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TECHNICAL MEMORANDUM

Date: June 14, 2023
To: Alex Levell, Lummi Nation Natural Resources Department
From: Brian Scott; Ian Mostrenko, PE; Herrera Environmental Consultants, Inc.
Subject: South Fork Nooksack River Skookum-Edfro Reach Phase 3 Existing Conditions and Habitat Restoration Opportunities

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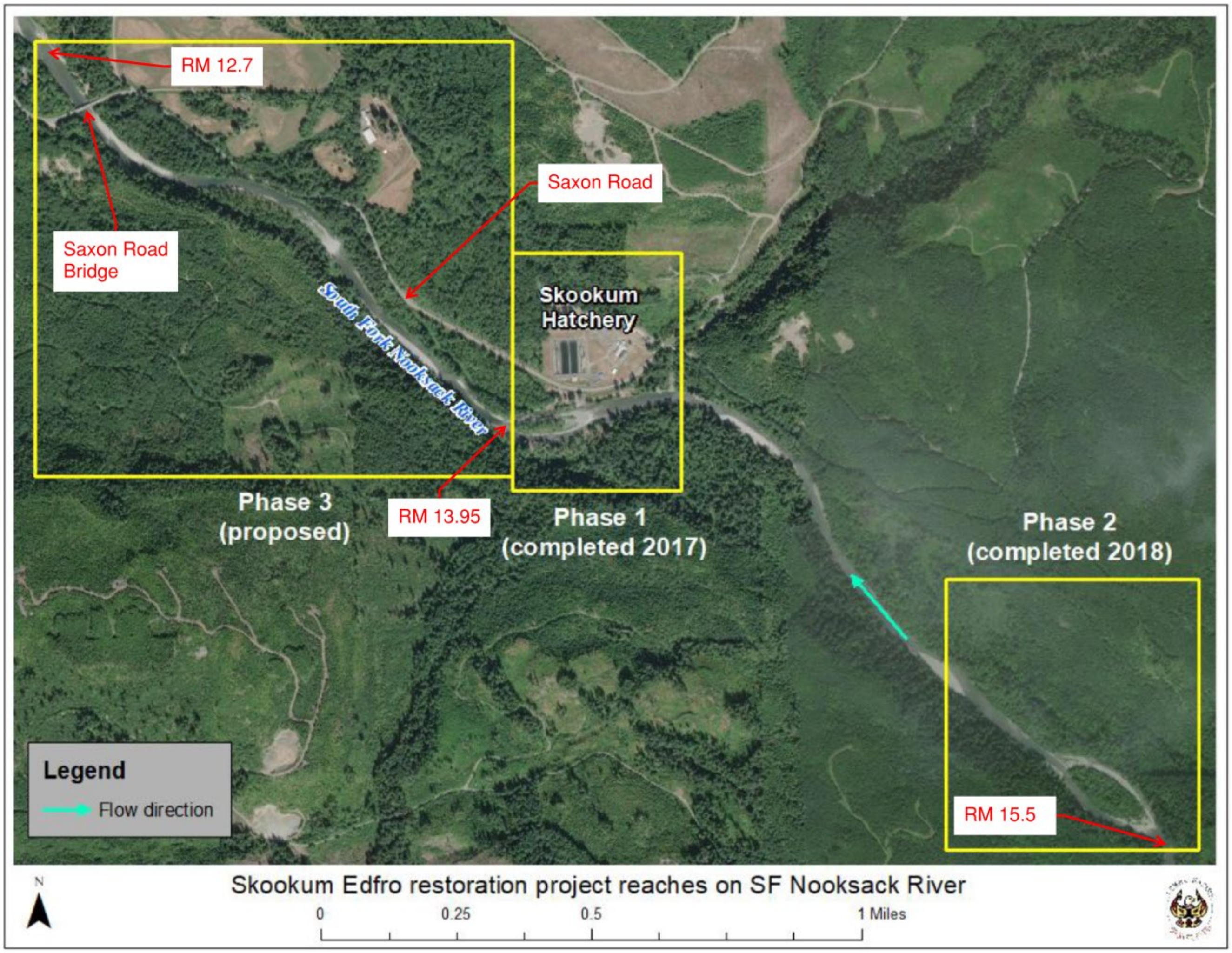
Introduction and Background

Since 2007 habitat restoration in the South Fork Nooksack River (South Fork) has been a high priority action for restoring and improving impaired habitat conditions for ESA listed salmon species including Puget Sound Chinook, Steelhead and Bull Trout. Specifically, recovery of the South Fork early Chinook is essential to recovering the threatened Puget Sound Evolutionarily Significant Unit (ESU) and for restoring runs to sustainable and harvestable levels for local tribal communities. The Lummi Nation Natural Resources Department (LNRD) has been implementing habitat restoration projects in the Skookum-Edfro Reach of the South Fork, located between river mile (RM) 12.70 and RM 15.50, since 2010 (Figure 1). The Skookum Reach Restoration Project was implemented in 2010 and included constructing three engineered logjams (ELJs) along the right bank of the South Fork adjacent to LNRD's Skookum Creek Fish Hatchery between RM 14.00 and RM 14.30 and realigning Saxon Road approximately 100 feet landward to its current location adjacent to the hatchery. Phase 1 of the South Fork Skookum-Edfro Reach Habitat Restoration Project (Project), also located adjacent to LNRD's Skookum Creek Fish Hatchery between RM 14.00 and RM 14.30, was completed in 2017 and included constructing four ELJs and four small habitat structures and enhancing the three ELJs constructed in 2010. Phase 2, located upstream of the Phase 1 project between RM 14.90 and RM 15.50, was completed in 2018 and included constructing 15 ELJs. Both phases focused on addressing key habitat limiting factors that continue to hinder WRIA 1 Chinook salmon recovery goals (WRIA 1 Salmon Recovery Board 2005), including:

- Reduced habitat diversity such as insufficient complex edge and floodplain habitats (e.g., undercut banks, backwater areas, side channels, sloughs and braids).
- Loss of stable instream large wood material (LWM) that creates thermal and velocity refugia, pools and cover adjacent to spawning areas, and promotes formation of complex channel and bed forms favorable for salmonid spawning, holding and rearing.
- Insufficient size, abundance and complexity of pool habitat (with and without cool water influences) for adult salmon holding.
- Seasonally elevated water temperatures.

In 2021 LNRD began moving forward with Phase 3 of the Project to develop and implement restoration actions to address the above listed habitat limiting factors in the Phase 3 reach, which is between RM 12.70 and RM 13.95. To support LNRD with implementing the early stages of the Phase 3 project, Herrera Environmental Consultants, Inc. (Herrera) has developed this memorandum summarizing the existing (pre-project) geomorphic and hydraulic conditions and habitat restoration opportunities within the Phase 3 reach. Herrera developed a two-dimensional (2D) hydraulic model of the Phase 3 reach following a site visit to it on September 15, 2022. Herrera used the model results and observations of the current geomorphic and habitat conditions of the reach made during the site visit to identify habitat restoration opportunities, and to identify existing flood and geomorphic related risks (i.e., bank erosion, channel migration and channel avulsion) to nearby infrastructure and private property.

Figure 1. Skookum-Edfro Reach of the South Fork Nooksack River.



Following submittal of this memorandum and receipt of feedback on the identified restoration opportunities from stakeholders, Herrera and LNRD will develop several conceptual level design alternatives for evaluation and selection of a preferred alternative that will be advanced to a preliminary design level and eventually to a final design level for future implementation. The conceptual design alternatives will be developed to achieve the targeted habitat conditions described later in this memorandum while minimizing potential flood and geomorphic related impacts based on an understanding of the hydraulic characteristics from the existing conditions hydraulic model. Once a preferred design alternative is selected Herrera will update the model to reflect proposed project conditions and use it to optimize the design to maximize improvements to habitat and geomorphic conditions. The preferred design alternative will also be refined to not increase flood or geomorphic related risks and will adhere to the Federal Emergency Management Agency (FEMA) and Whatcom County's "no-rise" regulations. Only upon modeling the preferred alternative to assess hydraulic impacts will refinement of the design occur to ensure project compliance with the regulations. Herrera will also use the proposed conditions model to support completing the project Conditional Letter of Map Revision (CLOMR) process that is required by Whatcom County and FEMA.

Phase 3 Reach Conditions

The intent of Herrera's site visit to the Phase 3 reach was to observe and document existing instream and floodplain geomorphic and hydraulic conditions; to identify restoration opportunities; to begin generating ideas for conceptual design alternatives; and to collect any data necessary to develop and run the hydraulic model as described later in this memorandum. Summaries of the existing geomorphic and hydraulic conditions is provided below. Flow in the South Fork that day (September 15, 2022), as measured by the Saxon Road USGS gage #12210000 averaged 75 cubic feet per second (cfs).

Geomorphic and Habitat Conditions

Geomorphic and habitat conditions in the Skookum-Edfro Reach are well documented in several previously completed assessments (Brown and Maudlin 2007; Maudlin et al. 2002) including the most recent assessment by Element Solutions (2015) that was specifically completed to inform Herrera's designs for the Phase 1 and Phase 2 projects in the Skookum-Edfro Reach. All previous geomorphic assessments documented significant anthropogenic hydromodifications and land use changes that have adversely impacted habitat conditions and geomorphic processes that create and sustain key habitats for salmonids at all life stages. For example, removal of existing instream logjams, installations of bank armoring (riprap), channel straightening and dredging, and loss of mature forested floodplains and riparian areas via logging and land use changes (e.g., road building, floodplain development, and agricultural) have significantly reduced the quantity, quality, diversity and accessibility of salmonid habitat in the Skookum-Edfro reach today.

Herrera's observations of geomorphic and habitat conditions during their site visit are consistent with conditions documented by Element Solutions (2015); the Phase 3 reach is highly modified, which has adversely altered geomorphic processes resulting in poor habitat conditions. Herrera reviewed said analysis before completing their site visit to refamiliarize themselves with the Phase 3 reach geomorphic conditions and to help determine if any notable changes in conditions have occurred from those described in the 2015 report.

Notable geomorphic conditions in the Phase 3 reach that have informed the restoration opportunities that are summarized later in this memorandum include the following:

- No stable instream LWM was observed. Some small transient LWM pieces were present along the left bank toe near RM 13.00 that had fallen from the top of the actively eroding bluff. A few LWM pieces were also present along the right bank in that area along the edge of the gravel bar vegetation but are likely not engaged until flows are much higher thus not providing any low flow habitat. Any LWM that is transported and deposited in the reach during a large flow event is transported out of the reach during subsequent high flows. Riparian vegetation is a mix of mostly immature coniferous and deciduous trees that if recruited into the channel will likely be transported out of the reach; however, it does provide the potential for some minor amounts of channel margin complexity and shade.

