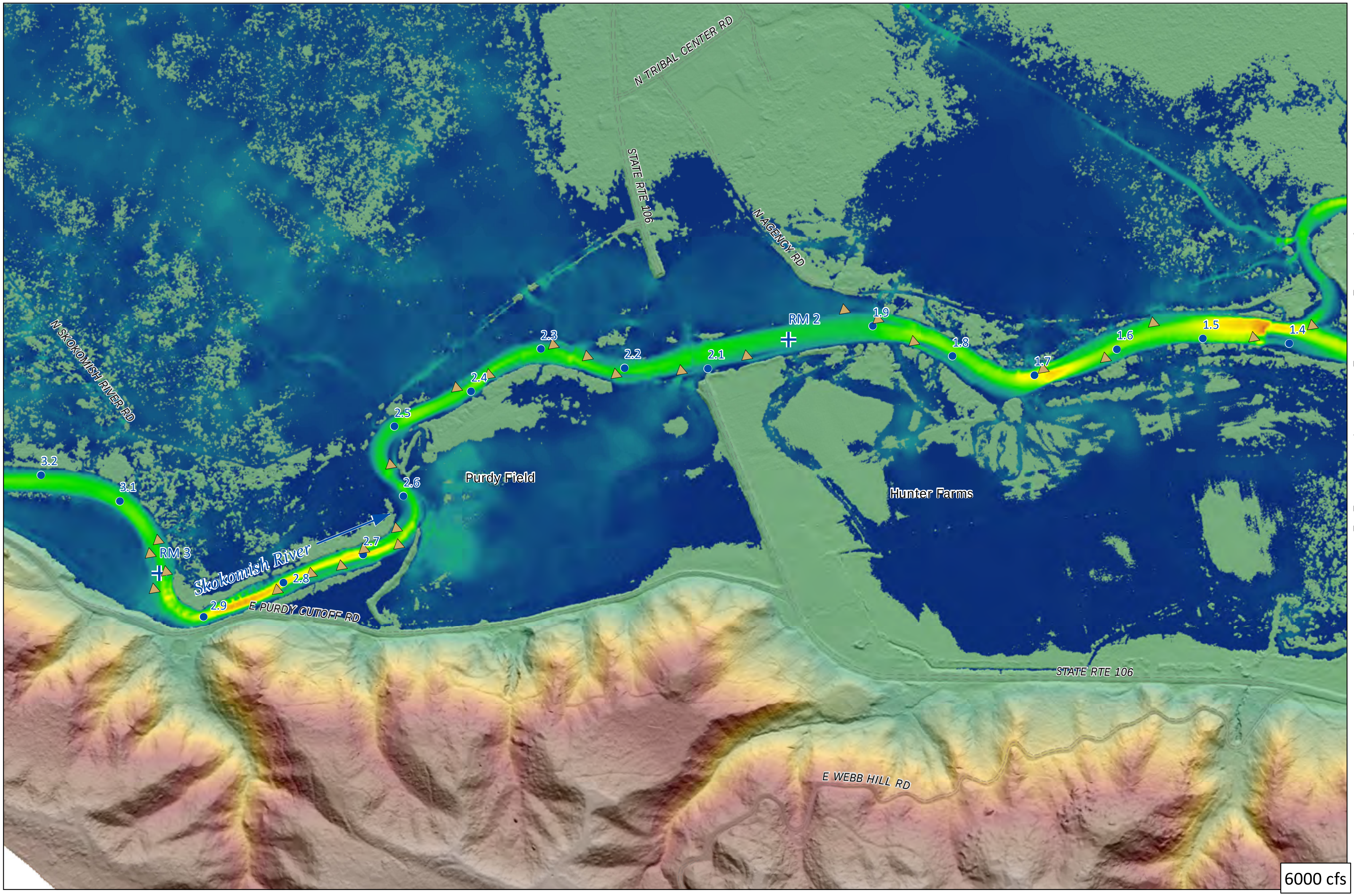
NAD 1983 StatePlane Washington North FIPS 4601 Feet

Change in Shear Stress (lb/ft^2)

- 0.25 - 1.0 decrease
- 0.01 - 0.25 decrease
- No change
- 0.01 - 0.25 increase
- 0.25 - 1.0 increase

Natural Systems Design

0 400 800
Feet



Skokomish River Mile 1.5

Map 9

ELJ Alternative 1 (Proposed Conditions)

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Proposed ELJ

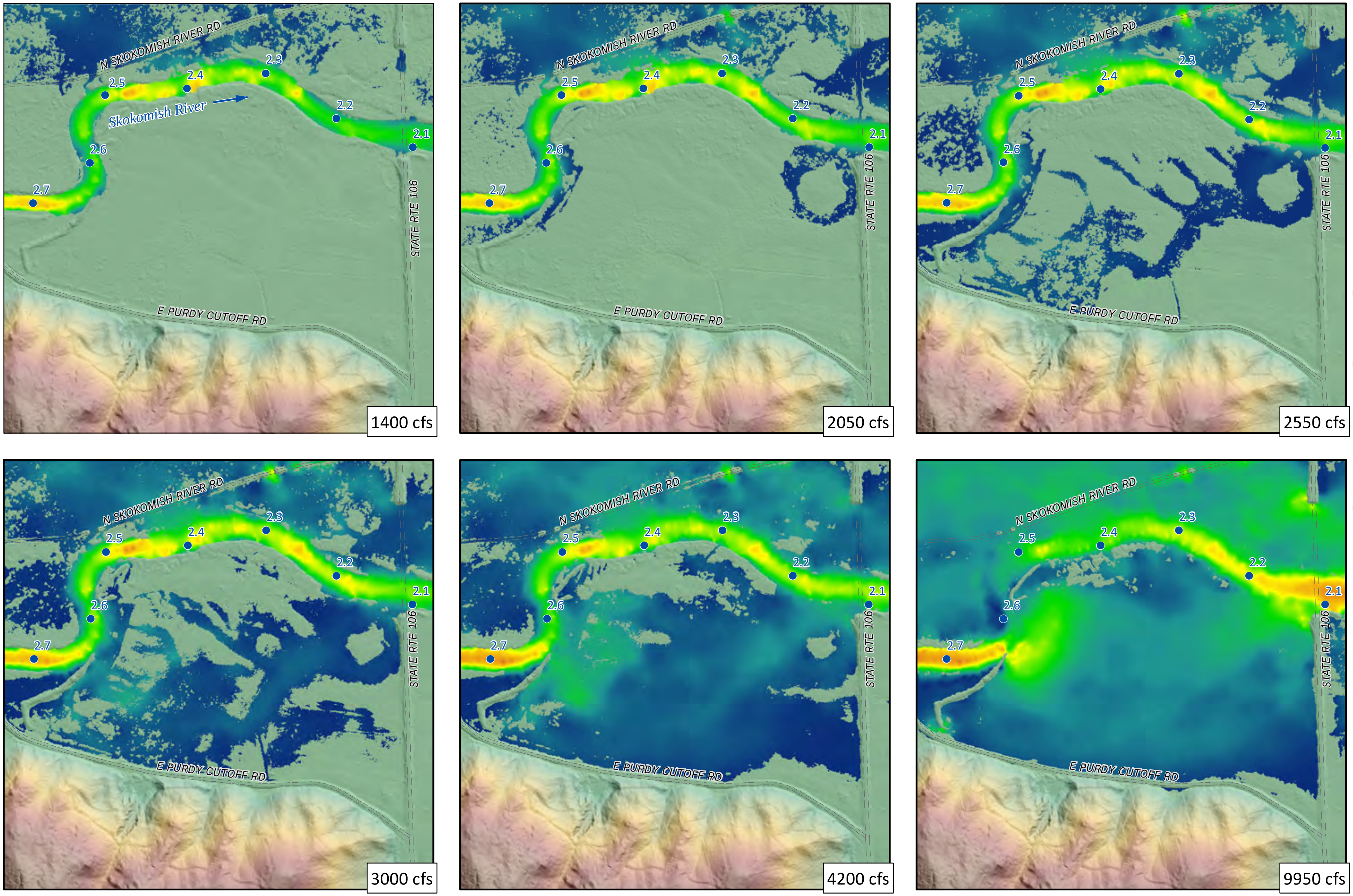
Velocity (fps)

11 — 0

Natural Systems Design

0 400 800

Feet



Author: D Stratten Date: 6/3/2021 Path: N:\Projects\Mason_CD\Skokomish_RM1.5\GIS\maps\mxd\DBS\EC_TimeStep.mxd

Skokomish River Mile 1.5

Map 10

Purdy Field Inundation (Existing Conditions)

Hydraulic conditions on the Skokomish River at Purdy field during a modelled rain event under existing conditions illustrated at a variable

NAD 1983 StatePlane Washington North FIPS 4601 Feet

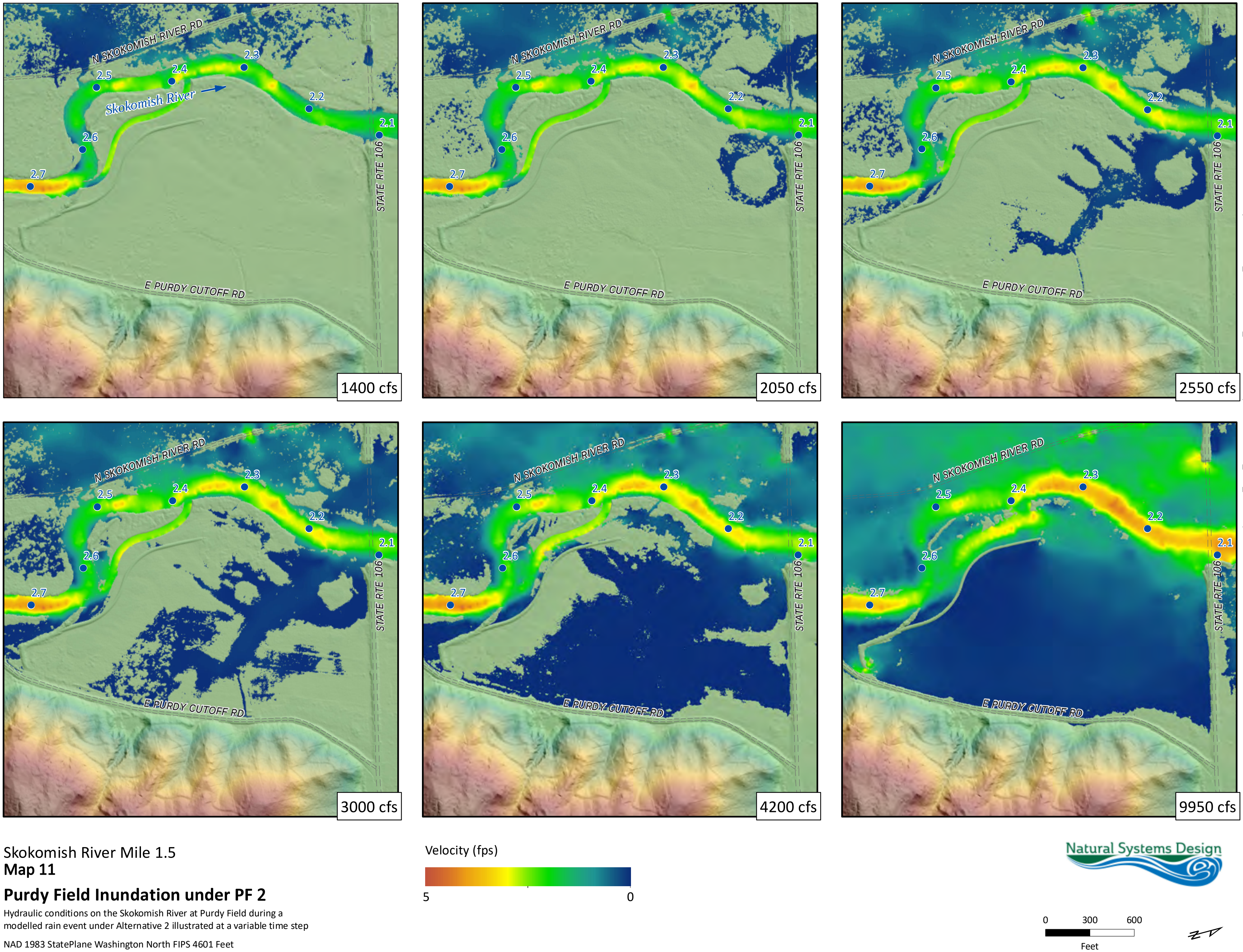
Velocity (fps)

5 0

Natural Systems Design

0 300 600

Feet



Author: D Stratten Date: 6/3/2021 Path: N:\Projects\Mason_CD\Skokomish_RM1.5\GIS\maps\mxd\DBS\PC_Alt2_TimeStep.mxd

