LOWER ISSAQUAH CREEK RESTORATION AT LAKE SAMMAMISH STATE PARK

PRELIMINARY DESIGN REPORT

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18 September 2020

NHC Ref. No. 002003907

THE WATERSHED COMPANY

NATURAL WATERS

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ACKNOWLEDGMENTS

The Mountains to Sound Greenway Trust, Northwest Hydraulic Consultants and The Watershed Company would like to thank the following interest groups comprised of various organizations and individuals for their assistance and guidance in the funding and development of the Lower Issaquah Creek Restoration Conceptual and Preliminary Design. Throughout this report, the entities mentioned below are referred to as interest groups.

- Washington State Parks and Recreation Commission (Landowner and Partner)
- Washington State Recreation and Conservation Office
- Muckleshoot Indian Tribe & Muckleshoot Indian Tribe Fisheries Department Staff
- Snoqualmie Tribe & Environmental & Natural Resources Department Staff
- Tulalip Tribes & Environmental Division Staff
- Confederated Tribes and Bands of the Yakama Nation & Yakama Nation Fisheries Department Staff
- City of Issaquah
- Washington Department of Fish and Wildlife
- King County Flood Control District
- King County Kokanee Work Group
- King County Water and Land Resources Division
- Lake Washington/Cedar/Sammamish Watershed (WRIA 8) and WRIA 8 Technical Committee
- Friends of Lake Sammamish State Park
- The Boeing Company

Project Funded By

This project is funded in part by the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) and the King County Flood Control District Cooperative Watershed Management Grant Program, the Washington State Salmon Recovery Funding Board (SRFB) via WRIA 8 and the Washington State Recreation and Conservation Office, and contributions from The Boeing Company.

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1 INTRODUCTION

The Mountains to Sound Greenway Trust (The Greenway Trust) and collaborating Partner, the Washington State Parks and Recreation Commission (State Parks) are partnering to study in-stream habitat and natural process improvements along the lower 6,000 feet of Issaquah Creek that flows through Lake Sammamish State Park. With 1.3 million annual visitors to the State Park, this project will be highly visible with tremendous community outreach and education opportunity. When completed, along with other efforts underway by State Parks and the City of Issaquah, it will finish nearly all restoration that is proposed in the lower reach of Issaquah Creek in the 2005 Chinook Salmon Conservation Plan (WRIA 8, 2005) and the 2017 update to the Plan (WRIA 8, 2017). This project will complete the Issaquah Creek portions of project IC-RA-1-INS (WRIA 8, 2017), which calls for addressing the poor habitat conditions in this former farmland (incised channel, extensive non-native vegetation) and recommends projects that includes stream, riparian, floodplain, lakeshore, and wetland restoration.

Funding for this effort comes through a King County Flood Control District Cooperative Watershed Management grant via the Lake Washington/Cedar/Sammamish Watershed (WRIA 8), the Washington State Salmon Recovery Funding Board (SRFB) through WRIA 8, the Washington State Recreation and Conservation Office (RCO), and a grant from The Boeing Company. The Greenway Trust has contracted with Northwest Hydraulic Consultants (NHC) and The Watershed Company to evaluate alternatives and develop a preliminary design to enhance this stretch of the creek. A previous conceptual design report (NHC, 2018) documented the assessment of conceptual design alternatives and the preferred alternative, which was selected by the Greenway Trust and key interest groups.

As part of the Chinook Salmon Recovery Plan, this project primarily targets enhancing and creating salmonid habitat, to accommodate rearing, spawning, resting, migration, food production, protective cover (from predation), and high-flow refuge, all within the footprint of an immensely popular state park. The emphasis is on ESA-listed Chinook salmon habitat restoration, with anticipated improvements for other fish and wildlife habitat, including but not limited to coho, sockeye, and kokanee salmon, as well as cutthroat and steelhead trout. The main project objectives include enhancing the quality and quantity of key, strategically located salmonid habitat, particularly for juvenile Chinook rearing and adult Chinook holding. As noted in project IC-RA-1-INS (WRIA 8, 2017), the current channel is incised in many locations and thus disconnected from the surrounding floodplain. This condition adversely impacts habitat for Chinook and other aquatic organisms by confining moderate to high flows to a primary, single-thread channel with minimal floodplain activation and thus little high-flow refugia. In addition, and as noted in the 2017 update to the Chinook Salmon Recovery Plan, the wood volume in the lower extent of Issaquah Creek is low or very low. The proposed preliminary design will facilitate future improvements in the lower stretch of Issaquah Creek to meet Chinook Salmon Recovery goals by adding Large Woody Material (LWM), reconnecting relict channels, encouraging increased floodplain connectivity, and adding trees and plantings to the creek corridor. These components, working together, will allow for natural ecosystem processes of LWM recruitment to increase hydraulic, geomorphic and habitat complexity. Specifically, the plantings of native conifers and other species will provide structure, diversity, and habitat within the channel and riparian corridor. As the active riparian restoration zones grow toward maturity in the coming years and decades, well-established trees will provide for future recruitment of LWM and habitat complexity as they fall into the creek due to erosion and channel migration.

As discussed in Section 5, outreach and engagement has been a critical element for this project's success to date. Several interest groups have provided invaluable information to develop a project that balances cost while offering the greatest uplift in habitat for Chinook Salmon and other aquatic organisms. As with most projects in a built environment, there are conditions that need to be met, in addition to other project goals. These conditions are explained in greater detail throughout the report, with the main conditions being: a no-rise at the State Park boundary so that there's no increase in flooding of the adjacent private properties; various critical park infrastructure (e.g. boardwalk, trails, bathhouse, bridge(s), and a pump house within the State Park (Appendix A); avoiding/minimizing environmental impacts such as grading and wetlands; and the need to limit certain size LWM from entering Lake Sammamish. A balance of the project's restoration goals and the identified conditions through collaboration with interest groups will continue to be refined as the project proceeds through design.

This report summarizes the project history and context (Section 2) and the preliminary analysis conducted on the selected alternative (NHC, 2018 and Section 6) to understand existing and proposed hydrologic (Section 3), hydraulic (Section 8), geomorphic (Sections 4 and 7), and habitat conditions (Sections 4 and 7) through the project reach.

2 PROJECT HISTORY AND BACKGROUND

The Greenway Trust's mission is to lead and inspire action to conserve and enhance the landscape from Seattle across the Cascade Mountains to Central Washington, ensuring a long-term balance between people and nature. Over the last 20 years, the Greenway Trust and State Parks, in collaboration with many different partners, have worked together to implement riparian restoration projects along Issaquah Creek, with funding from a variety of sources. The Greenway Trust's successful riparian restoration efforts within Lake Sammamish State Park have created the opportunity for more comprehensive in-stream and holistic ecological restoration. Section 2.1 describes the extensive community engagement managed by The Greenway Trust to accomplish the restoration efforts conducted in Issaquah Creek, fulfilling The Greenway Trust's mission to inspire people to take action to conserve and enhance the landscape.

In the mid-2000s, State Parks began a process to reassess the future of Lake Sammamish State Park. Many different visions for this urban Park were considered. The Greenway Trust worked with State Parks and the community on the creation of a new conceptual Master plan for the Park that highlighted the possibilities to serve as a recreational destination while highlighting the important and sensitive natural resources. This process culminated in the 2007 *Lake Sammamish State Park Redevelopment and Restoration Concept Plan* which included a vision for the Park as "an innovative model for the State's diverse system of recreational, cultural, historical, and natural sites. Lake Sammamish State Park will be Washington's signature park for protecting and celebrating urban natural areas, showcasing regionally significant wetlands and wildlife habitat, while enriching the lives of visitors and providing a valued legacy to future generations." Prior to the initiation of this Concept Plan, State Parks worked with The Watershed Company on the 2005 *Lake Sammamish State Park Wetland, Stream and Lakeshore Restoration Plan*, a document to guide the restoration efforts in the years to come. The *Restoration Plan* sorted areas of the Park into different conceptual restoration zones, and ascribed three different categories of work which incorporated project readiness and complexity.

These two documents have served as the basis for the ecological restoration undertaken by the Greenway Trust and other interest groups in the Park for the past 15+ years. From the early 2000s, the Greenway Trust has routinely initiated buffer enhancement along Issaquah Creek, Tibbetts Creek, parts of the Park lakeshore, and elsewhere in the Park as outlined in the 2005 *Restoration Plan.* Funding for these incremental improvements has come from a diversity of federal, state, county, and local sources matched with private contributions from individuals and local and national businesses. These efforts have been bolstered by the efforts of thousands of community volunteers.

After multiple years of incremental riparian restoration projects, adding three-to-five acres annually along the banks of Issaquah Creek, partners from the WRIA 8 Technical Committee encouraged the Greenway Trust to pursue a more comprehensive ecological in-stream restoration effort. Specifically, a restoration effort that would leverage the slowly maturing native forest by completing an analysis of in-stream habitat conditions, evaluating opportunities for increased relict-channel and floodplain connections, and placement of LWM features to improve conditions for juvenile Chinook and other salmonid species. This project represents the assessment of this effort to date, and includes most of the final remaining A-, B-, and C-level projects from the 2005 *Restoration Plan* along Issaquah Creek. As discussed in the Introduction and Section 4.4, the comprehensive in-stream aspects for salmon restoration are the primary objective of this project. The preferred design alternative focuses on the in-stream restoration elements which will work in unison with the riparian restoration efforts that have occurred previously (see Section 4.3), that will be included as part of this project (see Section 7.5), and that will continue in the future (see Section 9). As discussed throughout the remainder of this report, an extensive geomorphic, hydrologic, hydraulic, and habitat analysis of the lower reach of Issaquah Creek through Lake Sammamish State Park was conducted. Ultimately establishing the proposed preferred design alternative that includes LWM and grading elements (discussed in detail in Sections 6 and 7) in conjunction with riparian restoration (Section 7) to provide a holistic in-stream and riparian restoration effort and fulfill The Greenway Trust's mission of ensuring a long-term balance of habitat restoration within the lower reach of Issaquah Creek and public park use.

2.1 Community Engagement in Restoration

Volunteers have played a critical role in restoration efforts along Issaquah Creek. Since 2002, more than 16,000 community volunteers have provided over 64,000 volunteer hours toward restoration projects at Lake Sammamish State Park and on other public land in Issaquah. Volunteers include employees of local businesses, youth groups, local residents, school groups, and many others. Volunteer efforts have complemented the efforts of Greenway Trust staff and seasonal staff, State Parks staff, local ecological restoration contractors, non-profit partners at other organizations, and the contributions of hundreds of

AmeriCorps members from numerous programs who have participated in restoration activities at the Park.

Lake Sammamish State Park is a relatively unique State Park unit, with its proximity to the Seattle metro area and within a region undergoing significant population growth and shifting demographics. The Park receives more than 1.3 million visitors each year, representing diverse interests and abilities. For example, children are drawn to the playground, families and large gatherings enjoy the picnic areas and shelters, boaters and swimmers use the Sunset Beach facilities and the boat launch, those interested in birds (more than 100 species have been found in the Park, including bald eagles and one of the largest great blue heron rookeries in King County) come to bird watch, and many people enjoy midday walks through the park from the business complexes and nearby residential areas.

Park users will be engaged in the proposed project through interpretive signage that will be installed as part of the effort, informing users of the salmon recovery project underway and the larger connectivity of people with nature. Additionally, regular volunteer opportunities will be a central element of the Greenway Trust's riparian restoration. The Greenway Trust is pledging to work with the community to secure more than 4,000 volunteer hours toward invasive weed removal and control, native plant installation, plant establishment support, and restoration site maintenance activities.

The Greenway Trust's Education Program strives to reach students from schools that have access to fewer resources (which often correlates with schools that have more diverse student demographics). The program often uses Lake Sammamish State Park as an outdoor laboratory in lessons about salmon, as well as Issaquah Creek as a site to experiment on water quality, riparian habitat, and other investigations. Participating schools and students will be able to take an active role in the restoration project as in-stream and riparian restoration efforts are underway, providing a real-world example of salmon recovery in action and contextualizing lessons learned in the classroom and the field.

3 HYDROLOGY

3.1 Watershed Analysis

Issaquah Creek, at the mouth where it flows into Lake Sammamish, drains approximately 58.7 square miles, and receives a mean annual precipitation of 63 inches, as determined by PRISM rainfall data (PRISM Climate Group, 2019). The maximum and mean basin elevations are 2,990 feet and 897 feet, respectively. Issaquah Creek's headwaters originate in the steep slopes of the Squak, Cougar, Tiger, and Taylor Mountains (Figure 1). A significant portion of the basin's upper reaches reside in Washington State Forest Lands where development has been minimal; the lower reaches reside within Issaquah's city limits with an overall basin average canopy coverage of approximately 65.6%.

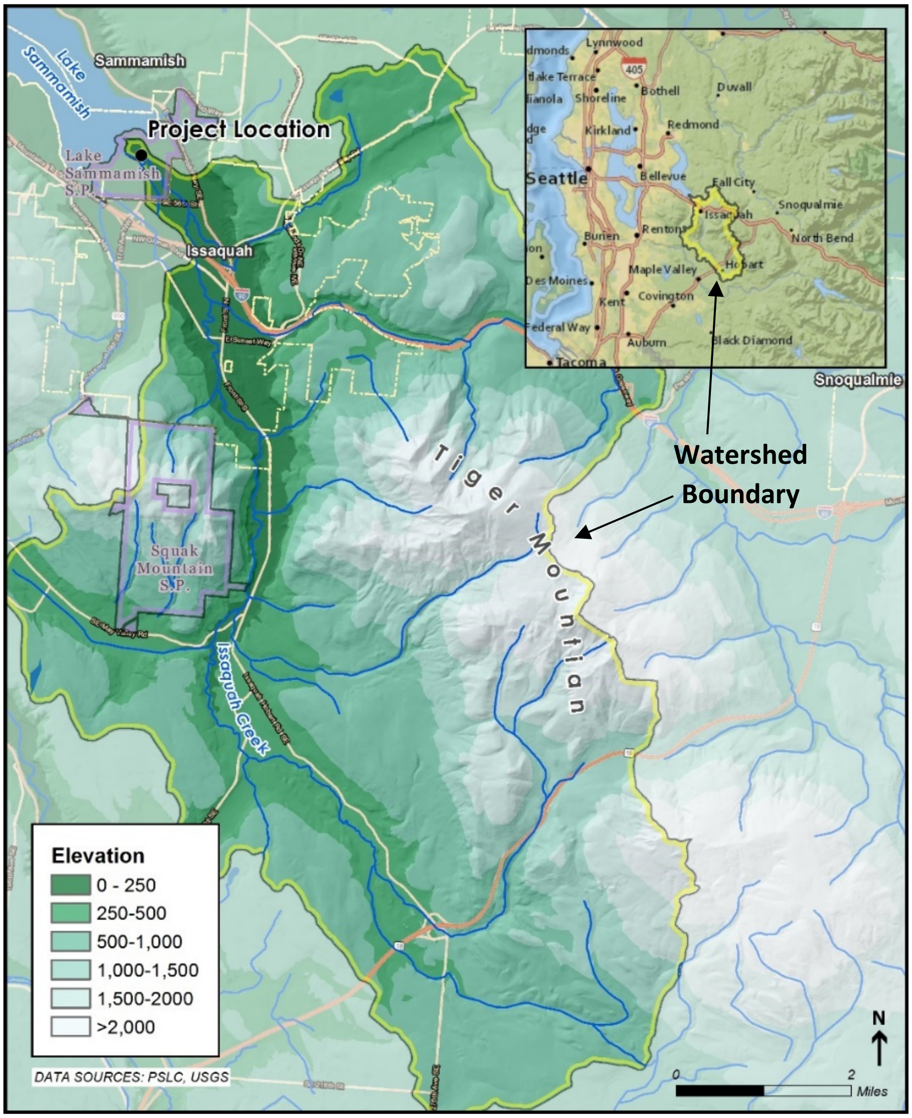

Figure 1. Project Location and Basin Overview

3.2 Peak Flow Analysis

The United States Geological Survey (USGS) has operated a continuous recording flow gage (Gage Number 12121600), located approximately 1.1 river miles upstream of the mouth of Issaquah Creek at Lake Sammamish, since 1964 (Table 1). To determine peak flows for the project, data from the USGS Issaquah Creek gage was evaluated utilizing the methods provided by the USGS document *Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington* (Mastin et al., 2016). The USGS PeakFQ statistical software was used to conduct a flow frequency analysis on the gage data. The flow frequency analysis outlined in the 2016 USGS publication mostly follows the methodology set by Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982). However, some proposed changes were included in the Bulletin 17B flow frequency analysis, including the Expected Moments Algorithm and the Multiple Grubbs-Beck low-outlier test.

As described in the 2016 USGS publication, a regional skew coefficient was developed to be used for basins with less than 5% impervious land cover. The basin draining into the Issaquah Creek gage (Gage Number 12121600) was documented as having an impervious land cover of 6.3%; therefore, the flow frequency analysis was developed for the Issaquah Creek gage based on the station skew alone, with no weighting from the regional skew coefficient. The peak flow estimates at the USGS gage were then scaled following guidelines in the 2016 USGS publication to obtain flows for the basin area at the mouth of Issaquah Creek. Table 2 contains the calculated peak flows for the mouth of Issaquah Creek at Lake Sammamish.

Table 1. USGS Operated Stream Gage Near the Mouth of Issaquah Creek

USGS Gage Number	Station Name / Location	Available Peak Data	Basin Area (mi^2)	Mean Annual Precipitation (in)	Maximum Basin Elevation (ft)	Mean Basin Elevation (ft)	Minimum Basin Elevation (ft)
12121600	Issaquah Creek Near Mouth Near Issaquah, WA	1964 - 2020	57.0	63.6	2,990	919	41.8

Throughout the project area, Issaquah Creek is in a Federal Emergency Management Agency (FEMA) regulatory floodway (See Appendix C). Peak flow values from the effective FEMA Flood Insurance Study (FIS) can be found in Table 2. Through discussions with the City of Issaquah and the FEMA Region X, the 100-year peak flow value from the Effective FEMA Flood Insurance Study (FIS) was required to be modeled to perform a preliminary floodplain and floodway analysis (Section 8.6). Since the effective FEMA flow values are higher than the flows assessed through the statistical analysis, the FEMA flow values were also utilized for hydraulic modeling of the preliminary design. Because the FEMA FIS does not contain a 2-year flow, the 2-year flow based on the flow frequency analysis described above was utilized.

In addition to modeling typical design events, a flood event that occurred on February 6, 2020 was modeled to verify hydraulic conditions, which were observed throughout the State Park. The peak flow from this event was measured as 2,620 at the USGS gage, which was then scaled to the mouth of Issaquah Creek at Lake Sammamish. This scaled value of 2,690 cubic feet per second (cfs), is approximately a 10-year peak flow event based on the results of the flow frequency analysis. The peak flow values used for the preliminary hydraulic modeling of Lower Issaquah Creek are contained in the last column of Table 2.

Table 2. Peak Flows for Issaquah Creek

Mean Recurrence Interval (MRI)	King County Flood Insurance Study at Mouth (FEMA, 2005), Flow (cfs)	Gage Analysis at Mouth from Issaquah Creek USGS Gage No. 12121600, Flow (cfs)	Lower Issaquah Creek Modeled Flow Values (cfs)
2	—	1,530	**1,530**
10	2,890	2,610	—
*	—	—	**2,690**
25	—	2,970	—
50	3,700	3,170	—
100	3,960	3,340	**3,960**

* Peak of February 6, 2020 Storm Event

3.3 Lake Level Analysis

The USGS operates a continuous recording lake level gage (Gage Number 12122000) located on the west shore of Lake Sammamish near the outfall of Squibbs Creek. The gage is approximately 2.5 miles away from where Issaquah Creek enters into Lake Sammamish at its south shore. Lake elevation data at the gage has been available since 1996, with gage height data beginning in 1939. A lake level duration analysis was performed to assist in determining the appropriate lake levels that are to be used as the downstream boundary conditions for the hydraulic modeling (Section 8).

As described in a report for King County, prepared by NHC in 2013, the outlet weir of Lake Sammamish was modified in 1998, including raising the crest elevation by up to half a foot. Water levels in Lake Sammamish have consequently been affected. Therefore, the lake level analysis excluded data prior to 1998. The analysis was also limited to the months of November through February, which is when peak flows tend to occur on Issaquah Creek based on the historic record. This allowed for the best representation of lake levels to be used as a downstream boundary condition with the peak flow events being used in the hydraulic model (Section 8.1.3). In addition to this analysis, the lake levels during the February 6, 2020 event were assessed and used in modeling for this event (Section 8.1.3). Figure 2 contains the results of the duration analysis, with lake elevations on the vertical axis and the percent of time a lake elevation being equaled or exceeded along the horizontal axis. A summary of key percent exceedance values and the February 6, 2020 event, along with their corresponding lake levels, are included in Table 3.

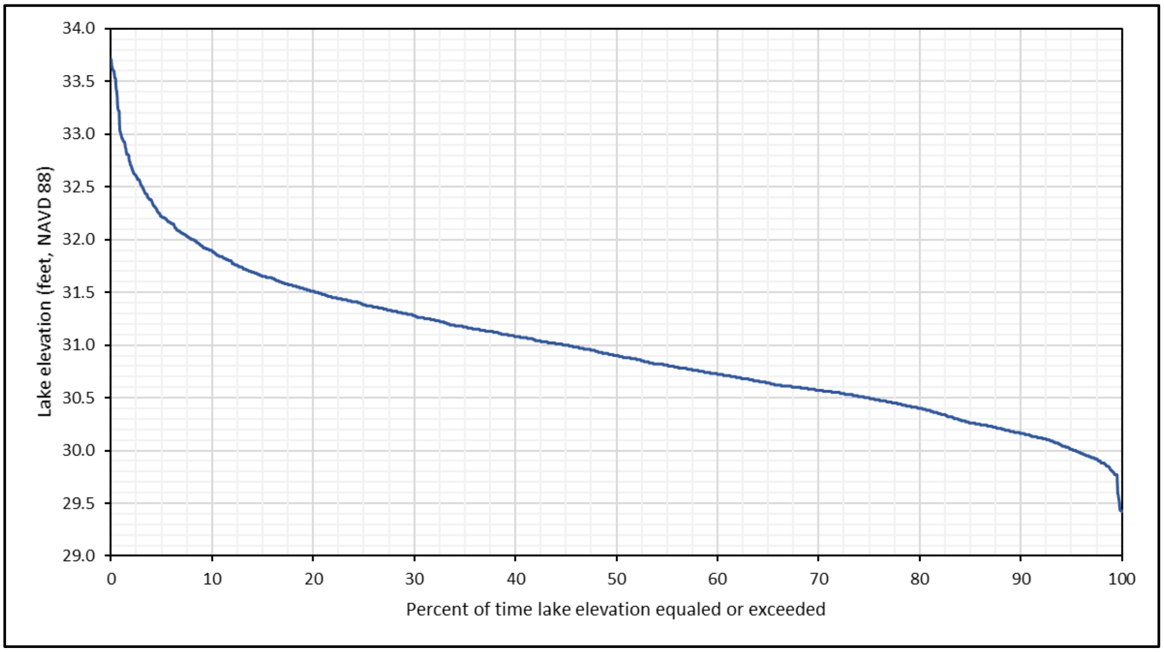

Figure 2. Lake Level Analysis for Lake Sammamish at USGS Gage Number 12122000 (Nov. Through Feb. Since 1998)

Table 3. Lake Elevation Values for Lake Sammamish at USGS Gage Number 12122000 (Nov. Through Feb. Since 1998)

Percent Exceedance	Lake Elevation Values at USGS Gage #12122000 (Feet, NAVD 88)
*	33.6
1-Percent	33.0
5-Percent	32.2
10-Percent	31.9
50-Percent	30.9
95-Percent	30.0

* February 6, 2020 Storm Event

4 EXISTING REACH CONDITIONS

The following sections describe the existing conditions of the project site. Sections 4.1 through 4.4 provide a summary of the project level geologic and geomorphic history, the channel migration assessment through the project reach, previous riparian restoration efforts conducted, and the overall project goals. To evaluate channel migration, aid in further project planning, and any future planning near Issaquah Creek within Lake Sammamish State Park, a Channel Migration Zone (CMZ) study was conducted as part of this project. This study is included in Appendix D.

To further describe existing channel conditions in detail, the project reach was divided into four distinct component reaches. The four reaches were divided based on the differences between the existing channel morphology, geomorphic history, biological conditions and potential, and hydraulic processes throughout each reach. These four reaches are depicted in the enclosed figures in Appendix E, *Geomorphic Overview – Reach 1 through Reach 4* and described in Sections 4.5 through 4.8. Reach descriptions include detailed evaluations of the geomorphic conditions, habitat conditions, existing infrastructure, and reach specific objectives for the project.

4.1 Project Level Geology and Geomorphic History

As discussed in Section 3, Issaquah Creek drains a basin of approximately 58.7 square miles that includes a heavily forest upper basin and a moderately developed lower basin. The mainstem of the creek follows a prominent glacial outwash channel (Figure 3) that formed during the recession of the Cordilleran Ice Sheet around 16,000 years ago (Booth et al., 2003) and has a correspondingly low gradient. In the upper basin, Issaquah Creek's main tributaries drain into the mountain slopes and are much steeper. The mountains are mantled by till and underlain by a folded sequence of Oligocene-Eocene aged sedimentary and volcanic rocks, including the Tukwila, Ranging River, and Renton Formations. Extensive coal mining occurred in the Renton Formation beginning in the late 19th century and some resulting tailings have impacted the creek.

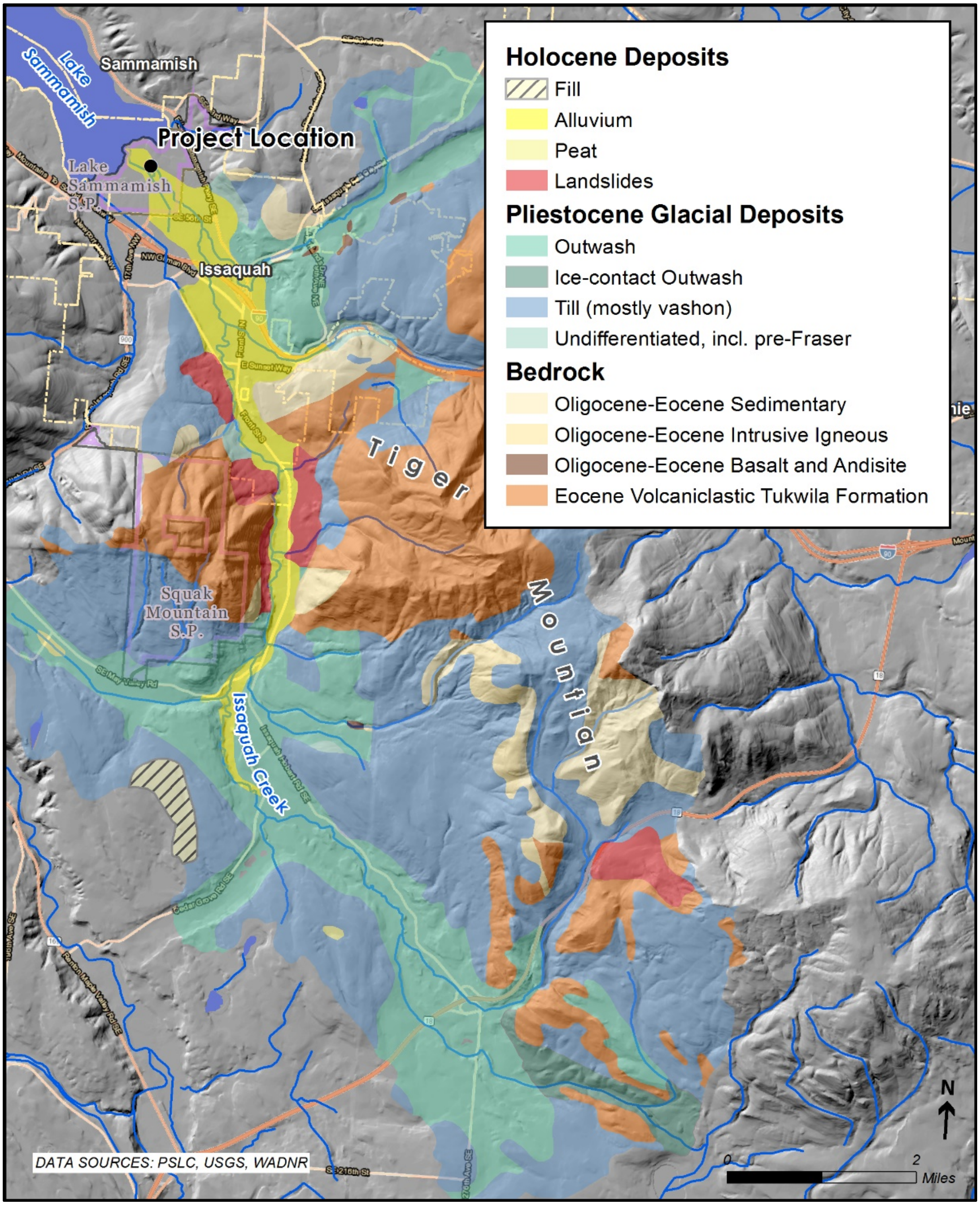

Figure 3. Generalized Geology of the Issaquah Creek Basin Derived From Division of Geology (2010)

Following deglaciation, Issaquah Creek formed a large delta into the southern end of Lake Sammamish. As is common in low-gradient delta environments, a substantial alluvial ridge formed along the historic position of the creek. Throughout the lower reaches of Issaquah Creek, the main channel averages five to eight feet (with maximum values approaching 12 feet) below the surrounding floodplain, which is described in more detail in the subsequent sections and the CMZ analysis included in Appendix D. Figure 3 in the CMZ analysis depicts typical channel sections that show the pattern of historical incision and inset floodplain formation. Three major historic changes could be attributed to this base level lowering of the creek.

The largest of these changes was most likely a late nineteenth- to early twentieth- century avulsion or realignment of Issaquah Creek. The General Land Office Survey (1864) and present-day topography shows a historic channel position along the top of the alluvial ridge and to the east of the present channel from about Chainage 4,000 to Lake Sammamish (Figure 4). This pathway was about 1,000 feet longer than the present channel. Based on the observed and inferred slope along that pathway, the avulsion would have lowered the base level for the channel upstream by approximately 10 feet. It can be assumed the avulsion was prior to 1937 as this is the date of the earliest available aerial photo, which shows the channel in its present alignment (see Appendix D, Figure 6).

The second factor potentially influencing the creek's base level was a project conducted by King County and the Army Corps of Engineers (1964) where the Lake Sammamish outlet was reconfigured. This reconfiguration lowered typical winter lake levels from a range of 33 to 36 feet to a range of 31 to 33 feet (NAVD88) (NHC, 2012). Further modifications were made to the Lake outlet in 1998 (see Section 3.3). Higher lake levels most likely corresponded to the geomorphically effective flood flows on the creek. As a result, this could have caused a two- to three-foot drop in the functional base level.

The last change occurred in the 1990s when a natural meander cut-off occurred at approximately Chainage 3,300, resulting in the removal of roughly 1,300 feet of channel length (Figure 4). The Issaquah Creek main channel slope in this area is low (0.1% or less); however, this likely reduced the base level for the channel upstream by about a foot and disconnected this side channel.

No knickpoints are apparent in the channel's longitudinal profile (Appendix D, Figure 2), but rather the channel profile has a consistent slope of about 0.3% above Chainage 4,500, a strongly concave profile between Chainage 2,200 and 4,500, and a flat profile, where affected by Lake Sammamish, below Chainage 2,200. This suggests there is no additional ongoing downcutting from the set of base level drops described above.

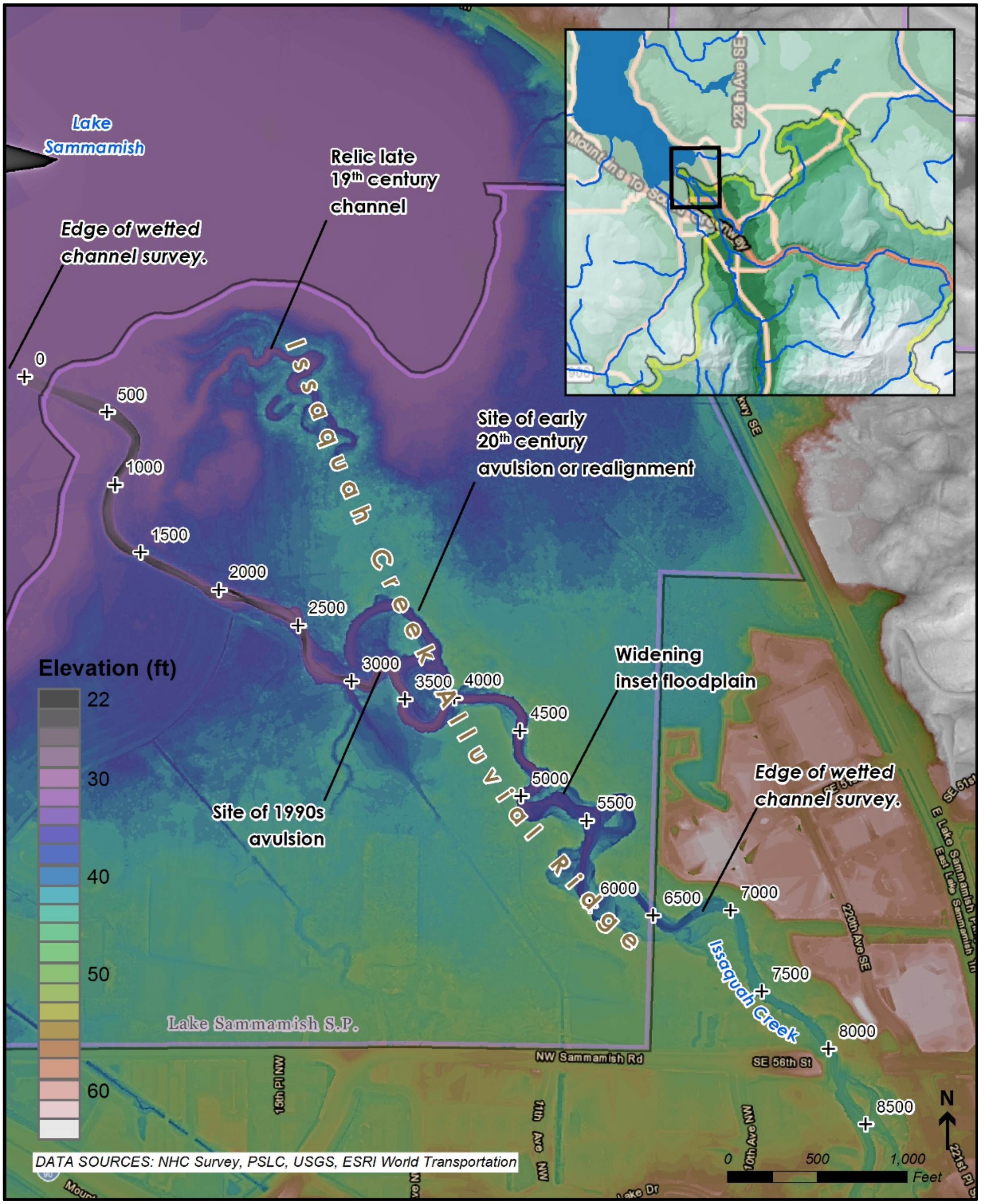

Figure 4. Topographic Base Map of Study Reach

4.2 Project Level Channel Migration

As previously mentioned, a channel migration analysis was completed to define the Issaquah Creek CMZ through Lake Sammamish State Park (see Appendix D). The analysis was conducted following the standard Washington Department of Ecology CMZ Delineation Methodology (Rapp and Abbe, 2003). The study evaluated historical channel migration, avulsion hazard areas, erosion hazard areas, and individual meander formation. Figure 7 in the CMZ analysis depicts the CMZ that Issaquah Creek could reach within the requested timeframe directed by State Parks of 50-years. As discussed in the CMZ summary, it is important to note that the delineated areas on the figure are based on historic average rates extrapolated 50 years into the future, following the established guidelines. Several unpredictable parameters could influence the actual migration path and rate the channel forms over time. For any future comprehensive planning and risk assessments, a full understanding of the limitations of the CMZ mapping method should be taken into consideration (see Appendix D for further discussion).

The CMZ analysis discusses how, with the base level lowering of the creek, the channel eroded into the surface of the abandoned alluvial ridge, creating a newly formed inset floodplain that extends from about Chainage 2,500 upstream through the project area. The sequence of channel positions mapped from historical aerial photos in the CMZ analysis shows how this inset floodplain has progressed over time (Appendix D, Figure 6). The CMZ analysis utilizes aerial photos from 1937 through the autumn of 2019 for this mapping. It is important to note that storm events, which occurred in the 2019-2020 high flow season, caused bank erosion that is not included in the referenced analysis due to no aerials being available.

As depicted in Figure 6 of Appendix D, slight lateral channel movement occurred between 1937 and 1965, which suggests that geomorphic work during this period was dominated by channel downcutting. Since 1965, channel migration rates increased in the upstream portion of the reach. High rates of channel migration in this upstream area are interpreted to reflect the low strength of sandy alluvial bank material, high bank heights that limit stabilization by vegetation, and the effect of gravel wedge progradation from upstream caused by channel steepening. Downstream of Chainage 2,500, the lateral channel position has been extremely stable. This stability reflects bank strength provided by riparian vegetation, backwatered conditions from Lake Sammamish, and lower stream energy and bed material transport rates. Sections 4.5 through 4.8, which describe reach specific conditions, discuss in more detail how geomorphic processes and channel migration have influenced each reach.

4.3 Previous Riparian Restoration Efforts

In 2005, the Washington State Parks & Recreation Commission approached The Watershed Company to prepare a *Wetland, Stream and Lakeshore Restoration Plan* for Lake Sammamish State Park. More than 40 individual restoration projects were identified in that plan, separated into A, B, and C level implementation groups based on their anticipated level of required permitting, with A being the simplest and C the most complicated. Since 2005, the Greenway Trust has worked collaboratively with State Parks to implement several of the identified restoration projects, securing more than $1.2 million in funding for ecological restoration efforts, with grants from local, county, state, and federal programs, and as well as contributions from private businesses, individuals, and corporations. In working closely with State Parks to implement these projects, the Greenway Trust has helped ensure and maintain State Parks' goals of connecting people with nature, to manage the natural areas for wildlife, and to ensure all future generations are taken care of. Additionally, State Parks has included the Greenway Trust in discussions on potential future sites of bridges, trails, and other infrastructure within the park, collaboratively developing a long-term plan for restoring this stretch of Issaquah Creek, while meeting State Parks goals (discussed further in Sections 4.5 through 4.8).

The Greenway Trust currently has more than 60 acres of active restoration sites along Issaquah Creek within Lake Sammamish State Park. Over nearly two decades, these projects have removed substantial amounts of invasive plants, and planted more than 50,000 native trees and shrubs. The Greenway Trust's ongoing goal is to keep these restoration sites maintained until they are mature enough to outcompete non-native threats, and to continue to meet other State Parks goals.

Comparisons of aerial imagery of the Park from 2002 against the same location in 2019 provides a compelling visual testament to the success of the long-term effort to improve the riparian buffer along the Creek, as well as forest canopy improvements elsewhere in the Park (see Appendix B). As late as 2002, the riparian buffer was either nonexistent, composed almost entirely of invasive blackberry and/or reed canarygrass, or (when it did include native tree cover) quite limited in depth, health, and composition. As of 2019, the recovered and improved forest canopy can be seen with the expansion of the buffer footprint (averaging more than 150 feet in most locations), and the reestablishment of native mixed coniferous-deciduous forest along the bank and throughout the active restoration zones. The pale green of blackberry monocultures is slowly being replaced with a more complex native forest throughout the Park (See Appendix B).

4.4 Project Level Objectives

The project primarily targets enhancing and creating salmonid habitat to accommodate spawning, rearing, resting, migration, food production, protective cover (from predation), and high-flow refuge. The emphasis is on ESA-listed Chinook salmon habitat restoration, with anticipated improvements for other fish and wildlife habitat, including but not limited to coho, sockeye, and kokanee salmon, as well as cutthroat and steelhead trout. As such, the main project objective is to enhance the quality and quantity of key, strategically located salmonid habitat, particularly for juvenile Chinook rearing and adult Chinook holding. To accomplish this, several objectives were defined as important to apply to every reach to establish a successful project.

1) **Increase total habitat area** – This lower reach of Issaquah Creek has limited existing available habitat as is discussed further in Sections 4.5 – 4.8. Increasing the available habitat areas would help meet the main project objective to enhance the quality and quantity of salmonid habitat.

2) **Increase available canopy cover within the perennially wetted channel –** Throughout the lower reach of Issaquah Creek, there is minimal canopy cover. Reestablishment of native mixed coniferous-deciduous forest along the bank and throughout the riparian zone would increase shading as well as nutrients for aquatic organisms.

3) **Increase channel complexity** – Several places throughout the project area have little to no channel complexity (See Sections 4.5 through 4.8). As such, there is minimal geomorphic diversity. Designing project features that would increase channel complexity, such as mid channel LWM jams that would split flow and increase sinuosity, would enhance the quality of aquatic species habitat.

4) **Increasing hydraulic diversity** – Increasing hydraulic diversity throughout this lower reach of Issaquah Creek would provide long term habitat benefits. For example, designing project features that create areas with local increases in channel velocity provide the potential for pool formations which are excellent rearing habitats for juvenile salmonids and holding areas for adults. Additionally, providing areas with local decreases in channel velocity provide the potential bar formation, increasing channel floodplain interaction and the quantity of available low-elevation floodplain habitat.

5) **Re-establishment of connected floodplain** – Designing project features that would re-establish low-level floodplain areas will also promote overbank deposition of fines due to the effects of dense vegetation, particularly fine-mesh groundcover, tall grasses, etc. This can reduce fines reaching Lake Sammamish and the lower reaches and increase the proportion of gravel for the substrate remaining in the channel. Less fines and more gravel means better spawning substrate and habitat for aquatic insect production (food supply for juvenile salmonid fish). Additionally, deposition of fines on the floodplain retains nutrients for use by riparian vegetation and reduces nutrient loading into Lake Sammamish, where it is problematic with respect to contributing to algae blooms and associated eutrophication.

6) **Vegetation management** – Providing vegetation management within the riparian zone along both banks to remove non-native invasive species and establish a forested condition (based on native tree and understory species) can assist in providing a long-term source of woody material to the creek. This would enhance the quality of habitat long-term as the riparian zone becomes re-established (see Section 4.3).

As previously mentioned, to further describe existing channel conditions in detail, the project reach was divided into four distinct reaches. In addition to the overall project objectives identified, specific objectives were further defined for each reach based on the reach's specific geomorphic, hydraulic, and habitat conditions. The following sections describe the existing reach conditions in more detail as well as the reach specific objectives.

4.5 Reach 1

4.5.1 Geomorphology

Reach 1 consists of the transition zone from Issaquah Creek into Lake Sammamish (Appendix E and Photo 1). This reach is a relatively stable segment of channel that is heavily influenced by Lake Sammamish. At low flow, the water surface is functionally flat and there is very little current. The bed material is dominated by sand and fine sediments, although some fine to medium-sized gravel is transported through this reach during large floods. Mature trees line the channel banks (Photo 2) and large wood is recruited to the channel primarily by windthrow, and possibly by undercutting of the banks.

Photo 1. Reach 1 – Issaquah Creek Outlet into Lake Sammamish

Photo 2. Reach 1 - View Looking Downstream from Existing Pedestrian Bridge at Chainage 1,750

As mentioned in Section 4.2, the channel migration rate in this reach has been extremely slow over the historic record, typically ranging from less than one to two feet per year. The abandoned historic nineteenth century channel (visible in Figure 4) had a much higher sinuosity in its lowest reach, probably reflecting a long period of channel development (allowing for meanders to develop) and possibly the influence of human activity in forming the present channel alignment. Actions to increase the sinuosity of this reach and/or encourage development of distributary channels would accelerate the formation of high-quality habitat through natural processes.

4.5.2 Habitat

Within Reach 1, in-stream wood is generally limited to widely spaced fallen trees. A previous project placed wood along the lakeshore near the mouth, but the wood was placed beyond and outside of the stream channel. Reach 1 is dominated by run-type habitat – long stretches of somewhat deep, uniform flow, with few deeper pockets uninterrupted by riffles, primarily due to low gradient and scarce wood. Suitable spawning gravel for salmonid fish is generally not present; however, the lower stream gradient approaching Lake Sammamish is not conducive to the establishment or maintenance of such a spawning substrate. If spawning gravel were to be placed, it would quickly silt in. Some bank vegetation is present along the existing banks, but vegetated buffers are narrow, especially along the left bank downstream of the parking lot and footbridge.

Since salmonid spawning is generally not expected to occur along this reach due to low velocities and stream energy, it functions primarily as migratory and a short-term rearing habitat. Salmonid fish of several species use this reach primarily to get to and from spawning and rearing reaches farther upstream in Issaquah Creek and its tributaries. Juvenile Chinook, in particular, tend to seek out and linger at creek mouths for short-term rearing opportunities along their seaward migration route. However, predation on juvenile salmonids by native (e.g. cutthroat trout) and non-native (e.g. bass) fish species along this reach, as it transitions into a lake-oriented habitat, is a concern.

4.5.3 Infrastructure

Several existing trails are located along both river banks, including a Boardwalk Trail along the left bank between roughly Chainage 500 and 1,400 (Photo 1 and Appendix E) and an existing pedestrian bridge crossing Issaquah Creek at approximately Chainage 1,750 (Photo 3, Photo 4, and Appendix E). A large parking area with a bathhouse is located southwest of the creek in Reach 1 as well. Appendix A depicts the existing infrastructure included in Reach 1.

As previously mentioned, and described in more detail in Section 5, various interest group involvement has been a large factor in understanding the project conditions. Through early discussions with State Parks, the bathhouse, parking lot, boardwalk trail, and pedestrian bridge were all determined critical park infrastructure features. As is discussed further in Sections 7.1.3 and 8.2.2, these features were taken into consideration during the evaluation of the preferred selected alternative. As the project progresses, further investigation of potential benefits/impacts to existing and planned infrastructure will continue to be examined and discussed with State Parks to develop a multi-beneficial project.

Photo 3. Reach 1 – Infrastructure

Photo 4. Pedestrian Trail Crossing Issaquah Creek in Reach 1

4.5.4 Reach Objectives

Reach 1 primarily functions as migratory and short-term rearing habitat (see Section 4.5.2). Currently, there is limited in-channel wood throughout this reach. As such, supplying additional cover with in-channel woody material, plantings, and/or minor channel grading, along with shrubby overhanging bank vegetation, would benefit aquatic species within this reach. In addition to the project objectives described in Section 4.4, another objective for Reach 1 is to increase the available distributary habitat potential. As mentioned in Section 4.5.2, Juvenile Chinook often seek out and linger at creek mouths for short-term rearing opportunities. Increasing the potential for distributary habitat would provide additional areas of refuge for juveniles along this reach of Issaquah Creek. Input from multiple interest groups during the design process indicated strong support for inclusion of the distributary channel in Reach 1. As the design moves forward, the Greenway Trust and NHC will work with key interest groups to continue to refine the proposed features in Reach 1, including determination of effectiveness and a cost-benefit analysis.

4.6 Reach 2

4.6.1 Geomorphology

Reach 2 is the lowest alluvial reach of the creek and has a pool-riffle morphology. Although it is mostly downstream of the late nineteenth/early twentieth century channel avulsion that occurred, the channel is incised, with new inset floodplain surfaces forming 4- to 8-feet below the abandoned surface of the alluvial ridge. It is dominated by a sand bed with local patches of gravel (Photo 5 and Photo 6). A meander cut-off avulsion in the 1990s left a large remnant low elevation oxbow feature in the floodplain that provides off-channel refugia habitat (Appendix E, Reach 2, Photo 7, and Photo 8).

Photo 5. Characteristic Sandy Substrate for Reach 2 at Chainage 3,900, Just Below the Gravel to Sand Transition

Photo 6. Location of Pebble Count and LWM Jam Upstream in Reach 2 at Chainage 2,400 (Left) and Material Sampled (Right)

Photo 7. Reach 2 – Oxbow Aerial Photo

Photo 8. Reach 2 – Oxbow

In addition to the abrupt avulsion event that resulted in the formation of an oxbow, persistent lateral channel migration in this reach has recruited LWM, which has accumulated into two prominent log jams (Appendix E, Reach 2). Local erosion is occurring around these jams, indicating the potential for local flow obstructions to concentrate flow and migrate, widening the channel area. Deep scour also occurs around small flow obstructions within this reach, probably due to the relatively fine bed material. Photo 9 depicts the nearly vertical bank remaining because of the persistent lateral channel migration. In early 2020, high peak flow events further eroded the bank in Photo 9, and contributed to the failure of the pedestrian trail crossing the Pickering Ditch (see Section 4.6.3 and Photo 12).

Photo 9. Steep Bank from Channel Migration, Looking Upstream from Approximately Chainage 3,600 (Photo Taken 10/08/2018)

4.6.2 Habitat

In Reach 2, at approximately Chainage 2,750, a large "old growth size" cottonwood has fallen, spanning the channel, and serving as an anchor for additional wood. Some bank erosion has occurred around the root end, widening the channel, and possibly indicating the beginnings of a more significant channel migration. As recently as 2014, there has been basically no wood in the lower portion of Issaquah Creek. Wood continues to accumulate due to the in-stream, channel-spanning jam, which serves as a log filter, intercepting and storing wood mobilized upstream and keeping it from reaching the lake. Wood in Lake Sammamish would be fine for habitat but would not be a desired outcome of the project from a lakeshore landowner or community perspective. Non-native vegetation is prevalent throughout Reach 2 with riparian areas consisting of mostly open or shrubby areas. Forested areas are scarce and immature where they are present, though The Greenway Trust has planted a large area on the upper left bank which will mature over time (see Section 4.3).

Pools are scoured by the log jams, beneath them and around them, with abundant and complex cover provided by the tangle of wood of various sizes. These pool areas beneath and around jams tend to provide excellent rearing habitat for juvenile Chinook and coho salmon, as well as holding areas for adults. Kokanee, anadromous sockeye, cutthroat, and steelhead would similarly make use of this habitat as well. This is the first such complex habitat adults may encounter on their way upstream and the last that juveniles may encounter on their way downstream to the lake. Substrate conditions are less than ideal for spawning, with finer-grained materials rather than gravel being more prevalent. As such, little spawning is expected to occur along this reach, either before or after project implementation. The substrate is still sand dominated throughout the reach, transitioning more to gravel only when approaching the upper reach boundary.

4.6.3 Infrastructure

Reach 2 includes existing trails along the top of the riverbanks. The trail on the left bank is immediately adjacent to the channel, while the trail on the right bank is set back into the riparian zone (Appendix A). In the middle of Reach 2, the Pickering Ditch outfalls into Issaquah Creek (Photo 10). Beaver activity is prevalent within this ditch system, and a large beaver dam was observed in October 2018 (Photo 11, right). A pedestrian bridge previously crossed the ditch at its outfall into Issaquah Creek (Photo 11, left). However, in February 2020, two large flood events contributed to the failure of this structure (Photo 12). State Parks will be removing the concrete ecology blocks that supported the pedestrian bridge during the 2021 in-water work window and there are no plans to replace this footbridge at this location. Per discussions with State Parks and the City of Issaquah, the Pickering Ditch is considered a critical park feature, with a specific goal of not increasing water surface elevations in adjacent properties upstream. As is discussed further in Sections 7.2.3 and 8.3.2, this feature was taken into consideration during the evaluation of the preferred selected alternative, specifically through evaluating hydraulic model results. Additionally, a new pedestrian crossing of the Pickering Ditch and a design to mitigate impacts from beavers through Pickering Ditch may be evaluated as part of the Lake Sammamish State Park Master Plan Update (Master Plan Update and EIS) and Environmental Impact Statement (a process currently underway by State Parks to updated the 2007 Lake Sammamish State Park Redevelopment and Restoration Concept Plan). As the project progresses, further investigation of the project's potential benefits/impacts to Pickering Ditch and any potential planned infrastructure will continue to be examined and discussed with key interest groups to develop a multi-beneficial project.

Photo 10. Reach 2 – Pickering Ditch

Photo 11. Pickering Ditch Previous Pedestrian Bridge (Left) and Beaver Dam Observed in Pickering Ditch in 2018 (Right)

Photo 12. Pickering Ditch Failed Pedestrian Bridge (Photo Taken 2/26/2020)

4.6.4 Reach Objectives

Reach 2 has diverse conditions and is the first reach with a complex habitat that adults may encounter on their way upstream and the last reach that juveniles may encounter on their way downstream (Section 4.6.2). Since this reach has some existing geomorphic and hydraulic diversity, with low-elevation floodplain habitat that include areas with slower velocity and shallow water depths, it serves as a natural filter for wood transported from upstream which might otherwise end up in Lake Sammamish. Unlike Reach 1, the existing log jam features, as well as some lower velocity floodplain areas, allow transported wood to be retained within this reach.

This reach also serves as a potential source for in-stream wood, as bank erosion leads to recruitment of trees near channel banks. As previously mentioned, State Parks would prefer to minimize the amount of LWM that migrates downstream to the Pedestrian Bridge in Reach 1 or into Lake Sammamish. LWM that migrates downstream could damage the Pedestrian Bridge or become an issue for property owners on Lake Sammamish. Collaboration with State Parks' staff is ongoing to balance the desire to maximize the amount of LWM in the reach with the minimum size and quantity of LWM State Parks has the capacity to manage in the lower reaches and downstream. In addition to the project objectives detailed in Section 4.4, the primary objectives for Reach 2 are to enhance the existing natural processes of this reach and increase the reliability to trap incoming wood.

4.7 Reach 3

4.7.1 Geomorphology

Reach 3 occurs immediately upstream of the site of the late nineteenth/early twentieth century avulsion (Figure 4). It is highly entrenched, with 8- to 12-feet of offset between the elevation of inset floodplain features and the top of the bank. The reach is immediately above the gravel to sand transition, has gravel-dominated substrate, and a strongly concave profile. Lateral channel migration in the reach has been extremely limited, leaving a straight channel with steep banks, little hydraulic diversity, and almost no off-channel refugia habitat (Photo 13).

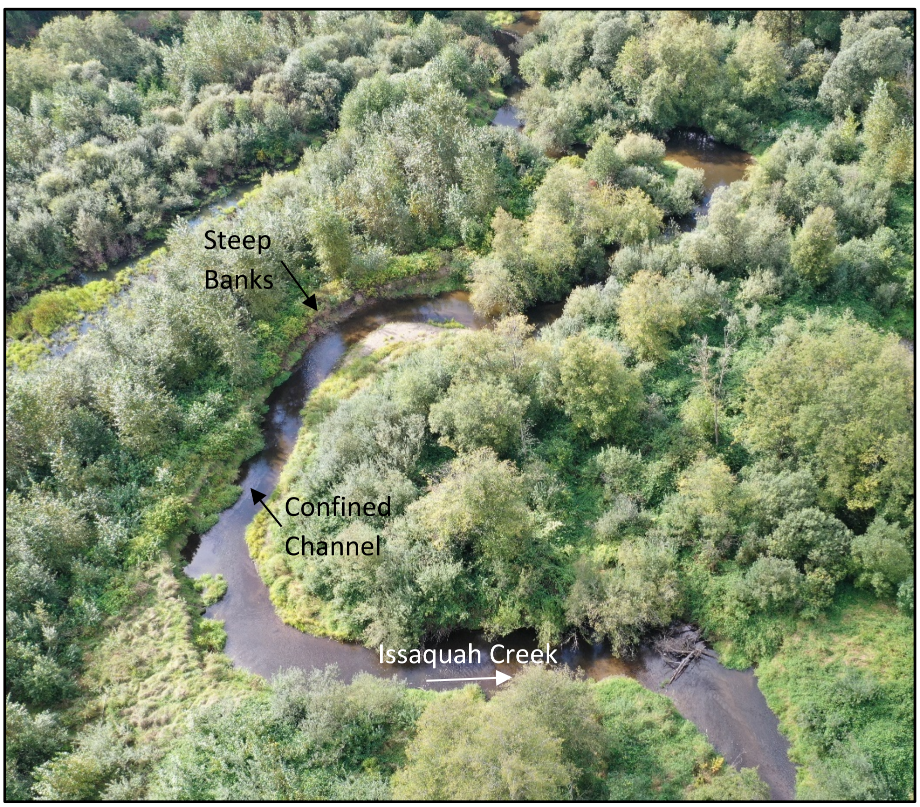

Photo 13. Reach 3 – Channel Confinement and Steep Banks

4.7.2 Habitat

Reach 3 has limited habitat features in terms of wood and pool/riffle sequence. The reach is narrow and incised with little wood and simple, fairly uninterrupted run habitat with little pool or riffle habitat. Shrubby willow and red-osier dogwood native vegetation lines the right bank (on the right in Photo 13), with lower, invasive species on the left bank. Little wood of any size would be recruited by channel migration. The reach currently serves more as a migration corridor for upstream-bound spawners and downstream-bound juvenile salmonids but has potential for improvement with respect to both rearing and holding. In 2015, a beaver dam spanning the entire channel width was observed at the upstream end of Reach 3. However, the dam has since been washed out and the wood transported downstream. Additional wood within this reach would increase the potential for channel migration, deepen in-stream pools, and provide cover.

The reach contains more gravel and less fines farther upstream. Localized riffle areas could provide limited spawning habitat for Chinook, though their primary spawning areas outside the hatchery occur farther upstream where the substrate tends to be coarser. The smaller salmonid species, such as kokanee, coho, and cutthroat, tend to use a smaller substrate size for spawning, as is found in Reach 3; however, they also tend to spawn in smaller streams. Water velocity and depth conditions in the reach for these smaller fish during their spawning periods may be less than ideal. Given that these fish tend to spawn in smaller streams during seasonally high-flow periods, both velocities and depths in the existing conditions of Reach 3 at those times may be too high.

The channel through this reach has moved little during the past century. As a result, banks are relatively stable but are also near-vertical in some places, and such stability does not necessarily lend itself to the development and maintenance of good habitat characteristics for fish or other wildlife. A migrating channel would lead to bar and floodplain formation, as well as in-stream pool and riffle habitat.

4.7.3 Infrastructure

Reach 3 includes existing trails along both riverbanks (Appendix A). As identified in previous studies and verified in the CMZ analysis (Appendix D), this reach historically had the least amount of channel migration, except for Reach 1. This could make it a good location for a proposed bridge to connect the planned State Park trails on the north and south sides of the creek. A cost-benefit assessment should be further investigated to balance the need for the crossing while also allowing for channel migration and the reconnection of the surrounding floodplain. Further discussions for bridge structure locations, structure types, and structure spans will continue to develop a mutually beneficial solution to promote natural stream processes, while providing a safe location for a new trail bridge.

4.7.4 Reach Objectives

Reach 3 has limited existing habitat and in-channel LWM features and consists of a mostly straight reach with tall, steep banks. The primary objectives for Reach 3 include the project objectives described in Section 4.4 as well as encouraging the initiation of new meander features. LWM and minor grading is recommended within the reach to actively encourage channel migration and natural, habitat-forming processes in this otherwise fairly simple, stable, and somewhat sterile reach. Newly formed meander features would be expected to migrate laterally and increase the quantity of available low elevation floodplain habitat.

4.8 Reach 4

4.8.1 Geomorphology

Similar to Reach 2, Reach 4 is an alluvial reach with diverse geomorphic conditions. Reach 4 is defined by the area where channel downcutting has been followed by channel widening and floodplain formation due to channel migration. For example, the growth of a gravel bar into this reach following initial downcutting at roughly Chainage 5,000 has resulted in persistent (reach-average rates of 4- to 8-feet per year) and, at times, rapid (up to a reach-average rate of 20-feet per year) channel migration (Photo 14). This has produced a reach with high hydraulic complexity including large areas of off-channel habitat (as well as one large backwater pool in an abandoned oxbow—Photo 15).

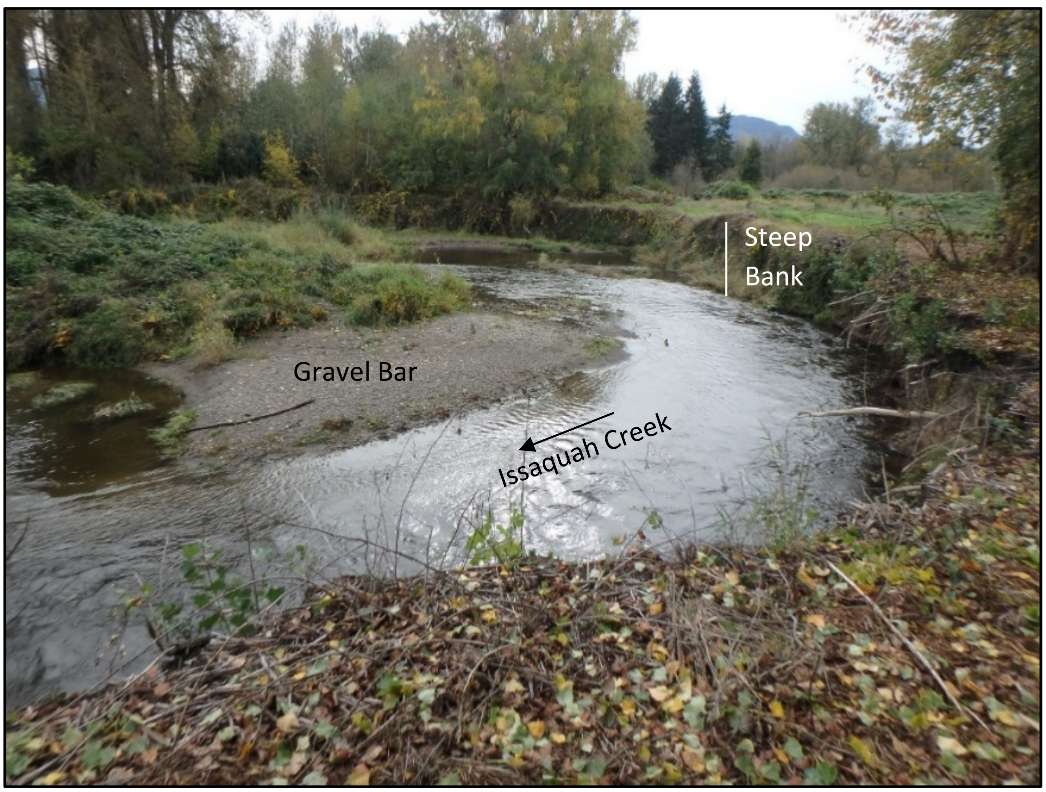

Photo 14. Example of Rapidly Growing Gravel Bar and Aggressively Migrating Meander in Reach 4; View is Looking Upstream from Approximately Chainage 5,000 (Photo Taken in Early 2017)

Photo 15. Large Backwater Pool in Oxbow at Approximately Chainage 5,400

Existing riparian forest vegetation in the reach is relatively limited. Fairly little wood is recruited from upstream largely due to the urbanized nature of the upstream reaches outside of Lake Sammamish State Park (Section 4.8.2). As mentioned in Section 4.3, ongoing restoration has taken place within this reach to help re-establish bank vegetation; however, most of this vegetation is still in early stages of growth and has not had the opportunity to be recruited as in-stream LWM. Consequently, although this reach is the most diverse within the project area, the channel is relatively lacking in-stream wood, with one exception. With the growth of the gravel bar depicted in Photo 14, two large trees were recruited in 2018 from the left bank through lateral channel migration, forming one large jam within the reach. Photos 16 and 17 depict the location of the jam before and after recruitment. Photo 18 shows an aerial view of the jam taken in 2019. Increased stable, in-channel LWM in this reach would enhance local-scale hydraulic diversity and provide cover for aquatic species.

Photo 16. Gravel Bar Growth in Reach 4 Before LWM Recruitment (Photo Taken in 2018)

Photo 17. Gravel Bar Growth in Reach 4 After LWM Recruitment (Photo Taken in 2019)

Photo 18. Ariel View of Gravel Bar Growth and LWM Recruitment (Photo Taken in 2019)

4.8.2 Habitat

A few medium- to large-sized logs have been deposited along Reach 4, but far fewer than would be needed for optimized fish and wildlife habitat. As mentioned, relatively little wood is recruited from upstream in part due to the urbanized nature of the reaches extending upstream. Upstream of Reach 4, the channel is largely prevented from migrating within the City of Issaquah to protect property and infrastructure, and any significant log jams forming or threatening to form there would likely be removed to prevent flooding and erosion.

The existing channel banks along Reach 4 are vertical cut banks in the direction of migration, with point bars, floodplain benches, and less steeply sloped banks in the opposite direction of the active migration. However, the migrating channel sections pass through non-forested areas that are often dominated by invasive, weedy vegetation which recruits little woody material to the channel and does not slow migration. These same weedy, invasive plants re-colonize the newly formed bar, floodplain, and bank areas on the banks opposite of the active erosion. Some outside-bend pools have formed in association with channel migration; however, these tend to be of moderate depth and are run-like in the absence of wood. Additional wood would increase scour and deepen pools as well as provide cover.

Similar to Reach 3, existing localized riffle areas throughout Reach 4 may function as limited spawning habitat for Chinook salmon. However, as mentioned above, the addition of wood throughout this reach would provide increased cover, adult holding habitat, and low-energy refuge habitat for juveniles, which is particularly important at high flows. The other salmonids using Issaquah Creek are also more likely to spawn farther upstream, though typically in smaller, tributary stream sections.

As an additional benefit, Reach 4 also provides perhaps the best potential spawning and adult holding habitats for kokanee within the overall project reach, with suitable pockets of gravel associated bars between Chainage 4,700 and 7,500 (Reach 4 and extending upstream off-site). However, during the typical spawning window for the local kokanee population from November through January, existing flow velocities that come with elevated discharge during the rainy season may generally be too high for kokanee spawning. The substrate class distribution is within the preferred range for kokanee (typically 0.5-1.5 inches with smaller amounts up to 3 inches), but the velocities and depths may generally be too high and therefore limiting.

