SKANSKA

January 16, 2026

Letter No. 322
BY-CRE-04464

Washington State Department of Transportation
I-405/SR 167Program
18911 N Creek Pkwy S, Suite 150
Bothell, WA 98011

Attention: Evelyn Pao, P.E.
Project Director

Project: I-405/Brickyard to SR 527 – Improvement Project
Contract No.: 009727

Subject: Protest 003 – PCO 126 – Supplemental Information – Lateral Migration

Reference:

- WSDOT SL No. 9727-116, Interpretive Engineering Decision for Lateral Migration (June 13, 2025)
- WSDOT SL No. 9727-125, RE: Sammamish River Lateral Migration (July 9, 2025)
- WSDOT SL No. 9727-139, RE: Lateral Migration Workshop Follow-up (August 15, 2025)
- WSDOT SL No. 9727-178, RE: Skanska Serial Letter 214 (October 13, 2025)
- WSDOT SL No. 9727-220, Follow-up on Lateral Migration (December 17, 2025)
- WSDOT SL No. 9727-228, RE: Protest 003 (December 31, 2025)
- Skanska Letter No. 204, Response to WSDOT's Interpretive Engineering Decision (June 27, 2025)
- Skanska Letter No. 214, RE: Sammamish River Lateral Migration Workshop (July 17, 2025)
- Skanska Letter No. 215, RE: AECOM Response (July 23, 2025)
- Skanska Letter No. 309, Protest 003 – PCO 126 (December 30, 2025)
- RFP Chapter 1, General Provisions
- RFP Chapter 2, Section 2.30, Water Crossings
- RFP Appendix H26, Sammamish River Migration Risk Assessment
- WSDOT Hydraulics Manual M 23-03
- RFP Addendum 9 (Addition of Appendix H26)
- RFP Addendum 14 (Addition of Section 2.30.5.2.1 Language)
- AECOM Notice of Protest dated January 15, 2026

Dear Ms. Pao:

EXECUTIVE SUMMARY

Skanska submits this supplemental information under RFP Section 1-04.5 in support of Protest 003 (PCO 126), in accordance with WSDOT SL No. 9727-228 dated December 31, 2025, which set January 16, 2026 as the deadline for submission. This letter incorporates and is submitted in conjunction with AECOM's Notice of Protest dated January 15, 2026, which provides detailed technical analysis supporting the Design-Builder's position.

WSDOT’s interpretation in SL-116 requires the Design-Builder to apply a predetermined “not low” lateral migration assumption to the Sammamish River crossings, including use of Figure 7-6 methodology, regardless of the results of the Contract-required final design analysis. This approach effectively predetermines the outcome of the required evaluation and undermines the purpose of Appendix H26 and the Final Hydraulic Design process. The Contract must be interpreted as an integrated whole: Appendix H26 identifies lateral migration as a risk requiring further analysis during final design; Chapter 2 requires lateral migration to be evaluated as part of scour and structural design in accordance with the Mandatory Standards; and Chapter 1 establishes the interpretive decision and ambiguity resolution framework, including the Contract’s order-of-precedence.

Notably, Appendix H26 was added to the RFP as a reference document in Addendum 9 without corresponding contract language; the "shall apply" language in Section 2.30.5.2.1 was not added until Addendum 14. This sequencing confirms the ‘not low’ classification was introduced as a risk identification and later incorporated into Section 2.30.5.2.1, however, it must still be harmonized with the Contract’s final design and analysis requirements.

The Design-Builder's Level 1, Level 2, and Level 3 assessments and BSTEM modeling demonstrate constrained migration, supporting the uniform-offset application recognized by the Hydraulics Manual. Imposing a fixed "not low" assumption would require redesign and potential reconstruction across multiple structures (per SL-220) and a CLOMR path with 12-18 months of review and multi-agency approvals (per SL-178), constituting a change under Section 1-04. Skanska requests WSDOT confirm acceptance of the FHD as contract compliant and consistent with Contract requirements—or, alternatively, processing PCO 126 for equitable adjustment.

I. TIMELINE OF EVENTS

Date	Event
Addendum 9 (Jan 19, 2023)	WSDOT adds Appendix H26 (Sammamish River Migration Risk Assessment) to the RFP as a reference document. No corresponding contract language is added requiring application of the "not low" determination.
Addendum 14 (Mar 2, 2023)	WSDOT adds language to Section 2.30.5.2.1 stating the "not low" lateral migration determination "shall apply" to new structures within 500-year flood limits.
July 12, 2024	Draft Final Hydraulic Design Report (FHD) for the Sammamish River Bridge crossing submitted by the Design-Build team to WSDOT.
August 6, 2024	Design-Build team receives 5 comments from WSDOT indicating to revise and resubmit. Comments #3 and #4 from Luke Assink (WSDOT) are relevant to this protest.
Sept 10, 2024	Design-Build team presents geotechnical data and lateral migration analysis to Fish Passage Task Force as requested by WSDOT.
Sept 30, 2024	Luke Assink (WSDOT) responds via email stating WSDOT considers lateral migration risk low only when geotechnical exploration shows non-erodible materials.
Oct 25, 2024	AECOM sends over-the-shoulder copy of revised FHD to WSDOT, updated based on WSDOT comments.
Nov 26, 2024	Meeting held to discuss lateral migration. AECOM and WSDOT independently concluded little to no movement since 1964.
Dec 23, 2024	AECOM sends revised FHD including Level 1, Level 2, and Level 3 analyses with BSTEM modeling.

Jan 13, 2025	WSDOT rejected the FHD submittal, stating comments weren't resolved.
Jan 21, 2025	Additional comments received from WSDOT (HQH consultants: Gabe Ng, Alan Black, Darrel Sofield) on the December 2024 over-the-shoulder copy.
Feb 4, 2025	AECOM sent WSDOT the revised SRH-2D model via ProCore, correcting the downstream boundary condition noted in WSDOT's January 10, 2025 comments.
Feb 10, 2025	Meeting discussing lateral migration held with WSDOT and Design-Build team leadership. WSDOT requested: (1) geotechnical validation of soil erosivity parameters, (2) explanation of historical delineations methodology, (3) revised BSTEM section views to scale, (4) investigation of previous King County bank repair project, and (5) pier scour analysis assuming channel migration to pier locations per HEC-18.
Mar 4, 2025	AECOM submits revised FHD with updated analyses. Conclusions remain consistent: no significant lateral migration anticipated.
June 13, 2025	WSDOT issues SL No. 9727-116 (IED): Asserts "not low shall apply" and directs Figure 7-6 application.
June 27, 2025	Skanska issues Letter No. 204: Seeks clarity, cites Appendix H's "further analysis during final design."
July 9, 2025	WSDOT issues SL No. 9727-125: States "not low is not open to interpretation."
July 17, 2025	Skanska issues Letter No. 214: Proposes workshop to discuss the matter.
July 23, 2025	Skanska issues Letter No. 215: Transmits AECOM's request for definition of "not low."
Aug 7, 2025	Meeting with WSDOT leadership. WSDOT stated they did not have calculations for lateral migration limits. WSDOT stated their position was the lateral migration horizontal boundary was the 500-year boundary.
Aug 15, 2025	WSDOT issues SL No. 9727-139 withholding final determination pending cooperative efforts.
Oct 13, 2025	WSDOT issues SL No. 9727-178: Advises 12-18 months FEMA review for CLOMR approach.
Dec 17, 2025	WSDOT issues SL No. 9727-220: States current design does not meet contract requirements.
Dec 30, 2025	Skanska issues Letter No. 309: Formal Notice of Protest; requests 75 calendar days.
Dec 31, 2025	WSDOT issues SL No. 9727-228: Denies extension; sets January 16, 2026 deadline.

II. CONTRACT REQUIREMENTS AND INTERPRETATION

A. The Relevant Contract Language

RFP Section 2.30.5.2.1, Certain Structure and Channel Design Characteristics, states in relevant part:

> *"The Sammamish River 'not low' lateral migration determination discussed in the Sammamish River Migration Risk Assessment (Appendix H) shall apply to the new structures within the river flow limits defined by the 500-year flood elevation."*

Appendix H26, Sammamish River Migration Risk Assessment, states in its conclusion:

> *"The risk of channel migration within the vicinity of I-405 MP 24.4 is NOT LOW and therefore will require further analysis during final design as part of the Hydraulic Design Report for this water crossing."*

Appendix H26 also states:

> *"If a channel is expected to migrate, further analysis will be the responsibility of the Design-Builder during final design."*

RFP Section 2.30.5.6, Scour Analysis, requires:

> *"The Design-Builder shall perform a scour analysis that includes all habitat and stream restoration components in accordance with the Mandatory Standards and this Section. The analysis shall include the risk of Lateral Migration (Structural), potential for long-term degradation, and evaluation of Total Scour."*

B. Contract Development History and Harmonization

The development history of the Contract language is critical to proper interpretation. Appendix H26 was added to the RFP in Addendum 9 as a reference document only - no corresponding contract language was added at that time requiring application of the "not low" determination. It was not until Addendum 14 that WSDOT added the language in Section 2.30.5.2.1 stating the determination "shall apply." This sequencing demonstrates that WSDOT did not initially intend Appendix H26 to establish a fixed design requirement.

Additionally, the contract-incorporated version of the Hydraulics Manual (Appendix D08 of the Contract, dated March 1, 2022) does not include a section on lateral migration or methodology. WSDOT subsequently issued an updated Hydraulics Manual in April 2023 that added Section 7-2.5.3 Lateral Migration, which provides that lateral migration risks "shall be considered 'not low' for all water crossings unless a detailed lateral migration risk assessment process is conducted." Consistent with that framework, the Design-Builder performed the detailed lateral migration risk assessment process and documented the results in the Final Hydraulic Design.

While RFP Section 2.30.5.2.1 states the Appendix H "not low" determination "shall apply" within the 500-year flood limits, that clause must be read together with:

1. Chapter 1 provisions on Interpretive Engineering Decisions and ambiguity resolution, which establish the framework for resolving differing interpretations of Contract requirements;

2. Chapter 1 order-of-precedence rules, which clarify that Reference Documents (such as Appendix H) are informational unless explicitly made mandatory;

3. The Contract's technical framework requiring a scour analysis including lateral migration using mandatory standards (HEC-18, HEC-20, WSDOT Hydraulics Manual).

The Contract establishes a process: apply the preliminary "not low" determination as a trigger, perform the required analysis during final design, then design for the expected migration as documented in the FHD.

C. WSDOT's Interpretation Is Incorrect

WSDOT's position - that "not low" is an immutable contractual requirement that cannot be refined through engineering analysis - is inconsistent with:

1. The Express Language of Appendix H26: Appendix H26 explicitly states that the "not low" determination "will require further analysis during final design." If WSDOT intended this to be a fixed design parameter requiring no analysis, there would be no purpose for the "further analysis" language.

2. The Purpose of the FHD: Section 2.30.5.6 requires the Design-Builder to perform a scour analysis including lateral migration risk. WSDOT's interpretation renders this analysis meaningless by predetermining the outcome.

3. The Hydraulics Manual Framework: The Manual contemplates site-specific determination of whether migration is expected - not a blanket assumption.

4. Despite repeated requests, WSDOT has not identified objective technical criteria or acceptance thresholds that demonstrate why the Design-Builder’s completed final design analysis is insufficient or must be replaced with a predetermined assumption.

5. The Addendum Sequencing: Appendix H26 was added in Addendum 9 without contract language. The "shall apply" language was added five addenda later in Addendum 14, supporting interpretation as triggering analysis rather than establishing an immutable parameter.

III. THE DESIGN-BUILDER'S ANALYSIS DEMONSTRATES CONSTRAINED LATERAL MIGRATION

A. Analysis Performed

In accordance with Appendix H26's directive for "further analysis during final design" and Section 2.30.5.6's scour analysis requirements, the Design-Builder performed a comprehensive lateral migration analysis following the procedures in HEC-20 and the WSDOT Hydraulics Manual. The analysis included:

- Level 1 Analysis: Qualitative geomorphic assessment indicating low lateral migration potential
- Level 2 Analysis: Quantitative analysis confirming low lateral migration risk at the project reach
- Level 3 Analysis: Detailed analysis showing little-to-no movement of the river channel since the 1964 USACE flood improvement project
- BSTEM Modeling: Bank Stability and Toe Erosion Model analysis per WSDOT Hydraulics Manual Section 7-2.5.3.3.2
- FHWA Rapid Assessment Method: Channel migration potential assessment per HEC-20 Tables 5.5-5.8

B. Engineering Conclusions

The Lateral Migration Assessment concludes: "Findings indicate that the risk of lateral migration near the I-405/SR 522 interchange is low."

The key findings supporting this conclusion are:

- The Sammamish River was straightened, deepened, and armored in the mid-1960s by the USACE
- The Sammamish River can be considered an engineered channel that receives regular maintenance
- The Sammamish River is a low-gradient stream, dropping approximately 14 feet over approximately 14 miles
- Floods are infrequent and well contained by the channel
- Little to no movement of the river channel has occurred since 1964

C. Channel Migration Processes Investigated

The processes by which channel migration can occur have been investigated: (1) meander bend migration, (2) avulsion, and (3) channel widening caused by bank retreat. AECOM's lateral migration assessment indicates none of these channel migration processes are occurring:

- No channel migration is observed from historical topo/aerial imagery
- Avulsion is unlikely because Sammamish River flows are well confined to the straightened channel

- Negligible bank toe erosion is predicted by BSTEM analysis - up to 1.6 feet of toe erosion, but stream banks remain stable
- Existing banks tend to stand at or less than the angle of repose, indicating equilibrium

D. Total Scour Analysis Results

Table 4 from the Scour Analysis memo presents the following:

Scour Component	Scour Design Flood	Scour Check Flood
Long-term degradation	2.4 feet	2.4 feet
Contraction scour	0.0 feet	0.0 feet
Local pier scour	0.0 feet	0.0 feet
Total scour	2.4 feet	2.4 feet

The analysis found that no contraction scour is anticipated at the Sammamish River bridge crossing for any flow event, and local hydraulics generate no pier scour.

IV. SCOPE OF WSDOT'S DIRECTED REQUIREMENTS

In SL No. 9727-220, WSDOT states that the current design does not meet the contract requirements and must be updated to include "not low" lateral migration conditions for:

1. **NB I-405 to EB SR 522 Ramp Bridge – Already constructed**
2. **NB I-405 Mainline Bridge – Currently in construction**
3. **Direct Access Ramp (DAR) Bridge – Currently in design**

This direction materially expands the design obligations across multiple structures at various stages of completion, with significant cost and schedule implications.

V. WSDOT'S POSITION CONSTITUTES A CHANGE

If WSDOT's interpretation is imposed as a Contract requirement, it would necessitate:

- Redesign of structures already constructed or in construction
- Potential reconstruction of completed work
- A Conditional Letter of Map Revision (CLOMR) application to FEMA.
  - The project was not permitted for inclusion of countermeasures and would constitute a basic configuration
- 12-18 months of FEMA review (as WSDOT advised in SL-178)
- Multiple regulatory agency approvals including King County, USACE, USCG, USFWS, and NMFS

The need for any measures is not supported by the Design-Builder from an engineering perspective and including any would be a direct consequence of WSDOT’s directed interpretation of the contract and the mitigation approach inherent to designing for full lateral migration under Figure 7-6, not supported by any engineering approach or discretionary means-and-methods decision by the Design-Builder.

These requirements exceed the scope of work reasonably anticipated under the Contract and constitute a change pursuant to RFP Section 1-04.

A. Schedule Impact

Proceeding via the CLOMR pathway introduces 12-18 months of FEMA review and multiple regulatory approvals as WSDOT advised in SL-178. This constitutes a schedule impact under Section 1-04 and Section 1-08.8.

Additionally, the unresolved lateral migration issue is currently preventing the Final Hydraulic Design report from being issued Released for Construction (RFC), which in turn is delaying the Direct Access Ramp (DAR) bridge design package from being issued RFC due to an open comment. The DAR construction work is scheduled to begin in April 2026. If this issue is not resolved promptly, there could be schedule impacts to that work, as procurement for the April start is currently occurring at risk.

B. Cost Impact

Skanska has developed preliminary cost estimates for two potential remediation scenarios:

Option 1 – Full Countermeasures (Vertical Sheet Pile to Total Scour Depth):

Item	Estimated Cost
Buy PZC39S x 50' Sheets (352 EA)	$1,996,133
Drive Sheet Pile (Low Overhead) (176 PAIR)	$2,552,000
Mobilization for Sheet Pile	$150,000
Access for Sheet Pile	$544,000
Design Sheet Pile Wall	$422,400
Update FHD	$475,200
Contingency (6%)	$368,384
Markup (20%)	$1,301,623
Scenario 1 Total	**$7,809,741**

Option 2 – Rock/Log Vanes (Erosion Diversion) to support bank stability:

Item	Estimated Cost
Set Foundation Boulder (40 EA)	$40,000
Install 12-18' Logs (80 EA)	$60,000
Lock In Logs in Bank with GeoWrap (1280 SF)	$76,800
Design Rock Vanes (422.4 HR)	$126,720
Update FHD (352 HR)	$105,600
Markup	$40,912
Scenario 2 Total	**$450,032**

These estimates are preliminary and subject to refinement. They do not include CLOMR application costs, extended general conditions, regulatory permitting fees, or potential reconstruction of completed work.

VI. RELIEF REQUESTED

Skanska respectfully requests that WSDOT select a resolution path as outlined below:

1. Withdraw the Interpretive Engineering Decision documented in SL No. 9727-116 and accept the Design-Builder's Scour Analysis and Lateral Migration Assessment as contract compliant.

2. Provide the contract definition of "not low" and the specific technical criteria that requires the application of Figure 7-6 total scour methodology, providing clear directions on how to proceed. The previous Interpretive Engineering Decision was not descriptive on how the Design-Builder would proceed but instead an ambiguous contract interpretation with no engineering guidelines or supportive facts to implement. The Design-Builder requests that, if WSDOT intends to pursue a bank revetment project, WSDOT formally direct the Design-Builder to provide such work.

3. WSDOT position is maintained however acknowledgement that WSDOT's interpretation constitutes a change to the Contract under Section 1-04 and process PCO 126 as a Change Order with contract language modifications and appropriate equitable adjustment.

4. Agree to proceed with the Disputes Review Board (DRB) process pursuant to Section 1-04.5(1).1 if the parties are unable to resolve this dispute through direct negotiation.

VII. RESERVATION OF RIGHTS

This submission is without prejudice to, and with full reservation of, Skanska's rights, remedies, causes of action, and defenses under the Contract, at law, in equity, or otherwise. Nothing in this letter shall be interpreted as a modification or waiver, or an estoppel of Skanska's right to assert the same.

Skanska reserves the right to supplement this protest with additional information, including detailed cost and schedule impacts, as such information becomes available or as WSDOT provides additional direction regarding acceptable design parameters.

Regards,

Patrick Prendergast, Vice President

Skanska USA Civil
18911 N Creek Parkway S
Suite 300
Bothell, WA 98011

Attachments:
Exhibit A: AECOM Notice of Protest dated January 15, 2026 – RE: Sammamish River Lateral Migration (includes WSDOT RCSR Comments #3, #4 and AECOM Responses)
Exhibit B: AECOM Sammamish River Bridge Crossing – Scour Analysis (July 8, 2024), including Appendix A: Lateral Migration Assessment

AECOM Technical Services, Inc.
1111 Third Ave., Suite 1600
Seattle, WA 98101, USA
aecom.com

1/15/2026

Via E-mail
Patrick Prendergast
Contractor's Representative
Skanska USA Civil West California District Inc.
18911 N Creek Pkwy, Suite 300
Bothell, WA 98011
Patrick.Prendergast@skanska.com

Project: I-405, Brickyard to SR 527 Improvement Project
Contract No: 009727
RE: Notice of Protest: Sammamish River Lateral Migration

I am writing on behalf of AECOM in response to WSDOT's Serial Letter No. 9727-220, dated December 17, 2025 and SL No. 9727-228, dated December 31, 2025. In accordance with the protest procedures outlined in Section 1-04.5 of the RFP: Procedure, Protest, and Dispute by the Design-Builder, AECOM hereby disputes WSDOT's statement that after review of Skanska Serial Letter 214, RE: Sammamish River Lateral Migration & Channel Migration Risk Mitigation Workshop, dated October 13, 2025, they believe "a contract compliant solution has not been presented, and the current design does not meet the contract requirements." As required per the agreement between Skanska USA Civil West California District Inc. ("Skanska") and AECOM Technical Services, Inc. ("AECOM"), dated October 25, 2022 (the "Design Subcontract"), please forward this to WSDOT as soon as possible, but no later than the deadline provided by WSDOT of January 16, 2026.

As a supplement to AECOM's Notice of Protest, dated December 30, 2025, entitled, "Response to WSDOT SL No. 9727-220, WSDOT SL No. 9727-178: RE: Skanska Serial Letter 214, RE: Sammamish River Lateral Migration & Channel Migration Risk Mitigation Workshop – Follow-up and Notice of Protest per RFP Section 1-04.5," AECOM provides additional information as requested by WSDOT, as follows:

a. The date and nature of the protested order, direction, instruction, interpretation, determination:

Date of Protested Order: December 17, 2025
Nature of Protested Order: The Design-Build team is protesting WSDOT's assertion in letter SL No. 9727-220 that after review of Skanska Serial Letter 214, RE: Sammamish River Lateral Migration & Channel Migration Risk Mitigation Workshop, WSDOT believes "a contract compliant solution has not been presented, and the current design does not meet the contract requirements."

b. A full discussion of the circumstances which caused the protest, including names of Persons involved, time, duration and nature of the Work involved, and a review of the Contract Documents/Design Documents referenced to support the protest.

The project technical requirements state, "[t]he Sammamish River 'not-low' lateral migration determination discussed in the Sammamish River Migration Risk Assessment (Appendix H) shall apply to the new structures within the river flow limits defined by the 500-year flood elevation." (2.30-13). The referenced determination in Appendix H26 of the TR states "[t]he risk of channel migration within the vicinity of the I-405 MP is NOT LOW and therefore will require further analysis during final design as part of the Hydraulic Design Report for this water crossing". Appendix H26 also states, "[i]f a channel is expected to migrate, further analysis will be the responsibility of the Design-Builder during final design".

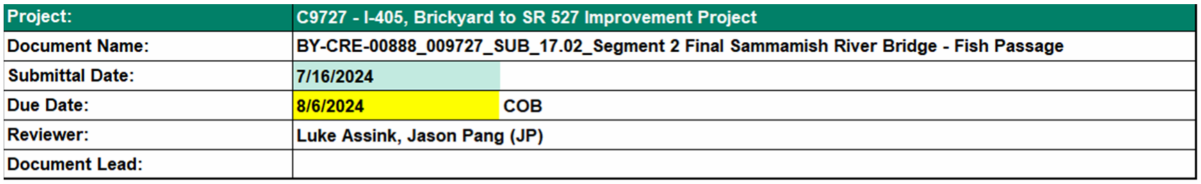
The Design-Build (DB) team has performed the contract-required “further analysis” using site-specific data, existing and historic river conditions, and methodology consistent with WSDOT and FHWA guidance. This analysis clearly demonstrates that no significant lateral migration is anticipated, and the calculated scour in the Final Hydraulic Design (FHD) was considered in the bridge design. This determination is supported by an assessment of multiple river stability indicators including: hydrologic, hydraulic, geotechnical, and vegetative characteristics, an assessment of the channel’s historic alignment, and fluvial entrainment, and bank stability calculations.

The design team’s approach is consistent with engineering best practices by relying on final design analyses and conclusions, and meets the DB team’s contractual responsibility to conduct further analyses and deliver a final design based on these analyses.

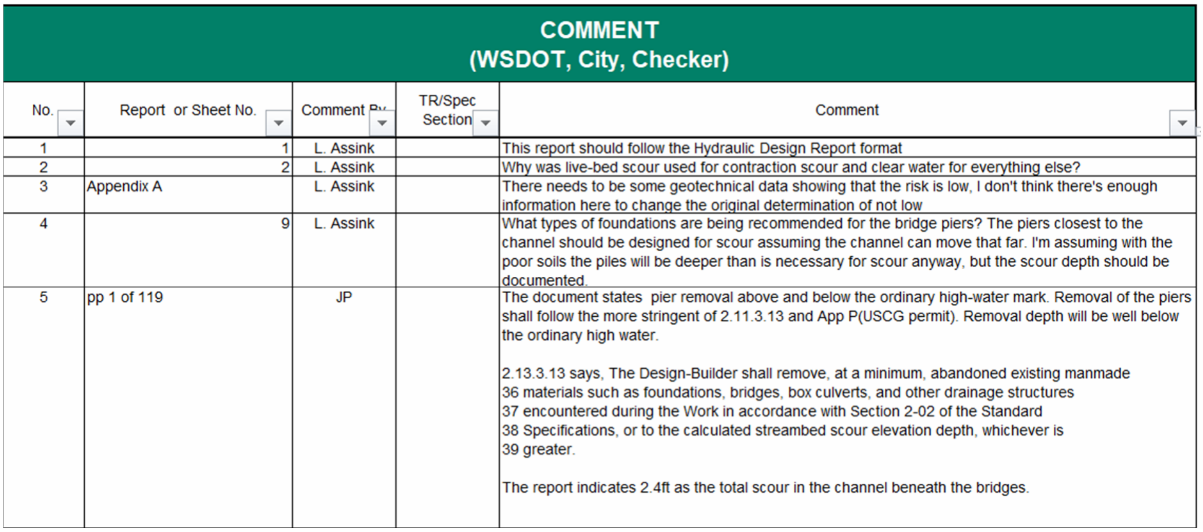
The hydraulic calculations were prepared following contractual obligations stated in Appendix H26. Subsequent hydraulic and structural submittals follow final design considerations and recommendations. Accordingly, we are protesting WSDOT’s position that the current hydraulic and structural calculations do not meet the contract.

Please find a detailed timeline that led to this request, below:

- 7/12/24 – Draft Final Hydraulic Design Report (FHD) for the Sammamish Bridge crossing submitted by the DB team to WSDOT
- 8/6/24 – DB team received 5 comments from WSDOT indicating to revise and resubmit. Comments #3 and #4 from Luke Assink (WSDOT) are relevant for the purposes of this protest.



Project:	**C9727 - I-405, Brickyard to SR 527 Improvement Project**	
Document Name:	**BY-CRE-00888_009727_SUB_17.02_Segment 2 Final Sammamish River Bridge - Fish Passage**	
Submittal Date:	**7/16/2024**	
Due Date:	**8/6/2024**	**COB**
Reviewer:	**Luke Assink, Jason Pang (JP)**	
Document Lead:		

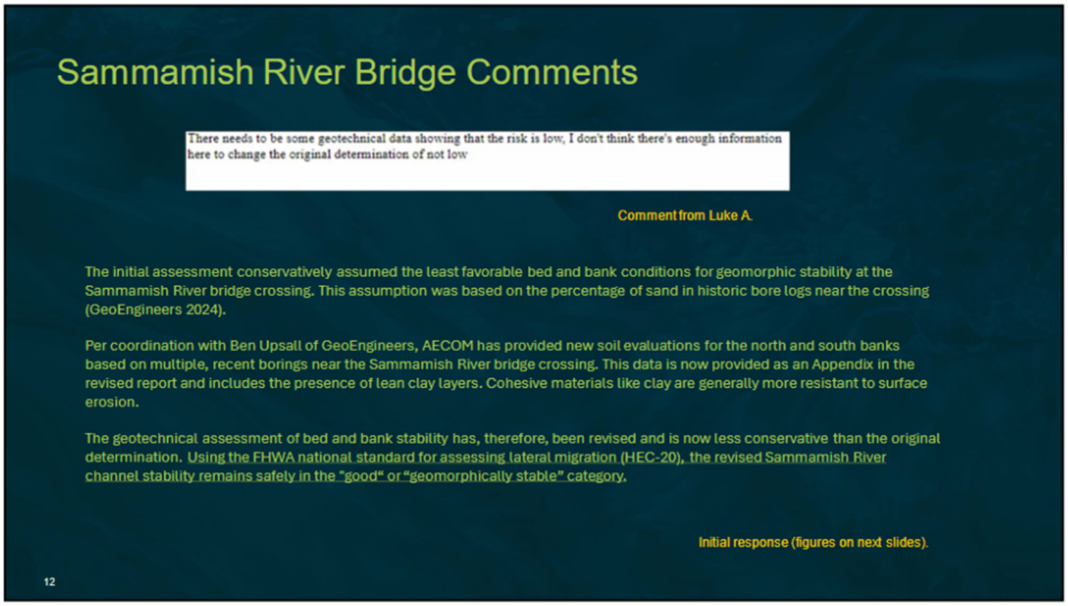


COMMENT
(WSDOT, City, Checker)

No.	Report or Sheet No.	Comment By	TR/Spec Section	Comment
1	1	L. Assink		This report should follow the Hydraulic Design Report format
2	2	L. Assink		Why was live-bed scour used for contraction scour and clear water for everything else?
3	Appendix A	L. Assink		There needs to be some geotechnical data showing that the risk is low, I don't think there's enough information here to change the original determination of not low
4	9	L. Assink		What types of foundations are being recommended for the bridge piers? The piers closest to the channel should be designed for scour assuming the channel can move that far. I'm assuming with the poor soils the piles will be deeper than is necessary for scour anyway, but the scour depth should be documented.
5	pp 1 of 119	JP		The document states pier removal above and below the ordinary high-water mark. Removal of the piers shall follow the more stringent of 2.11.3.13 and App P(USCG permit). Removal depth will be well below the ordinary high water. 2.13.3.13 says, The Design-Builder shall remove, at a minimum, abandoned existing manmade 36 materials such as foundations, bridges, box culverts, and other drainage structures 37 encountered during the Work in accordance with Section 2-02 of the Standard 38 Specifications, or to the calculated streambed scour elevation depth, whichever is 39 greater. The report indicates 2.4ft as the total scour in the channel beneath the bridges.

