Technical Memorandum

5 Milk Street ● Portland, ME 04101 ● 207.797.8901

Via Email:	Ernest.Martin@maine.com, Charles.Hebson@maine.gov, Eric.Ham@maine.gov
To:	Ernest Martin, Maine DOT; Charles Hebson, P.E., Maine DOT; Eric Ham, Maine DOT
From:	Leila Pike, P.E. (GEI); Lissa Robinson, P.E. (GEI)
Date:	January 23, 2025
Re:	Summary of Hydraulic Model Results for the Route 1 Crossing Revised for 75-foot Span Scarborough Route 1 Structure Opening Sizing
	Maine DOT WIN 25657.00 Scarborough, Maine
Project No.:	2305250

This memorandum provides a summary of the hydraulic model results related to the structure opening size for the US Route 1 Dunstan River crossing in Scarborough, Maine (bridge #2240) (Figure 1). The purpose of this memo is to compare model results for existing conditions of the crossing and the proposed design alternatives. Comparison of model results included the peak hydraulic head difference (PHHD) across the structure (i.e., difference in maximum water surface elevation upstream and downstream of the structure), peak water surface elevation within the marsh upstream of US Route 1, peak velocity through a single-span crossing, peak volumetric flow through the crossing, and the maximum extent of inundation upstream of US Route 1. The terms "upstream" and "downstream" in this report are referenced to the direction of river flow and tidal outflow rather than tidal inflow.

A report detailing the hydrologic and hydraulic analysis to support a Preliminary Design Report (PDR), including model setup, calibration, and presentation of results, will be provided at a later date.

Elevations in this memo are referenced to the North American Vertical Datum of 1988 (NAVD88) unless otherwise specified.

Model Development

Two-dimensional hydrodynamic modeling of the US Route 1 crossing was performed using the US Bureau of Reclamation Sedimentation and River Hydraulics – Two-Dimension (SRH-2D) software version 13.3.7 (SMS, 2023). The model mesh area was approximately 1.9-square-miles and extended from approximately 0.1 miles upstream of Payne Road to approximately 0.4 miles downstream of the Eastern Trail Bridge. The model included Phillips Brook from Payne Road to its downstream confluence with the Dunstan River. The model also included Cascade Brook, extending from Old Blue Point Road to its downstream confluence with the Dunstan River. The model was used to simulate flow on the Dunstan River at the existing hydraulic structure at US Route 1 and two proposed alternatives. The model mesh element sizes ranged from less than 5 ft near the hydraulic crossings to approximately 150 ft near the boundaries of the model.

The digital elevation model (DEM) (i.e., terrain) for the model was compiled from the following data sources: a survey performed by MaineDOT of the channel bottom and existing crossing elevations, a bathymetric survey along the Dunstan River performed by MaineDOT, the proposed roadway surface of Route 1 and Route 9 for both of their proposed elevated conditions provided by Fuss & O'Neill, and LiDAR collected in 2020 (OCM Partners, 2020). In some places, the terrain was modified using engineering judgement where channel definition was important, but survey data was lacking.

The model mesh was created using quadrilateral and triangular elements, with primarily quadrilateral elements within the channel to align the cell faces of the mesh perpendicular to the direction of water flow and in line with linear features such as the crossing and channel banks. Triangular elements were used above the channel banks and in the downstream, tidal portion of the mesh where the flow direction was less channelized.

Tidal boundary conditions at the downstream boundary, approximately 0.4 miles downstream of the Eastern Trail Bridge, were developed from observed water surface elevation data collected by Maine DOT between September and November of 2023. To model Highest Astronomical Tide (HAsT) conditions, the tidal hydrograph was adjusted so that the peak tide water surface elevation matched the reported HAsT elevation of 6.5 ft (MGS, 2024). Four feet of sea level rise (SLR) was represented in the tidal boundary conditions by adjusting the hydrograph linearly by four feet so that the peak tide water surface was at elevation 10.5 ft. Upstream boundary conditions were input as constant flows representing mean annual streamflow values.

The 2D flow area included spatially varied Manning's n-values based on the 2006 Maine Land Cover Database (MELCD) (MEGIS, 2006). Manning's n-values were assigned to land cover groups based on Chow (1959), USGS (2015), NRCS (2010), and our engineering judgement.

The existing crossing at US Route 1 was modeled, and results were compared to observed water surface elevations within the marsh to support a model calibration process. The model was calibrated through adjusting Manning's n values within the marsh and by refining channel bathymetry within areas where bathymetry data was important to the model hydraulic conveyance, but the bathymetry was not readily available. The calibration results indicated that water surface elevations were within 0.1 inches of observed water levels upstream and within 0.9 inches of observed water levels downstream of the Route 1 crossing (Figure 2).

Existing Crossing and Proposed Design Alternatives

The existing Route 1 Dunstan River crossing consists of four 8.3-foot-diameter culverts with inlet (i.e., upstream) invert elevations of approximately El. -6.0 ft and outlet (i.e., downstream) invert elevations of approximately El. -7.1 ft.