- Only four pools exist within the 1.25-mile-long reach, all of which were occupied during the site visit by many upstream migrating adult Chinook salmon. The two smallest pools were adjacent to the riprap armored left bank between RM 13.20 and RM 13.50. These secondary pools, meaning they occupy less than 50 percent of the channel area, are not well defined and have been previously mapped as runs (glides) due to the uniformly deep and slow-moving water along the armored bank. The third pool, at approximately RM 13.80, is a large and deep primary pool formed by scour around a large mid-channel boulder. A primary pool occupies more than 50 percent of the channel area. The fourth pool, at RM 13.95 is a large and deep secondary pool formed by the convergence of the two channels that flow around the north and south side of the large mid-channel island (Skookum Island) between RM 13.97 and RM 14.10. All four pools lacked woody cover as no LWM was present.

- The channel is predominantly a simplified and uniform plane-bed, single-threaded channel (i.e., no bifurcations) with very little planform and bedform complexity and low sinuosity. Channel morphology mainly consists of long and wide slowly flowing runs connected by short and steep riffle sections. There is much evidence of channel incision along the reach. Additionally, relic floodplain side channels are isolated from the main channel and are only activated during large flow events thus limiting the off-channel refugia and providing further evidence of channel incision and poor floodplain connectivity. Riprap is present along a significant length of the left and right banks between RM 12.90 at the Saxon Road Bridge and RM 13.50. This bank armoring arrests all channel migration and is a significant cause of habitat degradation and channel simplification. There is some evidence of recent bank erosion in the Phase 3 reach; however little to no channel migration has occurred since bank armoring was placed. Channel migration in the Phase 3 reach is also limited in part due to the channel incision (the channel is incising rather than laterally migrating via bank erosion) and the bedrock and steep valley wall present along the left bank.

- The average channel substrate size generally decreases slightly in the downstream direction through the reach as the channel gradient also decreases and floodplain width increases; however, channel substrate in the vicinity of the pools is much finer than the substrate downstream of them due to the general scouring of the channel bed and subsequent transport and deposition of the coarse bedload material downstream of the pools to form riffle crests. In addition, the reach has very few areas of suitable spawning substrate. Spawning survey data provided by LNRD shows limited spawning has occurred in several isolated areas along the reach with most of the spawning occurring between RM 13.10 and RM 13.20, which is consistent with Herrera's observation of channel conditions there. Gravel bar deposits are generally coarse (cobbles and small boulders) and imbricated indicating high flow velocities during large flow events. Channel bank composition was predominantly erodible alluvium, colluvium, and glacial deposits, except where riprap bank armoring is present.

In summary, the Phase 3 reach has been substantially modified from its historical conditions. The loss of the anastomosing channel morphology and resultant floodplain connectivity was likely the most significant historical impact to habitat function. The poor instream habitat conditions are further compounded by the incised channel conditions and a disconnected floodplain that is not engaged until very large flow events, resulting in increased stream velocity and scour potential. As a result, there is an acute lack of velocity and cool water refugia for juvenile and adult salmonids, rearing habitat for juvenile salmonids and poor adult holding and spawning opportunities. With the removal of woody debris and the subsequent transition into a single thread channel form, many of the habitat conditions that would have created high-functioning salmon habitat in this reach have been lost. These include channel planform and bedform complexity, velocity refugia, habitat diversity, and deep pool conditions.

Hydraulic Conditions

Herrera developed a two-dimensional (2D) hydraulic model for the existing Phase 3 reach conditions using the RiverFlow2D Plus software program (Hydronia 2016) version 7.5.1 and QGIS version 3.16 interface. Herrera used the model to characterize instream and overbank floodplain flow conditions for the 2-year (11,985 cfs), 10-year (20,200 cfs), and 100-year (29,300 cfs) recurrence interval floods and for a low flow that typically occurs during late summer and early fall during the Chinook salmon migration and spawning period (287 cfs). Model results of the 2-year flow provided insights into how much floodplain connection and inundation occurs during a relatively frequent flood. The 10-year flow results demonstrate how much flooding is expected to occur during a less frequent yet higher magnitude like the flood that occurred on November 15, 2021 (19,000 cfs approximately). The 100-year flow results are primarily used as a basis for comparing pre- and post-project construction conditions for permitting and other regulatory processes, and to complete engineering analysis of proposed design features such as ELJs for habitat improvements. The 10-year and 100-year flow rates are the same flows used in the FEMA Flood Insurance Study (FIS) one-dimensional (1D) HEC-RAS hydraulic model for the South Fork. The 2-year flow was developed as part of the Phase 1 and Phase 2 projects hydrologic and hydraulic analysis. The spawning period low flow rate was provided to Herrera by LNRD.

Herrera developed the model surface by merging the 2017 North Puget Sound bathymetric and non-bathymetric LiDAR data sets for the project reach and surrounding area, acquired from the Puget Sound LiDAR Consortium portal, with supplemental topobathymetric survey data of the project reach collected by LNRD on September 6 and 15, 2022, for the areas downstream of the Saxon Road Bridge where the non-bathymetric LIDAR data set did not include bathymetric data. Model calibration was completed by comparing modeled water surface elevations (WSEs) to WSEs either recorded or predicted to occur at the Saxon Road USGS gage #12210000 for the spawning period low flow, 2-year, 10-year, 100-year, for the November 28, 2021, flood (13,000 cfs approximately) and for the November 28, 2021, flood, and then adjusting the Manning's n values for surface roughness and editing parts of the model surface where LiDAR topography needed revising until water surface elevations were within approximately 0.1 to 0.2 foot of each other. The model was then validated by comparing modeled WSEs to WSEs established at various cross sections of the FEMA FIS 1D hydraulic model to ensure they were within acceptable differences of each other.

Notable hydraulic conditions within the Phase 3 reach for the four flow rates evaluated are summarized below. These conditions helped inform the restoration opportunities summarized in the following section. Graphics of the preliminary (not final) model results for existing conditions are in Appendix A at the end of this memorandum.

- For the spawning period flow (287 cfs): All flow is fully contained within the active channel and no relic side channels are active. There is very little hydraulic complexity (i.e., large variations in flow depths and velocities over a relatively short section of river) within the channel due to the dearth of instream structure like logjams, large logs and large boulders. Except for the four pools described in the previous section and a deep and slowly flowing run located between the two downstream most pools, flow depths are very generally quite shallow. This indicates there are few areas in the reach where upstream migrating adult salmon can hold and rest before continuing to upstream spawning areas. Froude numbers were categorized into certain biotopes (Demars et al. 2012; Entwistle et al. 2019) to identify pool, run, riffle, and rapid characteristics that corresponded well with physical habitat data collected by LNRD. This same type of analysis will be used on the preferred alternative to adjust design to achieve habitat goals.
- For the 2-year flow (11,985 cfs): All flow is fully contained within the active channel; no overbank flooding occurs and none of the relic high flow side channel are activated. This signifies the considerable extent of channel confinement and incision and the resulting floodplain disconnection that has occurred and will continue during flows that typically cause overbank flooding in less disturbed rivers where overbank flooding typically occurs between the 1-year and 2-year flow (or the effective discharge flow). There is very little hydraulic complexity within the channel due to the dearth of instream structure. In-channel flow velocities range from approximately 7 to 15 fps down the middle of the channel, which is enough to mobilize cobbles and boulders. Velocities along the banks drop to 1 to 2 fps in a few locations indicating very few areas where salmonids can seek refugia until the flow rate decreases substantially.
- For the 10-year flow (20,200 cfs): There is very little floodplain and relic side channel activation based on the low flow depths and velocities in areas where the floodplain is activated. This indicates the overall dearth of floodplain refugia in the reach. At the Saxon Road Bridge, all flow is forced under the bridge because the roadway functions like a levee with no flow overtopping it. This condition, and the resulting high flow velocities that occur under the bridge (up to 15 fps), is likely one of the causes of the general channel incision in the Phase 3 reach. This is evident by the exposed broken mid-channel wooden pilings observed just upstream of the bridge that were not visible 20 to 30 years ago based on observations made by a nearby landowner that has lived near the river since the 1970s. Like the 2-year flow, there is very little hydraulic complexity within the channel due to the dearth of instream structure. In-channel flow velocities generally range from approximately 10 to as much as 20 to 25 fps. Like the 2-year flow there is very little high flow refugia along the banks.
- For the 100-year flow (29,300 cfs): Significant floodplain inundation occurs, and many relic floodplain channels are active with flow depths and velocities likely low enough to provide refugia for salmonids; however, this floodplain connectivity is so infrequent that it provides little benefit. Yet

there is one section of the reach (Sub-reach 2; see Figure 3 in the subsequent section below) where the flow does not breach the right bank despite a lack of any feature like a steep bluff or elevated roadway that would otherwise contain the flow. At this flow rate the reach is considered a “losing reach” meaning some of the overbank flow does not return to the river until it is much farther downstream of the reach. There is still very little hydraulic complexity, and in-channel velocities range from approximately 12 to as much as 20 to 25 fps with much more of the river experiencing velocities above 15 fps than during the 10-year flow. Like the 2- and 10-year flows there is very little high flow refugia.

Phase 3 Reach Habitat Restoration Opportunities

The general approach to improving habitat conditions in the Phase 3 reach is to implement restoration measures that promote the natural physical processes that create and sustain diverse and complex habitat conditions that ultimately promote recovery of ESA listed salmon species including Puget Sound Chinook, Steelhead and Bull Trout. Specifically, recovery of the South Fork early Chinook is essential to recovering the threatened Puget Sound ESU and for restoring runs to sustainable and harvestable levels for local tribal communities. Therefore, the restoration strategy is to achieve increased habitat function through restoring lost channel processes and conditions by emulating, to the extent possible, the probable historical stream and channel conditions with immediate and/or near-term benefits under a range flows and conditions, for as long a duration as possible. To accomplish this WRIA 1 co-managers established the following target habitat conditions for the South Fork restoration project elements and performance monitoring:

- Eighteen (18) deep pools with greater than 1-meter residual depth per mile. A pool quantity of less than 1.4 channel widths per pool is considered a “good” condition, and a pool quantity of less than 1 channel width per pool is considered a “very good” condition.
- Two-thirds of all pools formed by naturally occurring wood or by LWM placed for restoration purposes.
- Thirty (30) stable logjams per mile in unconfined reaches (from approximately RM 12.70 to RM 14) and 10 per mile in confined reaches (RM 13.60 to RM 14.00). This equates to one logjam approximately every 180 feet (approximately one channel width for the Phase 3 reach). Note that logjams forming deep complex pools within cool water influence areas and within other areas is a Tier 1 restoration strategy identified by the WRIA 1 co-managers).
- Removal of “hardened” armored (riprap) banks.

