Nason Creek, RM 3.8-4.6 Floodplain Enhancement

Concepts Basis of Design Report

SUBMITTED TO
Confederated Tribes of the Yakama Nation

December 7, 2021

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Confederated Tribes and
Bands of the Yakama Nation
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December 7, 2021

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1. Preface

This report addresses concepts for the RM 3.8-4.6 subreach of the Nason Creek Floodplain project. The proposed river and floodplain concepts are in conjunction with relocation of Highway 207 out of the valley bottom providing Nason Creek access to the floodplain east of the current Hwy 207 alignment. 30% designs for river habitat and side channel enhancements along RM 3.2 through 3.8 are documented in a report by Inter-Fluve (March 25, 2021).

The overall Nason Creek Floodplain Project is located along Nason Creek between RM 3.2 and RM 4.6 in Chelan County, WA. The project reach is along Highway 207 on land owned by a private landowner, the U.S. Forest Service, Western Rivers Conservancy and Washington Department of Transportation (WSDOT) right of way (Figure 1). One privately owned parcel is located within the project area at the downstream end, east of Highway 207. The valley bottom within the project area is bisected by Highway 207, which was constructed circa 1942. Construction of Highway 207 significantly reduced the size of the river migration corridor, resulting in a reduction in stream length. This compressed migration corridor and shortened channel appears to be a factor in disrupted geomorphic equilibrium at the site, putting Nason Creek in an unbalanced state. Nason Creek has repeatedly damaged the highway embankment in multiple locations during flood events. An existing side channel near RM 3.3 to 3.75, which was likely the historical main channel, is located east of Highway 207, and is connected to Nason Creek via two culverts approximately 12-feet in diameter under the highway at the inlet and outlet of the side channel. From RM 4.1 to 4.4, approximately 10 acres of floodplain east of Highway 207 have been disconnected from Nason Creek by the existing highway embankment. Yakama Nation discussions with WSDOT indicate that relocating the highway may be feasible, allowing Nason Creek access to the floodplain area near RM 4.1-4.4.

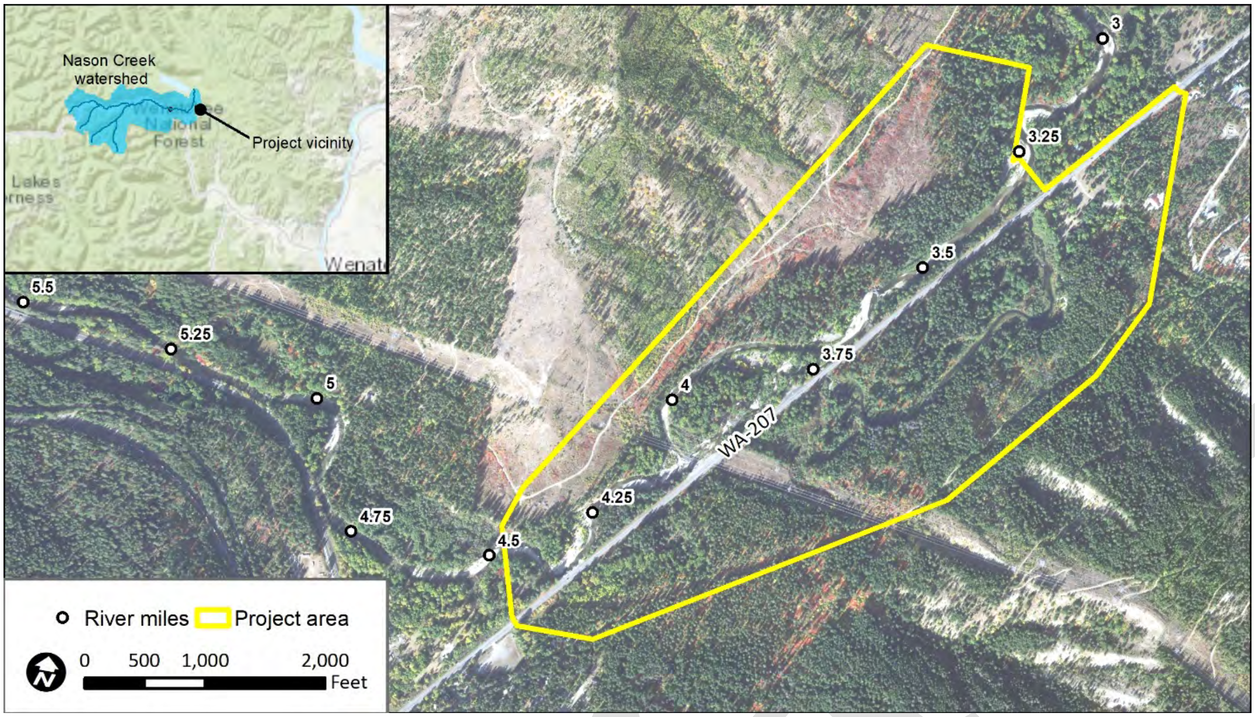

Figure 1. Nason Floodplain project area location.

The goal of the project is to create and enhance instream complexity and off channel aquatic habitats for salmon and steelhead, while also reducing river impacts to the Highway 207 embankment at three locations that have experienced repeated occurrences of erosion.

A number of alternatives for the RM 3.2-4.6 project area were considered and documented by Inter-Fluve in a 2019 report. 30% preliminary designs for selected project features that are intended to enhance aquatic habitats while reducing conflicts between Nason Creek and Highway 207 for RM 3.2 through 3.8 are documented in a report by Inter-Fluve (March 25, 2021). The memorandum herein addresses concepts from RM 3.8 to 4.6 along the main stem and floodplain along the upper half of the project reach. Discussions with WSDOT indicate relocating Hwy 207 between RM 3.9 and 4.5 may be feasible and will reduce stream and floodplain conflict. The concepts discussed herein assume relocation of the highway out of the existing floodplain and valley floor.

Currently, Nason Creek is contacting the Highway 207 road prism at three locations within the study area near RM 3.7, 4.1 and 4.4. An existing large and historically persistent log structure along the creek near RM 4.1 directs a portion of Nason Creek flow into the highway embankment (Figure 2). A mature meander bend near RM 4.4 (Figure 3b) has eroded the highway embankment. Both locations have required emergency placement of rock by WSDOT to stabilize the embankment. With relocation of the highway, these areas can be restored to more natural geomorphic condition and allow dynamic stream processes.

Figure 2. Looking downstream at existing log structure, BPA powerlines, and Highway 207 near RM 4.1. Note riprap placed at right to reduce damage to highway embankment.

1.1 NAME AND TITLES OF SPONSOR, FIRMS AND INDIVIDUALS RESPONSIBLE FOR DESIGN

The project is sponsored by the Yakama Nation with Chris Butler as project manager. Inter-Fluve is the engineering design firm with Dan Miller (PE) the licensed engineer of record for this project and the main point of contact for Inter-Fluve.

1.2 LIST OF PROJECT ELEMENTS THAT HAVE BEEN DESIGNED BY A LICENSED PROFESSIONAL ENGINEER

Dan Miller (PE) is the licensed engineer of record for this project. Project elements include the following, with BPA HIP activity and risk category included:

Table 1. Activity categories and risk included in the Nason Floodplain project from RM 3.8 to 4.6.

Description of Proposed Enhancement	Work Element	HIP Category	HIP Risk Level
Remove existing Highway 207 embankment. Match to adjacent floodplain including microtopography, and/or create wetland areas. Place floodplain roughness wood along cut surfaces to reduce avulsion risk. Designs are intended to not prevent channel migration across the valley bottom.	Road decommissioning. Levee/berm removal. Create wetlands	5b 2b 2a	Low Medium[1] Medium[1]
Note 1: suggest these categories are low risk as structures are removed from the floodplain and Nason Creek will be allowed to migrate laterally across the valley bottom. Wetlands would be created in existing disturbed areas and are not part of a mitigation requirement.			
Place whole trees and LW structures in main stem to increase hydraulic roughness for floodplain connection, instream habitats and encourage formation of vegetated gravel bars.	Improve floodplain interactions. Install habitat forming instream structures	2a 2d	Medium Medium
Conduct field investigations into feasibility of installing infiltration galleries to collect and deliver water to: 1) created side channel and 2) existing beaver dam complex.	Improve secondary channel and floodplain interactions	2a	Medium

Construct upland terrace to provide separation of relocated Highway 207 and Nason Creek side channel.	Component of highway relocation construction.	n/a	Medium
Revegetation of all disturbed surfaces (designed and installed by others).	Riparian vegetation planting	2e	Low

1.3 IDENTIFICATION AND DESCRIPTION OF RISK TO INFRASTRUCTURE OR EXISTING RESOURCES

This report discusses concepts developed along the upstream RM 3.8-4.6 subreach. These concepts may impact the amount of flow along the existing Nason Creek side channel located from RM 3.7-3.8.

Existing infrastructure in the project vicinity includes Highway 207, two 12ft diameter corrugated metal pipe culverts under the road (RM 3.3 [Figure 3.A] and 3.75), miscellaneous existing concrete culverts ranging from 18" to 48" diameter located through the road embankment, a BPA powerline corridor which crosses Nason Creek at RM 4.1, miscellaneous overhead and buried utilities along Highway 207 and private residences downstream of the project area. Risk to Highway 207 is high and has historically been high under existing conditions, as evidenced by erosion damage at three locations (RM 3.7, 4.1 and 4.4) of the embankment incurred regularly during high-flow events. Relocating Highway 207 from RM 3.7 to 4.4 will move the highway out of harm's way from Nason Creek and eliminate two stream-road conflict areas near RM 4.1 and 4.4. Risk to BPA powerlines is minimal because the towers are located outside of the present-day active channel and valley bottom. Risk to private residences is minimal because they are located on a higher terrace and well setback from the active channel.

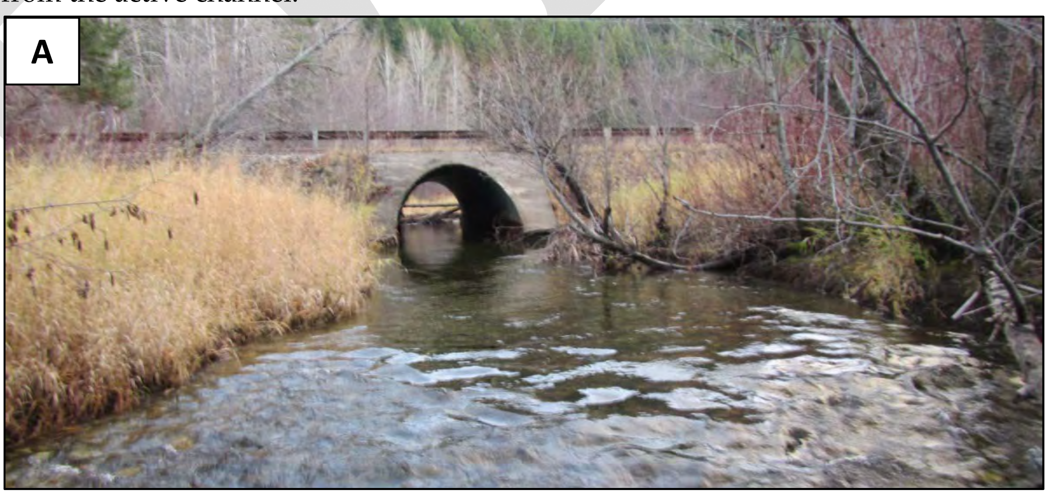

Figure 3. Infrastructure within the project area includes (A) CMP culvert with concrete headwalls (RM 3.75) which provide connectivity to the side channel on the east side of the highway, and (B) Highway 207 (RM 4.4) which has been reinforced with rock in several locations and can be removed with highway relocation and allow hydrologic connection to historic floodplain areas.

1.4 EXPLANATION AND BACKGROUND ON FISHERIES USE (BY LIFE STAGE – PERIOD) AND LIMITING FACTORS ADDRESSED BY THE PROJECT

Current fish known to utilize the project area include ESA-listed spring Chinook (endangered), steelhead (threatened), Bull Trout (*Salvelinus confluentus*, threatened), species-of-concern Pacific Lamprey (*Lampetra tridentate*) and westslope cutthroat trout (*O. clarkii*), and non-listed summer Chinook, Coho Salmon (*O. kisutch*), mountain whitefish (*Prosopium williamsoni*), and non-native brook trout (*Salvelinus fontinalis*). Past redd counts show high Chinook Salmon and steelhead redd densities within the project area (Figure 4). The project reach is a low gradient reach with high quality spawning gravels located throughout.

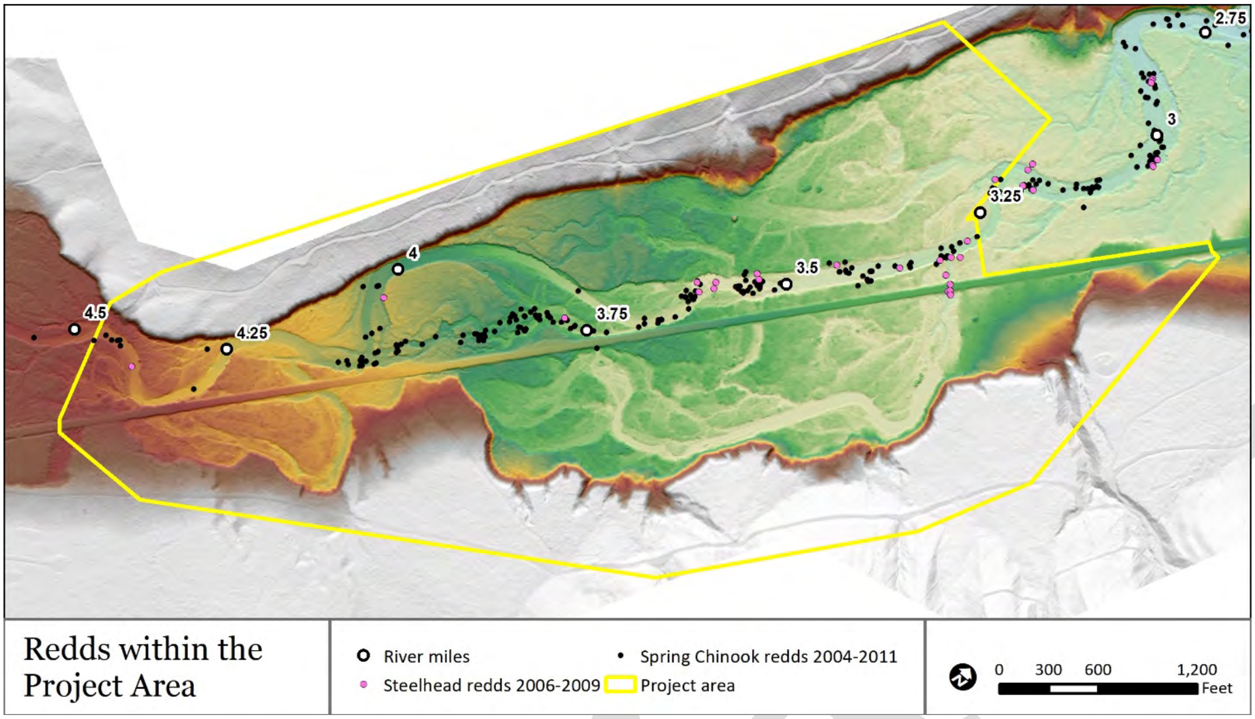

Figure 4. Steelhead and spring Chinook redds recorded in the project area for the specified years, displayed over LiDAR elevation data. The channel network is clearly visible in the LiDAR data. Redd data from Upper Columbia Salmon Recovery Board (2018).

According to the Subbasin Plan (NWPCC 2004), habitat in the project area has high potential to improve populations of aquatic species, including ESA-listed salmonids within the lower Nason Creek. Summary of life-history timing for aquatic species are presented below (Figure 5). Detailed descriptions of habitat requirements by life stage for ESA-listed species are included in the following sections.

Figure 5. Life history timing of target species within the project area.

1.4.1 Steelhead

Adult steelhead enter the Wenatchee basin from August through April, holding in deep pools with overhead cover. Spawning begins in very late March, peaks in mid-April, and lasts through May. Egg survival is highly sensitive to intra-gravel flow and temperature (NWPCC 2004), and is particularly sensitive to siltation earlier in the incubation period (Healy 1991). Fry emerge from the redds 6-10 weeks after spawning (Peven 2003).

Age-0 juveniles spend their first year primarily in shallow riffle habitats, feeding on invertebrates and utilizing overhanging riparian vegetation and undercut banks for cover (Moyle et al. 2002, US Fish and Wildlife Service 1995). Age-0 steelhead use slower, shallower water than Chinook Salmon, preferring small boulder and large cobble substrate (Hillman et al. 1989). Older juveniles prefer faster moving water including deep pools and runs over cobble and boulder substrate (US Fish and Wildlife Service 1995). Juveniles outmigrate between ages one and three, though some hold over and display a resident life history form. Smolts begin migrating downstream from natal areas in March (NWPCC 2004).

1.4.2 Chinook Salmon

Adult spring Chinook enter the Wenatchee in May, holding in deeper pools with overhanging cover until water temperatures are suitable for spawning. Spawning typically begins in very late July, peaks in late August, and ends in late September (NWPCC 2004). Eggs are very sensitive to changes in oxygen levels and percolation, both of which are affected by sediment deposition and siltation in the redd (Healy 1991, Peven 2003). Fry emerge in June and July, which coincides with the rising hydrograph, forcing juveniles to seek out backwater or margin areas with lower velocities, dense cover, and abundant food (Quinn 2005). Fry are extremely vulnerable when they emerge, because their swimming ability is poor and flows are high. Near-shore areas with eddies, large woody debris, undercut tree roots, and other cover are very important for post-emergent fry (Hillman et al. 1989, Healy 1991). The proposed project features are expected to provide low velocity rearing habitat for post-emergent spring Chinook salmon fry because there are high redd densities immediately upstream, and the large woody material (LWM) features are on the outside of a meander bend and create scour pools where the majority of water and fry are expected to be during high flows (Figure 4).

As they increase in size, juveniles begin to select for deeper and faster moving water, particularly areas with overhanging cover (Moyle et al 2002b). These areas provide more holding and feeding habitat area for the larger juveniles to occupy. Upper-Columbia spring Chinook express a stream-type life history, meaning they rear in freshwater for at least one year before outmigrating as yearlings. Smolts begin migrating in March from natal areas (NWPCC 2004).

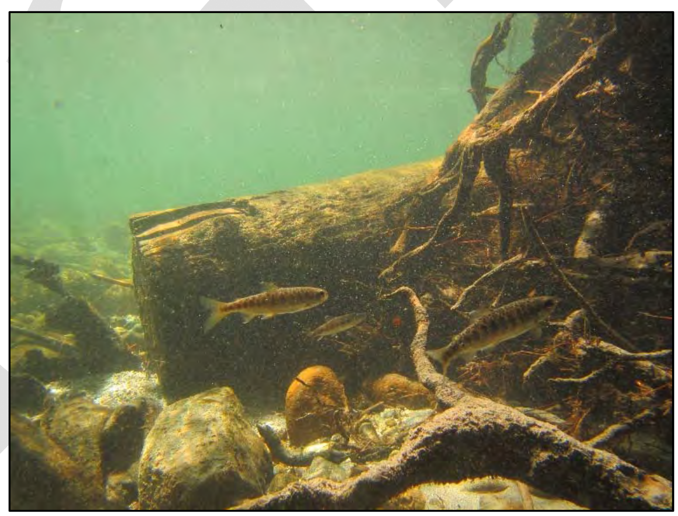

Figure 6. Chinook Salmon parr resting behind a constructed log structure in the Entiat River between feeding forays.

1.4.1 Bull trout

Nason Creek supports a population of resident and fluvial bull trout (NWPCC 2004). The project area is located in a reach of Nason Creek that is mapped as “possible bull trout spawning” in the Wenatchee Subbasin Plan (NWPCC 2004). Bull Trout spawn in the Wenatchee subbasin from August through October. Eggs incubate over the fall, winter, and spring, with fry emerging approximately 220 days after egg deposition. Juveniles select for margin habitat with overhanging cover, feeding primarily on aquatic insects until they grow larger and shift towards feeding on fish. Bull trout juveniles rear in headwater streams for at least two years before migrating downstream as adults or sub-adults to express fluvial life histories, or resident life histories in downstream reaches

(McPhail and Baxter 1996). Downstream movement of bull trout in the nearby Chiwawa River has been documented as bimodal, with one pulse in the spring and a second in the fall (NWPCC 2004).

1.4.2 Limiting factors

Regional objectives for salmonid habitat protection and restoration in the Upper Columbia Region have been evaluated and summarized in the document *A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region* (2017) by the Upper Columbia Salmon Recovery Board (UCSRB) Regional Technical Team (RTT). This Biological Strategy is part of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and recommends region-wide biological considerations and approaches for salmonid habitat restoration and protection actions. The RTT guides the development and evaluation of salmonid recovery projects within the Upper Columbia Region.

The Biological Strategy has identified several assessment units within the major watersheds of the Upper Wenatchee River. The Nason Floodplain project area falls within the Nason Creek Assessment Unit. Nason Creek is a Tier 1 watershed of highest priority for both protection and restoration.

All Chinook spawning that occurs in Nason Creek occurs in the lower 15 miles of the main stem, which also contains the poorest quality habitat (UCRTT 2017). The RTT has prioritized a list of restoration actions to address key ecological concerns in the Nason Creek Assessment Unit, and are listed below in priority order (UCRTT 2017):

1. **Peripheral and transitional habitat**: Reconnect side channels and off-channel habitat.
2. **Channel structure and form**: Increase large wood complexes, remove or modify levees and roads where feasible, restore channel structure and form to reduce sediment transport capacity to counteract recent incision and confinement.
3. **Riparian condition:** Improve riparian conditions to improve long term LWM recruitment.
4. **Channel structure and form:** Restore instream habitat diversity by enhancing large wood recruitment, retention, and complexity.
5. **Food**
6. **Sediment conditions:** Decommission roads that are affecting sediment delivery to the stream.
7. **Species interaction (competition)**

1.5 LIST OF PRIMARY PROJECT FEATURES INCLUDING CONSTRUCTED OR NATURAL ELEMENTS

As noted above, discussions with WSDOT indicate that Hwy 207 between RM 3.7 and 4.4 may be relocated from the valley bottom removing the stream-road conflict and allowing hydrologic connection to the historic floodplain. Following is discussion of the concepts developed for conditions with road relocation.

Primary project concept features along the upstream half of the project from RM 3.8 to 4.6 consist of the following:

- **Remove existing highway 207** and create floodplain or wetland areas:
    - Relocation of Hwy 207 will allow removal of the existing road embankment along the abandoned length of highway, reestablishing floodplain elevations and floodplain side channel continuity. Opportunities exist to excavate portions of the abandoned road deeper than adjacent floodplain to create wetland areas for additional complexity. Risk of avulsion along the road removal corridor can be reduced through selective grading and a dense placement of floodplain roughness wood and slash stabilized with vertical logs. Cut surfaces will be vegetated with appropriate wetland, riparian and upland species – designs will be completed by others at future phases of the project.
    - Locations for two possible infiltration galleries have been identified for future field investigations and analysis to determine if feasible. Near RM 4.1, an infiltration gallery could collect groundwater and discharge to an existing beaver dam complex east of the existing road and north of the BPA line. The second location for a possible infiltration gallery is located near RM 4.3-4.4. This gallery could discharge collected groundwater into a created wetland area and side channel complex.

- **Large wood installation**: A number of large wood structure types are proposed to be constructed in the main channel of Nason Creek and along Highway 207 embankment removal areas to provide complex salmonid holding and rearing habitat, floodplain inundation, allow channel migration and manage risk of avulsion along the removed road at a range of flow conditions.
    - **Deflector jams:** Deflector jams are smaller structures comprised of slash and a limited number of racking members braced against vibratory pile driven vertical logs. The intent is to deflect flow and create lower energy areas downstream of the jam that will encourage deposition of fine sediments and formation of vegetated gravel bars. Racking of floating debris is encouraged to augment the function of these structures. The deflector jams are positioned to encourage floodplain connectivity along the side channel of Nason Creek where the flow and energy are less than along the main stem.
    - **Margin large wood structure:** These are pile ballasted structures built against existing banks. Locations of structures were selected based on flow patterns to encourage scour, recruit floating debris, and provide habitat. The structures are comprised of logs with rootwads, slash, whole trees and tree tops, which will be restrained by vertical logs installed with a vibratory pile driver.

- **Bank buried log structures:** These are backfill ballasted structures built in the existing banks. Locations of structures were selected based on flow patterns to encourage scour, recruit floating debris with one goal of creating channel spanning structures, and enhance gaps in the riparian fringe. The structures are comprised of logs with rootwads, slash, whole trees and tree tops, which will be restrained by vertical logs installed with a vibratory pile driver and backfill with alluvial material.
- **Whole trees:** Whole trees are incorporated into many structures and placed individually as shown on the plans. Whole trees are used for main stem roughness near RM 4.4 to encourage floodplain hydrologic connectivity. Whole trees are anticipated to be sourced in part from the proposed west side channel near RM 3.2-3.5.
- **Floodplain roughness:** Large wood and whole trees restrained by vertical logs and bracing to existing trees will provide floodplain roughness to reduce risk of main stem avulsion along the removed road alignment.

- **Upland bench**: To maintain separation between the proposed relocated Highway 207 near RM and the existing side channel, an upland bench will be constructed. The bench will be resistant to erosion should full Nason Creek flows occupy the side channel with flow impinging directly on the new road embankment, sustain vegetation and may incorporate large wood to be added during future design phases. The core of the bench is envisioned to include a mix of fine soils, cobble/gravel alluvium and boulders. The gradation of this material and grading of the bench will be determined in future design phases.

- **Wetland, riparian and upland revegetation**: Native species will be planted in all disturbed areas to promote riparian function and increase food production and habitat complexity for target species. The planting plan will be developed separately in a future phase by Yakama Nation's planting consultant.

1.6 DESCRIPTION OF DISTURBANCE INCLUDING TIMING AND AREAL EXTENT AND POTENTIAL IMPACTS ASSOCIATED WITH IMPLEMENTATION OF EACH ELEMENT

Project disturbance at the site will be from excavation and temporary access routes used to remove portions of the existing road embankment and revetment, install large wood structures, and install plantings. Access for many sites will be along the abandoned road alignment. Trees and vegetation removed during excavation will be salvaged and used to supplement constructed large wood habitat structures. Disturbance during construction to large trees and riparian zones will be minimized, and all disturbed areas will be re-vegetated.

2. Resource inventory and evaluation

2.1 DESCRIPTION OF PAST AND PRESENT IMPACTS ON CHANNEL, RIPARIAN AND FLOODPLAIN CONDITIONS

Riparian and floodplain conditions in the project site and vicinity have been impacted most heavily by the construction of Highway 207 circa 1942 along the Nason Creek floodplain. The circa 1900 plat map indicates that the main stem of Nason Creek used to occupy the southeast side of the floodplain (Figure 7). The 1957 aerial shows Nason Creek in an alignment with planform similar to – though west of – what is seen today, and the BPA power corridor is also visible. Logging in the vicinity, and associated road building, has had impacts on large wood recruitment and sediment delivery to Nason Creek. Construction of the highway has reduced total off channel habitat connectivity, disconnected floodplain areas, and constricted channel migration zones, concentrated more flow into the main stem, and shortened overall channel length by cutting off a historical meander that is depicted in the circa 1900 plat map.

2.2 INSTREAM FLOW MANAGEMENT AND CONSTRAINTS IN THE PROJECT REACH

Not applicable to this project.

2.3 DESCRIPTION OF EXISTING GEOMORPHIC CONDITIONS AND CONSTRAINTS ON PHYSICAL PROCESSES

Figure 7, Figure 8, and Figure 9 show historical aerial imagery of the project area vicinity from 1957, 1963, 1974, 1991, 2006 and 2015. The 1942 Road Relocation plans include an indication of the Nason Creek alignment that appears similar to the 1957 photos. While in general the meandering plan form and bend locations are similar over the photographic history, the channel has migrated eastward closer to the highway. There appears to be a vegetated floodplain approximately 80- and 150-feet wide from the edge of Highway 207 to the right river bank at RM 4.4 and 4.1, respectively, in the 1942 plans (Chelan Co, 2012) and 1957 photos. It appears that Nason Creek encroached on to the road embankment during the time interval between the 1974 and 1991 photos. The side channel along the west side of highway between RM 3.7 to 4.1 is evident in all photos.

The Highway 207 embankment has isolated or limited flow to the east floodplain, leading to fewer off channel and side channel habitats. No pre-development survey is available to determine whether and to what degree incision may have occurred, however it is believed that this unnatural confinement has led to some level of incision (UCRTT 2017).

Nason Creek delivers a dynamic supply of substrate and wood to the project reach. Areas of wood accumulation exhibit defined scour pools and sediment deposit tail spills creating diverse habitats. The numbers and locations of redds mapped (Figure 4) indicate that diversity of LWM and bed forms provide spawning habitats.

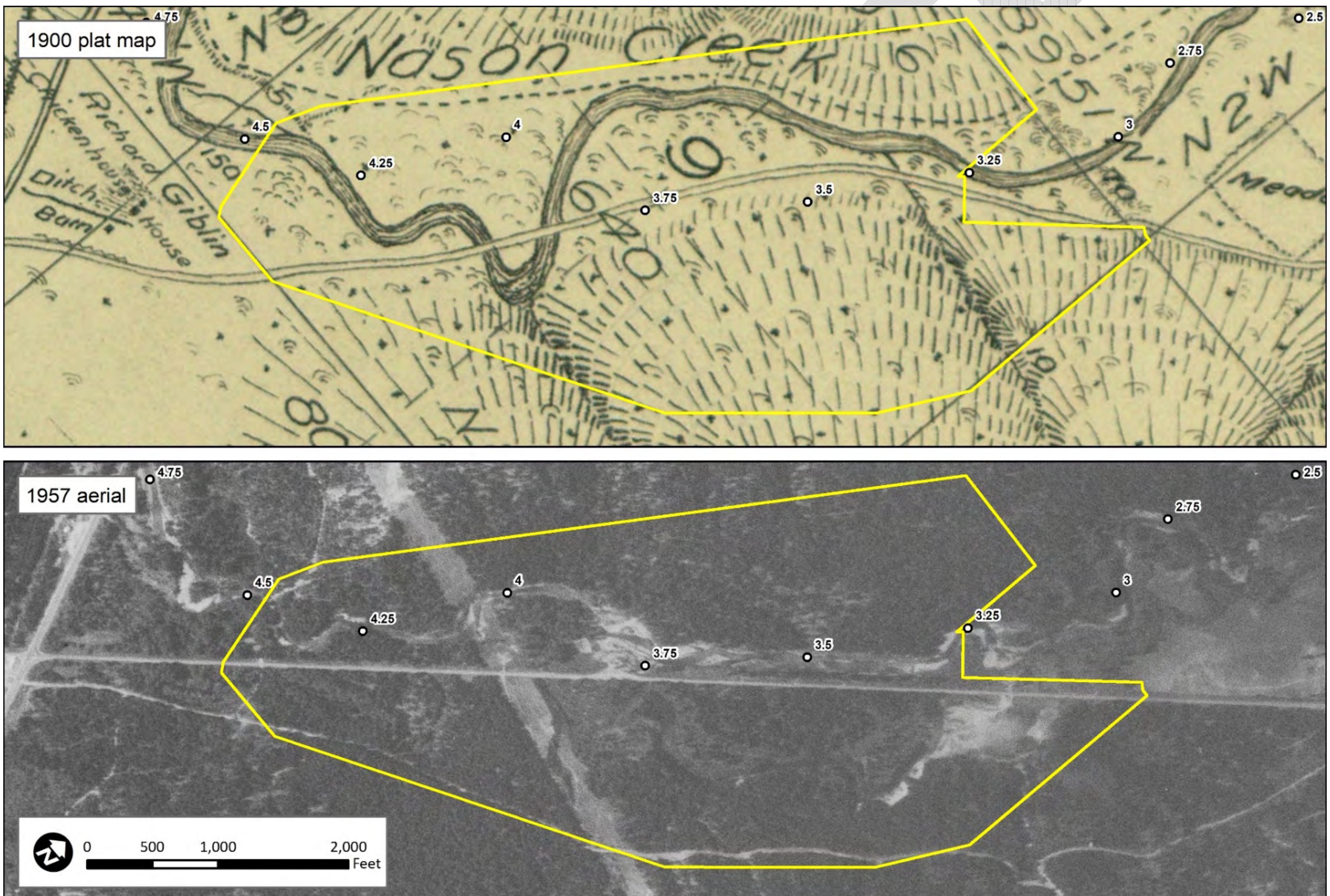

Figure 7. Historical plat map from 1900 and aerial image from 1957, project area boundary shown in yellow.

