HYDROLOGY REPORT

Hanson Bridge crosses Smith Brook. Hanson Brook joins Smith Brook just downstream of the bridge after being redirected in a manmade channel. Flow data for both streams was calculated by Charlie Hebson of the MaineDOT Environmental Office Hydrology Section using the regression equations developed by USGS. No measured or previously calculated flood elevations are available at this site.

SMITH BROOK

Drainage Area	3.14	mi^2
Q1.1	65	ft^3/s
Q10	255	ft^3/s
Q25	325	ft^3/s
Q50	380	ft^3/s
Q100	440	ft^3/s
Q500	585	ft^3/s

HANSON BROOK

Drainage Area	1.50	mi^2
Q1.1	35	ft^3/s
Q10	145	ft^3/s
Q25	190	ft^3/s
Q50	225	ft^3/s
Q100	265	ft^3/s
Q500	355	ft^3/s

Reported by: Hasbrouck, Joshua P
Date: August 8, 2022

HYDRAULIC REPORT

PROJECT SUMMARY

Hanson Bridge #1035 carries Saint Albans Road, a State Aid road, over Smith Brook. Hanson Brook joins Smith directly on the downstream side of the bridge. The existing bridge is a concrete slab on mass abutments that are joined by a bottom slab, creating a concrete box with flared wingwalls on each end. The bottom slab is about 1 foot above the streambed on each end, creating a passage barrier at low flows, with less than an inch of water flowing across the slab. Both ends of the slab have been protected against scour with grout bags. The flow in Hanson Brook is almost non-existent during dry summer weather, with the water disappearing into the rocky ditch bottom.

MODELING METHODOLOGY

The hydraulic models were built using Aquaveo SMS software (version 13.1.22) and used the SRH-2D analysis engine developed by the U.S. Bureau of Reclamation. SRH-2D is a 2D hydraulic analysis engine that uses an unstructured mesh for the terrain with separate defined area coverages for material roughness and boundary conditions.

The terrain for the models was created with a combination of traditional ground survey collected by MaineDOT and statewide LiDAR data from MaineGIS. The survey data was in the ME2000 Central Zone of the State Plane coordinate system using US Survey Feet as the units and the NAVD 88 vertical datum. The LiDAR data was in the UTM coordinate system, Zone 19, with units of meters and also used the NAVD 88 vertical datum.

MESH DEVELOPMENT

Since the ground survey data did not cover a large enough area to build an accurate model, the survey data was combined with flown LiDAR data. Prior to importing the LiDAR data, it was processed by the MaineDOT survey division to remove features like trees and telephone poles so only the ground remained. Since the LiDAR data is significantly less precise, it was only used outside the limits of the ground survey.