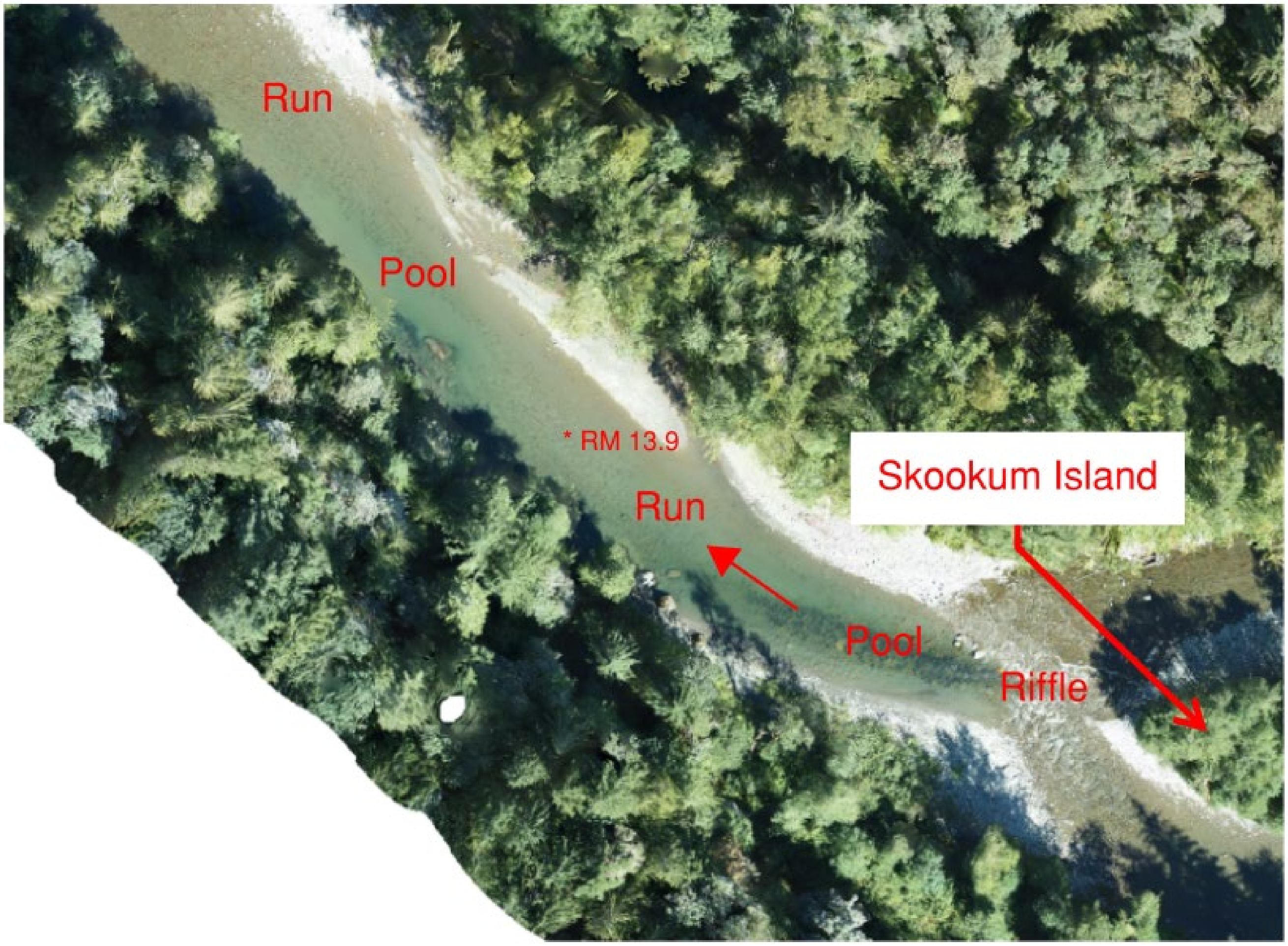
With these habitat targets in mind, Herrera identified many opportunities in the Phase 3 reach where restoration measures can be implemented to address the previously mentioned habitat limiting factors while simultaneously striving to achieve the above listed target habitat conditions and improve habitat diversity (habitat units that span the majority of the channel), complexity and accessibility while not increasing existing flood and geomorphic associated risks to nearby private property and infrastructure. The entire Phase 3 reach is considered a high-energy area based on the hydraulic model results and geomorphic conditions; therefore, ELJs of various sizes and function are the primary restoration measures that can be installed to slow flow velocities, encourage retention of finer spawning sized sediments and channel aggradation of incised sub-reaches, and create deep and complex pools while significantly increasing the overall hydraulic and geomorphic complexity within the Phase 3 reach. A combination of the ELJs with side channel regrading, riprap removal, gravel bar regrading and placement of gravel bar and surplus ELJ excavation spoils along riprap armored banks that must remain in place can also be implemented to achieve the above listed target habitat conditions.

For the purposes of summarizing restoration opportunities, the Phase 3 reach was divided into six distinct sub-reaches based on the reach geomorphology. Specific opportunities are summarized below for each sub-reach beginning at the upstream end near RM 14.00 and ending at the downstream end at RM 12.70.

Phase 3 Sub-Reach 1 (RM 13.95–RM 13.85)

Sub-reach 1 begins where the north and south channels that flow around Skookum Island converge to form a deep primary convergence pool (Figure 2). This sub-reach includes said pool and a large and deep secondary pool downstream. Deep and slowly flowing runs have developed downstream of each pool. No bank armoring (riprap) is present; however, the left bank is mostly bedrock and lateral migration rates into the left bank is extremely low. Both banks are vegetated with native trees and shrubs. Both pools are primary holding areas for upstream migrating adult salmon; therefore, restoration measures should not cause a decrease in size or depth of them but rather strive to provide woody cover in them if possible and increase channel planform and bed complexity to increase pool frequency.

Figure 2. Phase 3 Sub-Reach 1 (RM 13.95–RM 13.85).



Restoration opportunities in Sub-reach 1 include the following:

- Multiple small (5 to 10 feet wide/25 to 100 square feet (sf) in area) and medium sized (15 to 30 feet wide/225 to 900 sf) ELJs can be located near and between the pools and along the graveled banks to provide cover and significantly increase bed form and habitat complexity.
- One or two medium ELJs can be located along the left bank on the gravel bar at the downstream end of the sub-reach where the downstream most run begins to transition to the downstream riffle near RM 13.80, as shown in Figure 3 for Sub-reach 2.

Figure 3. Phase 3 Sub-Reach 2 (RM 13.85–RM 13.65).

Phase 3 Sub-Reach 2 (RM 13.85–RM 13.65)

Sub-reach 2 includes only riffles and runs; no pools are present (Figure 3). No bank armoring is present and both banks are vegetated with native trees and shrubs. A large left bank gravel bar directs lower flows towards the right bank. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity. Sub-reach 2 has a gradient of just under 0.5 percent slope and would support a more frequent pool-riffle sequence with the placement of larger LWM structures to induce more complex bedform and planform variability.

Restoration opportunities in the Sub-reach 2 include the following:

- Multiple medium and large (35 to 50 feet wide/1,225 to 2,500 sf) ELJs can be spaced along the right bank low flow channel. This configuration will encourage development of complex habitat units (pools, riffles and runs) between the ELJs.

- Multiple medium ELJs can be spaced along the left bank opposite of, and between, the right bank ELJs. Alternating the left bank and right bank ELJs in this manner will encourage flow to "zig zag" between the structures. This planform complexity and variability will help to slow flow velocities and encourage sediment to deposit locally thereby aggrading the incised channel to increase floodplain activation.
- Multiple small ELJs and individual large LWM pieces can be placed mid-channel between the bank ELJs to provide more instream LMW and encourage formation of complex mid-channel habitat features.

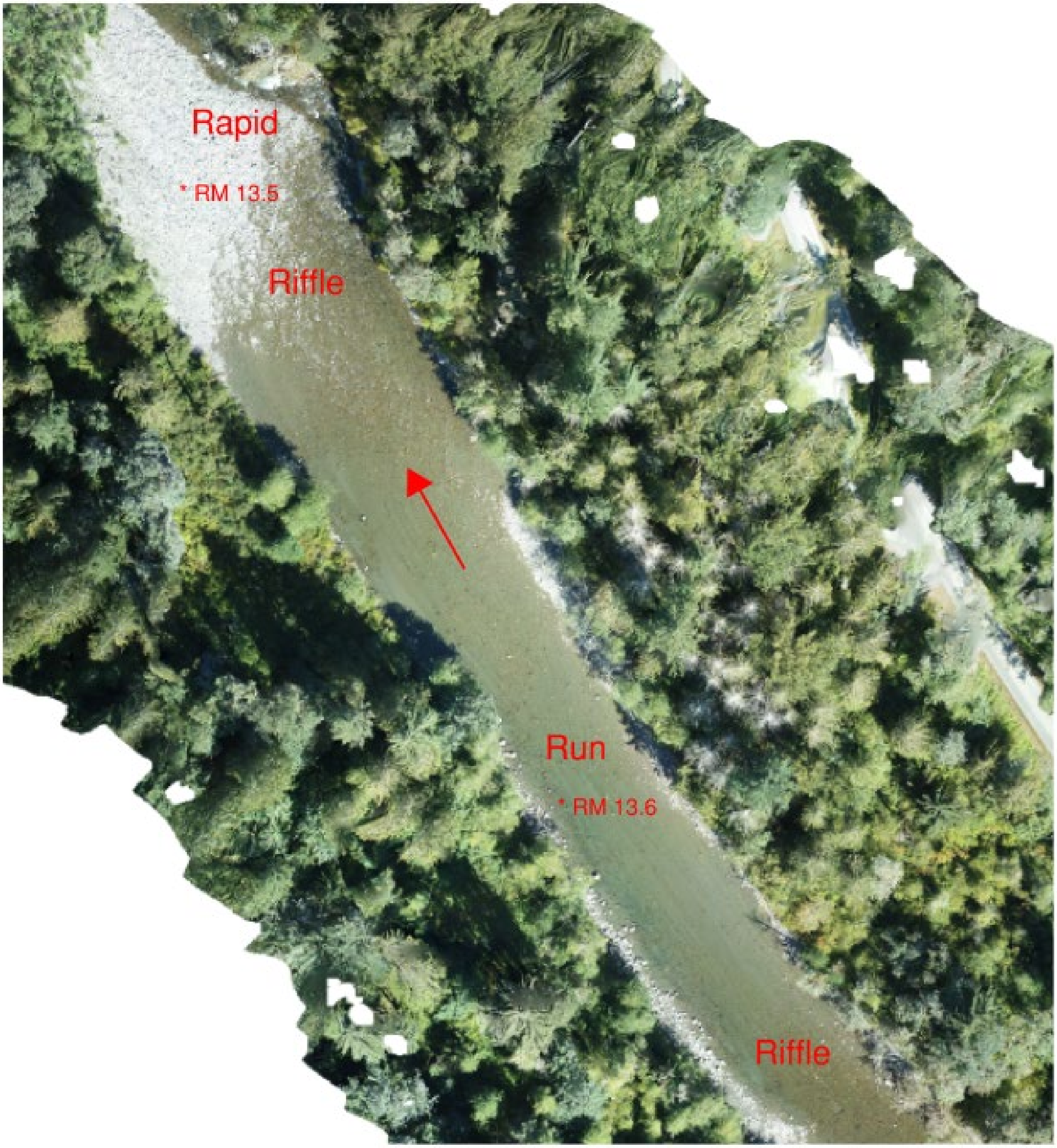
Phase 3 Sub-Reach 3 (RM 13.65–RM 13.50)

