HYDROLOGY, HYDRAULICS, AND SCOUR REPORT

General Information

Royal River Bridge carries Old Danville Road over Royal River in the city of Auburn. Royal River flows through the towns of New Gloucester and Yarmouth before flowing into Casco Bay. The existing bridge is a single span structure comprised of steel w beams with a concrete deck. The substructure consists of tall, vertical concrete abutments on spread footings. Wingwalls are concrete with stacked granite extensions, with the exception of the southeast wingwall which utilizes gabions. The river channel has a 75 degree skew to the roadway. The wingwalls flare out from the ends of the abutments. The elevation of the roadway at the bridge is approximately 183.0, and 180.8 at the low point 95 feet south of the bridge.

The Royal River approaches Old Danville Road from the west and flows northerly parallel to the roadway for a short distance before turning and flowing under the bridge. On the downstream side of the bridge, Royal River opens up into a large, deep pool surrounded by steep slopes. Soil erosion is present on the bank along the north side of the pool. The defined riverbank continues on the eastern end of the pool.

The profile of Royal River is nearly flat with minor pools just upstream of the bridge. Through the bridge opening, the river bottom steepens to about 2%. The bottom of the river is generally silty with little vegetative growth and stones, except at the bridge. Under the bridge, there are small boulders and stones in the riverbed. The banks of the river both upstream and downstream are heavily wooded.

Hydrology

The following information was obtained from MDOT hydrologists:

Drainage Area:	24.1 mi^2
Wetlands Percentage:	10.9%

Peak flows were calculated by MDOT hydrologists and are listed below:

Q1.1	390 cfs
Q50	2214 cfs
Q100	2548 cfs
Q500	3385 cfs

Hydraulics

The hydraulic opening of the existing structure was determined from field measurements and topographic survey. The opening is generally rectangular in shape with battered stems. It has a span of approximately 18.5 feet between the base of the stems and over 20.5 feet between the bridge seats. The rise is a little over 16 feet at the south abutment. The area of the opening is approximately 300 ft^2.

The bottom portion of the proposed bridge opening is trapezoidal up to the top of the pile caps, and the top portion is semicircular due to the arch structure. The total area of the opening is approximately 326 ft^2. The proposed bridge opening width of 32.7 ft between the pile caps is wider than the existing condition. The new width more closely matches the river width to the upstream of the bridge, reducing the flow constriction imposed by the existing abutments. As a result, the headwater elevations for all analyzed flow rates are lower and outlet velocities reduced when compared to existing conditions. The potential for clogging from debris is also reduced.

The total area for the bridge opening is slightly larger in the proposed condition with more of the area available at a lower elevation. River flow will not be as constricted as in the existing condition, resulting in lower hydraulic profiles.

Skew angles of the bridge abutments are being increased by about 5 degrees to reduce the turning angle of Royal River as it approaches the bridge.

<u>Wingwalls</u>

The proposed wingwall orientation was designed to minimize cost and impacts as well as facilitate hydraulics. The proposed wingwalls are flared at various angles to minimize length. This approach and layout is consistent with the existing wingwalls at the outlet. The layouts of the existing wingwalls do not pose as an obstruction or otherwise interrupt the water flow.

In all quadrants, the slopes retained by the wingwalls are steep. 1.5H:1V slopes were utilized to match into existing steep slopes as well as to reduce impacts and wingwall lengths. The slopes are armored with riprap to limit erosion potential.

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Hydraulic Model

The hydraulic analysis tool HY-8 was utilized to assess the existing and proposed structures. Tailwater effects from the downstream pool are assumed not to produce an effect on hydraulics near the bridge.

Due to software limitations of HY-8, the proposed opening was user defined with coordinates, which results in a series of linear approximations for the arch portion of the opening. This approach yields a slightly conservative result.

The following is a summary of the headwater elevations and outlet velocities of the 2 models for Q1.1, Q50, and Q100. Note for reference that the streambed elevation in the models at the inlet is approximately 164.1 feet.