- 8/13/24 - Meeting minutes from Fish Passage Task Force Meeting 8/13/24 indicate WSDOT requested geotechnical data that the banks are non-erodible.
- 9/10/24 – To adhere to WSDOT’s request, the DB team developed a presentation, including the geotechnical information at the Sammamish River, for Fish Passage Task Force on 9/10/24.

  - Slide 12 summarizes the open comment regarding lateral migration and AECOM’s updated response:



Sammamish River Bridge Comments

There needs to be some geotechnical data showing that the risk is low, I don't think there's enough information here to change the original determination of not low

Comment from Luke A.

The initial assessment conservatively assumed the least favorable bed and bank conditions for geomorphic stability at the Sammamish River bridge crossing. This assumption was based on the percentage of sand in historic bore logs near the crossing (GeoEngineers 2024).

Per coordination with Ben Upsall of GeoEngineers, AECOM has provided new soil evaluations for the north and south banks based on multiple, recent borings near the Sammamish River bridge crossing. This data is now provided as an Appendix in the revised report and includes the presence of lean clay layers. Cohesive materials like clay are generally more resistant to surface erosion.

The geotechnical assessment of bed and bank stability has, therefore, been revised and is now less conservative than the original determination. Using the FHWA national standard for assessing lateral migration (HEC-20), the revised Sammamish River channel stability remains safely in the "good" or "geomorphically stable" category.

Initial response (figures on next slides).

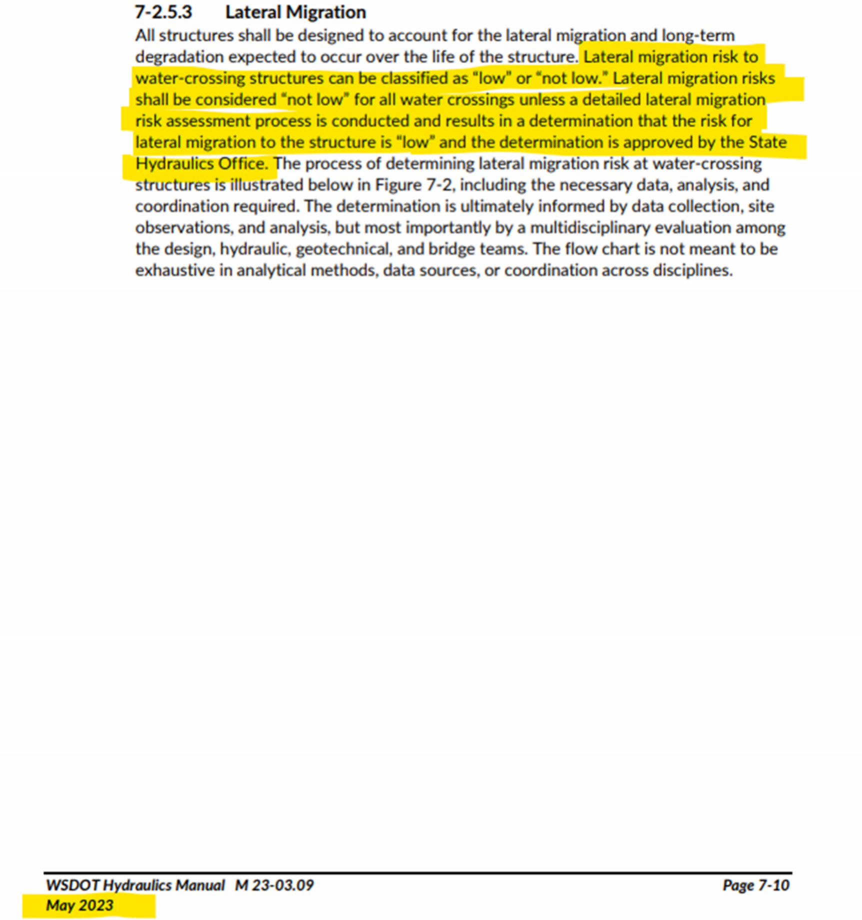
12

12

  - *Note that the full presentation is included in official meeting minutes.*
  - Design-Build team walked through the geotechnical data and recommendations from the project geotechnical engineer, Ben Upsall (GeoEngineers), as requested by WSDOT.
  - Internal meeting minutes (taken by Meredith Cote (AECOM)) note Luke Assink (WSDOT) stated that sending this information and presentation to him would suffice for closing this comment.
- 9/12/24 - Meredith Cote (AECOM) emailed Luke Assink (WSDOT) the presentation along with a copy of the official comment responses on 9/12/24.
- 9/30/24 - Luke Assink (WSDOT) responded via email on 9/30/24 stating, “WSDOT considers the risk of lateral migration low when the geotechnical exploration shows non-erodible materials or if the calculations show the material present will not be mobile during the scour design flood. The current report and as far as I can tell the attached presentation materials do not show that.”

- 10/8/24 - Fish Passage Task Force Meeting Minutes from 10/8/24 indicate Gabe Ng (WSDOT Consultant) is taking over for Luke Assink (WSDOT) on the project.
- 10/25/24 - Seth Gentzler (AECOM) sends over the shoulder copy of the revised FHD, along with a copy of Appendix H26, to Alex Strom (WSDOT Consultant) Gabe (WSDOT Consultant) via email on 10/25/24.
  - This version of the FHD is updated based on the five comments received from WSDOT on 8/6/24.
  - This version of the FHD followed the determination from Appendix H26, “[t]he risk of channel migration within the vicinity of the I-405 MP is NOT LOW and therefore will require further analysis during final design as part of the Hydraulic Design Report for this water crossing” and provided further analysis of the risk of channel migration, following WSDOT guidance.
- The contract version of the Hydraulics Manual (*Appendix D08 of the Contract, dated March 1, 2022*) does not include a section on lateral migration. In April 2023, an updated version of the WSDOT Hydraulics Manual was released that added Section 7-2.5.3 Lateral Migration. This section states the typical process for determining the risk of lateral migration for water-crossing structures, and how

risks are considered “not low” for all water crossings unless a detailed lateral migration risk assessment process is conducted:

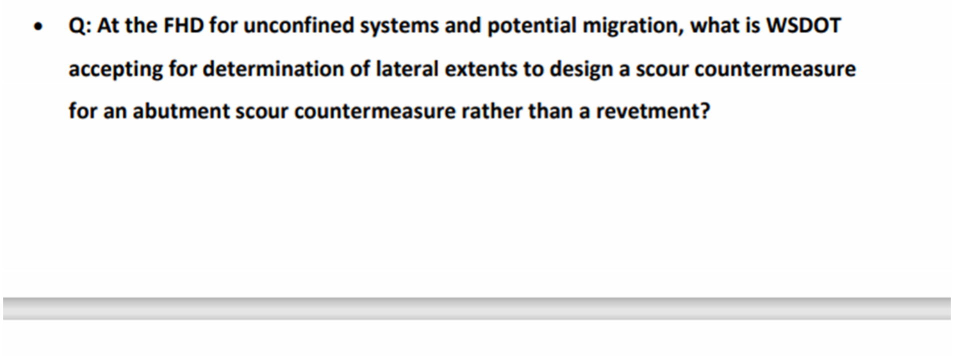


7-2.5.3 Lateral Migration

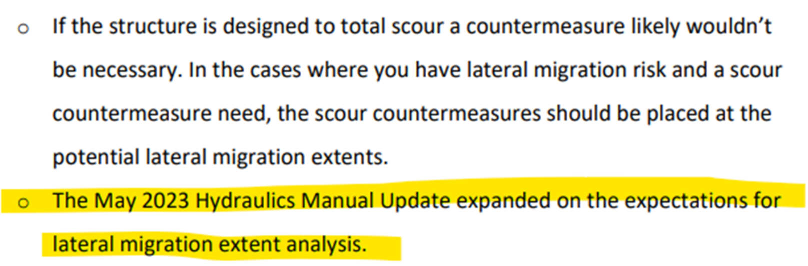
All structures shall be designed to account for the lateral migration and long-term degradation expected to occur over the life of the structure. Lateral migration risk to water-crossing structures can be classified as “low” or “not low.” Lateral migration risks shall be considered “not low” for all water crossings unless a detailed lateral migration risk assessment process is conducted and results in a determination that the risk for lateral migration to the structure is “low” and the determination is approved by the State Hydraulics Office. The process of determining lateral migration risk at water-crossing structures is illustrated below in Figure 7-2, including the necessary data, analysis, and coordination required. The determination is ultimately informed by data collection, site observations, and analysis, but most importantly by a multidisciplinary evaluation among the design, hydraulic, geotechnical, and bridge teams. The flow chart is not meant to be exhaustive in analytical methods, data sources, or coordination across disciplines.

WSDOT Hydraulics Manual M 23-03.09 ***Page 7-10***
May 2023

- Recommendations from WSDOT’s 2023 Scour Training (Question and Answer for Module 10) were followed which points to the May 2023 Hydraulics Manual for expanded expectations for lateral migration extent analysis.

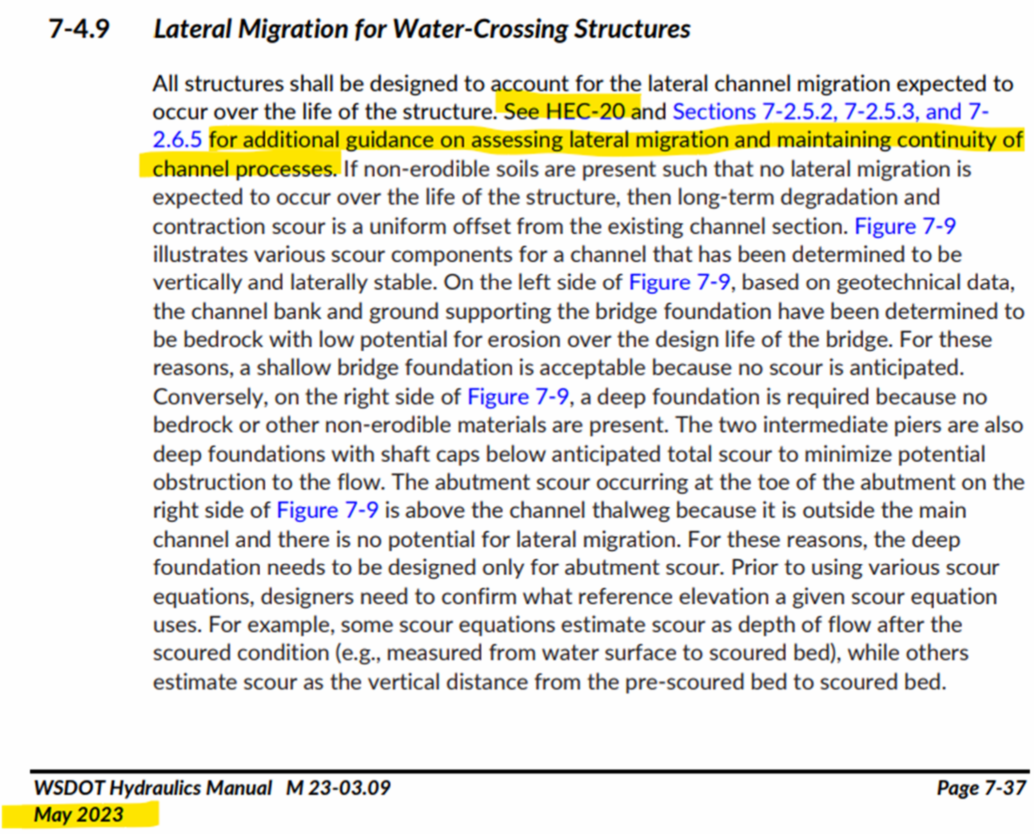


- **Q: At the FHD for unconfined systems and potential migration, what is WSDOT accepting for determination of lateral extents to design a scour countermeasure for an abutment scour countermeasure rather than a revetment?**



  - If the structure is designed to total scour a countermeasure likely wouldn't be necessary. In the cases where you have lateral migration risk and a scour countermeasure need, the scour countermeasures should be placed at the potential lateral migration extents.
  - The May 2023 Hydraulics Manual Update expanded on the expectations for lateral migration extent analysis.

- As discussed in the May 2023 version of the Hydraulics Manual, the non-contractual version, AECOM followed HEC-20 for a more detailed analysis for additional guidance on assessing lateral migration:



7-4.9 *Lateral Migration for Water-Crossing Structures*

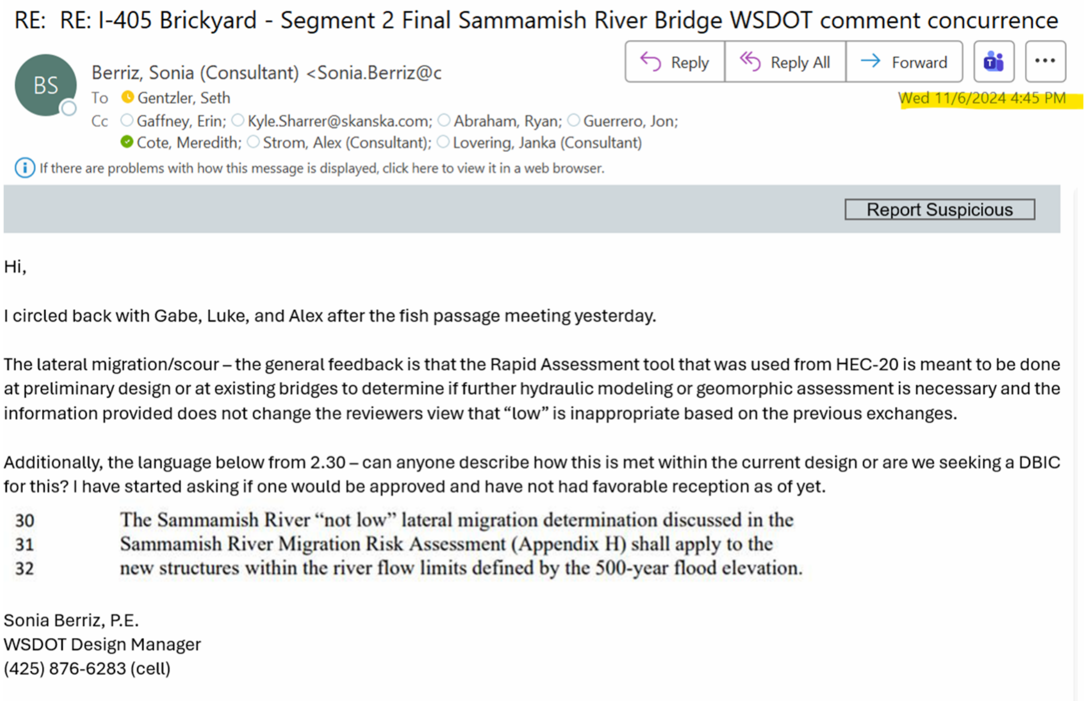
All structures shall be designed to account for the lateral channel migration expected to occur over the life of the structure. See HEC-20 and Sections 7-2.5.2, 7-2.5.3, and 7-2.6.5 for additional guidance on assessing lateral migration and maintaining continuity of channel processes. If non-erodible soils are present such that no lateral migration is expected to occur over the life of the structure, then long-term degradation and contraction scour is a uniform offset from the existing channel section. Figure 7-9 illustrates various scour components for a channel that has been determined to be vertically and laterally stable. On the left side of Figure 7-9, based on geotechnical data, the channel bank and ground supporting the bridge foundation have been determined to be bedrock with low potential for erosion over the design life of the bridge. For these reasons, a shallow bridge foundation is acceptable because no scour is anticipated. Conversely, on the right side of Figure 7-9, a deep foundation is required because no bedrock or other non-erodible materials are present. The two intermediate piers are also deep foundations with shaft caps below anticipated total scour to minimize potential obstruction to the flow. The abutment scour occurring at the toe of the abutment on the right side of Figure 7-9 is above the channel thalweg because it is outside the main channel and there is no potential for lateral migration. For these reasons, the deep foundation needs to be designed only for abutment scour. Prior to using various scour equations, designers need to confirm what reference elevation a given scour equation uses. For example, some scour equations estimate scour as depth of flow after the scoured condition (e.g., measured from water surface to scoured bed), while others estimate scour as the vertical distance from the pre-scoured bed to scoured bed.

WSDOT Hydraulics Manual M 23-03.09 *Page 7-37*
May 2023

-

HEC-20 includes methodologies for a Rapid Assessment of Channel Stability and Quantitative Techniques for Stream Stability Analysis. AECOM followed the Rapid Assessment methodology as outlined in HEC-20 guidance. This assessment is provided in Section 7.1.4 of the FHD report.

- 10/29/24 - Seth Gentzler (AECOM) followed up with Gabe Ng (WSDOT Consultant) and Alex Strom (WSDOT Consultant) via email on 10/29/24 with 3 requests (#1 Circling back on scour/lateral migration concurrence, #2 Requesting update on streambed sediment gradation discussions, and #3 Following up on comment concurrence on another package)
- 10/30/24, 11/1/24 - Alex Strom (WSDOT Consultant) replied via email to Items #2 and #3 from Seth Gentzler's (AECOM) email via emails on 10/30/24 and 11/1/24.
- 11/5/24 - Task Force Meeting Minutes from 11/5/24 do not indicate this topic was discussed; however, internal meeting minutes from Meredith Cote (AECOM) suggest that the next step is to set up a call with Gabe Ng (WSDOT Consultant), Alex Strom (WSDOT Consultant), Luke Assink (WSDOT).
- 11/6/24 - Email correspondence from Sonia Berriz (WSDOT Consultant):



RE: RE: I-405 Brickyard - Segment 2 Final Sammamish River Bridge WSDOT comment concurrence

Berriz, Sonia (Consultant) <Sonia.Berriz@c
To Gentzler, Seth
Cc Gaffney, Erin; Kyle.Sharrer@skanska.com; Abraham, Ryan; Guerrero, Jon; Cote, Meredith; Strom, Alex (Consultant); Lovering, Janka (Consultant)
Wed 11/6/2024 4:45 PM

If there are problems with how this message is displayed, click here to view it in a web browser.

Hi,

I circled back with Gabe, Luke, and Alex after the fish passage meeting yesterday.

The lateral migration/scour – the general feedback is that the Rapid Assessment tool that was used from HEC-20 is meant to be done at preliminary design or at existing bridges to determine if further hydraulic modeling or geomorphic assessment is necessary and the information provided does not change the reviewers view that "low" is inappropriate based on the previous exchanges.

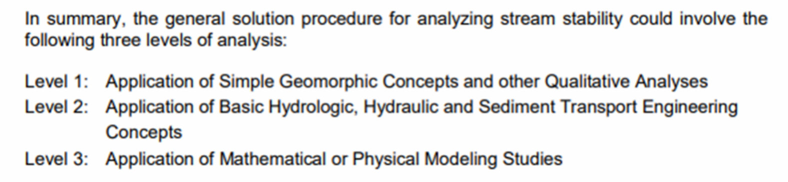
Additionally, the language below from 2.30 – can anyone describe how this is met within the current design or are we seeking a DBIC for this? I have started asking if one would be approved and have not had favorable reception as of yet.

> The Sammamish River "not low" lateral migration determination discussed in the Sammamish River Migration Risk Assessment (Appendix H) shall apply to the new structures within the river flow limits defined by the 500-year flood elevation.

Sonia Berriz, P.E.
WSDOT Design Manager
(425) 876-6283 (cell)

- 11/19/24 - Fish Passage Task Force official meeting minutes on 11/19/24 indicate DB is reviewing model and compiling exhibits and will set up a meeting to discuss lateral migration.
- 11/26/24 - A meeting was set up on 11/26/24 to discuss lateral migration. *Note there are no official meeting minutes available for this discussion.*
  - Attendees included: Seth Gentzler, Meredith Cote, Steve McNeely, Yacoub Raheem, Ryan Abraham (AECOM), Gabe Ng, Alan Black, Alex Strom (WSDOT Consultants).
  - Internal meeting minutes taken by Meredith Cote (AECOM) indicate that AECOM shared results of findings and technical analysis.
  - AECOM suggests that additional assessments (modeling meander migration) could be conducted, but they require calibration to known historical rates of bank retreats. The primary method of determining historical rates of bank retreat is to analyze historical aerial imagery.
  - AECOM and Black et al. (WSDOT) independently analyzed historical aerial imagery and came to the same conclusion that little to no movement of the river channel has taken place since 1964, since the USACE's project. This negligible rate of change presents a significant challenge with respect to calibration of a potential meander migration model.

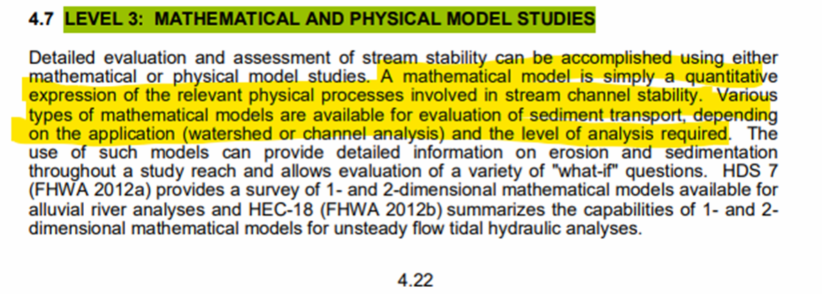
  - WSDOT mentioned their current opinion is the DB is not in compliance with the contract because their position is the contract requires DB to assume that lateral migration is not low.
  - Gabe Ng (WSDOT Consultant) offered to share examples of how this assessment has been done at other project sites.
  - WSDOT indicated next step would be for the DB to document how much lateral movement is expected.
- 12/23/24 - Seth Gentzler (AECOM) sent a revised, over the shoulder copy of the FHD to WSDOT via email. *Note: uploaded to Procore 1/9/25.*
  - This version of the FHD included Level 1, Level 2, and Level 3 analyses for analyzing stream stability, as discussed in HEC-20:



In summary, the general solution procedure for analyzing stream stability could involve the following three levels of analysis:

Level 1: Application of Simple Geomorphic Concepts and other Qualitative Analyses
Level 2: Application of Basic Hydrologic, Hydraulic and Sediment Transport Engineering Concepts
Level 3: Application of Mathematical or Physical Modeling Studies

  - As described in HEC-20, a Level 3 analysis can be accomplished using a mathematical or physical model study. Therefore, the DB Team utilized a mathematical model. Also as described in HEC-20, "[a] mathematical model is simply a qualitative expression of the relevant physical processes" and "[v]arious types of mathematical models are available".

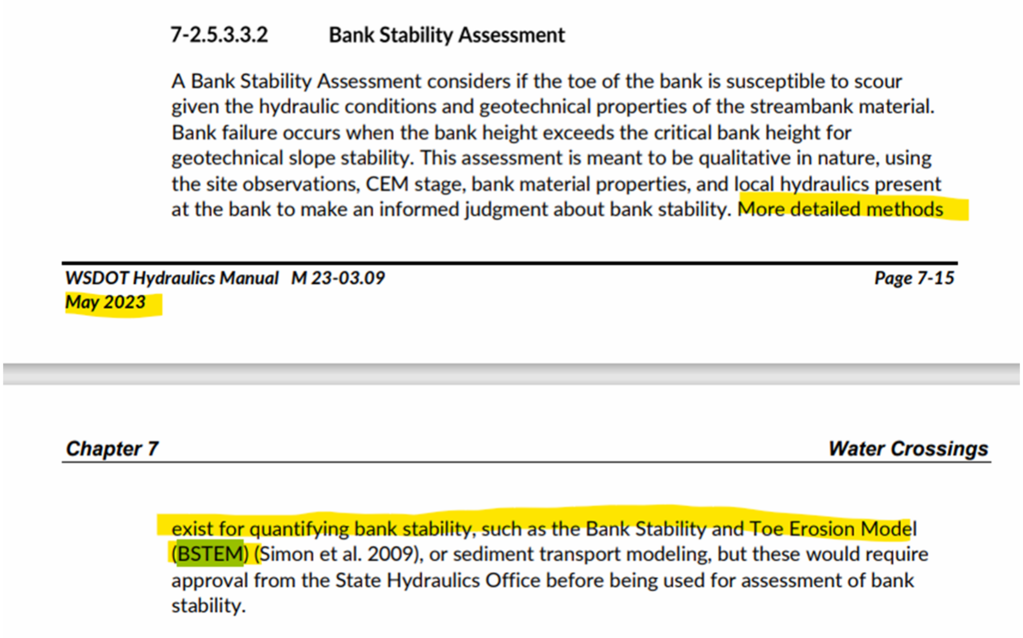


4.7 LEVEL 3: MATHEMATICAL AND PHYSICAL MODEL STUDIES

Detailed evaluation and assessment of stream stability can be accomplished using either mathematical or physical model studies. A mathematical model is simply a quantitative expression of the relevant physical processes involved in stream channel stability. Various types of mathematical models are available for evaluation of sediment transport, depending on the application (watershed or channel analysis) and the level of analysis required. The use of such models can provide detailed information on erosion and sedimentation throughout a study reach and allows evaluation of a variety of "what-if" questions. HDS 7 (FHWA 2012a) provides a survey of 1- and 2-dimensional mathematical models available for alluvial river analyses and HEC-18 (FHWA 2012b) summarizes the capabilities of 1- and 2-dimensional mathematical models for unsteady flow tidal hydraulic analyses.

4.22

  - For further guidance, the WSDOT Hydraulics Manual (May 2023 version, as recommended in the WSDOT's 2023 Scour Training (Question and Answer for Module 10)) was followed. Section 7-2.5.3.3.2 of this manual states that BSTEM is a more detailed method for quantifying bank stability, which is the physical process WSDOT is interested in quantifying.



7-2.5.3.3.2 Bank Stability Assessment

A Bank Stability Assessment considers if the toe of the bank is susceptible to scour given the hydraulic conditions and geotechnical properties of the streambank material. Bank failure occurs when the bank height exceeds the critical bank height for geotechnical slope stability. This assessment is meant to be qualitative in nature, using the site observations, CEM stage, bank material properties, and local hydraulics present at the bank to make an informed judgment about bank stability. More detailed methods

WSDOT Hydraulics Manual M 23-03.09 Page 7-15
May 2023

Chapter 7 *Water Crossings*

exist for quantifying bank stability, such as the Bank Stability and Toe Erosion Model (BSTEM) (Simon et al. 2009), or sediment transport modeling, but these would require approval from the State Hydraulics Office before being used for assessment of bank stability.

  - As such, a Level 3 analysis was conducted using BSTEM to determine the anticipated amount of bank erosion. This Level 3 analysis concluded up to 1.6 feet of toe erosion is predicted; however, stream banks remain stable and there is no predicted bank failure by indirect fluvial entrainment.