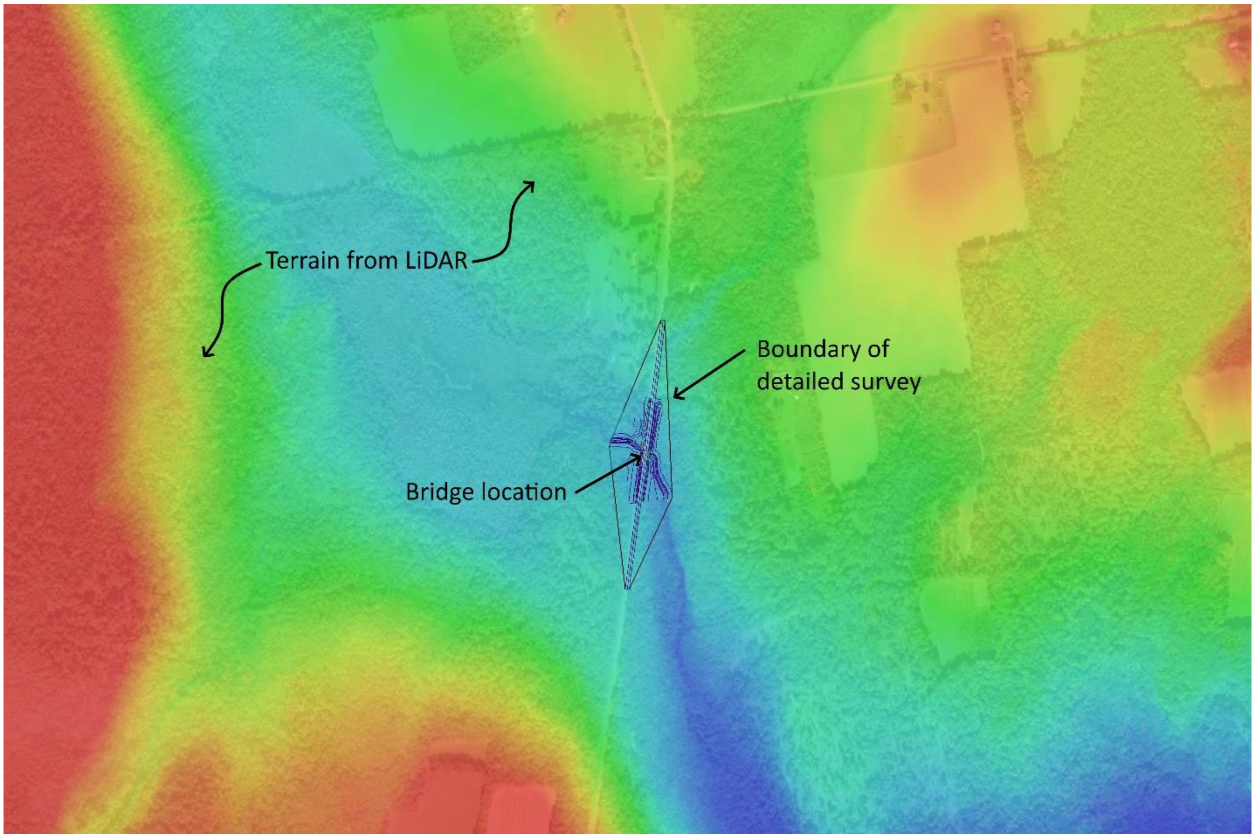

Figure 1: Detailed survey limits vs. LiDAR area

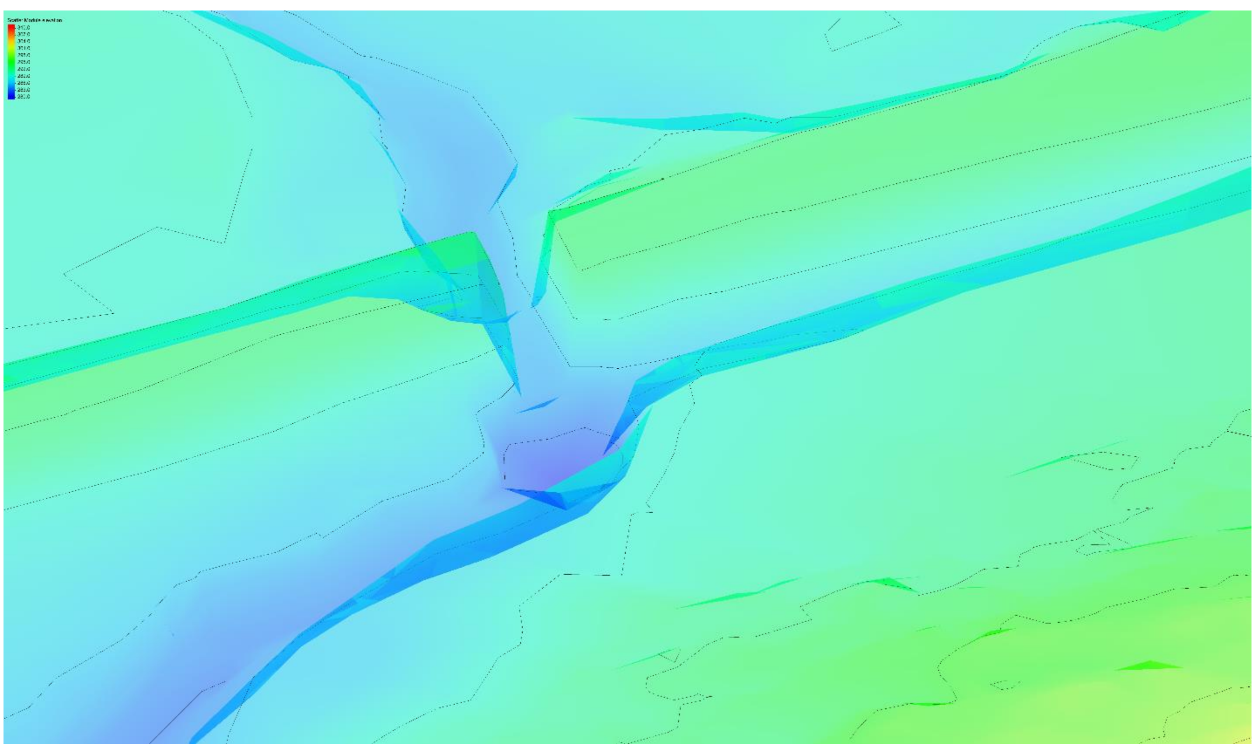

Figure 2: 3D view of existing terrain at bridge (height exaggerated)

Separate meshes were developed from the terrain for the existing and proposed conditions, and both of them covered an area of 79 acres and had about 17,000 elements. The number of elements was reduced by using variable mesh density ranging from 2-5 foot spacing at the bridge and immediate channel to 10-25 foot spacing on channel areas away from the bridge and 75 foot spacing at the outer edges of the model. For the mesh generation, lines were defined at the stream banks and centerline of the roadway to make sure that elements did not cross those points and the grade break was modeled accurately.

Most of the mesh used triangular elements, but rectangular elements were used through the bridge structure itself for better efficiency and compatibility with pressure flow condition modeling. The concrete bridge structure and proposed box culvert walls were modeled as holes in the mesh to completely block flow in those areas and provide vertical separation between the bottom of channel and top of the structure. This will slightly affect the results of roadway overtopping, but that only exists in the existing model with a Q500 flow.

