

HYDROLOGY REPORT

Whitney Brook Bridge (#2942) carries US Route 1 over Whitney Brook in Bridgewater. The watershed of the Whitney Brook Bridge is approximately 27.9 mi². Whitney Brook begins at the confluence of North and South Branches of Whitney Brook approximately 0.8 miles upstream from the bridge and ends approximately 3.3 miles downstream from the bridge at Prestile Stream.

There is no stream gage on Whitney Brook nor on other waterbodies near the bridge. There is no Flood Insurance Study (FIS) for the subject location. A Flood Insurance Rate Map (FIRM) exists, effective September 18, 1985, which identifies the subject location as Type C: areas outside 500-year flood. The existing bridge has no record of flooding and has not experienced an overtopping event in the recent past. The Bridge Scour Evaluation Report dated July 1996 states, "The FEMA report for Presque Isle notes the April 1973 flood to be the flood of record on the Aroostook River (25 miles west). No damage was reported at this bridge. Pressure flow is possible though overtopping is unlikely."

The Maine Department of Transportation (MaineDOT) Environmental Office - Hydrology Section provided the drainage basin characteristics and flow data for this bridge. The original flow data are based on peak flow calculations using U. S. Geological Survey (USGS) Regression Equations. The hydrology data and supporting calculations are included in Appendix E.

SUMMARY

Drainage Area	27.9	mi ²
Q1.1	204.7	ft ³ /s
Q10	641.7	ft ³ /s
Q25	788.2	ft ³ /s
Q50	898.8	ft ³ /s
Q100	1018.2	ft ³ /s
Q500	1296.9	ft ³ /s

The hydrology report indicates an estimated bankfull width (BFW) of 44.3 feet, and the proposed clear span is required to be at least 1.2*BFW or 53.2 feet.

Reported by: Ross S. Wood, PE
Date: March 15, 2021

HYDRAULIC REPORT

Hydraulic Modeling

The software package used to develop the SRH-2D (Sediment and River Hydraulics, Two-Dimensional) model for the existing and proposed crossings is Aquaveo's Surface-water Modeling System (SMS) Version 13.0. The program allows the user to develop a two-dimensional (2D) hydraulic, sediment, temperature, and vegetation model that incorporates the Finite Volume method in conjunction with implicit first- and second-order numerical schemes to approximate a solution for the 2D depth averaged Saint Venant equations.

The model development process is outlined in the following paragraphs. It consists of importing background data (including elevations, satellite imagery, GIS data, and CAD linework), defining a mesh, boundary conditions, material coverages, and monitoring points and lines, creating the simulations and defining model control parameters, and running the model.

Surface Generation

Conventional survey was completed for this project and incorporated as a DTM file. This file encompassed stream bathymetry near the existing bridge but did not adequately encompass the floodplain. A LiDAR surface was used to supplement the on-the-ground survey to incorporate missing floodplain areas. DEM/LiDAR panels were downloaded from the NOAA Data Access Viewer website <https://coast.noaa.gov/dataviewer/#/lidar/search/>. The LiDAR data reflects the water surface elevation; therefore, the feature stamping tool was used to create a channel bottom through the limits of the project which were not included in the survey. By inspection of the difference between the LiDAR water surface and the survey data, the channel bottom was taken to be 1.8 ft below the LiDAR water surface. The slope of the stream was taken to be 0.0016. A constriction exists approximately 550 ft upstream of the project site which appears to be the embankments of a bridge which no longer exists. The constriction causes backwater upstream of the embankments and restricts flow.

Mesh Development

The model domain was manually defined for both the existing and proposed conditions. Triangular mesh elements are used to model the floodplains and surrounding terrain and quadrilateral mesh elements are used to model the brook and roads. The size of the elements are adjusted based on their proximity to the bridge site in order to optimize the model. See the following page for an image of the mesh for the existing conditions.

Mesh Development (Cont.)

