# HYDROLOGY REPORT

## Frazier Bridge #2354 – Lisbon, Maine

General Information and Scope

This study is prepared to provide hydrologic information from water resources agencies on the Frazier Bridge crossing over Dearing Brook in Lisbon, Maine. It will be used in the hydraulic evaluation of the existing and proposed culvert replacements. The existing bridge is a galvanized corrugated steel arch built in 1952 with a span of 14' between spring lines; 15' across 20° skew, and a rise of 5'-7. The scope is to determine flood flow elevations, velocities, and overtopping potential for the existing and proposed culverts on Route 125 which is classified a major Arterial between the towns of Lisbon and Bowdoin. Dearing brook is a stream that flows West- East through the culvert at Maine Street, and is a tributary to the Little River that flows south into the Androscoggin River in Lisbon. With a measured BFW of 8.06', and with the requirement of having a minimum proposed culvert width of 1.2 x Bank full width or nearly 9.7', ensures that both the existing culvert width of 14' and proposed culvert width meet or exceed the required 1.2x bank full width.

Hydrologic information and flow data are sought from different sources:

1- Federal Emergency management Agency (FEMA)
2- United States Geological Survey (USGS)
3- Maine DOT Hydrology Department

Federal Emergency Management Agency, (FEMA)

The 2019 FEMA flood insurance maps for Lisbon indicated that the downstream portion of Dearing Brook on Route 125 is susceptible a 100-year flood event, and so is the north approach of the culvert with high possibility of roadway inundation in that area defined as Zone A. However, FEMA did not provide any other hydrologic information such as flood flows or base flood elevations.

United States Geological Survey, (USGS).

The USGS does not maintain any gaging stations at or near the culvert, or even on its confluence at the Little River. The only gaging station in the area is in the Androscoggin River, whose Little River is a tributary of. The data of that Gauge station cannot be used to measure the flow in Dearing Brook.

Maine DOT Hydrology Department

The Maine DOT hydrology department determined that the watershed area is 1.10 $mi^2$ with 3.77% wetlands. The flows were then calculated using Hodgkin's 1999 regression analysis of the rainfall data with the following tabulated amounts:

The following flood flow data is the resulting Maine DOT flows , and will be used in the hydraulic analysis of both the existing and the proposed culvert, such that conclusions can be drawn about their hydraulic adequacy.

| SUMMARY | | |
|---|---|---|
| Drainage Area | 1.1 | $mi^2$ |
| Q1.1 | 29.0 | $ft^3/s$ |
| Q2 | 60.8 | $ft^3/s$ |
| Q5 | 96.5 | $ft^3/s$ |
| Q10 | 122.7 | $ft^3/s$ |
| Q25 | 160.3 | $ft^3/s$ |
| Q50 | 188.9 | $ft^3/s$ |
| Q100 | 220.9 | $ft^3/s$ |
| Q250 | 252.0 | $ft^3/s$ |
| Q500 | 300.3 | $ft^3/s$ |

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# HYDRAULIC REPORT

## Frazier Bridge #2354 – Lisbon, Maine

Existing Culvert:

The mitered 14' wide by 5'-7 1/2" rise existing culvert is 61'-2" long laid at the natural existing stream bed slope. The analysis was conducted using Maine DOT data and HY-8 culvert analysis software. The model is considered representative of the current hydraulic conditions since the slopes used in the culvert and at the tail-water are same as the existing slopes. The downstream channel slope was calculated as the average slope for a long distance downstream based on survey and contour maps, and the culvert used in the model was the same as the existing.

| Discharge Names | Total Discharge | Culvert Discharge | 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 | 29.00 | 29.00 | 118.59 | **1.59~** | 0.95 | 3-M1t | 0.52 | 0.50 | 0.54 | 0.54 | 3.87 | 3.78 |
| Q2 | 60.80 | 60.80 | 119.59 | **2.59** | -0.12 | 1-S2n | 0.83 | 0.84 | 0.83 | 0.82 | 5.20 | 4.82 |
| Q5 | 96.50 | 96.50 | 120.14 | **3.14** | 0.26 | 1-S2n | 1.12 | 1.15 | 1.12 | 1.06 | 6.16 | 5.58 |
| Q10 | 122.70 | 122.70 | 120.46 | **3.46** | 0.53 | 1-S2n | 1.32 | 1.35 | 1.32 | 1.21 | 6.70 | 6.00 |
| Q25 | 160.30 | 160.30 | 120.07 | **3.07** | 0.91 | 1-S2n | 1.58 | 1.62 | 1.58 | 1.40 | 7.35 | 6.50 |
| Q50 | 188.90 | 188.90 | 120.39 | **3.39** | 1.21 | 1-S2n | 1.77 | 1.81 | 1.77 | 1.53 | 7.78 | 6.82 |
| Q100 | 220.90 | 220.90 | 120.76 | **3.76** | 1.56 | 1-S2n | 1.98 | 2.01 | 1.98 | 1.66 | 8.19 | 7.13 |
| Q250 | 252.00 | 252.00 | 121.12 | **4.12** | 1.91 | 1-S2n | 2.18 | 2.19 | 2.18 | 1.78 | 8.54 | 7.41 |
| Q500 | 300.30 | 300.30 | 121.74 | 4.66 | **4.74** | 2-M2c | 2.49 | 2.46 | 2.46 | 1.95 | 9.33 | 7.78 |

