Central Street Bridge Replacement Hydrologic and Hydraulic Analysis

TO: Massachusetts Department of Transportation (MassDOT)

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A hydrologic and hydraulic (H&H) analysis was performed by Tighe & Bond as part of the engineering design and permitting for the Central Street Bridge Reconstruction Project located on Sawmill Brook at the mouth of Manchester Harbor in Manchester-by-the-Sea. The primary reasons for performing the H&H analysis were to:

- Evaluate the hydraulics (e.g., capacity, freeboard, and velocities) for the existing culvert.
- Develop alternative design concepts for culvert.
- Provide recommendations based on the H&H analysis as to the preferred alternative replacement design approach.

The H&H analysis and subsequent recommendations are summarized in this report and builds on the "Task 2: Hydrologic Monitoring and Flushing Studies Sawmill Brook Flood Mitigation and Restoration Project" prepared for Manchester-by-the-Sea by Tighe & Bond in June 2018.

Based on the analysis we recommend the installation of a 20-foot span open bottom concrete arch culvert to meet the Massachusetts Department of Transportation (MassDOT) Municipal Bridge Projects MGL Chapter 85 Section 35 review requirements for the 25-year flood frequency hydraulic design. Note that the MassDOT Bridge Manual (2013) indicates that the hydraulic design flood return frequency for an Urban Minor Arterial or Rural Major Collector is the 25-year return frequency storm event. The proposed culvert has capacity to pass the 25-year frequency storm event with 0.4 feet of freeboard for MHHW conditions (compared to the low chord), and 4.2 of freeboard feet for MSL condition. Both of these scenarios assume MassDOT recommended increases in sea level due to climate change although the MHHW value is approximately the same with and without adding the MassDOT sea level rise. This alternative would also pass the 25-year flood frequency storm event during an annual storm surge with the water level 1.8 feet below the top of road at Central Street.

A Scour analysis for the preferred design alternative shows potential for scour up to existing bedrock located approximately 0 to 2 feet below the channel bottom upstream of Central Street Bridge. During the geotechnical boring investigation, the bedrock was found to be very hard to hard granite, and is therefore not anticipated to scour. Due to the tidal nature of Manchester Harbor and Central Pond it is anticipated that in general sediment aggradation will be anticipated when storms occur during higher tides (due to backwater) while sediment degradation will be anticipated when storms occur during lower tides.

Attachment A contains figures depicting an aerial overview of Central Street Bridge (Figure 1), a topographic map of the drainage-area (Figure 2), and the geometry used to define the cross-sections in the HEC-RAS model (Figure 3). Attachment B contains the 2016 Report with a description of the HEC-HMS model. Attachment C contains the HEC-RAS model

output for the existing and proposed alterative conditions. Attachment D contains the scour analysis calculations.

A summary of the proposed geometry is provided below, with elevations referencing the North American Vertical Datum of 1988 (NAVD88):

Item	Description
Bridge Size and Type	20-foot wide open bottom Arch
Low Chord Elevation	6.0 feet NAVD88
Top of Road Elevation	10.6 feet NAVD88 (+/-)
Upstream Stream Bed Elevation	-0.2 feet NAVD88
Downstream Stream Bed Elevation	-5.3 feet NAVD88 (culvert invert at -4.0 feet NAVD88)
Skew	12 degrees*
Design Scour Elevation	-2 feet NAVD88 (+/-)

*The culvert will be installed at a 12-degree angle; however, since it will be a culvert and not a bridge the full width of the culvert will be available for flow. For traditional bridges the upstream and downstream cross sections control flow under a bridge deck so the skew must be incorporated; however, for an open bottom arch culvert tied into to the walls of an existing channel the geometry of the culvert limits flow and not the upstream cross section. A skew angle was therefore excluded from hydraulic modeling.

1 Project Site Description

The Central Street Bridge spans the Sawmill Brook at the mouth of Manchester Harbor on Central Street (Route 127). The Town-owned crossing is constructed of three integrated parts, a bridge, tide gate and coastal wingwall. The bridge consists of a 13-foot span mortared stone masonry circular arch tidal bridge with stone masonry wingwalls and headwalls. Timber cribs functioning as weirs are imbedded into the bottom of the stream bed. A concrete and iron tide gate abuts the bridge to the south. The bridge was rebuilt around the mid 1900's and a tide gate was installed to control the Brook and create Central Pond just upstream. A stone and masonry wingwall abuts the bridge in the southwest quadrant, functioning as a seawall. The passage under the bridge discharges flow from Sawmill Brook via a narrow, channelized reach, with 12-foot- high granite walls and buildings abutting either side. Tidal flow from Manchester Harbor passes under the bridge, depending on the setting of the tide gate and tide height. When the tide gate is closed and water is impounded underneath the bridge, the hydrostatic pressure of water forces seepage through the wingwall. The gate and bridge design have been identified as contributing factor to upstream flooding, due to significant hydraulic restriction when large precipitation events and high tide elevations are concurrent.

The tide gate and weir design have been identified by the Massachusetts Division of Marine Fisheries (DMF) as an impediment to fish passage, notably impacting state-listed species, rainbow smelt (Osmerus mordax). The Town plans to remove the tide gate during the reconstruction of the Central Street Bridge.

2 Methodology

Tighe & Bond updated existing a hydrologic and hydraulic (H&H) models of the Central Street (Route 127) bridge watershed along Sawmill Brook as part of the bridge replacement alternatives analysis. The H&H model was developed by updating existing HEC-HMS (version 5.2.1) and HEC-RAS (version 5.0.3) models, both available from the U.S. Army Corps of Engineers. The hydrologic analysis was performed using HEC-HMS (version 5.2.1). The HEC-HMS model output was subsequently used to develop a steady-state HEC-RAS model to evaluate the hydraulic conditions for the existing and proposed structures. The methods used to develop both the hydrologic and hydraulic analysis are documented in the following sections.

2.1 Hydrologic Analysis

A detailed hydrologic analysis was performed using HEC-HMS as part of the February 2016 "Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation" prepared by Tighe & Bond. The 2016 study included 25-, 50-, and 100-year flow estimates for the present, 2025, 2050, and 2100 while incorporating multiple energy use climate change projections for rainfall, as well as sea level rise, and storm surge. The 2016 HEC-HMS model was developed using the runoff curve number and time of concentration methodologies outlined in the United States Department of Agriculture's (USDA) Technical Release 55 (TR-55)[1]. The drainage area upstream of Central Street (Route 127) was computed to be approximately 5 square miles, and was modeled using 23 sub-drainage areas. The computed runoff curve numbers ranged from 60 to 75, and the lag times (defined as 0.6 times the time of concentration) ranged from approximately 20 minutes to 70 minutes. The 2016 model developed inflow hydrographs using the 24-hour rainfall depths from the Northeast Regional Climate Center (NRCC) at Cornell University. Five storage areas were also included in the HEC-HMS model at culverts. The 2016 study is included as Attachment B of this memorandum.

Tighe & Bond updated the 2016 HEC-HMS model to include the 2-, 10-, and 500-year frequency storm event as recommended by the MassDOT LFRD Bridge Manual[2]. The 24-hour precipitation for the 2-, 10-, 25-, 50-, 100-, and 500-year frequency storms were estimated using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 point precipitation frequency tool. Table 2-1 provides the precipitation amounts from NOAA Atlas 14, as well as the NRCC precipitation amounts used as part of the 2016 study. The NOAA Atlas 14 and NRCC values are approximately the same for the 25-year frequency storm event (the depths are within less than 1-percent), whereas the NRCC 24-hour rainfall depths are 4-percent and 10-percent larger than the NOAA Atlas 14 depths for the 50-year and 100-year frequency storm events, respectively. NOAA Atlas 14 was published after the 2016 study was performed and is more current than the NRCC values; however, the NRCC rainfall depths will be used at this time for the 25-, 50-, and 100-year frequency storm events for consistency with the previous recent hydrologic and hydraulic studies performed and because the NRCC depths are either similar to or more conservative than the NOAA Atlas 14 rainfall depths.

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[1] Cronshey, R. G., R. T. Roberts, and N. Miller. "Urban hydrology for small watersheds (TR-55 Rev.)." *Hydraulics and Hydrology in the Small Computer Age*. ASCE, 1985.

[2] MassDOT (Massachusetts Dept. of Transportation. "LRFD bridge manual. Part I." (2013).

TABLE 2-1
24-hr Precipitation Values from the National Oceanic and Atmospheric Administration NOAA Atlas 14 and the Northeast Regional Climate Center (NRCC)

Storm Return Frequency	Precipitation Values from NOAA Atlas 14 (inches)	Precipitation Values from NRCC Used for Previous Modeling (inches)
2-year	3.20	
10-year	5.04	
25-year	6.20	6.16[1]
50-year	7.08	7.34[1]
100-year	7.97	8.77[1]
500-year	11.1	

[1]The NRCC rainfall depths will be used for the 25-, 50-, and 100-year frequency storm events for consistency with the previous recent hydrologic and hydraulic studies performed and because the NRCC depths are either similar to or more conservative than the NOAA Atlas 14 rainfall depths

Peak flows were also calculated through regression analysis using the Zarriello 2017[3] approach available in the USGS Streamstats program[4]. These flow estimates were used as a basis for comparison with the computed design storm flow rates.

2.2 Hydraulic Analysis

A hydraulic analysis of Sawmill Brook was prepared using HEC-RAS, a hydraulic modeling program available from the U.S. Army Corps of Engineers. This model updates the previous planning level modeling performed as part of the "Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation" prepared by Tighe & Bond in February 2016, with updates based on the November 2017 survey by Doucet Survey Inc., and surface water level monitoring. The updated model includes Sawmill Brook from approximately 50 feet upstream of Norwood Avenue to approximately 100 feet downstream of Central Street.

To update the model, Tighe & Bond first created a Triangular Irregular Network (TIN) elevation surface using the 2017 survey and MassGIS LiDAR topographic data for overbank areas beyond the extent of the surveyed cross sections. A geometric representation of the channel, banks, and cross-sections was created using the HEC-GeoRAS tool to extract cross sections from the TIN. Sawmill Brook was modeled using 30 cross sections, culverts at Norwood Avenue, School Street, and Central Street, as well as the existing tide gate structure immediately downstream of Central Street. The Manning's roughness coefficients were estimated to be 0.04 in the upstream area of the reach and 0.03 toward the downstream area based on the survey and orthographic imagery. The overbank area Manning's n varied from 0.035 (commercial/industrial land use) to 0.1 (forest cover). The overbank Manning's n varied horizontally along the cross sections and were calculated using the MassGIS 2015 land use dataset.

[3] Zarriello, P.J.,2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p.

[4] U.S. Geological Survey, 2016, The StreamStats program, online at http://streamstats.usgs.gov, accessed August 21, 2018.

Model geometry scenarios were developed for:

1. Existing Conditions with the Tide Gate Open/Closed
2. Proposed Alternatives

The downstream boundary conditions for the design storm hydraulic modeling were the Mean Higher High Water (MHHW) and the annual storm surge elevation. The modeled MHHW elevation was 4.77 feet NAVD88 based on the NOAA Long Term Tide Water Level Monitoring Station ID: 8443970. The annual storm surge elevation was provided in the February 2016 study as approximately 8.2 feet NAVD88. The 2016 study estimated that the annual storm surge elevation in 2100 would overtop Central Street so future storm surge scenarios were not modeled. For reference, the Mean Sea Level (MSL) is -0.3 feet NAVD88 at the NOAA Long Term Tide Water Level Monitoring Station ID: 8443970.

The sea level rise increase in 2100 used for this study is 2 feet. This value falls within the 66% probability range provided in the Northeast Climate Science Center (NECSC) sea level rise projections for the Boston area for the two emissions scenarios evaluated[5]. The MHHW elevation accounting for sea level rise was therefore 6.77 feet NAVD88. This sea level rise increase is more conservative than the 0.012 feet/year increase recommended in the LFRD Bridge Manual that corresponds with a 0.98-foot increase by 2100. This would correspond with a sea level rise MHHW of 5.75 feet NAVD88, and a MSL of 0.68 feet NAVD88.

Following the development of the geometric parameterization of the cross-sections along Sawmill Brook, flows from the updated HEC-HMS model were assigned by cross-section for both the existing and proposed condition. Water surface elevations and channel velocities were evaluated for the 2-, 10-, 25-, 50-, 100-, and 500-year storms.

MassDOT classifies Central Street (Route 127) as an Urban Minor Arterial or Rural Major Collector. The LRFD Bridge Manual suggests a hydraulic design storm as a 25-year frequency storm event, the scour design storm as the 50-year frequency storm event, and the scour design check storm as the 100-year frequency storm event. Freeboard is defined as the distance from the peak water surface elevation upstream of the culvert to the top of the culvert opening, which was evaluated across the range of storms.

2.3 Alternative Design Analysis

Three alternative designs were evaluated to replace the existing Central Street Bridge. All of the alternative designs included removing the existing tide gate. The first alternative (Alternative 1) was designed to pass the 50-year frequency storm event for predicted climate change rainfall and sea level rise conditions exceeding MassDOT requirements. The minimum hydraulic capacity structure was determined to be an open-bottomed concrete arch-culvert structure with a clear span width of 20-feet and a continuous low chord elevation at 6 feet NAVD88. The second alternative (Alternative 2) was sized to provide a span that could pass the 25-year frequency storm event with the MassDOT recommended sea level rise for 2100 using the tidal MHHW boundary condition, which was determined to be a structure with the geometry of Alternative 1 but with a span width of 12 feet. The third alternative (Alternative 3) is an in-kind replacement of the existing culvert.

1. Proposed Alternative 1 with 20-foot wide arch culvert with Tide Gate Removed
2. Proposed Alternative 2 with 12-foot wide arch culvert with Tide Gate Removed

[5] Northeast Climate Science Center (NECSC) "Massachusetts Climate Change Projections - Statewide and for Major River Basins" for the Massachusetts Executive Office of Energy and Environmental Affairs, January 2018. Available from http://www. massclimatechange.org/.

3. Proposed Alternative 3 with Culvert Replaced in-kind with Tide Gate Removed

2.4 Scour Analysis

Scour at the Central Street Bridge was evaluated in a manner consistent with the general guidelines set forth in the FHWA Hydraulic Engineering Circular Nos. 18 (HEC-18), HEC-20, and the MassDOT LRFD Bridge Manual section 1.3.3.4 Scour/Stability Analysis. The HEC-RAS model was used to estimate the hydraulic parameters required to compute the total scour potential. The scour design and scour check flood return frequencies were the 50-year and 100-year frequency storm event, based on Table 1.3.4-1 in the LRFD Bridge Manual for an Urban Minor Arterial or Rural Major Collector.

Total scour consists of the summation of contraction scour, abutment scour, pier scour, and long-term aggregation and degradation. Contraction scour is calculated using the Modified Laursen's equation (1960) and the Laursen's equation (1963) as outlined in HEC-18. Abutment scour was calculated using the National Cooperative Highway Research Program (NCHRP) methodology as outlined in HEC-18 that provides a peaking factor to contraction scour to estimate the sum scour anticipated from contraction and abutment scour. Scour was also calculated using the Clear-Water Scour Equation for Open-Bottom Culverts that incorporate both contraction and abutment scour. There are no piers proposed, so pier scour was not evaluated. Long-term aggregation and degradation were evaluated based on qualitative approaches outlined in HEC-20. Scour calculations did not include any potential scour countermeasures. The sediment transport analysis performed in "Task 3: Sediment Characterization and Flushing Studies - Sawmill Brook Flood Mitigation and Restoration Project" completed in June 2018 by Tighe & Bond was also reviewed as part of the scour analysis.

3 Analysis Results and Alternatives Discussion

The H&H model was evaluated for the existing and proposed alternatives using the above described methodology. The model results for existing and proposed conditions are presented in the following sections.

3.1 Hydrologic Analysis

Table 3-1 shows the peak flow results from the HEC-HMS model as well as the prediction interval from the regression analysis.

TABLE 3-1

Design Storm Peak Flow Rates from HEC-HMS Hydrologic Model with associated Downstream Boundary Condition for HEC-RAS hydraulic model.

Model Scenario	Downstream Boundary Condition[1]	Flow to Norwood Avenue (ft^3/s)	Flow to Central Pond (ft^3/s)	Regression Analysis Prediction Interval at Central Pond[2] (ft^3/s)
Present (2018) 2-Year	MHHW	232	254	63 to 242
Present (2018) 10-Year	MHHW	845	924	129 to 535
Present (2018) 25-Year	MHHW	1,228	1,363	167 to 739
Present (2018) 50-year	MHHW	1,565	1,772	195 to 920
Present (2018) 100-year	MHHW	2,000	2,267	223 to 1,120
Present (2018) 500-year	MHHW	2,671	3,078	303 to 1,610
Present (2018) 25-year with MassDOT recommended SLR	MHHW + MassDOT SLR	1,228	1,363	167 to 739
Present (2018) 25-year MSL with MassDOT recommended SLR	MSL + SLR	1,228	1,363	167 to 739
Future (2100) 25-Year	MHHW + SLR	1,706	1,930	N/A
Future (2100) 50-Year	MHHW + SLR	1,717	1,946	N/A
Future (2100) 100-Year	MHHW + SLR	2,562	2,943	N/A
Present (2018) 25-Year with Storm Surge	Annual Storm Surge	1,228	1,363	N/A
Present (2018) 50-year with Storm Surge	Annual Storm Surge	1,565	1,772	N/A

[1] MHHW = Mean Higher High Water, SLR = Sea Level Rise, MSL = Mean Sea Level

[2] Regression analysis completed using Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156 (Zarriello 2017)

In general, the peak flows estimated using HEC-HMS are larger than the values predicted by the regression analysis though within the same order of magnitude. Based on this comparison, the HEC-HMS model was considered to provide reasonable conservative estimate for the storms of interest at the Central Street (Route 127) culvert and the values from this model were used as the peak inflow values for the steady-state HEC-RAS hydraulic model.

3.2 Hydraulic Analysis

Peak flows evaluated in the hydrologic analysis were subsequently used as input to the HEC-RAS model to evaluate hydraulics at Central Street Bridge for existing and proposed alternative conditions. Results from this analysis, which include peak water surface elevations, distance from the peak water surface elevation to the top of the road, freeboard to low chord, and velocities within the structure are included in Tables 3-2 through 3-5. HEC-RAS model output for the existing and proposed alterative conditions are provided in Attachment C.

TABLE 3-2
HEC-RAS Results for Existing Conditions at Central Street Bridge (assuming tide gate closed)

Model Scenario	Peak Water Surface Elevation (NAVD88)	Freeboard (feet)	Distance to Top of Road (feet)	Average Velocity Upstream Inside Culvert (ft/s)	Average Velocity Downstream Inside Culvert (ft/s)
Present (2018) 2-Year	6.4	-0.4	4.2	4.0	4.0
Present (2018) 10-Year	11.2	-5.2	-0.6	12.1	12.1
Present (2018) 25-Year	11.8	-5.8	-1.2	12.2	12.2
Present (2018) 50-year	12.4	-6.4	-1.8	8.5	8.5
Present (2018) 100-year	12.5	-6.5	-1.9	9.9	9.9
Present (2018) 500-year	12.6	-6.6	-2.0	9.5	9.5
Present (2018) 25-year with MassDOT recommended SLR	11.9	-5.9	-1.3	12.3	12.3
Present (2018) 25-year MSL with MassDOT recommended SLR	11.8	-5.8	-1.2	12.2	12.2
Future (2100) 25-Year	12.2	-6.2	-1.6	12.9	12.9
Future (2100) 50-Year	12.1	-6.1	-1.5	12.9	12.9
Future (2100) 100-Year	12.6	-6.6	-2.0	9.5	9.5
Present (2018) 25-Year with Storm Surge	11.9	-5.9	-1.3	12.2	12.2
Present (2018) 50-year with Storm Surge	12.4	-6.4	-1.8	8.5	8.5

TABLE 3-3
HEC-RAS Results for Alternative 1 at Central Street Bridge (replace culvert with 20-foot wide open-bottom arch culvert)

Model Scenario	Peak Water Surface Elevation (NAVD88)	Freeboard (feet)	Distance to Top of Road (feet)	Average Velocity Upstream Inside Culvert (ft/s)	Average Velocity Downstream Inside Culvert (ft/s)
Present (2018) 2-Year	4.7	1.3	5.9	1.5	1.5
Present (2018) 10-Year	4.8	1.2	5.8	5.4	5.4
Present (2018) 25-Year	5.6	0.4	5.0	8.0	8.0
Present (2018) 50-year	6.6	-0.6	4.0	10.4	10.5
Present (2018) 100-year	7.7	-1.7	2.9	13.4	13.6
Present (2018) 500-year	10.9	-4.9	-0.3	16.9	16.9
Present (2018) 25-year with MassDOT recommended SLR	5.7	0.3	4.94	7.4	7.5
Present (2018) 25-year MSL with MassDOT recommended SLR	1.8	4.2	8.8	11.7	13.0
Future (2100) 25-Year	6.9	-0.9	3.7	10.5	10.5
Future (2100) 50-Year	7.0	-1.0	3.6	10.5	10.5
Future (2100) 100-Year	10.6	-4.6	-0.01	13.8	13.8
Present (2018) 25-Year with Storm Surge	8.8	-2.8	1.8	7.4	7.4
Present (2018) 50-year with Storm Surge	10.6	-4.6	-0.01	9.6	9.6

TABLE 3-4
HEC-RAS Results for Alternative 2 at Central Street Bridge (replace culvert with 12-foot wide open-bottom arch culvert

Model Scenario	Peak Water Surface Elevation (NAVD88)	Freeboard (feet)	Distance to Top of Road (feet)	Average Velocity Upstream Inside Culvert (ft/s)	Average Velocity Downstream Inside Culvert (ft/s)
Present (2018) 2-Year	4.8	1.2	5.8	2.4	2.4
Present (2018) 10-Year	6.0	0.0	4.6	8.8	8.9
Present (2018) 25-Year	8.6	-2.6	2.0	12.9	13.2
Present (2018) 50-year	10.6	-4.6	-0.01	15.0	15.8
Present (2018) 100-year	10.6	-4.6	-0.03	15.7	16.9
Present (2018) 500-year	10.9	-4.9	-0.3	16.2	17.5
Present (2018) 25-year with MassDOT recommended SLR	9.0	-3.0	1.6	12.1	12.1
Present (2018) 25-year MSL with MassDOT recommended SLR	8.7	-2.7	1.9	14.0	15.4
Future (2100) 25-Year	10.9	-4.9	-0.3	13.5	13.5
Future (2100) 50-Year	10.9	-4.9	-0.3	13.5	13.5
Future (2100) 100-Year	10.6	-4.6	-0.01	14.8	14.8
Present (2018) 25-Year with Storm Surge	10.9	-4.9	-0.3	10.6	10.6
Present (2018) 50-year with Storm Surge	11.3	-5.3	-0.7	11.6	11.6

TABLE 3-5
HEC-RAS Results for Alternative 3 at Central Street Bridge (replace culvert in-kind)

Model Scenario	Peak Water Surface Elevation (NAVD88)	Freeboard (feet)	Distance to Top of Road (feet)	Average Velocity Upstream Inside Culvert (ft/s)	Average Velocity Downstream Inside Culvert (ft/s)
Present (2018) 2-Year	5.3	0.7	5.3	4.5	4.4
Present (2018) 10-Year	10.9	-4.9	-0.3	14.7	14.9
Present (2018) 25-Year	11.6	-5.6	-1.0	14.3	18.3
Present (2018) 50-year	11.9	-5.9	-1.4	14.7	18.8
Present (2018) 100-year	12.1	-6.1	-1.5	15.0	19.2
Present (2018) 500-year	11.9	-5.9	-1.3	15.5	19.7
Present (2018) 25-year with MassDOT recommended SLR	11.6	-5.6	-1.0	14.3	18.3
Present (2018) 25-year MSL with MassDOT recommended SLR	11.6	-5.6	-1.0	14.3	18.3
Future (2100) 25-Year	12.1	-6.1	-1.5	14.3	14.3
Future (2100) 50-Year	12.1	-6.1	-1.5	14.3	14.3
Future (2100) 100-Year	12.1	-6.1	-1.5	15.3	15.3
Present (2018) 25-Year with Storm Surge	11.9	-5.9	-1.3	11.7	11.7
Present (2018) 50-year with Storm Surge	12.1	-6.1	-1.5	12.3	12.3

3.3 Alternative Design Evaluation

Three alternative designs were evaluated to replace the existing culvert at Central Street. All alternatives are expected to result in increase hydraulic capacity compared to existing conditions with the tide gate in place. Alterative 1 and Alternative 2 would results in a more natural river alignment under the road by reducing the hydraulic restriction that currently exists. Also, all alternatives were limited in height by the existing road grade, which was assumed to remain the same from existing to proposed. The span width was also limited to 20 feet due to the upstream channel.

3.3.1 Preferred Alternative

Alternative 1 exceeds MassDOT hydraulic requirements by passing the 50-year frequency storm event for predicted climate change conditions without overtopping the road. This alternative also passes the 25-year frequency storm event with 0.4 feet of freeboard for MHHW conditions (compared to the low chord), and 4.2 of freeboard feet for MSL condition. Both of these scenarios assume MassDOT recommended increases in sea level due to climate change. Note that MHHW elevation is 5.75 NAVD88 when assuming MassDOT tidal increases due to sea level rise (0.25 feet lower than the maximum low chord based on site constraints). This alternative can also pass the 25-year frequency storm event during the annual storm surge without overtopping the road. While Alternative 2 met the MassDOT minimum hydraulic constraints for culvert design, it is not anticipated to meet predicted climate change conditions in 2100 for the 50-year frequency storm event. Alterative 3 does not meet the recommended MassDOT minimum hydraulic requirements, although it does offer an improvement to existing conditions due to removal of the tide gate. Alternative 1 was considered the preferred alternative.

3.4 Scour Analysis

Abutment, contraction, and long-term aggregation and degradation scour processes were evaluated in detail for the preferred alternative. Attachment D contains the calculations for this analysis.

Abutment scour was calculated for the 50-year scour design storm, and is anticipated to extend to the granite bedrock located approximately 0 to 2 feet below the channel bottom. If the bedrock had not been observed scour would be anticipated to a depth of 3.7 feet at the center of the channel and up to 10.8 feet toward the left and right abutment. Under the 100-year scour design check storm, scour is also anticipated to extend to the granite bedrock located approximately 0 to 2 feet below the channel bottom. If the bedrock had not been observed the scour would be anticipated to a depth of 4.1 feet at the center of the channel and up to 6.8 feet toward the left and right abutment. A contraction scour analysis shows that live-bed scour conditions are likely to dominate with sediment transport limiting the contraction scour depth rather than the size of the bed material.

The natural bed material of this stream is mostly comprised of medium to fine grain sands and silt, with average D50 and D85 values of approximately 0.011 inches and 0.05 inches, respectively. An incipient diameter analysis was performed and results indicate that the hydraulic forces are adequate to transport bed material up to 1 foot for a 50-year storm, which is greater than the average D85.

Based on this comparison between the incipient diameter particle size for the 50-year storm and the streambed material, it is anticipated that sediment will be mobilized from the upstream reach following the installation of an open-bottom culvert. The granite bedrock located 0 to 2 feet below the channel bottom will provide a vertical control for scour.

3.5 Stream-Crossing Standards

The preferred alternative of a 20-foot span open-bottom arch culvert was not designed to meet Stream-Crossing standards due to site constraints and coastal influence but does meet some of the recommendations. For replacement projects, stream simulation design approaches typically result in greater hydraulic capacity for passing flood flows than the existing bridge or culvert. This is true in this case, as the existing structure is an approximately 13 feet wide semi-circular arch culvert, which is proposed to be replaced with an open-bottom culvert with a clear span of 20 feet.

The proposed culvert is approximately the same width as the concrete wall lined channel located upstream of the bridge, so the opening width is not anticipated to limit flow. The concrete channel contains the 10-year frequency storm event, and is therefore anticipated to exceed the bankfull flow event (typically between the 1.5-, and 2-year frequency storm events).

The predicted opening area of the preferred replacement culvert is approximately 100 square feet. With a total length of approximately 45 feet, the openness ratio is approximately 2.2 feet, which exceeds the recommended openness ratio of 0.82 feet and approaches the recommended optimum standard. The height of the opening of the structure at this location is limited by the cover from the existing road grade, and a maximum low chord elevation of 6 feet NAVD88 is proposed for the preferred alternative.

3.6 Hydraulic Design Table

The H&H analysis is summarized in the design drawings in a hydraulic design data table. Table 3-6 provides the hydraulic design data table for Central Street Bridge.

TABLE 3-6
Hydraulic Design Data Table Included in Design Drawings for Central Street Bridge for a 20-foot span open-bottom arch culvert with low chord at 6 feet NAVD88.

HYDRAULIC DATA	
DRAINAGE AREA	5.0 SQ. MILES
WATER CONTROL FLOOD DISCHARGE (2 YR)	254 CFS
DESIGN FLOOD DISCHARGE (25 YR)	1,363 CFS
DESIGN FLOOD ANNUAL CHANCE (RETURN FREQUENCY)	4% (25-YEARS)
DESIGN FLOOD VELOCITY (25 YR)	7.5 FPS
DESIGN FLOOD ELEVATION (25 YR)	5.7 FEET
BASE 100-YR FLOOD DATA	
BASE FLOOD DISCHARGE (100 YR)	2,267 CFS
BASE FLOOD ELEVATION (100 YR)	7.7 FEET
DESIGN AND CHECK SCOUR DATA	
SCOUR DESIGN FLOOD ANNUAL CHANCE (RETURN FREQUENCY)	2% (50-YEARS)
DESIGN FLOOD ABUTMENT SCOUR DEPTH	LEFT: 2 FT RIGHT: 2 FT
SCOUR CHECK FLOOD ANNUAL CHANCE (RETURN FREQUENCY)	1% (100-YEARS)
CHECK FLOOD ABUTMENT SCOUR DEPTH	LEFT: 2 FT RIGHT: 2 FT
FLOOD OF RECORD	
DISCHARGE	UNKNOWN
FREQUENCY (IF KNOWN)	N/A
MAXIMUM ELEVATION	N/A
DATE	N/A
HISTORY OF ICE FLOWS	UNKNOWN
EVIDENCE OF SCOUR AND EROSION	NO

4 Summary

The H&H analysis methodology and results described above will be used as the basis of design of the Central Street Bridge along the Sawmill Brook in the Town of Manchester-by-the-Sea. The analysis confirms that the preferred alternative will provide both adequate hydraulic capacity for the design storm as well as will meet predicted future conditions due to climate change. Furthermore, scour is not anticipated to extend beyond the granite bedrock located between 0 to 2 feet below the channel bottom for the scour design storm (50-year storm) nor the scour check storm (100-year storm).

J:\M\M1476 Manchester MA Hydro Study\011-Central Street Bridge\Report_Evaluation\Hydrologic and Hydraulic Analysis Report\H&H Memo Central Street Bridge Replacement MBTS.doc

ATTACHMENT A
Figures

FIGURE 1
SITE AERIAL OVERVIEW

Central Street Bridge Reconstruction
Manchester-by-the-Sea, Massachusetts

Tighe&Bond
Engineers | Environmental Specialists

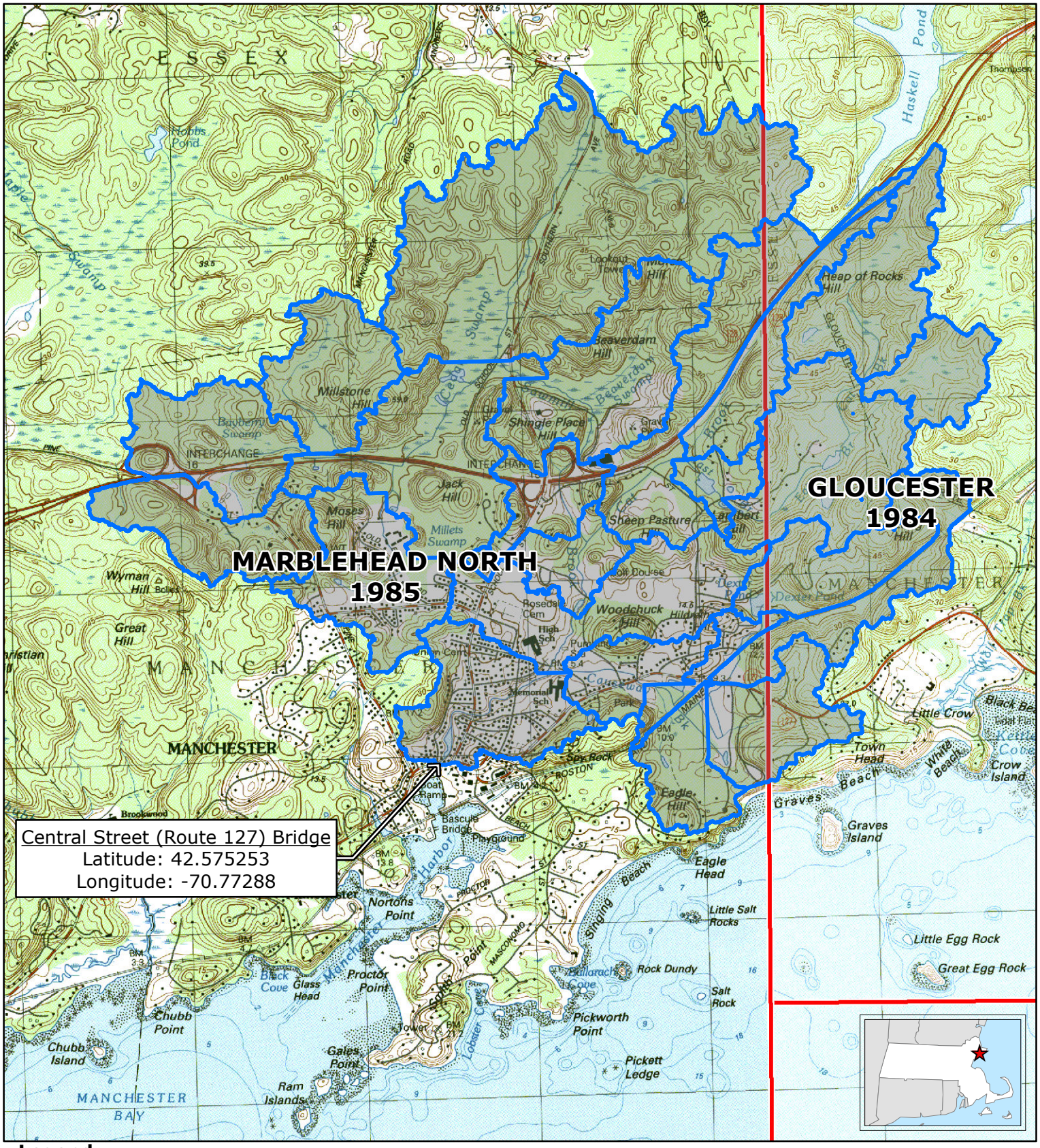
Based on MassGIS Color Orthophotography (2013)

1:3,600
0 150 300
Feet

August 2018

J:\M\M1476 Manchester MA Hydro Study\011-Central Street Bridge\Drawings_Figures\GIS\MXD\01_Central Street MBTS Overview.mxd

S-1852



Legend

- Central Street Bridge Drainage Area
- HEC-HMS Sub-Drainage Areas
- USGS Quadrangle Sheet Boundary

Based on USGS Topographic Map for Marblehead, MA Revised 1985. Gloucester, MA Revised 1984.

1:30,000

0 1,250 2,500

Feet

N

Tighe&Bond

Engineers | Environmental Specialists

FIGURE 1
DRAINAGE AREA MAP

Central Street Bridge Reconstruction
Manchester-by-the-Sea, Massachusetts

August 2018

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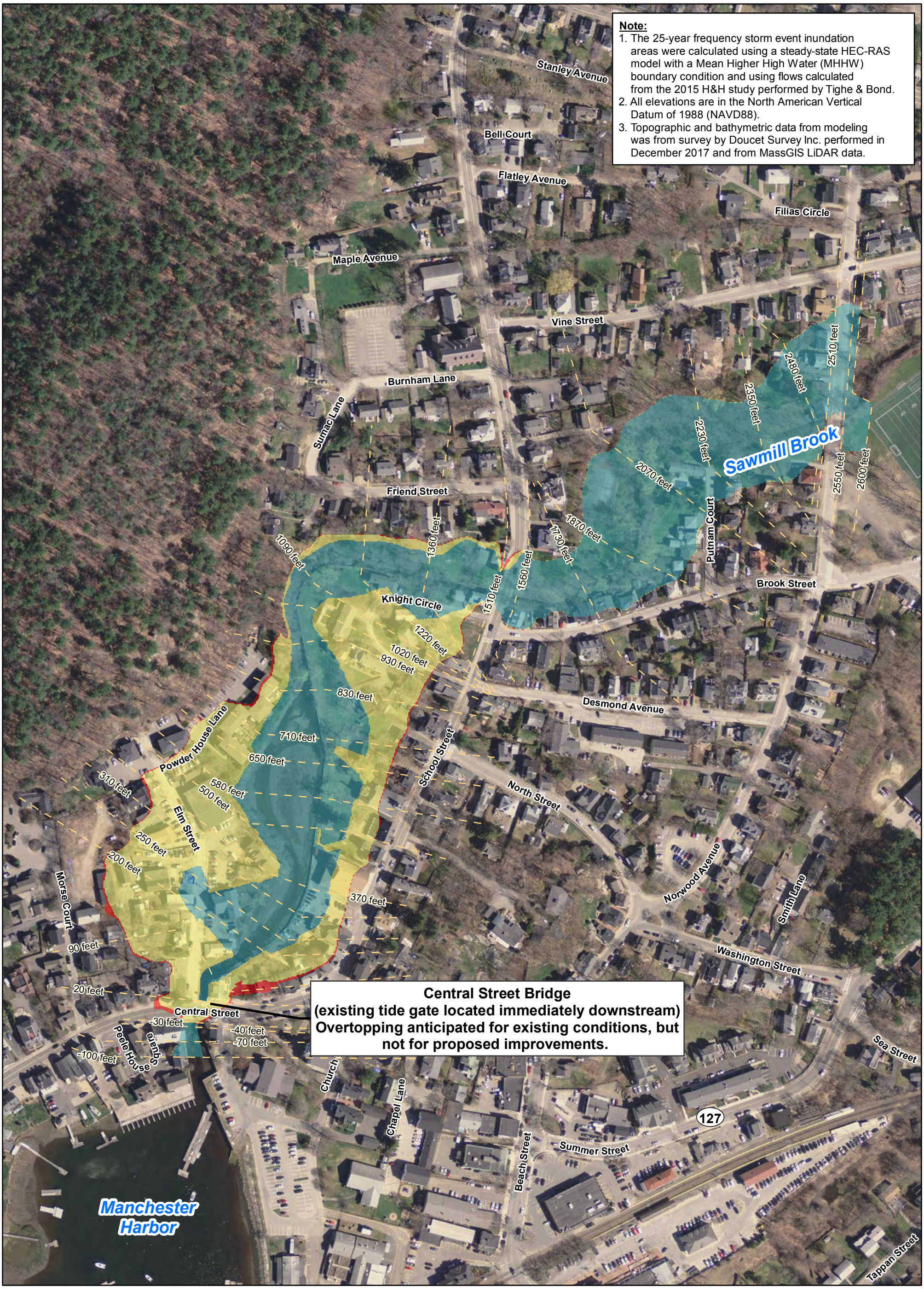
S-1852



LEGEND

- Model Cross Section (label indicates feet upstream of Central Street)
- Proposed Conditions 25-year Storm Flow (Larger Culvert, and tidegate removed) Inundation Area
- Existing Conditions Tide Gate Open 25-year Storm Flow Inundation Area
- Existing Conditions Tide Gate Closed 25-year Storm Flow Inundation Area

1 in = 200 ft

0 100 200
Feet

N

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2013).

FIGURE 3
25-YEAR FREQUENCY STORM EVENT INUNDATION AREA

Manchester-by-the-Sea
Sawmill Brook Feasibility Study

October 2018

V:\Projects\M\m1476\SawmillBrook_InundationFigures\SawmillBrook_MA_25Yr_StormEvent_Inundation.mxd

M-1476

ATTACHMENT B

"Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation" (Tighe & Bond, 2016)

H&H Memo Attachment B

NOTE: The hydraulic modeling and sea level rise estimates have been updated since this study was performed and were not included in this Appendix.

Tighe&Bond

SELECTION FROM

Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation

Prepared For:

Town of Manchester-by-the-Sea
Manchester-by-the-Sea, Massachusetts

February 2016

Table of Contents

Appendices

Appendix D and E Excluded.

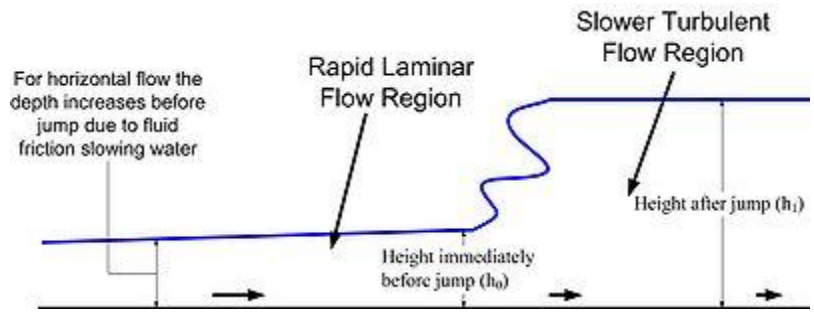
Figures

Tables

Definitions

GIS: acronym for Geographic Information Systems; a system designed to store, analyze, manage, and present all types of geographical data

Hydraulic Jump is a phenomenon in the science of hydraulics which is frequently observed in open channel flow such as rivers and spillways. When water at high velocity discharges into a zone of lower velocity water, a rather abrupt rise occurs in the water surface. The rapidly flowing water is abruptly slowed and increases in height, converting some of the flow's initial kinetic energy into an increase in potential energy, with some energy irreversibly lost through turbulence to heat. In open channel flow, this manifests as the fast flow rapidly slowing and piling up on top of itself similar to how a shockwave forms. The following figure illustrates the behavior in a hydraulic jump.



A hydraulic jump is a region of rapidly varied flow and is formed in a channel when a **supercritical flow** transitions into a **subcritical flow**. In general, supercritical flows are shallow and fast and subcritical flows are deep and slow.[1]

Hydrologic Soil Group is a designation by the Natural Resource Conservation Service (NRCS). The NRCS publishes a soil survey for most counties in the United States that classifies the soils into one of four hydrologic soil groups based upon how quickly the soil drains. Soils classified as "A" are the fastest draining (and have the smallest runoff potential) and soils classified as "D" are the slowest draining (and have the greatest runoff potential).

Hydrograph is a graph that shows the relationship of flow vs. time for a particular location within the watershed.

Hyetograph: A plot of cumulative rainfall or rainfall intensity versus time for a particular precipitation event

Inundation: to be covered with water

Lag time is the time between when the peak of a precipitation event occurs, and when that runoff makes it to the outlet of the watershed.

[1] Source: Wikipedia.org

LiDAR: Light Detection and Ranging, is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. It is a state-of-the-art method for collecting accurate elevation information for large areas.

NAVD88: North American Vertical Datum of 1988 is the vertical control datum established in 1991 for vertical control surveying. NAVD88 consists of a leveling network on the North American Continent, affixed to a single origin point. NAVD88 replaced NGVD29 as the official vertical datum.

Return Frequency: likelihood, or probability that a rainfall event (specific to the magnitude and duration) will be equaled or exceeded in any given year.

Riverine: Associated with a river

Sea Level Rise: An increase in sea level caused by a change in the volume of the world's oceans due to temperature increase, deglaciation (uncovering of glaciated land because of melting of the glacier), and ice melt (Source: NOAA).

Stage Storage Discharge Curves: define the relationship between the depth of water and the discharge or outflow for the flood storage areas behind a culvert or impoundment.

Stillwater Elevation: The projected elevation of floodwaters in the absence of waves resulting from wind or seismic effects. In coastal areas, stillwater elevations are determined when modeling coastal storm surge: the results of overland wave modeling are used in conjunction with the stillwater elevations to develop Base Flood Elevations (Source: FEMA).

Storm Surge: Storm surge is the water, combined with normal tides that push toward the shore by strong winds during a storm. This rise in water level can cause severe flooding in coastal areas, particularly when the storm coincides with the normal high tides. The height of the storm surge is affected by many variables, including storm intensity, storm track and speed, the presence of waves, offshore depths, and shoreline configuration (Source: FEMA).

Tributary: a stream or channel that joins with a larger stream

Tailwater: The elevation of the water surface downstream from a dam or culvert. In coastal areas, such as Manchester-by-the-Sea, the tailwater elevation downstream of a dam is affected by tides, storm surge and sea level rise.

Time of Travel: The time interval required for water to travel from one point to another through a part (reach) of a watershed

Weighted Runoff Curve Number (CN): is a parameter used for predicting direct runoff or infiltration. The CN characterizes the runoff properties for each particular soil and groundcover in modeling applications. The CN method was developed by the USDA Natural Resource Conservation Services, formerly the Soil Conservation Service or SCS.

10-year Storm: A storm event having a 10% probability of occurring in any given year

25-year Storm: A storm event having a 4% probability of occurring in any given year

50-year Storm: A storm event having a 2% probability of occurring in any given year

100-year Storm: A storm event having a 1% probability of occurring in any given year

Tighe&Bond

F&H Memo Attachment B

SECTION 1

Section 1
Introduction

1.1 Purpose of Study

This report describes the Sawmill Brook watershed modeling that was completed as part of the Coastal Zone Management Grant, **Manchester-by-the-Sea Sawmill Brook Culvert and Green Infrastructure Analysis**: Task 4 "Evaluation of Locations for Flood Mitigation". As part of the study existing conditions within the Sawmill Brook watershed were modeled and flooding impacts due to climate change, including increased levels of precipitation in combination with corresponding projections for sea level rise, were evaluated.