- 1/10/25 - Sonia Berriz (WSDOT Consultant) sent a question to DB team (via email) regarding the over the shoulder review copy.
  - The main concern was regarding the 100 year water surface elevation (WSE), which differs from the Zero Rise Report/FEMA model.
  - Other comment confirming the proposed grading for the new outfall on the north side of the Sammamish River was incorporated into the model. (*Note this comment was included in the email but sent via ProCore on 1/2/25).*
- 1/13/25 - WSDOT rejected the submittal, stating comments weren't resolved.
- 1/21/25 – Additional comments received via email from Sonia Berriz (WSDOT Consultant). Comments from HQH (Gabe Ng, Alan Black, Darrel Sofield, (WSDOT Consultants)) on the over the shoulder copy that was sent on 12/23/24.
- 1/29/25 - Ryan Abraham (AECOM) provided an email response to Sonia Berriz (WSDOT Consultant) responding to their questions sent on 1/10/25 regarding the boundary condition and outfall grading.
- 2/4/25 – Ryan Abraham (AECOM) sent WSDOT the revised the SRH-2D model via ProCore, (notified Sonia Berriz via email). Revised SRH-2D model corrected the downstream boundary condition, noted in the 1/10/25 email from Sonia Berriz (WSDOT Consultant) and additional comments received on 1/21/25.
- 2/10/25 – Meeting discussing Lateral Migration held with Berriz, Sonia; Ng, Gabe; Black, Alan; Darrell Sofield; Holmquist, Dan; Strom, Alex; Jessie Delight (WSDOT Consultants) Abraham, Ryan; Meredith Cote, Seth Gentlzer, Yacoub Raheem (AECOM), Sharrer, Kyle; Prendergast, Patrick (SKANSKA) Lovering, Janka, Pao, Evelyn C.; Heilman, Julie; Casey Kramer; Woeck, Robert (WSDOT). *Note there are no official meeting minutes available for this discussion.*
  - Internal meeting minutes from Meredith Cote (AECOM) indicate that WSDOT requested:
    - 1) a Geotechnical Engineer to validate the soil erosivity parameters and validate that the material is the same from the borings all the way out to the proposed piers,

    - 2) an explanation of how DB performed historical delineations,
    - 3) revise BSTEM section views to be to scale,
    - 4) investigate the previous King County bank repair project and include in the assessment,
    - 5) perform pier scour as if the channel can migrate over to the piers, based on HEC-18 guidance.
- 3/4/25 – Revised, over the shoulder report and comment responses to comments (received on 1/21/25) submitted by AECOM to WSDOT via ProCore.
    - This version included updated analyses with the corrected downstream boundary condition in the SRH-2D model and additional discussion as part of the Level 3 Analysis, following the Washington State Department of Ecology's *Channel Migration Processes and Patterns in Western Washington.* Predicting meander migration is described in HEC-20 as another quantitative technique for stream stability analysis.
    - Conclusions remain consistent with previous reports that the there is no significant lateral migration anticipated at the project reach. BSTEM analysis indicates that minimal bank erosion would occur during a 500-year flood and stream banks are stable with no impact to existing grade at the proposed pier locations.
- 6/13/25 – Evelyn Pao (WSDOT) sends Interpretive Engineering Decision for Lateral Migration letter, **SL No. 9727-116**. Letter states that the Contract concludes the Lateral Migration is "not low" and hydraulic and structural design need to be updated accordingly.
- 6/27/25 – SKANSKA sent letter SL 204 to WSDOT requesting clarifications on what they are willing to accept.
- 7/9/25 – Evelyn Pao (WSDOT) sends **SL No. 9727-125** regarding the Sammamish River Lateral Migration stating that WSDOT will only accept a solution based on a 'not low' determination as the basis of design.
- 7/17/25 – SKANSKA sent letter SL 214 to WSDOT requesting to resolve the issue in a workshop with the DB team and WSDOT.
- 7/23/25 – SKANSKA sent letter SL 215 to WSDOT providing AECOM's letter refuting WSDOT's position. AECOM requested a clarification of the definition of the term "not low". This clarification has not been provided.
- 8/7/25 Meeting with WSDOT and DB Team Leadership – Each side discussed their interpretation of the contract regarding a "low" and "not low" determination. DB Team requested WSDOT provide technical review of the FHD regarding the lateral migration determination and bank stability calculations. WSDOT did not commit to providing a technical review. DB Team asked WSDOT for how they determined the horizontal limits of the lateral migration. WSDOT stated they did not have calculations to provide. WSDOT stated their position was the lateral migration horizontal boundary was the 500yr boundary. WSDOT and the DB Team discussed possible option of re-grading the bank to move the 500yr water surface boundary. WSDOT stated this could be an option, the environmental permits and impacts would need to be reviewed and assessed. The DB Team was to review that option for feasibility.
- 8/15/25 – Evelyn Pao (WSDOT) sent letter **SL No. 97270139** to SKANSKA regarding Lateral Migration and solutions discussed in an 8/7/25 meeting indicating WSDOT is withholding the final determination while the project teams complete additional cooperative efforts to develop a Contract compliant solution.
- 10/13/25 – Evelyn Pao (WSDOT) sent letter **SL No. 9727-178** to SKANSKA regarding grading within the 500-year floodplain would require a Conditional Letter of Map Review (CLOMR).
- 12/17/25 - Evelyn Pao (WSDOT) sent letter **SL No. 9727-220** to SKANSKA regarding how DB team has not presented a contract compliant design solution and the current design does not meet the contract requirements.

The processes by which channel migration can occur have been investigated and are namely (1) meander bend migration, (2) avulsion, and (3) channel widening caused by bank retreat. AECOM's lateral migration assessment indicates none of these channel migration processes are occurring. No channel migration (either meander migration or direct fluvial entrainment of bank material) is observed from historical topo/aerial imagery. Avulsion is unlikely to occur because (1) Sammamish River flows are well confined to the straightened, deepened, and realigned river channel and its immediate overbank areas, and (2) no avulsion hazard zone has been identified; secondary channels, relic channels, and swales are vertically disconnected from the Sammamish River channel. Finally, negligible bank toe erosion is predicted by BSTEM analysis for the 500-year flood (0.2% AEP) or a series of storms assumed to occur during the life of the bridge structure. For all storms investigated, the riverbanks remain stable and there is no predicted bank failure by indirect fluvial entrainment. Existing banks tend to stand at or less than the angle of repose, indicating bank retreat processes are in a state of equilibrium.

It is AECOM's position that in the letter dated December 17, 2025, the WSDOT engineer's determination stating the current design for NB I-405 to EB SR 522 ramp bridge and the future NB I-405 mainline bridge does not meet contract requirements is incorrect. AECOM has worked diligently with WSDOT to provide a contract compliant design and has followed the project technical requirements and engineering best practices in process.

c. The estimated dollar cost, if any, of the protested Work and a detailed breakdown showing how that estimate was determined.

Currently, WSDOT has only indicated that AECOM does not fulfill the Contract requirements, but has not specified which specific criteria are unmet. If WSDOT or any other party introduces new criteria or provides additional information or direction, AECOM reserves the right to issue Contractual notices at that time.

The final cost of the protested work cannot be estimated at this time as we do not have enough information to provide a cost and schedule impact in accordance with 1-04.5.2.c. and with 1-04.5.2.d. WSDOT has neither provided direction nor sufficient information for the design team to assess a path forward that will be acceptable to WSDOT based on their interpretation of the contract.

d. An analysis of the progress schedule showing the schedule change or disruption if the Design-Builder is asserting a schedule change or disruption.

The schedule impact caused by the protested work cannot be determined at this time as resolution of this issue has yet to be determined. WSDOT has neither provided direction nor sufficient information for the design team to assess a path forward that will be acceptable to WSDOT based on their interpretation of the contract. Once a final path forward has been established, a schedule impact can be determined.

This letter is without prejudice to, and with a full reservation of, AECOM's rights, remedies, causes of action, and defenses under the Subcontract, at law, in equity, or otherwise. Nothing in this letter shall be interpreted as a modification or waiver, or an estoppel of AECOM's right to assert the same.

I appreciate your prompt attention to this matter. If you have any questions, please do not hesitate to contact me directly.

Yours sincerely,

AECOM Technical Services, Inc.

Jon Guerrero, PE
M: 206.579.0292
E: jon.guerrero@aecom.com

cc: Evan Grant (AECOM)
Jack Waldron (AECOM)

AECOM
1111 Third Avenue
Suite 1600
Seattle, WA, USA 98101
T +1-206-438-2700
aecom.com

Project name:
I-405, Brickyard to SR 527 Improvement

Project ref:
60713342

To:
Shukre Despradel, PhD, SE (AECOM)

CC:
Gavin Viriyincy, PE (AECOM)
Cori Yoshida, PE (AECOM)
Bradford Schaffer, PE, SE (AECOM)

From:
Samuel Boyce, PE (AECOM)
Curtis Jones, EIT (AECOM)
Yacoub Raheem, PE (AECOM)

Date:
July 8, 2024

Draft Final Hydraulic Design Report– Sammamish River Bridge Crossing

Subject: Scour Analysis

Summary

This technical memo provides scour estimations for the Sammamish River Bridges contained in the Segment 2 Design Package for the *I-405, Brickyard to SR 527 Improvement Project* (Project) in King and Snohomish Counties, Washington. As part of the Project to provide congestion relief and safety improvements along Interstate 405 (I-405), three new bridges will be constructed across the Sammamish River at the I-405/SR 522 interchange.

- I-405 direct access bridge at SR 522
- Northbound I-405 mainline over the Sammamish River
- Northbound I-405 off ramp to SR 522

Additionally, two existing bridges over the Sammamish River will be demolished, including pier removal above and below the ordinary high-water mark.

The proposed bridges are supported by a combination of cast-in-place stem walls with shallow foundations and intermediate drilled-shaft deep foundations. Only the intermediate drilled-shaft deep foundations adjacent to the Sammamish River (piers 3 and 4, for each bridge) are analyzed for scour. Each pier consists of three individual 6-foot-wide columns.

Thus, a total of 18 columns (6 piers x 3 columns per pier) supporting the proposed bridges have been evaluated for total scour using the United States Bureau of Reclamation Sedimentation and River Hydraulics (SRH-2D) computer program. The scour analysis consisted of 10-year, 50-year, 100-year, 500-year, and projected 2080 100-year flow events, considering local hydraulics. Additionally, the risk of lateral migration has been evaluated for the Sammamish River bridge crossing.

The following sections are included below:

- Methodology
- Model Development
- Hydraulic Modeling Scenarios
- Model Verification
- Limitations
- Conclusions
- References
- Appendices

Methodology

Total scour was estimated following the procedures outlined in the Federal Highway Administration (FHWA) *Evaluating Scour at Bridges, HEC No. 18* (Arneson et al. 2012). It is defined as the sum of long-term degradation, general contraction scour, and local scour.

The 10-year, 50-year, 100-year, 500-year, and projected 2080 100-year events were evaluated for general contraction and local pier scour. Bankfull discharge was used to estimate long-term degradation.

Long-Term Degradation

Long-term degradation is the lowering of a streambed's elevation over long reaches due to a deficit in upstream sediment supply. Long-term degradation is quantitatively analyzed using the equilibrium slope method described in FHWA's *Stream Stability at Highway Structures, HEC No. 20* (Lagasse et al. 2012).

Contraction Scour

Contraction scour is a component of total scour that results from a contraction of the flow area at the bridge, which increases flow velocity and bed shear stress. For this analysis, contraction scour was calculated using clear-water and live bed conditions for all flow events using the FHWA hydraulic toolbox, an industry standard.

Local Scour

Local scour is the removal of material around piers, abutments, or embankments caused by these elements obstructing flow and generating local vortices. For this effort, only local pier scour was evaluated. Other typical forms of local scour, such as abutment scour and bend scour, were disregarded, as abutments are well outside the 500-year flow elevations, and no river bends were identified near the crossing.

Local pier scour for all flow events was evaluated using the FHWA hydraulic toolbox, an industry standard. The bed condition was selected as clear-water, and the pier shape was conservatively selected as square nose.

Lateral Migration

Per the Project's contractual requirements, all new structures within the 500-year flow limits should consider the risk of lateral migration based on the opinion paper by Black et al. (2023), which found that the risk for migration is "not-low" and "require[s] further analysis." Lateral migration is therefore evaluated following the guidance of FHWA's *Stream Stability at Highway Structures, HEC-20* (Lagasse et al. 2009).

Model Development

Hydraulic analysis of the proposed I-405/SR 522 Sammamish River bridge crossing was performed using SRH-2D, version 3.2.0, a two-dimensional (2D) hydraulic and sediment transport numerical model (USBR 2017). Pre- and post-processing were completed using the Surface-Water Modeling Systems (SMS) Version 13.3.10 (Aquaveo 2024a).

Topography/Bathymetry

A 2D surface representing the Sammamish River and its overbanks was generated from the *2010 FEMA FIS Sammamish River HEC-RAS Model* provided by the Washington State Department of Transportation (WSDOT) in the project documents. The surface linearly interpolates elevation data from 148 unique cross-sections along 13.97 miles of the Sammamish River's longitudinal profile. The elevation data exported from the HEC-RAS model are in the North American Vertical Datum of 1988 (NAVD88).

Following SRH-2D best practices (Aquaveo 2024b), the proposed piers were modelled as explicit holes in the 2D mesh. This forces water to flow around the piers and accounts for resulting head loss, improving accuracy of velocity and shear stress distributions. Proposed pier locations and geometry were imported directly into SMS from working CADD files.

Model Extent and Computational Mesh

Overviews of the SRH-2D mesh with the underlying terrain are shown on **Figures 1** and **2**. Following the Sammamish River centerline (flowing roughly east to west), the eastern edge of the computational mesh is approximately 4,400 feet upstream of the bridge crossing, and the western edge is approximately 3,500 feet downstream of the bridge crossing. This distance is assumed sufficient to prevent the mesh boundary from affecting river hydraulics in the immediate vicinity of the bridge crossing.

Cross-sectional widths of the river channel and overbank areas range from approximately 325 feet to 770 feet; this distance is sufficient to prevent mesh-boundary-flow interactions along the entire simulated domain.

The mesh is a combination of quadrilateral (river) elements and triangular (overbank) elements. The mesh contains 42,685 elements in total, with distances between adjacent vertices ranging from 2 feet (near the proposed piers) to 25 feet (away from the area of interest). The overall area of the mesh is approximately 91.8 acres.

Boundary Conditions

Two boundary conditions were assigned. At the upstream boundary of the mesh (i.e., inlet), a constant sub-critical discharge was applied for the various return intervals described below (see **Hydraulic Modeling Scenarios**) using the SRH-2D conveyance approach, which applies flow normal to the inlet boundary. At the downstream boundary of the mesh (i.e., outlet), a rating curve was defined using the channel calculator tool in SMS with a Manning’s roughness of 0.03 and a slope of 0.015 feet/foot. SRH-2D then automatically calculated the water surface elevation at the exit based on the flow discharge through the exit.

Model Run Controls

Model control for the hydraulic model included a start time of 0 hours and an end time of 3 hours. Simulations were run with a 0.5-second time step and had an initial condition of “dry.” The output frequency was set to 30.0 minutes, and the default parabolic turbulence was left as 0.7. The model was run as unsteady with three iterations per timestep.

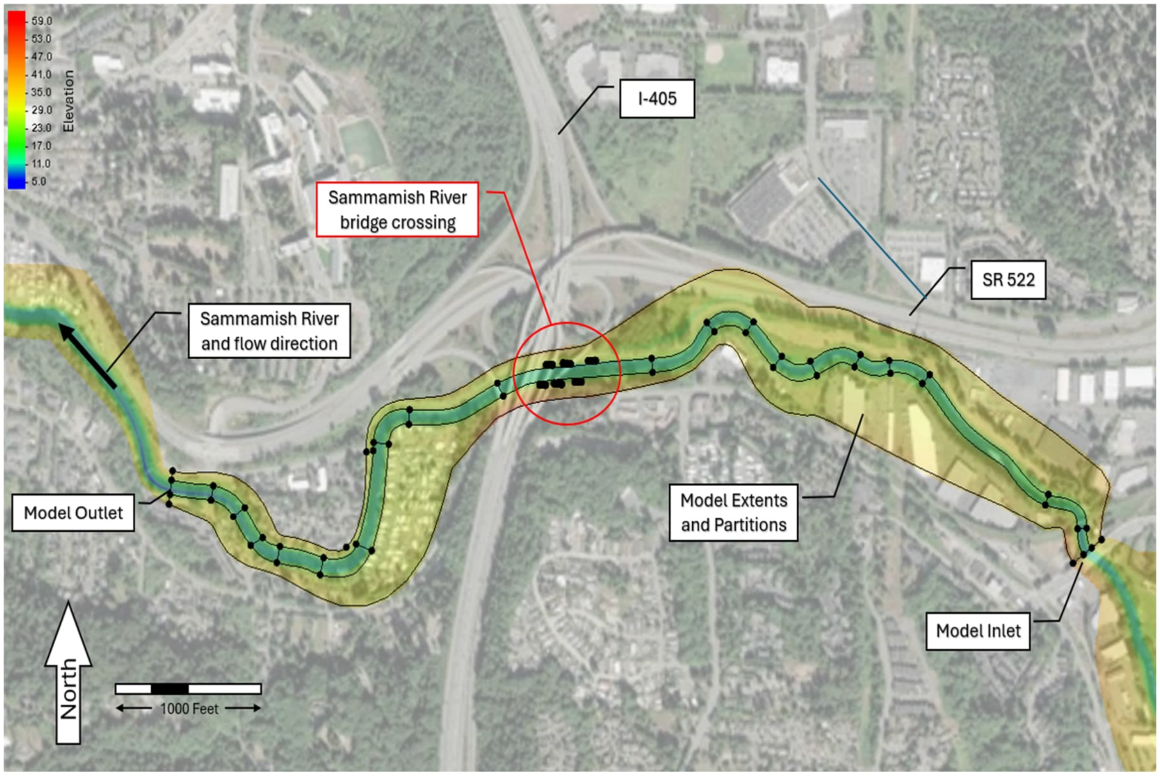


Figure 1. Hydraulic model extents and overview

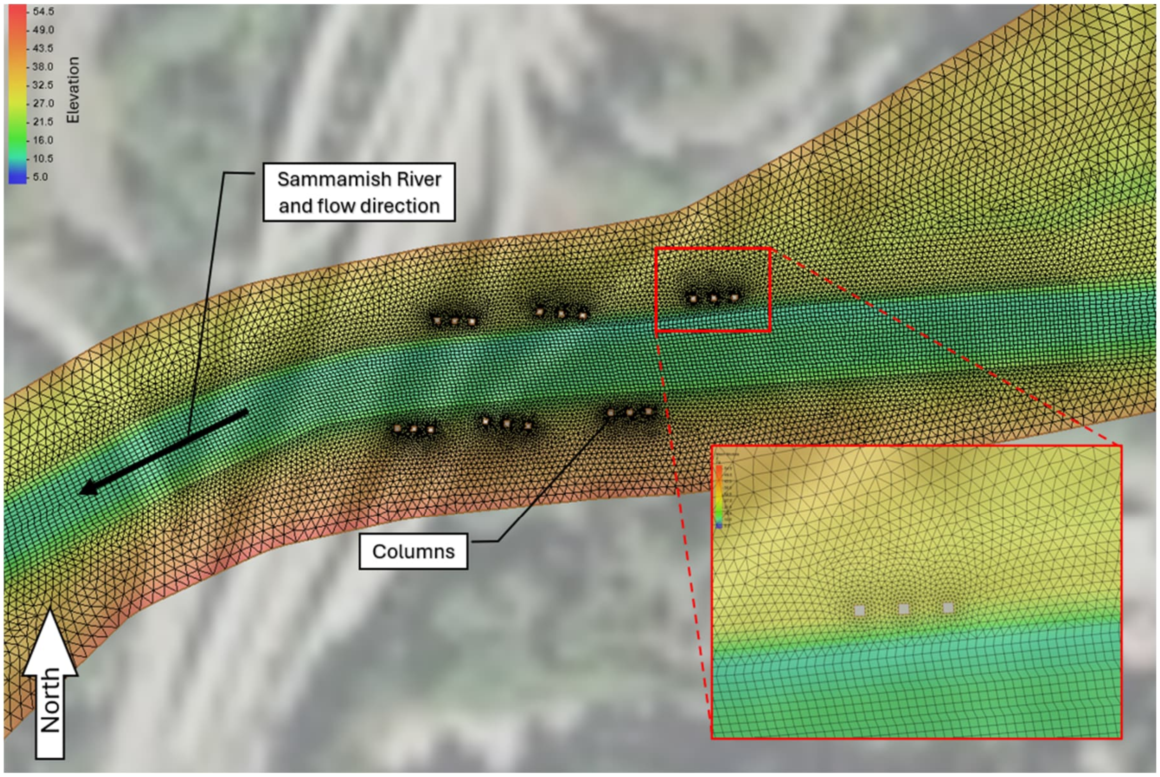


Figure 2. Hydraulic model mesh and detail at the Sammamish River bridge crossing

Materials and Manning’s Roughness

The Manning’s roughness values from the *2010 FEMA FIS Sammamish River HEC-RAS Model* were used in the SRH-2D model (see **Table 1**); they were confirmed through aerial imagery and standard empirical values. **Figure 3** indicates where the different Manning’s layers were applied.

Table 1 – Manning’s roughness summary

Material	Manning’s Roughness
Sammamish River channel	0.032
Overbanks	0.08

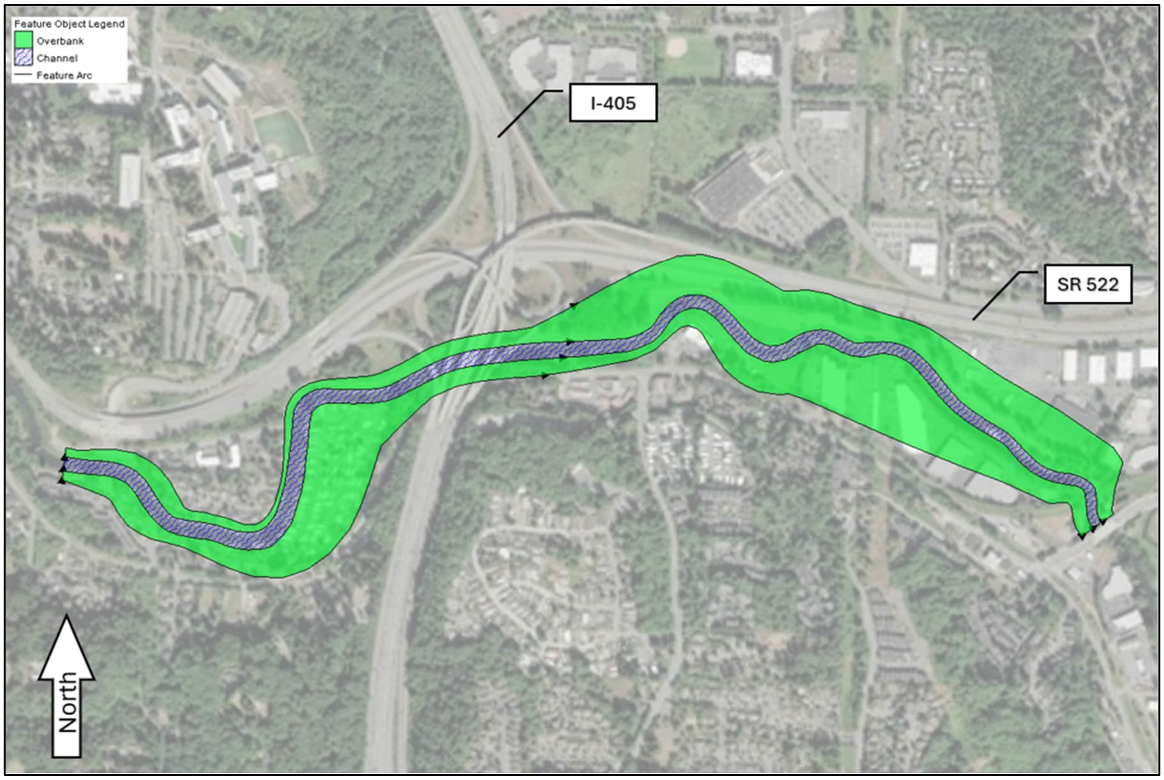


Figure 3. Manning’s values for hydraulic model material layers

Hydraulic Modeling Scenarios

The 10-year, 50-year, 100-year, and 500-year peak discharge flows from the *2010 FEMA FIS Sammamish River HEC-RAS Model* were used as boundary conditions for the SRH-2D model. The projected 2080 100-year peak discharge was estimated from the Washington Department of Fish and Wildlife Future Projections for Climate-Adapted Culvert Design program (WDFW 2024) and added as an additional boundary condition.

Table 2 summarizes the peak discharge for each scenario ran in the SRH-2D hydraulic model.

Table 2 – Model flow scenarios

Return Interval	Peak Discharge (cfs)
10-year	3,347
50-year	4,090
100-year	4,374
500-year	4,982
Projected 2080 100-year*	5,450

* 24.6% mean change in 100-year discharges (see **Appendix G**)

Model Verification

The hydraulic model was verified by comparing the simulated SRH-2D 100-year water surface elevations against a known solution, the Federal Emergency Management Agency (FEMA) 100-year Flood Zone (FEMA 2024).

As seen in **Figure 4**, the simulated water surface elevations are in agreement with the FEMA 100-year Flood Zone extents for all areas upstream of the confluence with North Creek.

Other inconsistencies between the simulated 100-year flood extents and the FEMA 100-year Flood Zone (like those seen adjacent to the river between Par Creek and Little Bear Creek) are explained by poor topographical resolution in the hydraulic model surface; see **Limitations** below.

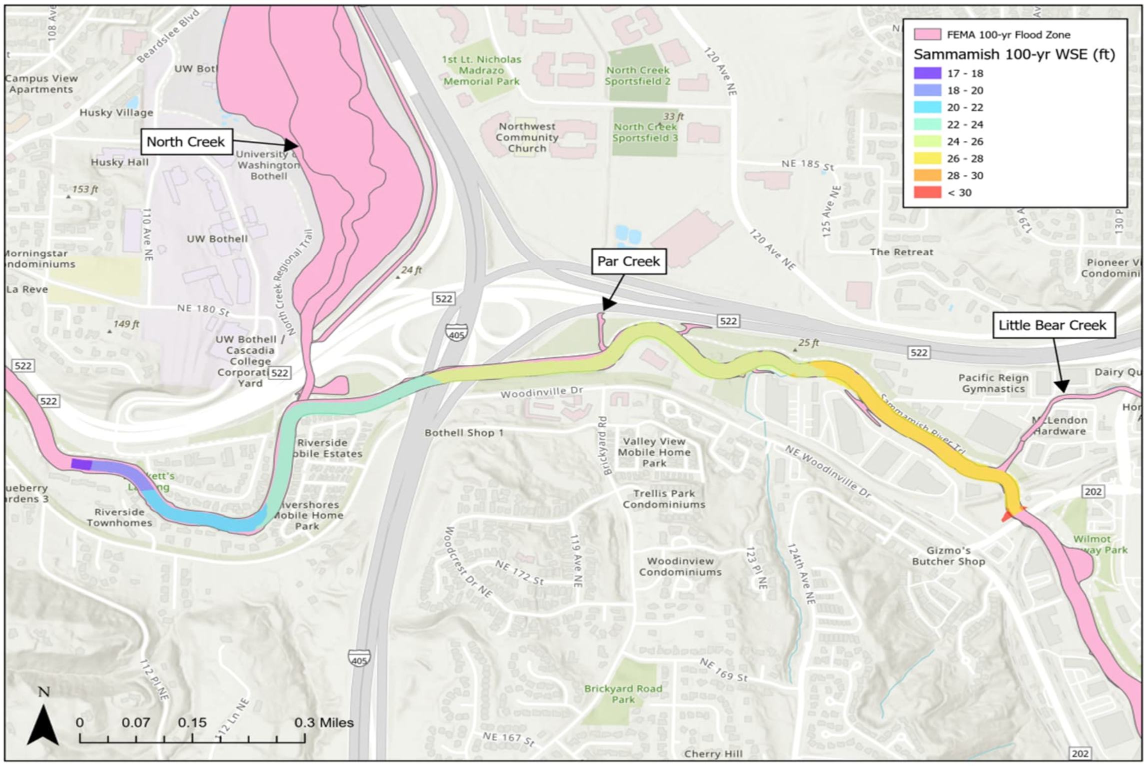


Figure 4. Comparison of simulated 100-year water surface elevations and FEMA 100-year Flood Zones

Limitations

Some background information, modeling files, and other data used by AECOM in preparing this document have been furnished by the client or third parties. AECOM has relied on this information as furnished and is neither responsible for nor has confirmed the accuracy of this information.

The lack of recent comprehensive bathymetry is a limitation for this hydraulic modeling effort.

Conclusions

A scour analysis has been performed for the Sammamish River bridge crossing. Total scour, in the form of long-term degradation, contraction scour, and local pier scour, was evaluated for the 10-year, 50-year, 100-year, 500-year, and projected 2080 100-year discharge events. Additionally, a lateral migration assessment of the Sammamish River channel has been performed. Results are summarized below.

Lateral Migration

Further analysis of the lateral migration potential was performed by AECOM and is presented in **Appendix A**. Analysis includes an overview of the Sammamish River's geomorphic condition, a qualitative evaluation of lateral migration, and a quantitative measure of channel migration potential. Findings indicate that the risk of lateral migration near the I-405/SR 522 interchange is low.