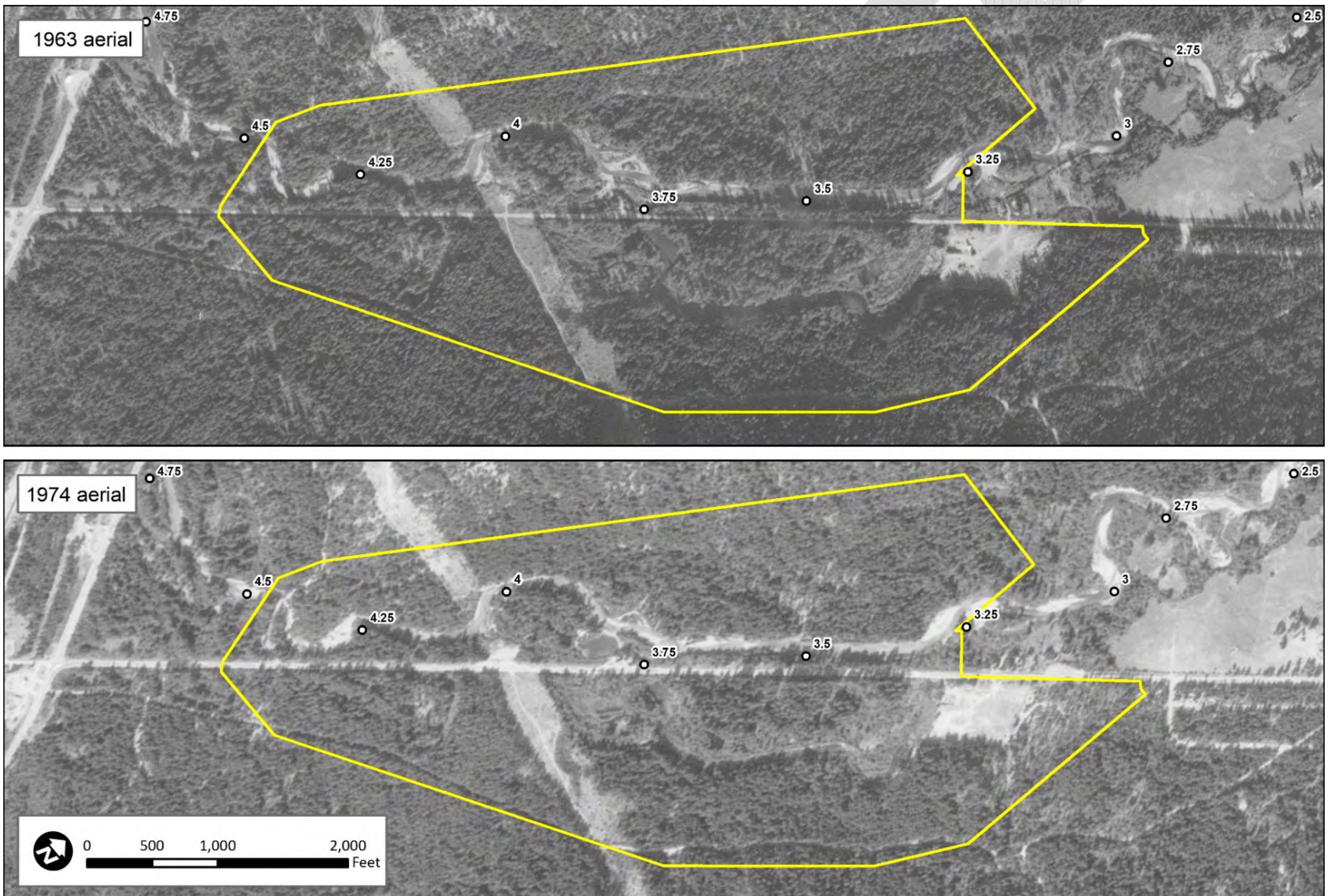

Figure 8. Aerial images from 1963 and 1974, project area boundary shown in yellow.

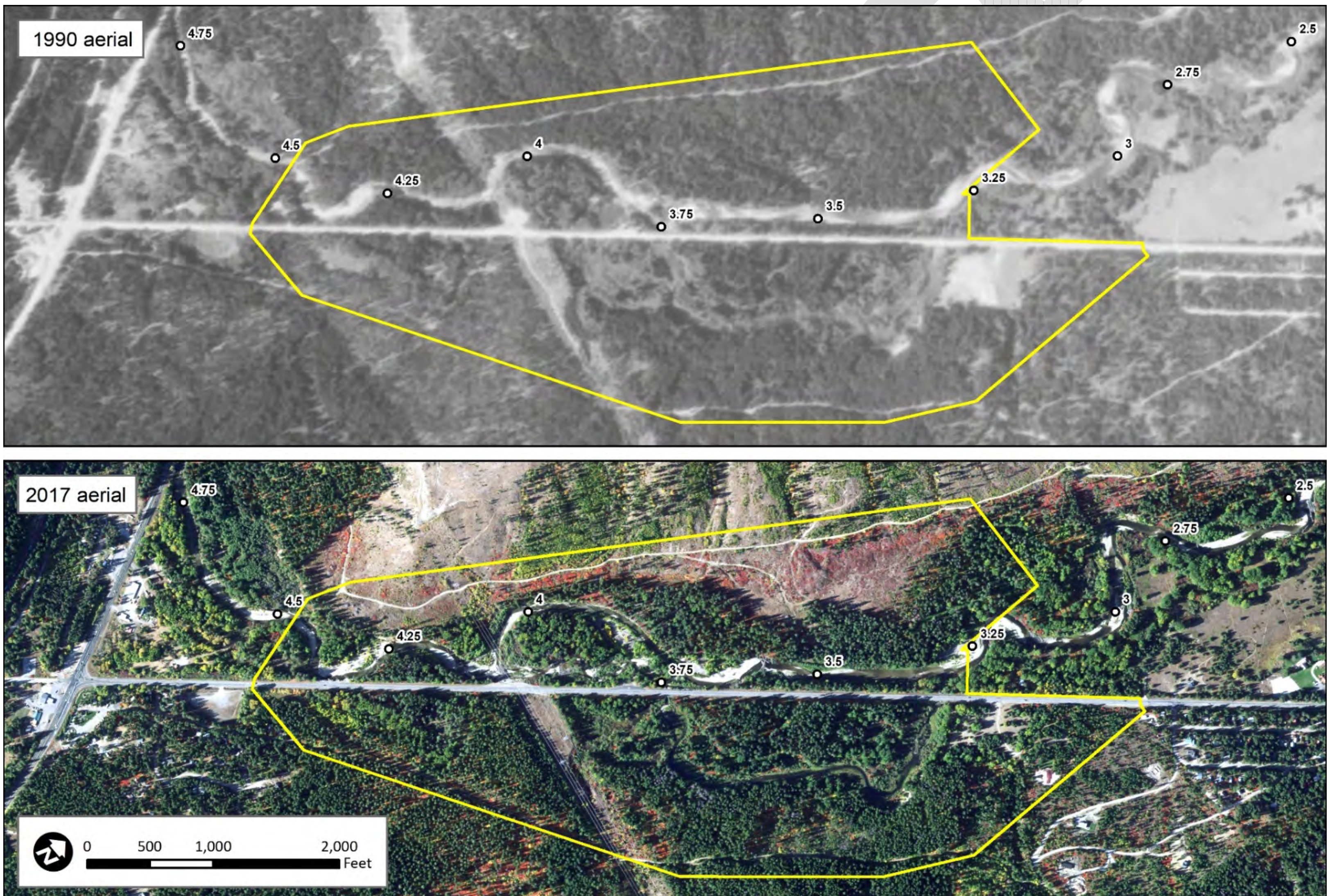

Figure 9. Aerial images from 1990 and 2017, project area boundary shown in yellow.

2.4 DESCRIPTION OF EXISTING RIPARIAN CONDITION AND HISTORICAL RIPARIAN IMPACTS

Riparian conditions in the project area are generally good. The forest is a mixed-age stand of Ponderosa Pine, Douglas fir, willow, dogwood and cottonwood. Typically, conifers occupy higher elevation terraces that have not been disturbed by river activity for a number of decades. Deciduous trees and woody shrubs occupy the riparian zones and areas disturbed by river migration in the recent past. Wetlands were delineated in August 2020 by Hamer Environmental. Coniferous trees have been removed along the BPA power line corridor and recently logged at the western edge of the river left floodplain from approximately RM 3.2-3.7.

2.5 DESCRIPTION OF LATERAL CONNECTIVITY TO FLOODPLAIN AND HISTORICAL FLOODPLAIN IMPACTS

Nason Creek historically had high floodplain connectivity with a myriad of off-channel wetlands, alcoves, and channels. This complexity was likely enhanced by large wood accumulations and beaver ponds. The current highway embankment and culvert system have reduced floodplain connectivity and eliminated lateral channel migration to the east of the highway by limiting water movement onto floodplain surfaces to areas east of the highway. Approximately 40.7-acres of active side channel, wetlands and floodplain are located east of the highway RM 3.3-3.9. Approximately 10.9-acres of inactive side channel, wetlands and floodplain are located east of the highway RM 4.15-4.4; which can be available to flow and channel migration with proposed highway relocation. The reduced floodplain width constricted by the highway embankment has reduced the available migration corridor

2.6 TIDAL INFLUENCE IN PROJECT REACH AND INFLUENCE OF STRUCTURAL CONTROLS (DIKES OR GATES)

Not applicable to this project.

3. Technical data

3.1 INCORPORATION OF HIP SPECIFIC ACTIVITY CONSERVATION MEASURES FOR ALL INCLUDED PROJECT ELEMENTS

HIP conservation measures will be included in future preliminary project plans and will be met during future project design. If necessary, requests for variances will be submitted for any conservation measures that cannot be met.

3.2 SUMMARY OF SITE INFORMATION AND MEASUREMENTS (SURVEY, BED MATERIAL, ETC) USED TO SUPPORT ASSESSMENT AND DESIGN

3.2.1 Elevation data

Inter-Fluve conducted ground surveys in November, 2018 and November 2020 using total station and RTK GPS survey equipment. Survey control was established throughout the project site and correlated to RTK GPS base station static data corrected using the Online Positioning User Service (OPUS). Survey effort was focused in the main channel and side channel areas of the project site, with focused survey along floodplain areas with high potential for project features. Channel survey data captured cross sections at hydraulic controls and geomorphic features (tops and bottoms of riffles, apex of bends, pools, etc.) for use in hydraulic model development. Survey was conducted by wading and collected data necessary for conceptual level analyses and designs, with the exception of two pools that were too deep to access. An existing conditions topographic surface was created for design and hydraulic modeling by supplementing survey data with existing LiDAR data from 2015. All data are referenced to the Washington State Plane North coordinate system, the NAVD88 vertical datum and US feet.

3.2.2 Fish use

Fish use data were collected from primary literature, the Wenatchee Subbasin Plan (NWPCC 2004), and the Upper Columbia biological strategy (UCRTT 2017).

3.2.3 Geomorphic data

A pebble count survey was conducted in the project area to evaluate substrate conditions and will be used during the design phase to estimate bed mobility along Nason Creek and scour potential. See section 3.4.

3.2.4 Hydrology data

Washington Department of Ecology (WDOE) records flows along Nason Creek at gage 45J070 located near the mouth. The WDOE gage has a period of record from 2002 to the present and is reported to have some inconsistencies – thus was not used solely for estimating flood peak flows.

The WDOE gage does provide useful information on seasonal flow variation during the available period of record.

The USGS maintains a stream flow gage on nearby Icicle Creek (USGS Gage #12458000) which has a period of record from 1937 to present. The Icicle Creek watershed has many similarities to the Nason Creek watershed and is viable as a paired watershed to understand Nason Creek hydrology. The Icicle Creek data was used for paired watershed analyses for a number of studies including the U.S. Bureau of Reclamation Nason Creek Tributary Assessment (BOR, 2008).

No field flow measurements were collected for this conceptual analysis.

3.3 SUMMARY OF HYDROLOGIC ANALYSES CONDUCTED, INCLUDING DATA SOURCES AND PERIOD OF RECORD INCLUDING A LIST OF DESIGN DISCHARGE (Q) AND RETURN INTERVAL (RI) FOR EACH DESIGN ELEMENT

3.3.1 General Hydrology

Nason Creek drains high-elevation areas of the Chiwaukum Mountains and has a snowmelt-dominated hydrologic regime. Figure 10 shows typical seasonal median, high, and low exceedance flows for Nason Creek at RM 12.

Although peak flows typically occur due to snowmelt in the late spring or early summer, some of the largest floods have occurred from rain-on-snow events in late fall. Large past flood events occurred in May 1948, November 1990, November 1995, and November 2006. As noted in Chelan County's Feasibility Study (2012), the November 1995 event washed out portions of Highway 207. As of 2011, three repairs to the highway embankment in 10 years at this location lead to nomination for the WSDOT Chronic Environmental Deficient (CED) program.

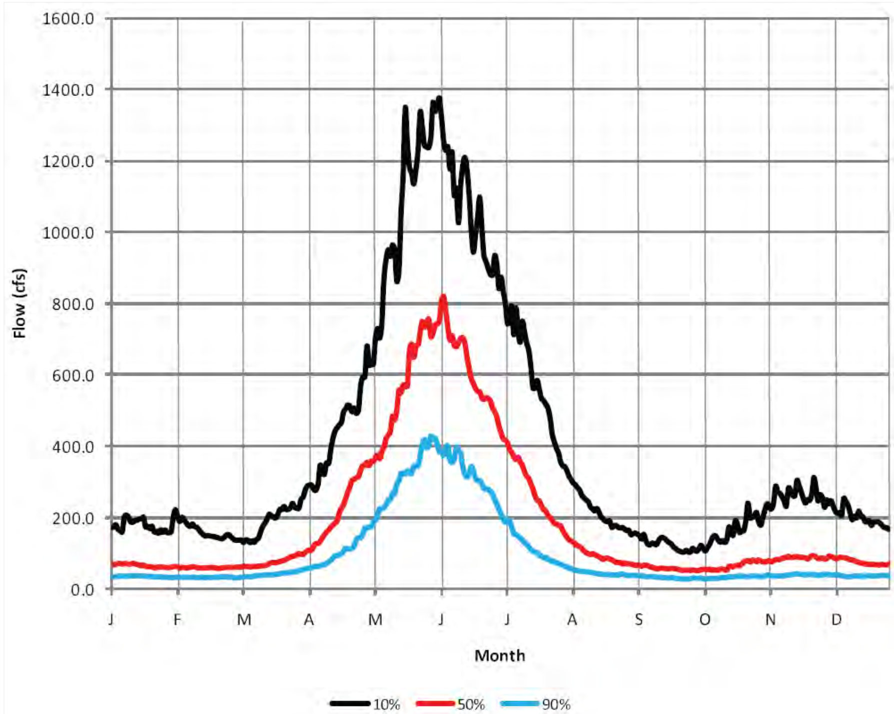

Figure 10. Modeled 10 percent, 50 percent, and 90 percent exceedance flows for RM 12 using data from 7 regional gages. Percentile flows represent the daily flow that is equaled or exceeded for the given percentage of time over the available period of record. Reprinted from Malmon (2010).

3.3.2 Peak Flow Hydrology

As noted in Section 3.2.4, Washington Department of Ecology operates gage 45J070 near the mouth of Nason Creek since 2002, but no long-term stream gage record is available on Nason to reliably estimate peak flows for the project reach. The US Bureau of Reclamation Nason Creek Tributary Assessment (Reclamation, 2008) completed a flood event peak flow analysis using data recorded at the nearby Icicle Creek USGS gage and considers the WDOE peak flow values. The Reclamation estimated flood magnitudes are presented in Table 2. These flows were used in the project hydraulic model.

Table 2. Peak flow estimates for Nason Creek at RM 4.0 (Reclamation, 2008. Appendix D, Table 5)

Recurrence Interval (years)	Estimated flow at RM 4 (cfs)
2	**2,600**
5	**3,900**
10	**4,900**
25	**6,500**
50	**7,900**
100	**9,400**

3.4 SUMMARY OF SEDIMENT SUPPLY AND TRANSPORT ANALYSES CONDUCTED, INCLUDING DATA SOURCES INCLUDING SEDIMENT SIZE GRADATION USED IN STREAMBED DESIGN

There are some bed rock expressions in the stream bed, banks and valley wall along the west edge of the Nason Creek flood plain. Occasional boulders that are not mobile during normal flood flows have been delivered to the valley bottom during much larger glacial outwash flows and delivered to the contemporary channel by being eroded out of the adjacent outwash terraces or exhumed as Nason Creek eroded down through the post glacial outwash. Upstream of the project reach, a number of actively eroding streambanks are seen which supply a significant volume of mobile sized sediments to the project reach. Placed riprap occurs at three locations along the Highway 207 embankment, some of which has moved downstream along the streambed a short distance.

With this understanding, substrate measured by the pebble count is a good approximation of mobile bedload sized sediments transported through the project reach and found in alluvial formed bed, bar and bank deposits. Wolman pebble counts were completed in Nason Creek near RM 4.45 to help estimate sediment particle sizes moving into and through the project reach. Pebble counts were performed at two locations along the river right bar surfaces at the crest (Figure 11.A) of a riffle and along the edge of the same riffle (Figure 11.B) to capture the range of substrates observed.

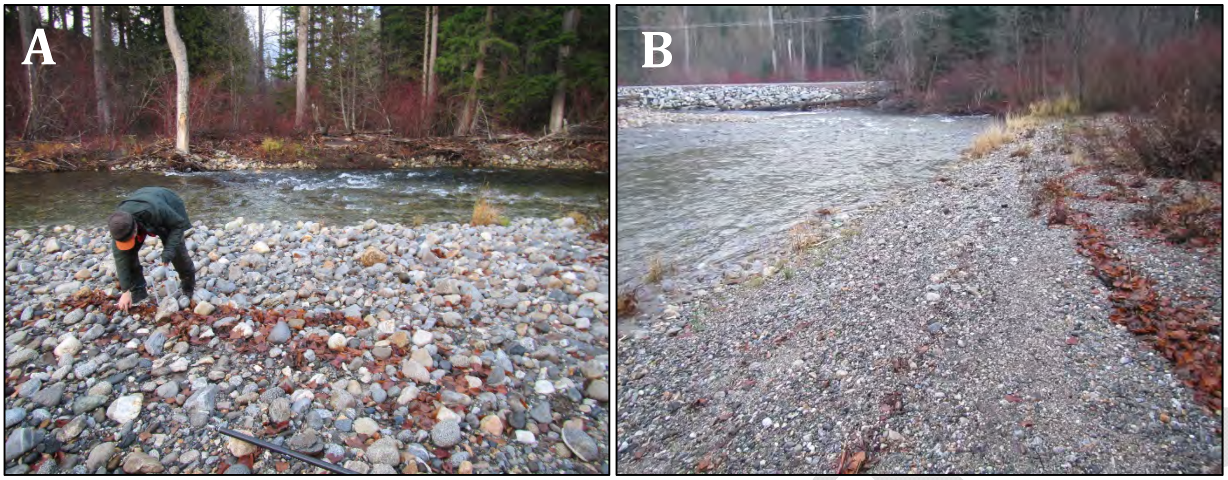

Figure 11. Location of pebble counts performed on Nason Creek. A) GC01 was performed on a gravel bar adjacent to a riffle, on river right of Nason Creek. B) GC02 was performed on a bar adjacent to a riffle on river left.

Results of the pebble count provide a grain size distribution. GC01 contained coarser material compared to GC02, with a d50 best described as very course gravel (Figure 12). Some sand and finer gravels were found within the interstices of larger material. GC02 contained finer material with a d50 best described as medium gravel.

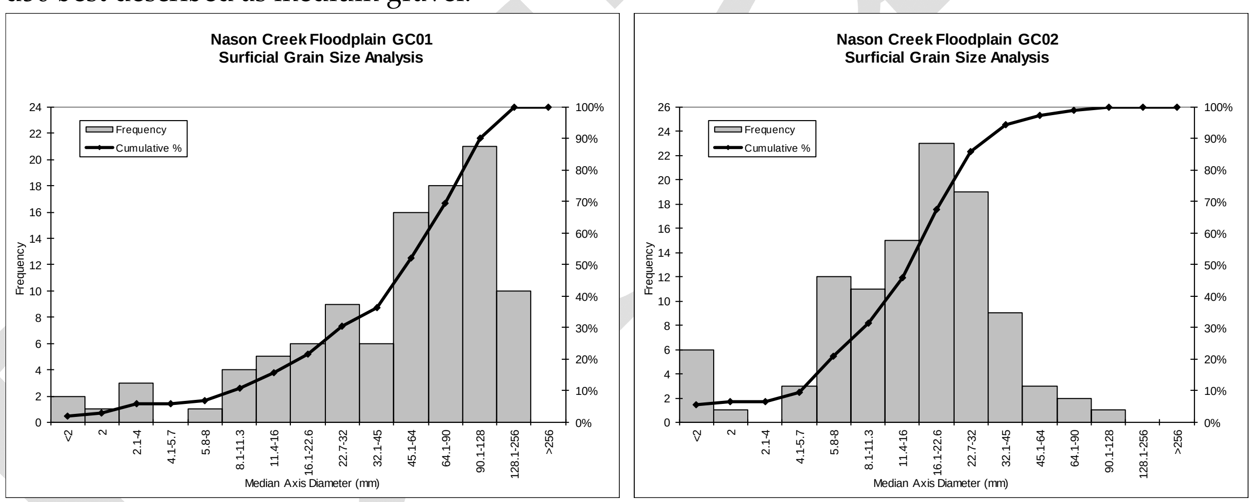

Figure 12. Grain size distribution at GC01 and GC02 based on Wolman pebble counts.

3.5 SUMMARY OF HYDRAULIC MODELING OR ANALYSES CONDUCTED AND OUTCOMES – IMPLICATIONS RELATIVE TO PROPOSED DESIGN

3.5.1 Hydraulic Modeling

The U.S. Army Corps of Engineers HEC-RAS 6.1 (USACE 2021) two-dimensional (2D) hydraulic model that was developed for the overall Nason Floodplain project reach and the RM 3.2-3.8 30% design conditions (described in Inter-Fluve, March 25, 2021) were copied and runs representing concept design features from RM 3.8-4.6 prepared. HEC-RAS computes hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. Model runs for both existing and proposed conditions were used to assess the current and proposed channel dynamics, as well as assess the overall impacts of a wide range of flows on the existing landscape with and without the proposed design improvements.

The following sections describe the capabilities and limitations of HEC-RAS 6.1 and document the development and output processing of the project existing and proposed conditions models.

3.5.2 Model Capabilities and Limitations

HEC-RAS 6.1 was used in its two-dimensional (2D) unsteady flow simulation mode with the capacity to model the complex flow patterns, on-site water storage, spatial variation of hydraulic roughness and temporally variable boundary conditions. The 2D hydraulic model calculates depth averaged water velocities (including magnitude and direction), water surface elevation, and mesh cell face conveyance throughout the simulation. Other hydraulic parameters such as: depth, shear stress, and stream power can be calculated by the model following completion of the simulation. The model does not simulate vertical variations in velocities or complex three-dimensional (3D) flow eddies.

3.5.3 Model Extent

The downstream extent of the model is near RM 2.9 about 1,750 feet downstream of the lower project boundary. The upstream extent is near RM 4.9 about 3,000 feet upstream of the upper project boundary. Width of the model is valley wide, encompassing channel and floodplain including east of the existing Highway 207. The extents of the model are shown by the computational mesh for existing conditions shown in Figure 13.

3.5.4 Model Terrain

The existing conditions model terrain was developed using both ground and bathymetric survey data collected by Inter-Fluve in November 2018; combined with aerial 2015 LiDAR (Quantum Spatial 2016). The LiDAR provided a 1 meter (3.28 feet) horizontal resolution bare earth digital elevation model (DEM) raster for the entire site, including floodplain areas and valley hillslopes. LiDAR was primarily used on the floodplain and hillslopes with select use to help define certain gravel bars where survey data were sparse. Ground and bathymetric survey data were used for river and side-channel bathymetry, active channel areas that may have changed since the LiDAR flight, and other areas of interest, including regions where potential project elements may occur. The ground and bathymetric survey data (points and break lines) were used to create a triangulated irregular network (TIN) surface for the surveyed areas. The ground survey surface was then resampled to a 1-foot resolution DEM raster and pasted into the LiDAR DEM to create the existing conditions model terrain. The ground survey surface superseded the LiDAR surface within the irregular extent of the ground survey. No transitional buffer between the ground survey and the LiDAR DEMs was used, occasionally resulting in minor surface discontinuities. The proposed condition model terrains were copied from the existing conditions terrain and modified to incorporate the design grading TIN surfaces. Large wood structures were represented in the model as regions of extremely rough Manning's n coefficient values. The model terrains are projected on the Washington State Plane North Zone, North American Datum 1983 (NAD83), coordinate system with US feet distance units. The terrain elevations are in US feet relative to the North American Vertical Datum of 1988 (NAVD88).

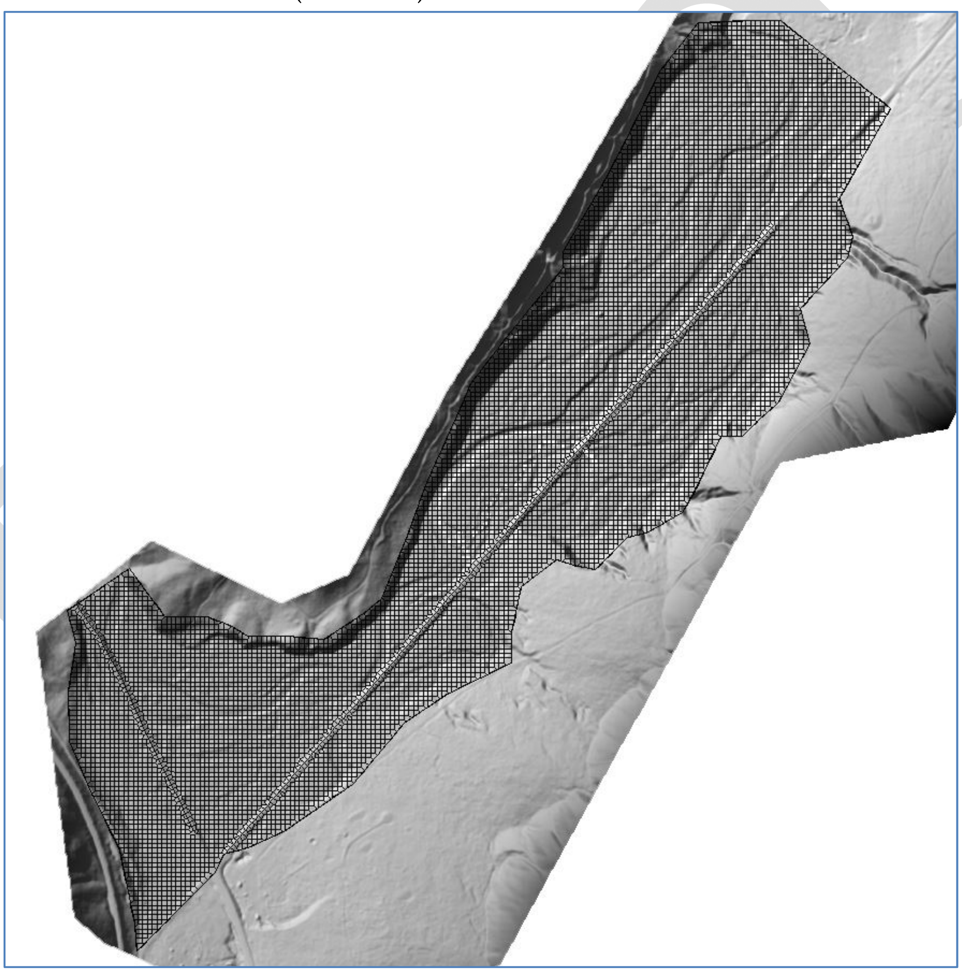

Figure 13. Existing conditions model mesh.

3.5.5 Model Geometry

At this conceptual level, to evaluate multiple scenarios in a timely manner yet providing realistic results, the 2D model geometry used a 40-ft square computational mesh for the entire area of interest for existing conditions as seen in Appendix C. Although the typical computation mesh size was greater than the terrain resolution, the modeling capabilities of HEC-RAS 6.1 integrates the sub-grid terrain into the computations and projects the results accordingly. For proposed conditions, a refinement region was used to model the RM 3.2-3.5 West Side Channel with a smaller sized mesh to capture the smaller channel size. The model domain mesh is seen in Appendix D. For future more detailed design phases the model geometry will be refined for greater resolution for better definition of individual project elements.

3.5.6 Model Roughness

Roughness coefficients (Manning's n values) are used by the 2D model to calculate flow energy losses, or frictional resistance, caused by channel bed materials, type and density of floodplain vegetation and large wood. Existing conditions roughness coefficients were applied across the model extent to represent the various types and densities of vegetation or surface conditions. Roughness coefficients were modified in the proposed conditions models to represent immediate post construction conditions. In general, roughness regions were delineated based on field observations, aerial photos, and proposed designs. Roughness values for each region were selected using professional judgment and guided by published guidelines (Arcement & Schneider 1989) for channel types and vegetation conditions. At this conceptual stage, Manning's n values were defined for:

- Main stem and side channel as 0.038-0.043 depending on complexity and amount of LWM.
- Forested bars as 0.055
- Forest and floodplain as 0.080
- LWM structures as 0.15 to 0.2.
- Floodplain roughness as 0.12

3.5.7 Model Boundary Conditions

HEC-RAS 6.1 2D models require boundary conditions at the upstream and downstream ends of the model to control the flow into and out of the model extent. The synthetic hydrograph described in the next section was applied as the upstream boundary condition. The flow was initially distributed along the boundary assuming normal flow depth at a friction slope estimated from topography to be approximately 0.005 feet per foot. The downstream boundary condition assumed normal flow depth at a friction slope estimated from topography to be 0.005 feet per foot. Boundary conditions were set far enough distant from the area of interest that potential uncertainties would be negligible within the project reach.

3.5.8 Model Discharges

The modeled discharges of interest included 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval peak flows listed in Table 2. Additional low flows of interest included summary low flow through extrapolated annual peak discharges and included: 20-, 50-, 100-, 200-, 300-, 600-, 1000-, and 2000--cfs. These discharges were incorporated into a synthetic hydrograph with periods of steady flow (at the discharges of interest) to create a stair-step like pattern similar to Figure 14. The periods of steady flow allow the model to come to a quasi-steady state condition, improving the interpretation of hydraulics at discharges of interest. It's worth noting that allowing the model to reach a steady state during large flood events may overestimate extents of flooding results, as floodplain storage throughout the model domain must reach capacity to reach steady-state conditions, which in reality may not occur during actual floods, especially short duration events. The receding limb of a typical flood hydrograph is also not represented when using this methodology.

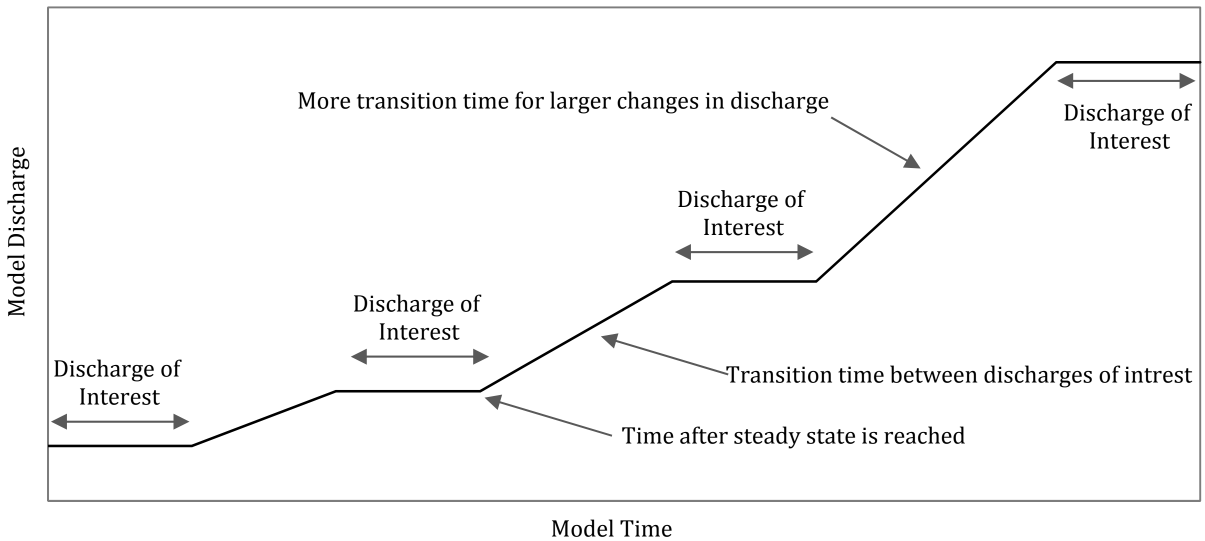

Figure 14. Stepped hydrograph Example

3.5.9 Model Output

To examine the inundation patterns, velocities, and other hydraulic parameters within the model extent for proposed conceptual conditions, the RAS Mapper utility of HEC-RAS 6.1 was used to generate results in the form of raster data sets at the discharges of interest. Model output graphics for computational mesh, Manning's n coverage, water depths for the entire modeled domain and velocities for the project area are included in Appendix C for existing conditions repeated from Inter-Fluve (March 25, 2021). Appendix D includes similar graphics for proposed conceptual conditions.