In addition to the existing conditions, there were two proposed crossing design alternatives evaluated in the hydraulic model. The first was a 26-foot-span by 12-foot-rise box culvert, located approximately 200 ft northeast of the existing crossing, in addition to the existing culverts. The invert of the box culvert was set at El. -4.0 ft and the slope of the culvert was assumed to be flat (i.e., same upstream and downstream invert elevations). This design alternative increased the hydraulic opening area of the

crossing by approximately 312.0 sq ft or 144% from an existing opening of approximately 216.4 ft^2 to a proposed opening of 528.4 ft^2.

The second proposed crossing design alternative included in the model was a single span bridge. The span was modeled as an open trapezoid channel with a bottom channel at El. -5.0 ft, a bottom width of approximately 22.0 ft, side slopes of approximately 1.77H:1.00V, and a width of approximately 75.0 ft at El. 10.0 ft (approximate water surface elevation at the crossing for HAsT plus 4.0 ft of SLR). The actual geometry of the hydraulic opening for the final design will change from these preliminary estimates. For example, the top width of this hypothetical span would likely be wider and will be dependent on the new road elevation.

The proposed elevated roadway used in the model had a maximum crest elevation near the centerline of the roadway of approximately 11.3 ft based on design information provided by Fuss & O'Neill. The results for the proposed single span bridge option do not consider the impact of pressure conditions (i.e., if the bridge were to be designed with a low chord below El. 10.0 ft). The impact of pressure flow due to a low chord should be modeled as part of the final design process as applicable. This design alternative increases the hydraulic opening area of the crossing by approximately 511.1 ft^2 or 236%, from an existing opening of approximately 216.4 ft^2 to a proposed opening of approximately 727.5 ft^2.

Model Results Summary

Two flow scenarios were modeled for each crossing alternative: HAsT tidal conditions with mean annual streamflows and HAsT tidal conditions plus 4.0 ft of SLR with mean annual streamflows. For this memo, we have compared the peak hydraulic head difference (PHHD) across the US Route 1 crossing, peak volumetric flow through the crossing, peak water velocity through the crossing, the maximum area of inundation upstream of Route 1, and the peak water surface elevations in the Dunstan River upstream of the US Route 1 crossing at a location approximately 30 ft downstream of Payne Road.

The model results indicated that the PHHD decreases with an increase in opening size. The model results also indicated that for present-day sea levels, the opening size for the design alternatives evaluated in the model did not impact the peak water surface elevation near Payne Road under HAsT conditions. For 4.0 ft of sea level rise, the model results indicated that the peak water surface elevation for HAsT conditions near Payne Road would be approximately 1.0 foot higher for the single span bridge alternative than for the existing culverts. It is likely that the increased hydraulic opening in the single span bridge would allow greater upstream tidal conveyance during tidal "flood" flow (i.e., opposite to the direction of river flow on an incoming tide) along the upstream reach.

Table 1 presents a summary of hydraulic model results for the three crossing configurations (i.e., existing conditions and two proposed design alternatives).

Table 1. Summary of Model Results

Results Parameter	Existing Conditions: four (4) 8.3-foot-diameter culverts	Design Alternative 1: 4 existing culverts (8.3-foot-diameter) plus box culvert (26-foot span x 12-foot rise)	Design Alternative 2: single span (trapezoidal) 22.0-foot-wide at El. -5.0 ft 75.0-foot-wide at El. 10.0 ft
Opening Area, ft^2	216.4	528.4	727.5
HAsT			
Max Peak-Peak Head Difference[1] (Δh), ft	0.23	0.10	0.03
Peak Water Surface Elevation[2], ft	5.5	5.5	5.5
Peak Velocity (V), ft/s	-	-	1.8
Peak Volumetric Flow (Q), cfs	546	621	624
Inundation Area Upstream of Route 1 (acres)	120.2	-	123.4
HAsT + 4.0 ft SLR			
Max Peak-Peak Head Difference[1] (Δh), ft	1.76	0.82	0.14
Peak Water Surface Elevation[2], ft	8.3	8.9	9.3
Peak Velocity (V), ft/s	-	-	7.0
Peak Volumetric Flow (Q), cfs	1,866	2,907	3,557
Inundation Area Upstream of Route 1 (acres)	166.6	-	174.8

Notes:
1. Max Peak-Peak Head Difference measured as difference between peak water surface elevation just upstream of the US Route 1 crossing and peak water surface elevation just downstream of the US Route 1 crossing.
2. Peak Water Surface Elevation results taken on the Dunstan River approximately 30 ft downstream of Payne Road.
3. Peak velocity values through the crossing were determined for the single-span bridge option only.
4. Peak volumetric flow values through the crossing were compared for the existing conditions and the single-span bridge option only.
5. Inundation area in Table 1 is based on maximum water surface elevation, which can occur at different times across the model domain.

The model results suggest that the maximum inundation extents upstream of Route 1 would increase for an increased opening size for both HAsT and HAsT plus 4.0 ft of SLR conditions. However, there are many areas along the inundation boundary where the increase in inundation extent would be negligible between the scenarios evaluated.