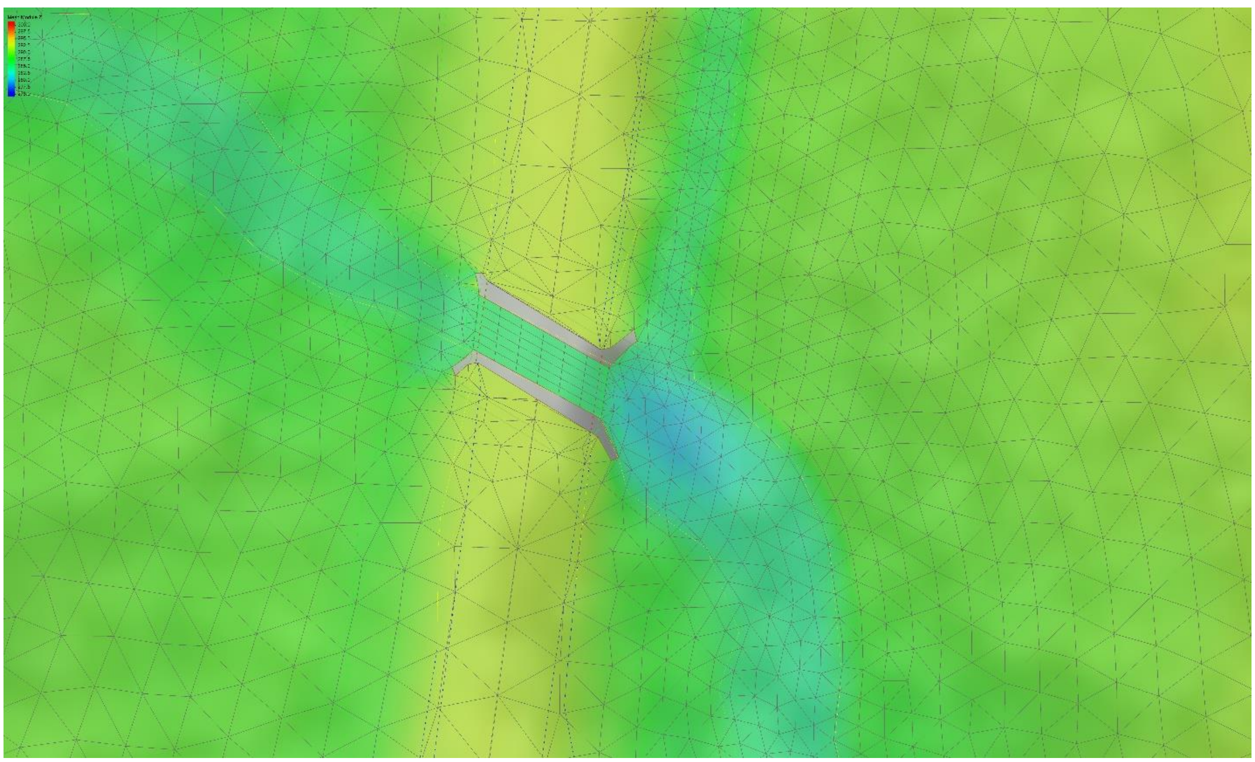

Figure 3: Existing mesh layout at bridge

BOUNDARY CONDITIONS

Because there are two streams in this model, there are two components to the inflow boundary condition. Smith Brook is defined as a standard Inlet-Q (defined flow) line at the outside edge of the model. Hanson Brook is defined as an Internal Sink (constant flow) with a negative flow value to assign it as water flowing into the model. The Internal Sink is located at the end of the driveway culvert upstream of the project, since that is a point where the flow is concentrated and a localized flow input would be appropriate.

The exit boundary is an Exit-H (water surface elevation) line. Elevations were estimated using normal flow calculations with an estimated stream slope of 0.0080 ft/ft and composite roughness of 0.06 with the built-in Channel Calculator tool in SMS. The stream slope was measured between contours on the USGS map for the area.

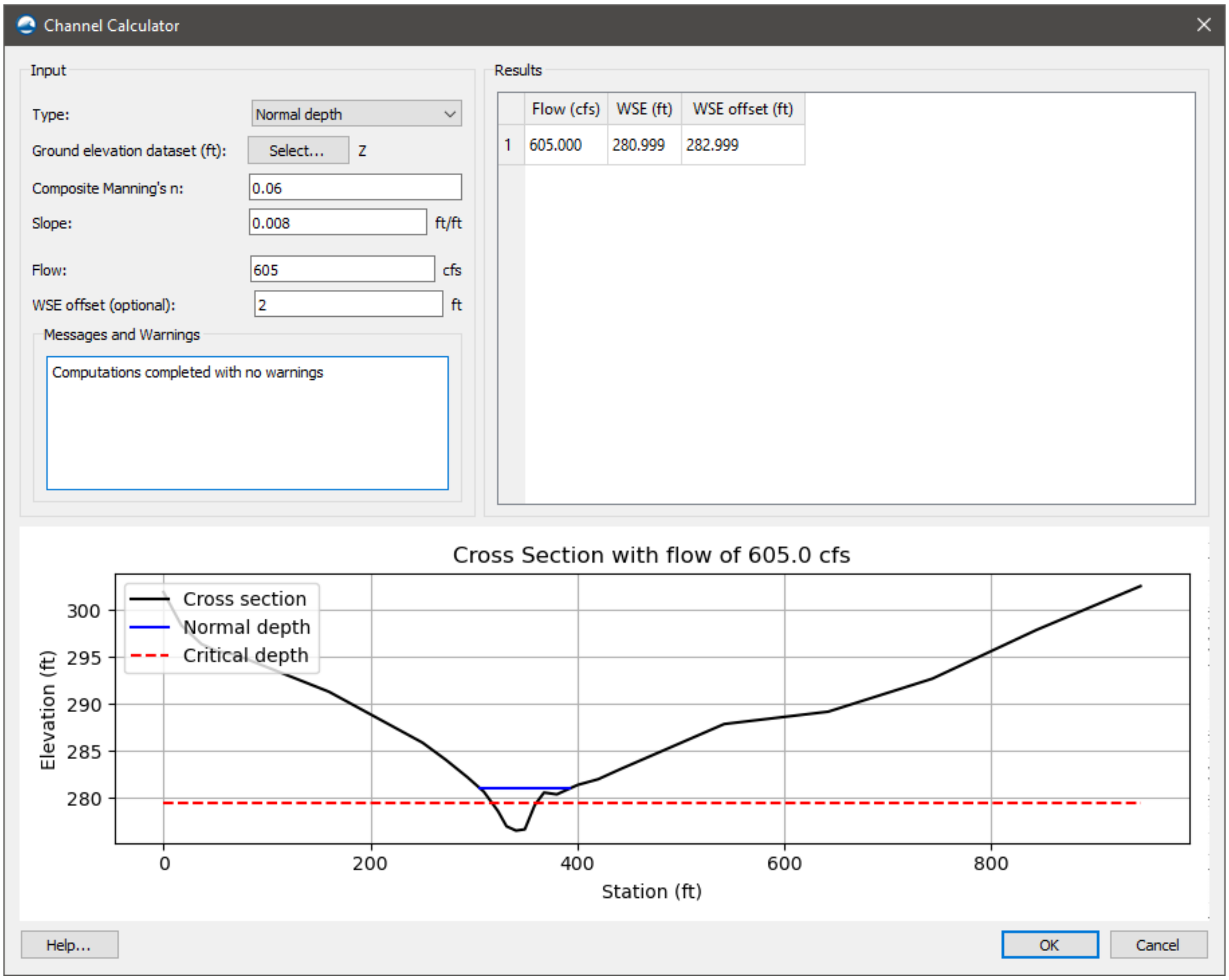

Figure 4: Screenshot of Channel Calculator tool with inputs for Q50 flow

At this site, there is limited information to check the calibration of the model. The modeling relied on visual comparisons to the terrain, vegetation, and the FEMA Flood Insurance Rate Map to estimate approximately where typical flood elevations could be expected and used those to evaluate the downstream boundary conditions. At the lower end, an approximate overbank is visible in the boundary condition cross section at just over 280 feet. The channel calculator estimates an elevation of 278.3 feet for Q1.1, which is significantly lower than expected. Testing with various combinations of roughness and slope confirmed that no slope or roughness values within a normal range affected the estimated water elevation by more than about 6”.