The modeling provides the data needed to evaluate adequacy of culvert sizing within the Sawmill Brook Watershed under climate change conditions and the mitigation value of proposed stormwater best management practices at specific locations, including green stormwater infrastructure, conveyance projects and flood storage. Additionally, the model will help determine projected flooding impacts upon important community assets identified as part of the Hazard Mitigation Plan enhancement under a Federal Emergency Management Agency (FEMA) Pre-disaster Mitigation Grant.

1.2 Project Methodology Overview

Tighe & Bond evaluated the existing hydrology and hydraulics within the study area under varying climatic events.

- **Existing watershed conditions were modeled** with HydroCAD and HEC-HMS (US Army Corps of Engineers, 2015) using information about soils, topography, ground cover (impervious cover and land uses), existing wetlands and waterbodies, water travel times, and existing structures that control discharges (e.g. Central Street tide gate, culverts, etc.). Existing conditions considered rainfall depths developed by the Cornell University Northeast Regional Climate Center and tidal influences using data from Flood Insurance Study for Essex County (July 2014). The existing conditions model was calibrated against the May 2006 storm (Mother's Day storm) that represent 25-year single day and 100-year consecutive day storm conditions.

- Building off the existing conditions model, **future watershed conditions** were predicted considering anticipated impacts from climate change and sea level rise in 2025, 2050, and 2100. For this model, precipitation estimates in the existing conditions scenario were replaced with estimates of future rainfall depths for 2025, 2050, and 2100 from the Oyster River Culvert Analysis project completed in Durham, New Hampshire (UNH, 2010). In addition, sea level rise and storm surge was incorporated into the model using data from the Inundation Risk Model (IRM) outputs developed by Keil Schmid (Geoscience, 2015).

- Using the future conditions model, the **potential impacts on existing infrastructure** (e.g. tide gate at Central Street, culverts, crossings) from storm surge, sea level rise, and future precipitation conditions in 2025, 2050, and 2100 were identified. The future condition model was also used to evaluate culvert sizes and needed upgrades, and the mitigation value of proposed stormwater

best management practices including green stormwater infrastructure, conveyance projects, and flood storage.

Tighe & Bond partnered with organizations to obtain data necessary to complete the evaluation. Tighe & Bond walked the river on May 30, 2015, along with the Town's Stream Team and other volunteers, to become familiar with the river and identify critical locations for survey cross sections. Measurements and inventories of culverts were taken during this visit.

Tighe & Bond coordinated with Keil Schmidt of Geoscience to obtain elevations from the Inundation Risk Model (IRM) outputs for sea level rise and storm surge for incorporation into our modeling.

Town Staff and Volunteers making observations at the Lincoln Street Culvert

Tighe & Bond subcontracted with Doucet Survey of Newmarket, New Hampshire to survey the upstream and downstream ends of critical culvert locations. Tighe & Bond also utilized MassGIS LiDAR topographic data for overbank areas beyond the extent of the surveyed cross sections. LiDAR, which stands for Light Detection and Ranging, is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. It is commonly used to make high-resolution contour mapping of large areas.

1.3 Sawmill Brook Watershed

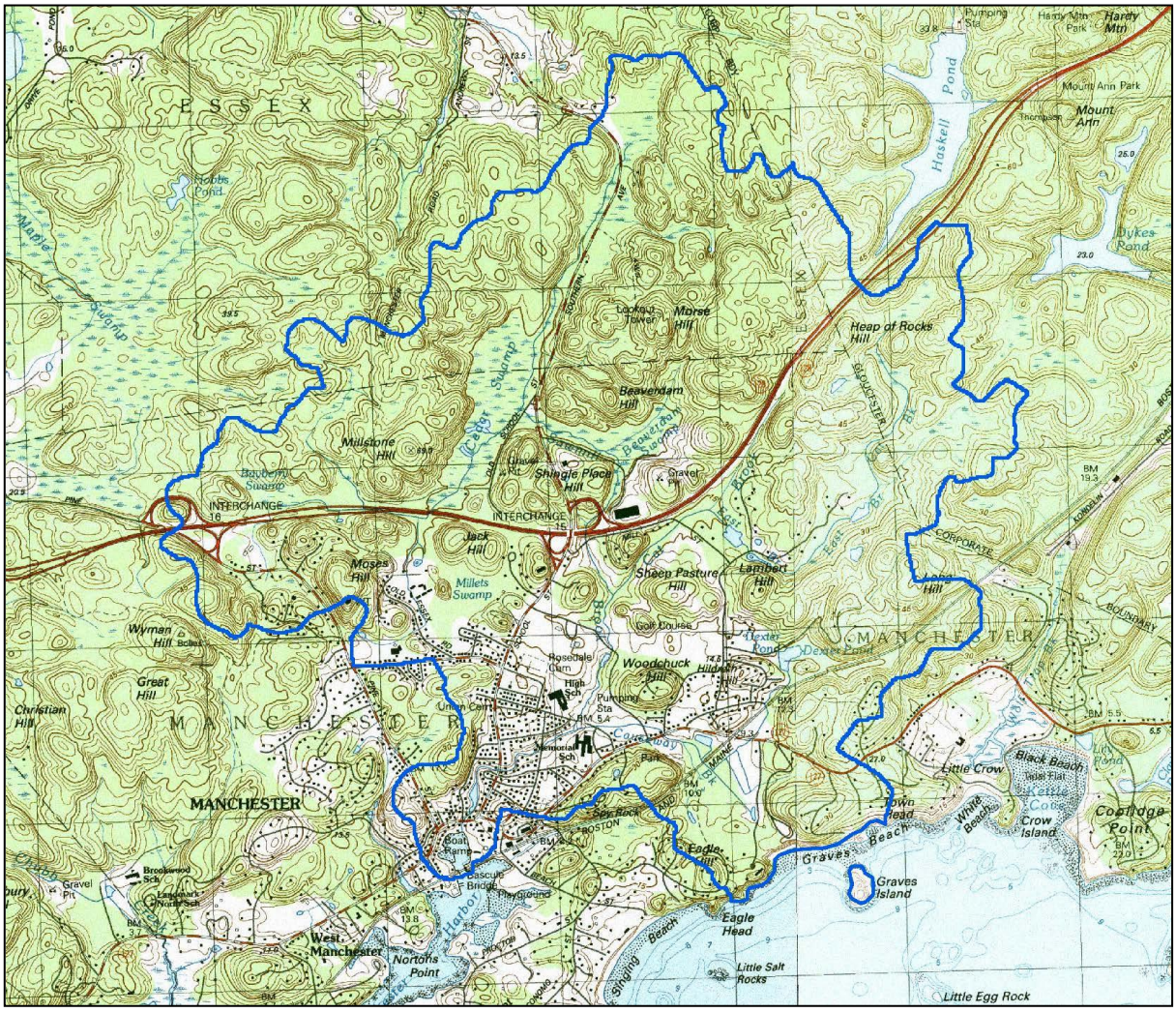
Sawmill Brook is the longest watercourse that flows through Manchester-by-the-Sea, and drains a majority of the Town. Please refer to **Figure 1** for the watershed's approximate boundaries. The watershed comprises a total of 4.8 square miles, most of which lies within Manchester-by-the-Sea, although portions of the watershed extend into Essex and Gloucester.

Sawmill Brook upstream of School Street, near its interchange with Route 128.

Main Stem of Sawmill Brook

The main stem of Sawmill Brook drains a circuitous route, beginning in the residential area just south of Interchange 16 of Route 128 (Pine Street). The watercourse passes

north, beneath Route 128, discharging into Bayberry Swamp, where the brook receives runoff from the undeveloped, forested hills to the north of the swamp, which are characterized by a large number of rock outcroppings.



Main Stem of Sawmill Brook

The main stem of Sawmill Brook drains a circuitous route, beginning in the residential area just south of Exit 16 of Route 128 (Pine Street). The watercourse passes north, beneath Route 128, discharging into Bayberry Swamp, where the brook receives runoff from the undeveloped, forested hills to the north of the swamp, which are characterized by a large number of rock outcroppings.

The brook flows easterly through the swamp, roughly paralleling the north side of Route 128, accepting runoff from a small tributary that drains the valley located west of Milestone Hill. The brook then meets another small watercourse carrying the discharge from Millet's Swamp, and then turns northeasterly, draining through Cedar Swamp. The area contributing to Cedar Swamp is forested and largely undeveloped, with steep slopes and a number of outcroppings.

The brook flows northeasterly for approximately 2,400 feet, before turning abruptly eastward, passing beneath Old School Street and School Street into Beaverdam Swamp. The brook then curves southeasterly, then southwesterly around the eastern side of Shingle Place Hill. The surrounding contributory area is largely steep, undeveloped forested hills.

Sawmill Brook then passes beneath Route 128 again, flowing southerly where it meets with Cat Brook at river left, approximately 1,300 feet downstream of Route 128.

Immediately downstream of the confluence with Cat Brook, Sawmill Brook passes through land of the Essex County Club golf course, where the overbanks are grassed to the edge of the watercourse, and also include small man-made impoundments. The brook gently begins an arc to the southwest where it passes Manchester-Essex Regional Middle-High School on river right, and property of the golf course on the left before passing beneath Lincoln Street.

Almost immediately below Lincoln Street, Sawmill Brook is joined by Causeway Brook, and enters an area of significantly increased residential development density, passing between the backyards of numerous residences. Sawmill Brook continues to flow along a gentle arc before flowing westerly at School Street, immediately north of Brook Street. Before this crossing, the river left side of the watercourse is channelized with a stone masonry wall with the adjacent residential structures located near the wall.

Sawmill Brook just upstream of its crossing of School Street near Brook Street.

Downstream of School Street, both sides of the brook are channelized by stone masonry walls. Approximately 425 feet downstream of School Street, the watercourse makes a sharp turn to the left, emptying into Central Pond, which is regulated by the existing tide gate and dam structure at Central Street. Once the flow passes through the structure, it discharges into Manchester Harbor.

Millet Swamp Brook

The area roughly bounded by Old Essex Road, School Street, and Route 128 drains toward Millet Swamp, which is located between these roadways. The edges of the development area include steep forested hills that drop down to residential development along the roadways to the low lying area where the swamp is located.

The stream has a number of crossings at residential roadways, including Blue Heron Lane, The Plains, Millet Lane, and Old Essex Road.

The stream in this area generally has flat topography and is slow-moving due to its low gradient. The swamp outlets to the north, where it joins Sawmill Brook just upstream of Route 128.

Cat Brook

The source of Cat Brook are the undeveloped and forested hills lying south and east of Route 128, extending into Gloucester. Cat Brook begins as two separate watercourses that converge east of Mill Street. The western branch runs generally parallel with Route 128, while the eastern branch flows southwesterly then northeasterly before joining the western branch 700 feet upstream of Mill Street.

Downstream of Mill Street, Cat Brook passes along property of the Essex County Club along river left before discharging into Sawmill Brook.

Causeway Brook

Causeway Brook begins as two separate watercourses that discharge from ponds on the eastern portion of the watershed, one of which is Dexter Pond. The two branches converge south of the MBTA railroad line, flowing westerly through a residential area along Summer Street, where it is briefly channelized, and passing through property of the Essex County Club before discharging beneath Lincoln Street. Causeway Brook discharges into Sawmill Brook just below Lincoln Street.

Causeway Brook downstream of Summer Street, showing the narrow channelized streambed

Culvert at Central Street

The Sawmill Brook culvert under Central Street consists of a seawall, tide gate structure, culvert and stream bed/weirs. Based on a review of documents available from the Town, it appears the tide gate was originally installed in the early 1900's for the purpose of creating a skating pond in the downtown area. This structure provides control for flooding caused by tides and maintains the elevation in Central Pond. The structure currently overtops during extreme storm events. Additionally, the tide gate design obstructs fish passage to upstream segments of Sawmill Brook that are known spawning habitat for Rainbow Smelt.

View of Tide Gate Structure from Harbor

View of Central Street tide gate towards the Harbor

Tighe&Bond

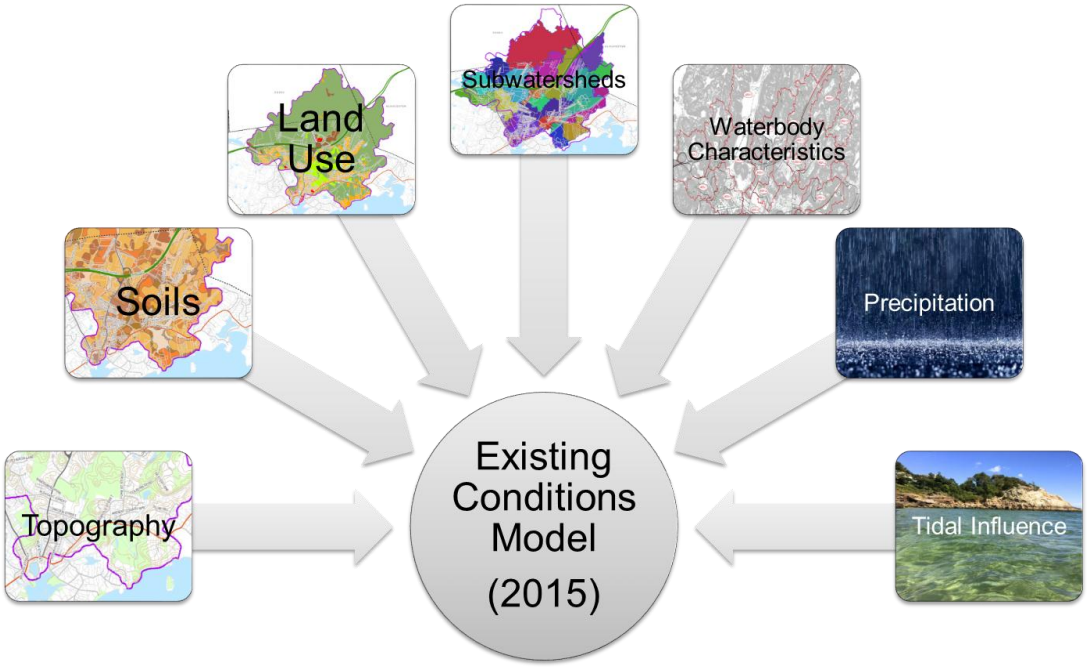
H&H Memo Attachment B

SECTION 2

Section 2
Modeling Existing Conditions

2.1 Overview

As part of the project, Tighe & Bond modeled existing conditions within the Sawmill Brook Watershed. The model considers information about soils, topography, ground cover (impervious cover and land uses), existing wetlands and waterbodies, water travel times, and existing structures that control discharges (e.g. Central Street tide gate, culverts, bridges, etc.). Existing conditions were based on rainfall depths developed by the Cornell University Northeast Regional Climate Center[2] and tidal influences using data from the Flood Insurance Study for Essex County (July 2014). The existing conditions model was calibrated against the largest storm in recent history, the May 2006 (aka "Mother's Day") storm.



2.2 Model Inputs

2.2.1 Watershed Conditions

The watershed contains steep topography in its upper reaches, which flattens out toward the main stem of the watershed as shown in **Figure 2.** Contours were developed using the LiDAR terrain and Digital Elevation Model (DEM) data available on the Massachusetts Geographic Information Systems (GIS) website.

[2] http://precip.eas.cornell.edu/

Soils within the watershed are classified by their Natural Resources Conservation Service (NRCS) Hydrologic Soil Group. Most of the soils within the swampy and steep areas of the watershed are slow draining, while the balance of the soils within the developed portion of the watershed are moderate to moderately well-drained. Please refer to **Figure 3** for the NRCS Hydrologic Soil Group (HSG) classifications of the watershed soils. **Appendix A-1** includes an NRCS Web Soil Survey report that provides further detail on the classifications.

Land uses within the watershed primarily consist of wetlands, forest, open space, and residential areas, along with small areas of industrial and commercial uses. Please refer to **Figure 4** for the distribution of land uses within the watershed and table describing the aggregation of categories from the MassGIS Land Use data for input into the model.

To facilitate the analysis of the stream, Tighe & Bond divided the watershed into 24 subwatershed areas to obtain a better understanding of the timing relationships between the numerous tributaries within the watershed. Please refer to **Figure 5** for the subwatershed mapping. Within each subwatershed, the land cover and underlying hydrologic soils group were evaluated and a lag time was developed in order to estimate the contribution of each subwatershed to Sawmill Brook.

In a complex watershed with a number of tributaries, such as Sawmill Brook, the time it takes various tributaries in the watershed to have peak flow can vary greatly from tributary to tributary depending on a number of factors, such as topography, impervious coverage, soil types and storage areas (reservoirs). Therefore, the timing of the peak flow from the tributaries could be different enough that they do not impact the receiving river simultaneously.

Tighe & Bond utilized available GIS mapping and data to develop the data inputs for the hydrologic analysis. Using the Soil Conservation Service (SCS) methodology in the HydroCAD software package, each subwatershed was routed through downstream subwatersheds and combined as necessary to develop a hydrograph of the main channel flow. The hydrographs were routed through the riverine network all the way to Manchester Harbor.

The weighted runoff curve number (CN) values for each of the subwatersheds were calculated based upon the land uses and hydrologic soil groups within the watershed. The lag time was computed based upon land cover, flow regime and basin topography. Please refer to **Appendix A-2** for the computation worksheets for both the weighted CN value and the lag time for each subwatershed.

2.2.1 Watershed Storage

The hydrologic model accounts for areas of flood storage within the watershed. Typically, these areas of storage can be found behind dams or behind culverts. As part of the hydrologic analysis, Tighe & bond developed stage-storage-discharge curves using Autodesk's Hydraflow for Hydrographs software program. The curves define the relationship between the depth of water and the discharge or outflow for the flood storage areas behind the existing culverts.

Appendix A-3 provides a summary table of the culverts within the watershed. More detail on these culverts can be found in the Tighe & Bond report titled "Manchester-by-the-Sea, Massachusetts, Stream Crossing Evaluation, Sawmill Brook Watershed" dated July 30, 2015. Please refer to **Figure 6** for the culvert locations.

In addition, the following locations in the watershed were modeled as storage areas:

- Pine Street (Pond 1)
- School Street north of Route 128 (Pond 2)
- Atwater Avenue (Pond 3)
- Mill Street (Cat Brook) (Pond 4)
- Lincoln Street (Causeway Brook) (Pond 5)

Please refer to **Appendix A-4** for the stage-storage-discharge computations for the storage areas.

2.2.2 Precipitation

The hydrologic model uses rainfall totals from the Northeast Regional Climate Center (NRCC) at Cornell University to develop the hydrographs. In the recent past, many flood studies historically used the climatic data published by the U.S. Weather Bureau in Publication TP-40, issued in 1961. The NRCC data is a more current data set and incorporates the increase in annual precipitation and storm intensity that has been documented by a number of studies since the 1961 publication of TP-40. **Table 2-1** lists the rainfall depths from a 24-hour duration storm that were used in the model.

Table 2-1
2015 Rainfall Depths for the Sawmill Brook Watershed (24 hour storm)

Frequency Storm	Annual Probability	Rainfall Depth (inches)
25-year	4%	6.16
50-year	2%	7.36
100-year	1%	8.76

This report refers to storm events by their return frequency, such as a 25-year storm, 50-year storm, and 100-year storm. The return frequency is the likelihood, or probability, that a rainfall event (specific to the magnitude and duration) will be equaled or exceeded in any given year. The reference will help the general public better understand the typical probability associated with a storm event. However, it is possible to have multiple 100-year storms in consecutive years, and it is also possible to have 50 years pass without a 25-year storm. Notable storm events for Manchester-by the Sea measured at the Town's Wastewater Treatment Facility include a near 100-year storm event of 8.27 inches recorded on October 20, 1996, and a 25-year storm event of 6.56 inches recorded on May 13, 2006, during the Mother's Day Storm.

Please refer to the Extreme Precipitation Tables in **Appendix B-1** for the completed data set for Manchester-by-the-Sea.

2.2.3 Surge and Tidal Influence

There is a tide gate structure that regulates the mouth of Sawmill Brook at Central Street. The structure normally limits the tidal influence of Manchester Harbor on the Sawmill Brook. Based on the current effective Flood Insurance Study (FIS) for Essex County, Massachusetts, dated July 16, 2014, the tidal stillwater surface elevations (that include storm surge) at the mouth of Sawmill Brook just downstream (ocean side) of Central Street are outlined in **Table 2-2** for existing conditions. Values presented in Table 2-2 are elevations associated with an annual probability (e.g. for the 1% annual probability, there is a 1% annual chance of the high tide influenced by storm surge to reach an elevation of 9.90 feet NAVD88 at the mouth of Sawmill Brook) shown in the

FIS.[3] The Base Flood elevation at this location is 10.6 ft NAVD 88, which includes the stillwater elevation and the effects of wave setup.

Table 2-2
2015 Stillwater Elevations at Central Street

Frequency Storm	Annual Probability	Elevation (NAVD88) (feet)
25-year	4%	9.15
50-year	2%	9.40
100-year	1%	9.90

The values in Table 2-2 were used as starting water surface elevations in the hydraulic (HEC-RAS) model to account for tidal influence and storm surge on Sawmill Brook. Based on the Inundation Risk Model (IRM) outputs for 2015, Sawmill Brook is tidally influenced to the School Street culvert under existing conditions. See Section 3.2.2 for additional detail on the IRM model.

The town is currently in the process of requesting a revision of the July 16, 2014 FEMA FIS based on an August evaluation by the Woods Hole Group. A Letter of Map Revision has been submitted by the Town. The revised 100-year still water level is 9.00 ft NAVD, and the Revised Flood Zone and Base Flood Elevation for the Central Street location is AE 10, one foot lower than the current effective FIRM. As the planning progresses, this information should be taken into consideration.

2.3 Modeling Approach

2.3.1 Hydrologic Modeling

Hydrologic analysis of existing and post-development conditions was carried out by generating a computer model using the HEC-HMS Computer Program developed by the U.S. Army Corps of Engineers at the Hydrologic Engineering Center in Davis, California.

The hydrologic equations used in the computer model are described in the U.S. Army Corps of Engineering publication "Hydrologic Modeling System, HEC-HMS User's Manual, Version 3.5", dated August 2010. The data requirements for the HEC-HMS computer model include the following categories:

1. Soil Cover
2. Ground Cover
3. Ground Slopes
4. Degree, Density and Type of Development
5. Location and extent of wetlands, including swamps and ponds
6. Time of concentration, travel time, lag time
7. Controlled discharge structures, pipes and channel

[3] See Table 11 – Transect Data. Transect 38 was used to represent Manchester Harbor.

The results of the HEC-HMS for existing conditions are included in **Appendix B-2.**

2.3.1 Hydraulic Modeling

Once hydrographs had been developed for the various watersheds, the next step was to build a model using the U.S. Army Corps of Engineers Hydraulic Engineering Center's HEC-RAS software to analyze the resultant water surface elevations. The HEC-RAS model evaluates stream gradient, cross section, and land cover within the channel and overbanks. It also accounts for energy losses through friction, and expansion and contraction at hydraulic structures, such as bridges and culverts.

The geometry of the HEC-RAS model was based upon a digital terrain model extracted from MassGIS LiDAR data, and then extrapolated cross sections from that data. The LiDAR data was supplemented by survey from third-party culvert surveys.

2.4 Model Calibration

In developing the existing conditions model, past storm events were examined to confirm if channel geometries, land use coverages and lag times used in the model can duplicate observations recorded during past rainfall events. Calibration efforts were focused on a historic storm in May 2006. The storm lasted over a 4-day period and dropped nearly 11 inches of rain on the area.

Table 2-3
May 2006 Rainfall Event recorded at Beverly Municipal Airport

Date	Precipitation (inches)
May 13, 2006	4.32
May 14, 2006	4.95
May 15, 2006	1.15
May 16, 2006	0.56
Total	**10.98**

Based on information provided by the NRCC, 11.29 inches of rain over a 4-day period is equivalent to a 100-year storm event, while 4.95 inches of rain in a 24 hour period is equivalent to a 25-year storm event.

Please refer to **Appendix C-1** for the precipitation data from Beverly Municipal Airport.

The May 2006 event was preceded by a wetter than normal weather pattern, which increased the moisture conditions in the ground. Therefore, the weighted runoff curve number (CN) values were adjusted in the calibration model to reflect the higher level of moisture in the soil at the time of the May 2006 rainfall event. The calculations for the CN values appear in **Appendix C-2.**

In order to calibrate the hydrology, observations of flooding elevations reported by the Town during the May 2006 flood event were compared to the elevations calculated by the HEC-HMS model for the storm event.

Please refer to **Table 2-4** for a comparison of observations and model predictions for the May 2006 flood event. The observations for the storm event come from the document titled "Hydrologic Study, Millets Brook and Sawmill Brook Watersheds" (Metcalf & Eddy, February 2008).

Table 2-4
May 2006 Flood Observations Compared to HEC-RAS Model Output

Location	Cross Section Number	Observed Elevation (NAVD 88) (feet)	HEC-RAS Model Prediction (NAVD 88) (feet)
School Street north of Route 128	11191	45.1	43.04
Mill Street at Cat Brook	2359	39.6	38.03

Note: Observed elevations presented in Table 2-4 are from Table 5 in the 2008 Metcalf & Eddy report. The survey from the 2008 report used vertical datum reference NGVD 29 (FT). They have been converted to NAVD 88 in Table 2-4 for consistency. An error was identified in Table 5 of the 2008 Metcalf & Eddy report. Table 5 indicates the observed elevation at School Street north of Route 128 was 48.75 feet (downstream) and 45.8 feet at Old School Street (upstream). To correct this error, the two points were swapped, and Table 2-4 includes the Metcalf & Eddy value for Old School Street, adjusted for NAVD88.

2.5 Model Output

After calibrating the model, existing conditions were simulated for the 25-year, 50-year and 100-year storm events. **Appendix D** provides the data outputs from the existing conditions modeling runs. To assist in interpretation of the results Table 2-5 provides a cross reference for each culverts and bridges in the model including identifying culvert number from the Task 2 culvert inventory, and their cross section number in the HEC-RAS model. Cross section numbering is based upon distance from the mouth of Sawmill Brook at Manchester Harbor for the main stem of Sawmill Brook, and from the distance with the confluence of the main stem of Sawmill Brook for the tributaries. **Figure 7** shows the existing conditions model results, where culvert overtopping may occur.

For the 2015 25-year storm, the existing conditions models indicate that 48% of the culverts overtop the roadway. For the 50-year storm, this number increases to 52%, and with a 100-year storm, 59% of culverts overtop.

Comparing the model existing conditions to the historic experience of culvert overtopping gives the reader an idea of where the model may be conservative. The model is consistently predicting the areas of historic flooding from the intersection of Causeway Brook to the Harbor, but may be conservative for culverts along Route 128 (culverts 33 and 35) and in the area of Old School Street at the Cedar Swamp, and Conservation Area on Winchester Drive. There are additional areas outside of Sawmill Brook that flood, so it is important to realize the limitations of the model extent and accuracy. The model can continue to be refined with observed flood elevations. It is an excellent screening tool to evaluate the impact of future flood conditions as discussed in Section 4 and the combined effect of flood mitigation projects, discussed in Section 5.

Table 2-6
Cross Reference for Hydraulic Structure Identification in HEC-RAS Model

Stream	Culvert Inventory Identification Number	Street Crossing	HEC-RAS Section Number
Sawmill Brook	25	Central Street	199
	23	School Street	1629
	22	Norwood Avenue	2653
	17	Lincoln Street	3686
	16	Golf Course Driveway	5192
	27	Mill Street	7533.5
	26	Route 128	7686
	36	Route 128 Ramp	8131.5
	4	Atwater Avenue	9168
	3	School Street	11161
	2	Old School Street	11479.5
	5	Old Essex Road	13499
	34	Route 128	14218
	31, 33	Route 128	15106
	32, 35	Route 128	16328
	28, 29	Route 128	17648
Causeway Brook	18	Lincoln Street	378
	19	Golf Course Driveway	1280
	20	Summer Street	1757
Cat Brook	11	Mill Street	1869
Millet Brook	12	Millet Lane	1777
	13	The Plains	1570
	15	Blue Heron Lane	1111

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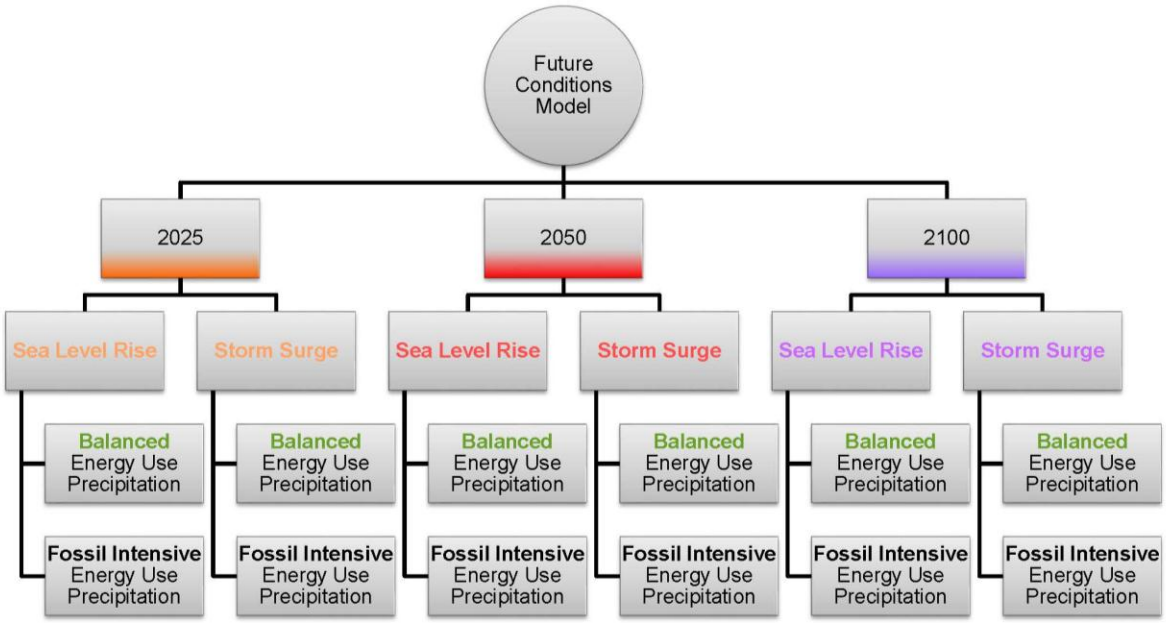
SECTION 3

Section 3
Modeling Future Conditions

3.1 Overview

As part of the project, future flooding conditions within the Town were projected as a result of anticipated climate change and sea level rise at three different points in the future: 2025, 2050 and 2100. Data on climate change was obtained from two sources. Future conditions precipitation relied upon the Oyster River Culvert (UNH, 2010) analysis, while the future conditions sea level utilized projections along the Manchester-by-the Sea coastline prepared by Kiel Schmid (GeoScience, 2015).



3.2 Inputs for Future Conditions Model

3.2.1 Precipitation

The Oyster River Culvert Analysis University of New Hampshire (2010) was utilized to project precipitation depths for future conditions. The Oyster River Culvert Analysis extreme precipitation model was developed based upon recent peer-reviewed studies for statistical analysis of climate change effects. The model focuses on fall precipitation events (September, October, November) since 25-year events for this time period were consistently greater than events for late spring (April, May, June)

The Oyster River watershed is located in Durham, New Hampshire, approximately 60 miles north of Manchester-by-the-Sea along the New Hampshire coast. The two areas have a similar climate and elevation, and therefore would experience similar precipitation patterns.

The rate of increase in future precipitation events is anticipated to be dependent upon the use of fossil fuels and the corresponding impacts on greenhouse gases. If a transition to a more balanced use of renewable and fossil fuel energy sources is used, the expectation is that the rate of increase in precipitation would be less than it would if fossil fuels continue to be a primary source of energy.

The Oyster River study model predicts a range of possible climate change outcomes by considering two peer-reviewed greenhouse gas emission scenarios [4]:

1. One scenario assumes a "balanced" global energy mix; i.e. an equal ratio of fossil fuel use to less greenhouse gas intensive sources of energy. This balanced scenario can be viewed as the more optimistic view of climate change's potential impacts in which the atmosphere has approximately 700 ppm of carbon dioxide equivalents by the year 2100.

2. The second scenario assumes a "fossil intensive" global energy mix; i.e. fossil fuels continue to be the primary fuel source. The fossil intensive scenario is the more pessimistic view of climate change's potential impacts in which the atmosphere has approximately 970 ppm of carbon dioxide equivalents by the year 2100.

The data in the Oyster River Culvert Analysis was utilized to project future precipitation in 2025, 2050, and 2100 for the balanced and fossil intensive scenarios, with the results shown in **Tables 3-1a** and **3-1b**. Data points from the 1964 U.S. Weather Bureau, the 2015 NRCC data, and the mid-century (2050) Oyster River Study precipitation estimates were plotted, and a logarithmic trend line was used to establish data points for balanced and fossil intensive energy use conditions in 2025 and 2100.

Table 3-1a
"Balanced Energy Use" Rainfall Depths for the Sawmill Brook Watershed (inches, 24-hour storm)

Frequency Storm	2025	2050	2100
25-year	6.36	6.86	7.84
50-year	7.42	7.58	7.88
100-year	8.85	9.31	10.69

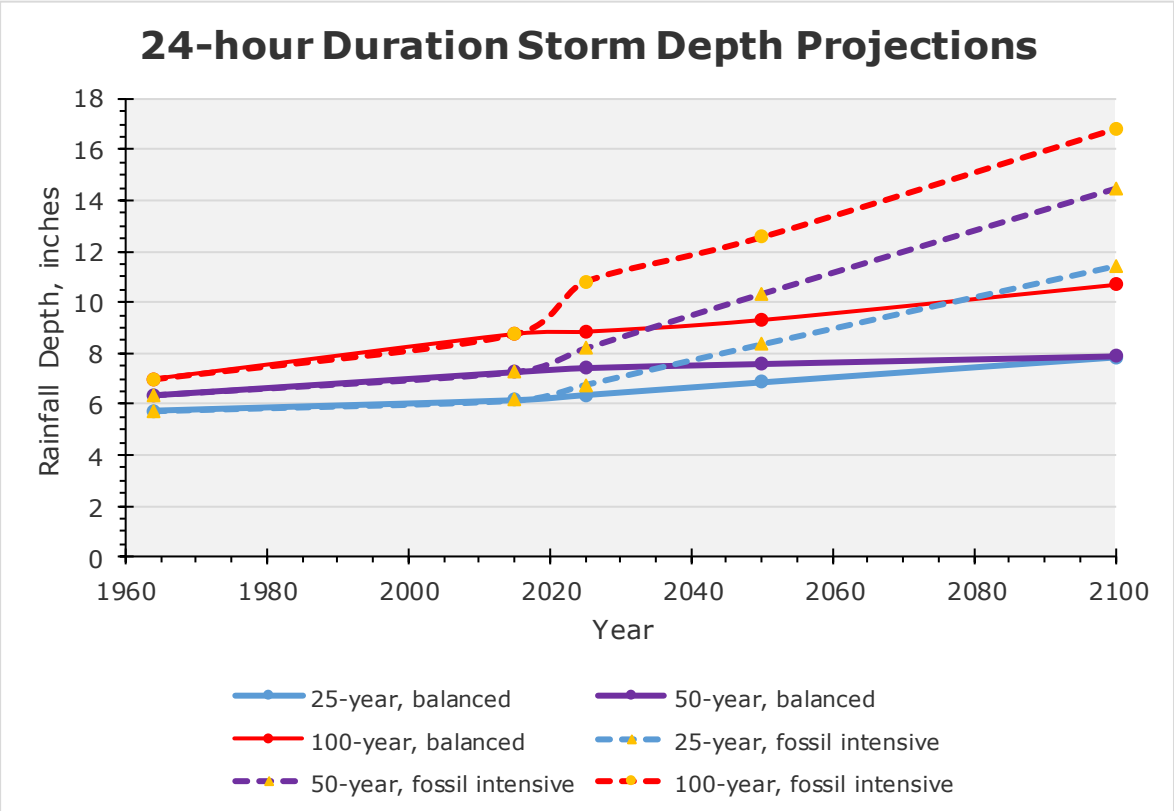
Table 3-1b
"Fossil Intensive Energy Use" Rainfall Depths for the Sawmill Brook Watershed (inches, 24-hour storm)

Frequency Storm	2025	2050	2100
25-year	6.77	8.35	11.39
50-year	8.19	10.34	14.48
100-year	10.82	12.58	16.82

[4] Intergovernmental Panel on Climate Change's (IPCC) 4th Report developed in 2007

Chart 3-1 offers a graphic representation of the changing rainfall depths for a 24-hour duration storm over time, beginning with the U.S. Weather Bureau Technical Paper-40 data from 1964, through the 2015 Northeast Regional Climate Center data, and also the balanced and fossil intensive energy use projections for 2025, 2050, and 2100. Please refer to **Appendix C-3** for the calculations of the precipitation values in 2025, 2050 and 2100.

Chart 3-1
Precipitation Depths Over Time, 24-hour Duration Storm



3.2.2 Coastal Climate Change Model

Potential sea level rise and future storm surge predictions for Manchester-by–the-Sea were obtained from the Inundation Risk Model (IRM). The IRM model was developed by Keil Schmidt of Geoscience Consultants in 2015 for the Salem Sound Coast Watch communities in Northeast Massachusetts, including Manchester-by-the-Sea. Tighe & Bond reviewed a number of coastal models with the Town and the Town's Coastal Resilience Advisory Group (CRAG) and elected to use the IRM model because of its balance of simplicity and detail. More information on the model selection may be found in a Tighe & Bond Technical Memorandum "Potential Climate Change Impacts to Manchester-by-the-Sea", September 30, 2015. Tighe & Bond worked with the model developer to refine data specific for Manchester-by-the-Sea.

The IRM is an expanded version of the National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise (SLR) viewer, which considers present and future inundation from SLR at mean higher high water (MHHW), shallow coastal flooding, Category 1 hurricanes and stillwater annual storm surge (including coastal storms other than hurricanes, i.e. Nor'easters). The goal of the model is to provide easily understandable

and self-contained information for decision makers and citizens that incorporates a probabilistic handling of the uncertainties involved in documenting future coastal hazards.

Model outputs are shown as risk of inundation presented in percent risk of occurrence ranging from 1% highly unlikely to 99% certain risk. The model outputs do not show water levels or depth of inundation. Data sets include sea level rise at mean high high water, shallow coastal flooding, Category 1 hurricanes and still-water annual storm surge for selected timeframes (2015, 2025, 2050 and 2100). The output, description of risk and data sources are included in **Table 3-2.**

Table 3-2
IRM Model Outputs, Descriptions and Data Sources

Output	Description of Risk	Data Sources
Sea Level Change	Level is mean higher high water (MHHW). Risk describes chance of being inundated at least once per day.	Sea Level Change NOAA curves are source for future water levels.
Shallow Coastal Flooding	Risk describes chance of area being flooded several times a year, where inundation becomes a deterrent to development.	
Storm Surge	Risk describes the chance of an area being inundated once a year from coastal storms other than hurricanes (i.e. Nor'easters).	Historic still water surge data (Boston gauge) is used to define surge height.
Hurricane/ Category 1	Risk describes chance of area being inundated if a Category 1 hurricane is predicted to strike in the area. Rare occurrence.	Data from SLOSH model defines hurricane surge height for grid cells.

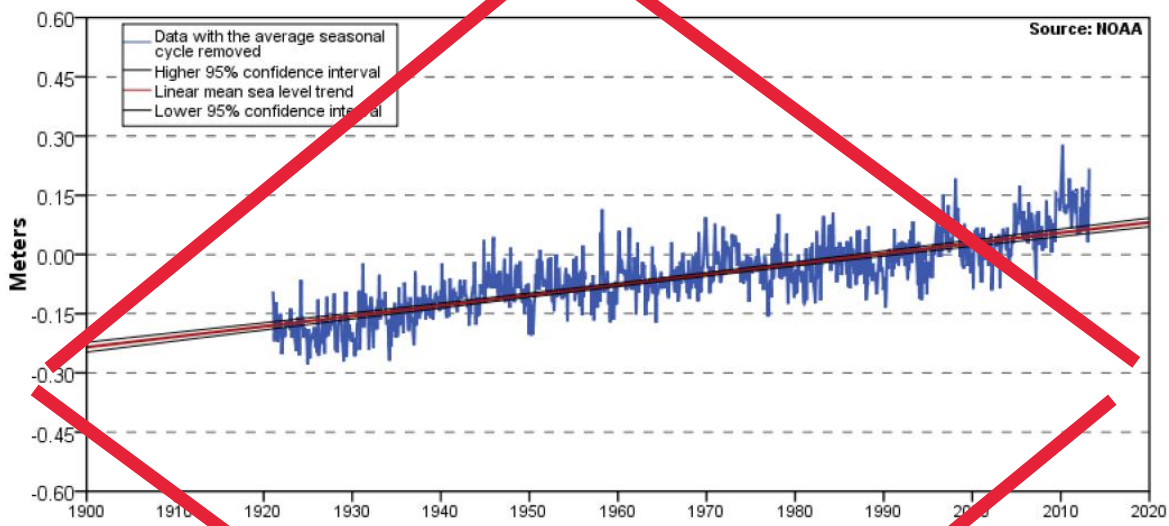
Keil Schmidt of Geoscience Consultants provided elevation values for use as model inputs to the HEC RAS software for future coastal tailwater conditions. The image on the left, below, shows the output of all probability values for areas impacted by sea level rise for a particular time period, from 1% in dark green as the least likely to occur to 99% in red as the most likely to occur. The right image shows the area covered by the 50 percent probability output, defined by the IRM author "flooding that is as likely to occur as not". Elevations provided by Keil Schmidt are based on the 50 percent output.

3.2.3 Sea Level Rise

Climate scientists are predicting a rise in sea level caused by a change in the volume of the world's oceans due to temperature increase, deglaciation (uncovering of glaciated land because of melting of the glacier), and ice melt. It is anticipated that as a result of sea level rise, the tidal influence of Manchester Harbor will exert a greater effect than it does today, and the boundary of tidal influence will shift further up Sawmill Brook.

NOAA has documented that the average sea level has been slowly increasing in Boston Harbor, and has increased by approximately 2 millimeters on average per year since 1920, for a cumulative increase of 0.67 feet (**Chart 3-2**) to the present.

Chart 3-2
Observed Mean Sea Level, Boston, MA
Source: NOAA



Keil Schmidt of Geoscience Consultants extracted the tidal elevations just downstream of the existing tide gate from the 50% probability of the IRM MHHW model output for sea level rise in 2025, 2050 and 2100 (**Table 3-3**). These elevations were utilized to evaluate tailwater impacts on the watershed flood model due only to sea level rise. The sea level rise flood elevations would impact affected properties on a daily basis, likely twice each day corresponding to the high tides.

Table 3-3
IRM Mean High High Water (Sea Level Rise) Tailwater Conditions for HEC-RAS Modeling
50% probability, approximate location 42° 34' 30.6664" N, 70° 46' 22.4346" W

Year	MHHW (Sea Level Rise) Feet Above Sea Level (NAVD88)
2025	5.1
2050	5.8
2100	8.0

3.2.4 Storm Surge Influence

Keil Schmidt of Geoscience Consultants provided elevation data interpreted from the 50% probability contours of IRM model just outside of the existing tide gate for annual stillwater flood scenarios, which include annual storm surge, as the governing elevation for the tailwater impact of coastal flooding. The annual stillwater scenarios were used because the stillwater methodology is consistent with what FEMA uses for determining backwater for riverine analyses. The annual flood elevation would impact affected properties on an annual basis.

Table 3-4 shows tidal elevations extracted from the 50% probability of the IRM stillwater output for storm surge in 2025, 2050 and 2100. It is interesting to note that these model outputs bracket the 25-, 50- and 100-year FIRM stillwater elevations presented in Table 2-2.

Table 3-4
IRM Mean Storm Surge Tailwater Conditions for HEC-RAS Modeling
50% probability, approximate location 42° 34' 30.6064" N, 70° 46' 22.4346" W

Year	Annual Stillwater Storm Surge Feet Above Sea Level (NAVD88)
2025	8.2
2050	8.9
2100	11.1

3.3 Future Conditions Modeling Approach

3.3.1 Hydrology

The rainfall depths presented in Section 3.2.1 were entered into the HEC-HMS model of the watershed to determine flow rates (discharge) along the river. The results of the HEC-HMS under future conditions is included in **Appendix B-3**. **Table 3-5** summarizes the discharge at Central Street comparing balanced energy use (A1b) and fossil intensive use (A1fi) greenhouse gas emissions scenarios as described previously in Section 3.2.1. for present and future time periods. Table 3-5 illustrates that the flow rates increase dramatically under the fossil intensive uses and by 2100, under the fossil intensive scenario, flow rates will be nearly 2.5 times greater than they are today

Table 3-5
Summary of Flow Rates (cubic feet per second) at Central Street

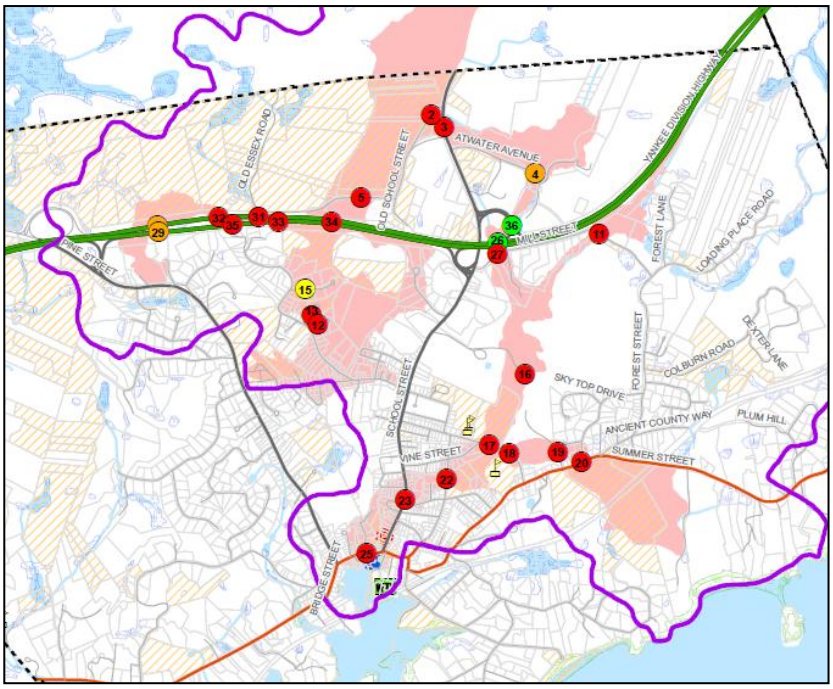
Frequency (years)	2015	2025		2050		2100	
		Bal.	Intensive	Bal.	Intensive	Bal.	Intensive
25	1,437	1,513	1,674	1,706	2,261	2,073	3,437
50	1,897	1,919	2,202	1,978	3,039	2,088	4,642
100	2,427	2,450	3,222	2,630	3,868	3,174	5,924

3.3.2 Future Conditions Hydraulics

The riverine flow data obtained from the hydrologic analysis was entered and combined with two different tailwater elevations (storm surge and sea level rise) to model the watershed under future climate change scenarios in 2025, 2050, and 2100 for the balanced and fossil intensive energy use precipitation projections. As anticipated, the floodplain expands considerably, especially under the fossil intensive energy use scenarios. HEC-RAS model data for future conditions appears in **Appendix D**.