It should be noted that the 100-year water surface for proposed conditions increases over existing conditions in a number of locations. Given the volume of wood introduced into the main stem, it is anticipated that increases in the 100-year WSEL will occur. Further, by removing the road embankment, the 100-year flow inundation extends east of the former road embankment beyond the established FEMA inundation limits. Both conditions will required that a FEMA CLOMR/LOMR be completed in a future design phase.

3.5.10 Model Findings

Model findings are preliminary, and the model will be updated with greater resolution and more analysis performed in future design phases. Model results will be used for design of LWM structures, bank resiliency and scour predictions in future design phases.

3.6 STABILITY ANALYSES AND COMPUTATIONS FOR PROJECT ELEMENTS, AND COMPREHENSIVE PROJECT PLAN

LWM structure stability and scour analyses will be prepared in future design phases. Stability analysis and computations for project elements will be prepared that generally follow professional practice guidelines for large wood design (Knutson et. al. 2014 and Reclamation/ERDC 2016), stream habitat restoration (Cramer 2012), and institutional knowledge combined with professional judgment for the design of specific project elements.

3.7 DESCRIPTION OF HOW PRECEDING TECHNICAL ANALYSIS HAS BEEN INCORPORATED INTO AND INTEGRATED WITH THE CONSTRUCTION – CONTRACT DOCUMENTATION

The preceding analysis is the basis for the project features shown in the conceptual design drawings. The drawings will be refined through a review and update process to develop preliminary and final engineering stamped construction drawing set with sufficient detail to allow contractors to bid and build the project.

3.8 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A LONGITUDINAL PROFILE OF THE STREAM CHANNEL THALWEG FOR 20 CHANNEL WIDTH UPSTREAM AND DOWNSTREAM OF THE STRUCTURE SHALL BE USED TO DETERMINE THE POTENTIAL FOR CHANNEL DEGRADATION

Not applicable to this project.

3.9 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A MINIMUM OF THREE CROSS-SECTIONS – ONE DOWNSTREAM OF THE STRUCTURE, ONE THROUGH THE RESERVOIR AREA UPSTREAM OF THE STRUCTURE, AND ONE UPSTREAM OF THE RESERVOIR AREA OUTSIDE OF THE INFLUENCE OF THE STRUCTURE) TO CHARACTERIZE THE CHANNEL MORPHOLOGY AND QUANTIFY THE STORED SEDIMENT

Not applicable to this project.

4. Construction – contract documentation

4.1 INCORPORATION OF HIP GENERAL AND CONSTRUCTION CONSERVATION MEASURES

General and construction conservation measures will be included in the preliminary and final plans.

4.2 DESIGN – CONSTRUCTION PLAN SET INCLUDING BUT NOT LIMITED TO PLAN, PROFILE, SECTION AND DETAIL SHEETS THAT IDENTIFY ALL PROJECT ELEMENTS AND CONSTRUCTION ACTIVITIES OF SUFFICIENT DETAIL TO GOVERN COMPETENT EXECUTION OF PROJECT BIDDING AND IMPLEMENTATION

Conceptual level plans are attached.

4.3 LIST OF ALL PROPOSED PROJECT MATERIALS AND QUANTITIES

Proposed materials types and quantities are included in the conceptual plans and attached opinion of probable construction quantities. Materials include logs, logs with rootwads, slash, whole trees, tree tops, logs without rootwads installed vertically as piles, excavation and backfill of alluvial materials. Additional materials may include boulders and fully threaded rods for bolting logs to piles or boulders. The project area will be planted with native riparian plant species to be designed by Yakama Nation's vegetation consultant.

4.4 DESCRIPTION OF BEST MANAGEMENT PRACTICES THAT WILL BE IMPLEMENTED AND IMPLEMENTATION RESOURCE PLANS INCLUDING:

HIP conservation measures will be included in the preliminary and final plans including an erosion and sediment control plan using standard BMPs.

4.5 CALENDAR SCHEDULE FOR CONSTRUCTION/IMPLEMENTATION PROCEDURES

A construction timeframe has not been determined at this time.

4.6 SITE OR PROJECT SPECIFIC MONITORING TO SUPPORT POLLUTION PREVENTION AND/OR ABATEMENT

Standard erosion and pollution control measure will be shown and detailed in the stamped construction drawing set.

5. Monitoring and adaptive management plan

The monitoring and adaptive management plan will be determined at the discretion of Yakama Nation Fisheries in subsequent design phases.

6. References

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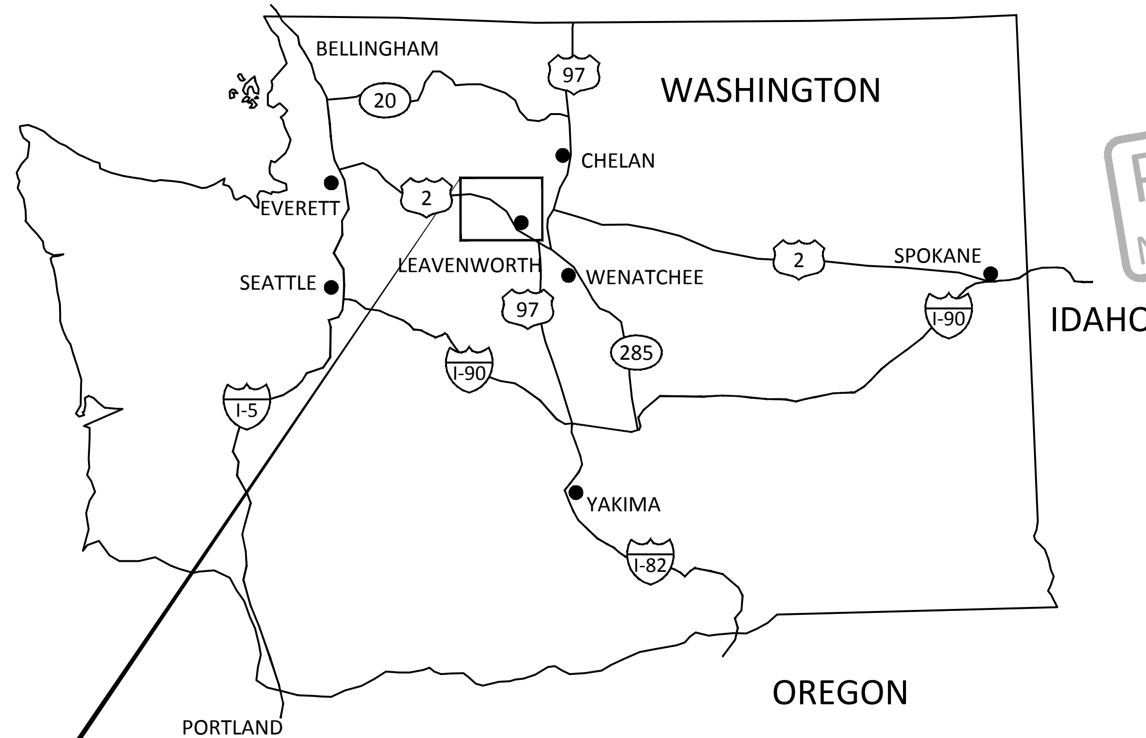
Appendix A – RM 3.8-4.6 conceptual project drawings

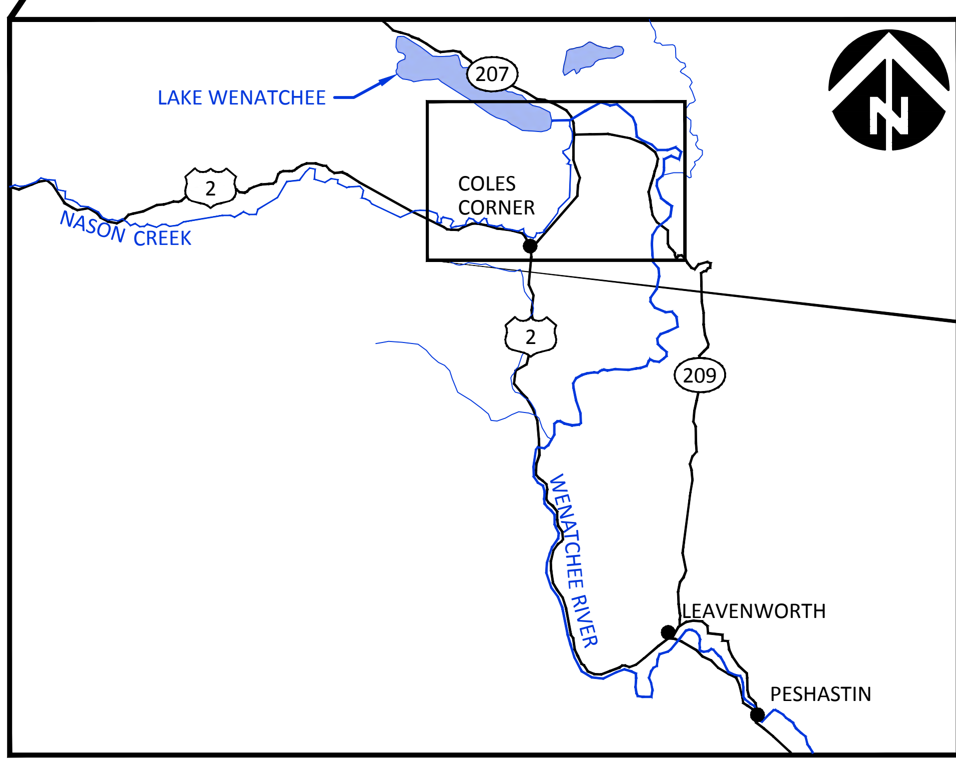
NASON CREEK FLOODPLAIN RESTORATION CONCEPTUAL DESIGN - UPSTREAM REACH

CHELAN COUNTY, WA

DECEMBER 2021



LOCATION MAP
STATE OF WASHINGTON
NOT TO SCALE



VICINITY MAP
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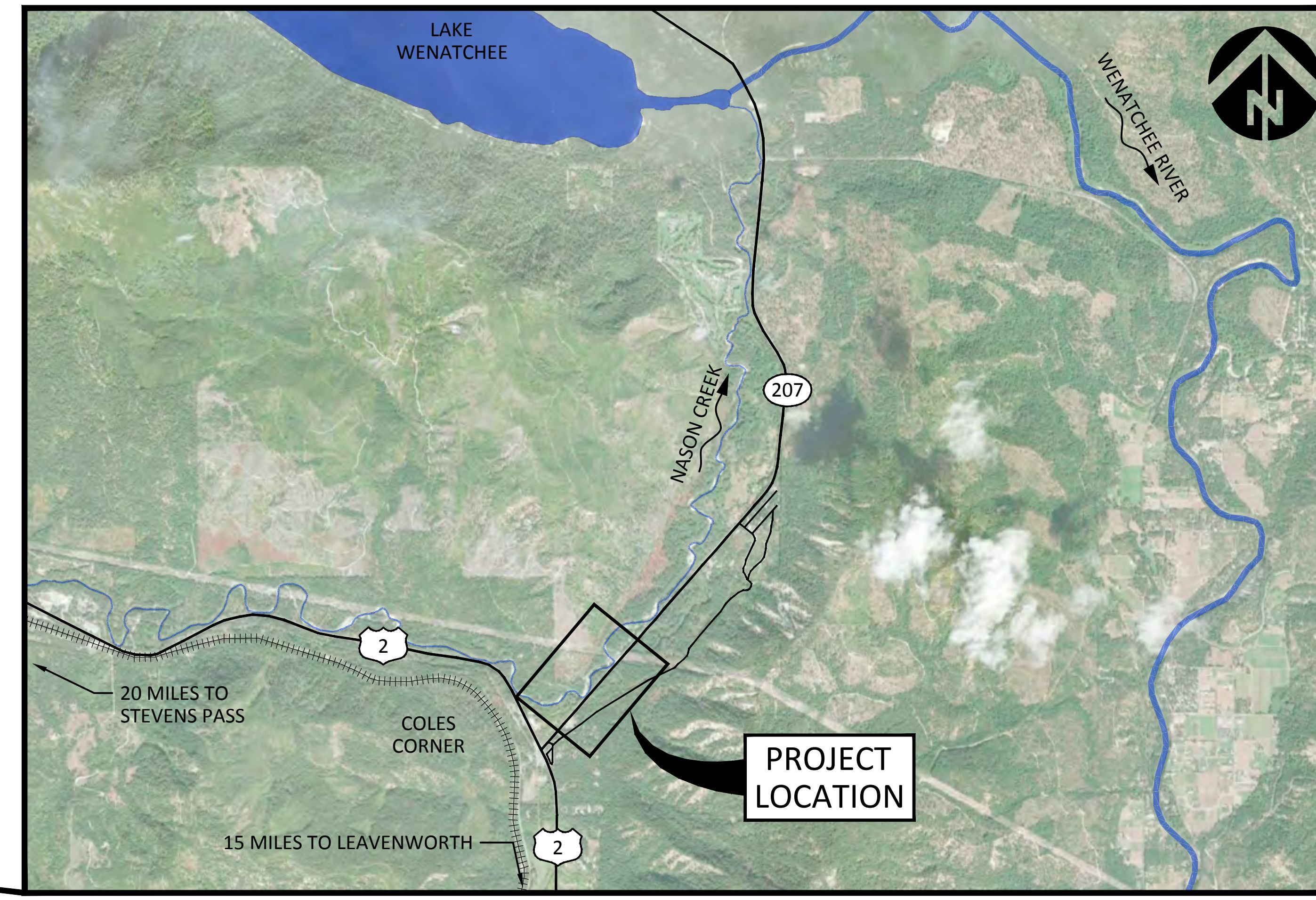

SITE MAP
1" = 1 MILE

SHEET INDEX:

COORDINATES:

LATITUDE: 47°45'48"N
LONGITUDE: 120°43'50"W

SECTION 9, TOWNSHIP 26N, RANGE 17E

WATERBODY: NASON CREEK
TRIBUTARY OF: WENATCHEE RIVER

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NO.	BY	DATE	REVISION DESCRIPTION

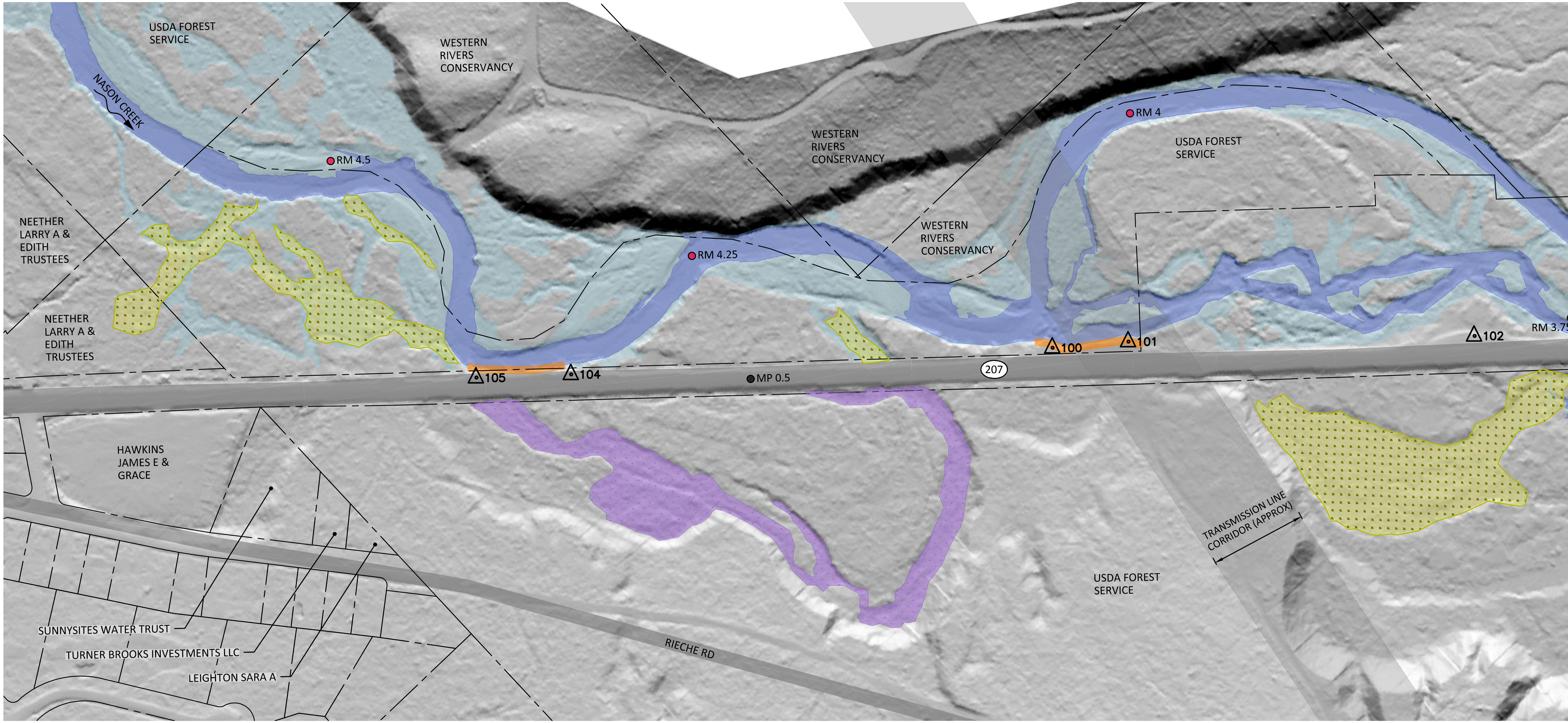
DRAWN	DESIGNED	CHECKED
NS	DM	MM, LS
APPROVED	**DATE**	**PROJECT**
DM	12/8/21	200237

YAKAMA NATION FISHERIES
NASON CREEK FLOODPLAIN RESTORATION
CONCEPTUAL DESIGN - UPSTREAM REACH

inter-fluve
501 Portway Avenue, Suite 101
Hood River, OR 97031
541.386.9003
www.interfluve.com

COVER, SHEET INDEX & VICINITY MAPS

SHEET
1 OF 10



LEGEND

- APPROXIMATE 1.5-YEAR EVENT FLOW INUNDATION LIMITS FOR EXISTING CONDITIONS
- APPROXIMATE EXISTING ACTIVE CHANNEL
- WETLAND - CHELAN COUNTY DELINEATION
- WETLAND - HAMER ENVIRONMENTAL DELINEATION
- TAXLOTS
- RM XX — NASON CREEK RIVER MILE
- MP XX — HIGHWAY 207 MILEPOST
- 100 — SURVEY CONTROL POINT

SURVEY CONTROL

POINT NUMBER	NORTHING	EASTING	ELEVATION	DESCRIPTION
100	278552.01	1665695.91	1954.74	REBAR
101	278700.56	1665813.38	1952.82	STAKE
104	277630.52	1664927.19	1964.70	REBAR
105	277452.23	1664772.04	1966.58	REBAR

NOTES:

1. CHELAN COUNTY WETLAND DELINEATION OCCURRED IN DECEMBER 2016. WETLAND BOUNDARY DEPICTED IS APPROXIMATE. ACTUAL WETLAND BOUNDARY SHALL BE VERIFIED IN THE FIELD.
2. HAMER ENVIRONMENTAL WETLAND DELINEATION OCCURRED ON AUGUST 4-5, 2020.

0 250 500
SCALE IN FEET

Preliminary
Not for Construction

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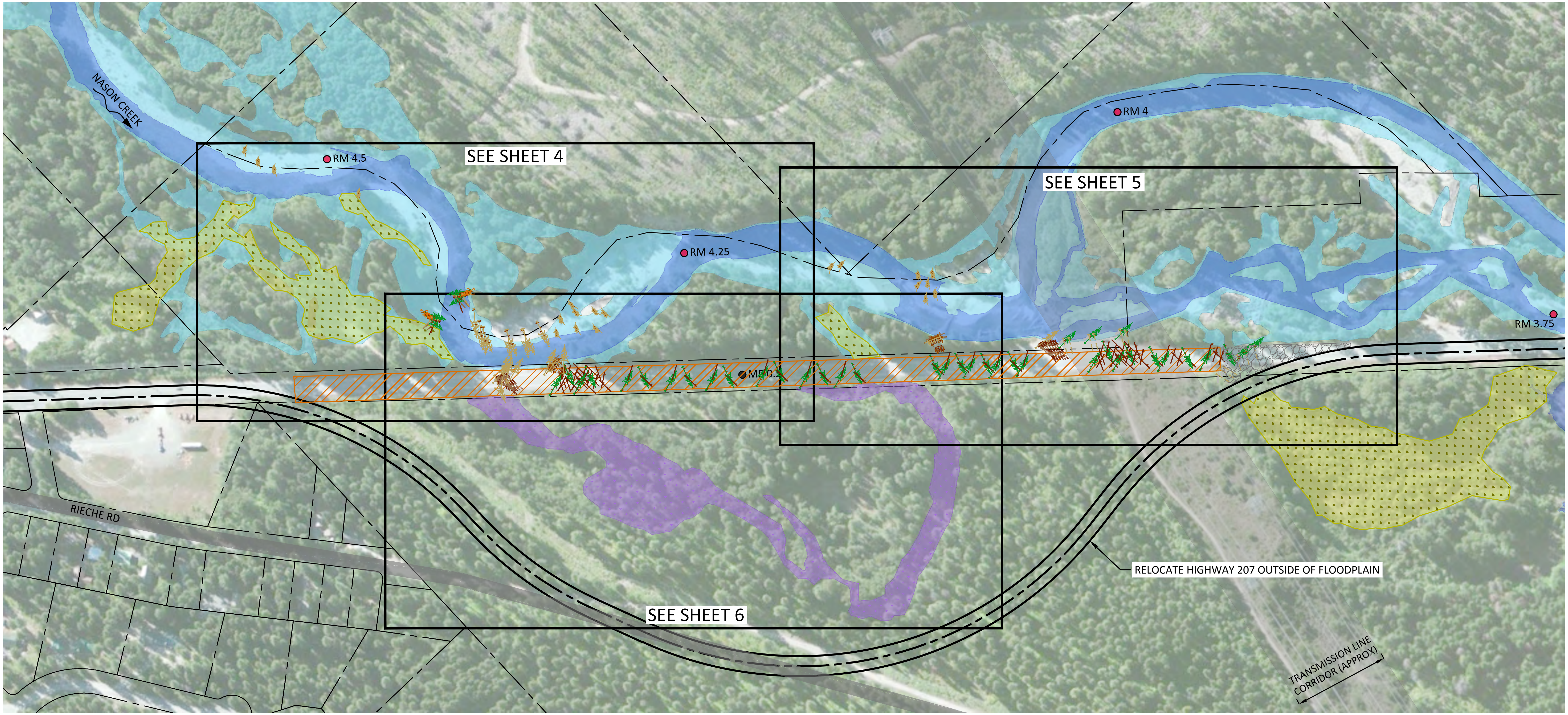
EXISTING CONDITIONS & PROPERTY OWNERSHIP



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- RM XX — NASON CREEK RIVER MILE
- MP XX — HIGHWAY 207 MILEPOST
- PROPOSED HIGHWAY 207 RELOCATION ALIGNMENT
- EXISTING ROAD PRISM REMOVAL

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SCALE IN FEET

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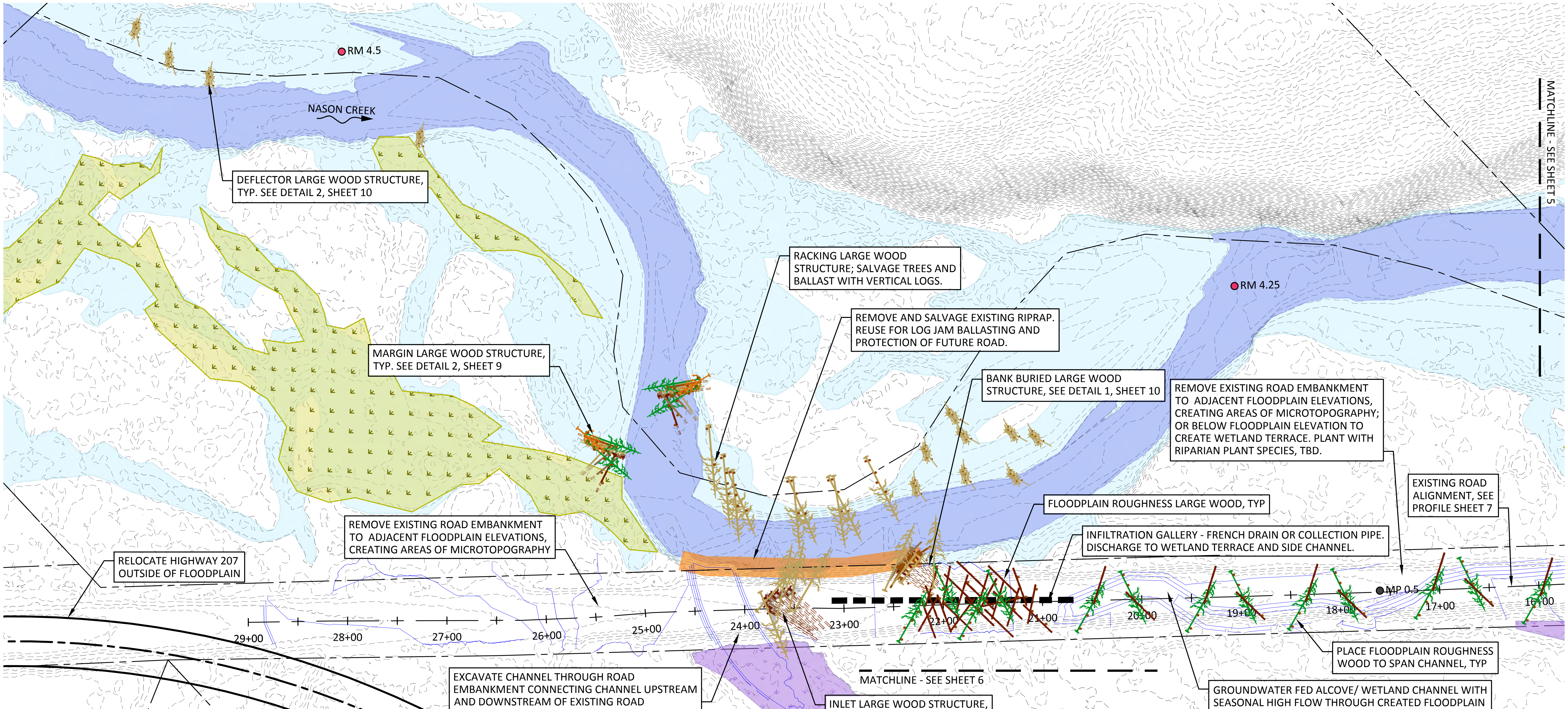
PROPOSED CONDITIONS AND SHEET INDEX



LEGEND

- EXISTING CONTOURS (1 FT)
- PROPOSED CONTOURS (1 FT)
- APPROXIMATE 1.5-YEAR EVENT FLOW INUNDATION LIMITS FOR EXISTING CONDITIONS
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- TAXLOTS
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- ● MP XX — HIGHWAY 207 MILEPOST

Preliminary
Not for Construction

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SCALE IN FEET

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NO.	BY	DATE	REVISION DESCRIPTION

NS (DRAWN)	DM (DESIGNED)	MM, LS (CHECKED)
DM (APPROVED)	12/8/21 (DATE)	200237 (PROJECT)

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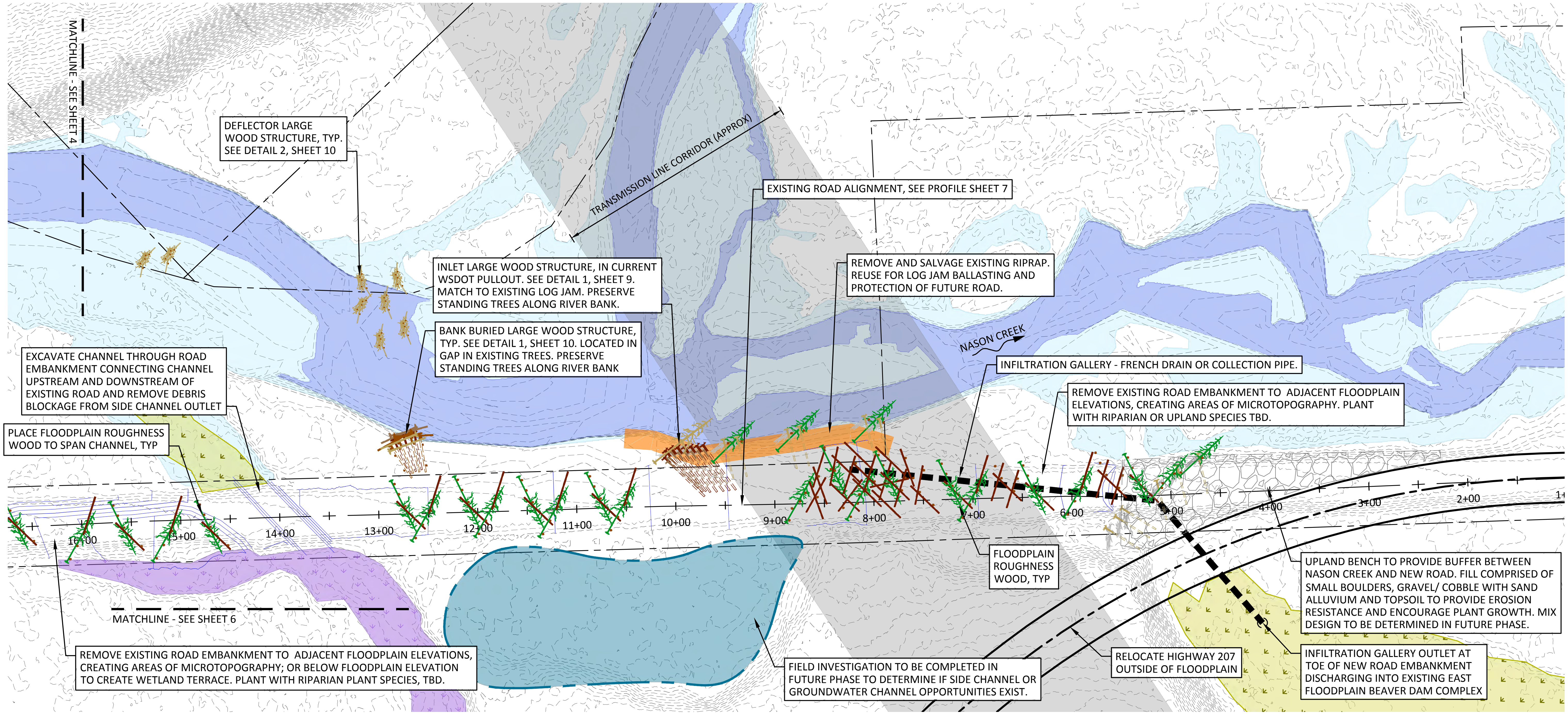
PROPOSED CONDITIONS
(1 OF 3)



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SCALE IN FEET

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NS (DRAWN)	DM (DESIGNED)	MM, LS (CHECKED)
DM (APPROVED)	12/8/21 (DATE)	200237 (PROJECT)