4.8.3 Infrastructure

Reach 4 includes existing trails along the top of both riverbanks as well as a pump house located on the left bank at about Chainage 6,100 (Photo 19). Trails on both sides of the creek are set back into the riparian zone (Appendix A and Appendix E, Reach 4). Rock riprap currently resides along the left bank of the channel near the pump house. The material does not appear to be maintained, allowing the channel to undercut the banks. As such, this material was not considered a permanent feature, contributing to a Disconnected Migration Area in the CMZ analysis (Appendix D). Per discussions with State Parks, the pump house was determined to be critical park infrastructure and, as discussed further in Sections 7.4.3 and 8.5.2, was taken into consideration during the design and hydraulic analysis of the preferred alternative. The need for the existing pump house and/or its protection is currently being evaluated by State Parks. As the project progresses, further investigation of potential benefits/impacts to relocating the pump house or protecting the existing infrastructure will continue to be examined and discussed with State Parks in order to develop a multi-beneficial project.

Photo 19. Existing Pump House in Reach 4

4.8.4 Reach Objectives

Reach 4 is far enough upstream to be largely free of backwater effects from Lake Sammamish. As such, active stream processes, including channel migration and the potential for wood and gravel recruitment, are more prevalent, providing one of the most diverse habitat areas within the project boundary. The primary objectives of Reach 4 are the main project objectives described in Section 4.4 as well as maintaining and enhancing the existing natural processes of this reach. As previously discussed in Sections 4.8.1 and 4.8.2, in-channel wood is not prevalent and although a few medium- to large-sized logs have been deposited along the reach, it is far fewer than what would be expected under natural conditions or for optimized fish and wildlife habitat. This is due to very little wood being available for recruitment from the upstream reaches of Issaquah Creek or available within the existing riparian zone. The inclusion of LWM features placed strategically to enhance the existing channel geomorphic and hydraulic processes within Reach 4 would increase pool areas to provide cover, increase bar and riffle areas for potential spawning, and increase the quantity of low elevation floodplain habitat.

5 OUTREACH AND ENGAGEMENT

Outreach and engagement have been a critical element for this project's success. The Greenway Trust has worked closely with multiple interest groups including:

- Washington State Parks and Recreation Commission (the Landowner and the primary Partner with the Greenway Trust on the project) on project design decisions and considerations;
- The Muckleshoot Indian Tribe, Snoqualmie Tribe, Tulalip Tribes, and Confederated Tribes and Bands of the Yakama Nation (Sovereign Indian Tribal Governments) on specific elements integrated within the multi-benefit design to benefit natural resource and salmon recovery efforts (including positive habitat improvements for coho);
- The City of Issaquah (Local Permitting Agency) on design, conditions and limitations, compliance, and connectivity with upstream restoration efforts;
- Washington Department of Fish and Wildlife (WDFW) on project design and permit planning;
- King County and the WRIA 8 Technical Committee on design elements and benefits, funding plans, and multiple presentations to the Committee;
- The Kokanee Work Group on improvements that may benefit Kokanee;
- Friends of Lake Sammamish State Park, Trout Unlimited, and other area non-profits;
- Businesses such as The Boeing Company (who provided funding to support the Conceptual Design phase of the project) and Lakeside Industries (who donated 5.3 acres of land just upstream of the project area to expand the Park boundaries in 2018); and
- The local community who have donated time toward ecological restoration efforts and Park-area improvements (see Section 2.5). The project is extensively described in outreach materials on the Greenway Trust's website, at volunteer events and park tours, in education programming when teaching local students about salmon and ecosystem health; and in other avenues.

Interest groups were engaged early and through the Preliminary Design phase, where their feedback on the selected alternative is being incorporated to provide a multi-beneficial project through the lenses of various views and goals. The following lists examples of various meetings that were held with the above-mentioned interest groups as well as various project decisions or important elements that resulted.

<u>List of Meetings During Preliminary Design Phase:</u>

December 11, 2018 with Snoqualmie Tribe → David Steiner (Habitat Program Manager for the Environmental and Natural Resources Department of the Snoqualmie Tribe) met with Dan Hintz and Mackenzie Dolstad to discuss the project, design concept, and multi-species benefits. Follow up conversations included engagement with Matt Baerwalde with the Snoqualmie Tribe to discuss project elements.

January 8, 2019 with The Tulalip Tribes → Kurt Nelson (Environmental Program Manager with The Tulalip Tribes), Tor Bell (Greenway Trust), and Dan Hintz (Greenway Trust). Met at Tulalip Administration Building in Tulalip, WA to provide project overview and solicit feedback on conceptual design.

January 25, 2019 with Muckleshoot Indian Tribe → Martin Fox (Fisheries Biologist with Muckleshoot Indian Tribe), Tor Bell, Dan Hintz, Katie Mozes (NHC), and Casey Kramer (NHC). Met on site at Lake Sammamish State Park to look at existing site conditions and review the conceptual design.

February 25, 2019 with King County and Muckleshoot Indian Tribe → Jim Bower (King County Environmental Scientist III), Martin Fox, Casey Kramer, Katie Moses, Tor Bell, and Dan Hintz. Met at King Street Center in Seattle to discuss conceptual design elements.

May 6, 2019 with Washington State Parks → Nikki Fields (Parks Planner with WSP), Jamie Van De Vanter (Parks Planner with WSP), Jessica Logan (Environmental Program Manager with WSP), Scott White (Environmental Planner with Confluence Environmental Company), Chris Berger (Senior Ecologist with Confluence Environmental Company), Steve Burke (Director of Major Construction with MIG), Justin Martin (Senior Landscape Architect with MIG), Casey Kramer, Katie Mozes, Mackenzie Dolstad, and Dan Hintz. Meeting at WSP headquarters in Olympia, WA to review conceptual design plans and discuss overlap and coordination with Sunset Beach Phase 7 renovations.

May 16, 2019 with Washington Department of Fish and Wildlife → Zeke Rohloff (Habitat Biologist with WDFW), Miles Penk (Habitat Biologist with WDFW), Channing Syms (Habitat Program Engineer with WDFW), Tor Bell, and Dan Hintz. Site visit at Lake Sammamish Park to discuss conceptual design and permitting process.

June 18, 2019 with WRIA 8 → Jason Wilkinson (Projects and Funding Coordinator with WRIA 8), Mackenzie Dolstad, and Dan Hintz. Met at King Street Center in Seattle to discuss project design and funding opportunities.

June 27, 2019 with City of Issaquah → Bob York (Utilities Engineering Manager with City of Issaquah), Allen Quynn (Senior Engineer with City of Issaquah), Stacey Rush (Senior Engineer with City of Issaquah), Dan Hintz, and Mackenzie Dolstad. Meeting in Issaquah at City Hall Northwest to discuss project design and local permitting.

July 11, 2019 with the Salmon Recovery Funding Board → Elizabeth Butler (Salmon Recovery Grant Manager with the State Recreation and Conservation Office), Dave Caudill (Outdoor Grants Manager with RCO), Mackenzie Dolstad, and Dan Hintz. Site visit at Lake Sammamish State Park to discuss project design and funding.

July 15, 2019 with City of Issaquah → Allen Quynn, Greg Johnston (Senior Fisheries Biologist with The Watershed Company), Dan Hintz, and Mackenzie Dolstad. Conference call to discuss hydraulic modeling results and floodplain permitting.

July 22, 2019 with Washington State Parks → Greenway Trust, Northwest Hydraulic Consultants, Confluence Environmental Company, MIG, and State Parks staff. Met at State Parks headquarters in

Olympia to discuss project design, hydraulic modeling, and overlap with Sunset Beach Phase 7 mitigation plans.

October 9, 2019 with WRIA 8 Technical Review Team (TRT) → Katie Mozes (NHC) presented to TRT at King Street Center on revised Conceptual Design and to solicit feedback on project, including distributary channel, cost-benefit of increasing excavation to create opportunities for more LWM, monitoring, and other details.

November 20, 2019 with Washington State Parks → Joelene Boyd (Environmental Planner with State Parks), Jamie Van De Vanter, Tor Bell, Mackenzie Dolstad, and Dan Hintz. Nikki Fields & Julie Morse (NW Region Steward with State Parks) (called in). Meeting at Greenway Trust office in Seattle to further discuss hydraulic modeling and better introduce Joelene and Julie to the project.

January 9, 2020 with Army Corps of Engineers → Meeting with Jordan Bunch (Army Corps of Engineers Biologist for west King County), Jenni Creveling (TWC), Casey Kramer (NHC), Mackenzie Dolstad, and Dan Hintz. Met at COE building in Seattle to discuss project permitting and applicability of Nationwide Permit 27.

January 9, 2020 with Department of Ecology → David Radabaugh (NFIP Coordinator with WA Dept. of Ecology), Jamie Van De Vanter (Washington State Parks & Recreation Commission), Casey Kramer, Dan Hintz, and Mackenzie Dolstad. Meeting to discuss National Flood Insurance Program and floodplain permitting for project.

March 12, 2020 with Washington State Parks → Nikki Fields, Shawn Tobin (Northwest Region Manager at State Parks), Dan Meatte (Archaeologist with State Parks), Joelene Boyd, Suzanne Kagen (Program Specialist 2, Cascade Foothills Region of State Parks), Julie Morse, Jamie Van De Vanter, Mackenzie Dolstad, Tor Bell, and Dan Hintz. Conference call to discuss project design, cultural review, a letter of support from State Parks, and project funding.

April 14, 2020 with The Muckleshoot Indian Tribe and Hancock Natural Resource Group → Martin Fox, Nate Hayden (North Cascades Area Manager for Hancock Forest Management), Ben Doumit (Harvest Operations Area Manager, Hancock Forest Management), Casey Kramer, Katie Mozes, Mackenzie Dolstad, and Dan Hintz. Zoom meeting to discuss wood sourcing cost estimates and project design updates.

June 8, 2020 with Yakama Nation Fisheries → Ryan DeKnikker (Fish Habitat Biologist), Casey Kramer, Katie Mozes, Mackenzie Dolstad, and Dan Hintz. Zoom meeting to discuss LWM, construction strategies, and cost estimates.

6 PREFERRED DESIGN ALTERNATIVE ASSESSMENT

Throughout the conceptual design phase of the project, different design alternatives were evaluated and are described in detail in the *Lower Issaquah Creek Restoration at Lake Sammamish State Park – Conceptual Design Report* (NHC, 2017). The two main design alternatives proposed included a less aggressive design approach with less LWM structures; compared to the preferred alternative that includes more LWM structures and grading actions to promote natural stream processes. As mentioned in Section 5, these design alternatives were discussed extensively with project interest groups; specifically, in regard to balancing the habitat goals and reach objectives with project conditions. Ultimately the alternative with more LWM, Alternative 2, was chosen as the preferred design alternative.

Once a preferred design alternative was selected, the project team continued to work with interest groups to solicit additional input on project details. For example, in Reach 1, through extensive discussions with the Muckleshoot Indian Tribe and King County Habitat Biologist, it was determined that the proposed wood included downstream of roughly Station 14+00 (Appendix F) did not provide the same habitat benefits as the upstream reaches. The interest groups suggested removing this wood from the main channel downstream of roughly Station 14+00 in Reach 1 and including it in the more upstream reaches. Additionally, in both Reaches 2 and 4, various interest groups suggested converting some of the smaller, single wood structures into larger LWM structures that would have more influence on hydraulics and geomorphology. As a result of the extensive collaboration with various interest groups, the design alternative, Alternative 2, was modified into the preferred design alternative depicted in Appendix F.

The preferred design alternative was evaluated utilizing Fox and Bolton's (2007) 75th percentile for selecting the number and size of key pieces and the total number of wood pieces and wood volume. Utilizing this methodology, the minimum recommended number of key pieces for the project site would be 4 pieces per 100 meters of channel length, with each key piece having a volume of at least 6 cubic meters. The recommended number of total wood pieces is 63 per 100 meters of channel length, with a total wood volume of 99 cubic meters per 100 meters of channel length. For the preferred alternative, this equates to 1,152 total pieces of wood, with at least 73 being key pieces. The total volume of wood recommended for the project site, following Fox and Bolton (2007), is 1,811 cubic meters. As discussed previously, through various interest groups involvement, the project was set up to balance habitat goals with project conditions (See Sections 1 and 5). As such, the number and volume of wood was maximized to the extent practicable while still meeting the no rise requirement at the park boundary set forth by the City of Issaquah (Sections 1 and 5). The preferred design alternative proposes utilizing 435 total pieces of wood, including 74 key pieces, for a total volume of 1,120 cubic meters. The total number of key pieces meets the recommended number utilizing the Fox and Bolton criteria; however, the total number and volume of wood does not meet the recommended 75th percentile by 717 pieces and roughly 691 cubic meters, respectively. Slash and small pieces of LWM will also be incorporated into the larger proposed LWM jam structures, increasing the total wood volume. Details for these features will be evaluated further as the design progresses.

Due to experience with many other restoration projects, acquiring the total quantity for some of the recommended wood sizes, per Fox and Bolton, can be a challenge. For this reason, the team is taking a proactive approach early in the design process and has already begun to coordinate with the Muckleshoot Indian Tribe and the Timber Industry. Based on this coordination, a wood inventory for all recommended LWM has been developed in order for the project to determine where LWM can be sourced from and the most efficient way to transport it to the site (Appendix K). In addition, the team is assessing the most efficient way to construct the LWM structures in each of the reaches to minimize costs and impacts to the surrounding terrain. This coordination and further evaluations will continue as the project progresses through construction.

The preferred design alternative consists of five different typical wood structures as well as specific grading elements designed to provide the objectives of each reach discussed in Section 4. The five different wood structures consist of single pieces of wood, log jacks, small spur jams, large spur jams, and apex jams (See Appendix F). Each structure provides a different habitat function and are designed to promote specific geomorphic and hydraulic processes within each reach, as is discussed in detail in Section 7.

Figure 5 depicts an example layout of the single wood pieces (shown here as two overlapping pieces of wood), the log jacks, and the small spur jams. The single wood pieces are 2-foot in diameter and 25-foot long logs with rootwads (see Appendix F, Sheets LWM 1 and LWM 2). The log jacks consist of one, 3-foot diameter, 15-foot long log with rootwad and three, 2-foot diameter, 10-foot long logs without rootwads (see Appendix F, Sheet LWM 3). The small spur jams consist of one, 2-foot diameter, 20-foot long log with rootwad; two, 2-foot diameter, 15-foot long logs with rootwads; and one, 1-foot diameter, 10-foot long log with rootwad (see Appendix F, Sheet LWM 4). These structures are strategically placed throughout the project area to increase channel and bank roughness, channel hydraulic complexity, available cover, and functional habitat. Additionally, these structures are often placed in conjunction with other wood features to help promote specific geomorphic responses and habitat functions, as is described further in Section 7. During further stages of design, stability analyses will be conducted for the various LWM structures to determine if any of these proposed features would require anchoring. Anchoring may be through wedging pieces of wood between existing trees along the banks, utilizing streambed boulders, or by burying a portion of the LWM. Collaboration will continue with various interest groups to determine the need for anchoring and minimizing LWM transport of a specific size (See Section 5) into Reach 1 and Lake Sammamish depending on the location of the LWM structure.

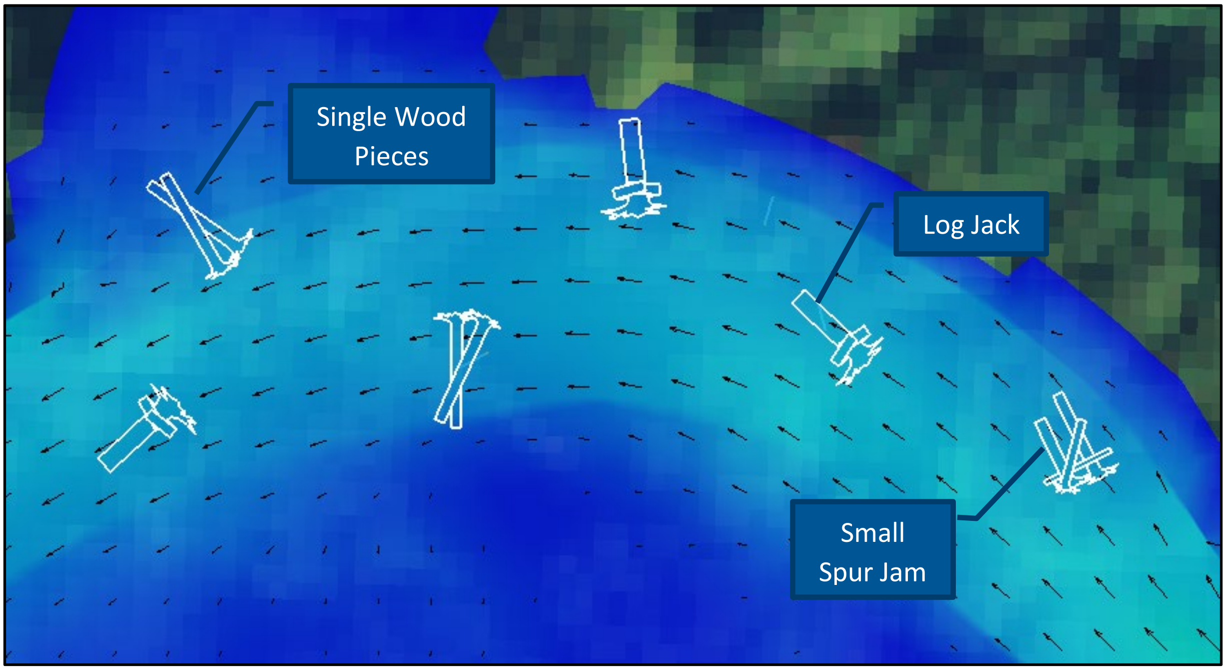

Figure 5. Wood Structure Example: Single Pieces, Log Jacks, and Small Spur Jams

Photo 20 depicts single pieces of wood and how they can provide functional habitat. At the front of the LWM shown in Photo 20, velocities accelerated around the rootballs, which scoured out the bed material and created a small pool. At some low-flow elevations, velocities in these types of small pools effectively becomes negligible. These types of temporal low-flow habitats, which are typically connected, but away from, mainstem flows, are frequently used by salmonid fry. Behind the rootball, velocities slowed down which allowed the channel to deposit sediment, forming bars. The Log Jack structures are designed to provide an amplification of this specific response to what you see in nature with single piece LWM structures. The triangle pieces of wood anchored around the rootball will function as an extension of the rootball itself, increasing the pool creation at the rootball and bar formation behind it.

Photo 20. Wood Structure Example: Single Pieces

The large spur jams are strategically utilized throughout the project area to provide various functions. Depending on the specific placement of each structure, they are intended to increase channel and bank roughness, channel hydraulic complexity, and available cover. They are also intended for promoting aggradation and channel migration/sinuosity, redirect and split flow, and/or provide cover and functional habitat. These large spur jam structures consist of two, 3-foot diameter, 30-foot long logs with rootwads and four, 2-foot diameter, 20-foot long logs with rootwads (see Appendix F, Sheet LWM 5).

Figure 6 shows one example of how the large spur jams can affect the hydraulic characteristics of the channel near the structure(s). The large spur jams depicted in this figure are proposed in Reach 2, on the outside of a bend, where channel velocities are higher (See Appendix F, Sheet PR 7, Logs #28 and #29). These specific structures were placed in order to redirect flow at this location, toward the center of the channel, as well as work congruently with a series of LWM structures upstream to promote aggradation and increase roughness (see Section 7.2.1). The arrow size and color in the figure denotes the velocity magnitude – the larger the arrow, the higher the velocity; the smaller the arrow, the lower the velocity. As depicted in these model results, with the inclusion of the large spur jams, the higher velocity values are moved towards the center of the channel while the velocity along the outside of the bend, upstream, and adjacent to these jams are lowered. The model results prove that the large spur jams have the ability to redirect flow and increase channel roughness. Additionally, with the local increase in channel velocity at the front of these structures, pool areas are expected to form in front of and under the wood, which provides a diverse range of habitats at various flows for both juvenile and adult salmonids and sculpins as well as other native fish. Furthermore, with the lower channel velocity behind the structures, bars would be expected to form, increasing channel floodplain interaction and the quantity of available low-elevation floodplain and low velocity edge habitats (see Photo 21 and Photo 22). Low-velocity edge habitats created by bars are frequently utilized by salmonid fry, juvenile sculpins, dace, and various other life stages of important native species. Photo 23 shows an aerial view of how bank erosion can be formed near large spur jams, promoting aggradation and increased sinuosity.

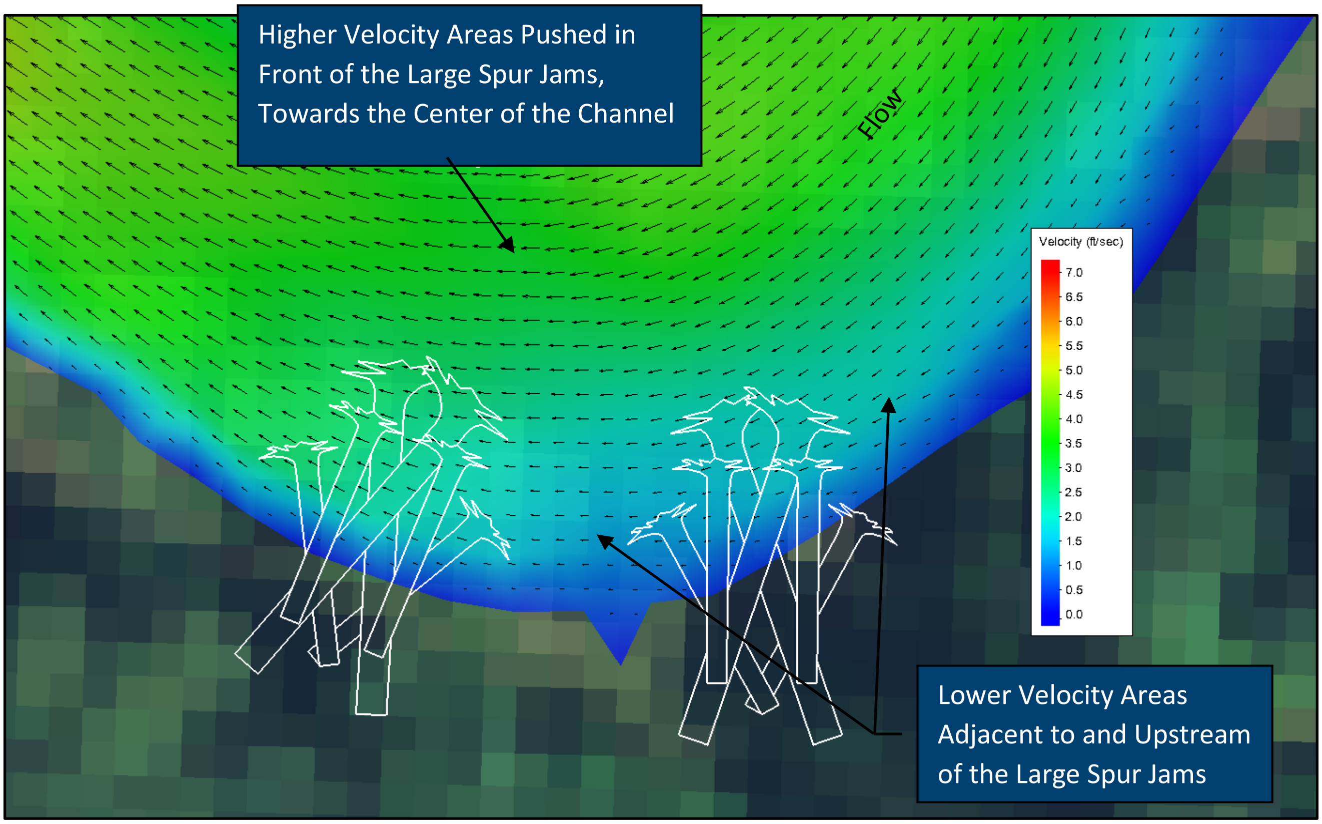

Figure 6. Wood Structure Example: Large Spur Jams

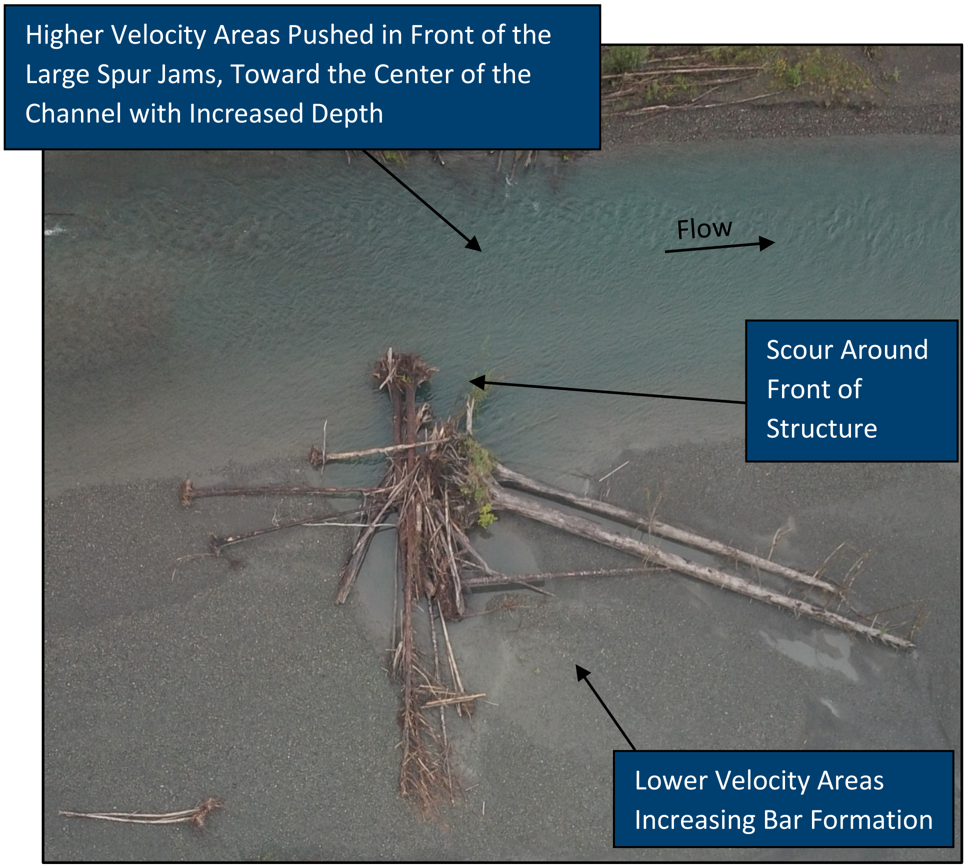

Photo 21. Large Spur Jam – Velocity Influence Example

Photo 22. Large Spur Jam Example

Photo 23. Large Spur Jam – Bank Erosion Example

The largest LWM structures utilized in the preferred design alternative are the apex jams. Figure 7 and Photo 24 show an example of how the apex jams affect the hydraulic characteristics of the channel near the wood structure. The apex jam structures consist of two, 3-foot diameter, 30-foot long logs with rootwads, and ten, 2-foot diameter, 20-foot long logs with rootwads (see Appendix F, Sheet LWM 6). These structures are strategically placed throughout the project area to primarily promote channel sinuosity, split flow, and provide wood recruitment. However, they also promote aggradation, provide channel complexity, increase cover, and provide functional habitat. The apex jam depicted in Figure 7 is located in Reach 4 at approximately Station 59+75 (Appendix F, Sheet PR 13, #88). As is depicted in the figure, flow is pushed around the outsides of the apex jam, increasing velocities as it moves around the structure while also providing a hydraulic shadow directly behind the apex jam. This hydraulic shadow promotes aggradation and bar formation while also providing a place of refuge for aquatic species. At nearly all flow stages, apex jam features typically support (both directly and indirectly) a high range of diverse habitats available to various life stages of most native fish species. Photo 25 depicts juvenile salmonids utilizing a large LWM structure constructed on the Skagit River for refuge. Similar to the large spur jams, the increase in channel velocity around these structures would be expected to not only split flows, but also promote the creation of pool areas adjacent to and under the wood (see Photo 21).

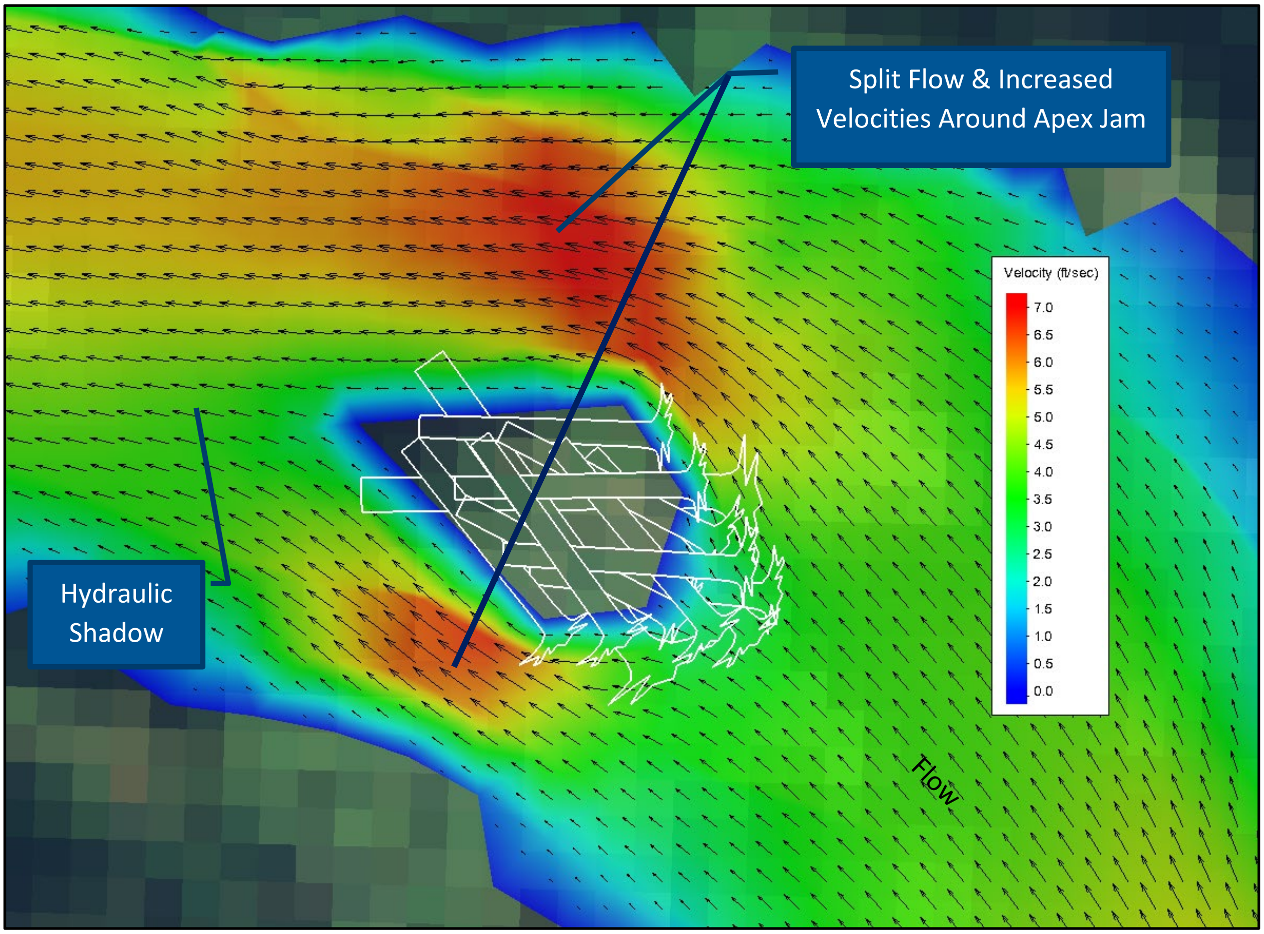

Figure 7. Wood Structure Example: Apex Jams

Photo 24. Apex Jam – Split Flow Example

Photo 25. Juveniles Utilizing a LWM Structure For Refuge

7 PRELIMINARY DESIGN ANALYSIS

As discussed in Section 4, the project area is divided into four distinct reaches. Sections 7.1 through 7.4 describe the in-stream elements of the preferred design alternative in detail through each reach. These elements in conjunction with the riparian restoration efforts that will be included as part of this project (see Section 7.5) and other restoration efforts within the State Park will provide a comprehensive, holistic, stream restoration effort.

7.1 Reach 1

As described in Section 4.5.4, the primary objectives in Reach 1 are to increase total habitat area, available woody debris cover within the perennially wetted channel, channel complexity, hydraulic diversity and the available distributary habitat potential; re-establishment of low-level floodplain; and provide vegetation management. Critical park infrastructure in the reach, as communicated by State Parks, include a pedestrian bridge that crosses Issaquah Creek at roughly Station 18+00, a bathhouse, parking lot, and a boardwalk trail that follows the left bank of the creek (see Appendix A). The preferred design alternative described here is designed to meet the primary goals of Reach 1, without adversely affecting the existing critical infrastructure identified by State Parks within the park. The plan sheets included in Appendix F, Sheets PR-1 through PR-4, depict the proposed preferred design alternative details.

The preferred design alternative in Reach 1 consists of four key elements:

1. A constructed distributary channel at roughly Station 16+00 that connects the existing creek channel to its historic location to the northeast (see Section 4, Figure 4) and includes the placement of single LWM pieces and structures along the new channel.
2. A set of engineered spur and apex log jams at the constructed distributary channel offtake location (Appendix F, Sheet PR-4, LWM #2 and #3).
3. A set of spur jams between the existing pedestrian bridge and distributary channel location (Appendix F, Sheet PR-4, LWM #4 and #15).
4. Riparian planting (Section 7.5 and Appendix F, Sheet RP-1).

7.1.1 Geomorphology

Each of the key elements proposed in Reach 1 are expected to enhance specific geomorphic functions. As mentioned in Section 4.5.1, multiple channel threads within the floodplain are what you would typically find in this type of an environment which would provide optimal hydraulic, geomorphic and habitat complexity. The constructed distributary channel is designed to accelerate this floodplain function and encourage the development of multiple channel threads throughout the right bank floodplain over time. During further stages of design, the proposed layout of the distributary channel will be further evaluated with various interest groups to balance the optimal location for this feature with potential impacts to existing wetlands. Section 8.2.2 further discusses the expected hydraulic response to the distributary channel. Preliminary model results indicate that approximately 55 cubic feet per second will be diverted into the distributary channel during the 2-year peak flow event. During this type of event, the corresponding velocities range between 1 and 2 feet per second, which is capable of transporting the type of sediment that is expected to be present. The distributary channel is designed to be dynamic, similar to what would be expected in a natural distributary channel. Some bed material may be deposited during periods of low velocities (e.g. high lake level); however, the LWM structures included are designed to deflect flows into the distributary channel and help increase velocities to flush this sediment out during periods of low lake level with high creek flows.

The set of engineered spur and apex jams located at the constructed distributary channel's offtake are designed to push flow from the existing channel into the distributary channel. It is expected that over time, these features would provide opportunity for additional small wood recruitment, further promoting flow to split into the distributary channel. As discussed in Sections 1, 4.6, and 5, State Parks would like to reduce the amount of LWM being transported into Lake Sammamish. Reach 2 has specific features designed to act as wood filters in order to minimize the transport. However, collaboration with State Parks' staff is ongoing to determine the minimum size of LWM the filters in Reach 2 should be designed to retain. As such, some LWM is expected to still freely move downstream into Reach 1. The set of engineered spur and apex jams will provide an additional location for retaining transported wood before it reaches Lake Sammamish.

The set of spur jams located between the existing pedestrian bridge and offtake channel are designed to increase thalweg sinuosity and low-moderate flow channel hydraulic diversity. As discussed in Section 6, the large spur jams have the ability to redirect flow and can be positioned to promote new channel features, as designed for Reach 1. Furthermore, continued vegetation management within the riparian zone along both banks (such as removing non-native invasive species and establishing a forested condition that is based on native trees and understory species) will assist in providing a long-term source of woody material to the creek (see Section 7.5). As mentioned in Section 4.5.1, the primary mechanism for in-channel wood sourcing in Reach 1 is from wind throw, which would be expected to continue after project construction.

7.1.2 Habitat

As discussed in Section 4.5.2, salmonid spawning is generally not expected to occur along this reach due to low velocities and stream energy that results in a substrate that is too fine grained to support spawning. Due to this, Reach 1 functions primarily as migratory and short-term rearing habitat. Features designed to increase the sinuosity of this reach, and/or the developmentment of distributary channels (such as the set of engineered spur and apex log jams at the constructed distributary channel offtake location), would accelerate the formation of high-quality habitat through natural processes. All of the salmonid species which use Issaquah Creek - Chinook, coho, steelhead, sockeye, kokanee, cutthroat - use this reach primarily to get safely to and from the spawning reaches and rearing habitat farther upstream in Issaquah Creek and its tributaries. The proposed distributary channel is expected to be beneficial to juveniles of some species year-round as it provides additional rearing habitat. For example, natural origin coho in life stages ranging from very small fry to year old juveniles would be expected to heavily utilize a feature like this with zero to low velocity year-round. Low velocity features develop a deep silty-loamy substrate, which is ideal for sustaining countless midge pupae, a preferred prey base that will support various species throughout the year. Juvenile Chinook tend to make use of stream mouth, delta, and estuary areas as intermediate-term rearing habitat, which typically include a network of distributary channels as is proposed.

7.1.3 Infrastructure

Reach 1 is primarily dominated by the backwater influence from Lake Sammamish. Therefore, the proposed preferred design alternative does not have a hydraulic impact during the FEMA 100-year event to the existing critical park infrastructure identified by State Parks (see Section 8.2.2 for further discussion).

7.2 Reach 2

Reach 2 is the lowest alluvial reach of the creek and includes a strongly concave channel profile with diverse habitat. As discussed in Section 4.6.4, the primary objectives for Reach 2 are to increase total habitat area, increase available woody debris cover within the perennially wetted channel, increase channel complexity, increase hydraulic diversity, re-establishment of low-elevation floodplain, provide vegetation management, maintain the existing natural processes of this reach, and increase the reliability to trap incoming woody material. The plan sheets depicted in Appendix F, Sheets PR-5 through PR-9, describe the proposed preferred design alternative in detail.

The preferred design alternative in Reach 2 has seven key elements:

1. A set of anchored individual wood pieces and log jacks near Station 21+00.
2. A set of two spur jams and one apex jam at approximately Station 25+00.
3. A pilot channel at approximately Station 41+00.
4. An extensive volume of large wood and large wood structures placed mostly between Stations 30+00 and 40+00.
5. An apex jam placed in the left bank floodplain of the pilot channel.
6. Various wood pieces and small structures placed throughout the historic oxbow feature.
7. Riparian planting (Section 7.5 and Appendix F, Sheet RP-1).

7.2.1 Geomorphology

Each of the seven key elements proposed within Reach 2 work together to provide specific geomorphic functions within the reach in order to meet the reach objectives. The set of two spur jams and one apex jam at approximately Station 25+00 are designed to act as a reliable long-term collector for wood transported into the reach from upstream. This would prevent loss of wood from the creek and reduce the transport of wood to the pedestrian bridge in Reach 1 and into Lake Sammamish, where it may pose or be perceived as a hazard. The set of anchored individual pieces and log jacks downstream of these features are included to help increase cover and add an additional location for wood recruitment. These anchored individual features would also be expected to collect wood that is being transported from upstream, minimizing the potential for this material to migrate into the lake. As previously mentioned, through ongoing discussions with State Parks (see Section 5), these wood features will be designed to collect specific sizes of transported LWM while allowing some LWM to be further transported downstream.

The pilot channel (at approximately Station 41+00) and the extensive volume of LWM structures placed within the main channel are expected to work together to promote hydraulic diversity, split flow, and reactivate the historic oxbow feature. The pilot channel, in conjunction with the large spur jam and log jacks at its entrance, are designed to push flow from the main creek into the oxbow. During later stages of design, the proposed layout of the pilot channel will be further evaluated with interest groups to balance the optimal location for this feature with limiting grading and potential impacts to wetlands, to the extent possible. As discussed in Section 6, large spur jams have the ability to redirect flow and log jacks will increase channel roughness, further encouraging flow to enter the oxbow. The additional pieces of large wood through the existing main channel are also expected to increase channel roughness as well as slow channel velocities (see Section 8.3.2 and Appendix H) and induce degradation in order to raise the channel grade upstream at the location of the pilot channel. This is expected to increase the hyporheic exchange and further promote the activation of the historic oxbow. The creek would be expected to move between the oxbow and the main channel over time, creating diverse geomorphic conditions following natural stream processes. Section 8.3.2 discusses the modeled hydraulic response to these features in more detail, which further verify the expected geomorphic response.

The apex jam placed in the left bank floodplain, downstream of the pilot channel, is designed to increase the complexity of the new pilot channel and protect the existing, relatively mature riparian forest south of the oxbow. This feature is expected to encourage flow around the oxbow, promoting a longer, more sinuous channel. The various single wood pieces and small structures placed throughout the oxbow feature are designed to provide cover and increase hydraulic diversity.

7.2.2 Habitat

There is an abundance of wood and pools with ample and complex cover in Reach 2 that has been scoured by log jams and a tangle of wood of various sizes (see Section 4.6). These pool areas beneath and around the jams tend to provide excellent rearing habitat for juvenile salmonids and holding areas for adults. This is the first such complex habitat adults may have encountered on their way upstream and the last that juveniles may encounter on their way down. Such rearing habitat is less important to sockeye and kokanee, which move more quickly to the lake, but is used extensively by other species like Chinook, coho, steelhead, and cutthroat. Though slightly improved compared to Reach 1, substrate conditions are still less than ideal for spawning, with finer-grained materials more prevalent than gravel. The proposed design features enhance the existing natural processes of this fully alluvial reach. The addition of the pilot channel and increased wood volume provide lower velocity areas of refuge for juveniles through the main channel, provide abundant off channel refugia habitat, and additional pool formation beneath and around the large jams. Additionally, the two spur jams, working in conjunction with the apex jam, prevent wood from moving further downstream, increasing the available habitat within Reach 2.

7.2.3 Infrastructure

Several pedestrian trails are located along both the left and right banks of Issaquah Creek through Reach 2. Additionally, the outfall of the Pickering Ditch is located at approximately Station 30+00 (see Appendix A). The potential effects of the proposed preferred design on the Pickering Ditch were evaluated in the hydraulic model (see Section 8.3.2). As previously mentioned, the pedestrian bridge over the Pickering Ditch and several areas of the existing trails were destroyed during two peak flow events in early February 2020 (Section 4.6). As the project progresses, interest group involvement will continue as part of the Park Master Plan Update and EIS and specific features, such as a new trail network throughout the park and new pedestrian bridge over the Pickering Ditch in relation to the preferred design alternative.

7.3 Reach 3

Reach 3 occurs immediately upstream of the site of the late nineteenth/early twentieth century avulsion and has had little to no channel migration since then. The reach consists of a highly entrenched channel with high flow velocities and relatively little available juvenile rearing or adult holding habitat and potential fish passage barrier conditions during higher flow events. As discussed in Section 4.7.4, the primary objectives for Reach 3 are to increase total habitat area, available woody debris cover within the perennially wetted channel, channel complexity, hydraulic diversity; re-establishment of low-level floodplain; provide vegetation management; and encourage the initiation of new meander features. The plan sheets depicted in Appendix F, Sheets PR-9 through PR-10, illustrate the proposed preferred design alternative details for Reach 3.

The preferred design alternative for Reach 3 has four key elements:

1. Various large wood structures and individual pieces placed along both banks.
2. One apex jam at Station 44+50 (Sheet PR-9, LWM #69).
3. Bank scraping.
4. Riparian planting (Section 7.5 and Appendix F, Sheet RP-1).

7.3.1 Geomorphology

The four key features proposed in Reach 3 are expected to promote natural stream processes with the encouragement of increased sinuosity and meander formation through an otherwise straight reach. The apex jam at roughly Station 44+50 is expected to split the flow, pushing higher channel velocities towards the outer banks to encourage bank erosion and meander formation. The various large wood structures and individual pieces placed along both banks are expected to increase thalweg sinuosity and hydraulic complexity by directing flow against the opposite banks and to also initiate meander formation. The bank scraping is expected to remove existing root strength and increase the likelihood of this meander formation in a shorter timeframe. During later stages of design, the proposed bank scraping limits will be further evaluated with interest groups to balance the optimal design for these features to encourage channel migration and increased sinuosity with limiting grading, to the extent possible.

7.3.2 Habitat

As discussed in Section 4.7.2, Reach 3 has limited habitat features in terms of wood and pool/riffle sequence in its existing condition. The reach currently serves more as a migration corridor for upstream-bound spawners and downstream-bound juveniles but has much potential for improvement with respect to both rearing and holding. The reach contains more gravel and less fines proceeding upstream so localized riffle areas could function as spawning habitat. Of note, kokanee requires a smaller-sized, finer-gravel substrate than other salmonid fish found in Issaquah Creek, and such a smaller substrate size would be more readily provided, fostered, and maintained along this reach than the larger-sized gravels suitable for the other salmonids, notably Chinook salmon. Furthermore, kokanee may tend, on average, to move a shorter distance upstream of Lake Sammamish to spawn than the other species. New meander features, as promoted and advanced by the preferred alternative, are expected to migrate laterally and increase the quantity of available low-elevation floodplain habitat. In addition to the expected additional floodplain habitat, the large spur jams would be expected to promote bar and pool formation, with protective cover, thus providing excellent rearing habitat for juvenile salmonids and holding areas for adults.

7.3.3 Infrastructure

As discussed in Section 4.7, this reach has historically had the least amount of channel migration with the exception of Reach 1. As such, this reach is being evaluated in the Park Master Plan Update and EIS as a potential location for a new pedestrian bridge crossing Issaquah Creek. Collaboration with State Parks will continue to take place to provide a design solution that is forward compatible with the long-term development of a comprehensive State Parks trail plan (a process that is currently underway, led by State Parks and a working group with the Friends of Lake Sammamish State Park) and a future bridge crossing in this Reach (State Parks is currently seeking funding for this feature).

7.4 Reach 4

Channel migration following initial incision in Reach 4 has restored a large area of existing floodplain and most large-scale geomorphic processes but has limited LWM recruitment potential from upstream, resulting in low large wood concentrations throughout the reach (see Section 4.8). The primary objectives for Reach 4 are to increase total habitat area, available woody debris cover within the perennially wetted channel, channel complexity, hydraulic diversity; re-establishment of low-elevation floodplain; provide vegetation management; and enhance the existing natural processes of this reach (see Section 4.8.4). The plan sheets included in Appendix F, Sheets PR-11 through PR-13, depict the proposed preferred design alternative details for Reach 4.

The preferred design alternative for Reach 4 has eight key elements:

1. Removal of riprap along the left bank at approximately Station 62+00 (Pending on-going discussions with State Parks).
2. Placement of several log jacks (See Appendix F, Detail Sheet LWM 3).

3. Placement of several individual pieces of wood (See Appendix F, Detail Sheets LWM 1 and LWM 2).
4. Placement of a few apex jams (See Appendix F, Sheet PR-12 and Detail Sheet LWM 6).
5. Placement of large spur jams at several locations (See Appendix F, Sheets PR-12, PR-13, and Detail Sheet LWM 5).
6. Excavation of a pilot channel at the upstream most spur jam (See Appendix F, Sheets PR-13).
7. Construction of two spur jams at the location of the revetment, protecting a State Parks Pump House facility on the left bank near Station 63+00 (Pending on-going discussions with State Parks).
8. Riparian planting (Section 7.5 and Appendix F, Sheet RP-1).

7.4.1 Geomorphology

The key elements proposed for Reach 4 are designed specifically to enhance the existing natural stream processes of the reach. For example, the placement of log jacks, in conjunction with other structure types, are expected to initiate the formation of LWM jams contributing to a wide range of geomorphic functions. The individual pieces of wood are placed strategically where high banks should allow self-ballasting, where they can be wedged amongst existing riparian trees or placed on bars where they can also initiate LWM jam formation. This wood will increase channel hydraulic complexity and available cover. Some future mobilization, transport, and reorganization of this material would be expected, further enhancing the natural processes within the reach.

The apex jams are designed to encourage stable island formation in the floodplain and pool formation in the channel. The apex jams, as well as the large spur jams, are placed in the middle of the active channel to encourage the development of flow splits. Excavation of a pilot channel, along the left bank at the upstream most spur jam, is designed to split the flow and accelerate the development of hydraulic complexity through the existing channel bend. The jam at Station 57+00 is designed to protect the existing island near the large abandoned oxbow and allow for the development of mature riparian vegetation. Additionally, the spur jams placed at various locations along the banks are designed to encourage the formation of deep pools. Riparian plantings throughout Reach 4 will further enhance natural stream processes and will provide a source for future wood recruitment as the channel evolves over time.

7.4.2 Habitat

Reach 4 is far enough upstream and has an increased gradient, allowing for it to be largely free of “lake effects”. As such, active stream processes, including channel migration with wood and gravel recruitment, are more prevalent. Existing localized riffle areas throughout Reach 4 may currently function as spawning habitat and floodplain areas, which are currently being re-established. This reach has more potential for diverse and dynamic habitat with all-around use by all the salmonid fish species present (Chinook, coho, steelhead, sockeye, kokanee, cutthroat) and across various life history stages – adults for upstream migration and holding and juveniles for downstream migration and rearing. The preferred design alternative features are expected to increase the total amount of stable to partially stable wood, which will enhance the existing natural processes of this reach, provide abundant cover and hydraulic diversity, and increase and improve habitat throughout the reach. For example, the proposed apex jams and large spur jams are expected to promote bar and pool formation, providing excellent rearing habitat for juvenile salmonids, and holding areas for adults.

7.4.3 Infrastructure

Reach 4 includes existing trails along the top of the riverbanks as well as a pump house located on the left bank at roughly Station 63+00 (see Appendix A). Construction of two spur jams is proposed as an optional feature on the left bank, at the upstream end of the revetment, protecting the State Parks Pump House facility. These jams would be placed at an elevation to minimize possible future channel migration from becoming entrained against the existing riprap revetment, compromising the pump house. However, with the removal of the riprap downstream of this section, channel migration through this area would be allowed. Collaboration with State Parks will continue to take place, identifying where pump house utilities are, in order to provide a design solution that meets the habitat objectives for the reach without adversely affecting any existing critical park infrastructures.

7.5 Proposed Riparian Restoration Efforts

The proposed riparian restoration efforts as part of the preferred design alternative, will enhance and connect with efforts currently taking place along Issaquah Creek in the Park and immediately upstream on property owned by the City of Issaquah. With the proposed preferred design alternative (See Sections 6 and 7.1 through 7.4), the Greenway Trust is proposing to bring the last untouched sections of the riparian buffer of Issaquah Creek into active restoration (See Sheet RP-1 in Appendix F), as well as continue restoration stewardship of the areas where restoration is already taking place (see Section 9). As previously mentioned, the riparian restoration included as part of the preferred design alternative, will work in unison with the in-stream elements to provide a comprehensive, holistic, stream restoration effort. The riparian restoration will involve two distinct elements:

Site C1 – Restoring approximately 3.5 acres of new riparian buffer in the area along the right bank of the creek near the upstream Park boundary (Appendix F). Currently a monoculture of blackberry and non-native grasses, Greenway Trust crews and contractors will use manual, mechanical, and chemical best practices to remove these invasive weeds and prep the site for the installation of 3,150 native trees and shrubs (a combination of potted plants and live stakes), supported by volunteers and sponsored AmeriCorps members. Restoration efforts will also include the planting of 2,000 native wetland emergent species in zone C1.2. Species that are planted will focus on native conifers, such as Douglas fir and Grand Fir, along with a wide diversity of native shrubs. Incorporating species that have strong ethnobotanical, cultural, and historical values, such as western redcedar, snowberry, salmonberry, thimbleberry, and native willows, is the goal. Wetland emergent plants will include species that have been successful at other nearby sites, including sawbeak sedge, slough sedge, and daggerleaf rush.

Site A6 – Re-establishment of approximately 1.5 acres of functioning stream buffers in order to create a wider, more vegetated stream buffer. The proposed areas are adjacent to the existing Sunset Beach sites, Wetland A and B, and along the left bank following the removal and/or reconfiguring of the Sunset Beach parking lot (Appendix F). This effort will include planting approximately 850 native trees and shrubs. These activities will be coordinated with State Parks as part of the redevelopment and recreational improvements that are currently underway in this area, including a setback of the existing Sunset Beach parking lot to increase the buffer zone.

8 HYDRAULIC MODELING

The hydraulic analysis for the existing and proposed conditions of Issaquah Creek was performed with Sedimentation and River Hydraulics – Two Dimension (SRH-2D; U.S. Bureau of Reclamation, 2016), a two-dimensional, depth-averaged hydraulic model. The SRH-2D model allowed for a detailed understanding of the hydraulics throughout the model domain.

8.1 Model Development

The development of the SRH-2D models for the existing and proposed conditions involved the following five successive steps: 1) gathering topographic and bathymetric data at the project site (Section 8.1.1); 2) delineating the domains of the existing and proposed conditions models and constructing the existing and proposed conditions meshes (Section 8.1.2); 3) specifying the appropriate boundary conditions (Section 8.1.3); 4) selecting appropriate hydraulic roughness values (Section 8.1.4); and 5) incorporating the LWM (Section 8.1.5).

8.1.1 Terrain Data

Terrain data for the existing channel, banks, oxbows, and Pickering Ditch was obtained from topographic surveys conducted by NHC personnel in 2016 and 2018. The collected data was used to generate existing conditions surfaces of the surveyed features. These surfaces were combined with a 2016 LiDAR dataset (Quantum Spatial, 2016) to create a composite existing conditions surface. Because the LiDAR dataset captured the lake water surface at the time it was collected, portions of the dataset near the lake's shoreline were lowered at a 30(h):1(v) grade to create a smooth transition to an assumed lake bottom elevation of 28 feet. This enabled lake levels lower than the water surface captured in the LiDAR to be used for the downstream boundary condition of the model (see Section 8.1.3). NHC generated a topographic surface for the proposed conditions model by modifying the existing conditions topographic surface so that it reflected the selected preferred alternative (see Sections 6 and 7 for details).

8.1.2 Model Domain and Computational Mesh

The existing and proposed conditions topographic surfaces were imported into the Surface-water Modeling System (SMS) (Aquaveo, 2020). SMS is a computer program which provides a user interface for building and running hydraulic models, including SRH-2D. Utilizing the topographic surfaces, a model domain was set to create meshes for both existing and proposed conditions. A mesh is the computational domain of the hydraulic model and is utilized by SRH-2D to calculate water depth, velocity, and other hydraulic parameters.

The SRH-2D model was run assuming a fixed bed, therefore the mesh represents the bed in the existing and proposed terrain data and does not change in response to flow and sediment transport, as would be expected under natural conditions. Consequently, the grading for the preferred alternative represents grading at the time of construction. Because the existing and proposed conditions meshes were created using the terrain data, as is described in Section 8.1.1, they do not represent any changes to infrastructure or the Issaquah Creek channel and banks since the surveys. Therefore, the meshes used for modeling do not include impacts from the floods in 2020 (e.g., failure of the pedestrian bridge at Pickering Ditch and the associated bank deformation described in Section 4.6).

The existing and proposed conditions model domains coincide with each other and extend from Lake Sammamish up to approximately 100 feet downstream of the Issaquah Creek crossing of NW Sammamish Road. The model domains are between approximately 400- and 4,400-feet wide. The upstream domain limit was set sufficiently far enough away from the areas of interest to minimize any effects on the hydraulics. The location of the downstream limit was controlled by Lake Sammamish (see Section 8.1.3 for a description of how the lake elevation was selected for various peak flow events). The existing and proposed conditions model domains are depicted in Figure G.1 in Appendix G and Figure H.1 in Appendix H, respectively.

Based on channel and floodplain topography, the meshes were created with an element density that represents the topographic survey and consist of approximately 150,200 elements for existing conditions and 153,400 elements for proposed conditions. For both existing and proposed conditions, the elements along Issaquah Creek have an approximate 6- to 7-foot vertex spacing to adequately represent the channel shape. An approximately 18-foot vertex spacing was used in the floodplain, roughly 100 feet away from the main channel. Elements in Lake Sammamish that are further away from Issaquah Creek range from 40- to 50-foot vertex spacing. In both the existing and proposed models, the mesh transitions gradually between the smaller and larger element resolutions to ensure stability.

8.1.3 Boundary Conditions

The existing and proposed conditions hydraulic models required various boundary conditions. The boundary conditions used included the inflow rate at the upstream end of the model domain and the water surface elevation (WSE) at its downstream end at Lake Sammamish. The existing and proposed conditions models also included boundary condition lines to represent two pedestrian bridges within the domain limits. One bridge crosses Issaquah Creek within Reach 1 and the other crosses Pickering Ditch near its confluence with Issaquah Creek in Reach 2.

The inflow rate specified at the upstream boundary condition, for a given simulation, was the one corresponding to the peak flow being modeled. The inflow rates specified as the upstream boundary conditions, in both the existing and proposed conditions models, are provided in Table 4 (see Table 2 and Section 3 for the determination of peak flows). The upstream boundary condition was placed far enough upstream to not influence the hydraulic results at areas of interest. The inflow for all peak flow simulations was designated subcritical, to match the expected flow regimes on Issaquah Creek at the boundary condition.

The model was run in steady-state mode for all modeled simulations. Running the model in steady-state may provide conservative inundation limits in some areas, as noted in the Reach 4 results discussion below (Section 8.5). This will continue to be evaluated during further stages of design.

A sensitivity analysis on the downstream boundary conditions was performed with various peak flood events to evaluate the impact of the elevation of Lake Sammamish on model results. The sensitivity analysis suggested that a backwatered condition is expected through Reach 1 of Issaquah Creek under all flow scenarios due to the elevation of the Lake Sammamish outlet weir (see Section 3).

The lake elevation used for the flows modeled, and included in this report, are included in Table 4. The lake elevation for the 2-year flow was selected as the 50% exceedance probability from the lake level analysis described in Section 3.3 (see Table 3). The lake level for the February 6, 2020 flood event (approximately a 10-year peak flow) was selected using the available recorded elevation data at the USGS Lake Sammamish gage (Gage Number 12122000). The lake level selected was based on the timing of the peak flow at the USGS Issaquah Creek stream gage (Gage Number 12121600). The lake level reached its max peak after the peak of the streamflow gage, which is consistent for other large flows measured both at the gage and lake. This is due to the lake continually filling after the peak flow has passed due to storage and outflow (outlet weir) of the lake. At the request of the City of Issaquah, the lake elevation for the 100-year flow was selected based on the Base Flood Elevation (BFE) indicated in the FEMA FIS report for Lake Sammamish (see Section 8.6 for additional information).

Table 4. Modeled Peak Flows for Issaquah Creek and Lake Sammamish Elevations

Mean Recurrence Interval (MRI)	Lower Issaquah Creek Modeled Flow Values (cfs)	Modeled Lake Sammamish Elevation (feet, NAVD 88)
2	1,530	30.9
*	2,690	33.6
100	3,960	37.0

* February 6, 2020 Storm Event

The pedestrian bridges were included in the existing and proposed conditions models through the specification of a pair of arcs located at the surveyed locations of each bridge's upstream and downstream faces. This boundary condition enables the model to calculate hydraulics for pressurized or overtopping flow, if applicable. The bridges' geometry, type, and site data obtained from the NHC survey and field visits were utilized for specifying the boundary condition arcs. As noted above in Section 8.1.2, the model was developed using terrain data from before the impacts of floods in 2020 (including the Pickering Ditch Bridge failure) and therefore includes the Pickering Ditch Bridge in place.

8.1.4 Hydraulic Roughness Values

The hydraulic roughness values assigned to both existing and proposed conditions models were based on standard values listed in *Open-Channel Hydraulics* (Chow, 1959) and recommended by the Federal Highway Administration (2008) for the observed and expected site conditions (Section 4 and Section 7). An aerial image of the project site, in addition to observations during the site reconnaissance, was utilized to delineate the general roughness boundaries for the model domain. A sensitivity analysis was performed to evaluate the effects of hydraulic roughness on depths and velocities. Table 5 contains the Manning's n values utilized within the model domain.

Table 5. Hydraulic Roughness Values

Location	Manning's n
Streambed	0.042
Channel Banks	0.06
Large Logjams	0.075
Oxbow	0.04
Lake	0.04
Trees	0.085
Shrubs	0.06
Grass	0.05
Beaver Dam	0.06
Pavement and Developments	0.02
Park Grounds	0.035

8.1.5 Large Woody Material

LWM was incorporated into the existing and proposed conditions models with different approaches in order to best represent hydraulic conditions. The apex logjams were removed from the computational mesh in order to simulate the expected hydraulic conditions, with water flowing around the structure, once constructed. Spur jams and log jacks were modeled with obstruction coverages within SMS. Features included on this type of coverage represent in-channel obstructions and were defined, including their elevation, size, porosity and drag coefficient, based on the LWM design or surveyed information. Based on previous modeling experience and sensitivity analyses, the drag coefficients and porosity for the LWM structures were selected as 1.2 and 0.5, respectively. The hydraulic roughness value for the channel banks was considered sufficient to represent the single pieces of wood under proposed conditions. The existing large logjams noted in the field were incorporated into the model with obstruction coverages and with a hydraulic roughness value representative of the woody material and sediment captured near these logjams.

8.2 Reach 1 Results

8.2.1 Existing Conditions

Reach 1 is influenced by backwater from Lake Sammamish during all flows to some degree. Velocity and water depth model results within Lake Sammamish are not accurate, as they are highly influenced by the estimated terrain data in that area. The terrain data for the lake was estimated by modifying the LiDAR dataset assuming a grade of 30(h):1(v) to an assumed lake bottom elevation of 28 feet, as described in Section 8.1.1. Based on preliminary hydraulic modeling, under the 10-year and larger peak flow events, the overbank areas through this reach are completely inundated (Appendix G, Figures G.5 and G.8). Under a 2-year peak flow event, channel depths range between 6 and 10 feet with channel velocities ranging between 1 and 4 feet per second (ft/s), and small pockets as high as 7 to 8 ft/s in the upper portion of the reach (Appendix G, Figures G.3 and G.4). The main channel through this reach has relatively deep, uniform flow. However, with the highly activated overbank areas, there is opportunity to create hydraulic diversity during high flow conditions.

Figure 8 contains a longitudinal profile for the creek and includes the modeled 2-year, February 6, 2020 flood event, and 100-year water surface profiles. The backwater influence from Lake Sammamish, which varies depending on the lake level and magnitude of the modeled peak flow, is visible in the water surface profiles. Through the sensitivity analysis on lake elevation, as described in Section 8.1.3, it was determined that Reach 1 and the lower portions of Reach 2 will be influenced by the lake elevation even during low flow conditions.

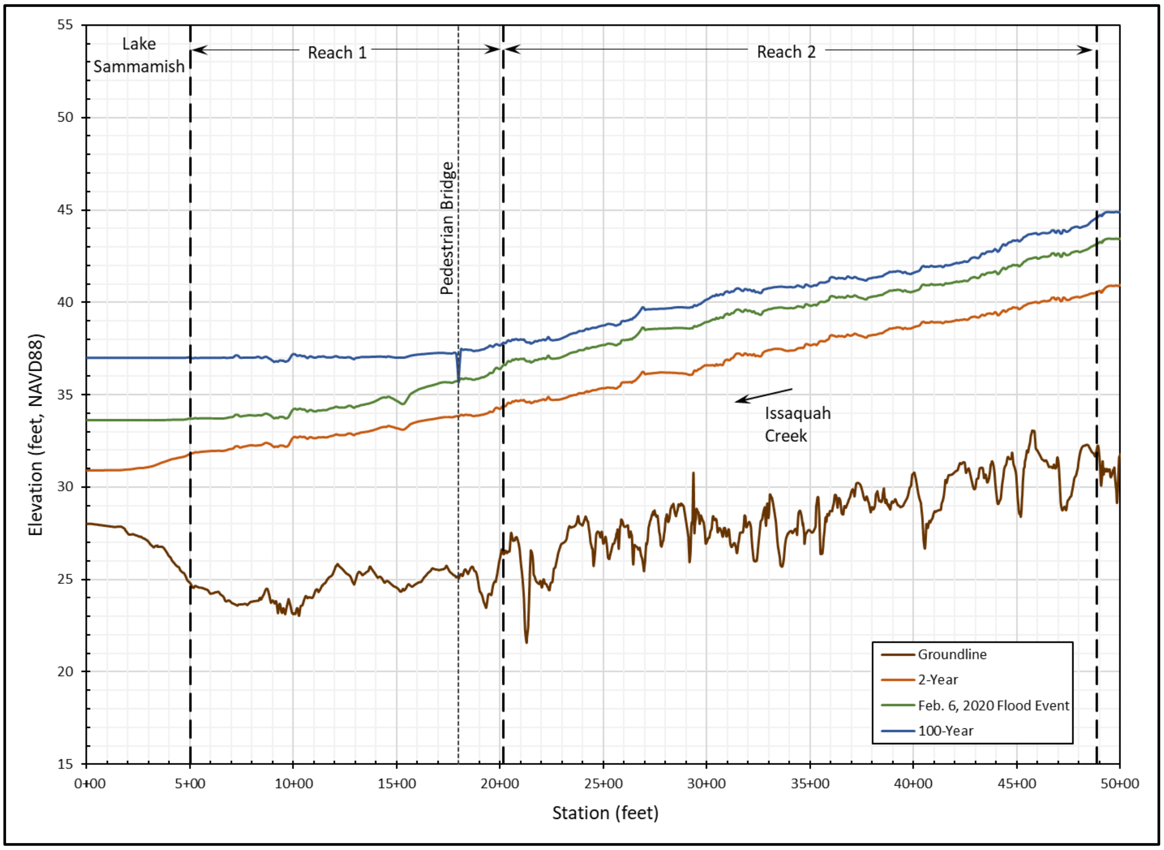

Figure 8. Water Surface Profiles for Issaquah Creek in Reaches 1 and 2

Model results for the February 6, 2020 flood event were compared to photographs taken by The Greenway Trust personnel near the time of the peak recorded flow value. Figure 9 shows the inundation limits of the flooding across the parking area and near the bath house. Consistent with the model results for the flood event (Appendix G, Figure G.5), a significant portion of the parking lot is inundated, but the bath house and playground in the background of the photograph remained dry.