Figures 3 and 4 compare the inundation extents, in plan view, upstream of the US Route 1 crossing during HAsT conditions for the existing conditions and the proposed single span design alternative under present-day sea levels and for 4.0 ft of SLR, respectively. Figures 5 and 6 show contours of velocity values through the proposed single-span bridge opening at a timestep when peak velocity occurs through the crossing for existing HAsT conditions and HAsT plus 4.0 ft of SLR conditions, respectively.

Figures 7 and 8 provide contours of water surface elevations near the crossing at a timestep when the peak instantaneous hydraulic head difference was reached within the model for existing HAsT conditions and HAsT plus 4.0 ft of SLR conditions, respectively.

Limitations

This memo presents preliminary hydraulic analysis for existing conditions and two design alternatives for the US Route 1 crossing at Dunstan River. The results are based on readily available online information, the proposed roadway elevation and crossing design information provided by the design team at the time of this report, and field observations of water surface elevations and survey information provided by MaineDOT. This analysis may require modification if there are any changes in the nature, design, and/or location of the data or proposed designs.

Actual conditions are expected to vary from the flow scenarios and water surface elevations presented in this report. This report did not evaluate stability of the existing or proposed crossing structures, embankments, or channels.

The hydraulic model geometry for the single span design alternative did not include a low chord of a proposed bridge (i.e., pressure flow conditions were not modeled). If pressure flow conditions are warranted, the analysis will need to be revised.

The professional services for this project have been performed in accordance with generally accepted engineering practices; no warranty, express or implied, is made.

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References

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Figures

Summary of Hydraulic Model Results for the Route 1 Crossing Revised for 75-foot Span
Error! No text of specified style in document.
Scarborough Route 1 Structure Opening Sizing
Maine DOT WIN 25657.00 Scarborough, Maine
January 23, 2025

Figures

Existing
Culverts

Proposed Box
Culvert Location

bing

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| 0 | 500 | 1,000 | | 2,000 |

Feet

Scarborough Rte. 1 Structure Opening Sizing
Maine DOT WIN 25657.00
Scarborough, Maine

Maine Department of Transportatation
Augusta, Maine

GEI Consultants

SITE LOCATION

Project 2301205 | January 2025 | Fig. 1

\\geiconsultants.com\data\Data_Storage\Working\FUSS AND ONEILL\2305250 Scarborough Rte 1 Adaption Proj\05_GIS\MXD\Fig1_Site

Downstream

0.85 in. difference

0.84 in. difference

WSEL (ft NAVD88)

Model Time (hrs)

Legend:
— Measured
- - Model

Upstream

0.02 in. difference

0.09 in. difference

WSEL (ft NAVD88)