	Existing Bridge	Proposed Concrete Arch
Hydraulic Opening	300 ft^2	326 ft^2
Headwater EL. @ $Q_{1.1}$	167.9 ft	167.0 ft
Headwater EL. @ Q_{50}	174.4 ft	172.9 ft
Headwater EL. @ Q_{100}	175.5 ft	173.7 ft
Outlet Velocity @ $Q_{1.1}$	9.0 ft/s	8.1 ft/s
Outlet Velocity @ Q_{50}	15.6 ft/s	13.7 ft/s
Outlet Velocity @ Q_{100}	16.3 ft/s	14.2 ft/s
Clearance @ Q50	5.8 ft	3.6 ft

The elevation at the top of the proposed pile cap (spring line) is 167.5 ft., which is 0.5 feet above the normal high water ($Q_{1.1}$) elevation. At the Q_{50} flow rate there is 3.6 feet of clearance between the flow line and bottom of the proposed arch structure.

Scour

A scour analysis was performed by Northstar Hydro for the Royal River Bridge. The analysis and recommendations are included in this report.

HYDROLOGY, HYDRAULICS, AND SCOUR DATA

Project Name:	AUBURN: ROYAL RIVER BR #0077	**PIN:**	17092
Stream Name:	Royal River	**Town:**	Auburn
Bridge Name:		**Bridge No.**	77
Route No.	Old Danville Rd	**USGS Quad:**	
Analysis by:	CSH	**Date:**	1/19/2010

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	mi^2	ac	
				Enter data in [mi^2]
A	62.30	24.054	15394.6	Watershed Area
W	6.82	2.633	1685.3	Wetlands area (by NWI)
P_c	482200	4986500		watershed centroid (E, N; UTM 19N; meters)
County	Cumberland SE			*choose county from drop-down menu*
pptA	44.4			mean annual precipitation (inches; by look-up)
SG	0.00			sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:

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Maine Dept. Transportation
Augusta, ME 04333-0016
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A (km^2)	62.30	**Conf Lvl**	0.67
W (%)	10.95		

Ret Pd T (yr)	Peak Flow Estimate Lower	Q_T (m^3/s)	Upper	Q_T (ft^3/s)	USE THIS
1.1		9.26		326.8	390
2	13.11	18.28	25.48	645.4	770
5	19.99	27.97	39.12	987.6	1190
10	24.83	35.08	49.57	1238.8	1486
25	31.11	44.56	63.83	1573.5	1887
50	35.86	51.96	75.28	1834.6	2214
100	40.82	59.86	87.76	2113.5	2548
500	52.38	79.26	119.91	2798.5	3385