Sub-reach 3 consists primarily of a long, wide and shallow run with short riffles at the upstream and downstream side. No pools or bank armoring are present and both banks are vegetated with native trees and shrubs. The main channel has migrated away from the bedrock valley wall and there is a remnant left bank valley wall channel that is only activated at higher magnitude floods (i.e., 10-year floods and higher). Significant aggradation would be required in this reach to activate the left bank valley wall channel at meaningful flows (higher frequency) to support a frequently inundated side channel and will probably only provide high flood refugia even after restoration unless the restoration efforts are very aggressive with promoting extensive aggradation (i.e., valley-spanning structures). This sub-reach is also considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity.

Restoration opportunities in Sub-reach 3 include the following:

- Small and medium ELJs can be located along both banks in an alternating pattern to encourage flow to "zig zag" between the structures. This will help to slow flow velocities and encourage sediment to deposit locally thereby aggrading the incised channel to increase floodplain activation.
- Medium and/or large ELJs can be located along the right bank and mid-channel near the downstream end of this sub-reach to help direct flow into a relic left bank side channel that begins near RM 13.50 that can be regraded to provide off-channel habitat as described in Sub-reach 4 below and as shown in Figure 4. These ELJs will also provide functions similar to the small and medium bank ELJs described in the previous bullet.
- Multiple small ELJs and individual large LWM pieces can be placed mid-channel between the bank ELJs to provide more instream LMW and encourage formation of complex mid-channel habitat features.
- Some left bank activation may be beneficial for habitat refugia for larger events near the downstream portion of the sub-reach. This may be valuable high flow refugia because floodplain connectivity is so limited in this sub-reach and the left bank is one of the few off-channel habitat opportunities.

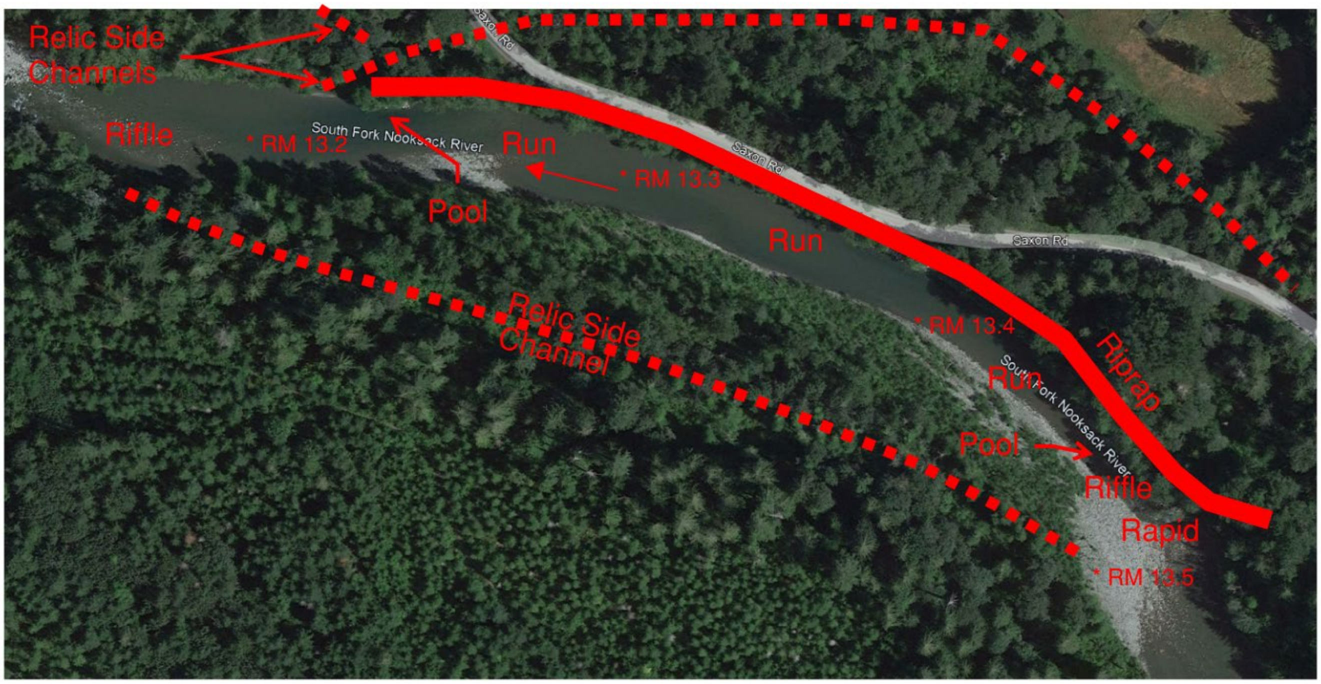
Figure 4. Phase 3 Sub-Reach 3 (RM 13.65–RM 13.50).



Phase 3 Sub-Reach 4 (RM 13.50–RM 13.20)

At the upstream end of Sub-reach 4 at RM 13.50 is a very short and steep rapid that quickly transitions to a short riffle then to a very small and shallow secondary pool. This pool quickly transitions to a very long, deep and slowly flowing run for most of the remainder of the sub-reach with a second bigger and deeper secondary pool at the downstream end of the sub-reach (Figure 5). Adult salmon migrating upstream will hold in both pools before ascending upstream. The channel is aligned parallel to Saxon Road for about half of the run. Riprap is present along most of the right bank between the top and toe of the bank to prevent further channel migration towards the roadway and the channel is entrained along it. This sub-reach is also a high energy environment; the channel is predominantly confined between the riprap and the left bank of the floodplain, and it is significantly incised downstream of the rapid. This is the result of a headcut that has propagated upstream in part because of the incision. A relic right bank high flow channel located in the vegetated right bank floodplain landward of Saxon Road crosses under the road via an 18- to 24-inch-diameter culvert and converges with the main channel at the downstream end of the riprap. Upstream migrating adult salmon will also hold in a deep section of the run at the downstream end of the riprap. Along the toe of the left/south bank valley wall is another relic, high flow floodplain side channel that has filled in with fine sediments and become overgrown with native trees and shrubs. This is due to the floodplain becoming disconnected with the main channel because of the incision. The floodplain between the valley wall and the main channel consists primarily of young native deciduous trees and shrubs.

Figure 5. Phase 3 Sub-Reach 4 (RM 13.50–RM 13.20).



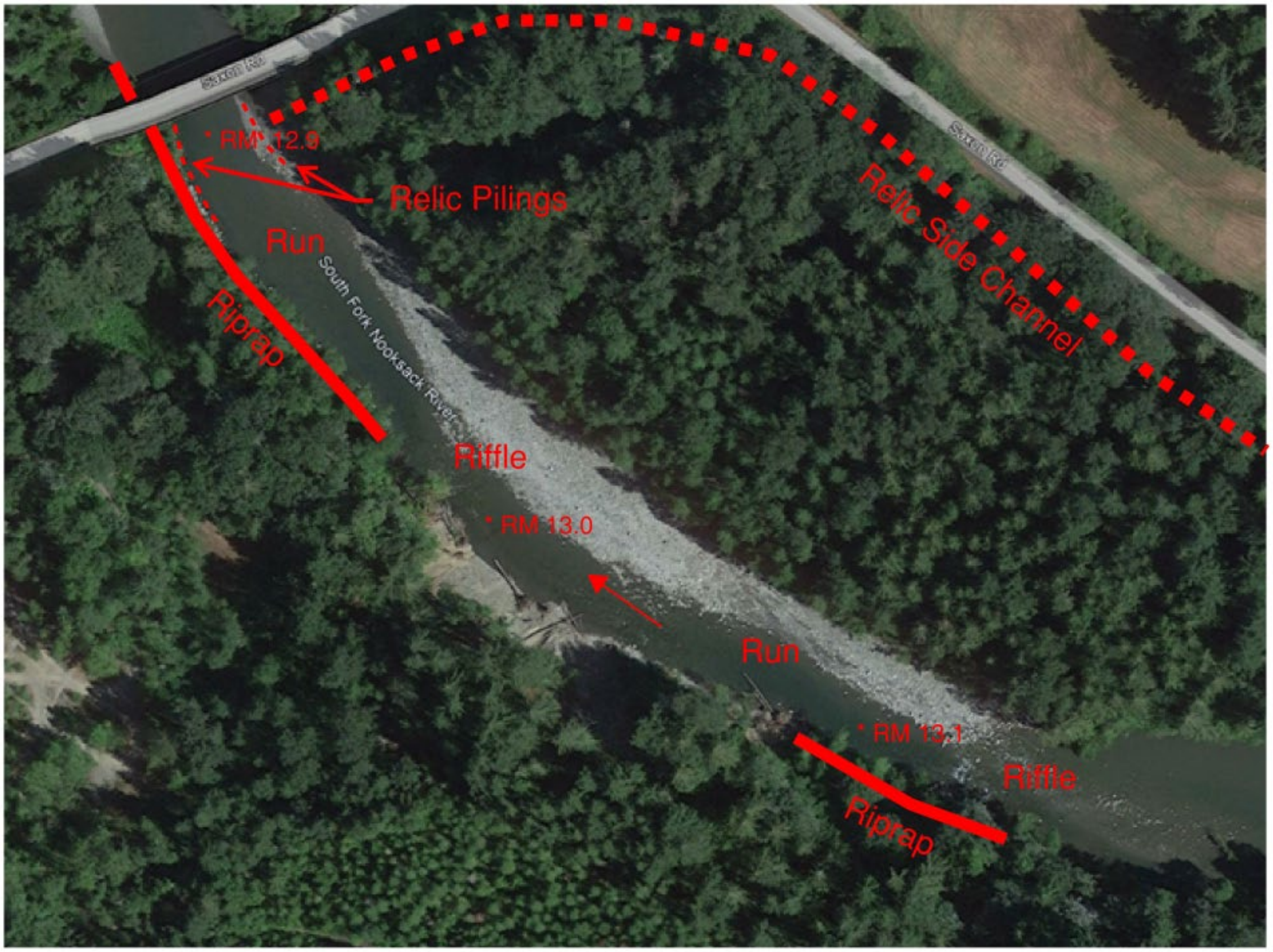
Restoration opportunities in Sub-reach 4 include the following:

- Multiple large ELJs can be spaced along the armored right bank to cover the riprap, create deep and complex pools, and dissipate flow energy to encourage sediment retention and begin reversing the effects of channel incision. A secondary benefit of these ELJs is that they can work in concert with the riprap to provide additional protection to the roadway while significantly improving habitat conditions. The ELJs can either be constructed into the bank by removing the riprap (and reusing it to ballast the structure) or the riprap can remain and the ELJs built completely landward of it. Riprap between the ELJs would not be disturbed. In lieu of multiple large ELJs, the riprap bank can be roughened by supplementing it with large logs and other smaller woody material; however, this will likely require disturbing much of the existing riprap and rebuilding the entire bank to secure the logs. Habitat improvements for this scenario would be considerably less than if ELJs were constructed.
- The main active channel along the riprap is much narrower and deeper than the main channel elsewhere in the Phase 3 reach due to the aforementioned incision; therefore, the large ELJs, by virtue of their size, will project into the channel approximately one-third to one-half of the channel width. This configuration will deflect flow towards left bank vegetated gravel bar inducing substantial, and much needed, localized bank erosion and bed scour. This will likely cause a significant rise in WSEs for a wide range of high flows (2-year flood and greater, including the FEMA regulated 100-year flood) before the bank can naturally erode, in response to the ELJs, to provide greater hydraulic conveyance and lower WSEs. Therefore, to mitigate the potential WSE rise and expedite bank erosion, the left bank of the gravel bar opposite of the ELJs and the riprap can be regraded in such a way to mimic the bank erosion that would occur there naturally to provide greater flow conveyance to help offset the potential WSE rise.
- The existing relic left bank side channel can be regraded to significantly increase activation and provide off-channel habitat. Increasing flow into this side channel will help to keep it open and result in less flow in the main channel, which will help to offset potential WSE rises and encourage sediment retention within this sub-reach to begin reversing the effects of channel incision. Small ELJs and LWM can also be placed in the side channel to provide habitat complexity.
- Alluvium removed as part of the left bank regrading and any surplus alluvium from ELJ construction and left bank side channel regrading can be regraded around the bank ELJs to keep the valuable alluvium in the system and available for downstream redistribution to address the channel incision. Finer alluvium and floodplain material can be placed over the riprap remaining between the ELJs. Topsoil and mulch can be placed over the finer alluvium and floodplain material, and over the tops of the ELJs, to provide a suitable substrate for riparian plantings to improve edge habitat conditions between the ELJs. This will also significantly improve the aesthetics of this area. Redistributing the excavated alluvium material and placement of the finer alluvium material and floodplain soils to cover the riprap will also help to reduce construction costs.

Phase 3 Sub-Reach 5 (RM 13.15–RM 12.90)

Sub-reach 5 includes two riffle-run sequences with no pools before reaching the Saxon Road Bridge with two discontinuous sections of riprap present along the left bank (Figure 6). Relic wooden pilings from previous bridges are also present near the current bridge. The channel is aligned along a steep eroding bluff in the vicinity of RM 13.00 that occasionally provides small transient woody debris to the channel. Riprap was likely present along the toe of the eroding bluff, thus making for a continuous revetment along the left bank to protect the current and past bridges, but it was likely loss due to bank erosion. The right bank floodplain is heavily vegetated primarily with second growth conifers and contains a relic high flow side channels that is aligned parallel to Saxon Road. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity.

Figure 6. Phase 3 Sub-Reach 5 (RM 13.15–RM 12.90).



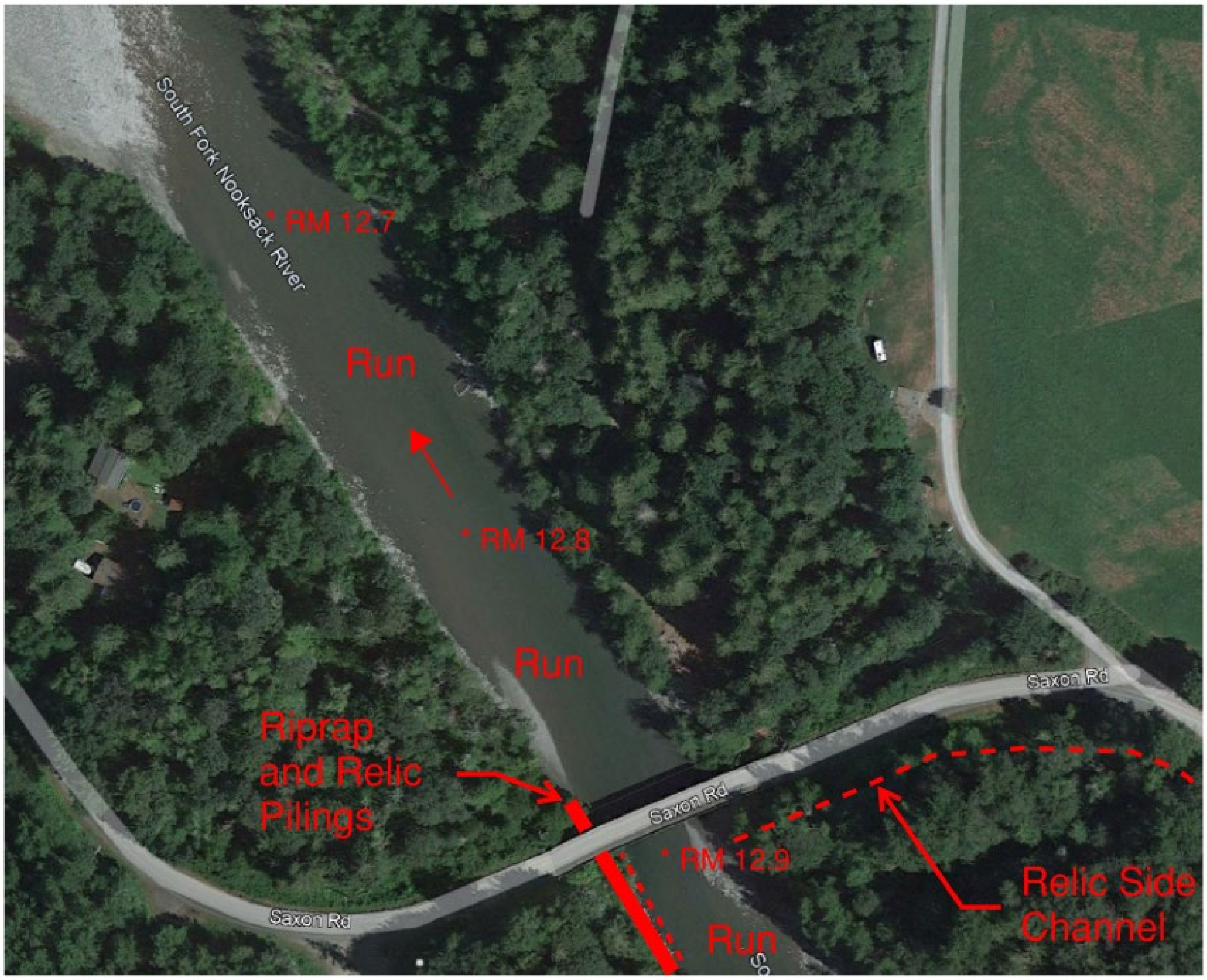
Restoration opportunities in Sub-reach 5 include the following:

- Medium and large ELJs can be located along the left bank to create deep and complex pools and to catch trees recruited into the river from the eroding bluff. When combined with the small and medium ELJs along the right bank (see next bullet) they can function collectively to dissipate flow energy to encourage sediment retention and begin reversing the effects of channel incision through this sub-reach. Channel aggradation in this sub-reach and in Sub-reach 4 upstream will increase the activation frequency of the relic right bank side channel thereby improving floodplain connectivity and off-channel habitat.
- Multiple small and medium ELJs can be spaced along the right bank at the edge of the vegetation and along the large right bank gravel bar to provide woody cover and improve channel bed complexity.
- The upstream segment of riprap near RM 13.10 can be removed to allow channel migration into the steep bluff to encourage recruitment of trees into the channel and to restore natural bank conditions that will significantly improve edge habitat. The downstream segment of riprap and relic pilings along the left bank should not be removed as doing so will increase risk to the bridge, which is maintained by Whatcom County. However, ELJs can potentially be placed in the channel near the riprap to mitigate the adverse effects of it on habitat but only if they do not increase risk of failure to the riprap and pilings.

Phase 3 Sub-Reach 6 (RM 12.90–RM 12.70)

Sub-reach 6 consists of one long, wide and shallow run with no pools or other notable instream habitat features (Figure 7). Bank vegetation consists of a mix of coniferous and deciduous trees and shrubs. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity. This sub-reach terminates at the Saxon Reach Habitat Restoration project of 2012, insinuating an opportunity to link the two projects.

Figure 7. Phase 3 Sub-Reach 6 (RM 12.90–RM 12.70).



Restoration opportunities in Sub-reach 6 include the following:

- Multiple small and medium ELJs can be spaced along the left and right banks and mid-channel to create deep and complex pools, provide woody cover and improve channel bed and planform complexity. This reach is likely sensitive to WSE rise with residences on the left bank, so these ELJs should target small and localized hydraulic complexity for lower flows but not for higher flows (i.e., ELJs should have a low profile so that larger flows skip over them). Privately owned, mostly unoccupied floodplain is on the right bank, therefore landowner outreach on both banks will guide restoration opportunities.