Figure 10 shows overbank flood waters running down the pedestrian trail near the bath house and onto Sunset Beach. State Park Staff have mentioned this area of the beach often loses material during larger flood events. During the February 6, 2020 event, The Greenway Trust personnel noted that sand was eroded during the flood in this area. The model results indicate higher velocities in this area relative to the other overbank velocities (Appendix G, Figure G.6), consistent with the observed erosion and higher velocity water evident in Figure 10.

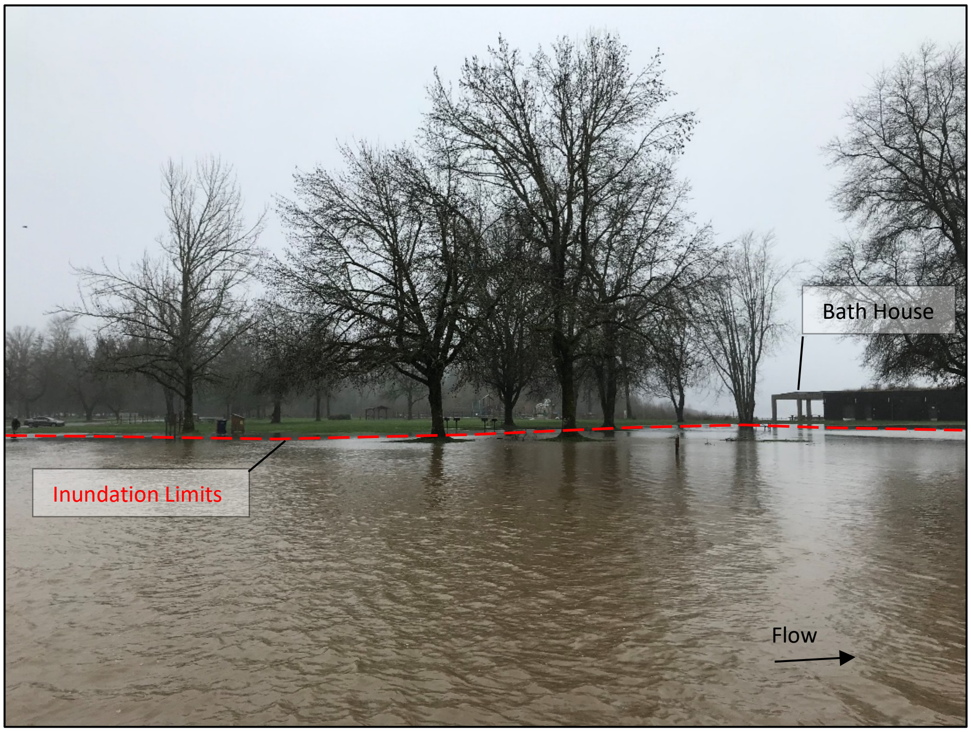

Figure 9. Inundation Extents of February 6, 2020 Flood Event Near Bath House

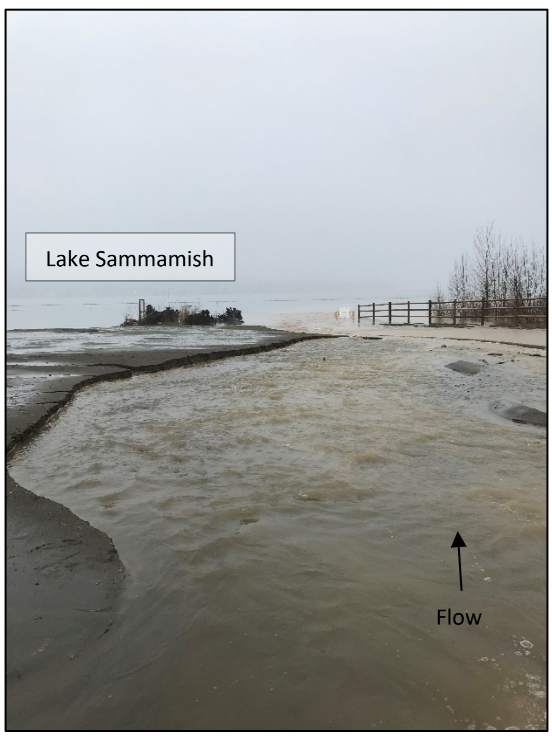

Figure 10. Water Flowing onto Sunset Beach During February 6, 2020 Flood Event

8.2.2 Proposed Conditions

The hydraulics for all modeled peak flows in Reach 1 are minimally affected by the proposed alternative design, partially due to the backwater influence from Lake Sammamish. The deep, uniform flow remains comparable to the existing conditions model results. The distributary channel does provide an additional flow path during the 2-year peak flow, with approximately 55 cfs being diverted into the channel (Appendix H, Figure H.2). For the 2-year peak flow, velocities throughout the distributary channel are approximately 1 to 1.5 ft/s, compared to 1 to 4 ft/s in the main channel (Appendix H, Figure H.3). Water depth in the distributary channel for the 2-year peak flow is about 2.5 feet, compared to 6 to 10 feet in the main channel (Appendix H, Figure H.5).

Because some water is being conveyed through the distributary channel, there is an approximately 0.1-foot drop in water surface elevation throughout the main channel for the 2-year peak flow further downstream. This effect is less pronounced for the modeled February 6, 2020 flood event, as some water was already predicted to be flowing overbank in this area under existing conditions. The 100-year flow shows no change, because the backwater from Lake Sammamish inundates the majority of this reach. There are minimal changes to the expected water surface elevations at the pedestrian bridge or boardwalk Trail in Reach 1 due to the proposed alternative for all flows modeled. The bathhouse near the shore of Lake Sammamish also experiences minimal change due to the selected proposed alternative (and remains dry under the 2- and 10-year peak flow conditions, consistent with the existing conditions model).

8.3 Reach 2 Results

8.3.1 Existing Conditions

Reach 2 is hydraulically diverse with the oxbow along the right bank. Based on preliminary hydraulic modeling during the 2-year peak flow event, the oxbow along the right bank of the main stem of Issaquah Creek is activated and provides relatively low velocity (0.2 ft/s) and moderate depth (6 to 8 feet). In the main stem, depths range between 4 and 10 feet, while velocities range from 3 to 6 ft/s (Appendix G, Figures G.3 and G.4).

Depths and velocity in the main stem reach as high as approximately 14 feet and 6.5 ft/s, respectively, for the modeled February 6, 2020 flood event. In the oxbow and overbank areas, velocities range between 1 and 1.5 ft/s (Appendix G, Figures G.6 and G.7). During the 100-year peak flow event, depths and velocity in the main stem reach as high as approximately 15 feet and 7 ft/s, respectively. In the oxbow and overbank areas, velocities remain low ranging between 1 and 2 ft/s (Appendix G, Figures G.9 and G.10).

The longitudinal profile in Figure 8 depicts the modeled 2-year, February 6, 2020 flood event, and 100-year water surface profiles in Reach 2. The backwater from Lake Sammamish is less pronounced in Reach 2 than in Reach 1, although the lower portion of the reach is still influenced, even under low flow events (Figure 8).

8.3.2 Proposed Conditions

Reach 2 becomes more hydraulically diverse based on the proposed alternative design, largely due to the pilot channel providing a direct conveyance path for Issaquah Creek into the oxbow. Model results are included in Appendix H. For the 2-year peak flow, approximately 600 cfs is conveyed through the pilot channel into the oxbow. Water surface elevation drops by nearly 1 foot in the main channel near the pilot channel and by 0.2 to 0.5 feet further downstream. Water depth in the oxbow increases by 0.5 feet and velocity increases by 0.7 to 1 ft/s. The changes are similar for the higher peak flows, with the results of the 100-year peak flow predicting an approximately 1-foot drop in water surface elevation in the main channel near the pilot channel, a 0.4-foot drop further downstream, and a 0.2-foot rise within the oxbow (Appendix I, Figure I-1). Main channel velocities decrease by about 2 ft/s with a 0.5 to 1 ft/s increase in the oxbow due to an additional 900 cfs, as compared to existing conditions, being conveyed through the pilot channel under proposed conditions.

The influence of the proposed alternative on the Pickering Ditch varies depending on the peak flow event. The 2-year flow indicates a rise of 0.2 feet within the first 400 feet of the ditch. It is, however, expected that the change in water surface will be negligible at the state park boundary. The 10-year peak flow results in a drop of 0.1 feet in the ditch, approximately 600 feet upstream of its outfall to Issaquah Creek. A 0.1-foot drop or no change is predicted for the 100-year peak flow within the first 750 feet of the ditch. The next 700 feet indicate a rise of 0.05 to 0.1 feet. There is no change in water surface in the ditch compared to the existing conditions upstream of this location, including at the state park boundary (Appendix I, Figure I-1).

In summary, based on preliminary model results, there is no expected change to water surface elevation in the Pickering Ditch under all modeled flow conditions at the state park boundary, satisfying the State Parks and City requirements (see Sections 1 and 5).

8.4 Reach 3 Results

8.4.1 Existing Conditions

Reach 3 is highly entrenched and disconnected from the surrounding floodplain resulting in high velocities and flow depths. Based on preliminary hydraulic modeling, all modeled flood events, including the 100-year peak flow, are contained within the channel with little to no floodplain connectivity (Appendix G, Figures G.2, G.5, and G.8). During a 2-year peak flow event, channel depths range between 6 and 10 feet with channel velocities ranging between 4 and 5 ft/s (Appendix G, Figures G.3 and G.4). During the modeled February 6, 2020 flood event, channel depths range between 8 and 13 feet with channel velocities ranging between 4 and 6.5 ft/s (Appendix G, Figures G.6 and G.7). During a 100-year peak flow event, channel depths range between 9 and 14 feet with channel velocities ranging between 4 and 7.5 ft/s (Appendix G, Figures G.9 and G.10). This reach would benefit from the incorporation of wood to assist in reconnecting the floodplain and provide more hydraulic diversity.

8.4.2 Proposed Conditions

The selected proposed alternative provides additional hydraulic diversity in Reach 3, though it still remains entrenched and disconnected from the floodplain overall. As described in Section 8.1.2, the model results (see Appendix H) are based on the proposed conditions mesh, which represents the grading at the time of construction. Over time, additional floodplain connectivity may be established as the creek responds to flood events in combination with the proposed inclusion of wood and bank scraping from the proposed alternative. In order to provide floodplain connectivity at the time of construction, it would entail a high cost and would require a significant amount of environmental impact due to the extent of grading, therefore the alternative allows the creek to do the work over time.

The proposed apex jam located midway through Reach 3 significantly influences the hydraulics in this reach. For all modeled flows, the water surface drops by approximately 0.4 to 0.6 feet from the apex jam downstream to the boundary with Reach 2 (near the pilot channel to the oxbow described previously in Section 7.2). Upstream of the apex jam, a water surface rise of 0.1 to 0.2 feet is predicted for all modeled flows (Appendix I, Figure I-1 depicts the change in water surface for the 100-year peak flow).

Due to the rise in water surface upstream of the apex jam, an associated decrease in velocity is predicted by the model throughout this upper portion of Reach 3. The difference ranges from a 0.05 ft/s decrease for the 2-year flow to a 0.2 ft/s decrease for the 100-year flow. Near and downstream of the apex jam, hydraulic diversity is increased, with additional flow paths along the locations where bank scraping is proposed and around the proposed wood. The impact from the pilot channel near the boundary, between Reaches 2 and 3, also likely influence hydraulics throughout the lower portion of Reach 3, with new flow paths and changes in velocity (e.g., various pockets with increased and decreased velocity magnitudes under all modeled peak flows), compared to that of the existing conditions.

8.5 Reach 4 Results

8.5.1 Existing Conditions

Reach 4 provides hydraulic diversity, including one large backwater pool and an oxbow (Photo 15). Based on preliminary hydraulic modeling, the oxbow is activated under low flow conditions, with depths during a 2-year peak flow reaching as high as 8 to 9 feet. In the main channel, during a 2-year peak flow, depths range between 4 and 10 feet and velocities range between 3 to 6 ft/s, with small isolated areas as high as 7 ft/s (Appendix G, Figures G.3 and G.4). During the modeled February 6, 2020 flood event, water depths range between 6 and 12 feet in the main channel and velocities range between 4 and 8 ft/s (Appendix G, Figures G.6 and G.7). During a 100-year peak flow, water depths range between 8 and 13 feet in the main channel and velocities range between 4 and 8 ft/s (Appendix G, Figures G.9 and G.10).

Model results for the 100-year peak flow indicate that a small amount of water overtops the high bank of the oxbow and flows north across park grounds where it outfalls into Lake Sammamish to the northeast of where Issaquah Creek enters the lake (Appendix G, Figures G.8 through G.10). Inundation throughout this area may be a result of the model being run in steady-state mode, where the modeled flow is held constant for the duration of the simulation's run time. The hydraulic models were run until reaching a stable equilibrium. In reality, the peak flow of a flood would not be maintained until reaching equilibrium and it is therefore possible that the inundation predicted by the model is overestimated. This will continue to be examined as the project progresses through design.

8.5.2 Proposed Conditions

Additional hydraulic diversity is provided throughout Reach 4 due to the preferred alternative design (see model results in Appendix H). All modeled peak flows indicate a rise in water surface of 0.1 to 0.15 feet throughout the lower portion of the reach, downstream of the State Park boundary, and in the oxbow. This rise is due to the inclusion of the LWM structures from the preferred alternative. At the State Park boundary, the 2-year peak flow indicates a 0.1-foot drop and no change in water surface further upstream at the upstream boundary of Reach 4. The modeled February 6, 2020 flood event and 100-year peak flows both show a 0.01-foot rise at the state park boundary, decreasing shortly upstream of the boundary to no change in water surface before reaching the upstream boundary of the reach (Appendix I, Figure I-1 depicts the change in water surface for the 100-year peak flow).

Main channel velocities decrease by approximately 0.2 ft/s for all modeled peak flows, though new flow paths and variable pockets of increased and decreased velocity are present under proposed conditions due to the proposed placement of LWM structures and channel grading. At the time of construction, the pilot channel midway through Reach 4 near the State Park boundary is expected to provide a new flow path at low flows. Over time, the channel will naturally deform in response to future flood events.

Negligible changes in water surface and velocity magnitude are predicted for all modeled peak flows near the irrigation pump house, located on a high south bank within Reach 4. The model shows no inundation of the pump house under both existing and proposed conditions.

Consistent with the existing conditions model results (Section 8.5.1), some water overtops the high bank of the oxbow in Reach 4 and connects to Lake Sammamish (Appendix H, Figures H.12 through H.16). The quantity of flow and thus inundation limits are potentially being overestimated throughout this area and will be evaluated at later stages of design.

8.6 Floodplain/Floodway Analysis

Lower Issaquah Creek is located in a FEMA designated Zone AE and includes a delineated floodway that begins near the boundary between Reaches 1 and 2. The pending Flood Insurance Rate Map (FIRM) panels for the creek are included for reference in Appendix C. The associated pending FEMA FIS numbers are 53033CV001B through 53033CV005B. The pending FEMA products are designated to become effective on August 19, 2020. These products will continue to be evaluated over time to determine if any changes are necessary at later stages of design.

Coordination with the Greenway Trust, State Parks, FEMA, the City of Issaquah, and the Department of Ecology has been ongoing to establish the process by which to evaluate whether the project's proposed restoration efforts meet the intent of a no-rise requirement. Through the conceptual and preliminary stages of design, several meetings have occurred to define the project parameters for floodplain evaluation. Direction was provided by State Parks to move forward using the 100-year peak flow and BFE for the elevation of Lake Sammamish from the FEMA FIS report for the modeling and design. A preliminary analysis was performed to begin evaluating the potential impacts of the preferred alternative design on water surface elevations throughout the project area. Negotiations are expected to continue with the aforementioned interest groups to determine next steps. The preliminary analysis included using SMS to compare the water surface elevations from the proposed conditions model to the results of the existing conditions model.

The difference in water surface elevations due to the preferred alternative predicted by the model relative to existing conditions are illustrated in Figure I-1 in Appendix I. Red shades in Figure I-1 indicate an increase in water surface elevation due to the preferred alternative, whereas blue shades indicate a decrease. A white shade indicates no change in water surface elevation. The results predict both a rise and drop in various portions of the creek. Negligible changes are predicted near critical State Park infrastructure, including the pedestrian bridge and bathhouse in Reach 1, the irrigation pump house in Reach 4, and the Pickering Ditch near the park boundary. As described in Section 8.5.2, there is an approximate rise of 0.01 feet at the State Park boundary in the main channel. This 0.01-foot rise diminishes to near zero within 500 feet upstream of the park boundary.

The analysis was also performed on a model domain that excluded certain floodplain areas by limiting the model extents to the effective floodway boundary identified in the FIRM. The elevation for Lake Sammamish at the downstream boundary condition was selected as 38.1 feet (NAVD 88) based on the value indicated in the floodway data table in the FIS report (FIS 53033CV002B, Table 6, Issaquah Creek, cross section A). The water surface comparison for the floodway is also included in Appendix I as Figure I-2. Because the floodway model contains the same amount of flow within a more confined model domain, the rise is slightly larger relative to the full domain floodplain model described above. The rise at the State Park boundary in the main channel is approximately 0.03 feet. It is recommended that the floodplain and floodway analyses be evaluated more extensively as discussions continue with the aforementioned interest groups.

9 MAINTENANCE AND MONITORING

Long-term monitoring of the project site will be critical to determining the overall success and effectiveness of the preferred design alternative. The Greenway Trust is working with State Parks, the WRIA 8 team, King County, and other project interest groups to determine a set of baseline, as-built, and effectiveness monitoring parameters that will provide the greatest value for the project.

The Greenway Trust intends to conduct a baseline assessment of the project site prior to construction with subsequent assessments immediately after construction. The Greenway Trust will work with project interest groups to develop a SMART (Specific, Measurable, Achievable, Relevant, and Time-Based) monitoring plan and identify and secure funding to demonstrate project effectiveness and conduct post-project monitoring. Baseline conditions will be established in 2021-2022, with as-built conditions documented during construction in 2022-2023. Monitoring will be performed such that the data is consistent with protocols established and used by King County and other interest groups, allowing for comparison and continuity with efforts that are occurring upstream. During project engagement and meetings (see Section 5), project interest groups have encouraged monitoring for specific data, such as: temperature; LWM recruitment; regular aerial drone surveys; predatory fish presence; juvenile Chinook presence (during the late winter, prior to hatchery release); creation of pools; changes in sediment size and composition; surveying for redds in Reaches 3 & 4; and an overall correlation between geomorphic, hydrologic, and hydraulic characteristics with fish habitat. This input from project interest groups will be utilized to help frame the long-term monitoring plan.

As previously mentioned, the preferred design alternative is intended to provide a holistic restoration effort to lower Issaquah Creek, both with in-stream elements and riparian restoration efforts. These two aspects are designed to work together to provide long-term habitat restoration to Issaquah Creek. The two subsections below describe the expected maintenance and monitoring strategies that are expected to meet this holistic vision.

In-Stream Restoration Maintenance

In-stream restoration will be monitored as outlined above and is not anticipated to be maintained. The in-stream elements of the project are designed and engineered with an intent to minimize anchoring, to mimic natural stream processes, and encourage specific functions as described extensively in Sections 6 and 7. LWM will likely move throughout Reaches 2 through 4 and is placed in a fashion that encourages and creates opportunities for dynamic conditions. As previously mentioned, through ongoing discussions (see Section 5), the Greenway Trust is working on developing an adaptive management strategy for addressing LWM recruitment and movement throughout the project area, in close coordination with interest groups on planning and design. The Greenway Trust will continue to work with State Parks staff on the evaluation of LWM transport into Lake Sammamish, and design considerations and strategies for maintaining Park infrastructure and project improvements within State Park's resources, which will be incorporated into the final project designs and plans.

Riparian Stewardship and Maintenance

In addition to the new riparian restoration proposed in Section 7.5, continued removal of invasive vegetation and replanting with native species will be completed on more than 40 acres across the existing sites that are currently under active restoration within the Creek buffer. These efforts will mirror those already in progress by the Greenway Trust and State Parks and will focus on the establishment of tree canopy and overhanging vegetation to help provide leaf litter and terrestrial insect inputs to the stream. Both of these are important, indirectly, and directly, to help increase the long-term food supply for juvenile salmonid fish, in conjunction with the proposed project in-stream LWM elements. Fostering a structurally diverse native plant species community in the riparian zone with high food and cover values for native terrestrial wildlife species is also a primary goal of the overall riparian restoration efforts in Issaquah Creek. These measures will be implemented throughout the Issaquah Creek riparian zone to the extent possible throughout the project area. Furthermore, any additional areas disturbed by the installation of LWM will be restored and revegetated. Long-term weeding and maintenance actions will also be included to assure success of revegetation efforts.

This restoration site stewardship component will include the survey and control of listed noxious weeds such as Himalayan blackberry, reed canarygrass, butterfly bush, tansy ragwort, spotted jewelweed, knotweed, and others. Control of these invasive weeds will include manual, mechanical, chemical, and cultural methods following the best practices that are outlined by the King County Noxious Weeds program. This work will be accomplished with Greenway Trust staff and seasonal crews, sponsored AmeriCorps members, and community volunteers. Control of noxious weeds will not only help with the establishment of native plants already installed, but will also allow for the installation of approximately 5,000 native trees and shrubs to continue to add to the diversity and complexity of the burgeoning riparian forest along Issaquah Creek.

The Greenway Trust has more than 20 years of experience performing similar activities in the Park, supported by local grants, Greenway Trust staff, sponsored AmeriCorps members, volunteers, and private restoration contractors, all supported by State Parks staff and other partners. As part of the maintenance and monitoring strategies that are expected for the preferred design alternative, the Greenway Trust is proposing to complete a minimum of five years of intensive maintenance of the riparian buffer restoration plantings with a focus on native plant survival and invasive weed control. Maintenance intervals will be reduced as viable after 5 years.

10 PRELIMINARY COST ESTIMATE

A preliminary construction cost estimate for implementing the preferred design alternative has been evaluated. The preferred alternative is set up such that each reach is independent and provides a scalable design to ultimately arrive at a solution that offers the most benefit with available project funding. At later stages of design, a phased approach can be evaluated depending on available project funding and input from project interest groups.

The estimated costs for the preferred design alternative constructed holistically and as phases by reach are included in Table 6. Appendix J includes additional detail. The WSDOT Bid Tabs was utilized to determine material costs and should be re-evaluated at later stages of design. Changes in prevailing wages, material availability, hauling costs, etc., could affect bid prices. The items evaluated for the preferred design alternative include material costs for the LWM, pilot channels, and potential planting measures as well as construction costs, such as potential dewatering and temporary erosion and sediment control measures. All quantities were developed on a preliminary level and should be re-evaluated at later stages of design once additional project details are determined.

The costs for the LWM structures include material costs for each structure and hauling materials to the project site, as well as constructing and placing the features. As previously mentioned, in working with interest groups, a wood inventory for all recommended LWM was developed to determine where LWM can be sourced from and the most efficient way to transport it to the site (Section 6 and Appendix K). As the project moves to the next stages of design, the most efficient way to construct the LWM structures to minimize costs and impacts to the surrounding terrain will continue to be evaluated and expanded upon. To evaluate potential costs of placing the LWM structures, based on direction from The Greenway Trust, it is assumed helicopters will be utilized for placement to minimize impacts to the existing stream channel and riparian zone to the extent practicable. Some of the larger LWM structures may exceed the weight requirements of a smaller twin rotor helicopter, so two different prices per hour were assumed based on the anticipated need per LWM structure. Per direction from The Greenway Trust and various interest groups, $8,000 per hour was estimated for the smaller twin rotor helicopters and $15,000 per hour was estimated for a larger helicopter. For some of the LWM structures, such as the apex jams and large spur jams, equipment is assumed to also be necessary to help complete the structures' construction including potential adjustments to LWM pieces and any anchoring (e.g. piles or ballasting), if needed. As previously discussed, collaboration will continue with various interest groups to determine the need for anchoring and minimizing LWM transport depending on the location of the LWM structure. These estimated construction and material costs are also encompassed in the prices for each LWM structure. These assumptions are based on a preliminary analysis and should be re-evaluated at later stages of design; ultimately working with interest groups to determine the best construction method for the proposed LWM structures.

To determine costs for the excavated features (the distributary channel, pilot channels, and bank scraping), it was assumed that all excavated material would be hauled off-site. These haul costs are included in the item price for stream excavation. As the project progresses, the details of these specific features will be further evaluated to balance their optimal location and design with minimizing grading and environmental impacts during construction.

The riparian restoration work includes the revegetation, removal, and maintenance work described in Sections 7.5 and 9. These items were not broken up and included in the individual estimates for each reach. It is anticipated that if the project is constructed in a phased approach this would be included as a separate piece with the first phase of the project.

Table 6. Estimated Cost for the Preferred Design Alternative

Phase	Cost
Project as a whole	$3.8M
Reach 1	$0.9M
Reach 2	$1.3M
Reach 3	$0.7M
Reach 4	$1.0M

11 REFERENCES

Aquaveo (2020). Surface-water Modeling System v13.0.12.

Booth, D.B., Haugerud, R.A., and K. Goetz Troost (2003). *The Geology of Puget Lowland Rivers*. University of Washington Press, Seattle, p. 14-45.

Chow, V.T. (1959). *Open Channel Hydraulics*, McGraw-Hill book Company, NY.

Federal Highway Administration (2008). Introduction to Highway Hydraulics. Federal Highway Administration Publication Number NHI-08-090. Available at: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/08090/appb.cfm.

Fox, M. and Bolton, S. (2007). A regional and geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins of Washington State. *North American Journal of Fisheries Management*, 27(1), 342-359.

Herzog, Peter, Droll, Robert W., Hafermann, Laura, and Patano, Christopher (2007). *Lake Sammamish State Park Redevelopment and Restoration Concept Plan*. Washington State Parks and Recreation Commission. Available at: https://parks.state.wa.us/DocumentCenter/View/1291/Draft-Lake-Sammamish-Concept-Plan-PDF

Interagency Advisory Committee on Water Data (1982). *Guidelines for Determining Flood Flow Frequency Bulletin #17B of the Hydrology Subcommittee.* Reston, Virginia.

Mastin, Mark C., Christopher P. Konrad, Andrea G. Veilleux, and Alison E. Tecca (2016). *Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington, Based on Data through Water Year 2014: Scientific Investigations Report 2016-5118*. United States Geological Survey. Reston, VA.

Northwest Hydraulic Consultants (2012). *Findings on Lake Sammamish Outflow into Sammamish River*.

Northwest Hydraulic Consultants (2013). *Willowmoor Restoration Design Hydrology Phase 1 – Hydrologic Characterization*. Seattle, WA. https://your.kingcounty.gov/dnrp/library/water-and-land/flooding/capital-projects/willowmoor/concept-design-appendices.pdf

NHC and The Watershed Company (2017). *Lower Issaquah Creek Restoration at Lake Sammamish State Park Conceptual Design Report* (002002182). Report prepared by Northwest Hydraulic Consultants and the Watershed Company for Mountains to Sound Greenway Trust.

PRISM Climate Group (2015). 30-Year Normal Precipitation: Annual. Oregon State University. Accessed at http://www.prism.oregonstate.edu/normals (Accessed August 2019).

Rapp, C., and Abbe, T. B. (2003). *A Framework for Delineating Channel Migration Zones* (#03-06-027). Ecology Publication. Washington State Department of Transportation and Washington State Department of Ecology.

The Watershed Company (2005). *Lake Sammamish State Park Wetland, Stream and Lakeshore Restoration Plan*. Washington State Parks and Recreation Commission. Available at: https://parks.state.wa.us/DocumentCenter/View/11225/02-Wetland-Stream-Lakeshore-Restoration-Plan-PDF?bidId=

United States Bureau of Reclamation (2016). Sedimentation and River Hydraulics – Two-Dimensional (SRH-2D) Model v3.

WRIA 8 Salmon Recovery Council (2017). *Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan 10-Year Update*. Available at: https://www.govlink.org/watersheds/8/reports/chinook-plan-update.aspx.

WRIA 8 Steering Committee and Forum (July 2005). *Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan*. Available at: https://www.govlink.org/watersheds/8/planning/chinook-conservation-plan.aspx.

APPENDIX A: EXISTING CRITICAL INFRASTRUCTURE

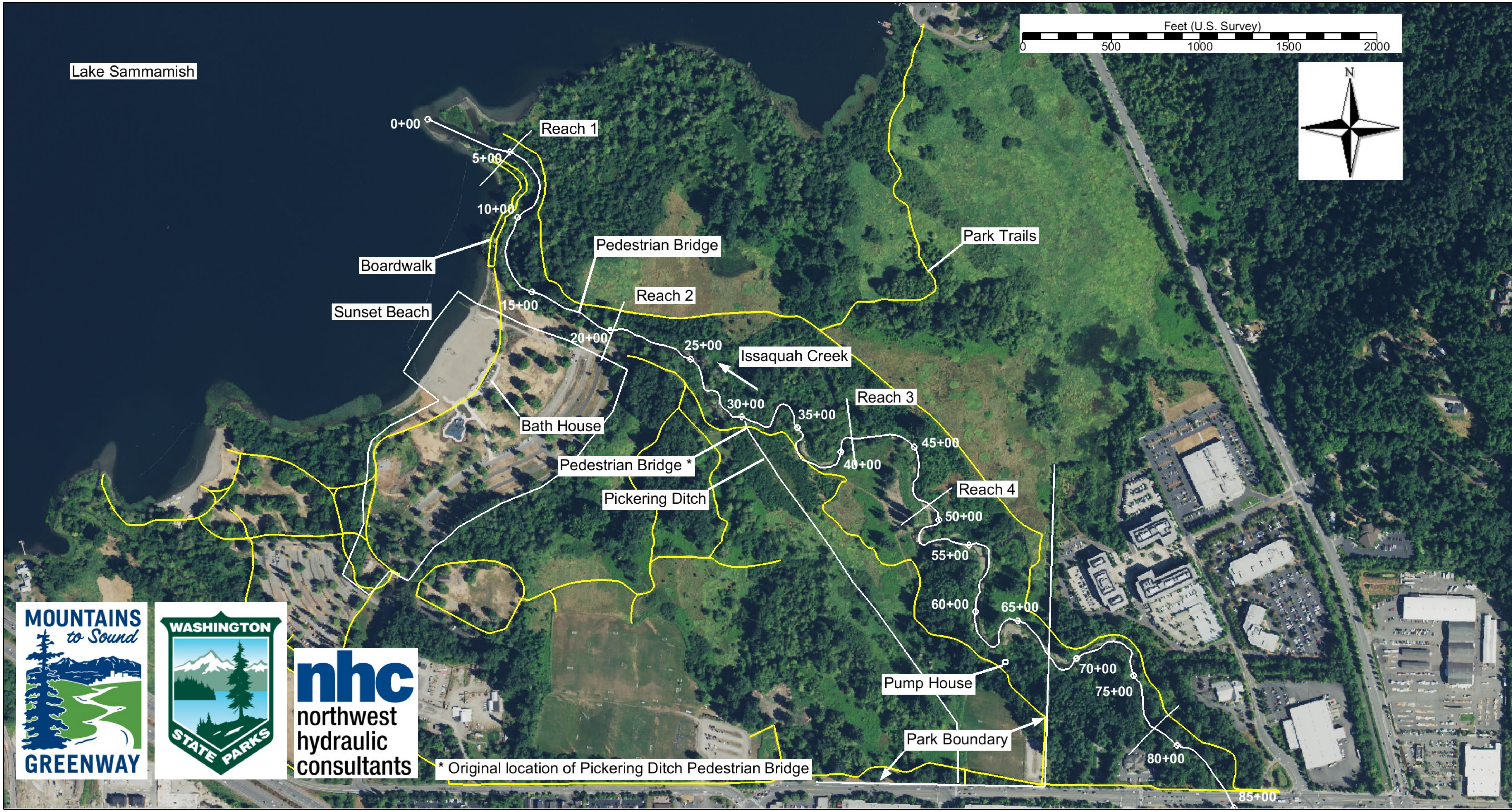

Figure A.1 Existing Critical Infrastructure for Lower Issaquah Creek Restoration at Lake Sammamish State Park

APPENDIX B: VEGETATION RESTORATION

Issaquah Creek at Lake Sammamish State Park 2019

Issaquah Creek at Lake Sammamish State Park 2002

Date: 4/30/2020

Notes:

N

King County

APPENDIX C: FEMA

NOTES TO USERS

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NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

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The **profile baselines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the **profile baseline**, in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.

Based on updated topographic information, this map reflects more detailed and up-to-date **stream channel configurations and floodplain delineations** than those shown on the previous FIRM for this jurisdiction. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on the map. Also, the road to floodplain relationships for unrevised streams may differ from what is shown on previous maps.

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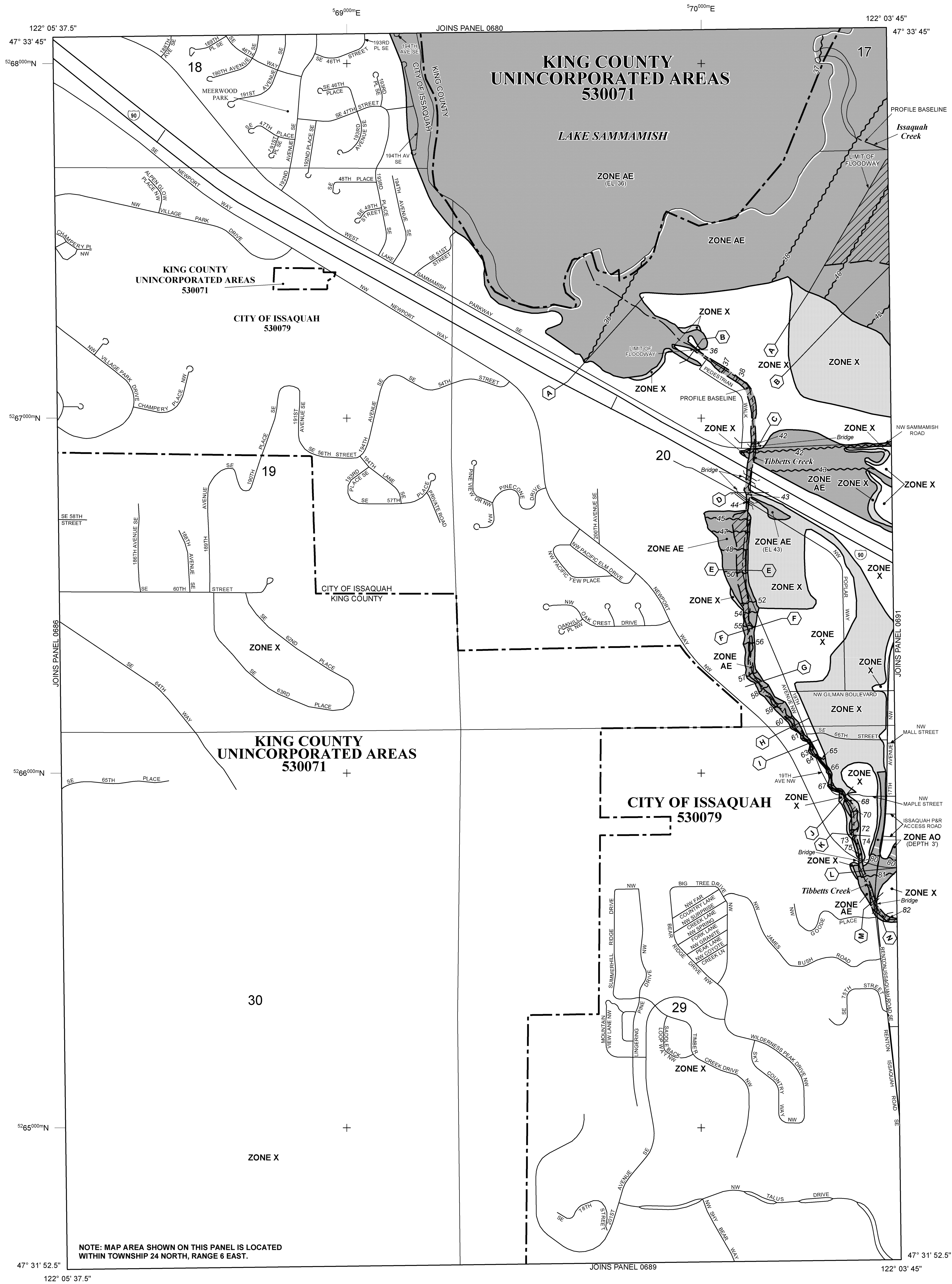

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
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ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	1% Annual Chance Floodplain Boundary
	0.2% Annual Chance Floodplain Boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths, or flood velocities.
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - - 23	Transect line
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
$^{49}89^{000m}$ N	1000-meter Universal Transverse Mercator grid values, zone 10
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
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MAP SCALE 1" = 500'

250 0 500 1000 FEET
150 0 150 300 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0687G

FIRM
FLOOD INSURANCE RATE MAP
KING COUNTY, WASHINGTON AND INCORPORATED AREAS

PANEL 687 OF 1725
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
ISSAQUAH, CITY OF	530079	0687	G
KING COUNTY	530071	0687	G

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MAP REVISED
AUGUST 19, 2020

Federal Emergency Management Agency

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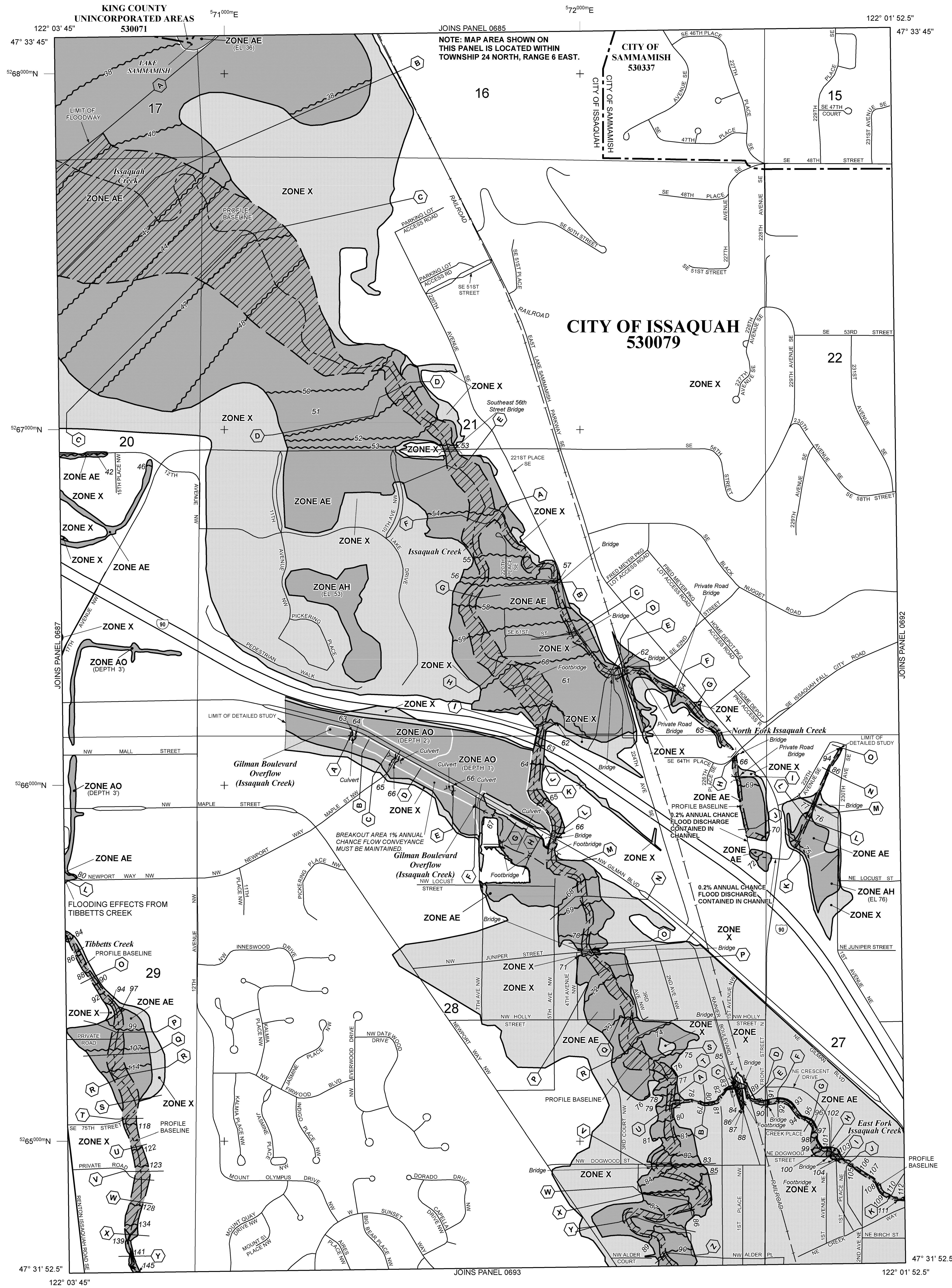

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NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0691J

FIRM

FLOOD INSURANCE RATE MAP

KING COUNTY, WASHINGTON

AND INCORPORATED AREAS

PANEL 691 OF 1725

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

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KING COUNTY	530071	0691	J
SAMMAMISH, CITY OF	530337	0691	J

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MAP NUMBER
53033C0691J

MAP REVISED
AUGUST 19, 2020

Federal Emergency Management Agency

APPENDIX D: CHANNEL MIGRATION ZONE ANALYSIS

12787 Gateway Drive South | Seattle, WA 98168 | 206.241.6000 | www.nhcweb.com

nhc
northwest hydraulic consultants

NHC Ref. No. 2003907

May 14, 2020

Mountains to Sound Greenway Trust
2701 First Avenue, Suite 240
Seattle, WA 98121

Attention: **Tor Bell**
Field Program Director

Re: **PRELIMINARY Issaquah Creek Channel Migration Zone Delineation**

1 INTRODUCTION

Northwest Hydraulic Consultants (NHC) is working with the Mountains to Sound Greenway Trust (the Greenway) to develop plans for habitat restoration in the lowest reach of Issaquah Creek, where the creek flows through Lake Sammamish State Park. This reach (the Project Reach) extends upstream approximately 6,500 feet from the delta of the creek into Lake Sammamish. The Greenway has also been focusing efforts on planting native forest vegetation in a buffer around the creek, to provide for long-term wood recruitment and shading of the channel. Throughout the design process, the Greenway has been coordinating the restoration plan with other projects within the park and Issaquah Creek, including a new trail network in the park, which may include a second pedestrian bridge crossing over the creek.

The Greenway has requested that NHC complete a channel migration zone (CMZ) delineation for the portion of the creek flowing through Lake Sammamish State Park to aid in the optimization of the restoration design, riparian planting effort, and ongoing comprehensive planning. This memo describes the methods, results, and limitations of the delineation. It is based on a background understanding of the creeks morphology and geomorphic history documented in a detailed analysis of geomorphic, hydrologic, and hydraulic conditions described in the Conceptual Design Report for the project (NHC and The Watershed Company, 2017). The CMZ delineation is based on the analysis of historical conditions documented in aerial photos from 1937 through the autumn of 2019. Significant floods occurred in the 2019-2020 high flow season and caused notable bank erosion that is not reflected in this assessment. For this reason, we recommend flying the site to delineate changes that occurred since the recent floods and observed bank erosion. In addition, it is important to note that some elements of the planned habitat restoration project may alter channel migration processes and patterns.

2 GEOMORPHIC BACKGROUND

The project reach (Figure 1) flows through surrounding deposits of somewhat cohesive, relatively fine-grained (silt with sand and clay) Holocene alluvium (NHC and The Watershed Company, 2017).

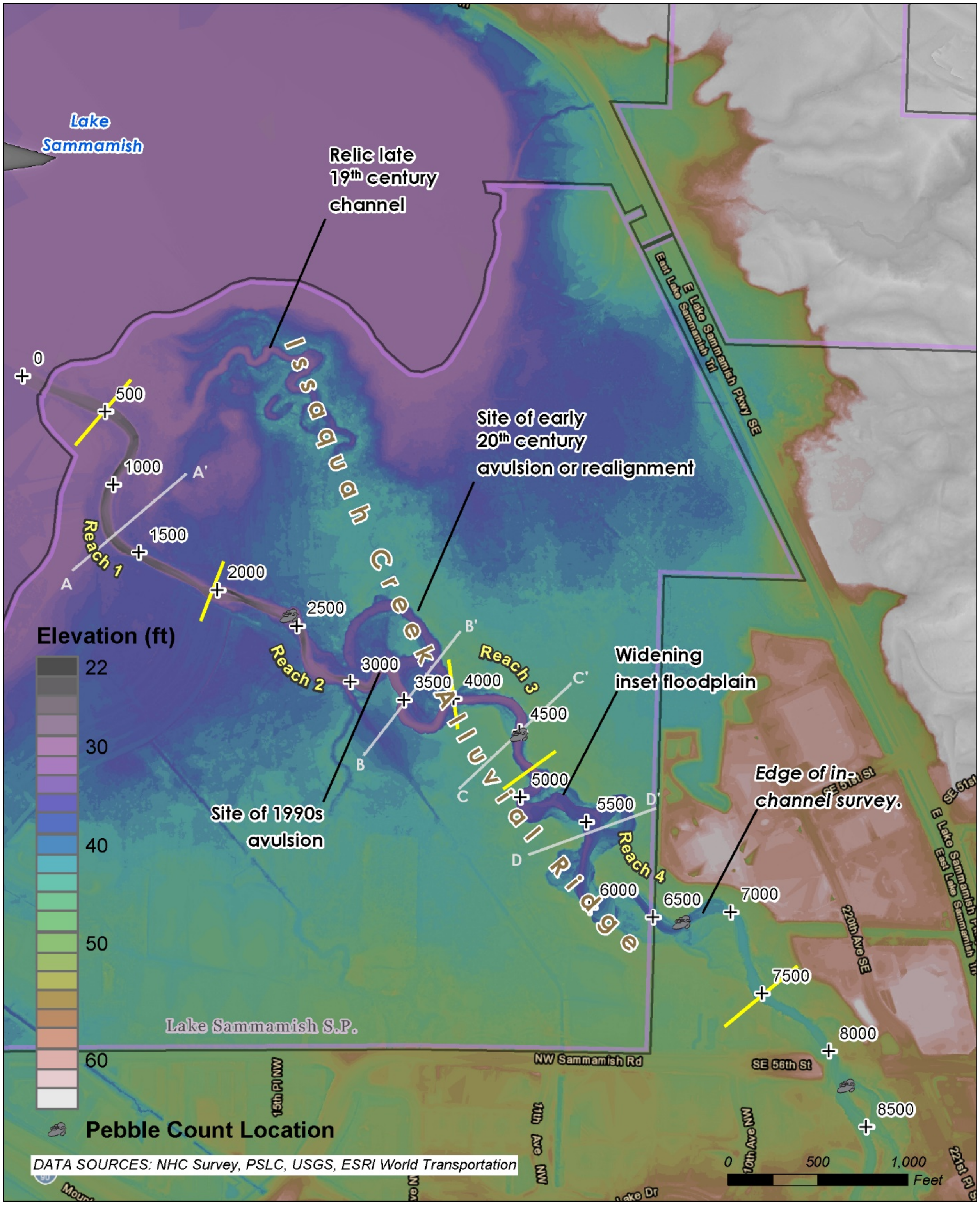


Figure 1: Topographic base map of study reach showing the merged LiDAR and field survey of the wetted channel area. Some key geomorphic features are also noted. Reproduced from NHC and The Watershed Company (2017).

The creek has a concave profile as it approaches Lake Sammamish (Figure 2). The creek profile declines from about a 4% slope near the upstream project boundary to about a 3% slope near Station 4,000 (Station refers to the distance in feet upstream of the mouth of the creek), and then rapidly declining to a nearly flat slope by Station 2,000.

The creek is presently incised up to about 12 feet below the surrounding alluvial surface (Figure 2 and Figure 3). This incision is interpreted to be mostly a result of a late 19th century or early 20th-century avulsion or realignment of the creek. The General Land Office Survey (1864) and present-day topography show a historic channel position along the top of the alluvial ridge to the east of the present channel from about Station 4,000 to Lake Sammamish (Figure 1). This alignment was historically about 1,000 feet longer than the present channel. Based on the observed and inferred slope along the historic alignment, the avulsion would have lowered the base level for the channel upstream by approximately 10 feet (Figure 2). A 1937 aerial photo shows the channel close to its current position, indicating the avulsion occurred between 1864 and 1937.

The base level for the creek was also lowered by a change in typical winter-season water levels in Lake Sammamish resulting from a reconfiguration of the lake's outlet in 1964. The reconfigured outlet lowered typical winter lake levels from a range of 33 to 36 feet to 31 to 33 feet (NAVD 88, from NHC, 2012). Based on an assessment of available USGS lake level and creek flow information, higher lake levels often correspond to geomorphically effective flood flows on Issaquah Creek. The change in the lake's outlet, therefore, may have contributed to an additional two to three-foot drop in the functional base-level control for the creek.

Channel migration following the incision has formed an inset floodplain below the creek's historic alluvial ridge (Figure 1 and Figure 3). This inset floodplain corresponds to the extent of lateral channel migration following the avulsion. It ranges from about 100 feet wide (compared to a typical channel width of about 50 feet) up to about 500 feet wide at locations where meanders have eroded into the surrounding alluvium. Sediment in the inset floodplain is coarser than the surrounding material, consisting of gravel-to cobble sized material that was deposited in the active channel, then buried by overlaying sandy material that was deposited in backwater features and across the floodplain.

The creek has bed material dominated by gravel- and cobble-sized sediment above approximately Station 4,000 and sand-dominated sediment below this. One isolated gravel bar is present at about Station 2,450. Pebble counts were collected at geomorphically-representative bar head locations along the channel profile to quantitatively characterize the texture of the bed material. The observed grain size distribution curves for the surface of four bars are shown in Figure 4.

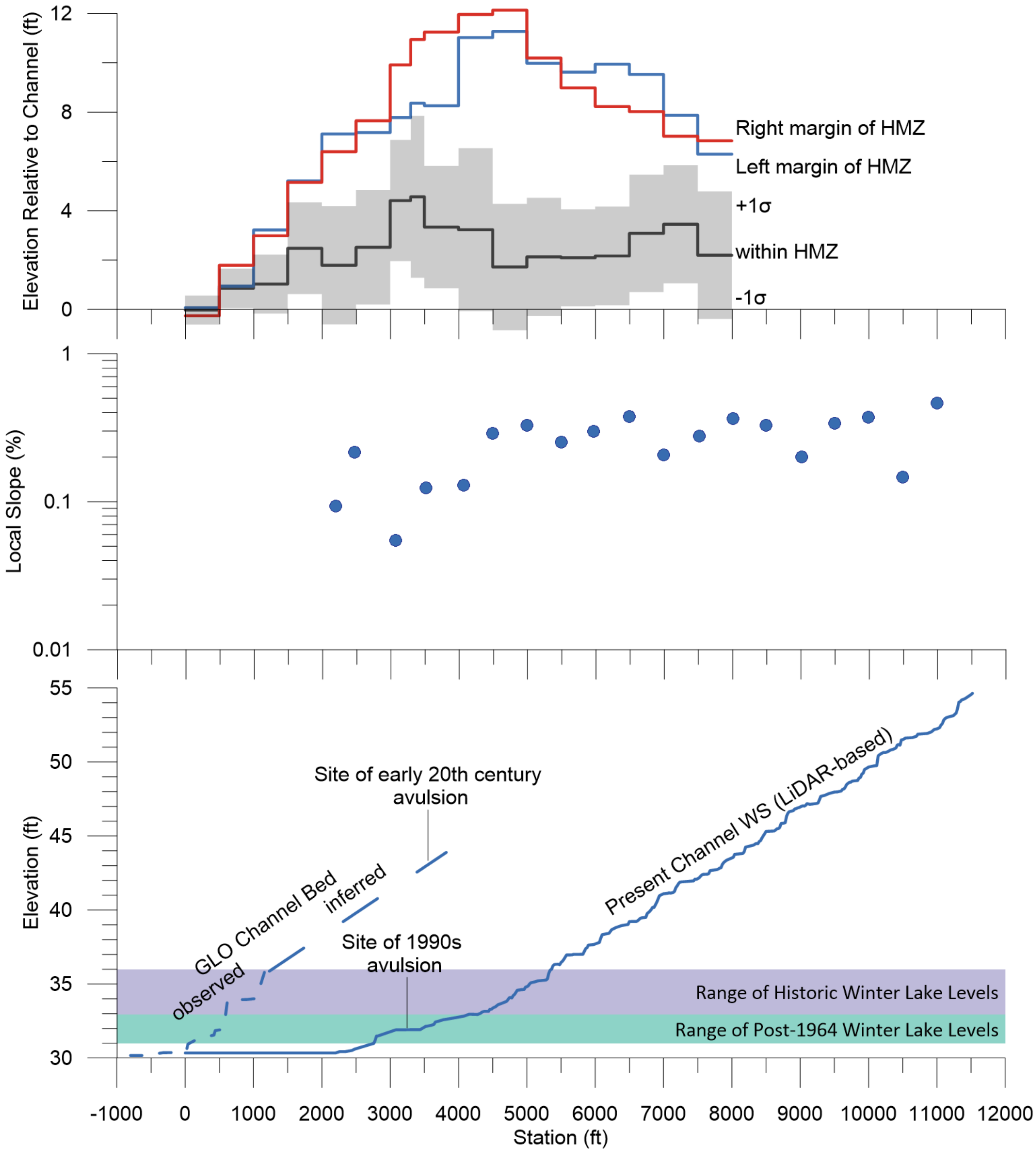


Figure 2: **Profile of Lower Issaquah Creek (bottom) showing slopes of the present channel (middle), and bank heights and hypsometry of the surface within the historic channel migration zone (top).**

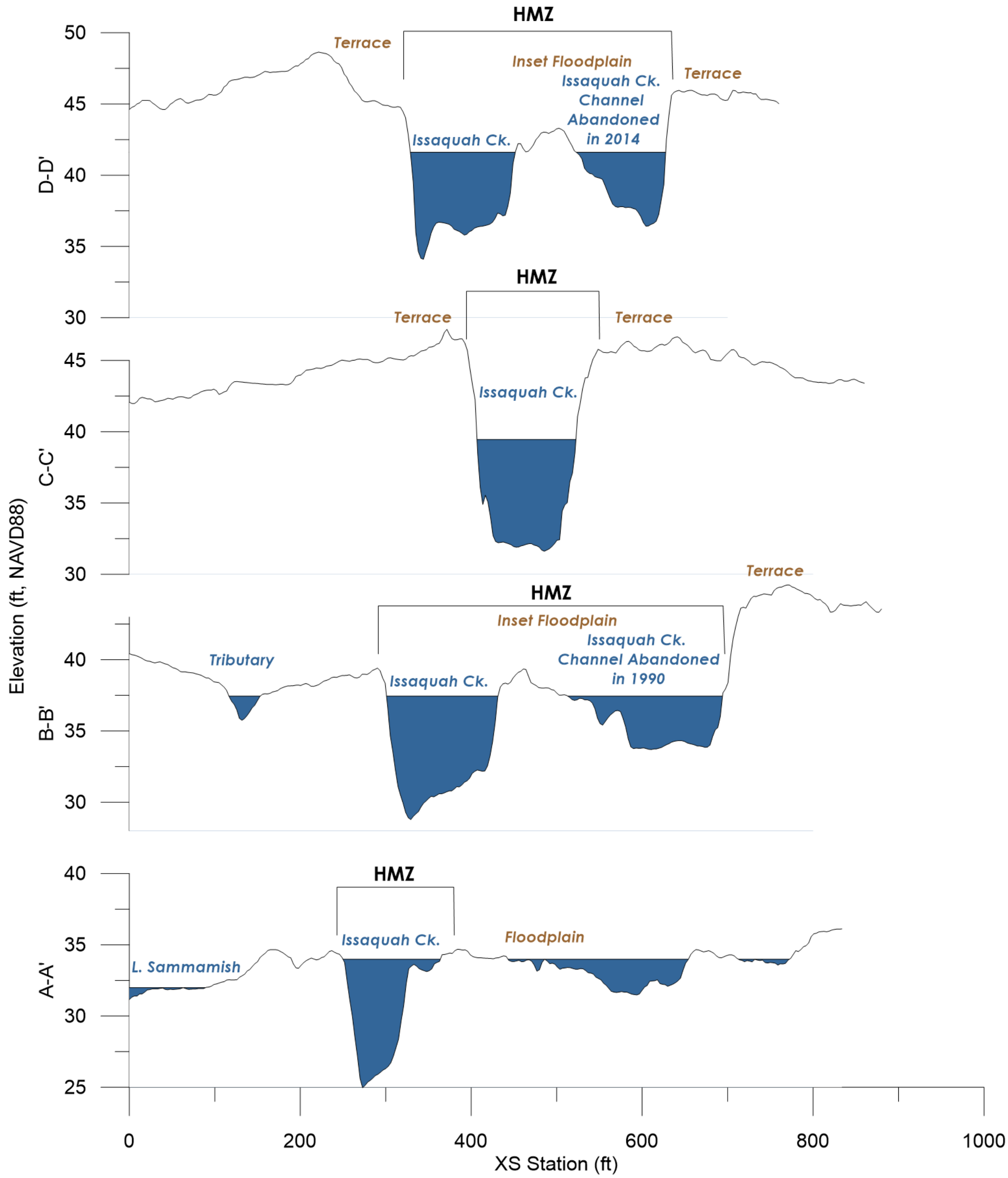


Figure 3: **Select cross sections showing the pattern of historical incision and inset floodplain formation. Cross section locations are shown in Figure 1.**

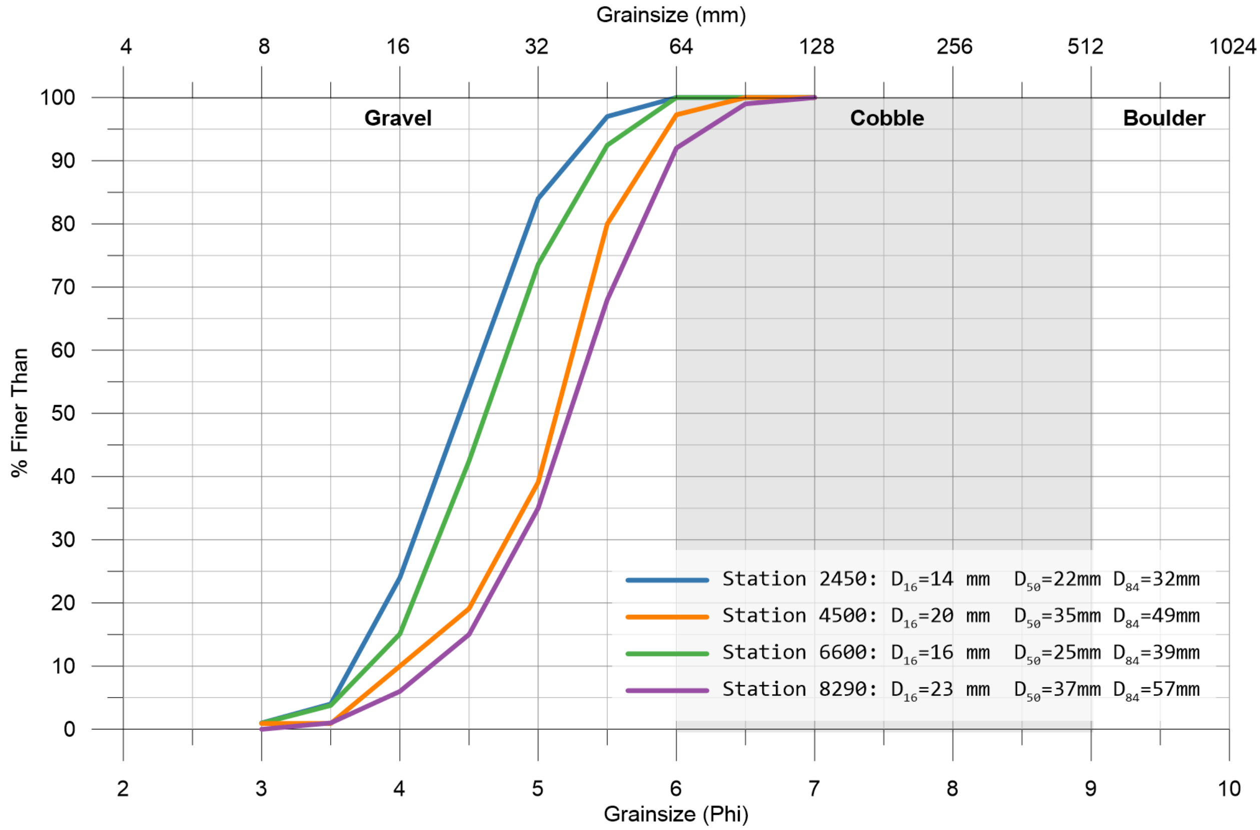


Figure 4: Observed surface grain size distributions based on Wolman pebble counts of bar and riffle-head locations.

3 REACH ANALYSIS

NHC and The Watershed Company (2017) defined four distinct reaches within the project reach based on the geomorphic and habitat conditions in Issaquah Creek, including the channel slope, bed material grain size distribution, floodplain character and extent, and channel migration history. Conditions in each reach are described in detail in the Conceptual Design Report (NHC and The Watershed Company, 2017). These reach divisions apply directly to the CMZ analysis process described here; however, the downstream and upstream limits require further refinement. The locations of the reach breaks adapted for this study are shown in Figure 1. For lateral erosion calculations, the downstream limit of Reach 1 was changed to Station 500 to exclude the active delta, where the primary geomorphic process is land-building into the lake. This allows channel migration rates for each reach to be calculated from the whole historical image time series in places were lateral bank erosion and accretion have been the dominant processes.

The other required refinement is an explicit definition of the upstream boundary of Reach 4, as the limit of that reach from a restoration planning perspective—the state park boundary—is not relevant from a geomorphic perspective. The upstream boundary of that reach was determined to be Station 7,500, where there is a distinct change in the degree of historical channel stability and width of the geomorphic floodplain (Figure 2 of NHC and The Watershed Company, 2017).

4 CHANNEL MIGRATION ZONE DELINEATION METHODS

4.1 Channel Migration Processes

Two distinct kinds of channel migration must be considered in the CMZ delineation process: lateral channel migration and avulsion. Avulsion occurs when a creek suddenly leaves its current path and activates a new (usually shorter and steeper) path across its floodplain.

Lateral channel migration is the more gradual movement of the channel due to erosion on one bank and deposition on the other. Bank erosion occurs when a creek's discharge has enough energy to erode the bank material. Since much of a creek's energy is usually concentrated along the outside and down-valley side of meander bends, bank erosion often occurs there. This often results in the migration of a creek channel toward the outside of bends (meander amplification) and translational movement of the meander down-valley. Erodible banks and high peak flows can result in relatively rapid channel migration during floods. Accumulations of large woody debris (e.g., log jams), accumulations of sediment, or other instream structures can also direct a creek's energy toward banks and result in bank erosion. For Issaquah Creek, the CMZ analysis considers the potential for channel migration via bank erosion by mapping past locations and rates of bank erosion. This is achieved by analyzing historical maps and aerial photographs, considering current bank erodibility, and large woody debris and sediment accumulation potential.

An avulsion is the process where a river suddenly shifts to a new channel location. Avulsions generally occur during peak flood flows, sometimes in response to a large log jam or obstruction in the river that diverts flow out of the former main channel. Avulsions can result in split channels where the flow is divided among several channels with vegetated islands between them. Over time, one of the split channels may become the main channel, and the others may only carry water during floods. Channel migration due to avulsions is more difficult to predict than migration due to bank erosion because the avulsion process is sporadic and often related to unpredictable accumulations of logs and debris in the stream during floods. Avulsion hazards were evaluated by assessing potential flowpaths following blockage of the channel.

4.2 CMZ Delineation Procedure

NHC has followed the standard Washington Department of Ecology CMZ Delineation Methodology, laid out by Rapp and Abbe (2003), to delineate the CMZ for Issaquah Creek at Lake Sammamish State Park. These results we also compared to what would be delineated following the planning level CMZ analysis procedure (Olson et al., 2014). The key steps in the standard methodology are described below and shown graphically in Figure 5. The way these were applied to this project are outlined in Section 5.

1) The approach is to first define the Historical Migration Zone (HMZ), which is the whole area of the valley bottom where channel presence can be documented from historical aerial

photos, historical maps, and/or interpretation of floodplain topography and riparian vegetation.

2) The avulsion hazard area (AHA) is defined based on the topography of the floodplain and characteristics of the channel and may include areas outside the HMZ.

3) The erosion hazard area (EHA) is a buffer around the combined HMZ and AHA. The EHA buffer width is defined based on the historical rate of floodplain erosion and the proportion of time that the channel is likely to be in contact with the edge of the valley at any given location. Channels will reoccupy positions along the edge of the valley through two mechanisms: down valley meander translation and channel migration back and forth across the valley bottom.

4) The width of the EHA is a function of the erosion setback (E_S) which is defined as follows:

$$E_S = T\ C_E\ ,$$

where T is the CMZ delineation timeframe (50 years in the case of this project, as directed by State Parks) and C_E is a coefficient that incorporates the average erosion rate and percentage of time that the river is likely to erode a given portion of the valley wall. Because the channel re-set in a new entrenched valley in the late 19th-early 20th century, most of the erosion since the earliest available aerial photo (1937) has been the erosion of the valley wall. Therefore, the difference in width between the HMZ in 2019 and the 1937 active channel, divided by the elapsed period (82 years), gives an excellent estimate of C_E in the project area.