Long-Term Degradation

Degradation, or the vertical lowering of a streambed over relatively long distances and time frames, is an important component of total scour at bridge crossing. Long-term degradation of the Sammamish River at the I-405/SR 522 interchange was estimated using the equilibrium slope method, as described in the FHWA HEC No. 20 (Lagasse et al. 2012).

The full calculation is presented in **Appendix B**. Findings indicate the most conservative estimate of long-term degradation is 2.4 feet.

Contraction Scour

The calculations carried out using the FHWA hydraulic toolbox showed that no contraction scour is anticipated at the Sammamish River bridge crossing for any flow event considered in this analysis. This conclusion is supported by recognizing that no flow constriction (either natural or man-made) is observed at the proposed crossing.

The toolbox considered both clear-water and live-bed conditions and recommended live-bed as the governing scenario. AECOM agrees with the selection of live-bed conditions for contraction scour, as simulated flow velocities exceed the critical velocity of the defined material gradation. Live-bed contraction scour for all simulated flow events is summarized in **Table 3**.

Sediment size distributions of streambed material are important input parameters for contraction scour. The sediment size distribution used for contraction scour calculations is taken from the grain size analysis of borehole NE-19p-19 (GeoEngineers 2024). The material (at a depth of 9.5 feet) is classified as a silty sand having a D_{50} of 0.128 millimeters (see **Appendix F**).

Local (Pier) Scour

For each hydraulic modeling scenario (see **Table 2**), figures depicting (1) water depth and (2) flow velocity are plotted near the bridge crossing and are provided in **Appendix C**. The findings indicate that for all scenarios, flow is primarily confined to the Sammamish River channel. Even for the highest flow event (projected 2080 100-year), water surface elevations at the bridge crossing only reach 8 of the 18 columns.

For these 8 columns, water depths and velocities are low, and subsequent scour analysis performed by the FHWA hydraulic toolbox indicates that local hydraulics generate no pier scour.

Table 3 – Contraction and pier scour summary table

Event	Peak Discharge (cfs)	Live Bed Contraction Scour (ft)	Pier Scour - Local Hydraulics (ft)
10-year	3,347	0.0	0.0
50-year	4,090	0.0	0.0
100-year	4,374	0.0	0.0
500-year	4,982	0.0	0.0
Projected 2080 100-year	5,450	0.0	0.0

Total Scour

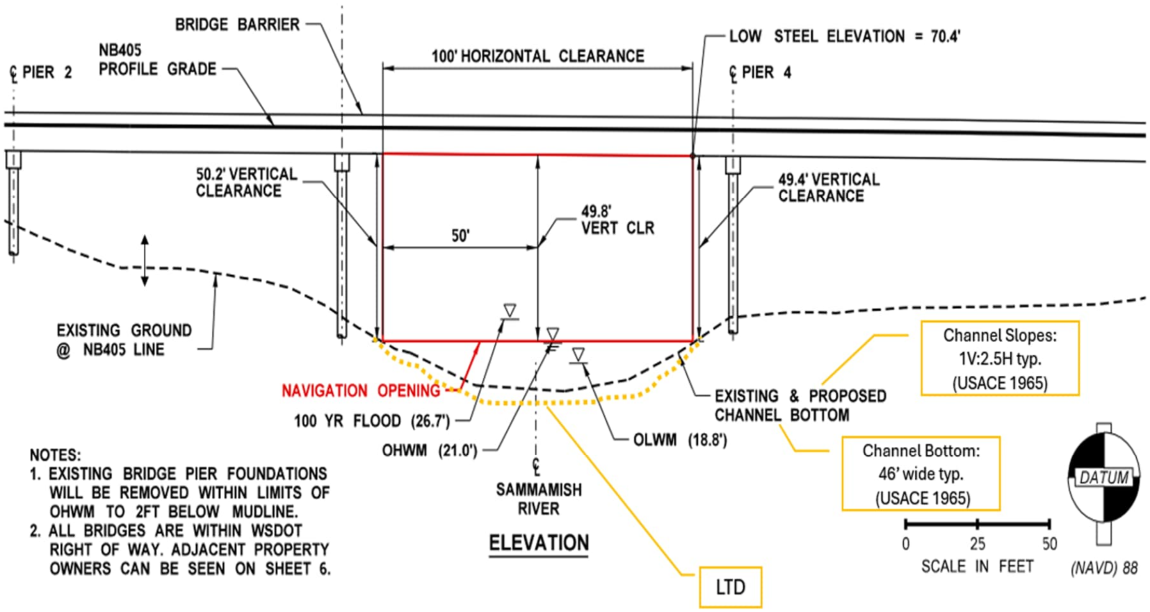
Total scour is the sum of long-term degradation, contraction scour, and local scour. **Table 4** presents a summary of the total scour estimates for the proposed Sammamish River bridge crossing at the I-405/SR 522 interchange.

Figure 5 provides a conceptual depiction of total scour at the proposed Sammamish River bridge crossing.

Table 4. Scour analysis summary

Calculated Scour Components and Total Scour for I-405/SR 522 at the Sammamish River		
Long-term degradation (feet)	2.4	
	Scour design flood*	**Scour check flood***
Contraction scour (feet)	0.0	0.0
Local pier scour (feet)	0.0	0.0
Total depth of scour (feet)	**2.4**	**2.4**

*The scour design flood as defined by the WSDOT *Hydraulics Manual* (2023) is the greater of the 100-year or projected 2080 100-year discharge; taken here as the projected 2080 100-year event. Similarly, the scour check flood is the greater of the 2080 100-year or 500-year discharge, which is also the projected 2080 100-year event.



NOTES:
1. EXISTING BRIDGE PIER FOUNDATIONS WILL BE REMOVED WITHIN LIMITS OF OHWM TO 2FT BELOW MUDLINE.
2. ALL BRIDGES ARE WITHIN WSDOT RIGHT OF WAY. ADJACENT PROPERTY OWNERS CAN BE SEEN ON SHEET 6.

Modified from WSDOT (2021). Conceptual Plans Utilized to Obtain Coast Guard Bridge Permit. Sheet 3 of 6. NB405 Mainline.

Figure 5. Conceptual depiction of total scour at the proposed Sammamish River bridge crossing

References

Aquaveo. 2024a. SMS Version 13.3.10.

Aquaveo. 2024b. SMS: SRH-2D Structures. Accessed May 22, 2024. https://www.xmswiki.com/wiki/SMS:SRH-2D_Structures

Arneson, L.A., L.W. Zevenbergen, P.F. Lagasse, and P.E. Clopper. 2012. *Evaluating Scour at Bridges—Fifth Edition, HEC No. 18.* Publication FHWA-HIF-12-003. Fort Collins, CO: Federal Highway Administration.

Black, A., Sofield, D., and Delight, J. 2023. “*Not-Low*” *Opinion Paper for I-405 MP 24.4, Sammamish River Channel Migration Zone*.

FEMA (Federal Emergency Management Administration). 2024. Flood Data Viewers and Geospatial Data. https://www.fema.gov/flood-maps/national-flood-hazard-layer.

GeoEngineers. 2024. *Geotechnical Design Services Project Segment 2 I-405, Brickyard to SR 527 Improvement Project King and Snohomish Counties, Washington*. Prepared for the I-405/Brickyard to SR 527 Design Build Team.

Lagasse, P.F., P.E. Clopper, J.E. Pagan-Ortiz, L.W. Zevenbergen, L.A. Arneson, J.D. Schall, and L.G. Girard. 2009. *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance—Third Edition, HEC No. 20*. Publication FHWA-NHI-09-111. Fort Collins, CO: Federal Highway Administration.

USBR (U.S. Bureau of Reclamation). 2017. SRH-2D Version 3.2.0.

WDFW (Washington Department of Fish and Wildlife). 2024. Culverts and Climate Change. Web application accessed May 21, 2024. https://geodataservices.wdfw.wa.gov/hp/culvert-app/.

WSDOT. 2023. *Hydraulics Manual*. Olympia, Washington. Publication M 23-03.09.

Appendices

Appendix A – Lateral Migration Assessment

Lateral Migration Assessment

I-405, Brickyard to SR 527 Improvement Project: Segment 2 – Sammamish River Bridges

Background

Three new bridges will be constructed across the Sammamish River at the I-405 SR/522 interchange. In addition to a scour analysis of the proposed bridge piers, an assessment of the lateral migration risk has been performed.

Purpose

An opinion paper by Black et al. (2023) found the risk for migration is “not-low” and “require[s] further analysis.” The objective of this assessment is to provide further analysis, including a quantitative measure of the Sammamish River’s potential for lateral migration near the I-405/SR 522 interchange.

Methodology

The Federal Highway Administration (FHWA) *Stream Stability at Highway Structures, HEC No. 20* (Lagasse et al. 2012) was used as the guidance document to assess lateral migration of the Sammamish River. The purpose of this document, commonly referred to as HEC-20, is to provide guidelines for identifying stream instability problems at highway crossings.

Following the general solution procedure presented in HEC-20, the lateral migration risk for the Sammamish River at the I-405 SR 522 interchange has been conducted by performing the following:

- Review of historical channel, bank, and floodplain improvements
- Review of inspection reports for the existing bridges across the Sammamish River at the I-405/SR 522 interchange
- Subject matter expert (SME) review of the 2023 opinion paper by Black et al.
- Rapid assessment method of migration potential

Results

Historical Improvements

The Sammamish River and its watershed are well characterized in existing literature. Recent examples include the *Sammamish River Corridor Action Plan* (TetraTech 2002), the *King County Flood Hazard Management Plan* (King County 2007) and *Update* (King County 2013), Northwest Hydraulic Consultants *Floodplain Mapping Study for the Sammamish River* (NHC 2010), the *Watershed Restoration and Enhancement Plan WRIA 8 - Cedar Sammamish Watershed* (Washington State Department of Ecology 2022), and the *2024 King County Flood Management Plan* (King County 2024).

These reports document that the Sammamish River flows approximately 14 miles from Lake Sammamish to Lake Washington, draining approximately 240 square miles. The Sammamish drops only 14 feet in elevation over its 14-mile length. Land uses in floodplain areas include agricultural, residential, and light industrial, with increasing urban development.

Notably, following the United States Army Corps of Engineers (USACE) flood control project in the mid-1960s, the entire 14-mile Sammamish River acts as a flood protection facility (King County 2013). The USACE conducted straightening, deepening, and bank armoring of the Sammamish River channel to reduce seasonal floods. Further work by USACE and King County in 1998 included extensive bank stabilization and revegetation; parts of the river have also occasionally been dredged (King County 2013). No levees are present along the Sammamish River, but dredged material was placed on overbanks during the 1964 USACE flood control project. Rock bank protection was placed in approximately 50 percent of the channel (TetraTech 2002).

Major river flooding, as indicated by US Geological Survey (USGS) stream gage 12125200, has become infrequent since the 1964 USACE flood control project. No major channel migration has been documented, and no channel migration zone has been mapped for the Sammamish River (King County 2013).

Inspection Reports

Inspection reports for existing bridges over the Sammamish River at the I-405/SR 522 interchange are available through the National Bridge Inventory (FHWA 2024). Information relevant to lateral migration found in these reports includes bridge substructures, stream channel and channel protection, and scour.

The most recent reports (November 2022) indicate that existing bridge substructures are in “good condition,” channel banks are “protected or well vegetated,” embankment protection are “not required or are in good condition,” and scour is “within the limits of footings or piles” (see **Attachment A**).

SME Review of 2023 Opinion Paper

The 2023 Opinion Paper by Black et al. assessed migration potential of the Sammamish River within the vicinity of I-405 milepost (MP) 24.4, by following the guidance of Rapp and Abbe (2003). It primarily consists of a review and comparison of historical and current conditions, relying on 1936, 1998, and 2021 aerial photographs and 1963 USACE realignment design plan sheets.

Key findings by Black et al. (2023) include the following:

- Human modification to the Sammamish River dates to the 1870s.
- Prior to 1964, the Sammamish River near MP 24.4 seasonally flooded due to backwater from its confluence with Lake Washington.
- The USACE straightened and deepened the channel to its present alignment in 1964.
  - Berms were constructed along channel banks.
  - A significant portion of banks (~50 percent) were armored with riprap to prevent erosion.
- Little to no movement of the channel has taken place since 1964.
- King County issued permits in 2017 to repair damaged banks.
  - There is evidence of slow erosion to the north bank where natural channel meanders were removed.
- A 2023 site visit was conducted.
  - North bank material was fine granular soil and potentially mobile.
  - Portions of the bank were possibly sloughing into the river.
  - Long-term local pier scour of bank material was noted near existing bridge piers.
  - An existing corrugated metal pipe projects beyond the south bank, indicating erosion or sloughing.

Rapid Assessment

A rapid assessment of channel stability for the Sammamish River was performed, following the method developed by Johnson (2005), as described in the HEC-20 manual (Lagasse et al. 2012). The rapid channel stability assessment scores 13 independent, equally weighted stream characteristics, called “stability indicators.” The sum of these 13 scores then provides an overall relative measure of channel stability. Although in part based on subjective observations, the rapid assessment provides a quantitative rating that can be used to judge whether more extensive geomorphic analyses are needed. A breakdown of the 13 stream characteristics and their respective scoring for the Sammamish River is found in **Table 1.**

To be conservative, this rapid assessment of the Sammamish River used the worst (e.g., highest) score for each rating category. For example, if a rating of “fair” was assigned, that indicator was scored a 9 out of the range of 7–9. Applying this rule to each of the 13 stream characteristics, the Sammamish River rapid assessment score was determined to be 84 out of a possible 156, which indicates stability for the river is categorized as “good.”

Finally, Table 5.6 in HEC-20 (Lagasse et al. 2012) was used to show that the Sammamish River—taken as an engineered channel —near the I-405/SR 522 interchange has “good” channel stability and that there is low potential for channel migration.

FHWA Tables 5.5 and 5.6 are provided in **Attachment B**.

Table 1. FHWA Rapid Assessment of Channel Migration Scoring for Sammamish River

Stability Indicator	Rating (Score)	Relevant FHWA Description[1]	AECOM Justification
Watershed and floodplain activity	Fair (9)	Frequent disturbances in the watershed, including…construction of buildings, roads, or other infrastructure. Urbanization over a significant portion of the watershed.	USGS Gage Station 12126500, just downstream of the crossing, reports the watershed basin is ~17% impervious (USGS 2024).
Flow habitat	Excellent (3)	Perennial stream with no flashy behavior.	Channelization by the USACE in 1966 significantly reduced the frequency and severity of flooding (King County 2007).
Channel pattern	Excellent (3)	Straight to meandering with low radius of curvature; primarily suspended load.	The Sammamish River is straight to meandering ~1,000 feet upstream and downstream of the crossing (NHC 2010).
Channel confinement	Fair (9)	Moderate confinement in…channel walls; levees are moderate in size and have minimal setback from the river	Minimal overtopping of banks during 100-year and 500-year floods indicate channel is moderately confined.
Bed material	Poor (12)	Very loose assortment with no packing. Large amounts of material <4 millimeters. Fraction of sand >70%.	Historic sediment distributions show bed material is >70% sands (GeoEngineers 2024).
Bar development	Excellent (3)	For S>0.02 and W/Y<12, no bars are evident.[2]	No bars evident in field visit photos. W/Y = 100/21 = 4.76 (WSDOT 2021).
Obstructions	Excellent (3)	Rare or not present.	Maintenance practices include keeping the channel clear [of obstructions] (King County 2007).
Bank soil	Poor (12)	Loamy sand to sand; noncohesive material; unconsolidated mixture of glacial or other materials.	Historic bore logs characterize soil as cohesionless alluvium (GeoEngineers 2024).
Average bank slope	Fair (9)	Bank slopes to 1H:1V in noncohesive or unconsolidated materials.	Average bank slopes are approximately 45 degrees (WSDOT 2021).
Vegetation or bank protection	Good (6)	Medium band of woody vegetation with 70-90% plant density and cover…oriented 80-90 degrees from horizontal.	Large areas of vegetation identified in plan view (NHC 2010). Black et al. (2023) Figures 4 – 6 show vegetation orientation.
Bank cutting	Good (6)	Some intermittently along channel bends and at prominent constrictions.	Black et al. (2023) Figures 4 and 5 indicate bank scour around existing piers.
Bank failure	Good (6)	Evidence of infrequent and/or minor mass wasting. Mostly healed over with vegetation. Relatively constant channel width and minimal scalloping of banks.	Black et al. (2023) Figure 3 indicates minor bank sloughs.
Upstream distance to bridge from meander impact point	Excellent (3)	More than 115 feet; bridge is well aligned with river flow.	More than 115 feet from bridge to the confluence of North Creek with the Sammamish River. Proposed piers are aligned with river flow direction.

[1] See FHWA Table 5.5 for a full description of each stability indicators’ category.
[2] “S” = channel slope; “W” = channel width; “Y” = channel depth.

Conclusion

The risk of lateral migration for the Sammamish River near the I-405/SR 522 interchange was assessed. A literature review of the river and its watershed was performed, focused on historical engineered improvements to the river channel and banks. Inspection reports for existing bridges near the proposed crossing were documented. An SME reviewed previous assessments of lateral migration. Finally, a FHWA rapid assessment method of channel migration was conducted.

These efforts provide an overview of the Sammamish River's geomorphic condition, a qualitative evaluation of lateral migration, and a quantitative measure of channel migration potential (both vertical and lateral).

The key findings of this lateral migration assessment are as follows:

- The Sammamish River was straightened, deepened, and armored in the mid-1960s by the USACE.
- No levees are present along the Sammamish River. However, dredged material was used to create berms atop channel banks.
- The Sammamish River can be considered an engineered channel that receives regular maintenance (including bank stabilization and revegetation).
- The Sammamish River is a low-gradient stream, dropping ~14 feet over ~14 miles.
- Floods are infrequent and well contained by the channel.
- Bank and bed materials are considered poor for geomorphic stability.
- Little to no movement of the river channel has occurred since 1964.

Despite the poor quality of the Sammamish River's bed and bank materials, all other factors indicate that the risk of lateral migration near the I-405/SR 522 interchange is low.

References

Black, A., Sofield, D., and Delight, J. 2023. *"Not-Low" Opinion Paper for I-405 MP 24.4, Sammamish River Channel Migration Zone*.

FHWA (Federal Highway Administration). 2024. *Bridge Summary Report – Structure Number 0008382B0000000*. LTBP InfoBridge (Web Application). Accessed June 12, 2024. https://infobridge.fhwa.dot.gov/Data/BridgeDetail/24999372.

GeoEngineers. 2024. *Geotechnical Design Services, Project Segment 2, I-405 Brickyard to SR 527 Improvement Project*. Prepared for I-405/Brickyard to SR 527 Design Build Team.

King County. 2007. *2006 King County Flood Hazard Management Plan.* Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division.

King County. 2013. *2013 King County Flood Hazard Management Plan Update and Progress Report*. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division.

King County. 2024. *2024 King County Flood Management Plan*. King County, Washington. King County Department of Natural Resources and Parks, Water and Land Resources Division. Seattle, Washington.

Lagasse, P.F., Zevenbergen, L.W., Spitz, W.J., and Arneson, L.A. 2012. *Stream Stability at Highway Structures – Fourth Edition, HEC No. 20*. Publication FHWA-HIF-12-004. Fort Collins, CO: Federal Highway Administration.

NHC (Northwest Hydraulic Consultants). 2010. *Floodplain Mapping Study for the Sammamish River*.

Rapp, C.F., and Abbe, T.B. 2003. *A Framework for Delineating Channel Migration Zones.* Washington State Department of Ecology, Publication No. #03-16-027.

Washington State Department of Ecology. 2022. *Watershed Restoration and Enhancement Plan WRIA 8 – Cedar Sammamish Watershed*. Publication 22-11-014.

TetraTech, Inc. 2002. *Sammamish River Corridor Action Plan*. Prepared for US Army Corps of Engineers, in partnership with King County Department of Natural Resources and Parks, Water and Land Resources Division.

USGS (United States Geologic Survey). 2024. StreamStats (Web Application). Accessed June 10, 2024. https://streamstats.usgs.gov/ss/.

WSDOT (Washington Department of Transportation). 2021. *Conceptual I-405 Sammamish River Bridges Plans*. Prepared for US Coast Guard.

Attachments

Attachment A – National Bridge Inventory (NBI) Bridge Summary Report (0008382B0000000)

Attachment B – HEC-20 Rapid Assessment Tables 5.5 – 5.8

Attachment C – NHC 2010 Sammamish River Workmap Plate 3

Attachment A – National Bridge Inventory (NBI) Bridge Summary Report (0008382B0000000)

Bridge Summary Report

State Name (1): 53 - Washington **Structure Number (8):** 0008382B0000000 **Inspection Date (90):** November 2022

Identification and Location

Highway Agency District (2): 01 - Northwest Region
County Name (3): 033 - King County
Place Code (4): 0
Features Intersected (6A): SR 522 SAMMAMISH R
Facility Carried By Structure (7): I-405
Location (9): 8.7 N JCT SR 520
Mile Point, miles (11): 23.53
Latitude, decimal (16): 47.75564
Longitude, decimal (17): -122.18564
Maintenance Responsibility (21): 1 - State Highway Agency
Owner (22): 1 - State Highway Agency
Year Built (27): 1968
Historical Significance Code (37): 5 - Not National Register eligible
Neighboring State Code (98A):
Neighboring State Percent Responsibility (98B):
Border Bridge Structure Number (99):
Parallel Structure Designation Code (101): L - Left of set in opposite d ...
Year Reconstructed (106): 1997

Structure Type and Materials

Main Span Material (43A): 2 - Concrete Continuous
Main Span Design (43B): 5 - Box Beam or Girders - Multiple
Approach Spans Material (44A): 0 - Other Material Main or N/A (No Ot ...
Approach Spans Design (44B): 0
Number of Spans in Main Unit (45): 13
Number of Approach Spans (46): 0
Deck Structure Type Code (107): 1 - Concrete Cast-in-Place
Wearing Surface Type Code (108A): 3 - Latex Concrete or similar addi ...
Membrane Type Code (108B): 0 - None
Deck Protection Code (108C): 0 - None

Dimensions and Clearances

Inventory Route - Minimum Vertical Clearance, ft. (10): 16.4
Approach Roadway Width, ft. (32): 40
Bridge Median Code (33): 0 - No Median
Skew Angle, degrees (34): 0
Structure Flared (35): 1 - Flared
Navigation Control Code (38): 0 - No Permit Required
Navigation Vertical Clearance, ft. (39): 0
Navigation Horizontal Clearance, ft. (40): 0
Inventory Route Total Horizontal Clearance, ft. (47): 40
Length of Maximum Span, ft. (48): 122
Structure Length, ft. (49): 1410.1
Left Curb/Sidewalk Width, ft. (50A): 0
Right Curb/Sidewalk Width, ft. (50B): 0.7
Bridge Roadway Width Curb to Curb, ft. (51): 40
Deck Width - Out to Out, ft. (52): 43
Minimum Vertical Clearance Over Bridge Roadway, ft. (53): 16.4
Minimum Vertical Underclearance, ft. (54B): 15.9
Minimum Lateral Underclearance on Right, ft. (55B): 5.9
Minimum Lateral Underclearance on Left, ft. (56): 10.4
Pier Abutment Protection Code (111):
Minimum Vertical Clearance - Lift Bridge, ft. (116):
Deck Area, sq. ft.: 60604.8

Inspection

Inspection Date (90): November 2022
Designated Inspection Frequency (91): 24
Fracture Critical Details (92A): N -Not needed
Underwater Inspection (92B): N -Not needed
Other Special Inspection (92C): N
Fracture Critical Detail Date (93A):
Underwater Inspection Date (93B):
Other Special Inspection Date (93C):

Condition Rating and Evaluation

Bridge Railings (36A): 1 - Meets currently acceptable standards
Transitions (36B): 1 - Meets currently acceptable standards
Approach Guardrail (36C): 1 - Meets currently acceptable standards
Bridge Guardrail Ends (36D): 1 - Meets currently acceptable standard ...
Deck Condition Rating (58): 6 - Satisfactory Condition
Superstructure Condition Rating (59): 6 - Satisfactory Condition
Substructure Condition Rating (60): 7 - Good Condition
Channel and Channel Protection Condition Rating (61): 8 - Channel pr ...
Culverts Condition Rating (62): N - Not a culvert
Structural Evaluation Appraisal (67): 6 - Equal to Present Minimum C ...
Deck Geometry Appraisal (68): 3 - Intolerable; High Priority Correct ...
Underclearance Appraisal Vertical and Horizontal (69): 3 - Intolerab ...
Waterway Adequacy Appraisal (71): 8 - Equal to Present Desirable Cri ...
Approach Alignment Appraisal (72): 8 - Equal to Present Desirable Cr ...
Scour Critical Bridges Code (113): 5 - Foundations Stable

Load Rating and Posting

Design Load Descriptor (31): 6 - MS 18+Mod / HS 20+Mod
Structure Operational Status Code (41): A - Open
Operating Rating Method Code (63): 1 - Load Factor(LF)
Operating Rating, US tons (64): 58
Inventory Rating Method Code (65): 1 - Load Factor(LF)
Inventory Rating, US tons (66): 34.9
Bridge Posting Code (70): 5 - Equal to or above legal loads

Traffic and Roadway Data

Record Type (5A): 1 - On Structure
Route Signing Prefix Code (5B): 1 - Interstate Highway
Designated Level of Service Code (5C): 1 - Mainline
Route Number (5D): 00405
Directional Suffix Code (5E): 0 - Not Applicable
Base Highway Network (12): 1 - On Base Network
Bypass or Detour Length, miles (19): 1.2
Toll Status (20): 3 - On Free Road
Functional Class Of Inventory Route (26): 11 - Urban Principal Arter ...
Lanes On the Structure (28A): 3
Lanes Under the Structure (28B): 8
Average Daily Traffic (29): 61,031
Year of Average Daily Traffic (30): 2019
Type of Service on Bridge Code (42A): 1 - Highway
Type Of Service Under Bridge Code (42B): 6 - Highway-waterway
STRAHNET Highway Designation (100): 1 - Interstate STRAHNET
Direction of Traffic Code (102): 1 - 1 - way traffic
Inventory Route NHS Code (104): 1 - On NHS
Federal Lands Highways Code (105): 0 - N/A
Average Daily Truck Traffic (Percent ADT) (109): 6
Designated National Truck Network Code (110): 1 - On National Truck ...
Future Average Daily Traffic (114): 86,175
Year of Future Average Daily Traffic (115): 2039

MPO, Political Districts, and Cities

Metropolitan Planning Organization (MPO): 53199100 - Puget Sound Regional Council
U.S. Congressional District: 01 - Congressional District 1
State Senate District: 001 - State Senate District 1
State House District: 001 - Legislative District 1
City (InfoBridge Place Code-Name): 7380 - Bothell city

Attachment B – HEC-20 Rapid Assessment Tables 5.5 – 5.8

5.4.3 Stability Indicators

The 13 indicators identified for this study are listed in Table 5.5 (FHWA 2006). For each indicator, a rating of poor, fair, good, or excellent can be assigned based on descriptors listed in the table. After a rating is assigned for each of the indicators, an overall score is obtained by summing the 13 ratings. This total score provides the overall relative stability of the channel. Table 5.6 provides the range of scores for Excellent, Good, Fair, and Poor ratings of stability for each of the three divisions of stream channels. The simplified data collection sheets of Appendix E assist in obtaining information necessary to score the stability indicators.

Occasionally, rating of each of the thirteen factors for a particular bridge will result in one factor which stands out as being much higher (worse) than the others. This situation is worth noting and making additional observations during future inspections.

5.4.4. Lateral and Vertical Stability

The indicators in Table 5.5 can be divided into those that indicate vertical stability and those that indicate lateral stability; vertical stability is described by indicators 4–6, while lateral stability is indicated by indicators 8 –13. Each of the lateral and vertical stability scores, based on summing the appropriate ratings, were normalized by the total number of points possible in each category so that they could be represented as a fraction and more readily compared. If the lateral fraction is greater than the vertical fraction, then it can be expected that channel instability is expressed primarily in the lateral direction. Lateral and vertical processes may be ongoing simultaneously or they may be occurring differentially; this is not indicated by the assessment method. If both fractions are relatively low, this suggests minimal instability in either direction.

As an example, if the lateral score is significantly higher than the vertical score (say for example, 0.93 versus 0.67), indicating that lateral instability is dominant. If, on the other hand, the vertical score fraction is greater than the lateral, then bed degradation is the dominant source of instability. If both scores are high, then the channel is unstable due to both lateral and vertical processes. For example, if a channel has lateral and vertical fractions of 0.86 and 0.92, this indicates that the channel is both degrading and widening.