3.4 Impact on Existing Infrastructure

Based upon the results of the HEC-RAS model, the impact on the existing culverts and bridges in the watershed was assessed based on the 50% probability for both stillwater (annual storm surge) and sea level rise. By 2100 almost all of the culverts in the watershed will be overtopped for storms more frequent than the 100-year event due to either tailwater condition (see inset below). **Table 3-6** shows where, when and how culverts in the Sawmill Watershed will be impacted with climate change conditions. For example, using the Balanced Energy Use projection, the culvert at Mill Street on Sawmill Brook will overtop under the Balanced Energy Use in the years 2025 and 2050 during a 50-year storm; and under both Balanced and Fossil Intense Energy Use, it will overtop in the year 2100 during a 25-year storm. Overtopping results with sea level rise tailwater conditions alone versus storm surge conditions does have overall lower surface elevations. For project specific applications, the data provided in Appendix D should be referenced.



Shown above are culverts that will overtop during specific flood events in the year 2100 with a fossil intensive precipitation scenario and storm surge. Culverts shown in red will overtop during a 25 year storm, orange will over top during a 50 year storm, yellow will overtop during a 100 year event and culverts in green will not overtop even with a 100 year storm event. Areas of surficial flooding are shown in pink.

Table 3-6
Storm Frequency at which Hydraulic Structures Overtop-
Storm Surge or Sea Level Rise

Stream	Culvert Crossing		Balanced Energy Use			Fossil Intense Energy Use		
	Location	Number	2025	2050	2100	2025	2050	2100
Sawmill Brook	Central Street	25						
	School Street	23						
	Norwood Avenue	22						
	Lincoln Street	17						
	Golf Course Driveway	16						
	Mill Street	27						
	Route 128	26						
	Route 128 Ramp	36						
	Atwater Avenue	4						
	School Street	3						
	Old School Street	2						
	Old Essex Road	5						
	Route 128	34						
	Route 128	31, 33						
	Route 128	32, 35						
	Route 128	28, 29						
Causeway Brook	Lincoln Street	18						
	Golf Course Driveway	19						
	Summer Street	20						
Cat Brook	Mill Street	11						
Millet Brook	Millet Lane	12						
	The Plains	13						
	Blue Heron Lane	15						

Precipitation Storm Event Frequency

25-year
50-year
100-year
>100-year

Another way of examining the model output is to look at flood profiles created by the HEC RAS model. The profiles across the Sawmill Brook Watershed are shown in Chart 3-3 for existing conditions. The chart shows the graphic output directly from the HEC-RAS model including the elevation profile of the land surface, the water table elevation resulting from a 100 year storm event in 2015, and the location of the 27 culverts that were included in the model. Locations are highlighted for Central Street, School Street, Norwood Avenue and Lincoln Street where culvert projects are proposed. The County Golf Course and Old School Street are highlighted where flood storage projects are proposed. These mitigation projects are further described in Section 4- Modeling Improvements for Flood Mitigation.

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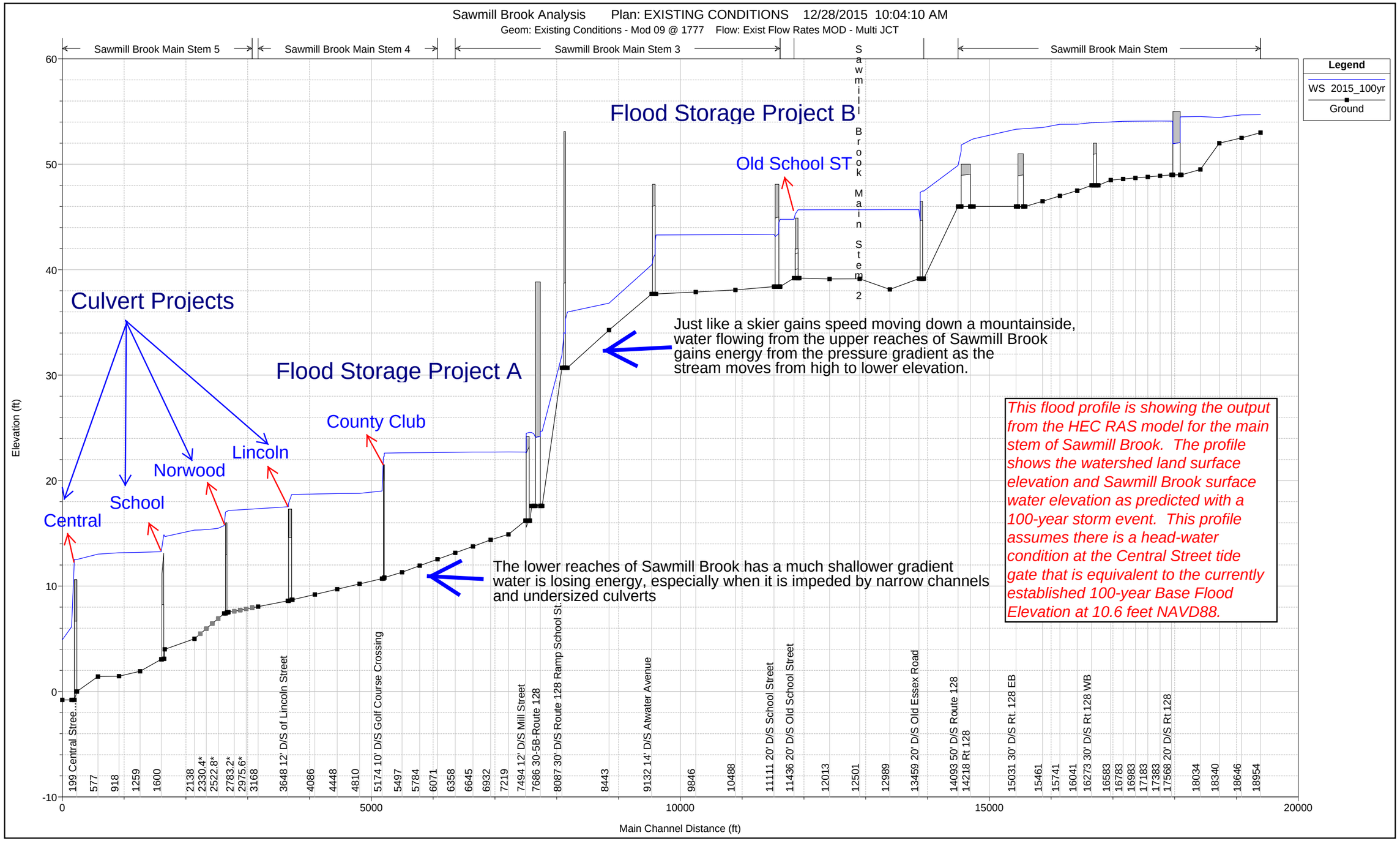
CHART 3-3 FLOOD PROFILE FOR EXISTING CONDITIONS SAWMILL BROOK MAIN STEM 2015 100-YEAR FLOOD



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SECTION 4

Section 4 Modeling Improvements for Flood Mitigation

The watershed modeling was expanded to look at potential improvements to flooding by relieving channel restrictions at Central Street, providing additional flood storage north of Route 128, managing flooding through culvert rightsizing, and utilizing green infrastructure best management practices at a variety of pre-screened locations. Modeling for the flood mitigation scenarios was based on conditions in the year 2050, assuming precipitation based on a balanced energy use and the 50 year storm event. This section provides a description of the specific flood mitigation projects considered, the model iteration process to evaluate the impact of different project combinations, and the resulting improvements.

4.1 Central Street Culvert and Tide Gate

The Town of Manchester-by-the-Sea has recognized that the Central Street tide gate, dam and related structures are in need of modification to provide better functionality with respect to drainage and fish passage. This location has been identified for many years as a source of flooding upstream due to this hydraulic restriction, particularly during large rainfall events. The elevated water behind the tide gate is also putting pressure on the seawall at Central Street, causing seepage though the rock voids in the wall.

Reviewing the flood elevations and profiles from Chart 3-3 in the previous section, the flood elevations change significantly across the Central Street Bridge and tide gate area, indicating that this location is a significant bottleneck along the channel. The structures were observed by Tighe & Bond in July 2015, and improvements were identified to address safety, drainage and fish passage.

Looking upstream (low tide) toward tide gate and Central St culvert

The options for the Central Street crossing and tide gate are presented in Table 4-1, while stream restoration options are presented in Table 4-2.

Table 4-1
Sawmill Brook Central Street Design Concept Alternatives

Option	Design Element
Option 1	Remove tide gate Rehabilitate existing bridge/culvert/seawall structure Restore Sawmill Brook at Central Pond
Option 2	Remove tide gate Replace and widen culvert /restore seawall and guard rail Restore Sawmill Brook at Central Pond

Table 4-2
Sawmill Brook Stream Restoration and Flood Stage Alternatives

Design Element	Purpose
Widen bottleneck	Improve hydraulic flow through system, decrease upstream impounding
Augment instream vegetation	Stabilize sediment, reduce downstream deposition, provide wildlife habitat
Build up island and augment instream vegetation	Stabilize sediment, reduce downstream deposition, provide wildlife habitat
Connect islands and augment instream vegetation	Direct stream flow into main channel, provide wildlife habitat
Dredge central channel	Improve hydraulics, improve fish passage
Dredge sediment from central pond	Remove fines and sources of nutrients, increase flood storage
Maintain shallow channel	Minimize sediment management requirements, accommodate spawning areas
Build up rock outcrop at mouth	Increase aeration, improve fish passage, naturalize transition between harbor and stream
Create rock riffles	Improve fisheries/spawning habitat
Stabilize banks	Minimize sedimentation of stream channel and harbor, protect adjacent land uses
Flood bank storage	Improve flood storage capacity, reduce downstream flooding severity

Water seepage (flow) coming from the stone culvert side wall

The HEC-RAS model was used to evaluate Option 2, removal of the tide gate, and widening the current dimensions of the Central Street culvert to maximize the cross sectional area available for flow. Stream restoration options will be considered in the conceptual design phase of the project.

Tables 4-3 and 4-4 summarize modeling runs for widening the culvert and removing the tide gate. The tables compare combinations of flooding and emissions scenarios for the years 2015-2100 to evaluate the range of conditions under which flooding would be mitigated. The results indicate that the improvements will substantially improve capacity for most storm events, even with sea level rise, however with the addition of storm surge, the roadway would be overtopped after the year 2050. Although water elevations are lowered significantly, improvements are only achieved near term under 25-year and 50-year storm events. In addition, the modeling runs with only Central Street improvements lowered water elevations in the stream reach immediately upgradient from Central Street, but did not alleviate flooding problems further upstream. Culverts continued to overtop for School Street, Norwood Street, Lincoln and other locations upstream.

Removal of the tide gate has two additional benefits beyond flood mitigation. The gate is set with a partial opening, which is not conducive for smelt migration due to the head pressure and high velocity of water exiting the gate. Removal of the tide gate will significantly improve the ability of fish to migrate upstream, particularly Rainbow Smelt, who cannot jump up the existing weirs.

In addition, removal of the tide gate will alleviate the hydraulic pressure on the Central Street Seawall. With the tide gate in place, the seawall is technically define by the state

as dam because the water impounded behind the wall exceeds five feet in height at a 100-year design storm. With removal of the tide gate, the technical definition will no longer apply, along with any jurisdictional responsibilities.

Table 4-3
Overtopping at Central Street with Tide Gate Removed and Culvert widened, Balanced Energy Use with Sea Level Rise

Year	25 yr		50 yr		100 yr	
	Exist.	Prop.	Exist.	Prop.	Exist.	Prop.
2015	Overtops	Capacity	Overtops	Capacity	Overtops	Overtops
2025	Overtops	Capacity	Overtops	Capacity	Overtops	Overtops
2050	Overtops	Capacity	Overtops	Capacity	Overtops	Overtops
2100	Overtops	Capacity	Overtops	Capacity	Overtops	Overtops

Table 4-4
Overtopping at Central Street with Tide Gate Removed and Culvert widened, Balanced Energy Use with Storm Surge

Year	25 yr		50 yr		100 yr	
	Exist.	Prop.	Exist.	Prop.	Exist.	Prop.
2015	Overtops	Capacity	Overtops	Capacity	Overtops	Overtops
2025	Overtops	Capacity	Overtops	Overtops	Overtops	Overtops
2050	Overtops	Overtops	Overtops	Overtops	Overtops	Overtops
2100	Overtops	Overtops	Overtops	Overtops	Overtops	Overtops

Enlarging the culvert and eliminating the tide gate would result in significant reductions in water surface elevation. Although the water surface elevation would drop in comparison with existing conditions if the proposed improvements were undertaken, the roadway would still eventually overtop because the surge elevation exceeds the roadway centerline elevation for 2050 and beyond. When only sea level rise is taken into account, the improvements have a larger impact on reducing water surface elevations.

Given the existing constraints in the area of the existing roadway elevation and development on both banks of the river, options to improve the situation at Central Street will need to included additional upstream culvert improvements and flood storage. Reducing storm surge might be achieved with some sort of hurricane barrier. A hurricane barrier might be situated at the mouth of Manchester Harbor.

4.2 Increasing Flood Storage

Four locations were evaluated for potential flood storage:

- Old School Street north of 128;
- Municipal land near Knights Circle;
- Land abutting the Coach Field Playground, and
- The Essex County Golf Course.

Modeling involved adjustment of model parameters at the project site to simulate potential flood attenuation. The model was run to determine the change in stream discharge for a 50-year storm, in the year 2050 using a balance energy emission scenario.

The land next to Coach Field Playground consists of municipally owned area abutting Sawmill Brook upstream of Norwood Avenue. This area is lightly vegetated (with some large diameter trees) with opportunity to create flood storage on the bank of the stream. A project would include re-grading the area and installing natural plantings while leaving the large diameter trees. Approximately 13,000 square feet of area could potentially be utilized.

Municipal land upstream of the School Street culvert, across from Knight's Circle, includes a potential opportunity to create a flood storage area to the left side of the Sawmill Brook looking upstream from School Street culvert. The project would include re-grading the bank area to allow for storage of flood waters by increasing the floodplain. It was assumed that the area on the north bank would be excavated beginning at 12 inches above the bottom of the stream in order to maintain a low-flow channel.

Tighe & Bond modeled these potential flood storage opportunities by modifying the corresponding cross sections in the HEC-RAS model. Because these two areas manage such small areas of floodwater compared to the overall Sawmill Brook watershed, they did not produce any discernable benefit. Two sites for flood storage, Old School Street and the Essex County Golf Course, produced discernable benefits and are described in more detail below.

4.2.1 Upstream of Old School Street

There is a significant area of storage upstream of Old School Street north of Route 128. If the road centerline of Old School Street were raised, additional stormwater could be impounded behind it. Increasing the storage behind Old School Street attenuates storm discharge and reduces the frequency and amount of instances where culverts overtop downstream. Providing flood storage at the top of the Sawmill Brook Watershed would provide greatest benefit for locations immediately downstream of Route 128, where flooding occurs frequently. The conceptual design included replacing the three existing culverts with two reinforced concrete box culverts with natural bottoms and one reinforced concrete pipe culvert. The road elevation of Old School Street would be raised by approximately 4 feet to elevation 46 feet NAVD88.

In order to model the raising of Old School Street, the stage-storage-discharge table at Old School Street was updated to account for the additional flow attenuation. The revised tabular data was then entered the into the HEC-HMS model to measure the flood attenuation that would result along the watercourse with the proposed modification.

Inlet of one of Old School Street Culverts

To assess the benefit of increasing storage behind Old School Street, flow rates on the main stem of Sawmill Brook downstream of Old School Street were modeled for a 50-year storm event in the year 2050, utilizing a balanced energy emission scenario. Flows were entered into the HEC-RAS model to determine the resultant water surface elevations downstream and to demonstrate the impact of the proposed additional flood attenuation capacity at select locations on the river..

Increasing the storage behind Old School Street reduces the flow rates downstream and reduces the frequency and amount of instances where culverts overtop downstream. The flood reduction benefit is limited to a stream reach of approximately one mile. The flood storage project has the potential to reduce flows by 16% to 85% in the area south of Old School Street before the Essex County Club, but by 1% or less downstream from the County Club, particularly in the downtown area.

4.2.2 Golf Course

The golf course was selected based on opportunities to manage flooding on both municipally owned or privately owned portions of the Essex County Club. Projects would include increasing flood storage areas abutting the stream channel by generally increasing the cross sectional area of the waterbody. In addition, restoring the channel to a more natural orientation would improve aesthetics. Improvements to this location would require coordination with the golf course and considerations for public safety.

Essex County Club flood plain area

Tighe & Bond looked at increasing flood storage on the course by re-grading an area abutting the stream channel to create approximately 6.6 acre-feet of storage. This would alter approximately 13.8 acres on the golf course property.

Providing flood storage within the golf course by increasing the cross sectional area of the existing stream channel will attenuate flood waters below

Route 128, reducing downstream flooding severity.

Restoring the channel to a more natural orientation would improve aesthetics. This public location presents an excellent opportunity for a public education kiosk describing how open space parcels can help flood attenuation.

Based on the HEC-RAS watershed modeling completed, this project has limited potential to reduce water surface elevations and water flows during the 50 year storm in 2050, due to the extensive size of the watershed.

4.3 Culvert Rightsizing

Flooding can be managed by changing the dimensions of (i.e. "rightsizing") culverts throughout the watershed. Using the HEC-RAS model, Tighe & Bond evaluated culverts throughout Manchester-by-the-Sea to identify the preliminary impact on downstream and upstream flooding. Based on our evaluation, increasing the cross-sectional area of the following culverts has the most benefit to reducing overall watershed flooding:

- Culvert 23, School Street
- Culvert 22, Norwood Avenue
- Culvert 17, Lincoln Street

Inlet of School Street Culvert

4.3.1 Culvert Improvements at School Street

Several design concepts were evaluated for culvert improvements at School Street to maximize flood mitigation. Additional HEC-RAS modeling runs were performed using a 50-year future design storm for the year 2050 under a balanced energy precipitation scenario, incorporating parameters for several sizes of culverts, and channel widening. After carefully evaluating the physical environment, site constraints and HEC-RAS modeling results, the following project elements were proposed to re-size the culvert at School Street to accommodate existing and future flood conditions.

- Remove the existing School Street culvert and replace with 6.6 foot tall by 16 foot wide box culvert
- Widen and lower limited segments of Sawmill Brook.
  - At School Street, lower stream channel by approximately 1.2 feet.
  - Downstream of School Street, widen by approximately 4 feet until Central Pond.
  - Upstream of School Street to Norwood Avenue, widen by approximately 4 to 8 feet depending on location and conflicts with private property.

Outlet of School Street Culvert

Enlargement of the School Street culvert and limited widening of Sawmill Brook stream channel will improve hydraulic capacity of the stream channel and limit backwater flooding to alleviate flooding of private properties adjacent to Sawmill Brook. Improvements to stormwater drainage will benefit water quality. Sediment removal and stabilization of the streambank as part of the stream widening will improve rainbow smelt habitat.

Based on the HEC-RAS modeling completed, increasing the size of this culvert, widening and lowering of limited segments of Sawmill Brook, in addition to improving the downstream Central Street Culvert and upstream Norwood Avenue culvert, will decrease water surface elevations in flood conditions by approximately 5% upstream of School Street and approximately 13% downstream of School Street. Without making channel improvements, the downstream water surface elevations will only be reduced by only approximately 8%. It should be noted that some channel improvements are necessary for culvert widening.

4.3.2 Culvert Improvements at Norwood Avenue

Several design concepts were evaluated for culvert improvements at Norwood Avenue to maximize flood mitigation. Additional HEC-RAS modeling runs were performed using a 50-year future design storm for the year 2050 under a balanced energy precipitation scenario, incorporating parameters for several sizes of culverts, and channel widening. After carefully evaluating the physical environment, site constraints and HEC-RAS modeling, the following project elements were proposed to re-size the culvert at Norwood Avenue to accommodate existing and future flood conditions.

- Remove existing Norwood Avenue culvert and replace with 7’ tall by 20’ wide box culvert
- Widen Sawmill Brook stream channel downstream of Norwood Avenue by approximately 4 to 8 feet depending on location and conflicts with private property.
- Lower Sawmill Brook channel by approximately 3.1 feet at Norwood Avenue Culvert

Enlargement of the Norwood Avenue culvert and limited widening of Sawmill Brook stream channel will improve hydraulic capacity of the stream channel and limit backwater flooding to alleviate flooding of private properties and municipal facilities adjacent to Sawmill Brook.

Based on the HEC-RAS modeling completed, increasing the size of this culvert, widening and lowering of limited segments of Sawmill Brook, along with improving the downstream School Street and Central Street culverts, will decrease water surface elevations in flood conditions by approximately 6% downstream before School Street and approximately 13% downstream of School Street. As noted for the School Street culvert, some channel improvements are necessary for culvert widening.

Outlet of Norwood Avenue Culvert

4.3.3 Culvert Improvements at Lincoln Street

Several design concepts were evaluated for culvert improvements at Lincoln Street to maximize flood mitigation. Additional HEC-RAS modeling runs were performed using a 50-year future design storm for the year 2050 under a balanced energy precipitation scenario, incorporating parameters for several sizes of culverts. After carefully evaluating the physical environment, site constraints and HEC-RAS modeling, the following project elements were proposed to re-size the culvert at Lincoln Street to accommodate the 50-year storm for existing and future flood conditions.

- Remove existing Lincoln Street culvert and replace with 6.5 foot tall by 20 foot wide box culvert
- Full-depth roadway reconstruction including guardrail replacement.
- Sediment and organic debris removal in vicinity of culvert.

Enlargement of the Lincoln Street culvert will increase the hydraulic capacity of Sawmill Brook and reduce backwater flooding impacting the High School property and Lincoln Street Wellfield upgradient of the site, which has flooded in previous storm events. The

stone culvert is aging, and replacement will eliminate safety concerns, especially during large flood events which are currently undercutting the banks at the culvert sidewalls.

Based on the HEC-RAS modeling completed, increasing the size of this culvert along with improving the downstream Norwood Avenue, School Street, and Central Street culverts, will decrease water surface elevations in flood conditions by up to 10% in the upstream segment, by approximately 3% directly downstream of Lincoln Street, almost 10% downstream of Norwood Avenue and School Street.

Stone Arch Construction of the Lincoln Street Culvert

4.4 Green Infrastructure

Tighe & Bond conducted an assessment of the potential benefit of installation of green infrastructure practices also known as Low Impact Development Best Management Practices (LID BMP's). For a complete description of the Green Infrastructure BMP Analysis, please refer to the Tighe & Bond Report, "Opportunities for Flood Mitigation within Sawmill Brook", July 30, 2015. As described in this report, opportunities to install green infrastructure throughout the watershed included the following locations:

- Parking lot abutting the Town Fire Station at 12 School Street;
- Parking lot for the Coach Field Playground;
- High School; and
- Elementary School.

Green infrastructure practices manage small areas of runoff compared to the overall Sawmill Brook watershed. Tighe & Bond evaluated these locations as part of the HEC RAS modeling. For example, for the Elementary School, we assumed that all of the existing pavement would be converted to permeable pavement, approximately 39,000 square feet. The curve number calculation for this location was adjusted for the land use coverage assuming that the area would be converted to permeable pavement. The runoff curve number dropped from 74 to 73, which is not significant. Additional model runs were performed to account for the reduced runoff curve number. We found that, under all modeling conditions, there was only a slight reduction (generally 2 cfs) in the flow rate downstream of the elementary school and that culvert overtopping was not reduced (i.e. the project would not have a significant impact on the water surface elevations).

Of the areas identified as potentially feasible for green infrastructure installation, the Coach Field Parking Area was selected by the Town to further explore the flood benefits from installation of porous pavement or LID BMPs.

4.4.1 Recommended Project - Porous Asphalt for Coach Field Parking

HEC-RAS modeling was evaluated for the potential benefit of installing porous asphalt in the Coach Field parking lot. Because the parking area is small (approximately 0.4 acres) in comparison to the overall watershed (approximately 3,400 acres), this improvement will have limited benefit to reducing flows during larger precipitation events (e.g. the 25, 50, and 100 year storms in 2025, 2050, and 2100 that range from 6.3 inches to almost 11 inches in a 24-hour storm). However, it will have some benefit during small storm events. In addition, installing porous aspahlt on the parking area will improve water quality and reduce thermal loading to Sawmill Brook. This project would consist of the following elements:

View of parking area from Norwood Avenue

- Construction of a porous asphalt parking area to replace existing gravel parking, including excavation of existing parking lot and installation of sub-base.
- Installation of small bathroom facilities as part of project
- Project would include a public education component through signs and displays.

Water quality improvements would be attained with the implementation of this project. Sediment routinely migrates from the unpaved parking area to Sawmill Brook, negatively impacting smelt habitat. Porous asphalt, the green stormwater infrastructure recommended for the site, has the ability to reduce total suspended solids up to 80%. Porous asphalt will also help reduce runoff to Sawmill Brook during smaller storms. The public location of the parking area, and high use volume makes this an ideal spot for a public education kiosk, to inform the public about impacts of stormwater runoff on Sawmill Brook and the benefits of green stormwater infrastructure.

4.5 Storm Surge Barrier

A storm surge barrier would be an option to protect Manchester Harbor and vicinity from moderate storm surge, some sea level rise, wave action and if closed during low tide, a way to hold a low tail-water condition to minimize back-watered river flooding. These types of structures can range from large structures, such as the New Bedford Hurricane Barrier (right), to smaller tidal dikes, lower right. From the existing topographic land height limitations in Manchester Harbor, a surge barrier would likely be a structure size in between these two example photographs.

The site of the conceptual surge barrier illustrated in Figure 1 was selected as a balance between vicinity protected (most of the harbor area) and finding an area with adjacent high shoreline and relative shallow water depths to minimize structure costs. Several sites were considered, including the railroad bridge that benefits from the existing railroad fill, and were viewed and discussed with town officials. The preferred site from a technical perspective is the harbor entrance between Tucks Point and Proctor Point. This site is just inshore of mapped/historical eelgrass beds, thus avoiding sensitive benthic habitat.

View of Manchester Harbor

The conceptual design of the surge barrier is a traditional stone armored dike/breakwater with a navigation opening aligned with the harbor entrance channel. A boat navigation opening at least 60 feet wide would be provided in the barrier, aligned with the channel, formed by side walls and a hinged steel gate, typically open, lying on the seabed. The opening end walls might consist of steel sheet pile cells, or concrete structures. The concept layout is based on a 12 foot wide crest path that would likely be needed for periodic maintenance and a crest elevation about 21 feet above mean lower low water, based on the present FEMA 100 year velocity zone elevation. The barrier structure might also need to include submerged tunnels with gates, normally open, to maintain good tidal water exchange and water quality in the harbor. The existing town sewer outfall pipe is buried along the edge of the existing navigation channel and this would need to be investigated to see if modifications including armoring and a back flooding prevention valve might be needed.

4.6 Evaluation of Combined Projects

To achieve optimal flood reduction benefits, a combination of culvert resizing projects and flood storage is desirable. HEC-RAS modeling runs were completed for a series of combined projects as shown below in **Table 4-5** to evaluate the potential benefits from cumulative flood mitigation. **Appendix E** provides a summary of the HEC-RAS modeling iterations with the project combinations. This information will be used in combination with other considerations to refine and prioritize projects for the final Task 6 memo.

Table 4-5
Summary Table of Combined Flood Mitigation Projects

Project Elements	**Modeling Iterations**												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Culvert Improvements*													
Central Street	X		X			X	X	X	X	X	X	X	X
School Street	X		X			X	X	X	X	X	X	X	X
Norwood	X		X			X	X	X	X	X	X	X	X
Lincoln						X	X	X	X				
Channel Improvements													
School –Norwood Widen	X		X			X					X	X	X
School-Norwood Widen and Deepen												X	X
Flood Storage													
Essex County Golf Course				X	X								
Old School Street		X	X		X	X		X					

The following presents notes on the various model iterations:

- Iteration 1: Includes increasing dimension of culverts at Central Street to 19’ wide 8’ tall, School Street to 20’ wide by 7.5’ tall, and Norwood Avenue to 20’ wide 7’ tall (all three are proposed box culverts) and widening the Sawmill Brook channel between School Street and Norwood Avenue by eight feet on each side of the stream channel.

- Iteration 2: Includes only flood storage by raising Old School Street by approximately 4 feet to elevation 48.1.

- Iteration 3: Includes increasing dimension of culverts at Central Street to 19' wide 8' tall, School Street to 20' wide by 7.5' tall, and Norwood Avenue to 20' wide 7' tall (all three are proposed box culverts) and widening the Sawmill Brook channel between School Street and Norwood Avenue by eight feet on each side of the stream channel, and raising Old School street by approximately 4 feet to elevation 48.1 to create flood storage (Iteration 2).

- Iteration 4: Includes only flood storage at the Essex County Club by expanding area by 38 acre-feet at elevation 18.

- Iteration 5: Combines flood storage using Old School Street and the Essex County Club (Iterations 2 and 4).

- Iteration 6: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 20' wide by 7.5' tall, Norwood Avenue to 20' wide 7' tall, and Lincoln Street to 20' wide by 6' tall (all four are proposed box culverts) and widening the Sawmill Brook channel between School Street and Norwood Avenue by ten feet on each side of the stream channel.

- Iteration 7: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 20' wide by 7.5' tall, Norwood Avenue to 20' wide 7' tall, and Lincoln Street to 20' wide by 6' tall (all four are proposed box culverts) along with using flood storage at the Essex County Club (Iteration 4).

- Iteration 8: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 20' wide by 7.5' tall, Norwood Avenue to 20' wide 7' tall, and Lincoln Street to 20' wide by 6' tall (all four are proposed box culverts) along with raising Old School Street to create flood storage (Iteration 2).

- Iteration 9: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 20' wide by 7.5' tall, and Norwood Avenue to 20' wide 7' tall (all three as box culverts) and reducing the Lincoln Street to 10' wide by 5.9' tall (as an arch culvert) for creation of upstream flooding in Essex County Club.

- Iteration 10: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 20' wide by 7.5' tall, and Norwood Avenue to 20' wide 7' tall (all three are proposed box culverts), with no other channel improvements.

- Iteration 11: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 14' wide by 5.64' tall, and Norwood Avenue to 20' wide 4.65' tall (all three are proposed Con/Span® culverts), with widening Sawmill Brook by approximately four feet on each side in the vicinity of School Street, ten feet on each side in the vicinity of Norwood Avenue, and seven feet on each side in the area between School Street and Norwood Avenue.

- Iteration 12: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 16' wide by 8' tall, and Norwood Avenue to 20' wide 7' tall (all three are proposed Con/Span® culverts), with widening Sawmill Brook

by approximately four feet on each side in the vicinity of School Street, ten feet on each side in the vicinity of Norwood Avenue, and seven feet on each side in the area between School Street and Norwood Avenue. This also includes deepening Sawmill Brook by approximately 1.9 feet at School Street, 2.3 feet at Norwood Avenue, and up to 2 feet in the channel between the two culverts.

- Iteration 13: Includes increasing dimension of culverts at Central Street to 20' wide 8' tall, School Street to 16' wide by 8' tall, and Norwood Avenue to 16' wide 7' tall (all three are proposed Con/Span® culverts), with widening Sawmill Brook by approximately four feet on each side in the vicinity of School Street, ten feet on each side in the vicinity of Norwood Avenue, and seven feet on each side in the area between School Street and Norwood Avenue. This also includes deepening Sawmill Brook by approximately 1.9 feet at School Street, 2.3 feet at Norwood Avenue, and up to 2 feet in the channel between the two culverts.

Tighe&Bond

H&H Memo Attachment B

SECTION 5

Section 5
Project Summary & Recommendations

5.1 Summary

Tighe & Bond evaluated the existing and future hydrology and hydraulics within the Sawmill Brook watershed under varying climatic events. Evaluation including modeling existing watershed conditions using information about soils, topography, ground cover (impervious cover and land uses), existing wetlands and waterbodies, water travel times, existing structures that control discharges (e.g. Central Street tide gate, culverts, etc.), rainfall depths developed by the Cornell University Northeast Regional Climate Center, and tidal influences using data from Flood Insurance Study for Essex County (July 2014). The existing conditions model was calibrated against the May 2006 storm (Mother's Day storm) that represent 25-year single day and 100-year consecutive day storm conditions.

Future watershed conditions were modeled to build off the existing conditions model and consider anticipated impacts from climate change and sea level rise in 2025, 2050, and 2100. For the future conditions model, precipitation estimates from the existing conditions scenario were replaced with estimates of future rainfall depths for 2025, 2050, and 2100 from the Oyster River Culvert Analysis project completed in Durham, New Hampshire (UNH, 2010). In addition, sea level rise and storm surge were considered using data from the Inundation Risk Model (IRM) outputs developed by Keil Schmid (Geoscience, 2015).

Using the future conditions model, we evaluated potential impacts on existing infrastructure (e.g. Central Street tide gate, culverts, crossings) from storm surge, sea level rise, and future precipitation conditions in 2025, 2050, and 2100. The future condition model for the year 2050 using a 50-year storm and a balance energy emission scenario was also used to evaluate right sizing culverts sizes and needed upgrades, and the mitigation value of proposed stormwater best management practices including green stormwater infrastructure, conveyance projects, and flood storage.

In general, the floodplain will continue to expand over time for the proposed climate change scenarios, and as a result of the increased flow and higher tailwater elevations exerted by tidal forces, by 2100, under a fossil intensive projection, 60% of the culverts in the watershed will overtop during a 25-year storm, and 70% will overtop during a 100-year storm under both storm surge conditions and sea level rise conditions.

Tighe & Bond expanded the modeling to look at potential improvements to flooding by relieving channel restrictions at Central Street, providing additional flood storage north of Route 128, rightsizing culverts, and utilizing green infrastructure best management practices at a variety of pre-screened locations. Based on the modeling results looking at individual projects, the scenario with resizing the culvert at Central Street has by far the largest improvement in the watercourse's flood carrying capacity.

To achieve optimal flood reduction benefits, a combination of culvert resizing projects and flood storage is desirable. HEC-RAS modeling runs were completed for a series of combined projects. This information will be utilized to make recommendations for prioritizing projects as part of Task 6.

5.2 Recommendations

Tighe & Bond met with Town staff on October 26, 2015, to review the modeling effort and preliminary results and to identify projects for further evaluation under Task 5, conceptual designs and preliminary permitting evaluation. Based on discussions at this meeting, conceptual designs will be prepared for the following nine projects:

1. Removing channel restrictions at Central Street (Option 1) consists of removing the tide gate and keeping the configuration of the culvert, potentially with a rock riffle to keep Central Pond full of water
2. Removing channel restrictions at Central Street (Option 2) consist of removing the tide gate, opening the culvert, removing the dam, and changing the entire crossing to be a bridge, and restoring the historic stream channel
3. Increasing the dimensions of the School Street culvert (23) with modifications to the channel of Sawmill Brook to account for increased culvert sizing
4. Increasing the dimensions of the Norwood Avenue culvert (22) with modifications to the Sawmill Brook channel to account for the increased culvert dimensions
5. Increasing the dimensions of the Lincoln Avenue culvert (17)
6. Flood storage in the Essex County Club Golf Course.
7. Flood storage upstream of Old School Street culvert (2)
8. Development of a hurricane barrier located in Manchester Harbor to manage overtopping from storm surge and hurricanes
9. Installation of a green infrastructure practice, porous pavement, at the Coach Field parking lot

Removing Channel Restrictions at Central Street & Installation of a Hurricane Barrier

- When only sea level rise is taken into account, the Central Street improvements have the largest impact on reducing water surface elevations upstream. Due to the locations of business on the east bank of the river, and the roadway on the west bank, any widening of the river approach would be difficult, but eliminating the tide gate would result in reductions in water surface elevation. Culvert enlargements would also result in significant reductions in water surface elevation upstream, and would restore the stream crossing to historic conditions. Both improvement alternatives will improve smelt passage and spawning potential.

- Under worst case future storm conditions, even with modifications to the Central Street Bridge, the roadway would still overtop because the surge elevation exceeds the roadway centerline elevation for 2050 and beyond. This may be addressed with use of a hurricane barrier or raising the elevation of Central Street. A hurricane barrier might be located at the mouth of Manchester Harbor.

Removing Channel Restrictions at Culverts

- Improving conveyance of Sawmill Brook in the "downtown" area of Manchester (i.e. culverts at School Street, Norwood Avenue, and Lincoln Street) will reduce the overall watershed flooding.

Increasing Flood Storage at the Golf Course

- The golf course is located at approximately the halfway point in the watershed, includes Town-owned land, and has a large area for flood management before Sawmill Brook flows into Manchester's downtown area. These reasons make the golf course an excellent candidate for managing floodwaters with limited impacts to abutters.

Improving Flood Storage behind Old School Street

- Increasing the storage behind Old School Street (north of Route 128) reduces the flow rate for the stretch of stream channel between School Street and the confluence of Causeway Brook at Lincoln Street for large storm events. Most improvement would be between School Street and Mill Street. Further downstream, flows from other areas in the watershed combine, increasing flow in the watershed, so the contribution of the storage decreases until it disappears by the time the brook meets Causeway Brook.

Installation of Green Infrastructure at the Coach Field Playground Parking Area

- The Coach Field Playground parking area was identified as a priority over the Elementary School parking area due to proximity to Sawmill Brook and planned improvements at the Elementary School. While installation of porous pavement at the Coach Field Playground parking area does not reduce flood elevations in Sawmill Brook, it does have an excellent opportunity to improve water quality and result in localized reductions in discharge from the parking lot. This is also an excellent location for public education.

References

University of New Hampshire (2010). The Oyster River Culvert Analysis.

Schmidt, Keil. Integrated Risk Model Website:
http://www.geosciconsultants.com/projects/2015/5/27/coastal-risk-mapping-in-salem-sound

Tighe & Bond (6/2015). Memo to Mary Reilly, "Manchester-by-the-Sea, Grants Coordinator, Sawmill Brook Central St Seawall, Tide Gate & Culvert Observations".

Tighe & Bond (7/2015). Report, "Opportunities for Flood Mitigation within Sawmill Brook

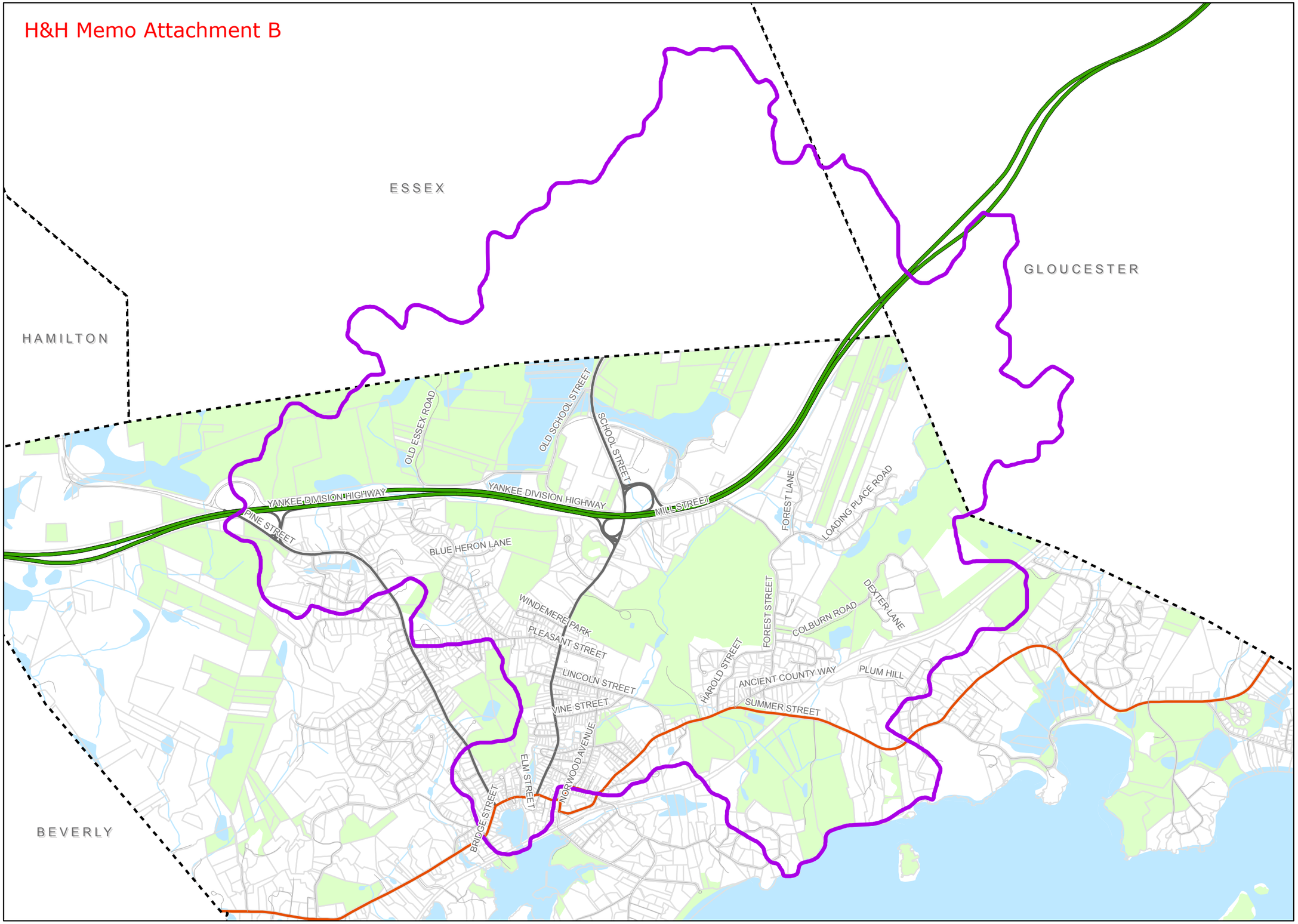
Tighe & Bond (7/2015). "Manchester-by-the-Sea, Massachusetts, Stream Crossing Evaluation, Sawmill Brook Watershed".

Tighe & Bond (9/ 2015). Technical Memorandum "Potential Climate Change Impacts to Manchester-by-the-Sea".