Skokomish River Mile 1.5

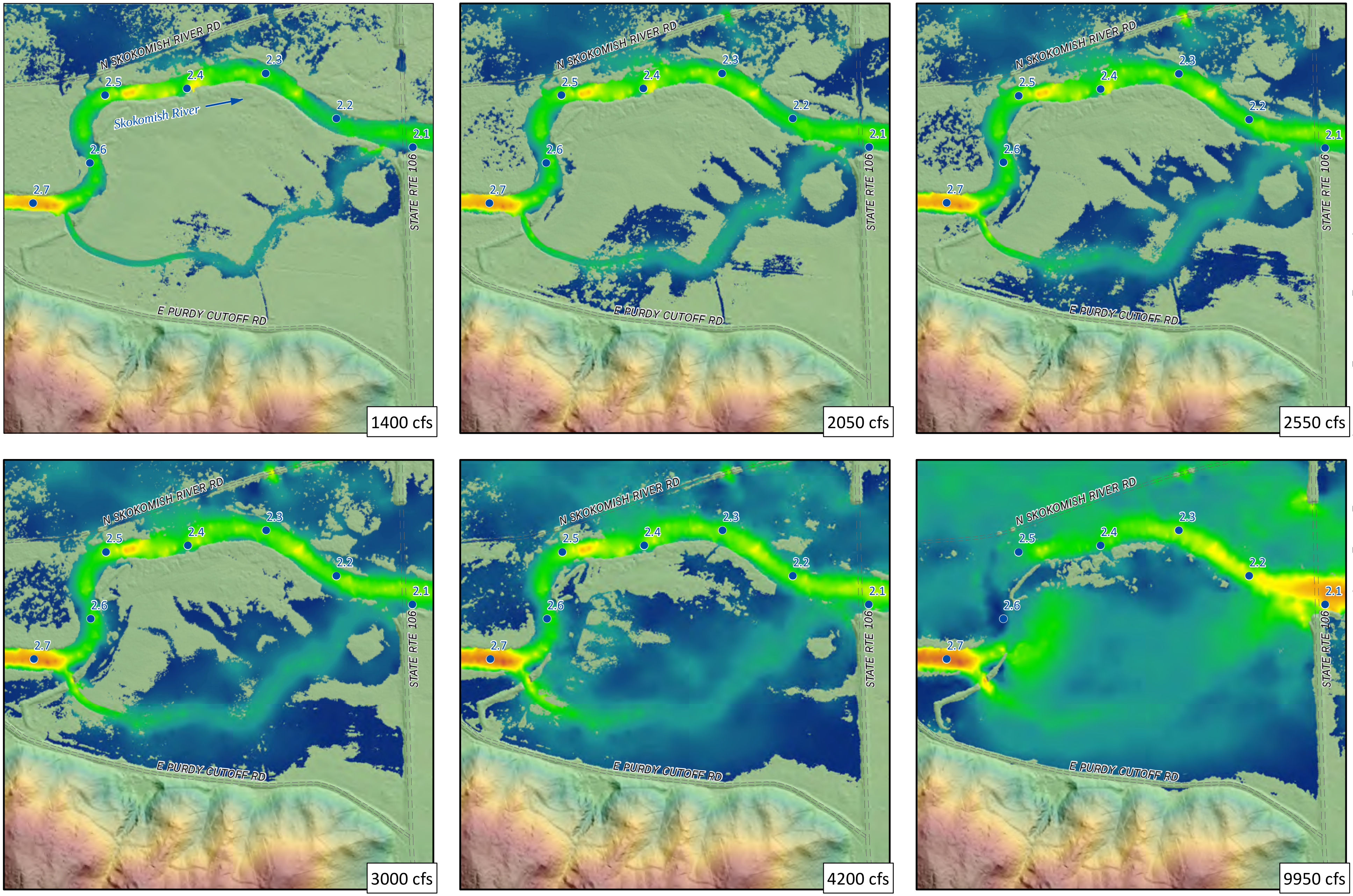
Map 11

Purdy Field Inundation under PF 2

Hydraulic conditions on the Skokomish River at Purdy Field during a modelled rain event under Alternative 2 illustrated at a variable time step

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Natural Systems Design



Author: D Stratten Date: 6/3/2021 Path: N:\Projects\Mason_CD\Skokomish_RM1.5\GIS\maps\mxd\DBS\PC_FullRest_TimeStep.mxd

Skokomish River Mile 1.5

Map 12

Purdy Field Inundation (Alternative PF3)

Hydraulic conditions on the Skokomish River at Purdy Field during a modelled rain event

NAD 1983 StatePlane Washington North FIPS 4601 Feet

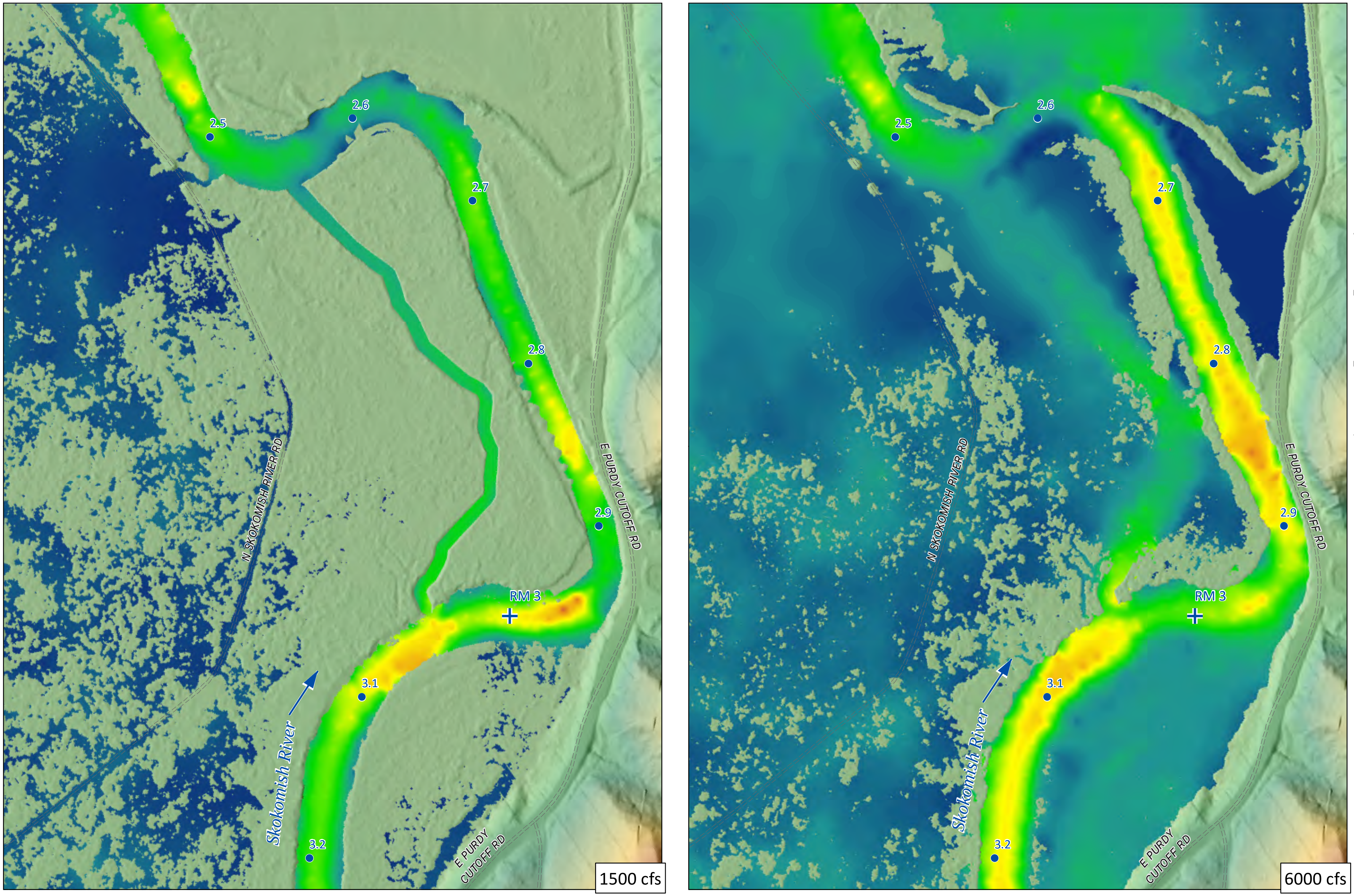
Velocity (fps)

5 — 0

Natural Systems Design

0 300 600

Feet



Skokomish River Mile 1.5 **Map 13**

Left Side Channel - SC11

Hydraulic conditions on the Skokomish River under proposed conditions with the short left side channel alternative.

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Velocity (fps)

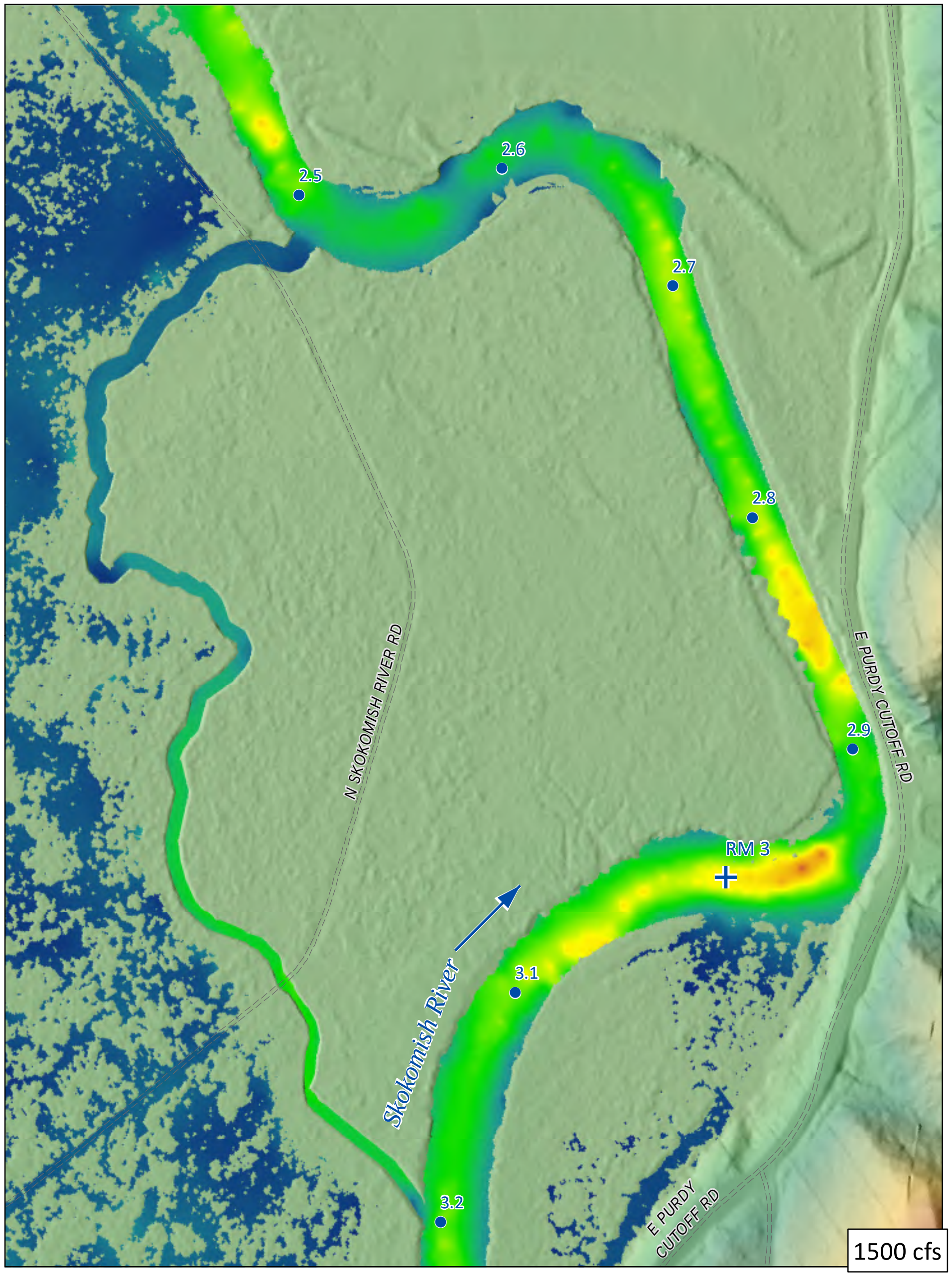
6 — 0

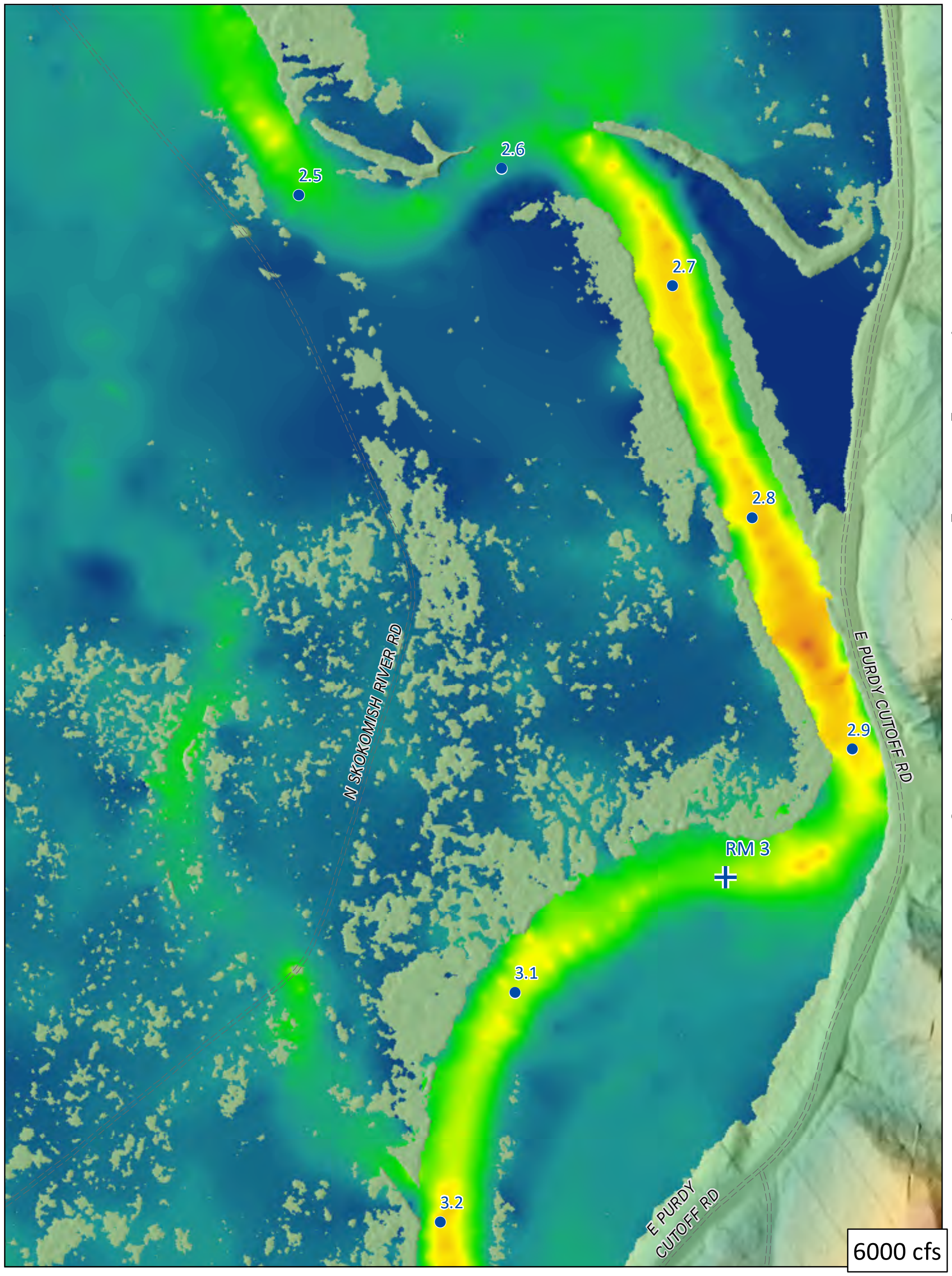
Natural Systems Design

0 200 400

Feet

Author: D Stratten Date: 6/3/2021 Path: N:\Projects\Mason_CD\Skokomish_RM1.5\GIS\maps\mxd\DBS\SideChnl-Short.mxd





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Skokomish River Mile 1.5 **Map 14**

Left Side Channel - SC2

Hydraulic conditions on the Skokomish River under proposed conditions with the long left side channel alternative.