5.4.5. Examples

In this section, examples are provided using the stream stability assessment method. Figures 5.11 to 5.14 show four streams, along with their overall ratings. The streams represent a wide range of conditions, stream types, and physiographic regions, including Pacific Coastal (Figure 5.11), Great Plains (Figure 5.12), Atlantic Coastal (Figure 5.13), and New England (Figure 5.14). Tables 5.7 and 5.8 provide details of the ratings based on the stream stability assessment method. Indicators 1 and 3 were primarily based on a view of the area surrounding the bridge as seen from satellite imagery or aerial photos. Viewing the bridge and surrounding area from above provides a "big picture" view that cannot be easily obtained in a short visit to a bridge. The overall stability was obtained from Table 5.6, in each case using the category of "pool-riffle, plane-bed, dune-ripple, and engineered channels." The lateral and vertical fractions of stability indicate that in each case neither lateral nor vertical problems predominate.

Table 5.5. Stability indicators, descriptions, and ratings. Range of values in ratings columns provide possible rating values for each factor.

Stability Indicator	Ratings			
	Excellent (1-3)	Good (4-6)	Fair (7-9)	Poor (10-12)
1. Watershed and floodplain activity and characteristics	Stable, forested, undisturbed watershed.	Occasional minor disturbances in the watershed, including cattle activity (grazing and/or access to stream), construction, logging, or other minor deforestation. Limited agricultural activities.	Frequent disturbances in the watershed, including cattle activity, landsliding, channel sand or gravel mining, logging, farming, or construction of buildings, roads, or other infrastructure. Urbanization over significant portion of watershed. 9	Continual disturbances in the watershed. Significant cattle activity, landsliding, channel sand or gravel mining, logging, farming, or construction of buildings, roads, or other infrastructure. Highly urbanized or rapidly urbanizing watershed.
2. Flow habit	Perennial stream with no flashy behavior 3	Perennial stream or ephemeral 1st order stream with slightly increased rate of flooding	Perennial or intermittent stream with flashy behavior	Extremely flashy; flash floods prevalent mode of discharge; ephemeral stream other than 1st order stream
3. Channel pattern	Straight to meandering with low radius of curvature; primarily suspended load 3	Meandering, moderate radius of curvature; mix of suspended and bed loads; well maintained engineered channel	Meandering with some braiding; tortuous meandering; primarily bed load; poorly maintained engineered channel.	Braided; primarily bed load; unmaintained engineered channel.
4. Entrenchment / channel confinement	Active floodplain exists at top of banks; no sign of undercutting infrastructure; no levees	Active floodplain abandoned, but is currently rebuilding; minimal channel confinement; infrastructure not exposed; levees are low and set well back from the river	Moderate confinement in valley or channel walls; some exposure of infrastructure; terraces exist; floodplain abandoned; levees are moderate in size and have minimal setback from the river. 9	Knickpoints visible downstream; exposed water lines or other infrastructure; channel width to top of banks ratio small; deeply confined; no active floodplain; levees are high and along the channel edge.
5. Bed material Fs = approximate portion of sand in the bed	Assorted sizes tightly packed, overlapping, and possibly imbricated. Most material > 4 mm. Fs < 20%	Moderately packed with some overlapping. Very small amounts of material < 4 mm. 20 < Fs < 50%	Loose assortment with no apparent overlap. Small to medium amounts of material < 4 mm. 50 < Fs < 70%	Very loose assortment with no packing. Large amounts of material < 4 mm. Fs > 70% 12
6. Bar development S = Slope W/Y = Width to Depth ratio	For S < 0.02 and W/Y > 12, bars are mature, narrow relative to stream width at low flow, well vegetated, and composed of coarse gravel to cobbles. For S > 0.02 and W/Y < 12, no bars are evident. 3	For S < 0.02 and W/Y > 12, bars may have vegetation and/or be composed of coarse gravel to cobbles, but minimal recent growth of bar evident by lack of vegetation on portions of the bar. For S > 0.02 and W/Y < 12, no bars are evident.	For S < 0.02 and W/Y > 12, bar widths tend to be wide and composed of newly deposited coarse sand to small cobbles and/or may be sparsely vegetated. Bars forming for S > 0.02 and W/Y < 12.	Bar widths are generally greater than ½ the stream width at low flow. Bars are composed of extensive deposits of fine particles up to coarse gravel with little to no vegetation. No bars for S < 0.02 and W/Y > 12.
7. Obstructions, including bedrock outcrops, armor layer, large woody debris jams, grade control, bridge bed paving, revetments, dikes or vanes, riprap	Rare or not present. 3	Occasional, causing cross currents and minor bank and bottom erosion.	Moderately frequent and occasionally unstable obstructions, cause noticeable erosion of the channel. Considerable sediment accumulation behind obstructions.	Frequent and often unstable causing a continual shift of sediment and flow. Traps are easily filled causing channel to migrate and/or widen.

Table 5.5. Stability indicators, descriptions, and ratings. Range of values in ratings columns provide possible rating values for each factor.

Stability Indicator	Ratings			
	Excellent (1-3)	Good (4-6)	Fair (7-9)	Poor (10-12)
8. Bank soil texture and coherence	Clay and silty clay; cohesive material	Clay loam to sandy clay loam; minor amounts of noncohesive or unconsolidated mixtures; layers may exist, but are cohesive materials.	Sandy clay to sandy loam; unconsolidated mixtures of glacial or other materials; small layers and lenses of noncohesive or unconsolidated mixtures	Loamy sand to sand; noncohesive material; unconsolidated mixtures of glacial or other materials; layers or lenses that include noncohesive sands and grave 12
9. Average bank slope angle (where 90° is a vertical bank) V = Vertical H = Horizontal	Bank slopes < 3H:1V (18°) for noncohesive or unconsolidated materials to < 1:1 (45°) in clays on both sides	Bank slopes up to 2H:1V (27°) in noncohesive or unconsolidated materials to 0.8:1 (50°) in clays on one or occasionally both banks	Bank slopes to 1H:1V (45°) in noncohesive or unconsolidated materials to 0.6:1 (60°) in clays com 9 on one or both banks.	Bank slopes over 45° in noncohesive or unconsolidated materials or over (60°) in clays common on one or both banks
10. Vegetative or engineered bank protection	Wide band of woody vegetation with at least 90% density and cover. Primarily hard wood, leafy, deciduous trees with mature, healthy, and diverse vegetation located on the bank. Woody vegetation oriented vertically. In absence of vegetation, both banks are lined or heavily armored.	Medium band of woody vegetation with 70-90% plant density and cover. A majority of hard wood, leafy, deciduous trees with maturing, diverse vegetation located on the blank. Woody vegetation oriented 80-90° from horizontal with minimal root exposure. Partial lining or armoring of one or both banks. 6	Small band of woody vegetation with 50-70% plant density and cover. A majority of soft wood, piney, coniferous trees with young or old vegetation lacking in diversity located on or near the top of bank. Woody vegetation oriented at 70-80° from horizontal often with evident root exposure. No lining of banks, but some armoring may be in place on one bank.	Woody vegetation band may vary depending on age and health with less than 50% plant density and cover. Primarily soft wood, piney, coniferous trees with very young, old and dying, and/or monostand vegetation located off of the bank. Woody vegetation oriented at less than 70° from horizontal with extensive root exposure. No lining or armoring of banks.
11. Bank Cutting	Little or none evident. Infrequent raw banks, insignificant percentage of total bank.	Some intermittently along 6 channel bends and at prominent constrictions. Raw banks comprises minor portion of bank in vertical direction.	Significant and frequent on both banks. Raw banks comprise large portion of bank in vertical direction. Root mat overhangs.	Almost continuous cuts on both banks, some extending over most of the banks. Undercutting and sod-root overhangs.
12. Mass wasting or bank failure	No or little evidence of potential or very small amounts of mass wasting. Uniform channel width over the entire reach.	Evidence of infrequent and/or minor mass wasting. Mostly healed over with vegetation. Relatively constant channel width and minimal scalloping of banks. 6	Evidence of frequent and/or significant occurrences of mass wasting that can be aggravated by higher flows, which may cause undercutting and mass wasting of unstable banks. Channel width quite irregular and scalloping of banks is evident.	Frequent and extensive mass wasting. The potential for bank failure, as evidenced by tension cracks, massive undercuttings, and bank slumping, is considerable. Channel width is highly irregular and banks are scalloped.
13. Upstream distance to bridge from meander impact point and alignment	More than 115 ft (35 m); bridge is well aligned with river flow 3	66-115 ft (20 - 35 m); bridge is aligned with flow	33 - 66 ft (10 - 20 m); bridge is skewed to flow or flow alignment is otherwise not centered beneath bridge	Less than 33 ft (10 m); bridge is poorly aligned with flow

Sammamish River can be categorized as "Engineered Channel"

Table 5.6. Overall Scores for Three Classifications of Channels.

Category	Score, R		
	Pool-Riffle, Plane-Bed, Dune-Ripple, and Engineered Channels	Cascade and Step-Pool Channels	Braided Channels
Excellent	R < 49	R < 41	N/A
Good	49 ≤ R < 85	41 ≤ R < 70	R < 94
Fair	85 ≤ R < 120	70 ≤ R < 98	94 ≤ R < 129
Poor	120 ≤ R	98 ≤ R	129 ≤ R

Max score (most conservative) = 84
Median score = 71
Min score (least conservative) = 58
Result: **Good** for Engineered Channel

Table 5.8. Lateral and Vertical Stability for Streams in Figures 5.11 – 5.14.

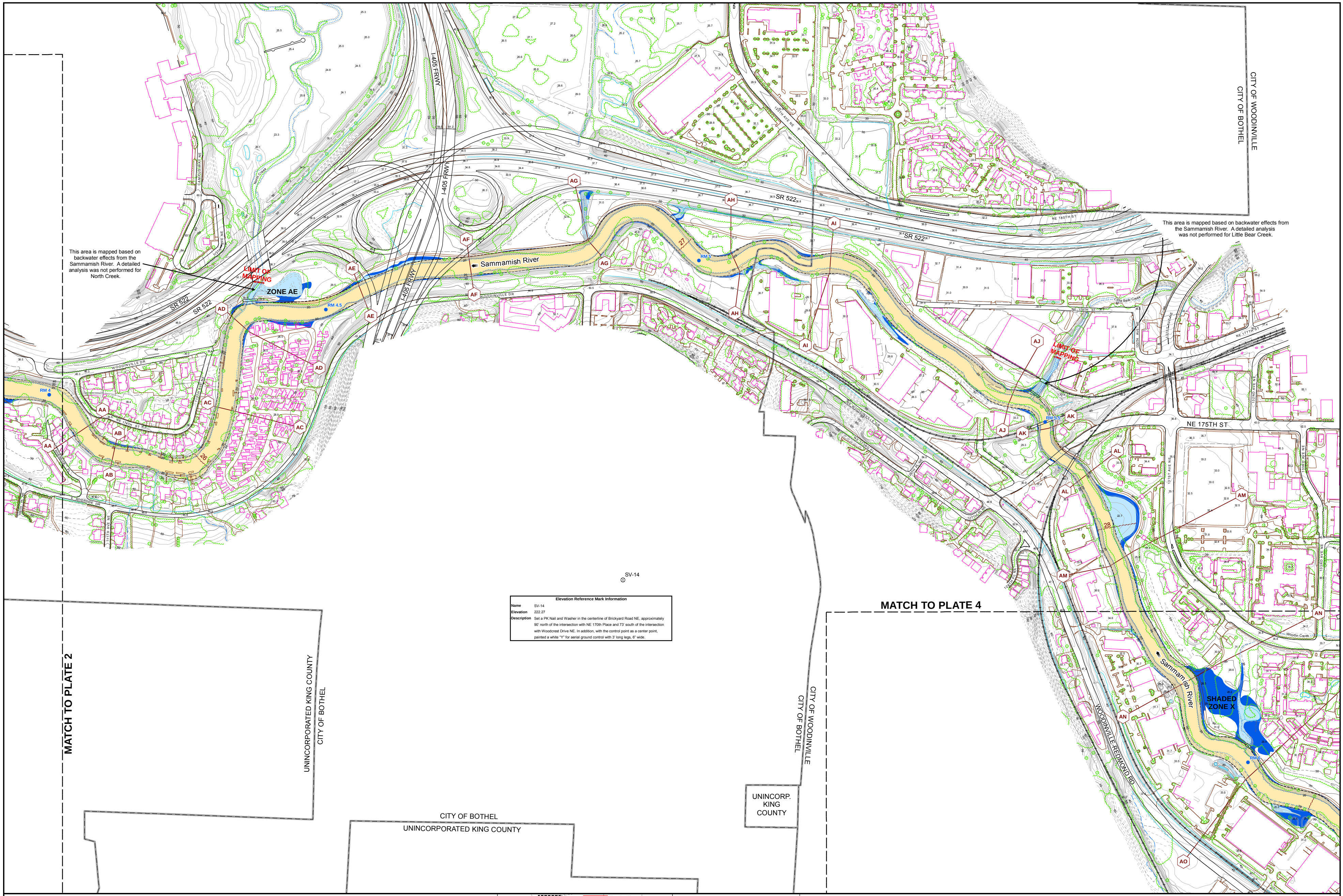
Stream	Lateral	Vertical	Lateral Fraction	Vertical Fraction
Figure 5.11	62	33	0.86	0.92
Figure 5.12	50	26	0.69	0.72
Figure 5.13	25	13	0.35	0.36
Figure 5.14	23	10	0.32	0.28

Lateral Fraction = sum[4:6] = 8+11+2 = 21/36 = 0.58
Vertical Fraction = sum[8:13] = 11+8+5+5+5+2 = 36/72 = 0.50

Channel has roughly equally low-to-moderate potential for both vertical and lateral migration.

See 5.4.4

Attachment C – NHC 2010 Sammamish River Workmap Plate 3



This area is mapped based on backwater effects from the Sammamish River. A detailed analysis was not performed for North Creek.

This area is mapped based on backwater effects from the Sammamish River. A detailed analysis was not performed for Little Bear Creek.

Elevation Reference Mark Information

Name SV-14

Elevation 222.27

Description Set a PK Nail and Washer in the centerline of Brickyard Road NE, approximately 90' north of the intersection with NE 170th Place and 73' south of the intersection with Woodcrest Drive NE. In addition, with the control point as a center point, painted a white "Y" for aerial ground control with 3' long legs, 6" wide.

LEGEND

Base Flood Elevation
Cross-Section
Limit of Mapping
FEMA Floodway
100-year Floodplain (Zone AE)
500-year Floodplain (Shaded Zone X)

Where floodway and 100-year boundaries are coincident, only the floodway boundaries are shown, and where the 100-year and 500-year floodplain boudaries are coincident, only the 100-year boundaries are shown.

25.7 Spot Elevation
Index Contour (10-foot interval)
Index Contour - Obscured
Intermediate Contour (2-foot interval)
Intermediate Contour - Obscured
Road, Bridge
Railroad
Building
Plate Match Line
Fence Line
Corporate Boundary
County Boundary

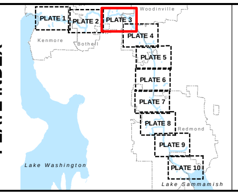
BM1-W2 Elevation Reference Mark
RM 2.5 River Mile Marker and Number
Tree or Tree Canopy Line
Wetland Outline
River Edge, Lake, Stream
Stream Intermittent
Other Hydro Features includes: filtration ponds, ditches, culverts, canals and other unidentified water bodies
Miscellaneous Features includes: playgrounds, athletic fields, curbs, guard rails, driveways, parking lots, unimproved roads, unpaved roads, helipads, wing walls, retaining walls, gates, tanks, stairs, walkways, trails, boat docks, bicycle paths and other unidentified features

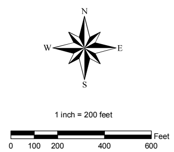
This map has been photogrammetrically compiled from 152.861 mm C.F.L. aerial photos with a photo scale of 1" = 600' to meet National Map Accuracy Standards (NMAS) at a map scale of 1" = 100' (1:1200). Publication or use at any larger scale will void any implied or stipulated accuracy standards. This map has not been comprehensively verified by field checks. Note: Field verification of map accuracy should occur prior to design level tasks that are dependent upon this map. Obscured areas are indicated by dashed contour lines, accuracy within these areas may vary in accordance with NMAS standards.

Topography created by 3Di West of Eugene, Oregon and based upon March 2009 Aerial Photographs (Bergman Photographic Services, Inc.), Horizontal/Vertical control (Pacific GeoMatic Services, Inc. [PGS]), Airborne GPS (Orbitech), and Ground and Bathymetric Surveys (PGS).
Contour Interval: 2-feet
Vertical Datum: NAVD 88, Horizontal Datum: NAD 83 (HARN)
Coordinate System: Washington State Plane North Zone - US feet

NGVD29 = NAVD88 - 3.62
(adjustment estimated for the center point of PLATE 3 using Corpscon 6.0.1 - U.S. Army Corps of Engineers datum conversion program.)

PLATE INDEX





Sammamish River Workmap
King County, Washington

nhc northwest hydraulic consultants

16300 Christensen Rd., Suite 350
Seattle, Washington 98188
(206) 241-6000
www.nhcweb.com

King County
River and Floodplain Management Section

17-May-2010

PLATE 3
Bothell East / Woodinville Town Center
(SR 405 / SR 522)

Q:\21683_Sammamish_River_Floodplain_Analysis\GIS\ArcMap\Sammamish_workmap_2010_5_17.mxd

Appendix B – Long-Term Degradation Calculation

Long-Term Degradation Calculation

I-405, Brickyard to SR 527 Improvement Project: Segment 2 - Sammamish River Bridges

Background

Three new bridges will be constructed across the Sammamish River at the I-405/SR 522 interchange. As part of the total scour analysis of the proposed bridge piers, an estimate of the long-term degradation is required.

Purpose

The purpose of this calculation is to provide a preliminary estimate of long-term degradation in the Sammamish River at the I-405/SR 522 interchange.

Methodology

The Federal Highway Administration *Stream Stability at Highway Structures, HEC No. 20* (Lagasse et al. 2012) was used as the guidance document to assess long-term degradation of the Sammamish River. The purpose of this document, commonly referred to as HEC-20, is to provide guidelines for identifying stream instability problems at highway crossings. It defines degradation as the progressive lowering of a stream channel bed due to erosion, over a relatively long channel length.

Following the procedures presented in HEC-20 Chapter 6.4, the long-term degradation for the Sammamish River at the I-405/SR 522 interchange has been conducted using an equilibrium slope analysis. Two methods (Meyer-Peter Muller and Schoklitsch) are used to estimate the equilibrium slope of the Sammamish River.

Important considerations for using these methods include a selection of an appropriate discharge and base level control. These are discussed in more detail below.

Once the equilibrium slope has been estimated, it is compared to the existing Sammamish River longitudinal slope to calculate potential long-term degradation, as described in HEC-20.

Results

Dominant Discharge

The HEC-20 manual (Lagasse et al. 2012) recommends that initial estimates for the Meyer-Peter Muller method should use the bankfull discharge. This is consistent with the Schoklitsch method, which recommends the dominant discharge for degradation analysis use the bankfull or 2-year return flow (Pemberton and Lara 1984).

Bankfull discharge for the Sammamish River at the I-405/SR 522 interchange is extrapolated as the 2-year flow from known discharges in **Table 1**. Peak discharge for the 10-year, 50-year, 100-year, and 500-year events was generated by the *2010 FEMA FIS Sammamish River HEC-RAS* model. The extrapolated bankfull discharge is 2,894 cubic feet per second (cfs).

The mean bankfull width at the same location is taken as 105.0 feet from the ordinary high-water mark (OHWM) in the *Conceptual I-405 Sammamish River Bridges Plans* (WSDOT 2021).

The unit discharge is the bankfull discharge divided by bankfull width; or 27.6 square feet per second (ft^2/s).

Table 1. Sammamish River peak discharges upstream of the I-405/SR 522 interchange

Return Interval	AEP	Peak Discharge (cfs)
2-year*	0.5	2,894
10-year	0.1	3,347
50-year	0.02	4,090
100-year	0.01	4,374
500-year	0.002	4,982

* Extrapolated using a log-log trendline of annual exceedance probability (AEP) and discharge.

Meyer-Peter Muller Method

For clear-water releases of flow from dams, there is no sediment supply from upstream. In this case, the equilibrium slope at which no bed material moves can be estimated using the Meyer-Peter Muller equation (Lagasse et al. 2012). Presented as equation 6.18 in HEC-20, the Meyer-Peter Muller equation is given as:

$$S_{eq} = 60.1 \frac{\left(D_{50}^{\left(\frac{10}{7}\right)}\right)\left(n^{\left(\frac{9}{7}\right)}\right)}{\left(D_{90}^{\left(\frac{5}{14}\right)}\right)\left(q^{\left(\frac{6}{7}\right)}\right)} \qquad \text{(Eqn. 1)}$$

where,

$$D_{50} := median\ particle\ size\ (ft)$$

$$D_{90} := 90th\ percintile\ particle\ size\ (ft)$$

$$n := Manning's\ roughness\ coeffecient$$

$$q := channel\ discharge\ per\ unit\ width\ (ft^2/s)$$

Table 2 summarizes the input parameters and results for the Meyer-Peter Muller equilibrium slope method (Eqn. 1).

Table 2. Input parameters and Meyer-Peter Muller equilibrium slope

	Input				Output	
Parameter	D_{50} (ft)	D_{90} (ft)	Manning's N	q (ft^2/s)	Equilibrium Slope (ft/ft)	Equilibrium Slope (%)
Value	4.2e-04	8.1e-04	0.032	27.6	7.9e-06	0.0008
Source	Borehole NE-19p-19[1]	Borehole NE-19p-19[1]	AECOM 2024[2]	see **Dominant Discharge**	-	-

[1] GeoEngineers 2024

[2] Manning's parameters were determined in the accompanying *Preliminary Scour Analysis* technical memo.

Schoklitsch Method

The Schoklitsch Method, as presented by Pemberton and Lara (1984), provides an alternative equilibrium slope estimation for zero bedload transport conditions. It is given as:

$$S_{eq} = 0.00174\left(\frac{D_{50} * W}{Q}\right)^{0.75} \quad \text{(Eqn. 2)}$$

where,

$$D_{50} := median\ particle\ size\ (mm)$$

$$W := channel\ width\ (ft)$$

$$Q := dominant\ discharge\ (ft^3/s)$$

Table 3 summarizes the input parameters and results for the Schoklitsch equilibrium slope method (Eqn. 2). Note that Equation 2 uses both metric and imperial units for the various input parameters.

Table 3. Input parameters and Schoklitsch equilibrium slope

	Input			**Output**	
Parameter	D_{50} (mm)	Q (cfs)	W (ft)	Equilibrium Slope (ft/ft)	Equilibrium Slope (%)
Value	0.128	2894.0	105.0	3.1e-05	0.0031
Source	Borehole NE-19p-19[1]	see **Dominant Discharge**	see **Dominant Discharge**	-	-

[1] GeoEngineers 2024

Base Level Control

If degradation initiates at the upstream end of a given reach it progresses downstream until limited by a base level control. Typical base level controls include engineered grade control, geologic outcrops of bedrock (or similarly erosion-resistant material), and confluences with larger streams, lakes, reservoirs, or oceans.

Lake Washington is taken as the base level control for the long-term degradation analysis of the Sammamish River. The I-405/SR 522 crossing of the Sammamish River is conservatively taken as 5.0 miles upstream of its confluence with Lake Washington, as seen in **Attachment A** (King County 2013).

Existing Sammamish Profile

A survey of the Sammamish River's longitudinal profile has not been made available for this analysis. However, as described in the accompanying *Lateral Migration Assessment*, the Sammamish River is well characterized in existing literature.

The Sammamish River drops only 14.0 feet in elevation over approximately 14.0 miles between the outlet weir at Lake Sammamish to the river mouth at Lake Washington (King County 2007). It is important to note that there is a 1,432-foot-long transition zone between the outlet weir at Lake Sammamish and the main river channel, which drops 6.7 feet in elevation. This means that downstream of the transition zone, the Sammamish River only drops 7.3 feet over 13.7 miles for an average slope of 0.01 percent.

This average slope is used for comparison against the Meyer-Peter Muller and Schoklitsch equilibrium slope methods.

Conclusion

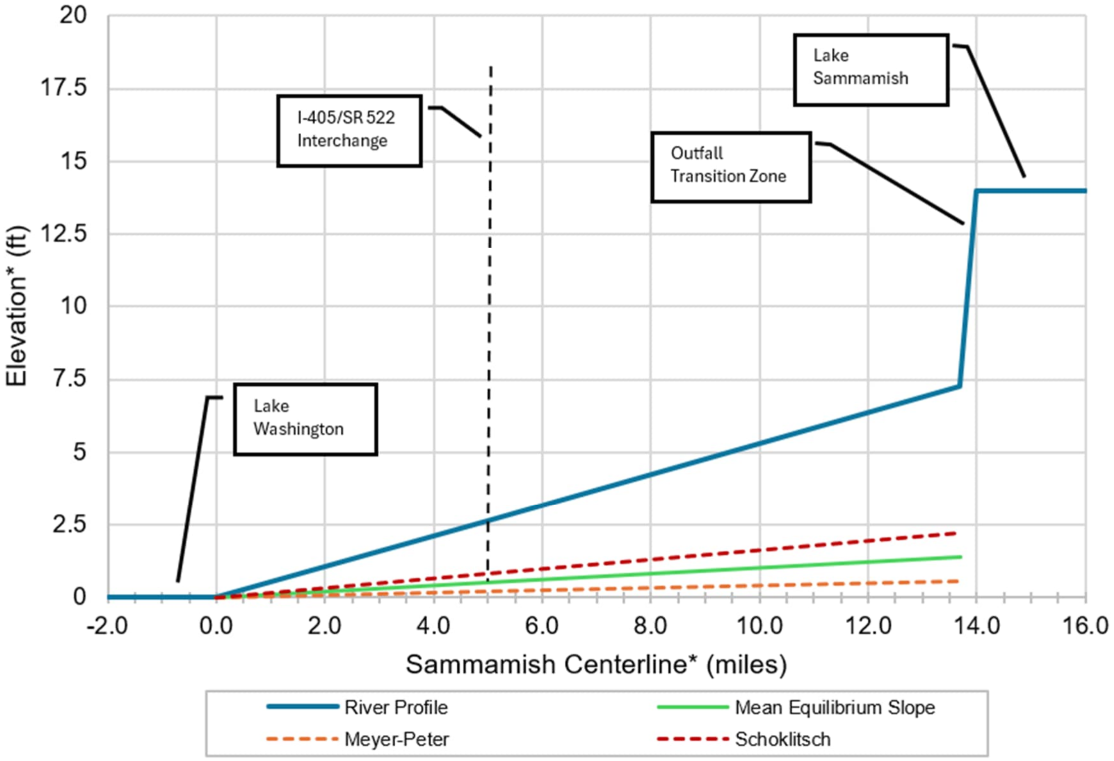
The characterization of the Sammamish River found in the accompanying *Lateral Migration Assessment* indicates that the potential for vertical channel instability (either by aggradation or degradation) is minimal even though the fine-grained streambed material is mobile at low flow velocities.

A comprehensive assessment of the streambed's vertical stability requires considerable sediment transport analyses. By contrast, the equilibrium slope methodologies utilized in this calculation offer a straightforward approach for predicting vertical stability of the Sammamish River channel.

Figure 1 provides a comparison of the Meyer-Peter Muller, Schoklitsch, and their mean equilibrium slopes against the simplified Sammamish River profile (see **Existing Sammamish Profile**). However, if the most conservative result is considered (e.g., Meyer-Peter Muller), then the difference between the existing channel slope and the estimated equilibrium slope could result in up to 2.4 feet of degradation. **Table 4** summarizes the potential long-term degradation for the different equilibrium slope methods.

Table 4. Potential long-term degradation at the I-405/SR 522 interchange

	Sammamish River	Meyer-Peter Muller	Schoklitsch	Mean Equilibrium Slope
Slope (ft/ft)	1.00e-04	7.9e-06	3.1e-05	1.9e-05
Distance from Base Level Control (ft)	-	26,400	26,400	26,400
Long-Term Degradation (ft)	-	2.4	1.8	2.1



* Elevations and centerline distances are approximated from the Sammamish River / Lake Washington confluence.

Figure 1. Potential long-term degradation at the proposed crossing

References

GeoEngineers. 2024. *Geotechnical Design Services, Project Segment 2, I-405 Brickyard to SR 527 Improvement Project*. Prepared for I-405/Brickyard to SR 527 Design Build Team.

King County. 2007. *2006 King County Flood Hazard Management Plan*. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division.