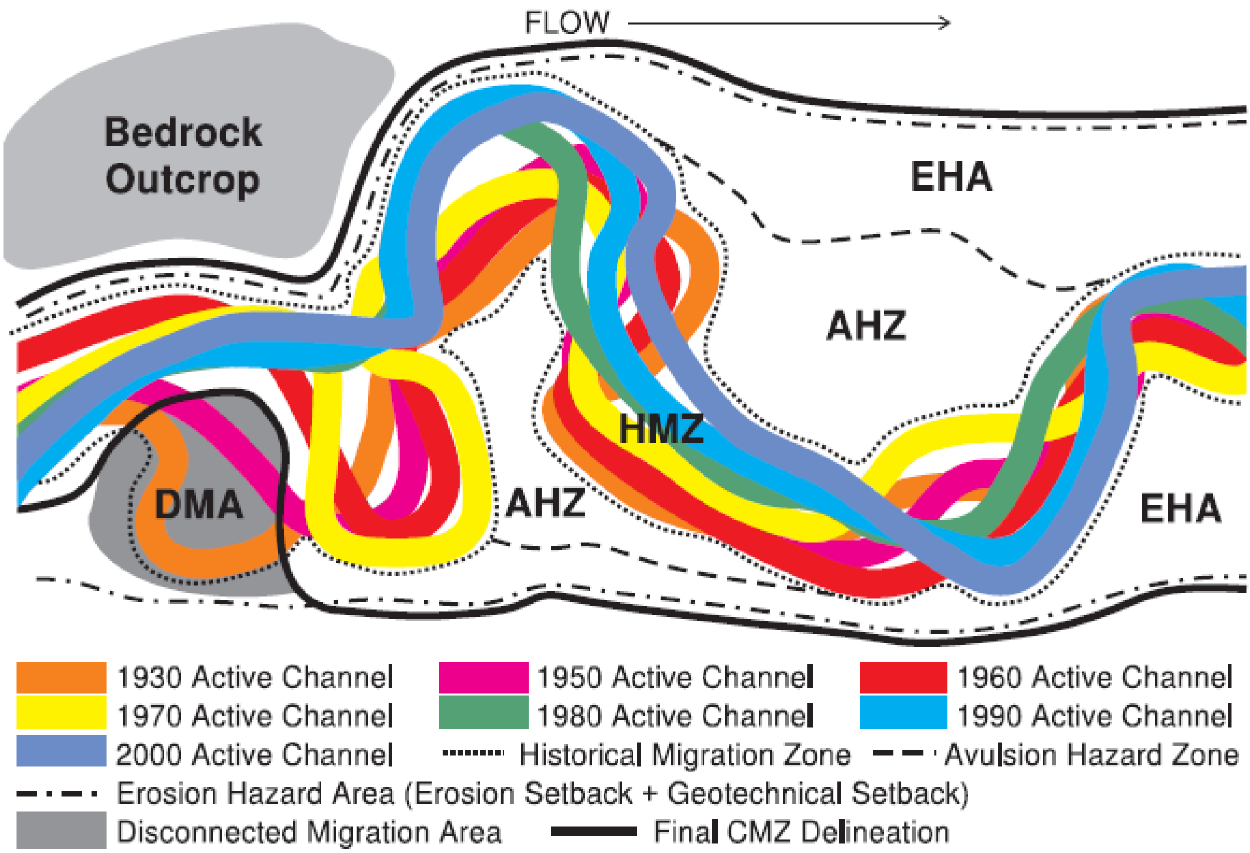


Figure 5: Graphical illustration of the relationship between CMZ components, from Rapp and Abbe (2003).

5) The CMZ analysis also determines areas that are behind permanently maintained dikes, levees, or revetments where it is assumed active human intervention will prevent channel migration. These areas are delineated as the Disconnected Migration Area (DMA). No such areas were identified within the Project Reach.

6) The final Channel Migration Zone is then mapped as the extents of the EHA minus areas within the DMA.

The average erosion setback can be reduced, at the discretion of the CMZ analyst, in areas of relatively unerodable floodplain or valley wall soils (e.g. the bedrock outcrop illustrated in Figure 5). It can also be extended, at the discretion of the CMZ analyst, in areas near individual actively migrating meanders based on the specific rate of movement of that feature. In that case, the erosion rate for the specific feature is calculated using the same approach as for the reach-scale EHA, but the input data are restricted to the period and area of active bank erosion. For this assessment, the reach-average EHA was used as the minimum value but widened around individual actively migrating channel segments based on the historical rate of movement for each feature.

5 CMZ ASSESSMENT RESULTS

5.1 Historical Channel Migration and Historical Channel Migration Zone

The channel position was mapped in historical aerial photos form 1937, 1965, 1981, 1990, 2002, 2005, 2009, 2011, 2014, and 2019 to determine the extent of the HMZ, which is the total area occupied by the channel at any of those dates and any areas in between those (as shown in Figure 6). Evaluation of LiDAR data also showed a few areas of inset floodplain that were identified outside of this zone. It is assumed that these areas must have been occupied by the Issaquah Creek channel, so they were also included in the HMZ. These are areas where overhanging vegetation may have obscured the true bank line in an aerial photo or where a cycle of erosion and channel abandonment occurred between aerial photos. Due to the channel evolution history described in Section 2, the average rate of historic channel occupancy zone expansion (net erosion rate) is interpreted to be a close approximation of C_E in this project area. The width of the eroded area and calculated net erosion rates for each reach are listed in Table 1.

These average rates mask the rapid amplification of numerous individual meanders, which have grown on the order of 150 to 200 feet within one to two decades (Table 2). A meander cutoff avulsion occurred at Station 5,600 between 2014 and 2017, which may indicate a maximum expected meander amplitude of about 200 feet.

Table 1: Observed historical erosion rates for each reach.

Reach	Average Eroded Width (feet)	Erosion Rate (feet/year)
1	57	0.7
2	117	1.4
3	42	0.5
4	139	1.7

Table 2: Rapid amplification of select individual meanders in the historic channel migration record for Issaquah Creek.

Location (Station)	Erosion Period	Maximum Local Erosion Distance (feet)	Erosion Rate (feet/year)
3750	1981-2019	150	3.9
5100	2002-2019	135	7.9
5600	1990-2014	210	8.8
6250	2005-2019	150	10.7
6900	1990-2014	175	6.0

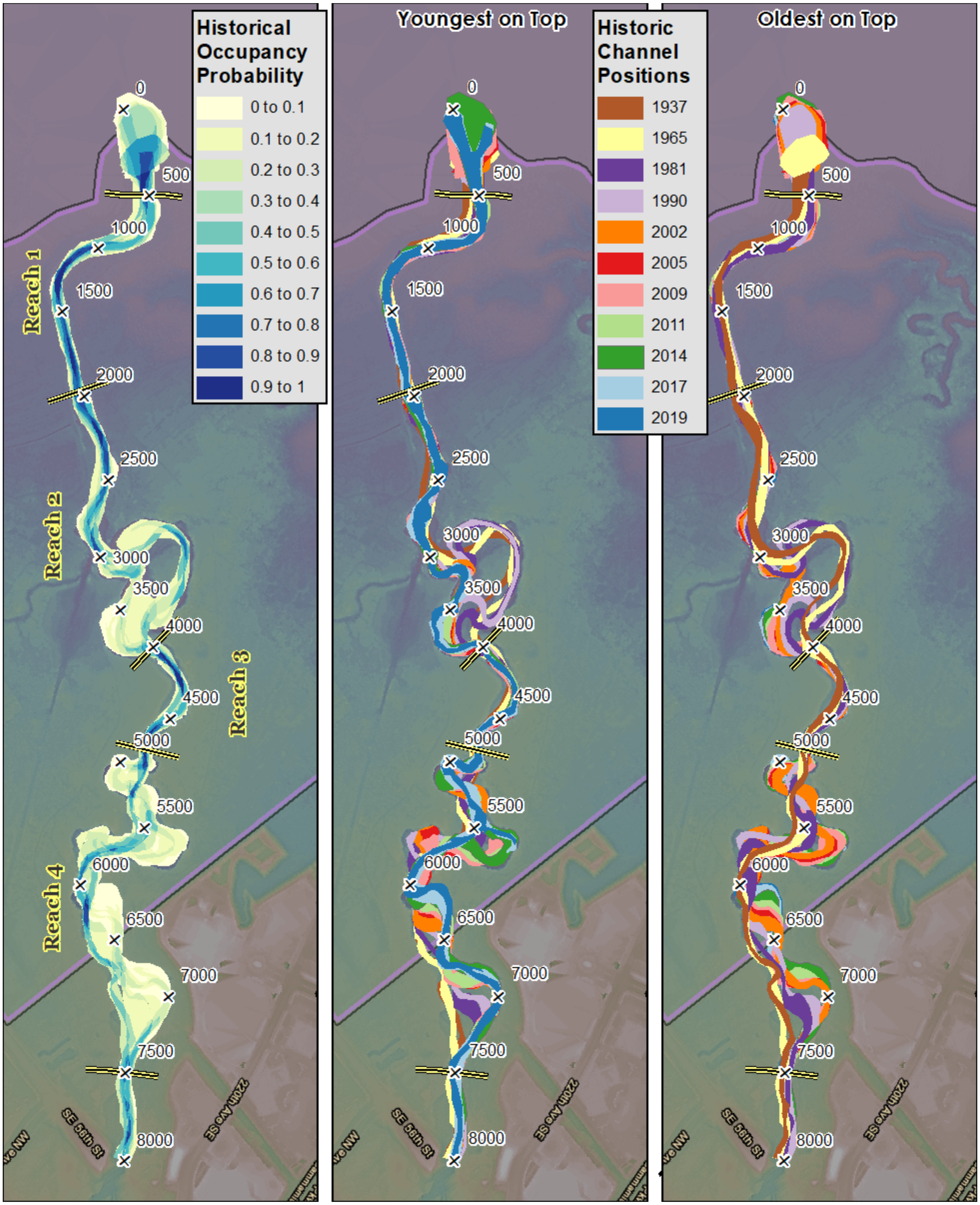


Figure 6: **Historic channel occupancy probability (left, calculated as the proportion of the historical period during which the channel was in any given location) and historical channel positions mapped showing the most recent (youngest) channel occupancy (middle) and the oldest channel occupancy (right).**

5.2 Avulsion Hazard Areas

CMZ delineation guidance (Rapp and Abbe, 2003) suggests that about 2 m (6.5 feet) of vertical bed instability should be assumed in determining the extent of the AHA. Most of the channel length within the project area is incised significantly below the surrounding alluvial surface (Figure 2), limiting avulsion potential to areas already mapped as being within the HMZ. This is not true, however, for the lowest portion of the creek (Reach 1), where the bank height relative to the top of bank elevation for the channel decreases from about six- to zero-feet moving from upstream to downstream. Avulsions are, therefore, possible along this reach. They are most likely to cut across the narrow strip of land between the left bank of the creek and Lake Sammamish, but could also cause the creek to occupy areas of the relict channel and wetland on the right bank (see Figure 7).

5.3 Erosion Hazard Area

The width of the erosion hazard area was calculated for each of the four reaches in the project area based on the historical net erosion rates for each reach (Table 1). For a 50-year delineation timeframe (as directed by State Parks), this yields EHA buffer widths for each side of the channel of 17 feet for Reach 1, 36 feet for Reach 2, 13 feet for Reach 3, and 42 feet for Reach 4. A preliminary erosion hazard area was then mapped as a buffer of the specified width around the delineation HMZ and AHA. This defines the expected position of the edge of the active channel following erosion.

The erosion rate for select individual meanders was evaluated and the width of the EHA was increased to account for the possibility that these features may continue to move at their historical rate over the CMZ delineation timeframe. To do this, the time when the feature started to migrate was determined from the historical channel mapping inventory, and the area between the current bankline and the bankline at the time the feature began to move was divided by the length of the current bankline to determine the average migration distance. This distance was divided by the period of time elapsed since the feature formed to determine an average migration rate. The average erosion timeframe for the identified features was 33- ± 21-years (±1σ), and the shortest and longest durations were 8- and 82-years, respectively. The average calculated erosion rate for these features was 1.78 ±1.31 feet/year.

The banks at the outside edge of the CMZ are relatively high (up to 12 feet above the bankfull water surface Figure 2 and Figure 3). The edge of the CMZ represents the edge of the active channel and so in areas where the bank height is substantially higher than the bankfull water surface, geotechnical relaxation of the slope outside of the delineated CMZ is expected. A formal geotechnical assessment should evaluate slope stability above the channel thalweg elevation starting from the edge of the CMZ as a part of the design process for any structure foundations situated near the edge of the CMZ.

5.4 Other CMZ Features and Constraints on Lateral Migration

Disconnected migration areas are created by revetments meeting the specific criteria of Washington Administrative Code (WAC) 173-26-221 (3)(B) or other permanent infrastructure (e.g. single access roads or railways). Two revetments impact channel migration processes between about Station 5,900 and

Station 6,500 (Reach 4 Geomorphic Overview Map in NHC and The Watershed Company, 2017), but these do not appear to have been maintained to meet the criteria laid out in the WAC. Therefore, no DMAs are mapped within the project area.

5.5 CMZ Summary

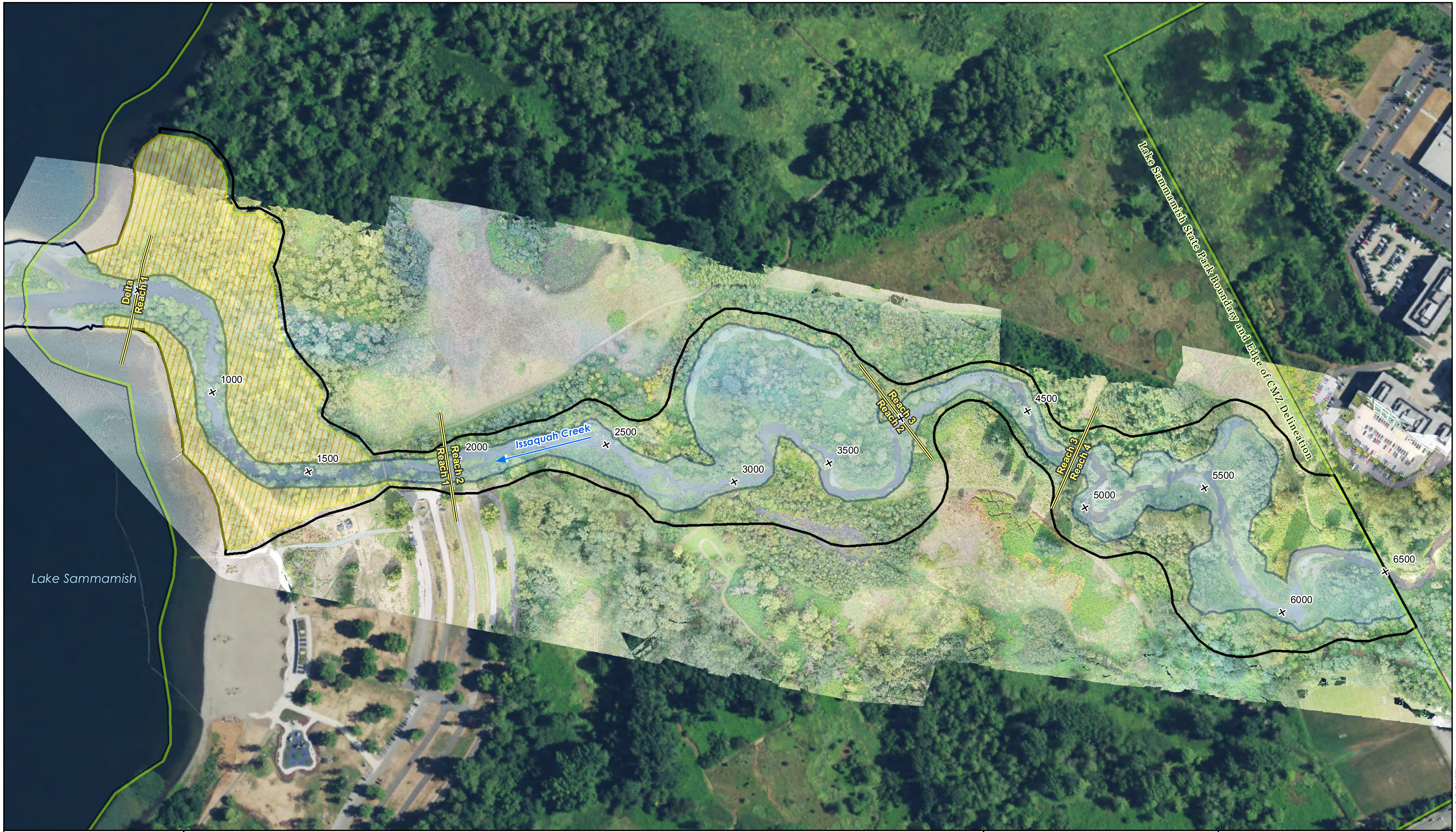
Figure 7 shows the map resulting from the CMZ analysis described above. It is important to note that the Erosion Hazard Area buffers shown in this map are based on historic average migration rates extrapolated into the future, following established guidelines (Rapp and Abbe, 2003) for this procedure. It represents a reasonable projection of the possible channel migration extent over the 50-year delineation timeframe (as directed by State Parks), that follows existing regulatory guidelines. For future comprehensive planning and risk assessments, in addition to the mapped CMZ according to the established guidelines, some further understanding of limitations of the CMZ mapping method and controlling geomorphic processes may provide useful information. The following section provides this information.

5.6 CMZ Limitations and Uncertainty

The exact location of the CMZ boundary identified in this study is not a function of any fundamental barrier to channel migration (e.g. bedrock or a maintained revetment), as described in Section 5.4. Therefore, due to the nature of the mapping procedure, stochastic creek behavior, and uncertainty of the geologic materials along the creek, the actual zone occupied by the channel over the next 50 years may be expected to extend beyond the edge of the CMZ in some locations while not approaching it in other locations. The highest risk areas of the CMZ boundary are expected to be those closest to the present-day active channel—especially areas near the outside and downstream segments of meander bends. The lowest risk areas of the CMZ boundary are expected to be those farthest away from the active channel. This section discusses key underlying assumptions that may result in migration patterns different from those assumed in the regulatory CMZ delineation process (Rapp and Abbe, 2003).

As mentioned previously, the CMZ delineation procedure followed for this assessment is based on the extrapolation of historic patterns under the assumption that they will continue. This produces a reasonable prediction of expected future migration, but it is not (and is not intended to be) a conservative outer boundary for all possible channel movement. The reach-average buffer calculations produce a boundary with about a 50 percent probability of exceedance within the selected time frame.

To reduce the probability that the channel will exceed the reach-average buffer calculations, areas around individual active meanders, based on their individual migration history, were assessed. Although this provides a more refined assessment compared to the reach-average, uncertainty in future channel migration rates remain. This is due to the erodibility of material surrounding the HMZ and stochastic channel migration patterns, as described below.



Channel Migration Zone Subunits

Historic Migration Zone

Erosion Hazard Area/Outer CMZ boundary.

Avulsion Hazard Zone

DATA SOURCES: 2017 NAIP Orthophoto (background) 2019 NHC uav orthomosaic (foreground)

SCALE - 1:3,500

0 100 200 300 400 Feet

N

Coordinate System: NAD 1983 NSRS2007 STATEPLANE WASHINGTON NORTH FIPS 4601 FT

Job: 2003907

Date: March 2020

nhc northwest hydraulic consultants

Lower Issaquah Creek

CMZ Delineation

FIGURE 7

Future erosion rates may change as the creek encounters materials different from those it interacted with during the historical expansion of the HMZ. For example, some areas (e.g. the banks adjacent to the channel in Reach 3) appear to be more erosion resistant than other areas (e.g. the banks adjacent to the channel in Reach 2 and Reach 4). The longitudinal lateral variability in bank strength along the creek suggests that bank strength likely varies perpendicular to the channel as well. Therefore, erosion into the terrace could cause the channel to reach relatively erosion-resistant material that would prevent further migration in Reach 2 or Reach 4. Conversely, erosion could make its way through the higher strength material that has been limiting migration in Reach 3 and begin interacting with less-resistant material and result in accelerated channel migration rates at any point in that reach.

The historic record shows that individual meanders can form and rapidly erode a substantial distance into the terrace (Table 2), as numerous meanders have grown on the order of 150 to 200 feet within one to two decades. Given a relatively short typical lifespan (20- to 30-year average) of individual meanders along the creek over the historical record, it is likely that, in some places, new meanders will form. These may erode at relatively fast rates in concentrated areas, which could result in lateral migration outside of the delineated CMZ. Granting the (very reasonable) assumption that only one episode of meander amplification will occur at any given location along the edge of the HMZ over the 50-year CMZ delineation timeframe, is it possible to apply the observed history of meander cutoffs. The observed history indicates that meanders on the creek rarely exceed an amplitude of about 200 feet before a cutoff occurs, which provides the outer limit of expected channel migration at any given point along the creek. A 200-foot buffer beyond the HMZ, therefore, provides a robust estimate of the maximum expected lateral channel movement away from the HMZ over a 50-year timeframe. This buffer is not shown in the CMZ map (Figure 7) as it exceeds the standards set by the guidance documents followed to produce this study. It may, however, be helpful information for future comprehensive planning and risk assessments for a given asset.

6 REFERENCES

NHC (2012). *Findings on Lake Sammamish Outflow into Sammamish River*.

NHC, and The Watershed Company (2017). *Lower Issaquah Creek Restoration at Lake Sammamish State Park Conceptual Design Report* (002002182). Report prepared by Northwest Hydraulic Consultants and the Watershed Company for Mountains to Sound Greenway Trust.

Olson, P. L., Legg, N. T., Abbe, T. B., Reinhart, M. A., and Radloff, J. K. (2014). *A Methodology for Delineating Planning-Level Channel Migration Zones* (14-06–025). Washington Department of Ecology Shorelands and Environmental Assistance, Olympia, WA. [online] Available from: https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html.

Rapp, C., and Abbe, T. B. (2003). *A Framework for Delineating Channel Migration Zones* (#03-06-027). Ecology Publication. Washington State Department of Transportation and Washington State Department of Ecology.

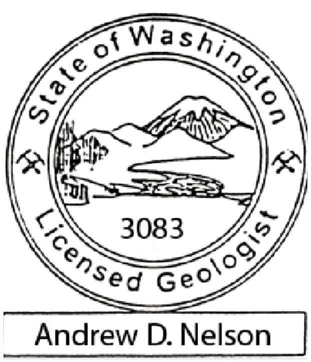
DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Inc. in accordance with generally accepted engineering practices and is intended for the exclusive use and benefit of Mountains to Sound Greenways Trust and their authorized representatives for specific application to the Lower Issaquah Creek Habitat Restoration Project in Lake Sammamish State Park, Issaquah, WA. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from Northwest Hydraulic Consultants Inc. No other warranty, expressed or implied, is made. Northwest Hydraulic Consultants Inc. and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than Mountains to Sound Greenways Trust.

Sincerely,

Northwest Hydraulic Consultants Inc.

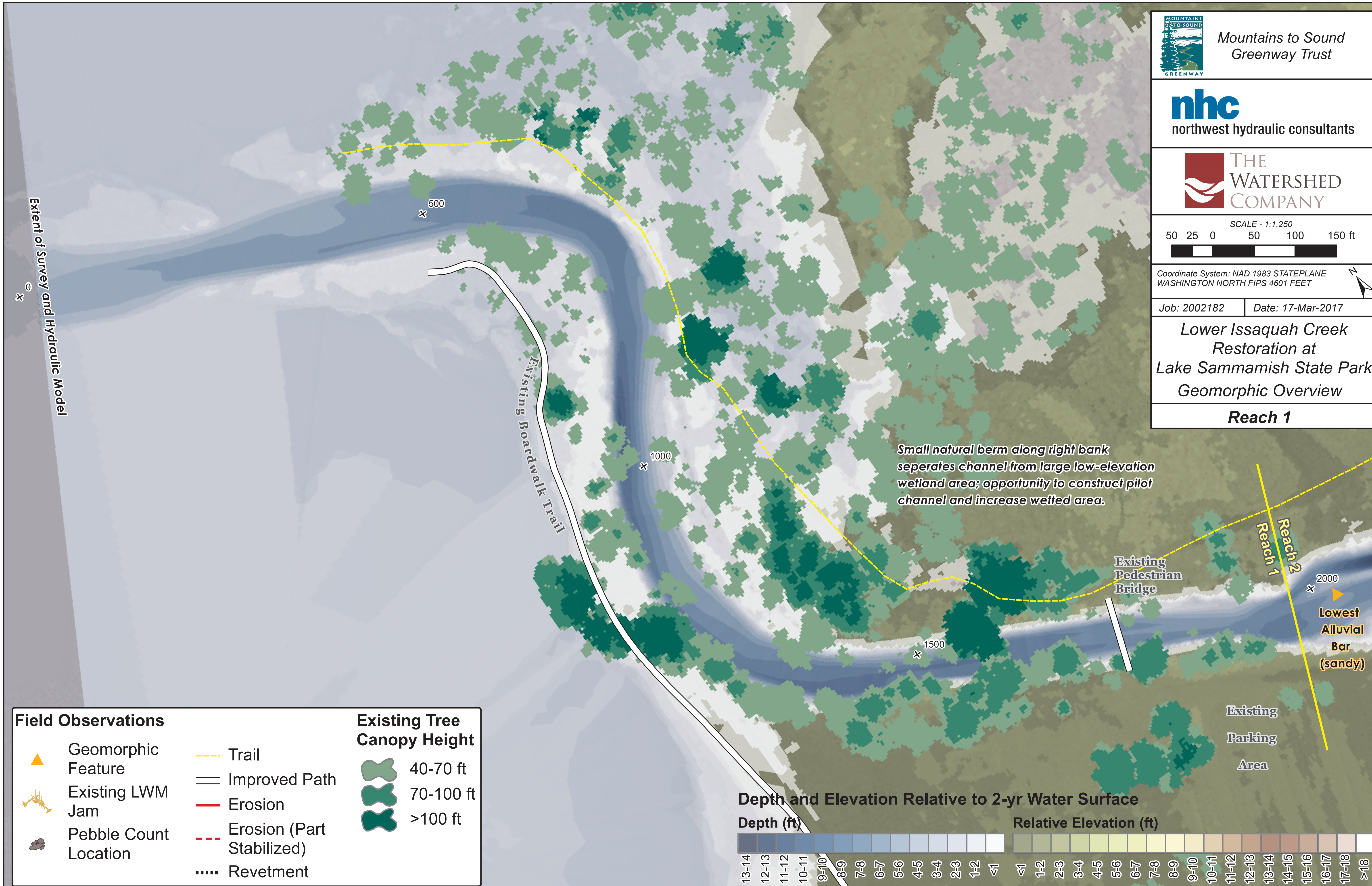
Prepared by or under the direct supervision of:



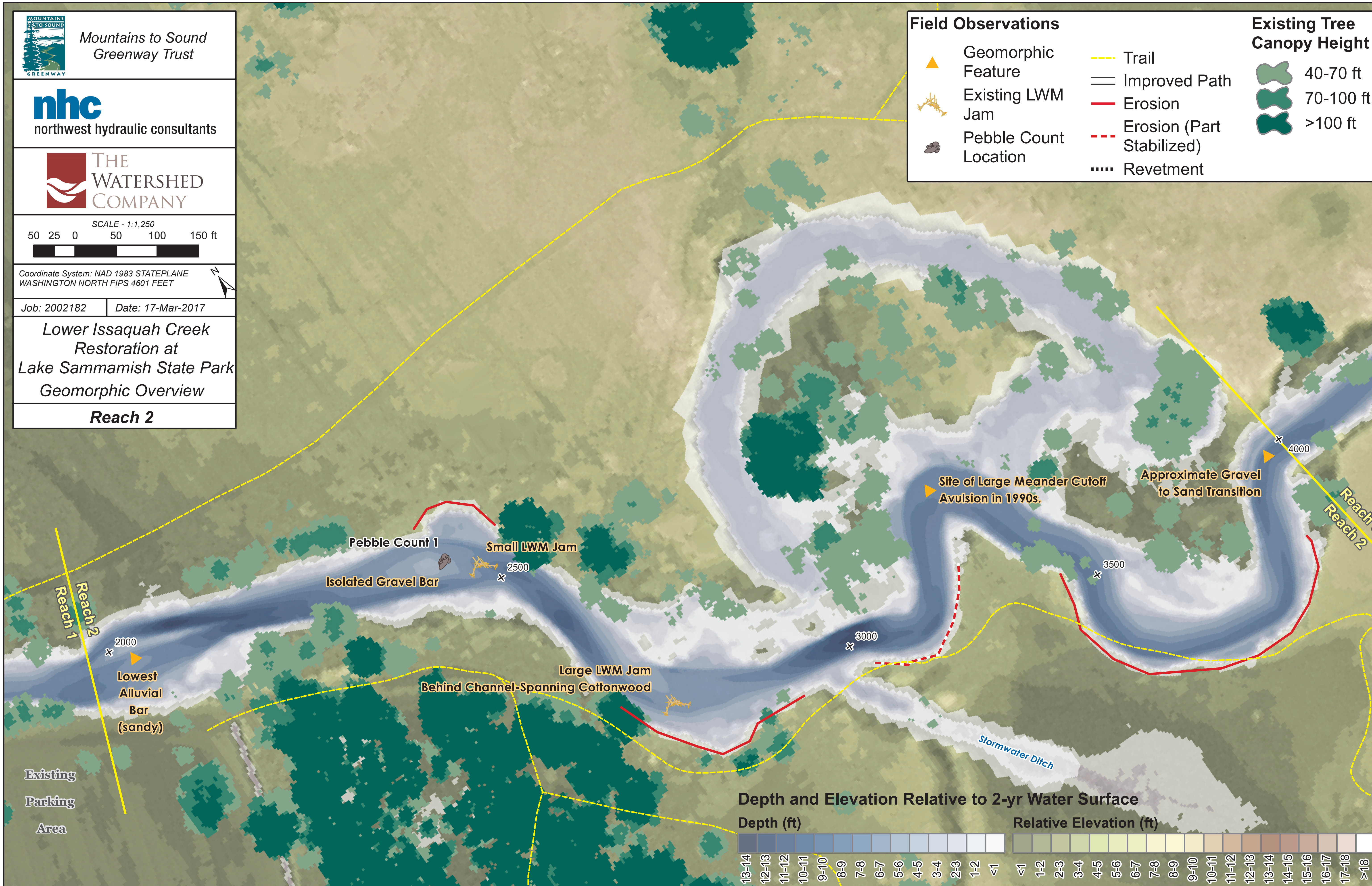
Andrew Nelson, M.Sc., L.G.,
Associate I Senior Geomorphologist
Author

Casey Kramer, PE
Principal River Engineer
Reviewer

APPENDIX E: GEOMORPHIC OVERVIEW



Mountains to Sound Greenway Trust
nhc
northwest hydraulic consultants
The Watershed Company
SCALE - 1:1,250
50 25 0 50 100 150 ft
Coordinate System: NAD 1983 STATEPLANE WASHINGTON NORTH FIPS 4601 FEET
Job: 2002182
Date: 17-Mar-2017
Lower Issaquah Creek Restoration at Lake Sammamish State Park
Geomorphic Overview
Reach 1
Extent of Survey and Hydraulic Model
0
500
1000
1500
2000
Existing Boardwalk Trail
Small natural berm along right bank seperates channel from large low-elevation wetland area; opportunity to construct pilot channel and increase wetted area.
Existing Pedestrian Bridge
Reach 1
Reach 2
Lowest Alluvial Bar (sandy)
Existing Parking Area
Field Observations
Geomorphic Feature
Existing LWM Jam
Pebble Count Location
Trail
Improved Path
Erosion
Erosion (Part Stabilized)
Revetment
Existing Tree Canopy Height
40-70 ft
70-100 ft
>100 ft
Depth and Elevation Relative to 2-yr Water Surface
Depth (ft)
13-14 12-13 11-12 10-11 9-10 8-9 7-8 6-7 5-6 4-5 3-4 2-3 1-2 <1
Relative Elevation (ft)
<1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15 15-16 16-17 17-18 >18



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SCALE - 1:1,250
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Date: 17-Mar-2017
Lower Issaquah Creek Restoration at Lake Sammamish State Park
Geomorphic Overview
Reach 2
Field Observations
Geomorphic Feature
Existing LWM Jam
Pebble Count Location
Trail
Improved Path
Erosion
Erosion (Part Stabilized)
Revetment
Existing Tree Canopy Height
40-70 ft
70-100 ft
>100 ft
Site of Large Meander Cutoff Avulsion in 1990s.
Approximate Gravel to Sand Transition
Reach 3
Reach 2
4000
3500
3000
2500
2000
Pebble Count 1
Small LWM Jam
Isolated Gravel Bar
Reach 2
Reach 1
Lowest Alluvial Bar (sandy)
Large LWM Jam Behind Channel-Spanning Cottonwood
Stormwater Ditch
Existing Parking Area
Depth and Elevation Relative to 2-yr Water Surface
Depth (ft)
13-14
12-13
11-12
10-11
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
<1
Relative Elevation (ft)
<1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
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9-10
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11-12
12-13
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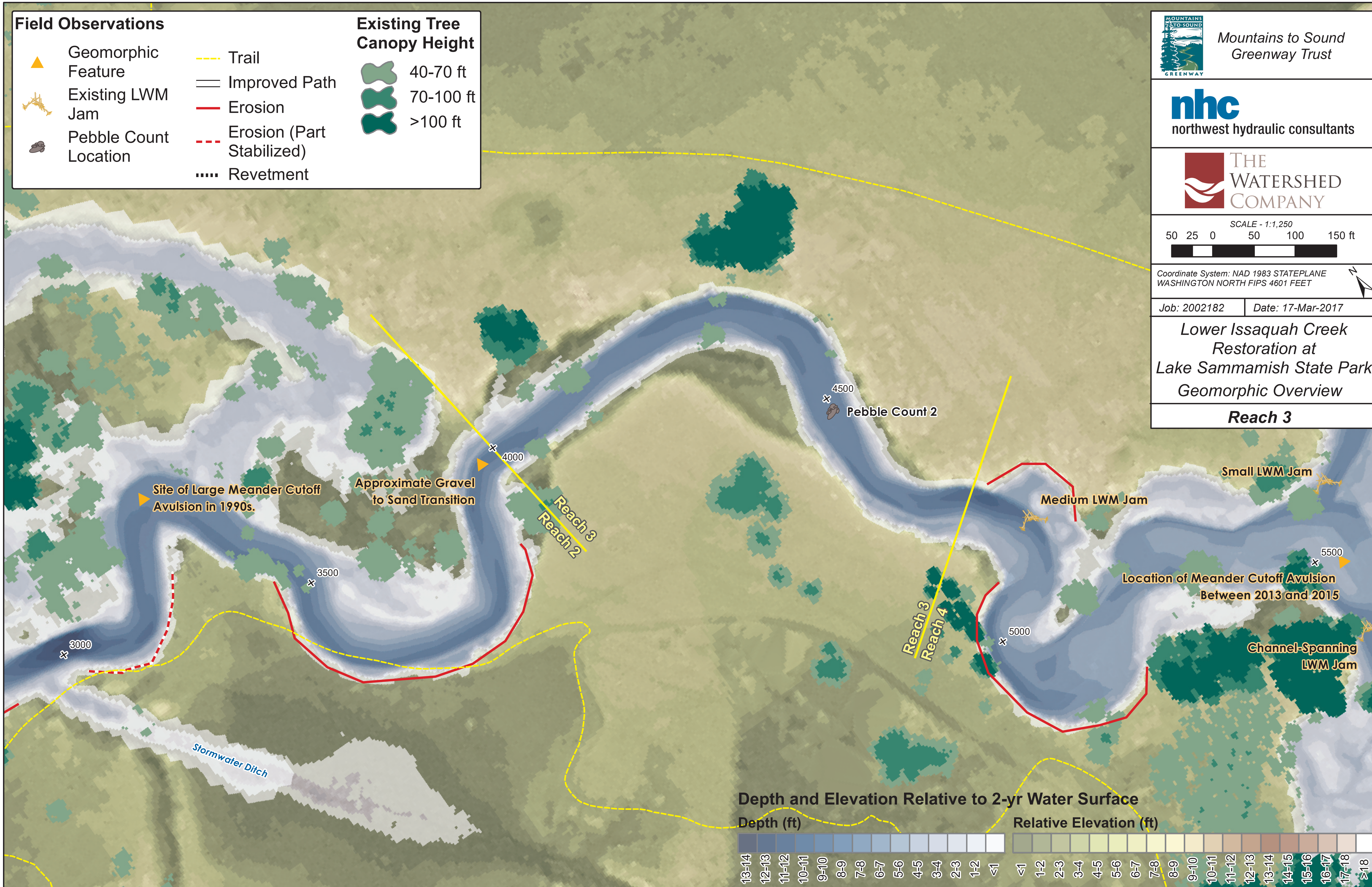
15-16
16-17
17-18
>18



Field Observations
Geomorphic Feature
Existing LWM Jam
Pebble Count Location
Trail
Improved Path
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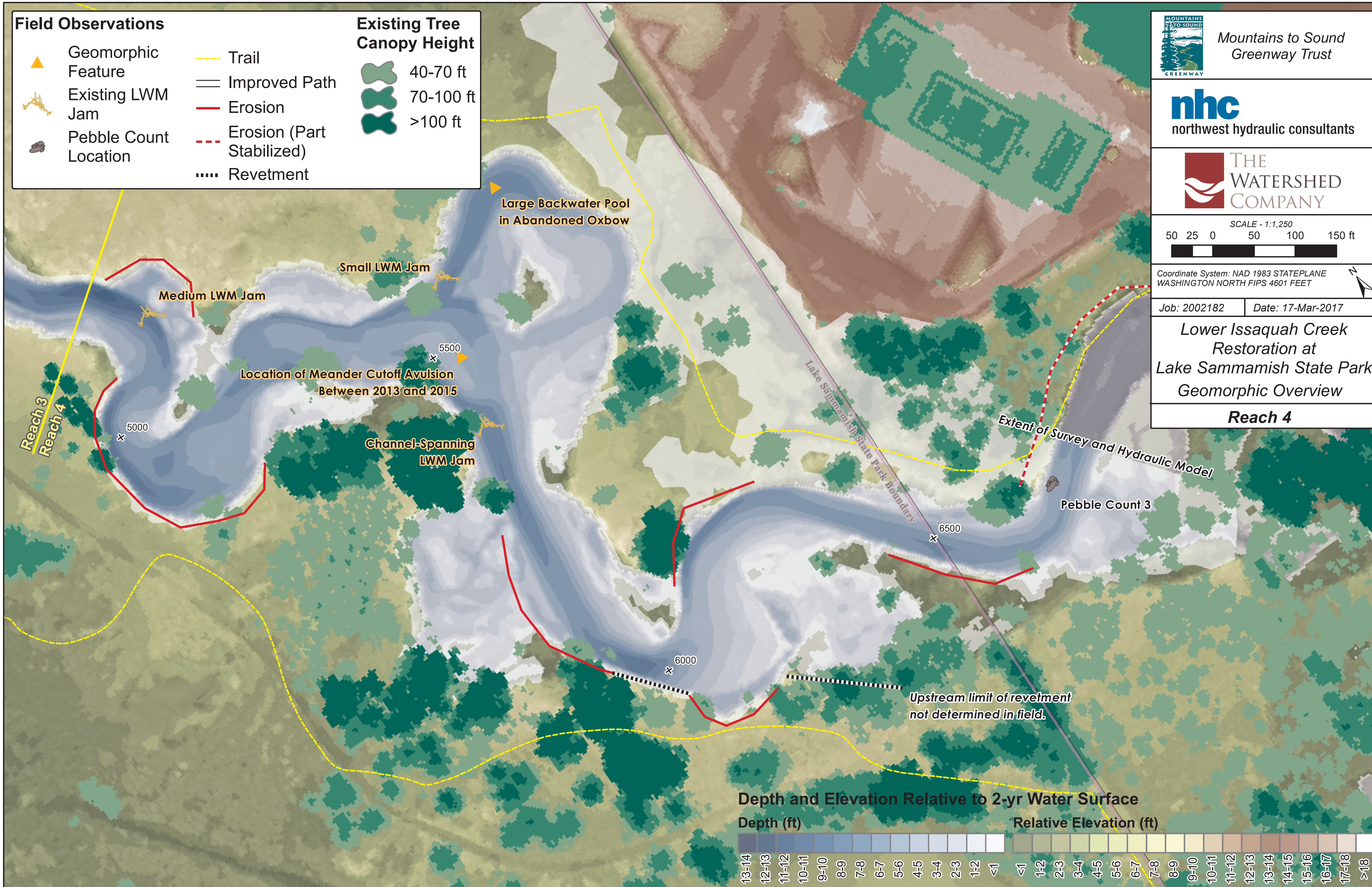
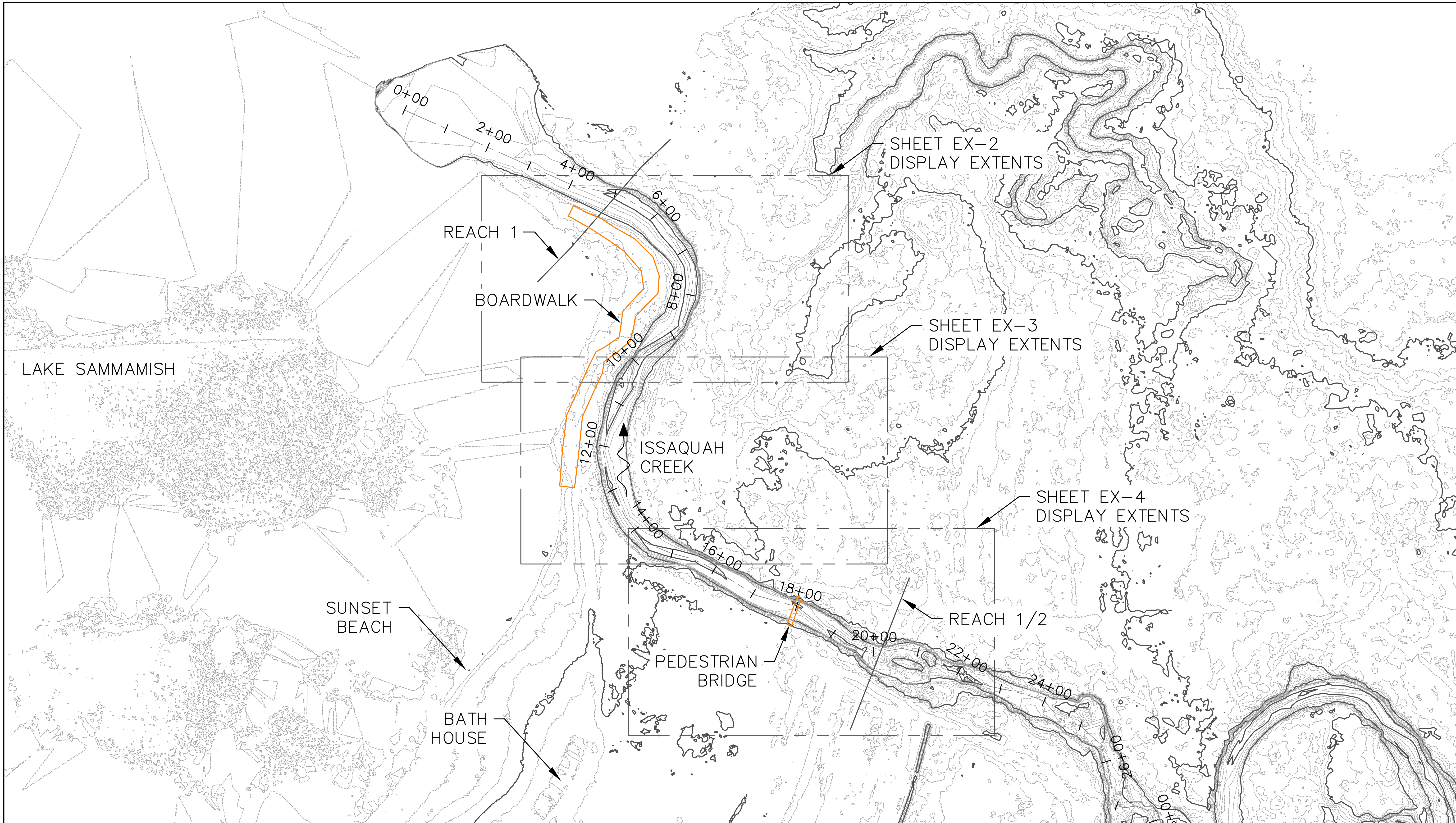
Date: 17-Mar-2017
Lower Issaquah Creek Restoration at Lake Sammamish State Park
Geomorphic Overview
Reach 3
Site of Large Meander Cutoff Avulsion in 1990s.
Approximate Gravel to Sand Transition
Reach 3
Reach 2
Pebble Count 2
Medium LWM Jam
Small LWM Jam
Location of Meander Cutoff Avulsion Between 2013 and 2015
Channel-Spanning LWM Jam
Reach 3
Reach 4
Stormwater Ditch
3000
3500
4000
4500
5000
5500
Depth and Elevation Relative to 2-yr Water Surface
Depth (ft)
13-14 12-13 11-12 10-11 9-10 8-9 7-8 6-7 5-6 4-5 3-4 2-3 1-2 <1
Relative Elevation (ft)
<1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15 15-16 16-17 17-18 >18



Field Observations
Geomorphic Feature
Existing LWM Jam
Pebble Count Location
Trail
Improved Path
Erosion
Erosion (Part Stabilized)
Revetment
Existing Tree Canopy Height
40-70 ft
70-100 ft
>100 ft
Mountains to Sound Greenway Trust
nhc
northwest hydraulic consultants
The Watershed Company
SCALE - 1:1,250
50 25 0 50 100 150 ft
Coordinate System: NAD 1983 STATEPLANE WASHINGTON NORTH FIPS 4601 FEET
Job: 2002182
Date: 17-Mar-2017
Lower Issaquah Creek Restoration at Lake Sammamish State Park
Geomorphic Overview
Reach 4
Large Backwater Pool in Abandoned Oxbow
Small LWM Jam
Medium LWM Jam
Location of Meander Cutoff Avulsion Between 2013 and 2015
Channel-Spanning LWM Jam
Reach 3
Reach 4
5000
5500
6000
6500
Lake Sammamish State Park Boundary
Extent of Survey and Hydraulic Model
Pebble Count 3
Upstream limit of revetment not determined in field.
Depth and Elevation Relative to 2-yr Water Surface
Depth (ft)
13-14 12-13 11-12 10-11 9-10 8-9 7-8 6-7 5-6 4-5 3-4 2-3 1-2 <1
Relative Elevation (ft)
<1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15 15-16 16-17 17-18 >18

APPENDIX F: PRELIMINARY PLANS



northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584-9810

N

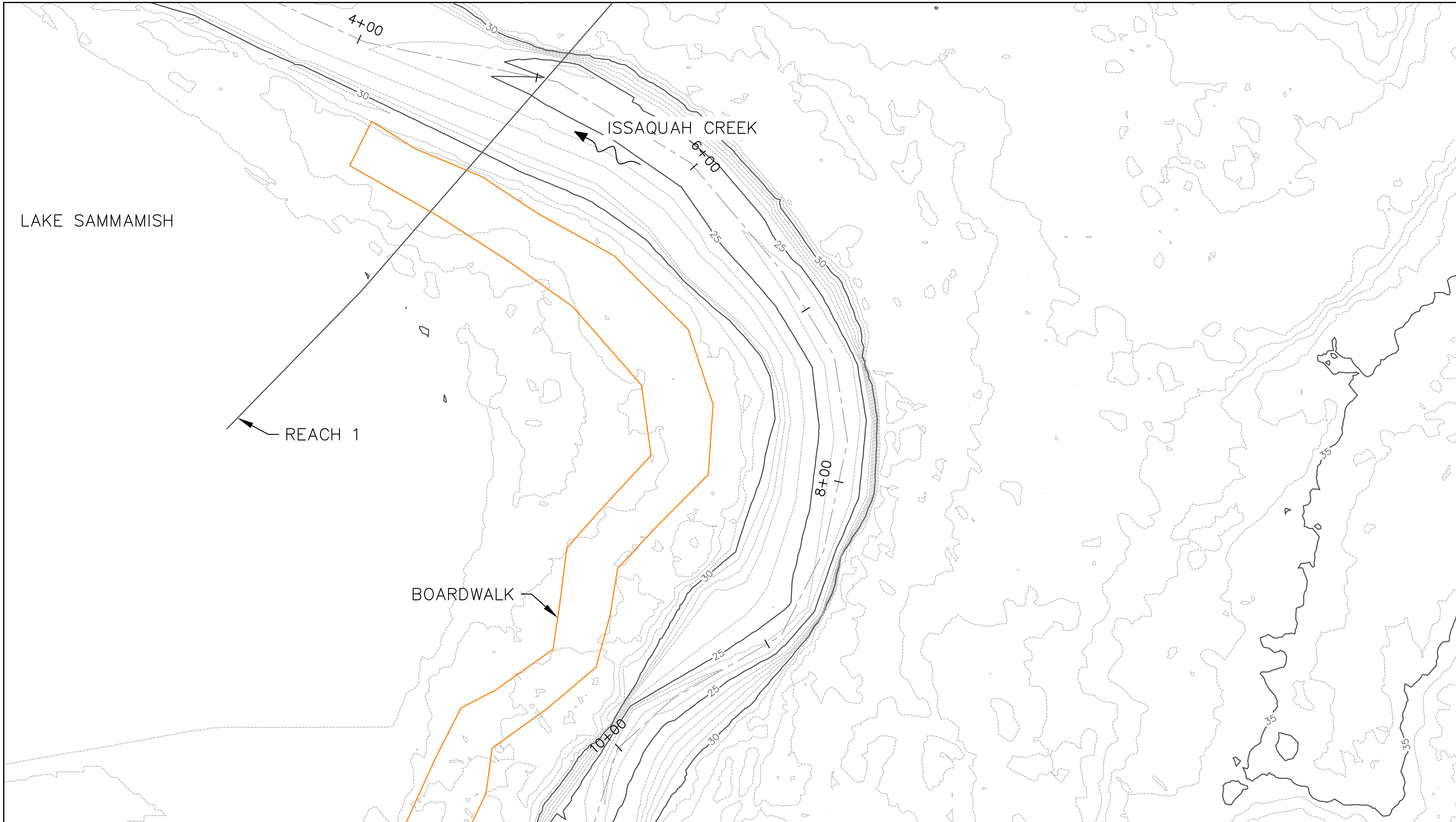
0 200 400 Feet

Job:2003907
Rev:
Drft: MWG
Chkd:
Date:19Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 1 Overview

Sheet EX-1



MOUNTAINS to Sound GREENWAY

WASHINGTON STATE PARKS

nhc
northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584–9810

N

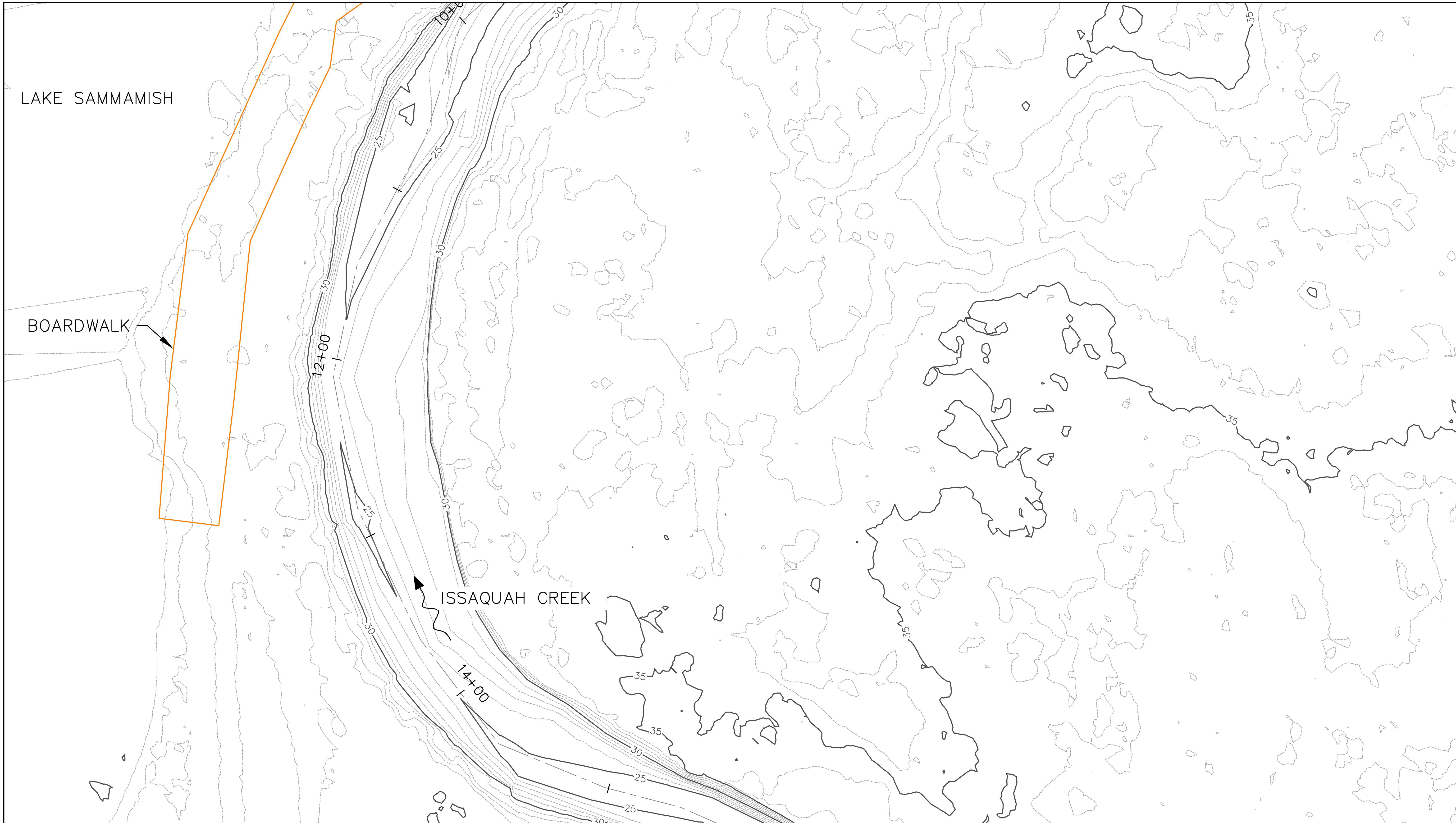
0 50 100
Feet

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date:18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 1

Sheet EX-2



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northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584-9810

N

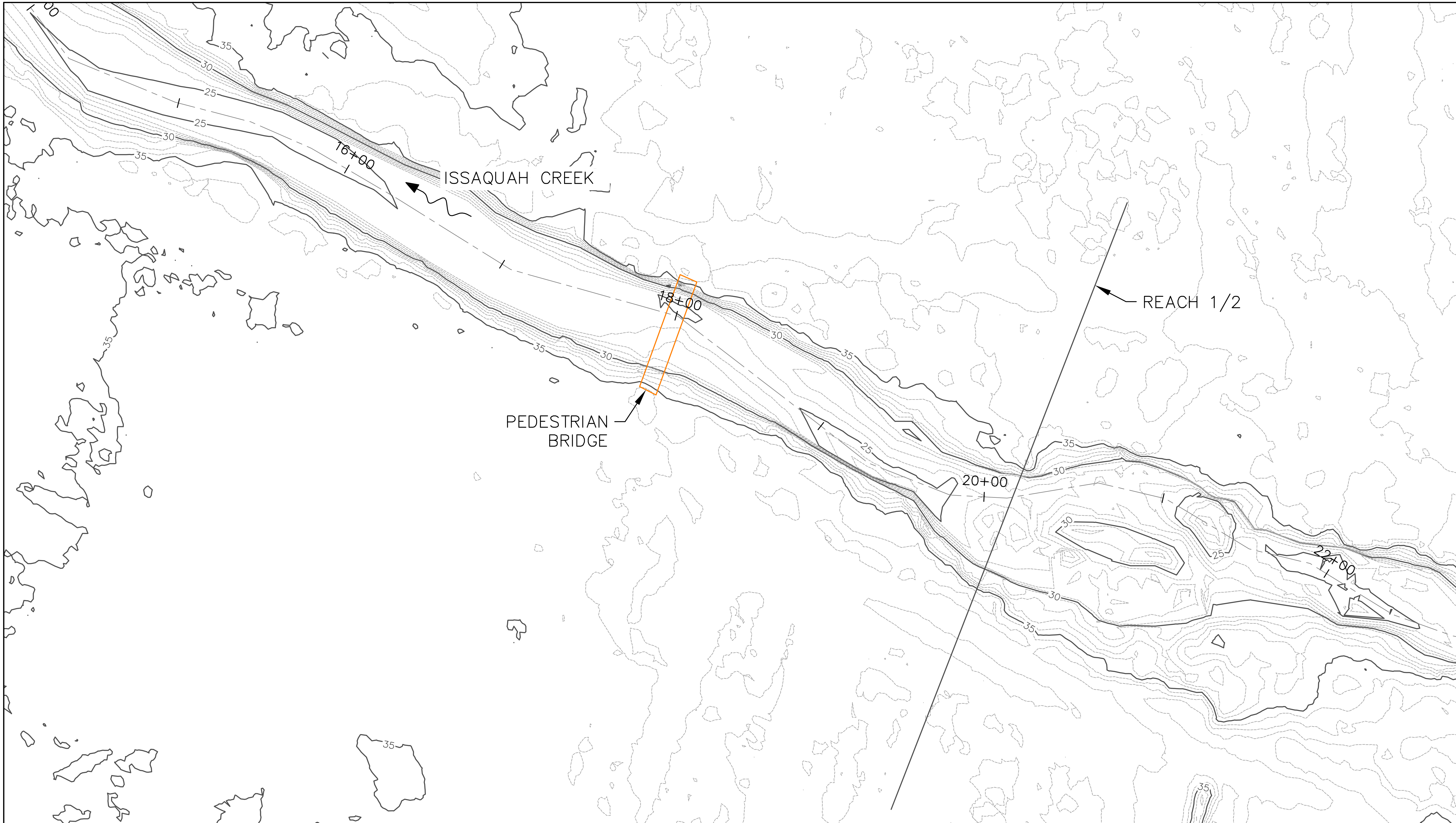
0 50 100 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 1

Sheet EX-3



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olympia, washington 98501
phone: (360) 584-9810

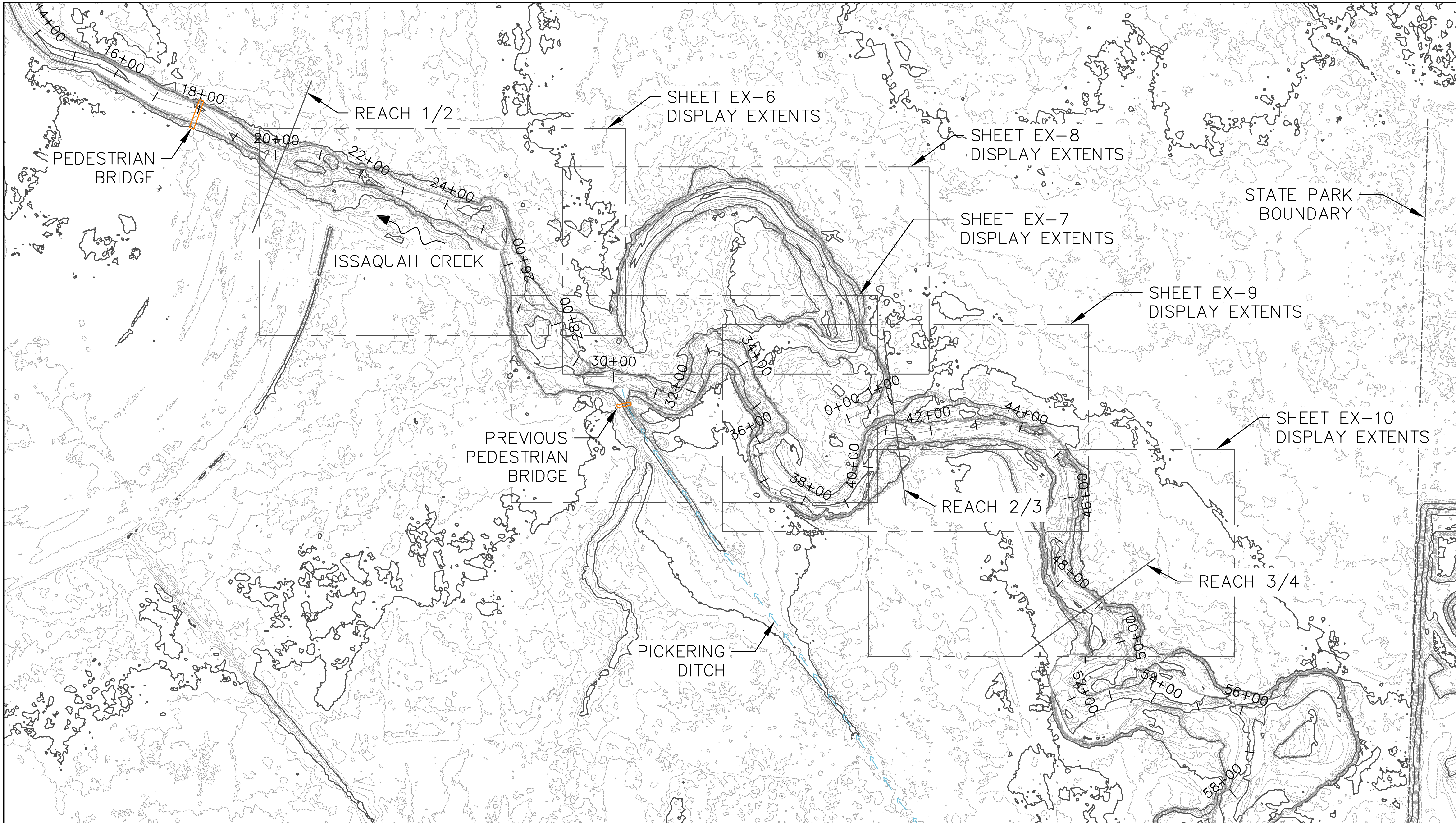
0 50 100 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 1

Sheet EX-4



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olympia, washington 98501
phone: (360) 584-9810

N

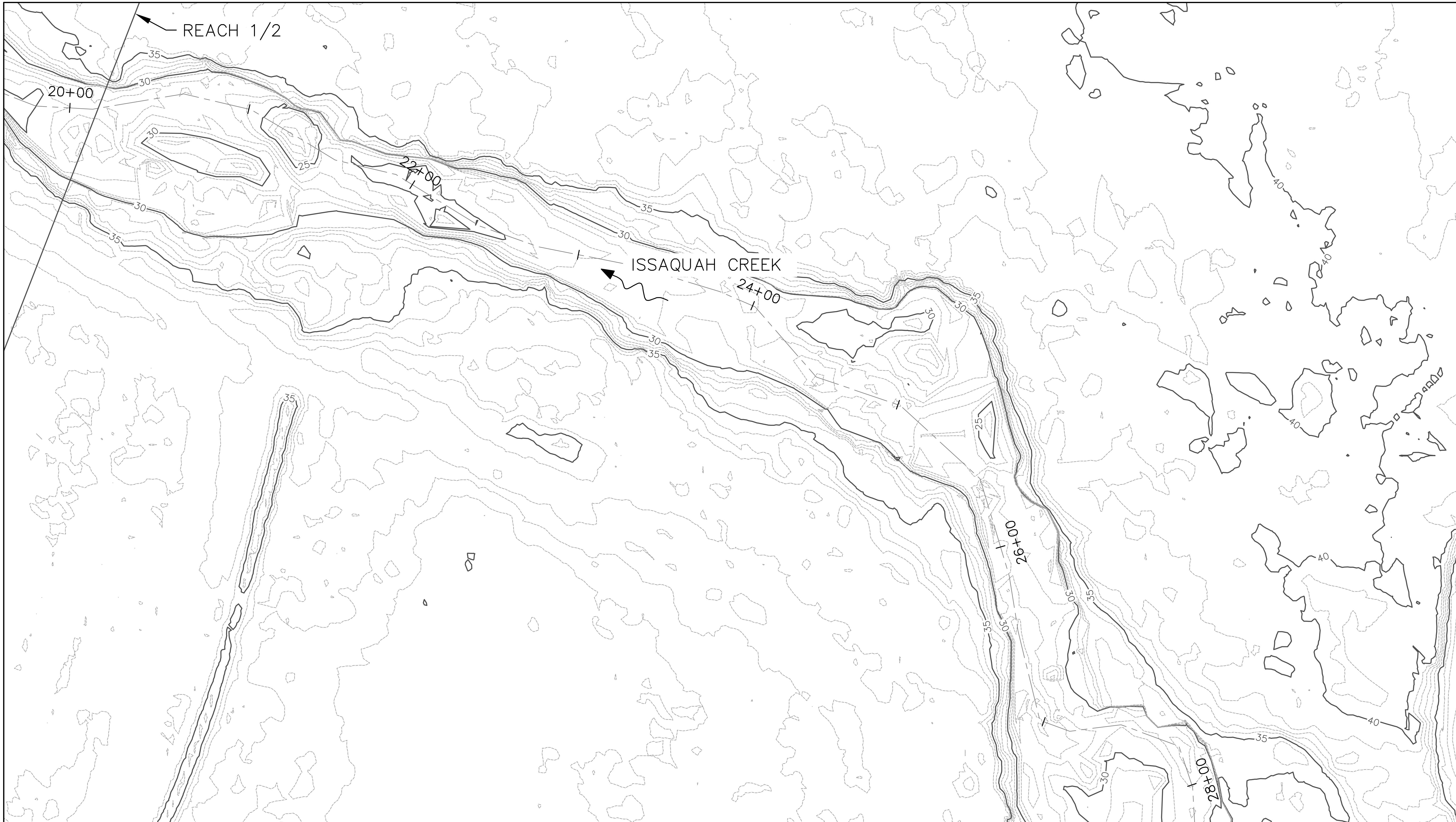
0 200 400 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reaches 2 and 3 Overview