Model Time (hrs)
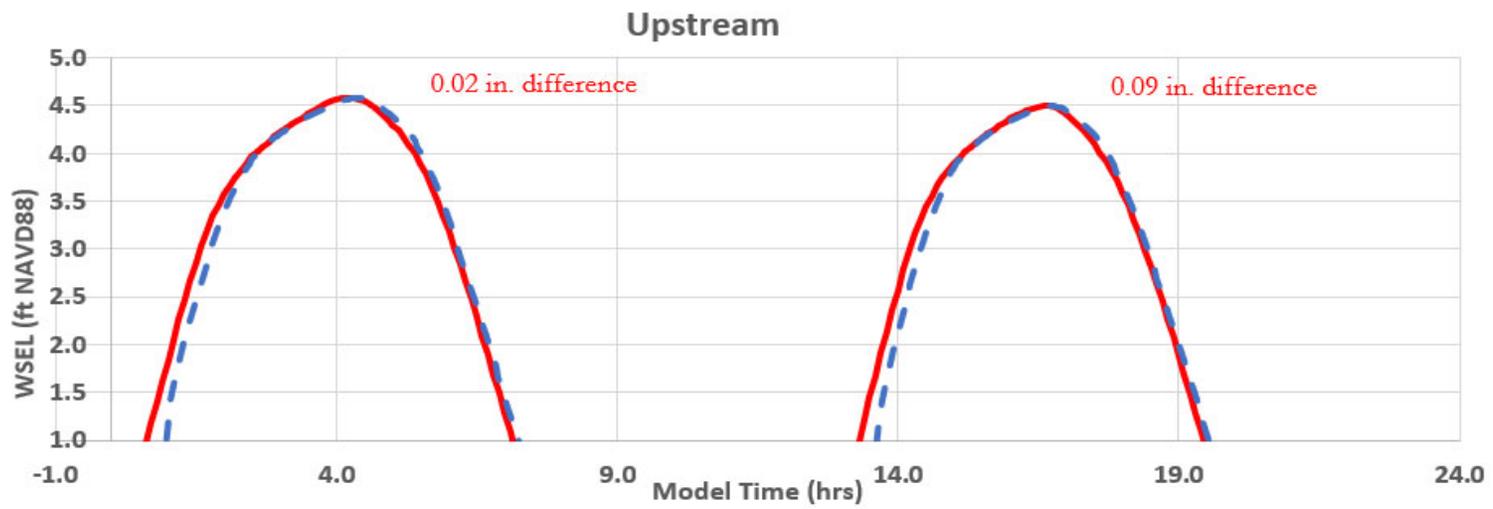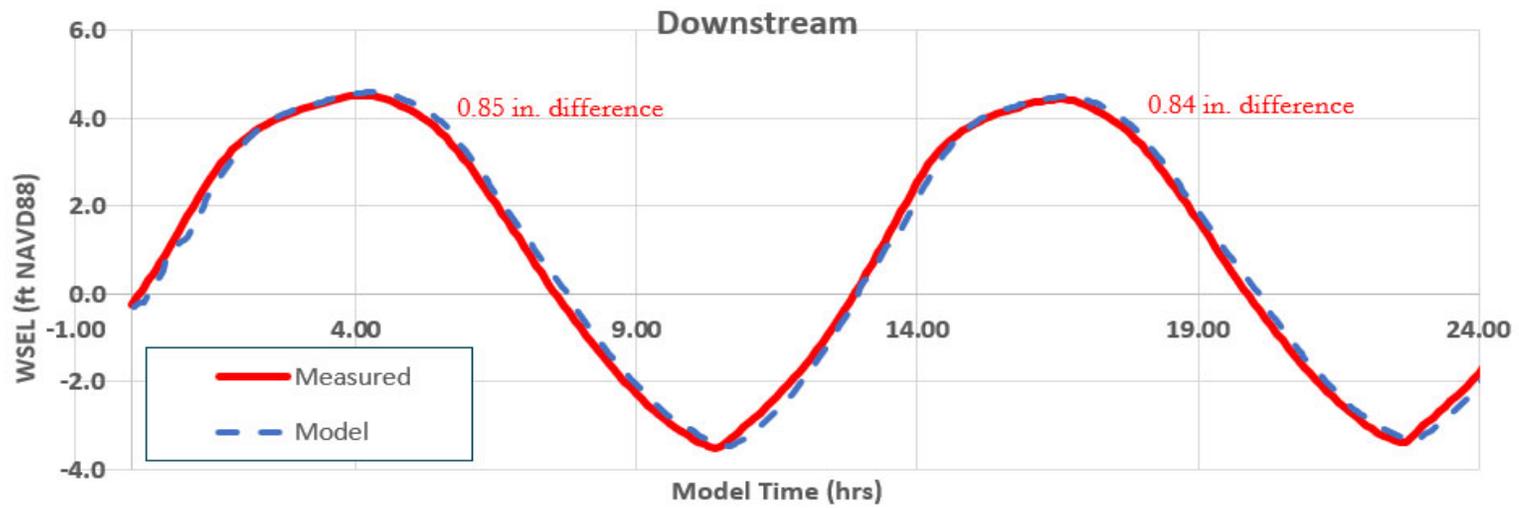
Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	**GEI** Consultants	MODELED VS MEASURED EXISTING CONDITIONS RESULTS US ROUTE 1 CROSSING	
Maine Department of Transportation Augusta, Maine	Project 2305250	January 2025	Fig. 2
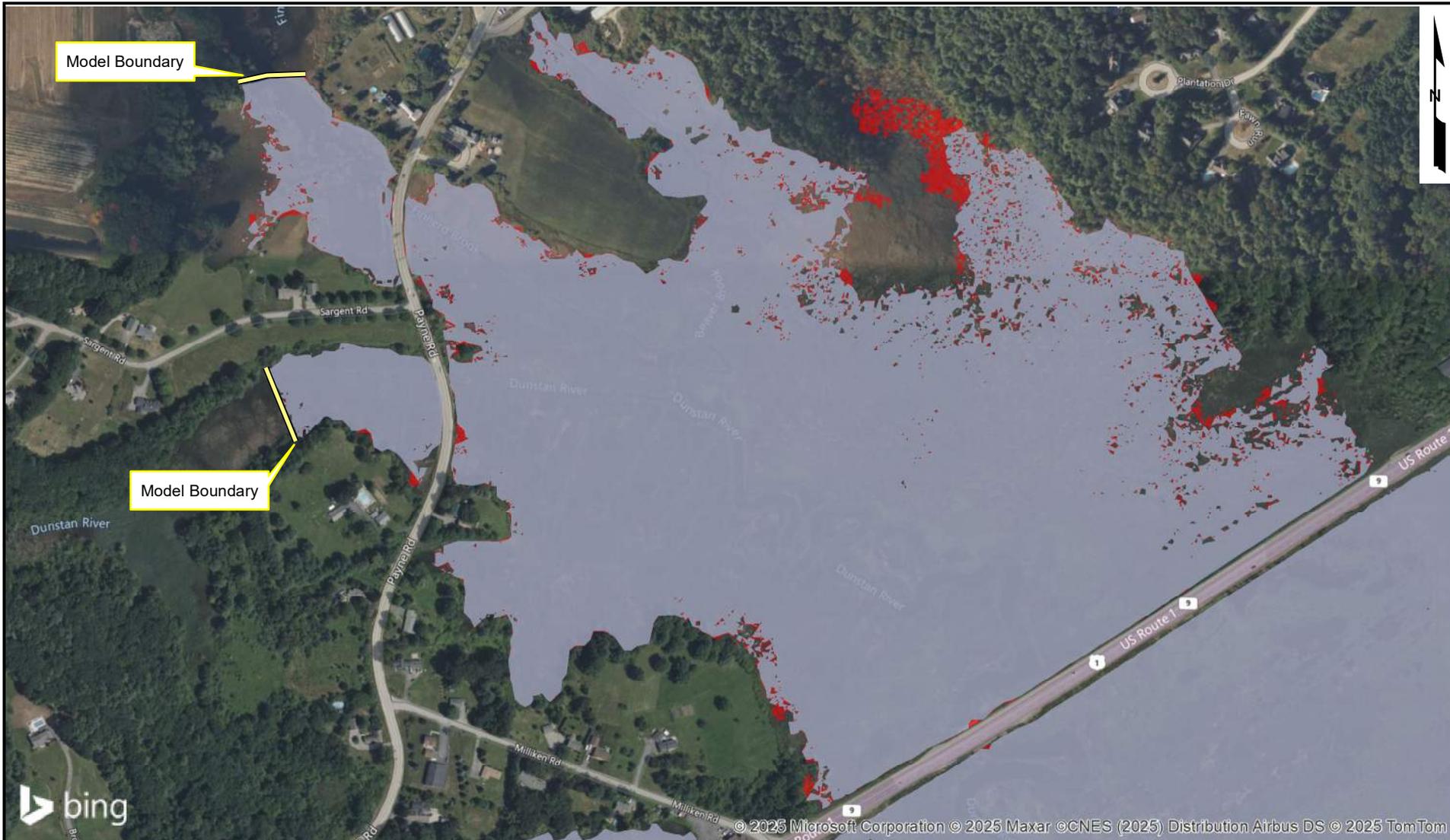
Model Boundary