NAD 1983 StatePlane Washington North FIPS 4601 Feet

Velocity (fps)

6 — 0

Natural Systems Design

0 200 400

Feet

Attachment B

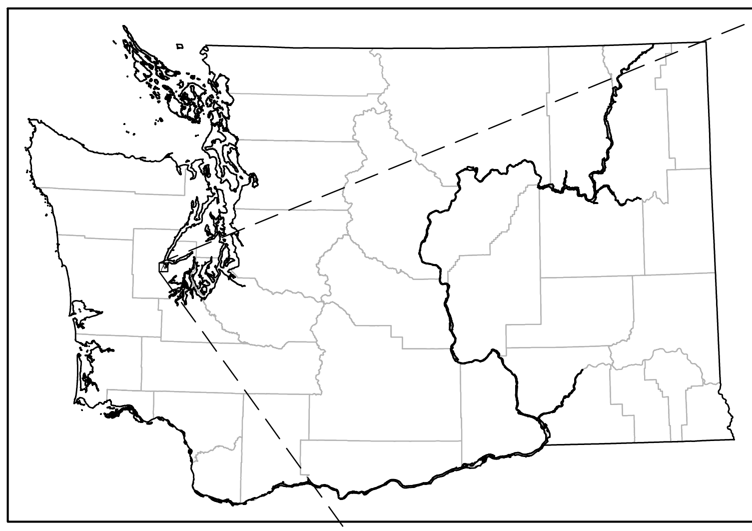
Preliminary Alternatives Drawing Set

Natural Systems Design

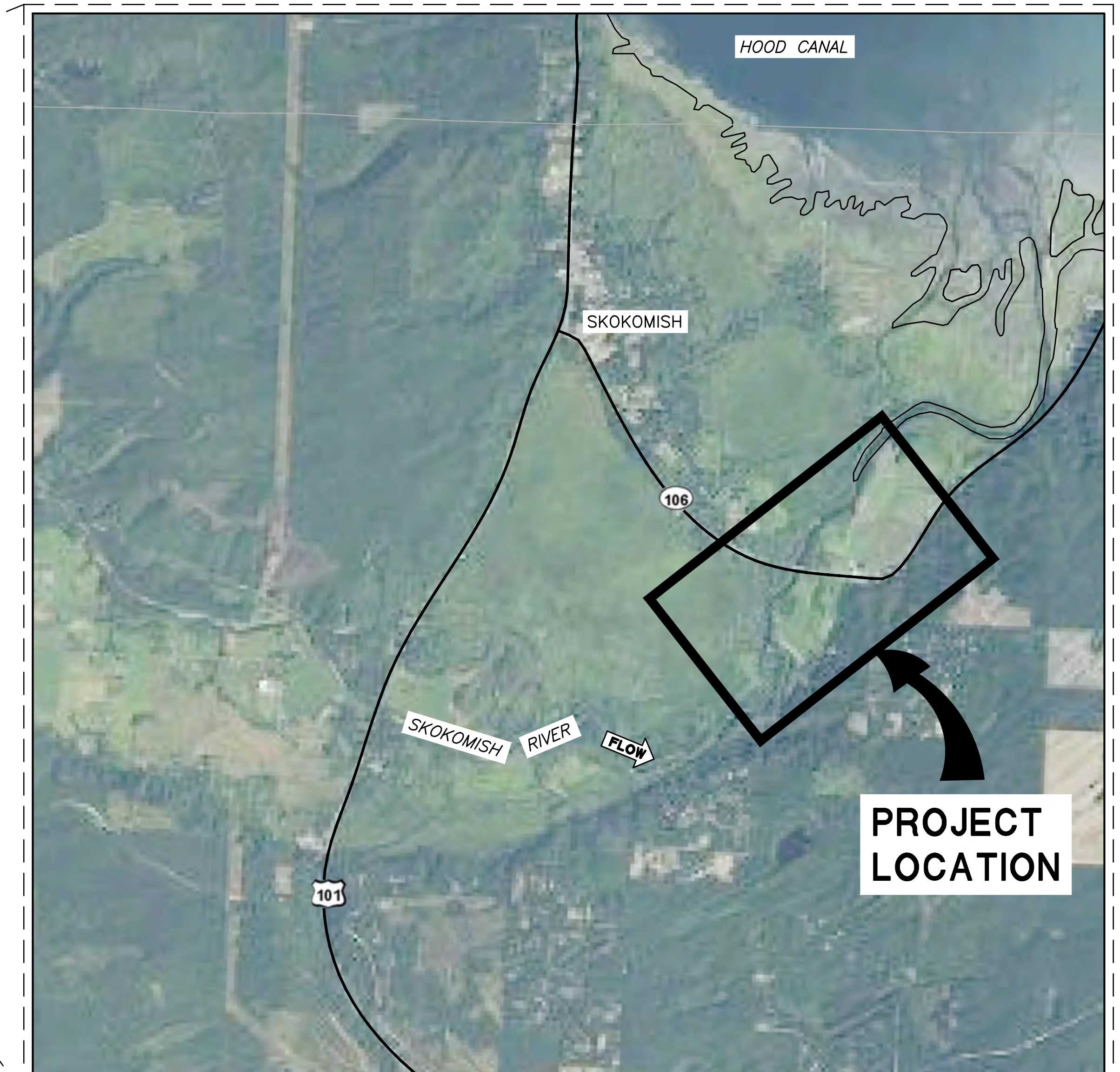
SKOKOMISH RIVER

MAINSTEM MILE 1.5 HABITAT RESTORATION ALTERNATIVES

MASON CONSERVATION DISTRICT



WASHINGTON STATE
SCALE: 1" = 50 MILES



VICINITY MAP
SCALE: 1" = 2000'

2000' 1000' 0 2000' 4000'
SCALE: 1"=2000'

SHEET LIST	
SHEET NUMBER	SHEET TITLE
1	COVER SHEET
2	LEGEND
3	EXISTING CONDITIONS OVERVIEW
4	MS1 – MAINSTEM ELJ PLACEMENT – OVERVIEW
5	MS1 – MAINSTEM ELJ PLACEMENT – VIEW 1
6	MS1 – MAINSTEM ELJ PLACEMENT – VIEW 2
7	MS1 – MAINSTEM ELJ PLACEMENT – VIEW 3
8	MS1 – MAINSTEM ELJ PLACEMENT – VIEW 4
9	MS1 – MAINSTEM ELJ PLACEMENT – VIEW 5
10	MS2 – MAINSTEM ELJ PLACEMENT – OVERVIEW
11	PF1 – PURDY FIELD – REVETMENT ONLY
12	PF2 – PURDY FIELD – SIDE CHANNEL AND BERM
13	PF3 – PURDY FIELD – FULL RESTORATION
14	SC1 – UPSTREAM SIDE CHANNEL CREATION – SHORT PATH
15	SC2 – UPSTREAM SIDE CHANNEL CREATION – LONG PATH
16	TESC DETAILS 1
17	TESC DETAILS 2
18	APEX ELJ
19	DEFLECTOR ELJ
20	ELJ DETAILS

CONTACT INFORMATION

NATURAL SYSTEMS DESIGN, INC
1900 N NORTHLAKE WAY, SUITE 211
SEATTLE, WA 98103
(206) 834-0175

MASON CONSERVATION DISTRICT
450 W BUSINESS PARK ROAD
SHELTON, WA 98584
PHONE (360) 427-9436

PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

Jun 04, 2021

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
CHECKED	SMW
DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

COVER SHEET

1

SHEET 1 OF 20

GENERAL LEGEND

———--	PROPERTY LINE
— —	RIGHT OF WAY LINE
═══	EXISTING ROAD
—CL—CL—	CLEARING LIMIT
—GL—GL—	GRADING LIMIT
— — -5- — —	EXISTING MAJOR CONTOUR
— — -1- — —	EXISTING MINOR CONTOUR
——5——	PROPOSED MAJOR CONTOUR
——1——	PROPOSED MINOR CONTOUR
	LOW FLOW CHANNEL
— > — > — > —	EXISTING FLOW
—— OHWM ——	EXISTING OHWM
—— OHWM ——	PROPOSED OHWM
—— 2-YR ——	2-YEAR FLOOD BOUNDARY
—— 100-YR ——	100-YEAR FLOOD BOUNDARY
—WL—WL—	EXISTING WETLAND
	DEMOLITION/REMOVAL AREA
	EXISTING FENCE
- - - - - -	TOP OF BANK
	EXISTING CONIFEROUS TREE
	EXISTING DECIDUOUS TREE
	CONTROL POINT LOCATION

	APEX ELJ 1/18
	DEFLECTOR ELJ 1/19
	NATIVE ALLUVIUM
	STREAMBED GRAVEL

RESTORATION LEGEND

▶———	FILL SLOPE LINE
▷- - - -	EXCAVATION SLOPE LINE

TEMPORARY EROSION CONTROL LEGEND

—SB—SB—	SILT BOOM
—BN—BN—	BLOCK NETS
—SF—SF—	SILT FENCE
—SW—SW—	STRAW WATTLE
	DEWATERING LINE DISCHARGE
	PROPOSED STAGING AREA
	BULK BAG COFFERDAM
	TEMPORARY ACCESS ROAD
	TEMPORARY ACCESS BRIDGE
(O)	PUMP DISCHARGE OUTLET
(P)	DEWATERING PUMP

DETAIL AND SECTION REFERENCING

1	NOTE REFERENCING NUMBER
4 / 6	DETAIL REFERENCE NUMBER SHEET ON WHICH DETAIL APPEARS
(TITLE) (SCALE) 4 / 2	DETAIL REFERENCE NUMBER SHEET FROM WHICH DETAIL WAS TAKEN
(TYP)	SPECIFIES THAT DETAIL IS UNIFORMLY TYPICAL THROUGHOUT PROJECT EXCEPT WHERE OTHERWISE NOTED
(VAR)	SPECIFIES THAT DETAIL WAS TAKEN FROM SEVERAL SHEETS
A ... A 32	SECTION A–A IS SHOWN ON SHEET 32
SECTION A–A 32 SCALE: NTS	SECTION A–A IS SHOWN ON SHEET 32

Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

Jun 04, 2021

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Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
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DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

EXISTING CONDITIONS OVERVIEW

3

SHEET 3 OF 20

MS 1: SKOKOMISH RIVER MAINSTEM ELJ INSTALLATION

- DENSE INSTALLATION OF APEX AND DEFLECTOR ELJS TO DEVELOP A MORE COMPLEX FLOW PATH WITHIN THE MAINSTEM AND INCREASE THE POTENTIAL FOR INCREASED NET SEDIMENT TRANSPORT.
- INCREASE IN POOL DENSITY AND COVER QUALITY SCALED TO THE NUMBER OF ELJS (31 PROPOSED).
- CAN BE DESIGNED TO AVOID FLOOD IMPACTS BUT MAY LIMIT EFFECTIVENESS; CURRENT ALTERNATIVE SHOWN INCREASES 1% AC FLOOD STAGE BY APPROXIMATELY 0.1 FOOT.
- POTENTIAL REACH SCALE INCREASE IN SEDIMENT TRANSPORT RATES THROUGH A COMBINATION OF CHANNEL NARROWING AND INTEGRATIVE HYDRAULIC EFFECTS OF LOG JAMS, BUT OUTCOME HAS A HIGH DEGREE OF UNCERTAINTY.
- NO CHANGES TO OVERBANK FLOW PATTERNS FOR INUNDATION FREQUENCY, DIRECTION, OR DURATION.
- DEFLECTORS PROVIDE INCREASED PROTECTION FOR PURDY CUTOFF ROAD.
- WILL REQUIRE INSTREAM WORK TO INSTALL, INCLUDING TEMPORARY ACCESS AND DEWATERING.
- VEHICLE ACCESS FROM RIGHT BANK MAY BE CHALLENGING DUE TO EXTENSIVE WETLAND AREAS.
- MOST COSTLY OF THE MAINSTEM OPTIONS DUE TO NUMBER OF ELJS AND DIFFICULT ACCESS.

Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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Natural Systems Design

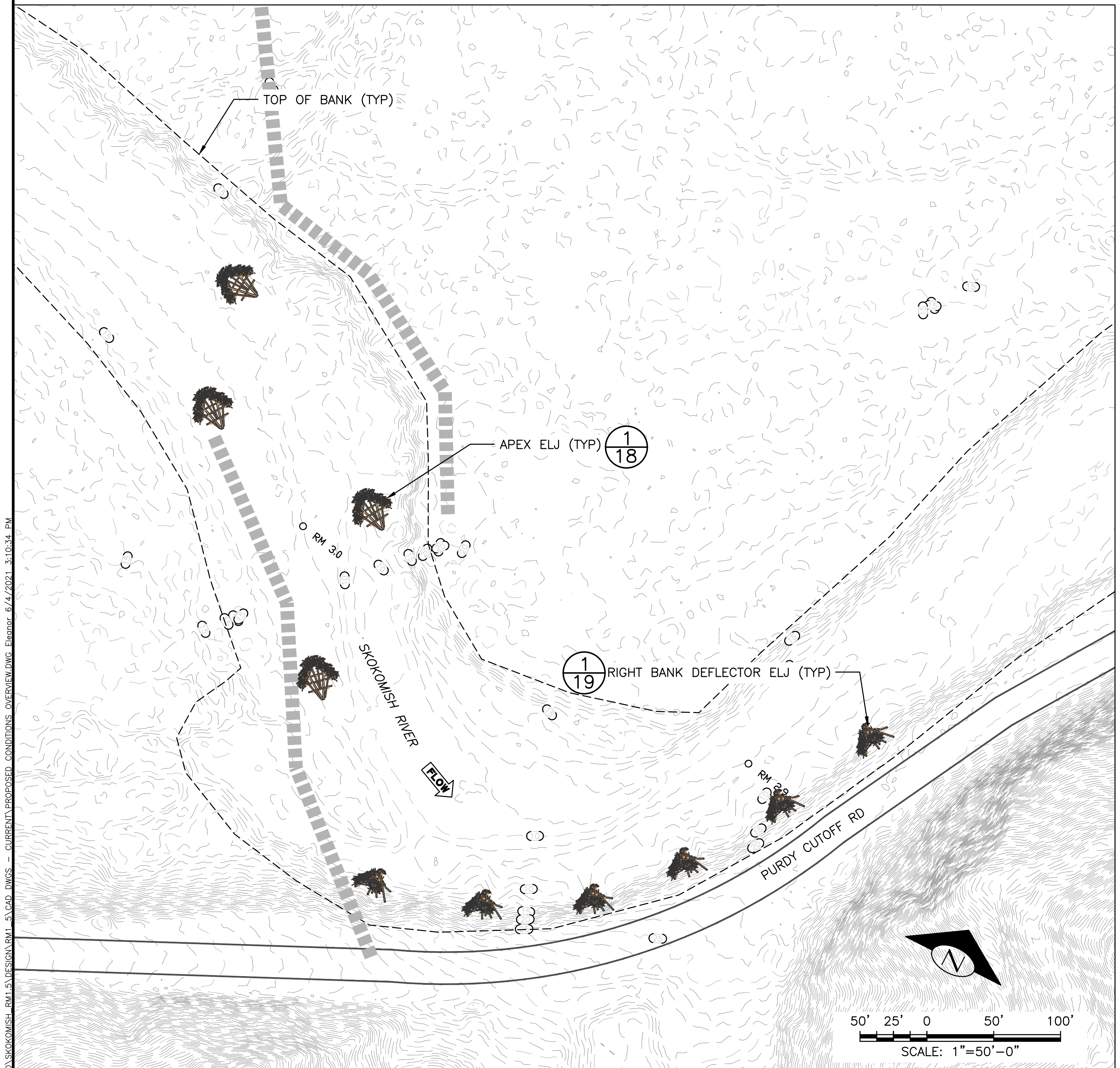
NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	ESB	LATITUDE	47°18'53"N
CHECKED	SMW	LONGITUDE	123°8'32"W
DRAWN	EB, GM	TN/SC/RG	T21N/S13/R4W
CHECKED	SMW	DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

MS1 – MAINSTEM ELJ PLACEMENT – OVERVIEW

4

SHEET 4 OF 20



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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
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DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER
MAINSTEM MILE 1.5
HABITAT RESTORATION

MS1 – MAINSTEM ELJ
PLACEMENT – VIEW 1

5

SHEET 5 OF 20

PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

Jun 04, 2021

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PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

Jun 04, 2021

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Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
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DRAWN	EB, GM
CHECKED	SMW

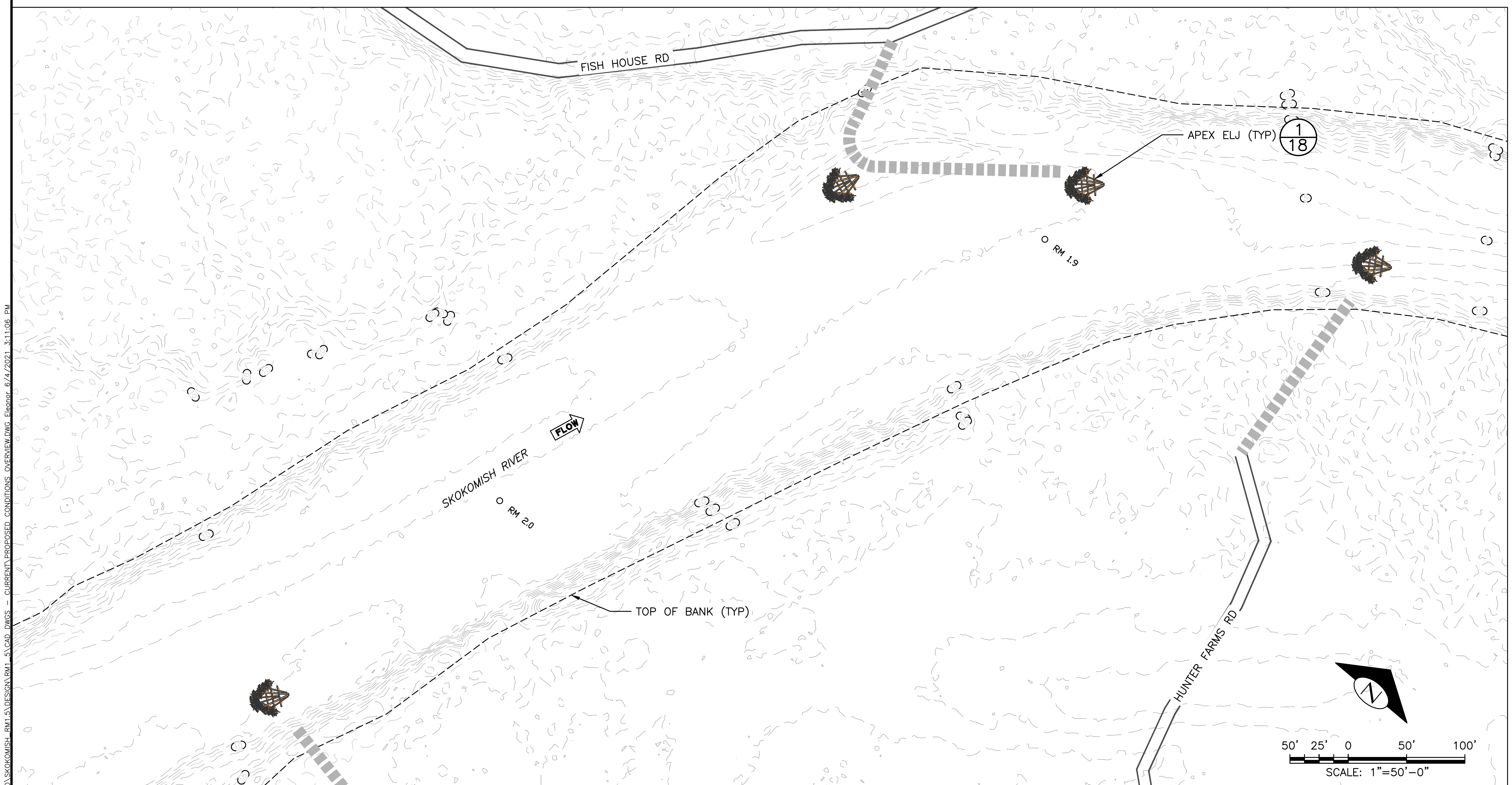
GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

MS1 – MAINSTEM ELJ PLACEMENT – VIEW 3

7

SHEET 7 OF 20



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Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
CHECKED	SMW
DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER
MAINSTEM MILE 1.5
HABITAT RESTORATION

MS1 – MAINSTEM ELJ PLACEMENT – VIEW 4

8

SHEET 8 OF 20

Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
CHECKED	SMW
DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER
MAINSTEM MILE 1.5
HABITAT RESTORATION

MS1 – MAINSTEM ELJ PLACEMENT – VIEW 5

9

SHEET 9 OF 20

MS 2: SKOKOMISH RIVER MAINSTEM ELJ INSTALLATION

- INSTALLATION OF APEX ELJS ALIGNED TO EXISTING GRAVEL BARS.
- INCREASE IN POOL DENSITY AND COVER QUALITY SCALED TO NUMBER OF ELJS (8 PROPOSED).
- CAN BE DESIGNED TO AVOID FLOOD IMPACTS.
- LOCAL INCREASES OF TRANSPORT WITH INCREASES IN CHANNEL STORAGE ON BARS. LESS LIKELY TO PRODUCE REACH SCALE CHANGES IN SEDIMENT TRANSPORT.
- NO CHANGES TO OVERBANK FLOW PATTERNS FOR INUNDATION FREQUENCY, DIRECTION, OR DURATION.
- WILL REQUIRE INSTREAM WORK TO INSTALL, INCLUDING TEMPORARY ACCESS AND DEWATERING.
- VEHICLE ACCESS FROM RIGHT BANK CHALLENGING DUE TO EXTENSIVE WETLAND AREAS.
- LEAST COSTLY OF THE MAINSTEM OPTIONS DUE TO REDUCED NUMBER OF ELJS AVOIDING THE MOST DIFFICULT ACCESS.

PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

Jun 04, 2021

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MS2 – MAINSTEM ELJ PLACEMENT – OVERVIEW

10

SHEET 10 OF 20

PF1: PURDY FIELD – REVETMENT ONLY

- REPLACE EXISTING LOG REVETMENT WITH LONGER COMPLEX WOOD REVETMENT.
- LOCALIZED POOL FORMATION AND IMPROVED COVER AT THE REVETMENT LOCATION.
- MINIMAL FLOOD CHANGES; SLIGHT REDUCTION IN OVERBANK FLOW VELOCITY.
- NO CHANGE TO EXISTING PROPERTY USE (EXCLUDING TEMPORARY CONSTRUCTION IMPACTS).
- REQUIRES LOCALIZED DEWATERING OF MAINSTEM.
- HIGH COST TO INSTALL 400 FEET OF ROBUST REVETMENT.

NOTES

- MAINSTEM ELJS FROM ALTERNATIVE MS1 ARE SHOWN. ELJ POSITIONS WOULD BE MODIFIED TO MATCH THE COMPLEX WOOD REVETMENT.

Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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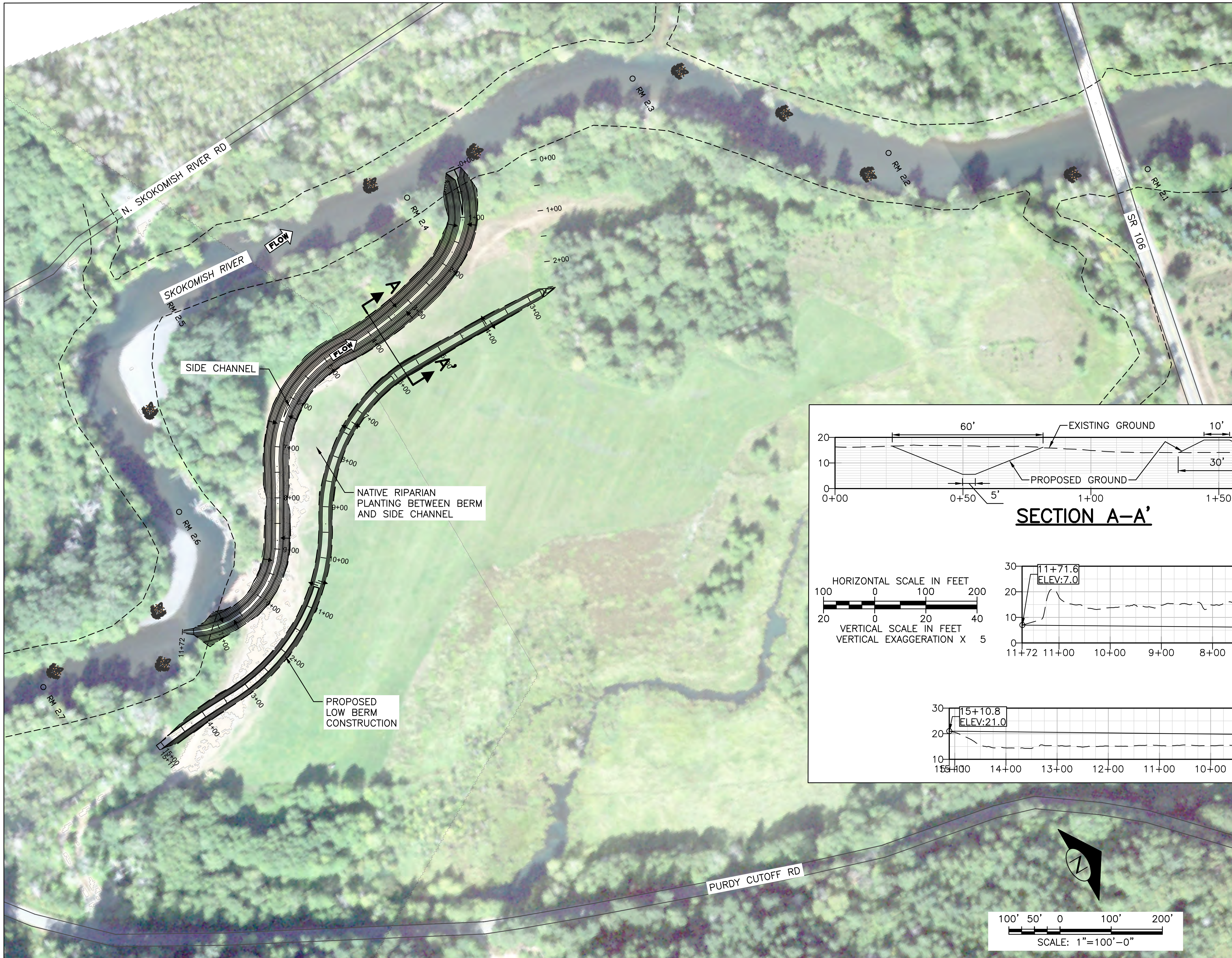
SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