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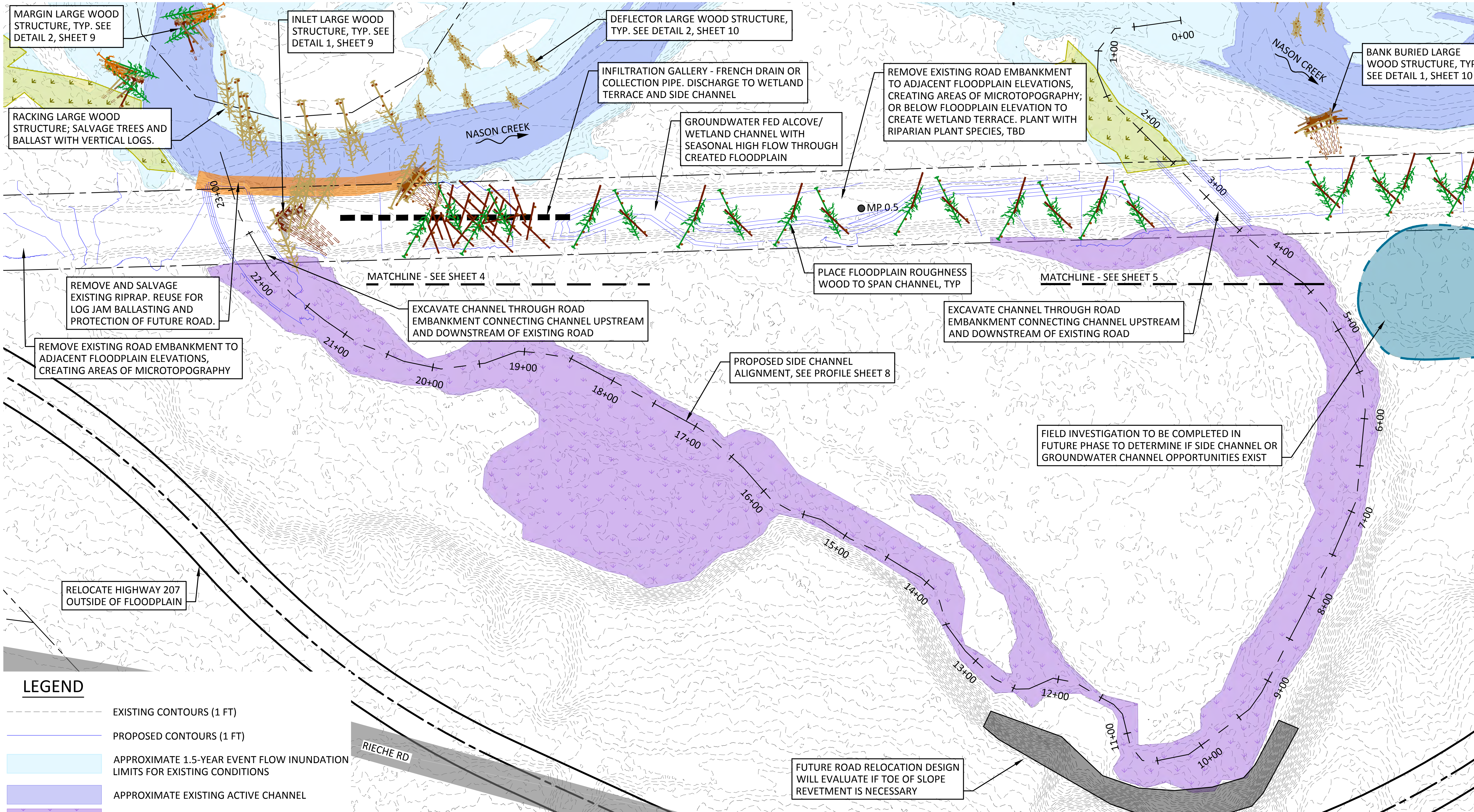
PROPOSED CONDITIONS
(2 OF 3)



LEGEND

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SCALE IN FEET

NO.	BY	DATE	REVISION DESCRIPTION

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DM APPROVED	12/8/21 DATE	200237 PROJECT

YAKAMA NATION FISHERIES
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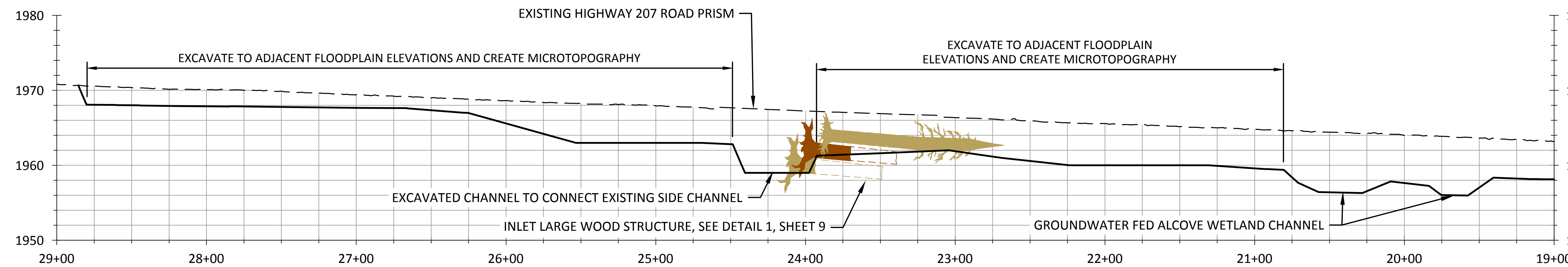
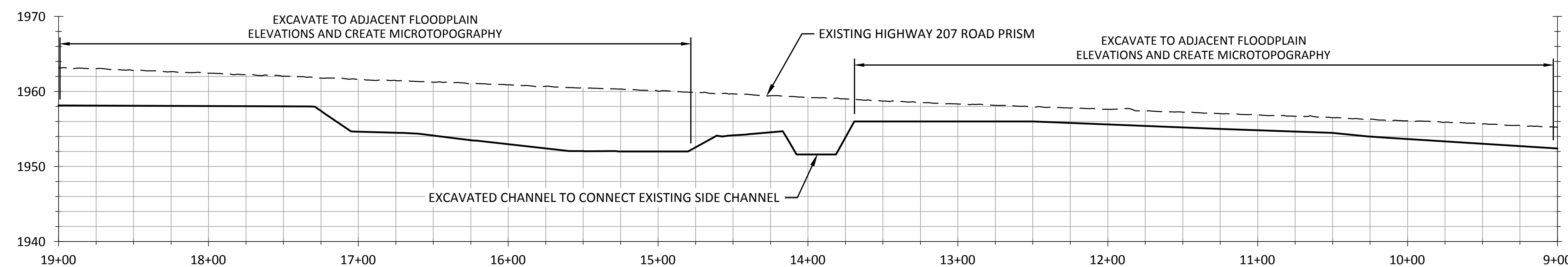
PROPOSED CONDITIONS
(3 OF 3)



PROFILE - EXISTING ROAD PRISM, STA 29+00 - 19+00



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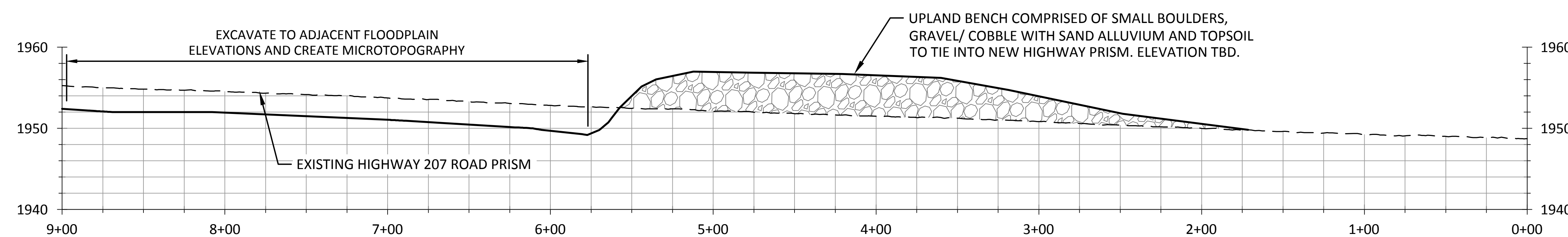

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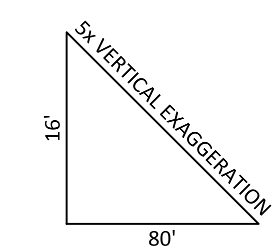

NO.	BY	DATE	REVISION DESCRIPTION

DRAWN	DESIGNED	CHECKED
NS	DM	MM, LS
APPROVED	**DATE**	**PROJECT**
DM	12/8/21	200237

YAKAMA NATION FISHERIES
NASON CREEK FLOODPLAIN RESTORATION
CONCEPTUAL DESIGN - UPSTREAM REACH

inter·fluve
501 Portway Avenue, Suite 101
Hood River, OR 97031
541.386.9003
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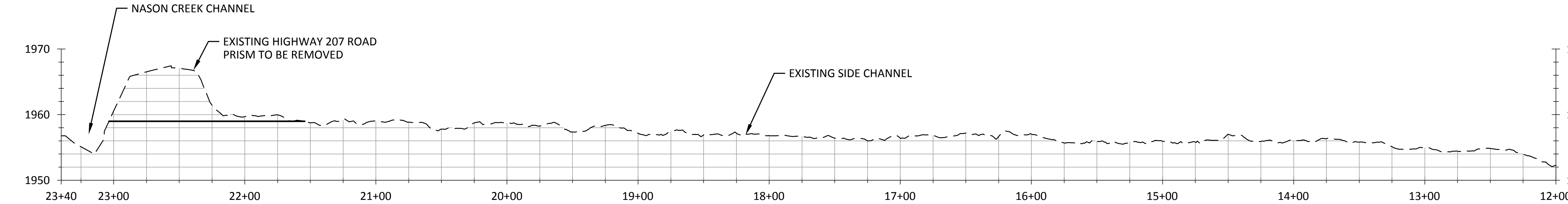
PROFILE - EXISITNG
ROAD PRISM



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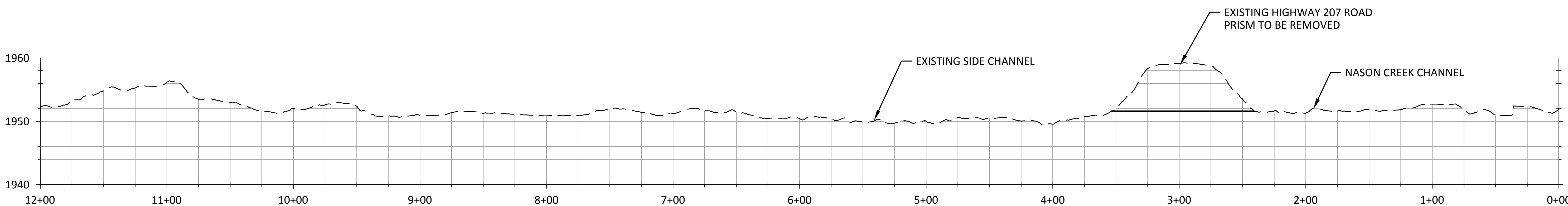

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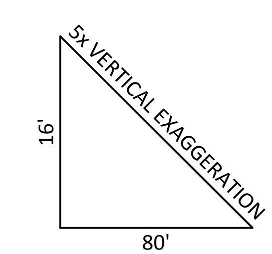

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NO.	BY	DATE	REVISION DESCRIPTION

NS DRAWN	DM DESIGNED	MM, LS CHECKED
DM APPROVED	12/8/21 DATE	200237 PROJECT

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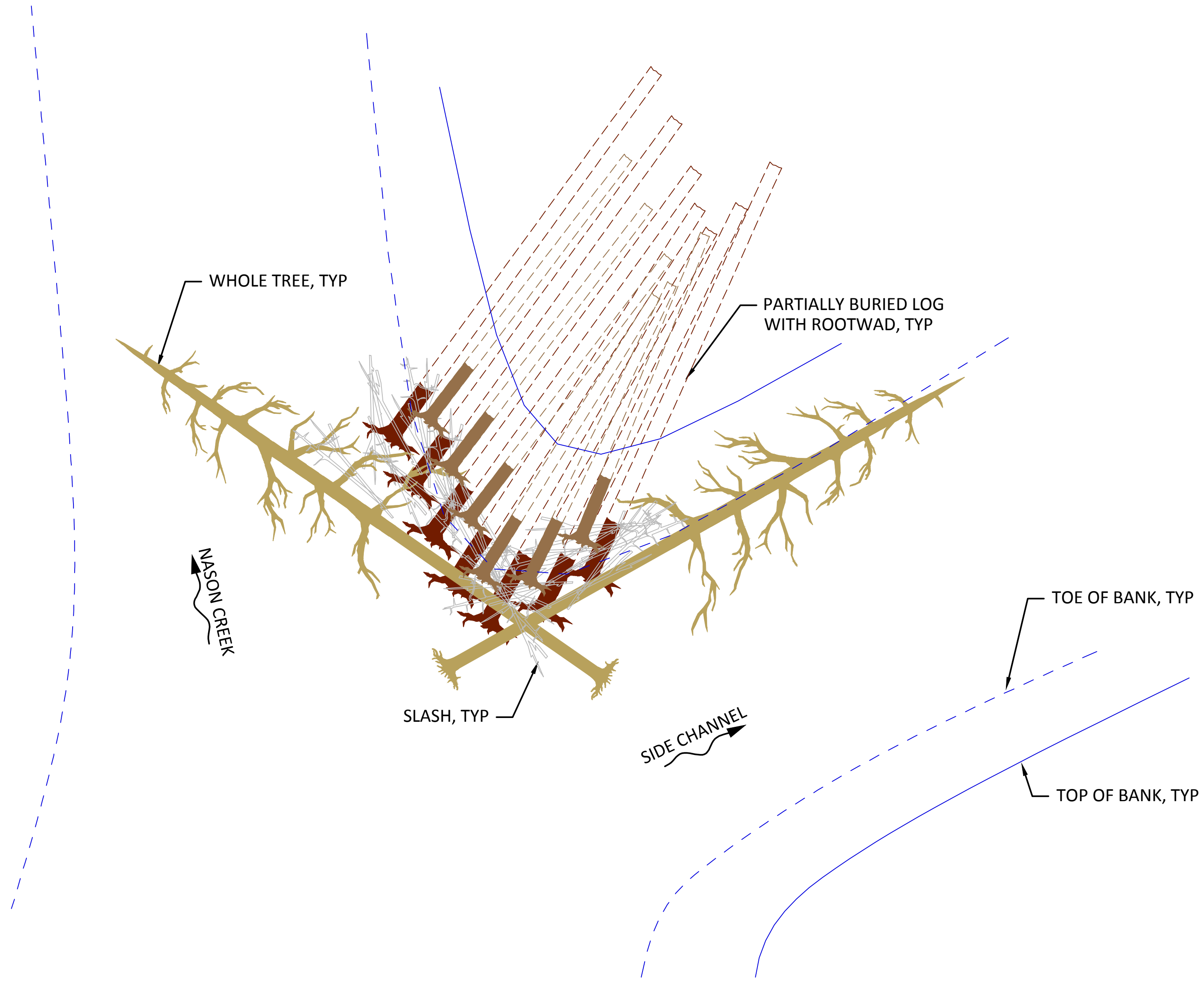
PROFILE - SIDE CHANNEL



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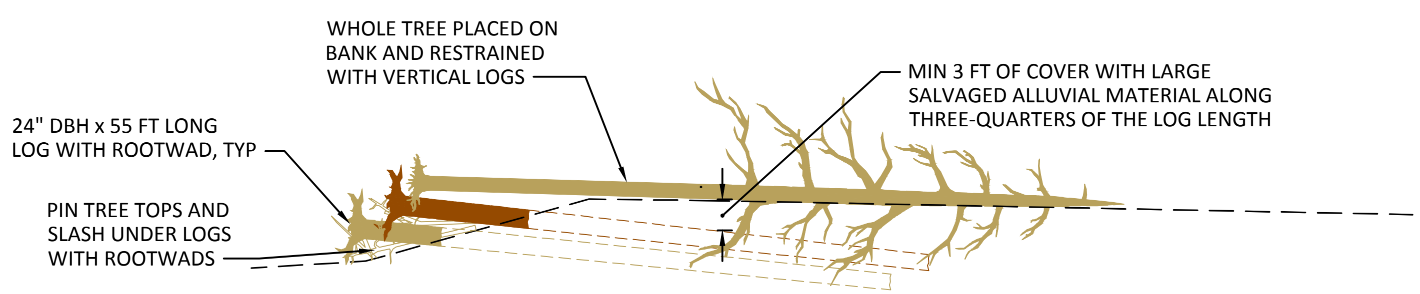
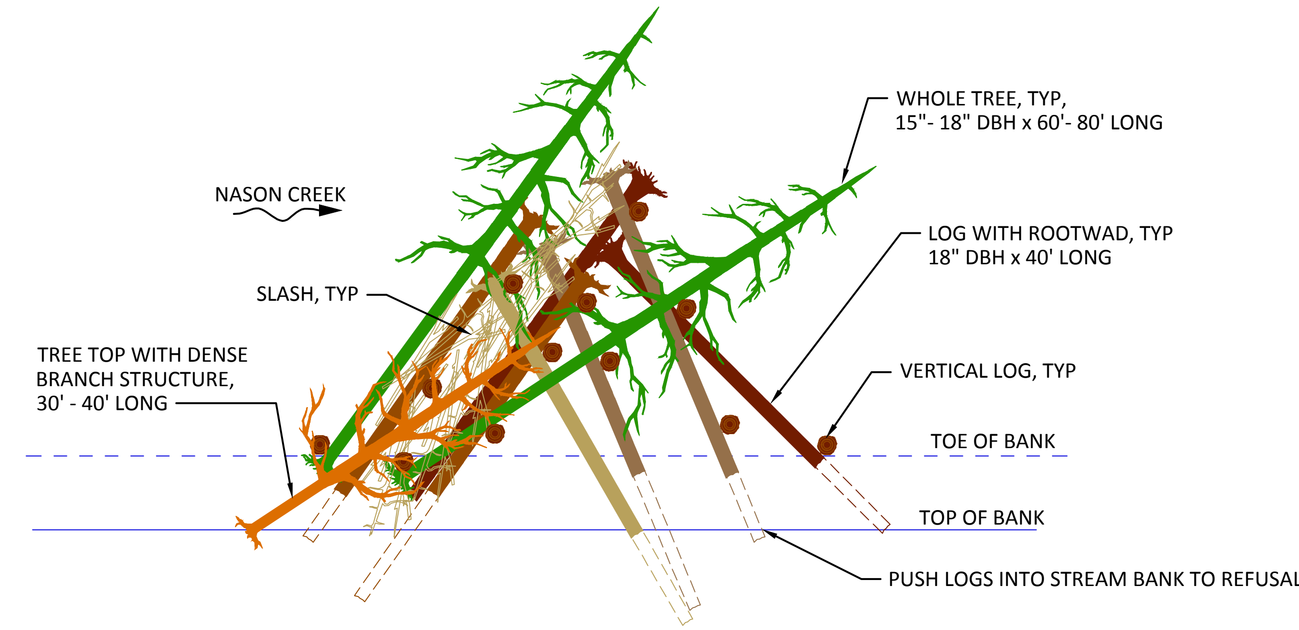


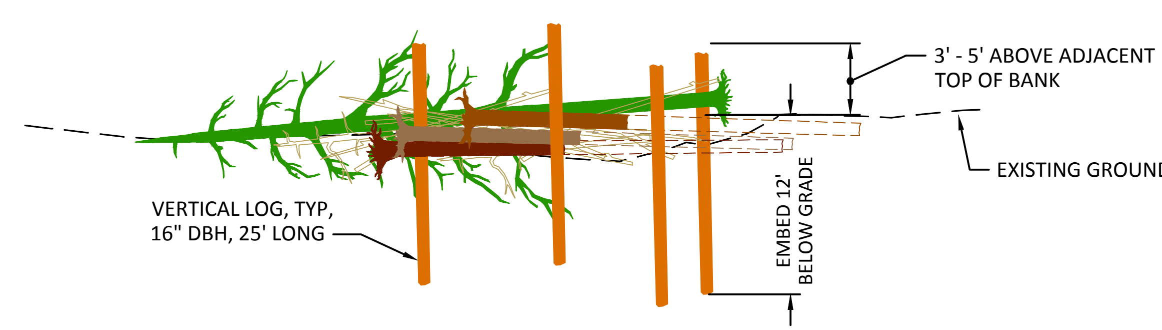
SECTION

1/9 TYPICAL DETAIL - INLET LARGE WOOD STRUCTURE

NOT TO SCALE



PLAN



SECTION

2/9 TYPICAL DETAIL - MARGIN LARGE WOOD STRUCTURE

NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

NS DRAWN	DM DESIGNED	MM, LS CHECKED
DM APPROVED	12/8/21 DATE	200237 PROJECT

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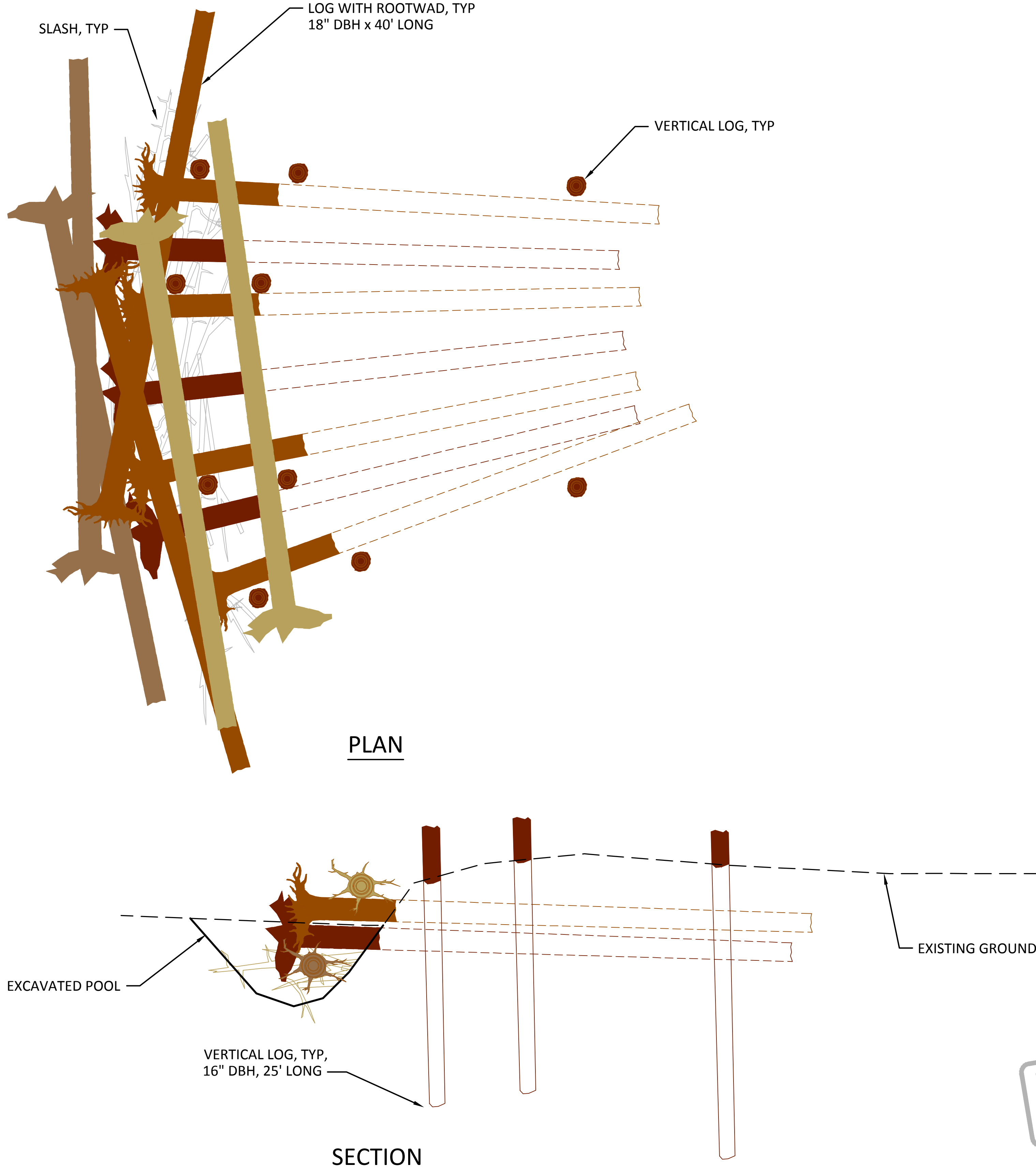
LARGE WOOD TYPICAL
DETAILS (1 OF 2)



1/10 TYPICAL DETAIL - BANK-BURIED LARGE WOOD STRUCTURE

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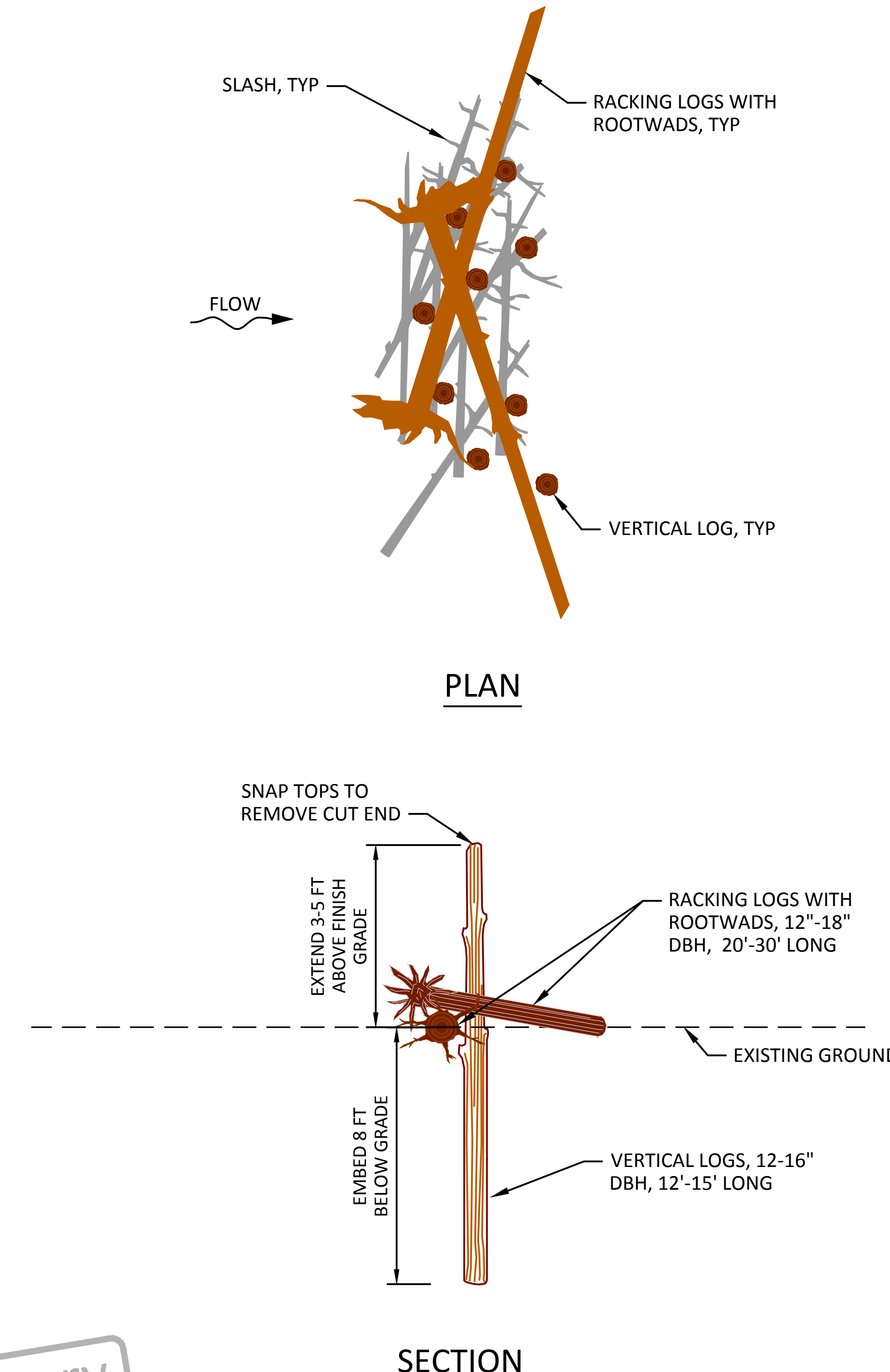

Preliminary
Not for Construction

2/10 TYPICAL DETAIL - DEFLECTOR STRUCTURE

NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

NS DRAWN	DM DESIGNED	MM, LS CHECKED
DM APPROVED	12/8/21 DATE	200237 PROJECT

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LARGE WOOD TYPICAL
DETAILS (2 OF 2)

Appendix B – Opinion of probable construction quantities

Nason Floodplain RM 3.8-4.6 Concepts: Opinion of Probable Construction Cost

version: 12/06/2021

Item	Description	Quantity	Units	Unit Cost	Subtotal	Notes
1	TESC, SPCC Plan and Implementation	1	LS	$ 30,000	$ 30,000	Includes wet-wading spill plan for wet crossings
2	Mobilization	1	LS	$ 70,000	$ 70,000	Approx. 9 percent
3	Traffic Control	1	LS	$ 5,000	$ 5,000	Assumes road is abandoned
4	Clearing and Grubbing	1	LS	$ 5,000	$ 5,000	Miscellaneous: salvage and re-use (e.g. slash)
5	Cofferdam and Diversion	1	LS	$ 25,000	$ 25,000	Cofferdam will be defined in future design phase
6	Pumping	1	LS	$ 10,000	$ 10,000	Construction site dewatering
7	Road embankment removal and off site disposal	17150	CY	$ 12	$ 205,800	
8	Riprap removal and salvage	700	CY	$ 25	$ 17,500	Approximately 225+250LF x 3ft thick x 12ft high plus barbs
9	Upland bench	1250	CY	$ 15	$ 18,750	Approx. 200 L x 60 W x 3ft deep
10	Bank attached margin wood structures	2	EA	$ 13,000	$ 26,000	Install Owner provided logs and salvaged slash and trees
11	Deflector jam structures	20	EA	$ 5,500	$ 110,000	d.o.
12	Bank buried jam	4	EA	$ 18,000	$ 72,000	d.o.
13	Bank buried log with rootwad	12	EA	$ 750	$ 9,000	d.o.
14	Whole tree-large	17	EA	$ 1,500	$ 25,500	d.o.
15	Whole tree-medium (FP roughness)	38	EA	$ 1,250	$ 47,500	d.o.
16	FP roughness logs	77	EA	$ 500	$ 38,500	d.o.
17	Piles for floodplain roughness and whole trees	185	EA	$ 500	$ 92,500	
				Total =	**$ 810,000**	

Abbreviations:

CY = Cubic Yards

EA = Each

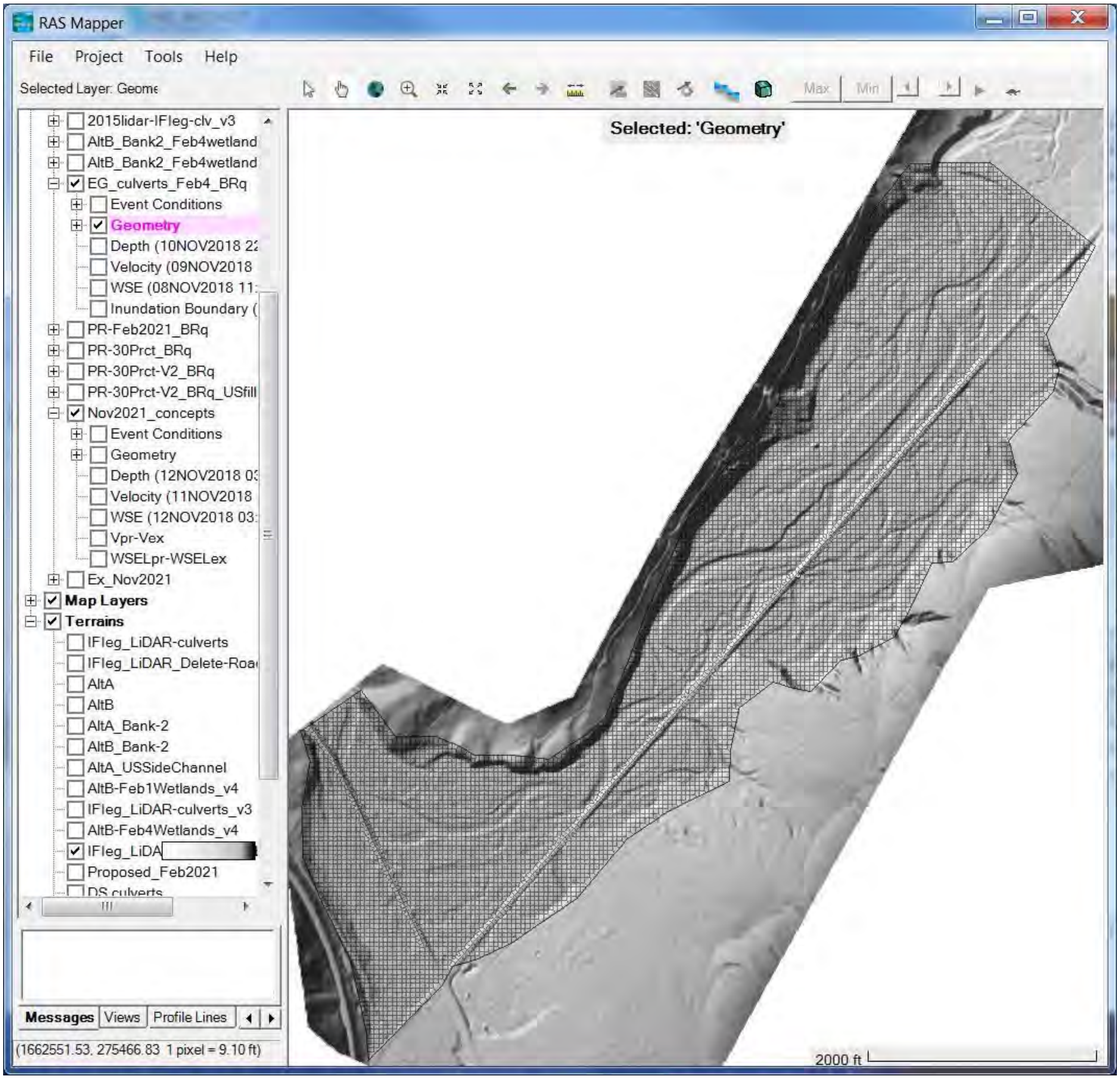
LS = Lump Sum

Assumptions:

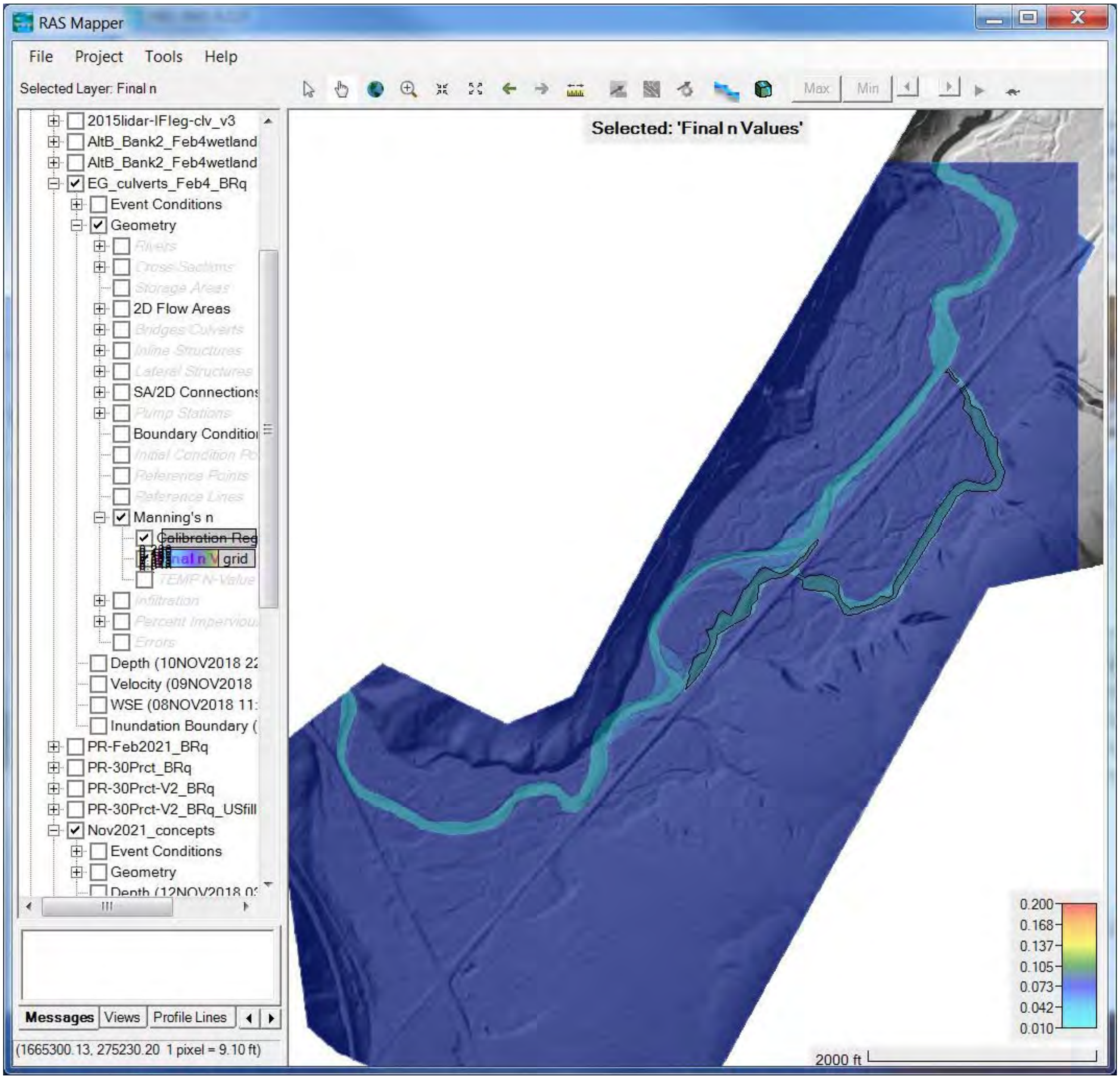
Planting plan and revegetation are designed by others

Appendix C – Existing conditions HEC-RAS model

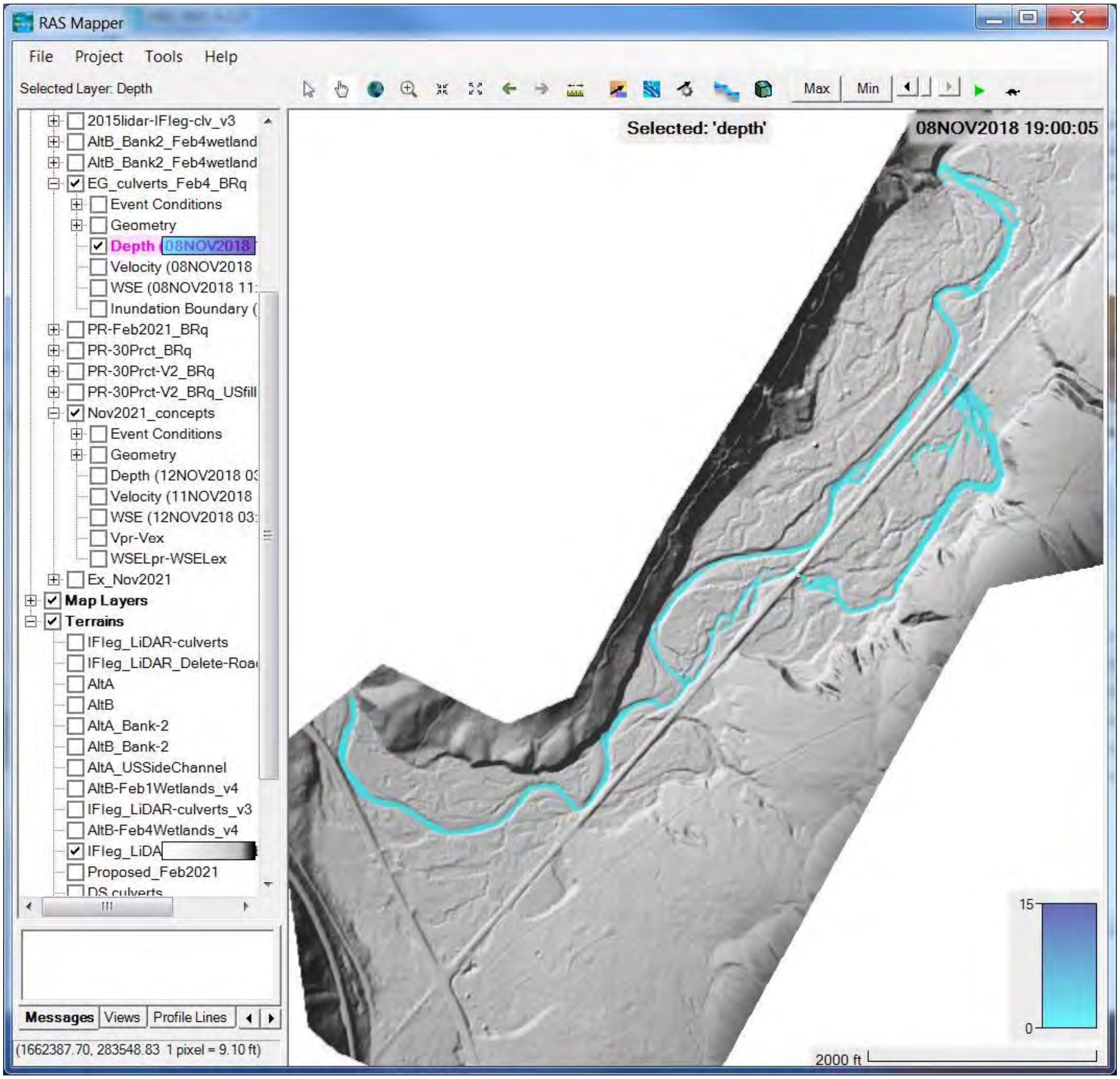
Existing condition model mesh



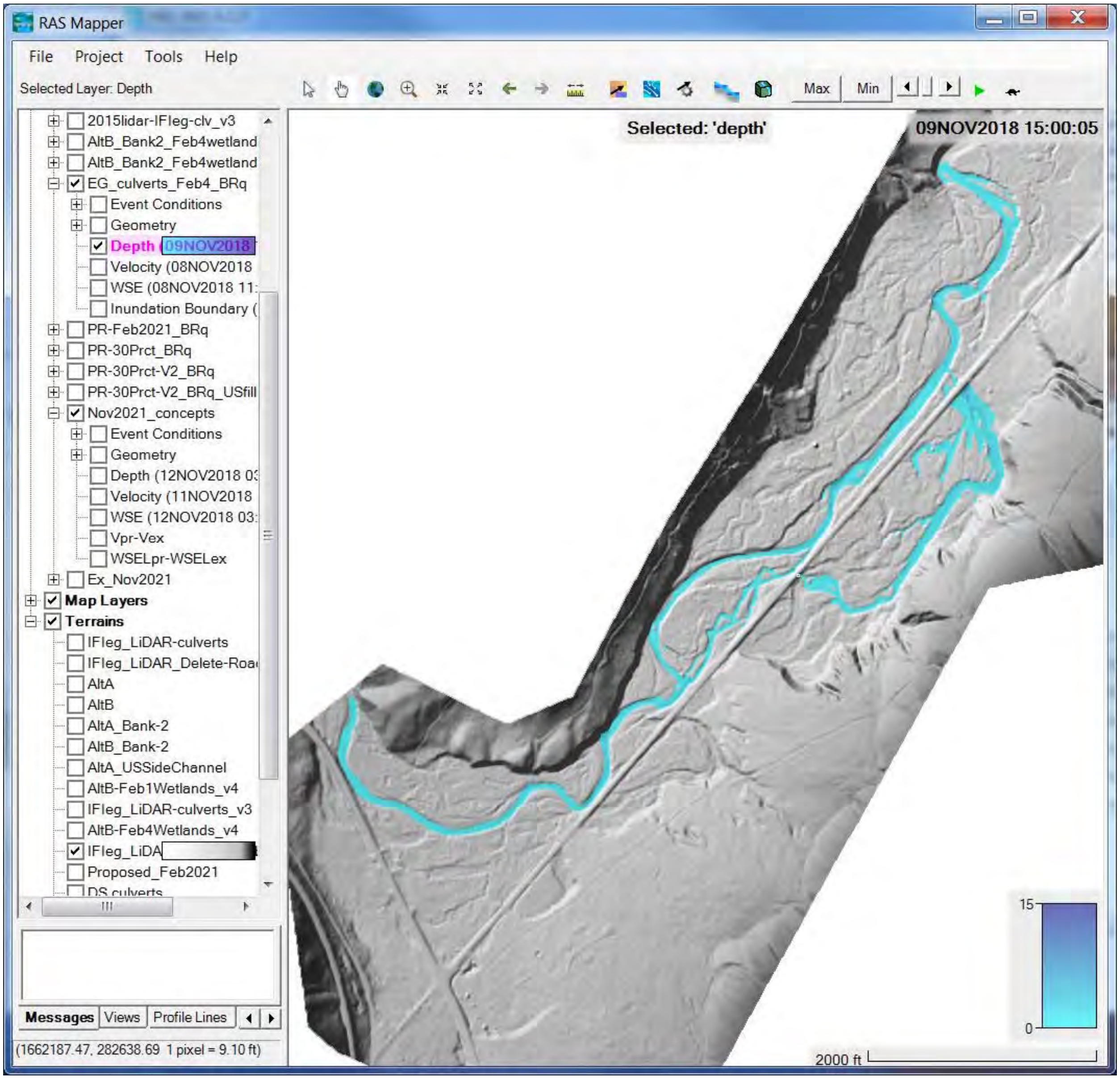
Existing condition Manning's n



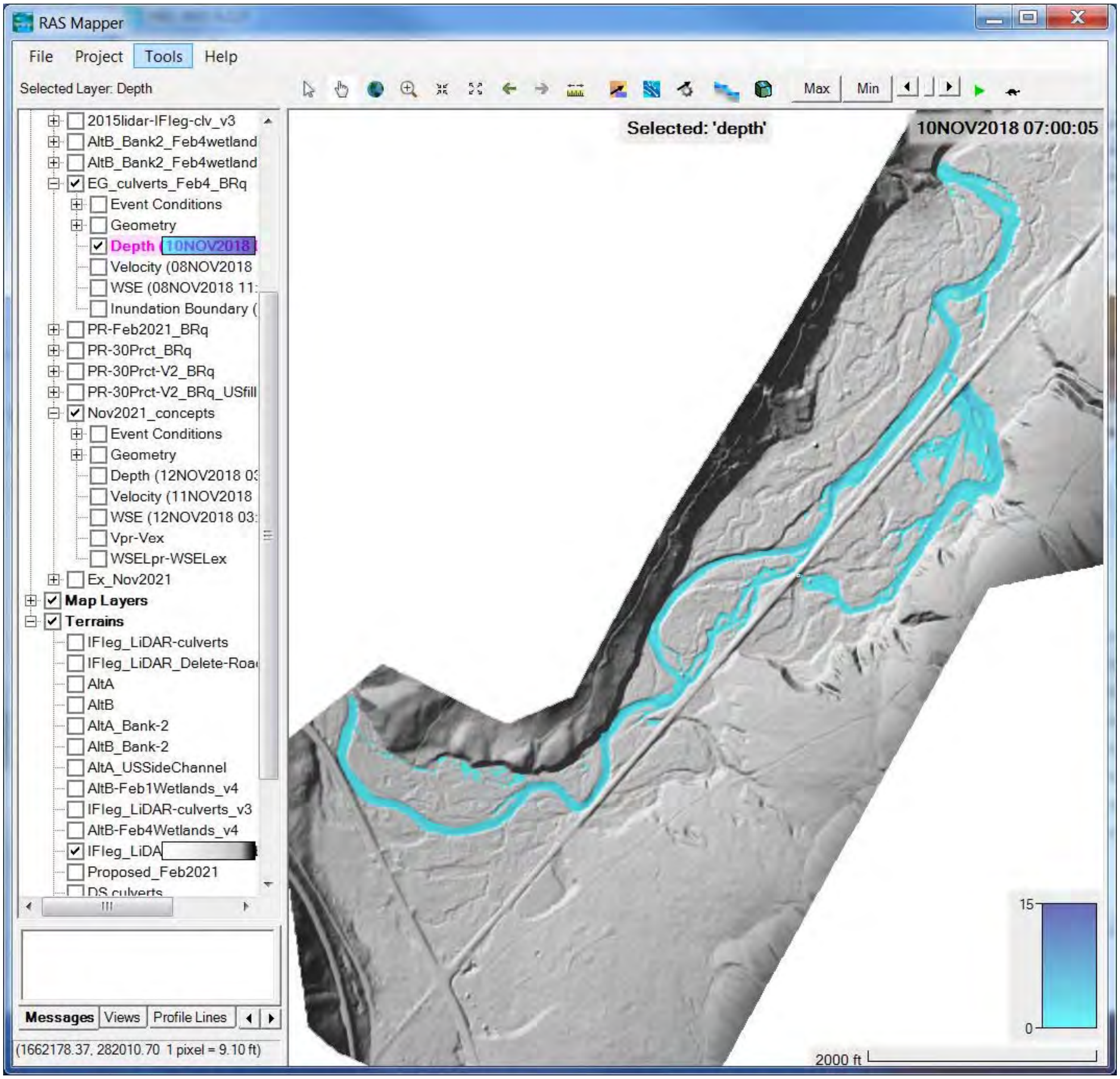
Existing condition: 50-cfs flow depth through project area



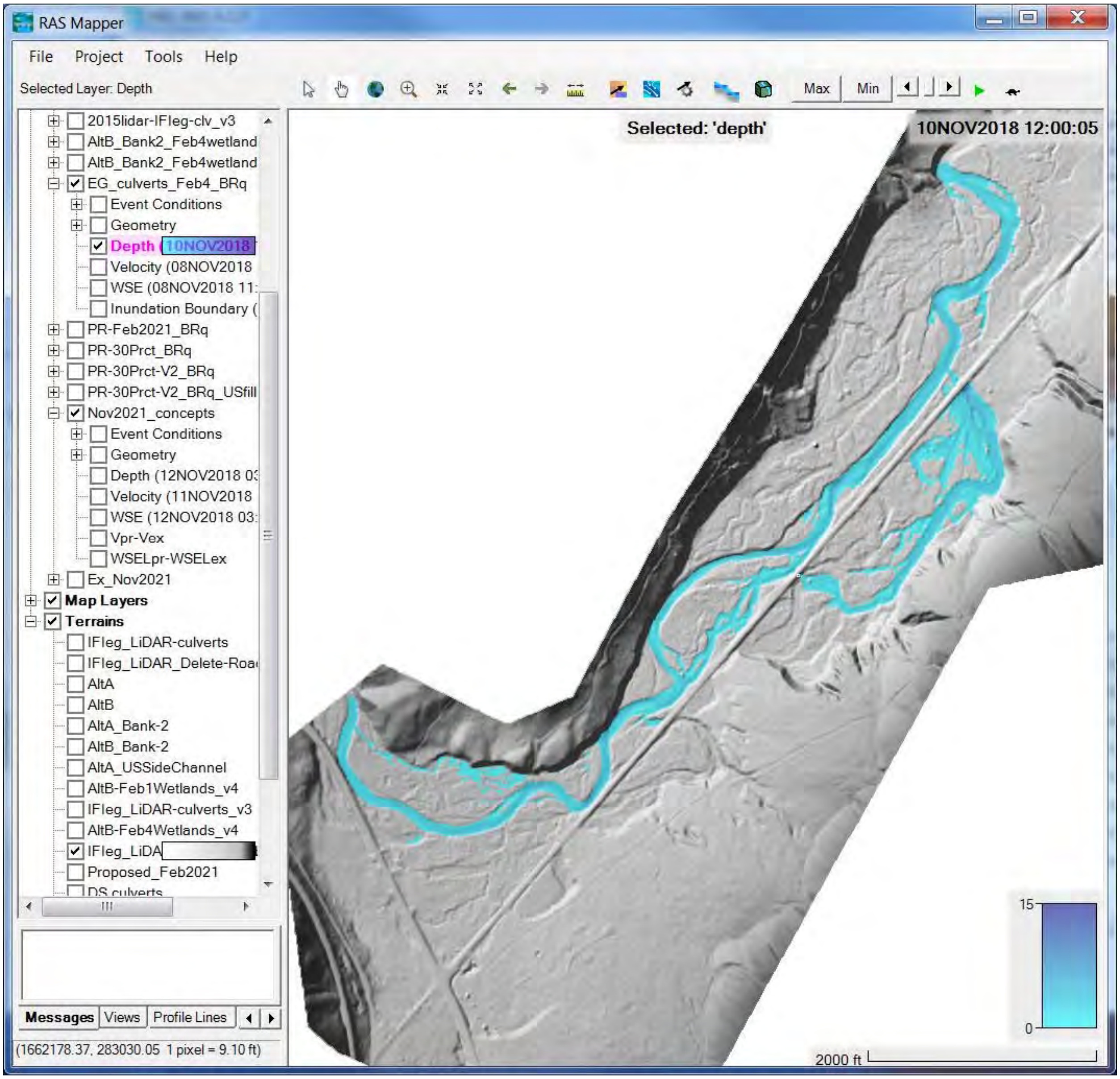
Existing condition: 200-cfs flow depth through project area



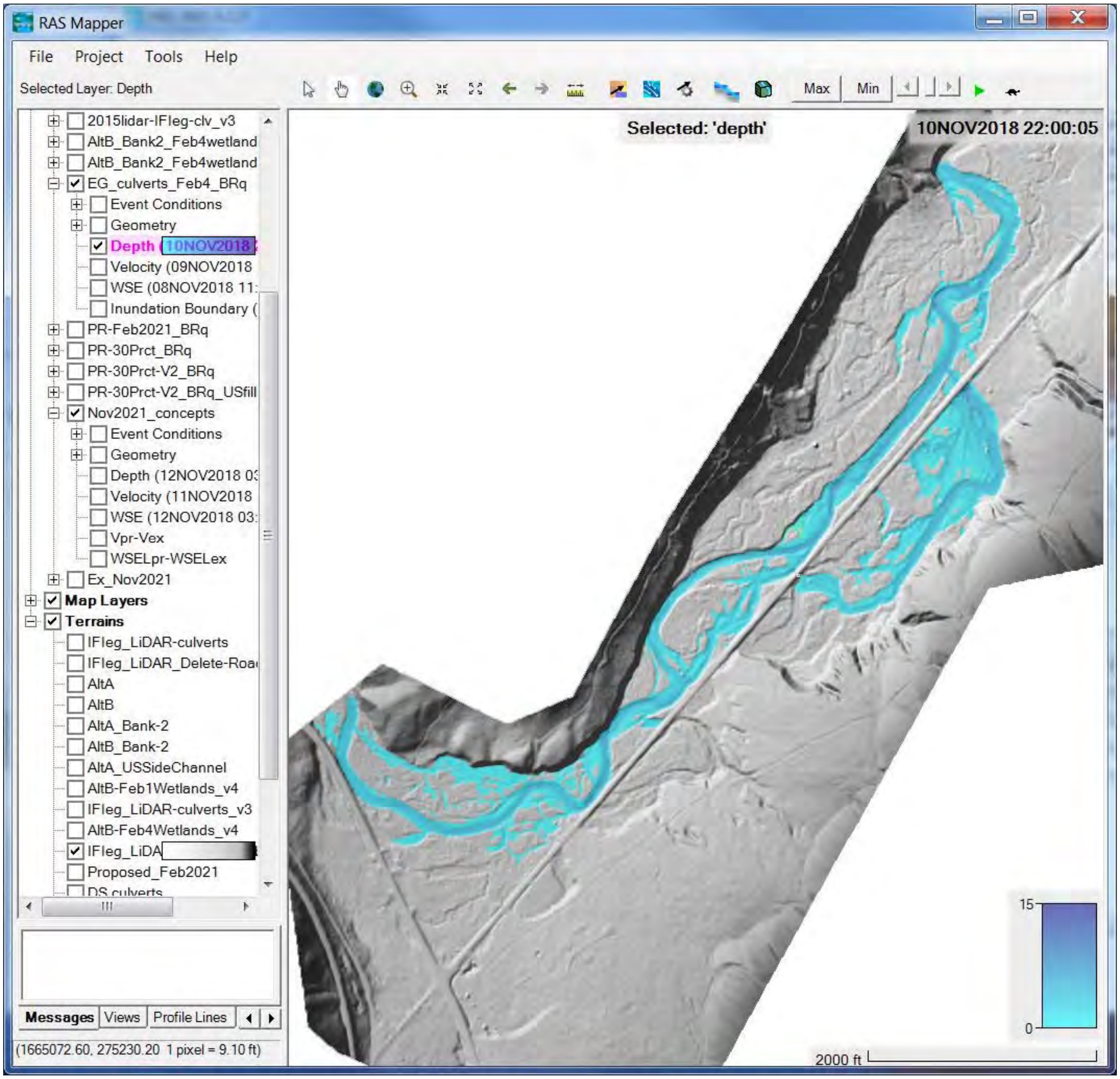
Existing condition: 600-cfs flow depth through project area



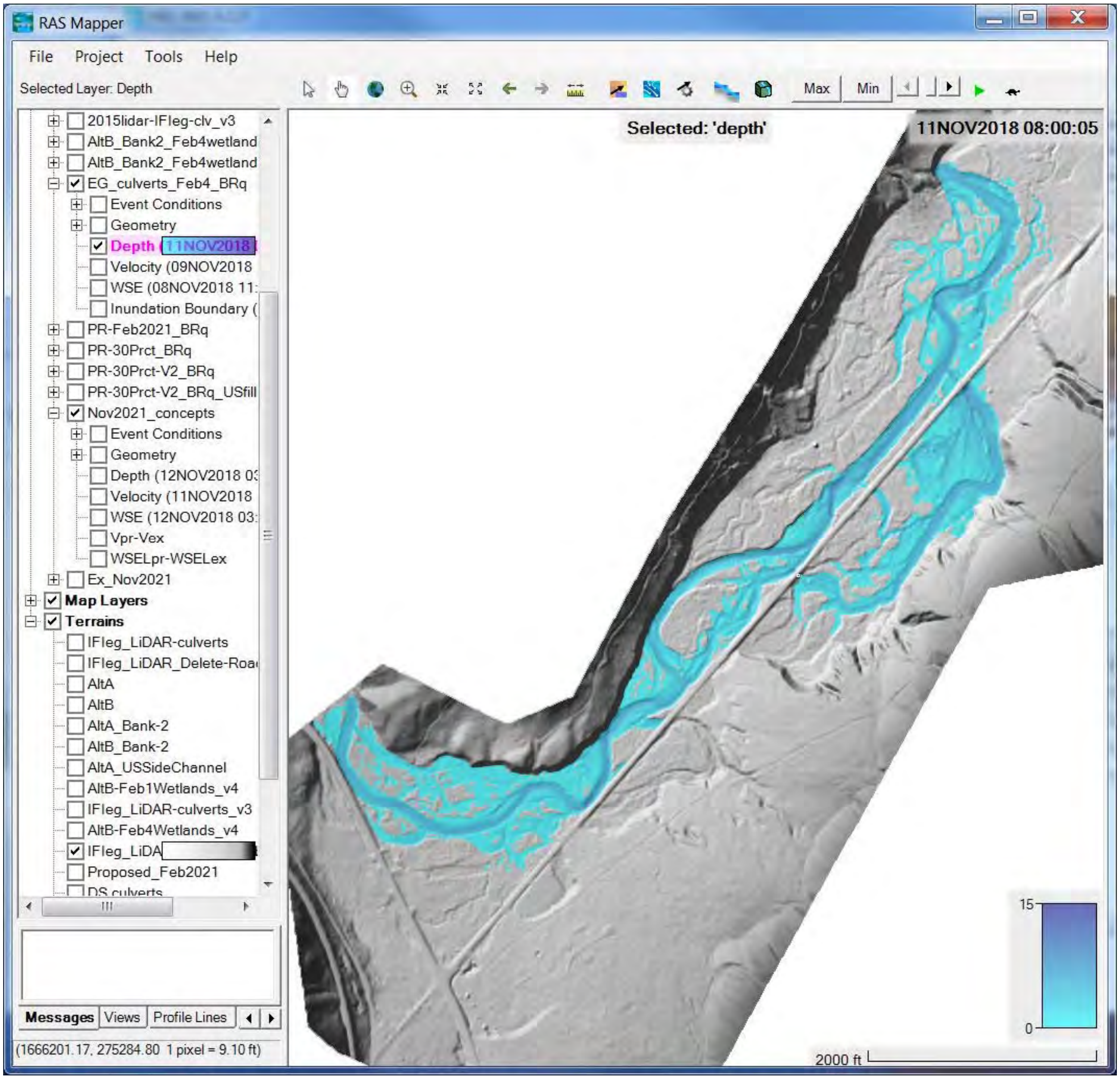
Existing condition: 1,000-cfs flow depth through project area



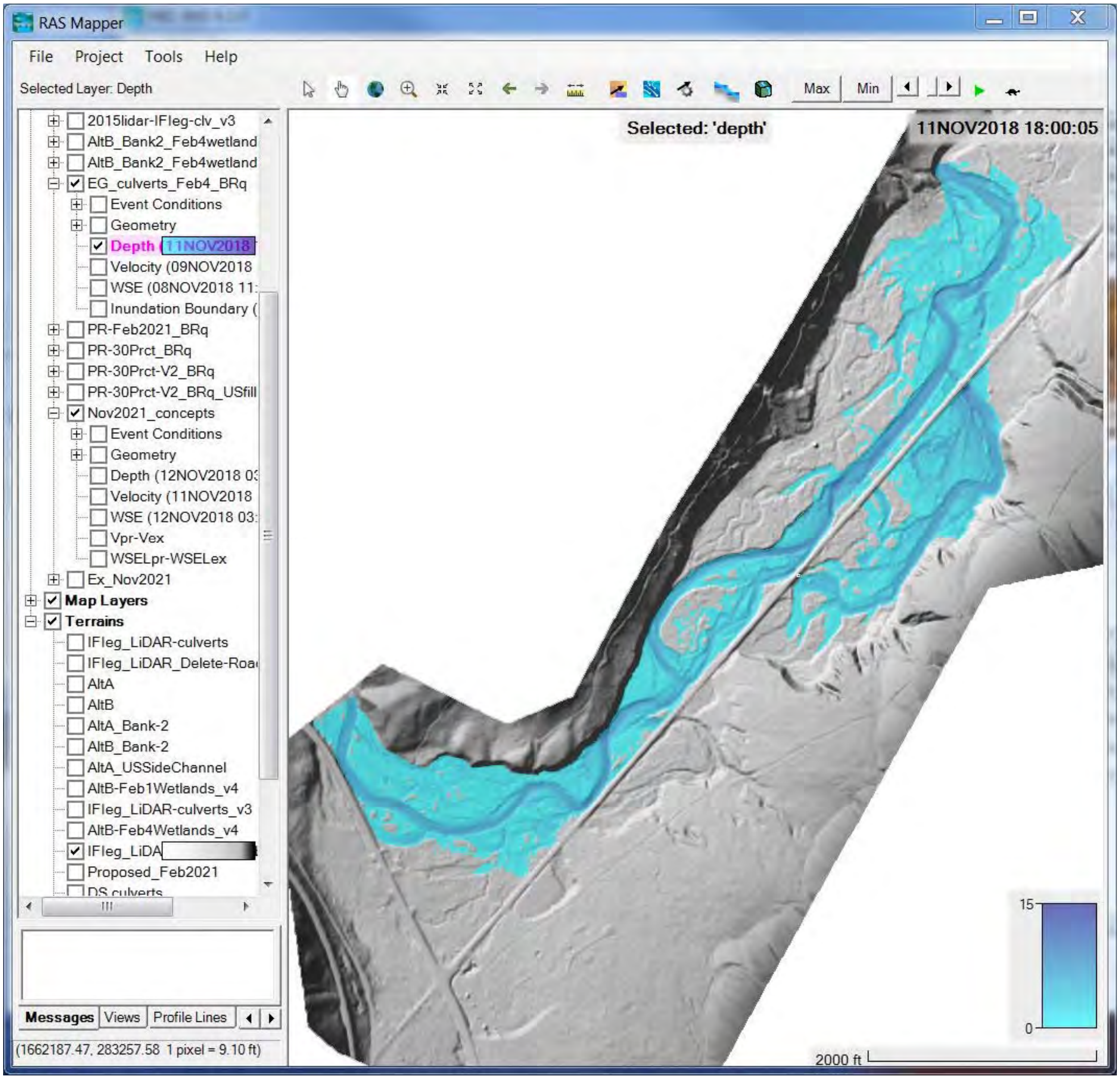
Existing condition: 1.5-year (2,200-cfs) flow depth, entire model domain