King County. 2013. *2013 King County Flood Hazard Management Plan Update and Progress Report*. Prepared for King County Department of Natural Resources and Parks, Water and Land Resources Division.

Lagasse, P.F., Zevenbergen, L.W., Spitz, W.J., and Arneson, L.A. 2012. *Stream Stability at Highway Structures – Fourth Edition, HEC No. 20*. Publication FHWA-HIF-12-004. Fort Collins, CO: Federal Highway Administration.

Pemberton, E.L., and Lara, J.M. 1984. *Computing Degradation and Local Scour*. Denver, Colorado: Bureau of Reclamation.

WSDOT (Washington Department of Transportation). 2021. *Conceptual I-405 Sammamish River Bridges Plans*. Prepared for U.S. Coast Guard.

Attachments

Attachment A – King County Sammamish River Map

Attachment A – King County Sammamish River Map

Appendix C – Hydraulic Model Results

List of Figures

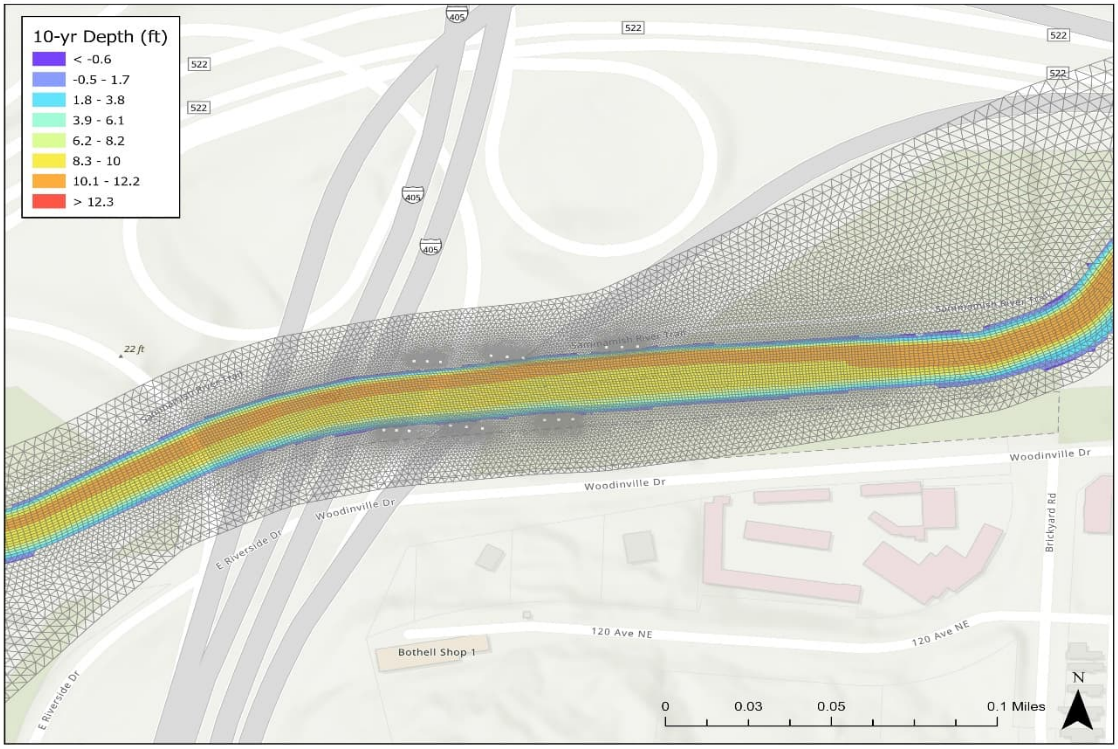


Figure 1. 10-year simulation; water depth (ft).

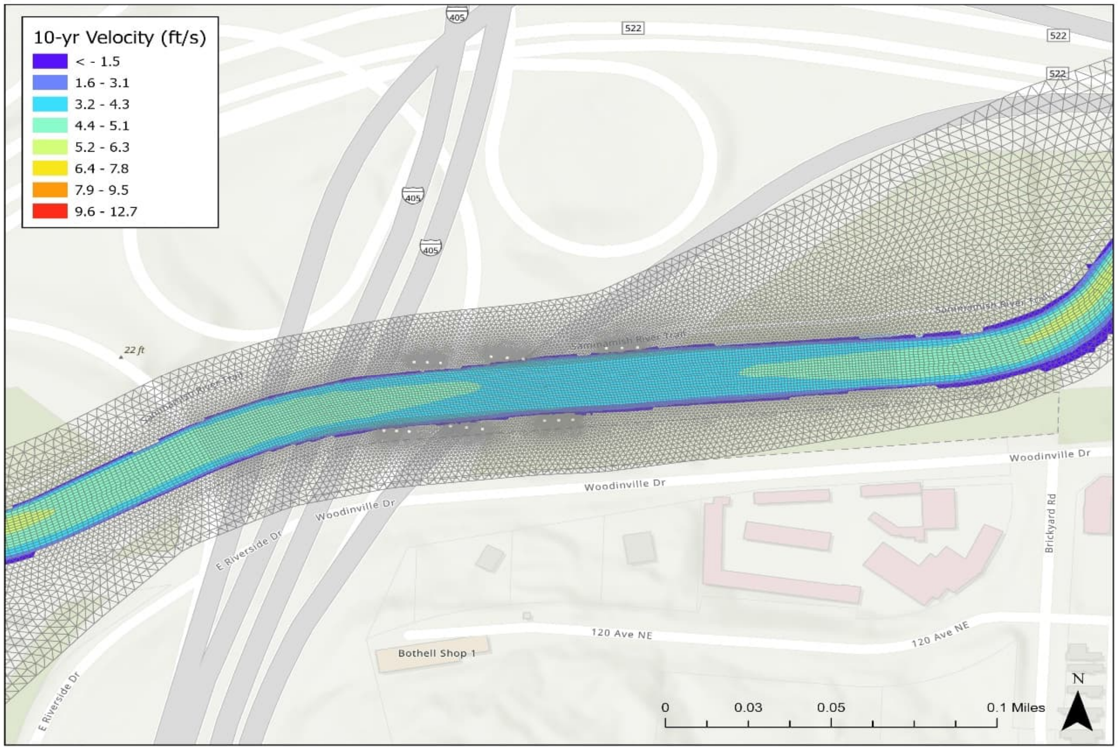


Figure 2. 10-year simulation; water velocity (ft/s).

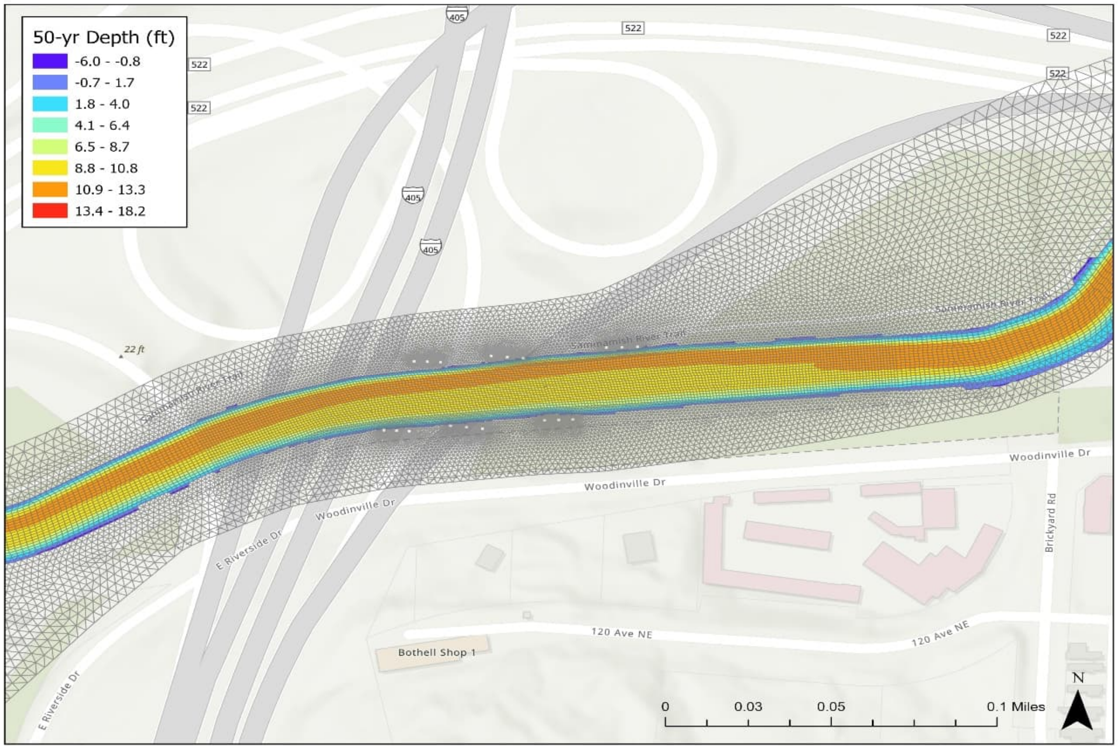


Figure 3. 50-year simulation; water depth (ft).

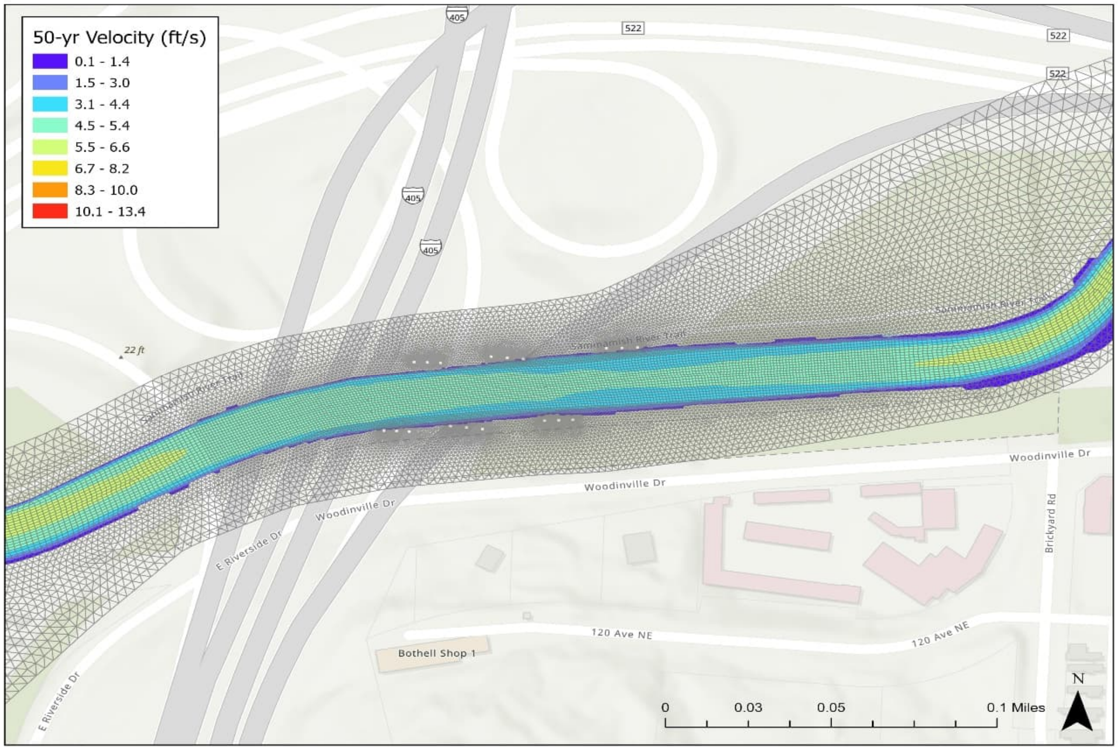


Figure 4. 50-year simulation; water velocity (ft/s).

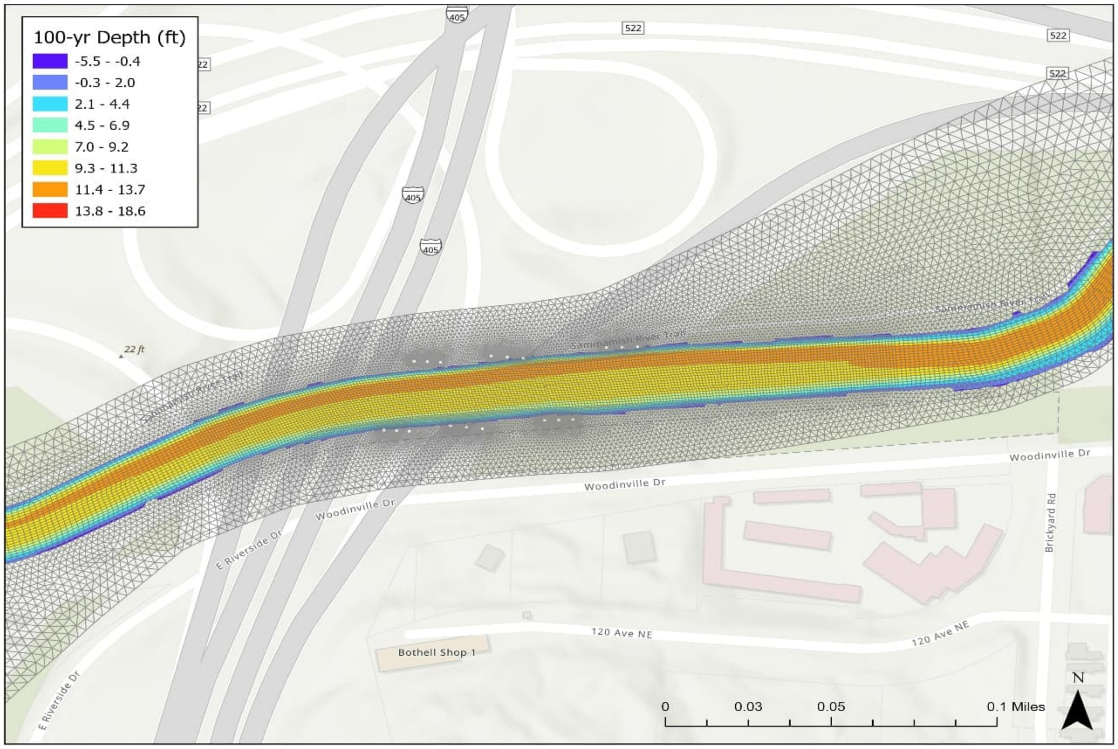


Figure 5. 100-year simulation; water depth (ft).

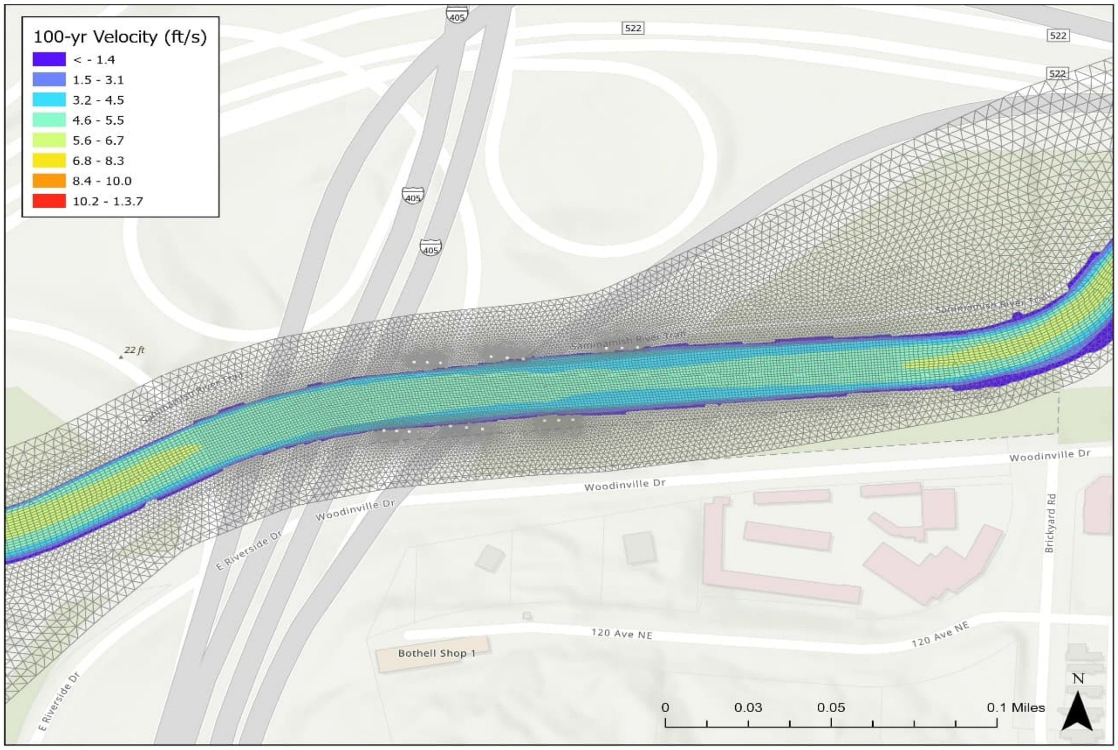


Figure 6. 100-year simulation; water velocity (ft/s).

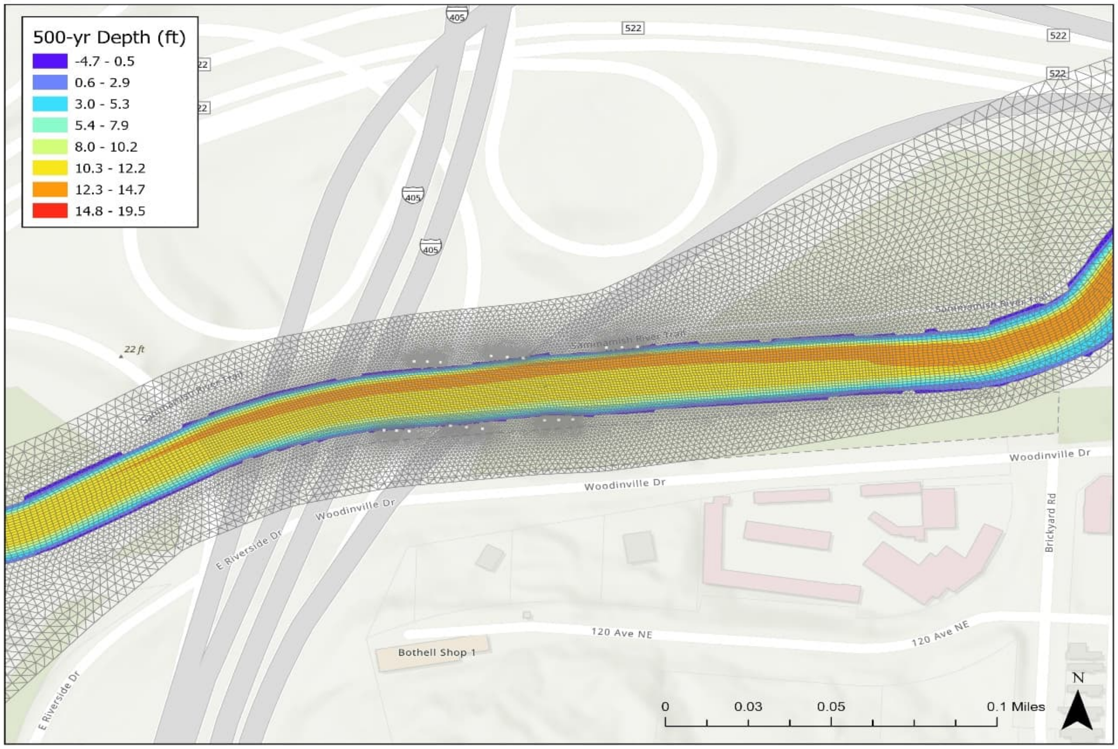


Figure 7. 500-year simulation; water depth (ft).

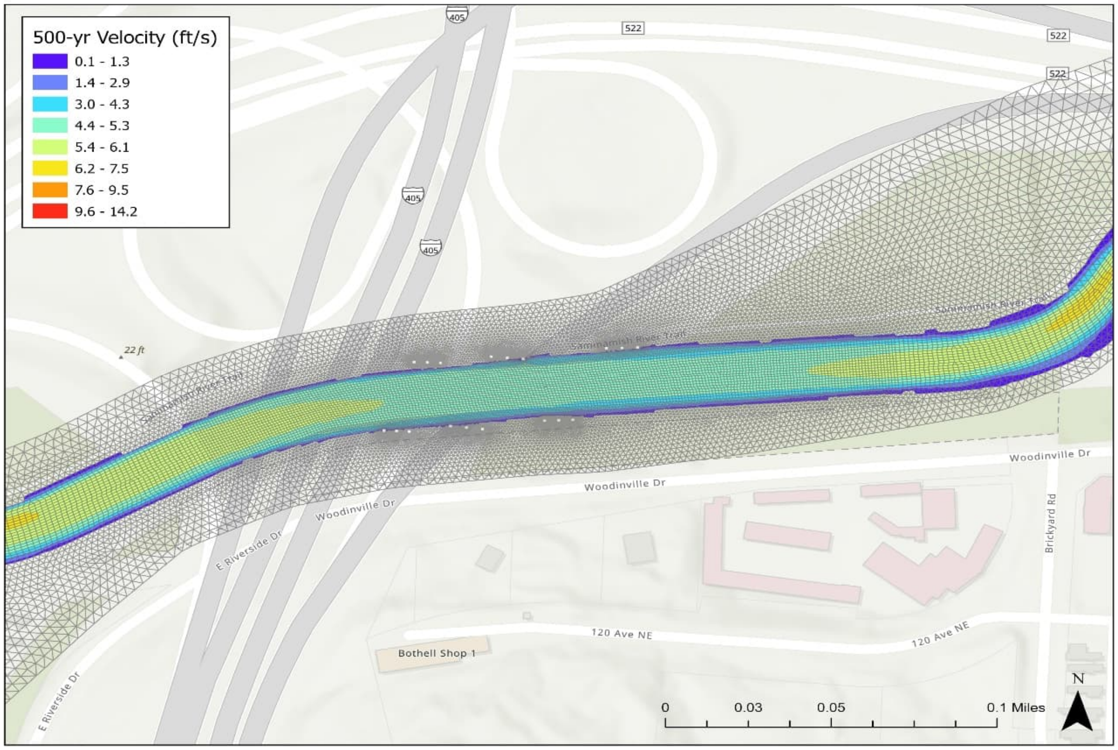


Figure 8. 500-year simulation; water velocity (ft/s).

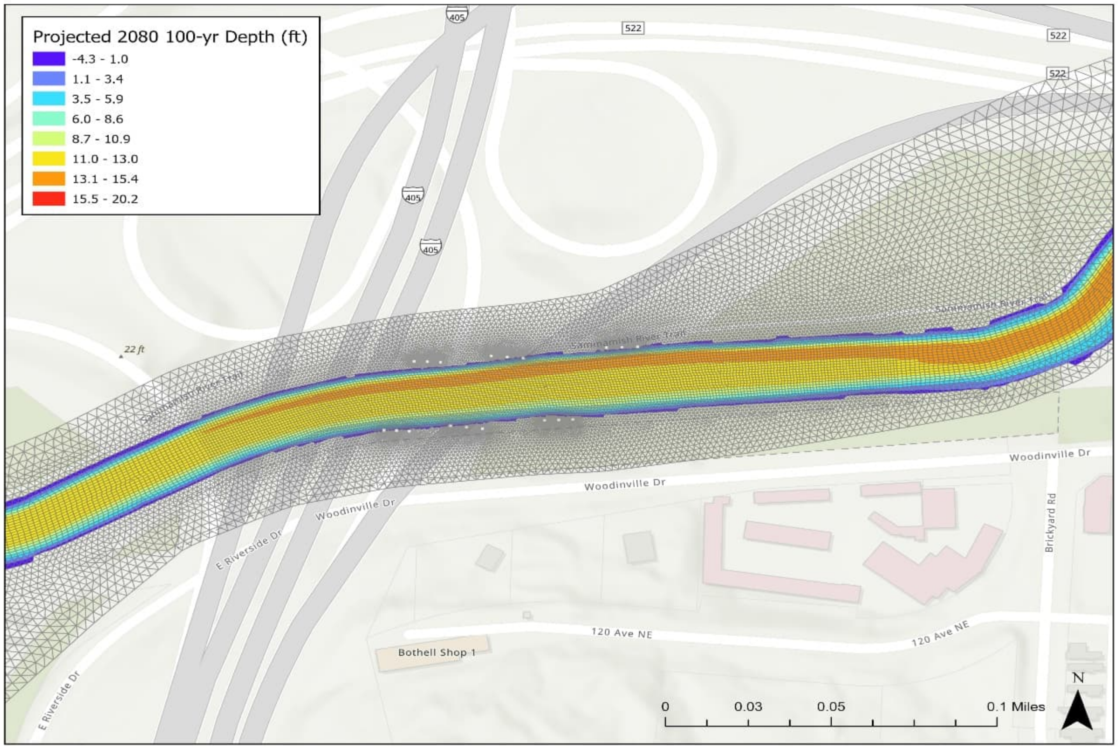


Figure 9. Year 2080 100-year simulation; water depth (ft).

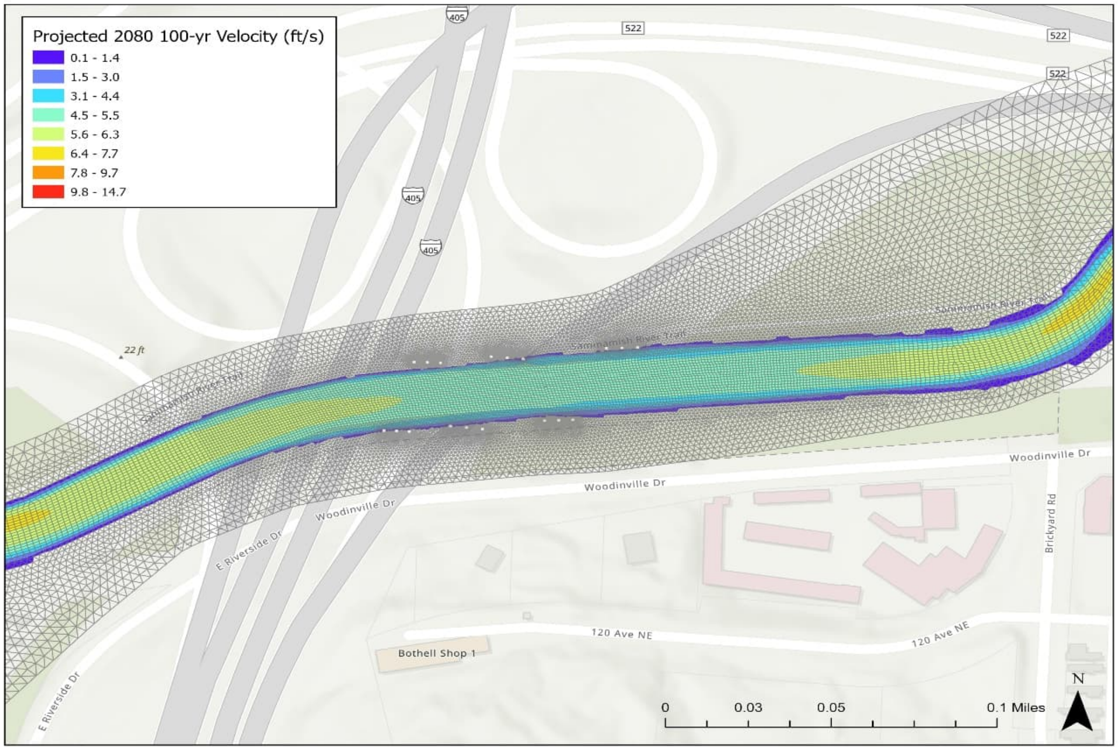


Figure 10. Year 2080 100-year simulation; water velocity (ft/s).

Appendix D – FHWA Hydraulic Toolbox Output

Hydraulic Analysis Report 1

Project Data

Project Title: I-405, Brickyard to SR 527 Improvement Project

Designer: Samuel Boyce (AECOM)

Project Date: Friday, June 14, 2024

Project Units: U.S. Customary Units

Notes: Considers local hydraulics at piers.