PF1 – PURDY FIELD – REVETMENT ONLY

11

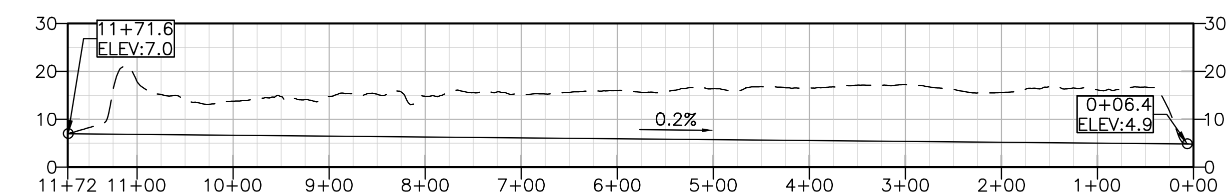


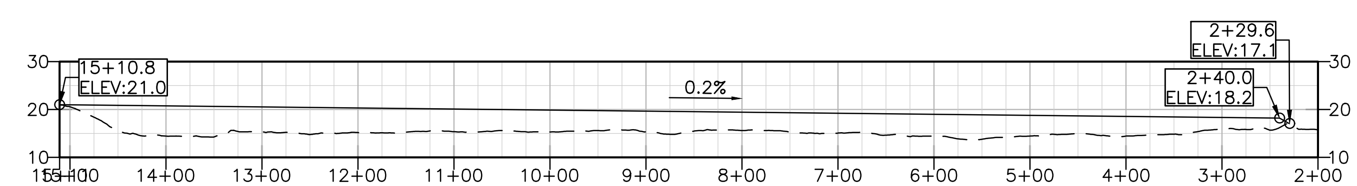
PF2: PURDY FIELD – SIDE CHANNEL & OFFSET BERM

- SET BACK LOW BERM AND EXCAVATE NEW SIDE CHANNEL TO FORM FORESTED ISLAND.
- NATIVE RIPARIAN RESTORATION WITHIN THE SETBACK AREA.
- INCREASED PERENNIALLY INUNDATED SIDE CHANNEL HABITAT (1.4 AC).
- INCREASED RIPARIAN COVER (5 ACRES).
- NEW SIDE CHANNEL IS EFFECTIVE AT LOWERING FLOOD STAGE AT THE UPSTREAM SIDE OF THE PURDY FIELD, BUT NOT ON THE DOWNSTREAM. NO CHANGES FOR 1% AC FLOW.
- INCREASED CONVEYANCE IN THE MAIN AND PROPOSED CHANNEL SLIGHTLY INCREASES VELOCITY IN BOTH CHANNELS, SUGGESTING THAT PF2 WOULD NOT INCREASE AGGRADATION AND COULD SLIGHTLY INCREASE SEDIMENT CONVEYANCE AT RM 2.5.
- REDUCTION OF 5 ACRES OF CURRENT AGRICULTURAL FIELD FOR NEW CHANNEL AND SETBACK.
- RELATIVELY STRAIGHTFORWARD CONSTRUCTION, PRIMARILY IN UPLANDS WITH UP AND DOWNSTREAM CONNECTIONS TO THE MAINSTEM.
- APPROX. 12,250 CY OF CUT AND PLACEMENT.
- MODERATE TO LOW CONSTRUCTION COSTS BASED ON EXCAVATION, LOCAL HAUL AND TRANSPORT OF MATERIALS, AND NATIVE REVEGETATION.

NOTES

- MAINSTEM ELJS FROM ALTERNATIVE MS1 ARE SHOWN. ELJ POSITIONS WOULD BE MODIFIED SLIGHTLY TO MAXIMIZE INTERACTION WITH THE PROPOSED SIDE CHANNEL.





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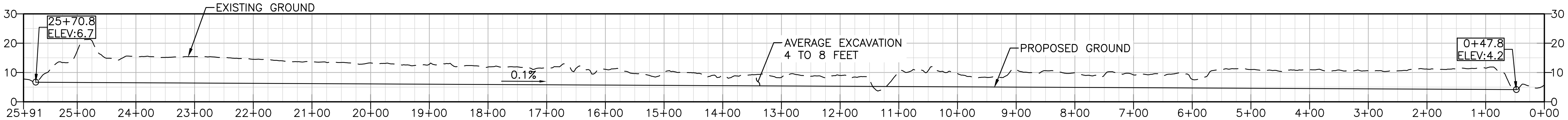
SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

PF2 – PURDY FIELD – SIDE CHANNEL AND BERM

12

SHEET 12 OF 20



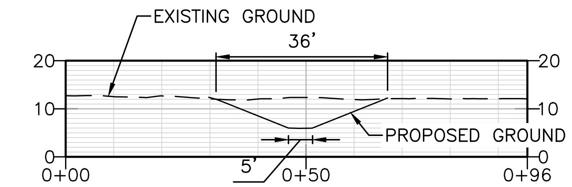
HORIZONTAL SCALE IN FEET
100 0 100 200

VERTICAL SCALE IN FEET
20 0 20 40

VERTICAL EXAGGERATION X 5

100' 50' 0 100' 200'

SCALE: 1"=100'-0"



SECTION B–B'

PF3: PURDY FIELD – FULL RESTORATION

- FULL RESTORATION OF PURDY FIELD WITH CONNECTION OF NEW SIDE CHANNEL AND NATIVE RIPARIAN REVEGETATION.
- INCREASED PERENNIALLY INUNDATED SIDE CHANNEL HABITAT (2.2 AC).
- INCREASED RIPARIAN COVER (30 TO 50 ACRES).
- REMOVAL OF AGRICULTURAL LAND USE IN THE FLOODPLAIN (13.5 ACRES).
- PURDY FIELD BEGINS TO FLOOD AT LOWER FLOWS THAN UNDER EXISTING CONDITIONS, BUT THERE IS REDUCED FLOOD RISK DUE TO LAND USE CONVERSION. NO CHANGES FOR 1% AC FLOW.
- NEW SIDE CHANNEL PROVIDES TEMPORARY SEDIMENT STORAGE IN THE CHANNEL AND ON THE FLOODPLAIN.
- REDUCTION IN RISK FOR SR 106 WITH RE–ROUTING SIDE CHANNEL AWAY FROM ROADBED.
- DESIGN WOULD AVOID TYPICAL EROSION ALONG THE DRIVEWAY AT PURDY CUTOFF ROAD
- STRAIGHTFORWARD CONSTRUCTION WITH GOOD ACCESS.
- WILL REQUIRE HAUL OF ~12,000 CY OF MATERIAL TO AVOID FLOODPLAIN IMPACTS.
- MODERATE INITIAL CONSTRUCTION COSTS DUE TO LONGER SIDE CHANNEL AND GREATER AREA OF RIPARIAN VEGETATION.
- POTENTIALLY LOWER LONGTERM COSTS AS THE SITE WOULD BE RETURNED TO THE RIVER.

NOTES

- MAINSTEM ELJS FROM ALTERNATIVE MS1 ARE SHOWN. ELJ POSITIONS WOULD BE MODIFIED SLIGHTLY TO MAXIMIZE INTERACTION WITH THE PROPOSED SIDE CHANNEL.

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CHECKED	SMW

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SKOKOMISH RIVER
MAINSTEM MILE 1.5
HABITAT RESTORATION

PF3 – PURDY FIELD –
FULL RESTORATION

13

SHEET 13 OF 20

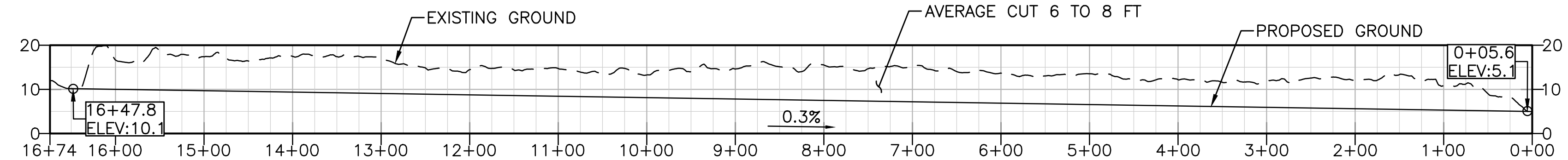
SC1: UPSTREAM SIDE CHANNEL CREATION, SHORT PATH

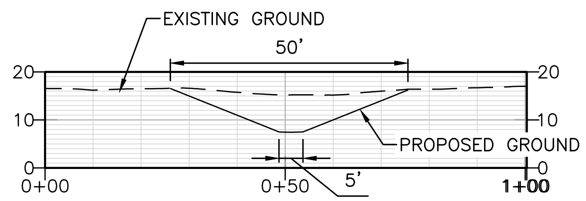
- EXCAVATION OF 1,675 LINEAR FEET OF NEW SIDE CHANNEL ON LEFT OVERBANK FROM RM 3.05 TO 2.55.
- INCREASED PERENNIALLY INUNDATED SIDE CHANNEL HABITAT (1.6 AC).
- ROUTES FLOW THROUGH SHADED RIPARIAN AREAS.
- MINIMAL FLOOD ELEVATION CHANGES, WITH NO INCREASE IN 1% AC STAGE.
- NEW SIDE CHANNEL PROVIDES TEMPORARY SEDIMENT STORAGE IN THE CHANNEL AND ON THE FLOODPLAIN.
- NEW SIDE CHANNEL WOULD REDUCE FLOWPATH LENGTH AND MARGINALLY INCREASE SLOPE, WHICH COULD CAPTURE THE MAINSTEM AND INCREASE SEDIMENT TRANSPORT EFFICIENCY.
- NO PROPERTY IMPACTS BASED ON CURRENT USES.
- POTENTIAL TO REDUCE THE AMOUNT OF FLOW IN THE EXISTING MAINSTEM, WHICH COULD CHANGE HABITAT AND TRIBAL FISHING LOCATIONS.
- POTENTIALLY DIFFICULT CONSTRUCTION ACCESS.
- WOULD REQUIRE HAUL OF ~10,000 CY OF MATERIAL TO AVOID WETLAND IMPACTS.
- HIGH UNIT COST FOR EXCAVATION AND HAUL GIVEN ACCESS CONSTRAINTS.

NOTES

- MAINSTEM ELJS FROM ALTERNATIVE MS1 ARE SHOWN. ELJ POSITIONS WOULD BE MODIFIED SLIGHTLY TO MAXIMIZE INTERACTION WITH THE PROPOSED SIDE CHANNEL.

HORIZONTAL SCALE IN FEET
100 0 100 200
20 0 20 40
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION X 5





SECTION C–C'

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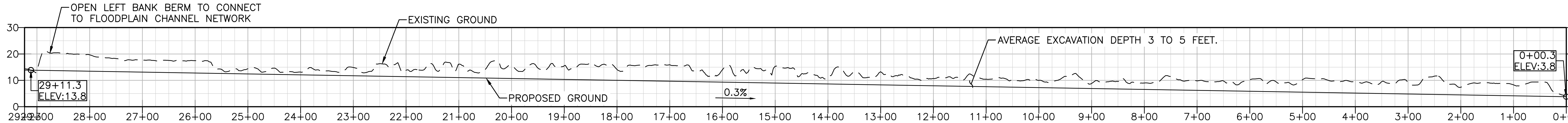
SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

SC1 – UPSTREAM SIDE CHANNEL CREATION – SHORT PATH

14



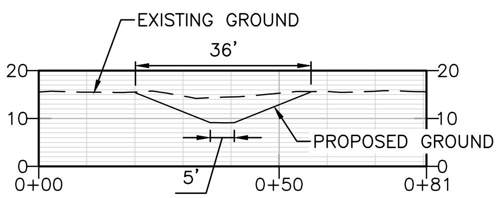
HORIZONTAL SCALE IN FEET

100 0 100 200

20 0 20 40

VERTICAL SCALE IN FEET

VERTICAL EXAGGERATION X 5



SECTION D–D

SC2: UPSTREAM SIDE CHANNEL CREATION – LONG PATH

- EXCAVATION OF 2,925 LINEAR FEET OF NEW SIDE CHANNEL ON LEFT OVERBANK FROM RM 3.2 TO 2.5.
- INCREASED PERENNIALLY INUNDATED SIDE CHANNEL HABITAT (1.9 AC).
- FOLLOWS, CONNECTS, AND EXPANDS EXISTING FLOODPLAIN DRAINAGES.
- ROUTES FLOW THROUGH SHADED RIPARIAN AREA.
- MINIMAL FLOOD CHANGES, WITH NO INCREASE IN 1% AC STAGE.
- NEW SIDE CHANNEL PROVIDES TEMPORARY SEDIMENT STORAGE IN THE CHANNEL AND ON THE FLOODPLAIN.
- NEW SIDE CHANNEL WOULD SLIGHTLY REDUCE FLOWPATH LENGTH AND MARGINALLY INCREASE SLOPE, WHICH COULD CAPTURE THE MAINSTEM AND INCREASE SEDIMENT TRANSPORT EFFICIENCY.
- POTENTIAL CHANGE FOR SKOKOMISH TRIBE BY REMOVING PORTION OF SKOKOMISH RIVER ROAD OR INSTALLING WATER CROSSING STRUCTURES.
- POTENTIAL TO REDUCE THE AMOUNT OF FLOW IN THE EXISTING MAINSTEM, WHICH COULD CHANGE HABITAT AND TRIBAL FISHING LOCATIONS.
- DIFFICULT CONSTRUCTION ACCESS.
- WOULD REQUIRE HAUL OF ~7,100 CY OF MATERIAL TO AVOID WETLAND IMPACTS.
- HIGH UNIT COST FOR EXCAVATION AND HAUL GIVEN ACCESS CONSTRAINTS.
- LESS OVERALL EXCAVATION THAN SC1 AND PROVIDES A LONGER FLOWPATH.

NOTES

- MAINSTEM ELJS FROM ALTERNATIVE MS1 ARE SHOWN. ELJ POSITIONS WOULD BE MODIFIED SLIGHTLY TO MAXIMIZE INTERACTION WITH THE PROPOSED SIDE CHANNEL.