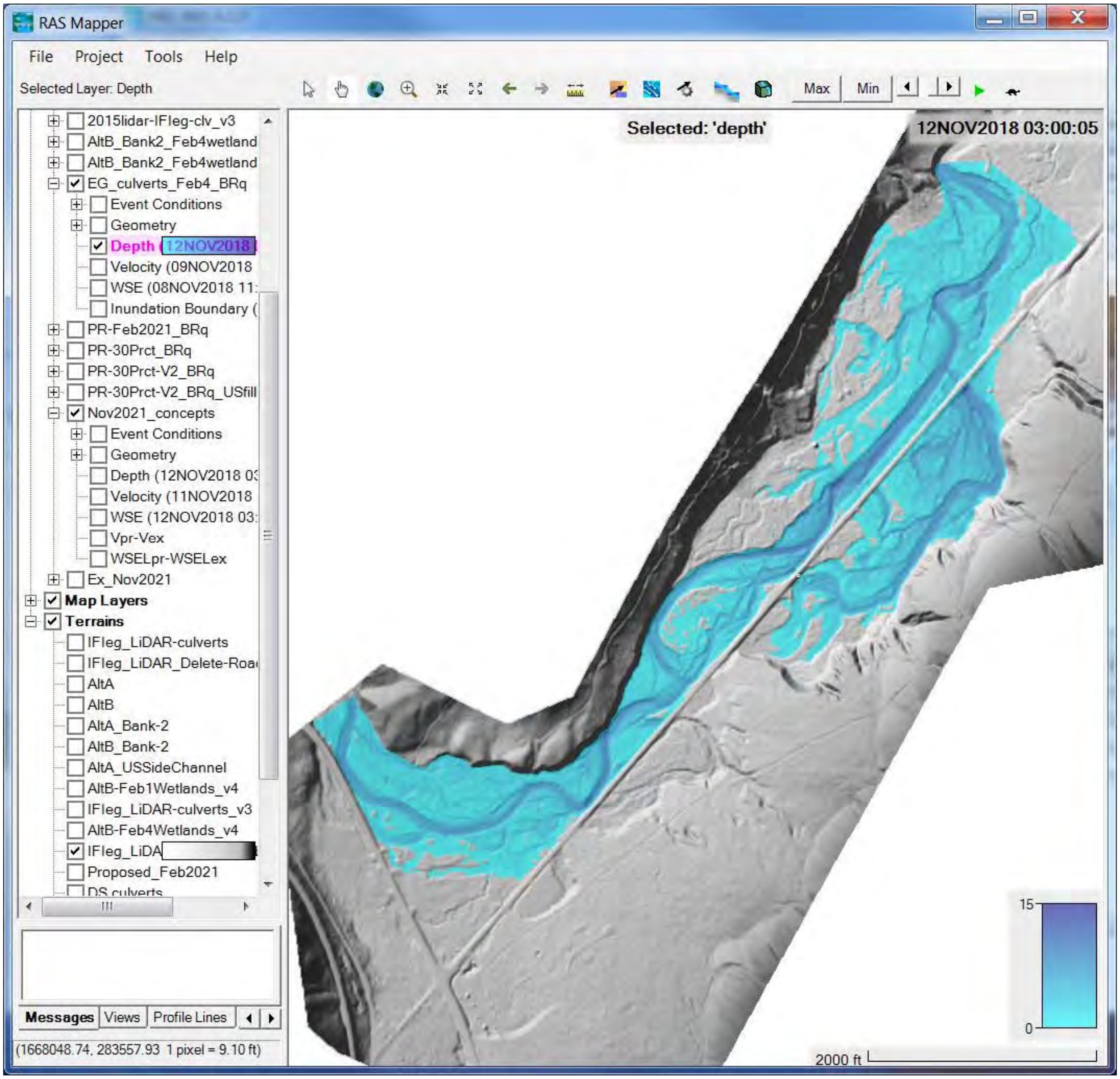
Existing condition: 5-year (3,900-cfs) flow depth, entire model domain



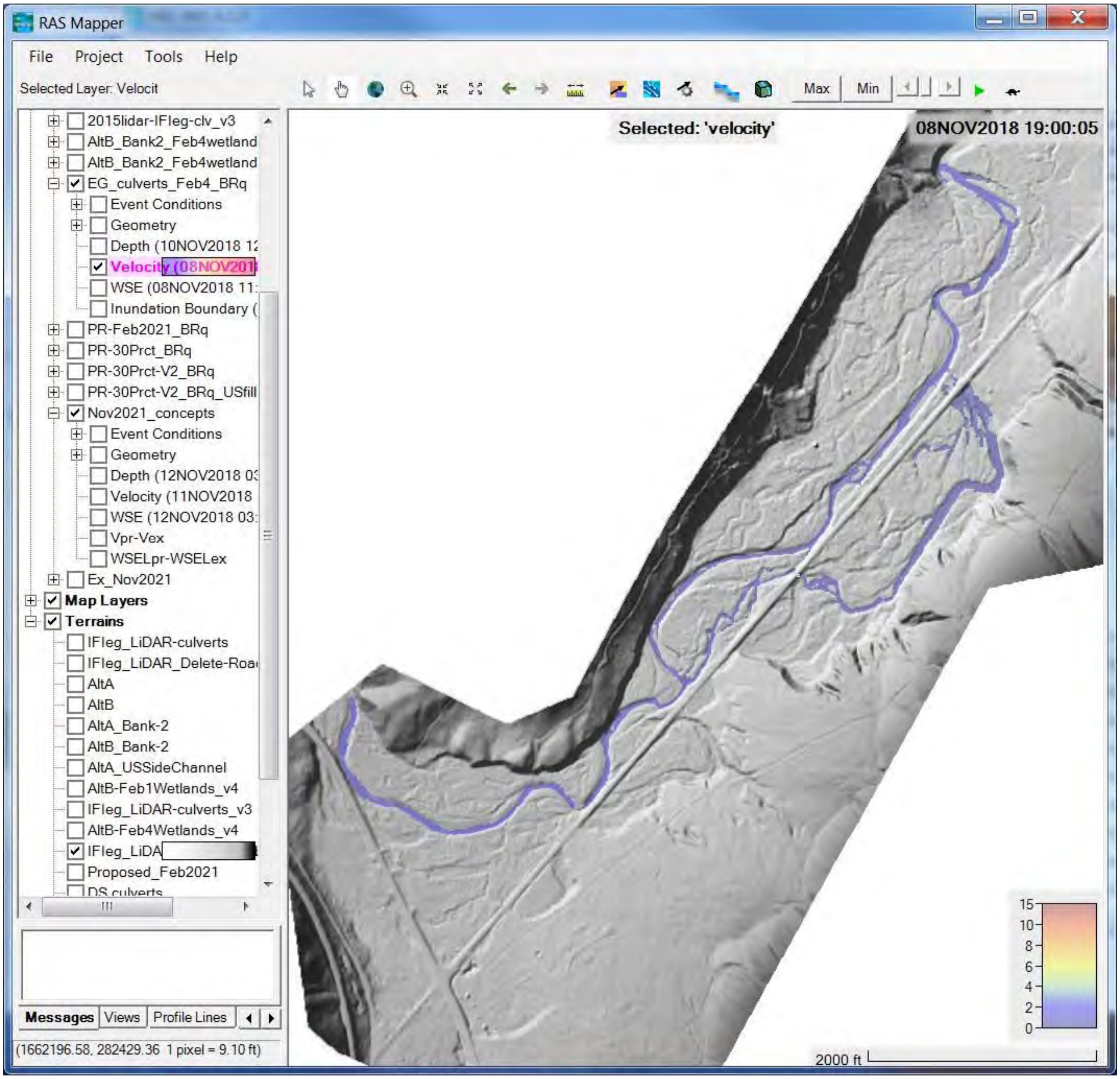
Existing condition: 25-year (6,500-cfs) flow depth, entire model domain



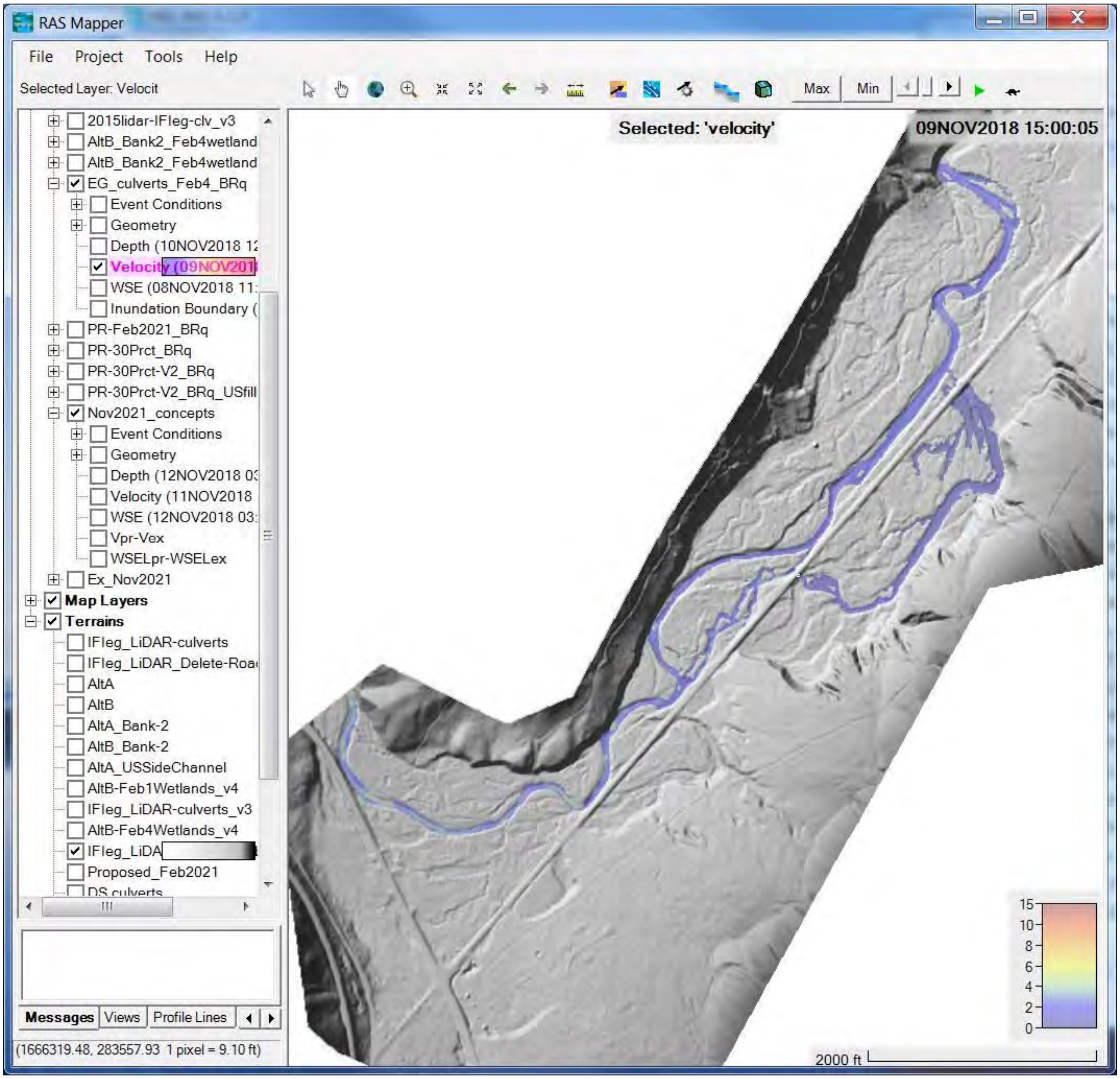
Existing condition: 100-year (9,400-cfs) flow depth, entire model domain



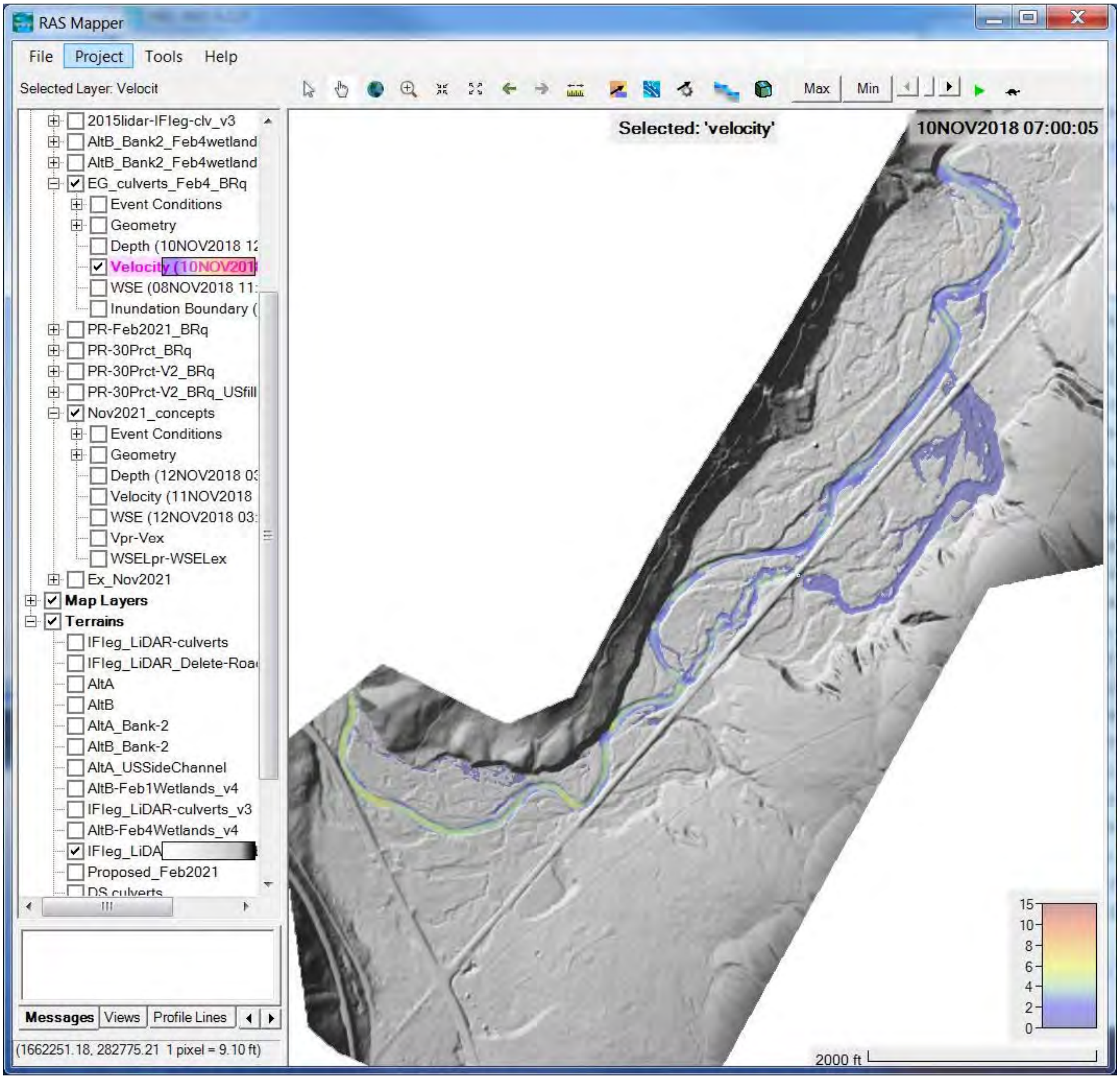
Existing condition: 50-cfs flow velocity through project area



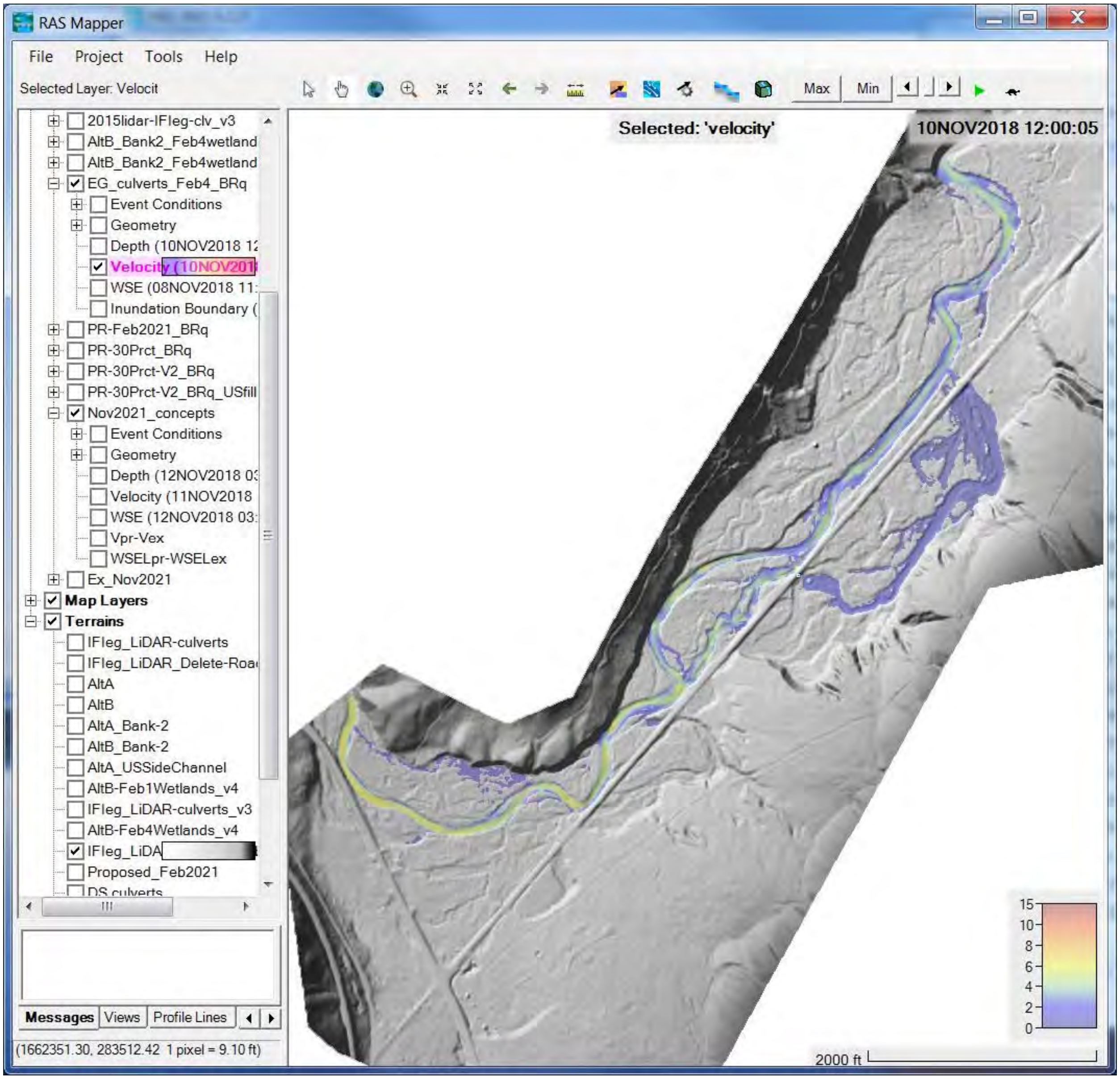
Existing condition: 200-cfs flow velocity through project area



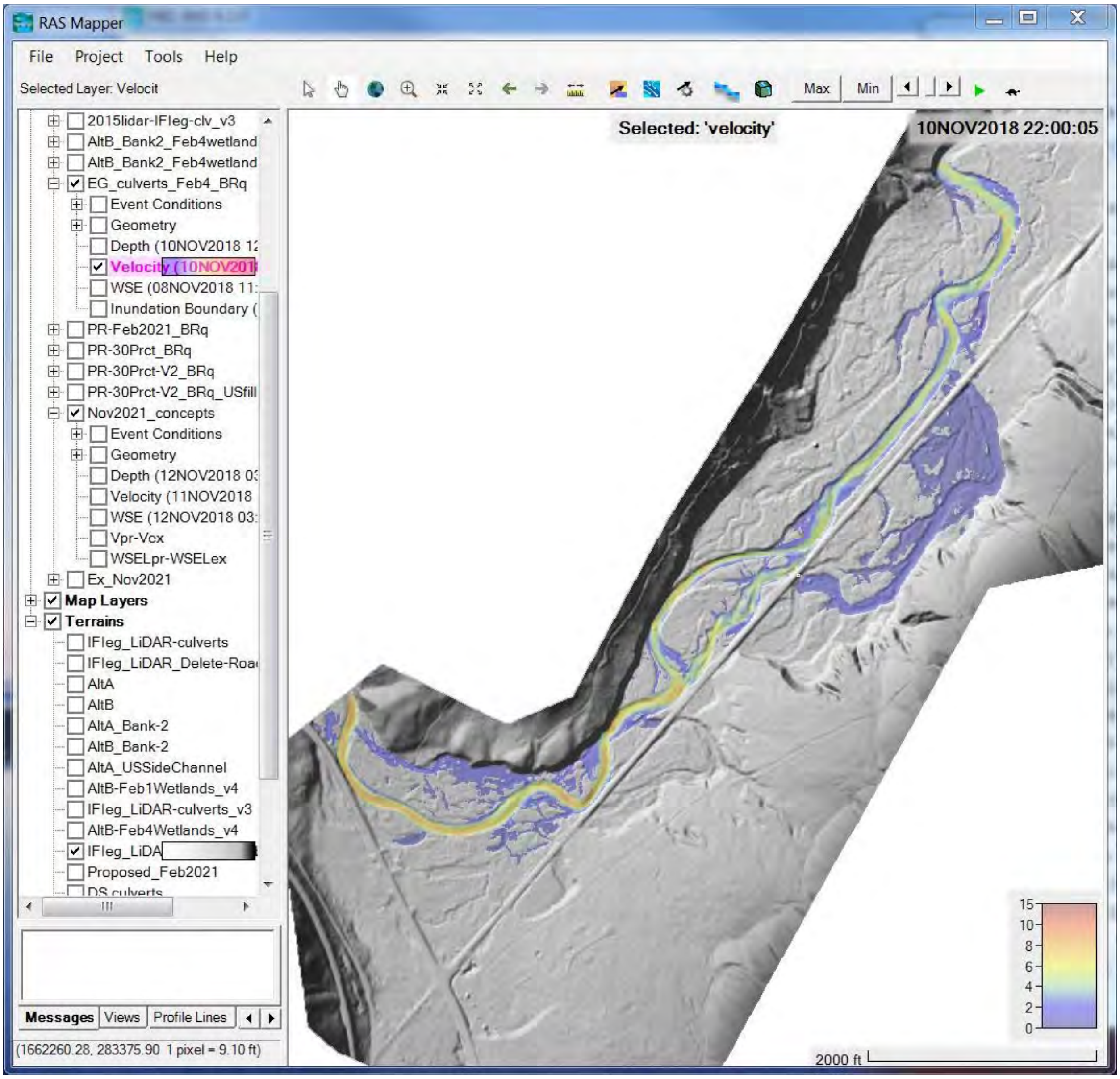
Existing condition: 600-cfs flow velocity through project area



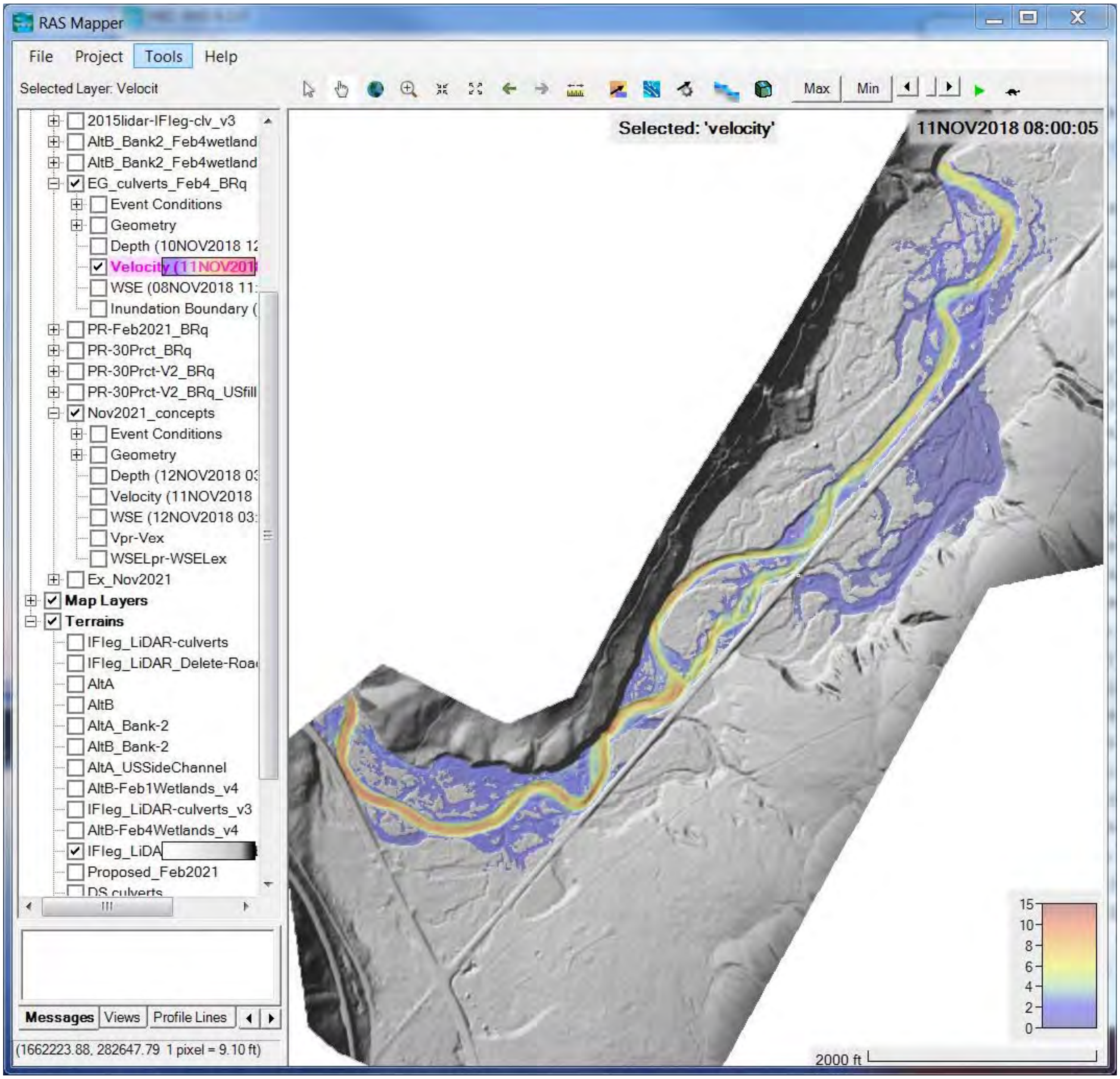
Existing condition: 1,000-cfs flow velocity through project area



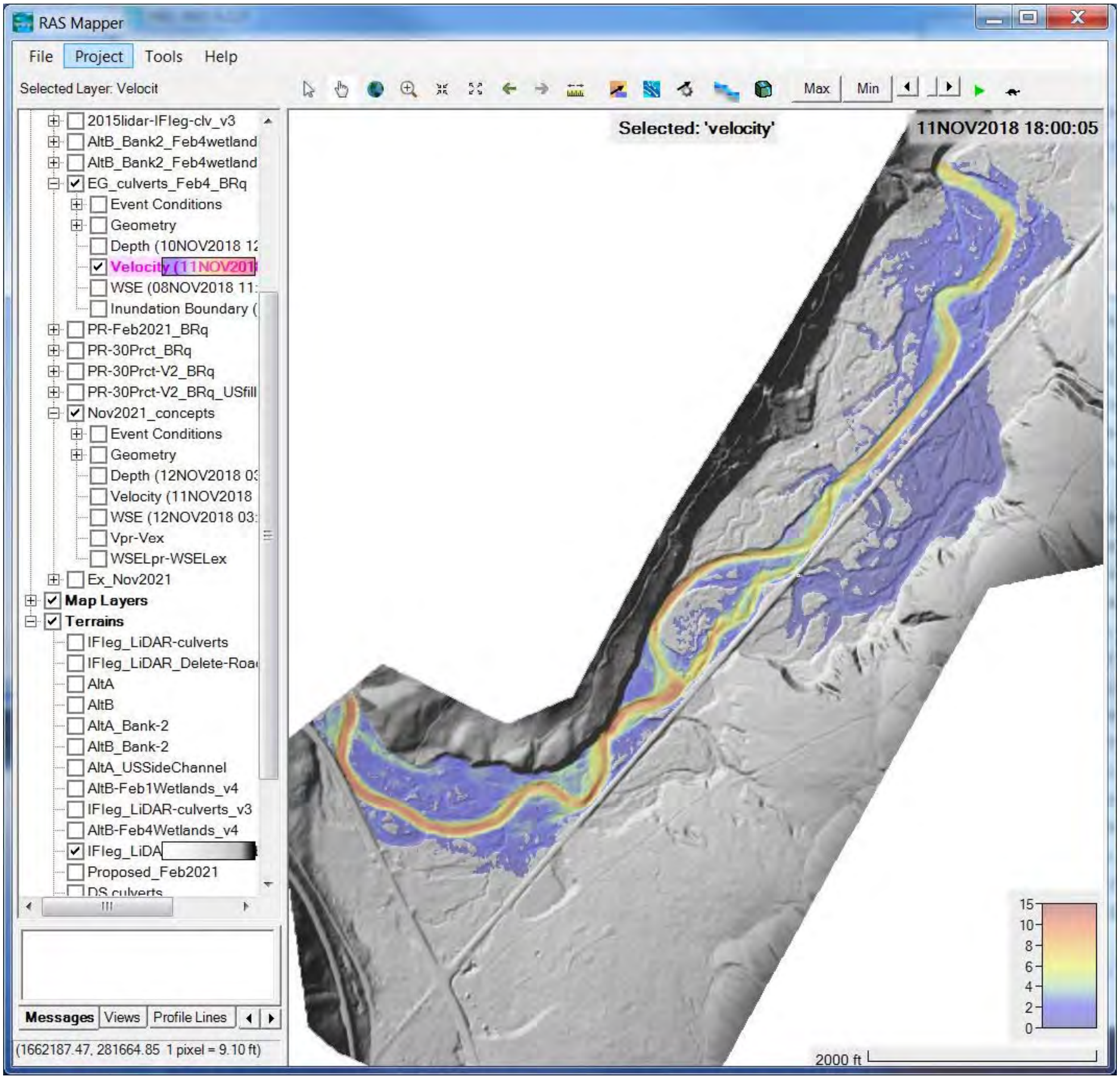
Existing condition: 1.5-year (2,200-cfs) flow velocity through project area



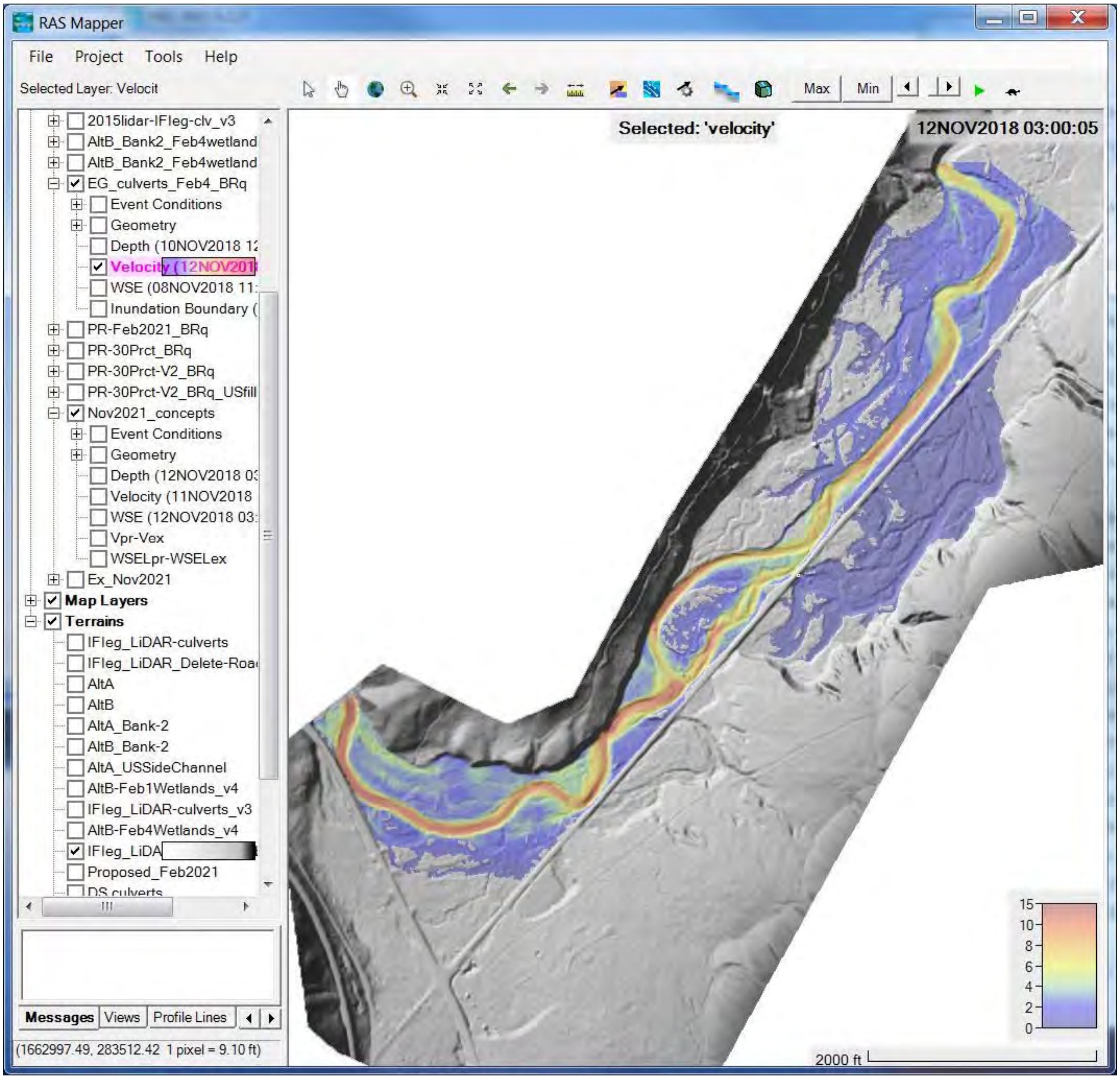
Existing condition: 5-year (3,900-cfs) flow velocity through project area