Contents

Scenario: 20240603_RefinedMesh-PIERS_10yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 11

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 12

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 15

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 16

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 17

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 18

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Scenario: 20240603_RefinedMesh-PIERS_50yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition
Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed
Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition
Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method
Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method
k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations
Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details
Pier Name: Pier 1

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 2

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 3

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 4

Pier Scour
Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 10

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 11

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 12

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 13

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 14

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 15

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 16

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 17

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 18

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Scenario: 20240603_RefinedMesh-PIERS_100yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition
Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed
Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition
Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method
Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method
k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations
Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details
Pier Name: Pier 1

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 2

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 3

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 4

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 5

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 6

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 7

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 8

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 11

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 12

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Scenario: 20240603_RefinedMesh-PIERS_500yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition
Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed
Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition
Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method
Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method
k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations
Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details
Pier Name: Pier 1

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 2

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 9

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 10

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 11

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 12

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 13

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 14

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Scenario: 20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 9

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 10

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 11

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 12

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 13

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 14

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 0.00 ft

Velocity Upstream of Pier: 0.00 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Scour Summary Table [Local Hydraulics]

Contraction Scour

Parameter	20240603_RefinedMesh-PIERS_10yr (SRH-2D)	20240603_RefinedMesh-PIERS_50yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr (SRH-2D)	20240603_RefinedMesh-PIERS_500yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)	Units	Notes
Selected Contraction Computation Method	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour		
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	Live Bed
Clear Water Contraction Scour Depth	15.02	18.34	19.60	22.28	24.30	ft	
Live Bed Contraction Scour Depth	-0.49	-0.53	-0.54	-0.55	-0.56	ft	

Local Scour at Piers

Parameter	20240603_RefinedMesh-PIERS_10yr (SRH-2D)	20240603_RefinedMesh-PIERS_50yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr (SRH-2D)	20240603_RefinedMesh-PIERS_500yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)	Units	Notes
Piers							
Pier Name	Pier 1	Pier 1	Pier 1	Pier 1	Pier 1		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 2	Pier 2	Pier 2	Pier 2	Pier 2		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 3	Pier 3	Pier 3	Pier 3	Pier 3		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 4	Pier 4	Pier 4	Pier 4	Pier 4		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	6.09	6.74	7.03	6.60	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 5	Pier 5	Pier 5	Pier 5	Pier 5		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	

Max Flow Depth including Pier Scour	6.09	5.79	6.00	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 6	Pier 6	Pier 6	Pier 6	Pier 6		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	5.73	5.68	5.81	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 7	Pier 7	Pier 7	Pier 7	Pier 7		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 8	Pier 8	Pier 8	Pier 8	Pier 8		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 9	Pier 9	Pier 9	Pier 9	Pier 9		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 10	Pier 10	Pier 10	Pier 10	Pier 10		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	6.09	6.72	6.07	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 11	Pier 11	Pier 11	Pier 11	Pier 11		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	5.46	5.70	-7.34	4.83	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 12	Pier 12	Pier 12	Pier 12	Pier 12		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	5.11	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 13	Pier 13	Pier 13	Pier 13	Pier 13		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation +

							contraction scour + pier scour
Piers							
Pier Name	Pier 14	Pier 14	Pier 14	Pier 14	Pier 14		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 15	Pier 15	Pier 15	Pier 15	Pier 15		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 16	Pier 16	Pier 16	Pier 16	Pier 16		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 17	Pier 17	Pier 17	Pier 17	Pier 17		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 18	Pier 18	Pier 18	Pier 18	Pier 18		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	
Max Flow Depth including Pier Scour	-9.38	-8.44	-8.10	-7.34	-6.90	ft	
Total Scour at Pier	0.00	0.00	0.00	0.00	0.00	ft	Longterm degradation + contraction scour + pier scour

Hydraulic Analysis Report 2

Project Data

Project Title: I-405, Brickyard to SR 527 Improvement Project

Designer: Samuel Boyce (AECOM)

Project Date: Friday, June 14, 2024

Project Units: U.S. Customary Units

Notes: Considers main channel hydraulics acting on piers.

This report was generated by SMS and has been adjusted for formatting and clarity.

Contents

Scenario: 20240603_RefinedMesh-PIERS_10yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 11

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 12

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Scenario: 20240603_RefinedMesh-PIERS_50yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 11

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 12

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Scenario: 20240603_RefinedMesh-PIERS_100yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 4

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 5

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 6

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 11

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 12

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 13

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 16

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Scenario: 20240603_RefinedMesh-PIERS_500yr (SRH-2D)

Input Parameters

Input Parameters for Scour Condition
Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed
Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition
Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method
Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method
k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations
Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Left Bank Contraction Scour
Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition
Average Depth Upstream of Contraction (y1): 3.94 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 2.75 ft/s

Results

More input is required for complete calculations

Right Bank Contraction Scour
Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 5.39 ft

D50 (D50): 0.000000 mm

Average Velocity Upstream (V): 2.83 ft/s

Results

More input is required for complete calculations

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 2

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 3

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 4

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 5

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 6

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 7

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 10

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 11

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 12

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 14

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 15

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 16

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 17

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 18

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Scenario: 20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)

Input Parameters

Input Parameters for Scour Condition

Average Depth Upstream of Contraction (y1): 10.02 ft

D50 (D50): 0.128016 mm

Average Velocity Upstream (V): 4.48 ft/s

Computed Contraction Scour Condition: Live Bed

Input Parameters for Live Bed

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section (S1): 0.000399 ft/ft

Discharge in Contracted Section (Q2): 2961.87 cfs

Discharge Upstream that is Transporting Sediment (Q1): 2950.85 cfs

Bottom Width in Contracted Section (W2): 77.11 ft

Width Upstream that is Transporting Sediment (W1): 65.78 ft

Depth Prior to Scour in Contracted Section (y0): 9.50 ft

Unit Weight of Water (gamma w): 62.40 lb/ft^3

Unit Weight of Sediment (gamma s): 165.00 lb/ft^3

Results

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported (Vc): 1.23 ft/s

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material (Dm): 0.160020 mm

Average Depth in Contracted Section after Scour (y2): 24.51 ft

Scour Depth (ys): 15.02 ft

Results of Live Bed Method

k1 (k1): 0.69

Shear Velocity (V*): 0.36 ft/s

Fall Velocity (V*): 0.04 ft/s

Scour Depth (ys): -0.49 ft

Shear Applied to Bed by Live-Bed Scour (theta 0): 0.0926 lb/ft^2

Shear Required for Movement of D50 Particle (Tau c): 0.0017 lb/ft^2

Recommendations

Recommended Scour Condition: Live Bed

Recommended Scour Depth: 0.00 ft

Pier Details

Pier Name: Pier 1

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 2

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 3

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 4

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 5

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 6

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 7

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 8

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 9

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 10

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 11

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 12

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 13

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 14

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 15

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters
Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 16

Pier Scour
Computation Type: HEC-18

Input Parameters
Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 17

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Pier Name: Pier 18

Pier Scour

Computation Type: HEC-18

Input Parameters

Pier Shape: Square Nose

Bed Condition: Clear-Water Scour

Depth Upstream of Pier: 11.76 ft

Velocity Upstream of Pier: 3.88 ft/s

Width of Pier: 6.00 ft

Length of Pier: 6.13 ft

Angle of Attack: 0.00 Degrees

Result Parameters

Froude Number Upstream: 0.20

Correction Factor for Pier Nose Shape (K1): 1.10

Correction Factor of Angle of Attack (K2): 1.00

Pier Length to Pier Width (L/a): 1.02

Correction Factor for Bed Condition (K3): 1.10

Scour Depth: 9.19 ft

Scour Summary Table [Main Channel Hydraulics]

Contraction Scour

Parameter	20240603_RefinedMesh-PIERS_10yr (SRH-2D)	20240603_RefinedMesh-PIERS_50yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr (SRH-2D)	20240603_RefinedMesh-PIERS_500yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)	Units	Notes
Selected Contraction Computation Method	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour	Clear-Water and Live-Bed Scour		
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	ft	Live Bed
Clear Water Contraction Scour Depth	15.02	18.34	19.60	22.28	24.30	ft	
Live Bed Contraction Scour Depth	-0.49	-0.53	-0.54	-0.55	-0.56	ft	

Local Scour at Piers

Parameter	20240603_RefinedMesh-PIERS_10yr (SRH-2D)	20240603_RefinedMesh-PIERS_50yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr (SRH-2D)	20240603_RefinedMesh-PIERS_500yr (SRH-2D)	20240603_RefinedMesh-PIERS_100yr-2080 (SRH-2D)	Units	Notes
Piers							
Pier Name	Pier 1	Pier 1	Pier 1	Pier 1	Pier 1		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 2	Pier 2	Pier 2	Pier 2	Pier 2		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 3	Pier 3	Pier 3	Pier 3	Pier 3		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 4	Pier 4	Pier 4	Pier 4	Pier 4		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.29	22.79	23.81	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 5	Pier 5	Pier 5	Pier 5	Pier 5		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.29	22.79	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 6	Pier 6	Pier 6	Pier 6	Pier 6		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.29	22.79	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 7	Pier 7	Pier 7	Pier 7	Pier 7		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 8	Pier 8	Pier 8	Pier 8	Pier 8		

Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 9	Pier 9	Pier 9	Pier 9	Pier 9		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 10	Pier 10	Pier 10	Pier 10	Pier 10		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.29	22.79	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 11	Pier 11	Pier 11	Pier 11	Pier 11		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.29	22.79	23.80	24.54	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 12	Pier 12	Pier 12	Pier 12	Pier 12		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 13	Pier 13	Pier 13	Pier 13	Pier 13		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 14	Pier 14	Pier 14	Pier 14	Pier 14		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 15	Pier 15	Pier 15	Pier 15	Pier 15		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation +

							contraction scour + pier scour
Piers							
Pier Name	Pier 16	Pier 16	Pier 16	Pier 16	Pier 16		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 17	Pier 17	Pier 17	Pier 17	Pier 17		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour
Piers							
Pier Name	Pier 18	Pier 18	Pier 18	Pier 18	Pier 18		
Pier Computation Method	HEC-18	HEC-18	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	9.19	9.63	9.78	10.09	10.30	ft	
Max Flow Depth including Pier Scour	20.87	22.24	22.73	23.80	24.46	ft	
Total Scour at Pier	9.19	9.63	9.78	10.09	10.30	ft	Longterm degradation + contraction scour + pier scour

Appendix E – Model Stability and Continuity Plots

List of Figures

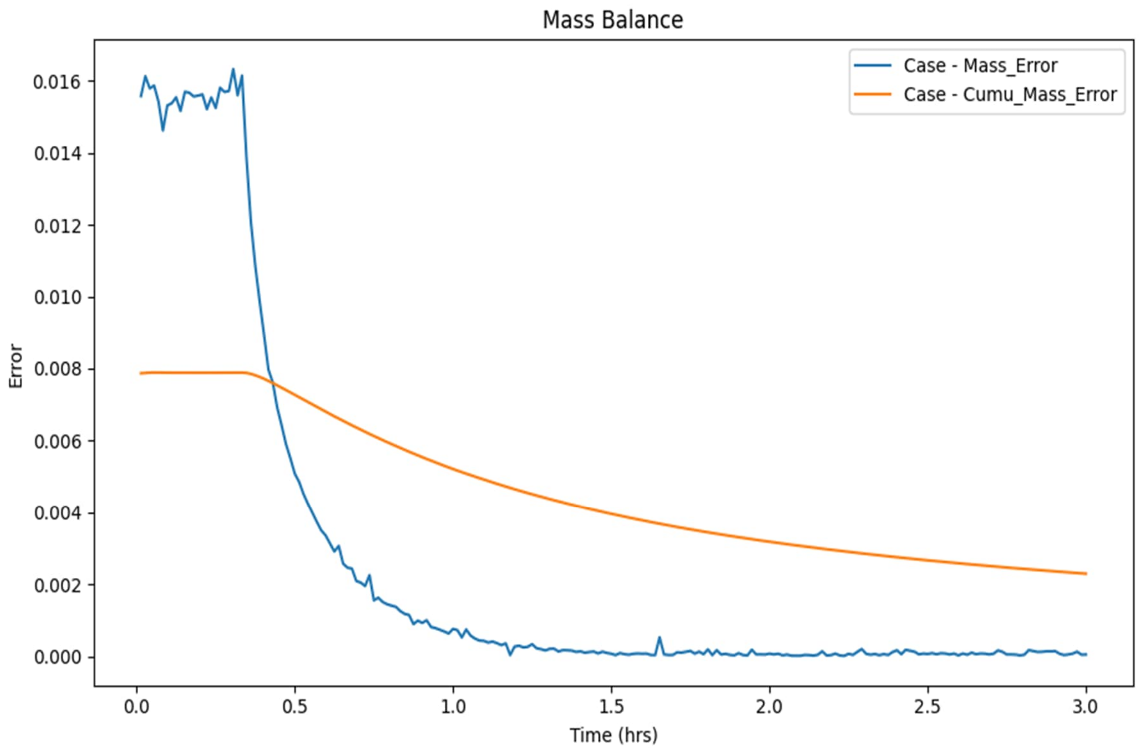


Figure 1. 10-year simulation; mass balance monitor plot.

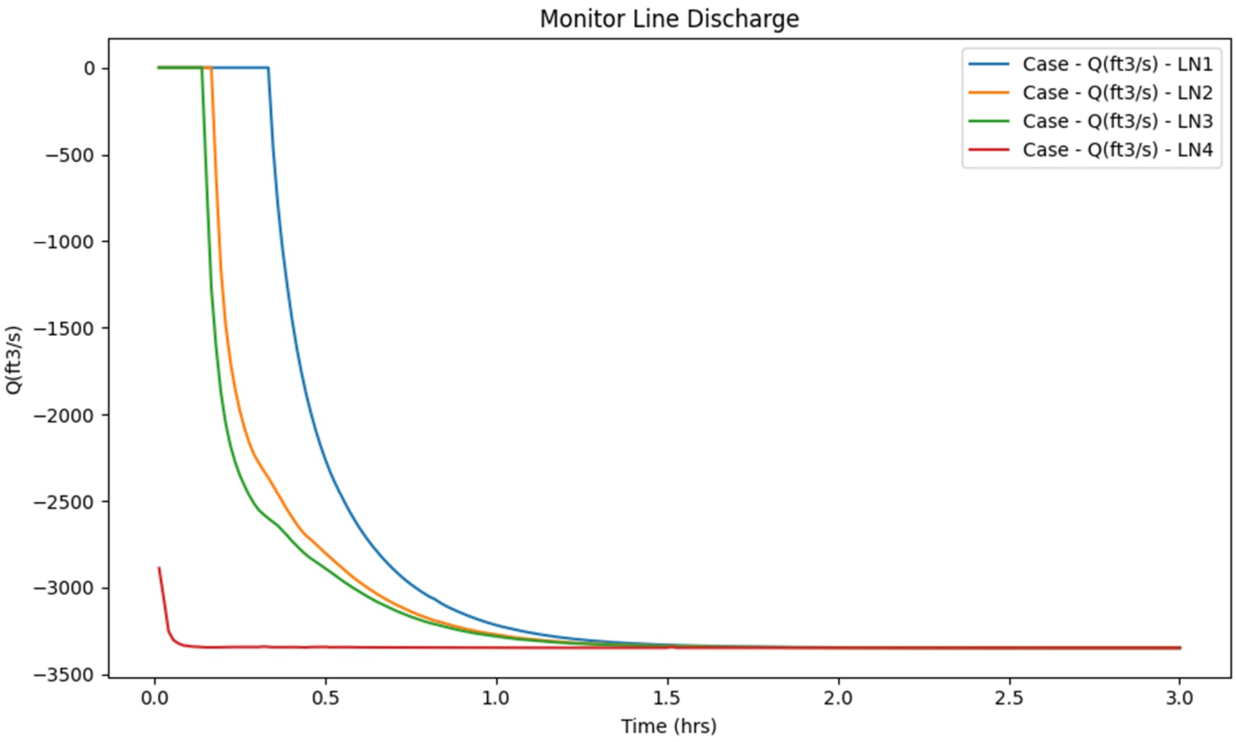


Figure 2. 10-year simulation; monitor line results.

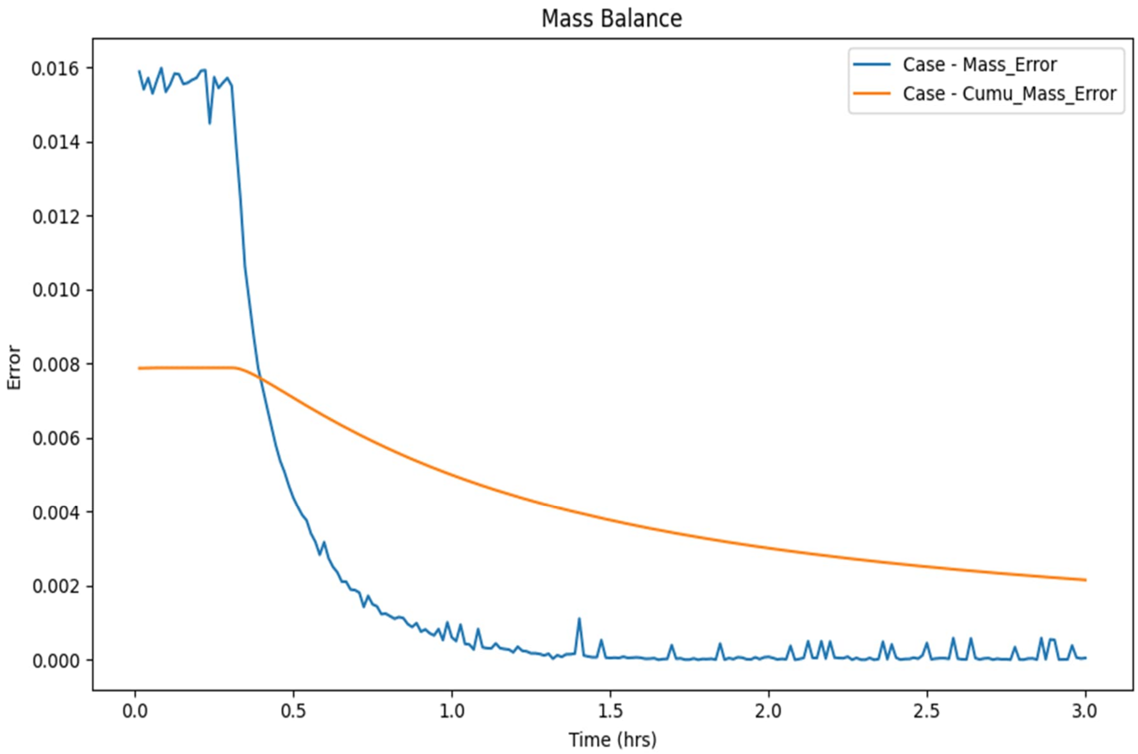


Figure 3. 50-year simulation; mass balance monitor plot.

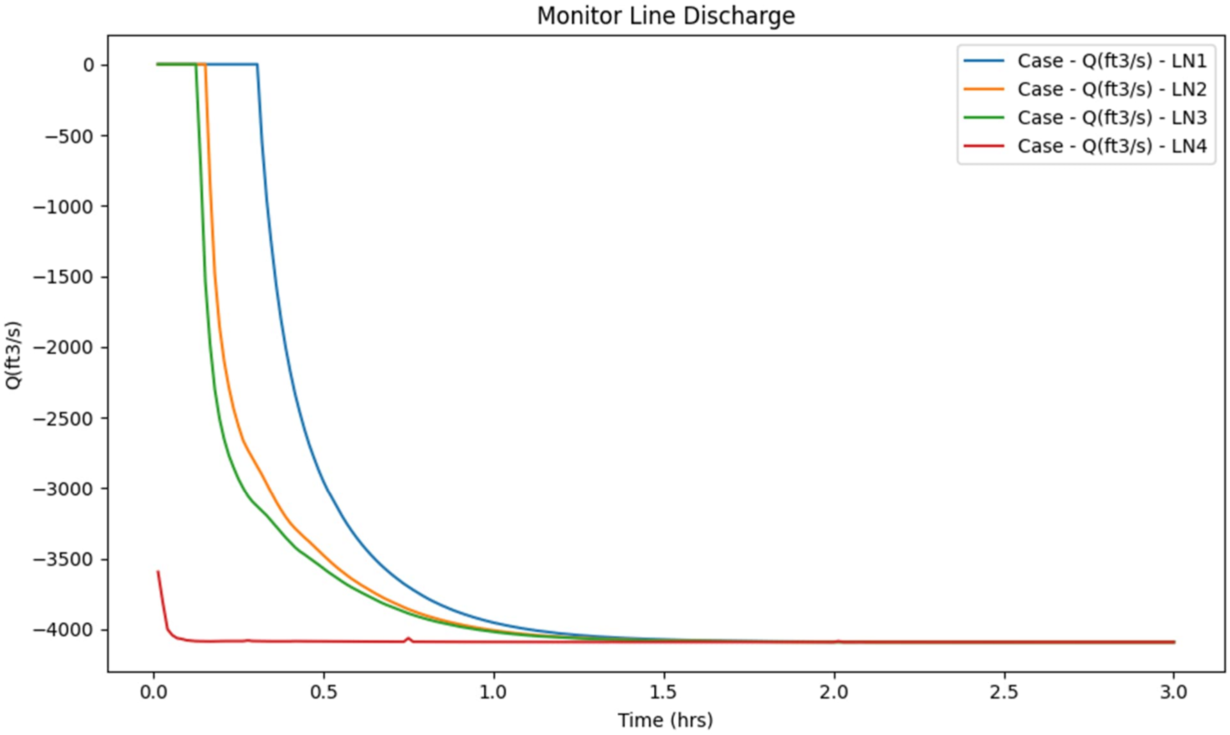


Figure 4. 50-year simulation; monitor line results.

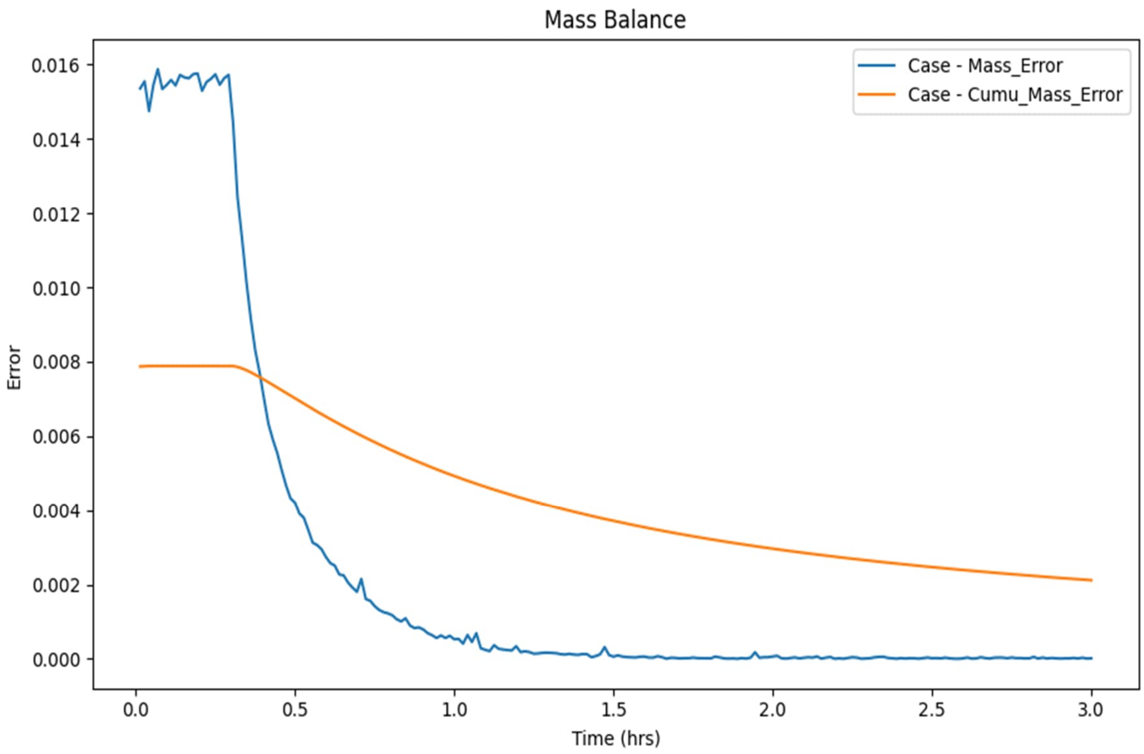


Figure 5. 100-year simulation; mass balance monitor plot.

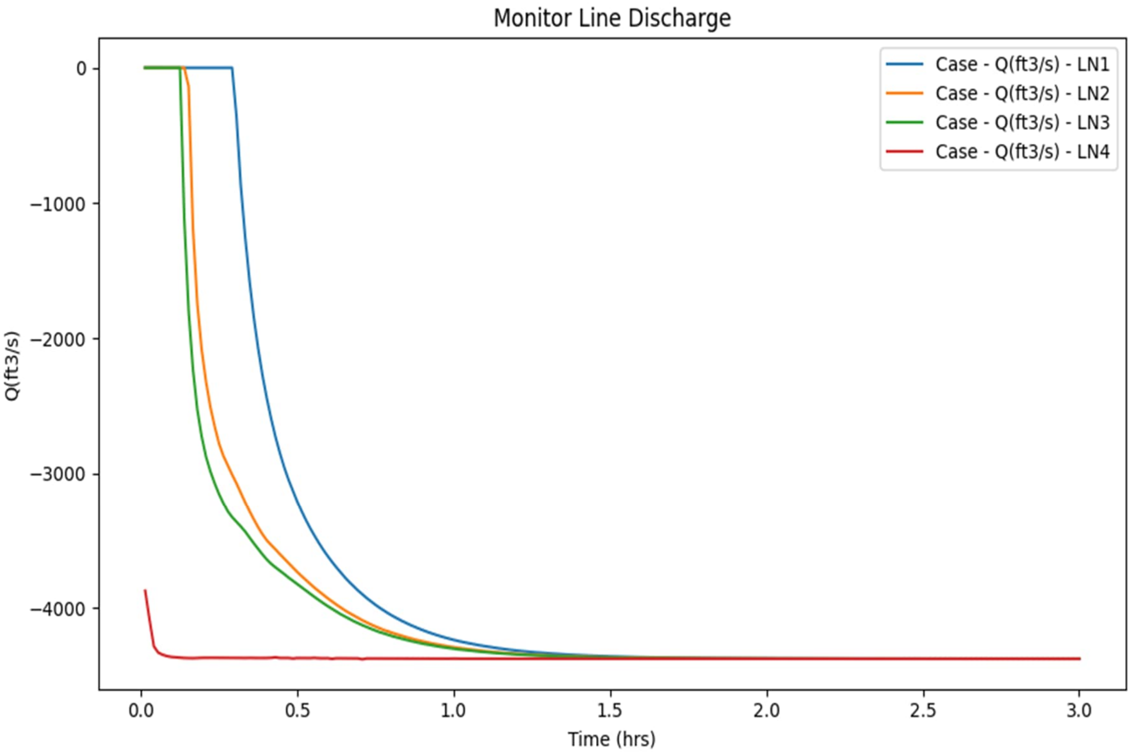


Figure 6. 100-year simulation; monitor line results.

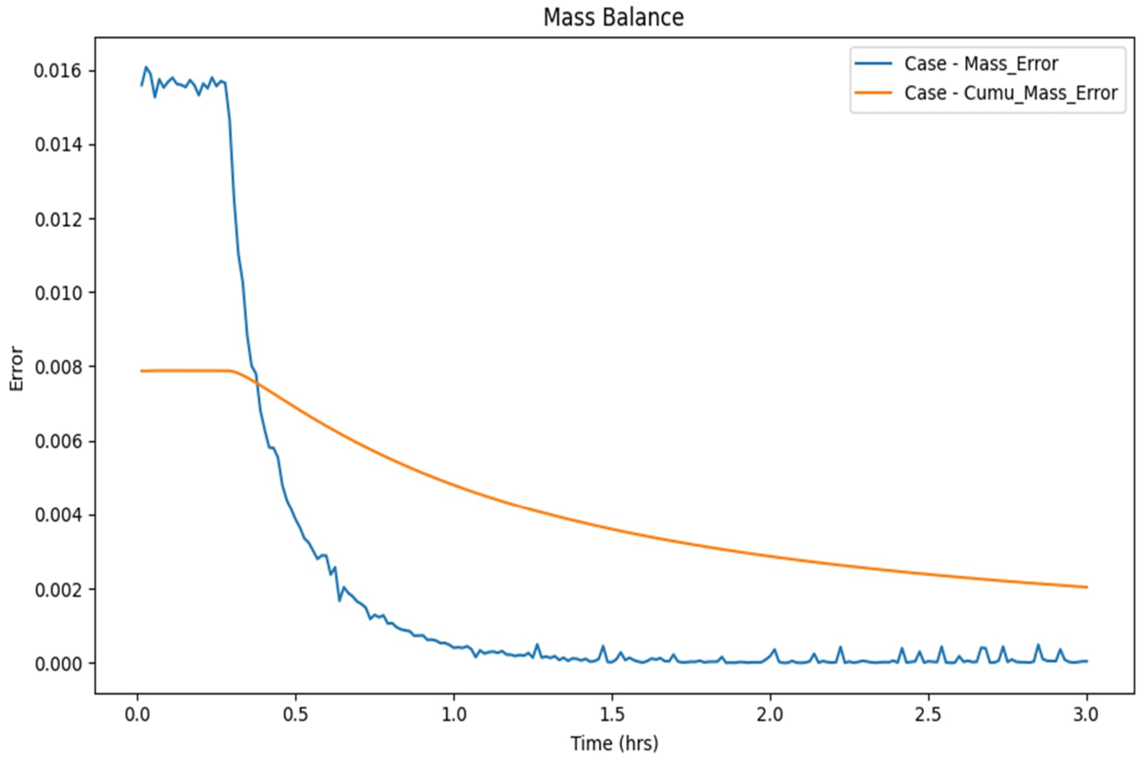


Figure 7. 500-year simulation; mass balance monitor plot.