The results indicate that the $Q_{50}$ design flow with a head water elevation of 120.39' has an HW/D value of 0.61, and the $Q_{500}$ flow with a headwater elevation of 121.74' has a HW/D value of 0.83. Therefore, there is freeboard available at all flows that are mostly inlet controlled with both the Headwater HW < D, and the Tail water TW < D, with the outlet at normal water level, and the culvert flowing less than full. The only exception is the Q1.1 flow that is an outlet control flow with the tail water at the outlet depth, and the Q500 flow which is outlet control with tail water at critical depth. In all cases roadway over topping does not occur, and velocities are over 9 feet per second at the Q500 flow. However, with minimal stream bed erosion experienced over the life span of the culvert, it can be concluded that the existing culvert is adequate for both flow and velocity. Thus, a slightly larger culvert with a milder slope than the existing can be put in place to reduce downstream velocities and the possibility of bank erosion. It was noted that the results of the HY-8 analysis correlated well with manual hydraulic calculations. See Appendix E.

Proposed Culvert 1:

A 16’ wide x 6’ rise proposed concrete box culvert is laid to align with the stream. To achieve this, the culvert skew is increased from 20 to 25 degrees, and the culvert length is increased to 70.5 feet. The proposed culvert was sized to meet or exceed 1.2 x bank full width and to accommodate the design flows, with little or no possibility of overtopping at largest flood flows. The culvert is embedded two feet into the stream bed to form a natural stream bed channel and will contain wildlife banks and a low flow channel for fish passage. The inlet and outlet invert elevations were set at 114.94’ and 114.34’ respectively. The culvert was mitered to conform to embankments slope. An HY-8 analysis was done, and computations were cross checked by hand calculations. The analysis results are as tabulated below:

| Discharge Names | Total Discharge | Culvert Discharge | 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 | 29.00 | 29.00 | 116.99 | 1.42 | **2.05** | 3-M1t | 1.70 | 1.46 | 2.20 | 0.54 | 1.84 | 3.78 |
| Q2 | 60.80 | 60.80 | 117.60 | 1.81 | **2.66** | 3-M1t | 2.24 | 1.87 | 2.48 | 0.82 | 3.00 | 4.82 |
| Q5 | 96.50 | 96.50 | 118.11 | 2.19 | **3.17** | 3-M1t | 2.59 | 2.26 | 2.72 | 1.06 | 4.01 | 5.58 |
| Q10 | 122.70 | 122.70 | 118.44 | 2.36 | **3.50** | 3-M1t | 2.82 | 2.44 | 2.87 | 1.21 | 4.63 | 6.00 |
| Q25 | 160.30 | 160.30 | 118.88 | 2.68 | **3.94** | 3-M2t | 3.12 | 2.68 | 3.06 | 1.40 | 5.44 | 6.50 |
| Q50 | 188.90 | 188.90 | 119.19 | 3.03 | **4.25** | 3-M2t | 3.34 | 2.85 | 3.19 | 1.53 | 5.99 | 6.82 |
| Q100 | 220.90 | 220.90 | 119.52 | 3.42 | **4.58** | 3-M2t | 3.57 | 3.03 | 3.32 | 1.66 | 6.57 | 7.13 |
| Q250 | 252.00 | 252.00 | 119.83 | 3.80 | **4.89** | 3-M2t | 3.79 | 3.19 | 3.44 | 1.78 | 7.09 | 7.41 |
| Q500 | 300.30 | 300.30 | 120.29 | 4.36 | **5.35** | 3-M2t | 4.10 | 3.44 | 3.61 | 1.95 | 7.85 | 7.78 |

The results indicate that overtopping will not occur at any of the flows, and the type of flows for all flows are outlet controlled with both the headwater HW and the tail water TW < D, and with the outlet at tail water depth. At the design headwater level of Q50 the HW/D value is 0.71 and the culvert flows 71% full. At Q100, the HW/D value is 0.76 or 76% full. At Q500, the culvert flows 89% full and overtopping will not occur. With the culvert embedded two feet into the stream bed, and with the stream bed restored, the roughness of the culvert combined with a reduced stream bed slope helped in somewhat reducing outlet velocities and the possibility of downstream scour. This option is preferred due to its structural sustainability, and its long design life in this type of environment.