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$

HY-8 Analysis Results

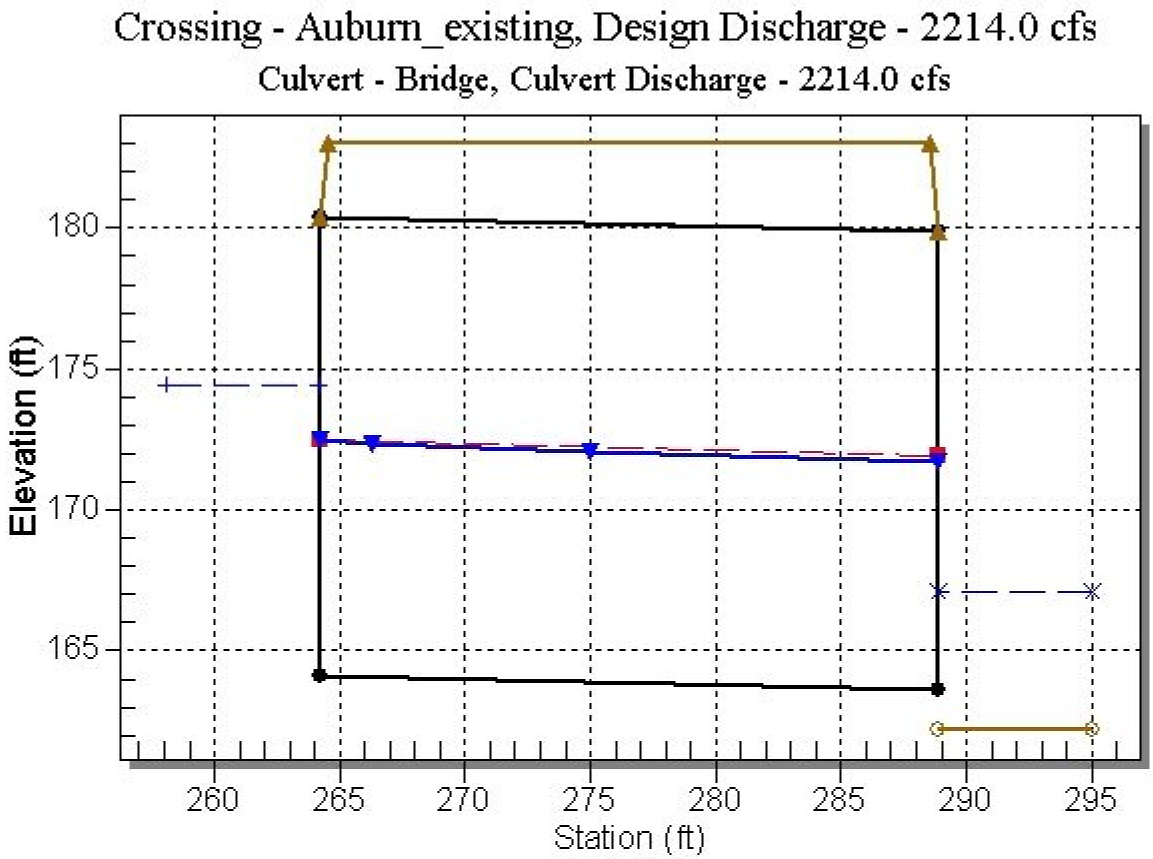
Summary Table – Existing Bridge

Culvert Crossing: Auburn

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)
390.00	390.00	167.86	3.759	0.0*	1-S2n	3.126	3.201	3.151	1.765	9.021	5.181
605.80	605.80	168.85	4.746	0.393	1-S2n	3.883	4.004	3.934	2.293	10.433	6.081
821.60	821.60	169.76	5.659	0.848	1-S2n	4.596	4.788	4.618	2.748	11.547	6.776
1037.40	1037.40	170.53	6.432	1.253	1-S2n	5.222	5.416	5.246	3.153	12.420	7.355
1253.20	1253.20	171.26	7.161	1.626	1-S2n	5.787	6.021	5.811	3.526	13.203	7.848
1469.00	1469.00	171.96	7.858	1.970	1-S2n	6.352	6.610	6.360	3.870	13.860	8.288
1684.80	1684.80	172.64	8.539	2.294	1-S2n	6.866	7.125	6.915	4.194	14.349	8.678
1900.60	1900.60	173.36	9.257	2.599	1-S2n	7.359	7.640	7.430	4.499	14.835	9.036
2116.40	2116.40	174.07	9.975	2.890	1-S2n	7.851	8.154	7.889	4.790	15.374	9.365
2214.00	2214.00	174.40	10.299	3.018	1-S2n	8.074	8.359	8.079	4.918	15.635	9.503
2548.00	2548.00	175.51	11.411	3.434	1-S2n	8.768	9.060	8.790	5.334	16.252	9.951

