HYDROLOGY REPORT

East Branch Penobscot River Bridge carries Grand Lake Road over the East Branch Penobscot River on a southerly flowing reach of the river. The bridge is programmed for a new wearing surface and repairs to concrete curbs and substructure.

750 feet upstream is the Matagamon Lake dam which spans the entire width of the river. The 493 square mile watershed is heavily attenuated with Chamberlain Lake, Telos Lake, Webster Lake, Round Pond, Mud Pond and Allagash Lake all falling within the watershed area. The outlet to Telos Lake is controlled by a dam, with Round Pond, Chamberlain Lake, Mud Pond and Allagash Lake all directly tributary to this dam, which is in turn tributary to Matagamon Lake and Matagamon Dam. The entire 493 square mile watershed is tributary to the bridge with the majority of it passing through two dams in series.

The river below the dam, between the bridge and the dam is estimated to slope at about 0.005 feet per foot with flows controlled by the release from the dam. The river is about 150' wide just upstream of the bridge and about 200' wide just downstream of the bridge. The two bridge openings total about 100' in width. The easterly abutment protrudes more into the river than the west.

Refer to Appendix E for a further narrative regarding the method used to determine peak flows from the various design storms. An existing downstream USGS Gage was used to calibrate and adjust flows at the smaller watershed tributary to the bridge. Review of data provided by the Matagamon Dam operator for the years 2008 through 2015 with part of 2016 reported shows general agreement with peak annual flows over and through the dam with the Q1.1 value from the hydrology report. See chart below. In the second chart there is a comparison of the maximum recorded flow over the dam for each year of record compared to the Q1.1 predicted peak flow.

Also listed under "SUMMARY" are the predicted peak flows from the hydrology report in Appendix E prepared by Charles Hebson.

Water flows under both bridge spans, but the rate of flow through the easterly span is significantly higher at lower, more routine river flow rates.

It should be noted, that the heavily attenuated watershed, coupled with an actively operated dam immediately upstream, protects this bridge from high stage, high velocity flows that increase the risk of scour at the abutments and pier. This bridge has minor scour damage currently. If this dam were to be replaced with a fixed crest spillway without benefit of active operation, at some future time, scour risk would increase. When this bridge is replaced at some future date, scour risk should be addressed.

	HISTORY OF FLOW RATES OVER AND THROUGH MATAGAMON DAM									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	Ave.	High
June	1743	2299	826	2390	2272	4522	1093	2065	1248	1912	**4522**
July	1919	2299	256	583	871	2416	1720	422	---	1311	**2416**
August	2037	1230	243	6423	334	1046	855	801	---	1621	**6423**
September	966	640	1045	2466	558	1772	606	3101	---	1394	**3101**
October	1079	916	3227	1788	2509	2187	1050	2180	---	1867	**3227**

	MAXIMUM YEARLY FLOW RATE OVER AND THROUGH MATAGAMON DAM BY YEAR										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	Q1.1	DIFF
1-May	7764									4438	**3326**
8-Apr		5347								4438	**909**
11-Nov			5372							4438	**934**
29-Aug				6423						4438	**1985**
23-Mar					3437					4438	**-1001**
4-Jun						4522				4438	**84**
17-Apr							5019			4438	**581**
25-Apr								4353		4438	**-85**
2-Apr									4275	4438	**-163**
										AVE	730.033
						DROP HIGH AND LOW				AVE	606.543

SUMMARY

Drainage Area	493	mi^2
Q1.1	4,438	ft^3/s
Q10	11,606	ft^3/s
Q25	13,978	ft^3/s
Q50	15,785	ft^3/s
Q100	17,628	ft^3/s
Q500	22,118	ft^3/s

Reported by: Charles Hebson
Date: May 10, 2016

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

HEC-RAS 5.0.1 April 2016, is the software used to predict stream elevations and velocities for the various design storms. In addition to the Q1.1, Q25, Q50, Q100 and Q500 storm peak flows, a representative “lower summer”, “medium summer”, and “higher summer flow” was modelled to provide additional information to potential bidders in planning for cofferdam construction. The peak flow rates for the design storms are shown in the hydrology section above. The flows selected for lower summer, middle summer and higher summer flows were approximately selected from the flow data provided by the operator of Matagamon Dam and are 1,000 cfs, 1,500 cfs and 2,000 cfs respectively.

Four river cross sections were prepared from survey data provided by Maine DOT’s survey division; two sections upstream and two sections downstream. The bridge opening was modelled with the software’s bridge algorithm, with the two openings separated by a pier.

Input parameters used area as follows:

1. Boundary conditions upstream and downstream were normal flow with a slope of 0.005 feet per foot.
2. Contraction coefficient 0.3; Expansion coefficient 0.5
3. Mannings roughness coefficients were as follows:
    a. Stream bottom 0.049
    b. Land over bank 0.035
    c. Brush over bank 0.045
    d. Heavy brush over bank 0.065
4. No backwater from downstream impoundments was assumed.
5. The steady flow analysis was utilized with the mixed flow regime checking for both supercritical and subcritical energy states.

The following chart shows the results from the HEC-RAS analysis at the upstream edge of the bridge opening for the various peak flow rates calculated. Results include water elevation, average flow velocity and flow area. The structural depth of the bridge (vertical distance from finished grade at bridge centerline to the lower girder flange) is approximately 4.06 feet.

		Existing Bridge				
Storm	**Peak Flow cfs**	**Water Surface Elevation**	**Flow Area SF**	**Channel Velocity fps**	**Clearance over Water Surface - Feet**	**Water Depth Downstream of Pier - Feet**
"lower summer"	1,000.0	624.9	230	4.4	9.7	3.7
"middle summer"	1,500.0	625.4	280	5.4	9.2	4.2
"higher summer"	2,000.0	625.9	320	6.3	8.7	4.7
Q1.1	4,438.0	627.8	448	9.9	6.8	6.6
Q25	13,978.0	631.1	837	16.7	3.5	9.9
Q50	15,785.0	631.9	908	17.4	2.7	10.7
Q100	17,628.0	632.6	977	18.1	2.0	11.4

The results show adequate clearance over the Q50 design storm (2 feet), but very high average velocities through the bridge. The flow data over the past 8 years correlates quite well for the more frequent smaller large annual flows. It may well be that the less frequent, larger storms are conservatively sized. Scour is a concern for larger storms. On April 23, 2017, water levels were observed between HEC-RAS sections 310 and 238 to be about elevation 628.7. The model was calibrated by adjusting roughness coefficients, adding ineffective flow areas and increasing expansion and compression coefficients for the sections on either side of the bridge.

Pier scour was investigated using HEC 18, section 7.2, which yielded a pier scour depth of 8.3 feet for the Q100 storm and 8.6’ for the Q500 storm. Comparison of the limited information from the 1964 record bridge drawings with the current survey information supports the belief that there does not appear to have been a lowering of the elevation of the river bottom at the pier or abutments. So over the past 50 plus years, there has not been a flood event large enough to cause significant scour at the abutments or pier. There is currently over 4’ of cover over the bottom of the soil-supported west abutment; over 4.5’ of cover over the bottom of the soil-supported pier; and about 5.5’ of cover over the easterly soil-supported abutment footings. The elevation of the scour hole centered under the easterly span is about elevation 619. The bottom of the easterly abutment footing is at elevation 616.4 and the bottom of the pier foundation is at elevation 616.0.

It is concluded that undermining of the soil-supported pier is the major risk to the structure. This pier should be monitored periodically, as is currently done, and especially monitored after storm events over 10,000 cfs.