Sheet EX-5



MOUNTAINS to Sound GREENWAY

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northwest hydraulic consultants
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olympia, washington 98501
phone: (360) 584-9810

N

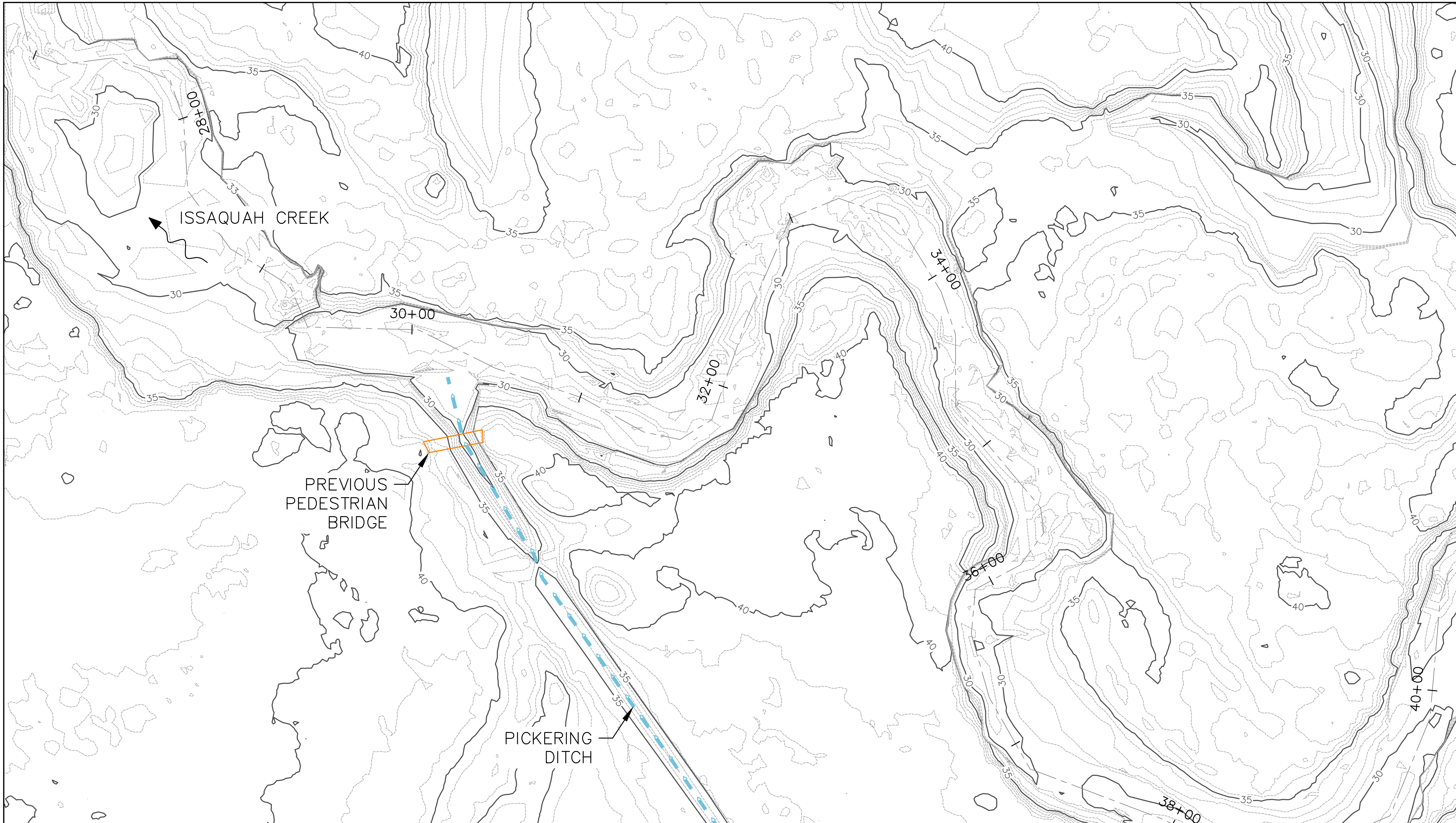
0 50 100 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 2

Sheet EX-6



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olympia, washington 98501
phone: (360) 584-9810

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 2

Sheet EX-7

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N

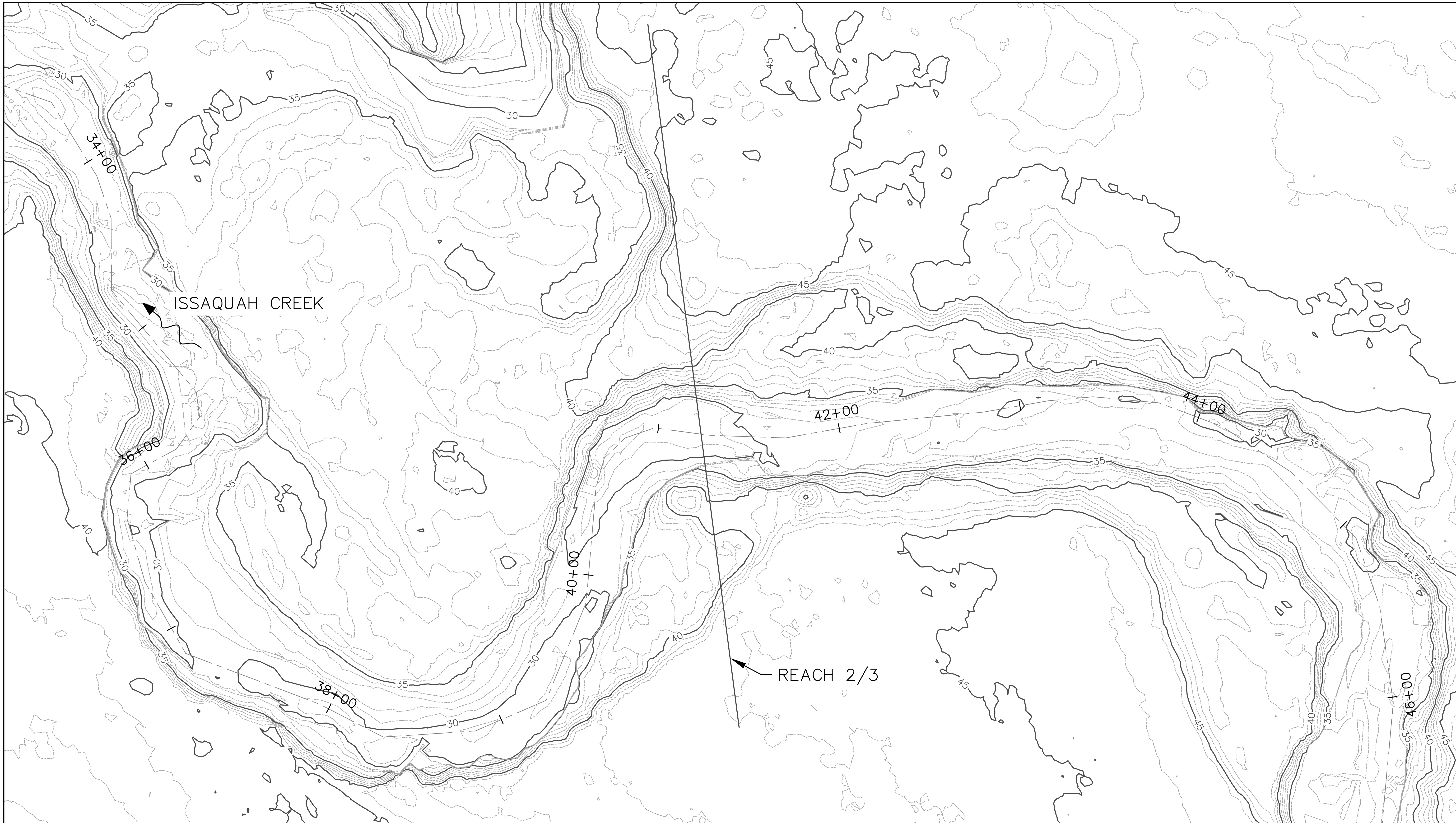
0 50 100 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 2

Sheet EX-8



N

0 50 100 Feet

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northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584-9810

MOUNTAINS to Sound GREENWAY

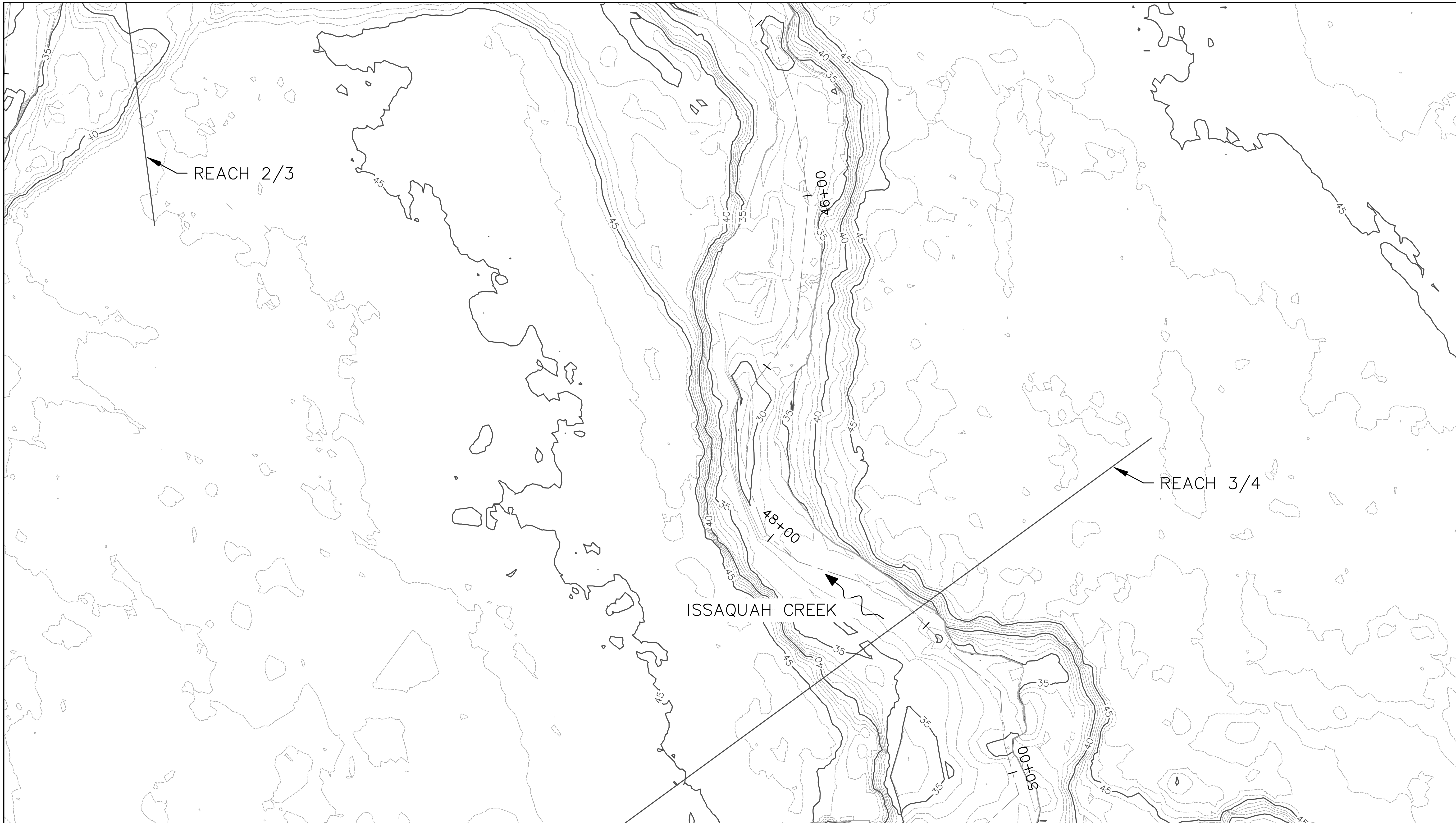
WASHINGTON STATE PARKS

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date:18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reaches 2 and 3

Sheet EX-9



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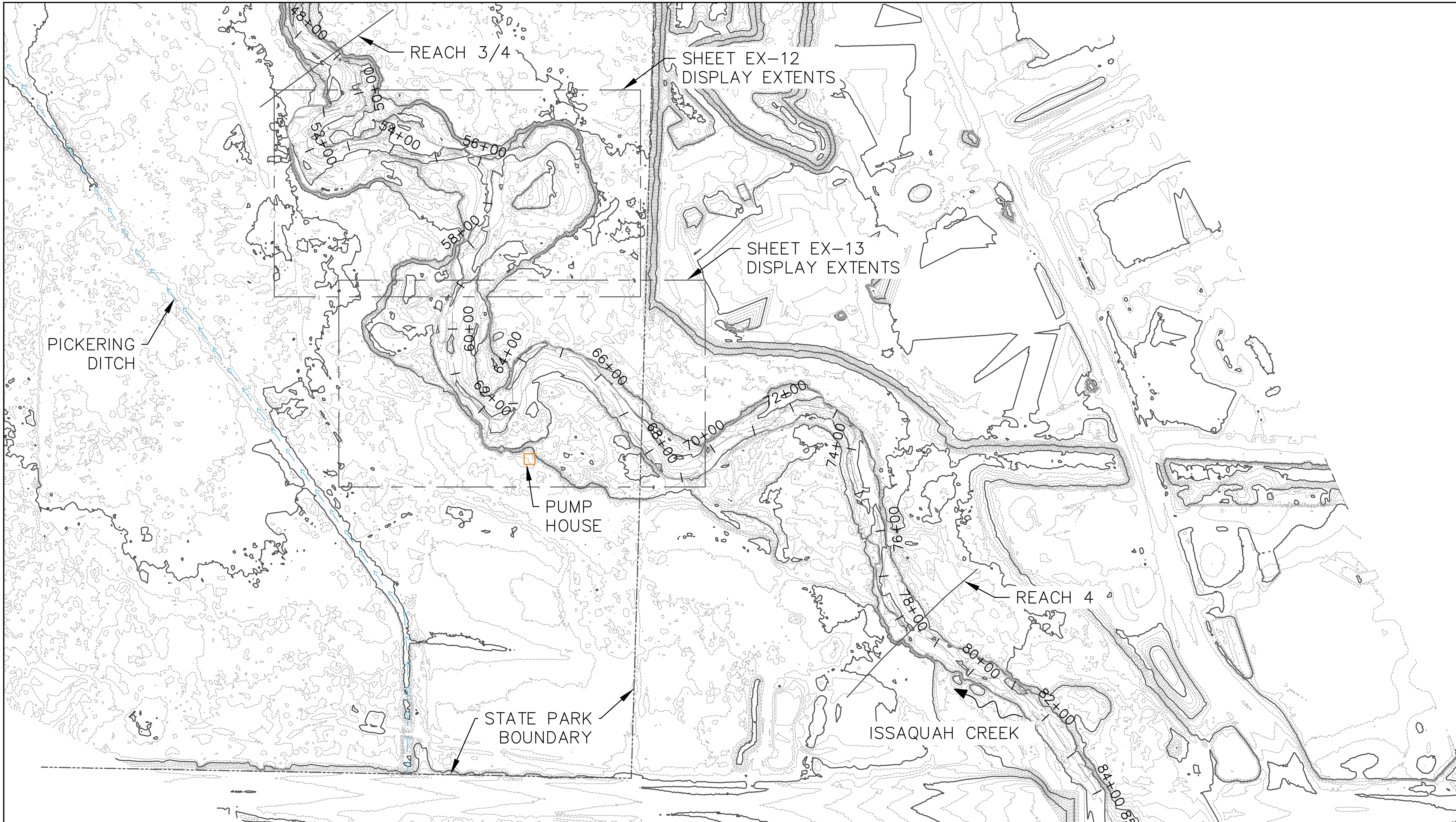
northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584-9810

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 3

Sheet EX-10



nhc
northwest hydraulic consultants
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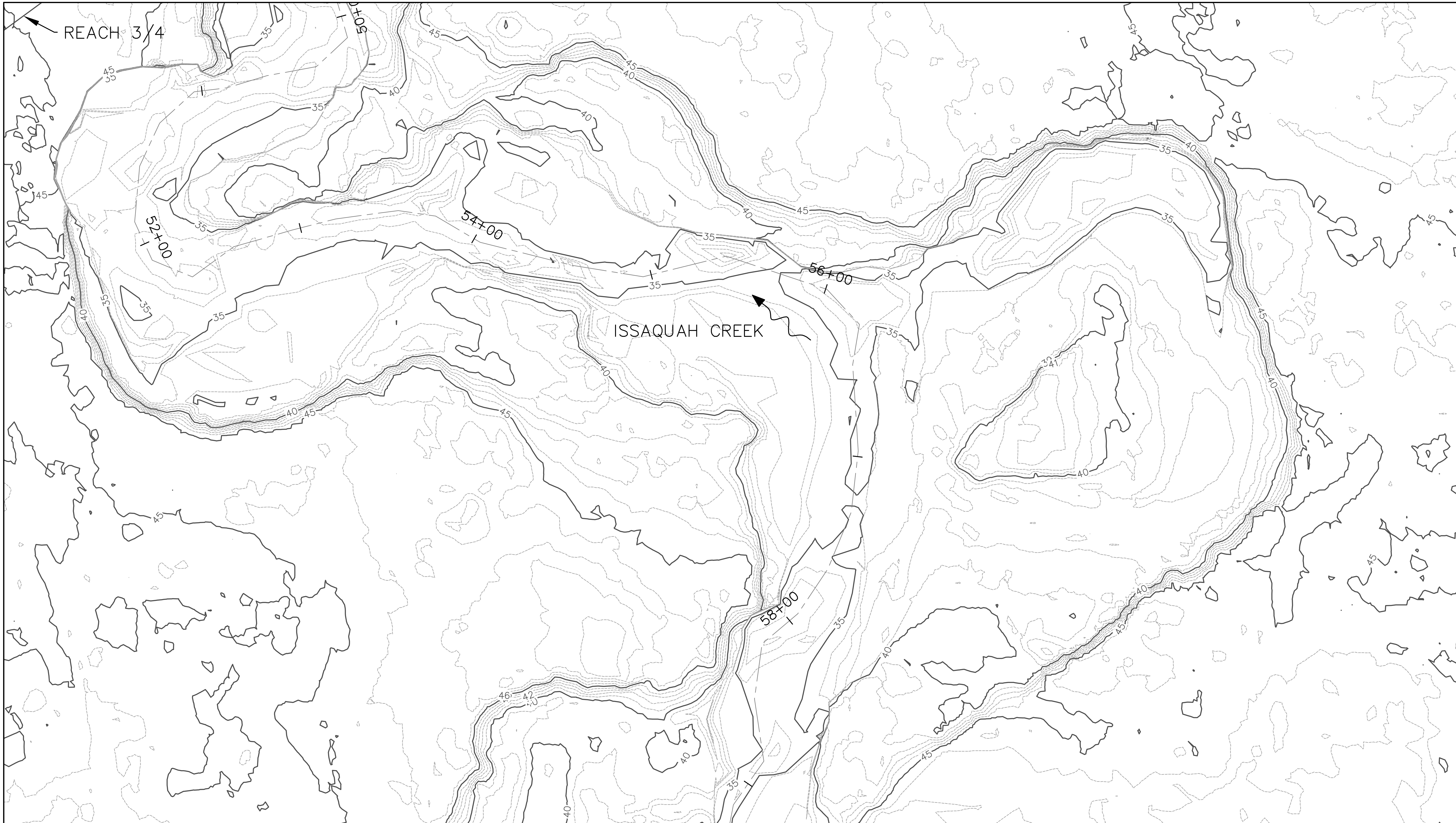
olympia, washington 98501
phone: (360) 584-9810

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 4 Overview

Sheet EX-11



MOUNTAINS to Sound GREENWAY

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northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584–9810

N

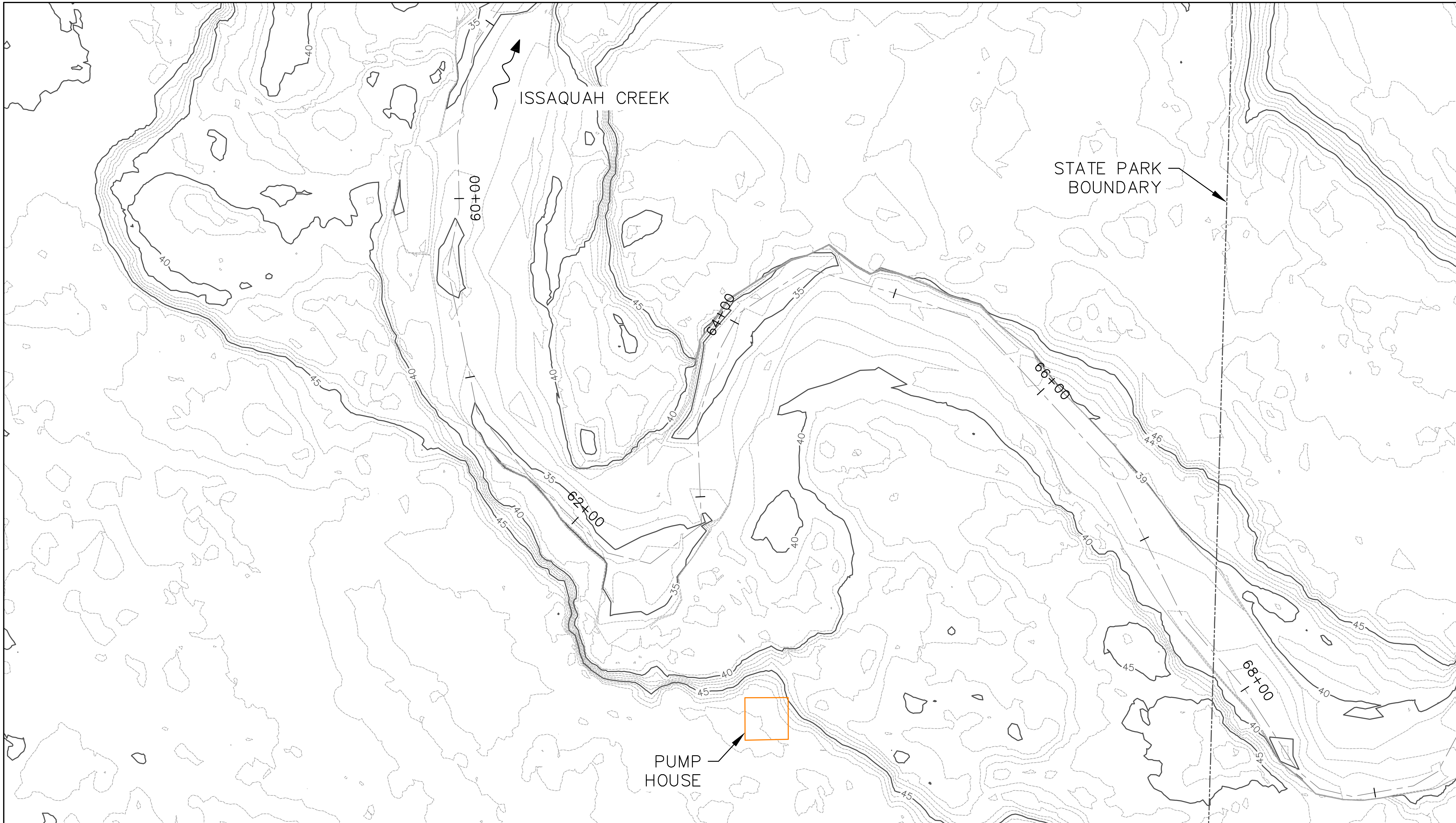
0 50 100 Feet

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date:18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Existing Site Plan - Reach 4

Sheet EX-12



MOUNTAINS to Sound GREENWAY

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northwest hydraulic consultants

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olympia, washington 98501
phone: (360) 584–9810

N

0 50 100
Feet

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date:18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

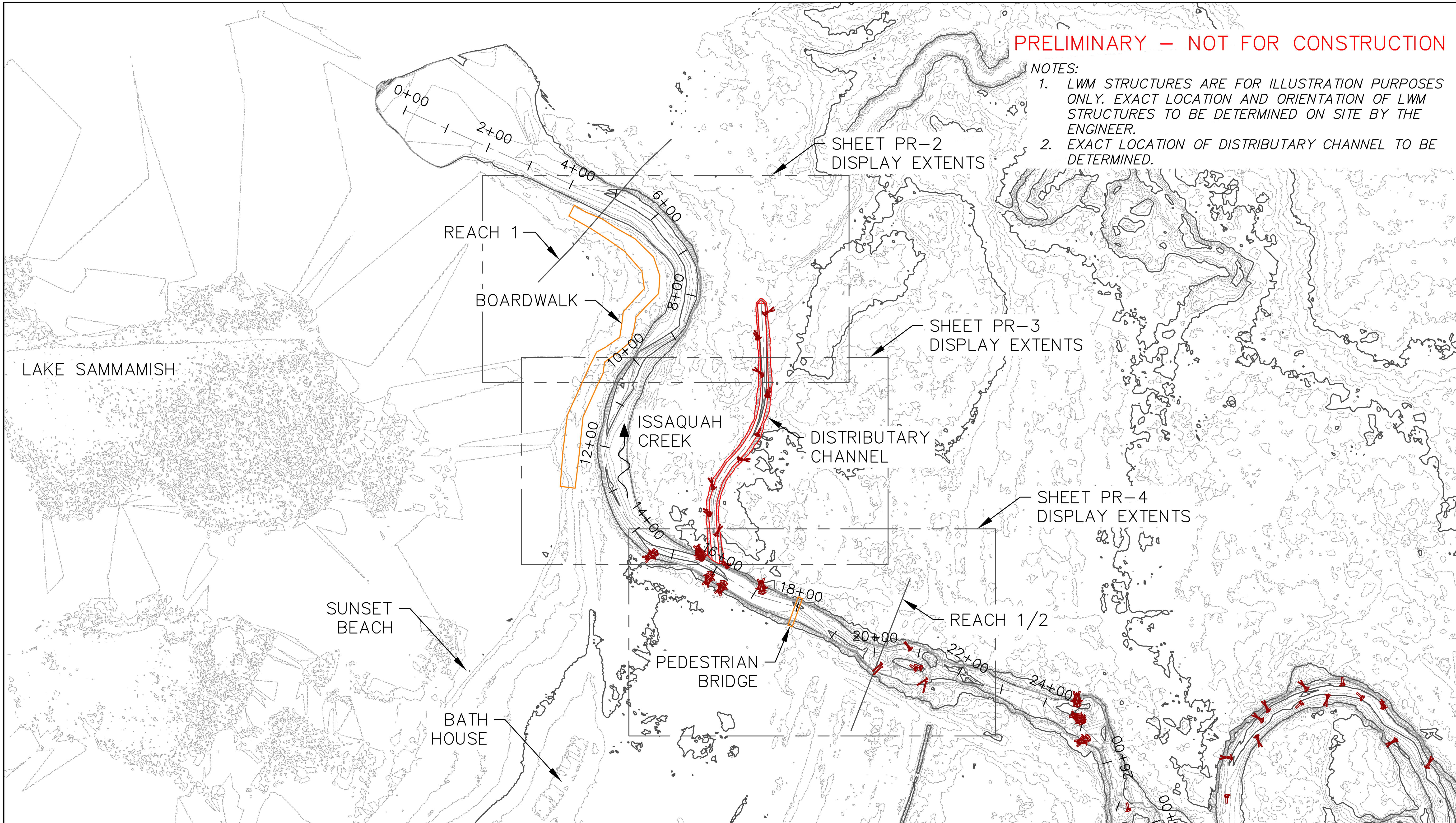
Existing Site Plan - Reach 4

Sheet EX-13

PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
2. *EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.*



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olympia, washington 98501
phone: (360) 584–9810

N

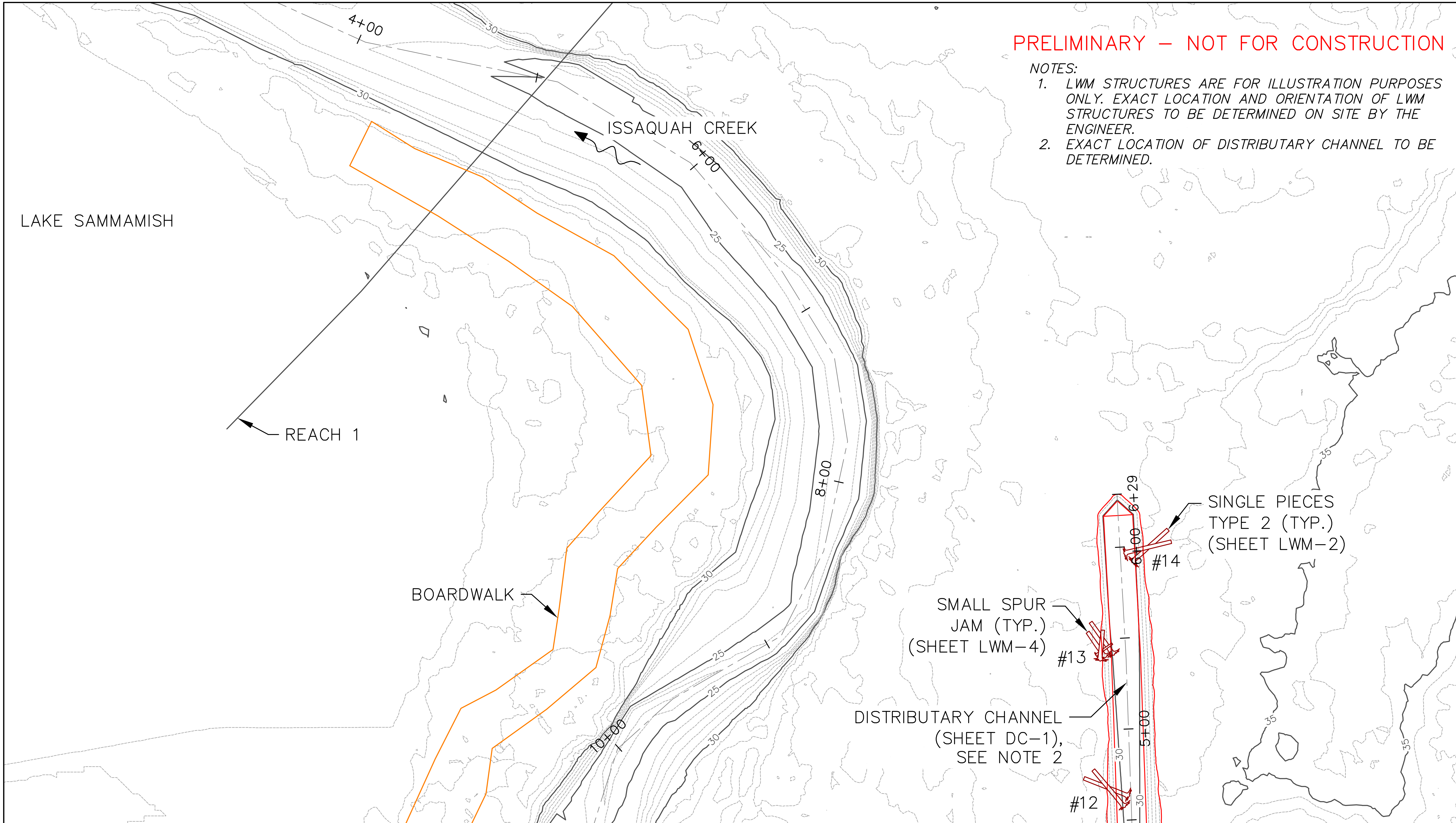
0 200 400 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 1 Overview

Sheet PR-1



PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

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MOUNTAINS to Sound GREENWAY

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N

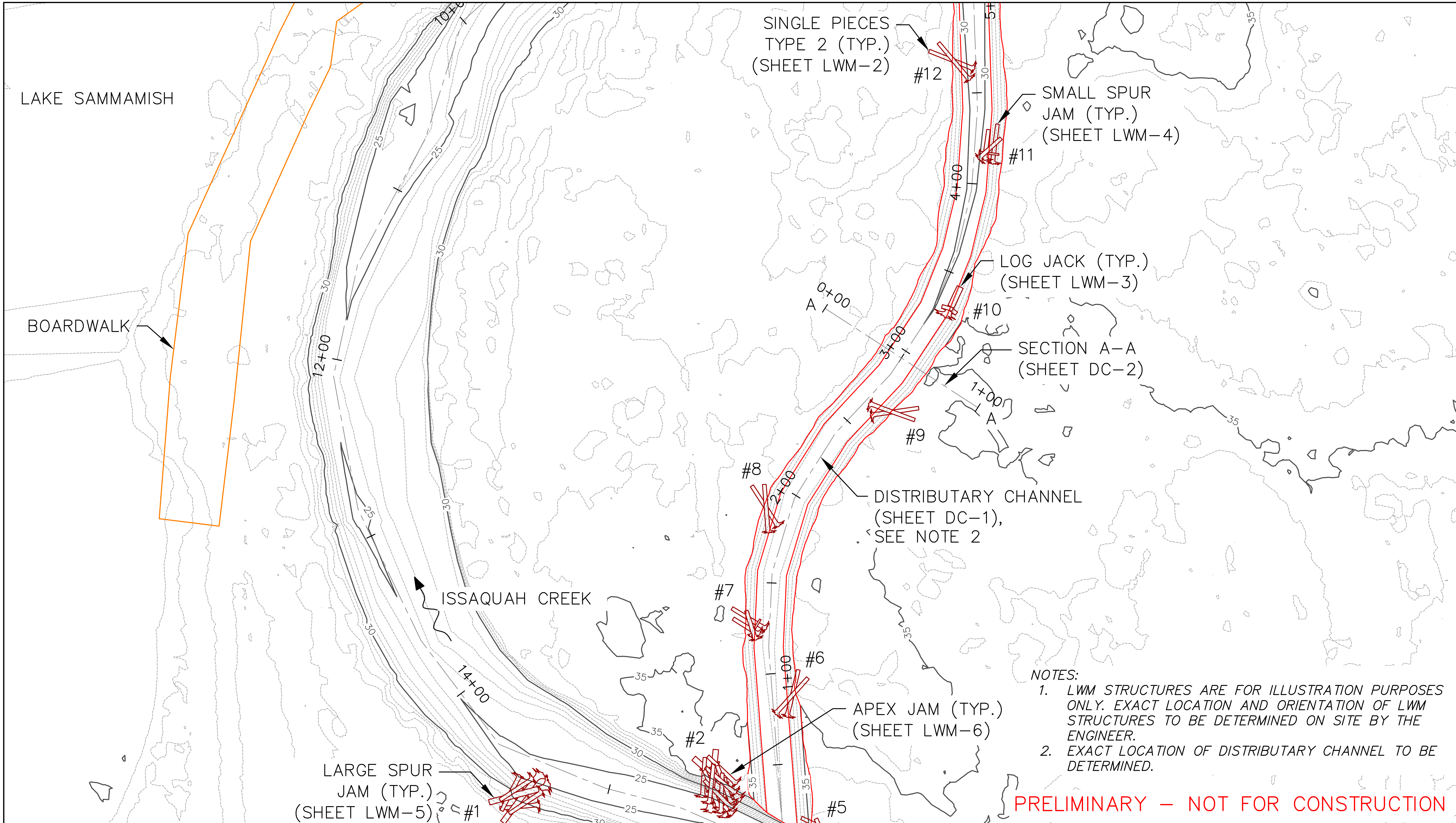
0 50 100 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 1

Sheet PR-2



NOTES:

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2. *EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.*

PRELIMINARY — NOT FOR CONSTRUCTION

MOUNTAINS to Sound GREENWAY

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olympia, washington 98501
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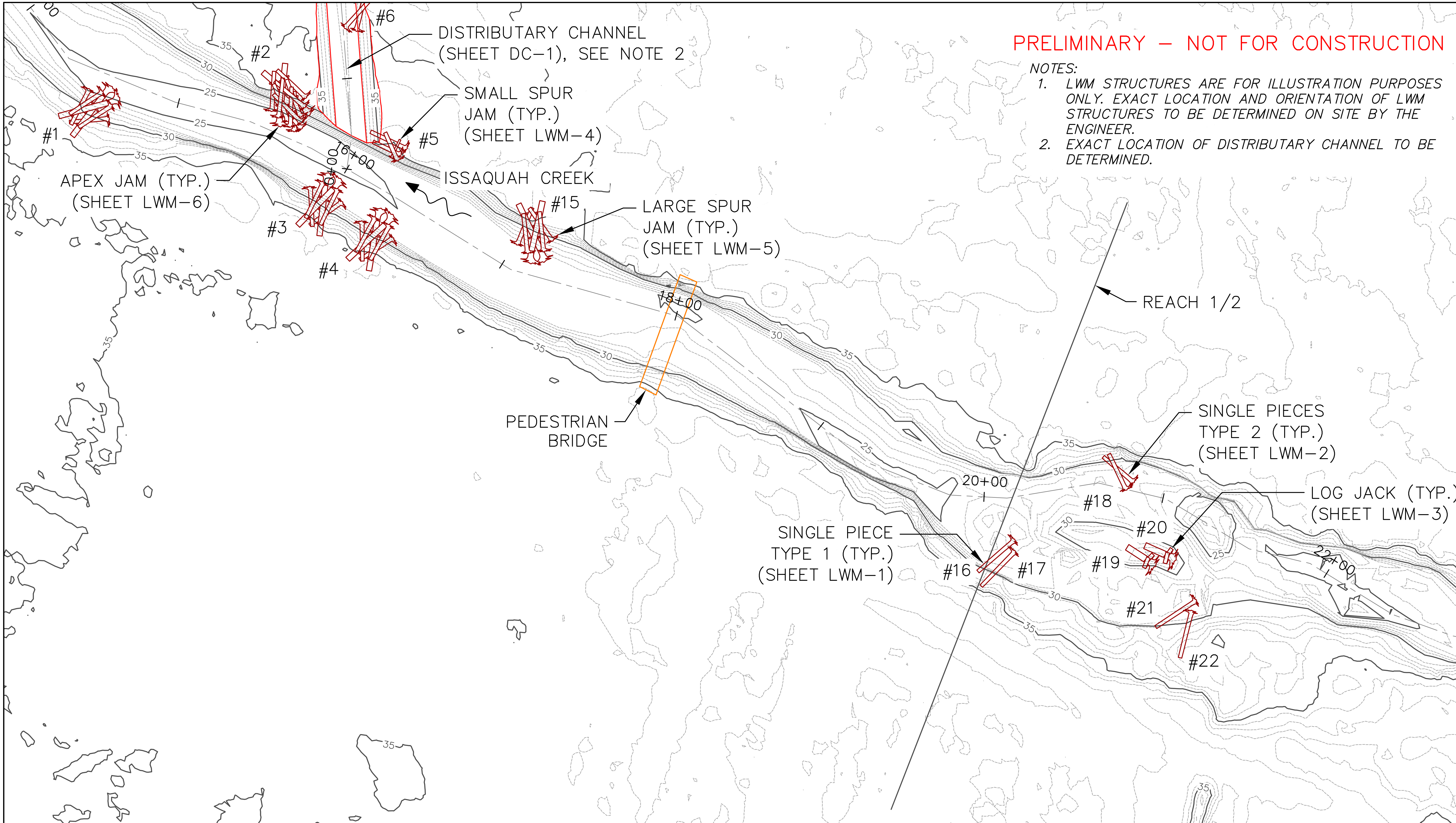
N

0 50 100 Feet

Job: 2003907	Lower Issaquah Creek Restoration at Lake Sammamish State Park
Rev:	
Drft: MWG	Proposed Site Plan - Reach 1
Chkd:	
Date: 18Jun20	Sheet PR-3



PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

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2. *EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.*

MOUNTAINS to Sound GREENWAY

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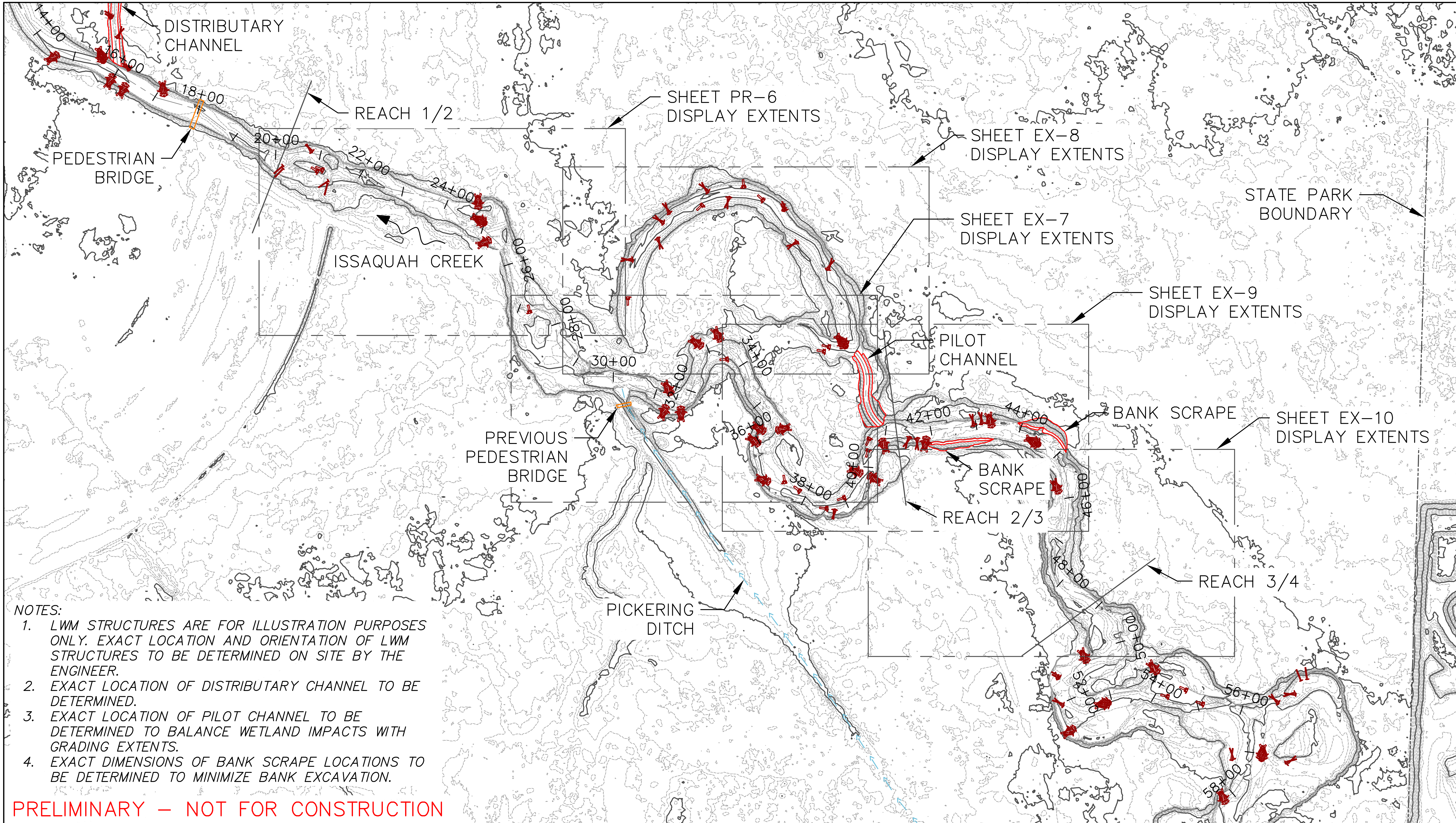
Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 1



NOTES:

1. LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.
2. EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.
3. EXACT LOCATION OF PILOT CHANNEL TO BE DETERMINED TO BALANCE WETLAND IMPACTS WITH GRADING EXTENTS.
4. EXACT DIMENSIONS OF BANK SCRAPE LOCATIONS TO BE DETERMINED TO MINIMIZE BANK EXCAVATION.

PRELIMINARY – NOT FOR CONSTRUCTION

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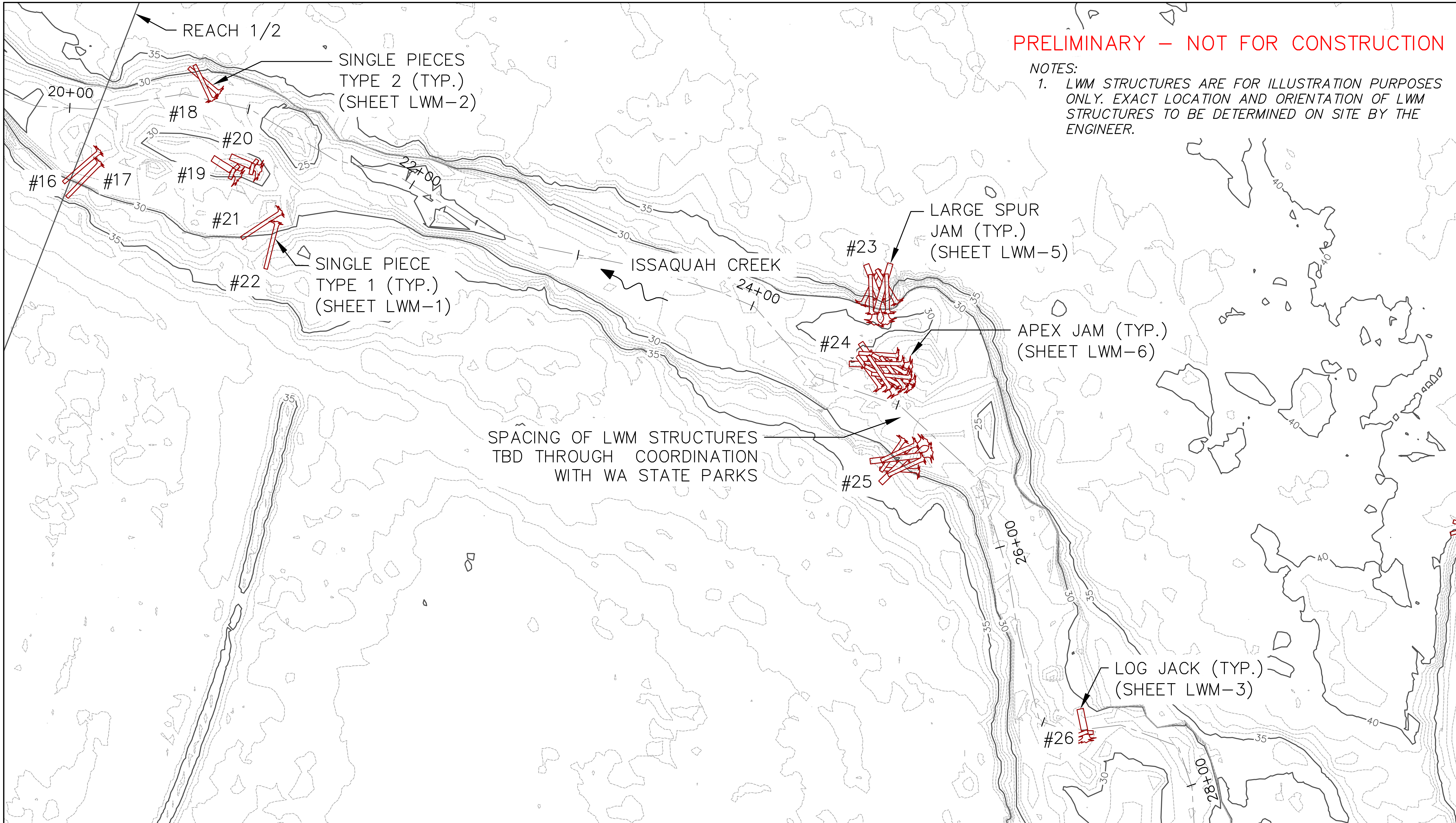
olympia, washington 98501
phone: (360) 584–9810

N

0 200 400 Feet

Job: 2003907	Lower Issaquah Creek Restoration at Lake Sammamish State Park
Rev:	
Drft: MWG	Proposed Site Plan - Reaches 2 and 3 Overview
Chkd:	
Date: 18Jun20	Sheet PR-5



MOUNTAINS to Sound GREENWAY | WASHINGTON STATE PARKS

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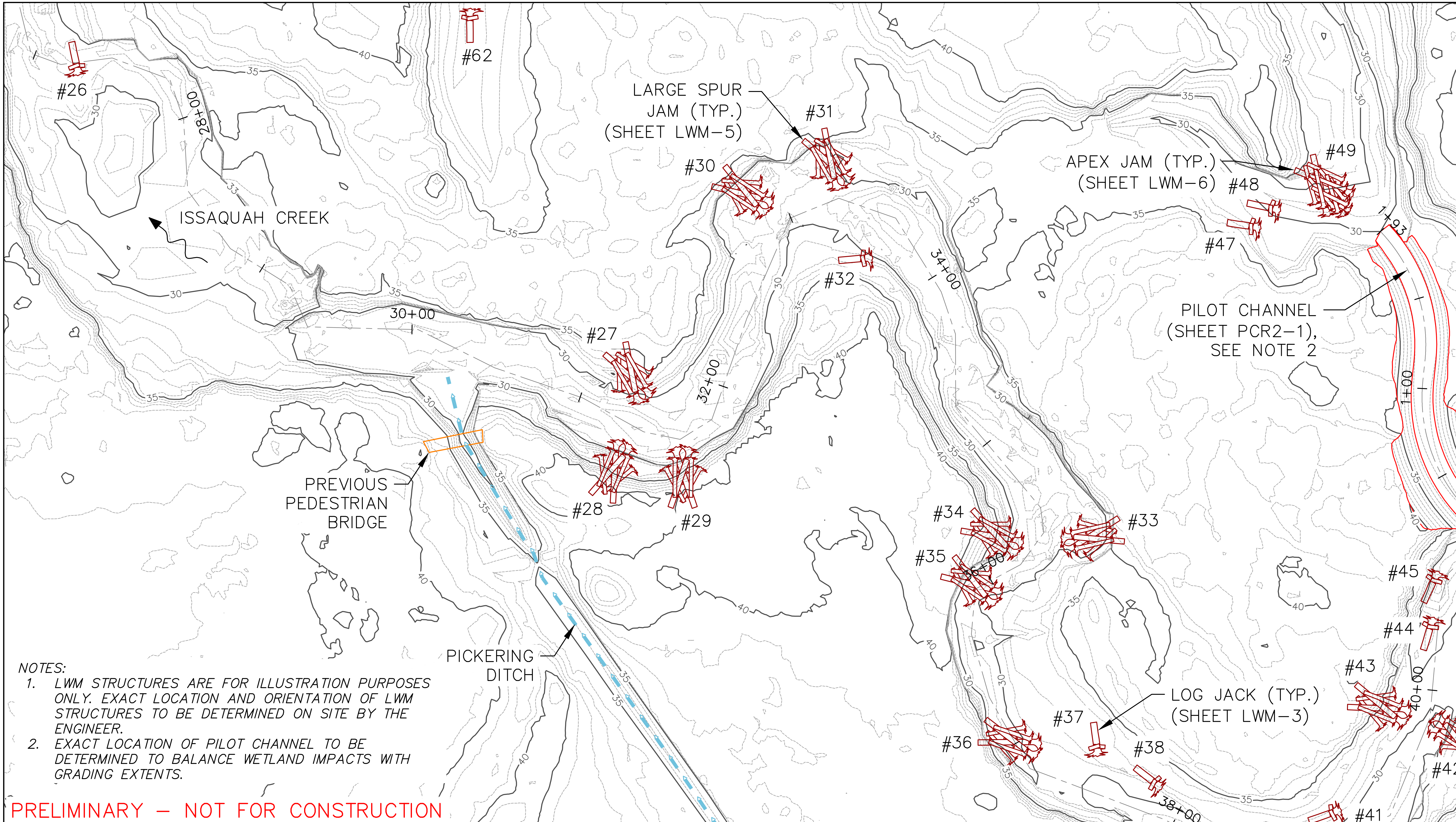
olympia, washington 98501
phone: (360) 584-9810

Job:2003907	
Rev:	
Drft: MWG	
Chkd:	
Date:18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 2

Sheet PR-6



NOTES:

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2. *EXACT LOCATION OF PILOT CHANNEL TO BE DETERMINED TO BALANCE WETLAND IMPACTS WITH GRADING EXTENTS.*

PRELIMINARY — NOT FOR CONSTRUCTION

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N

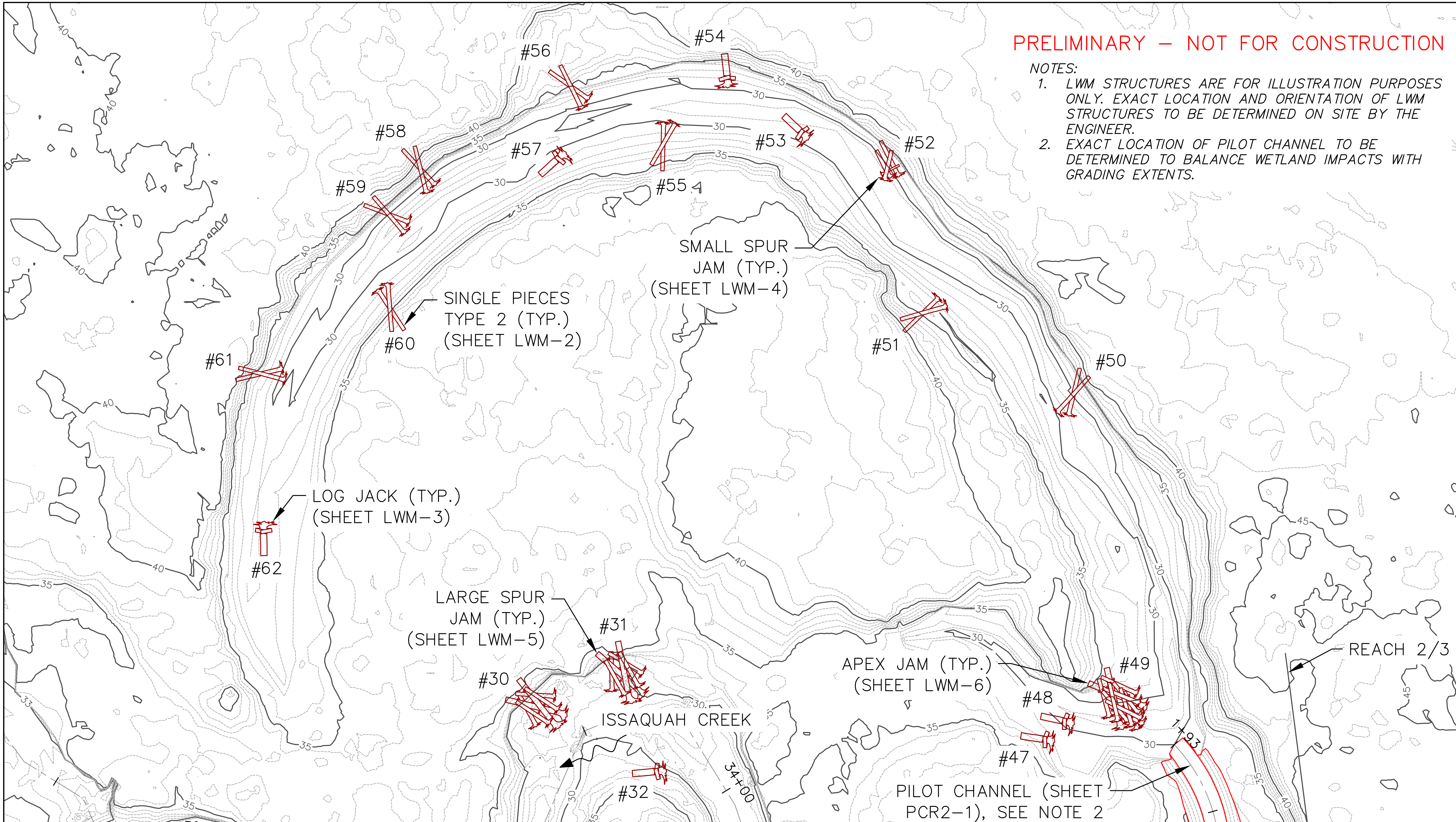
0 50 100 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 2

Sheet PR-7



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711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584-9810

N

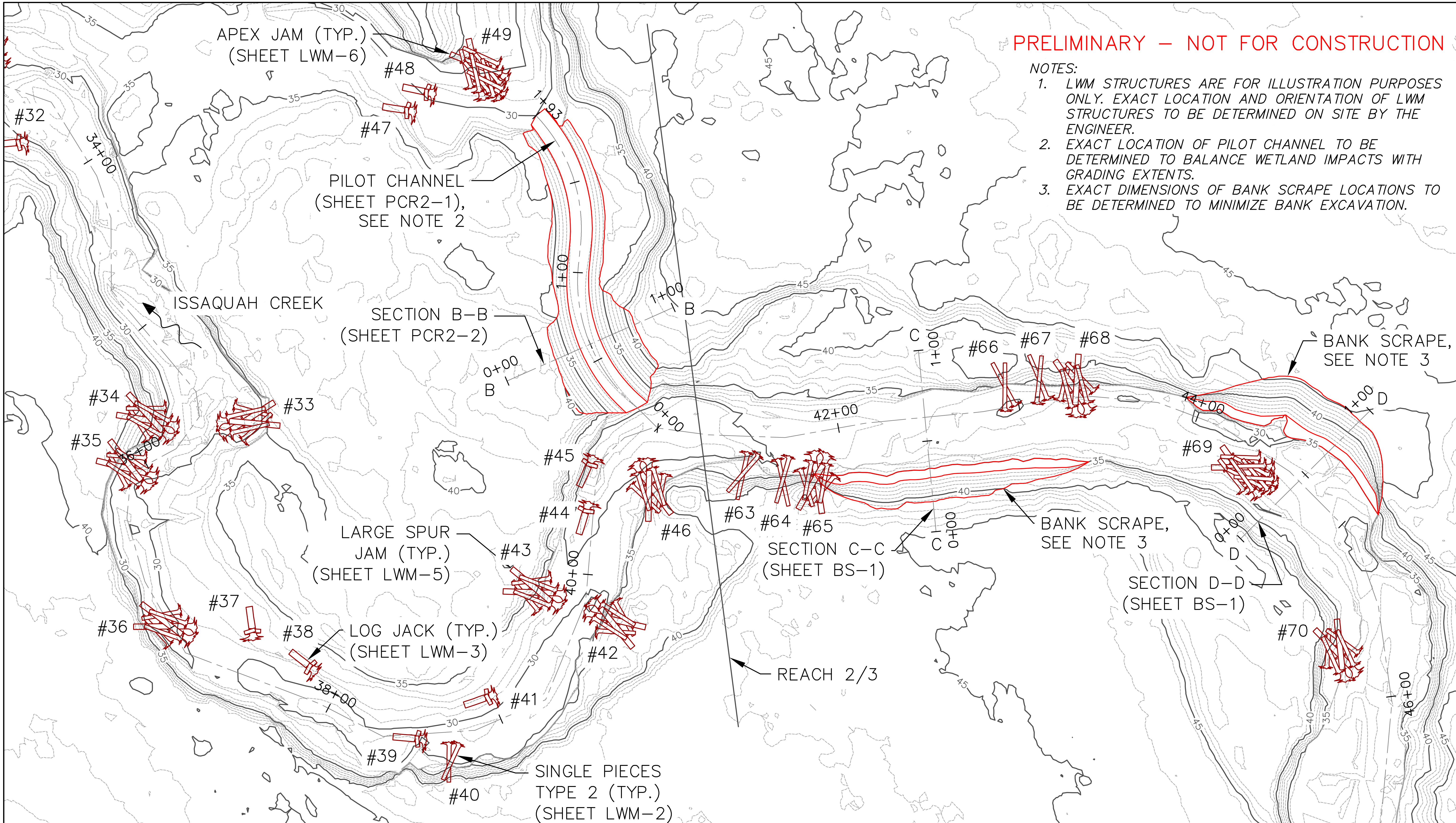
0 50 100 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 2

Sheet PR-8



PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

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2. EXACT LOCATION OF PILOT CHANNEL TO BE DETERMINED TO BALANCE WETLAND IMPACTS WITH GRADING EXTENTS.
3. EXACT DIMENSIONS OF BANK SCRAPE LOCATIONS TO BE DETERMINED TO MINIMIZE BANK EXCAVATION.

