HYDROLOGY REPORT

Farrar Bridge carries Route 105 (Razorville Road) over Davis Stream in the Town of Washington. Davis Stream begins as a combination of several smaller, unnamed streams around Cunningham Mountain approximately 3 miles upstream of the Farrar Bridge. Davis Stream flows from its source for 3 miles until the dam directly upstream of the project site. Davis Stream then flows for 8.4 miles in a southerly direction, converging with several other streams, until it feeds into Damariscotta Lake located in Jefferson.

The existing channel is wider than the culvert. Downstream it varies in width following a meandering path for about 150 feet, which indicates possible channel instability and migration potential. This observation is evidenced by loss of vegetation at the banks and felled trees in the stream. On the upstream side, there is a rock dam about 75 feet from the culvert inlet, which stretches across the channel. The dam acts as an overflow weir with a sloped front. Just downstream of the dam there seem to be two streams that flow from the dam and converge at the culvert inlet. After site investigation, it was determined that all the flow was coming from the spillway, and the other apparent stream was backwater due to poor culvert alignment with the flow. The Town of Washington Road Foreman, has not observed water flowing over the dam even during high flow events, indicating that all flow comes down the spillway even during storm flood surcharges.

The Hydrologic information and flow data are sought from three different sources:

- Federal Emergency Management Agency (FEMA)
- United States Geological Survey (USGS)
- Maine DOT Hydrology Department

Federal Emergency Management Agency (FEMA)

FEMA flood insurance studies were conducted for Washington and a flood map was produced for the town. The area around the bridge is characterized by Zone A where base flood elevations are not determined. From the flood zone map produced, the 100-year flood limits are a little beyond the channel on both sides upstream and downstream but does not seem to cause concerning inundation of the surrounding area and the flood plain.

United States Geological Survey (USGS)

The USGS does not have a gauging station at the site. In fact, there are no USGS gauging stations in the entire Knox County. The closest station is in Waldo County on Ducktrap River in Lincolnville, Maine. So, in the absence of measured data, USGS estimated flows in a streamstats report that can be found in Appendix C. Streamstats flows are as follows:

Drainage Area (mi^2)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Q200 (cfs)	Q500 (cfs)
4.37	215	339	433	559	660	767	875	1030

Maine DOT Hydrology Department

The Maine Hydrology Department provided a formal report and estimated flows based on regression equations:

Drainage Area (mi^2)	Q1.1 (cfs)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Q200 (cfs)
4.37	105	215	340	435	560	660	765	875

The flows calculated by both methods are similar. For design, the flows calculated by the MaineDOT Hydrology Department will be used.

SUMMARY

Drainage Area	4.37	mi^2
Q(bfw)	24.4	ft^3/s
Q1.1	105	ft^3/s
Q2	215	ft^3/s
Q5	340	ft^3/s
Q10	435	ft^3/s
Q25	560	ft^3/s
Q50	660	ft^3/s
Q100	765	ft^3/s
Q200	875	ft^3/s

Reported by: Aguilar, Timothy
Date: March 17, 2023

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

HYDRAULIC REPORT

The existing structure carries Route 105 over Davis Stream in Washington. The existing structure is a steel plate arch with a natural stream bottom on cast-in-place concrete footings founded on grade. The proposed structure is a four-sided concrete precast box with a V-shaped natural stream bottom. The existing conditions and proposed conditions were modeled in HY-8 software.

The existing culvert is poorly aligned with the flow. The proposed culvert is being realigned with the stream to provide more favorable flow conditions. The stream flows over a dam spillway approximately 75' upstream of the structure. The proposed structure will be aligned with this spillway. After the spillway, the existing stream is gently sloped, with a grade of approximately 0.27% measured over 400'.

Below are the parameters used to model the existing and proposed culverts.

<u>Existing Culvert</u>

- Corrugated Steel Arch
- 20' span x 8.2' rise x 64' long
- Straight culvert with mitered ends to conform to the roadway sideslopes
- Manning's n:
    - Culvert Walls: 0.026
    - Channel Bottom: 0.035
- Inlet Elevation: 274.91' (surveyed)
- Outlet Elevation: 274.84' (surveyed)

<u>Proposed Culvert</u>

- Precast Concrete Box
- 24' span x 9' rise x 72' long
- 2'-6" stream material at centerline of culvert, 3'-9" of stream material at edges
    - Results in available depth for flow of 6.5'
- Straight culvert with 0-degree wingwalls
- Manning's n:
    - Culvert Walls: 0.012
    - Channel Bottom: 0.035
- Inlet Elevation: 274.72'
- Outlet Elevation: 274'

Note: Proposed inlet/outlet elevations are given for the channel, not the culvert itself.