Based on those results, an additional 2 feet was added to the downstream boundary condition elevations to bring them up to a level that better agreed with expected elevations. Why the initial elevations were lower is unknown, but local stream features or variation that does not show up in large scale maps like USGS could be a factor. To verify that a change of this magnitude would not throw the model off and provide erroneous results, the results with the initial downstream water elevation were compared to the results with the 2 feet added. All differences in water elevation at the bridge were less than 0.5 feet, and most were about 0.1 feet or less, showing that the model was not sensitive to the downstream water surface elevation. For the final model, the water elevations with the additional 2 feet added were used as the downstream boundary conditions and are summarized here.

Q1.1	280.3	ft
Q10	282.0	ft
Q25	282.7	ft
Q50	283.0	ft
Q100	283.3	ft
Q500	283.8	ft

Table 1: Downstream boundary condition water surface elevations

The limits of the flooding for the Q100 model were also compared to the Flood Insurance Rate Map from 1985. This map is not highly accurate, and there were no mapped water elevations to compare, so an approximate visual check was the only method available. Roughly the same areas seemed to be flooded in the model at Q100 as on the FIRM.

The existing culvert was modeled as an SRH-2D Pressure Flow boundary condition with a flat ceiling elevation at 290.5 feet upstream and downstream and a surface roughness of 0.012. For the Q500 flow where there was overtopping, the roadway crest elevation to define the weir flow was set at 292 feet, with a length of weir of 20 feet.

MATERIAL ROUGHNESS

The model uses a channel roughness of 0.04 for Smith Brook, a channel roughness of 0.045 for Hanson Brook, a roadway surface roughness of 0.013, an overbank roughness of 0.12 for heavily forested areas, and a roughness of 0.075 for the boggy area upstream.

Figure 5: Surface roughness definitions

To evaluate how sensitive the model was to changes in roughness, the roughness values for the various areas were changed by ±0.01. The channel roughness showed a moderate change of about 0.25 feet up or down. Modifying the overbank forest roughness resulted in a insignificant change of 0.05 feet and all other changes were even smaller.

MODEL STABILITY AND RUNTIME

The combined flows in a small area resulted in some model instability in the initial runs, so the timestep was reduced to 0.5 seconds and a report interval of 5 minutes. This allowed the model run to complete successfully. A default runtime of 3 hours was used for all the scenarios. Most of the simulations stabilized during that time period and showed a steady state of elevations and number of elements wetted. The exception was the Q1.1 simulations where the flow was not large enough to completely flood the boggy area upstream and reach the end of the model in 3 hours. Both the existing and proposed Q1.1 simulations were run a second time using the results of the first run as the starting point, reaching a stable state within that second run.

CHANGES FOR PROPOSED CONDITIONS

To modify the terrain for the proposed condition, the shape of the proposed box and rerouted Hanson Brook channel were imported as a CAD file and used to create a stamping coverage. The bottom of the box was stamped as a flat section in the channel, and the Hanson

Brook channel as a flat-bottomed ditch. Those stamped scatter sets were then combined with existing terrain to create the proposed surface. The mesh definition areas and material roughness were updated for the new channel widths and box wall locations, but no changes were required to the boundary conditions since the new box does not have pressure flow except for the Q500 flood.