MOUNTAINS to Sound GREENWAY

WASHINGTON STATE PARKS

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phone: (360) 584-9810

N

0 50 100 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

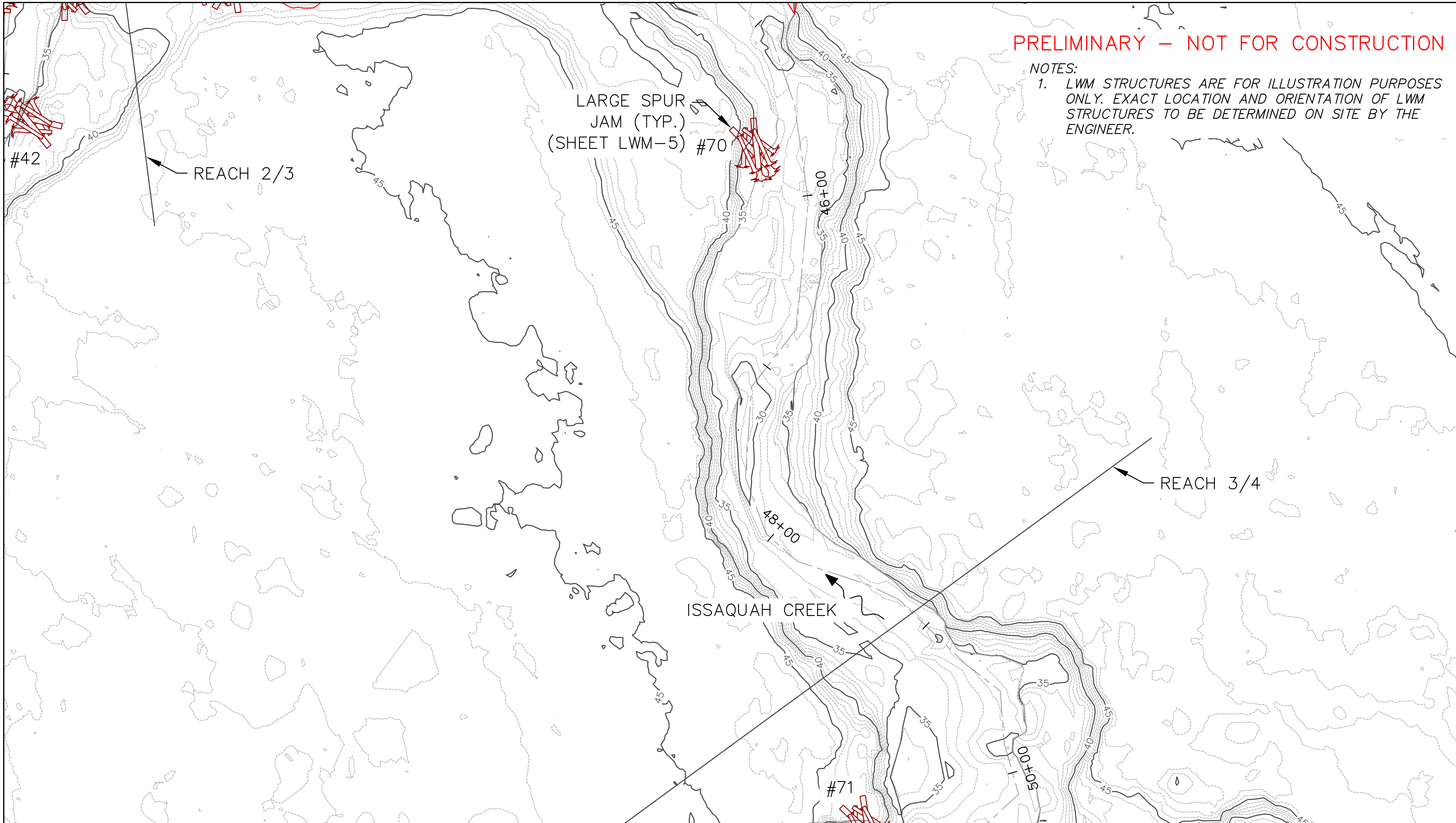
Proposed Site Plan - Reaches 2 and 3

Sheet PR-9

PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

1. LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.



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olympia, washington 98501
phone: (360) 584–9810

0 50 100 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

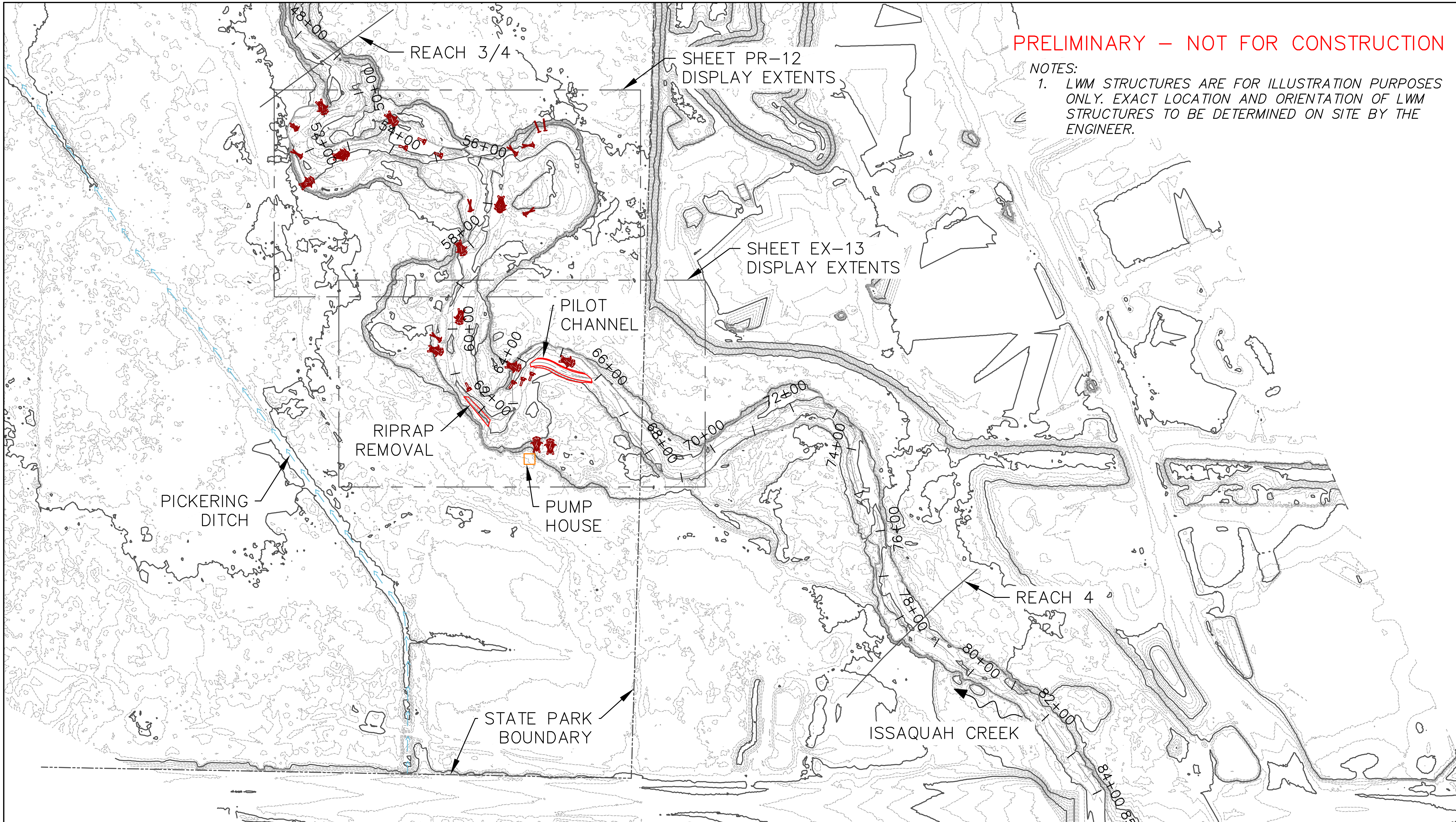
Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 3

Sheet PR-10

NOTES:

1. LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.



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northwest hydraulic consultants
711 capitol way south, suite 607
olympia, washington 98501
phone: (360) 584–9810

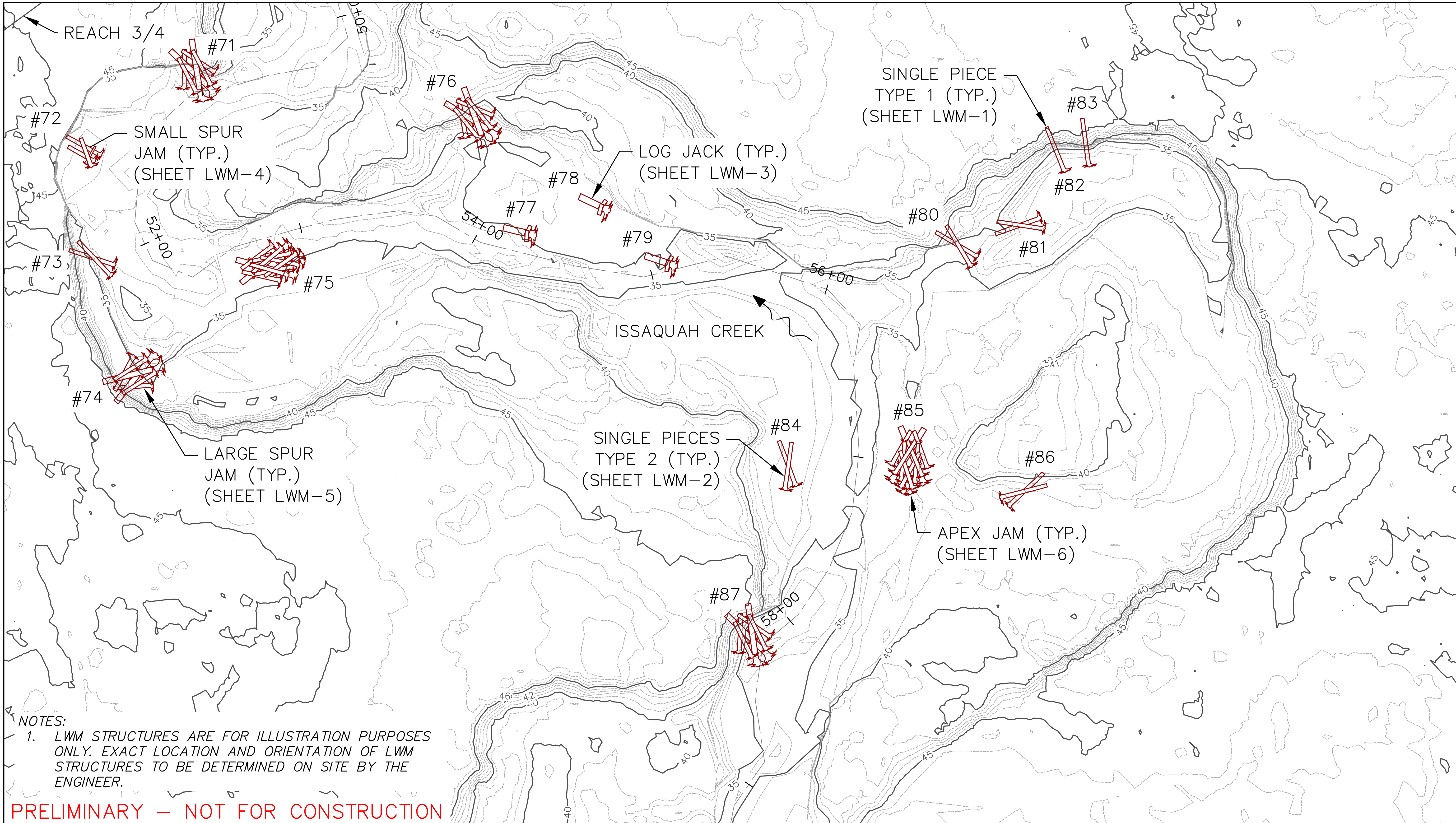
N

0 200 400 Feet

Job: 2003907
Rev:
Drft: MWG
Chkd:
Date: 18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 4 Overview



NOTES:

1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*

PRELIMINARY – NOT FOR CONSTRUCTION

MOUNTAINS to Sound GREENWAY

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olympia, washington 98501
phone: (360) 584-9810

N

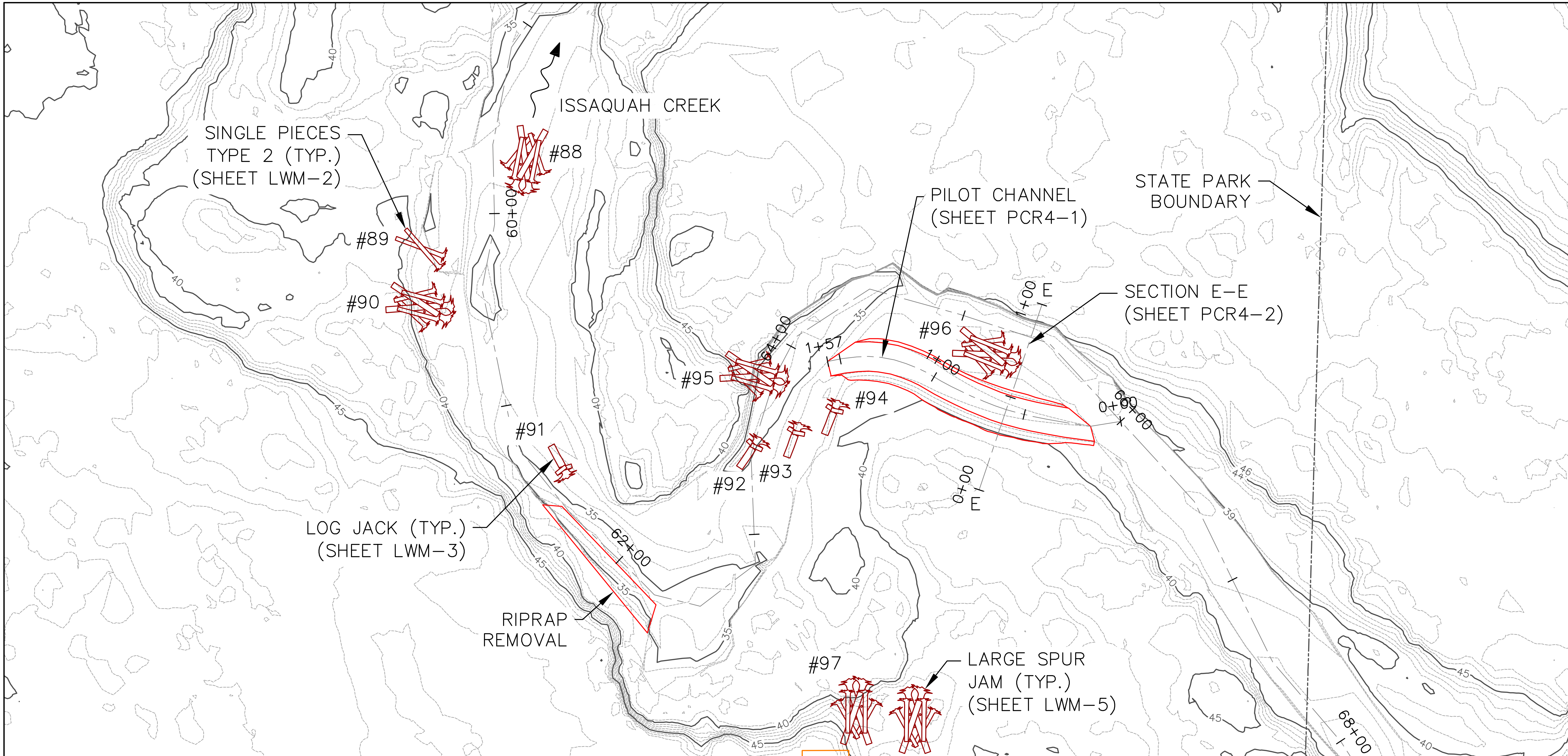
0 50 100 Feet

Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 4

Sheet PR-12



NOTES:
1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*

PRELIMINARY – NOT FOR CONSTRUCTION

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olympia, washington 98501
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N

0 50 100 Feet

Job:2003907
Rev:
Drft: MWG
Chkd:
Date:18Jun20

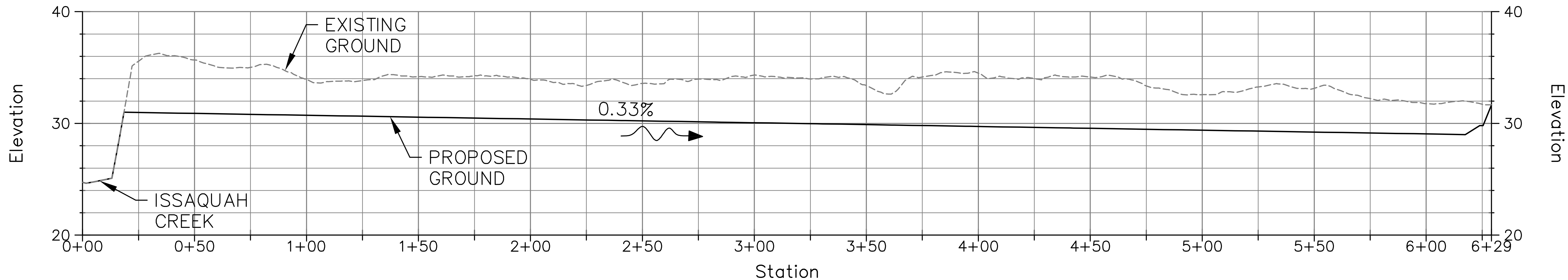
Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Proposed Site Plan - Reach 4

Sheet PR-13

PRELIMINARY – NOT FOR CONSTRUCTION

DISTRIBUTARY CHANNEL PROFILE



NOTES:
1. 5X VERTICAL EXAGGERATION FOR PROFILE
2. TYPICAL SECTION DETAIL ON SHEET DC-2
3. EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.

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Job: 2003907	
Rev:	
Drft: MWG	
Chkd:	
Date: 18Jun20	

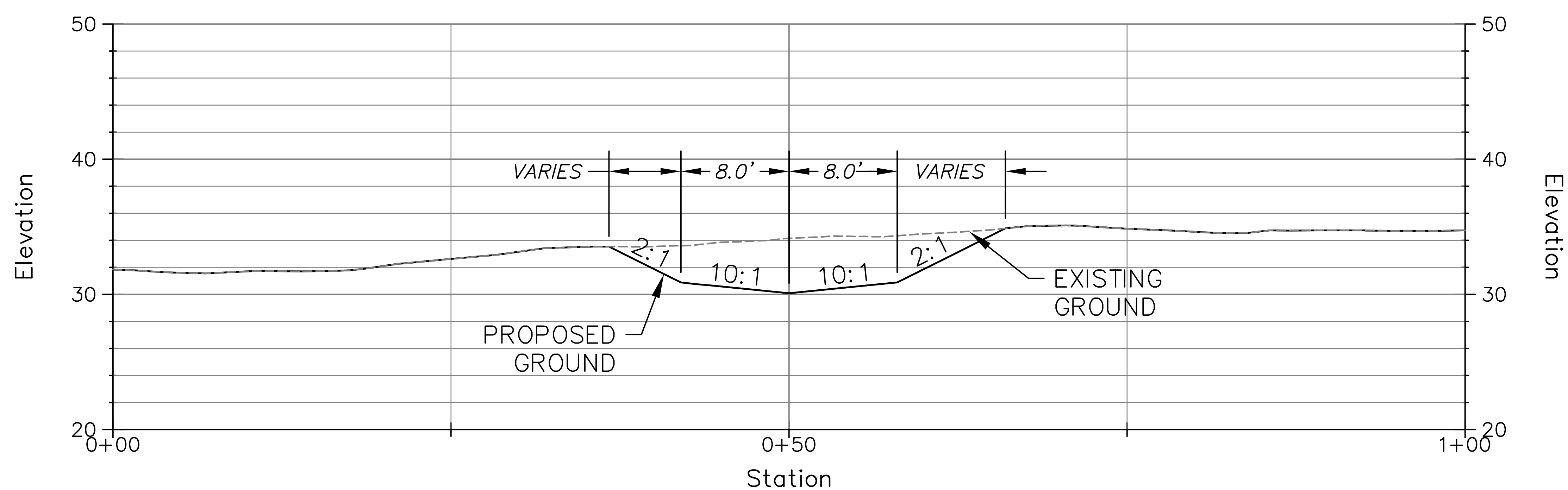
Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Distributary Channel - Reach 1

Sheet DC-1

PRELIMINARY – NOT FOR CONSTRUCTION

DISTRIBUTARY CHANNEL SECTION A-A



NOTES:
1. CROSS SECTION LOOKING DOWNSTREAM
2. PROFILE ON SHEET DC–1
3. EXACT LOCATION OF DISTRIBUTARY CHANNEL TO BE DETERMINED.

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Lower Issaquah Creek Restoration
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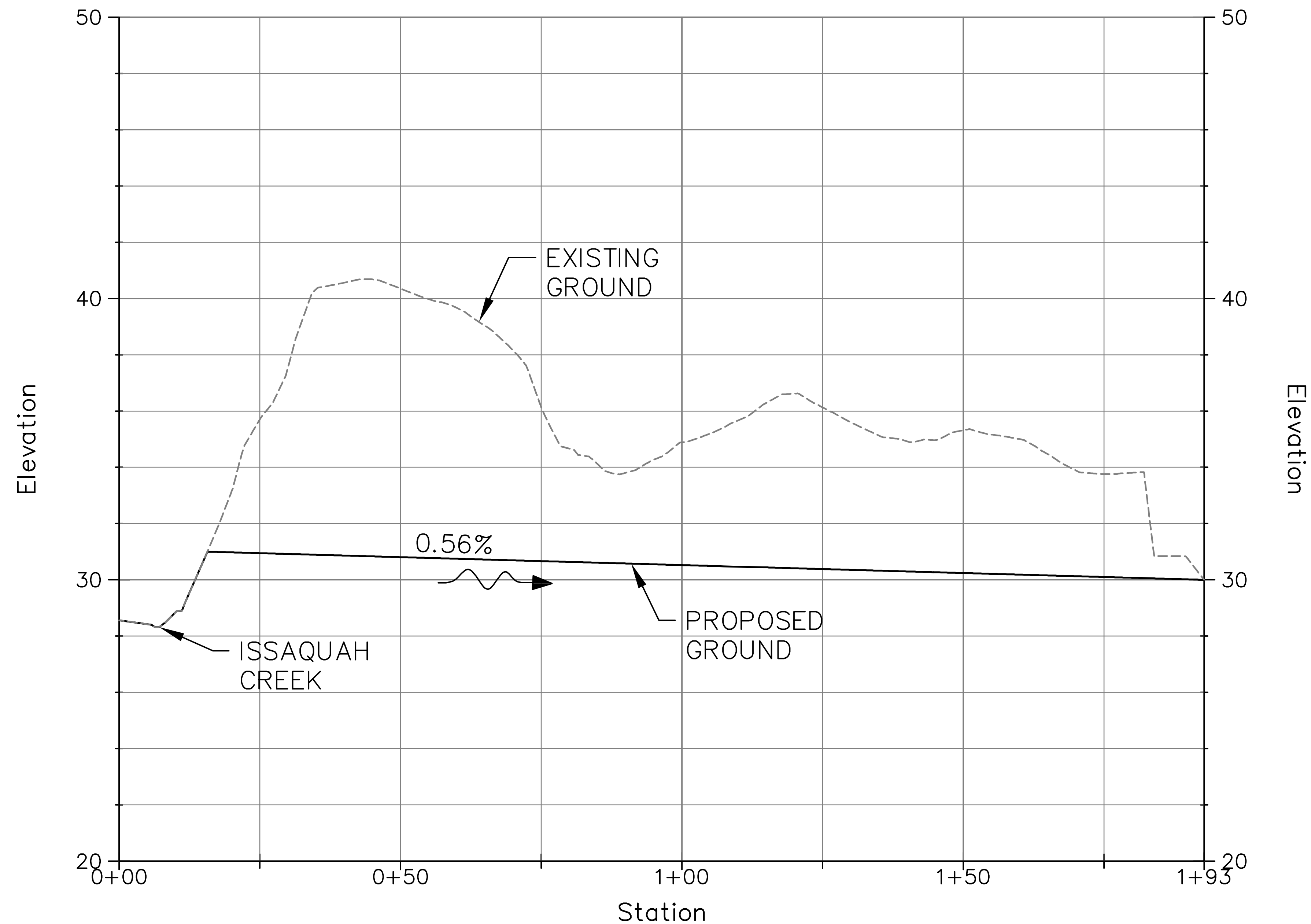
Distributary Channel - Reach 1

Sheet DC-2

PRELIMINARY – NOT FOR CONSTRUCTION

PILOT CHANNEL (REACH 2) PROFILE



NOTES:
1. *5X VERTICAL EXAGGERATION FOR PROFILE*
2. *TYPICAL SECTION DETAIL ON SHEET PCR2–2*
3. *EXACT LOCATION OF PILOT CHANNEL TO BE DETERMINED TO BALANCE WETLAND IMPACTS WITH GRADING EXTENTS.*

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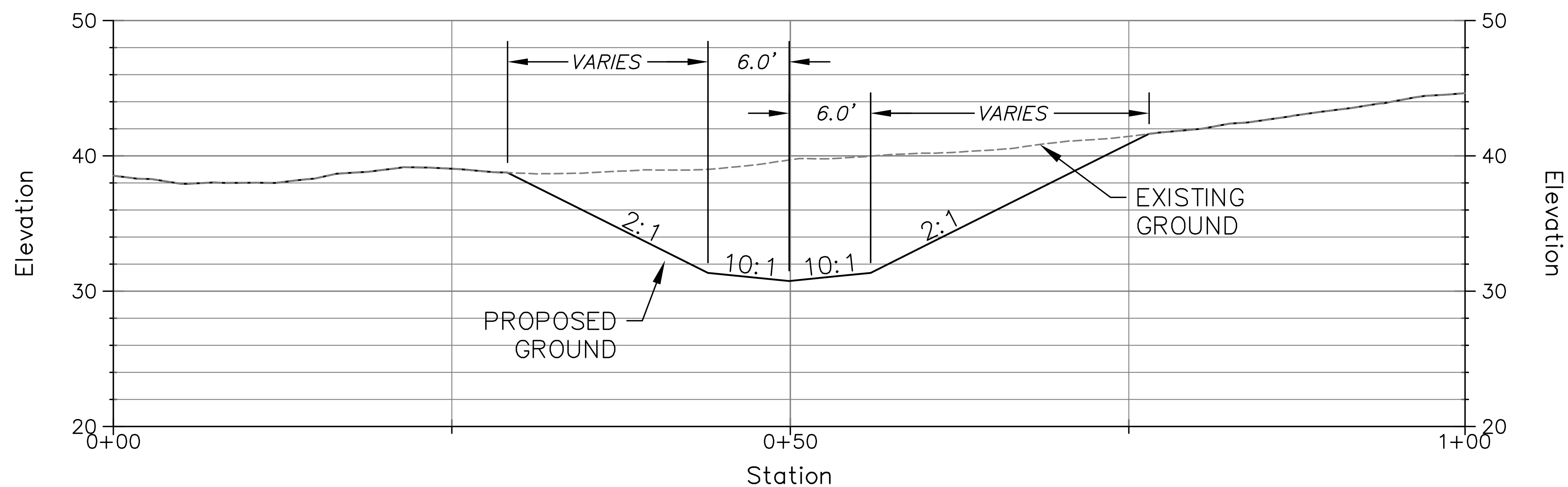
Pilot Channel - Reach 2

Sheet PCR2-1

PRELIMINARY – NOT FOR CONSTRUCTION

PILOT CHANNEL (REACH 2) SECTION B-B



NOTES:
1. CROSS SECTION LOOKING DOWNSTREAM
2. PROFILE ON SHEET PCR2–1
3. EXACT LOCATION OF PILOT CHANNEL TO BE DETERMINED TO BALANCE WETLAND IMPACTS WITH GRADING EXTENTS.

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Chkd:	
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Lower Issaquah Creek Restoration
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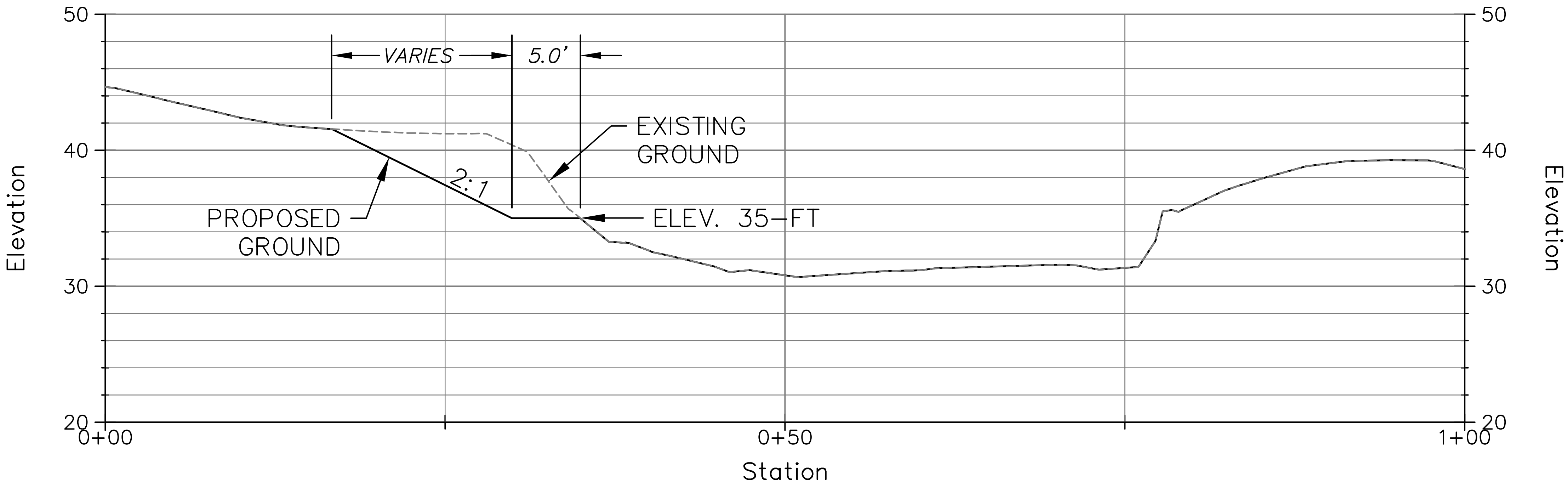
Pilot Channel - Reach 2

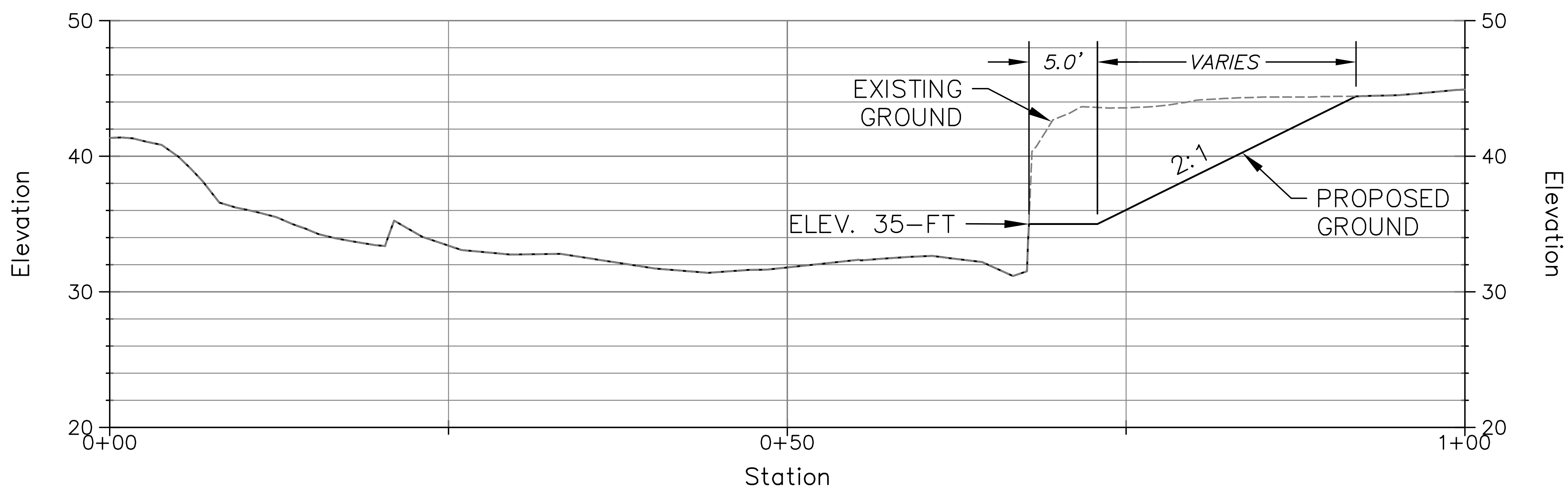
Sheet PCR2-2

PRELIMINARY — NOT FOR CONSTRUCTION

BANK SCRAPE SECTION C-C



BANK SCRAPE SECTION D-D



NOTES:
1. *CROSS SECTIONS LOOKING DOWNSTREAM*
2. *EXACT DIMENSIONS OF BANK SCRAPE LOCATIONS TO BE DETERMINED TO MINIMIZE BANK EXCAVATION.*

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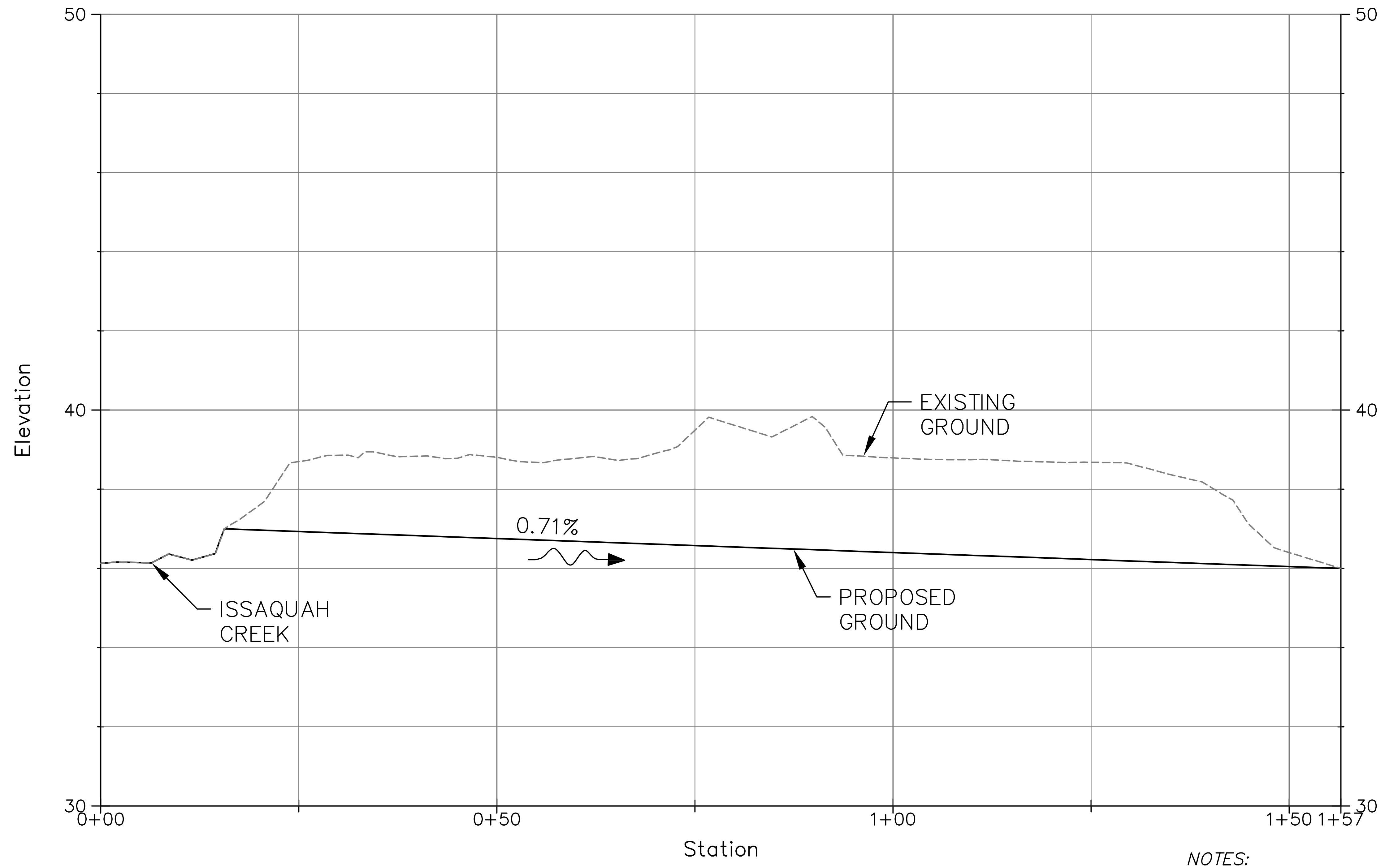
Bank Scrapes - Reach 3

Sheet BS-1

PILOT CHANNEL (REACH 4) PROFILE

PRELIMINARY — NOT FOR CONSTRUCTION



NOTES:
1. *5X VERTICAL EXAGGERATION FOR PROFILE*
2. *TYPICAL SECTION DETAIL ON SHEET PCR4–2*

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Lower Issaquah Creek Restoration
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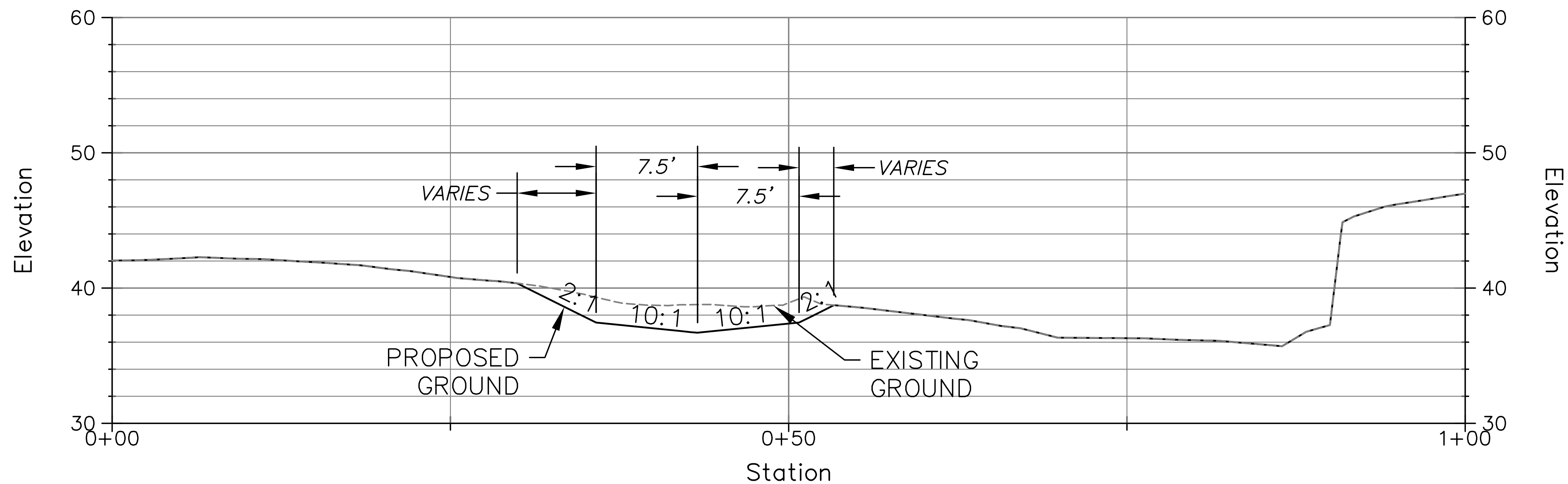
Pilot Channel - Reach 4

Sheet PCR4-1

PRELIMINARY – NOT FOR CONSTRUCTION

PILOT CHANNEL (REACH 4) SECTION E-E



NOTES:
1. *CROSS SECTION LOOKING DOWNSTREAM*
2. *PROFILE ON SHEET PCR4-1*

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Lower Issaquah Creek Restoration
at Lake Sammamish State Park

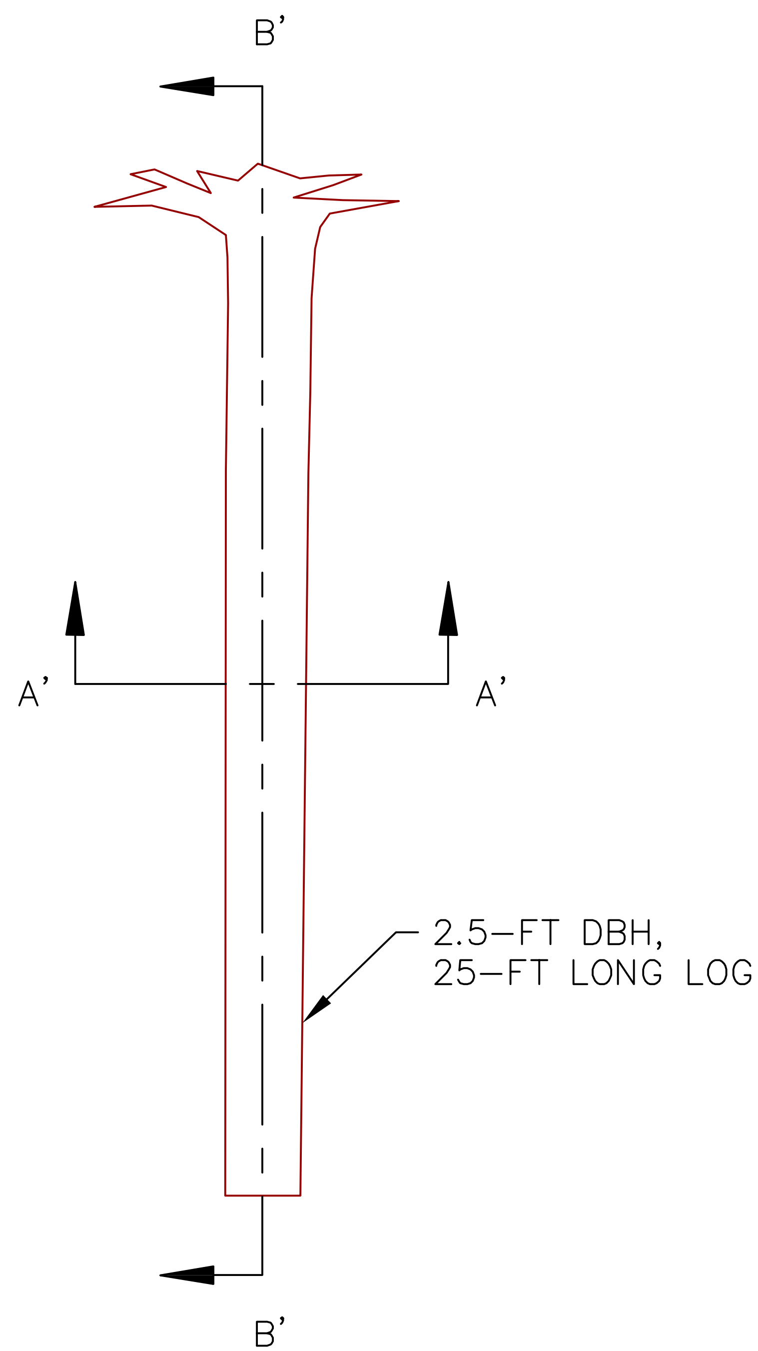
Pilot Channel - Reach 4

Sheet PCR4-2

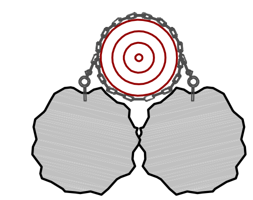
PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

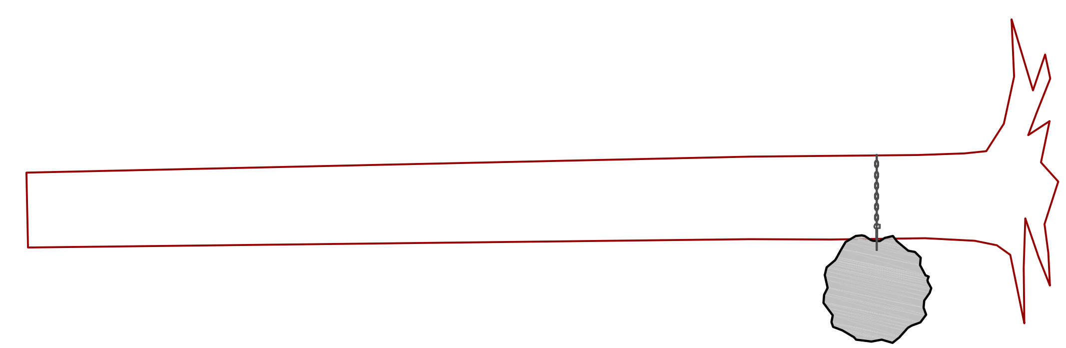
1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
2. *ANCHORING TO BE DETERMINED AT LATER STAGES OF DESIGN.*



PLAN VIEW



SECTION A'–A'



SECTION B'–B'

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Date:18Jun20	

Lower Issaquah Creek Restoration
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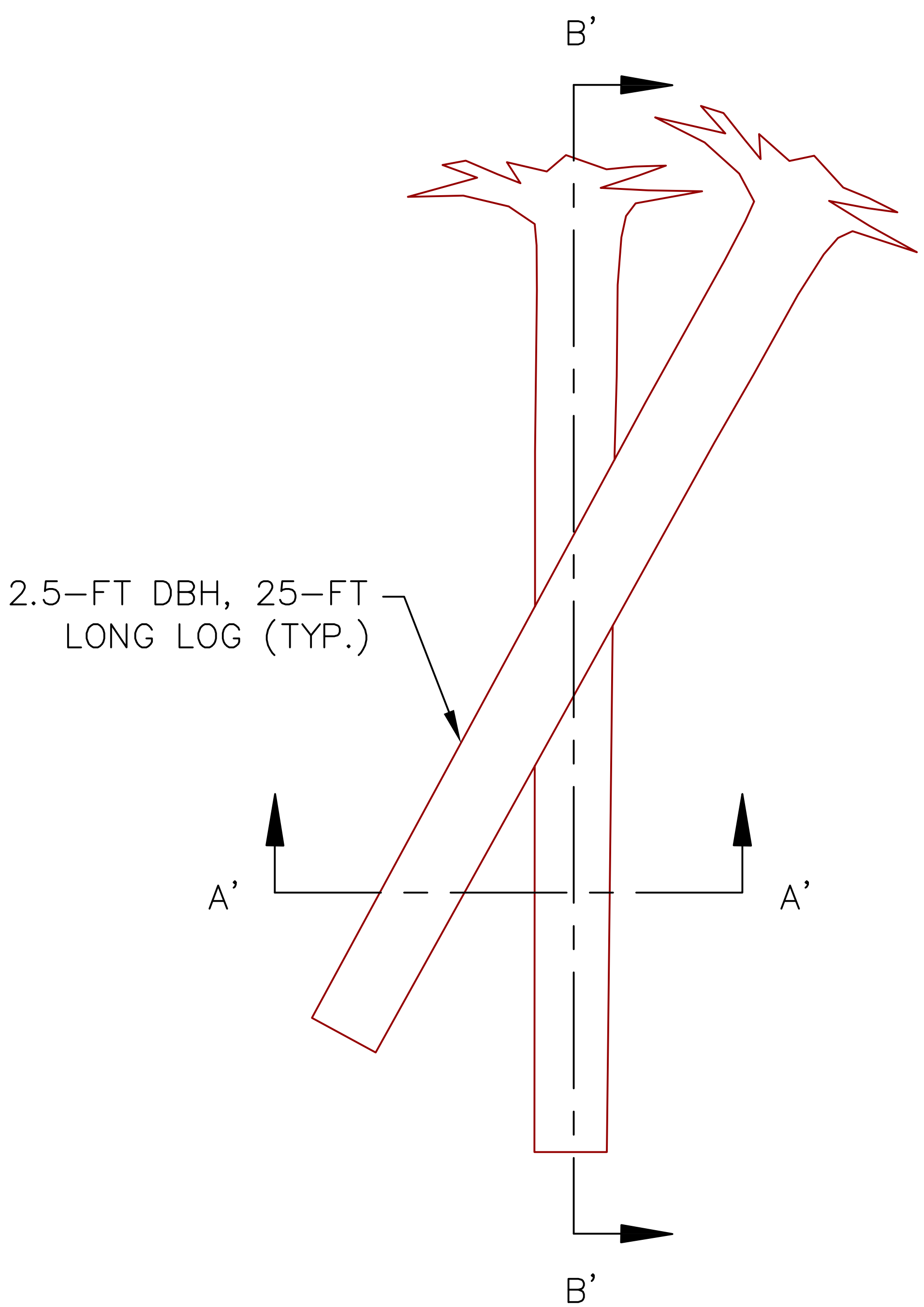
Single Piece - Type 1

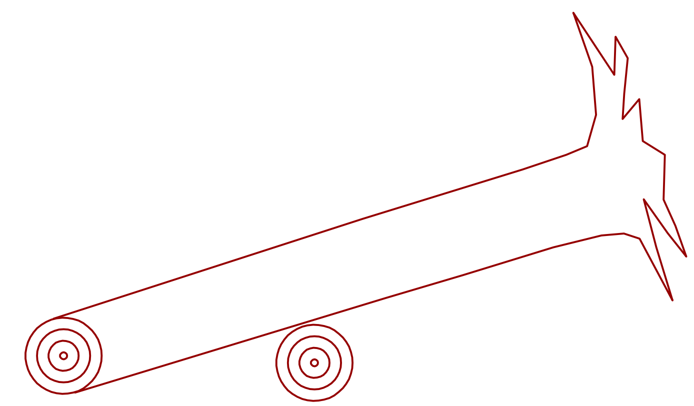
Sheet LWM-1

PRELIMINARY – NOT FOR CONSTRUCTION

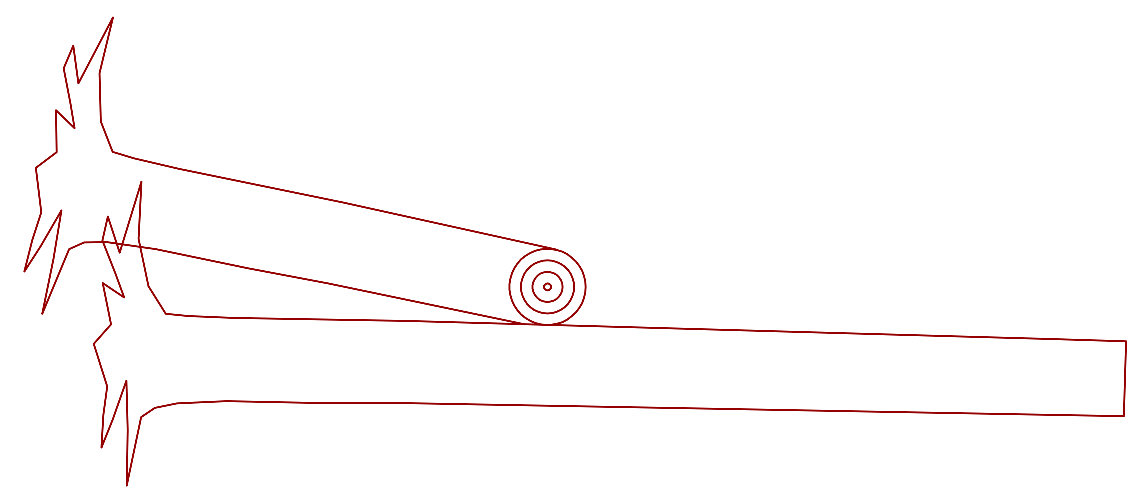
NOTES:
1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
2. *ANCHORING TO BE DETERMINED AT LATER STAGES OF DESIGN.*



PLAN VIEW



SECTION A'–A'



SECTION B'–B'

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Lower Issaquah Creek Restoration
at Lake Sammamish State Park

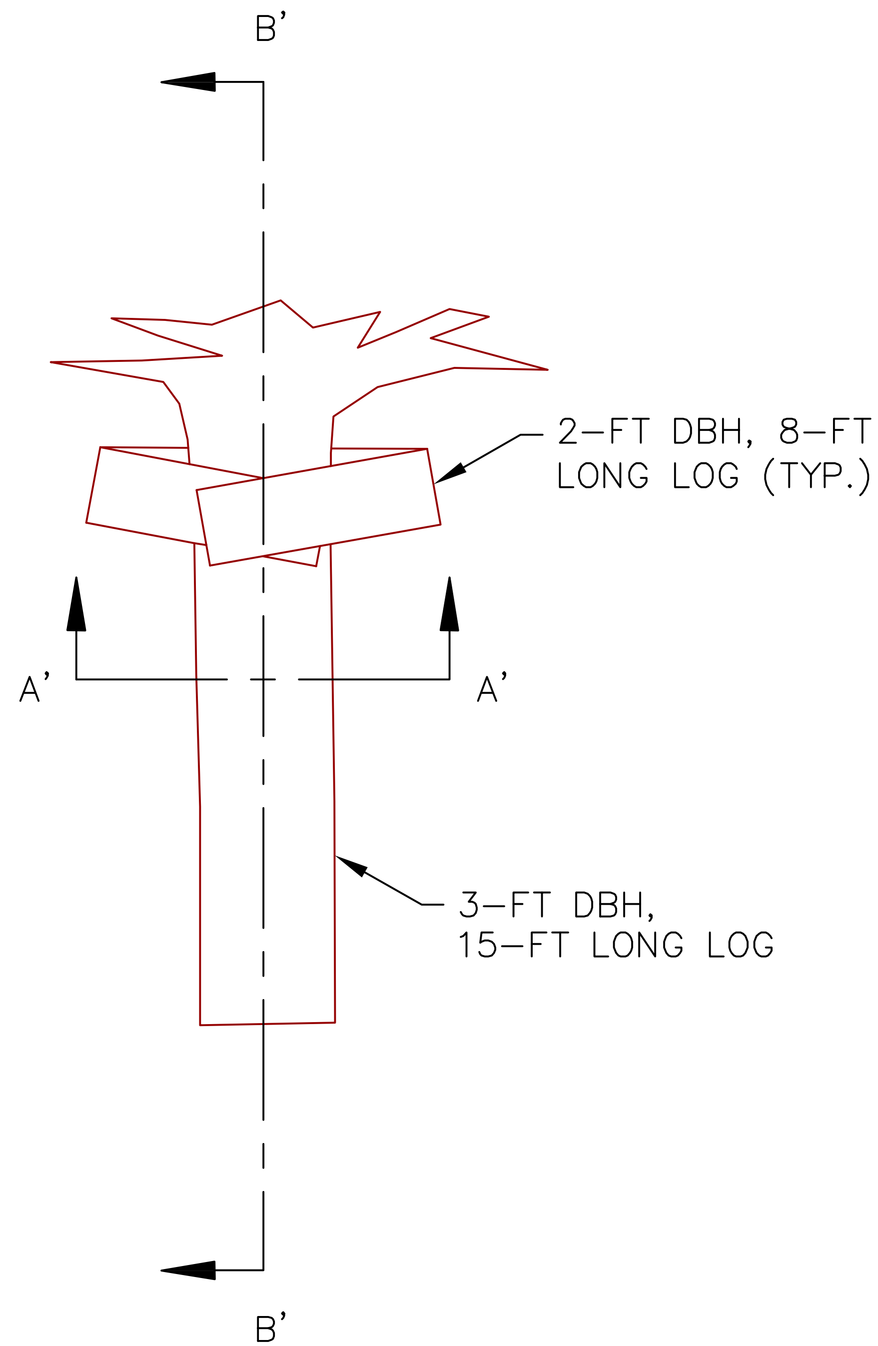
Single Pieces - Type 2

Sheet LWM-2

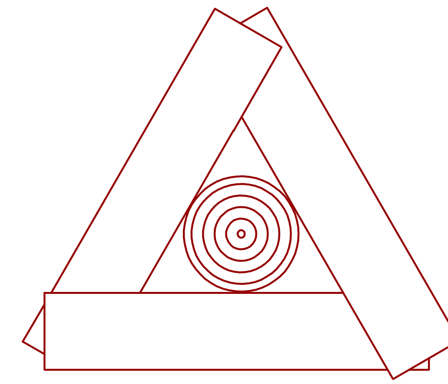
PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

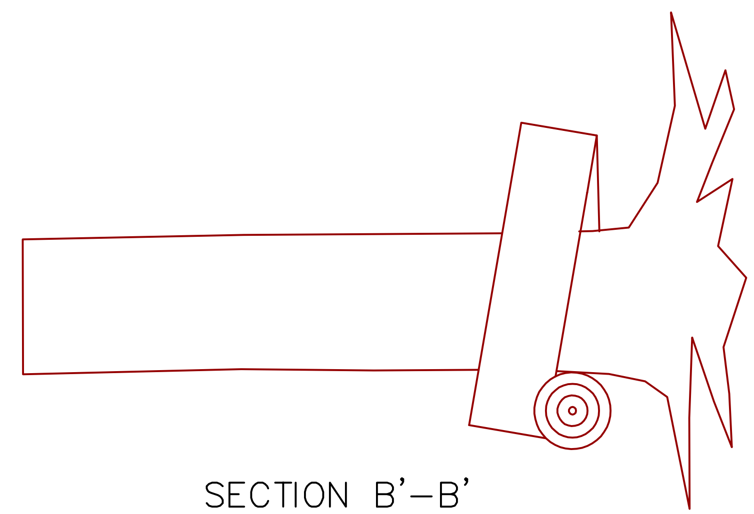
1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
2. *ANCHORING TO BE DETERMINED AT LATER STAGES OF DESIGN.*



PLAN VIEW



SECTION A'–A'



SECTION B'–B'

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Date: 18Jun20	

Lower Issaquah Creek Restoration
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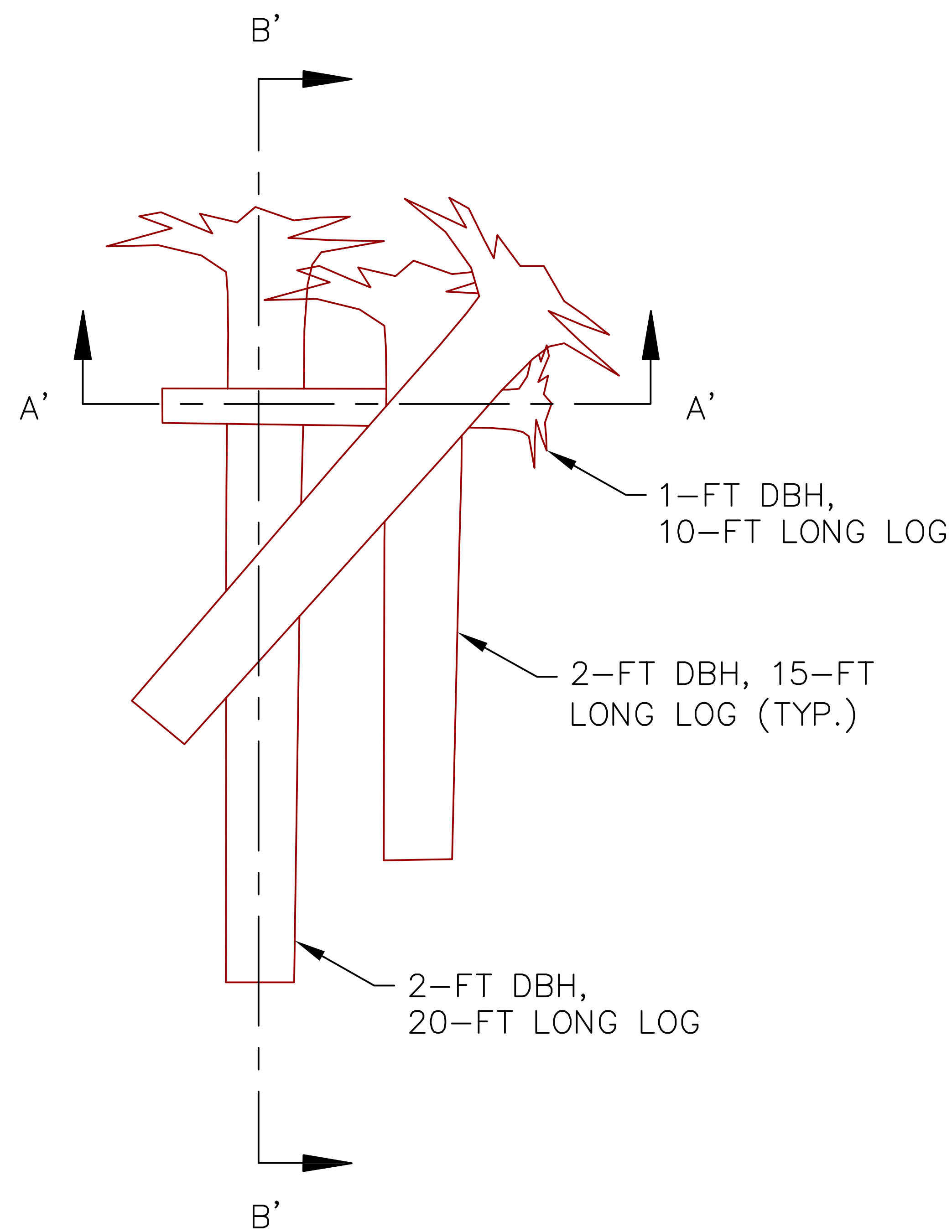
Log Jack

Sheet LWM-3

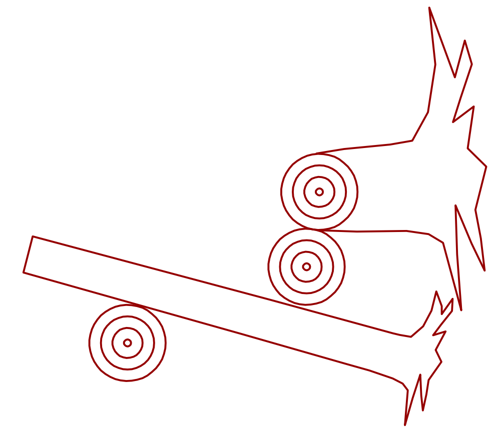
PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

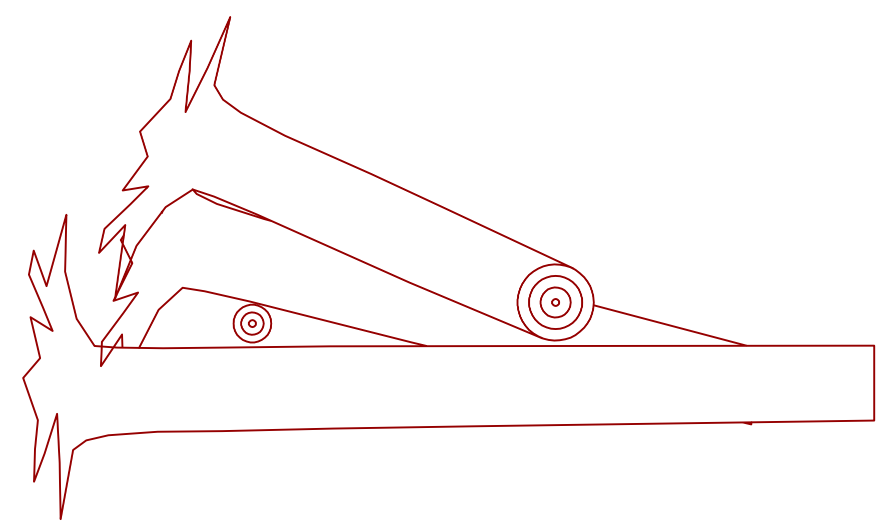
1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
2. *SLASH TO BE INCLUDED IN LWM STRUCTURE.*
3. *ANCHORING TO BE DETERMINED AT LATER STAGES OF DESIGN.*



PLAN VIEW



SECTION A'–A'



SECTION B'–B'

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Date:	18Jun20

Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Small Spur Jam

Sheet LWM-4

PRELIMINARY – NOT FOR CONSTRUCTION

NOTES:

1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
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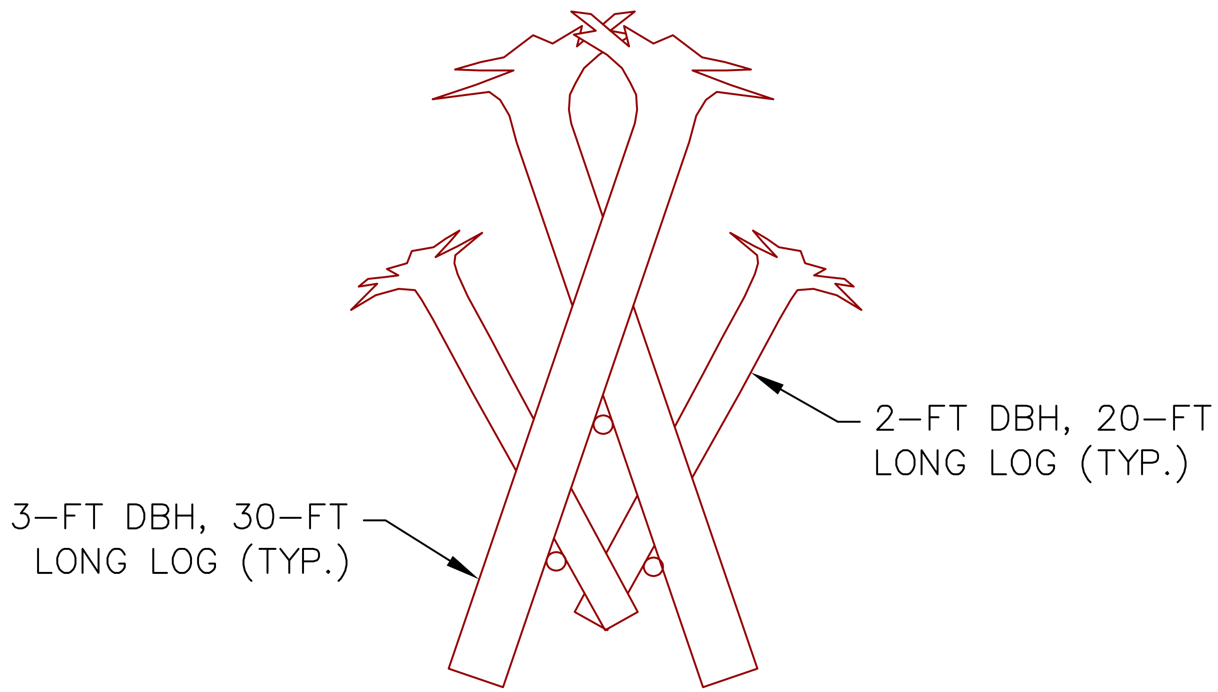
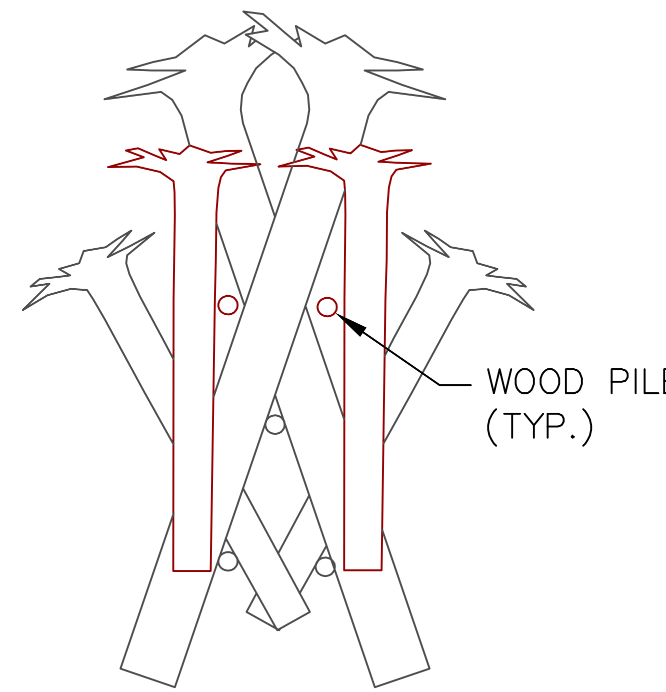


PLAN VIEW,
CONSTRUCTION
LAYER 1



PLAN VIEW,
CONSTRUCTION
LAYER 2

Job:2003907	
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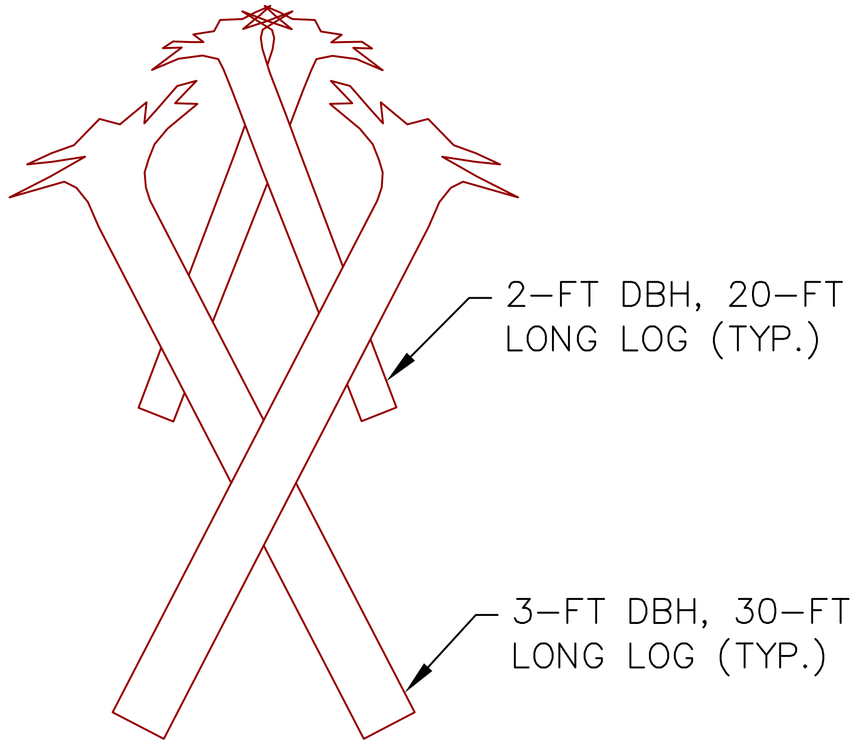
Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Large Spur Jam