HYDROLOGY, HYDRAULICS, AND SCOUR DATA

Water Surface Profile Plot for Culvert: Bridge



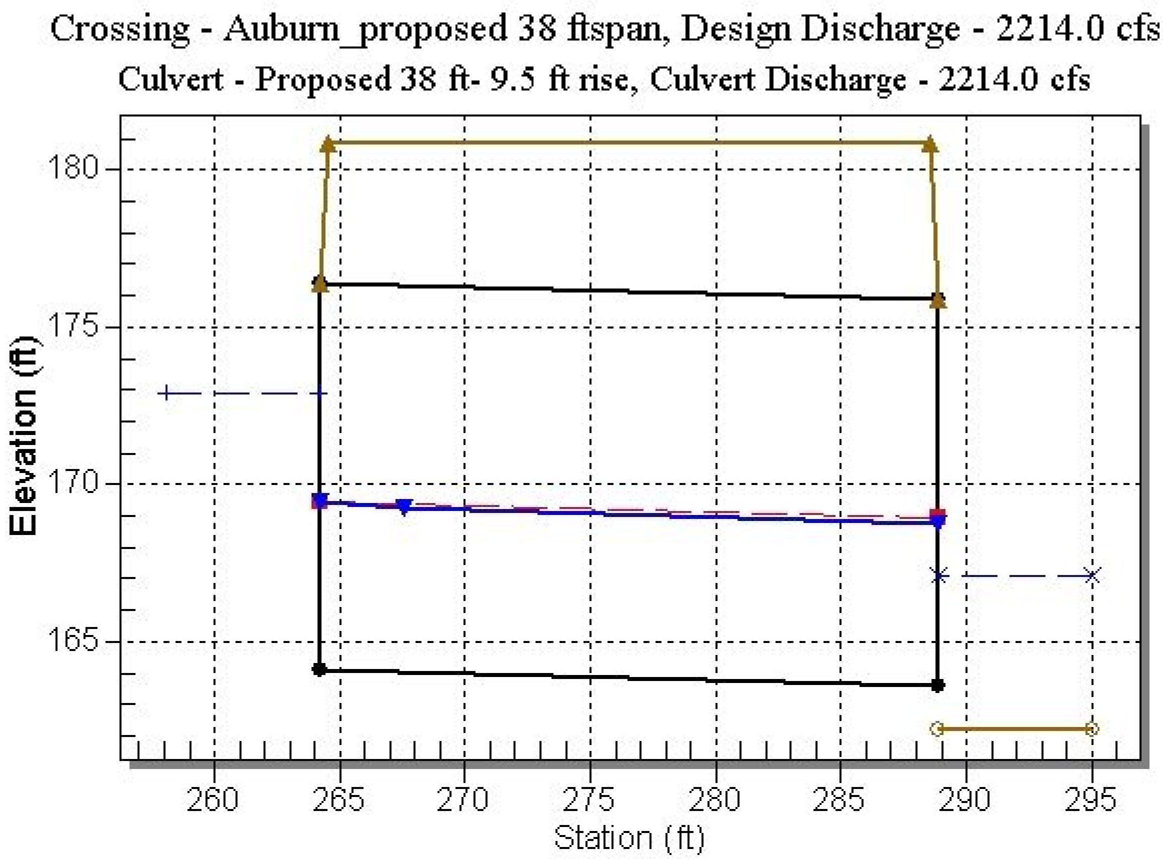
HY-8 Analysis Results

Summary Table - Proposed 38 ft- 9.5 ft rise

Culvert Crossing: Auburn

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)
390.00	390.00	166.97	2.867	0.0*	1-S2n	1.650	1.794	1.684	1.765	8.146	5.181
605.80	605.80	167.87	3.775	0.393	1-S2n	2.186	2.455	2.245	2.293	9.276	6.081
821.60	821.60	168.66	4.556	0.848	1-S2n	2.661	2.940	2.730	2.748	10.141	6.776
1037.40	1037.40	169.36	5.263	1.253	1-S2n	3.072	3.423	3.146	3.153	10.927	7.355
1253.20	1253.20	170.02	5.924	1.626	1-S2n	3.484	3.849	3.499	3.526	11.741	7.848
1469.00	1469.00	170.66	6.565	1.970	1-S2n	3.866	4.203	3.967	3.870	11.991	8.288
1684.80	1684.80	171.30	7.204	2.294	1-S2n	4.221	4.557	4.317	4.194	12.539	8.678
1900.60	1900.60	171.94	7.843	2.599	1-S2n	4.575	4.911	4.652	4.499	13.044	9.036
2116.40	2116.40	172.58	8.482	2.890	1-S2n	4.929	5.215	5.035	4.790	13.359	9.365
2214.00	2214.00	172.87	8.771	3.018	1-S2n	5.099	5.352	5.152	4.918	13.656	9.503
2548.00	2548.00	173.73	9.626	3.434	1-S2n	5.681	5.821	5.711	5.334	14.174	9.951

Water Surface Profile Plot for Culvert: Proposed 38 ft- 9.5 ft rise



Northstar Hydro, Inc.