H&H Memo Attachment B

FIGURES

H&H Memo Attachment B

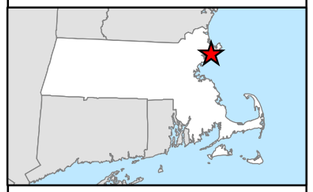


SAWMILL BROOK WATERSHED

LEGEND

Sawmill Brook Watershed

LOCUS MAP



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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 1

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

September 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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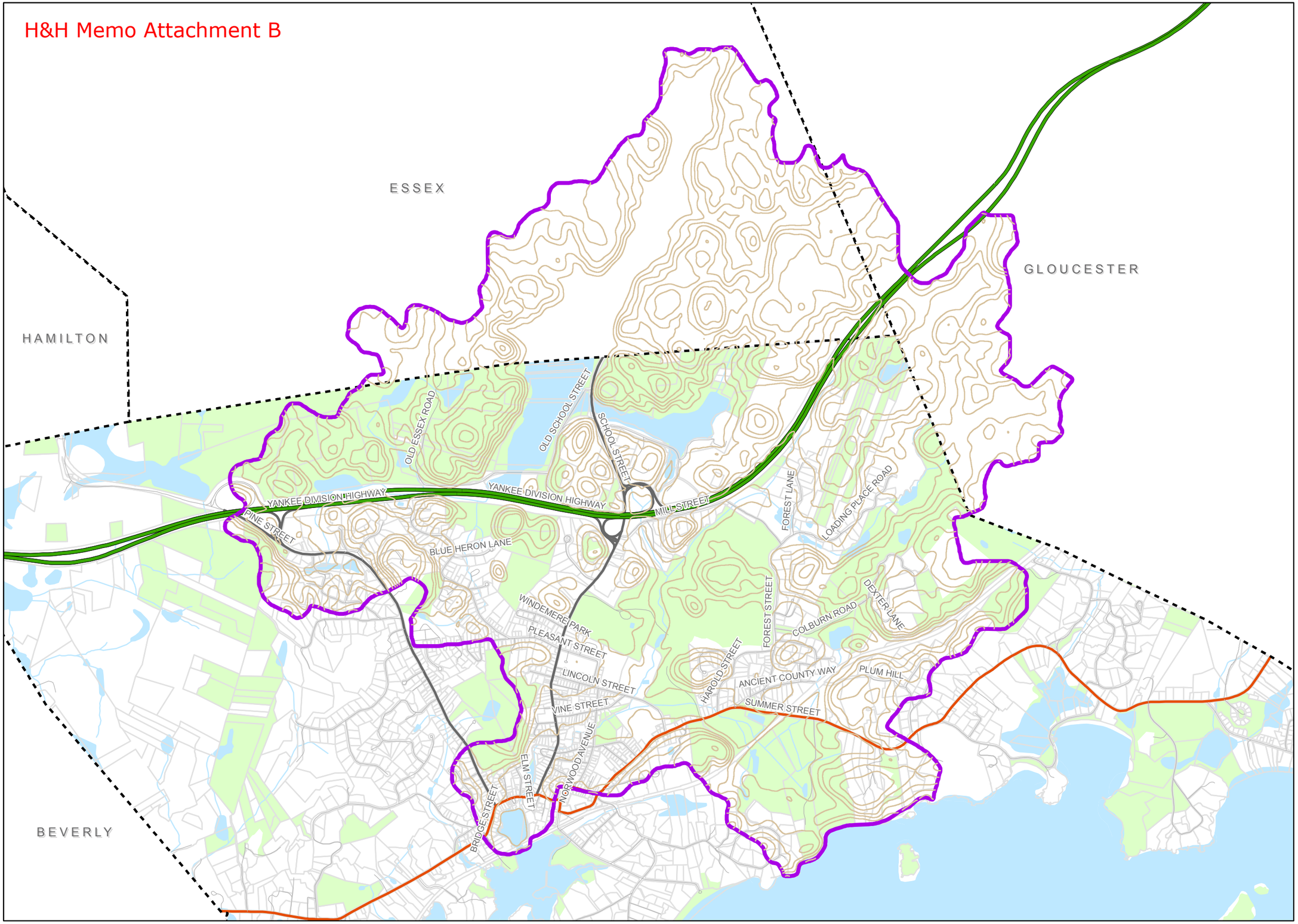
H&H Memo Attachment B



SAWMILL BROOK TOPOGRAPHY

LEGEND

20' Contours

Sawmill Brook Watershed

LOCUS MAP

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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 2

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

September 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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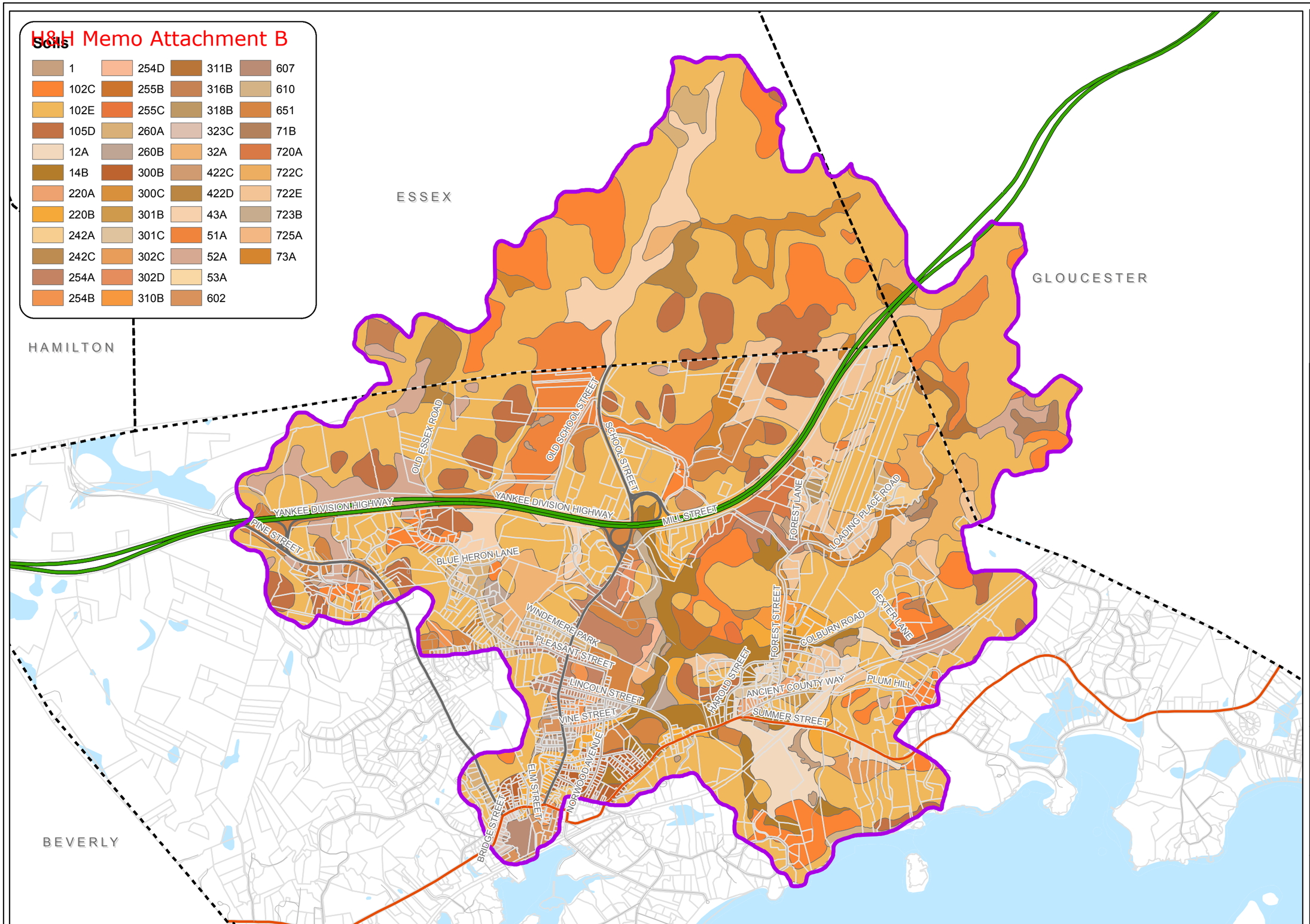

SAWMILL BROOK SOILS

LEGEND

Sawmill Brook Watershed

LOCUS MAP

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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 3

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

September 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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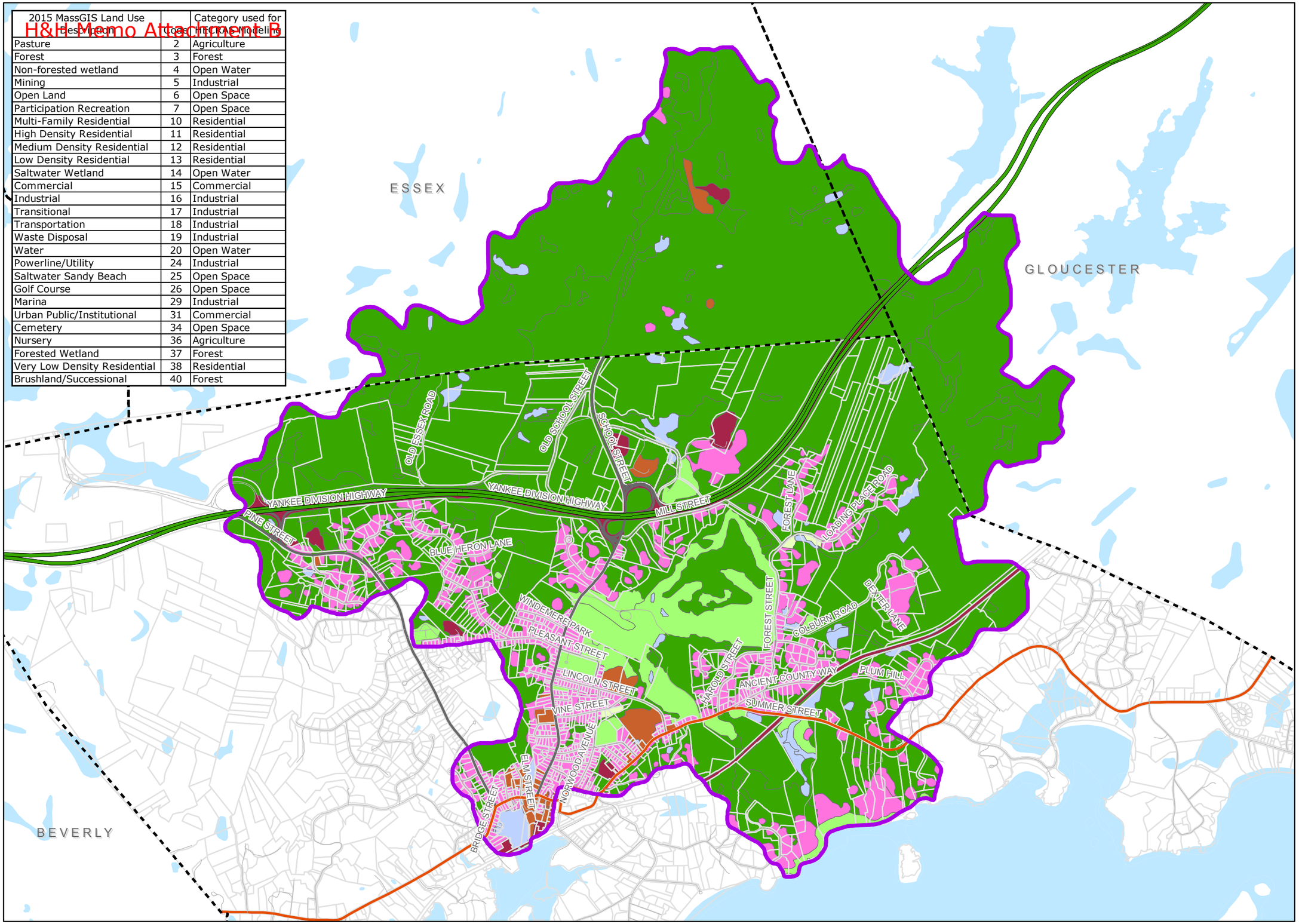
2015 MassGIS Land Use Description	Code	Category used for Hydrologic Modeling
Pasture	2	Agriculture
Forest	3	Forest
Non-forested wetland	4	Open Water
Mining	5	Industrial
Open Land	6	Open Space
Participation Recreation	7	Open Space
Multi-Family Residential	10	Residential
High Density Residential	11	Residential
Medium Density Residential	12	Residential
Low Density Residential	13	Residential
Saltwater Wetland	14	Open Water
Commercial	15	Commercial
Industrial	16	Industrial
Transitional	17	Industrial
Transportation	18	Industrial
Waste Disposal	19	Industrial
Water	20	Open Water
Powerline/Utility	24	Industrial
Saltwater Sandy Beach	25	Open Space
Golf Course	26	Open Space
Marina	29	Industrial
Urban Public/Institutional	31	Commercial
Cemetery	34	Open Space
Nursery	36	Agriculture
Forested Wetland	37	Forest
Very Low Density Residential	38	Residential
Brushland/Successional	40	Forest



SAWMILL BROOK LAND USE

LEGEND

Sawmill Brook Watershed

Aggregated Land Use

- Agriculture
- Commercial
- Forest
- Industrial
- Open Space
- Open Water
- Residential

LOCUS MAP

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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 4

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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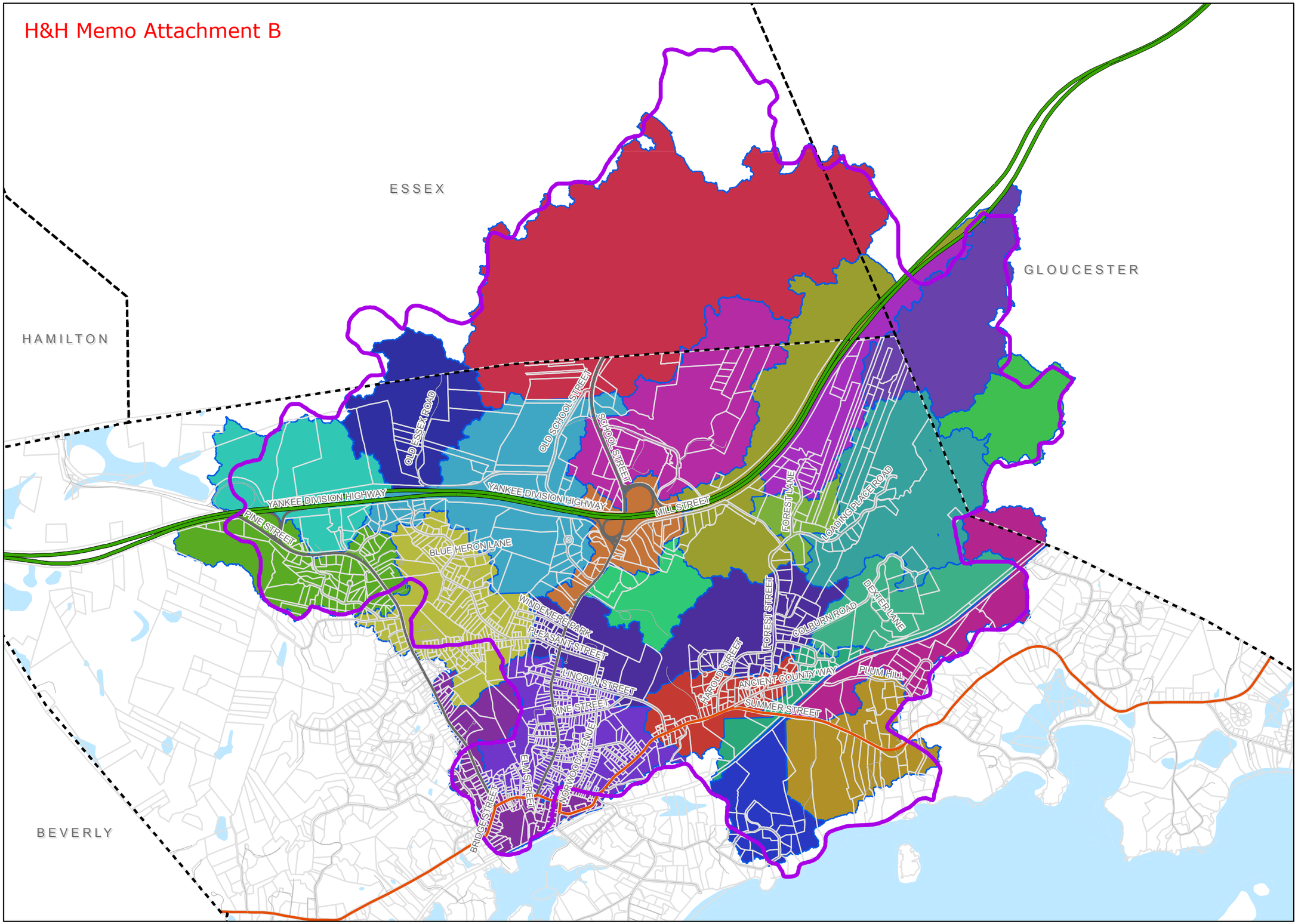

SAWMILL BROOK SUBAREAS

LEGEND

- Sawmill Brook Watershed
- Watershed Subareas

LOCUS MAP

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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 5

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

September 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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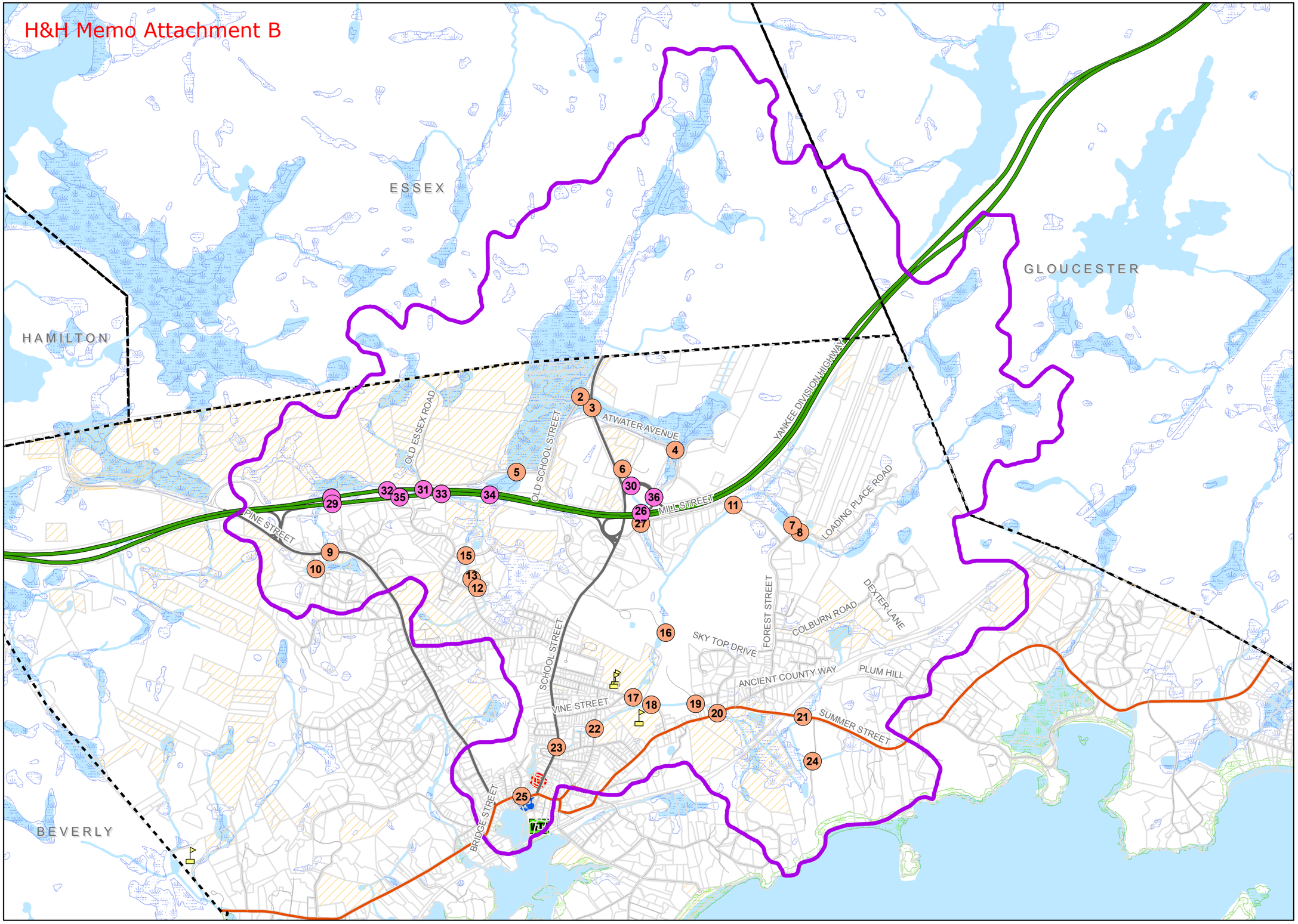

SAWMILL BROOK CULVERT LOCATIONS

LEGEND

- Sawmill Brook Watershed
- Town Boundary
- MassDOT Culvert
- Culvert
- Fire Station
- Police Station
- Wastewater Treatment Plant
- Schools (PK - High School)
- Town Owned Property
- Inland Wetlands
- Coastal Wetlands
- Waterbodes

LOCUS MAP

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NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 6

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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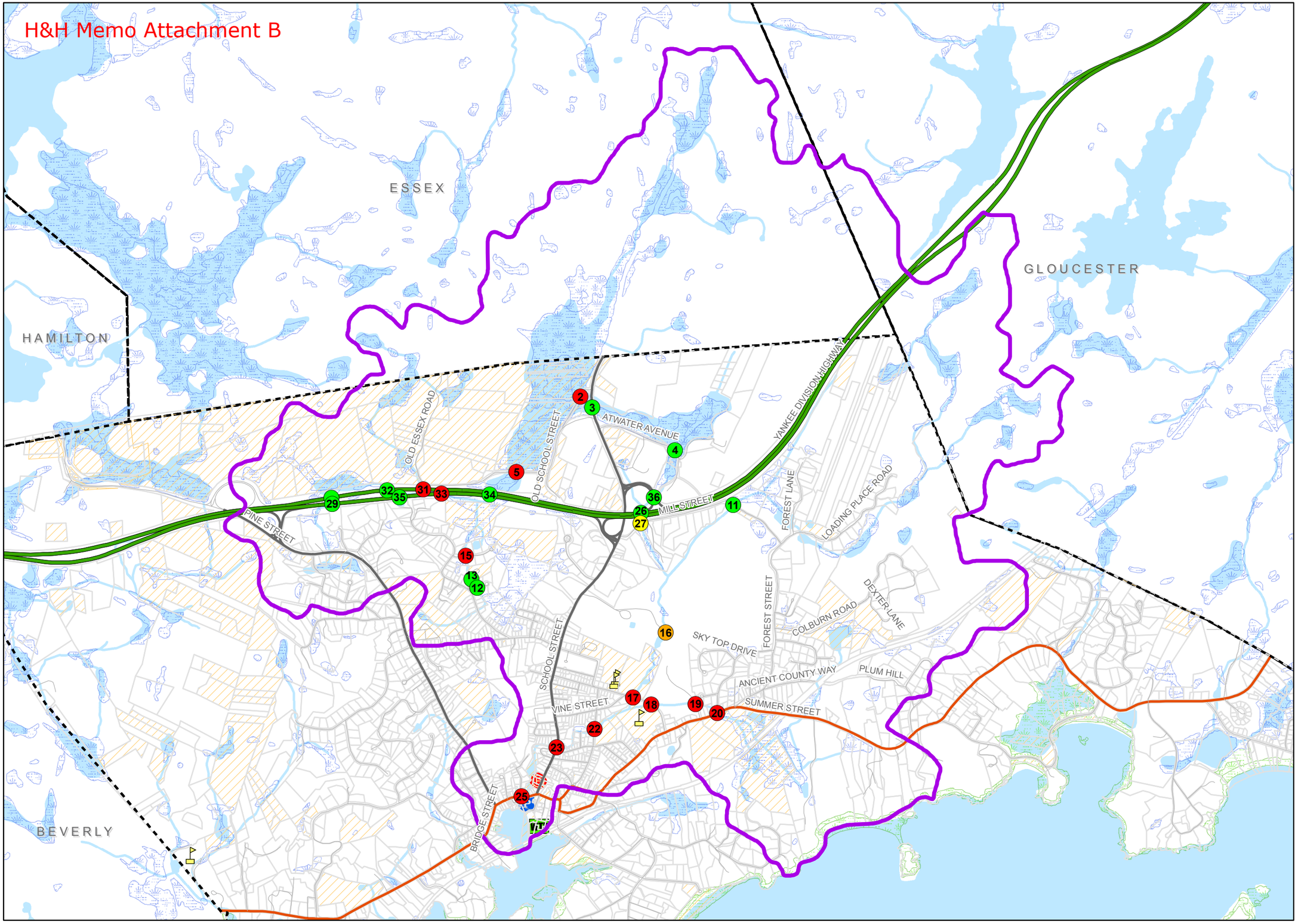
H&H Memo Attachment B



2015 STORM FREQUENCY CAUSING OVERTOPPING Existing Conditions Model

LEGEND

Culvert Overtopped

- >100 Year
- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- Sawmill Brook Watershed
- Town Boundary
- Town Owned Property
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750

Feet

1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 7

Sawmill Brook Culvert & Green Infrastructure Analysis Manchester-by-the-Sea, Massachusetts

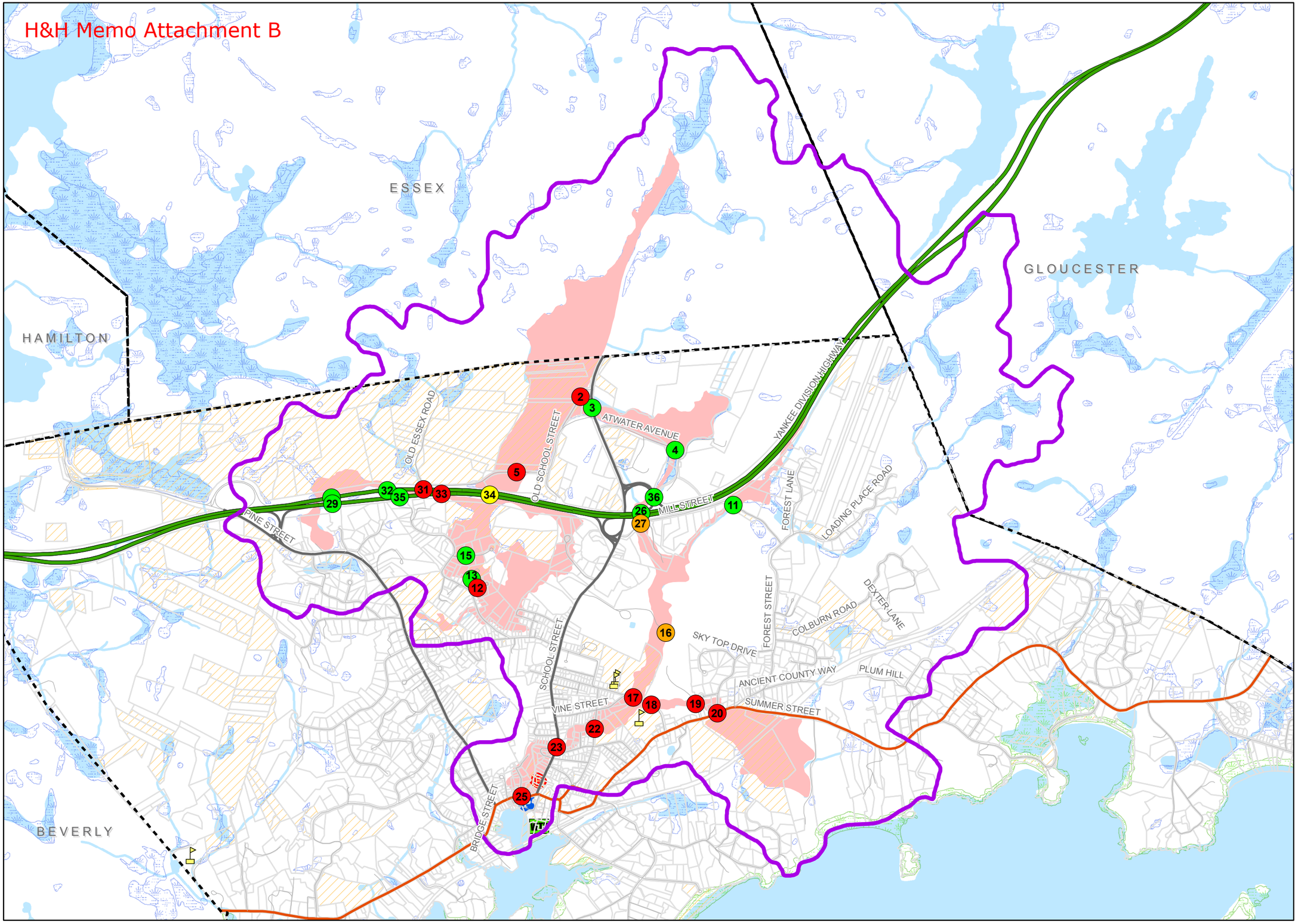
November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\CulvertOvertopping_2015.mxd

M-1476

H&H Memo Attachment B



2025 STORM FREQUENCY CAUSING OVERTOPPING
Balanced Energy Use,
Storm Surge or Sea Level Rise

LEGEND

Storm Frequency Causing Overtopping

- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Sea Level Rise Balanced
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750
Feet
1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 8A

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

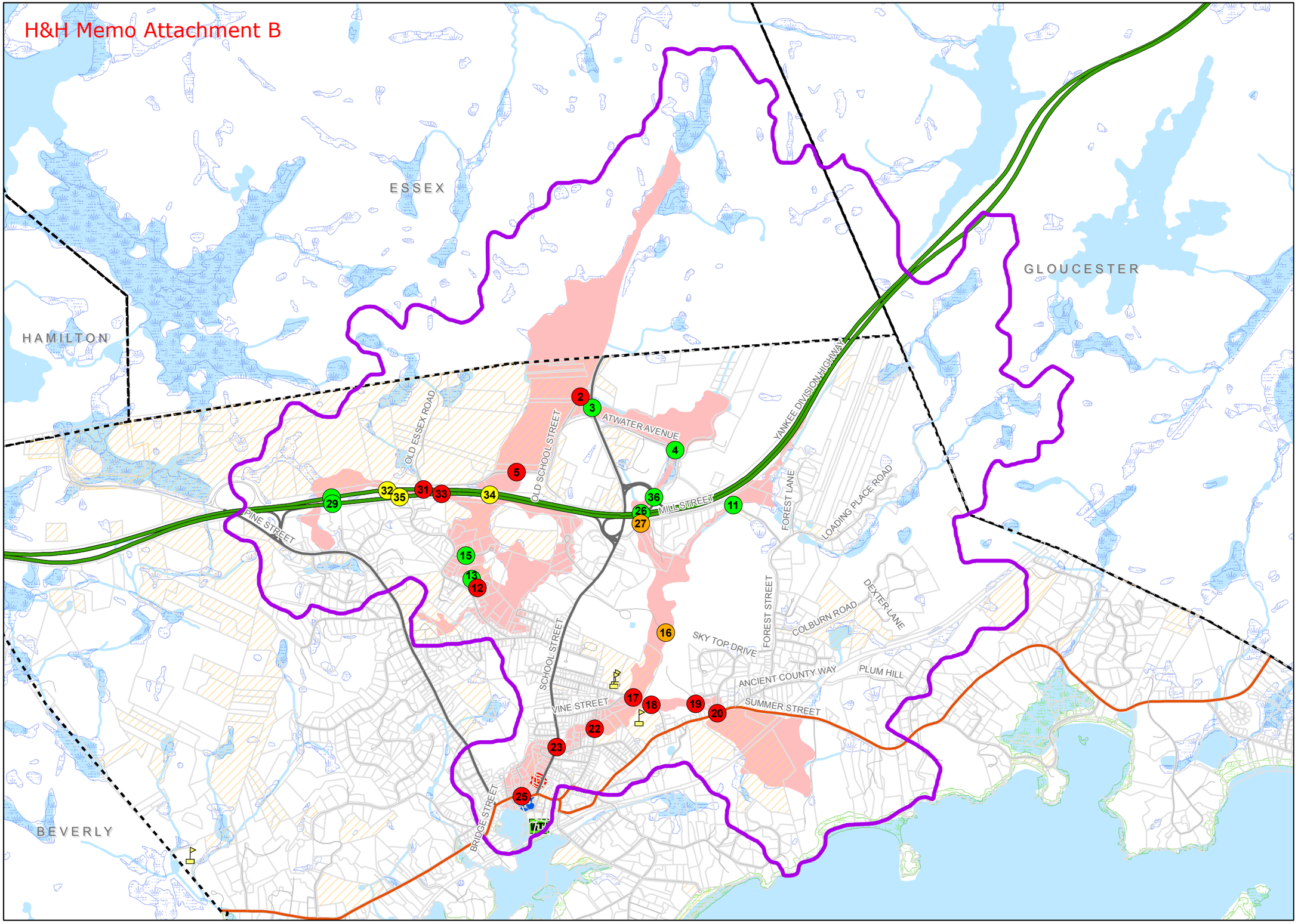
November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\SeaLevelRise_BalancedEnergy2025.mxd

M-1476

H&H Memo Attachment B



2050 STORM FREQUENCY CAUSING OVERTOPPING

Balanced Energy Use,

Storm Surge or Sea Level Rise

LEGEND

Storm Frequency Causing Overtopping

- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Sea Level Rise Balanced
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750

Feet

1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 8B

Sawmill Brook Culvert & Green Infrastructure Analysis

Manchester-by-the-Sea, Massachusetts

November 2015

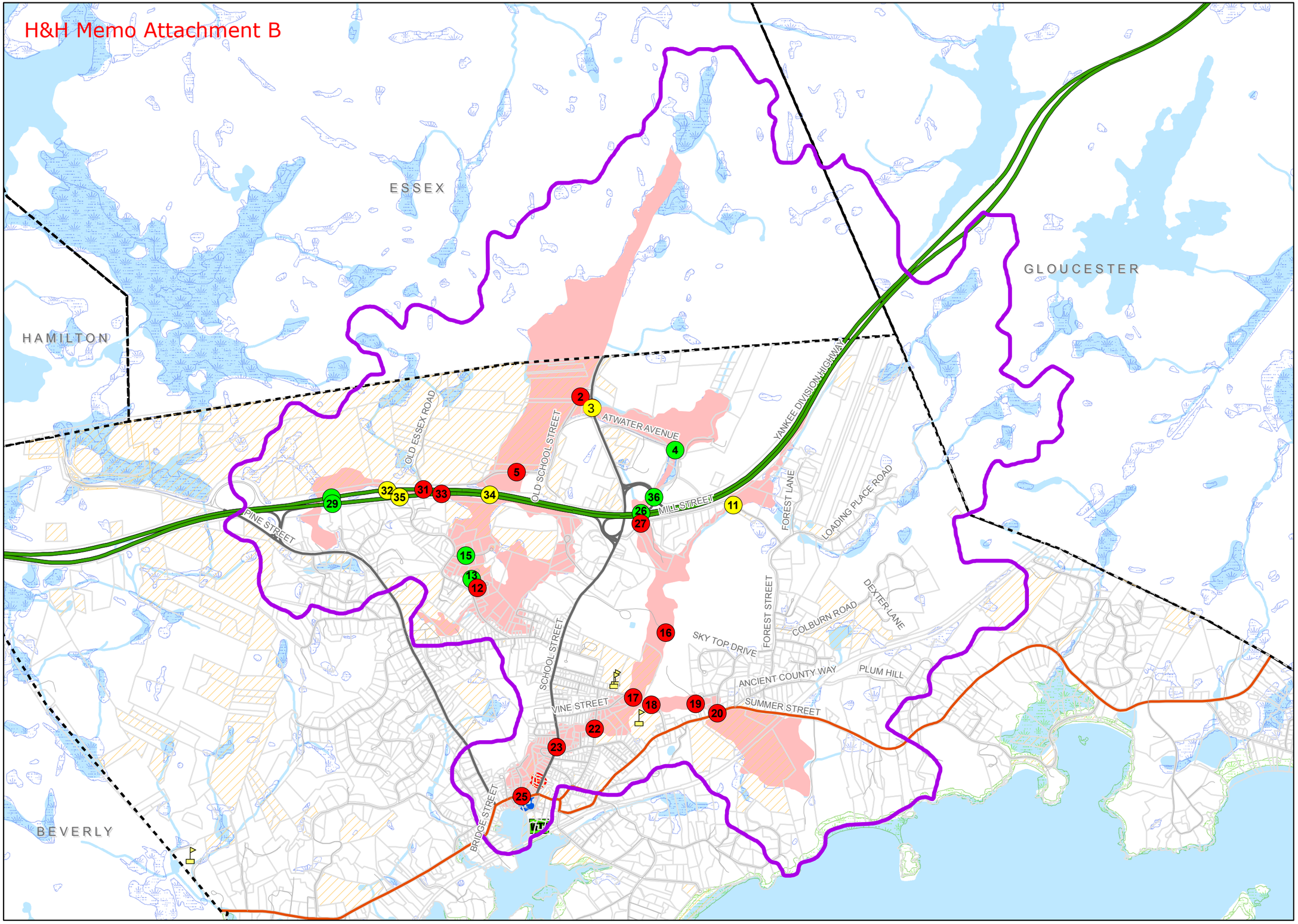
Tighe&Bond

Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\SeaLevelRise_BalancedEnergy2050.mxd

M-1476

H&H Memo Attachment B



2100 STORM FREQUENCY CAUSING OVERTOPPING
Balanced Energy Use,
Storm Surge and Sea Level Rise

LEGEND

Storm Frequency Causes Overtopping

- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Sea Level Rise Balanced
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750
Feet
1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 8C

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

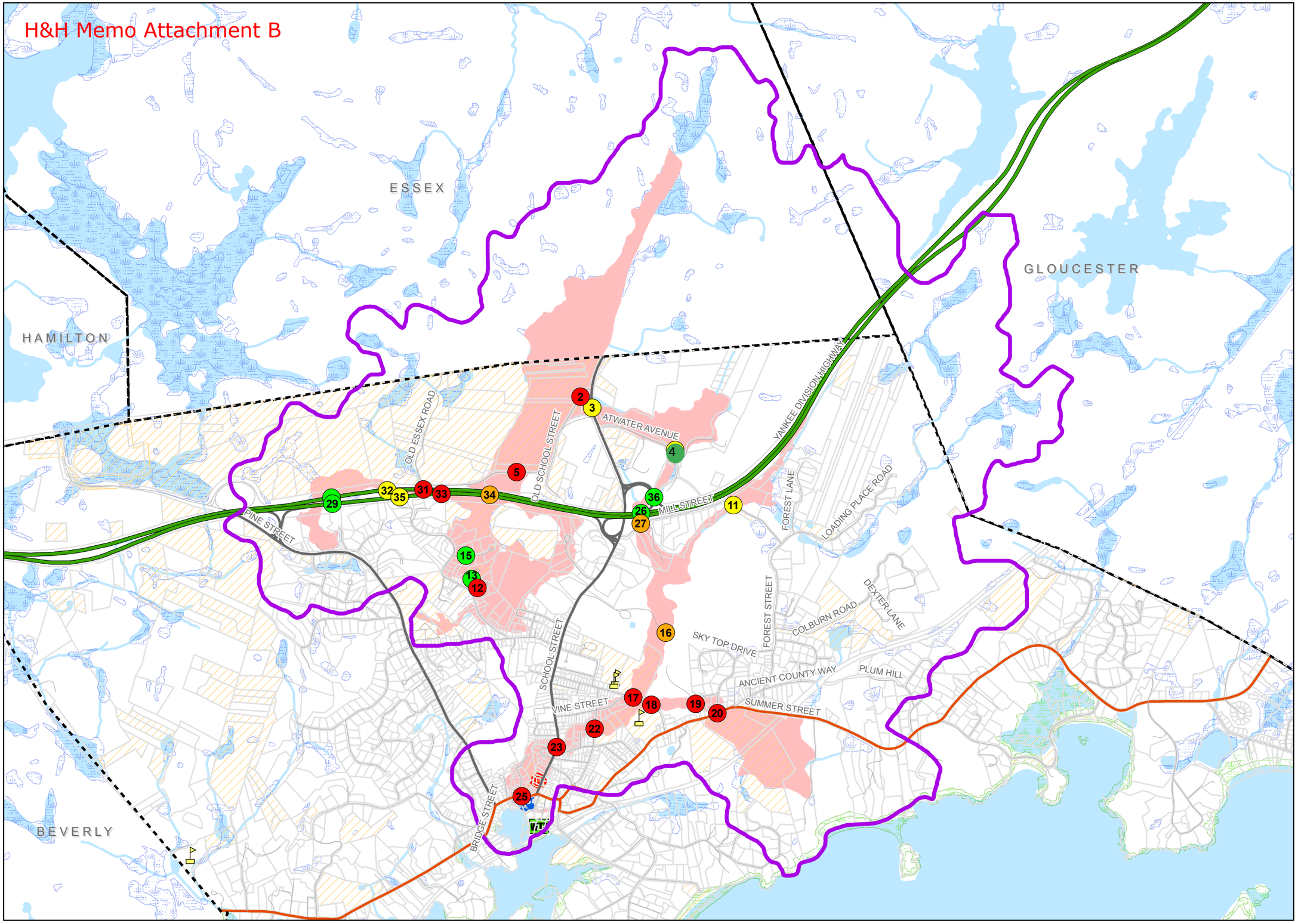
November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\SeaLevelRise_BalancedEnergy2100.mxd

M-1476

H&H Memo Attachment B



2025 STORM FREQUENCY CAUSING OVERTOPPING
Fossil Intensive Energy Use
Storm Surge or Sea Level Rise

LEGEND

Storm Frequency Causing Overtopping

- 25 Year storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Model Output
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750
Feet
1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 9A

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

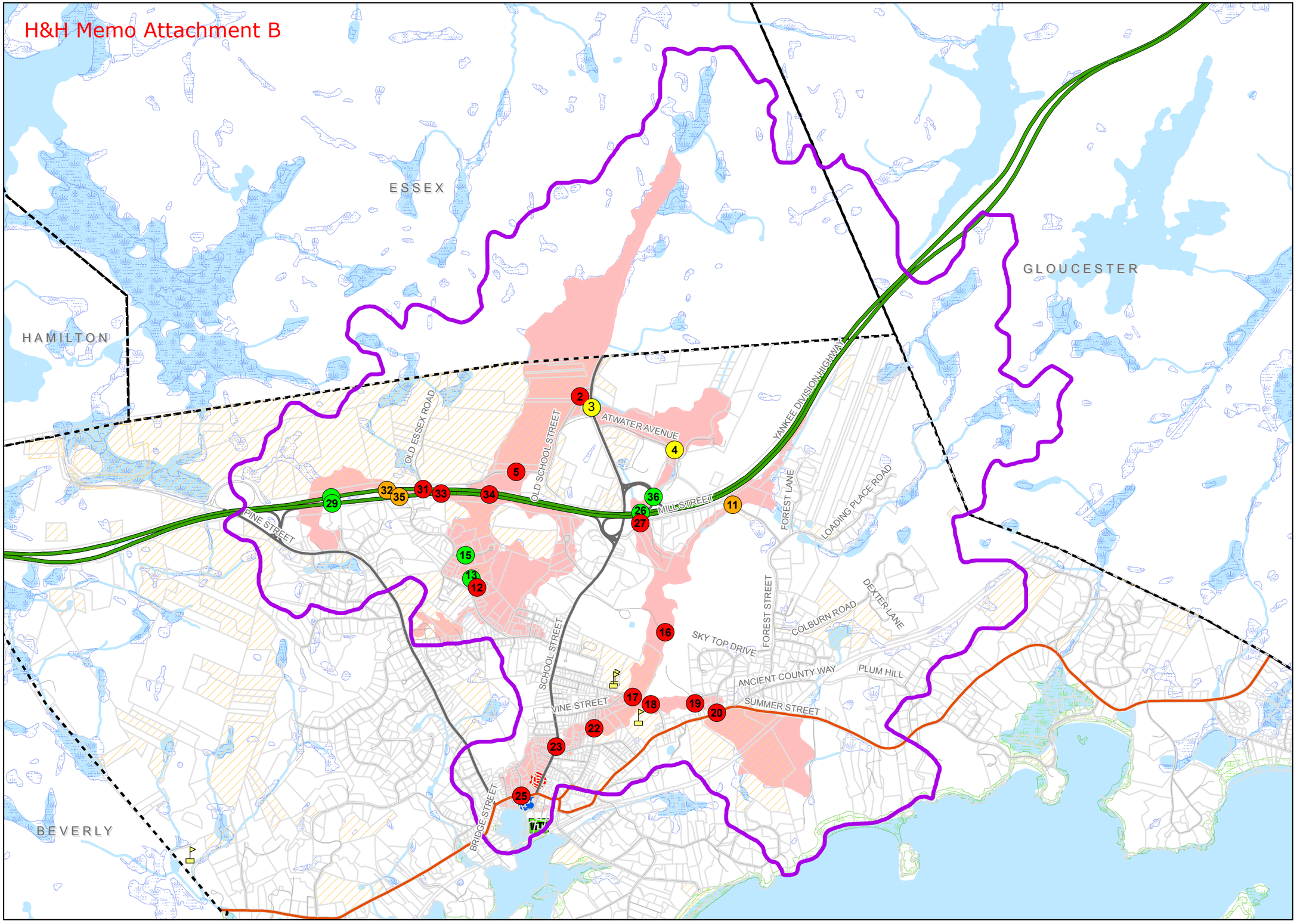
November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\StormSurge_FossilIntensive_2025.mxd

M-1476

H&H Memo Attachment B



2050 STORM FREQUENCY CAUSING OVERTOPPING
Fossil Intensive Energy Use
Storm Surge or Sea Level Rise

LEGEND

Storm Frequency Causing Overtopping

- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Model Output
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP

N

0 875 1,750
Feet
1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 9B

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

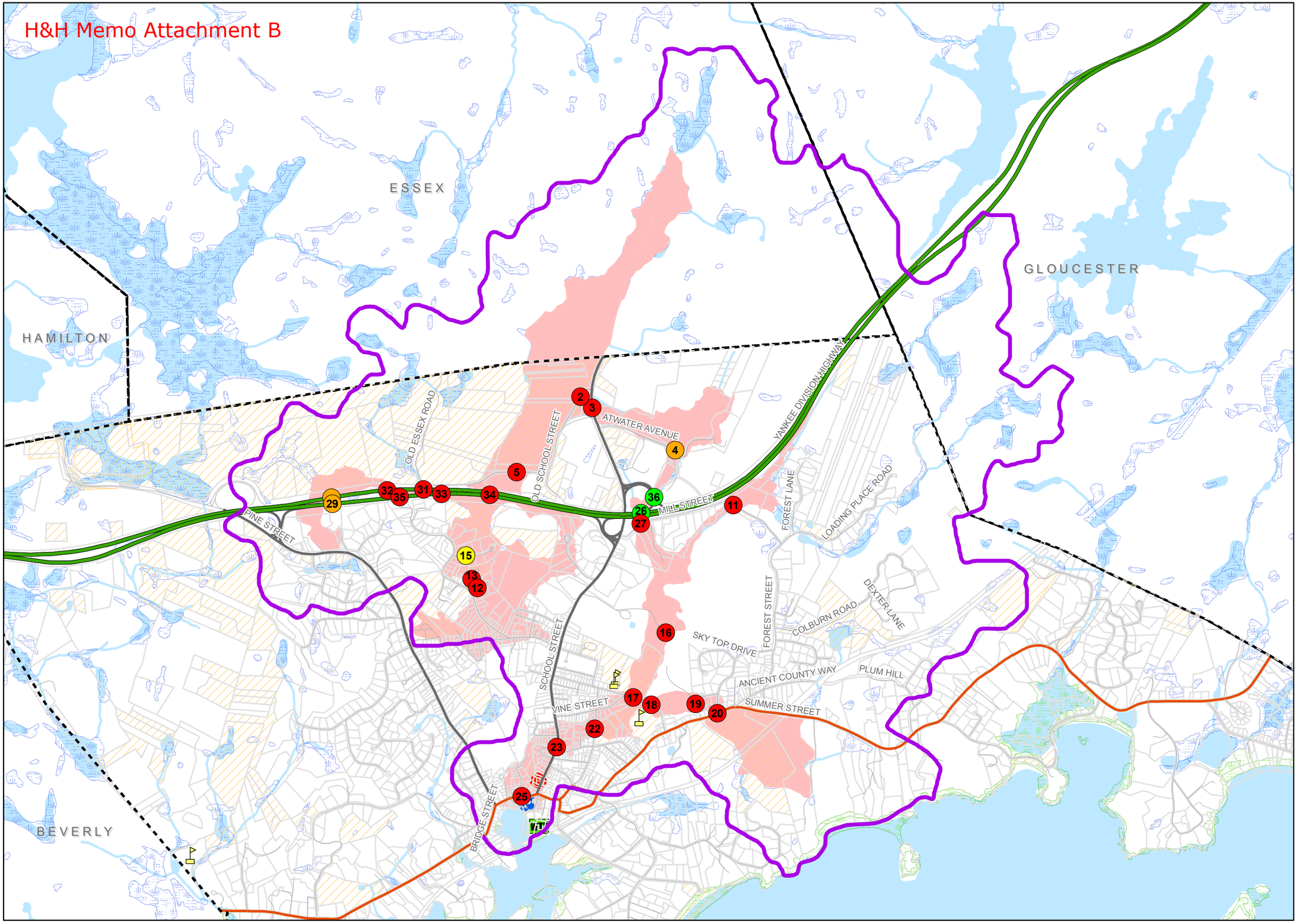
November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\StormSurge_FossilIntensive_2050.mxd

M-1476

H&H Memo Attachment B



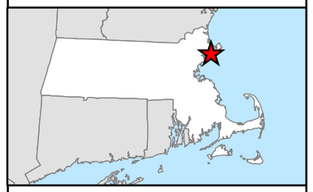
2100 STORM FREQUENCY CAUSING OVERTOPPING
Fossil Intensive Energy Use
Storm Surge or Sea Level Rise

LEGEND

Storm Frequency Causing Overtopping

- 25 Year Storm
- 50 Year Storm
- 100 Year Storm
- >100 Year Storm
- Sawmill Brook Watershed
- Town Owned Property
- Sea Level Rise Fossil Intensive
- Inland Wetlands
- Coastal Wetlands
- Waterbodies

LOCUS MAP



N

0 875 1,750
Feet
1:21,000

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Figure 9C

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, Massachusetts

November 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\avproj\SeaLevelRise_FossilIntensive2100.mxd

M-1476

H&H Memo Attachment B

H&H Memo Attachment B

Tighe&Bond

APPENDIX A

H&H Memo Attachment B

United States Department of Agriculture

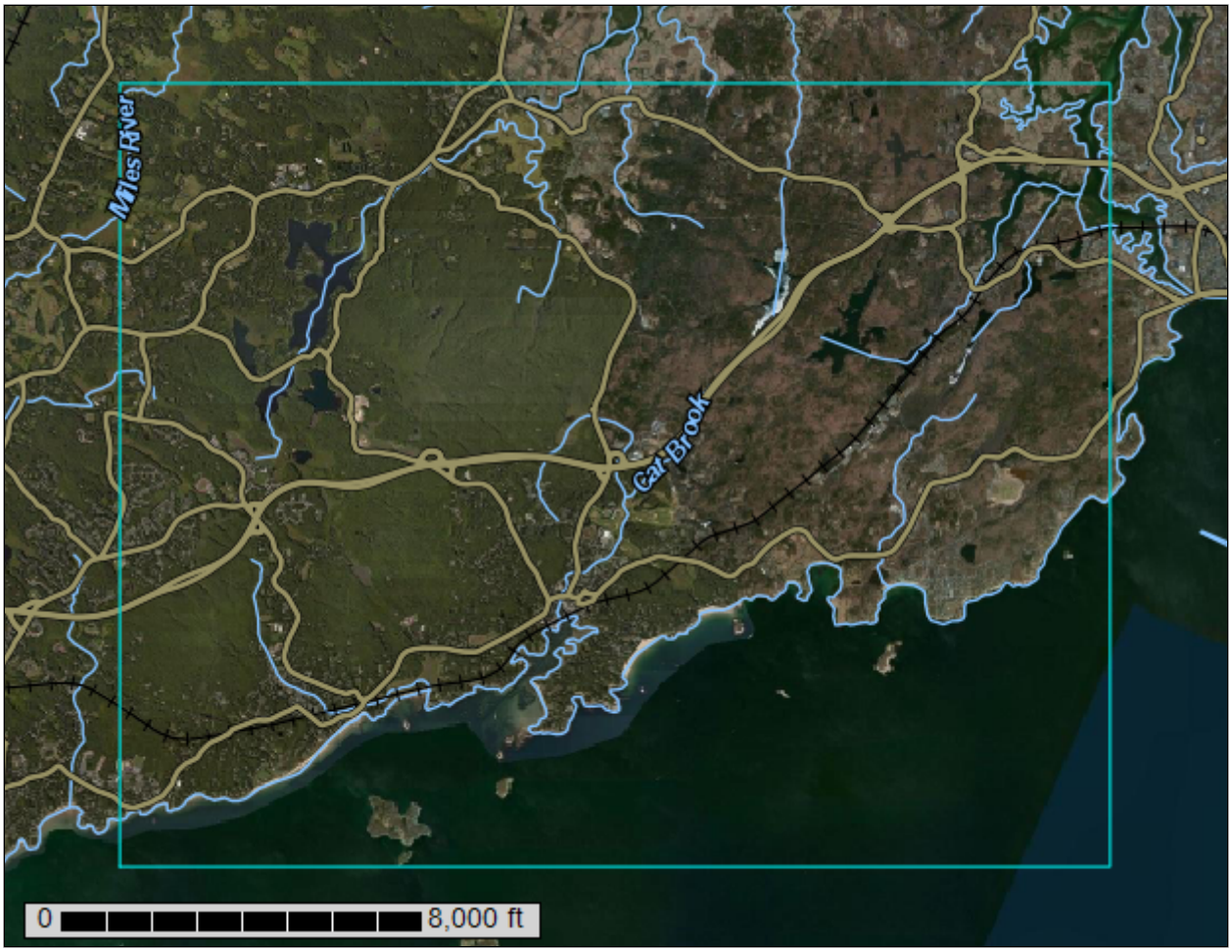
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Essex County, Massachusetts, Southern Part

NOTE: The original report included additional data on the soil types. The full report can be provided upon request.



October 10, 2015

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means

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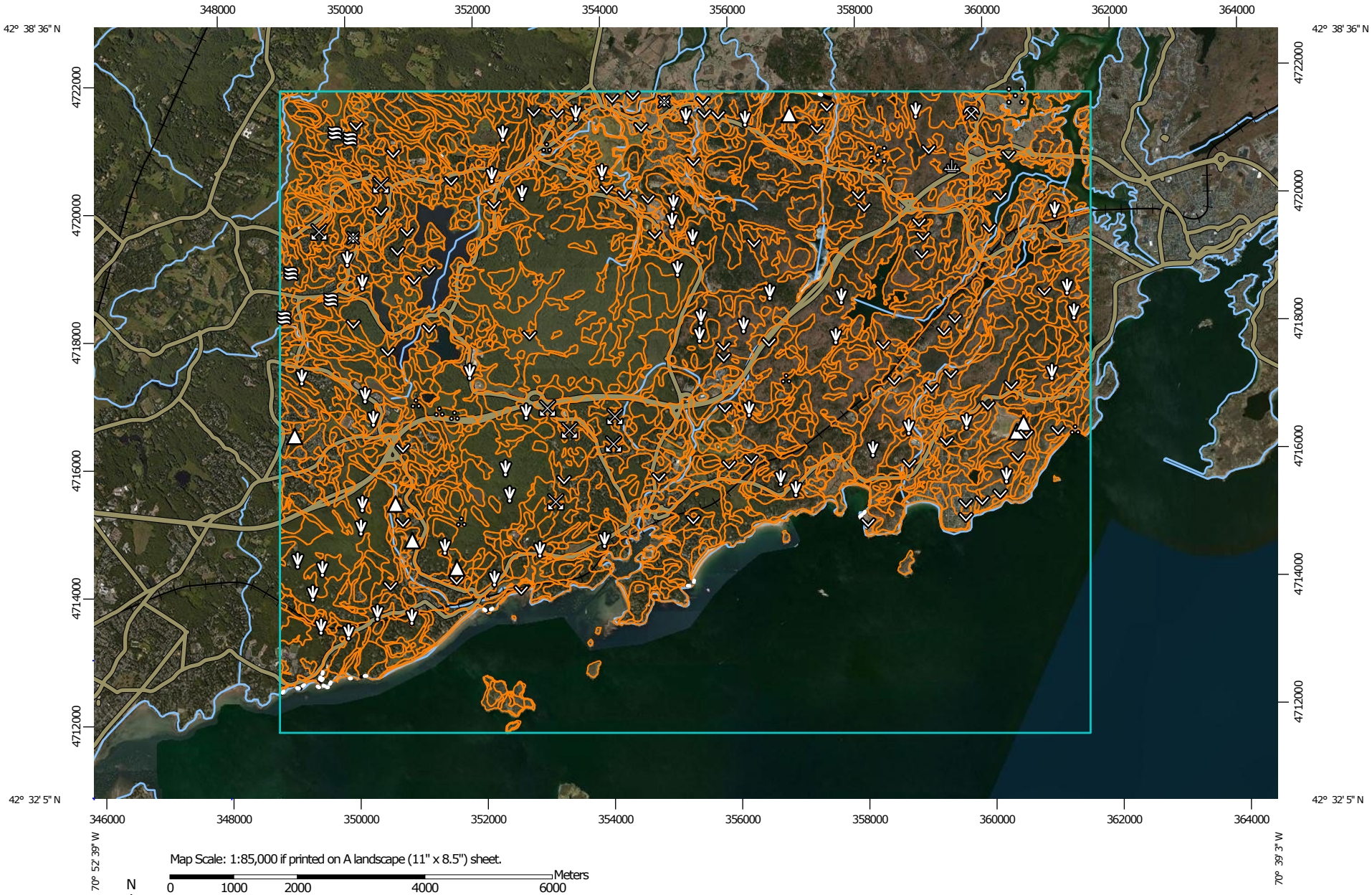
H&H Memo Attachment B

Custom Soil Resource Report
Soil Map



Map Scale: 1:85,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 1000 2000 4000 6000

Feet: 0 4000 8000 16000 24000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Essex County, Massachusetts, Southern Part
Survey Area Data: Version 11, Sep 19, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 1, 1999—Sep 19, 2014

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Essex County, Massachusetts, Southern Part (MA606)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
1	Water	715.7	2.3%
12A	Maybid silt loam, 0 to 3 percent slopes	259.0	0.8%
14B	Scitico silt loam, 0 to 5 percent slopes	432.7	1.4%
31A	Walpole sandy loam, 0 to 3 percent slopes	166.0	0.5%
31B	Walpole fine sandy loam, 3 to 8 percent slopes	10.9	0.0%
32A	Wareham loamy sand, 0 to 3 percent slopes	101.1	0.3%
38A	Pipestone loamy fine sand, 0 to 3 percent slopes	6.3	0.0%
43A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	352.8	1.1%
51A	Swansea muck, 0 to 1 percent slopes	256.8	0.8%
52A	Freetown muck, 0 to 1 percent slopes	1,344.9	4.2%
53A	Freetown muck, ponded, 0 to 1 percent slopes MLRA 144A	107.2	0.3%
70B	Ridgebury fine sandy loam, 0 to 6 percent slopes	16.6	0.1%
71A	Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony	27.5	0.1%
71B	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony	300.2	0.9%
73A	Whitman loam, 0 to 3 percent slopes, extremely stony	530.9	1.7%
102C	Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes	2,499.8	7.9%
102E	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes	7,900.6	24.9%
105D	Rock outcrop-Hollis complex, 3 to 25 percent slopes	616.9	1.9%
220A	Boxford silt loam, 0 to 3 percent slopes	65.8	0.2%
220B	Boxford silt loam, 3 to 8 percent slopes	264.6	0.8%
220C	Boxford silt loam, 8 to 15 percent slopes	16.1	0.1%

Essex County, Massachusetts, Southern Part (MA606)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
225B	Belgrade very fine sandy loam, 0 to 8 percent slopes	33.8	0.1%
242A	Hinckley gravelly fine sandy loam, 0 to 3 percent slopes	222.9	0.7%
242B	Hinckley gravelly fine sandy loam, 3 to 8 percent slopes	297.2	0.9%
242C	Hinckley gravelly fine sandy loam, 8 to 15 percent slopes	124.0	0.4%
242D	Hinckley gravelly fine sandy loam, 15 to 25 percent slopes	89.7	0.3%
242E	Hinckley gravelly fine sandy loam, 25 to 45 percent slopes	49.8	0.2%
250B	Pollux fine sandy loam, 0 to 8 percent slopes	31.3	0.1%
254A	Merrimac fine sandy loam, 0 to 3 percent slopes	181.7	0.6%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	349.3	1.1%
254C	Merrimac fine sandy loam, 8 to 15 percent slopes	111.3	0.4%
254D	Merrimac fine sandy loam, 15 to 25 percent slopes	44.6	0.1%
255A	Windsor loamy sand, 0 to 3 percent slopes	15.8	0.0%
255B	Windsor loamy sand, 3 to 8 percent slopes	36.7	0.1%
255C	Windsor loamy sand, 8 to 15 percent slopes	2.4	0.0%
256A	Deerfield loamy fine sand, 0 to 3 percent slopes	121.7	0.4%
260A	Sudbury fine sandy loam, 0 to 3 percent slopes	547.6	1.7%
260B	Sudbury fine sandy loam, 3 to 8 percent slopes	237.5	0.7%
276B	Ninigret fine sandy loam, 3 to 8 percent slopes	8.3	0.0%
300B	Montauk fine sandy loam, 3 to 8 percent slopes	44.6	0.1%
300C	Montauk fine sandy loam, 8 to 15 percent slopes	2.8	0.0%
301B	Montauk fine sandy loam, 3 to 8 percent slopes, very stony	70.8	0.2%
301C	Montauk fine sandy loam, 8 to 15 percent slopes, very stony	43.5	0.1%
301D	Montauk fine sandy loam, 15 to 25 percent slopes, very stony	22.5	0.1%
302C	Montauk fine sandy loam, 8 to 15 percent slopes, extremely stony	8.9	0.0%

Essex County, Massachusetts, Southern Part (MA606)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
302D	Montauk fine sandy loam, 15 to 25 percent slopes, extremely stony	10.0	0.0%
305B	Paxton fine sandy loam, 3 to 8 percent slopes	37.4	0.1%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	30.7	0.1%
305D	Paxton fine sandy loam, 15 to 25 percent slopes	4.6	0.0%
306B	Paxton fine sandy loam, 3 to 8 percent slopes, very stony	58.6	0.2%
306C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	28.6	0.1%
306D	Paxton fine sandy loam, 15 to 25 percent slopes, very stony	81.9	0.3%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	44.1	0.1%
310C	Woodbridge fine sandy loam, 8 to 15 percent slopes	16.7	0.1%
311B	Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony	138.7	0.4%
311C	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony	69.9	0.2%
311D	Woodbridge fine sandy loam, 15 to 25 percent slopes, very stony	14.1	0.0%
315B	Scituate fine sandy loam, 3 to 8 percent slopes	11.1	0.0%
316B	Scituate fine sandy loam, 3 to 8 percent slopes, very stony	190.4	0.6%
316C	Scituate fine sandy loam, 8 to 15 percent slopes, very stony	22.1	0.1%
317B	Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony	4.3	0.0%
318B	Scituate fine sandy loam, 3 to 8 percent slopes, extremely bouldery	176.5	0.6%
318C	Scituate fine sandy loam, 8 to 15 percent slopes, extremely bouldery	53.3	0.2%
323B	Poquonock loamy sand, 3 to 8 percent slopes, very stony	14.4	0.0%
323C	Poquonock loamy sand, 8 to 15 percent slopes, very stony	30.6	0.1%
323D	Poquonock loamy sand, 15 to 25 percent slopes, very stony	10.0	0.0%

Essex County, Massachusetts, Southern Part (MA606)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
392E	Paxton and Montauk fine sandy loams, 25 to 45 percent slopes, extremely stony	4.4	0.0%
420B	Canton fine sandy loam, 3 to 8 percent slopes	25.6	0.1%
420C	Canton fine sandy loam, 8 to 20 percent slopes	3.2	0.0%
421B	Canton fine sandy loam, 3 to 8 percent slopes, very stony	139.3	0.4%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	168.4	0.5%
421D	Canton fine sandy loam, 15 to 25 percent slopes, very stony	76.2	0.2%
422B	Canton fine sandy loam, 3 to 8 percent slopes, extremely stony	72.6	0.2%
422C	Canton fine sandy loam, 8 to 15 percent slopes, extremely stony	162.3	0.5%
422D	Canton fine sandy loam, 15 to 25 percent slopes, extremely stony	120.7	0.4%
422E	Canton fine sandy loam, 25 to 35 percent slopes, extremely stony	45.3	0.1%
600	Pits, gravel	84.8	0.3%
602	Urban land	185.2	0.6%
607	Water, saline	421.3	1.3%
610	Beaches	65.0	0.2%
616A	Fluvaquents, frequently flooded, 0 to 3 percent slopes	11.3	0.0%
626B	Merrimac-Urban land complex, gently sloping	69.1	0.2%
651	Udorthents, smoothed	389.2	1.2%
652	Udorthents, refuse substratum	69.5	0.2%
702C	Udipsamments, rolling	7.0	0.0%
712A	Ipswich and Westbrook mucky peats, 0 to 2 percent slopes, very frequently flooded	565.2	1.8%
714B	Melrose fine sandy loam, 3 to 8 percent slopes	21.4	0.1%
720A	Whately Variant mucky fine sandy loam, 0 to 1 percent slopes	26.1	0.1%
722B	Annisquam fine sandy loam, 3 to 8 percent slopes, extremely bouldery	184.3	0.6%

Essex County, Massachusetts, Southern Part (MA606)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
722C	Annisquam fine sandy loam, 8 to 15 percent slopes, extremely bouldery	349.6	1.1%
722E	Annisquam fine sandy loam, 15 to 35 percent slopes, extremely bouldery	711.1	2.2%
723A	Elmridge fine sandy loam, 0 to 3 percent slopes	1.7	0.0%
723B	Elmridge fine sandy loam, 3 to 8 percent slopes	35.8	0.1%
725A	Shaker fine sandy loam, 0 to 3 percent slopes	45.0	0.1%
Subtotals for Soil Survey Area		**23,799.5**	**75.0%**
Totals for Area of Interest		**31,724.8**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic

classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 1**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.4813295	92	44.2823
Commercial - Soil Type C	0.2013695	94	18.9287
Commercial - Soil Type D	0.7687470	95	73.0310
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	59.7666670	55	3287.1667
Forest - Soil Type C	4.5745470	70	320.2183
Forest - Soil Type D	22.3574500	77	1721.5237
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	3.3827060	88	297.6781
Industrial - Soil Type C	1.5265560	91	138.9166
Industrial - Soil Type D	0.1003350	93	9.3312
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.1823675	61	11.1244
Open Space - Soil Type C	0.1823675	74	13.4952
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	0.7380440	98	72.3283
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	21.2265220	68	1443.4035
Residential - Soil Type C	3.0271120	79	239.1418
Residential - Soil Type D	5.8960520	84	495.2684
	124.4121720		8185.8382

Weighted CN: 66

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.16	22.2

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.11	5.35	610	1.9
Segment C - D	unpaved	0.02	2.28	230	1.7
Segment D - E	unpaved	0.15	6.25	210	0.6
Segment E - F	unpaved	0.01	1.61	620	6.4

Total Tc = 32.7 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 2**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.0295055	92	2.7145
Commercial - Soil Type C	0.0295055	94	2.7735
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	78.5247715	55	4318.8624
Forest - Soil Type C	1.0337415	70	72.3619
Forest - Soil Type D	39.3928500	77	3033.2495
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	6.6709650	88	587.0449
Industrial - Soil Type C	5.1479850	91	468.4666
Industrial - Soil Type D	3.2584850	93	303.0391
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.3073545	61	18.7486
Open Space - Soil Type C	0.0123755	74	0.9158
Open Space - Soil Type D	0.0000000	80	0.0000
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	2.1432190	68	145.7389
Residential - Soil Type C	0.2189090	79	17.2938
Residential - Soil Type D	0.3870230	84	32.5099
	137.1566900		9003.7195

Weighted CN: 66

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.06	32.8

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.055	3.78	290	1.3
Segment C - D	unpaved	0.01	1.61	3990	41.2

Total Tc = 75.3 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 3**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.0000000	92	0.0000
Commercial - Soil Type C	0.0000000	94	0.0000
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	91.2347725	55	5017.9125
Forest - Soil Type C	0.4559385	70	31.9157
Forest - Soil Type D	25.7968300	77	1986.3559
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	0.0000000	88	0.0000
Industrial - Soil Type C	0.0000000	91	0.0000
Industrial - Soil Type D	0.4411070	93	41.0230
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.7374990	61	44.9874
Open Space - Soil Type C	0.0000000	74	0.0000
Open Space - Soil Type D	2.3157050	80	185.2564
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	0.0000000	68	0.0000
Residential - Soil Type C	0.0000000	79	0.0000
Residential - Soil Type D	0.0000000	84	0.0000
	120.9818520		7307.4509

Weighted CN: 60

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.12	24.9

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.18	6.85	365	0.9
Segment C - D	unpaved	0.02	2.28	2150	15.7
Segment D - E	unpaved	0.01	1.61	1660	17.1

Total Tc = 58.6 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
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Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 4**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.0000000	72	0.0000
Cultivated Land - Soil Type B	0.2832580	81	22.9439
Cultivated Land - Soil Type C	0.0000000	88	0.0000
Cultivated Land - Soil Type D	0.0000000	91	0.0000
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.2121410	92	19.5170
Commercial - Soil Type C	0.0000000	94	0.0000
Commercial - Soil Type D	0.3709880	95	35.2439
Forest - Soil Type A	1.9701730	25	49.2543
Forest - Soil Type B	66.3823440	55	3651.0289
Forest - Soil Type C	7.9728160	70	558.0971
Forest - Soil Type D	6.7207360	77	517.4967
Industrial - Soil Type A	0.1547980	81	12.5386
Industrial - Soil Type B	0.8209655	88	72.2450
Industrial - Soil Type C	0.7870605	91	71.6225
Industrial - Soil Type D	0.0000000	93	0.0000
Open Space - Soil Type A	1.0156190	39	39.6091
Open Space - Soil Type B	2.1298345	61	129.9199
Open Space - Soil Type C	1.8269695	74	135.1957
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	0.0160190	98	1.5699
Residential - Soil Type A	2.1383920	51	109.0580
Residential - Soil Type B	53.2291420	68	3619.5817
Residential - Soil Type C	2.8236280	79	223.0666
Residential - Soil Type D	3.7732600	84	316.9538
	152.6281440		9584.9426

Weighted CN: 63

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.07	30.9

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.12	5.59	365	1.1
Segment C - D	unpaved	0.01	1.61	3390	35.0

Total Tc = 67.0 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 5**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	4.5807180	92	421.4261
Commercial - Soil Type C	0.0000000	94	0.0000
Commercial - Soil Type D	0.4414000	95	41.9330
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	400.1507000	55	22008.2885
Forest - Soil Type C	7.0185110	70	491.2958
Forest - Soil Type D	158.6166000	77	12213.4782
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	2.7357220	88	240.7435
Industrial - Soil Type C	0.0000000	91	0.0000
Industrial - Soil Type D	0.0000000	93	0.0000
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	5.1837990	61	316.2117
Open Space - Soil Type C	0.0546360	74	4.0431
Open Space - Soil Type D	5.0924340	80	407.3947
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	0.8820270	68	59.9778
Residential - Soil Type C	0.0000000	79	0.0000
Residential - Soil Type D	0.7779140	84	65.3448
	585.5344610		36270.1372

Weighted CN: 62

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.1	26.8

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.11	5.35	340	1.1
Segment C - D	unpaved	0.023	2.45	2840	19.3
Segment D - E	unpaved	0.005	1.14	4300	62.8

Total Tc = 110.0 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 6**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	77.1055250	55	4240.8039
Forest - Soil Type C	31.6154950	70	2213.0847
Forest - Soil Type D	79.9118000	77	6153.2086
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	4.7944175	88	421.9087
Industrial - Soil Type C	2.9058525	91	264.4326
Industrial - Soil Type D	5.7669230	93	536.3238
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.7483435	61	45.6490
Open Space - Soil Type C	0.2092595	74	15.4852
Open Space - Soil Type D	0.0771170	80	6.1694
Open Water	1.5568290	98	152.5692
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	11.6022500	68	788.9530
Residential - Soil Type C	1.1815200	79	93.3401
Residential - Soil Type D	4.9056750	84	412.0767
	222.3810070		15344.0048

Weighted CN: 69

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.15	22.7

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.1	5.10	620	2.0
Segment C - D	unpaved	0.004	1.02	4890	79.9

Total Tc = 104.6 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 7**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	7.6448645	92	703.3275
Commercial - Soil Type C	1.5274255	94	143.5780
Commercial - Soil Type D	0.1847730	95	17.5534
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	82.2797180	55	4525.3845
Forest - Soil Type C	22.0388780	70	1542.7215
Forest - Soil Type D	54.5009900	77	4196.5762
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	7.4969680	88	659.7332
Industrial - Soil Type C	3.2601710	91	296.6756
Industrial - Soil Type D	0.4708370	93	43.7878
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.7639410	61	46.6004
Open Space - Soil Type C	0.0000000	74	0.0000
Open Space - Soil Type D	5.8189200	80	465.5136
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	8.3506505	68	567.8442
Residential - Soil Type C	3.9453645	79	311.6838
Residential - Soil Type D	0.7794350	84	65.4725
	199.0629360		13586.4523

Weighted CN: 68

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.3	17.2

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.06	3.95	1290	5.4
Segment C - D	unpaved	0.005	1.14	1211	17.7
Segment D - E	unpaved	0.01	1.61	841	8.7

Total Tc = 49.1 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Designation: **Area 8**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0030000	89	0.2670
Commercial - Soil Type B	0.8806055	92	81.0157
Commercial - Soil Type C	0.1805565	94	16.9723
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	1.3140500	25	32.8513
Forest - Soil Type B	24.5143300	55	1348.2882
Forest - Soil Type C	16.4080900	70	1148.5663
Forest - Soil Type D	0.0396170	77	3.0505
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	7.8476305	88	690.5915
Industrial - Soil Type C	6.2926515	91	572.6313
Industrial - Soil Type D	0.1354370	93	12.5956
Open Space - Soil Type A	1.1303490	39	44.0836
Open Space - Soil Type B	0.0010770	61	0.0657
Open Space - Soil Type C	0.0000000	74	0.0000
Open Space - Soil Type D	0.0000000	80	0.0000
Residential - Soil Type A	2.6127490	51	133.2502
Residential - Soil Type B	5.6295575	68	382.8099
Residential - Soil Type C	3.6306515	79	286.8215
Residential - Soil Type D	0.0000000	84	0.0000
	70.6203520		4753.8605

Weighted CN: 67

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.15	22.7

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.008	1.44	1420	16.4

Total Tc = 39.1 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Description: **Existing Conditions CN & Tc Calculations**
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Designation: **Area 9**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	114.3190950	55	6287.5502
Forest - Soil Type C	11.3404050	70	793.8284
Forest - Soil Type D	23.0580800	77	1775.4722
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	0.8992280	88	79.1321
Industrial - Soil Type C	0.0000000	91	0.0000
Industrial - Soil Type D	0.0000000	93	0.0000
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.5846950	61	35.6664
Open Space - Soil Type C	0.8978510	74	66.4410
Open Space - Soil Type D	2.0889870	80	167.1190
	153.1883410		9205.2091

Weighted CN: 60

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.15	22.7

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.1	5.10	530	1.7
Segment C - D	unpaved	0.008	1.44	3540	40.9

Total Tc = 65.4 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 10**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	49.0138700	55	2695.7629
Forest - Soil Type C	9.5524960	70	668.6747
Forest - Soil Type D	12.5813700	77	968.7655
	71.1477360		4333.2031

Weighted CN: 61

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment		**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B		0.4	300	0.12	24.9

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.02	2.28	2254	16.5

Total Tc = 41.3 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 11**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.0000000	72	0.0000
Cultivated Land - Soil Type B	0.0685500	81	5.5526
Cultivated Land - Soil Type C	0.0685500	88	6.0324
Cultivated Land - Soil Type D	0.8803650	91	80.1132
Forest - Soil Type A	2.6996860	25	67.4922
Forest - Soil Type B	91.1689330	55	5014.2913
Forest - Soil Type C	63.1804330	70	4422.6303
Forest - Soil Type D	16.5103600	77	1271.2977
Open Space - Soil Type A	0.6526330	39	25.4527
Open Space - Soil Type B	0.9131650	61	55.7031
Open Space - Soil Type C	1.6288510	74	120.5350
Open Space - Soil Type D	0.5415190	80	43.3215
Open Water	0.2306420	98	22.6029
Residential - Soil Type A	2.4906710	51	127.0242
Residential - Soil Type B	4.3719895	68	297.2953
Residential - Soil Type C	8.4222135	79	665.3549
Residential - Soil Type D	1.5005030	84	126.0423
	195.3290640		12350.7414

Weighted CN: 63

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.05	35.3

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.07	4.27	840	3.3
Segment C - D	unpaved	0.01	1.61	4120	42.6

Total Tc = 81.1 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 12**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.6340950	72	45.6548
Cultivated Land - Soil Type B	0.0069025	81	0.5591
Cultivated Land - Soil Type C	0.2796655	88	24.6106
Cultivated Land - Soil Type D	0.1347230	91	12.2598
Forest - Soil Type A	2.6848930	25	67.1223
Forest - Soil Type B	6.1097505	55	336.0363
Forest - Soil Type C	10.8562465	70	759.9373
Forest - Soil Type D	4.3346270	77	333.7663
Open Water	2.5482710	98	249.7306
Residential - Soil Type A	1.5636160	51	79.7444
Residential - Soil Type B	1.0276765	68	69.8820
Residential - Soil Type C	4.7672715	79	376.6144
Residential - Soil Type D	0.1794950	84	15.0776
	35.1272330		2370.9954

Weighted CN: 67

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.086	28.4

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.056	3.82	920	4.0
Segment C - D	unpaved	0.012	1.77	1290	12.2

Total Tc = 44.6 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 13**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	15.0106400	55	825.5852
Forest - Soil Type C	16.3488900	70	1144.4223
Forest - Soil Type D	0.6096530	77	46.9433
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	1.6537130	88	145.5267
Industrial - Soil Type C	2.7249300	91	247.9686
Industrial - Soil Type D	0.2542820	93	23.6482
	36.6021080		2434.0944

Weighted CN: 67

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.053	34.5

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.11	5.35	700	2.2
Segment C - D	unpaved	0.01	1.61	2595	26.8

Total Tc = 63.5 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 14**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.0610400	72	4.3949
Cultivated Land - Soil Type B	0.0000000	81	0.0000
Cultivated Land - Soil Type C	0.1430460	88	12.5880
Cultivated Land - Soil Type D	0.0000000	91	0.0000
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.7424845	92	68.3086
Commercial - Soil Type C	0.6956585	94	65.3919
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	4.3478540	25	108.6964
Forest - Soil Type B	64.2755335	55	3535.1543
Forest - Soil Type C	35.1635835	70	2461.4508
Forest - Soil Type D	43.7558400	77	3369.1997
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	7.6404400	88	672.3587
Industrial - Soil Type C	13.8440500	91	1259.8086
Industrial - Soil Type D	0.8397800	93	78.0995
Open Space - Soil Type A	2.5349470	39	98.8629
Open Space - Soil Type B	5.6881740	61	346.9786
Open Space - Soil Type C	3.3474700	74	247.7128
Open Space - Soil Type D	0.5405180	80	43.2414
Residential - Soil Type A	0.4185010	51	21.3436
Residential - Soil Type B	2.8704970	68	195.1938
Residential - Soil Type C	1.4716380	79	116.2594
Residential - Soil Type D	0.8012590	84	67.3058
	189.1823140		12772.3497

Weighted CN: 68

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.086	28.4

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.11	5.35	825	2.6
Segment C - D	unpaved	0.01	1.61	3590	37.1
Segment E - F	unpaved	0.015	1.98	1900	16.0

Total Tc = 84.1 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 15**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	1.1053290	89	98.3743
Commercial - Soil Type B	2.7624160	92	254.1423
Commercial - Soil Type C	3.6066940	94	339.0292
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	1.4780120	25	36.9503
Forest - Soil Type B	7.0487515	55	387.6813
Forest - Soil Type C	11.6029625	70	812.2074
Forest - Soil Type D	0.0000000	77	0.0000
Open Space - Soil Type A	6.2413210	39	243.4115
Open Space - Soil Type B	4.3844480	61	267.4513
Open Space - Soil Type C	12.2569380	74	907.0134
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	0.7575120	98	74.2362
Residential - Soil Type A	2.8504210	51	145.3715
Residential - Soil Type B	1.2505335	68	85.0363
Residential - Soil Type C	1.6199555	79	127.9765
Residential - Soil Type D	0.0039260	84	0.3298
	56.9692200		3779.2112

Weighted CN: 66

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.12	24.9

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.11	5.35	225	0.7
Segment C - D	unpaved	0.013	1.84	2420	21.9

Total Tc = 47.5 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 16**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.0000000	72	0.0000
Cultivated Land - Soil Type B	0.0000000	81	0.0000
Cultivated Land - Soil Type C	0.0738820	88	6.5016
Cultivated Land - Soil Type D	0.0000000	91	0.0000
Commercial - Soil Type A	0.5998970	89	53.3908
Commercial - Soil Type B	6.2823150	92	577.9730
Commercial - Soil Type C	6.9572250	94	653.9792
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	1.0710070	25	26.7752
Forest - Soil Type B	25.8914065	55	1424.0274
Forest - Soil Type C	27.1233665	70	1898.6357
Forest - Soil Type D	3.3719570	77	259.6407
Open Space - Soil Type A	28.2593400	39	1102.1143
Open Space - Soil Type B	16.9178495	61	1031.9888
Open Space - Soil Type C	29.2607295	74	2165.2940
Open Space - Soil Type D	0.0000000	80	0.0000
Residential - Soil Type A	7.6001010	51	387.6052
Residential - Soil Type B	16.7912330	68	1141.8038
Residential - Soil Type C	17.5399530	79	1385.6563
Residential - Soil Type D	1.6941540	84	142.3089
	189.4344160		12257.6947

Weighted CN: 65

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.19	20.7

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.04	3.23	1395	7.2
Segment C - D	unpaved	0.005	1.14	3055	44.6

Total Tc = 72.5 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 17**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	58.8637300	55	3237.5052
Forest - Soil Type C	7.2655540	70	508.5888
Forest - Soil Type D	16.8892200	77	1300.4699
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	0.8738010	88	76.8945
Industrial - Soil Type C	0.0000000	91	0.0000
Industrial - Soil Type D	0.3864040	93	35.9356
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.0983860	61	6.0015
Open Space - Soil Type C	0.5108140	74	37.8002
Open Space - Soil Type D	0.2498860	80	19.9909
Open Water	2.3070120	98	226.0872
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	8.9858820	68	611.0400
Residential - Soil Type C	2.2805250	79	180.1615
Residential - Soil Type D	0.5916320	84	49.6971
	99.3028460		6290.1723

Weighted CN: 63

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.06	32.8

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.09	4.84	1150	4.0
Segment C - D	unpaved	0.01	1.61	3280	33.9

Total Tc = 70.7 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 18**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	67.5319475	55	3714.2571
Forest - Soil Type C	8.9334105	70	625.3387
Forest - Soil Type D	10.7447800	77	827.3481
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	2.3922210	88	210.5154
Industrial - Soil Type C	0.6760360	91	61.5193
Industrial - Soil Type D	1.8701820	93	173.9269
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	1.0169250	61	62.0324
Open Space - Soil Type C	0.3940770	74	29.1617
Open Space - Soil Type D	3.7764440	80	302.1155
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	12.0038800	68	816.2638
Residential - Soil Type C	0.0974100	79	7.6954
Residential - Soil Type D	0.2069950	84	17.3876
	109.6443080		6847.5620

Weighted CN: 62

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.09	27.9

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.12	5.59	505	1.5
Segment C - D	unpaved	0.011	1.69	4615	45.5

Total Tc = 74.9 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 19**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	56.7524920	55	3121.3871
Forest - Soil Type C	10.5942720	70	741.5990
Forest - Soil Type D	10.8942400	77	838.8565
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.9408105	61	57.3894
Open Space - Soil Type C	0.9948375	74	73.6180
Open Space - Soil Type D	6.1952120	80	495.6170
Open Water	3.8543420	98	377.7255
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	17.0980300	68	1162.6660
Residential - Soil Type C	2.7846000	79	219.9834
Residential - Soil Type D	0.3797200	84	31.8965
	110.4885560		7120.7384

Weighted CN: 64

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.1	26.8

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.064	4.08	1190	4.9
Segment C - D	unpaved	0.013	1.84	1430	13.0

Total Tc = 44.6 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 20**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	0.5878800	92	54.0850
Commercial - Soil Type C	0.8112100	94	76.2537
Commercial - Soil Type D	0.0089780	95	0.8529
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	6.0729415	55	334.0118
Forest - Soil Type C	4.2213490	70	295.4944
Forest - Soil Type D	7.7075540	77	593.4817
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	0.4432680	88	39.0076
Industrial - Soil Type C	0.3894590	91	35.4408
Industrial - Soil Type D	1.6570170	93	154.1026
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.0000000	61	0.0000
Open Space - Soil Type C	0.0000000	74	0.0000
Open Space - Soil Type D	0.0003650	80	0.0292
Open Water	0.3600720	98	35.2871
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	1.8431930	68	125.3371
Residential - Soil Type C	8.6666330	79	684.6640
Residential - Soil Type D	3.5837980	84	301.0390
	36.3537175		2729.0868

Weighted CN: 75

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.13	24.1

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.07	4.27	470	1.8
Segment C - D	unpaved	0.005	1.14	2085	30.5

Total Tc = 56.4 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

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Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 21**
Location:

Cover Type	Area, ac	CN	A x CN
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	30.9244700	55	1700.8459
Forest - Soil Type C	7.7738120	70	544.1668
Forest - Soil Type D	17.5871800	77	1354.2129
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.2626280	61	16.0203
Open Space - Soil Type C	0.1036110	74	7.6672
Open Space - Soil Type D	1.6182250	80	129.4580
Open Water	0.5985200	98	58.6550
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	14.9731800	68	1018.1762
Residential - Soil Type C	0.1875550	79	14.8168
Residential - Soil Type D	0.4614880	84	38.7650
	74.4906690		4882.7841

Weighted CN: 66

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.19	20.7

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.015	1.98	2355	19.9

Total Tc = 40.6 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 22**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	0.0000000	89	0.0000
Commercial - Soil Type B	1.6856195	92	155.0770
Commercial - Soil Type C	4.4715885	94	420.3293
Commercial - Soil Type D	1.0450260	95	99.2775
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	11.5052245	55	632.7873
Forest - Soil Type C	8.3242075	70	582.6945
Forest - Soil Type D	5.8662210	77	451.6990
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	1.6990270	61	103.6406
Open Space - Soil Type C	8.0298160	74	594.2064
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	0.2445050	98	23.9615
Residential - Soil Type A	0.0000000	51	0.0000
Residential - Soil Type B	5.1140770	68	347.7572
Residential - Soil Type C	20.2266740	79	1597.9072
Residential - Soil Type D	1.3563090	84	113.9300
	69.5682950		5123.2676

Weighted CN: 74

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.2	20.3

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.01	1.61	2640	27.3

Total Tc = 47.5 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 23**
Location:

Cover Type	Area, ac	CN	A x CN
Cultivated Land - Soil Type A	0.0000000	72	0.0000
Cultivated Land - Soil Type B	0.1615515	81	13.0857
Cultivated Land - Soil Type C	1.1720855	88	103.1435
Cultivated Land - Soil Type D	0.0000000	91	0.0000
Commercial - Soil Type A	1.0393830	89	92.5051
Commercial - Soil Type B	6.1427160	92	565.1299
Commercial - Soil Type C	14.1682360	94	1331.8142
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	1.1550670	25	28.8767
Forest - Soil Type B	31.1801290	55	1714.9071
Forest - Soil Type C	8.2102310	70	574.7162
Forest - Soil Type D	0.0000000	77	0.0000
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	0.0000000	88	0.0000
Industrial - Soil Type C	2.2760550	91	207.1210
Industrial - Soil Type D	0.0000000	93	0.0000
Open Space - Soil Type A	1.2117320	39	47.2575
Open Space - Soil Type B	0.0000000	61	0.0000
Open Space - Soil Type C	0.1933880	74	14.3107
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	1.9125480	98	187.4297
Residential - Soil Type A	17.9797300	51	916.9662
Residential - Soil Type B	21.4814870	68	1460.7411
Residential - Soil Type C	38.9467670	79	3076.7946
Residential - Soil Type D	0.0000000	84	0.0000
	147.2311060		10218.5700

Weighted CN: 69

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.013	60.5

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.017	2.10	2970	23.5

Total Tc = 84.0 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Existing Conditions CN & Tc Calculations**
Prepared By: **CRD** Date: **September 8, 2015**

Designation: **Area 24**
Location:

Cover Type	Area, ac	CN	A x CN
Commercial - Soil Type A	1.9172210	89	170.6327
Commercial - Soil Type B	4.5329700	92	417.0332
Commercial - Soil Type C	5.4558450	94	512.8494
Commercial - Soil Type D	0.0000000	95	0.0000
Forest - Soil Type A	0.0000000	25	0.0000
Forest - Soil Type B	26.7715400	55	1472.4347
Forest - Soil Type C	0.1550690	70	10.8548
Forest - Soil Type D	3.0804360	77	237.1936
Industrial - Soil Type A	0.0000000	81	0.0000
Industrial - Soil Type B	2.2327755	88	196.4842
Industrial - Soil Type C	2.2327755	91	203.1826
Industrial - Soil Type D	0.0000000	93	0.0000
Open Space - Soil Type A	0.0000000	39	0.0000
Open Space - Soil Type B	0.0024505	61	0.1495
Open Space - Soil Type C	0.3150935	74	23.3169
Open Space - Soil Type D	0.0000000	80	0.0000
Open Water	8.1189770	98	795.6597
Residential - Soil Type A	0.5921410	51	30.1992
Residential - Soil Type B	20.2509870	68	1377.0671
Residential - Soil Type C	11.8766070	79	938.2520
Residential - Soil Type D	0.0000000	84	0.0000
	87.5348880		6385.3097

Weighted CN: 73

Time of Concentration

(computed in accordance with ConnDOT Drainage Manual, Sec. 6C)

Overland				
Segment	**Surface "n"**	**Flow Length (ft.)**	**Slope (ft/ft)**	**Time (min.)**
Segment A - B	0.4	300	0.06	32.8

Shallow Concentrated Flow					
Segment		**Slope (ft/ft)**	**V (ft/s)**	**Length (ft)**	**Time (min.)**
Segment B - C	unpaved	0.165	6.55	230	0.6
Segment C - D	unpaved	0.017	2.10	3465	27.5

Total Tc = 60.9 Min.