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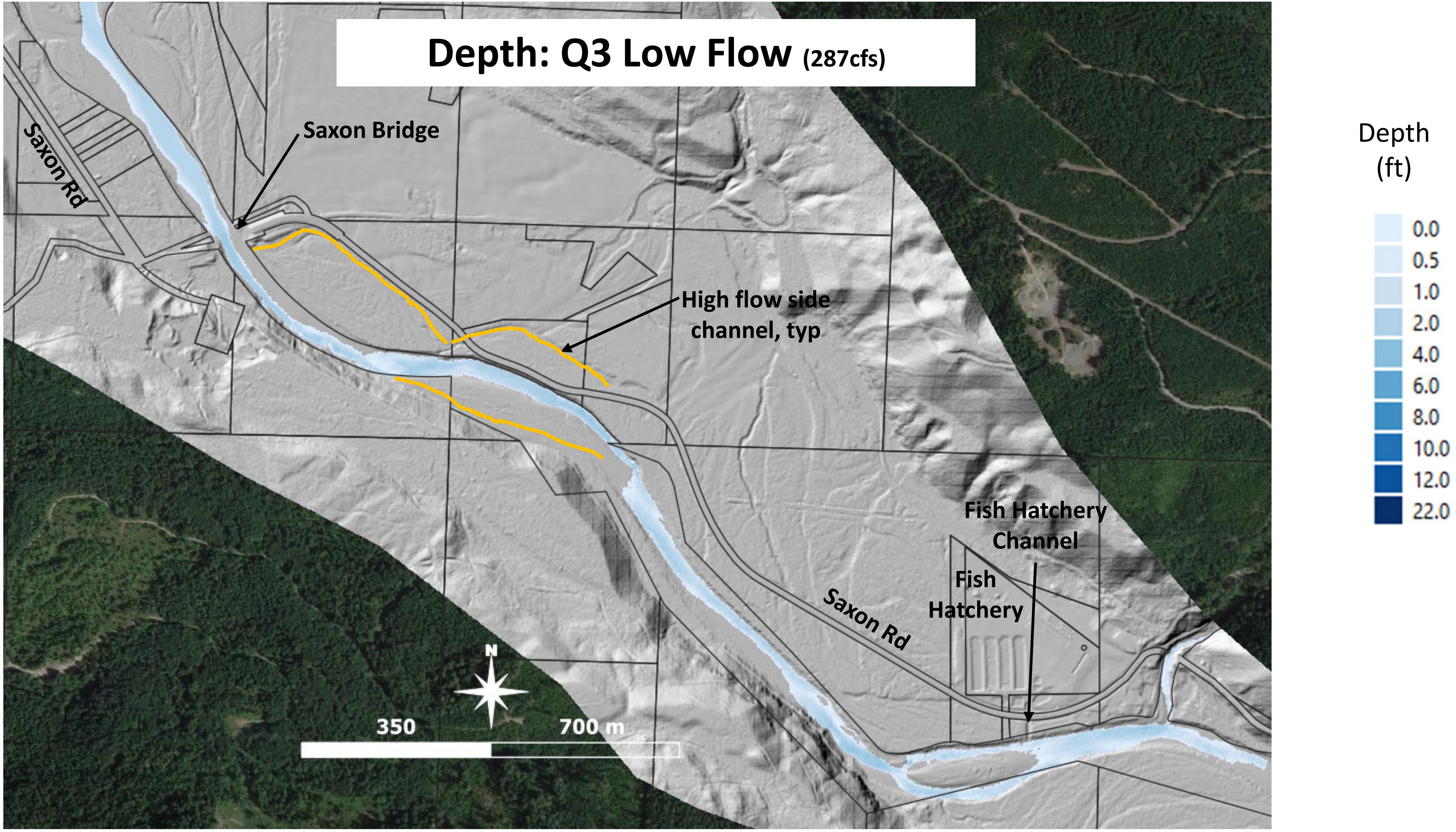
Appendix A

Existing Conditions Hydraulic Model Results Graphics

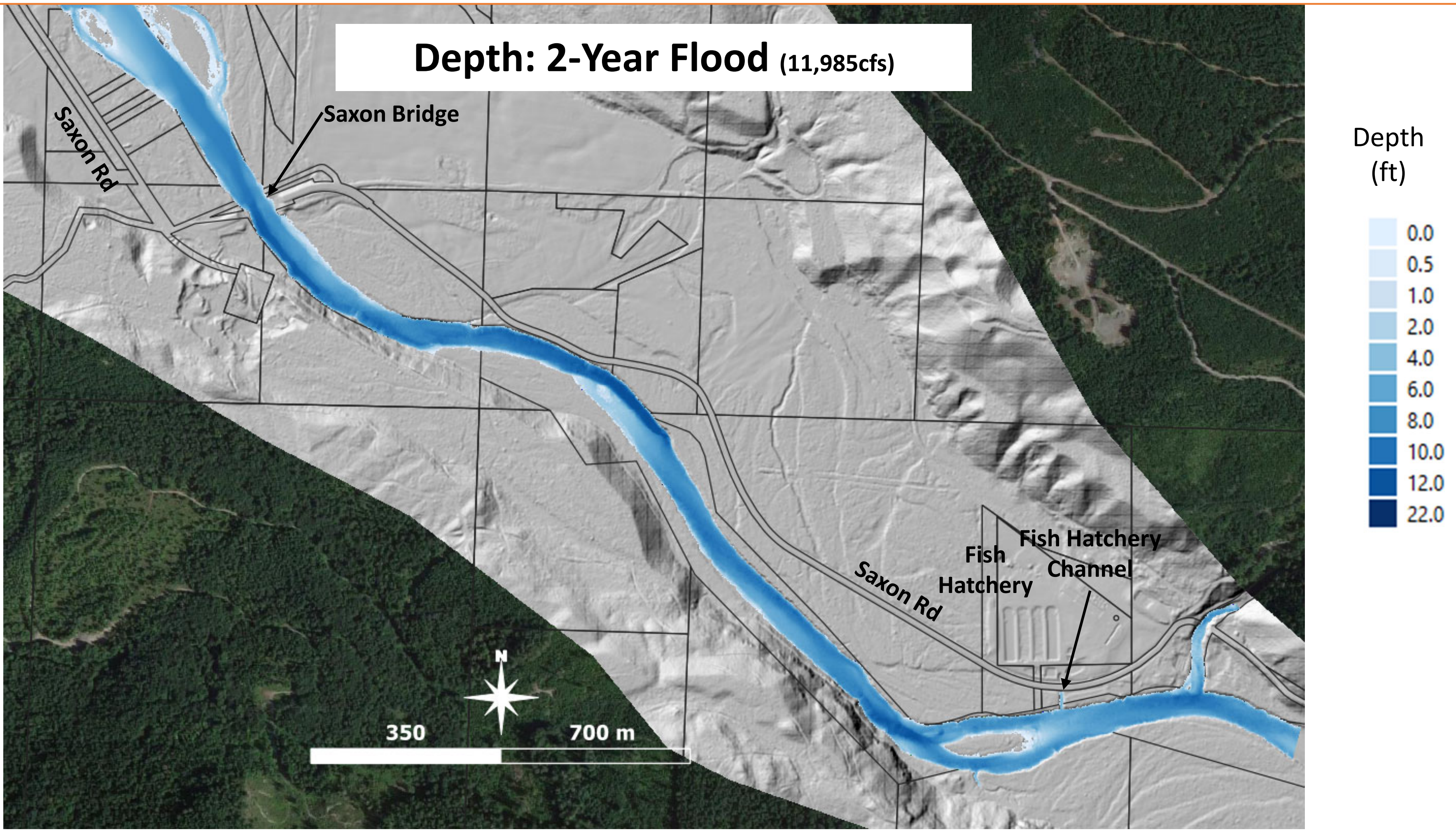
HERRERA
Science + Planning + Design

HYDRAULIC MODEL RESULTS

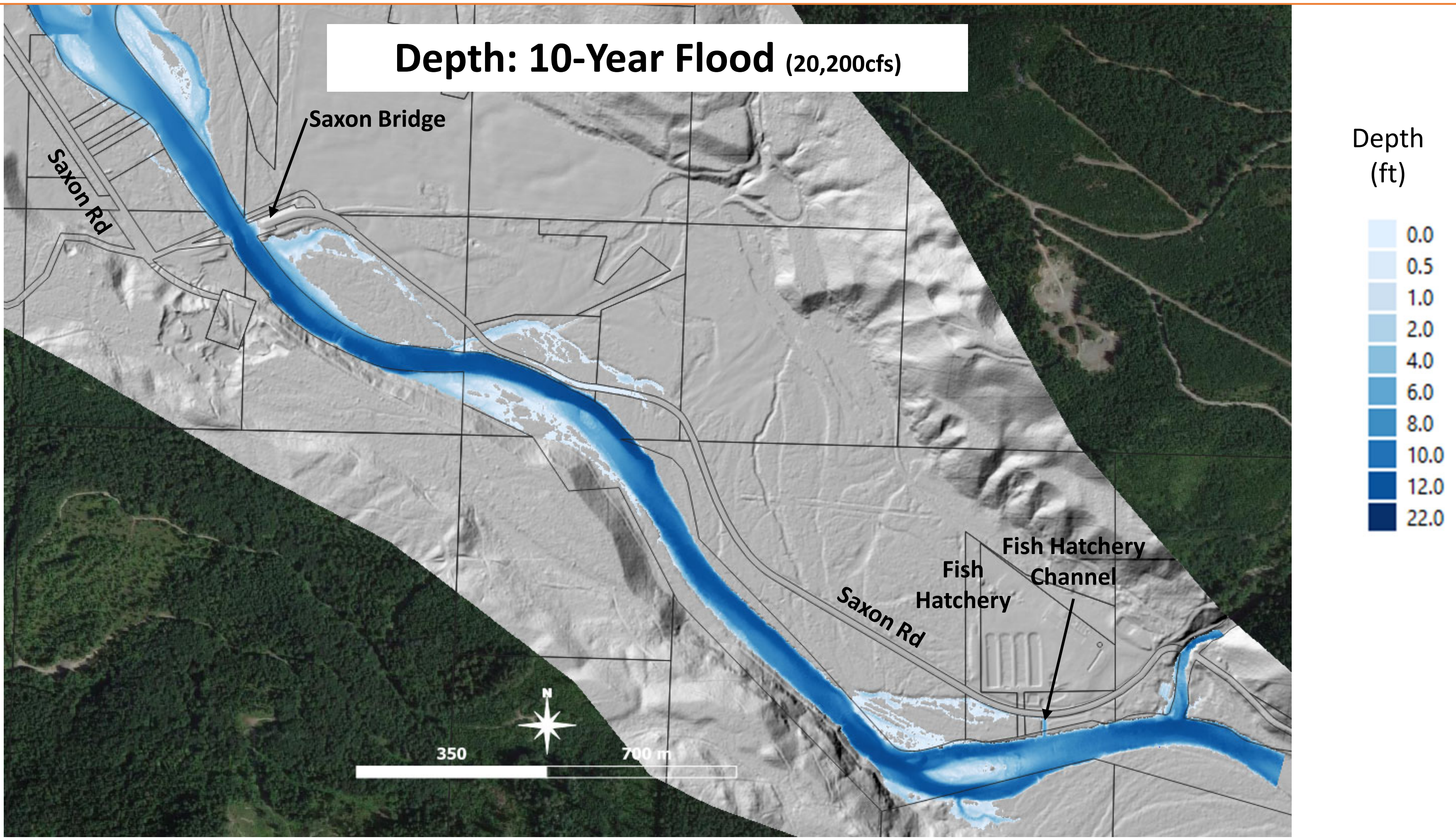


Depth: Q3 Low Flow (287cfs)