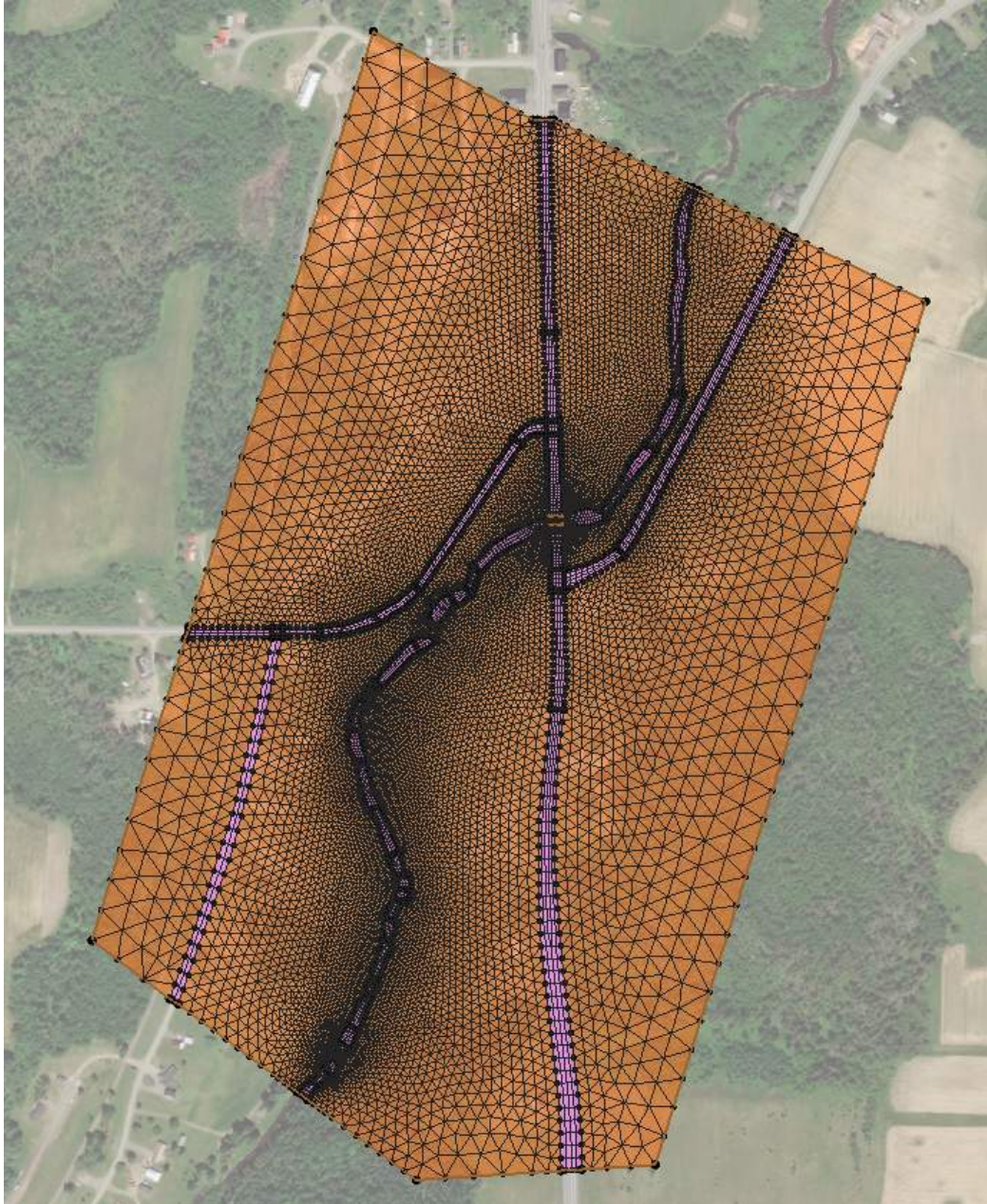
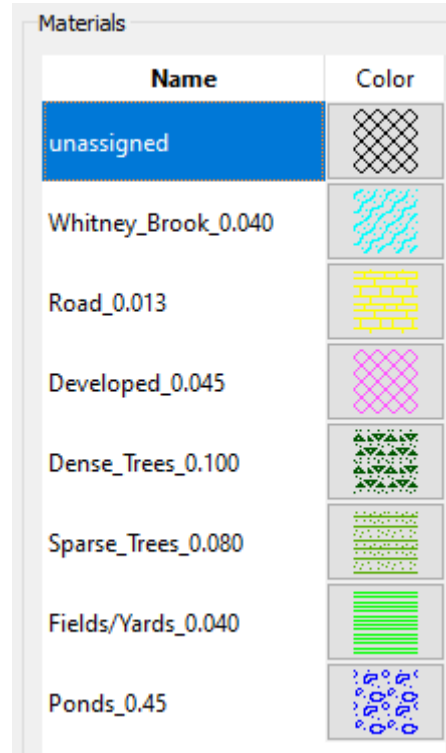


Figure 1 – Plan View of Project Site and Mesh Elements

Material Properties

The following array of material properties, and their associated Manning's roughness coefficient, n , for open channels, are used in the analysis.




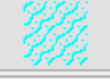
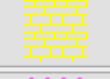



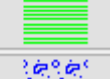

Name	Color
unassigned	
Whitney_Brook_0.040	
Road_0.013	
Developed_0.045	
Dense_Trees_0.100	
Sparse_Trees_0.080	
Fields/Yards_0.040	
Ponds_0.45	

Figure 2 – Array of Materials and Manning's n

Boundary Conditions

The upstream boundary conditions for the Whitney Brook analysis are determined using mass conservation. The different flows from the Hydrology summary are input as constant inflows in their respective boundary condition definitions.

The downstream boundary conditions are taken to be Exit-H type because subcritical outflow is anticipated for these events. Constant water surface elevations are calculated for each flow scenario based on the outflow cross-section, Manning's n value, and channel slope.