Note: Overland time of concentration computed using "Kinematic Wave" equation
Gutter and pipe time of concentration computed using Manning's equation

H&H Memo Attachment B

Appendix A-3
Saw Mill Brook Culvert Summary

Culvert #	Stream	Street	Inlet Dimensions (ft)		Inlet Elevation	Doucet Inlet Elevation	Doucet Road Centerline	Top of Road	Outlet Dimensions (ft)		Outlet Elevation	Doucet Outlet Elevation	Top of Road	Length (ft)	# of Crossings	Culvert Type	Culvert	
			Width	Height					Width	Height							Material	Condition
2	Cedar Swamp	School Street	2.67	2.67	40.20	***39.20***	***44.90***	45.80	3.33	2.83	39.10	***39.30***	45.80	45.00	3	box culvert	Dry Stone	old
2a	Cedar Swamp	School Street	1.50	1.50	41.40	***40.00***	***44.70***	45.40	1.50	1.50	41.10	***40..7***	45.40			round culvert	clay pipie	
2b	Cedar Swamp	School Street	3.00	2.58	40.80	***39.50***	***39.10***	44.90	3.00	3.33	40.40	***39.10***	45.00			dry stone culvert box		
3	Sawmill Brook	School Street	15.35	6.58	40.10	***38.40***	***48.10***	50.10	15.35	6.58	40.20	***38.40***	48.90	58.00	1	open bottom arch	Metal	new
4	Sawmill Brook	Atwater Avenue	14.70	8.30		***37.70***	***48.10***		14.70	8.30		***37.70***		42.00	1	open bottom arch	Metal	old
5	Sawmill Brook	Conservation Winchester Drive	9.00	5.58	40.10			47.10	9.00	5.67	39.80		47.10	38.00	1	open bottom arch	Metal	rusted
6	Sawmill Brook	School Street	1.10	1.10	N/A			N/A	1.10	1.10	N/A		N/A	28.00	1	round culvert	Concrete	new
7	Cat Brook	Forrest Road	11.60	2.90	43.60			48.20	11.60	2.90	43.90		48.50	20.20	1	open bottom arch	Stone	old- collapsing
8	Cat Brook	Load Place	2.00	2.00	44.30			47.90	2.00	2.00	44.30		47.30	30.70	3	round culvert	Plastic	new
9	Sawmill Brook	Pine Street	2.92	2.92	N/A			N/A	2.92	2.92	N/A		N/A	42.00	2	round culvert	Metal	old
10	Sawmill Brook	Rockwood Heights	1.83	1.58	N/A				1.83	1.25	N/A		N/A	25.00	2	embedded round culvert	concrete/stone	old
11	Cat Brook	Mill Street	12.50	3.70	33.50			40.40	12.00	5.58	31.70		40.50	20.10	1	open bottom arch	concrete	
12	Sawmill Brook	Millet Lane	5.00	5.00	46.50			49.30	2.50	2.50	46.30		52.20	35.00	1	round culvert	Concrete/metal	rusty outlet
13	Sawmill Brook	The Plains	5.00	2.00	45.80			51.20	5.00	2.75	45.00		51.80	40.00	1	open bottom arch (actually round)	Concrete	new
15	Sawmill Brook	Blue Heron Lane	2.50	2.50	N/A			N/A	2.50	2.50	N/A		N/A	28.00	1	open bottom arch	concrete	new
16	Sawmill Brook	Golf Course	12.00	9.42	11.50			21.60	11.50	9.58	11.40		21.60	20.00	*1*	*open bottom box culvert*	*stone*	
17	Sawmill Brook	Lincoln Street	12.00	6.00		***8.70***	***17.30***		12.00	6.00		***8.60***		50.00	1	open bottom arch	stone	good

H&H Memo Attachment B

Table 2-1
Saw Mill Brook Culvert Summary

Culvert #	Stream	Street	Inlet Dimensions (ft)		Inlet Elevation	Doucet Inlet Elevation	Doucet Road Centerline	Top of Road	Outlet Dimensions (ft)		Outlet Elevation	Doucet Outlet Elevation	Top of Road	Length (ft)	# of Crossings	Culvert Type	Culvert	
			Width	Height					Width	Height							Material	Condition
18	Causeway Brook	Lincoln Street	14.50	3.67		***8.20***	***16.30***		13.00	3.67		***8.20***		60.00	1	open bottom arch	stone	old but good
19	Causeway Brook	School Street- Golf	8.33	4.50		***9.00***	***15.60***		7.75	4.08		***8.90***		41.25	1	open bottom arch	metal	old but good
20	Causeway Brook	Summer Street	8.17	4.25		***10.70***	***17.90***		10.25	4.92		***10.70***		15.00	1	open bottom arch	metal	old
21	Causeway Brook	Summer Street	5.42	3.10	N/A			N/A	5.42	3.10	N/A		N/A	59.25	1	box culvert	concrete	old
22	Sawmill Brook	Norwood Avenue	14.25	5.50		***7.50***	***16.00***		13.00	5.42		***7.50***		42.00	1	bridge with abutments	metal/stone	old
23	Sawmill Brook	School Street	8.76	4.67		***3.60***	***13.10***		8.92	4.83		***3.10***		36.00	2	open bottom arch	concrete/stone	old
24	Causeway Brook	Summer Street	3.58	2.10	N/A			N/A	1.58	1.58	N/A		N/A	60.15	1	upstream bridge with abutments, dowstream round culvert	concrete/plastic	old- rusted
25	Sawmill Brook	Central Street	16.00	6.67		***-0.04***	***10.60***		14.00	8.25		***-4.00***		42.00	1	open bottom arch	stone	old collapsing
26	Sawmill Brook	MassDOT Mill Street	14.70	8.10		***17.80***			14.70	8.10		***17.50***			1	bridge with abutments	concrete	old
27	Sawmill Brook	Mill Street	7.10	7.10		***16.20***	***24.40***		6.80	6.80		***15.60***		47.00	1	round culvert	metal	old
30	Sawmill Brook	MassDOT Rte 128	14.00	6.50	26.1			44.6	14	6.5	18.3		45,5	60	1	box culvert	concrete	
36	Sawmill Brook	Mass DOT Rte 128 ramp	14.00	8.00	31.4			53.8	14	8	31.4		51.6	60	1	box culvert	concrete	

Notes:
July 2015 Survey completed by Doucet Survey Associates. Horizontal datum reference NAD83/2011 Massachusetts State Plane, Verticle Datum NAVD88.
August 24, 20017 Survey completed by Corcoran Associates, Inc. Horizantal Reference NAD 83 (FT), Vertical Datum NGVD 29 (FT)
Reminder of information results of May 30, 2015, volunteer data collection in Manchester-by-the-Sea

Pond Report

H&H Memo Attachment B

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2015 by Autodesk, Inc. v10.4

Friday, 10 / 2 / 2015

Pond No. 1 - Pond 1

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 56.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	56.00	23,500	0	0
2.00	58.00	148,330	153,898	153,898
4.00	60.00	247,610	391,685	545,583

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 35.16	0.00	0.00	0.00
Span (in)	= 35.16	0.00	0.00	0.00
No. Barrels	= 2	0	0	0
Invert El. (ft)	= 56.00	0.00	0.00	0.00
Length (ft)	= 40.00	0.00	0.00	0.00
Slope (%)	= 2.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Contour)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	56.00	0.00	---	---	---	---	---	---	---	---	---	0.000
0.20	15,390	56.20	0.61 ic	---	---	---	---	---	---	---	---	---	0.611
0.40	30,780	56.40	2.38 ic	---	---	---	---	---	---	---	---	---	2.384
0.60	46,169	56.60	5.24 ic	---	---	---	---	---	---	---	---	---	5.240
0.80	61,559	56.80	9.12 ic	---	---	---	---	---	---	---	---	---	9.118
1.00	76,949	57.00	13.86 ic	---	---	---	---	---	---	---	---	---	13.86
1.20	92,339	57.20	19.43 ic	---	---	---	---	---	---	---	---	---	19.43
1.40	107,729	57.40	25.64 ic	---	---	---	---	---	---	---	---	---	25.64
1.60	123,119	57.60	32.45 ic	---	---	---	---	---	---	---	---	---	32.45
1.80	138,508	57.80	39.70 ic	---	---	---	---	---	---	---	---	---	39.70
2.00	153,898	58.00	47.22 ic	---	---	---	---	---	---	---	---	---	47.22
2.20	193,067	58.20	54.87 ic	---	---	---	---	---	---	---	---	---	54.87
2.40	232,235	58.40	62.37 ic	---	---	---	---	---	---	---	---	---	62.37
2.60	271,404	58.60	68.99 oc	---	---	---	---	---	---	---	---	---	68.99
2.80	310,572	58.80	72.03 oc	---	---	---	---	---	---	---	---	---	72.03
3.00	349,740	59.00	75.30 oc	---	---	---	---	---	---	---	---	---	75.30
3.20	388,909	59.20	83.50 oc	---	---	---	---	---	---	---	---	---	83.50
3.40	428,077	59.40	90.31 ic	---	---	---	---	---	---	---	---	---	90.31
3.60	467,246	59.60	94.86 ic	---	---	---	---	---	---	---	---	---	94.86
3.80	506,414	59.80	99.21 ic	---	---	---	---	---	---	---	---	---	99.21
4.00	545,583	60.00	103.37 ic	---	---	---	---	---	---	---	---	---	103.37

Pond Report

H&H Memo Attachment B

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2015 by Autodesk, Inc. v10.4 Friday, 10 / 9 / 2015

Pond No. 2 - Pond 2

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 38.40 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	38.40	00	0	0
3.60	42.00	890,820	1,068,877	1,068,877
5.60	44.00	3,846,995	4,392,245	5,461,122
7.60	46.00	4,733,124	8,563,968	14,025,090
9.60	48.00	5,262,020	9,989,478	24,014,568
11.60	50.00	5,717,121	10,974,896	34,989,464
13.60	52.00	6,237,440	11,949,588	46,939,052

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 78.96	0.00	0.00	0.00
Span (in)	= 184.20	0.00	0.00	0.00
No. Barrels	= 1	1	0	0
Invert El. (ft)	= 38.40	0.00	0.00	0.00
Length (ft)	= 58.00	0.00	0.00	0.00
Slope (%)	= 0.10	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 150.00	0.00	0.00	0.00
Crest El. (ft)	= 50.00	0.00	0.00	0.00
Weir Coeff.	= 2.60	3.33	3.33	3.33
Weir Type	= Broad	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Contour)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	38.40	0.00	---	---	---	0.00	---	---	---	---	---	0.000
0.36	106,888	38.76	6.53 oc	---	---	---	0.00	---	---	---	---	---	6.529
0.72	213,775	39.12	15.12 oc	---	---	---	0.00	---	---	---	---	---	15.12
1.08	320,663	39.48	23.84 oc	---	---	---	0.00	---	---	---	---	---	23.84
1.44	427,551	39.84	32.57 oc	---	---	---	0.00	---	---	---	---	---	32.57
1.80	534,439	40.20	41.29 oc	---	---	---	0.00	---	---	---	---	---	41.29
2.16	641,326	40.56	50.01 oc	---	---	---	0.00	---	---	---	---	---	50.01
2.52	748,214	40.92	58.71 oc	---	---	---	0.00	---	---	---	---	---	58.71
2.88	855,102	41.28	67.41 oc	---	---	---	0.00	---	---	---	---	---	67.41
3.24	961,989	41.64	76.11 oc	---	---	---	0.00	---	---	---	---	---	76.11
3.60	1,068,877	42.00	84.80 oc	---	---	---	0.00	---	---	---	---	---	84.80
3.80	1,508,102	42.20	89.62 oc	---	---	---	0.00	---	---	---	---	---	89.62
4.00	1,947,326	42.40	94.45 oc	---	---	---	0.00	---	---	---	---	---	94.45
4.20	2,386,551	42.60	99.27 oc	---	---	---	0.00	---	---	---	---	---	99.27
4.40	2,825,775	42.80	104.10 oc	---	---	---	0.00	---	---	---	---	---	104.10
4.60	3,265,000	43.00	108.92 oc	---	---	---	0.00	---	---	---	---	---	108.92
4.80	3,704,224	43.20	113.74 oc	---	---	---	0.00	---	---	---	---	---	113.74
5.00	4,143,449	43.40	118.56 oc	---	---	---	0.00	---	---	---	---	---	118.56
5.20	4,582,673	43.60	123.39 oc	---	---	---	0.00	---	---	---	---	---	123.39
5.40	5,021,898	43.80	128.21 oc	---	---	---	0.00	---	---	---	---	---	128.21
5.60	5,461,122	44.00	133.03 oc	---	---	---	0.00	---	---	---	---	---	133.03
5.80	6,317,519	44.20	137.85 oc	---	---	---	0.00	---	---	---	---	---	137.85
6.00	7,173,916	44.40	142.67 oc	---	---	---	0.00	---	---	---	---	---	142.67
6.20	8,030,313	44.60	147.49 oc	---	---	---	0.00	---	---	---	---	---	147.49
6.40	8,886,709	44.80	152.31 oc	---	---	---	0.00	---	---	---	---	---	152.31
6.60	9,743,106	45.00	179.32 oc	---	---	---	0.00	---	---	---	---	---	179.32
6.80	10,599,503	45.20	338.53 oc	---	---	---	0.00	---	---	---	---	---	338.53
7.00	11,455,900	45.40	443.90 oc	---	---	---	0.00	---	---	---	---	---	443.90
7.20	12,312,297	45.60	528.67 oc	---	---	---	0.00	---	---	---	---	---	528.67
7.40	13,168,694	45.80	601.61 oc	---	---	---	0.00	---	---	---	---	---	601.61
7.60	14,025,090	46.00	666.62 oc	---	---	---	0.00	---	---	---	---	---	666.62
7.80	15,024,038	46.20	725.83 oc	---	---	---	0.00	---	---	---	---	---	725.83
8.00	16,022,986	46.40	780.56 oc	---	---	---	0.00	---	---	---	---	---	780.56
8.20	17,021,934	46.60	831.70 oc	---	---	---	0.00	---	---	---	---	---	831.70

Continues on next page...

Curve 2

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
8.40	18,020,882	46.80	879.87 oc	---	---	---	0.00	---	---	---	---	---	879.87
8.60	19,019,830	47.00	925.53 oc	---	---	---	0.00	---	---	---	---	---	925.53
8.80	20,018,778	47.20	969.05 oc	---	---	---	0.00	---	---	---	---	---	969.05
9.00	21,017,726	47.40	1010.70 oc	---	---	---	0.00	---	---	---	---	---	1010.70
9.20	22,016,674	47.60	1050.69 oc	---	---	---	0.00	---	---	---	---	---	1050.69
9.40	23,015,622	47.80	1089.22 oc	---	---	---	0.00	---	---	---	---	---	1089.22
9.60	24,014,568	48.00	1126.43 oc	---	---	---	0.00	---	---	---	---	---	1126.43
9.80	25,112,058	48.20	1162.45 oc	---	---	---	0.00	---	---	---	---	---	1162.45
10.00	26,209,548	48.40	1197.39 oc	---	---	---	0.00	---	---	---	---	---	1197.39
10.20	27,307,038	48.60	1231.33 oc	---	---	---	0.00	---	---	---	---	---	1231.33
10.40	28,404,528	48.80	1264.37 oc	---	---	---	0.00	---	---	---	---	---	1264.37
10.60	29,502,018	49.00	1296.56 oc	---	---	---	0.00	---	---	---	---	---	1296.56
10.80	30,599,508	49.20	1327.97 oc	---	---	---	0.00	---	---	---	---	---	1327.97
11.00	31,696,998	49.40	1350.38 ic	---	---	---	0.00	---	---	---	---	---	1350.38
11.20	32,794,488	49.60	1367.78 ic	---	---	---	0.00	---	---	---	---	---	1367.78
11.40	33,891,976	49.80	1384.97 ic	---	---	---	0.00	---	---	---	---	---	1384.97
11.60	34,989,464	50.00	1401.94 ic	---	---	---	0.00	---	---	---	---	---	1401.94
11.80	36,184,424	50.20	1418.71 ic	---	---	---	34.88	---	---	---	---	---	1453.59
12.00	37,379,384	50.40	1435.28 ic	---	---	---	98.66	---	---	---	---	---	1533.95
12.20	38,574,344	50.60	1451.67 ic	---	---	---	181.26	---	---	---	---	---	1632.92
12.40	39,769,304	50.80	1467.87 ic	---	---	---	279.06	---	---	---	---	---	1746.93
12.60	40,964,264	51.00	1483.90 ic	---	---	---	390.00	---	---	---	---	---	1873.90
12.80	42,159,224	51.20	1499.75 ic	---	---	---	512.67	---	---	---	---	---	2012.42
13.00	43,354,184	51.40	1515.44 ic	---	---	---	646.04	---	---	---	---	---	2161.48
13.20	44,549,144	51.60	1530.97 ic	---	---	---	789.31	---	---	---	---	---	2320.27
13.40	45,744,104	51.80	1546.34 ic	---	---	---	941.84	---	---	---	---	---	2488.17
13.60	46,939,052	52.00	1561.56 ic	---	---	---	1103.09	---	---	---	---	---	2664.64

...End

Pond Report

H&H Memo Attachment B

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2015 by Autodesk, Inc. v10.4 Friday, 10 / 2 / 2015

Pond No. 3 - Pond 3

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 37.70 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	37.70	8,961	0	0
4.30	42.00	896,992	1,426,895	1,426,895
6.30	44.00	1,270,225	2,156,208	3,583,103
8.30	46.00	1,403,064	2,671,921	6,255,024
10.30	48.00	1,728,489	3,125,588	9,380,612

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 99.60	0.00	0.00	0.00
Span (in)	= 176.40	0.00	0.00	0.00
No. Barrels	= 1	0	0	0
Invert El. (ft)	= 37.70	0.00	0.00	0.00
Length (ft)	= 42.00	0.00	0.00	0.00
Slope (%)	= 1.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Contour)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	37.70	0.00	---	---	---	---	---	---	---	---	---	0.000
0.43	142,690	38.13	14.11 ic	---	---	---	---	---	---	---	---	---	14.11
0.86	285,379	38.56	39.92 ic	---	---	---	---	---	---	---	---	---	39.92
1.29	428,068	38.99	73.33 ic	---	---	---	---	---	---	---	---	---	73.33
1.72	570,758	39.42	102.92 oc	---	---	---	---	---	---	---	---	---	102.92
2.15	713,447	39.85	129.76 oc	---	---	---	---	---	---	---	---	---	129.76
2.58	856,137	40.28	156.57 oc	---	---	---	---	---	---	---	---	---	156.57
3.01	998,826	40.71	183.36 oc	---	---	---	---	---	---	---	---	---	183.36
3.44	1,141,516	41.14	210.14 oc	---	---	---	---	---	---	---	---	---	210.14
3.87	1,284,205	41.57	236.90 oc	---	---	---	---	---	---	---	---	---	236.90
4.30	1,426,895	42.00	263.66 oc	---	---	---	---	---	---	---	---	---	263.66
4.50	1,642,516	42.20	276.10 oc	---	---	---	---	---	---	---	---	---	276.10
4.70	1,858,136	42.40	288.55 oc	---	---	---	---	---	---	---	---	---	288.55
4.90	2,073,757	42.60	300.99 oc	---	---	---	---	---	---	---	---	---	300.99
5.10	2,289,378	42.80	313.43 oc	---	---	---	---	---	---	---	---	---	313.43
5.30	2,504,999	43.00	325.87 oc	---	---	---	---	---	---	---	---	---	325.87
5.50	2,720,620	43.20	338.30 oc	---	---	---	---	---	---	---	---	---	338.30
5.70	2,936,240	43.40	350.74 oc	---	---	---	---	---	---	---	---	---	350.74
5.90	3,151,861	43.60	363.18 oc	---	---	---	---	---	---	---	---	---	363.18
6.10	3,367,482	43.80	375.61 oc	---	---	---	---	---	---	---	---	---	375.61
6.30	3,583,103	44.00	388.05 oc	---	---	---	---	---	---	---	---	---	388.05
6.50	3,850,295	44.20	400.48 oc	---	---	---	---	---	---	---	---	---	400.48
6.70	4,117,487	44.40	412.92 oc	---	---	---	---	---	---	---	---	---	412.92
6.90	4,384,679	44.60	425.35 oc	---	---	---	---	---	---	---	---	---	425.35
7.10	4,651,871	44.80	437.79 oc	---	---	---	---	---	---	---	---	---	437.79
7.30	4,919,063	45.00	450.22 oc	---	---	---	---	---	---	---	---	---	450.22
7.50	5,186,255	45.20	462.65 oc	---	---	---	---	---	---	---	---	---	462.65
7.70	5,453,447	45.40	475.08 oc	---	---	---	---	---	---	---	---	---	475.08
7.90	5,720,639	45.60	487.52 oc	---	---	---	---	---	---	---	---	---	487.52
8.10	5,987,831	45.80	499.95 oc	---	---	---	---	---	---	---	---	---	499.95
8.30	6,255,024	46.00	512.38 oc	---	---	---	---	---	---	---	---	---	512.38
8.50	6,567,583	46.20	618.01 oc	---	---	---	---	---	---	---	---	---	618.01
8.70	6,880,142	46.40	710.73 oc	---	---	---	---	---	---	---	---	---	710.73
8.90	7,192,701	46.60	792.68 oc	---	---	---	---	---	---	---	---	---	792.68
9.10	7,505,260	46.80	866.92 oc	---	---	---	---	---	---	---	---	---	866.92
9.30	7,817,819	47.00	935.28 oc	---	---	---	---	---	---	---	---	---	935.28

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H&H Memo Attachment B

Pond 3

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
9.50	8,130,378	47.20	998.98 oc	---	---	---	---	---	---	---	---	---	998.98
9.70	8,442,936	47.40	1058.85 oc	---	---	---	---	---	---	---	---	---	1058.85
9.90	8,755,495	47.60	1115.52 oc	---	---	---	---	---	---	---	---	---	1115.52
10.10	9,068,054	47.80	1169.44 oc	---	---	---	---	---	---	---	---	---	1169.44
10.30	9,380,612	48.00	1220.97 oc	---	---	---	---	---	---	---	---	---	1220.97

...End

Pond Report

H&H Memo Attachment B

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2015 by Autodesk, Inc. v10.4 Friday, 10 / 2 / 2015

Pond No. 4 - Pond 4

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 32.80 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	32.80	00	0	0
1.20	34.00	5,000	2,000	2,000
3.20	36.00	13,887	18,145	20,145
5.20	38.00	103,621	103,618	123,762
7.20	40.00	262,510	354,005	477,767
9.20	42.00	262,510	524,967	1,002,734

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 44.40	0.00	0.00	0.00
Span (in)	= 150.00	0.00	0.00	0.00
No. Barrels	= 1	0	0	0
Invert El. (ft)	= 32.80	0.00	0.00	0.00
Length (ft)	= 20.00	0.00	0.00	0.00
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	32.80	0.00	---	---	---	---	---	---	---	---	---	0.000
0.12	200	32.92	1.77 ic	---	---	---	---	---	---	---	---	---	1.769
0.24	400	33.04	5.00 ic	---	---	---	---	---	---	---	---	---	5.004
0.36	600	33.16	8.26 oc	---	---	---	---	---	---	---	---	---	8.261
0.48	800	33.28	11.39 oc	---	---	---	---	---	---	---	---	---	11.39
0.60	1,000	33.40	14.52 oc	---	---	---	---	---	---	---	---	---	14.52
0.72	1,200	33.52	17.64 oc	---	---	---	---	---	---	---	---	---	17.64
0.84	1,400	33.64	20.77 oc	---	---	---	---	---	---	---	---	---	20.77
0.96	1,600	33.76	23.89 oc	---	---	---	---	---	---	---	---	---	23.89
1.08	1,800	33.88	27.00 oc	---	---	---	---	---	---	---	---	---	27.00
1.20	2,000	34.00	30.12 oc	---	---	---	---	---	---	---	---	---	30.12
1.40	3,814	34.20	35.31 oc	---	---	---	---	---	---	---	---	---	35.31
1.60	5,629	34.40	40.49 oc	---	---	---	---	---	---	---	---	---	40.49
1.80	7,443	34.60	45.67 oc	---	---	---	---	---	---	---	---	---	45.67
2.00	9,258	34.80	50.85 oc	---	---	---	---	---	---	---	---	---	50.85
2.20	11,072	35.00	56.03 oc	---	---	---	---	---	---	---	---	---	56.03
2.40	12,887	35.20	61.21 oc	---	---	---	---	---	---	---	---	---	61.21
2.60	14,701	35.40	66.38 oc	---	---	---	---	---	---	---	---	---	66.38
2.80	16,516	35.60	71.55 oc	---	---	---	---	---	---	---	---	---	71.55
3.00	18,330	35.80	76.73 oc	---	---	---	---	---	---	---	---	---	76.73
3.20	20,145	36.00	81.90 oc	---	---	---	---	---	---	---	---	---	81.90
3.40	30,506	36.20	87.07 oc	---	---	---	---	---	---	---	---	---	87.07
3.60	40,868	36.40	92.24 oc	---	---	---	---	---	---	---	---	---	92.24
3.80	51,230	36.60	132.85 oc	---	---	---	---	---	---	---	---	---	132.85
4.00	61,592	36.80	187.88 oc	---	---	---	---	---	---	---	---	---	187.88
4.20	71,953	37.00	230.10 oc	---	---	---	---	---	---	---	---	---	230.10
4.40	82,315	37.20	265.70 oc	---	---	---	---	---	---	---	---	---	265.70
4.60	92,677	37.40	297.06 oc	---	---	---	---	---	---	---	---	---	297.06
4.80	103,039	37.60	325.41 oc	---	---	---	---	---	---	---	---	---	325.41
5.00	113,400	37.80	351.49 oc	---	---	---	---	---	---	---	---	---	351.49
5.20	123,762	38.00	375.76 oc	---	---	---	---	---	---	---	---	---	375.76
5.40	159,163	38.20	398.55 oc	---	---	---	---	---	---	---	---	---	398.55
5.60	194,563	38.40	420.11 oc	---	---	---	---	---	---	---	---	---	420.11
5.80	229,964	38.60	440.61 oc	---	---	---	---	---	---	---	---	---	440.61
6.00	265,364	38.80	453.66 ic	---	---	---	---	---	---	---	---	---	453.66

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H&H Memo Attachment B

Pond 4

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
6.20	300,764	39.00	464.46 ic	---	---	---	---	---	---	---	---	---	464.46
6.40	336,165	39.20	475.02 ic	---	---	---	---	---	---	---	---	---	475.02
6.60	371,565	39.40	485.35 ic	---	---	---	---	---	---	---	---	---	485.35
6.80	406,966	39.60	495.46 ic	---	---	---	---	---	---	---	---	---	495.46
7.00	442,366	39.80	505.37 ic	---	---	---	---	---	---	---	---	---	505.37
7.20	477,767	40.00	515.09 ic	---	---	---	---	---	---	---	---	---	515.09
7.40	530,263	40.20	524.63 ic	---	---	---	---	---	---	---	---	---	524.63
7.60	582,760	40.40	534.00 ic	---	---	---	---	---	---	---	---	---	534.00
7.80	635,257	40.60	543.21 ic	---	---	---	---	---	---	---	---	---	543.21
8.00	687,754	40.80	552.26 ic	---	---	---	---	---	---	---	---	---	552.26
8.20	740,250	41.00	561.17 ic	---	---	---	---	---	---	---	---	---	561.17
8.40	792,747	41.20	569.94 ic	---	---	---	---	---	---	---	---	---	569.94
8.60	845,244	41.40	578.57 ic	---	---	---	---	---	---	---	---	---	578.57
8.80	897,741	41.60	587.08 ic	---	---	---	---	---	---	---	---	---	587.08
9.00	950,237	41.80	595.47 ic	---	---	---	---	---	---	---	---	---	595.47
9.20	1,002,734	42.00	603.74 ic	---	---	---	---	---	---	---	---	---	603.74

...End

Pond Report

H&H Memo Attachment B

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2015 by Autodesk, Inc. v10.4 Friday, 10 / 2 / 2015

Pond No. 5 - Pond 5

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 10.70 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	10.70	00	0	0
3.30	14.00	13,888	15,275	15,275
5.30	16.00	1,450,420	1,070,717	1,085,992
7.30	18.00	2,260,770	3,680,971	4,766,963

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 51.00	0.00	0.00	0.00
Span (in)	= 98.04	0.00	0.00	0.00
No. Barrels	= 1	0	0	0
Invert El. (ft)	= 10.70	0.00	0.00	0.00
Length (ft)	= 15.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	10.70	0.00	---	---	---	---	---	---	---	---	---	0.000
0.33	1,528	11.03	5.27 ic	---	---	---	---	---	---	---	---	---	5.273
0.66	3,055	11.36	14.91 ic	---	---	---	---	---	---	---	---	---	14.91
0.99	4,583	11.69	27.40 ic	---	---	---	---	---	---	---	---	---	27.40
1.32	6,110	12.02	42.19 ic	---	---	---	---	---	---	---	---	---	42.19
1.65	7,638	12.35	58.96 ic	---	---	---	---	---	---	---	---	---	58.96
1.98	9,165	12.68	77.50 ic	---	---	---	---	---	---	---	---	---	77.50
2.31	10,693	13.01	97.66 ic	---	---	---	---	---	---	---	---	---	97.66
2.64	12,220	13.34	119.32 ic	---	---	---	---	---	---	---	---	---	119.32
2.97	13,748	13.67	142.38 ic	---	---	---	---	---	---	---	---	---	142.38
3.30	15,275	14.00	166.75 ic	---	---	---	---	---	---	---	---	---	166.75
3.50	122,347	14.20	182.14 ic	---	---	---	---	---	---	---	---	---	182.14
3.70	229,419	14.40	197.97 ic	---	---	---	---	---	---	---	---	---	197.97
3.90	336,490	14.60	214.24 ic	---	---	---	---	---	---	---	---	---	214.24
4.10	443,562	14.80	230.93 ic	---	---	---	---	---	---	---	---	---	230.93
4.30	550,634	15.00	50.09 oc	---	---	---	---	---	---	---	---	---	50.09
4.50	657,705	15.20	112.01 oc	---	---	---	---	---	---	---	---	---	112.01
4.70	764,777	15.40	150.28 oc	---	---	---	---	---	---	---	---	---	150.28
4.90	871,849	15.60	180.61 oc	---	---	---	---	---	---	---	---	---	180.61
5.10	978,920	15.80	206.54 oc	---	---	---	---	---	---	---	---	---	206.54
5.30	1,085,992	16.00	229.56 oc	---	---	---	---	---	---	---	---	---	229.56
5.50	1,454,089	16.20	250.47 oc	---	---	---	---	---	---	---	---	---	250.47
5.70	1,822,186	16.40	269.76 oc	---	---	---	---	---	---	---	---	---	269.76
5.90	2,190,283	16.60	287.77 oc	---	---	---	---	---	---	---	---	---	287.77
6.10	2,558,380	16.80	304.71 oc	---	---	---	---	---	---	---	---	---	304.71
6.30	2,926,477	17.00	320.76 oc	---	---	---	---	---	---	---	---	---	320.76
6.50	3,294,574	17.20	336.04 oc	---	---	---	---	---	---	---	---	---	336.04
6.70	3,662,671	17.40	350.65 oc	---	---	---	---	---	---	---	---	---	350.65
6.90	4,030,768	17.60	364.69 oc	---	---	---	---	---	---	---	---	---	364.69
7.10	4,398,866	17.80	372.91 ic	---	---	---	---	---	---	---	---	---	372.91
7.30	4,766,963	18.00	380.33 ic	---	---	---	---	---	---	---	---	---	380.33

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APPENDIX B

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Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	70.772 degrees West
Latitude	42.575 degrees North
Elevation	Unknown/Unavailable
Date/Time	Sat, 19 Sep 2015 14:15:15 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.27	0.41	0.51	0.67	0.84	1.06	**1yr**	0.72	0.98	1.24	1.60	2.08	2.72	3.00	**1yr**	2.41	2.88	3.31	4.01	4.70	**1yr**
2yr	0.33	0.51	0.64	0.84	1.06	1.34	**2yr**	0.91	1.24	1.56	1.99	2.53	3.25	3.61	**2yr**	2.87	3.47	3.99	4.75	5.39	**2yr**
5yr	0.39	0.61	0.77	1.03	1.32	1.69	**5yr**	1.14	1.56	1.97	2.51	3.21	4.09	4.61	**5yr**	3.62	4.43	5.08	6.01	6.77	**5yr**
10yr	0.44	0.69	0.88	1.19	1.55	2.00	**10yr**	1.34	1.86	2.35	3.01	3.83	4.88	5.56	**10yr**	4.32	5.34	6.10	7.18	8.05	**10yr**
25yr	0.52	0.83	1.05	1.45	1.92	2.51	**25yr**	1.66	2.34	2.96	3.79	4.85	6.16	7.11	**25yr**	5.45	6.84	7.79	9.10	10.14	**25yr**
50yr	0.58	0.93	1.20	1.68	2.27	3.00	**50yr**	1.96	2.78	3.55	4.56	5.80	7.34	8.58	**50yr**	6.50	8.25	9.37	10.89	12.07	**50yr**
100yr	0.67	1.08	1.39	1.97	2.68	3.56	**100yr**	2.31	3.32	4.22	5.43	6.93	8.77	10.35	**100yr**	7.76	9.96	11.28	13.04	14.38	**100yr**
200yr	0.75	1.23	1.60	2.29	3.17	4.24	**200yr**	2.73	3.95	5.04	6.50	8.29	10.47	12.49	**200yr**	9.26	12.01	13.58	15.61	17.14	**200yr**
500yr	0.91	1.49	1.95	2.82	3.95	5.32	**500yr**	3.41	4.98	6.35	8.21	10.48	13.24	16.03	**500yr**	11.72	15.41	17.36	19.82	21.62	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.23	0.35	0.43	0.58	0.71	0.84	**1yr**	0.62	0.82	1.04	1.43	1.83	2.42	2.65	**1yr**	2.14	2.54	2.93	3.56	4.19	**1yr**
2yr	0.32	0.49	0.60	0.82	1.01	1.23	**2yr**	0.87	1.20	1.41	1.85	2.37	3.13	3.47	**2yr**	2.77	3.34	3.85	4.60	5.21	**2yr**
5yr	0.37	0.56	0.70	0.96	1.22	1.46	**5yr**	1.06	1.43	1.66	2.15	2.76	3.72	4.20	**5yr**	3.29	4.04	4.64	5.54	6.23	**5yr**
10yr	0.41	0.62	0.77	1.08	1.40	1.67	**10yr**	1.21	1.64	1.88	2.41	3.09	4.25	4.83	**10yr**	3.76	4.64	5.34	6.34	7.10	**10yr**

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25yr	0.46	0.71	0.88	1.25	1.65	1.98	**25yr**	1.42	1.94	2.21	2.80	3.57	5.08	5.79	**25yr**	4.49	5.57	6.42	7.57	8.34	**25yr**
50yr	0.51	0.77	0.96	1.39	1.87	2.26	**50yr**	1.61	2.21	2.50	3.12	3.98	5.83	6.63	**50yr**	5.16	6.37	7.37	8.66	9.70	**50yr**
100yr	0.57	0.86	1.07	1.55	2.13	2.56	**100yr**	1.84	2.51	2.82	3.49	4.42	6.69	7.59	**100yr**	5.92	7.29	8.46	9.92	11.01	**100yr**
200yr	0.63	0.95	1.20	1.74	2.42	2.92	**200yr**	2.09	2.86	3.19	3.88	4.89	7.70	8.71	**200yr**	6.81	8.38	9.73	11.36	12.46	**200yr**
500yr	0.73	1.08	1.39	2.02	2.88	3.48	**500yr**	2.48	3.40	3.76	4.47	5.61	9.30	10.47	**500yr**	8.23	10.07	11.73	13.63	14.69	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.30	0.46	0.56	0.75	0.93	1.08	**1yr**	0.80	1.06	1.34	1.72	2.21	2.99	3.35	**1yr**	2.65	3.22	3.71	4.34	5.18	**1yr**
2yr	0.35	0.54	0.67	0.90	1.11	1.33	**2yr**	0.96	1.30	1.53	2.02	2.59	3.40	3.78	**2yr**	3.01	3.63	4.17	4.98	5.63	**2yr**
5yr	0.42	0.65	0.81	1.11	1.42	1.74	**5yr**	1.22	1.70	2.00	2.65	3.39	4.49	5.04	**5yr**	3.97	4.85	5.52	6.51	7.31	**5yr**
10yr	0.51	0.78	0.96	1.35	1.74	2.14	**10yr**	1.50	2.09	2.45	3.27	4.16	5.55	6.31	**10yr**	4.91	6.07	6.87	8.04	8.97	**10yr**
25yr	0.64	0.98	1.22	1.74	2.29	2.82	**25yr**	1.98	2.76	3.22	4.33	5.48	7.34	8.52	**25yr**	6.49	8.19	9.18	10.60	11.77	**25yr**
50yr	0.77	1.17	1.46	2.09	2.82	3.49	**50yr**	2.43	3.41	3.96	5.36	6.77	9.06	10.70	**50yr**	8.01	10.29	11.43	13.08	14.18	**50yr**
100yr	0.93	1.40	1.76	2.54	3.48	4.30	**100yr**	3.00	4.20	4.87	6.64	8.37	11.17	13.45	**100yr**	9.88	12.93	14.26	16.16	17.40	**100yr**
200yr	1.11	1.67	2.12	3.07	4.28	5.32	**200yr**	3.70	5.20	6.00	8.24	10.34	13.75	16.90	**200yr**	12.17	16.25	17.79	20.00	21.36	**200yr**
500yr	1.43	2.12	2.73	3.96	5.64	7.02	**500yr**	4.87	6.86	7.91	10.98	13.73	18.14	22.78	**500yr**	16.06	21.90	23.75	26.49	28.05	**500yr**

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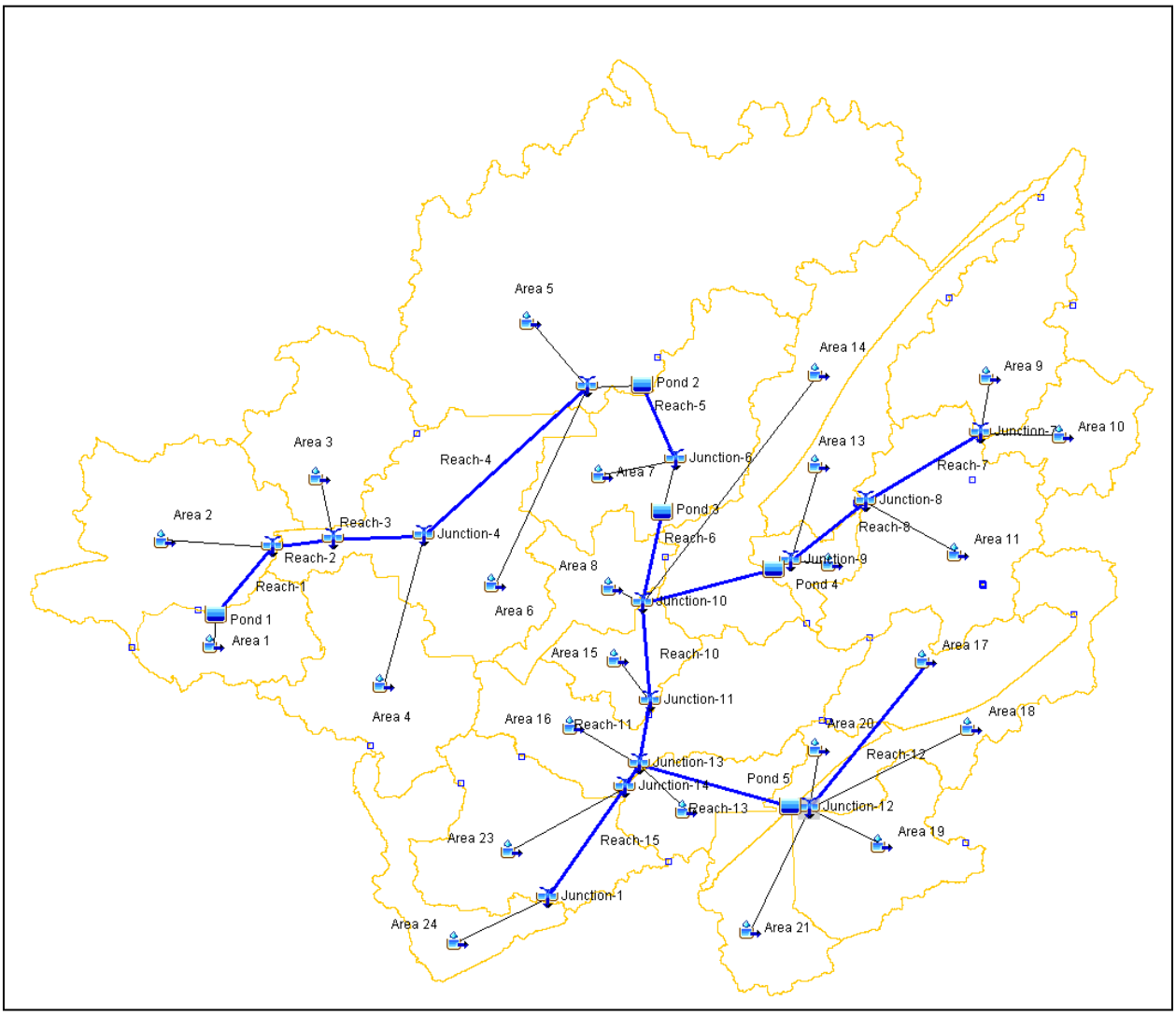
HEC-HMS

Project: MBTS

Basin Model : MBTS Watershed – Normal

Oct 09 13:58:03 EDT 2015



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Project: MBTS Simulation Run: 2015 - 025 yr

Start of Run: 19Sep2015, 00:00
End of Run: 20Sep2015, 00:01
Compute Time: 29Sep2015, 16:28:52

NOTE: The original report included multiple model runs, for simplicity only one example was included for this appendix (using precipitation values from the NRCC). The full report can be provided upon request

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Area 5	0.9149000	409.0	19Sep2015, 13:17	2.14
Area 2	0.2143070	146.6	19Sep2015, 12:52	2.52
Area 1	0.1202500	130.4	19Sep2015, 12:27	2.72
Pond 1	0.1202500	56.7	19Sep2015, 12:59	2.68
Reach-1	0.1202500	56.7	19Sep2015, 13:12	2.65
Junction-2	0.3345570	199.7	19Sep2015, 12:55	2.57
Reach-2	0.3345570	199.6	19Sep2015, 12:57	2.56
Area 3	0.1890000	114.7	19Sep2015, 12:43	2.00
Junction-3	0.5235570	304.5	19Sep2015, 12:51	2.36
Reach-3	0.5235570	304.4	19Sep2015, 12:53	2.35
Area 4	0.2384815	154.2	19Sep2015, 12:47	2.26
Junction-4	0.7620385	456.6	19Sep2015, 12:51	2.32
Reach-4	0.7620385	456.5	19Sep2015, 13:00	2.30
Area 6	0.3474700	215.2	19Sep2015, 13:11	2.78
Junction-5	2.0244085	1054.8	19Sep2015, 13:07	2.31
Pond 2	2.0244085	198.1	19Sep2015, 16:34	1.37
Reach-5	2.0244085	198.1	19Sep2015, 16:40	1.35
Area 7	0.3110400	294.5	19Sep2015, 12:35	2.72
Junction-6	2.3354485	349.4	19Sep2015, 12:44	1.53
Pond 3	2.3354485	212.7	19Sep2015, 17:34	1.39
Reach-6	2.3354485	212.7	19Sep2015, 17:38	1.38
Area 9	0.2393600	136.1	19Sep2015, 12:47	2.00
Area 10	0.1111700	85.5	19Sep2015, 12:31	2.09
Junction-7	0.3505300	207.7	19Sep2015, 12:40	2.03
Reach-7	0.3505300	207.5	19Sep2015, 12:49	2.00
Area 11	0.3052000	161.7	19Sep2015, 13:04	2.24
Junction-8	0.6557300	359.7	19Sep2015, 12:55	2.11

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Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Reach-8	0.6557300	359.6	19Sep2015, 12:59	2.11
Area 13	0.0571908	45.1	19Sep2015, 12:44	2.62
Area 12	0.0548863	52.6	19Sep2015, 12:32	2.63
Junction-9	0.7678071	432.3	19Sep2015, 12:55	2.18
Pond 4	0.7678071	394.0	19Sep2015, 13:10	2.18
Reach-9	0.7678071	394.0	19Sep2015, 13:13	2.17
Area 14	0.2956000	203.8	19Sep2015, 12:57	2.70
Area 8	0.1103443	112.8	19Sep2015, 12:28	2.63
Junction-10	3.5091999	774.7	19Sep2015, 13:04	1.71
Reach-10	3.5091999	774.7	19Sep2015, 13:08	1.69
Area 15	0.0890144	79.4	19Sep2015, 12:34	2.53
Junction-11	3.5982143	815.7	19Sep2015, 13:03	1.71
Reach-11	3.5982143	815.7	19Sep2015, 13:19	1.67
Area 19	0.1726400	146.4	19Sep2015, 12:32	2.36
Area 18	0.1713200	98.8	19Sep2015, 12:53	2.16
Area 17	0.1551600	97.1	19Sep2015, 12:50	2.25
Reach-12	0.1551600	97.0	19Sep2015, 12:56	2.24
Area 21	0.1163900	112.3	19Sep2015, 12:29	2.54
Area 20	0.0568027	62.9	19Sep2015, 12:38	3.38
Junction-12	0.6723127	465.5	19Sep2015, 12:39	2.40
Pond 5	0.6723127	211.4	19Sep2015, 13:31	2.40
Reach-13	0.6723127	211.4	19Sep2015, 13:33	2.39
Area 16	0.2959900	198.9	19Sep2015, 12:51	2.43
Area 22	0.1087000	128.1	19Sep2015, 12:33	3.29
Junction-13	4.6752170	1228.2	19Sep2015, 13:12	1.86
Reach-14	4.6752170	1227.8	19Sep2015, 13:20	1.84
Area 23	0.2300500	164.7	19Sep2015, 12:57	2.79
Junction-14	4.9052670	1363.5	19Sep2015, 13:19	1.88
Reach-15	4.9052670	1362.7	19Sep2015, 13:21	1.87
Area 24	0.1367700	128.0	19Sep2015, 12:46	3.18
Junction-1	5.0420370	1437.7	19Sep2015, 13:21	1.91

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APPENDIX C

H&H Memo Attachment B

NOTE: The original report included additional tabular detail. Only the preliminary summary and figure summaries were included for this appendix.