Existing condition: 25-year (6,500-cfs) flow velocity through project area

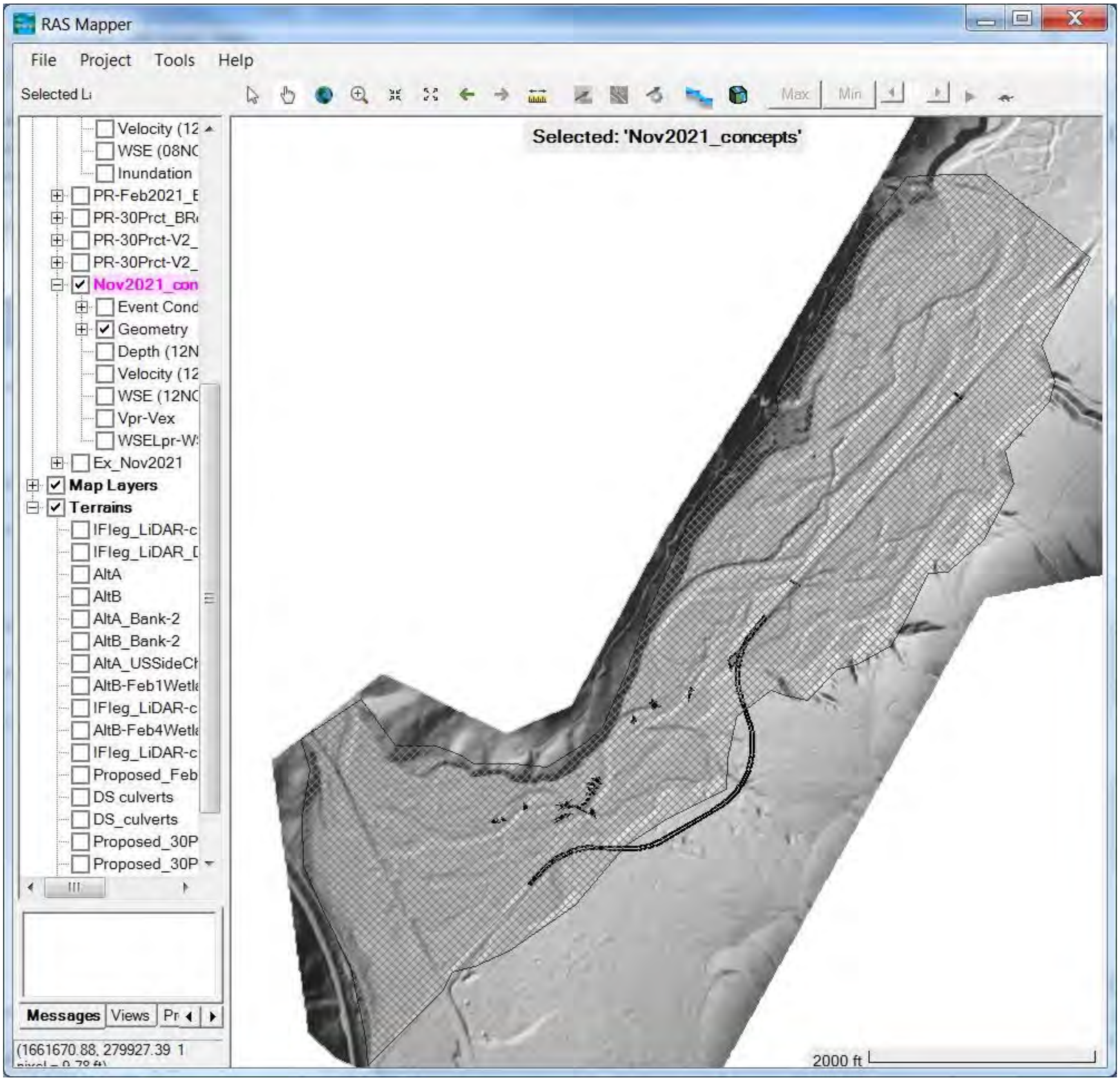


Existing condition: 100-year (9,400-cfs) flow velocity through project area

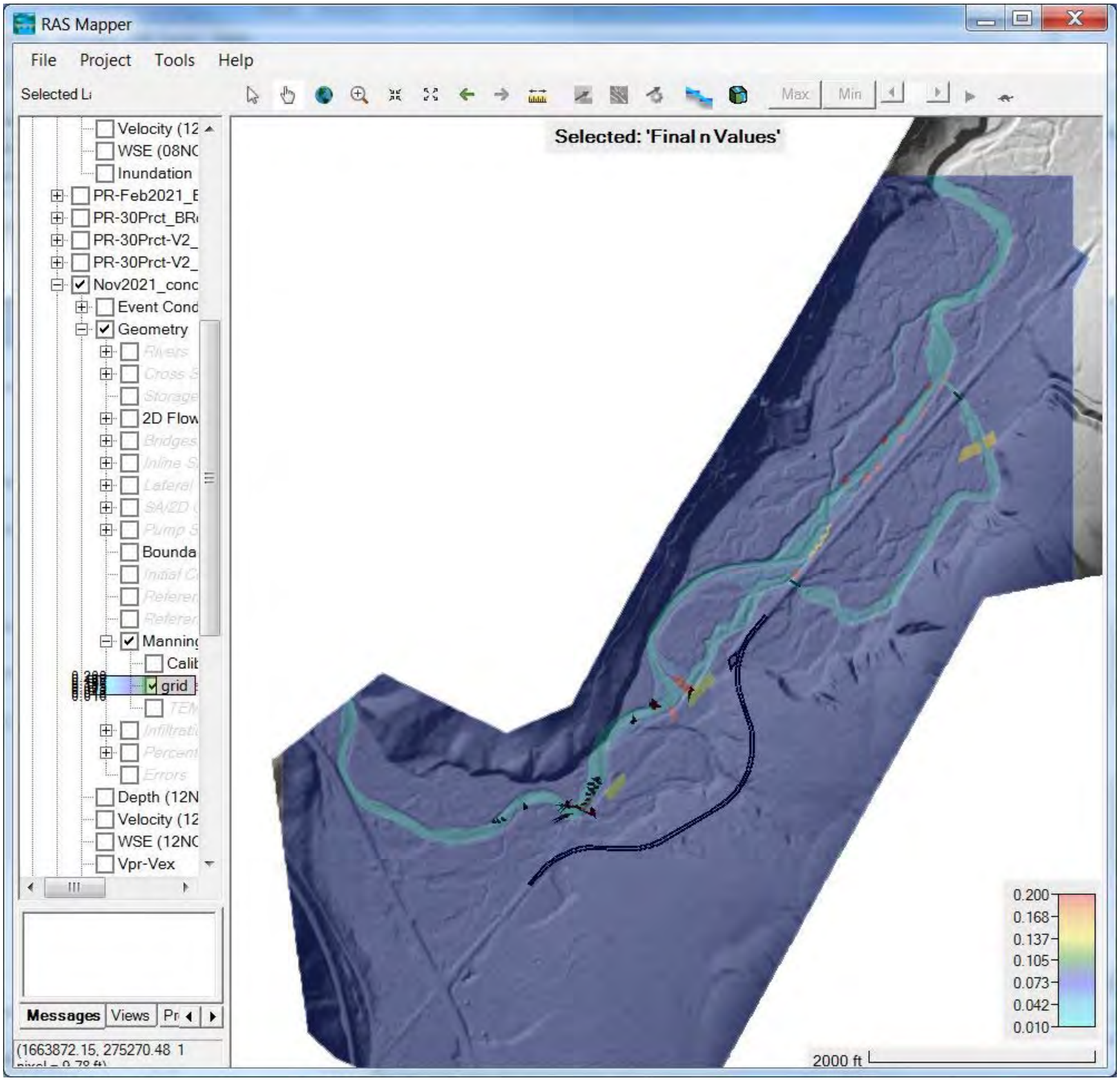


Appendix D – Proposed conceptual conditions HEC-RAS model

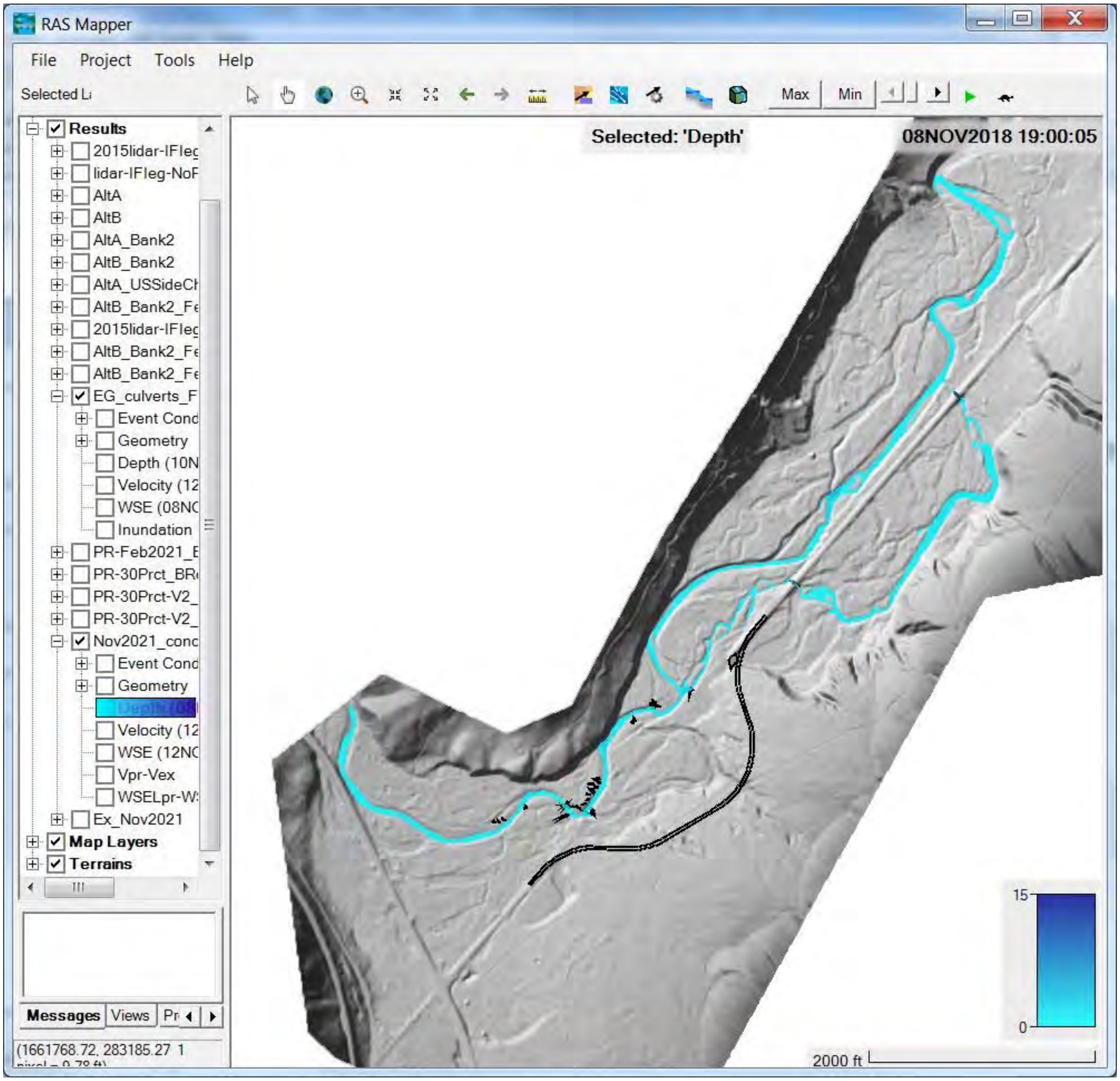
Proposed condition model mesh



Proposed condition Manning's n



Proposed condition: 50-cfs flow depth through project area



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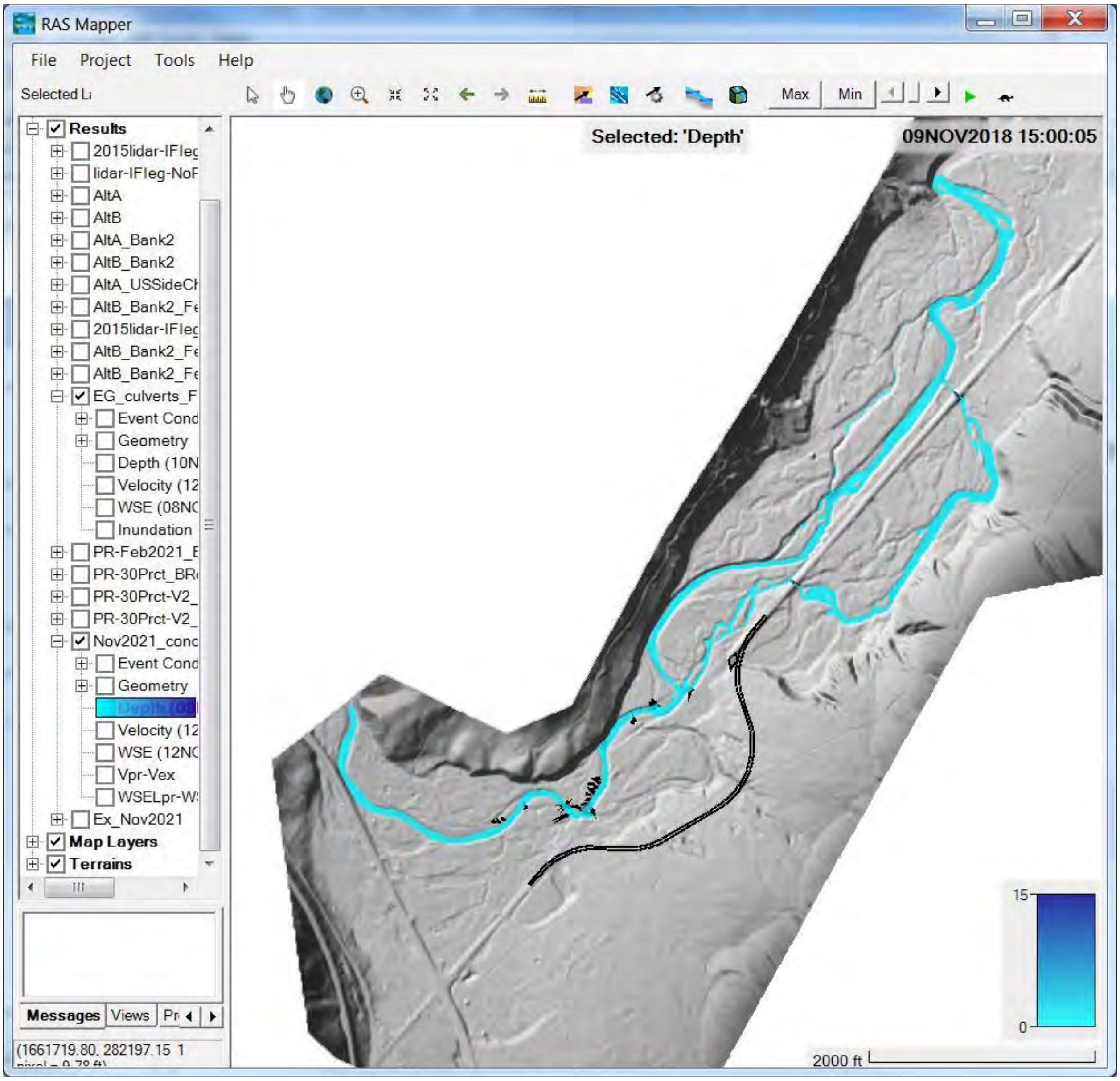
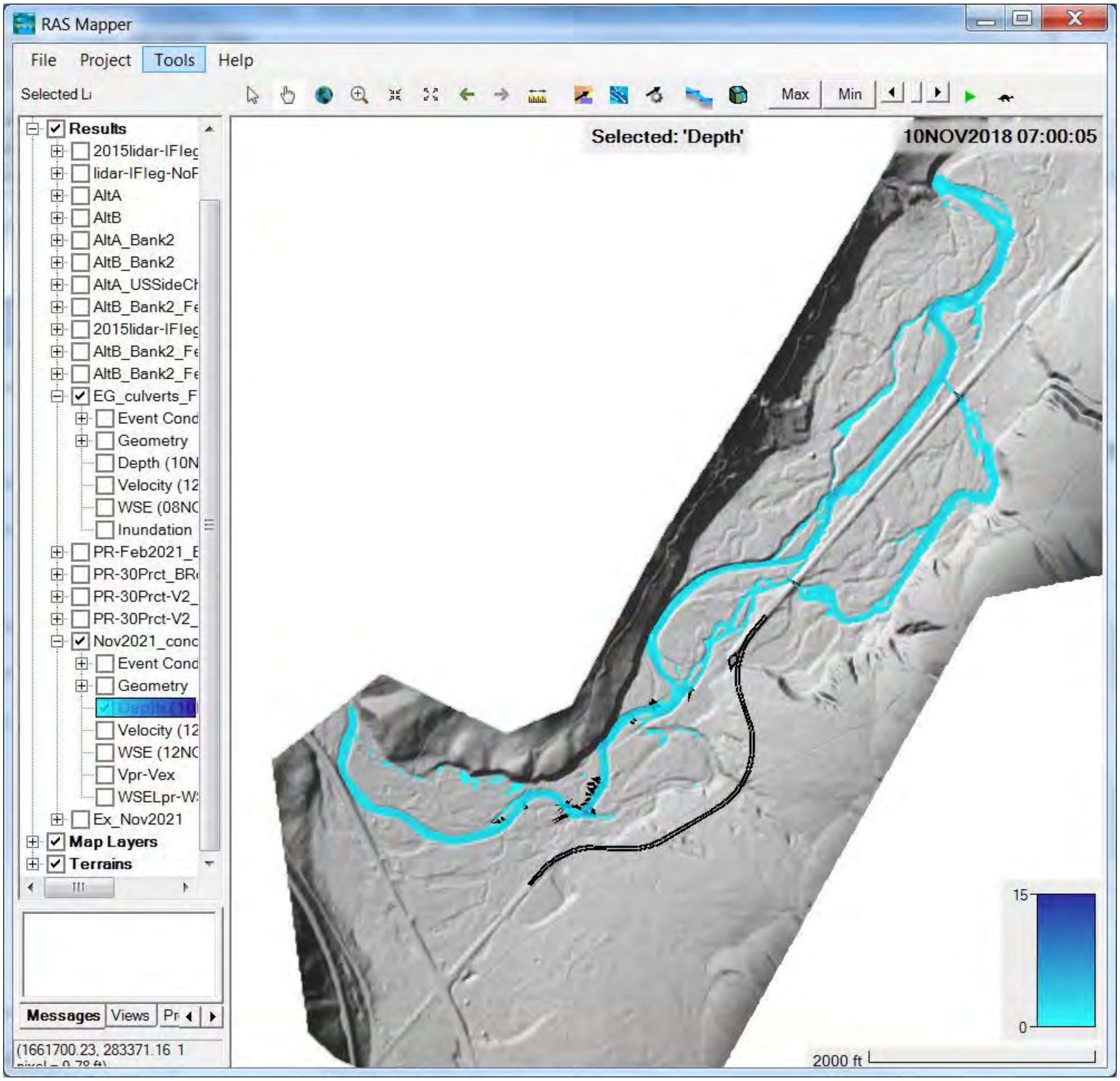


Proposed condition: 600-cfs flow depth through project area



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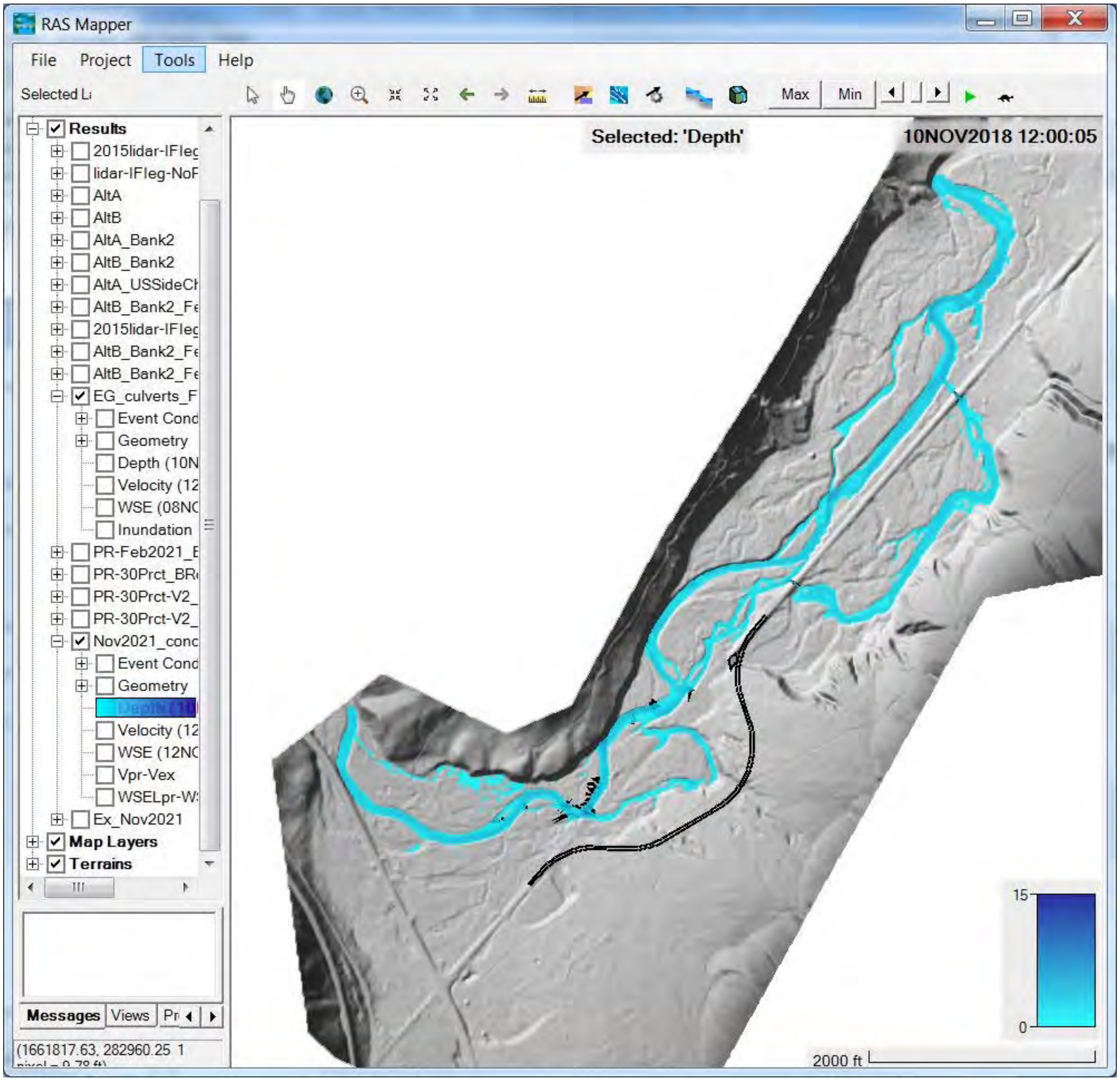
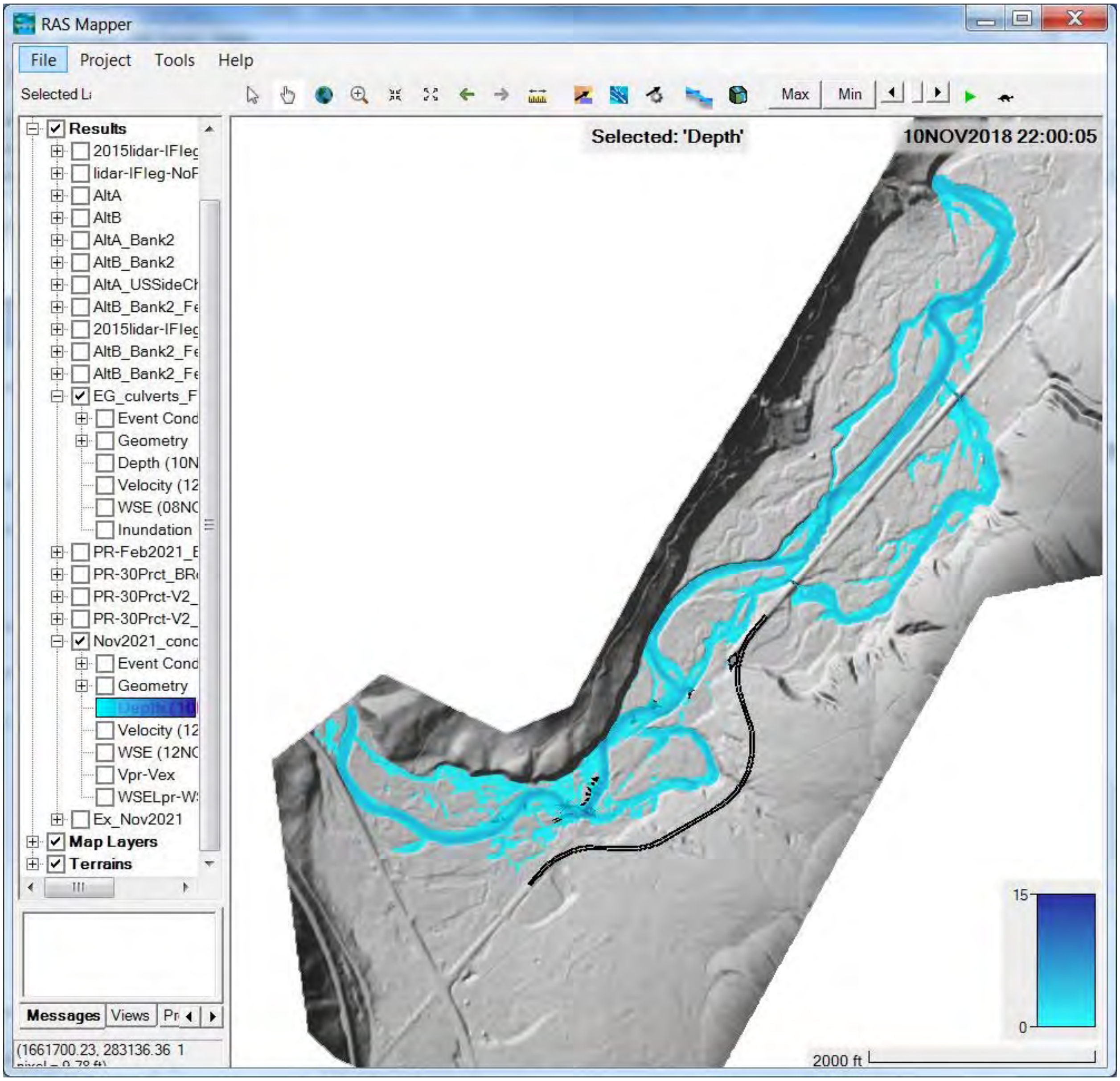
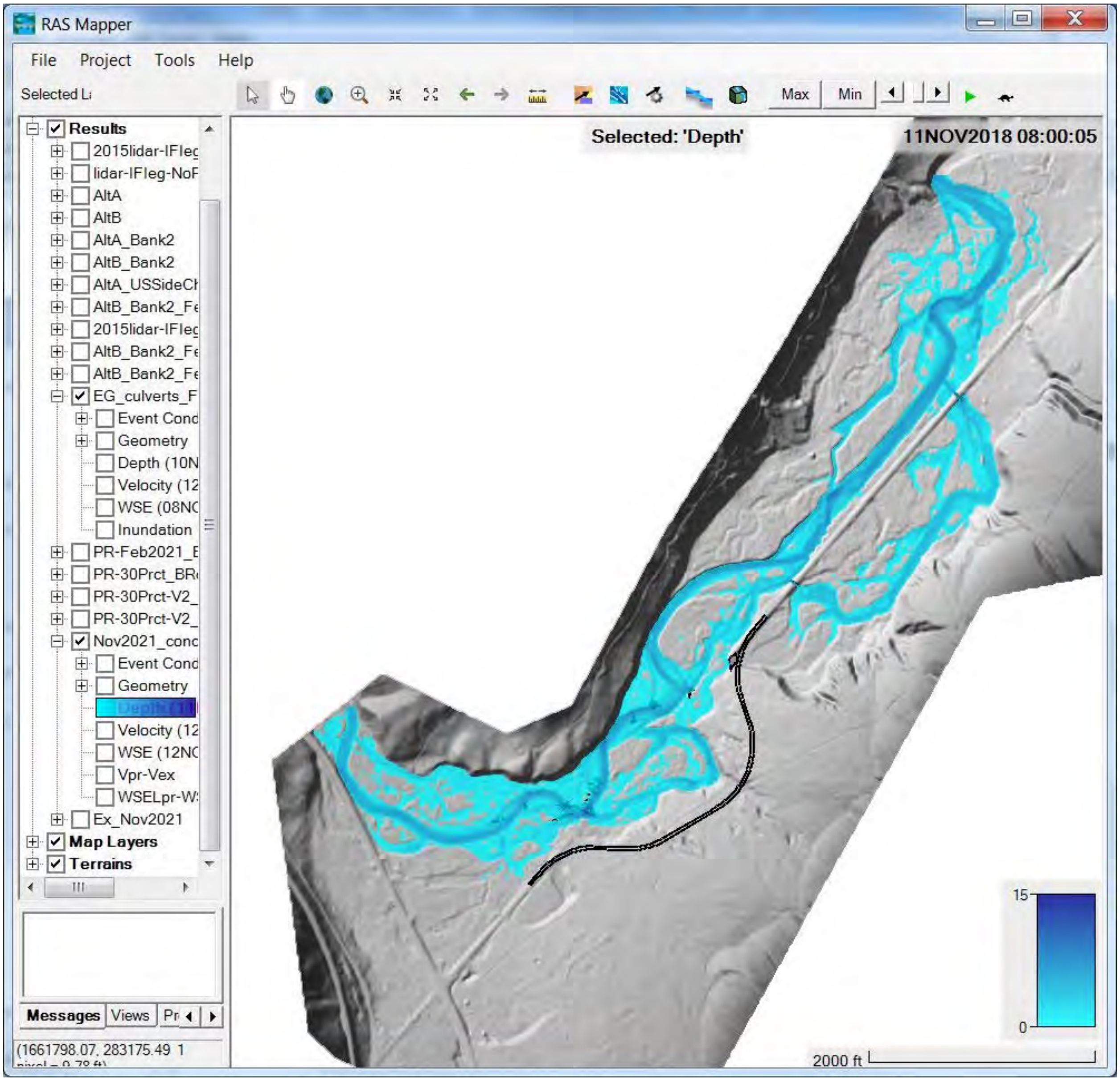


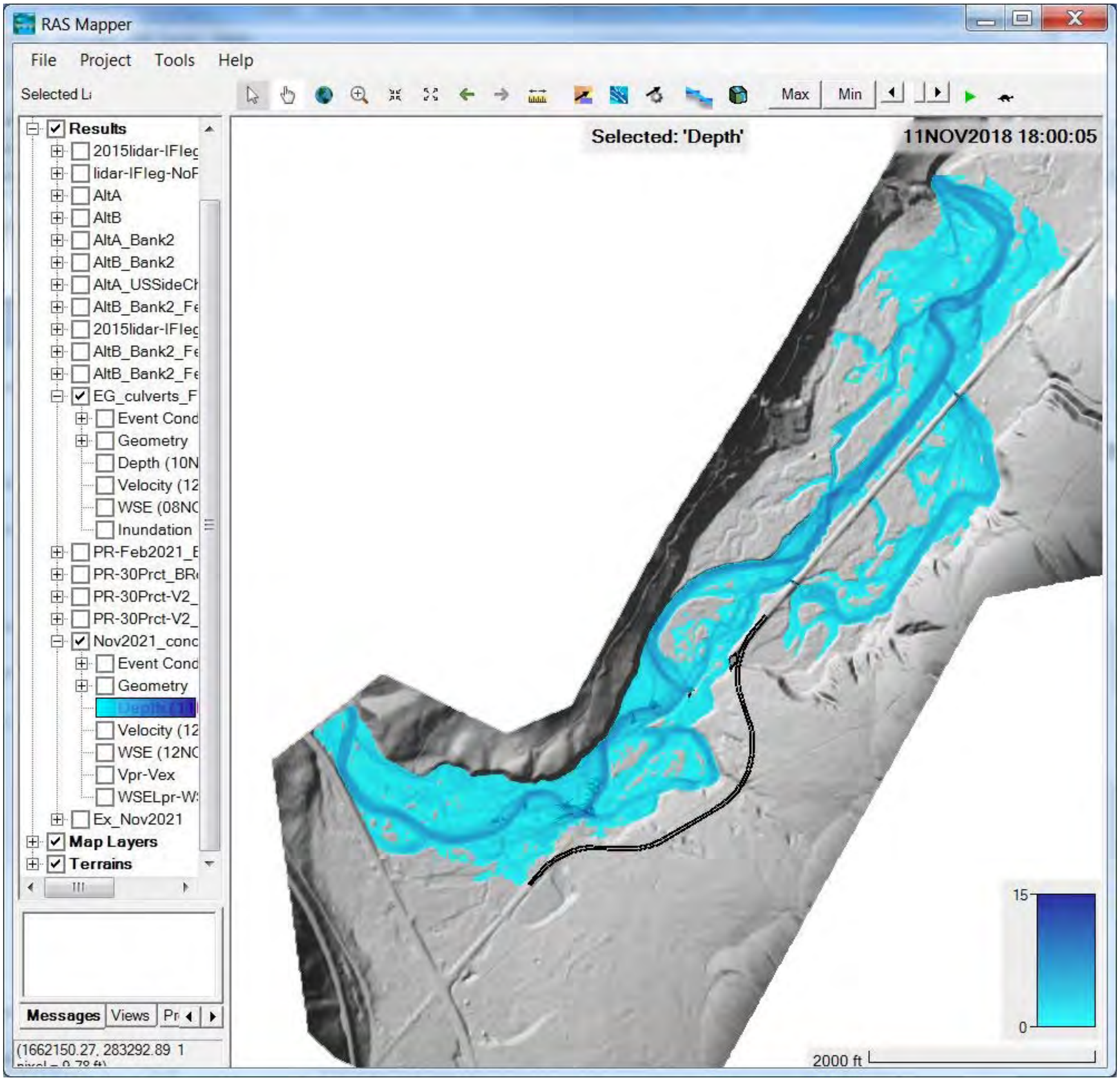
Proposed condition: 1.5-year (2,200-cfs) flow depth, entire model domain