Existing Bridge Analysis

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q1.1	105.00	105.00	276.85	1.73	**1.94**	2-M2c	2.46	0.95	0.95	1.50	5.60	3.05
Q2	215.00	215.00	277.96	2.82	**3.05**	2-M2c	4.08	1.55	1.55	2.26	7.16	3.87
Q5	340.00	340.00	279.02	3.86	**4.11**	2-M2c	6.07	2.10	2.10	2.94	8.40	4.48
Q10	435.00	435.00	279.76	4.60	**4.85**	3-M2t	8.20	2.49	2.53	3.37	9.02	4.83
Q25	560.00	560.00	280.68	5.56	**5.77**	3-M2t	8.20	2.95	3.03	3.87	9.78	5.21
Q50	660.00	660.00	281.38	6.34	**6.47**	3-M2t	8.20	3.29	3.40	4.24	10.37	5.47
Q100	756.00	756.00	282.05	7.04	**7.14**	3-M2t	8.20	3.60	3.72	4.56	10.94	5.69
Q200	875.00	875.00	282.86	7.88	**7.95**	3-M2t	8.20	3.96	4.09	4.93	11.62	5.94

The results of the analysis show that for all flow scenarios the inlet is not submerged (Hw<D), the culvert does not flow full, and the culvert is outlet controlled. During high flows, the flow is controlled by the tailwater depth.

At the inlet the culvert crown is at 283.11'. The Q50 head water elevation is 281.38', resulting in a freeboard of 1.73' and Hw/D ratio of 0.79. At Q100, the headwater elevation is at 282.05' reducing freeboard to 1.06' and increasing the HW/D ratio to 0.87. The roadway does not overtop at any design flow events.

Proposed Bridge Analysis

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q1.1	105.00	105.00	276.85	1.77	**2.13**	2-M2c	1.65	1.47	1.47	1.42	5.20	3.24
Q2	215.00	215.00	277.77	2.48	**3.05**	2-M2c	2.20	1.98	1.98	2.15	6.61	4.11
Q5	340.00	340.00	278.65	3.14	**3.93**	2-M2c	2.71	2.47	2.47	2.79	7.70	4.76
Q10	435.00	435.00	279.25	3.61	**4.53**	2-M2c	3.04	2.79	2.79	3.20	8.36	5.14
Q25	560.00	560.00	279.97	4.25	**5.25**	2-M2c	3.45	3.19	3.19	3.69	9.09	5.55
Q50	660.00	660.00	280.52	4.75	**5.80**	2-M2c	3.75	3.49	3.49	4.03	9.60	5.83
Q100	756.00	756.00	281.02	5.23	**6.30**	2-M2c	4.02	3.76	3.76	4.34	10.05	6.07
Q200	875.00	875.00	281.61	5.81	**6.89**	7-M2c	4.34	4.08	4.08	4.70	10.55	6.33

At Q50 there is 0.7' of freeboard and a Hw/D ratio of 0.89, which meet the design requirement of the department of Hw/D <= 0.9. At Q100, the freeboard reduces to 0.2' and the Hw/D ratio increases to 0.97. At Q200, the headwater depth is greater than the proposed opening and the culvert runs partially full. None of the design flows overtop the roadway.

The headwater elevation and the velocities both decrease in the proposed condition when compared to the existing structure. However, the proposed structure has reduced depth on account of the structure design, and therefore ends up with a larger Hw/D ratio than the existing structure. Since the proposed structure meets the headwater-to-depth design criteria, and flooding of the roadway has not been reported as a concern, this is considered acceptable.

SUMMARY TABLE

		Existing Structure	Recommended Structure
		20' Span x 8.2' Rise Corrugated Metal Arch Culvert	24' Span x 9' Rise Precast Concrete Box Culvert
Total Area of Waterway Opening	ft^2	123	140
Headwater elevation @ $Q_{1.1}$	ft	276.85	276.85
Headwater elevation @ Q_{10}	ft	279.76	279.25
Headwater elevation @ Q_{25}	ft	280.68	279.97
Headwater elevation @ Q_{50}	ft	281.38	280.52
Headwater elevation @ Q_{100}	ft	282.05	281.02
Headwater elevation @ Q_{200}	ft	282.86	281.61
Freeboard @ Q_{50}	ft	1.73	0.70
Freeboard @ Q_{100}	ft	1.06	0.20
Outlet Velocity @ $Q_{1.1}$	ft/s	5.6	5.20
Outlet Velocity @ Q_{10}	ft/s	9.02	8.36
Outlet Velocity @ Q_{25}	ft/s	9.78	9.09
Outlet Velocity @ Q_{50}	ft/s	10.37	9.60
Outlet Velocity @ Q_{100}	ft/s	10.94	10.05
Outlet Velocity @ Q_{200}	ft/s	11.62	10.55

Reported by: Aguilar, Timothy
Date: March 17, 2023

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