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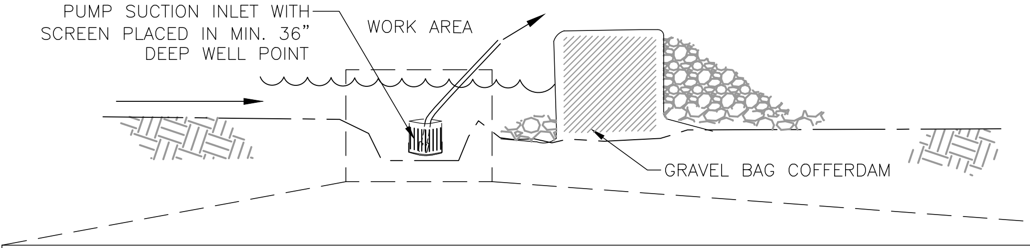
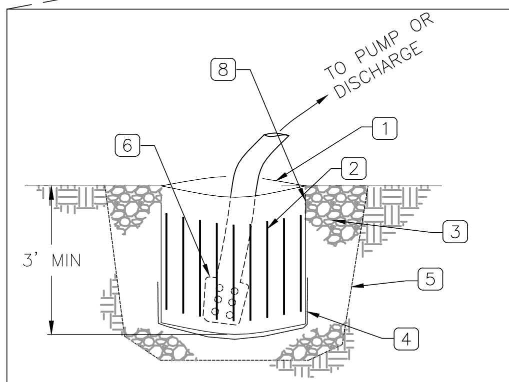
SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

SC2 – UPSTREAM SIDE CHANNEL CREATION – LONG PATH

15

SHEET 15 OF 20

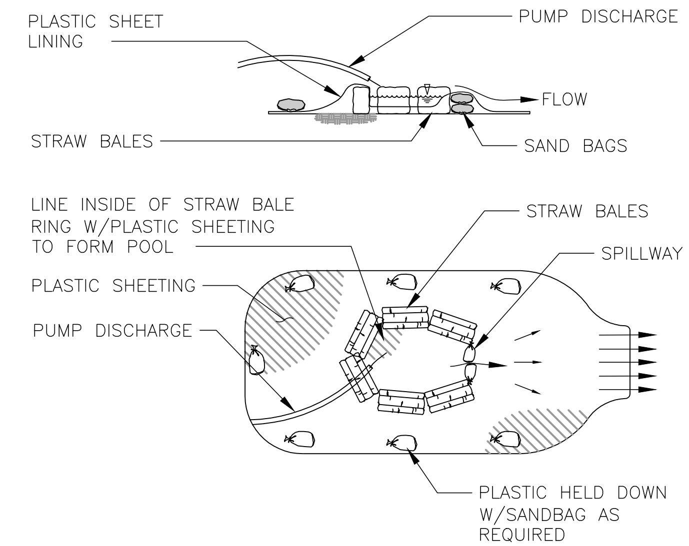




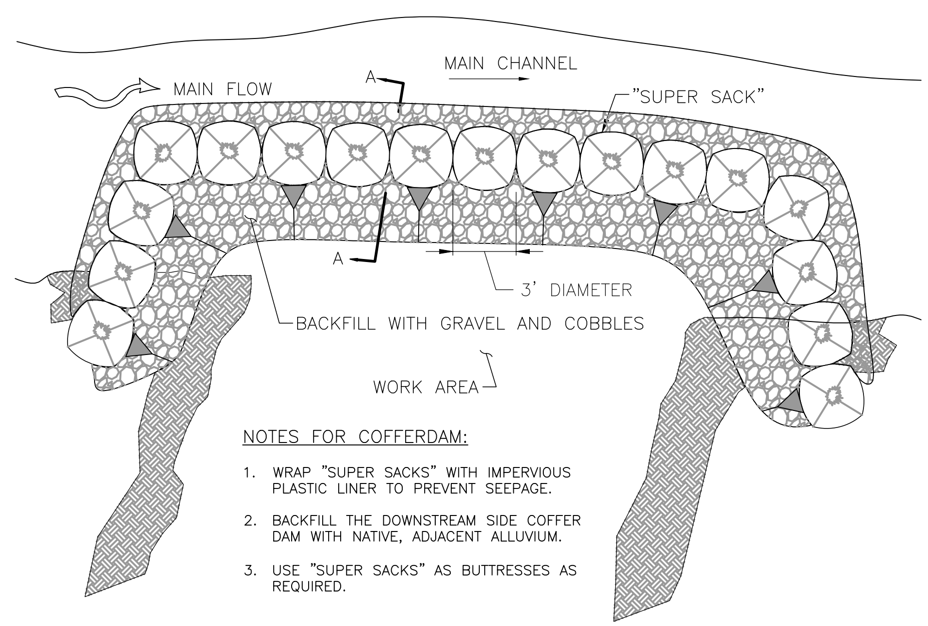
NOTES:

1. CORRUGATED PLASTIC OR METAL PIPE 36" MIN DIAMETER, ONE PER EACH PUMP.
2. ¼" SLOTS 24" LONG AT 4" SPACING ALL THE WAY AROUND PIPE.
3. STREAMBED SEDIMENT
4. WIRE SCREEN ½" MESH COVERING PIPE BOTTOM, ANCHORED TO PIPE.
5. LIMIT OF EXCAVATION. INSTALL PIPE AND BACKFILL WITH STREAMBED SEDIMENT.
6. PUMP SUCTION INTAKE OR ELECTRIC SUBMERSIBLE PUMP WITH 1" SCREEN INSTALLED AT INLET OR PUMP SUCTION FACE, OR OTHER SIZE RECOMMENDED BY PUMP SUPPLIER.
7. PUMP SUCTION SHALL BE OPERATIONAL ONLY WHILE ALL CREEK FLOW IS FULLY FILTERED BY FISH BLOCK NETS AND AFTER FISH EXCLUSION IS COMPLETED. BYPASS PUMPS SHALL BE SHUTDOWN DURING ANY FAILURE OF THE FISH BLOCK NET OR ANY CONDITION THAT CAN ALLOW FISH TO ENTER THE PUMP INTAKE.
8. DIRECT DISCHARGE TO APPROVED UPLAND DISPERSION AREA.

WORK AREA DEWATERING PUMP INTAKE (1/16)
NOT TO SCALE

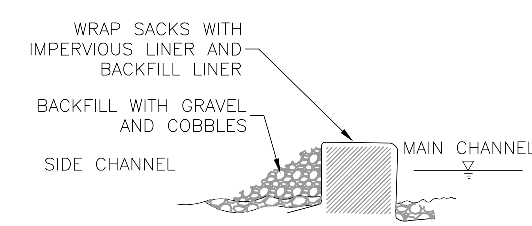


ENERGY DISSIPATOR (2/16)
NOT TO SCALE



NOTES FOR COFFERDAM:

1. WRAP "SUPER SACKS" WITH IMPERVIOUS PLASTIC LINER TO PREVENT SEEPAGE.
2. BACKFILL THE DOWNSTREAM SIDE COFFER DAM WITH NATIVE, ADJACENT ALLUVIUM.
3. USE "SUPER SACKS" AS BUTTRESSES AS REQUIRED.



SECTION A–A

COFFERDAM (3/16)
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SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

TESC DETAILS 1

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SHEET 16 OF 20

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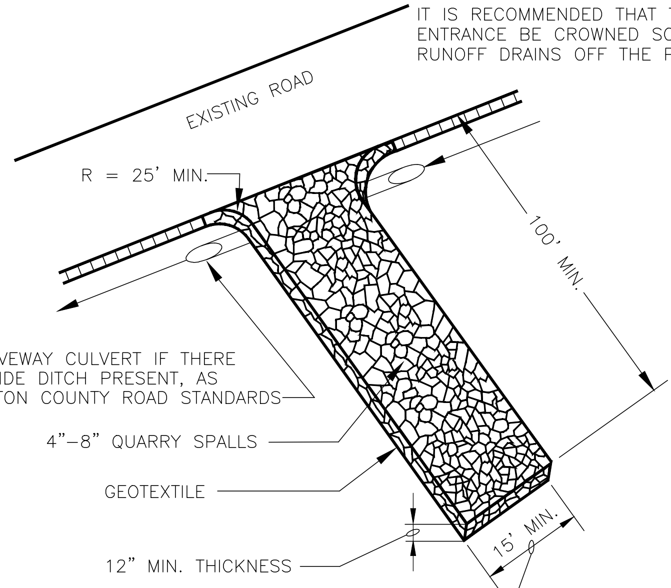
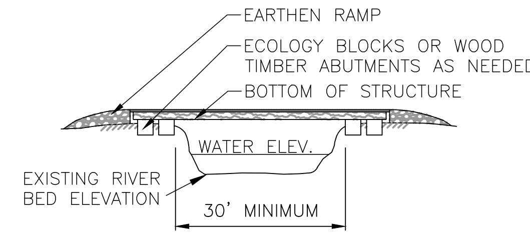


CONSTRUCTION ENTRANCE (1/17)
NOT TO SCALE



NOTES FOR TEMPORARY BRIDGE TYPE 1:

1. CONTRACTOR TO DESIGN TEMPORARY BRIDGE.
2. BRIDGE SHALL BE LOCATED SUCH THAT ONLY ONE SPAN IS USED TO ELIMINATE IMPACTS TO SUBSTRATE OF CHANNEL.
3. END OF BRIDGE SHALL BEAR ON HIGH BANKS WITH SUFFICIENT BEARING CAPACITY TO PREVENT SLOUGHING OR COLLAPSE OF SIDE CHANNEL BANKS.
4. CONCRETE ECOLOGY BLOCKS OR WOOD ABUTMENTS MAY BE USED TO SUPPORT ENDS OF TEMPORARY BRIDGE AS NEEDED.
5. BRIDGES MAY BE CONSTRUCTED FROM LOGS, RAIL CAR BEDS OR APPROVED EQUAL AND DECKED WITH STEEL SHEET, WOOD LAGGING OR APPROVED EQUAL.

TEMPORARY BRIDGE (2/17)
NOT TO SCALE

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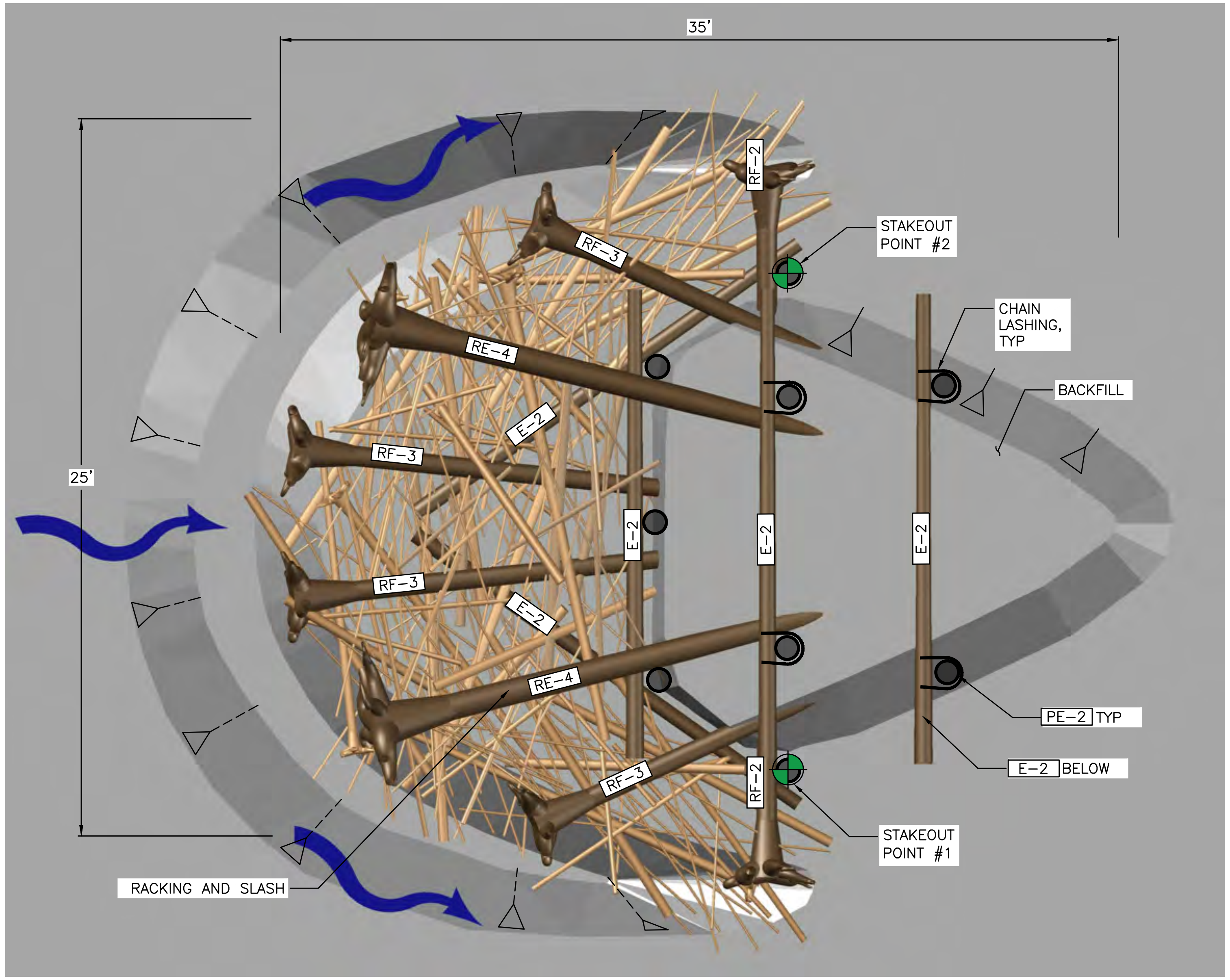
SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