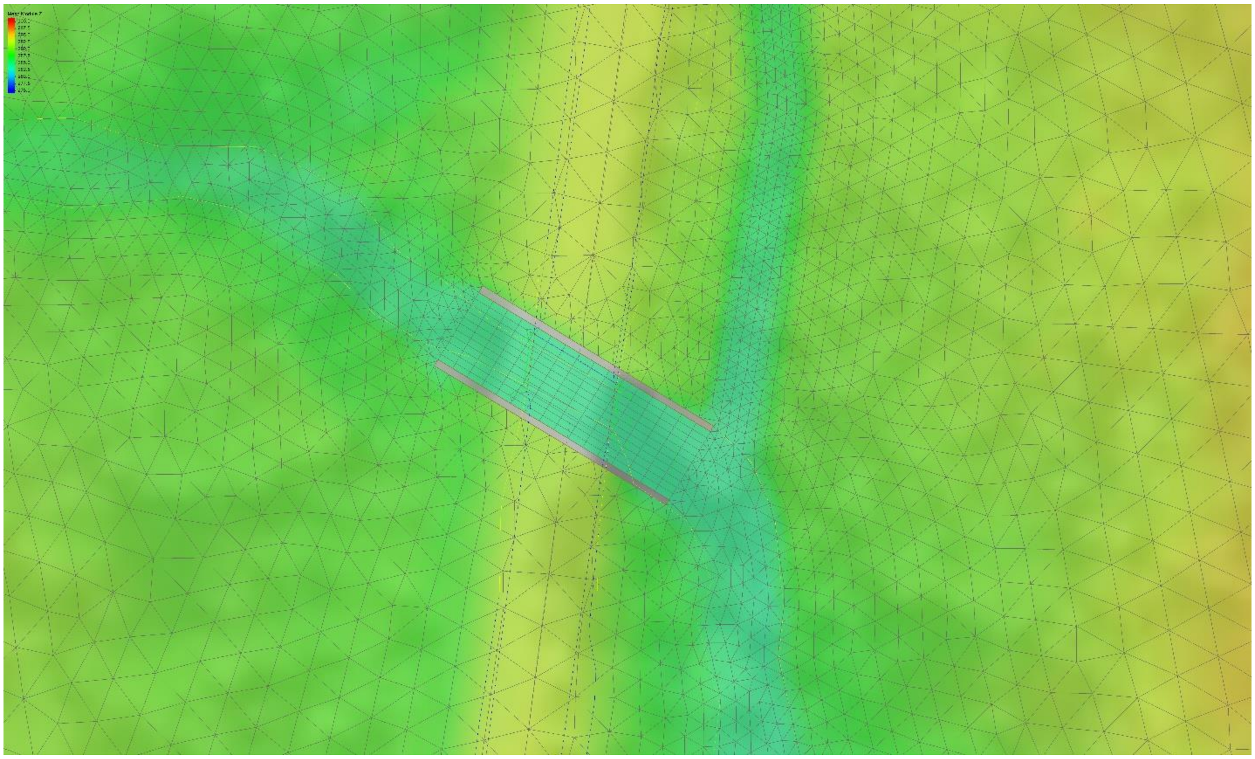

Figure 6: Proposed mesh at bridge

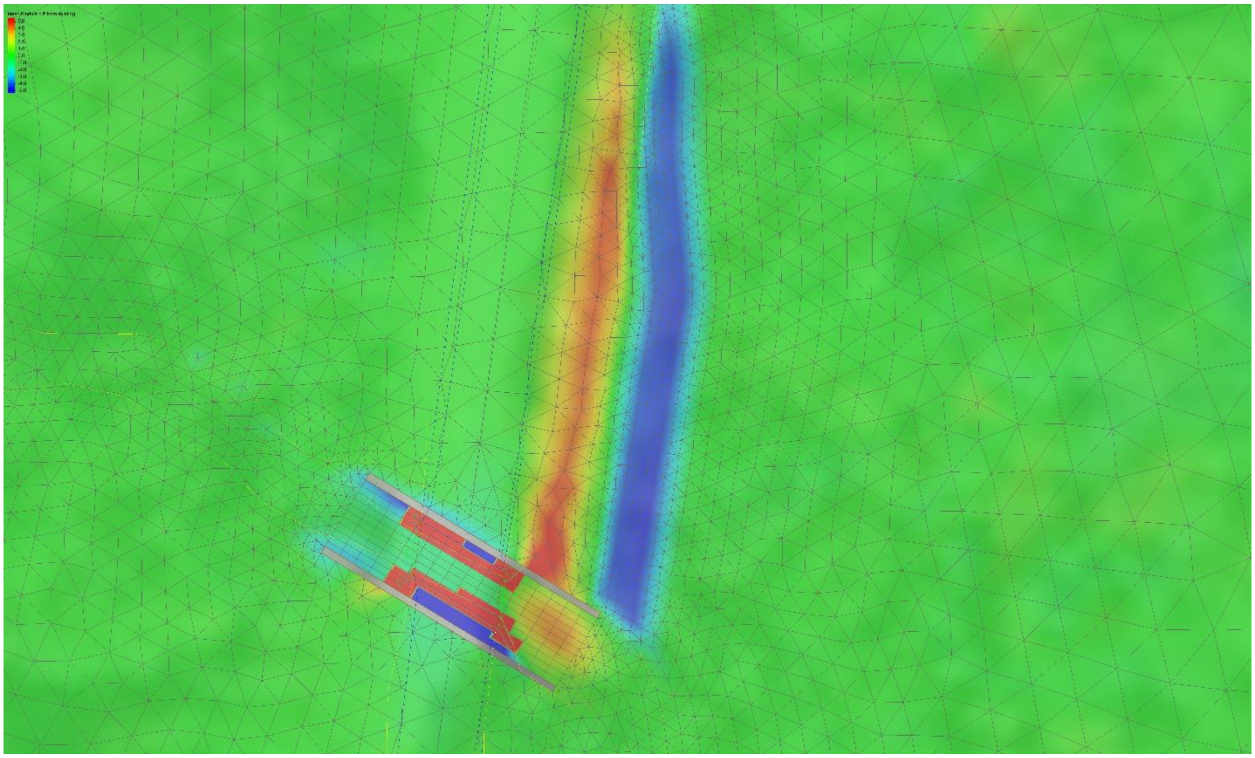

Figure 7: Difference between existing and proposed meshes

HYDRAULIC ANALYSIS RESULTS FOR EXISTING CONDITIONS

Figure 8: Existing Q1.1 simulation elevations

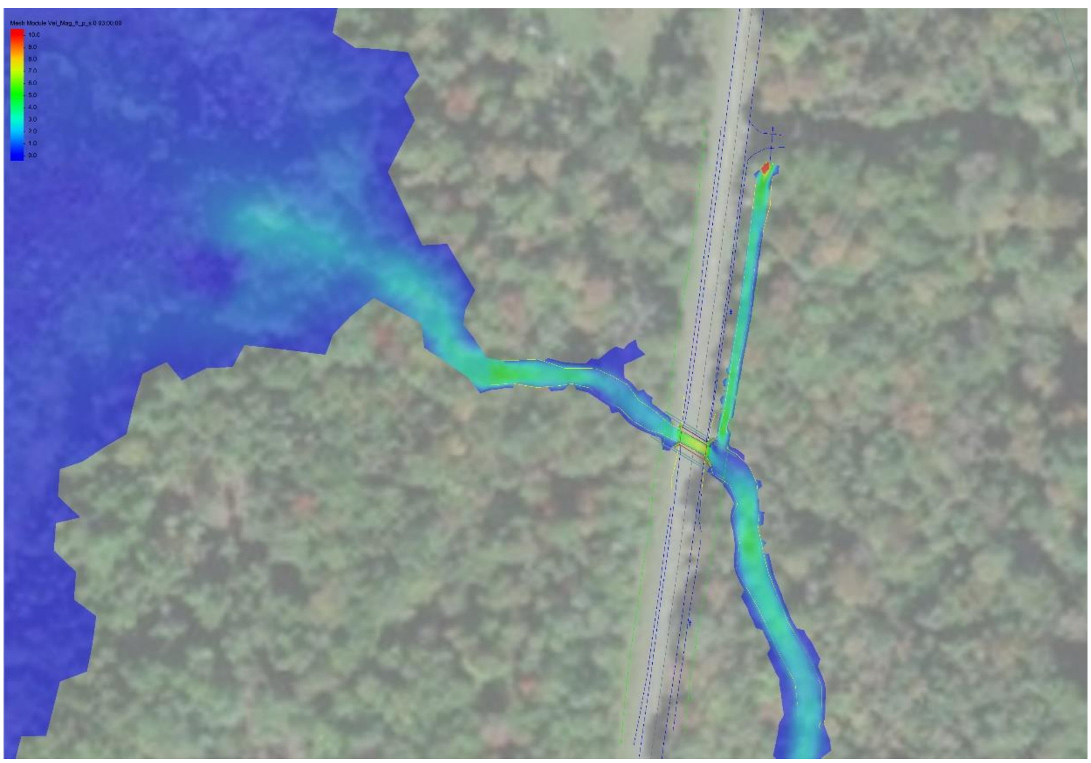

Figure 9: Existing Q1.1 simulation velocities

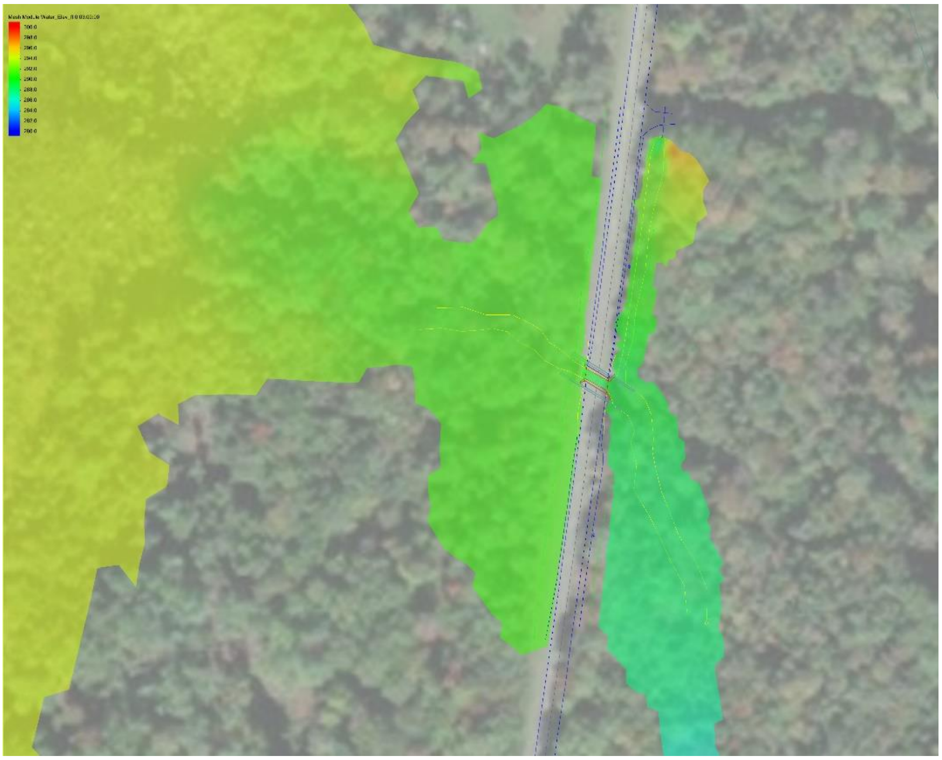

Figure 10: Existing Q50 simulation elevations

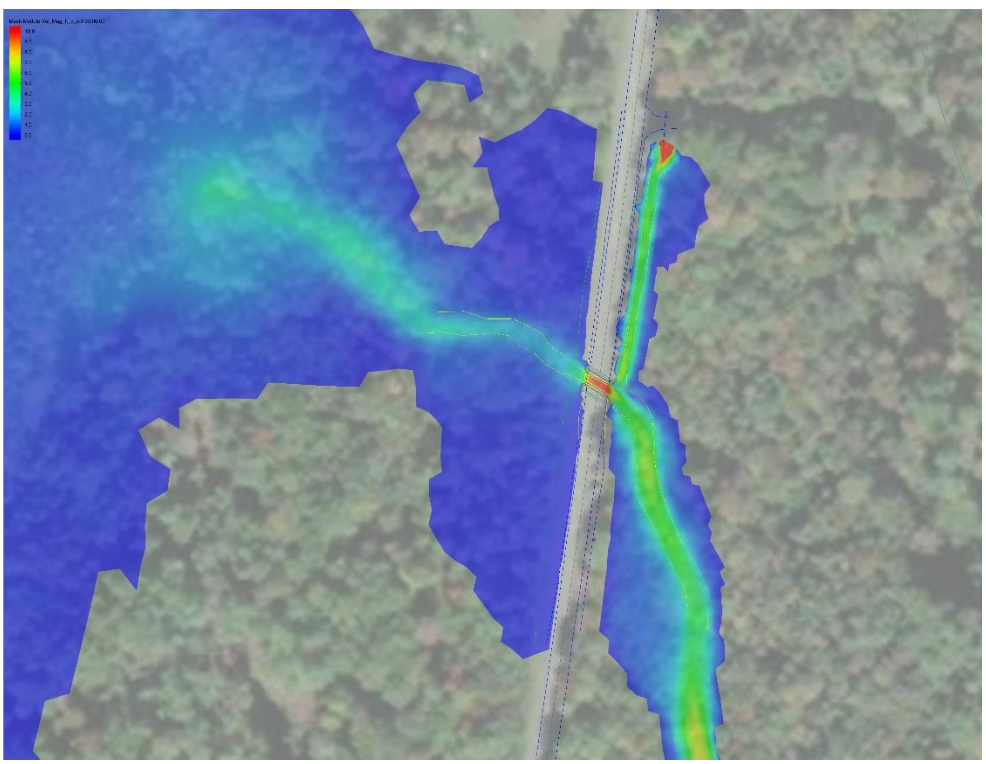

Figure 11: Existing Q50 simulation velocities

HYDRAULIC RESULTS FOR PROPOSED CONDITIONS

Figure 12: Proposed Q1.1 simulation elevations