Ms. Pam Hetherly, P.E., LEED AP
Principal Engineer
SEA Consultants
331 State Street
Augusta, ME 04330

January 6, 2009

Re: Scour Analysis, Royal River Bridge, Old Danville Rd., Auburn, Maine.

Dear Pam;

Enclosed, please find computations for scour analysis at the proposed replacement bridge over the Royal River at Old Danville Road in Auburn, Maine. According to project data, an existing 24' span bridge is to be replaced with an arch with a 38' span and 9.5' rise.

SEA provided hydraulic computations based on HY8 for the proposed and existing bridges, and the geotechnical report for the project.

Scour computations were done according to FHWA HEC-18. Full computations are attached.

The following design inputs were used:

D50:
Abutment 1 (Right facing downstream) = 0.077 mm = 0.00025 ft.
Abutment 2 (Left facing downstream) = 0.8 mm = 0.0026 ft.

Q50 = 1835 cfs, Elev.50 = 172.4', V50 = 12.1 fps.
Q100= 2114 cfs, Elev.100 = 173.2', V100 = 12.8 fps

Streambed elev. at bridge = 164'
Streambed elev. upstream = 164'

Critical Velocity @ abutment 1 = 1.03 fps
Critical Velocity @ abutment 2 = 2.22 fps
= Live Bed Scour

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*email: ekobrien@northstarhydro.com * www.northstarhydro.com*

HYDROLOGY, HYDRAULICS, AND SCOUR DATA

The following summarizes scour computations and implications.

Contraction Scour Total

Existing Bridge: **4'**
Proposed Bridge: 1'

Abutment Scour Assuming no riprap:

Abutment 1 ~ 3.34'
Abutment 2 ~ 8.7'

Advisement in HEC-18 states the following for abutment scour:

"Designing for Scour at Abutments

" The preferred design approach is to place the abutment foundation on scour resistant rock or on deep foundations. Available technology has not developed sufficiently to provide reliable abutment scour estimates for all hydraulic flow conditions that might reasonably be expected to occur at an abutment. Therefore, engineering judgement is required in designing foundations for abutments. In many cases, foundations can be designed with shallower depths than predicted by the equations when they are protected with rock riprap and/or with a guide bank placed upstream of the abutment designed in accordance with guidelines in HEC-23. Cost will be a deciding factor.

"... Where spread footings are place on erodible soil, the preferred approach is to place the footing below the elevation of total scour. If this is not practicable, a second approach is to place the top of footings below the depth of the sum of contraction scour and long-term degradation and to provide scour countermeasures. For spread footings on erodible soil, it becomes especially important to protect adjacent embankment slopes with riprap or other appropriate scour countermeasures. The toe or apron of the riprap serves as the base for the slope protection and must be carefully designed to resist scour while maintaining the support for the slope protection.

" In summary, as a minimum, abutment foundations should be designed assuming no ground support (lateral or vertical) as a result of soil loss from long-term degradation, stream instability, and contraction scour. The abutment should be protected from local scour using riprap and/or guidebanks. Guidelines for the design of riprap and guide banks are given in HEC-23."

This guidance indicates the following for the Royal River Bridge:

Without scour protection, the abutments should be designed to withstand 3' and 9' of scour respectively. With protection, at a minimum, 1' of scour should be assumed. To be conservative, designing for 3' of scour would provide additional protection.

Please do not hesitate to ask if you need more information.

Sincerely

Ellen K. O'Brien, P.E.
President, Northstar Hydro, Inc.