Proposed Culvert 2:

An in kind 15’ wide x 5’-8” rise proposed Corrugated Steel arch culvert 70.5 ft. long and laid on 25 deg skew to align with the stream. The culvert will have an open bottom utilizing the natural streambed and includes wildlife shelves and a low flow channel to facilitate fish passage. It will be supported at each of its sides with a concrete foundation walls and footing pads embedded a minimum of 4’ into the ground and connected to the culvert base at its spring lines. The culvert

slope is identical to the existing stream bed with invert stream bed elevations of 117.00' and 116.00' respectively upstream and downstream. An HY-8 analysis was performed, and computations were cross checked by hand calculations. The analysis results are in the table below:

| Discharge Names | Total Discharge | Culvert Discharge | 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 | 29.00 | 29.00 | 118.23 | 1.73 | **2.23** | 2-M2c | 1.68 | 1.59 | 1.59 | 0.54 | 4.88 | 3.78 |
| Q2 | 60.80 | 60.80 | 118.93 | 2.32 | **2.93** | 2-M2c | 2.23 | 2.15 | 2.15 | 0.82 | 5.31 | 4.82 |
| Q5 | 96.50 | 96.50 | 119.53 | 2.70 | **3.53** | 2-M2c | 2.60 | 2.45 | 2.45 | 1.06 | 6.28 | 5.58 |
| Q10 | 122.70 | 122.70 | 119.94 | 3.06 | **3.94** | 2-M2c | 2.85 | 2.66 | 2.66 | 1.21 | 6.86 | 6.00 |
| Q25 | 160.30 | 160.30 | 120.48 | 3.75 | **4.48** | 2-M2c | 3.21 | 2.93 | 2.93 | 1.40 | 7.58 | 6.50 |
| Q50 | 188.90 | 188.90 | 120.89 | 4.28 | **4.89** | 2-M2c | 3.51 | 3.12 | 3.12 | 1.53 | 8.09 | 6.82 |
| Q100 | 220.90 | 220.90 | 121.34 | 4.84 | **5.34** | 2-M2c | 3.88 | 3.31 | 3.31 | 1.66 | 8.65 | 7.13 |
| Q250 | 252.00 | 252.00 | 121.80 | 5.36 | **5.80** | 7-M2c | 4.29 | 3.49 | 3.49 | 1.78 | 9.17 | 7.41 |
| Q500 | 300.30 | 300.30 | 122.55 | 6.16 | **6.55** | 7-M2c | 5.67 | 3.76 | 3.76 | 1.95 | 9.95 | 7.78 |

The results show that overtopping will not occur at any of the flows. The flows are all outlet controlled with both the headwater and tail-water HW and TW < D for all flows; except for Q250 and Q500 flows whose HW > D and TW < D. The outlet is at critical flow depth for all flows except for Q1.1 whose outlet is at tail-water. At the design headwater level of Q50, the HW/D value is 0.76 and the culvert flows 76% full. At Q100, the HW/D value is 0.85 and the culvert flows 85% full. Results show that the outlet velocities of the proposed in-kind culvert do not differ much from those in the existing culvert. Scour can be mitigated by armoring, which naturally exist due to presence of pebbles and rocks in the stream bed. Taking into consideration the stable conditions of the channel, and some additional armoring measures, the channel may be satisfactory for scour. Because of geotechnical considerations and concern about the type of foundations used, and the possibility of future corrosion associated with limited design life for this type of culvert, this option was considered but not selected after all.

## SUMMARY

| | | Existing Structure | Recommended Structure |
|---|---|---|---|
| | | 14' x 5'-7" Rise Steel Plate Arch | 16'x 6'-0" Conc Box Culvert |
| Total Area of Waterway Opening | $ft^2$ | 58 | 61.5 |
| Headwater elevation @ $Q_{1.1}$ | ft | 118.59 | 116.99 |
| Headwater elevation @ $Q_{10}$ | ft | 120.46 | 118.44 |
| Headwater elevation @ $Q_{25}$ | ft | 120.07 | 118.88 |
| Headwater elevation @ $Q_{50}$ | ft | 120.39 | 119.19 |
| Headwater elevation @ $Q_{100}$ | ft | 120.76 | 119.52 |
| Headwater elevation @ $Q_{500}$ | ft | 121.74 | 120.29 |
| Freeboard @ $Q_{50}$ | ft | 3.01 | 1.75 |
| Freeboard @ $Q_{100}$ | ft | 1.82 | 1.42 |
| | | | |
| Outlet Velocity @ $Q_{1.1}$ | ft/s | 3.87 | 1.84 |
| Outlet Velocity @ $Q_{10}$ | ft/s | 6.70 | 4.63 |
| Outlet Velocity @ $Q_{25}$ | ft/s | 7.35 | 5.44 |
| Outlet Velocity @ $Q_{50}$ | ft/s | 7.78 | 5.99 |
| Outlet Velocity @ $Q_{100}$ | ft/s | 8.19 | 6.57 |

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