The full report can be provided upon request

Weather History for KBVY - May, 2006

Saturday, May 13, 2006

Daily | Weekly | Monthly | Custom

	Actual	Average (KBOS)	Record (KBOS)
Temperature			
Mean Temperature	**48** °F	**57** °F	
Max Temperature	**51** °F	**65** °F	**87** °F (1947)
Min Temperature	**44** °F	**49** °F	**38** °F (1882)
Degree Days			
Heating Degree Days	18	8	
Month to date heating degree days		133	
Since 1 July heating degree days		5514	
Cooling Degree Days	0	0	
Month to date cooling degree days		0	
Year to date cooling degree days		3	
Moisture			
Dew Point	**46** °F		
Average Humidity	96		
Maximum Humidity	100		
Minimum Humidity	93		
Precipitation			
Precipitation	**4.32** in	**0.10** in	**3.84** in (2006)
Month to date precipitation		1.36	
Year to date precipitation		16.03	

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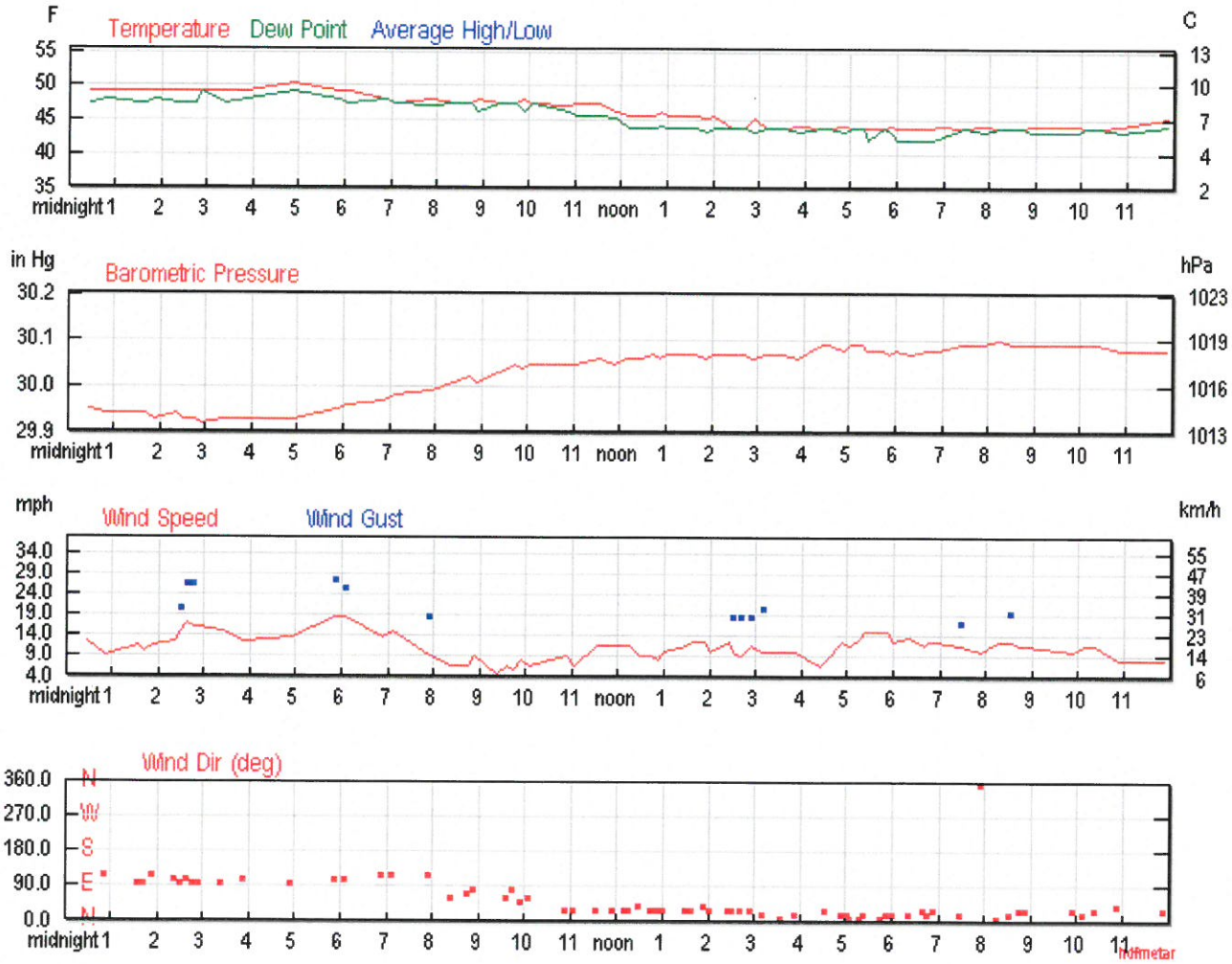
Sea Level Pressure	
Sea Level Pressure	**30.04** in
Wind	
Wind Speed	**12** mph (NE)
Max Wind Speed	**18** mph
Max Gust Speed	**28** mph
Visibility	**2** miles
Events	Fog , Rain

T = Trace of Precipitation, MM = Missing Value

Source: NWS Daily Summary

Daily Weather History Graph



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KBVY

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Weather History for KBVY - May, 2006

Sunday, May 14, 2006

Daily | Weekly | Monthly | Custom

	Actual	Average	Record
Temperature			
Mean Temperature	**46** °F	-	
Max Temperature	**48** °F	**62** °F	**79** °F (1981)
Min Temperature	**44** °F	**42** °F	**33** °F (1999)
Degree Days			
Heating Degree Days	19		
Moisture			
Dew Point	**44** °F		
Average Humidity	94		
Maximum Humidity	100		
Minimum Humidity	93		
Precipitation			
Precipitation	**4.95** in	-	- ()
Sea Level Pressure			
Sea Level Pressure	**30.11** in		
Wind			
Wind Speed	**10** mph (NE)		
Max Wind Speed	**21** mph		
Max Gust Speed	**28** mph		
Visibility	**2** miles		

Events Rain , Thunderstorm

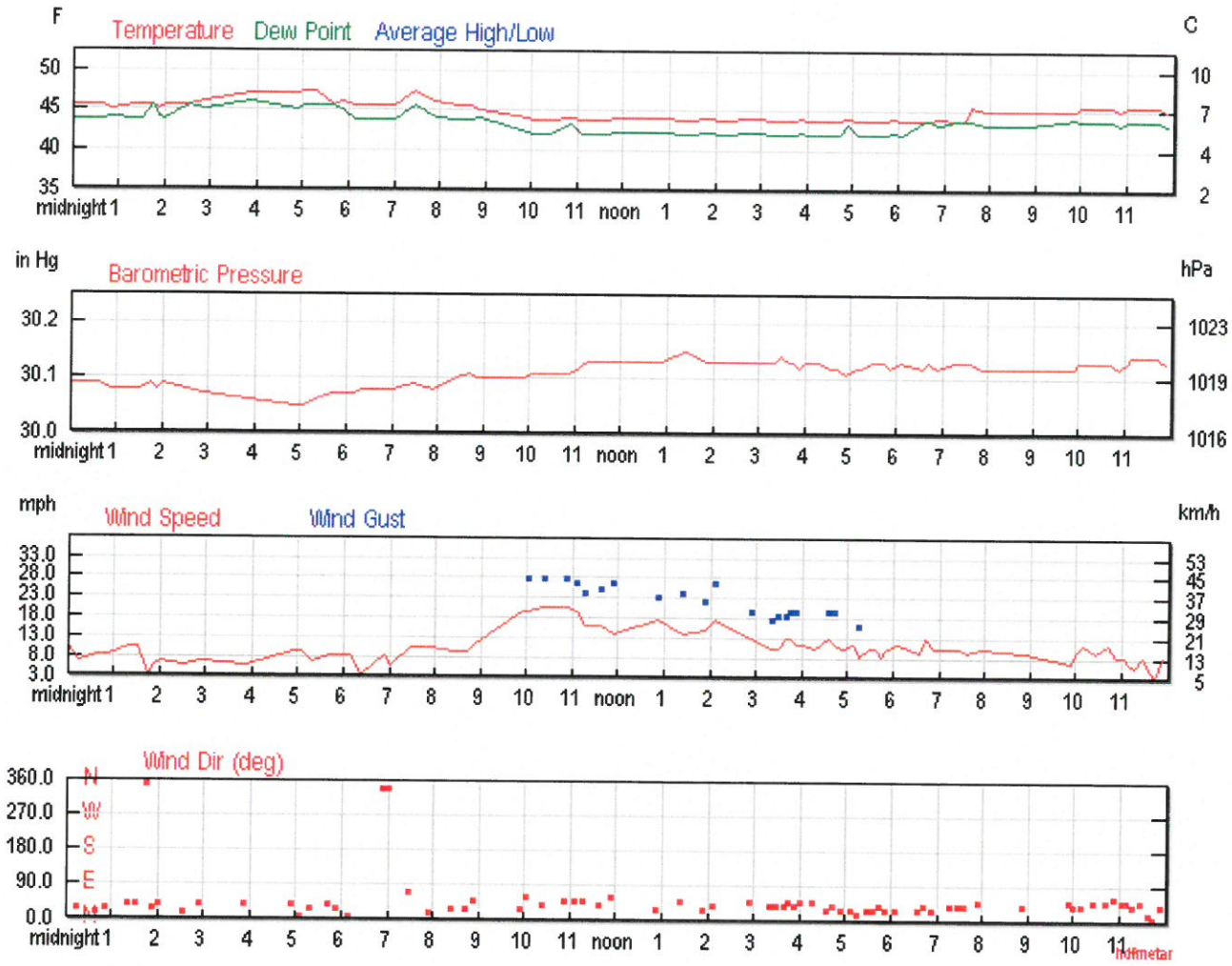
Averages and records for this station are not official NWS values.

H&H Memo Attachment B

T = Trace of Precipitation, MM = Missing Value

Source: NWS Daily Summary

Daily Weather History Graph



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KBVY

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Trip Planner

Search our weather history database for the weather conditions in past years. The results will help you decide how hot, cold, wet, or windy it might be!

Date:

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Weather History for KBVY - May, 2006

Monday, May 15, 2006

Daily | Weekly | Monthly | Custom

	Actual	Average	Record
Temperature			
Mean Temperature	**48** °F	-	
Max Temperature	**50** °F	**62** °F	**88** °F (2004)
Min Temperature	**46** °F	**42** °F	**37** °F (2013)
Degree Days			
Heating Degree Days	17		
Moisture			
Dew Point	**46** °F		
Average Humidity	96		
Maximum Humidity	100		
Minimum Humidity	93		
Precipitation			
Precipitation	**1.15** in	-	- ()
Sea Level Pressure			
Sea Level Pressure	**30.04** in		
Wind			
Wind Speed	**7** mph (NE)		
Max Wind Speed	**13** mph		
Max Gust Speed	**18** mph		
Visibility	**2** miles		

Events	Fog , Rain , Thunderstorm

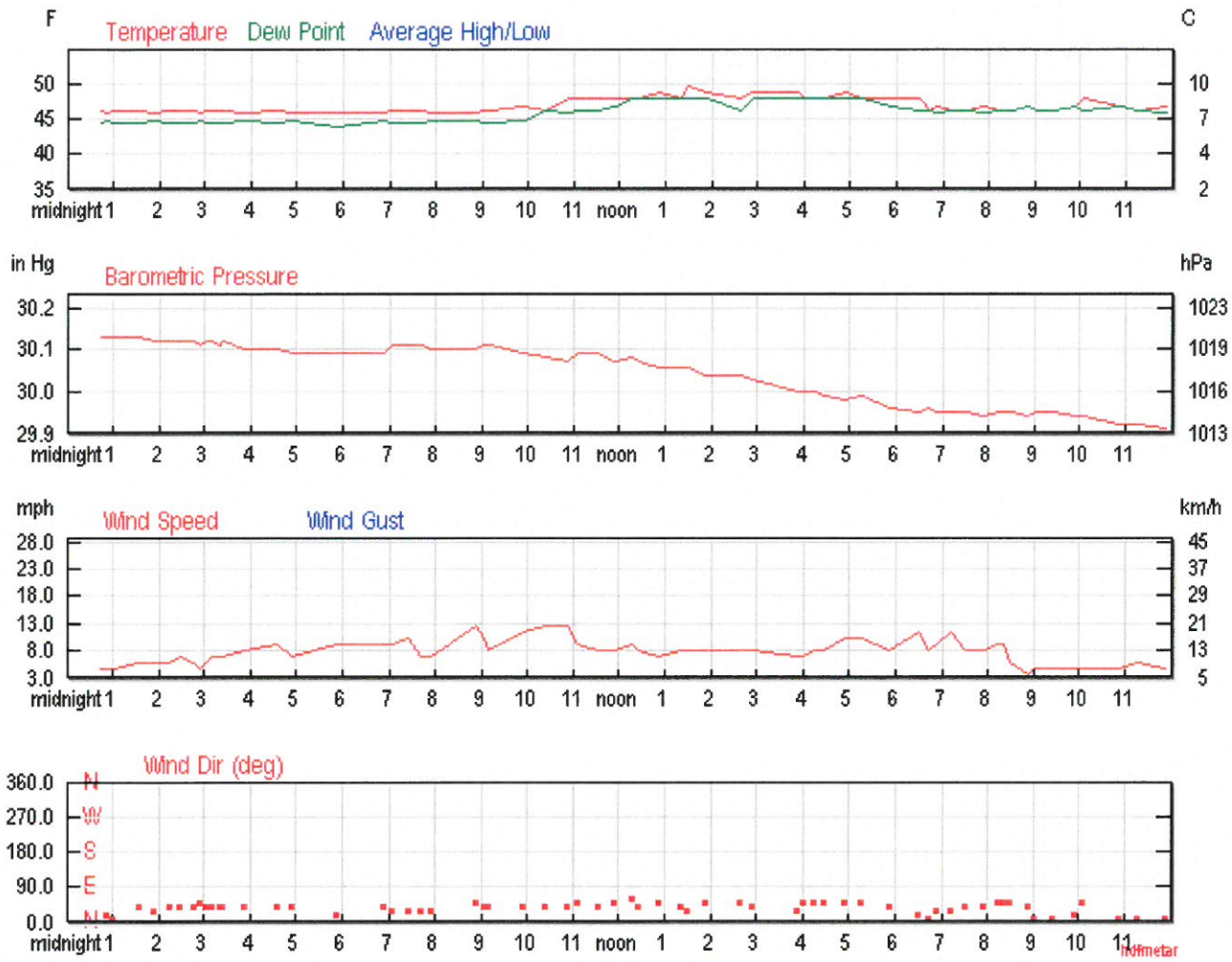
Averages and records for this station are not official NWS values.

H&H Memo Attachment B

T = Trace of Precipitation, MM = Missing Value

Source: NWS Daily Summary

Daily Weather History Graph



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Search our weather history database for the weather conditions in past years. The results will help you decide how hot, cold, wet, or windy it might be!

Date:

H&H Memo Attachment B

Weather History for KBVY - May, 2006

Tuesday, May 16, 2006

Daily	Weekly	Monthly	Custom

	Actual	Average	Record
Temperature			
Mean Temperature	**50** °F	-	
Max Temperature	**55** °F	**62** °F	**84** °F (1980)
Min Temperature	**46** °F	**42** °F	**35** °F (1999)
Degree Days			
Heating Degree Days	14		
Moisture			
Dew Point	**48** °F		
Average Humidity	94		
Maximum Humidity	100		
Minimum Humidity	82		
Precipitation			
Precipitation	**0.56** in	-	- ()
Sea Level Pressure			
Sea Level Pressure	**29.62** in		
Wind			
Wind Speed	**8** mph (North)		
Max Wind Speed	**17** mph		
Max Gust Speed	**21** mph		
Visibility	**6** miles		

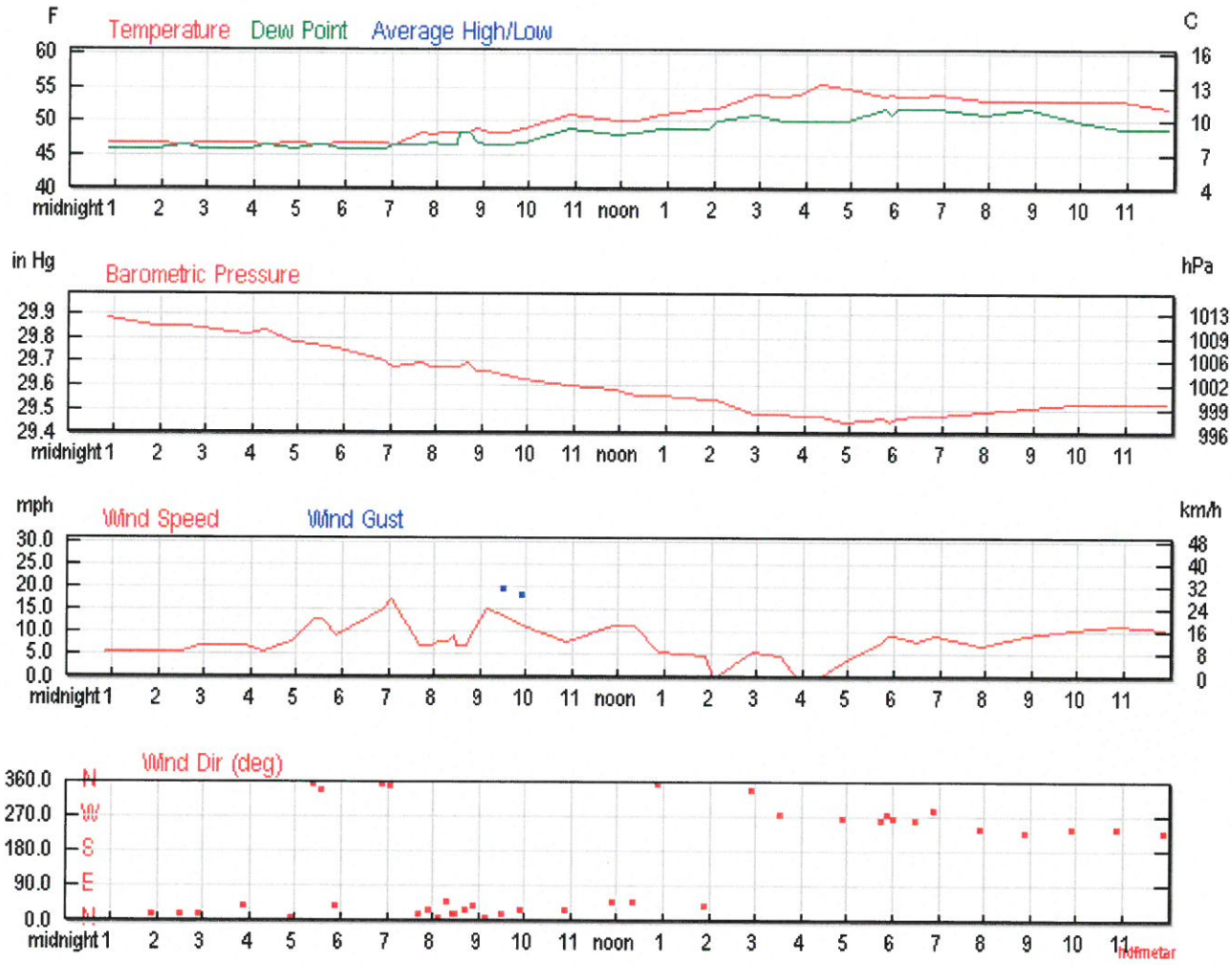
Events Fog , Rain

Averages and records for this station are not official NWS values.

H&H Memo Attachment B

T = Trace of Precipitation, MM = Missing Value Source: NWS Daily Summary

Daily Weather History Graph



Search for Another Location

Airport or City:

KBVY

Submit

Trip Planner

Search our weather history database for the weather conditions in past years. The results will help you decide how hot, cold, wet, or windy it might be!

Date:

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Antecedent Moisture Conditions Adjustment**
Prepared By: **CRD** Date: **September 22, 2015**

Designation: **Area 1**

Weighted CN: **68** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **83**

Designation: **Area 2**

Weighted CN: **66** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 3**

Weighted CN: **60** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **78**

Designation: **Area 4**

Weighted CN: **63** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **80**

Designation: **Area 5**

Weighted CN: **62** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **79**

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Antecedent Moisture Conditions Adjustment**
Prepared By: **CRD** Date: **September 22, 2015**

Designation: **Area 6**

Weighted CN: **69** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **84**

Designation: **Area 7**

Weighted CN: **68** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **83**

Designation: **Area 8**

Weighted CN: **67** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 9**

Weighted CN: **60** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **78**

Designation: **Area 10**

Weighted CN: **61** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **78**

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Antecedent Moisture Conditions Adjustment**
Prepared By: **CRD** Date: **September 22, 2015**

Designation: **Area 11**

Weighted CN: **63** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **80**

Designation: **Area 12**

Weighted CN: **67** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 13**

Weighted CN: **67** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 14**

Weighted CN: **68** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **83**

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Antecedent Moisture Conditions Adjustment**
Prepared By: **CRD** Date: **September 22, 2015**

Designation: **Area 15**

Weighted CN: **66** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 16**

Weighted CN: **65** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **81**

Designation: **Area 17**

Weighted CN: **63** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **80**

Designation: **Area 18**

Weighted CN: **62** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **79**

Designation: **Area 19**

Weighted CN: **64** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **80**

Tighe&Bond
Consulting Engineers
Environmental Specialists

Project Name: **Sawmill Brook Watershed Analysis**
Project Number: **M-1476-3-4**
Project Location: **Manchester-by-the-Sea, MA**
Description: **Antecedent Moisture Conditions Adjustment**
Prepared By: **CRD** Date: **September 22, 2015**

Designation: **Area 20**

Weighted CN: **75** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **87**

Designation: **Area 21**

Weighted CN: **66** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **82**

Designation: **Area 22**

Weighted CN: **74** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **87**

Designation: **Area 23**

Weighted CN: **69** (AMC_2)

$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **84**

Designation: **Area 24**

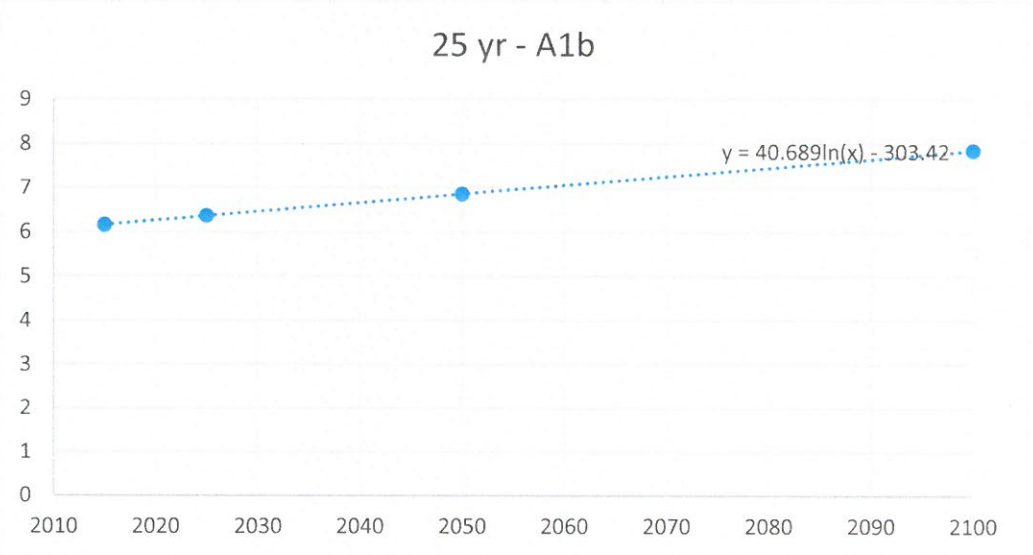
Weighted CN: **73** (AMC_2)

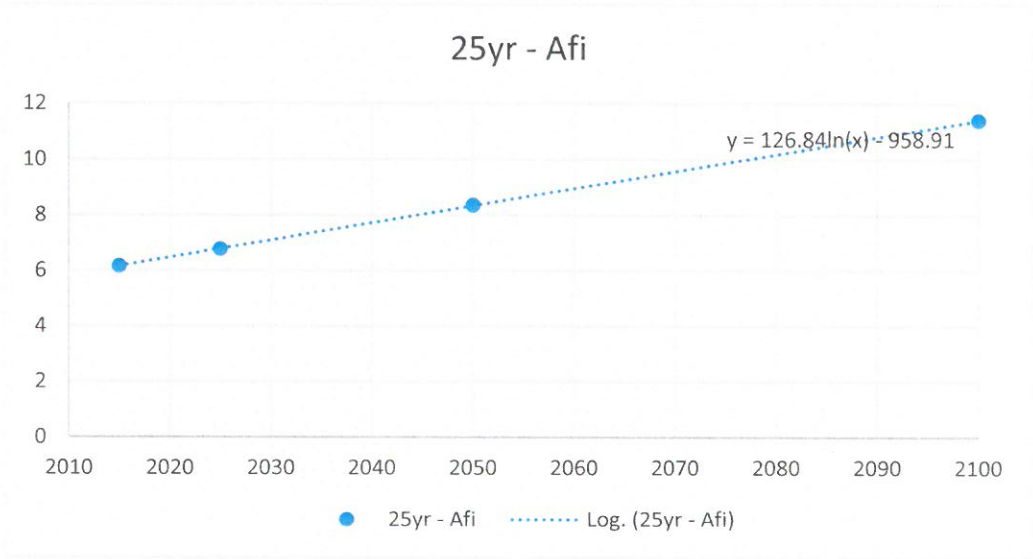
$$RCN_{AMC3} = \frac{23RCN_{AMC2}}{10+0.13RCN_{AMC2}}$$

RCN_{AMC3} = **86**

H&H Memo Attachment B

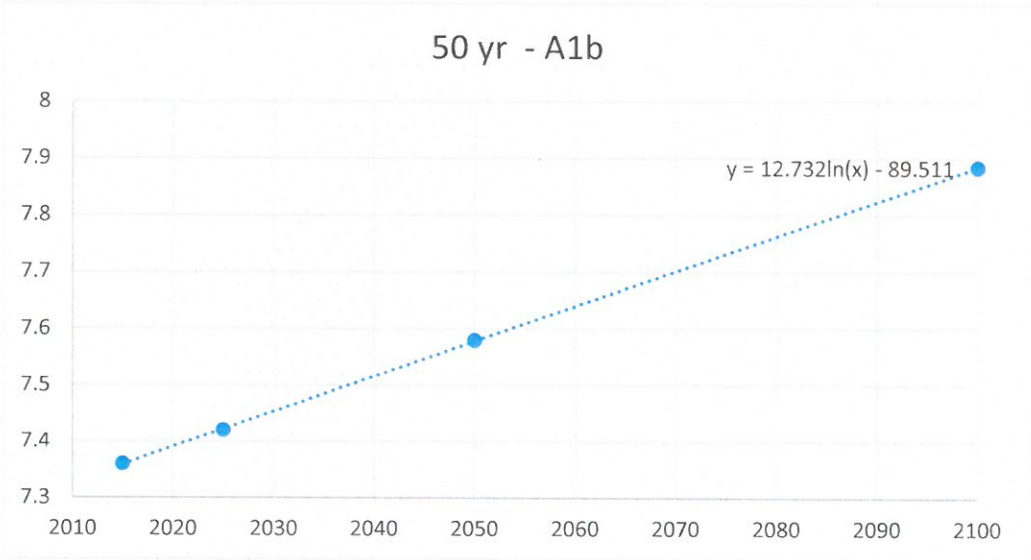
Year	25 yr -A1b	25yr - Afi
2015	6.16	6.16
2025	6.36	6.77
2050	6.86	8.35
2100	7.84	11.39

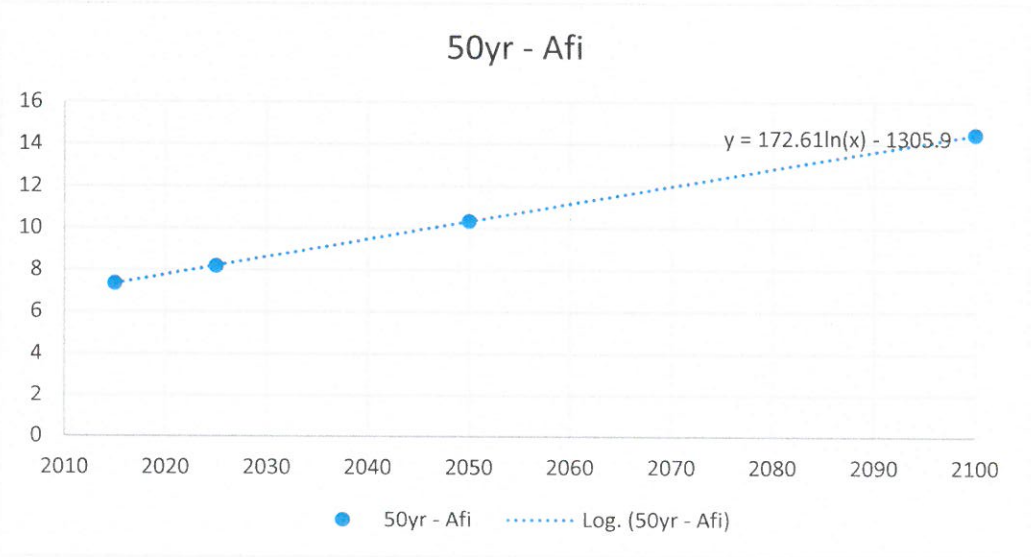




H&H Memo Attachment B

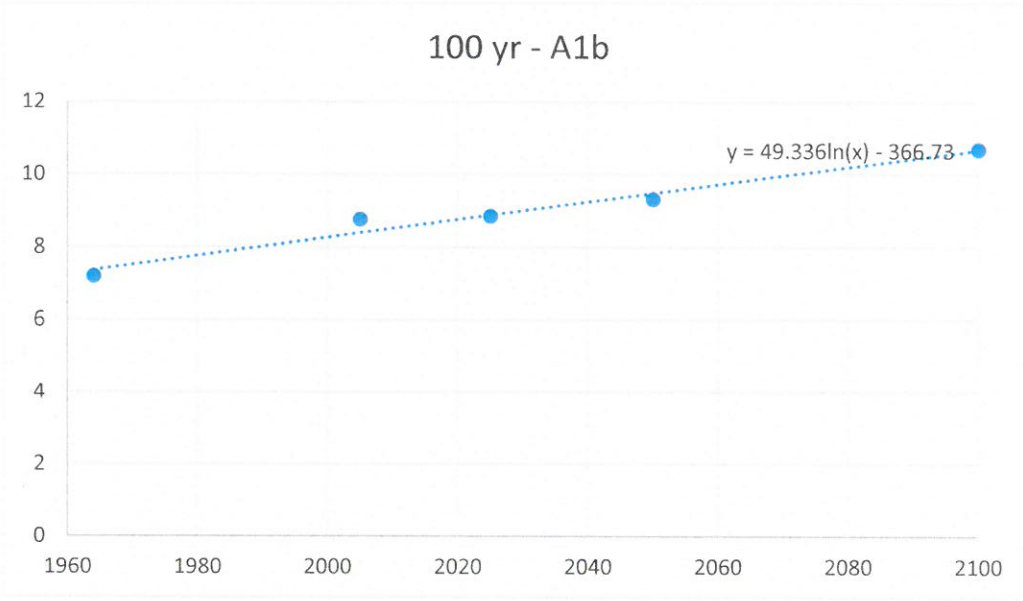
Year	50 yr -A1b	50yr - Afi
2015	7.36	7.36
2025	7.42	8.19
2050	7.58	10.34
2100	7.88	14.48

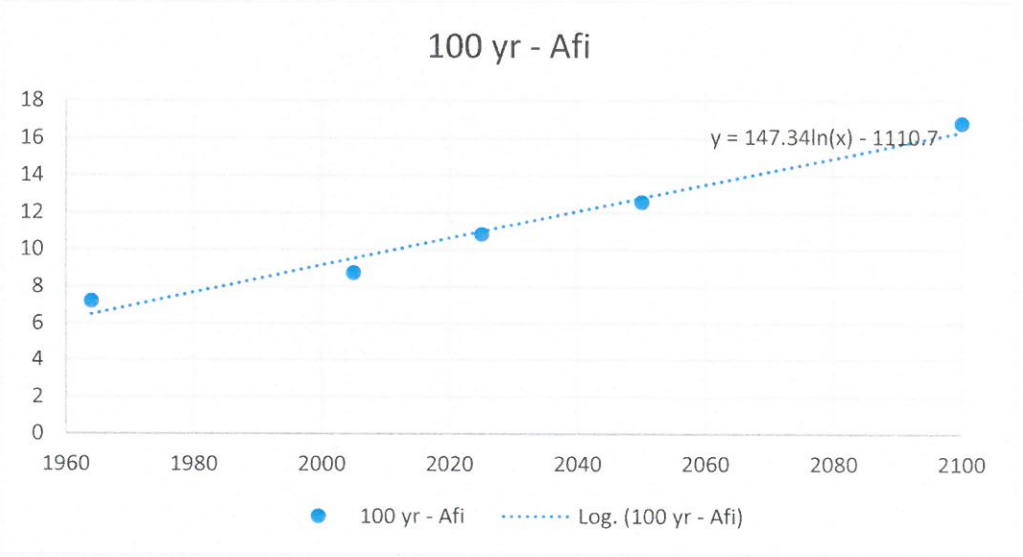




H&H Memo Attachment B

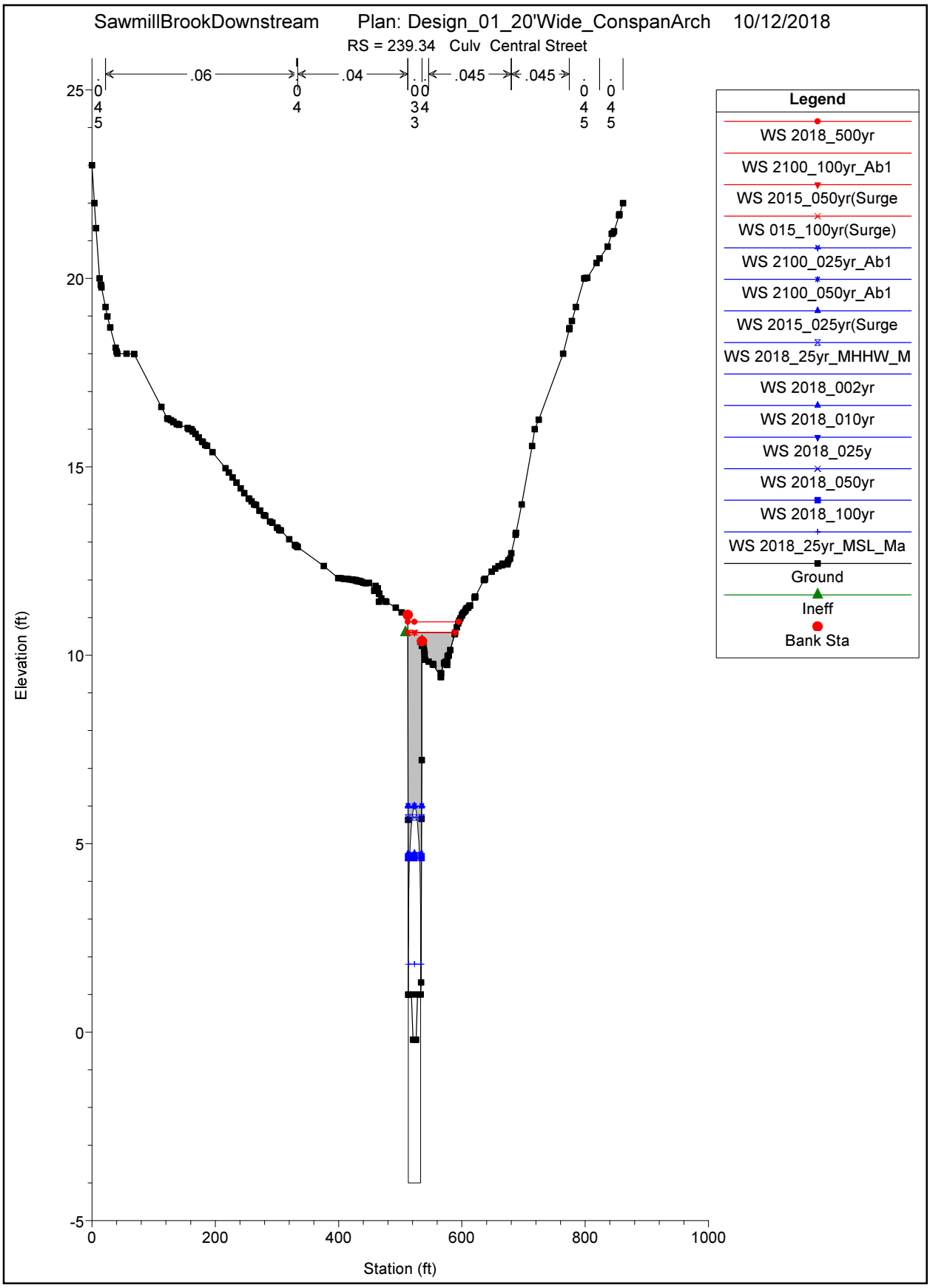
Year	100 yr -A1b	100 yr - Afi
1964	7.2	7.2
2005	8.76	8.76
2025	8.85	10.82
2050	9.31	12.58
2100	10.69	16.82

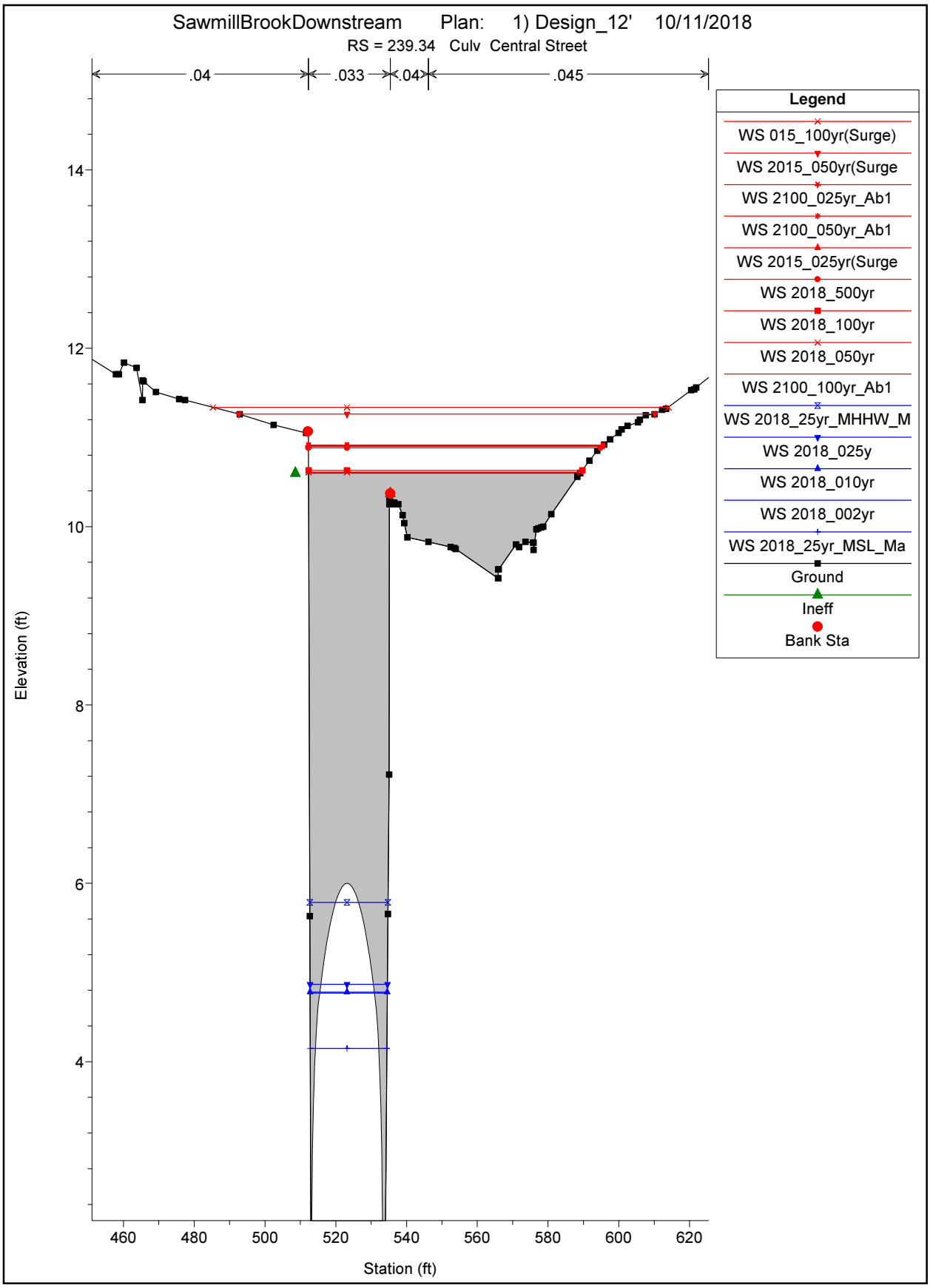




ATTACHMENT C

HEC-RAS Results


SawmillBrookDownstream
Plan: Design_01_20'Wide_ConspanArch
10/12/2018
RS = 239.34 Culv Central Street
.06
.04
.045
.045
Legend
WS 2018_500yr
WS 2100_100yr_Ab1
WS 2015_050yr(Surge
WS 015_100yr(Surge)
WS 2100_025yr_Ab1
WS 2100_050yr_Ab1
WS 2015_025yr(Surge
WS 2018_25yr_MHHW_M
WS 2018_002yr
WS 2018_010yr
WS 2018_025y
WS 2018_050yr
WS 2018_100yr
WS 2018_25yr_MSL_Ma
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
25
20
15
10
5
0
-5
0
200
400
600
800
1000


SawmillBrookDownstream Plan: 1) Design_12' 10/11/2018
RS = 239.34 Culv Central Street
.04
.033
.04
.045
Legend
WS 015_100yr(Surge)
WS 2015_050yr(Surge
WS 2100_025yr_Ab1
WS 2100_050yr_Ab1
WS 2015_025yr(Surge
WS 2018_500yr
WS 2018_100yr
WS 2018_050yr
WS 2100_100yr_Ab1
WS 2018_25yr_MHHW_M
WS 2018_025y
WS 2018_010yr
WS 2018_002yr
WS 2018_25yr_MSL_Ma
Ground
Ineff
Bank Sta
Elevation (ft)
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12
10
8
6
4
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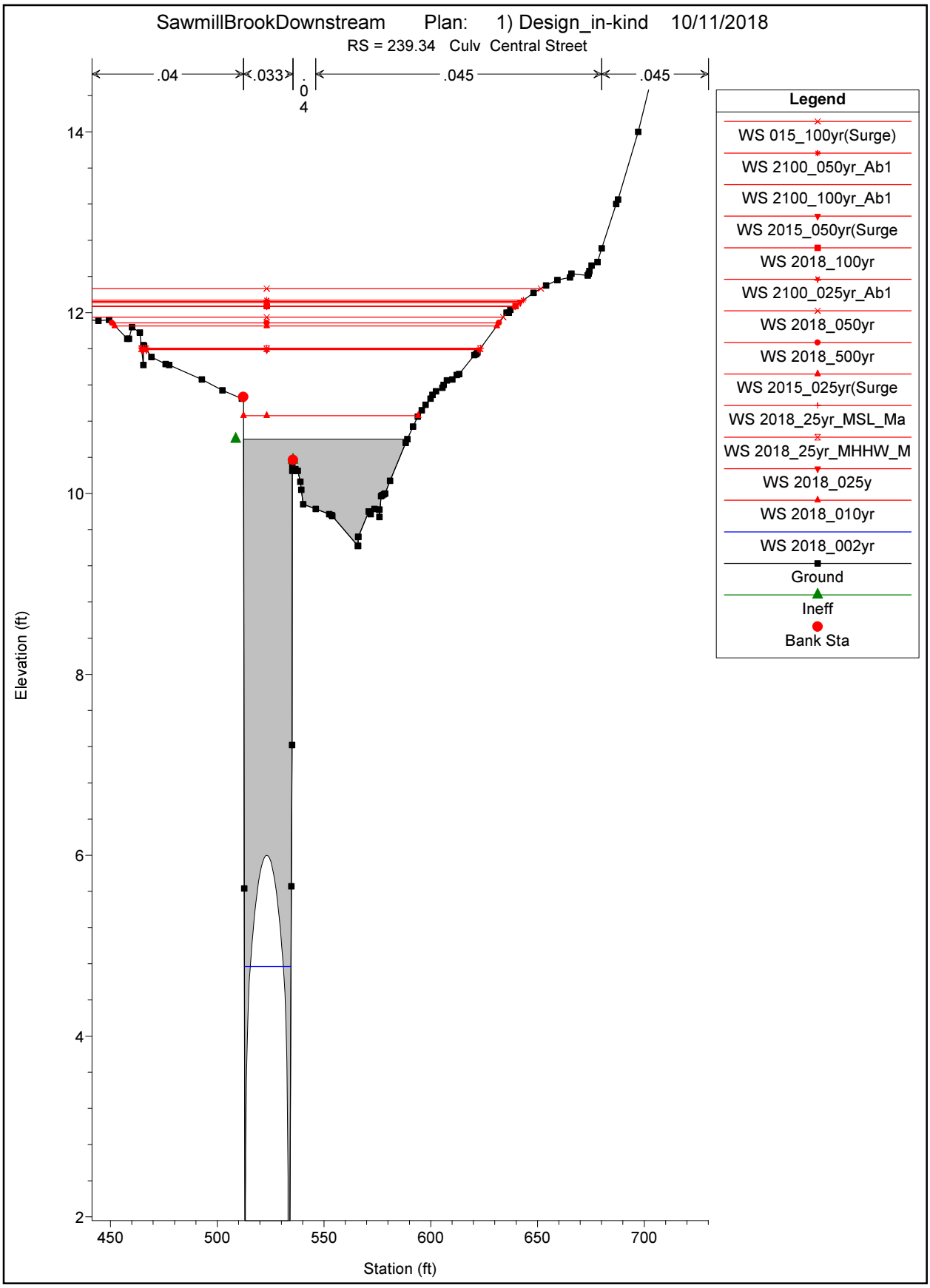
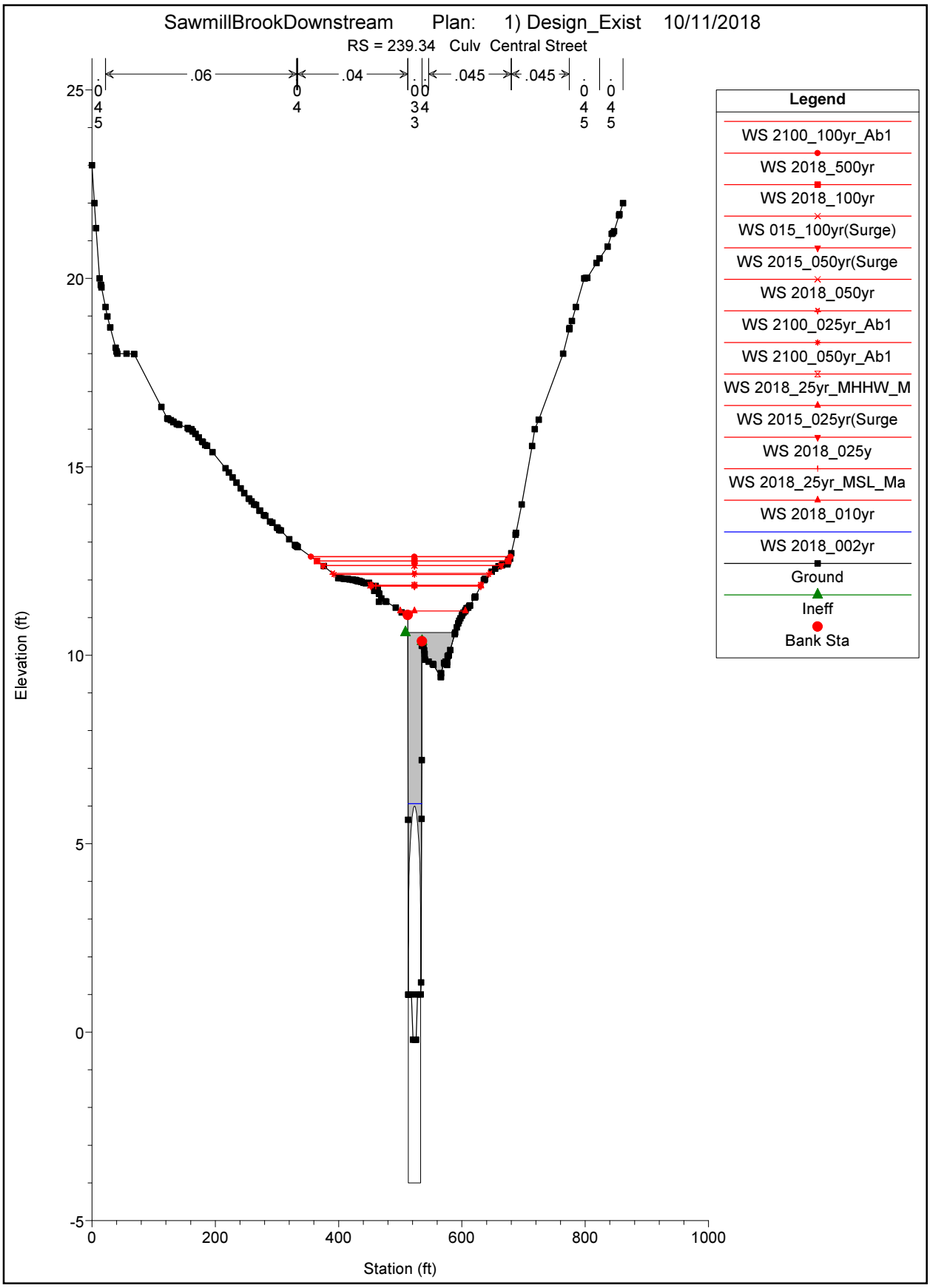
480
500
520
540
560
580
600
620
Station (ft)