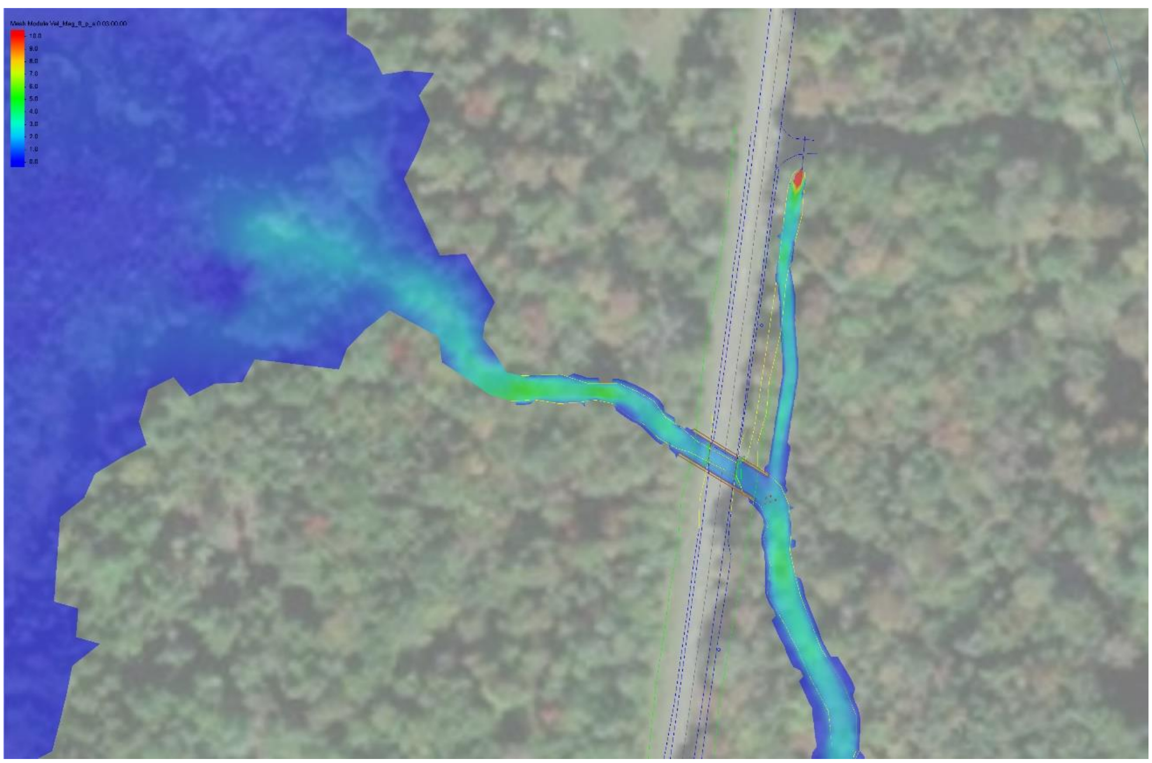

Figure 13: Proposed Q1.1 simulation velocities

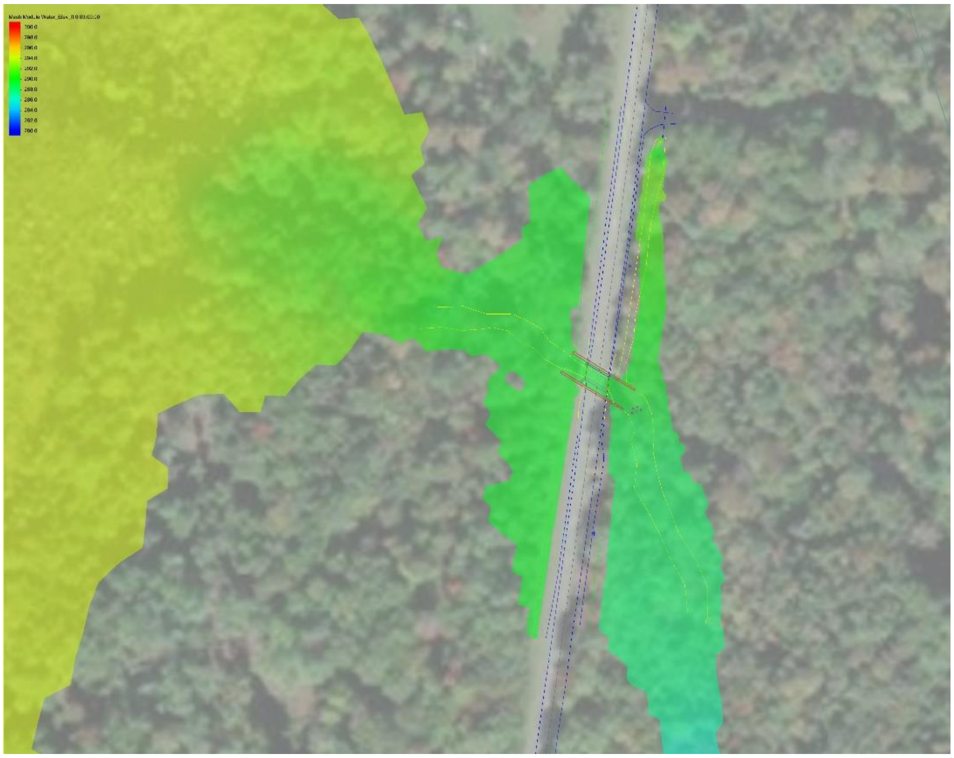

Figure 14: Proposed Q50 simulation elevations

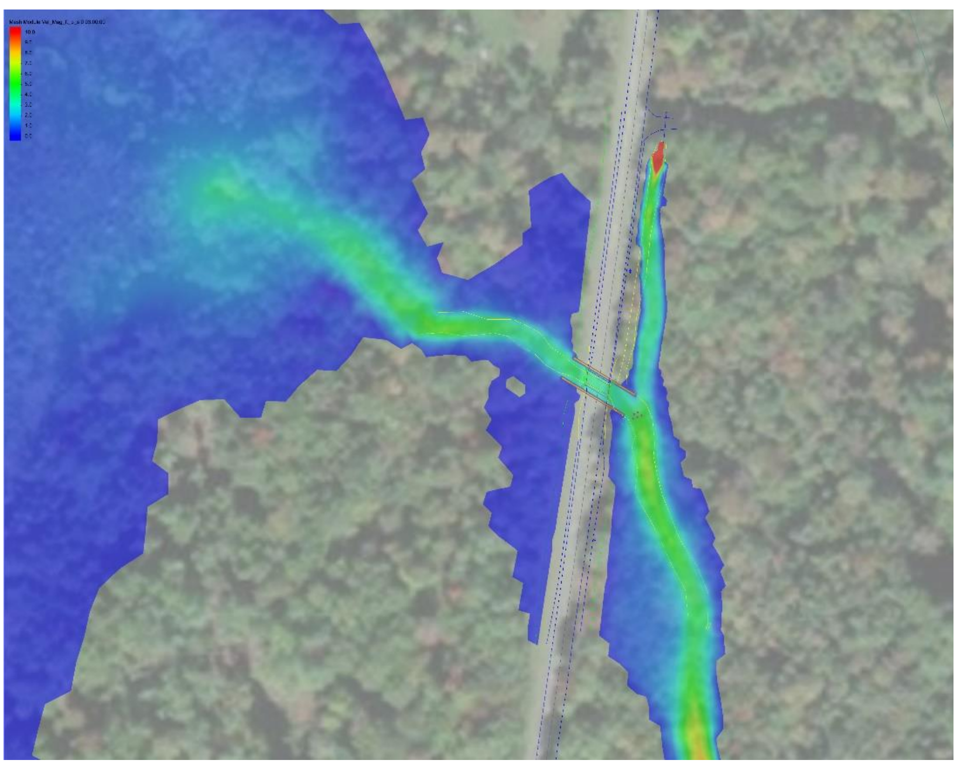

Figure 15: Proposed Q50 simulation velocities

By calculating the difference in elevations at the Q50 design flow, we can clearly see that the primary changes are in the backwater upstream of the bridge.

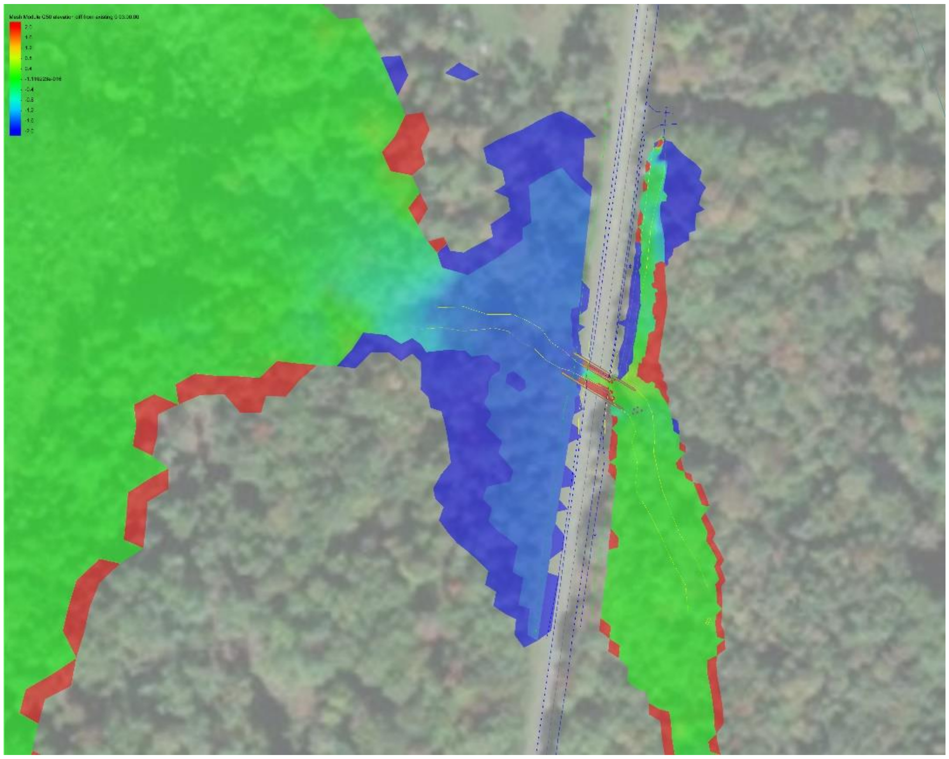

Figure 16: Difference between existing and proposed Q50 elevations

CONCLUSION

