HYDROLOGY REPORT

Limestone, Greenlaw Brook No. 2 Bridge #5626 over Greenlaw Brook, WIN 021696

There are no USGS gaging stations located on Greenlaw Brook in Limestone, Maine. The available flow data for the subject bridge was computed using USGS Regression Equations (Hodgkins, 1990 and Lombard/Hodgkins, 2015) by the Maine Department of Transportation Office of the Environment – Hydrology Section. The watershed for Greenlaw Brook at the bridge includes portions of the Aroostook National Wildlife Refuge and Loring Commerce Centre. The drainage area used in the computations was 8.1 square miles and the percentage of storage (combined water bodies and wetlands) from the National Wetland Inventory was 18.49%.

The following flows were used in the hydraulic analysis:

SUMMARY

Drainage Area	8	mi^2
Q1.1	91	ft^3/s
Q10	348	ft^3/s
Q50	523	ft^3/s
Q100	613	ft^3/s
Q500	811	ft^3/s

Reported by: JAB
Date: February 4, 2019

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

HYDRAULIC REPORT

Greenlaw Brook No. 2 Bridge #5625 in Limestone carries West Gate Road over Greenlaw Brook. The existing bridge is a 14'-0" diameter steel structural plate pipe by approximately 190' long. The culvert is skewed 33 degrees to the centerline of the roadway and located at the bottom of a 25' deep fill. The culvert ends are skewed and mitered but protrude several feet beyond 2H to 1V embankment slopes. The inlet is perched approximately 1' above streambed. Aggraded material has collected in the upstream channel and a 7' deep, 50' wide, and 65' long scour hole lies just downstream. The existing culvert is in poor condition and has noticeable settlement and distortion along its length.

The bridge has a drainage area of 8.1 square miles and design and check flows of 523 cfs and 613 cfs, respectively. The drainage area includes portions of the Aroostook National Wildlife Refuge and the Loring Commerce Centre (the former Loring Air Force Base). IF&W has indicated that Greenlaw Brook is an important cold-water brook trout resource. Millions of dollars in restoration efforts have been completed upstream and IF&W would like to restore fish passage at the bridge. Measured and calculated bankfull width is approximately 23 feet.

A review of available flood information from the FEMA Flood Map Service Center found a 34-year old Flood Insurance Rate Map (FIRM) dated 9-27-1985 (See Appendix E). It shows the bridge site in a "Zone A" designation which is defined as "areas of 100-year flood; base flood elevations and flood hazard factors not determined". An additional review of the Maine Flood Hazard Maps did not find any flood hazard zones at the bridge site or within the neighboring communities of Limestone and Caribou.

The hydraulic performance of the existing and replacement culverts was analyzed using HY-8 revision 7.50 software developed by the Federal Highway Administration in cooperation with Aquaveo LLC and the Environmental Modeling Research Laboratory. The streambed of Greenlaw Brook is gravelly with a few small cobbles. The banks of the brook are lined with heavy brush. Based on this information, a Manning's n value of 0.040 was used to model the streambed channel roughness in HY-8.

EXISTING CULVERT HYDRAULICS

The existing 14' diameter steel structural plate pipe was modeled in HY-8 using a 190' length, 1.93% slope and a mitered to slope inlet configuration. The hydraulic analysis found the culvert to be inlet controlled. Although the culvert has a relatively low headwater to structure depth ratio (Hw/D) of 0.52 at Q50, which is less than the maximum 0.9 recommended by the MaineDOT Bridge Design Guide Section 2.3.10.2, the outlet velocity at Q50 was found to be relatively high at 14.1 feet per second. The high outlet velocity could be a contributing factor to

the 7’ deep scour hole. The freeboard between the headwater elevation and low point in the roadway at Q100 and Q500 is 8.71’ and 7.39’, respectively.

The existing culvert has adequate hydraulic capacity to pass the design and check flows without flooding, but improper embedment and high outlet velocity has resulted in upstream aggradation and a deep downstream scour hole.