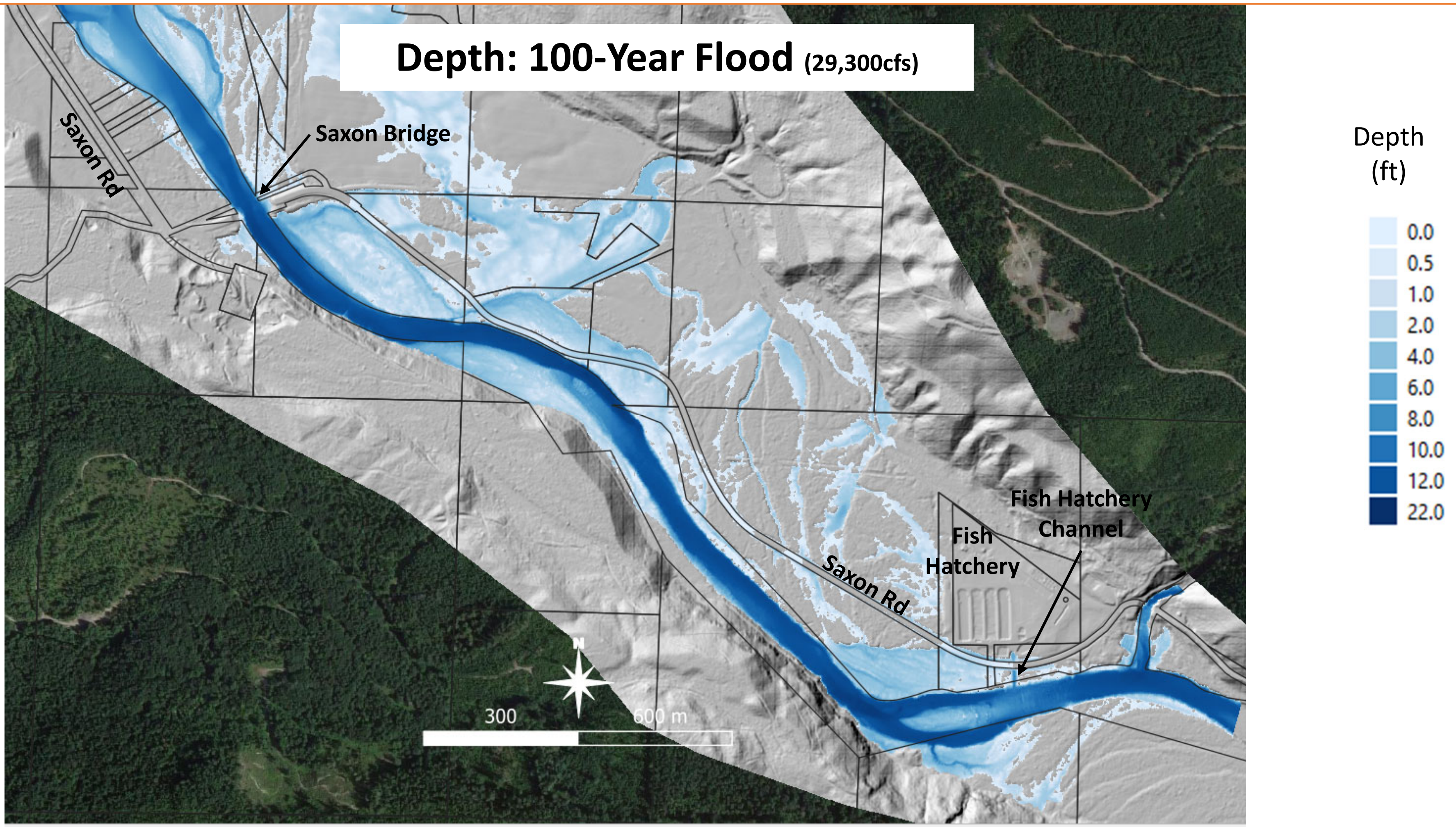
HYDRAULIC MODEL RESULTS



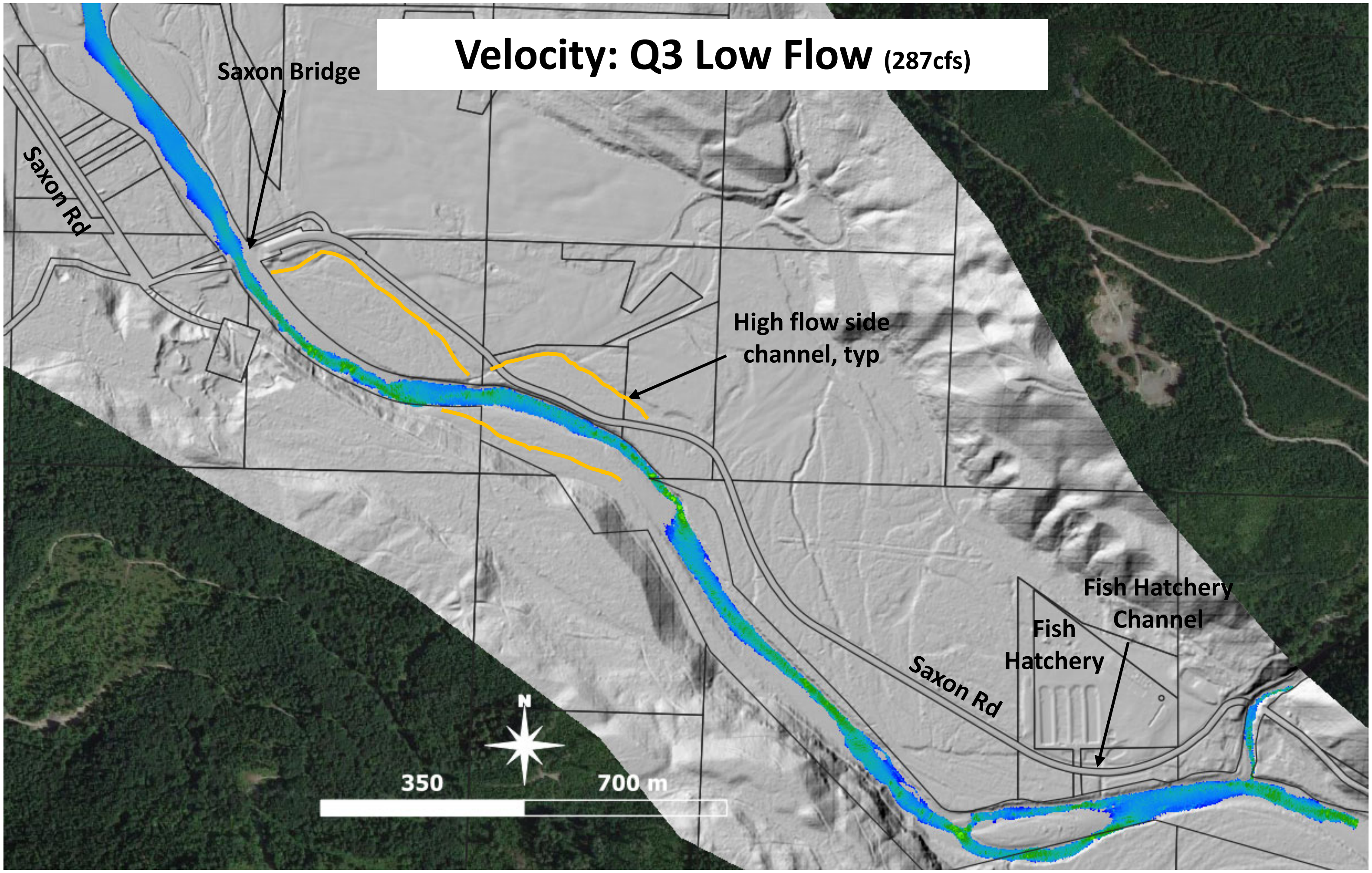
HYDRAULIC MODEL RESULTS


Depth: 10-Year Flood (20,200cfs)