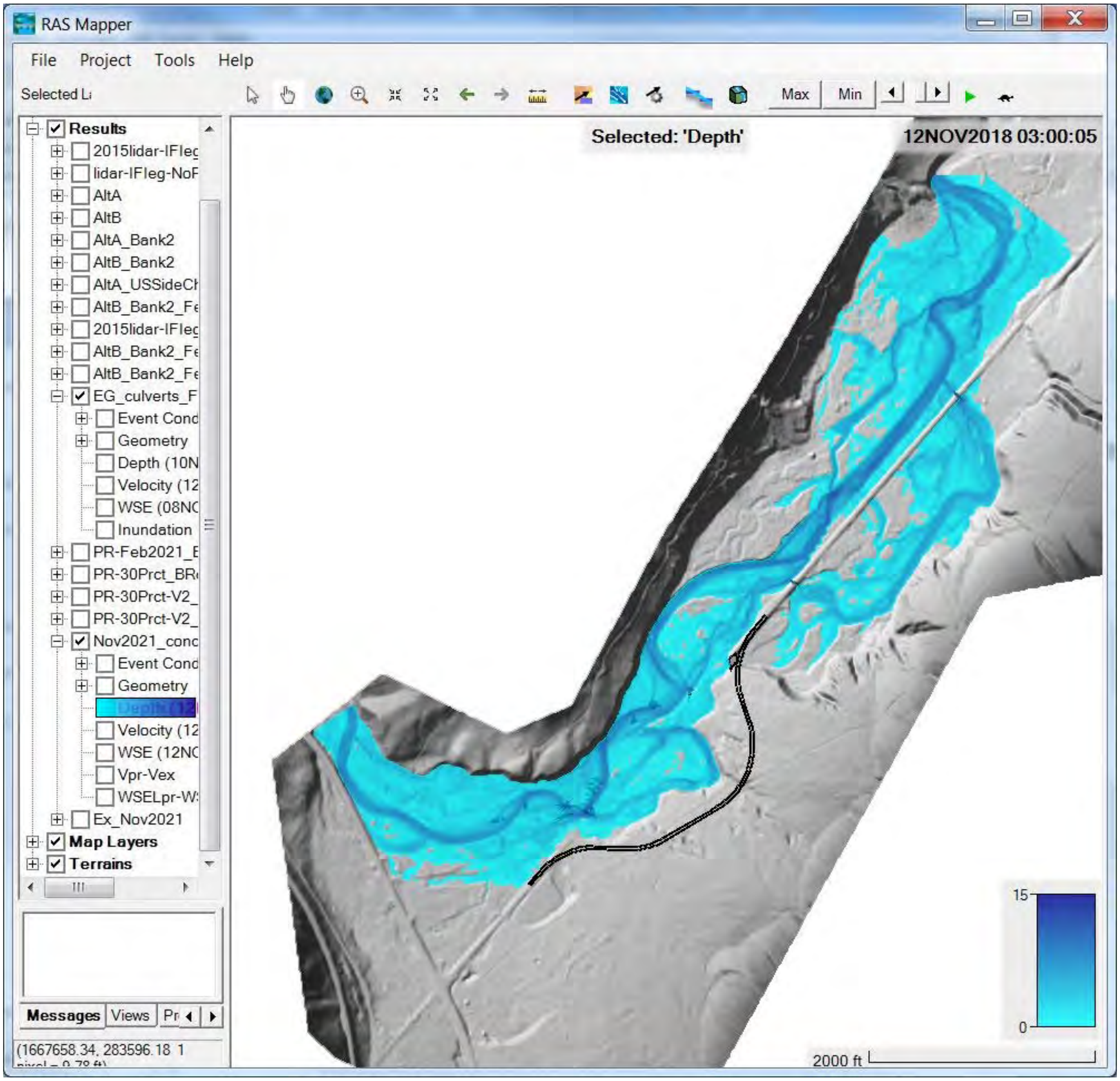
Proposed condition: 5-year (3,900-cfs) flow depth, entire model domain



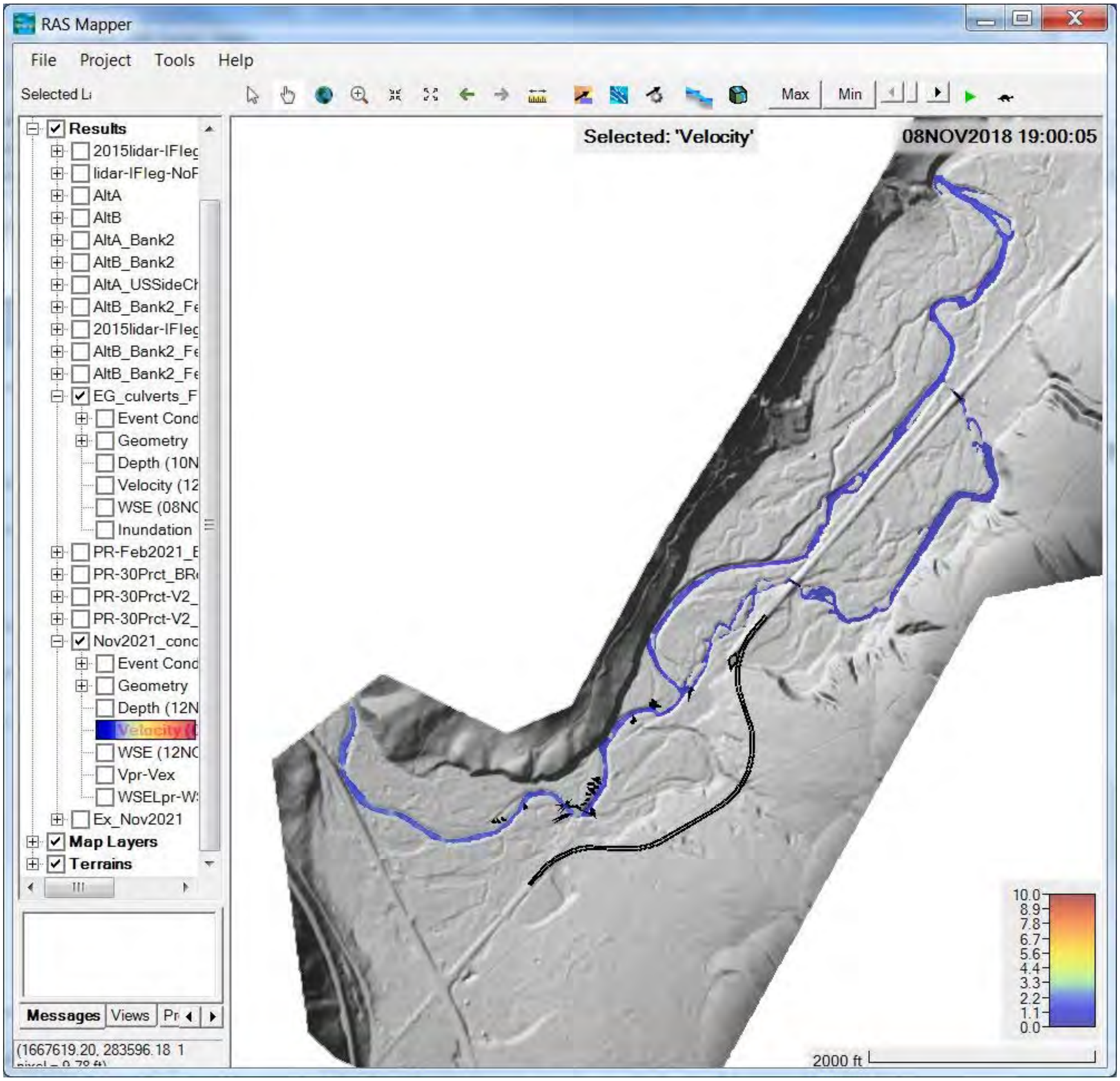
Proposed condition: 25-year (6,500-cfs) flow depth, entire model domain



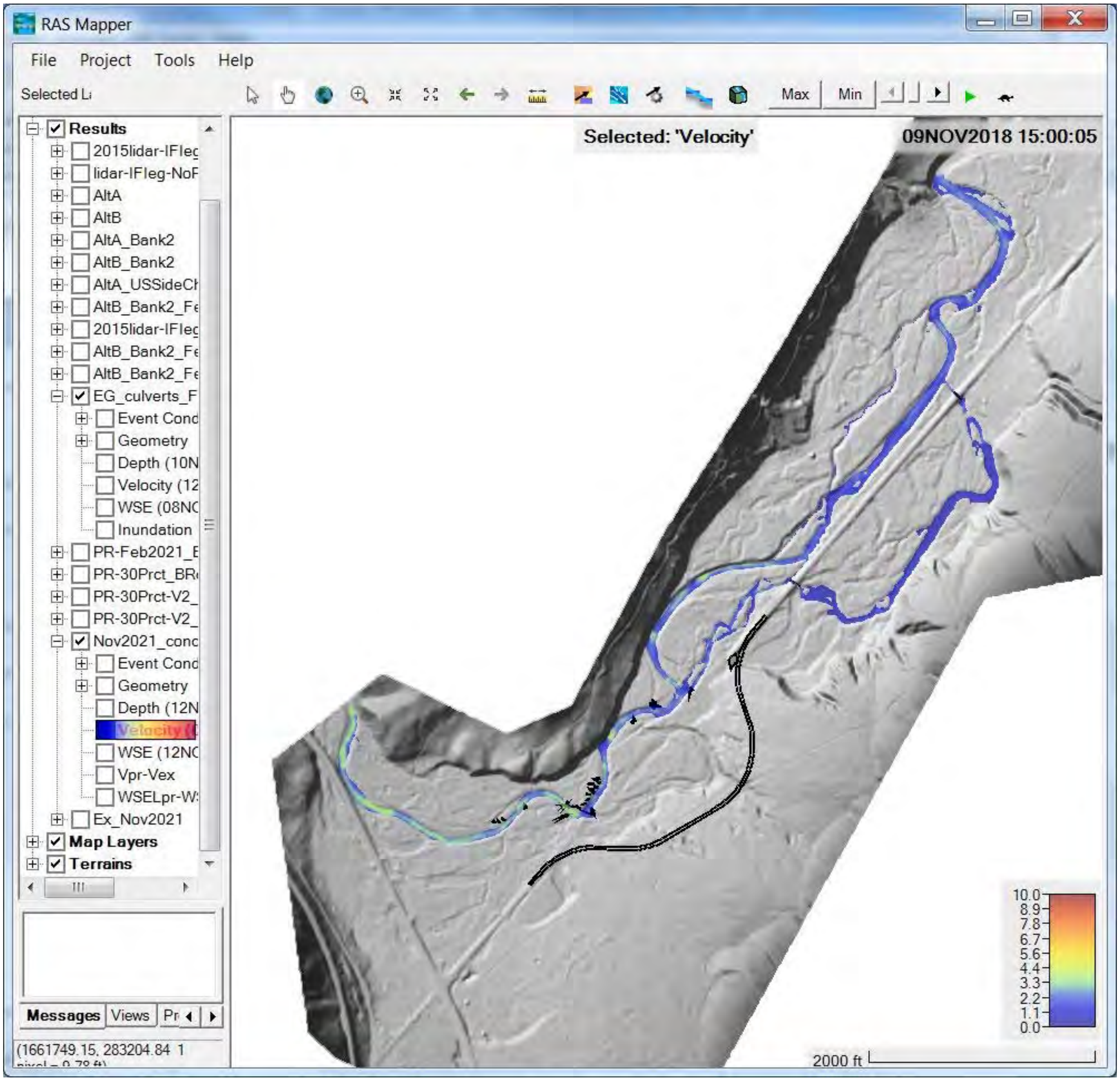
Proposed condition: 100-year (9,400-cfs) flow depth, entire model domain



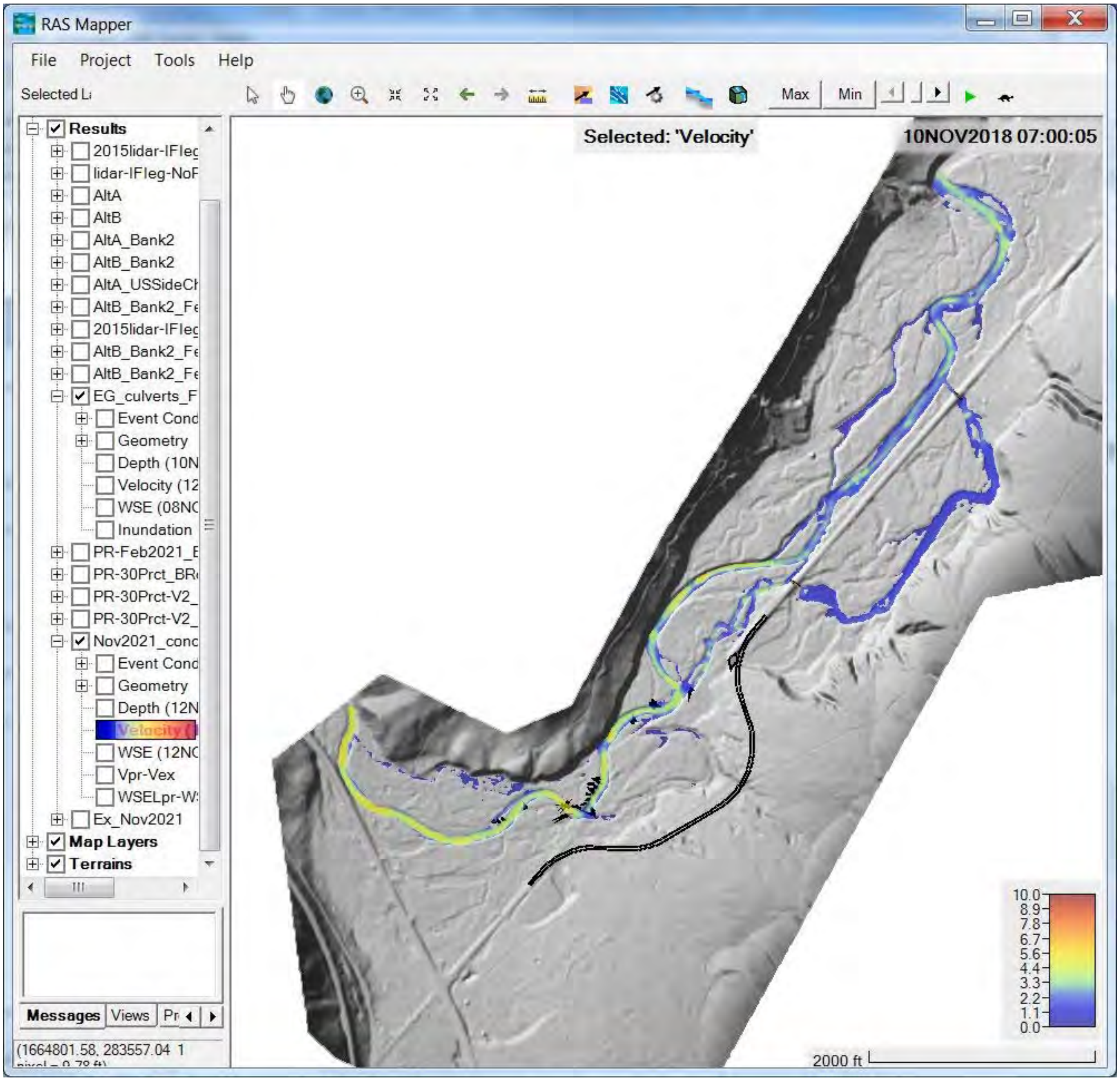
Proposed condition: 50-cfs flow velocity through project area



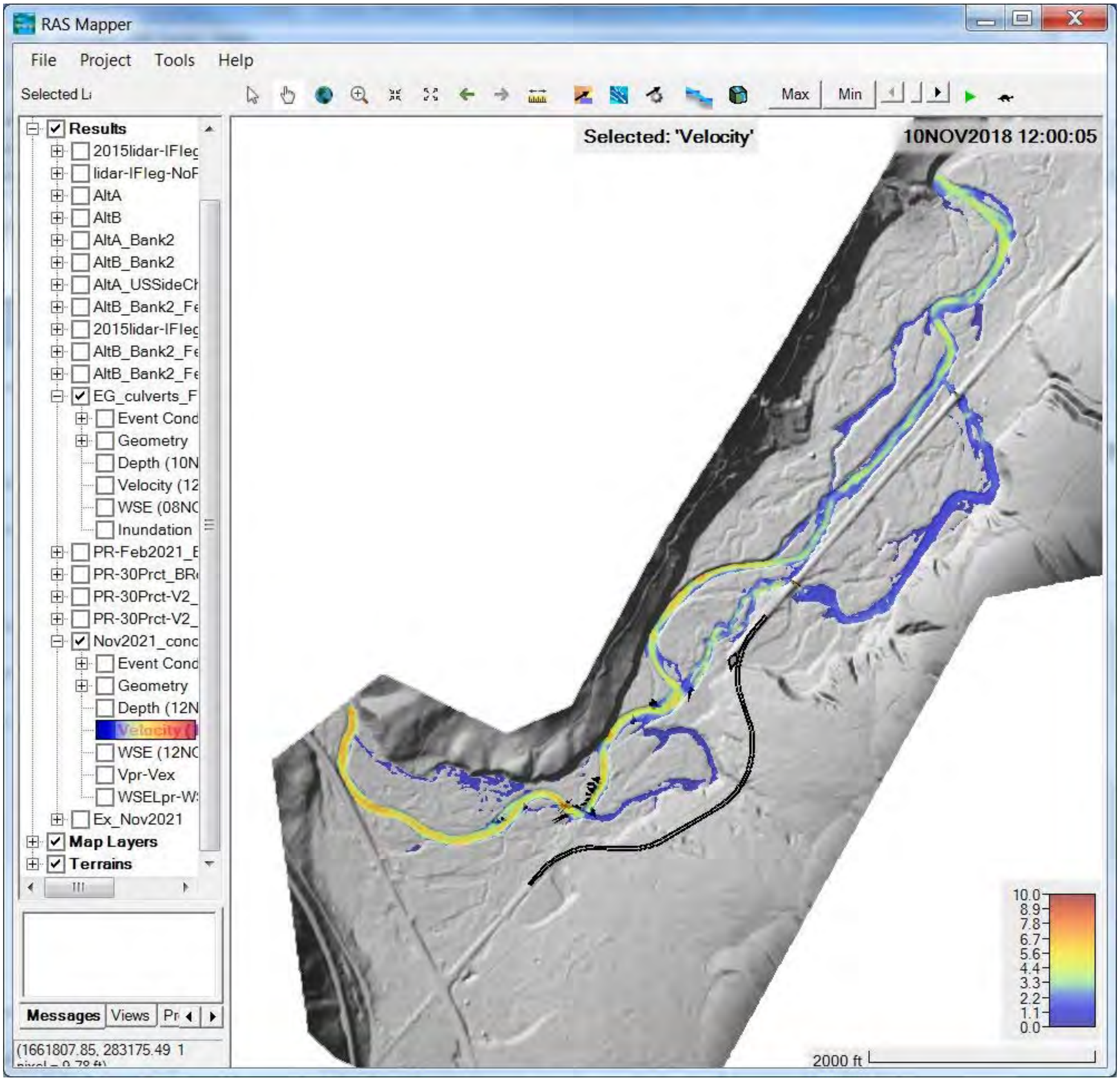
Proposed condition: 200-cfs flow velocity through project area



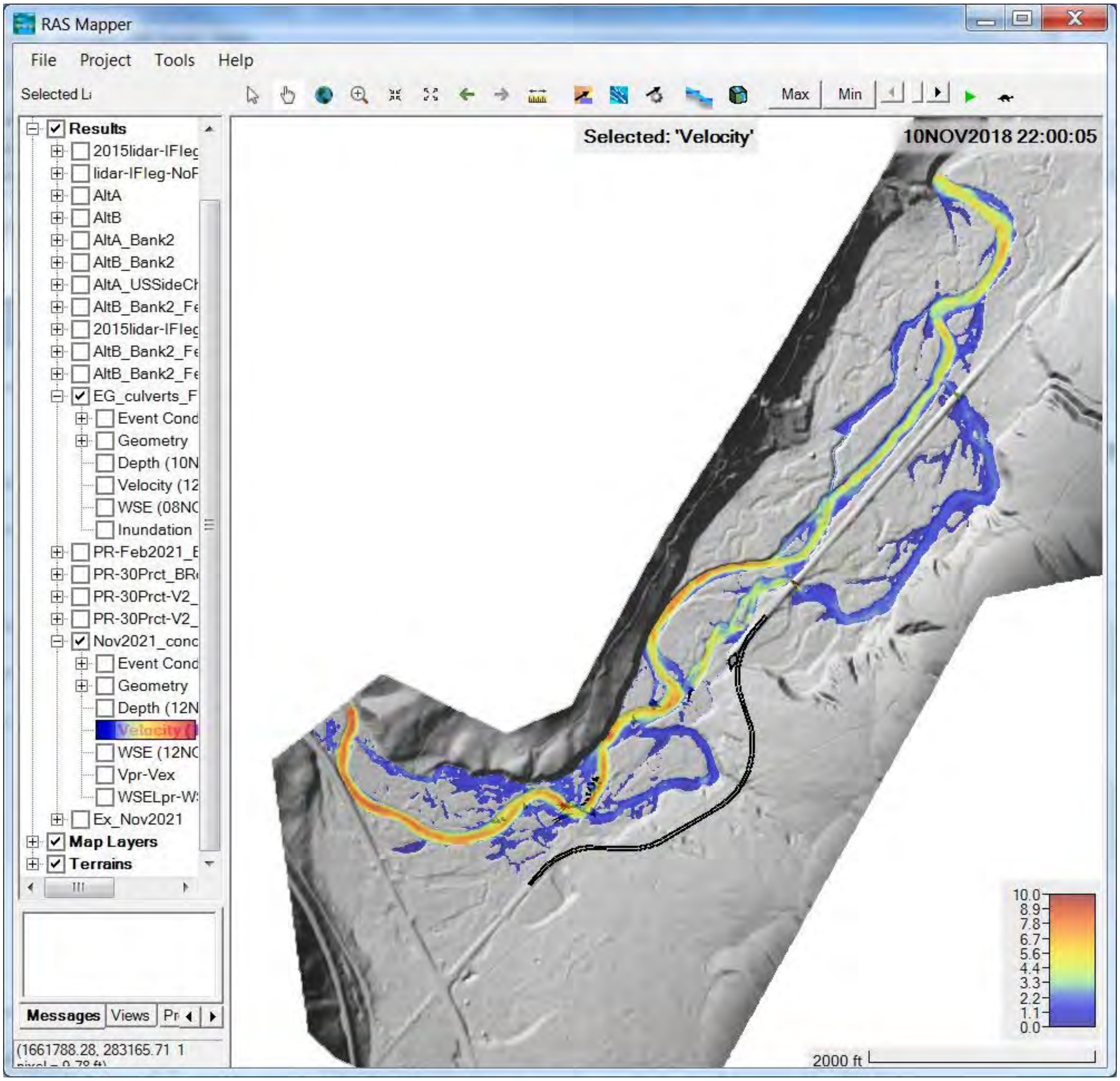
Proposed condition: 600-cfs flow velocity through project area



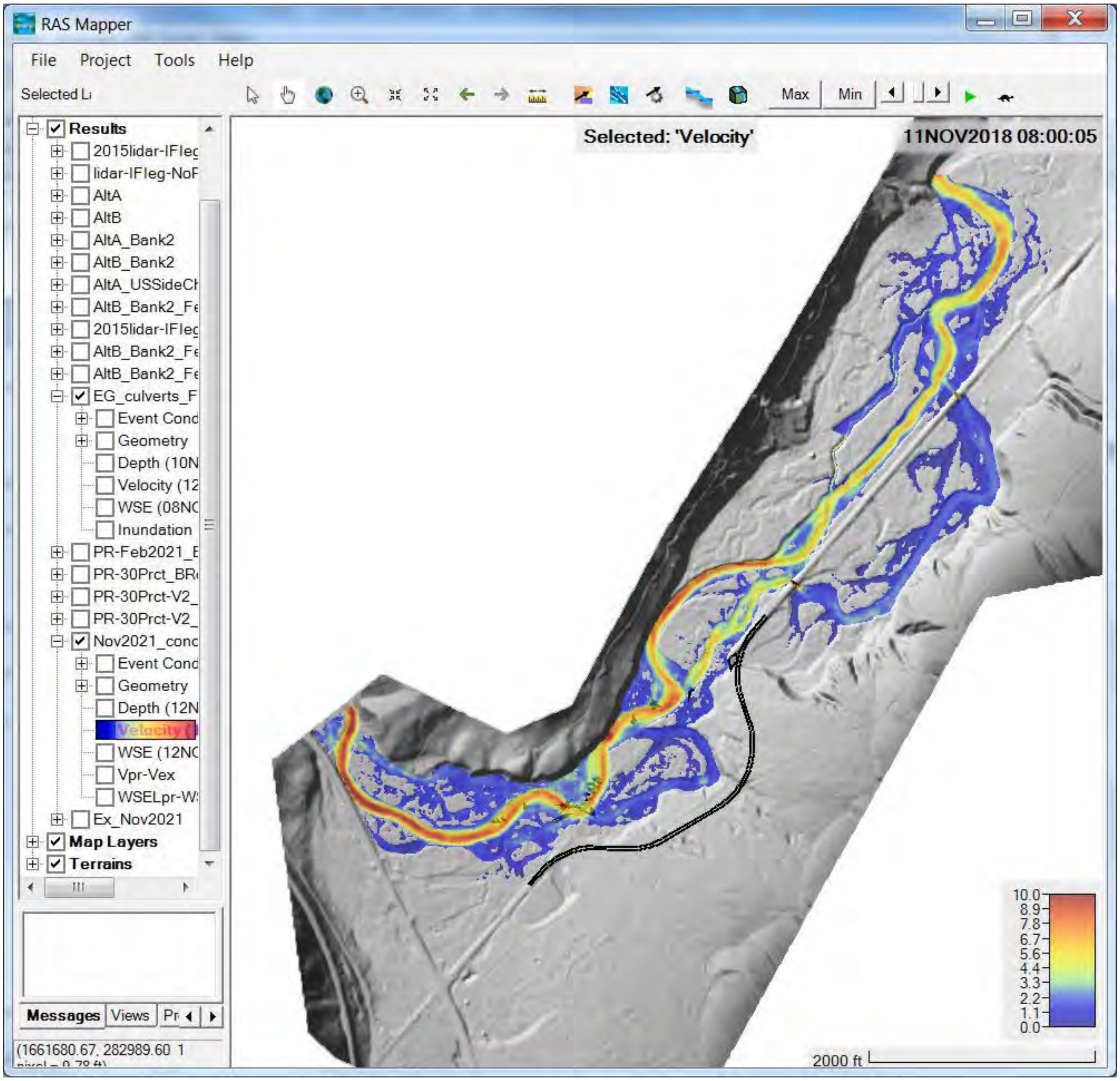
Proposed condition: 1,000-cfs flow velocity through project area



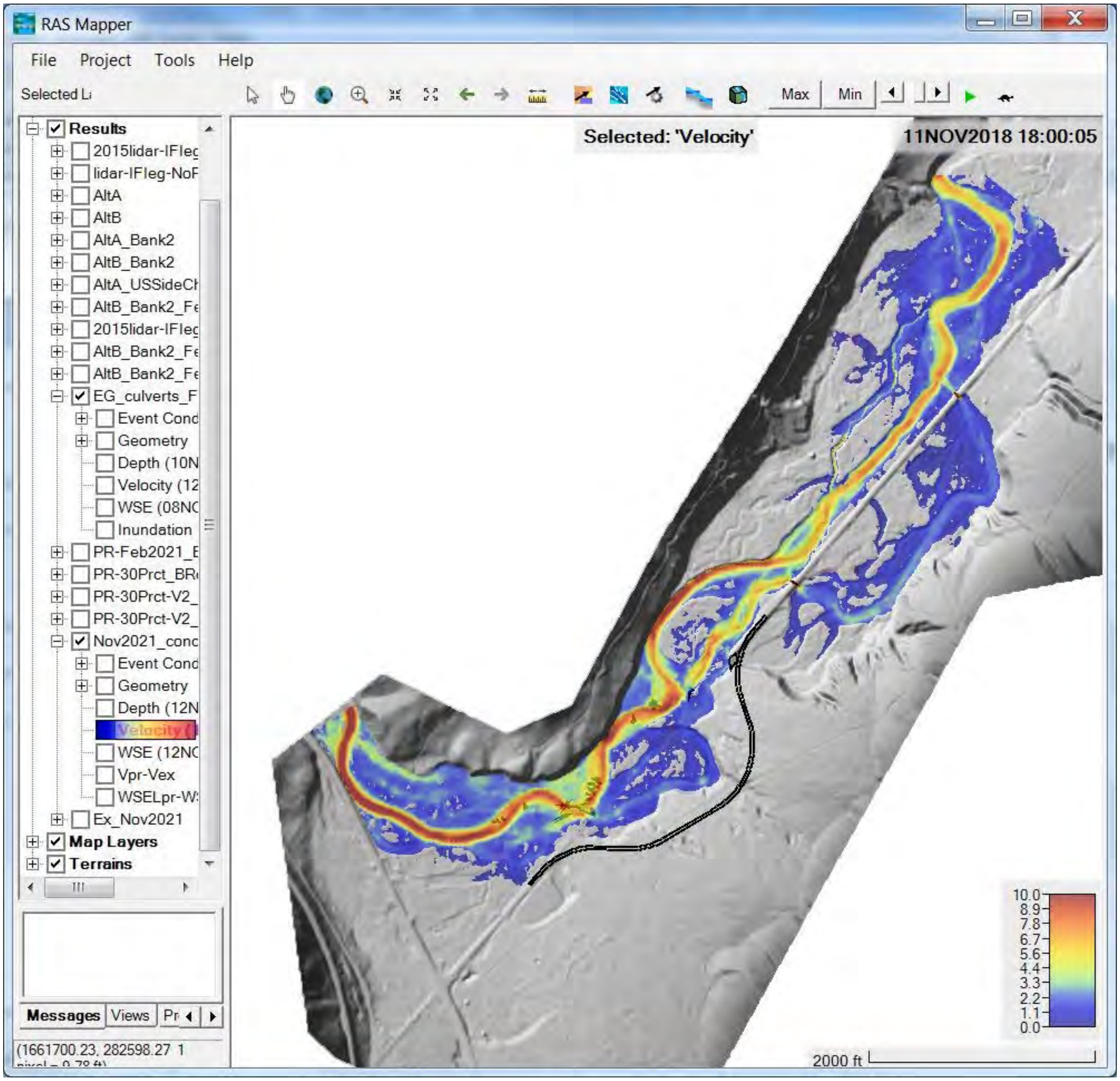
Proposed condition: 1.5-year (2,200-cfs) flow velocity through project area



Proposed condition: 5-year (3,900-cfs) flow velocity through project area



Proposed condition: 25-year (6,500-cfs) flow velocity through project area



Proposed condition: 100-year (9,400-cfs) flow velocity through project area