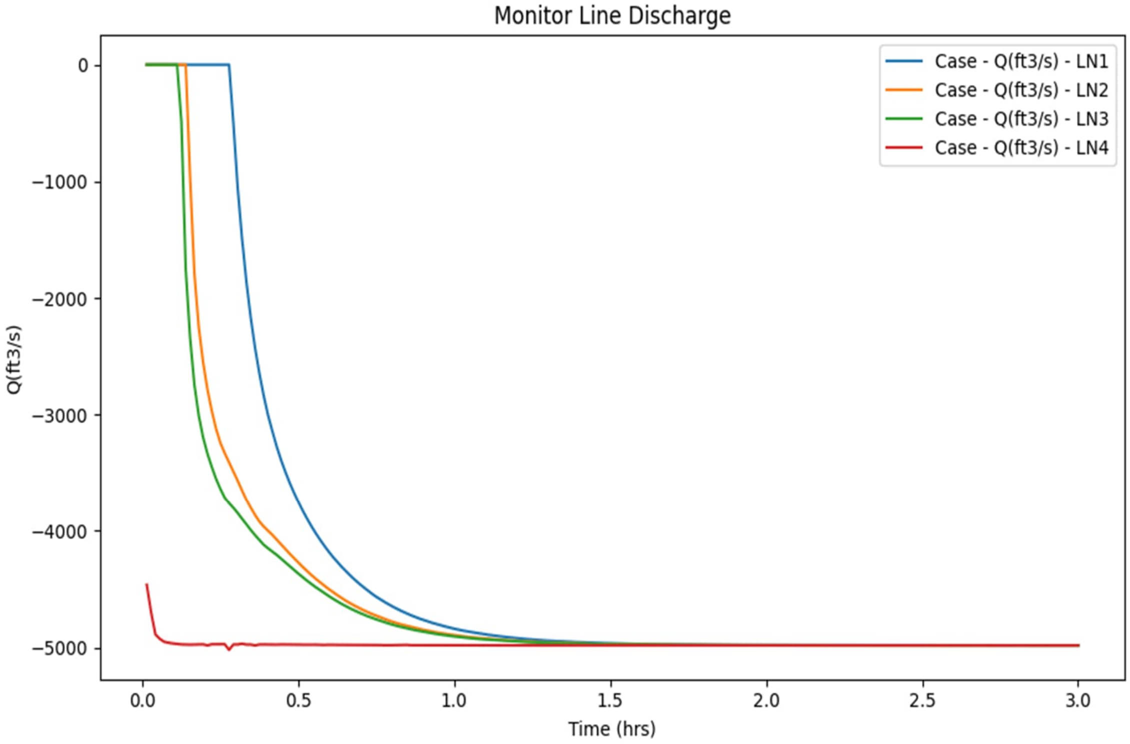


Figure 8. 500-year simulation; monitor line results.

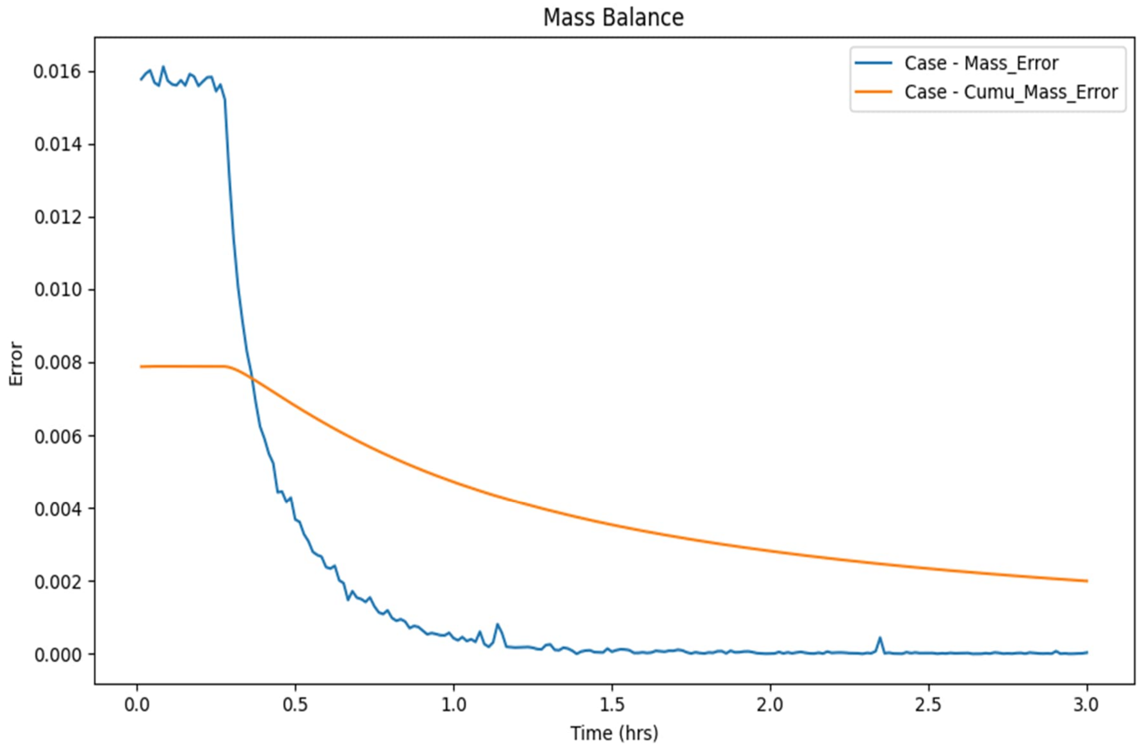


Figure 9. Year 2080 100-year simulation; mass balance monitor plot.

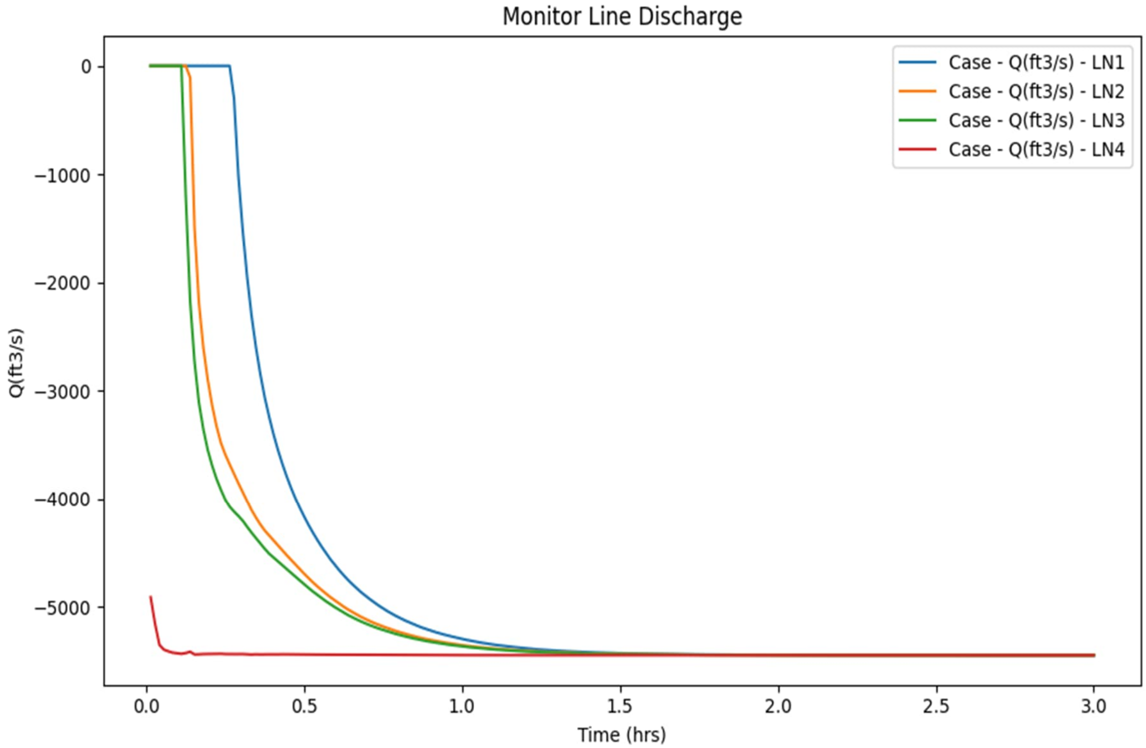
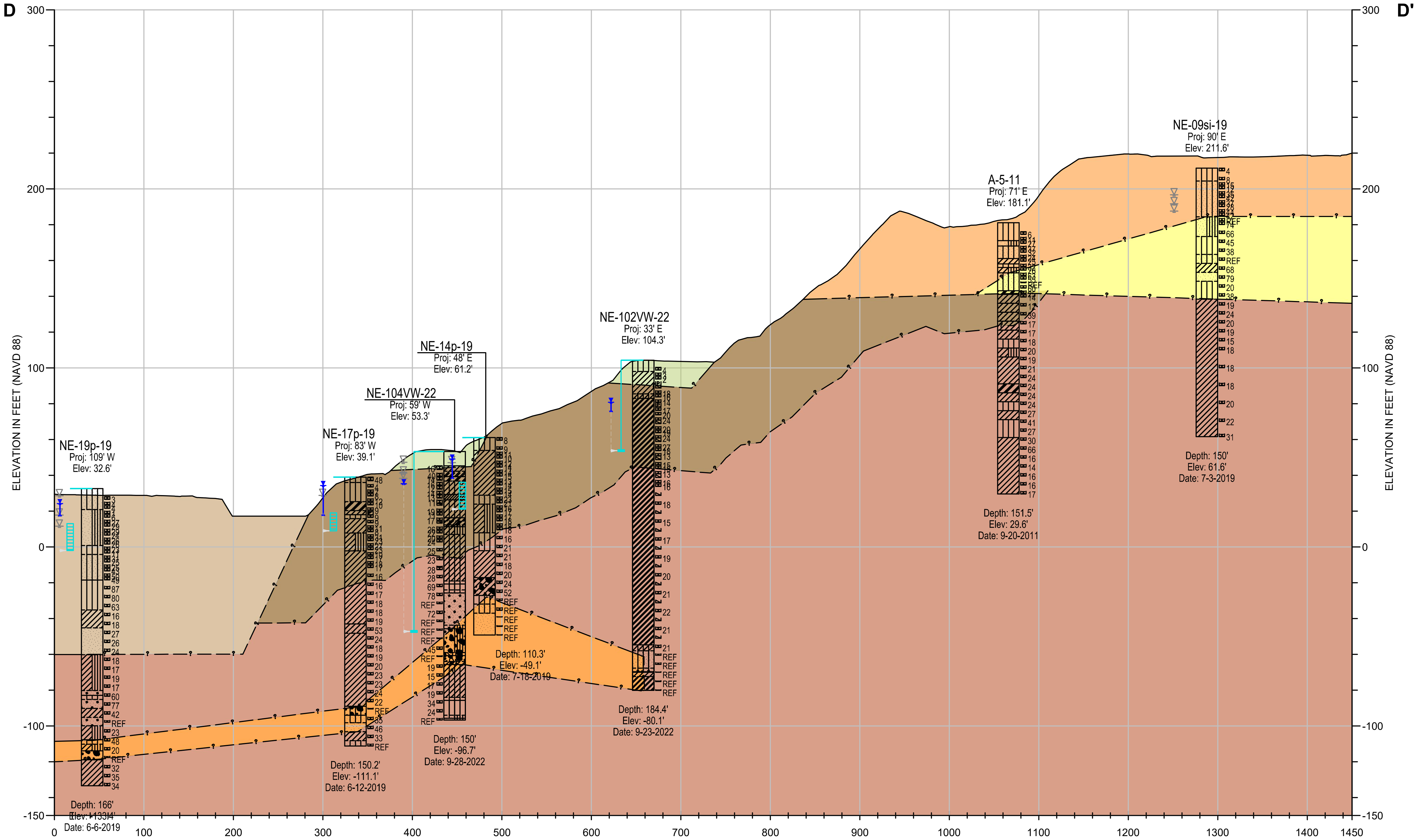
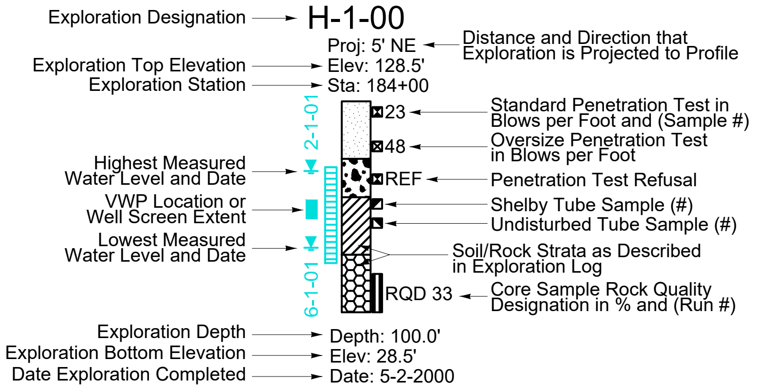


Figure 10. Year 2080 100-year simulation; monitor line results.

Appendix F – Borehole NE-19p-19 Data

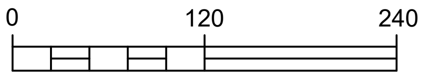


EXPLORATION LOG LEGEND



ENGINEERING STRATIGRAPHIC UNIT (ESU) COLOR LEGEND

- ▨ ESU1: Historically Placed Granular Fill
- ▨ ESU2: Weather Glacial Drift
- ▨ ESU3: Glacially Overridden Glacial Drift
- ▨ ESU4: Fine-Grained Colluvium (slickensided)
- ▨ ESU5: Fine-Grained Colluvium (intact)
- ▨ ESU6: Advance Outwash
- ▨ ESU7: Alluvium



Scale in Feet
Vertical Exaggeration = 2x

NOTES:

1. The datum reference for this figure is: NAD 83/91 HARN, NAVD88, SPN (ft). The exploration locations were surveyed by HQ Geotech Office.
2. ESUs, if shown, are subjective and are provided for reference only.
3. Groundwater table assumed to be at ground surface.
4. Stratigraphic layer divisions, if shown, are estimated at borings. Layer divisions may vary in between borings.

JOB# XL-5446 **STATE ROUTE**

FIGURE 5: GENERALIZED SUBSURFACE PROFILE D-D'

WSDOT GEOTECHNICAL OFFICE

PREPARED BY

Date: February 1, 2023

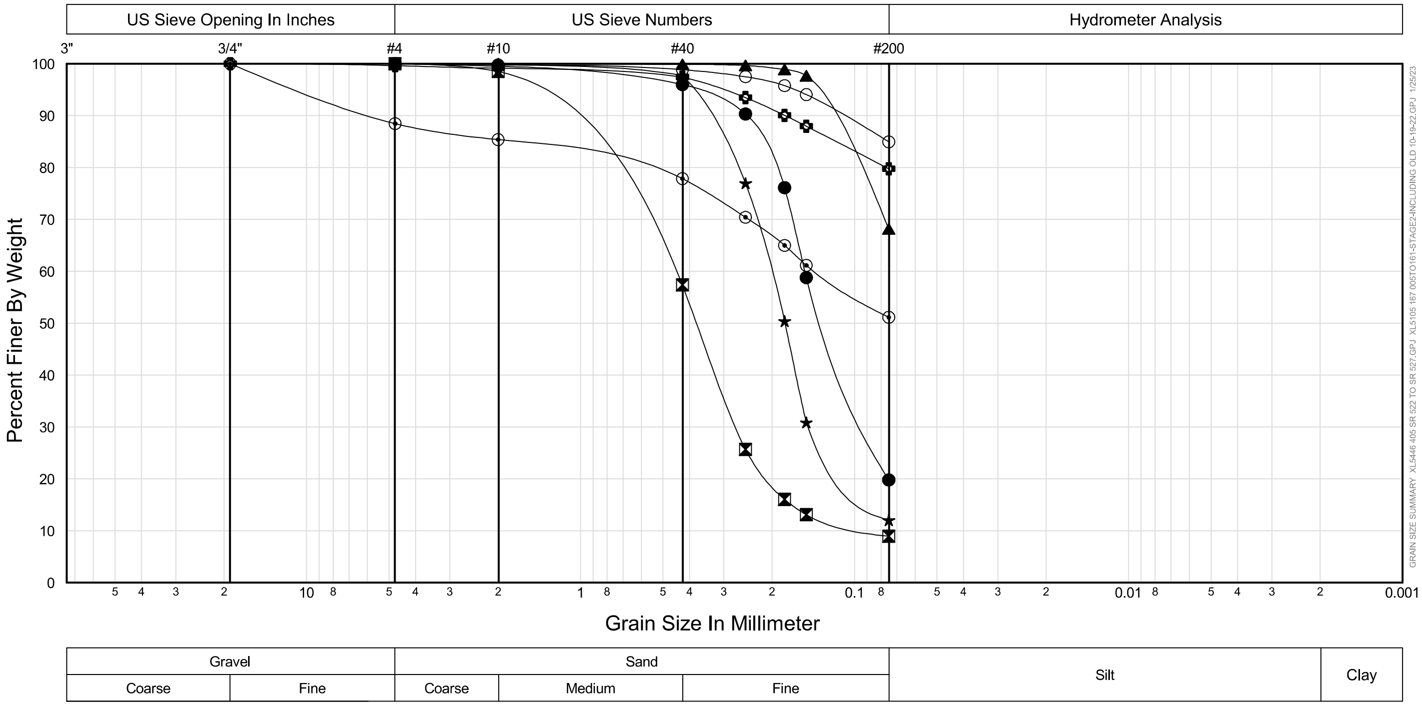
I405 khaskins **MILEPOST(S)** 21.4 - 27.1

GRAIN SIZE ANALYSIS SUMMARY FOR NE-19p-19

Job No: **XL5446**
Project: **I-405 / SR 522 Vicinity to SR 527 Express Toll Lanes Improvement Project**

Symbol	Depth (feet)	Sample No.	USCS	Description	Test Date	MC (%)	LL	PL	PI	Moist Density (lbs/ft^3)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	C_c	C_u	D_{90} (mm)	D_{60} (mm)	D_{50} (mm)	D_{30} (mm)	D_{20} (mm)	D_{10} (mm)
●	9.5	D-3	SM	SILTY SAND	6-20-19	52	n/a	n/a	NP			0.0	80.2	19.8			0.248	0.152	0.128	0.090	0.075	
⧗	17.5	D-6	SP-SM	POORLY GRADED SAND with SILT	6-20-19	18	n/a	n/a	NP			0.0	91.1	8.9	1.7	5	1.452	0.469	0.376	0.269	0.206	0.090
▲	32.5	D-12	ML	SANDY SILT	6-20-19	26	n/a	n/a	NP			0.0	31.8	68.2			0.125					
★	39.5	D-15	SM	SILTY SAND	6-20-19	23	n/a	n/a	NP			0.0	87.9	12.1	1.5	3	0.349	0.203	0.179	0.145	0.101	
⊙	64.5	D-22	ML	SANDY SILT	6-20-19	21	15	14	1			11.5	37.3	51.1			5.717	0.139				
✚	74.5	D-24	CL	LEAN CLAY with SAND	6-20-19	26	36	19	17			0.4	19.9	79.8			0.179					
○	94.5	D-28	CL-ML	SILTY CLAY with SAND	6-20-19	24	26	19	7			0.0	15.1	84.9			0.110					

**Sample was assumed to be non-plastic based on visual-manual examination procedures. Therefore, the ASTM Group Name is estimated based on the grain size distribution only.*



Appendix G – Future Projections for Climate Adapted Culvert Design

Future Projections for Climate-Adapted Culvert Design

Project Name: WSDOT I-405 Brickyard Project

Stream Name: Sammamish River

Street Name: I-405

Culvert coordinates: 47.7571, -122.1814

Grid ID 47.78125_-122.15625

Ecoregion Pacific Maritime Mountains

Projected mean percent change in bankfull flow:

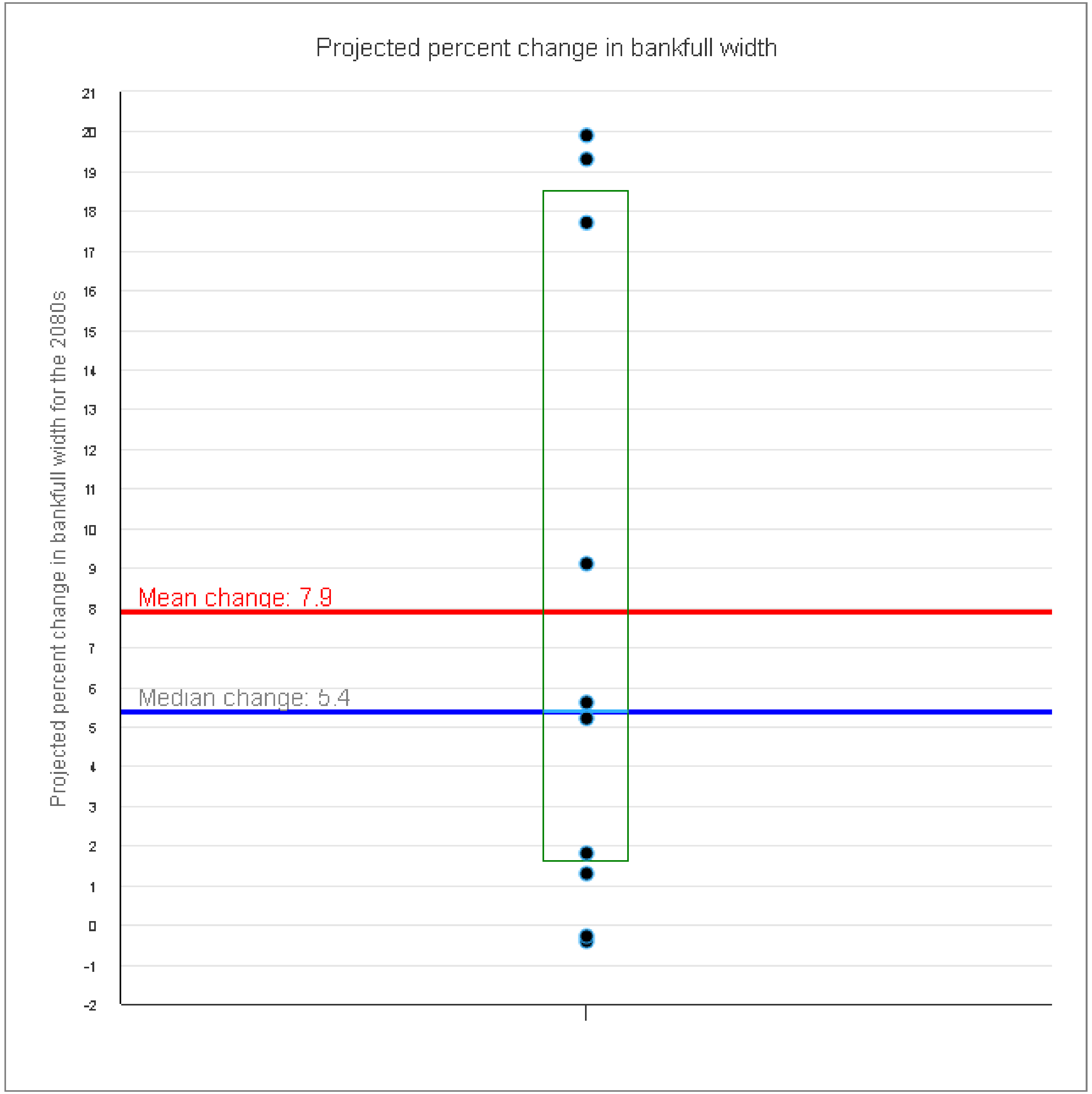
2040s: 13.9% **2080s:** 17.1%

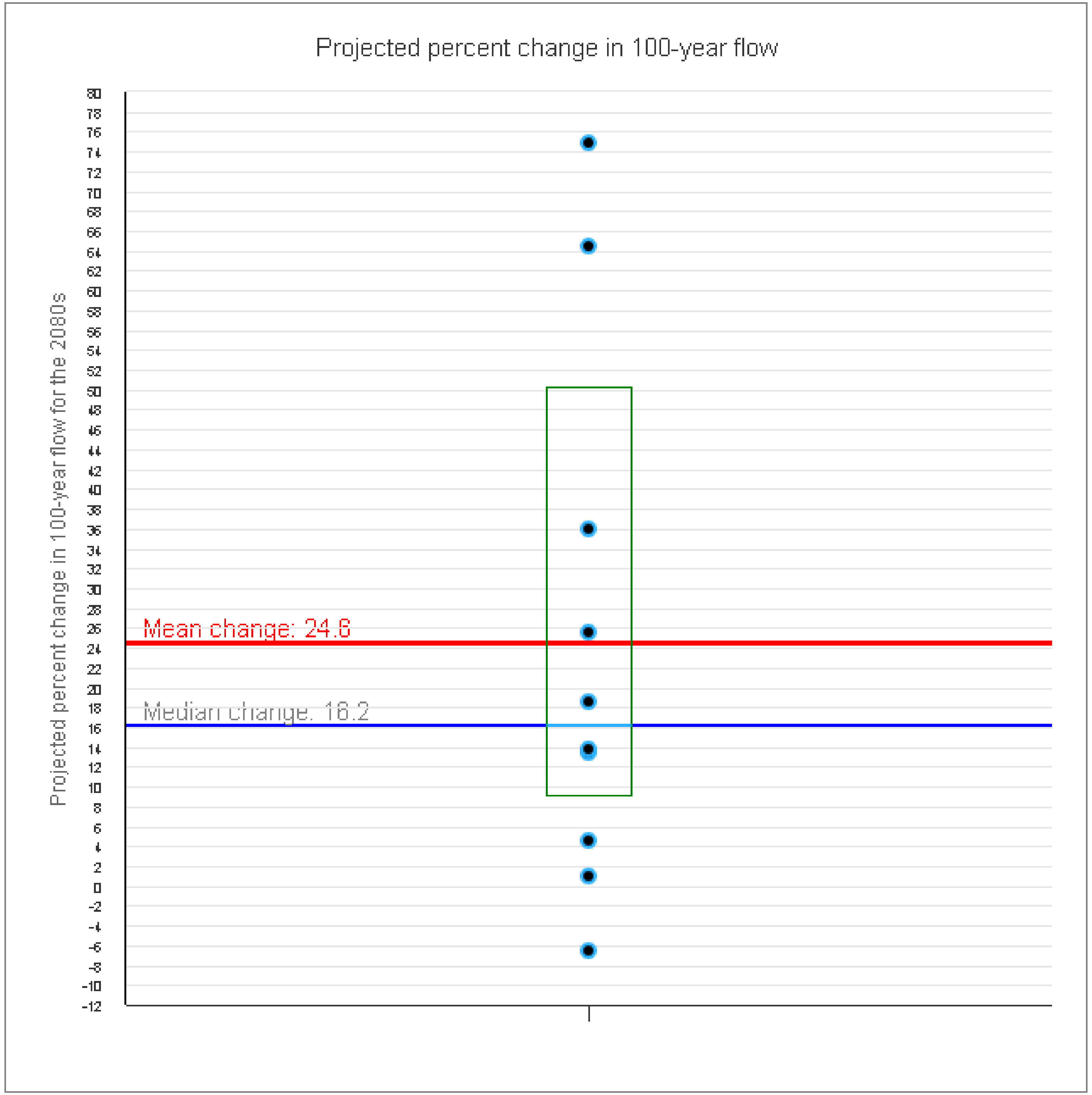
Projected mean percent change in bankfull width:

2040s: 6.6% **2080s:** 7.9%

Projected mean percent change in 100-year flood:

2040s: 11.2% **2080s:** 24.6%


Projected percent change in bankfull width
Projected percent change in bankfull width for the 2080s
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
Mean change: 7.9
Median change: 5.4


Projected percent change in 100-year flow
Projected percent change in 100-year flow for the 2080s
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
Mean change: 24.6
Median change: 16.2