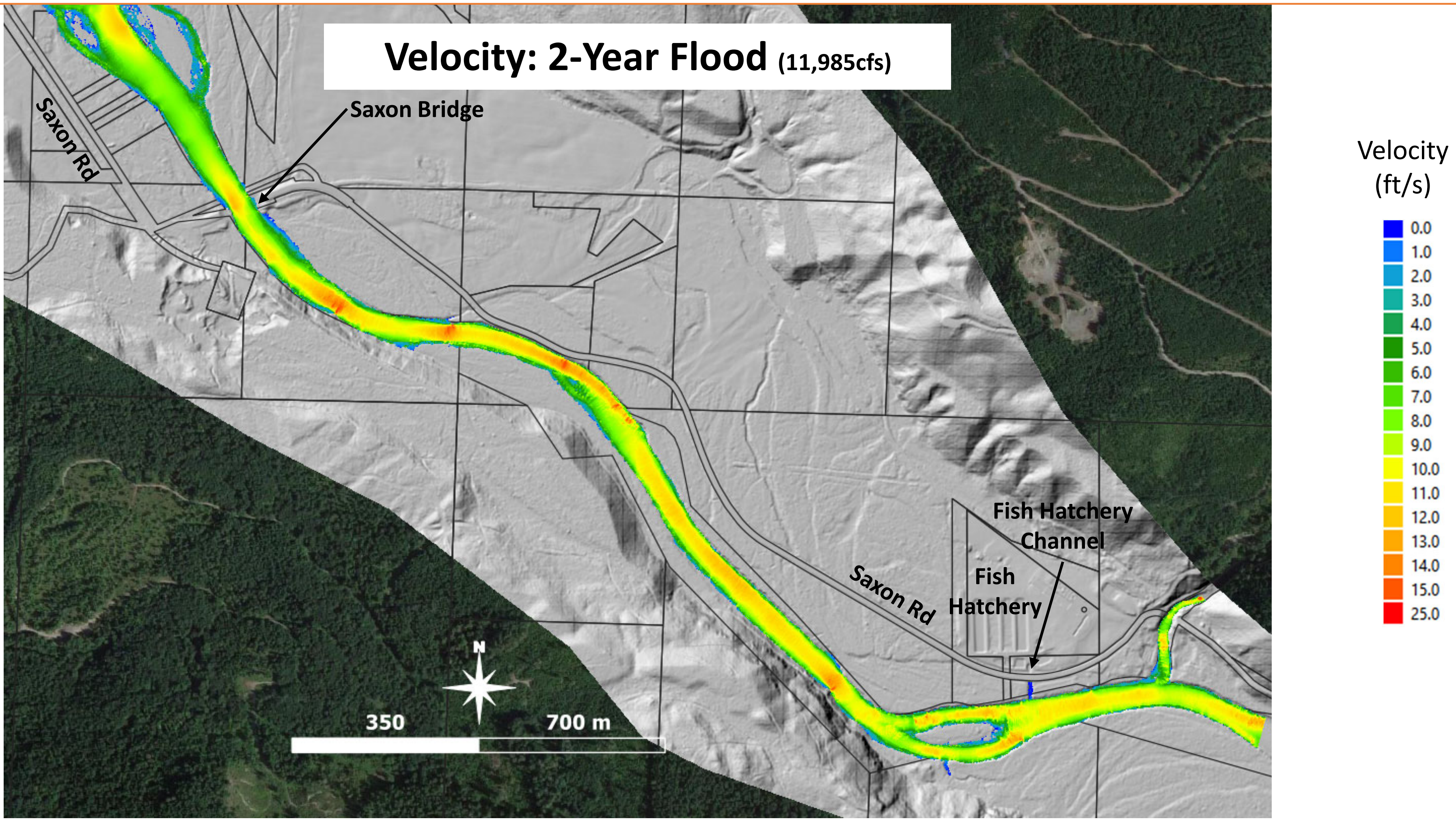
HYDRAULIC MODEL RESULTS



HYDRAULIC MODEL RESULTS

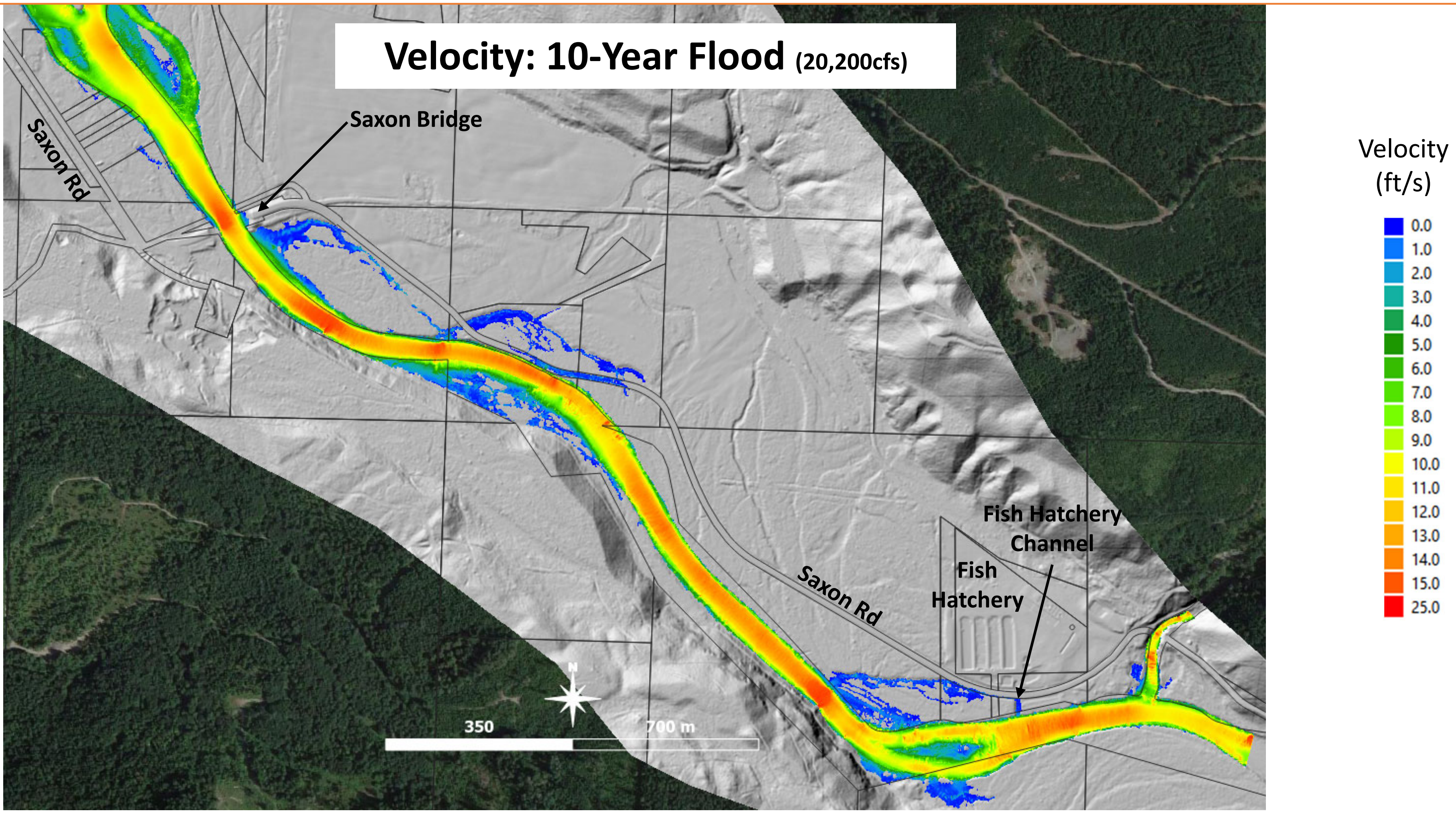


HYDRAULIC MODEL RESULTS

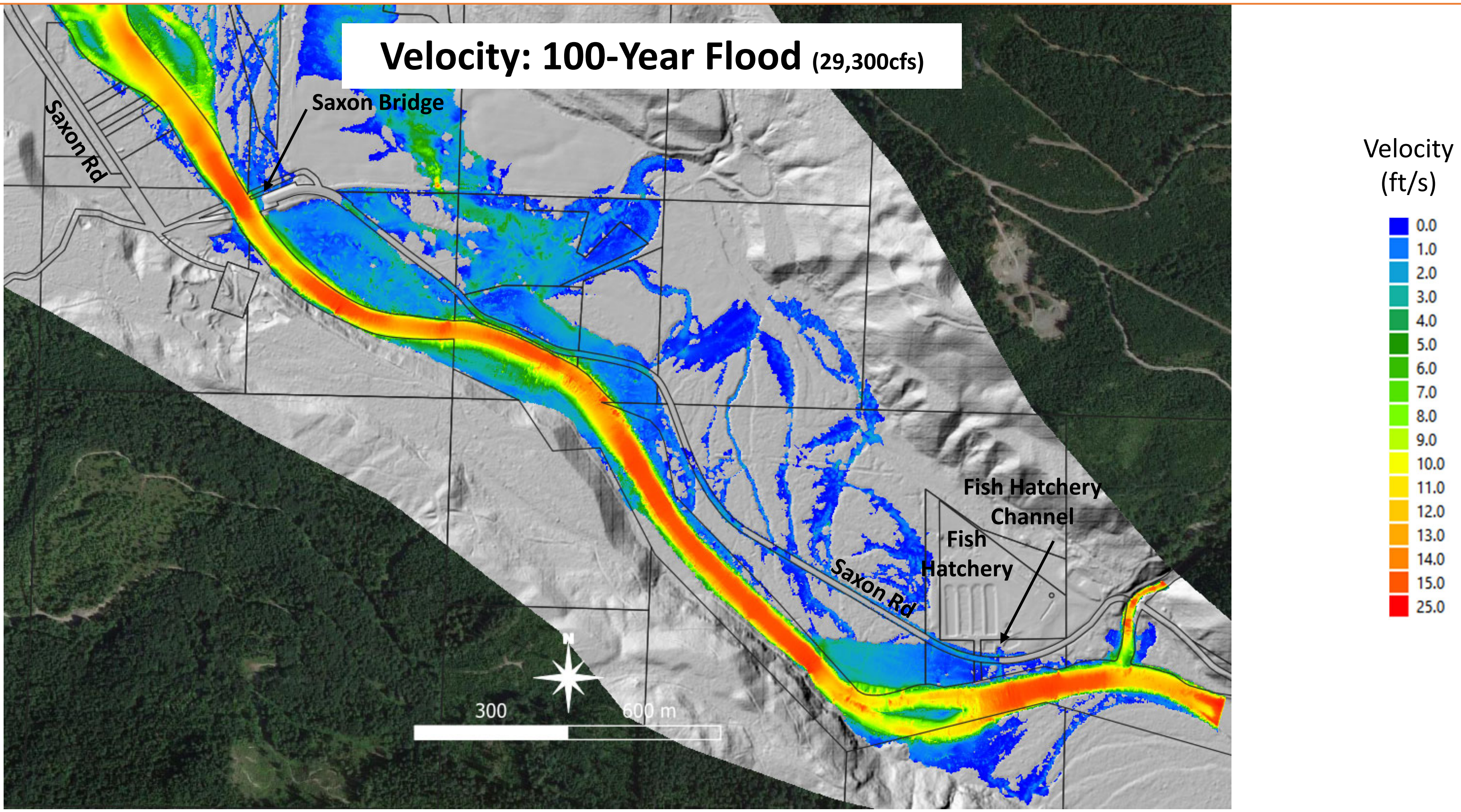


Velocity: 2-Year Flood (11,985cfs)

HYDRAULIC MODEL RESULTS



HYDRAULIC MODEL RESULTS



Velocity: 100-Year Flood (29,300cfs)