

HYDROLOGY REPORT

The peak flows for Crocker Bridge on US Route 202 in Dixmont over Crocker Brook were calculated using the USGS peak flow regression equations for small, ungaged streams in Maine (See USGS Water-Resources Investigations Report 99-4008). Crocker Brook is not located in a FEMA detailed study area, and the brook itself has not been evaluated in a flood insurance study (FIS). The flood flows reported by MaineDOT were calculated with the NCRS TR-20 rainfall/runoff model. The USGS peak flow regression equations are considered more reliable and are the basis of the peak flow rate summary below.

SUMMARY

Drainage Area	2.75	mi ²
Q1.1	75	ft ³ /s
Q10	325	ft ³ /s
Q50	500	ft ³ /s
Q100	580	ft ³ /s
Q200	660	ft ³ /s

Reported by: Matt Schley

Date: July 11, 2023

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

HYDRAULIC REPORT

The existing and proposed culverts were analyzed using HEC-RAS 6.3.1, developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center. The Crocker Bridge culvert is located in an area where no digital data is available from FEMA regarding flood hazard, so no comparison to FEMA modeling could be completed. The hydraulic model for this project represents an approximately 575 linear foot reach of Crocker Brook including the crossing at Crocker Bridge on US Route 202. This reach was modeled using seven cross sections upstream and six cross sections downstream of Crocker Bridge.

The hydraulic analysis assumes steady flow and a subcritical flow regime. Expansion and contraction coefficients were selected at bridge cross sections to best reflect the hydraulic impacts of the structure. All flow scenarios were modeled using a downstream normal depth boundary condition with a downstream slope of 0.01197 ft/ft, determined by measuring the contour spacing downstream of the culvert on the 2014 7.5-minute USGS topo map for Dixmont, ME (see Appendix C for measurement details). Since HEC-RAS is a step-backwater deterministic model where conditions are calculated from downstream to upstream, an upstream boundary condition is not required to run a model with a subcritical flow regime; accordingly, no upstream boundary conditions were applied here. Flood flows associated with each storm event (e.g. 1.1-year, 2-year...200-year) were provided by MaineDOT.

Crocker Bridge is located in a predominantly rural area where floodplains consist of mixed forest with varying age stands and some undergrowth. The appropriate Manning's n condition for this floodplain is between condition 3.d.3, "cleared land with tree stumps and heavy growth of sprouts" and condition 3.d.4, "heavy stand of timber, a few down trees, little undergrowth, flood stage below branches" (Chow, 1959); the selected Manning's n was therefore 0.08, the maximum value for condition 3.d.3 and minimum value for condition 3.d.4. Given the dominance of gravel and cobble on the streambed, the channel was modeled using condition 1.f, "clean, winding, some pools and shoals with many stones" with a corresponding Manning's n of 0.045.

EXISTING BRIDGE

The existing culvert is a structural plate corrugated metal pipe arch with span 14'-1", rise 8'-9", and length 70'-4". The crossing was originally constructed in 1953 and is now in satisfactory to poor condition. The culvert pipe is exhibiting large spalls, heavy scaling and wide cracks while the adjacent channel exhibits bank slumping and minor damage. The culvert is undersized relative to the bankfull width of Crocker Brook (~16.5 feet on average) and prevents a barrier to fish passage due to low water surface elevations, a lack of bed sediment, and a lack of velocity diversity within the culvert. The HEC-RAS profile plot shows that the culvert creates a constriction and resulting backwatering effect during larger storm flows, as indicated by the significant difference between water surface elevations immediately upstream and downstream of the culvert, respectively.

The Crocker Bridge crossing does not have historic stormflow data against which to calibrate the existing conditions HEC-RAS model. We therefore chose to calibrate this model by comparing flow max depth and top width at respective cross sections to field-measured bankfull flow depth and top width. HEC-RAS sections 312 (upstream of the crossing) and 43 (downstream of the crossing) approximately correspond to the locations of field bankfull measurements. It is generally accepted that the bankfull flow event in most of New England is between the 1- and 2-year storm event (approximately the 1.5-year event), therefore we would generally expect our existing conditions HEC-RAS output for the 1.1- and 2-year storm events to border the field-measured bankfull values, particularly flow depth. HEC-RAS and field measurements are as follows:

XS 312 (Upstream)	Flow Depth (ft)	Flow Width (ft)
1.1-Year HEC-RAS	1.3	17.2
Field Measurement	1.8	15.2
2-Year HEC-RAS	2.3	25.0
XS 43 (Downstream)	Flow Depth (ft)	Flow Width (ft)
1.1-Year HEC-RAS	1.4	18.7
Field Measurement	1.7	16.6
2-Year HEC-RAS	2.2	27.3

The calibration table above shows that field-measured bankfull flow depths align almost equally between the 1.1- and 2-year flow depths, suggesting agreement with the premise of a 1.5-year bankfull event at this location. Field estimates of flow width were underestimated relative to modeled values, though this may be due to field bias in selecting cross section locations that appear less affected by scour and overwidening. The 0.5-foot max differences in bankfull flow depth were considered acceptable for calibration of the model.