Model Boundary
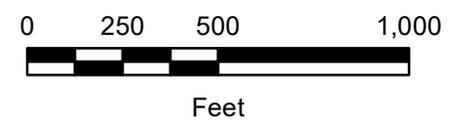
Legend

Existing Culverts Maximum Inundation Extents

Proposed Single Span Bridge Maximum Inundation Extents

Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	**HAsT INUNDATION EXTENTS**
Maine Department of Transportation Augusta, Maine	
Project 2301205	January 2025	Fig. 3

GEI Consultants

0   250   500   1,000

Feet

Legend

Existing Culverts Maximum Inundation Extents

Proposed Single Span Bridge Maximum Inundation Extents

Model Boundary

Model Boundary

Model Boundary

Scarborough Rte. 1 Structure Opening Sizing
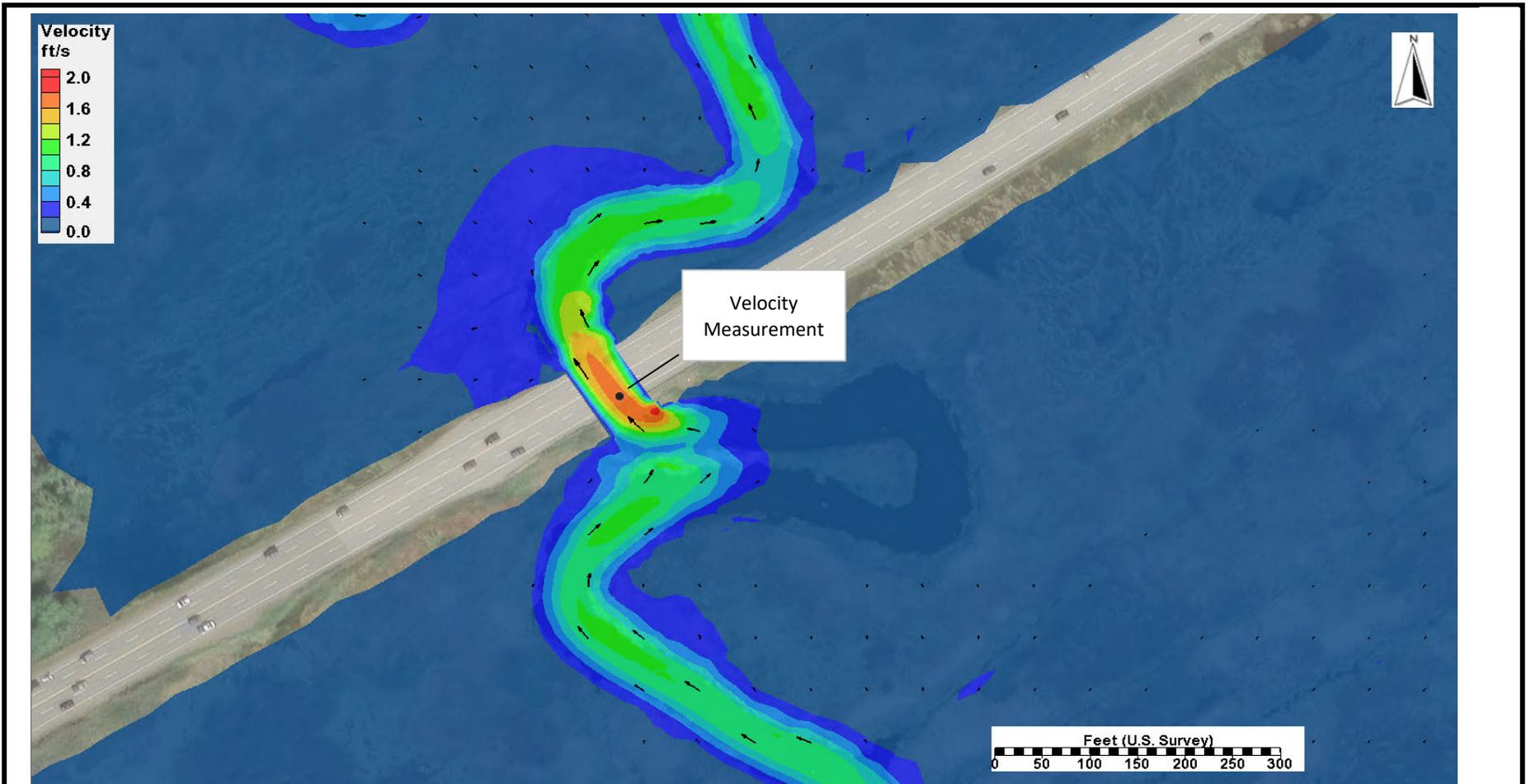Maine DOT WIN 25657.00
Scarborough, Maine