The modeling shows a substantial reduction in backwater elevation and velocities through the bridge with the new BFW structure. The proposed simulation results in velocities through the bridge similar to the rest of the stream channel and an insignificant water elevation change through the bridge for the design flow, indicating the structure matches the site well and is a suitable size.

The precast concrete box is a stable structure that protects against scour, so no scour risk needs to be evaluated.

SUMMARY

		Existing Structure	Recommended Structure
		10' Span Slab Bridge	23' Span Box Culvert
Total Area of Waterway Opening	ft^2	60	138
Headwater elevation @ $Q_{1.1}$	ft	287.0	286.4
Headwater elevation @ Q_{10}	ft	289.6	288.4
Headwater elevation @ Q_{25}	ft	290.4	289.0
Headwater elevation @ Q_{50}	ft	291.0	289.3
Headwater elevation @ Q_{100}	ft	291.6	289.7
Headwater elevation @ Q_{500}	ft	292.4	290.5
Hw/D Ratio @ Q_{50}		Full	0.88
Hw/D Ratio @ Q_{100}		Full	0.94
Outlet Velocity @ $Q_{1.1}$	ft/s	4.0	2.1
Outlet Velocity @ Q_{10}	ft/s	5.3	3.8
Outlet Velocity @ Q_{25}	ft/s	6.3	4.3
Outlet Velocity @ Q_{50}	ft/s	9.0	4.6
Outlet Velocity @ Q_{100}	ft/s	9.7	5.0
Outlet Velocity @ Q_{500}	ft/s	10.0	5.7

Reported by: Hasbrouck, Joshua P
Date: November 4, 2022

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