PROPOSED 24-FOOT CONCRETE BOX CULVERT

In the design kick-off meeting, MaineDOT conveyed bankfull width (BFW) values of 16.5 feet (calculated) and 15 feet (field-measured), respectively, for Crocker Brook in the vicinity of the project area. F&O verified these numbers with field measurements at representative cross sections. These measurements indicated BFW of 15.2 feet and 16.6 feet; F&O therefore utilized 16 feet as the average BFW for Crocker Brook in this location. MaineDOT staff accordingly recommended that the replacement structure be a concrete box with span of 20 feet and rise of 8 feet, to be confirmed by hydraulic modeling. Due to the presence of brook trout in this stream, the proposed crossing is required to include channel streamlines and banklines through the structure to create flow conditions suitable for brook trout migration. The wider-than-BFW 20' span would accommodate this channel and provide small benches for terrestrial wildlife. The channel was designed to approximately mimic the bankfull channel dimensions in Crocker Brook with a top width of 16 feet, bottom width of 12 feet, and average depth of 2 feet. Per the MaineDOT Fish Passage Policy and Design Guide (MaineDOT FPP), mimicking the geometry of the bankfull channel should create flow velocity and depth conditions resemblant of those in the adjoining natural channel.

A stream profile was developed using survey data at the project location (survey provided by MaineDOT). The stream bed elevations at the box culvert inlet and outlet were selected to preserve the average reach slope of 0.9% to 1.0% through the project area. The bottom concrete slab of the culvert structure will be buried 2 feet below the proposed streambed invert to ensure that the structure holds sediment and promotes fish passage while allowing for sediment transport and local scour processes. The culvert inlet and outlet will each be protected with a 2-foot thick riprap apron with concrete cutoff walls as scour countermeasures per MaineDOT standards. In accordance with the Maine Bridge Design Guide (MaineDOT BDG), the culvert structure was designed long enough to preclude the need for wingwalls and should instead use beveled ends conforming to the fill slope.

In the hydraulic analysis, a 20-foot-span by 8-foot-rise structure was specified with 2 feet of fill inside of the culvert in the configuration noted above. The culvert was analyzed under a variety of flow events including the Q1.1 flow used to evaluate fish passage conditions (MaineDOT FPP) and the Q50 event used to analyze hydraulic conditions (MaineDOT BDG). Under 50-year storm flow conditions, this configuration resulted in a headwater depth of 5.54 feet and therefore a headwater depth to structure depth ratio (HW/D) greater than the suggested maximum of 0.9. This configuration also notably resulted in hydraulic jump conditions in various locations throughout the modeled reach, with the location varying per each storm profile.

The proposed culvert structure was enlarged to a 22-foot-span by 8-foot-rise. Span was adjusted, rather than rise, due to thin roadway cover on top of the structure. The 22-foot-span would include the same interior channel configuration as the 20-foot-span structure, but with 3-foot benches on either side of the channel instead of the original 2-foot benches. In this configuration, the HW/D ratio during Q50 flow conditions was equal to 0.9, though the Q100 flow showed a HW/D ratio exceeding 1.0 meaning the depth of flow exceeded the open rise of the culvert. For this reason, the proposed culvert configuration was upsized again to a 24-foot-span by 8-foot-rise with the same interior channel configuration and 4-foot benches on either side of the channel. In this configuration, the HW/D ratios during Q50 and Q100 flow conditions are 0.88 and 0.96, respectively. This indicates that the designed culvert is sufficiently sized to pass the design storm events. Under Q1.1 flow conditions, flow depth and velocity conditions required for brook trout passage are met; see the Habitat Connectivity Design (HCD) report for additional details.

CONCLUSION

A 24-foot-span by 8-foot-rise concrete box culvert with beveled ends buried 2 feet and with 4-foot wide by 2-foot tall benches along both interior walls will satisfy the HW/D ratio of 0.9 specified in the Maine BDG. A trapezoidal channel with a top width of 16 feet, bottom width of 12 feet, and average depth of 2 feet will be constructed through the structure to ensure habitat connectivity conditions. The proposed structure will reduce headwater elevations during high flows and will promote fish passage at lower flows.

SUMMARY

		Existing Structure	Recommended Structure
	Units	14'-1" x 8'-9" Structural Plate Corrugated Metal Pipe Arch	24' x 8' Concrete Box Culvert
Total Area of Waterway Opening	ft ²	99*	124
Headwater Elevation @ Q _{1.1}	ft	386.67	387.25
Headwater Elevation @ Q ₂	ft	387.72	388.14
Headwater Elevation @ Q ₅	ft	388.71	388.91
Headwater Elevation @ Q ₁₀	ft	389.30	389.43
Headwater Elevation @ Q ₂₅	ft	390.18	390.05
Headwater Elevation @ Q ₅₀	ft	390.92	390.57
Headwater Elevation @ Q ₁₀₀	ft	391.61	391.05
Outlet Velocity @ Q _{1.1}	ft/s	2.90	3.21
Outlet Velocity @ Q ₂	ft/s	4.08	4.39
Outlet Velocity @ Q ₅	ft/s	5.22	5.24
Outlet Velocity @ Q ₁₀	ft/s	6.33	5.82
Outlet Velocity @ Q ₂₅	ft/s	7.54	6.68
Outlet Velocity @ Q ₅₀	ft/s	8.51	7.48
Outlet Velocity @ Q ₁₀₀	ft/s	9.47	8.20

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