RECOMMENDED REPLACEMENT CULVERT HYDRAULICS

An on-site meeting and stream walk with IF&W established the following criteria for the replacement structure (See Appendix E for email summary dated 7-13-2017):

- 24’ wide box culvert (calculated and measured bankfull width = 23’)
- Embed and fill culvert with a minimum of 2’-6” of special fill.
- Slope culvert at approximate 2% slope
- Set culvert inverts using existing stable streambed section located below scour pool as reference point.

The recommended replacement culvert is a 24’ wide by 12’ high by 182’ long concrete box culvert set at a 1.79% slope and embedded 2’-6” below streambed. Special fill and stream channel rock would be placed in the bottom of the culvert. The thickness of the special fill would be 2’-6” in a low flow v-shaped channel and 3’-0” elsewhere. In the HY-8 model, a Manning’s n value of 0.0120 was used for the top and sides of the concrete barrel and 0.040 for the special fill which matches the downstream channel roughness.

The recommended box culvert provides several hydraulic improvements over the existing structural plate pipe. First, the larger bankfull-width structure provides a 40% increase in waterway area. Second, a box is a more hydraulically efficient shape than a pipe. These improvements reduce the Hw/D ratio from 0.52 to 0.47 and the outlet velocity from 14.1 to 8.9 feet per second at Q50.

HY-8 Version 7.50 does model embedded culvert but is important to note two limitations. First, the inlet control depth is determined by linear interpolation of coefficients derived from limited testing reported the NCHRP 15-24 report versus using the more accurate 5th degree polynomial equations developed for non-embedded culverts. Second, the inlet configuration options are limited. The “square edge with headwall” configuration was assumed for the analysis of the concrete box culvert based on a note on page 37 of the HY-8 User Manual which indicates from limited hydraulic tests, flared end sections are equivalent in operation to a headwall in both inlet and outlet control conditions.

The recommended replacement structure will improve fish passage and reduce outlet velocities. However, by lowering the proposed culvert inlet to eliminate the existing perched

inlet, there is a potential risk of the head cutting the aggraded streambed up to the ATV/snowmobile bridge and town treatment plant bridge located 210’ and 250’ upstream, respectively. It is recommended to install 3 rock bands upstream and not to remove the existing beaver dam/log step to mitigate the potential head cut. The stream stabilizing structures will not impede fish passage and be spaced at approximately bankfull width starting at the culvert inlet. Plain riprap will be placed in the scour hole only to the extent to support the outlet of the new structure and to maintain the special fill placed in it. The aggraded material upstream will not be removed but will be allowed to naturally fill in portions of the downstream scour pool. With outlet velocities less than 10 fps at Q50, plain riprap is recommended for the aprons and side slopes.

SUMMARY

		Existing Structure	Recommended Structure
		14' Steel Plate Pipe	24' x 12' Concrete Box
Total Area of Waterway Opening	ft^2	154	216
Headwater elevation @ $Q_{1.1}$	ft	537.15	534.06
Headwater elevation @ Q_{10}	ft	540.08	535.98
Headwater elevation @ Q_{25}**	ft	541.00	536.64
Headwater elevation @ Q_{50}	ft	541.51	537.00
Headwater elevation @ Q_{100}	ft	542.19	537.48
Headwater elevation @ Q_{500}	ft	543.51	538.47
Hw/D @ Q_{50}	ft	0.52	0.47
Hw/D @ Q_{100}	ft	0.57	0.53
Outlet Velocity @ $Q_{1.1}$	ft/s	8.92	4.65
Outlet Velocity @ Q_{10}	ft/s	12.65	7.73
Outlet Velocity @ Q_{25}	ft/s	13.60	8.48
Outlet Velocity @ Q_{50}	ft/s	14.13	8.86
Outlet Velocity @ Q_{100}	ft/s	14.76	9.34
Outlet Velocity @ Q_{500}	ft/s	15.90	10.27

Reported by: JAB
Date: September 30, 2020

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