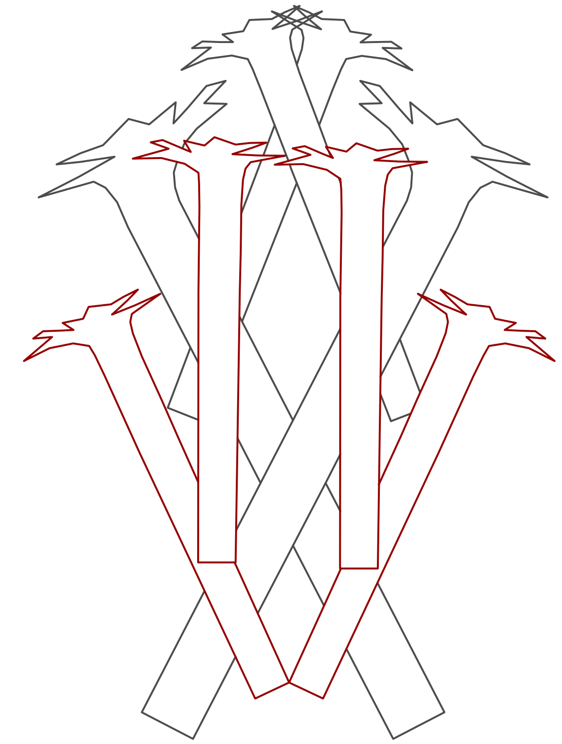
Sheet LWM-5

PRELIMINARY –
NOT FOR CONSTRUCTION

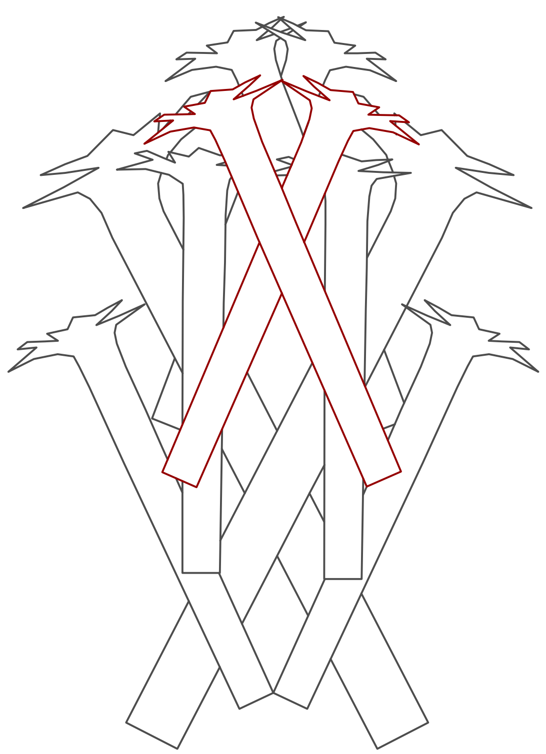
PLAN VIEW,
CONSTRUCTION
LAYER 1



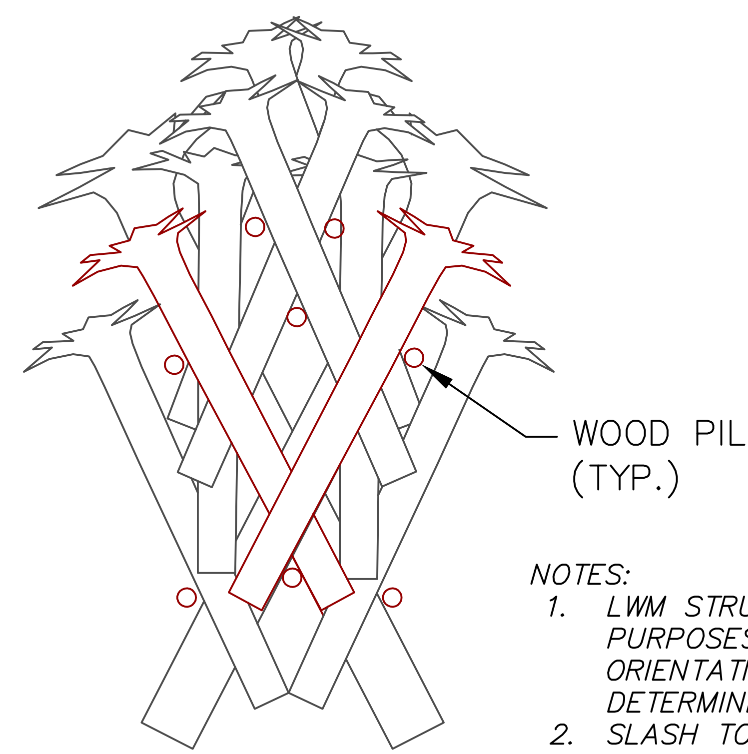
PLAN VIEW,
CONSTRUCTION
LAYER 2



PLAN VIEW,
CONSTRUCTION
LAYER 3



PLAN VIEW,
CONSTRUCTION
LAYER 4



NOTES:

1. *LWM STRUCTURES ARE FOR ILLUSTRATION PURPOSES ONLY. EXACT LOCATION AND ORIENTATION OF LWM STRUCTURES TO BE DETERMINED ON SITE BY THE ENGINEER.*
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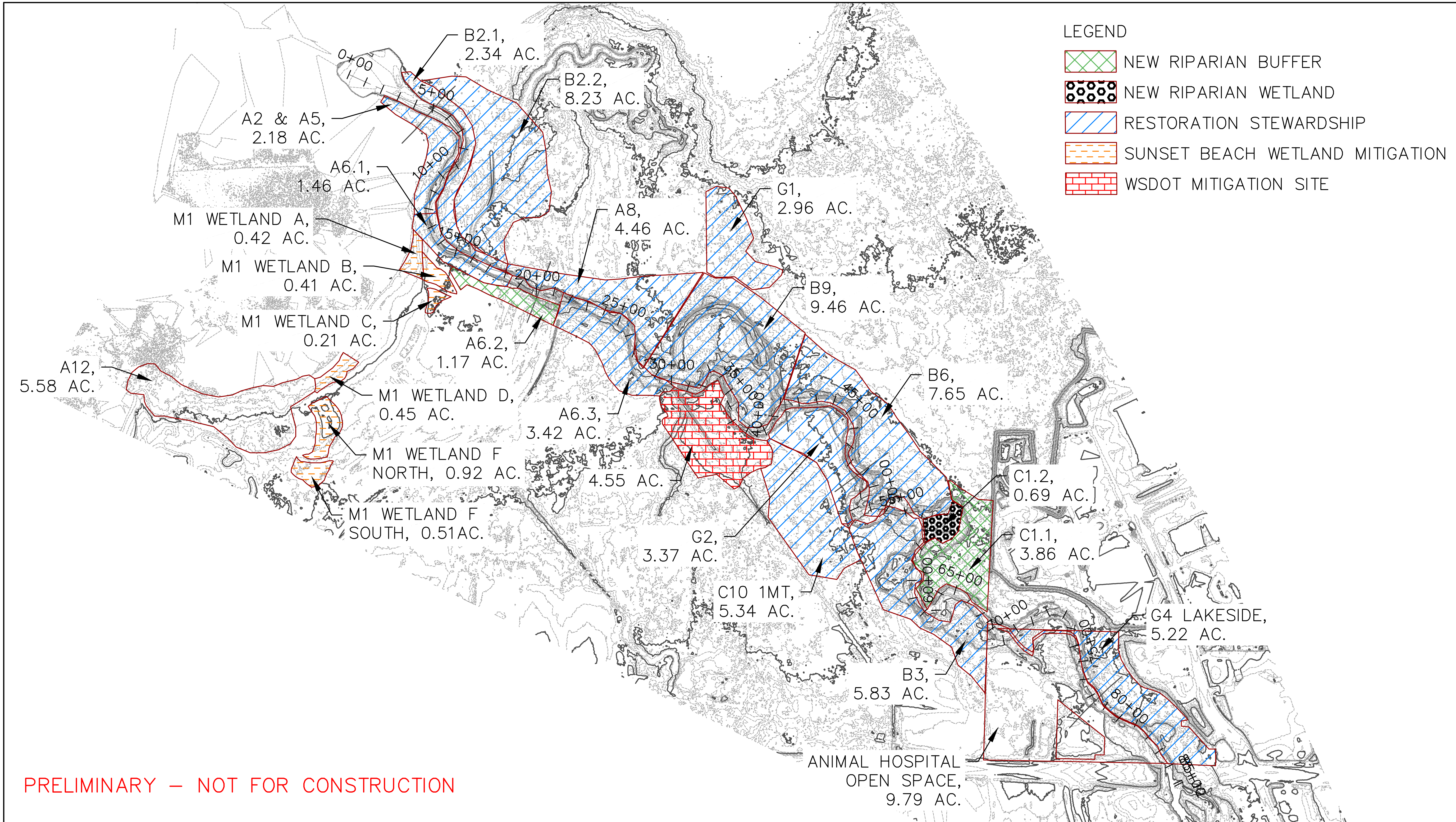
Lower Issaquah Creek Restoration
at Lake Sammamish State Park

Apex Jam

Sheet LWM-6



PRELIMINARY – NOT FOR CONSTRUCTION

MOUNTAINS to Sound GREENWAY

WASHINGTON STATE PARKS

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phone: (360) 584-9810

Job: 2003907	Lower Issaquah Creek Restoration at Lake Sammamish State Park
Rev:	
Drft: MWG	Restoration Plan
Chkd:	
Date: 18Jun20	Sheet RP-1

APPENDIX G: HYDRAULIC ANALYSIS RESULTS – EXISTING CONDITIONS

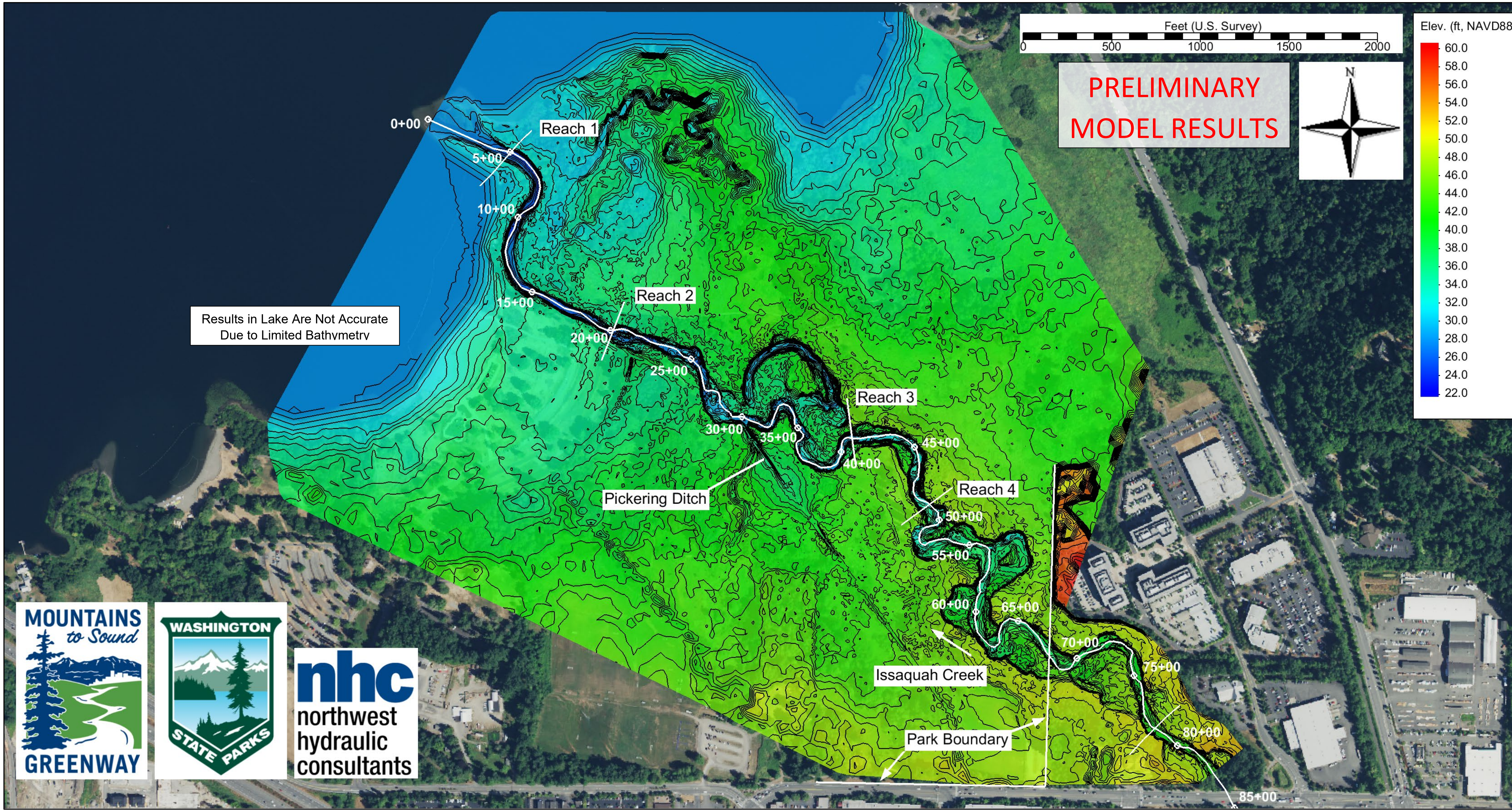

Figure G.1 Lower Issaquah Creek Existing Conditions Model Domain

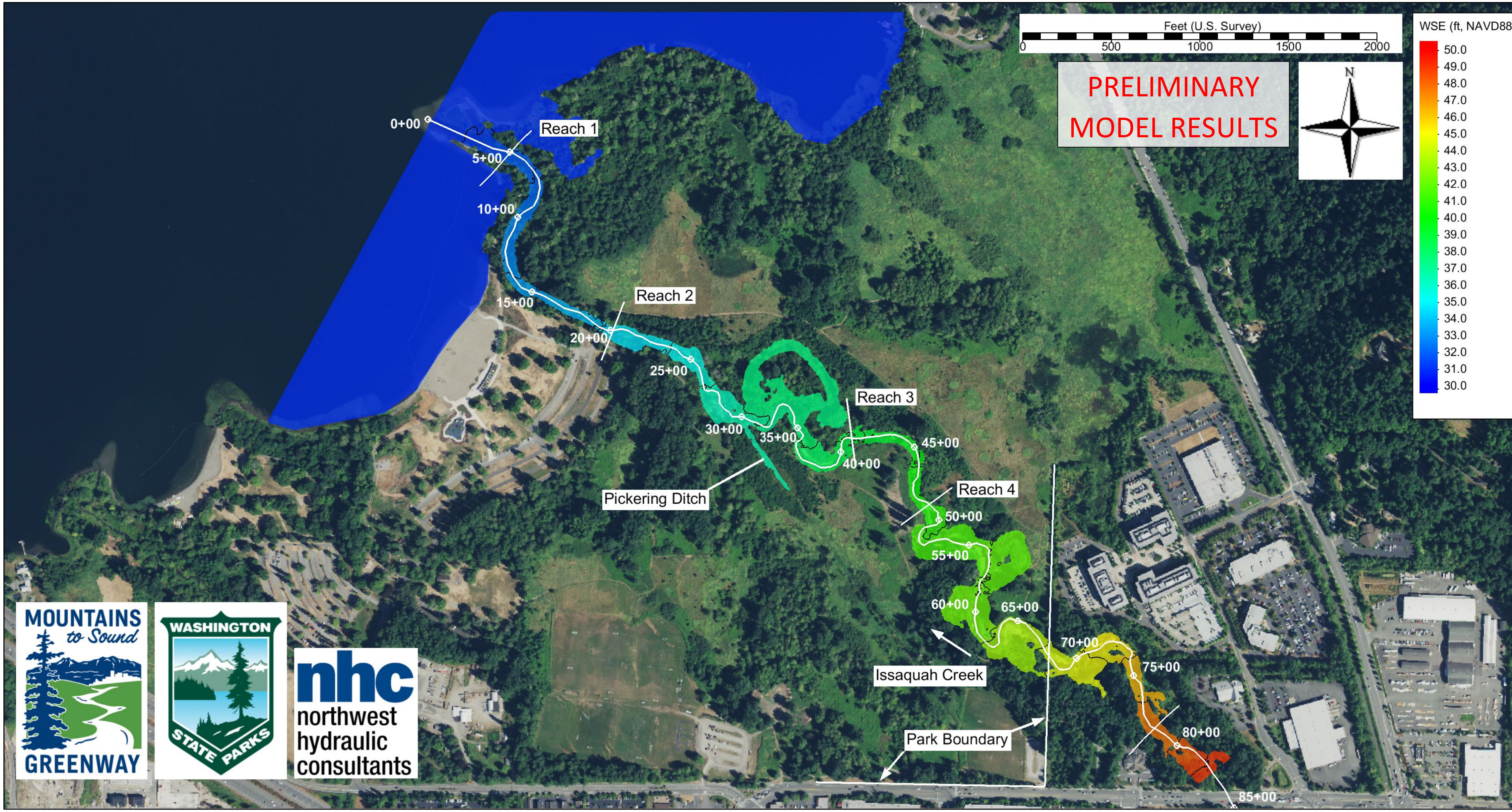

Figure G.2 Lower Issaquah Creek Existing Conditions 2-Year Water Surface Elevation (WSE)

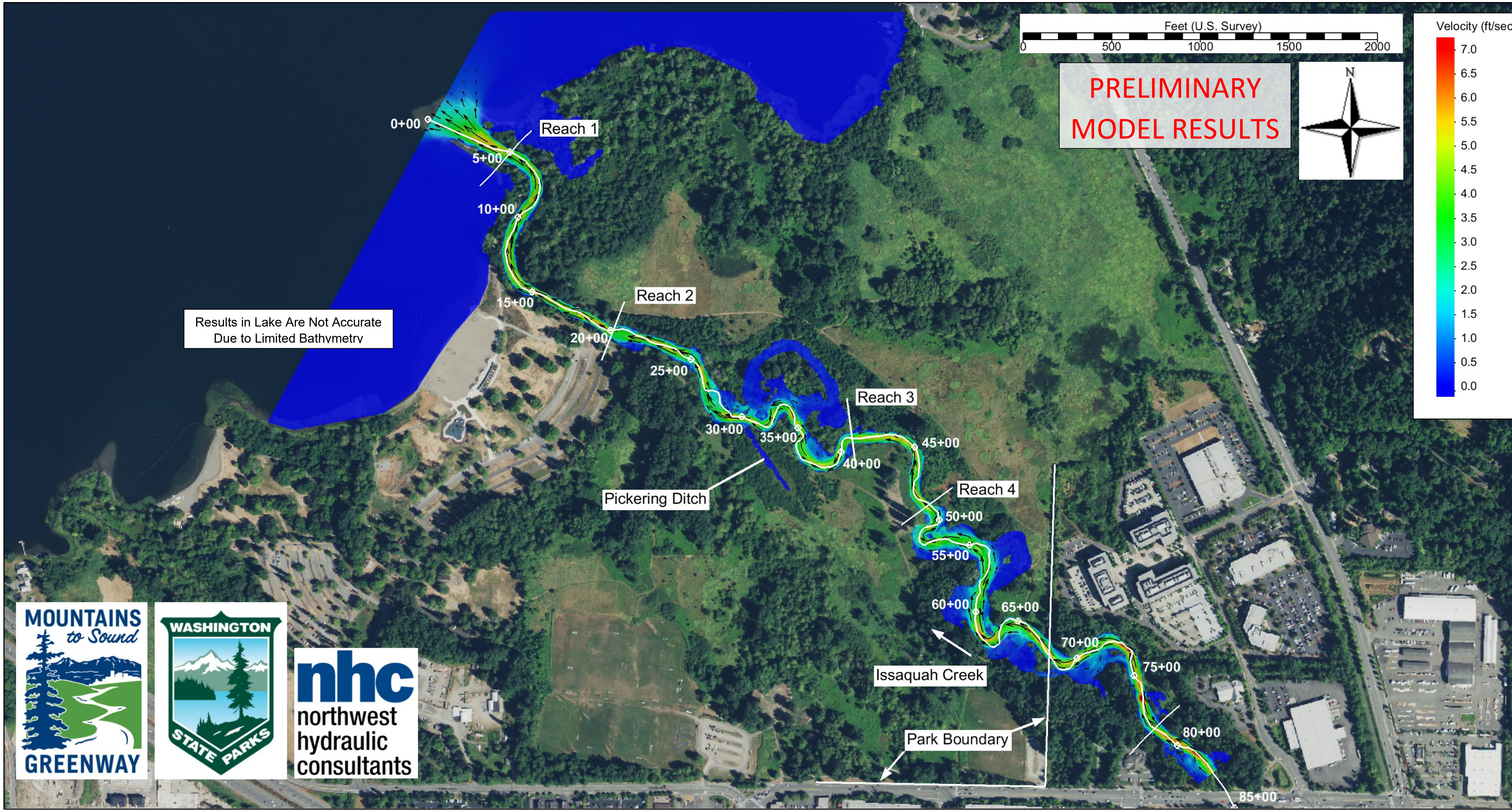

Figure G.3 Lower Issaquah Creek Existing Conditions 2-Year Velocity

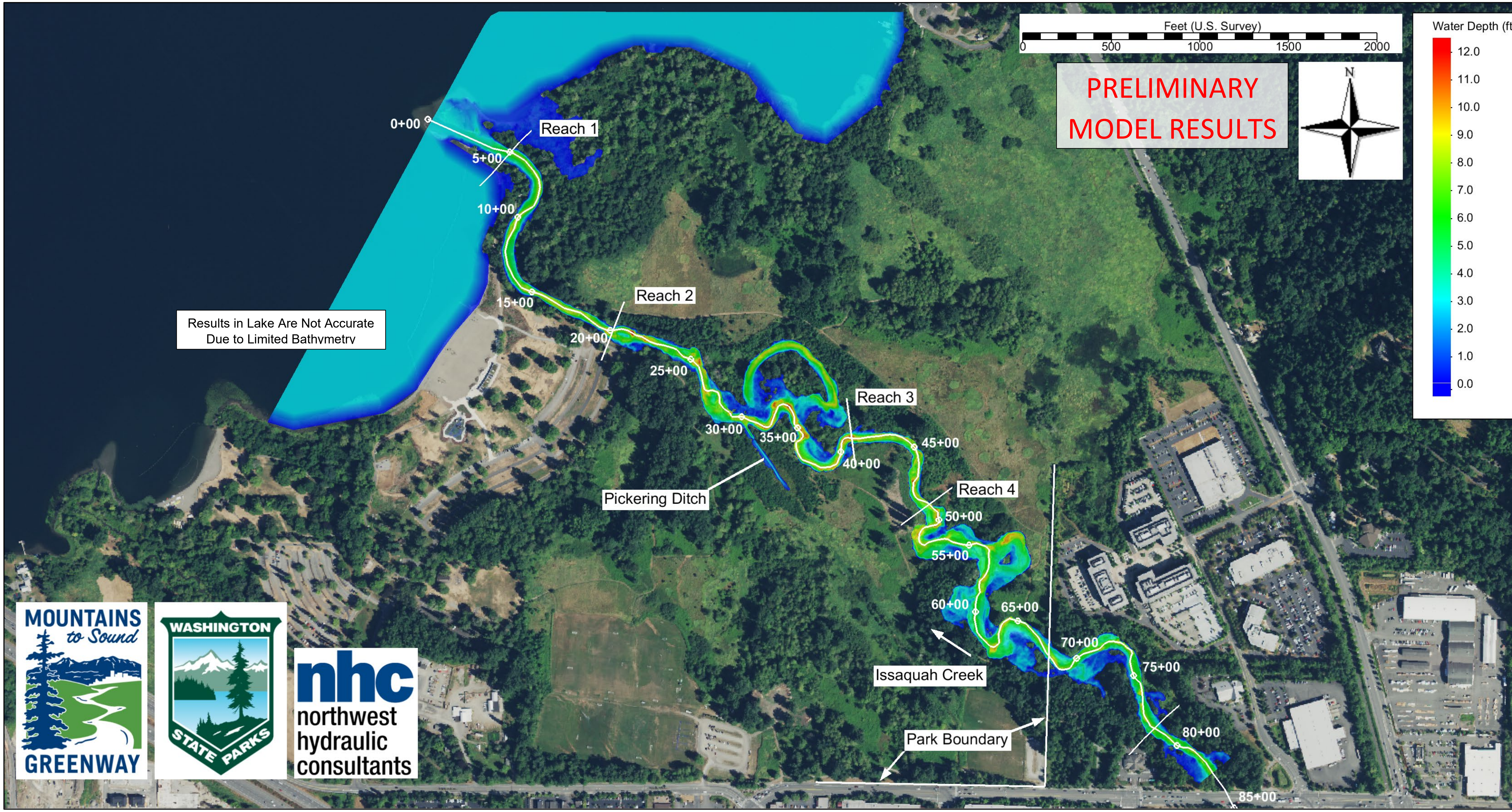

Figure G.4 Lower Issaquah Creek Existing Conditions 2-Year Water Depth

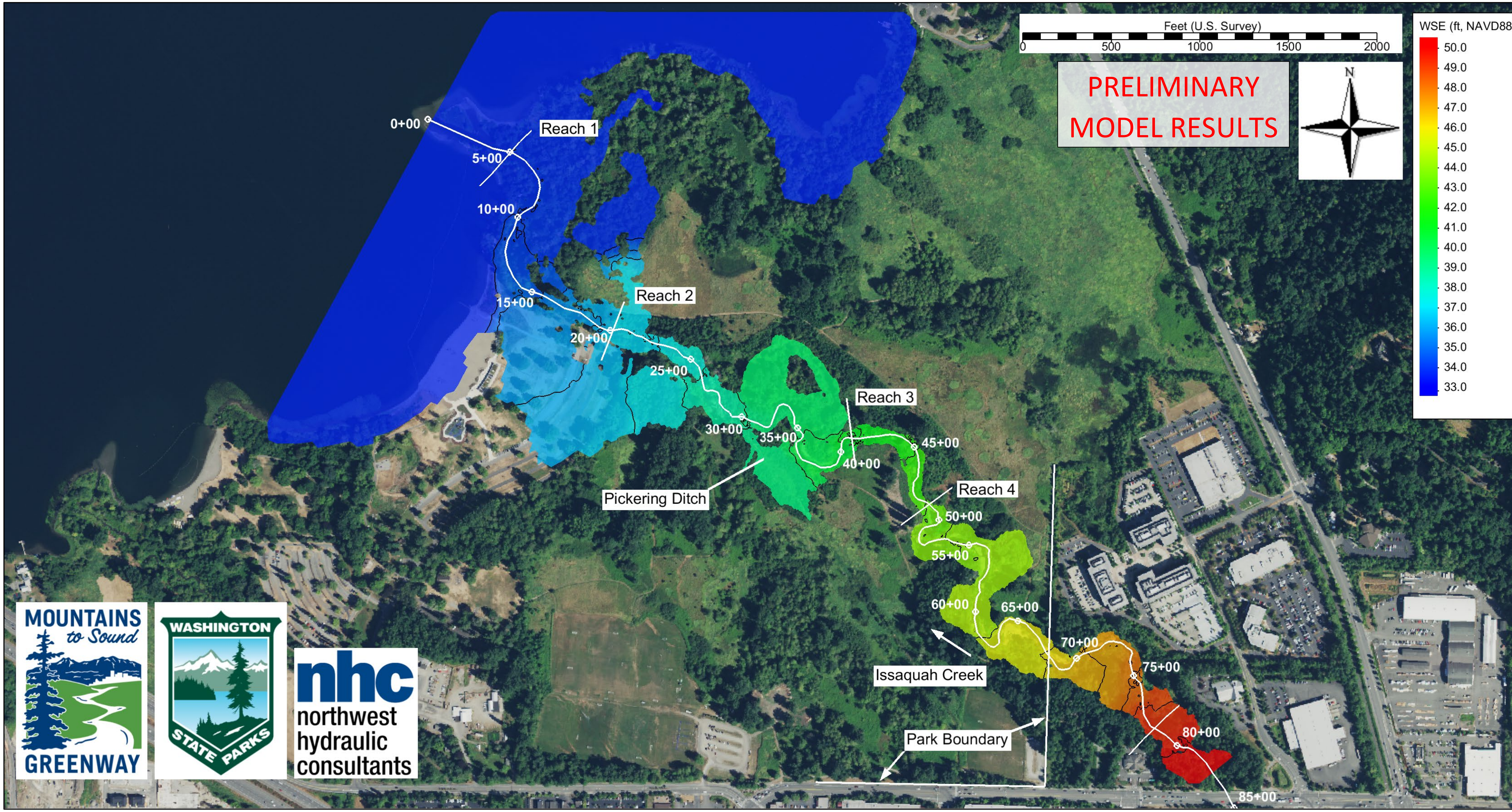

Figure G.5 Lower Issaquah Creek Existing Conditions February 6, 2020 Flood Event Water Surface Elevation (WSE)

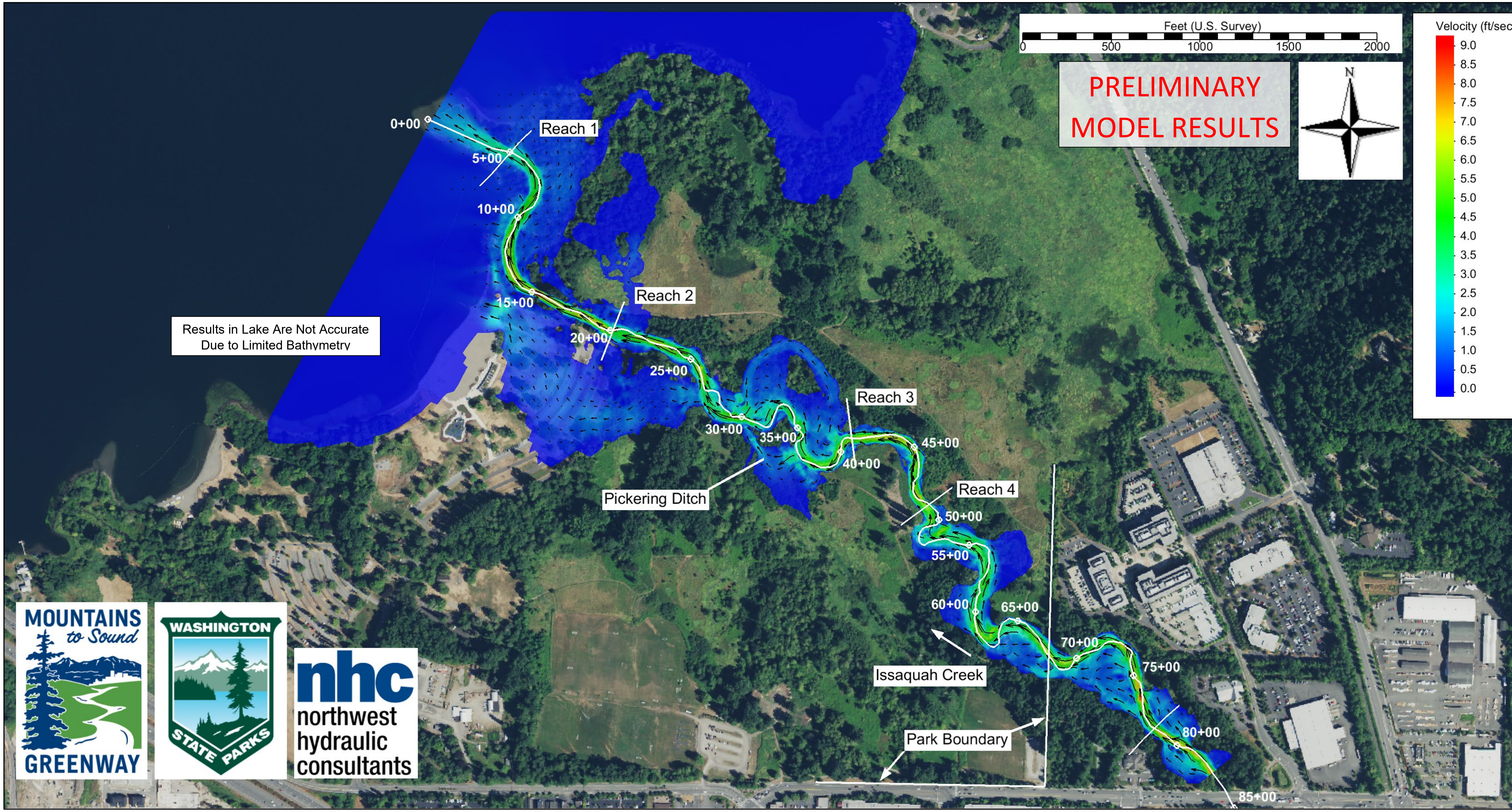

Figure G.6 Lower Issaquah Creek Existing Conditions February 6, 2020 Flood Event Velocity

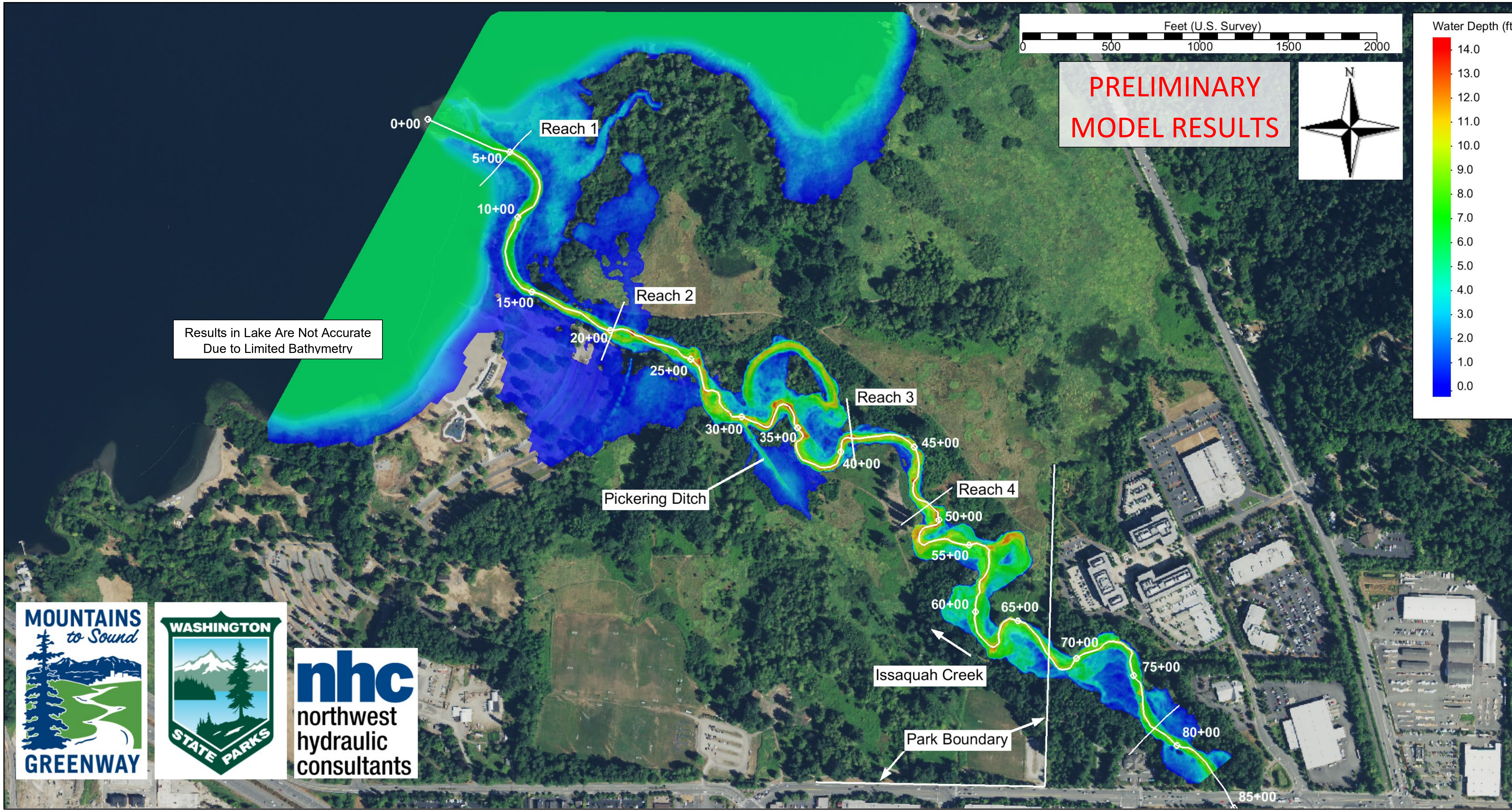

Figure G.7 Lower Issaquah Creek Existing Conditions February 6, 2020 Flood Event Water Depth

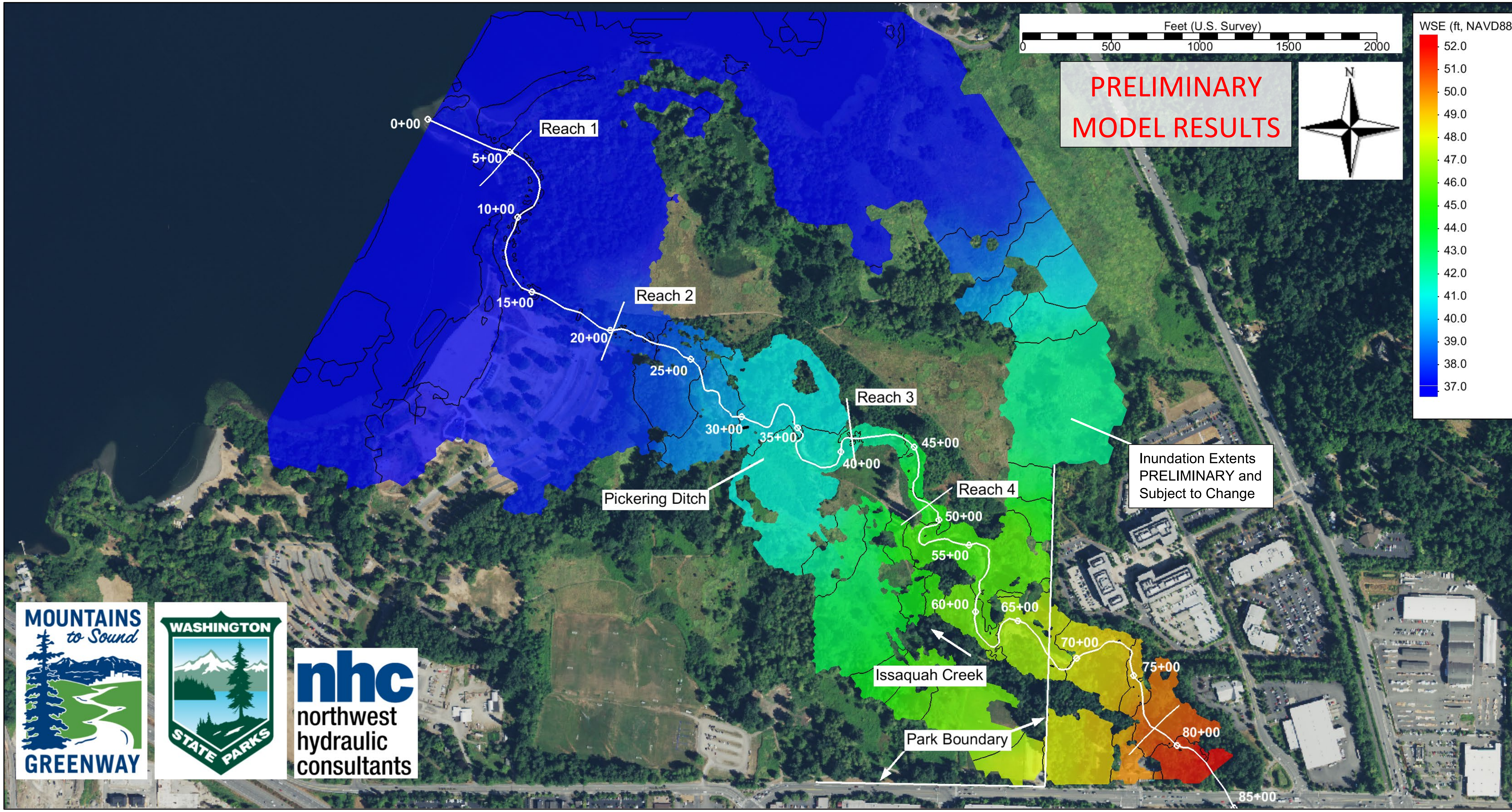

Figure G.8 Lower Issaquah Creek Existing Conditions 100-Year Water Surface Elevation (WSE)

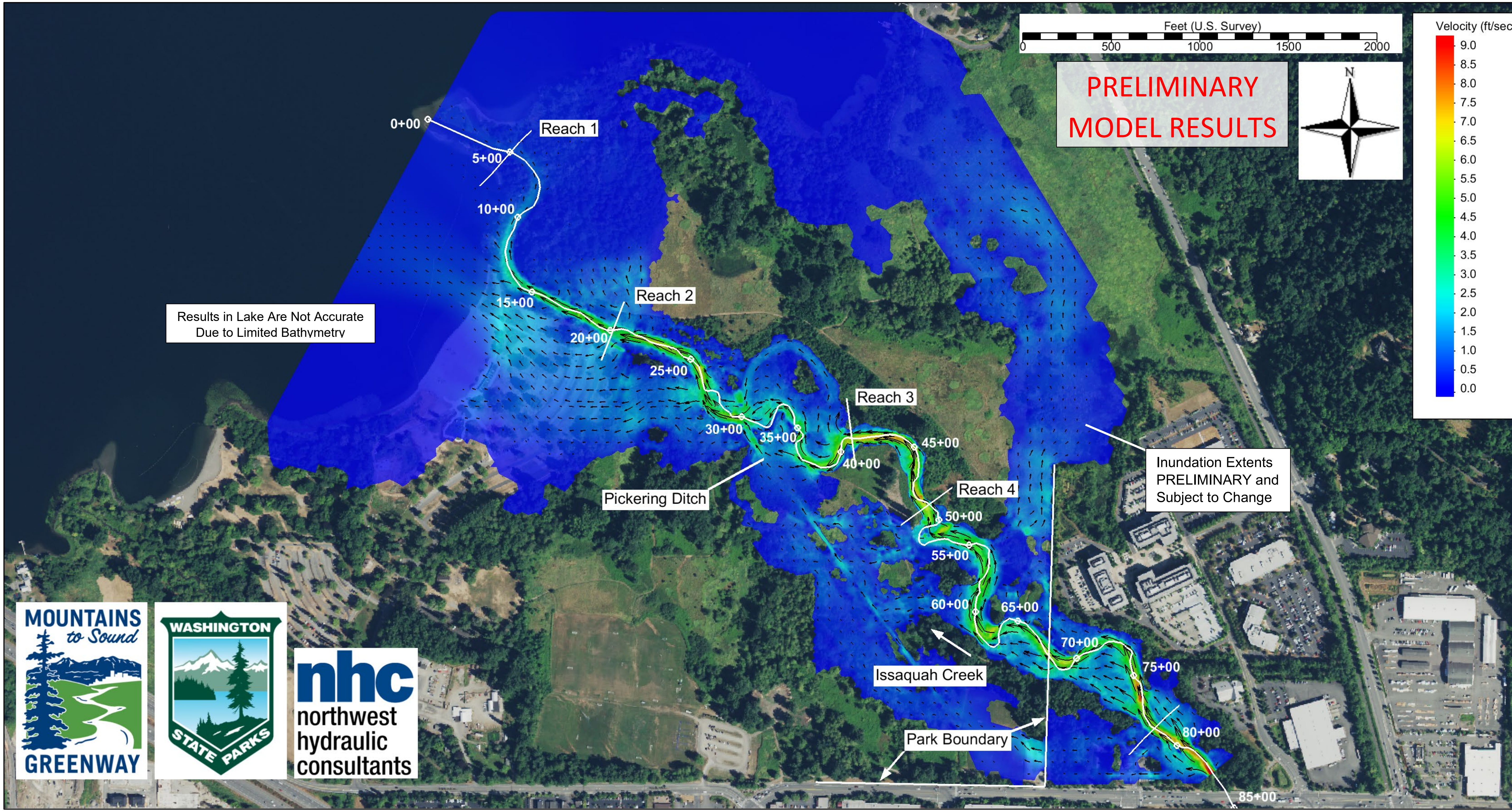

Figure G.9 Lower Issaquah Creek Existing Conditions 100-Year Velocity

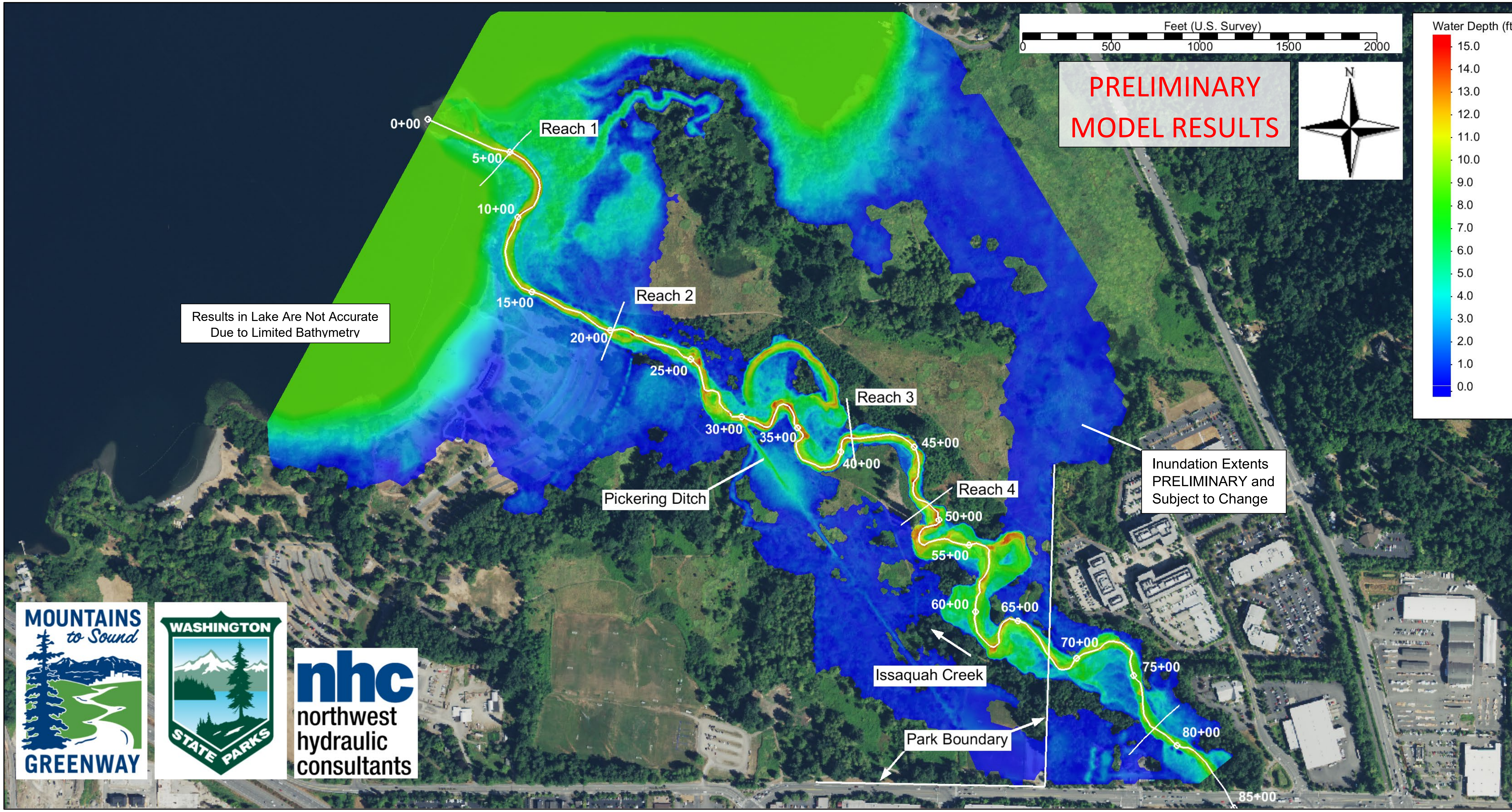

Figure G.10 Lower Issaquah Creek Existing Conditions 100-Year Water Depth

APPENDIX H: HYDRAULIC ANALYSIS RESULTS – PROPOSED CONDITIONS

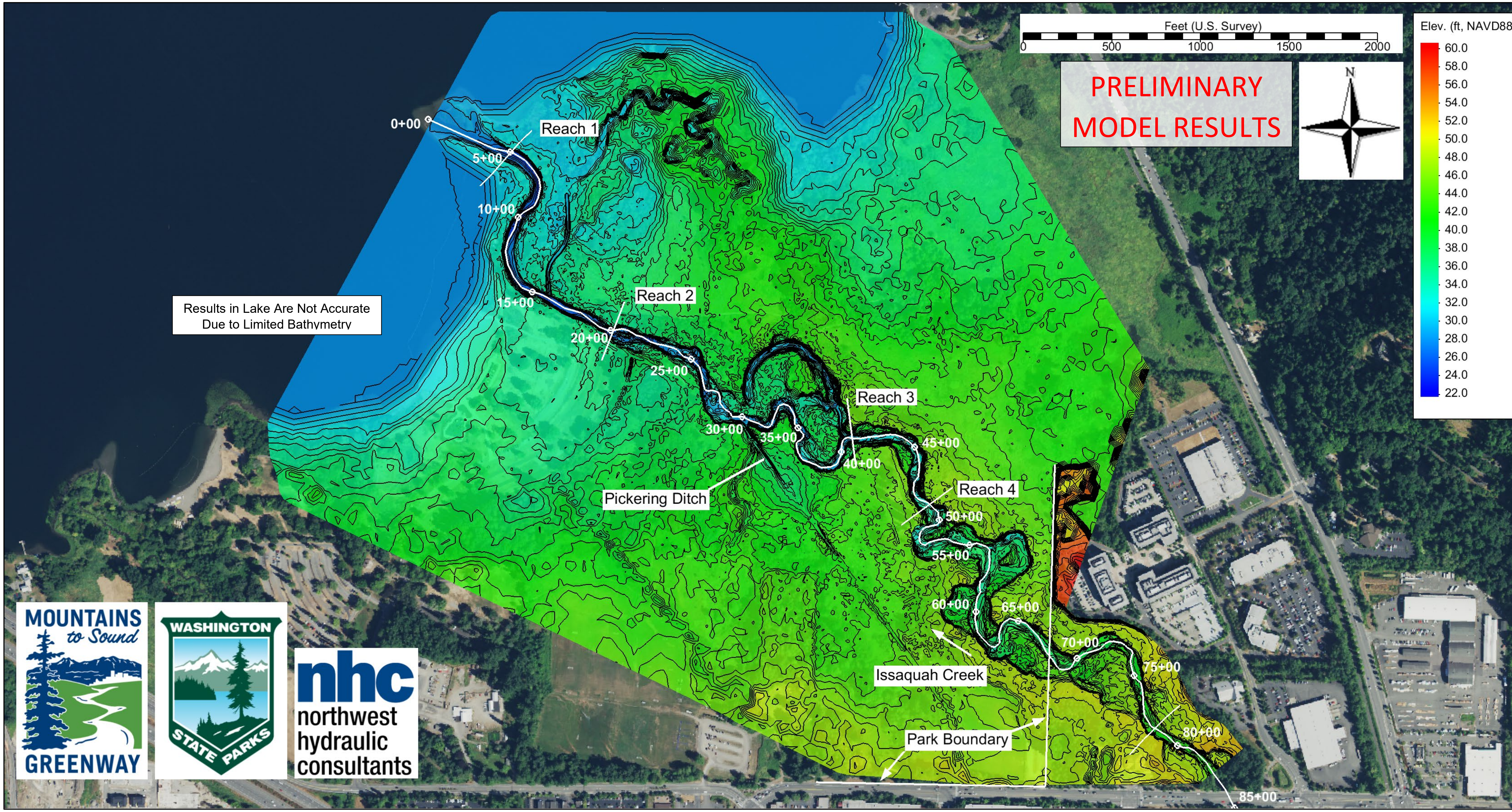

Figure H.1 Lower Issaquah Creek Proposed Conditions Model Domain

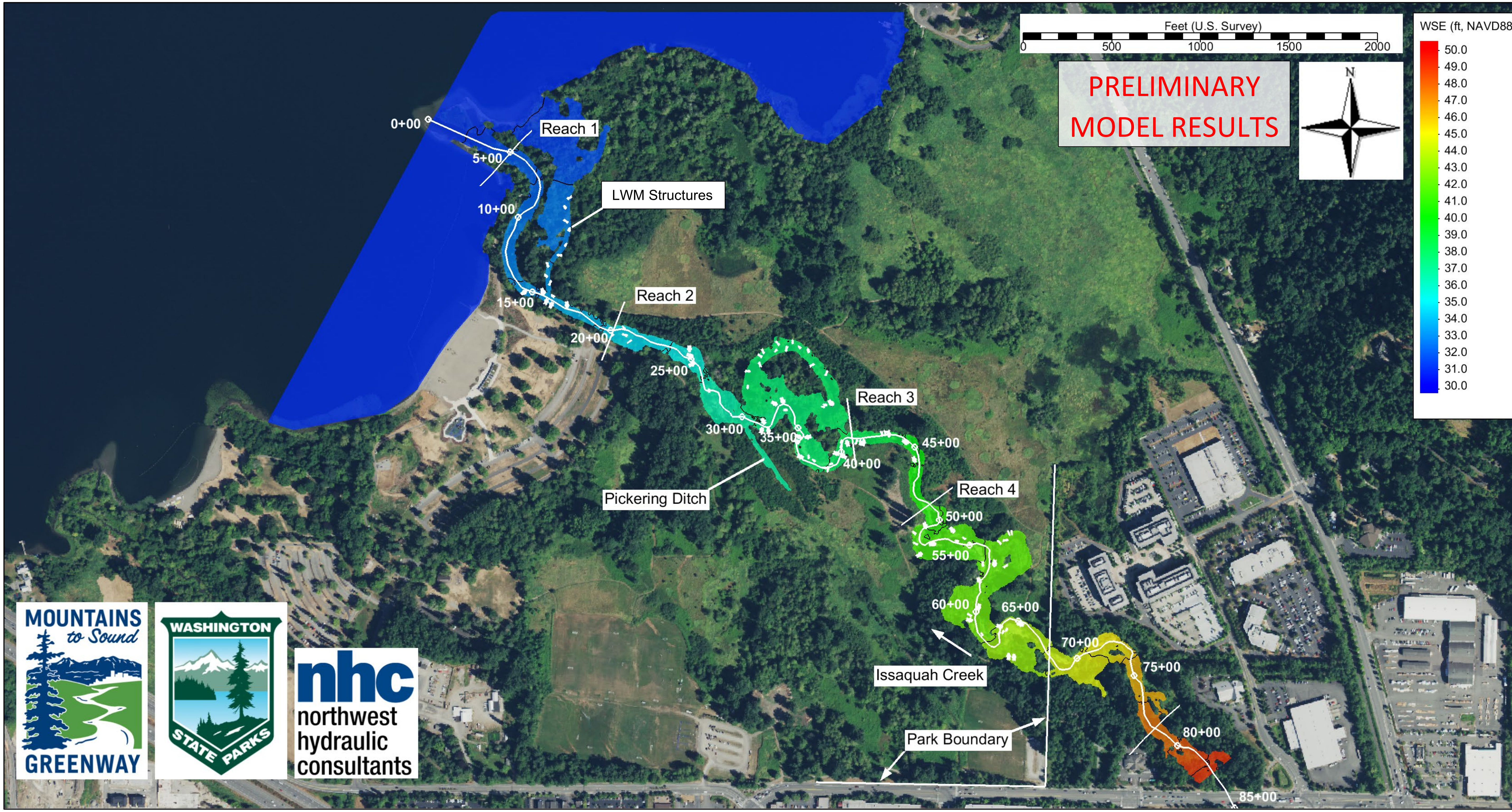

Figure H.2 Lower Issaquah Creek Proposed Conditions 2-Year Water Surface Elevation (WSE)

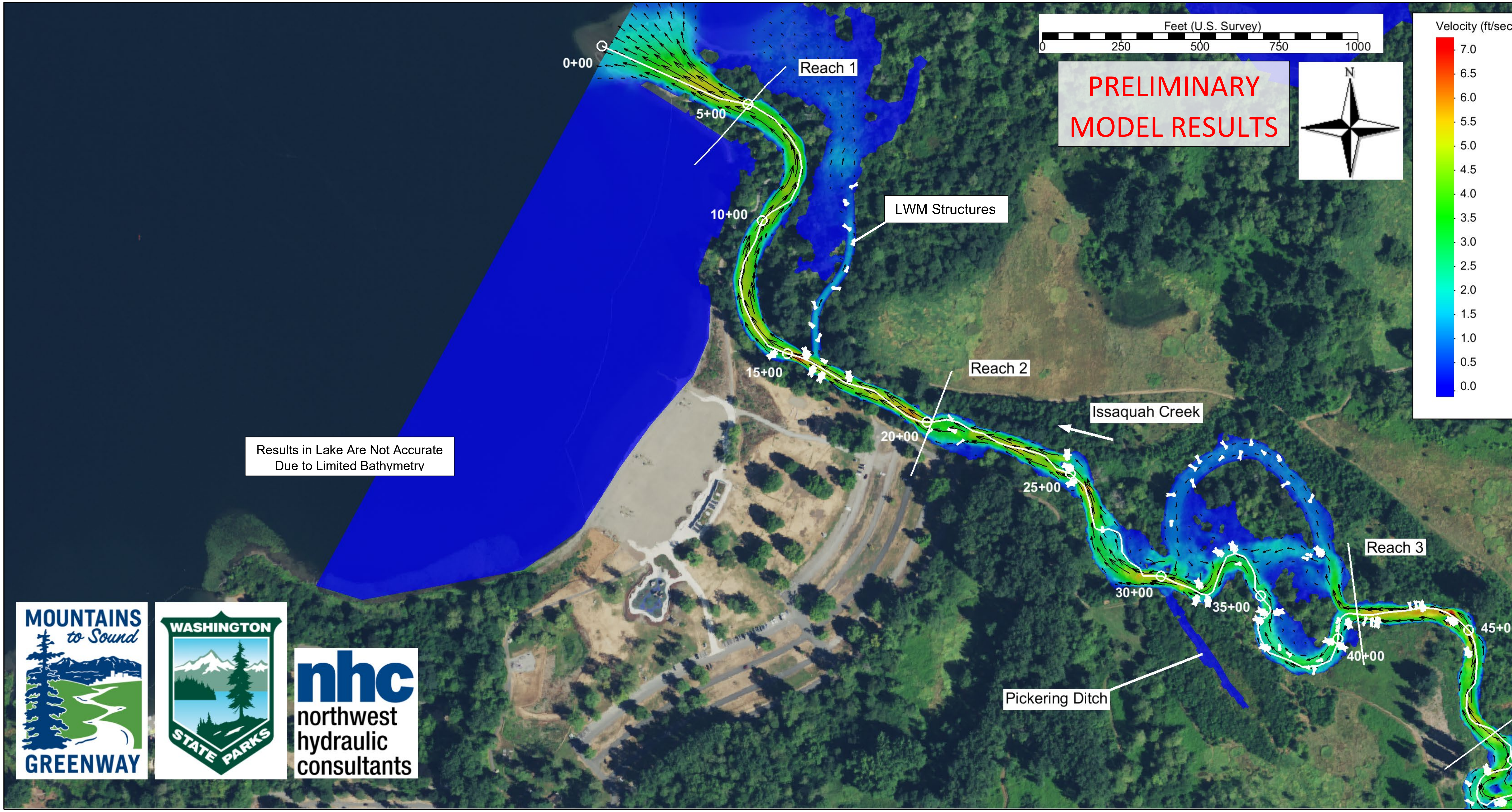

Figure H.3 Lower Issaquah Creek Proposed Conditions 2-Year Velocity (Reaches 1 and 2)

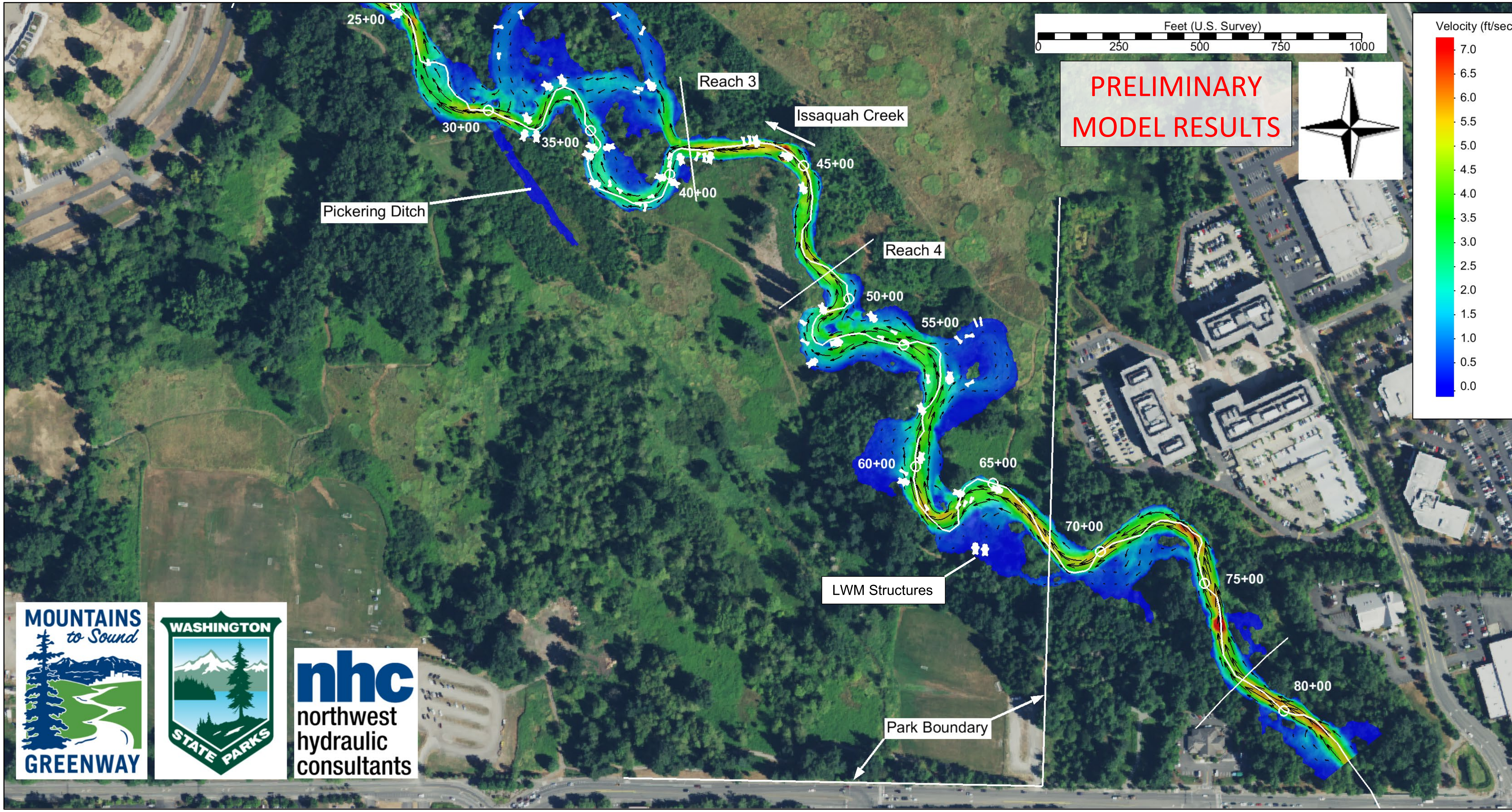

Figure H.4 Lower Issaquah Creek Proposed Conditions 2-Year Velocity (Reaches 3 and 4)

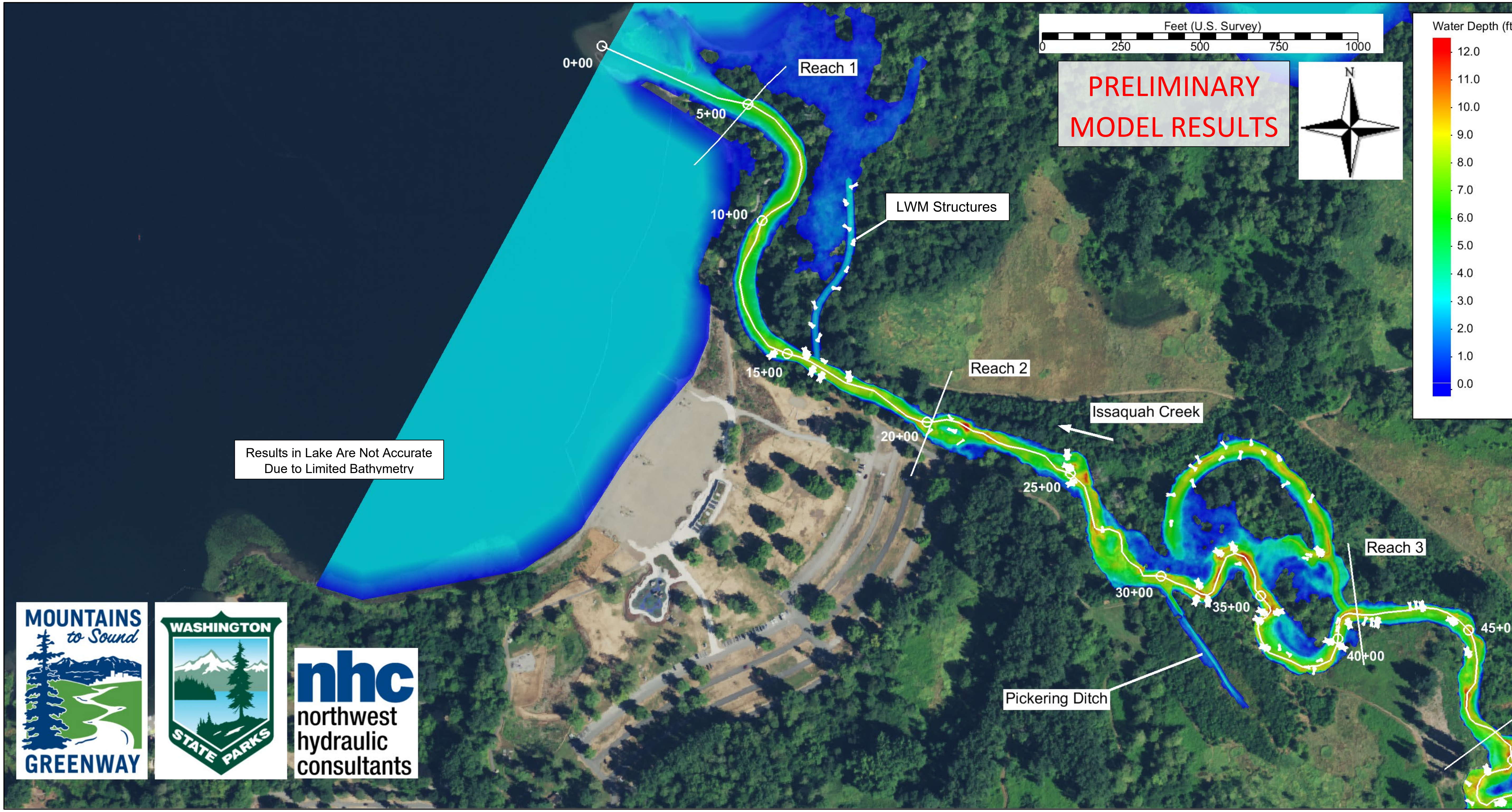

Figure H.5 Lower Issaquah Creek Proposed Conditions 2-Year Water Depth (Reaches 1 and 2)