TESC DETAILS 2

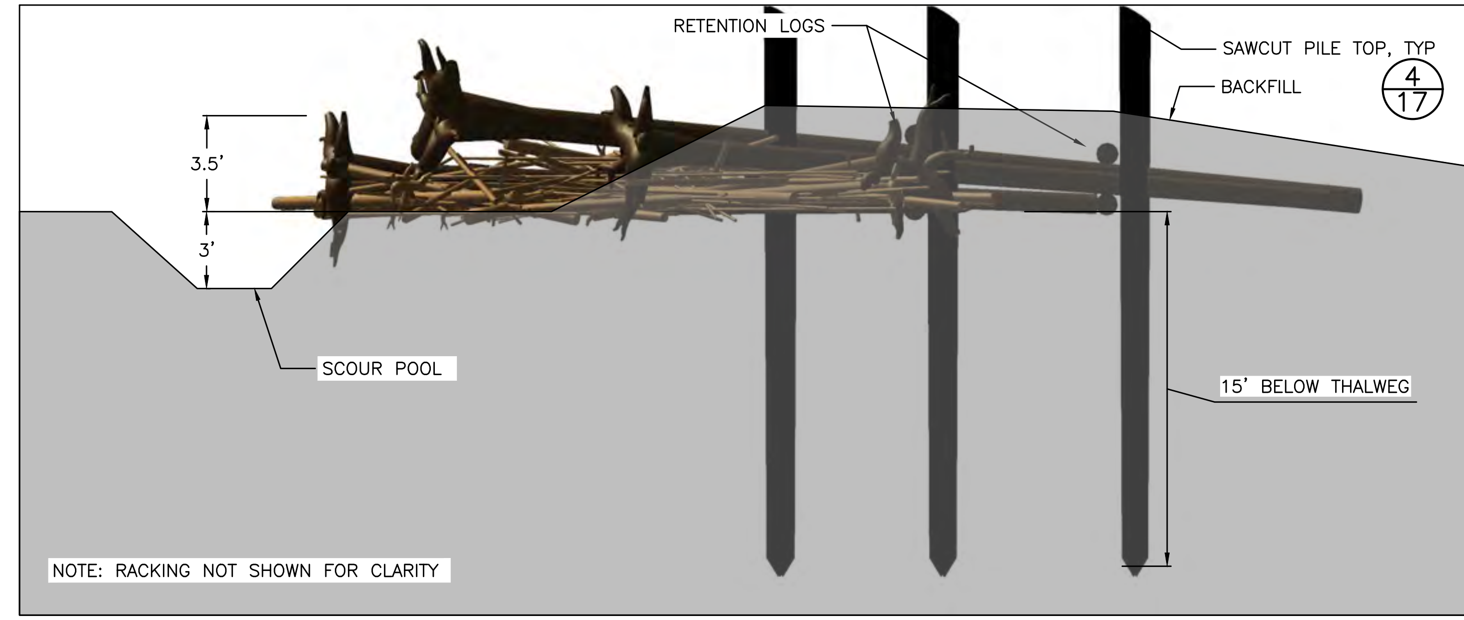
17

SHEET 17 OF 20



APEX ELJ PLAN
SCALE: 1" = 4'

4' 2' 0 4' 8'
SCALE: 1"=4'–0"

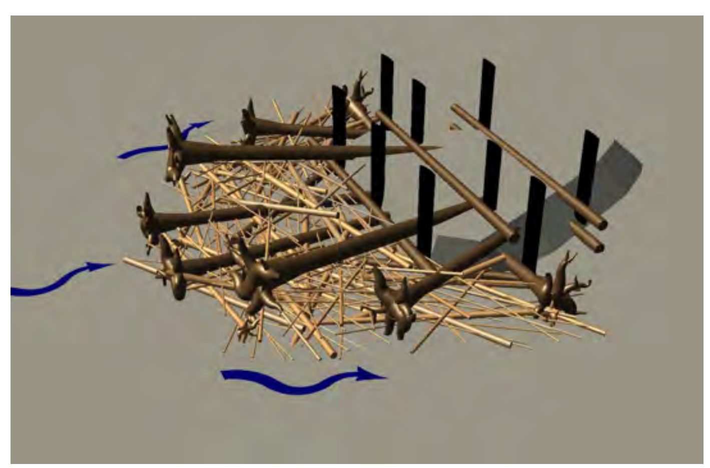


APEX ELJ PROFILE
SCALE: 1" = 4'

4' 2' 0 4' 8'
SCALE: 1"=4'–0"

NOTES

1. ALL LOGS SHALL BE DOUGLAS FIR OR WESTERN RED CEDAR.
2. ALL PILES SHALL BE ROUND, UNTREATED TIMBER PILES AND SHALL BE DOUGLAS FIR. PILES SHALL BE FREE FROM DEFECTS, CRACKS, AND SPLITTING AT THE TIME OF DRIVING.
3. LOGS WITH ROOTWADS SHALL HAVE A DIAMETER AS SHOWN MEASURED AT DBH, DEFINED AS 4.5 FEET ABOVE GROUND WHEN TREE WAS STANDING.
4. THE CONTRACTOR SHALL PLACE LOGS AS ILLUSTRATED ON THIS SHEET UNLESS DIRECTED OTHERWISE BY THE CONTRACTING OFFICER.
5. SOIL EXCAVATED DURING CONSTRUCTION SHALL BE REPLACED TO ORIGINAL GROUND FOLLOWING PLACEMENT OF ALL LOGS.
6. THE LOCATIONS SHOWN IN THE PLANS ARE APPROXIMATE AND MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER.
7. THE LOCATION SHOWN ON THE SHEET IS APPROXIMATE AND MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER.
8. RACKING LOGS SHALL CONSIST OF TREES WITH BRANCHES HAVING A BASE DIAMETER AND LENGTH PER THE LOG SCHEDULE. TOTAL NUMBER OF RACKING LOGS PER STRUCTURE SHALL BE PER LOG SCHEDULE. RACKING MATERIAL SHALL OCCUR WITH EACH LAYER TO ENSURE THAT RACKING MATERIAL EXTENDS THROUGH THE STRUCTURE AND IS PINNED BY SUBSEQUENT LAYERS. SLASH MATERIAL SHALL CONSIST OF LIMBS AND BRANCHES WITH A BASE DIAMETER PER THE LOG SCHEDULE. TOTAL SLASH MATERIAL QUANTITY SHALL BE PER THE LOG SCHEDULE. SLASH MATERIAL SHALL BE PLACED AS DIRECTED BY THE CONTRACTING OFFICER. RACKING AND SLASH MATERIAL SHALL BE DOUGLAS FIR, PONDEROSA PINE, WESTERN RED CEDAR, OR WESTERN LARCH TREES.
9. RETENTION LOGS TO BE INSTALLED TO HOLD RACKING MATERIAL IN PLACE AT THE DIRECTION OF THE CONTRACTING OFFICER.
10. CONNECT LOGS WITH WRAPPED CHAIN CONNECTION WHERE INDICATED ON THE DRAWINGS. SEE DETAILS.
11. AT LOCATIONS WHERE SITE CONDITIONS ALLOW (IN DRY OR LIMITED DEWATERING), SCOUR POOL TO BE EXCAVATED. EXCAVATED ALLUVIUM TO BE PLACED BEHIND THE STRUCTURE AS DIRECTED BY THE CONTRACTING OFFICER. EXTENTS AND LOCATION OF THE SCOUR POOL IS APPROXIMATE AND TO BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER.
12. EXISTING WOODY MATERIAL AT THE STRUCTURE CONSTRUCTION SITE SHALL BE MOVED OR PROTECTED FROM CONSTRUCTION ACTIVITIES AND THEN INCORPORATED INTO THE STRUCTURE AS DIRECTED BY THE CONTRACTING OFFICER.



APEX ELJ PERSPECTIVE
NOT TO SCALE

APEX ELJ LOG SCHEDULE

LOG ID	DIA* (INCHES)	LENGTH ** (FEET)	ROOTWAD (Y/N)	QUANTITY PER STRUCTURE	NOTES
RE–4	16–20	40	Y	2	
E–2	16–20	20	N	6	
RF–3	14–18	30	Y	4	
RF–2	14–18	20	Y	2	
PE–2 ***	18	20	N	9	
RACKING	6–12	20–30	N	80	TREES WITH BRANCHES
SLASH	1–3	–	–	20 CY	LIMBS AND BRANCHES

* MINIMUM DIAMETER AT BREAST HEIGHT (1" PER 10' MAXIMUM TAPER)
** TOTAL LENGTH INCLUDING ROOTWAD
*** TURNED PILES – DIA (IN) IS BUTT DIAMETER

APEX ELJ DETAILS
SCALE: AS NOTED

1
18

PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION
Jun 04, 2021

0 Ø 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Mason Conservation District

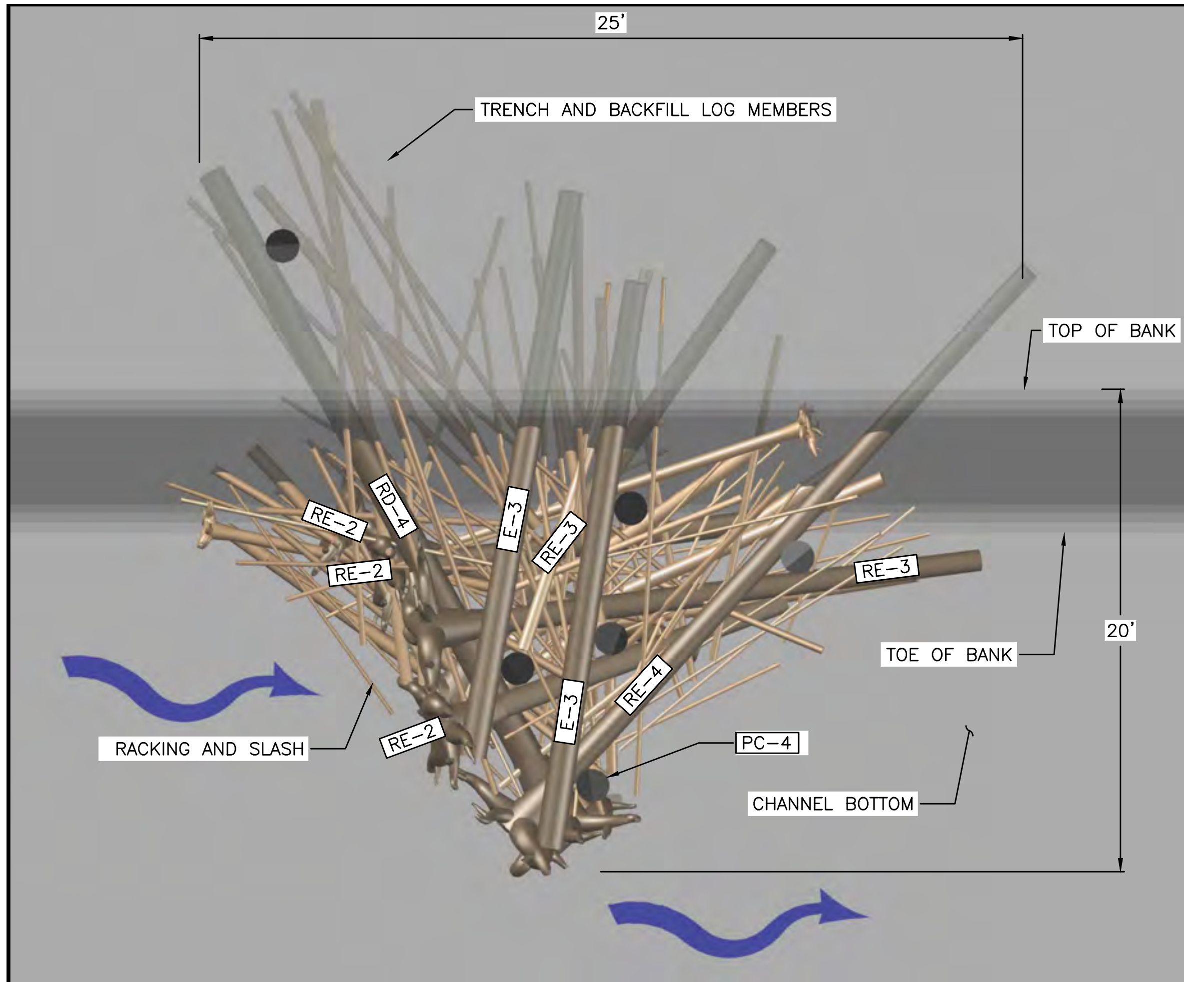
Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
CHECKED	SMW
DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

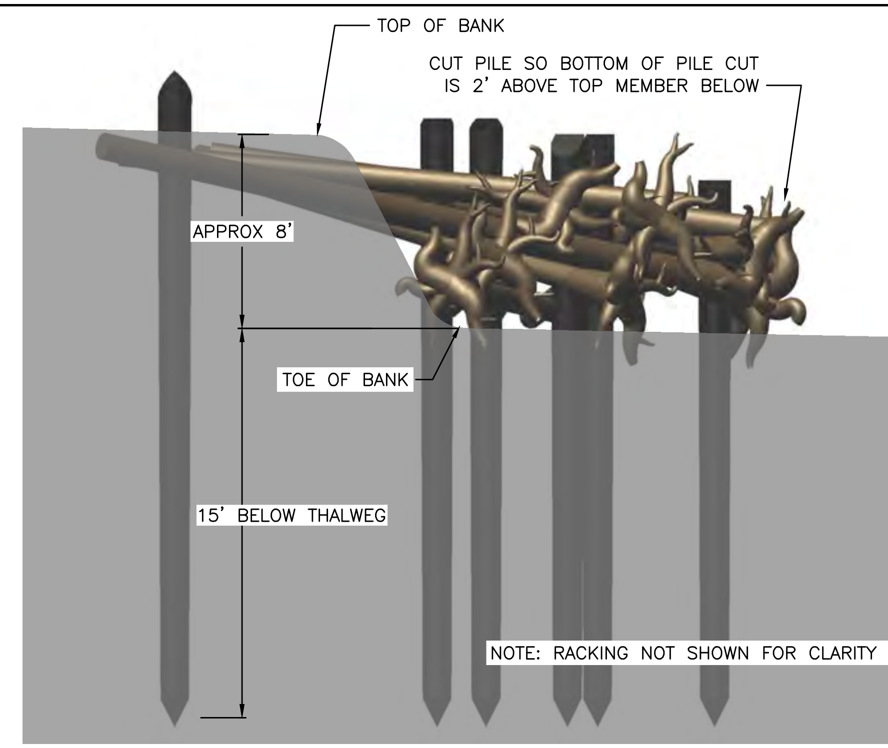
APEX ELJ



5' 0 5' 10'
SCALE: 1"=5'-0"