Maine Department of Transportation
Augusta, Maine

GEI Consultants

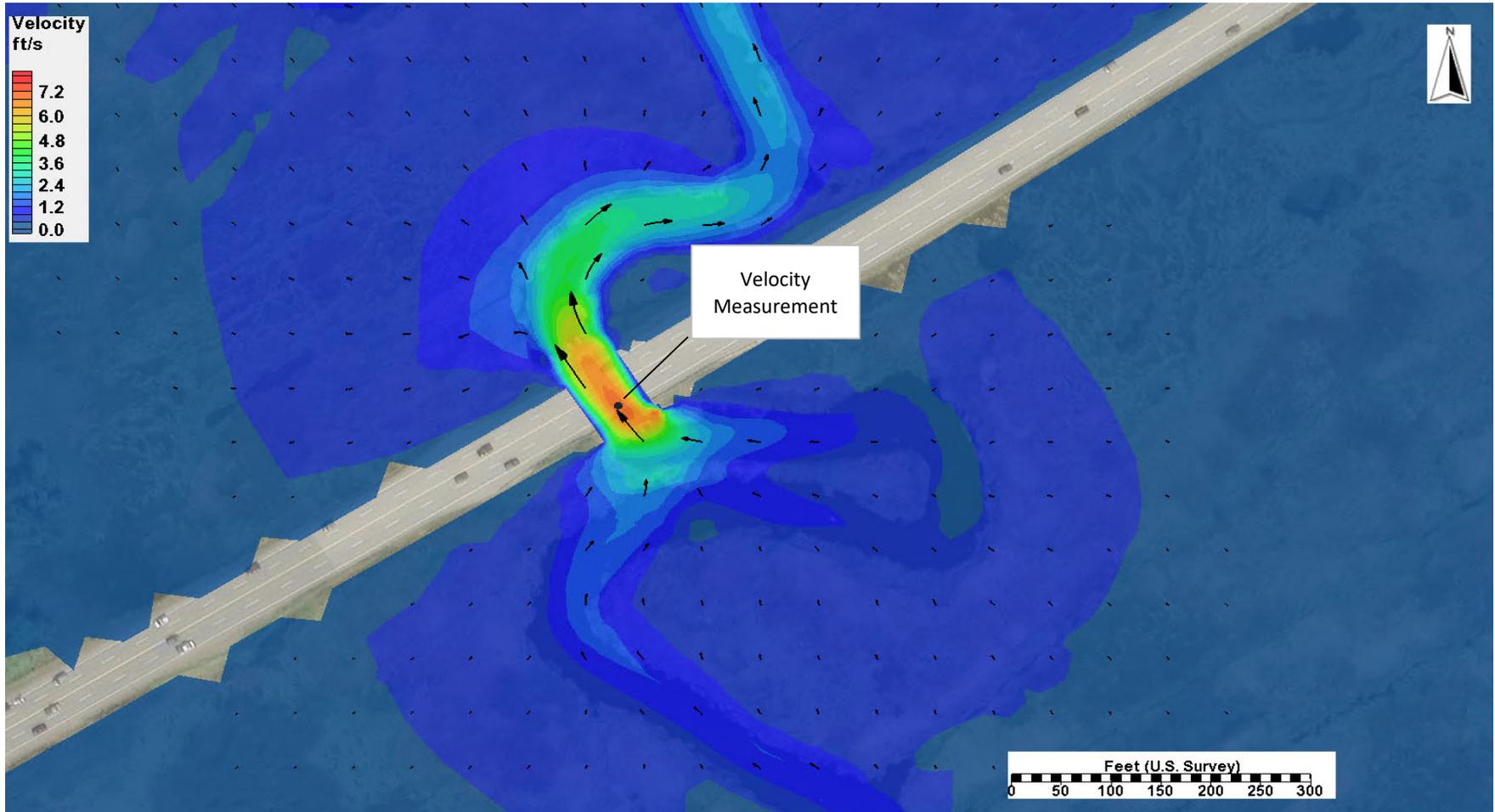**HAsT PLUS SLR INUNDATION EXTENTS**

Project 2301205 | January 2025 | Fig. 4

B:\Working\FUSS AND ONEILL\2305250 Scarborough Rte 1 Adaption Proj\05_GIS\MXD\Fig4_HAST Plus Sea Level Rise rev.mxd

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Velocity ft/s
- 2.0
- 1.6
- 1.2
- 0.8
- 0.4
- 0.0

Velocity Measurement

Feet (U.S. Survey)
0 50 100 150 200 250 300

Notes:
1. Contour intervals are drawn to 0.2-ft/s increments and represent water velocity.
2. Vectors show direction of flow.

Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	GEI Consultants	HAsT MAX VELOCITY THROUGH CROSSING 75-FOOT SPAN
Maine Department of Transportation Augusta, Maine	Project 2305250	January 2025 Fig. 5

Notes:
1. Contour intervals are drawn to 0.4-ft/s increments and represent water velocity.
2. Vectors show direction of flow.

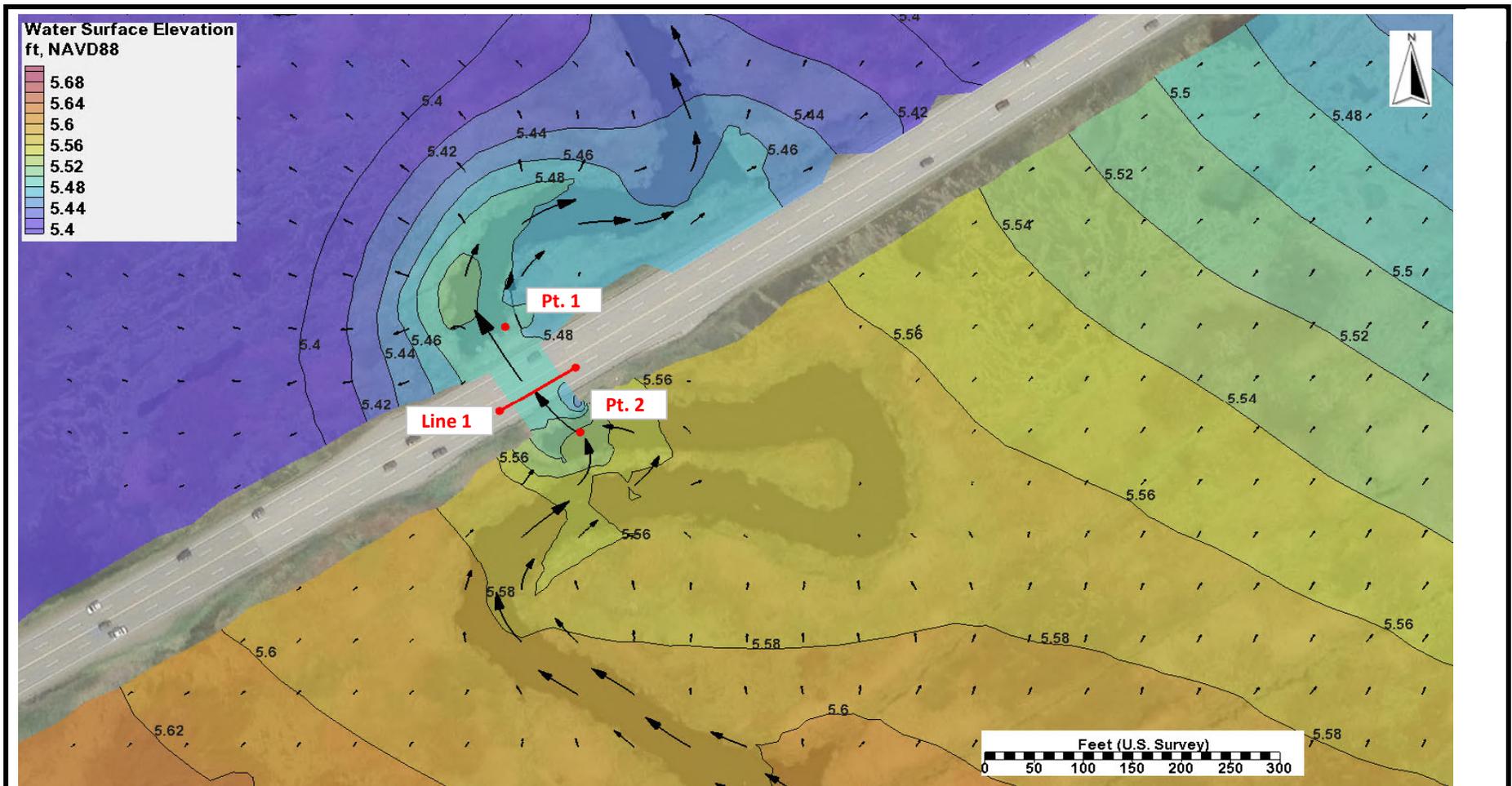| Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	GEI Consultants	HAsT PLUS SLR MAX VELOCITY THROUGH CROSSING 75-FOOT SPAN
Maine Department of Transportation Augusta, Maine	Project 2305250	January 2025 — Fig. 6

Notes:
1. Contour intervals are drawn to 0.02-ft increments and represent water surface elevation in ft NAVD88.
2. Vectors show direction of flow.
3. Red lines and points represent observation locations for flow and water surface elevation results.