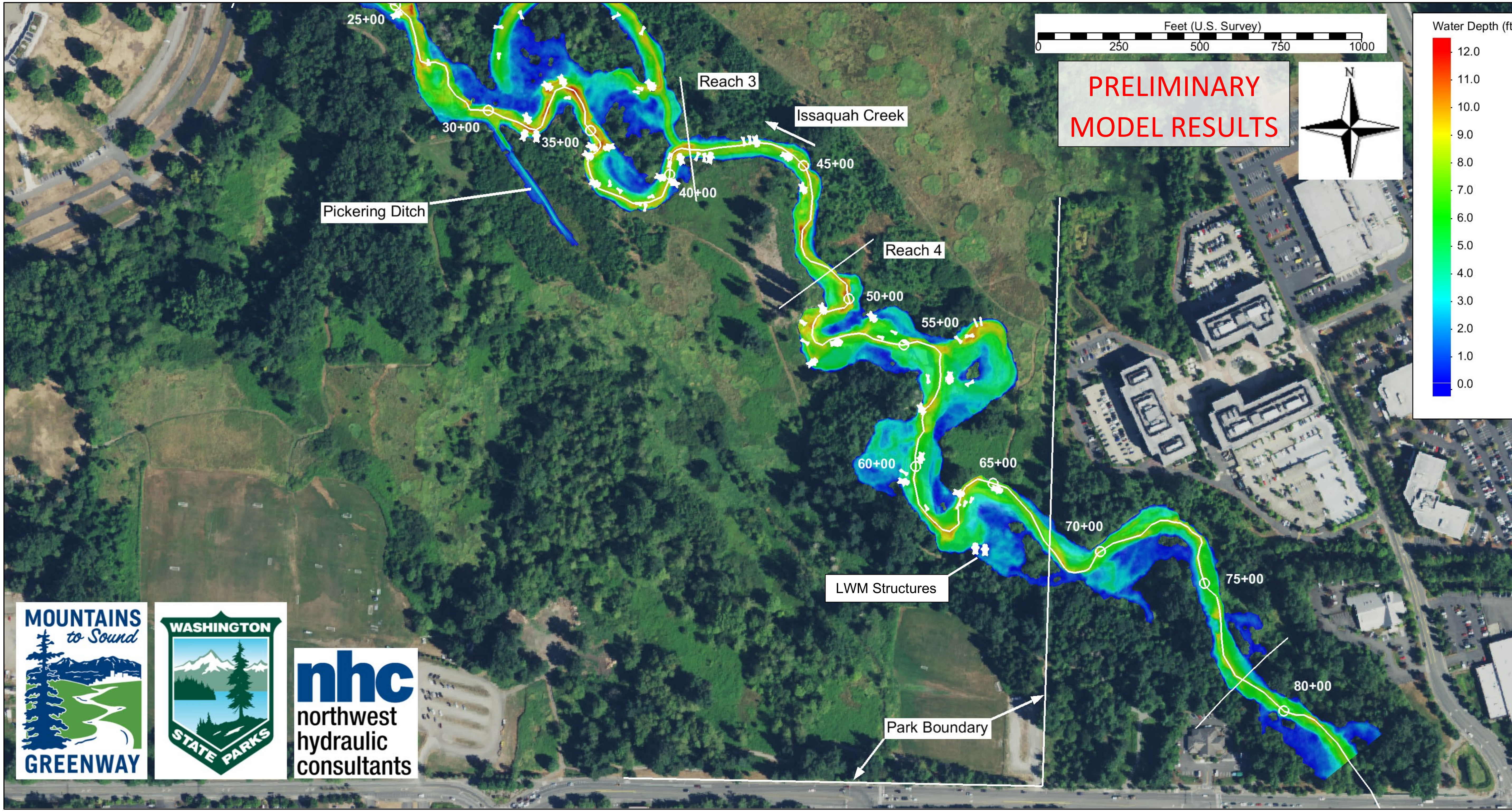

Figure H.6 Lower Issaquah Creek Proposed Conditions 2-Year Water Depth (Reaches 3 and 4)

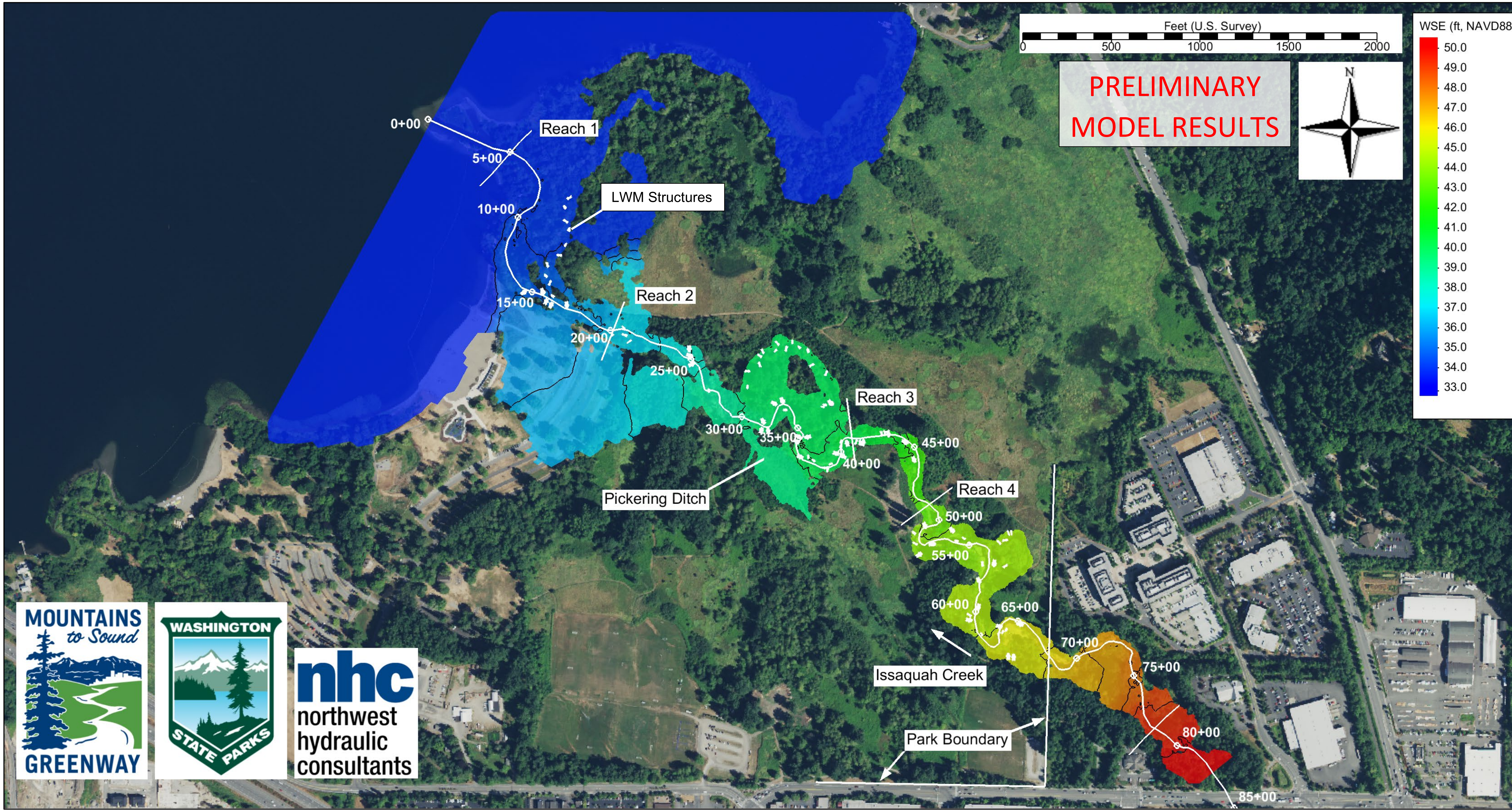

Figure H.7 Lower Issaquah Creek Proposed Conditions February 6, 2020 Flood Event Water Surface Elevation (WSE)

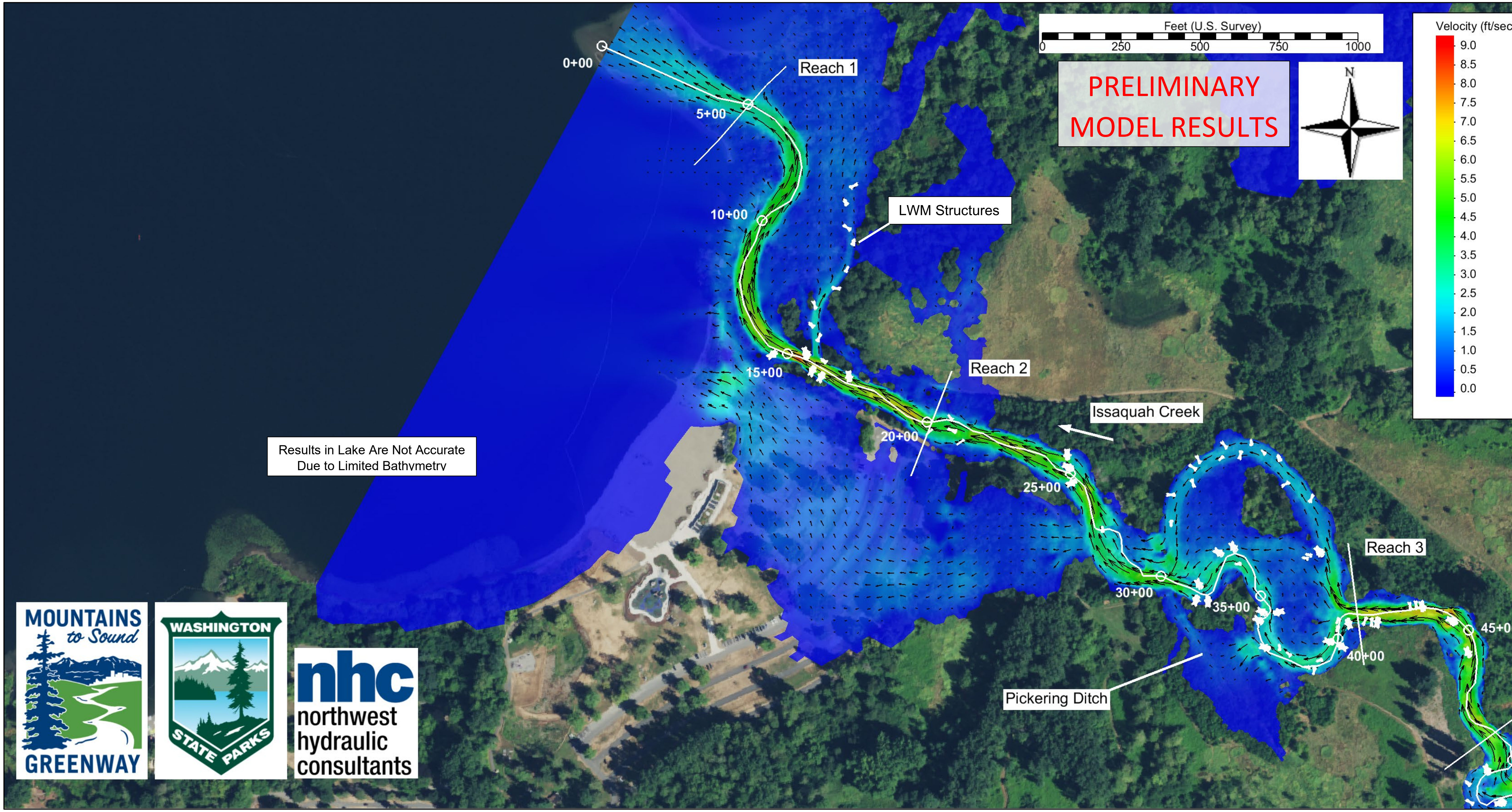

Figure H.8 Lower Issaquah Creek Proposed Conditions February 6, 2020 Flood Event Velocity (Reaches 1 and 2)

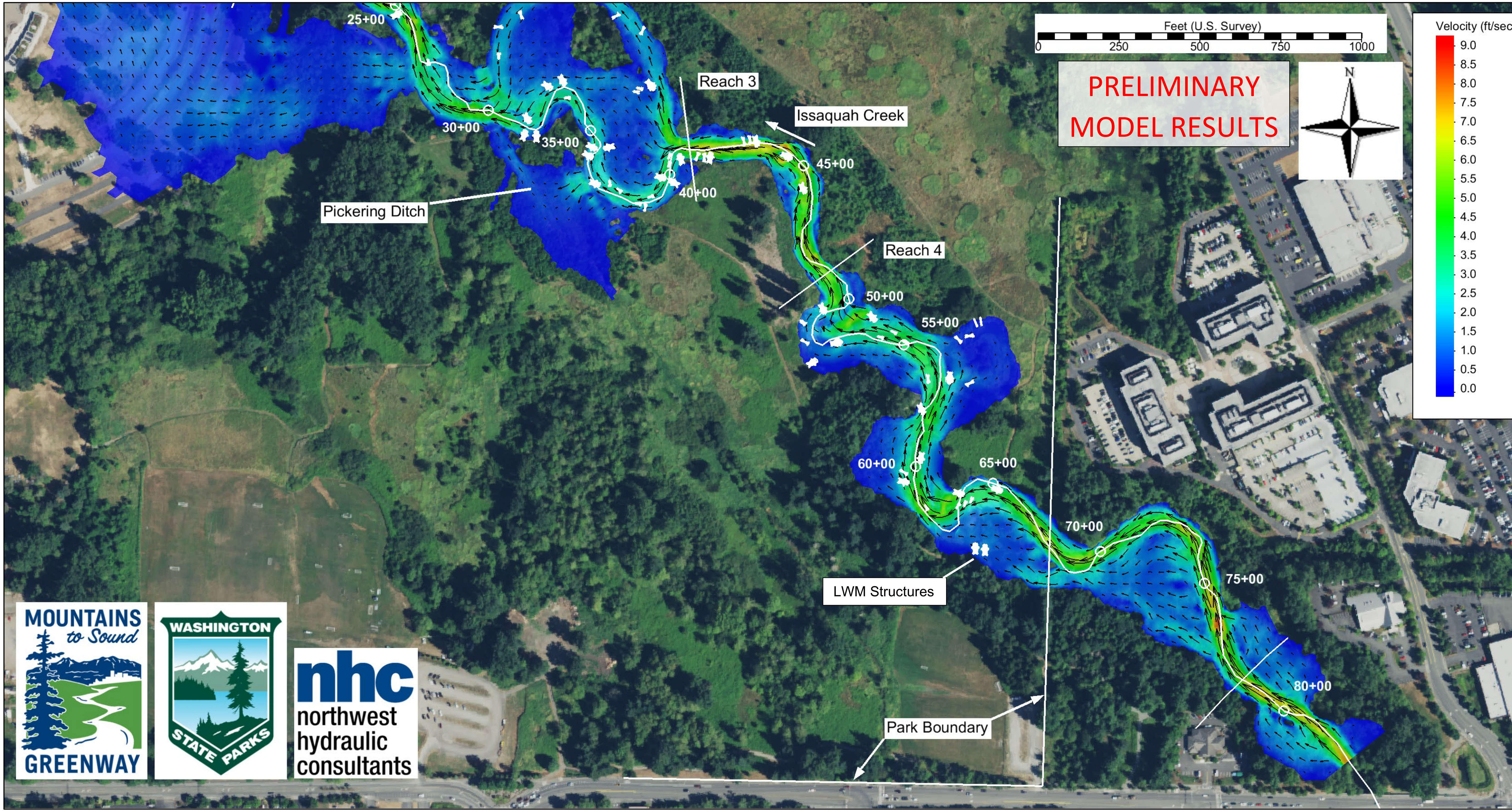

Figure H.9 Lower Issaquah Creek Proposed Conditions February 6, 2020 Flood Event Velocity (Reaches 3 and 4)

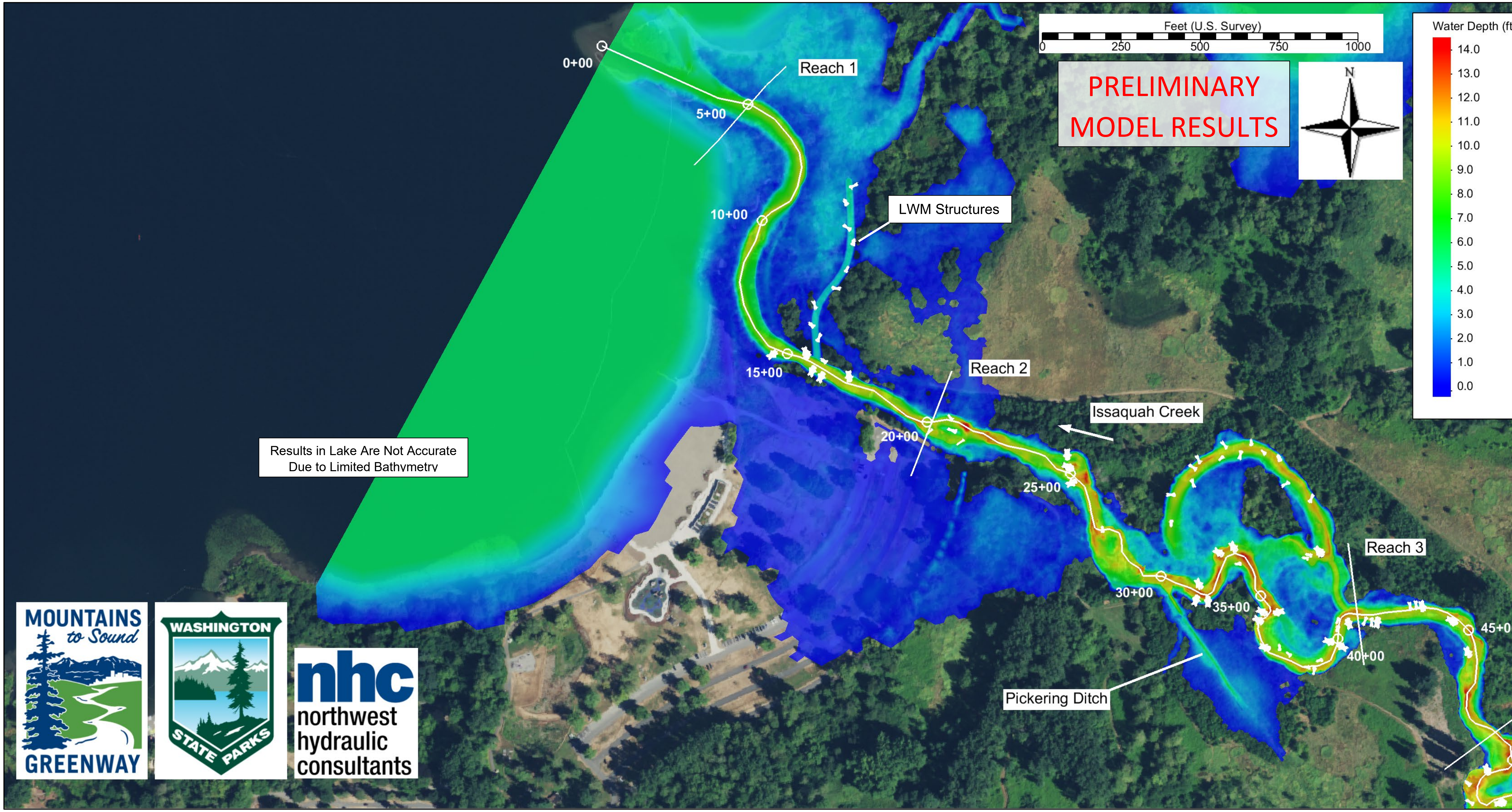

Figure H.10 Lower Issaquah Creek Proposed Conditions February 6, 2020 Flood Event Water Depth (Reaches 1 and 2)

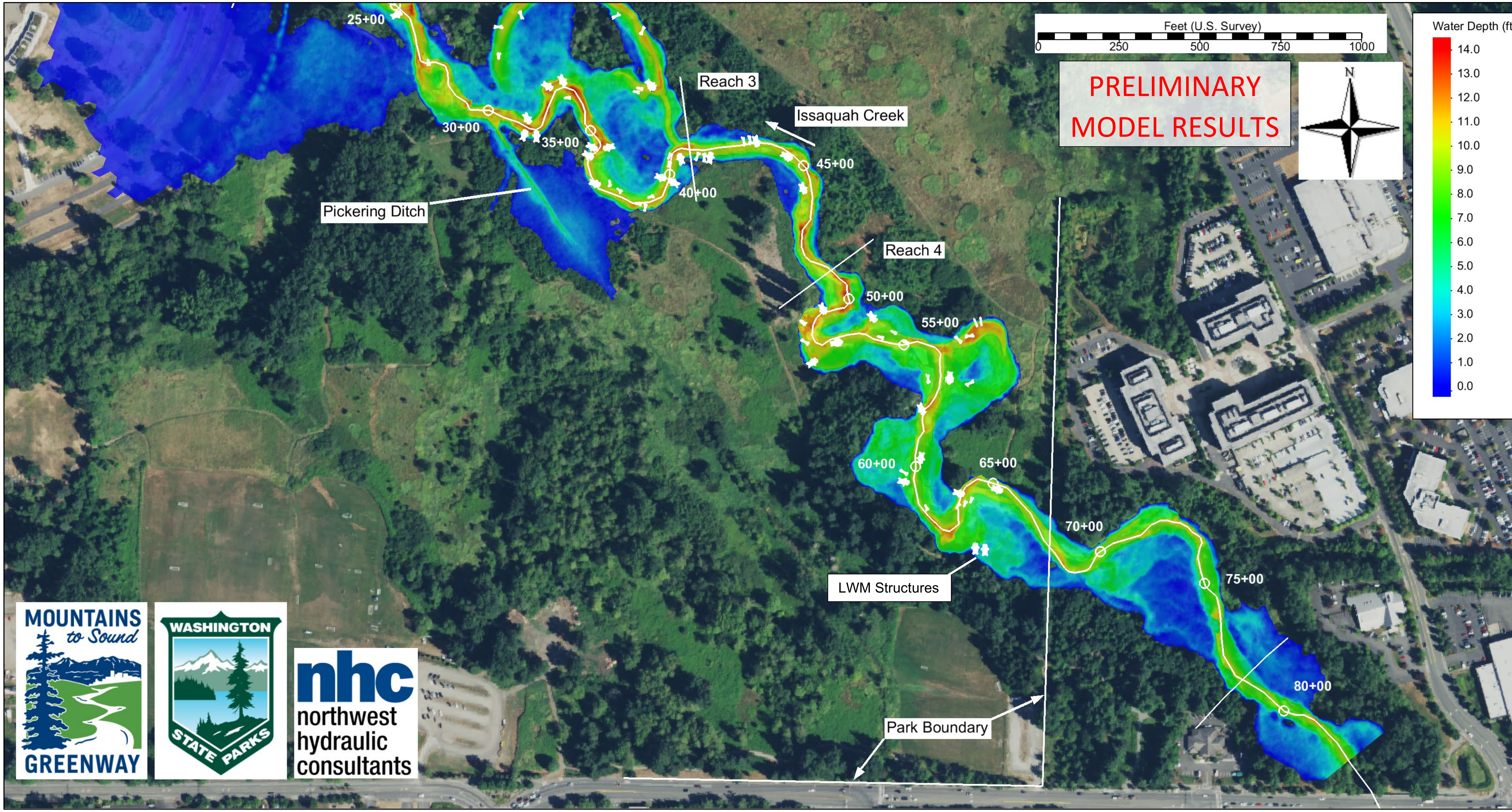

Figure H.11 Lower Issaquah Creek Proposed Conditions February 6, 2020 Flood Event Water Depth (Reaches 3 and 4)

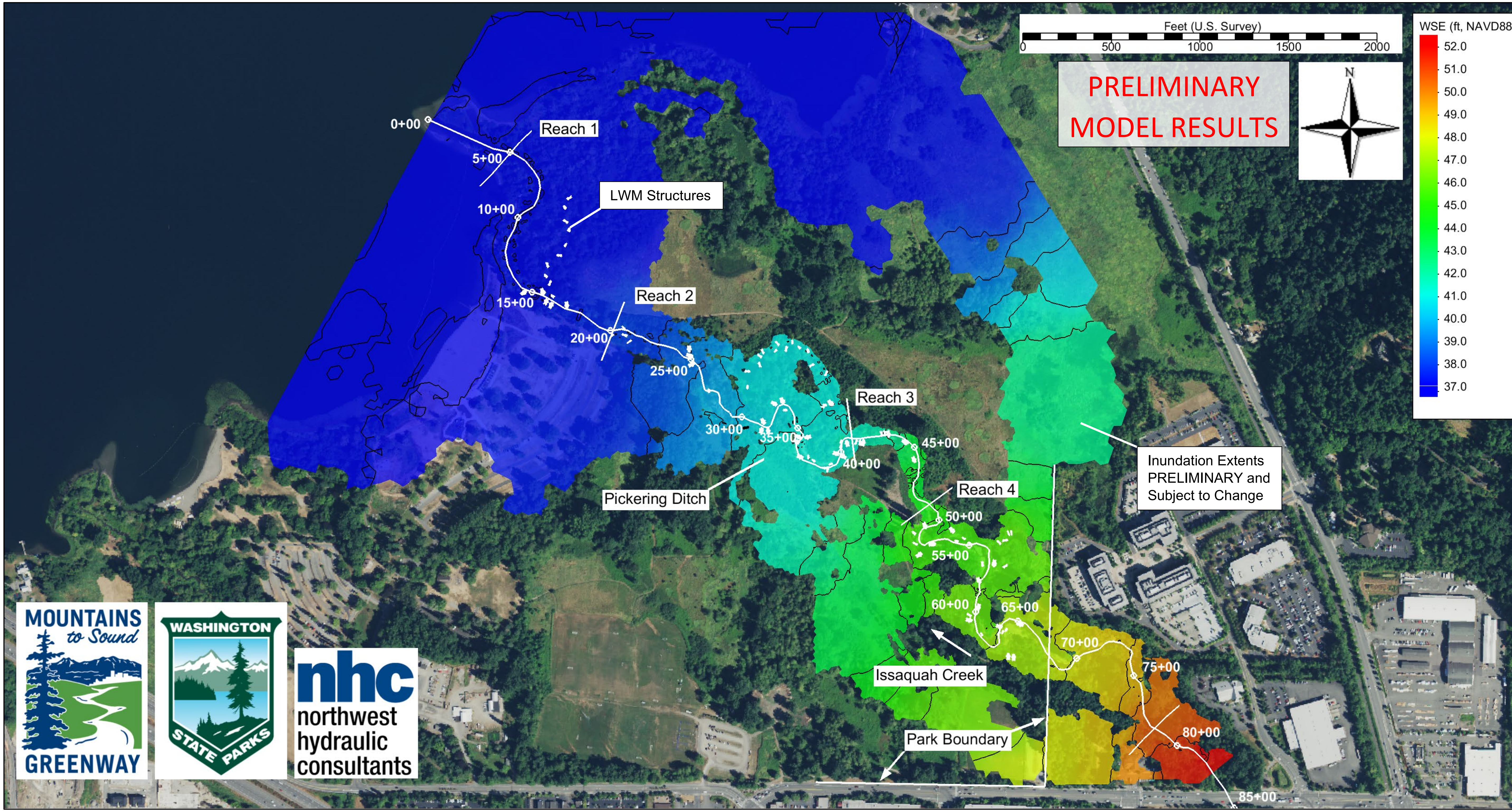

Figure H.12 Lower Issaquah Creek Proposed Conditions 100-Year Water Surface Elevation (WSE)

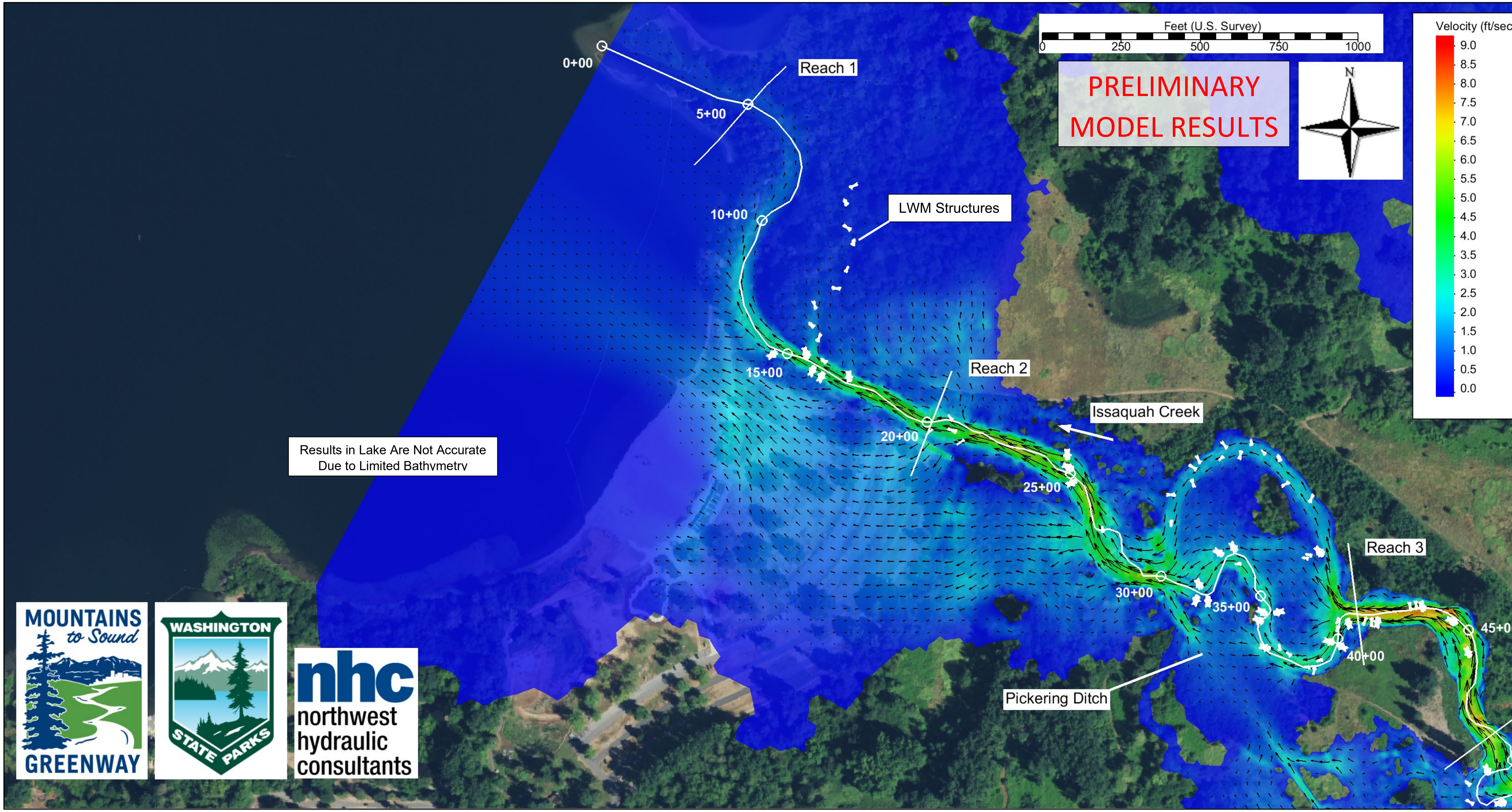

Figure H.13 Lower Issaquah Creek Proposed Conditions 100-Year Velocity (Reaches 1 and 2)

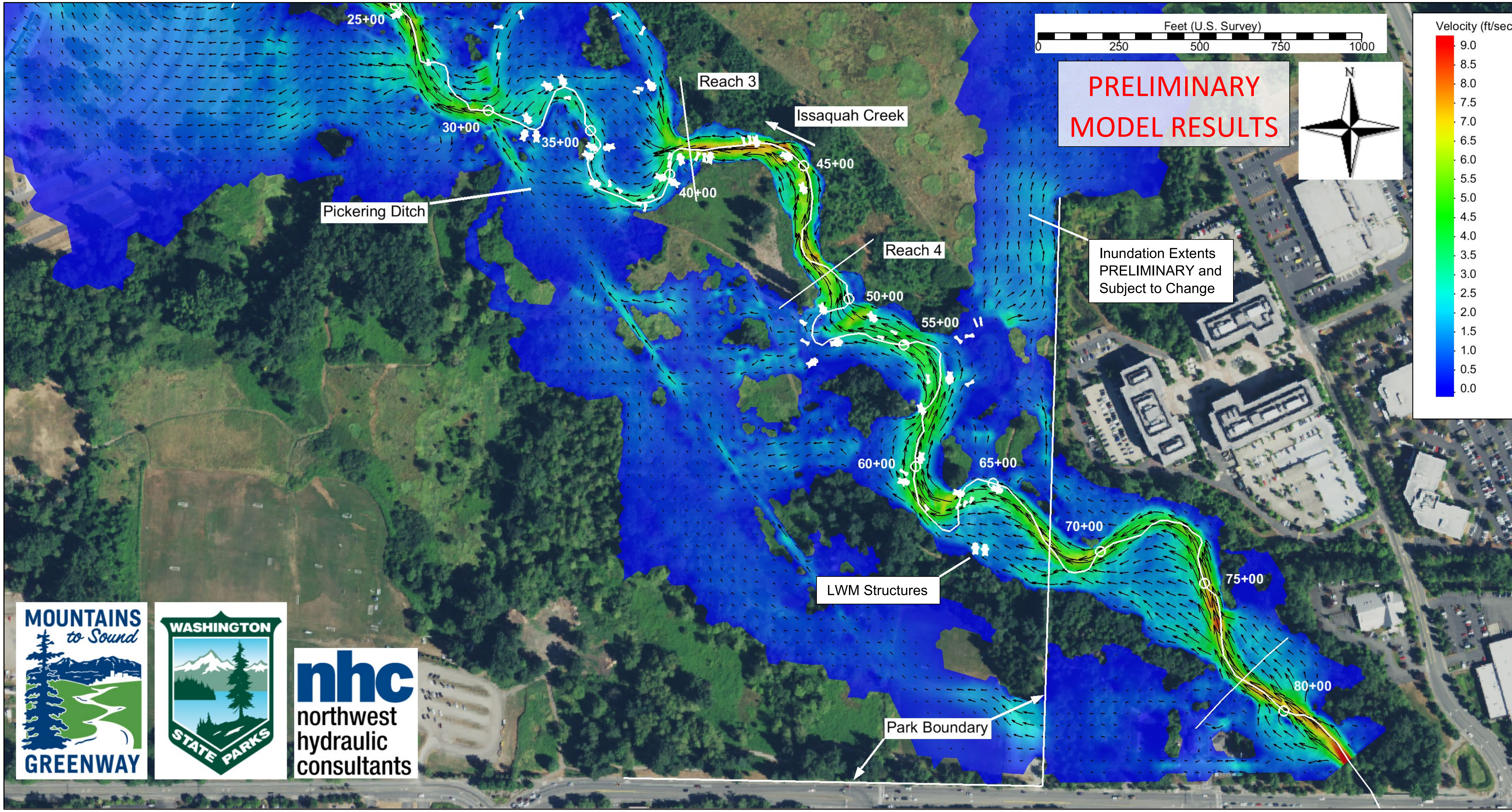

Figure H.14 Lower Issaquah Creek Proposed Conditions 100-Year Velocity (Reaches 3 and 4)

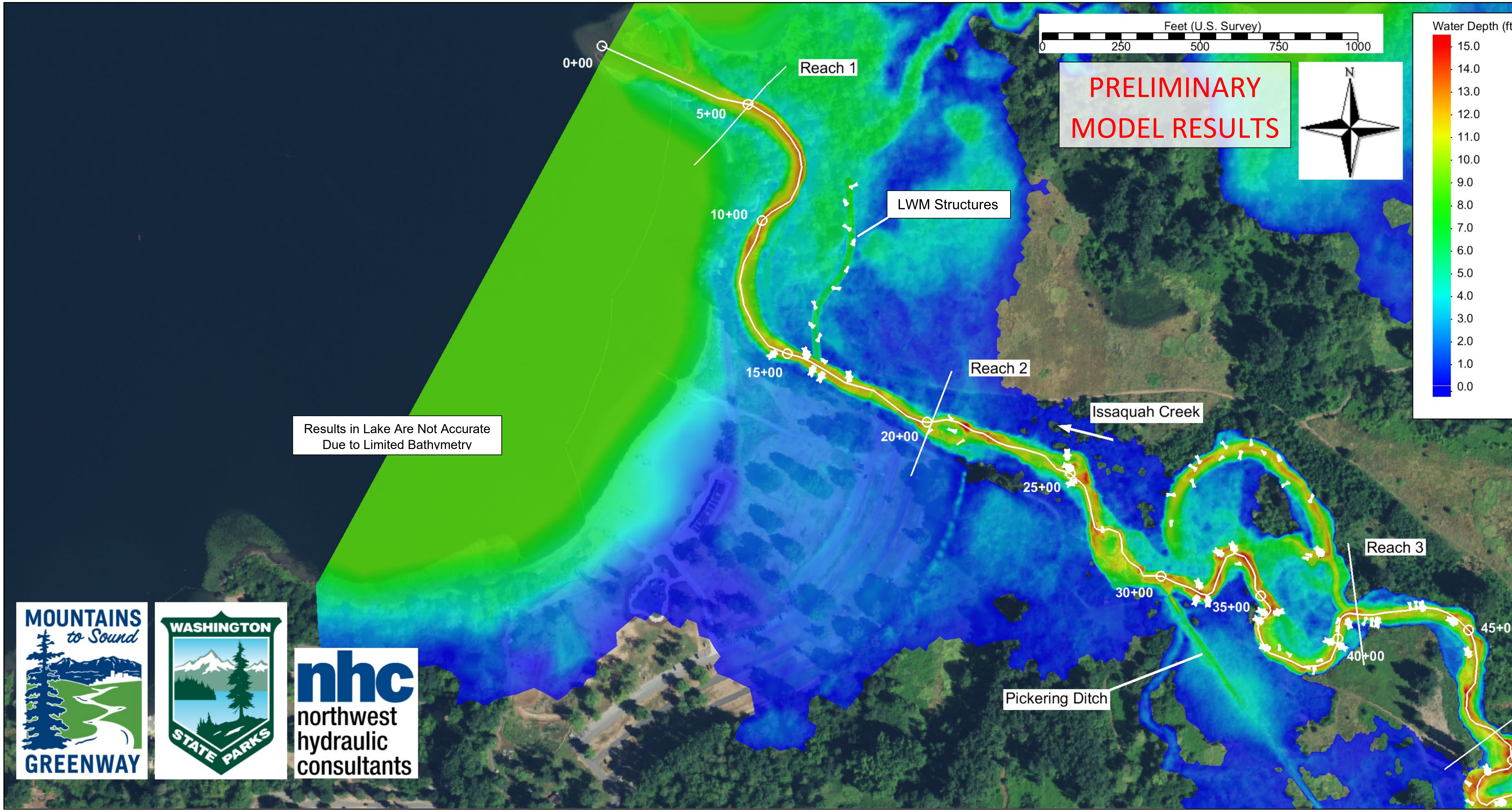

Figure H.15 Lower Issaquah Creek Proposed Conditions 100-Year Water Depth (Reaches 1 and 2)

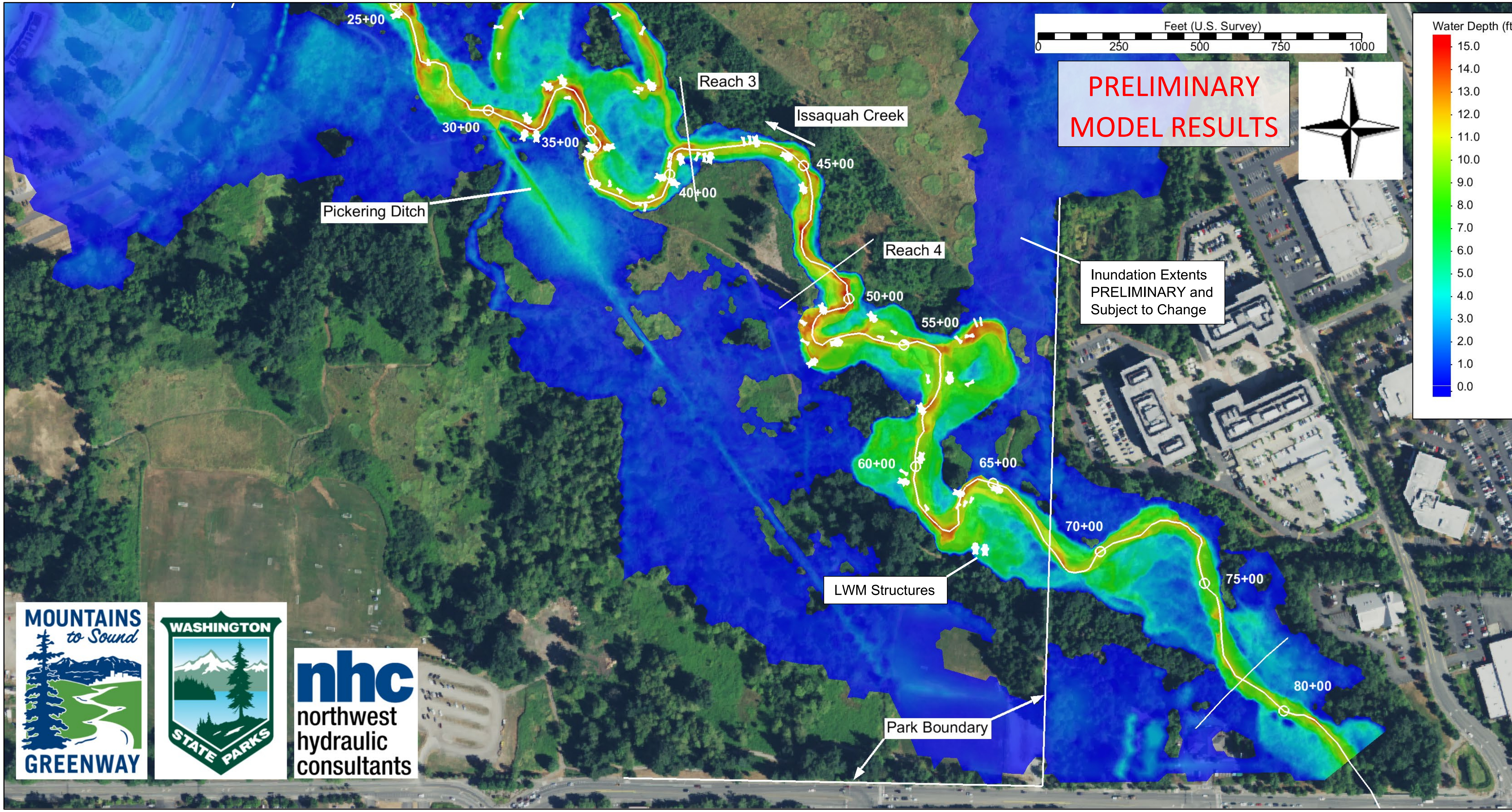

Figure H.16 Lower Issaquah Creek Proposed Conditions 100-Year Water Depth (Reaches 3 and 4)

APPENDIX I: FLOODPLAIN AND FLOODWAY ANAYLSIS

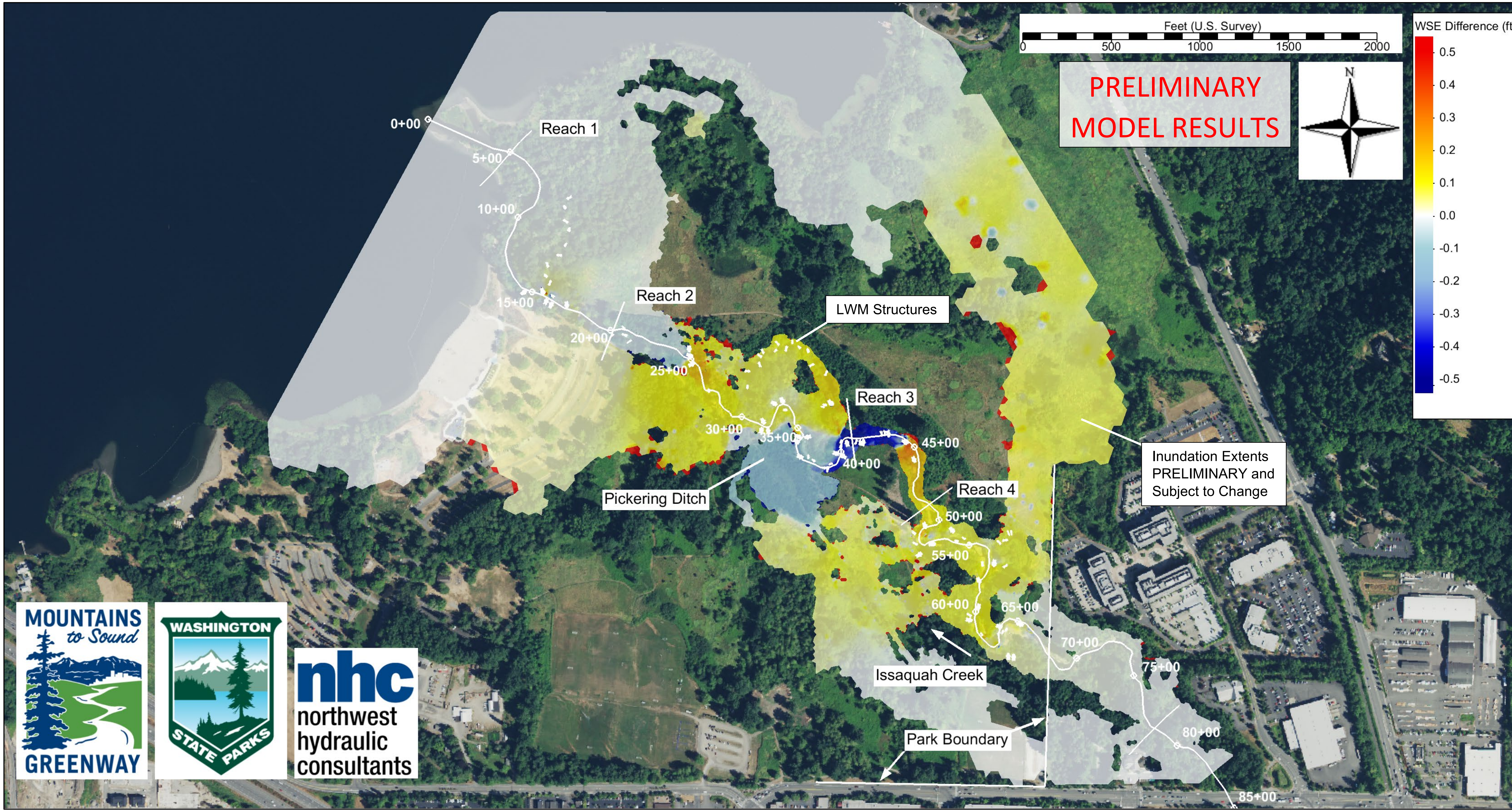

Figure I.1 Lower Issaquah Creek Change in Water Surface Due to the Preferred Alternative (Warm Colors = Increase in WSE, Cool Colors = Decrease in WSE Compared to Existing Conditions)

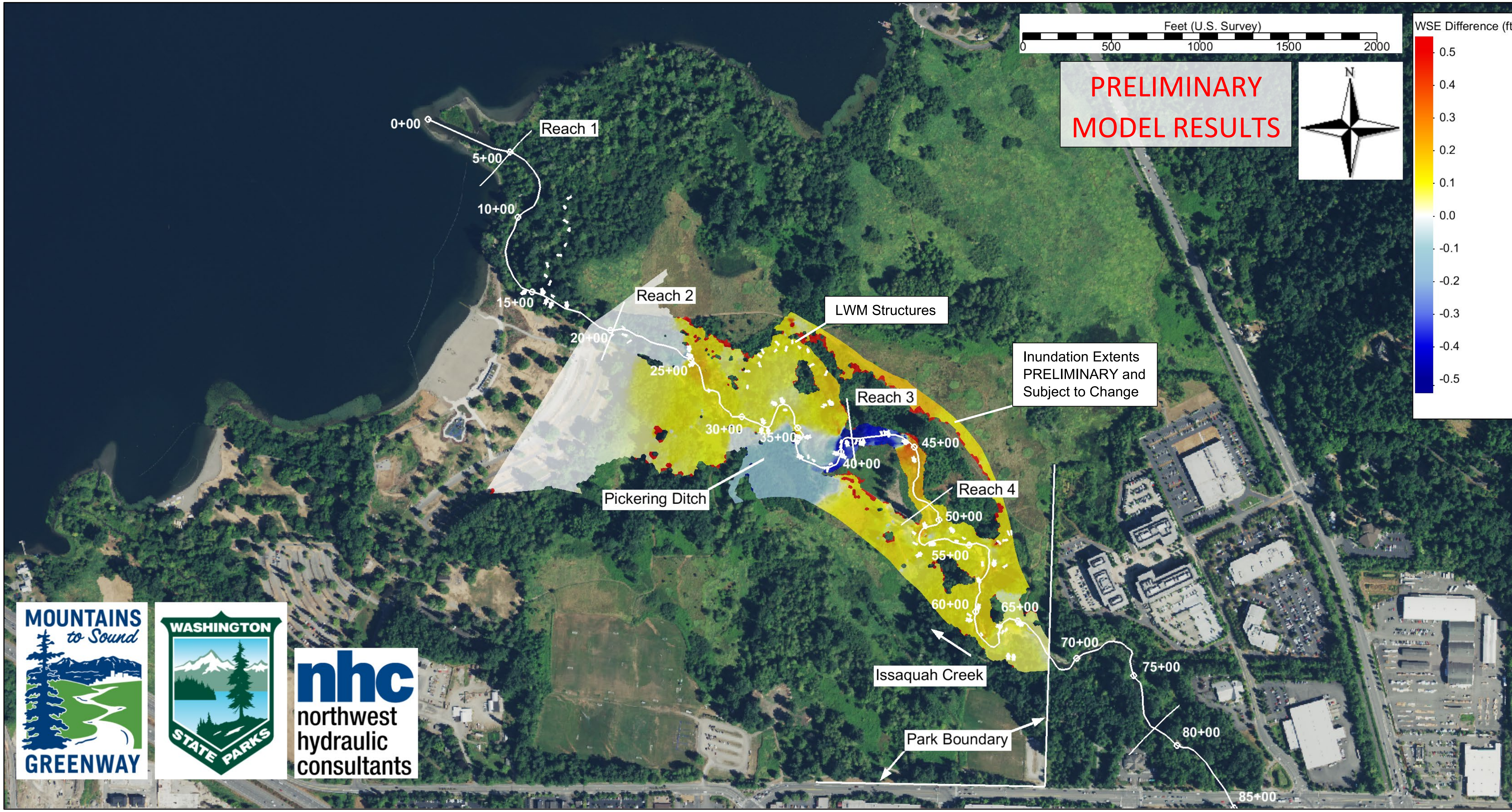

Figure I.2 Lower Issaquah Creek Floodway Change in Water Surface Due to the Preferred Alternative (Warm Colors = Increase in WSE, Cool Colors = Decrease in WSE Compared to Existing Conditions)

APPENDIX J: PRELIMINARY COST ESTIMATE

PROJECT COST ESTIMATE

Bid Item			Selected Alternative	
Name	Unit	Unit Cost	Quantity	Cost
Excavated Features				
Channel Excavation Incl. Haul	CY	$50	3,500	$ 175,000
Streambed Material	TON	$45	1,650	$ 74,300
LWM				
Helicopter Mobilization - Small Twin Rotor	LS	$30,000	1	$ 30,000
Helicopter Mobilization - Large Helicopter	LS	$55,000	1	$ 55,000
Helicopter Supplies/Fuel/Etc...	LS	$20,000	1	$ 20,000
Individual Logs	EACH	$3,000	57	$ 171,000
Log Jacks	EACH	$7,000	24	$ 168,000
Small Spur Jam	EACH	$8,000	6	$ 48,000
Large Spur Jam	EACH	$25,000	31	$ 775,000
Apex Jams	EACH	$40,000	6	$ 240,000
Riparian Restoration				
Staffing	LS	$240,000	1.0	$ 240,000
Project Supplies	LS	$75,000	1.0	$ 75,000
Commerical Services & Crew Time	LS	$90,000	1.0	$ 90,000
Transportation	LS	$5,000	1.0	$ 5,000
Office Expenses/Overhead	LS	$60,000	1.0	$ 60,000
Signs	EACH	$5,000	6.0	$ 30,000
		Items Subtotal		**$ 2,256,300**
Erosion Control and Construction				
Clearing and Grubbing	LS	$75,000	1	$ 75,000
Construction Entrance/Staging Area	EACH	$5,000	2	$ 10,000
Access Road	EACH	$15,000	11	$ 165,000
Turbidity Monitoring	DAY	$250	90	$ 22,500
Cultural Resources	LS	$25,000	1	$ 25,000
Temporary Stream Diversion	LS	$40,000	5	$ 200,000
Water Control	EACH	$5,000	13	$ 65,000
Spill Pevention, Control & Countermeasures (SPCC) Plan	LS	$4,000	1	$ 4,000
ESC Lead	DAY	$300	90	$ 27,000
		Items Subtotal		**$ 593,500**
Mobilization	LS	10%	1	$ 285,000
Construction Engineering Support	LS	10%	1	$ 285,000
		Subtotal		**$ 3,419,800**
Taxes	LS	10%	1	$ 342,000
		Total		***$ 3,762,000***

REACH 1 COST ESTIMATE

Bid Item			Selected Alternative	
Name	Unit	Unit Cost	Quantity	Cost
Distributary Channel				
Channel Excavation Incl. Haul	CY	$50	1,815	$ 90,800
Streambed Material	TON	$45	1,210	$ 54,500
LWM				
Helicopter Mobilization - Small Twin Rotor	LS	$30,000	1	$ 30,000
Helicopter Mobilization - Large Helicopter	LS	$55,000	1	$ 55,000
Helicopter Supplies/Fuel/Etc...	LS	$20,000	1	$ 20,000
Individual Logs	EACH	$3,000	10	$ 30,000
Log Jacks	EACH	$7,000	1	$ 7,000
Small Spur Jam	EACH	$8,000	4	$ 32,000
Large Spur Jam	EACH	$23,000	4	$ 92,000
Apex Jams	EACH	$38,000	1	$ 38,000
Riparian Restoration				
Staffing	LS	$240,000		$ -
Project Supplies	LS	$75,000		$ -
Commerical Services & Crew Time	LS	$90,000		$ -
Transportation	LS	$5,000		$ -
Office Expenses/Overhead	LS	$60,000		$ -
Signs	EACH	$5,000		$ -
Items Subtotal				**$ 449,300**
Erosion Control and Construction				
Clearing and Grubbing	LS	$15,000	1	$ 15,000
Construction Entrance/Staging Area	EACH	$5,000	1	$ 5,000
Access Road	EACH	$15,000	3	$ 45,000
Turbidity Monitoring	DAY	$250	30	$ 7,500
Cultural Resources	LS	$25,000	1	$ 25,000
Temporary Stream Diversion	LS	$40,000	1	$ 40,000
Water Control	EACH	$5,000	4	$ 20,000
Spill Pevention, Control & Countermeasures (SPCC) Plan	LS	$4,000	1	$ 4,000
ESC Lead	DAY	$300	30	$ 9,000
Items Subtotal				**$ 170,500**
Mobilization	LS	10%	1	$ 62,000
Construction Engineering Support	LS	15%	1	$ 93,000
Subtotal				**$ 774,800**
Taxes	LS	10%	1	$ 77,500
Total				***$ 853,000***

REACH 2 COST ESTIMATE

Bid Item			Selected Alternative	
Name	Unit	Unit Cost	Quantity	Cost
Pilot Channel				
Channel Excavation Incl. Haul	CY	$50	880	$ 44,000
Streambed Material	TON	$45	410	$ 18,500
LWM				
Helicopter Mobilization - Small Twin Rotor	LS	$30,000	1	$ 30,000
Helicopter Mobilization - Large Helicopter	LS	$55,000	1	$ 55,000
Helicopter Supplies/Fuel/Etc...	LS	$20,000	1	$ 20,000
Individual Logs	EACH	$3,000	24	$ 72,000
Log Jacks	EACH	$7,000	16	$ 112,000
Small Spur Jam	EACH	$8,000	1	$ 8,000
Large Spur Jam	EACH	$23,000	14	$ 322,000
Apex Jams	EACH	$38,000	2	$ 76,000
Riparian Restoration				
Staffing	LS	$240,000		$ -
Project Supplies	LS	$75,000		$ -
Commerical Services & Crew Time	LS	$90,000		$ -
Transportation	LS	$5,000		$ -
Office Expenses/Overhead	LS	$60,000		$ -
Signs	EACH	$5,000		$ -
Items Subtotal				**$ 757,500**
Erosion Control and Construction				
Clearing and Grubbing	LS	$15,000	1	$ 15,000
Construction Entrance/Staging Area	EACH	$5,000	1	$ 5,000
Access Road	EACH	$15,000	3	$ 45,000
Turbidity Monitoring	DAY	$250	30	$ 7,500
Cultural Resources	LS	$25,000	1	$ 25,000
Temporary Stream Diversion	LS	$40,000	1	$ 40,000
Water Control	EACH	$5,000	4	$ 20,000
Spill Pevention, Control & Countermeasures (SPCC) Plan	LS	$4,000	1	$ 4,000
ESC Lead	DAY	$300	30	$ 9,000
Items Subtotal				**$ 170,500**
Mobilization	LS	10%	1	$ 92,800
Construction Engineering Support	LS	15%	1	$ 139,200
Subtotal				**$ 1,160,000**
Taxes	LS	10%	1	$ 116,000
Total				***$ 1,276,000***

REACH 3 COST ESTIMATE

Bid Item			Selected Alternative	
Name	Unit	Unit Cost	Quantity	Cost
Bank Scraping				
Channel Excavation Incl. Haul	CY	$50	500	$ 25,000
Streambed Material	TON	$45	0	$ -
LWM				
Helicopter Mobilization - Small Twin Rotor	LS	$30,000	1	$ 30,000
Helicopter Mobilization - Large Helicopter	LS	$55,000	1	$ 55,000
Helicopter Supplies/Fuel/Etc...	LS	$20,000	1	$ 20,000
Individual Logs	EACH	$3,000	8	$ 24,000
Log Jacks	EACH	$7,000	0	$ -
Small Spur Jam	EACH	$8,000	0	$ -
Large Spur Jam	EACH	$23,000	3	$ 69,000
Apex Jams	EACH	$38,000	1	$ 38,000
Riparian Restoration				
Staffing	LS	$240,000		$ -
Project Supplies	LS	$75,000		$ -
Commerical Services & Crew Time	LS	$90,000		$ -
Transportation	LS	$5,000		$ -
Office Expenses/Overhead	LS	$60,000		$ -
Signs	EACH	$5,000		$ -
		Items Subtotal		**$ 261,000**
Erosion Control and Construction				
Clearing and Grubbing	LS	$15,000	1	$ 15,000
Construction Entrance/Staging Area	EACH	$5,000	1	$ 5,000
Access Road	EACH	$15,000	2	$ 30,000
Turbidity Monitoring	DAY	$250	30	$ 7,500
Cultural Resources	LS	$25,000	1	$ 25,000
Temporary Stream Diversion	LS	$40,000	2	$ 80,000
Water Control	EACH	$5,000	3	$ 15,000
Spill Pevention, Control & Countermeasures (SPCC) Plan	LS	$4,000	1	$ 4,000
ESC Lead	DAY	$300	30	$ 9,000
		Items Subtotal		**$ 190,500**
Mobilization	LS	10%	1	$ 45,200
Construction Engineering Support	LS	15%	1	$ 67,800
		Subtotal		**$ 564,500**
Taxes	LS	10%	1	$ 56,500
		Total		***$ 621,000***

REACH 4 COST ESTIMATE

Bid Item			Selected Alternative	
Name	Unit	Unit Cost	Quantity	Cost
Pilot Channel				
Channel Excavation Incl. Haul	CY	$50	250	$ 12,500
Streambed Material	TON	$45	0	$ -
LWM				
Helicopter Mobilization - Small Twin Rotor	LS	$30,000	1	$ 30,000
Helicopter Mobilization - Large Helicopter	LS	$55,000	1	$ 55,000
Helicopter Supplies/Fuel/Etc...	LS	$20,000	1	$ 20,000
Individual Logs	EACH	$3,000	15	$ 45,000
Log Jacks	EACH	$7,000	7	$ 49,000
Small Spur Jam	EACH	$8,000	1	$ 8,000
Large Spur Jam	EACH	$23,000	10	$ 230,000
Apex Jams	EACH	$38,000	2	$ 76,000
Riparian Restoration				
Staffing	LS	$240,000		$ -
Project Supplies	LS	$75,000		$ -
Commerical Services & Crew Time	LS	$90,000		$ -
Transportation	LS	$5,000		$ -
Office Expenses/Overhead	LS	$60,000		$ -
Signs	EACH	$5,000		$ -
		Items Subtotal		**$ 525,500**
Erosion Control and Construction				
Clearing and Grubbing	LS	$15,000	1	$ 15,000
Construction Entrance/Staging Area	EACH	$5,000	1	$ 5,000
Access Road	EACH	$15,000	3	$ 45,000
Turbidity Monitoring	DAY	$250	30	$ 7,500
Cultural Resources	LS	$25,000	1	$ 25,000
Temporary Stream Diversion	LS	$40,000	1	$ 40,000
Water Control	EACH	$5,000	4	$ 20,000
Spill Pevention, Control & Countermeasures (SPCC) Plan	LS	$4,000	1	$ 4,000
ESC Lead	DAY	$300	30	$ 9,000
		Items Subtotal		**$ 170,500**
Mobilization	LS	10%	1	$ 69,600
Construction Engineering Support	LS	15%	1	$ 104,400
		Subtotal		**$ 870,000**
Taxes	LS	10%	1	$ 87,000
		Total		***$ 957,000***

APPENDIX K: LARGE WOODY MATERIAL INVENTORY

Lower Issaquah LWM Inventory - Pieces Needed

REACH 1

Structure Type	Total Structures	Total Logs	Key Pieces (3 ft diameter, 30 ft long, with rootwad)	Non-Key Pieces (3 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2.5 ft diameter, 25 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 20 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 10 ft long, without rootwad)	Non-Key Piece (1 ft diameter, 10 ft long, with rootwad)
Single Pieces	10	10	0	0	10	0	0	0	0
Log Jack	1	4	0	1	0	0	0	3	0
Small Spur Jam	4	16	0	0	0	4	8	0	4
Large Spur Jam	4	24	8	0	0	16	0	0	0
Apex Jam	1	12	2	0	0	10	0	0	0
TOTAL		66	10	1	10	30	8	3	4

REACH 2

Structure Type	Total Structures	Total Logs	Key Pieces (3 ft diameter, 30 ft long, with rootwad)	Non-Key Pieces (3 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2.5 ft diameter, 25 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 20 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 10 ft long, without rootwad)	Non-Key Piece (1 ft diameter, 10 ft long, with rootwad)
Single Pieces	24	24	0	0	24	0	0	0	0
Log Jack	16	64	0	16	0	0	0	48	0
Small Spur Jam	1	4	0	0	0	1	2	0	1
Large Spur Jam	14	84	28	0	0	56	0	0	0
Apex Jam	2	24	4	0	0	20	0	0	0
TOTAL		200	32	16	24	77	2	48	1

REACH 3

Structure Type	Total Structures	Total Logs	Key Pieces (3 ft diameter, 30 ft long, with rootwad)	Non-Key Pieces (3 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2.5 ft diameter, 25 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 20 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 10 ft long, without rootwad)	Non-Key Piece (1 ft diameter, 10 ft long, with rootwad)
Single Pieces	8	8	0	0	8	0	0	0	0
Log Jack	0	0	0	0	0	0	0	0	0
Small Spur Jam	0	0	0	0	0	0	0	0	0
Large Spur Jam	3	18	6	0	0	12	0	0	0
Apex Jam	1	12	2	0	0	10	0	0	0
TOTAL		38	8	0	8	22	0	0	0

REACH 4

Structure Type	Total Structures	Total Logs	Key Pieces (3 ft diameter, 30 ft long, with rootwad)	Non-Key Pieces (3 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2.5 ft diameter, 25 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 20 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 10 ft long, without rootwad)	Non-Key Piece (1 ft diameter, 10 ft long, with rootwad)
Single Pieces	15	15	0	0	15	0	0	0	0
Log Jack	7	28	0	7	0	0	0	21	0
Small Spur Jam	1	4	0	0	0	1	2	0	1
Large Spur Jam	10	60	20	0	0	40	0	0	0
Apex Jam	2	24	4	0	0	20	0	0	0
TOTAL		131	24	7	15	61	2	21	1

PROJECT TOTALS

NUMBER OF PIECES PER WOOD TYPE:	**74**	**24**	**57**	**190**	**12**	**72**	**6**

KEY PIECES TOTAL **74**

TOTAL LOGS **435**

Lower Issaquah LWM Inventory - Pieces Identified

Source	Logs Identified						
	Key Pieces (3 ft diameter, 30 ft long, with rootwad)	Key Pieces (3 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 25 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 20 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 15 ft long, with rootwad)	Non-Key Piece (2 ft diameter, 10 ft long, without rootwad)	Non-Key Piece (1 ft diameter, 10 ft long, with rootwad)
TOTAL REMAINING	74	24	57	190	12	72	6