The existing and proposed bridges are modeled using additional internal boundary conditions known as pressure types. The respective upstream and downstream low chord elevations are input along with a concrete ceiling Manning's n value of 0.012. The low chord elevations of the existing and proposed bridges are taken to be 400.7' and 400.5', respectively.

Sensitivity Analysis

Due to the lack of stream gauge data to correlate water surface elevations to known discharges, a sensitivity analysis was performed to evaluate the modeling assumptions. For this analysis, the downstream boundary condition was adjusted to evaluate whether the water surface elevations converge before the subject bridge. Convergence is considered to occur when a variable is adjusted but the solution does not change significantly. The downstream exit water surface elevation for the existing conditions Q50 event was both decreased and increased by one foot of elevation; refer to the following table for a summary of the results. Supporting profile plots are included in Appendix E. The results indicate that the water surface elevations converge downstream of the bridge. Additional tests were performed by increasing and decreasing the Manning’s n values with no appreciable effect on the water surface elevations or stream velocities near the bridge. For these reasons, the model is taken to be reliable.

Scenario Name	Exit WSEL (ft)	Downstream WSEL (ft)	Downstream Delta (in)	Upstream WSEL (ft)	Upstream Delta (in)
Low Tailwater Elevation	394.05	397.86	-0.04	398.37	-0.02
Q50 Tailwater Elevation	395.05	397.90	0	398.39	0
High Tailwater Elevation	396.05	397.99	+0.09	398.46	+0.07

Table 1 – Water Surface Elevation (WSEL) Sensitivity Analysis Summary

Proposed Structure

The design flows were used for the existing structure and the proposed structure models. The following assumptions were used when modeling the proposed structure:

- Single span clear distance of 63’ between abutment faces,
- Low chord elevation of 400.9’,
- The grading in front of the north and south abutments reflect 2.5’ wide berms (elevations 397.64’ and 398.08’, respectively), 1.75:1 end slopes, and 4’ wildlife shelves at the assumed bankfull elevation of 395’,
- And a stream bed elevation of 392’ +/-.

Headwater elevations and stream velocities are reported in the table on the following page for the peak flows for both the existing and proposed structures. Supporting profile plots and velocity plans are included in Appendix E.

SUMMARY

		Existing Structure	Recommended Structure
		30' Single Span Concrete Tee Beams	66' Single Span Concrete NEXT Beams
Total Area of Waterway Opening	ft ²	235	455
Headwater elevation @ Q _{1.1}	ft	395.6	395.5
Headwater elevation @ Q ₁₀	ft	397.6	397.3
Headwater elevation @ Q ₂₅	ft	398.1	397.7
Headwater elevation @ Q ₅₀	ft	398.4	398.0
Headwater elevation @ Q ₁₀₀	ft	398.7	398.2
Headwater elevation @ Q ₅₀₀	ft	399.5	398.8
Freeboard @ Q ₅₀	ft	2.3	2.9
Freeboard @ Q ₁₀₀	ft	2.0	2.7
Flood of Record - Unknown			
Outlet Velocity @ Q _{1.1}	ft/s	3.1	2.1
Outlet Velocity @ Q ₁₀	ft/s	5.7	3.7
Outlet Velocity @ Q ₂₅	ft/s	6.5	4.1
Outlet Velocity @ Q ₅₀	ft/s	7.0	4.4
Outlet Velocity @ Q ₁₀₀	ft/s	7.7	4.7
Outlet Velocity @ Q ₅₀₀	ft/s	8.9	5.3

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

Scour Analysis

A scour analysis was performed based on procedures outlined in FHWA publication HEC-18, 5th Edition. The 100-year and 500-year events were analyzed for contraction scour and local scour at the proposed site. The D_{50} of the streambed was taken to be 1 mm based on the soil descriptions included in the boring logs. A sensitivity analysis was performed by varying the particle size from the HEC-18 identified reasonable lower limit of 0.2 mm to the upper limit of 12 mm, which is about the grain size limit for live-bed scour conditions before clear-water scour conditions would be exhibited at this site. HEC-18 states that scour depths with live-bed scour may be limited by coarse sediments in the bed material armoring the bed and recommends that scour depths also be calculated using clear-water scour equations. A clear-water scour analysis was also performed, and scour depths of 3 ft and 6 ft were calculated for the Q100 and Q500 events, respectively. These depths correlate to elevations of 389 feet and 386 feet based on a streambed elevation of 392 feet.

The existing bridge previously received scour repairs when the north abutment exposed footing was armored, per the maintenance work items listed in the bridge inspection report. The proposed hydraulic opening is greater than the existing bridge and the constriction of the channel by the bridge is reduced. The proposed structure will utilize integral abutments, which will be located outside the brook, and incorporate riprap slopes to protect against scour. The scour analysis calculations are included in Appendix E.

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Date: March 15, 2021