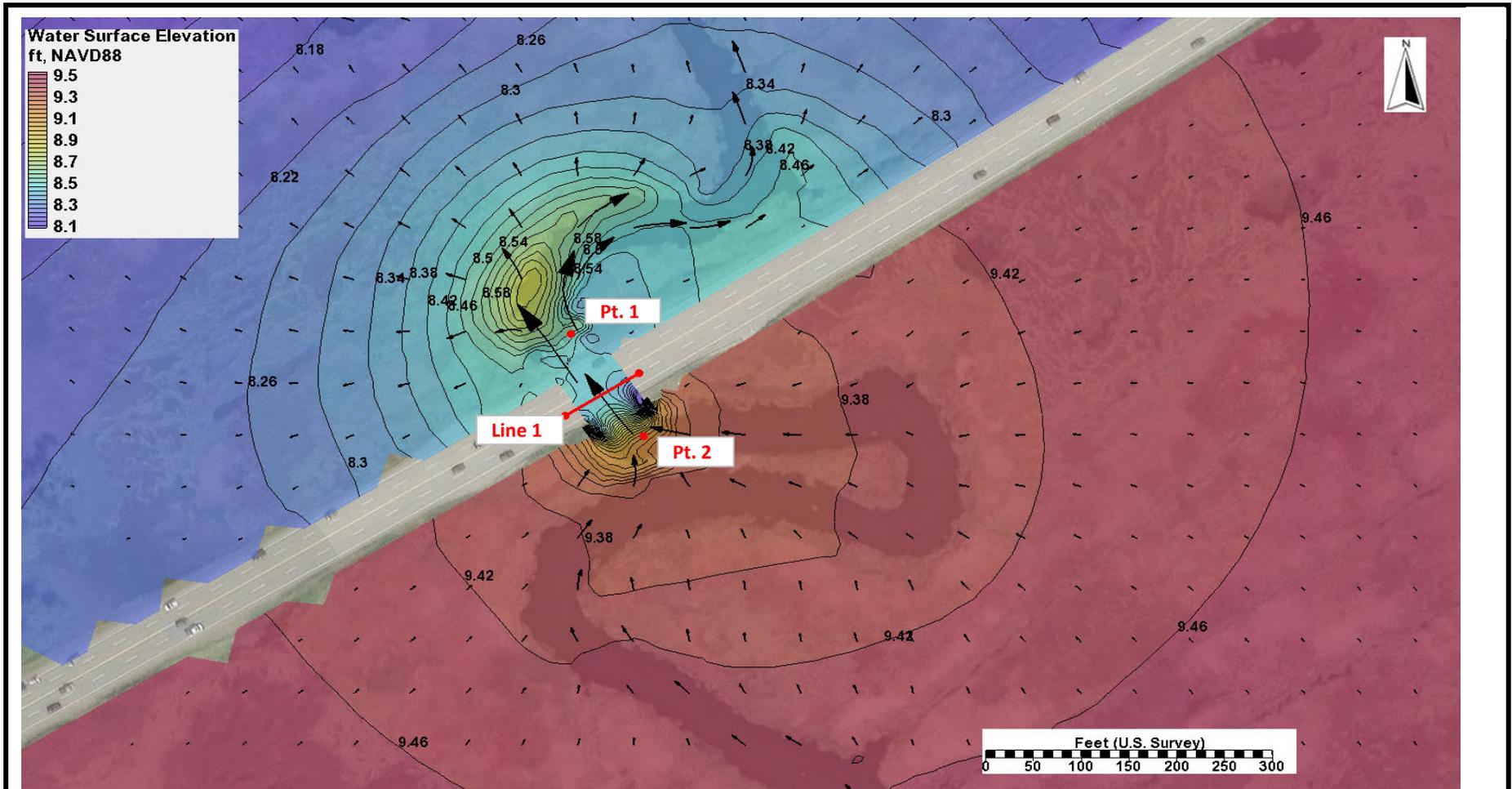|	Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	GEI Consultants	HAsT PEAK INSTANTANEOUS HYDRAULIC HEAD DIFFERENCE 75-FOOT SPAN	
	Maine Department of Transportation Augusta, Maine	Project 2305250	January 2025	Fig. 7

Notes:
1. Contour intervals are drawn to 0.04-ft increments and represent water surface elevation in ft NAVD88.
2. Vectors show direction of flow.
3. Red lines and points represent observation locations for flow and water surface elevation results.

Scarborough Rte. 1 Structure Opening Sizing Maine DOT WIN 25657.00 Scarborough, Maine	GEI Consultants	HAsT PLUS SLR PEAK INSTANTANEOUS HYDRAULIC HEAD DIFFERENCE 75-FOOT SPAN	
Maine Department of Transportation Augusta, Maine		Project 2305250	January 2025 Fig. 8