Figure 4: Flooding South of Existing Culvert, March 10, 2024

Hydrology was evaluated for Mill Brook by the Maine Department of Transportation Environmental Office- Hydrology Section. Peak flows were calculated with techniques described in the USGS WRIR 99-4408 (Hodgkins, 1999), and the USGS SIR 2015-4059 (Lombard, 2015). Peak flows were also calculated with techniques described in the USGS SIR 2020-5092 (Lombard, 2020). The table below summarizes the peak flows calculated from the 1999/2015 equations and the 2020 equations, as well as the design flows used for the hydraulic model.

SUMMARY

Drainage Area			4.16	mi^2
	1999/2015	2020	Design	
Q1.1		99	100	ft^3/s
Q10	321	469	470	ft^3/s
Q50	494	747	745	ft^3/s
Q100	578	878	880	ft^3/s
Q500	783	1214	1215	ft^3/s

Reported by: Daniel Myers
Date: November 29, 2022

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

HYDRAULIC REPORT

The existing 13’-5” pipe arch culvert conveys flow from Mill Brook below Route 9/Longwoods Road. Per the 1962 existing plans, the normal water depth under the previous timber bridge was about 2 feet. This previous bridge was a timber bridge on stone abutments with a hydraulic opening width of about 13 feet. The hydraulic opening width was increased by about half a foot when the existing culvert was installed. However, the hydraulic opening area was reduced due to the decreased vertical opening of a pipe arch with roadway fill. The roadway elevation was increased about 1.5 feet over the culvert at that time.

The roadway south of the culvert has a history of flooding, which was discussed in the Hydrology Report. The existing culvert has approximately 1 foot of sediment within it and evidence of regular debris issues that further restrict the hydraulic opening.

The hydraulics of the existing bridge and proposed bridge alternatives were evaluated using HEC-RAS 6.3.1 software. The complete HEC-RAS reports for these models are provided in Appendix C.

The upstream and downstream reaches are winding, with vegetation and debris in the stream and shallow gradients. The flood plains have medium to dense brush. This information was used to select the Manning’s n value for the stream cross-sections. Four cross-sections were used to model the upstream reach. Nine cross-sections were used to model the downstream reach. A separate reach was modeled to represent the roadway overtopping as a split flow condition, with the flow diverting through the roadway ditch and over the low point of the road. Two cross-sections were used to model the ditch. Two cross-sections were used to model the road, with a broad-crested weir placed at an elevation of 48.63’. This diverted flow reenters the downstream reach several cross sections below the bridge.

The HEC-RAS models were based on the following assumptions:

- One-directional steady flow
- Manning’s numbers:
  - Channel: 0.033 (natural stream, winding, some pools, shoals, clean)
  - Overbanks: 0.15
    - Grassy area upstream: 0.03
- Default expansion and contraction values, which are 0.3 and 0.1 respectively
- Reach boundary conditions: normal depth with a downstream slope of 0.1%. This represents the very low gradient downstream channel.
  - A downstream slope of 1.0% was also modelled to do a sensitivity analysis vs. the 0.1% used for the design model. The Q50 elevation

difference between the 0.1% slope and 1.0% slope was less than 6" upstream of the culvert.

- Existing Bridge Geometry:
    - 13'-5" span by 8'-5" rise steel pipe arch
    - 2' of sediment included to calibrate existing model to fit reported/observed field sediment and debris conditions
    - Manning's number:
        - Culvert: 0.024
        - Sediment: 0.033
    - Entrance Loss Coefficient: 0.7 (mitered to conform to slope)
    - Exit Loss Coefficient: 1.0 (typical culvert)
    - Culvert length: 65' (average of top culvert and full length)
    - Upstream Invert Elevation: 39.86'
    - Downstream Invert Elevation: 39.05'
    - Roadway high point elevation over Proposed Bridge: 52.7'
- Proposed Alternative 2 (Recommended) Geometry
    - 22'-0" span by 10'-0" rise concrete box culvert
    - Culvert length: 114' with sloped ends
    - Upstream Invert Elevation: 37.75'
    - Downstream Invert Elevation: 37.0'
    - A minimum of 2' of fill material within the culvert, sloping up to 5' of fill material at each edge of the culvert.
    - Roadway high point elevation over Proposed Bridge: 53.2'
- Proposed Alternative 3 (Span Bridge) Geometry
    - 18' bridge opening at Q1.1 elevation
    - 44'-0" clear opening single span with 1.75:1 abutment slope
    - Low chord slopes with profile. Minimum low chord elevation is 49.2' (Note, this is not adequate freeboard. This span bridge is for comparison only.)
    - Superstructure Depth (not including cross slope): 2.5'
    - Stream thalweg elevations similar to proposed box culvert: 39.0 downstream side of bridge at toe of slope; 39.75 upstream side of bridge at toe of slope.

The flows estimated by Maine DOT were used to analyze the bridge's hydraulics. The water elevations and flow velocities are summarized in the table below for all three bridge geometries. Per the Maine DOT Bridge Design Guide Section 2.3.10.2A, the headwater depth versus structure ratio for culverts should be equal to or less than 0.9 at Q50. For other riverine bridges, a freeboard depth of 2 feet at Q50 is recommended. There should be a minimum of 1 foot of freeboard at the edge of pavement at Q100 when possible. For the existing culvert the water is estimated to overtop the road right around Q10; field observations indicate overtopping at an even greater frequency, closer to Q5.

The recommended structure would include raising the roadway and creating a berm to prevent bypass flow at approximately station 12+00. This minimum roadway elevation proposed is elevation 49.8 or so, which achieves the desired freeboard elevation of 1.0' feet at Q100 for the recommended structure. This cutting off of the roadway ditch will prevent water flowing down and crossing the roadway at its low point further to the south.

The recommended box culvert structure would be flowing full at Q50 rather than the preferred 90% of height at that flow (The headwater is calculated at 4 inches above the top of the culvert at Q50). Note that at high flows, backwater from the downstream boundary condition has a significant effect on the behavior of the structures.

SUMMARY

		Existing Structure	Recommended Structure	Alternative 3: 44'-0" single span with 1.75:1 abutment slope
		13'-5" x 8'-5" steel pipe arch with 2' sediment	22'-0" x 10'-0" concrete box culvert with min. 2' stream channel fill	
Total Area of Waterway Opening	ft^2			
Headwater elevation @ Q1.1	ft	44.15	43.73	43.73
Headwater elevation @ Q5	ft	47.53	46.36	46.41
Headwater elevation @ Q10	ft	48.59*	46.99	47.07
Headwater elevation @ Q25	ft	49.52*	47.69	47.77
Headwater elevation @ Q50	ft	50.07*	48.19	48.27
Headwater elevation @ Q100	ft	50.50*	48.71	48.77
Headwater elevation @ Q500	ft	50.68*	49.86*	49.85*
Outlet Velocity @ Q1.1	ft/s	1.98	1.92	1.75
Outlet Velocity @ Q5	ft/s	3.37	3.27	2.3
Outlet Velocity @ Q10	ft/s	3.64*	3.79	2.51
Outlet Velocity @ Q25	ft/s	3.59*	4.45	2.79
Outlet Velocity @ Q50	ft/s	3.44*	4.95	2.99
Outlet Velocity @ Q100	ft/s	3.25*	5.44	3.18
Outlet Velocity @ Q500	ft/s	4.49*	5.72*	3.39*

* = A portion of the flow bypassing structure and overtopping road

Reported by: Daniel Myers
Date: July 29, 2024

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