DEFLECTOR ELJ PLAN

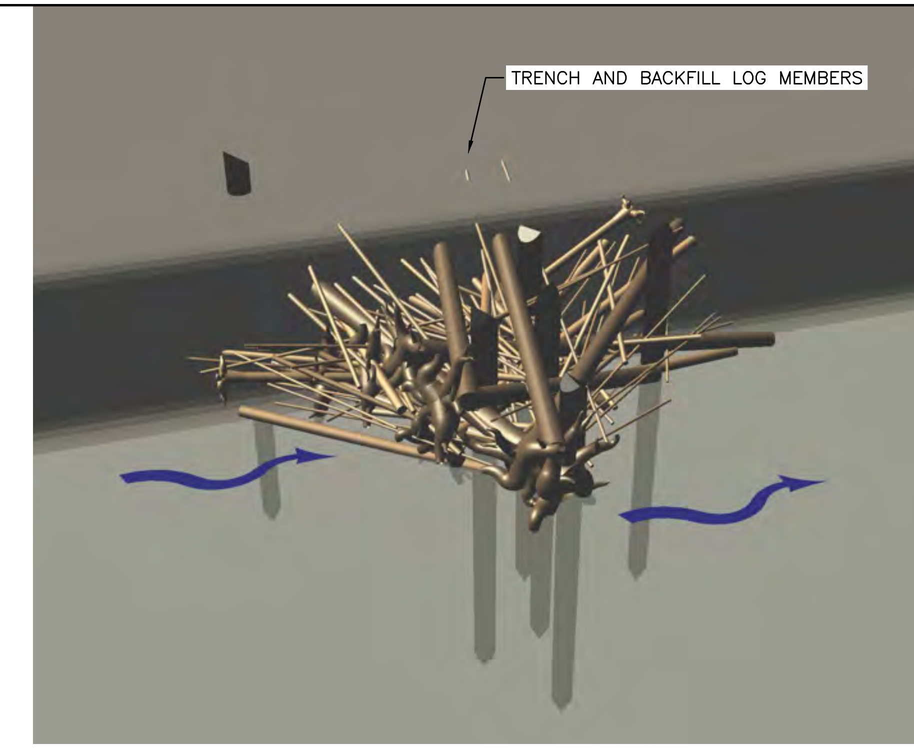
SCALE: 1" = 5'



DEFLECTOR ELJ PROFILE

SCALE: 1" = 5'

5' 0 5' 10'
SCALE: 1"=5'-0"



DEFLECTOR ELJ PERSPECTIVE

NOT TO SCALE

DEFLECTOR ELJ LOG SCHEDULE

LOG ID	DIA* (INCHES)	LENGTH ** (FEET)	ROOTWAD (Y/N)	QUANTITY PER STRUCTURE	NOTES
RD-4	18-22	40	Y	1	
RE-4	14-18	40	Y	1	
RE-3	14-18	30	Y	2	
RE-2	14-18	20	Y	3	
E-3	14-18	30	N	2	
PC-4	21-23	40	N	6	
RACKING	6-12	20-40	N	90	TREES WITH BRANCHES
SLASH	1-3	-	-	20 CY	LIMBS AND BRANCHES

* MINIMUM DIAMETER AT BREAST HEIGHT (1" PER 10' MAXIMUM TAPER)

** TOTAL LENGTH INCLUDING ROOTWAD

*** TURNED PILES - DIA (IN) IS BUTT DIAMETER

NOTES

1. ALL LOGS SHALL BE DOUGLAS FIR OR WESTERN RED CEDAR.
2. ALL PILES SHALL BE ROUND, UNTREATED TIMBER PILES AND SHALL BE DOUGLAS FIR. PILES SHALL BE FREE FROM DEFECTS, CRACKS, AND SPLITTING AT THE TIME OF DRIVING.
3. LOGS WITH ROOTWADS SHALL HAVE A DIAMETER AS SHOWN MEASURED AT DBH, DEFINED AS 4.5 FEET ABOVE GROUND WHEN TREE WAS STANDING.
4. THE CONTRACTOR SHALL PLACE LOGS AS ILLUSTRATED ON THIS SHEET UNLESS DIRECTED OTHERWISE BY THE CONTRACTING OFFICER.
5. SOIL EXCAVATED DURING CONSTRUCTION SHALL BE REPLACED TO ORIGINAL GROUND FOLLOWING PLACEMENT OF ALL LOGS.
6. THE LOCATIONS SHOWN IN THE PLANS ARE APPROXIMATE AND MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER.
7. RACKING LOGS SHALL CONSIST OF TREES WITH BRANCHES HAVING A BASE DIAMETER AND LENGTH PER THE LOG SCHEDULE. TOTAL NUMBER OF RACKING LOGS PER STRUCTURE SHALL BE PER LOG SCHEDULE. RACKING MATERIAL SHALL OCCUR WITH EACH LAYER TO ENSURE THAT RACKING MATERIAL EXTENDS THROUGH THE STRUCTURE AND IS PINNED BY SUBSEQUENT LAYERS. SLASH MATERIAL SHALL CONSIST OF LIMBS AND BRANCHES AND A BASE DIAMETER PER THE LOG SCHEDULE. TOTAL SLASH MATERIAL QUANTITY SHALL BE PER THE LOG SCHEDULE. SLASH MATERIAL SHALL BE PLACED AS DIRECTED BY THE CONTRACTING OFFICER. RACKING AND SLASH MATERIAL SHALL BE DOUGLAS FIR, PONDEROSA PINE, WESTERN RED CEDAR, OR WESTERN LARCH TREES.
8. RETENTION LOGS TO BE INSTALLED TO HOLD RACKING MATERIAL IN PLACE AT THE DIRECTION OF THE CONTRACTING OFFICER.
9. CONNECT LOGS WITH WRAPPED CHAIN CONNECTION WHERE INDICATED ON THE DRAWINGS. SEE DETAILS.
10. EXISTING WOODY MATERIAL AT THE STRUCTURE CONSTRUCTION SITE SHALL BE MOVED OR PROTECTED FROM CONSTRUCTION ACTIVITIES AND THEN INCORPORATED INTO THE STRUCTURE AS DIRECTED BY THE CONTRACTING OFFICER.

DEFLECTOR ELJ DETAILS 1/19

SCALE: AS NOTED

Jun 04, 2021 PRELIMINARY DESIGN ALTERNATIVES NOT FOR CONSTRUCTION

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Mason Conservation District

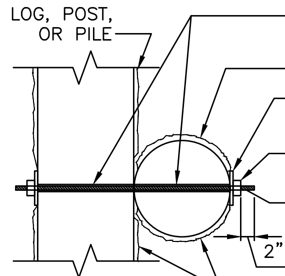
Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	ESB
CHECKED	SMW
DRAWN	EB, GM
CHECKED	SMW

GEOGRAPHIC INFORMATION	
LATITUDE	47°18'53"N
LONGITUDE	123°8'32"W
TN/SC/RG	T21N/S13/R4W
DATE	--

SKOKOMISH RIVER MAINSTEM MILE 1.5 HABITAT RESTORATION

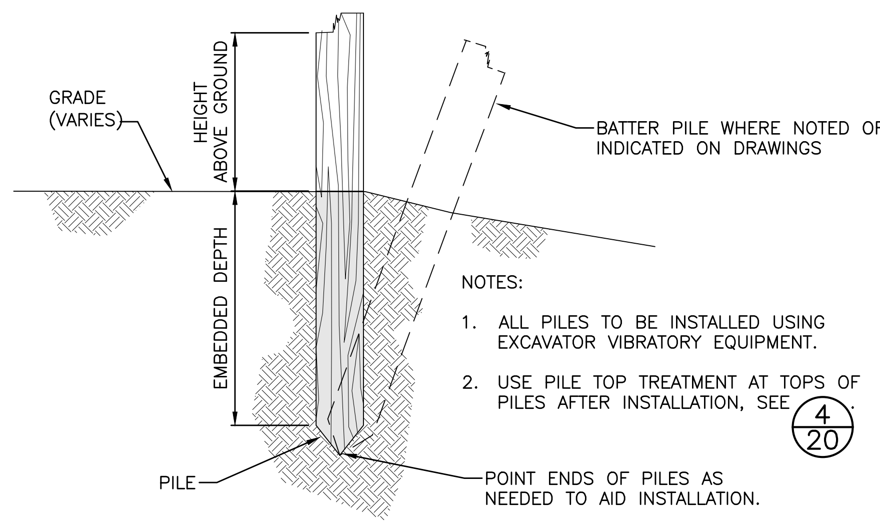
DEFLECTOR ELJ



NOTES:

1. REMOVE BARK AT CONNECTION POINTS.
2. DRILL HOLE THROUGH CENTER OF LOGS.
3. TIGHTEN SUFFICIENTLY TO ELIMINATE GAP BETWEEN LOGS BUT NOT CRUSH BOLES. PEEN THREADS OR TACK WELD NUT TO ALL-THREAD FOLLOWING TIGHTENING.
4. ALL-THREAD TO BE ASTM TYPE A 307, GRADE A. LENGTH VARIES BY CONNECTION.
5. MULTIPLE LOG CONNECTIONS AT SAME JOINT WILL USE SINGLE PIECE OF ALL-THREAD TO MINIMIZE HOLES IN POSTS.

BOLTED CONNECTION 1/20
NOT TO SCALE



NOTES:

1. ALL PILES TO BE INSTALLED USING EXCAVATOR VIBRATORY EQUIPMENT.
2. USE PILE TOP TREATMENT AT TOPS OF PILES AFTER INSTALLATION, SEE 4/20.

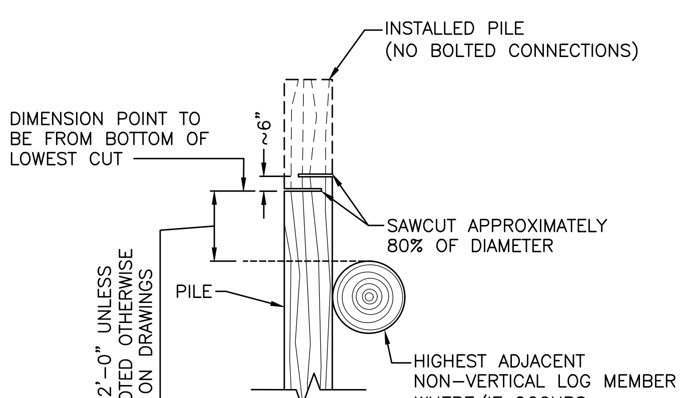
PILE INSTALLATION 2/20
NOT TO SCALE

NOTE:

1. PLACEMENT OF RACKING AND SLASH MATERIAL IS INTENDED TO OCCUR THROUGHOUT STRUCTURE CONSTRUCTION.
2. PLACEMENT OF MAJORITY OF RACKING AND SLASH MATERIAL UPON COMPLETION IS NOT DESIRABLE.
3. CONTRACTOR SHALL PLACE RACKING AND SLASH MATERIAL AS SHOWN ON THESE PLANS AS DIRECTED BY THE THE CONTRACTING OFFICER. THE GENERAL INTENT IS TO INCORPORATE A MAJORITY OF THE RACKING AND SLASH MATERIAL INTO THE STRUCTURE SUCH THAT RETENTION LOGS WORK TO SECURE THE PLACED MATERIAL. RACKING AND SLASH PLACEMENT SHALL BE CONCENTRATED ON THE UPSTREAM FACE OF THE STRUCTURE WITH LOGS CLOSEST TO THE STRUCTURE FACE ORIENTED ROUGHLY PERPENDICULAR TO FLOW DIRECTION.

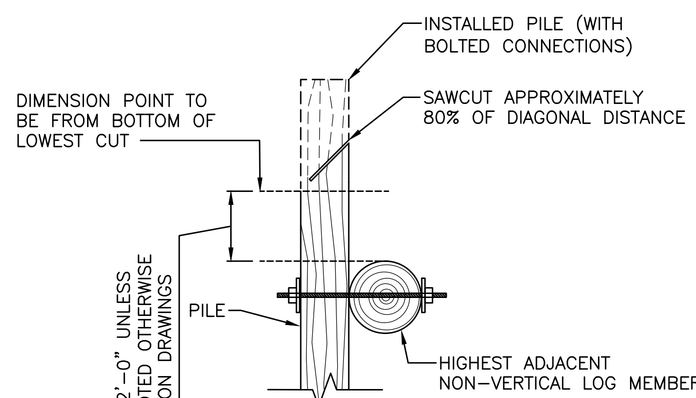
RACKING AND SLASH MATERIAL PLACEMENT DETAIL 3/20
SCALE: NA

METHOD 1 (NO BOLTED CONNECTION)



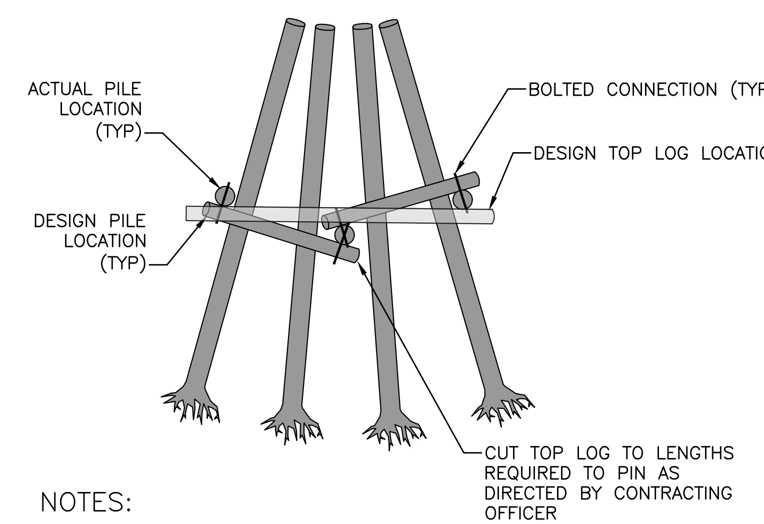
NOTE:
FOLLOWING SAWCUT, MANUALLY BREAK BY PUSHING OVER PILE TOP.

METHOD 2 (ABOVE BOLTED CONNECTION)



NOTE:
FOLLOWING SAWCUT, MANUALLY BREAK BY PUSHING OVER PILE TOP.

PILE TOP TREATMENT 4/20
NOT TO SCALE



NOTES:

1. MODIFY LAYOUT OF TOP LOGS AS DIRECTED BY CONTRACTING OFFICER TO ACHIEVE MINIMUM NUMBER OF BOLTED AND/OR PINNED CONNECTIONS SHOWN IN THE PLANS.
2. TOP LOGS SHALL BE PLACED SUCH THAT THEY ARE IN CONTACT WITH THE LOWER LAYERS WHEN PINNED.

MODIFIED BOLTED CONNECTION DETAIL 5/20
NOT TO SCALE

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