SawmillBrookDownstream Plan: 1) Design_in-kind 10/11/2018
RS = 239.34 Culv Central Street
.04
.033
.045
.045
Legend
WS 015_100yr(Surge)
WS 2100_050yr_Ab1
WS 2100_100yr_Ab1
WS 2015_050yr(Surge
WS 2018_100yr
WS 2100_025yr_Ab1
WS 2018_050yr
WS 2018_500yr
WS 2015_025yr(Surge
WS 2018_25yr_MSL_Ma
WS 2018_25yr_MHHW_M
WS 2018_025y
WS 2018_010yr
WS 2018_002yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2
4
6
8
10
12
14
450
500
550
600
650
700


SawmillBrookDownstream Plan: 1) Design_Exist 10/11/2018
RS = 239.34 Culv Central Street
.06
.04
.045
.045
Elevation (ft)
Station (ft)
Legend
WS 2100_100yr_Ab1
WS 2018_500yr
WS 2018_100yr
WS 015_100yr(Surge)
WS 2015_050yr(Surge
WS 2018_050yr
WS 2100_025yr_Ab1
WS 2100_050yr_Ab1
WS 2018_25yr_MHHW_M
WS 2015_025yr(Surge
WS 2018_025y
WS 2018_25yr_MSL_Ma
WS 2018_010yr
WS 2018_002yr
Ground
Ineff
Bank Sta

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2841.083	2018_002yr	Design_20'	232	7.12	12.0851	9.14	12.13	0.000529	1.85	200.94	166.43	0.17
1	2841.083	2018_002yr	Design_12'	232	7.12	12.0851	9.14	12.13	0.000529	1.85	200.94	166.43	0.17
1	2841.083	2018_002yr	Design_in-kind	232	7.12	12.0851	9.14	12.13	0.000529	1.85	200.94	166.43	0.17
1	2841.083	2018_002yr	Design_Exist	232	7.12	12.0843	9.14	12.13	0.000529	1.85	200.81	166.41	0.17
1	2841.083	2018_010yr	Design_20'	845	7.12	15.4289	11.7	15.45	0.000158	1.57	1068.18	357.02	0.1
1	2841.083	2018_010yr	Design_12'	845	7.12	15.4289	11.7	15.45	0.000158	1.57	1068.18	357.02	0.1
1	2841.083	2018_010yr	Design_in-kind	845	7.12	15.4138	11.7	15.43	0.000161	1.57	1062.78	356.61	0.11
1	2841.083	2018_010yr	Design_Exist	845	7.12	15.4322	11.7	15.45	0.000158	1.56	1069.34	357.11	0.1
1	2841.083	2018_025y	Design_20'	1228	7.12	15.7738	12.45	15.8	0.000249	2.03	1192.86	365.98	0.13
1	2841.083	2018_025y	Design_12'	1228	7.12	15.7698	12.45	15.8	0.000249	2.03	1191.41	365.88	0.13
1	2841.083	2018_025y	Design_in-kind	1228	7.12	15.7832	12.45	15.81	0.000247	2.02	1196.31	366.23	0.13
1	2841.083	2018_025y	Design_Exist	1228	7.12	15.8006	12.45	15.83	0.000243	2.01	1202.68	366.68	0.13
1	2841.083	2018_050yr	Design_20'	1565	7.12	16.219	12.76	16.26	0.000295	2.3	1369.34	432.19	0.15
1	2841.083	2018_050yr	Design_12'	1565	7.12	16.2411	12.76	16.28	0.00029	2.28	1378.89	433.44	0.14
1	2841.083	2018_050yr	Design_in-kind	1565	7.12	16.2343	12.76	16.27	0.000292	2.29	1375.95	433.05	0.14
1	2841.083	2018_050yr	Design_Exist	1565	7.12	16.2593	12.76	16.3	0.000286	2.27	1386.78	434.47	0.14
1	2841.083	2018_100yr	Design_20'	2000	7.12	16.7766	13.09	16.82	0.000312	2.47	1619.19	464.08	0.15
1	2841.083	2018_100yr	Design_12'	2000	7.12	16.8017	13.09	16.84	0.000306	2.46	1630.88	465.52	0.15
1	2841.083	2018_100yr	Design_in-kind	2000	7.12	16.775	13.09	16.82	0.000313	2.48	1618.44	463.98	0.15
1	2841.083	2018_100yr	Design_Exist	2000	7.12	16.7826	13.09	16.82	0.000311	2.47	1621.99	464.42	0.15
1	2841.083	2018_500yr	Design_20'	2671	7.12	17.4201	13.55	17.47	0.000344	2.73	1927.38	492.84	0.16
1	2841.083	2018_500yr	Design_12'	2671	7.12	17.4759	13.55	17.52	0.000331	2.69	1954.95	494.89	0.16
1	2841.083	2018_500yr	Design_in-kind	2671	7.12	17.4398	13.55	17.49	0.000339	2.72	1937.11	493.57	0.16
1	2841.083	2018_500yr	Design_Exist	2671	7.12	17.4845	13.55	17.53	0.000329	2.68	1959.19	495.46	0.16
1	2841.083	2018_25yr_MHHW_M	Design_20'	1228	7.12	15.7738	12.45	15.8	0.000249	2.03	1192.86	365.98	0.13
1	2841.083	2018_25yr_MHHW_M	Design_12'	1228	7.12	15.7716	12.45	15.8	0.000249	2.03	1192.04	365.92	0.13
1	2841.083	2018_25yr_MHHW_M	Design_in-kind	1228	7.12	15.7933	12.45	15.82	0.000244	2.01	1200.02	366.49	0.13
1	2841.083	2018_25yr_MHHW_M	Design_Exist	1228	7.12	15.7955	12.45	15.83	0.000244	2.01	1200.79	366.54	0.13
1	2841.083	2018_25yr_MSL_Ma	Design_20'	1228	7.12	15.7738	12.45	15.8	0.000249	2.03	1192.86	365.98	0.13
1	2841.083	2018_25yr_MSL_Ma	Design_12'	1228	7.12	15.7736	12.45	15.8	0.000249	2.03	1192.79	365.98	0.13
1	2841.083	2018_25yr_MSL_Ma	Design_in-kind	1228	7.12	15.8002	12.45	15.83	0.000243	2.01	1202.51	366.67	0.13
1	2841.083	2018_25yr_MSL_Ma	Design_Exist	1228	7.12	15.8008	12.45	15.83	0.000243	2.01	1202.73	366.68	0.13
1	2841.083	2100_025yr_Ab1	Design_20'	1706	7.12	16.4194	12.87	16.46	0.000299	2.35	1457.1	443.6	0.15
1	2841.083	2100_025yr_Ab1	Design_12'	1706	7.12	16.4321	12.87	16.47	0.000296	2.34	1462.7	444.32	0.15
1	2841.083	2100_025yr_Ab1	Design_in-kind	1706	7.12	16.4296	12.87	16.47	0.000297	2.35	1461.63	444.18	0.15
1	2841.083	2100_025yr_Ab1	Design_Exist	1706	7.12	16.4146	12.87	16.45	0.0003	2.36	1454.96	443.32	0.15
1	2841.083	2100_050yr_Ab1	Design_20'	1717	7.12	16.436	12.88	16.48	0.000299	2.36	1464.45	444.55	0.15
1	2841.083	2100_050yr_Ab1	Design_12'	1717	7.12	16.4355	12.88	16.48	0.000299	2.36	1464.23	444.52	0.15
1	2841.083	2100_050yr_Ab1	Design_in-kind	1717	7.12	16.4312	12.88	16.47	0.0003	2.36	1462.32	444.27	0.15
1	2841.083	2100_050yr_Ab1	Design_Exist	1717	7.12	16.4322	12.88	16.47	0.0003	2.36	1462.78	444.33	0.15
1	2841.083	2100_100yr_Ab1	Design_20'	2562	7.12	17.348	13.48	17.4	0.000333	2.67	1891.94	489.27	0.16
1	2841.083	2100_100yr_Ab1	Design_12'	2562	7.12	17.3199	13.48	17.37	0.00034	2.69	1878.21	488.34	0.16
1	2841.083	2100_100yr_Ab1	Design_in-kind	2562	7.12	17.302	13.48	17.35	0.000345	2.71	1869.5	487.75	0.16
1	2841.083	2100_100yr_Ab1	Design_Exist	2562	7.12	17.3406	13.48	17.39	0.000335	2.68	1888.32	489.03	0.16
1	2841.083	2018_025yr(Surge	Design_20'	1228	7.12	15.7698	12.45	15.8	0.000249	2.03	1191.41	365.88	0.13
1	2841.083	2015_025yr(Surge	Design_12'	1228	7.12	15.775	12.45	15.81	0.000248	2.03	1193.31	366.01	0.13
1	2841.083	2015_025yr(Surge	Design_in-kind	1228	7.12	15.7999	12.45	15.83	0.000243	2.01	1202.44	366.66	0.13
1	2841.083	2015_025yr(Surge	Design_Exist	1228	7.12	15.8023	12.45	15.83	0.000243	2.01	1203.29	366.72	0.13
1	2841.083	2018_050yr(Surge	Design_20'	1565	7.12	16.2228	12.76	16.26	0.000294	2.29	1370.96	432.4	0.15
1	2841.083	2015_050yr(Surge	Design_12'	1565	7.12	16.252	12.76	16.29	0.000288	2.27	1383.61	434.05	0.14
1	2841.083	2015_050yr(Surge	Design_in-kind	1565	7.12	16.243	12.76	16.28	0.00029	2.28	1379.71	433.54	0.14
1	2841.083	2015_050yr(Surge	Design_Exist	1565	7.12	16.2507	12.76	16.29	0.000288	2.27	1383.05	433.98	0.14
1	2841.083	015_100yr(Surge)	Design_20'	2000	7.12	16.7691	13.09	16.81	0.000314	2.48	1615.72	463.65	0.15
1	2841.083	015_100yr(Surge)	Design_12'	2000	7.12	16.7641	13.09	16.81	0.000315	2.48	1613.41	463.36	0.15
1	2841.083	015_100yr(Surge)	Design_in-kind	2000	7.12	16.8114	13.09	16.85	0.000304	2.45	1635.38	466.07	0.15
1	2841.083	015_100yr(Surge)	Design_Exist	2000	7.12	16.7743	13.09	16.82	0.000313	2.48	1618.13	463.95	0.15
1	2788.571	2018_002yr	Design_20'	232	7.44	12.0082	9.07	12.09	0.000809	2.33	101.22	80.24	0.2
1	2788.571	2018_002yr	Design_12'	232	7.44	12.0082	9.07	12.09	0.000809	2.33	101.22	80.24	0.2
1	2788.571	2018_002yr	Design_in-kind	232	7.44	12.0082	9.07	12.09	0.000809	2.33	101.22	80.24	0.2
1	2788.571	2018_002yr	Design_Exist	232	7.44	12.0074	9.07	12.09	0.000809	2.33	101.2	80.21	0.2
1	2788.571	2018_010yr	Design_20'	845	7.44	15.348	11.19	15.43	0.000557	2.84	629.69	304.19	0.19
1	2788.571	2018_010yr	Design_12'	845	7.44	15.348	11.19	15.43	0.000557	2.84	629.69	304.19	0.19
1	2788.571	2018_010yr	Design_in-kind	845	7.44	15.3316	11.19	15.41	0.000566	2.85	625.49	303.51	0.19
1	2788.571	2018_010yr	Design_Exist	845	7.44	15.3516	11.19	15.43	0.000555	2.83	630.6	304.34	0.19
1	2788.571	2018_025y	Design_20'	1228	7.44	15.6439	12.31	15.78	0.0009	3.7	706.16	316.5	0.24
1	2788.571	2018_025y	Design_12'	1228	7.44	15.6394	12.31	15.77	0.000903	3.71	704.98	316.31	0.24
1	2788.571	2018_025y	Design_in-kind	1228	7.44	15.6546	12.31	15.78	0.000891	3.69	708.95	316.94	0.24
1	2788.571	2018_025y	Design_Exist	1228	7.44	15.6744	12.31	15.8	0.000876	3.66	714.12	317.76	0.23
1	2788.571	2018_050yr	Design_20'	1565	7.44	16.133	13.04	16.23	0.00074	3.5	987.41	371.21	0.22
1	2788.571	2018_050yr	Design_12'	1565	7.44	16.1572	13.04	16.25	0.000725	3.47	996.4	373.09	0.22
1	2788.571	2018_050yr	Design_in-kind	1565	7.44	16.1497	13.04	16.25	0.000729	3.48	993.6	372.54	0.22

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2788.571	2018_050yr	Design_Exist	1565	7.44	16.177	13.04	16.27	0.000712	3.45	1003.8	374.54	0.21
1	2788.571	2018_100yr	Design_20'	2000	7.44	16.6892	13.89	16.79	0.000778	3.75	1204.48	407.38	0.23
1	2788.571	2018_100yr	Design_12'	2000	7.44	16.7165	13.89	16.82	0.00076	3.72	1215.65	408.96	0.22
1	2788.571	2018_100yr	Design_in-kind	2000	7.44	16.6874	13.89	16.79	0.000779	3.76	1203.77	407.27	0.23
1	2788.571	2018_100yr	Design_Exist	2000	7.44	16.6958	13.89	16.8	0.000773	3.74	1207.17	407.76	0.23
1	2788.571	2018_500yr	Design_20'	2671	7.44	17.3351	15.06	17.44	0.0008	4	1479.71	444.83	0.23
1	2788.571	2018_500yr	Design_12'	2671	7.44	17.3956	15.06	17.5	0.000761	3.91	1506.71	448.33	0.23
1	2788.571	2018_500yr	Design_in-kind	2671	7.44	17.3565	15.06	17.46	0.000786	3.97	1489.25	446.07	0.23
1	2788.571	2018_500yr	Design_Exist	2671	7.44	17.4048	15.06	17.51	0.000755	3.9	1510.86	448.85	0.23
1	2788.571	2018_25yr_MHHW_M	Design_20'	1228	7.44	15.6439	12.31	15.78	0.0009	3.7	706.16	316.5	0.24
1	2788.571	2018_25yr_MHHW_M	Design_12'	1228	7.44	15.6414	12.31	15.77	0.000902	3.71	705.48	316.39	0.24
1	2788.571	2018_25yr_MHHW_M	Design_in-kind	1228	7.44	15.6661	12.31	15.79	0.000882	3.67	711.96	317.42	0.24
1	2788.571	2018_25yr_MHHW_M	Design_Exist	1228	7.44	15.6685	12.31	15.8	0.00088	3.67	712.59	317.52	0.24
1	2788.571	2018_25yr_MSL_Ma	Design_20'	1228	7.44	15.6439	12.31	15.78	0.0009	3.7	706.16	316.5	0.24
1	2788.571	2018_25yr_MSL_Ma	Design_12'	1228	7.44	15.6437	12.31	15.78	0.0009	3.7	706.09	316.49	0.24
1	2788.571	2018_25yr_MSL_Ma	Design_in-kind	1228	7.44	15.6738	12.31	15.8	0.000876	3.66	713.98	317.74	0.24
1	2788.571	2018_25yr_MSL_Ma	Design_Exist	1228	7.44	15.6745	12.31	15.8	0.000876	3.66	714.16	317.77	0.23
1	2788.571	2100_025yr_Ab1	Design_20'	1706	7.44	16.335	13.33	16.43	0.000739	3.56	1063.88	386.06	0.22
1	2788.571	2100_025yr_Ab1	Design_12'	1706	7.44	16.3487	13.33	16.45	0.00073	3.54	1069.19	387.06	0.22
1	2788.571	2100_025yr_Ab1	Design_in-kind	1706	7.44	16.3461	13.33	16.44	0.000732	3.54	1068.18	386.87	0.22
1	2788.571	2100_025yr_Ab1	Design_Exist	1706	7.44	16.3298	13.33	16.43	0.000742	3.56	1061.87	385.68	0.22
1	2788.571	2100_050yr_Ab1	Design_20'	1717	7.44	16.3518	13.35	16.45	0.000738	3.56	1070.38	387.28	0.22
1	2788.571	2100_050yr_Ab1	Design_12'	1717	7.44	16.3513	13.35	16.45	0.000738	3.56	1070.18	387.25	0.22
1	2788.571	2100_050yr_Ab1	Design_in-kind	1717	7.44	16.3466	13.35	16.45	0.000741	3.57	1068.37	386.91	0.22
1	2788.571	2100_050yr_Ab1	Design_Exist	1717	7.44	16.3477	13.35	16.45	0.00074	3.56	1068.8	386.99	0.22
1	2788.571	2100_100yr_Ab1	Design_20'	2562	7.44	17.2645	14.88	17.37	0.000781	3.93	1448.46	440.73	0.23
1	2788.571	2100_100yr_Ab1	Design_12'	2562	7.44	17.234	14.88	17.34	0.000801	3.97	1435.02	438.96	0.23
1	2788.571	2100_100yr_Ab1	Design_in-kind	2562	7.44	17.2145	14.88	17.32	0.000814	4	1426.49	437.83	0.23
1	2788.571	2100_100yr_Ab1	Design_Exist	2562	7.44	17.2565	14.88	17.36	0.000786	3.94	1444.91	440.27	0.23
1	2788.571	2018_025yr(Surge	Design_20'	1228	7.44	15.6394	12.31	15.77	0.000903	3.71	704.98	316.31	0.24
1	2788.571	2015_025yr(Surge	Design_12'	1228	7.44	15.6453	12.31	15.78	0.000899	3.7	706.52	316.55	0.24
1	2788.571	2015_025yr(Surge	Design_in-kind	1228	7.44	15.6736	12.31	15.8	0.000876	3.66	713.92	317.73	0.24
1	2788.571	2015_025yr(Surge	Design_Exist	1228	7.44	15.6762	12.31	15.8	0.000874	3.66	714.61	317.84	0.23
1	2788.571	2018_050yr(Surge	Design_20'	1565	7.44	16.1371	13.04	16.24	0.000737	3.5	988.92	371.51	0.22
1	2788.571	2015_050yr(Surge	Design_12'	1565	7.44	16.169	13.04	16.26	0.000717	3.46	1000.81	373.95	0.21
1	2788.571	2015_050yr(Surge	Design_in-kind	1565	7.44	16.1591	13.04	16.26	0.000723	3.47	997.12	373.23	0.22
1	2788.571	2015_050yr(Surge	Design_Exist	1565	7.44	16.1677	13.04	16.26	0.000718	3.46	1000.31	373.86	0.21
1	2788.571	015_100yr(Surge)	Design_20'	2000	7.44	16.681	13.89	16.79	0.000783	3.76	1201.17	406.91	0.23
1	2788.571	015_100yr(Surge)	Design_12'	2000	7.44	16.6756	13.89	16.78	0.000787	3.77	1198.96	406.59	0.23
1	2788.571	015_100yr(Surge)	Design_in-kind	2000	7.44	16.727	13.89	16.83	0.000753	3.7	1219.95	409.56	0.22
1	2788.571	015_100yr(Surge)	Design_Exist	2000	7.44	16.6867	13.89	16.79	0.000779	3.76	1203.48	407.23	0.23
1	2767			Culvert									
1	2746.289	2018_002yr	Design_20'	232	7.4	11.6705		11.77	0.00101	2.49	103.83	65.72	0.22
1	2746.289	2018_002yr	Design_12'	232	7.4	11.6705		11.77	0.00101	2.49	103.83	65.72	0.22
1	2746.289	2018_002yr	Design_in-kind	232	7.4	11.6705		11.77	0.00101	2.49	103.83	65.72	0.22
1	2746.289	2018_002yr	Design_Exist	232	7.4	11.6681	8.99	11.77	0.001031	2.51	93.3	65.61	0.23
1	2746.289	2018_010yr	Design_20'	845	7.4	15.2811		15.34	0.000453	2.55	712.82	301.48	0.17
1	2746.289	2018_010yr	Design_12'	845	7.4	15.2811		15.34	0.000453	2.55	712.82	301.48	0.17
1	2746.289	2018_010yr	Design_in-kind	845	7.4	15.2708		15.33	0.000458	2.56	709.71	301.03	0.17
1	2746.289	2018_010yr	Design_Exist	845	7.4	15.3056	11.13	15.36	0.000442	2.53	720.21	302.42	0.17
1	2746.289	2018_025y	Design_20'	1228	7.4	15.5834		15.68	0.000713	3.29	805.84	313.98	0.21
1	2746.289	2018_025y	Design_12'	1228	7.4	15.5819		15.68	0.000714	3.29	805.35	313.92	0.21
1	2746.289	2018_025y	Design_in-kind	1228	7.4	15.6018		15.7	0.000701	3.27	811.62	314.74	0.21
1	2746.289	2018_025y	Design_Exist	1228	7.4	15.6065	12.68	15.7	0.000698	3.26	813.11	314.94	0.21
1	2746.289	2018_050yr	Design_20'	1565	7.4	16.0558		16.16	0.000785	3.59	960.45	365.81	0.22
1	2746.289	2018_050yr	Design_12'	1565	7.4	16.054		16.16	0.000786	3.6	959.78	365.69	0.22
1	2746.289	2018_050yr	Design_in-kind	1565	7.4	16.0628		16.17	0.00078	3.59	963	366.27	0.22
1	2746.289	2018_050yr	Design_Exist	1565	7.4	16.0773	13.11	16.18	0.00077	3.57	968.32	367.23	0.22
1	2746.289	2018_100yr	Design_20'	2000	7.4	16.5919		16.7	0.000838	3.88	1166.61	401.75	0.23
1	2746.289	2018_100yr	Design_12'	2000	7.4	16.5945		16.71	0.000836	3.88	1167.66	401.9	0.23
1	2746.289	2018_100yr	Design_in-kind	2000	7.4	16.6023		16.71	0.000831	3.86	1170.8	402.36	0.23
1	2746.289	2018_100yr	Design_Exist	2000	7.4	16.615	13.97	16.73	0.000822	3.85	1175.92	403.09	0.23
1	2746.289	2018_500yr	Design_20'	2671	7.4	17.2939		17.41	0.000823	4.05	1462.91	442.44	0.24
1	2746.289	2018_500yr	Design_12'	2671	7.4	17.2908		17.4	0.000825	4.05	1461.55	442.26	0.24
1	2746.289	2018_500yr	Design_in-kind	2671	7.4	17.2994		17.41	0.000819	4.04	1465.36	442.76	0.23
1	2746.289	2018_500yr	Design_Exist	2671	7.4	17.2961	14.89	17.41	0.000821	4.05	1463.89	442.56	0.23
1	2746.289	2018_25yr_MHHW_M	Design_20'	1228	7.4	15.5834		15.68	0.000713	3.29	805.84	313.98	0.21
1	2746.289	2018_25yr_MHHW_M	Design_12'	1228	7.4	15.5837		15.68	0.000713	3.29	805.92	313.99	0.21
1	2746.289	2018_25yr_MHHW_M	Design_in-kind	1228	7.4	15.6027		15.7	0.000701	3.27	811.89	314.78	0.21
1	2746.289	2018_25yr_MHHW_M	Design_Exist	1228	7.4	15.6108	12.68	15.7	0.000695	3.26	814.45	315.12	0.21

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2746.289	2018_25yr_MSL_Ma	Design_20'	1228	7.4	15.5834		15.68	0.000713	3.29	805.84	313.98	0.21
1	2746.289	2018_25yr_MSL_Ma	Design_12'	1228	7.4	15.5834		15.68	0.000713	3.29	805.85	313.98	0.21
1	2746.289	2018_25yr_MSL_Ma	Design_in-kind	1228	7.4	15.6052		15.7	0.000699	3.26	812.68	314.88	0.21
1	2746.289	2018_25yr_MSL_Ma	Design_Exist	1228	7.4	15.6059	12.68	15.7	0.000698	3.26	812.92	314.92	0.21
1	2746.289	2100_025yr_Ab1	Design_20'	1706	7.4	16.2317		16.34	0.0008	3.68	1025.9	378.53	0.23
1	2746.289	2100_025yr_Ab1	Design_12'	1706	7.4	16.248		16.35	0.000789	3.66	1032.06	379.71	0.23
1	2746.289	2100_025yr_Ab1	Design_in-kind	1706	7.4	16.2533		16.36	0.000785	3.65	1034.09	380.1	0.23
1	2746.289	2100_025yr_Ab1	Design_Exist	1706	7.4	16.2544	13.46	16.36	0.000784	3.65	1034.5	380.18	0.22
1	2746.289	2100_050yr_Ab1	Design_20'	1717	7.4	16.2524		16.36	0.000796	3.68	1033.74	380.03	0.23
1	2746.289	2100_050yr_Ab1	Design_12'	1717	7.4	16.2582		16.37	0.000792	3.67	1035.94	380.46	0.23
1	2746.289	2100_050yr_Ab1	Design_in-kind	1717	7.4	16.2695		16.38	0.000784	3.66	1040.25	381.28	0.23
1	2746.289	2100_050yr_Ab1	Design_Exist	1717	7.4	16.2722	13.47	16.38	0.000782	3.65	1041.29	381.48	0.22
1	2746.289	2100_100yr_Ab1	Design_20'	2562	7.4	17.1744		17.29	0.000837	4.05	1410.47	435.51	0.24
1	2746.289	2100_100yr_Ab1	Design_12'	2562	7.4	17.1818		17.29	0.000832	4.04	1413.69	435.93	0.24
1	2746.289	2100_100yr_Ab1	Design_in-kind	2562	7.4	17.1896		17.3	0.000826	4.03	1417.1	436.39	0.24
1	2746.289	2100_100yr_Ab1	Design_Exist	2562	7.4	17.1811	14.82	17.29	0.000832	4.04	1413.39	435.89	0.24
1	2746.289	2018_025yr(Surge	Design_20'	1228	7.4	15.5819		15.68	0.000714	3.29	805.35	313.92	0.21
1	2746.289	2015_025yr(Surge	Design_12'	1228	7.4	15.592		15.69	0.000708	3.28	808.54	314.34	0.21
1	2746.289	2015_025yr(Surge	Design_in-kind	1228	7.4	15.6049		15.7	0.000699	3.26	812.61	314.87	0.21
1	2746.289	2015_025yr(Surge	Design_Exist	1228	7.4	15.6118	12.68	15.7	0.000695	3.25	814.76	315.16	0.21
1	2746.289	2018_050yr(Surge	Design_20'	1565	7.4	16.0499		16.16	0.000789	3.6	958.29	365.42	0.22
1	2746.289	2015_050yr(Surge	Design_12'	1565	7.4	16.055		16.16	0.000786	3.6	960.17	365.76	0.22
1	2746.289	2015_050yr(Surge	Design_in-kind	1565	7.4	16.0724		16.18	0.000773	3.57	966.52	366.91	0.22
1	2746.289	2015_050yr(Surge	Design_Exist	1565	7.4	16.0759	13.11	16.18	0.000771	3.57	967.83	367.14	0.22
1	2746.289	015_100yr(Surge)	Design_20'	2000	7.4	16.6009		16.71	0.000832	3.87	1170.25	402.28	0.23
1	2746.289	015_100yr(Surge)	Design_12'	2000	7.4	16.5959		16.71	0.000835	3.87	1168.23	401.98	0.23
1	2746.289	015_100yr(Surge)	Design_in-kind	2000	7.4	16.611		16.72	0.000825	3.85	1174.32	402.86	0.23
1	2746.289	015_100yr(Surge)	Design_Exist	2000	7.4	16.612	13.97	16.72	0.000824	3.85	1174.71	402.92	0.23
1	2723.129	2018_002yr	Design_20'	232	7.34	11.2416	9.87	11.68	0.00616	5.32	43.58	12.37	0.5
1	2723.129	2018_002yr	Design_12'	232	7.34	11.2416	9.87	11.68	0.00616	5.32	43.58	12.37	0.5
1	2723.129	2018_002yr	Design_in-kind	232	7.34	11.2416	9.87	11.68	0.00616	5.32	43.58	12.37	0.5
1	2723.129	2018_002yr	Design_Exist	232	7.34	11.2416	9.87	11.68	0.00616	5.32	43.58	12.37	0.5
1	2723.129	2018_010yr	Design_20'	845	7.34	13.9544	13.86	15.19	0.011232	9.49	115.04	75.56	0.67
1	2723.129	2018_010yr	Design_12'	845	7.34	13.9544	13.86	15.19	0.011232	9.49	115.04	75.56	0.67
1	2723.129	2018_010yr	Design_in-kind	845	7.34	13.9964	13.86	15.19	0.010817	9.34	118.23	88.58	0.66
1	2723.129	2018_010yr	Design_Exist	845	7.34	13.8649	13.86	15.21	0.012147	9.8	109.31	68.2	0.7
1	2723.129	2018_025y	Design_20'	1228	7.34	15.2678	14.9	15.62	0.004021	6.27	346.01	240.78	0.41
1	2723.129	2018_025y	Design_12'	1228	7.34	15.2644	14.9	15.62	0.00404	6.29	345.31	240.6	0.41
1	2723.129	2018_025y	Design_in-kind	1228	7.34	15.3059	14.9	15.64	0.003816	6.13	353.93	242.85	0.4
1	2723.129	2018_025y	Design_Exist	1228	7.34	15.3153	14.9	15.64	0.003768	6.1	355.88	243.35	0.39
1	2723.129	2018_050yr	Design_20'	1565	7.34	15.8501	15.16	16.11	0.00305	5.75	474.54	274.39	0.36
1	2723.129	2018_050yr	Design_12'	1565	7.34	15.8474	15.16	16.11	0.003061	5.76	473.91	274.25	0.36
1	2723.129	2018_050yr	Design_in-kind	1565	7.34	15.8603	15.16	16.12	0.003012	5.72	476.93	274.93	0.36
1	2723.129	2018_050yr	Design_Exist	1565	7.34	15.8808	15.16	16.13	0.002937	5.65	481.77	276.02	0.35
1	2723.129	2018_100yr	Design_20'	2000	7.34	16.4411	15.43	16.66	0.002451	5.4	618.59	298.21	0.33
1	2723.129	2018_100yr	Design_12'	2000	7.34	16.4443	15.43	16.66	0.002443	5.4	619.4	298.34	0.32
1	2723.129	2018_100yr	Design_in-kind	2000	7.34	16.4538	15.43	16.67	0.002417	5.37	621.8	298.74	0.32
1	2723.129	2018_100yr	Design_Exist	2000	7.34	16.4693	15.43	16.68	0.002375	5.33	625.7	299.56	0.32
1	2723.129	2018_500yr	Design_20'	2671	7.34	17.2124	15.79	17.37	0.00169	4.75	939.26	323.35	0.27
1	2723.129	2018_500yr	Design_12'	2671	7.34	17.2091	15.79	17.37	0.001696	4.76	938.18	323.29	0.27
1	2723.129	2018_500yr	Design_in-kind	2671	7.34	17.2184	15.79	17.38	0.001681	4.74	941.17	323.45	0.27
1	2723.129	2018_500yr	Design_Exist	2671	7.34	17.2148	15.79	17.37	0.001687	4.75	940.03	323.39	0.27
1	2723.129	2018_25yr_MHHW_M	Design_20'	1228	7.34	15.2678	14.9	15.62	0.004021	6.27	346.01	240.78	0.41
1	2723.129	2018_25yr_MHHW_M	Design_12'	1228	7.34	15.2684	14.9	15.62	0.004018	6.27	346.12	240.81	0.41
1	2723.129	2018_25yr_MHHW_M	Design_in-kind	1228	7.34	15.3077	14.9	15.64	0.003807	6.13	354.29	242.94	0.4
1	2723.129	2018_25yr_MHHW_M	Design_Exist	1228	7.34	15.3236	14.9	15.65	0.003725	6.07	357.61	243.8	0.39
1	2723.129	2018_25yr_MSL_Ma	Design_20'	1228	7.34	15.2678	14.9	15.62	0.004021	6.27	346.01	240.78	0.41
1	2723.129	2018_25yr_MSL_Ma	Design_12'	1228	7.34	15.2679	14.9	15.62	0.004021	6.27	346.02	240.78	0.41
1	2723.129	2018_25yr_MSL_Ma	Design_in-kind	1228	7.34	15.3126	14.9	15.64	0.003781	6.11	355.32	243.21	0.39
1	2723.129	2018_25yr_MSL_Ma	Design_Exist	1228	7.34	15.3141	14.9	15.64	0.003774	6.1	355.63	243.29	0.39
1	2723.129	2100_025yr_Ab1	Design_20'	1706	7.34	16.045	15.26	16.29	0.002854	5.65	521.03	283.8	0.35
1	2723.129	2100_025yr_Ab1	Design_12'	1706	7.34	16.0674	15.26	16.31	0.002775	5.58	526.45	284.54	0.34
1	2723.129	2100_025yr_Ab1	Design_in-kind	1706	7.34	16.0746	15.26	16.31	0.00275	5.56	528.21	284.77	0.34
1	2723.129	2100_025yr_Ab1	Design_Exist	1706	7.34	16.0761	15.26	16.31	0.002745	5.56	528.56	284.82	0.34
1	2723.129	2100_050yr_Ab1	Design_20'	1717	7.34	16.0699	15.26	16.31	0.002802	5.61	527.06	284.62	0.35
1	2723.129	2100_050yr_Ab1	Design_12'	1717	7.34	16.0778	15.26	16.32	0.002774	5.59	528.98	284.88	0.34
1	2723.129	2100_050yr_Ab1	Design_in-kind	1717	7.34	16.0931	15.26	16.33	0.002722	5.54	532.7	285.38	0.34
1	2723.129	2100_050yr_Ab1	Design_Exist	1717	7.34	16.0968	15.26	16.33	0.00271	5.53	533.59	285.5	0.34
1	2723.129	2100_100yr_Ab1	Design_20'	2562	7.34	17.0916	15.74	17.25	0.001751	4.8	900.32	321.22	0.28
1	2723.129	2100_100yr_Ab1	Design_12'	2562	7.34	17.0996	15.74	17.26	0.001737	4.78	902.88	321.36	0.28
1	2723.129	2100_100yr_Ab1	Design_in-kind	2562	7.34	17.108	15.74	17.27	0.001723	4.76	905.59	321.5	0.28

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2723.129	2100_100yr_Ab1	Design_Exist	2562	7.34	17.0989	15.74	17.26	0.001739	4.78	902.65	321.34	0.28
1	2723.129	2018_025yr(Surge	Design_20'	1228	7.34	15.2644	14.9	15.62	0.00404	6.29	345.31	240.6	0.41
1	2723.129	2015_025yr(Surge	Design_12'	1228	7.34	15.286	14.9	15.63	0.003922	6.21	349.78	241.77	0.4
1	2723.129	2015_025yr(Surge	Design_in-kind	1228	7.34	15.3122	14.9	15.64	0.003784	6.11	355.23	243.19	0.4
1	2723.129	2015_025yr(Surge	Design_Exist	1228	7.34	15.3254	14.9	15.65	0.003716	6.06	358	243.91	0.39
1	2723.129	2018_050yr(Surge	Design_20'	1565	7.34	15.8414	15.16	16.1	0.003084	5.78	472.49	273.93	0.36
1	2723.129	2015_050yr(Surge	Design_12'	1565	7.34	15.849	15.16	16.11	0.003055	5.75	474.27	274.33	0.36
1	2723.129	2015_050yr(Surge	Design_in-kind	1565	7.34	15.8739	15.16	16.13	0.002962	5.68	480.14	275.65	0.35
1	2723.129	2015_050yr(Surge	Design_Exist	1565	7.34	15.879	15.16	16.13	0.002944	5.66	481.32	275.92	0.35
1	2723.129	015_100yr(Surge)	Design_20'	2000	7.34	16.4521	15.43	16.67	0.002421	5.38	621.38	298.67	0.32
1	2723.129	015_100yr(Surge)	Design_12'	2000	7.34	16.446	15.43	16.66	0.002438	5.39	619.84	298.42	0.32
1	2723.129	015_100yr(Surge)	Design_in-kind	2000	7.34	16.4645	15.43	16.68	0.002388	5.34	624.48	299.27	0.32
1	2723.129	015_100yr(Surge)	Design_Exist	2000	7.34	16.4656	15.43	16.68	0.002385	5.34	624.78	299.34	0.32
1	2594.622	2018_002yr	Design_20'	232	6.84	11.1335		11.27	0.001295	2.97	89.89	43.86	0.29
1	2594.622	2018_002yr	Design_12'	232	6.84	11.1335		11.27	0.001295	2.97	89.89	43.86	0.29
1	2594.622	2018_002yr	Design_in-kind	232	6.84	11.1335		11.27	0.001295	2.97	89.89	43.86	0.29
1	2594.622	2018_002yr	Design_Exist	232	6.84	11.1335		11.27	0.001295	2.97	89.89	43.86	0.29
1	2594.622	2018_010yr	Design_20'	845	6.84	14.3182		14.54	0.00111	4.31	381.61	191.95	0.3
1	2594.622	2018_010yr	Design_12'	845	6.84	14.3182		14.54	0.00111	4.31	381.61	191.95	0.3
1	2594.622	2018_010yr	Design_in-kind	845	6.84	14.3474		14.56	0.001082	4.27	387.22	192.92	0.29
1	2594.622	2018_010yr	Design_Exist	845	6.84	14.3827	11.46	14.59	0.001049	4.22	394.05	194.09	0.29
1	2594.622	2018_025y	Design_20'	1228	6.84	15.06		15.32	0.001247	4.91	534.44	222.57	0.32
1	2594.622	2018_025y	Design_12'	1228	6.84	15.0562		15.31	0.001251	4.92	533.6	222.46	0.32
1	2594.622	2018_025y	Design_in-kind	1228	6.84	15.1028		15.35	0.001203	4.84	543.99	223.74	0.32
1	2594.622	2018_025y	Design_Exist	1228	6.84	15.1133		15.36	0.001193	4.82	546.34	224.03	0.31
1	2594.622	2018_050yr	Design_20'	1565	6.84	15.5784		15.85	0.001325	5.3	653.51	236.82	0.34
1	2594.622	2018_050yr	Design_12'	1565	6.84	15.5752		15.85	0.001329	5.3	652.74	236.73	0.34
1	2594.622	2018_050yr	Design_in-kind	1565	6.84	15.5906		15.86	0.001313	5.28	656.41	237.15	0.33
1	2594.622	2018_050yr	Design_Exist	1565	6.84	15.6152		15.88	0.001287	5.24	662.25	237.83	0.33
1	2594.622	2018_100yr	Design_20'	2000	6.84	16.0997		16.4	0.00145	5.79	781.47	259.19	0.35
1	2594.622	2018_100yr	Design_12'	2000	6.84	16.104		16.41	0.001445	5.78	782.59	259.31	0.35
1	2594.622	2018_100yr	Design_in-kind	2000	6.84	16.117		16.42	0.001431	5.76	785.95	259.67	0.35
1	2594.622	2018_100yr	Design_Exist	2000	6.84	16.1378		16.43	0.001408	5.72	791.37	260.24	0.35
1	2594.622	2018_500yr	Design_20'	2671	6.84	16.8095		17.14	0.001539	6.3	972.19	277.81	0.37
1	2594.622	2018_500yr	Design_12'	2671	6.84	16.8048		17.14	0.001544	6.31	970.89	277.69	0.37
1	2594.622	2018_500yr	Design_in-kind	2671	6.84	16.8178		17.15	0.00153	6.29	974.51	278.02	0.37
1	2594.622	2018_500yr	Design_Exist	2671	6.84	16.8128		17.14	0.001536	6.29	973.12	277.9	0.37
1	2594.622	2018_25yr_MHHW_M	Design_20'	1228	6.84	15.06		15.32	0.001247	4.91	534.44	222.57	0.32
1	2594.622	2018_25yr_MHHW_M	Design_12'	1228	6.84	15.0606		15.32	0.001247	4.91	534.58	222.58	0.32
1	2594.622	2018_25yr_MHHW_M	Design_in-kind	1228	6.84	15.1047		15.35	0.001201	4.84	544.42	223.8	0.32
1	2594.622	2018_25yr_MHHW_M	Design_Exist	1228	6.84	15.1226		15.36	0.001183	4.81	548.42	224.29	0.31
1	2594.622	2018_25yr_MSL_Ma	Design_20'	1228	6.84	15.06		15.32	0.001247	4.91	534.44	222.57	0.32
1	2594.622	2018_25yr_MSL_Ma	Design_12'	1228	6.84	15.06		15.32	0.001247	4.91	534.45	222.57	0.32
1	2594.622	2018_25yr_MSL_Ma	Design_in-kind	1228	6.84	15.1102		15.35	0.001196	4.83	545.66	223.95	0.32
1	2594.622	2018_25yr_MSL_Ma	Design_Exist	1228	6.84	15.112		15.36	0.001194	4.83	546.04	223.99	0.32
1	2594.622	2100_025yr_Ab1	Design_20'	1706	6.84	15.7415		16.03	0.001386	5.49	692.51	241.2	0.34
1	2594.622	2100_025yr_Ab1	Design_12'	1706	6.84	15.7694		16.05	0.001356	5.45	699.25	241.94	0.34
1	2594.622	2100_025yr_Ab1	Design_in-kind	1706	6.84	15.7785		16.06	0.001347	5.43	701.43	242.17	0.34
1	2594.622	2100_025yr_Ab1	Design_Exist	1706	6.84	15.7803		16.06	0.001345	5.43	701.87	242.22	0.34
1	2594.622	2100_050yr_Ab1	Design_20'	1717	6.84	15.7667		16.05	0.001377	5.49	698.59	241.86	0.34
1	2594.622	2100_050yr_Ab1	Design_12'	1717	6.84	15.7766		16.06	0.001366	5.47	700.99	242.13	0.34
1	2594.622	2100_050yr_Ab1	Design_in-kind	1717	6.84	15.7958		16.08	0.001346	5.44	705.63	242.63	0.34
1	2594.622	2100_050yr_Ab1	Design_Exist	1717	6.84	15.8003		16.08	0.001342	5.43	706.74	242.75	0.34
1	2594.622	2100_100yr_Ab1	Design_20'	2562	6.84	16.688		17.02	0.001542	6.25	938.64	274.75	0.37
1	2594.622	2100_100yr_Ab1	Design_12'	2562	6.84	16.6993		17.03	0.00153	6.23	941.74	275.03	0.37
1	2594.622	2100_100yr_Ab1	Design_in-kind	2562	6.84	16.7112		17.04	0.001517	6.21	945.01	275.33	0.37
1	2594.622	2100_100yr_Ab1	Design_Exist	2562	6.84	16.6983		17.03	0.001531	6.23	941.45	275.01	0.37
1	2594.622	2018_025yr(Surge	Design_20'	1228	6.84	15.0562		15.31	0.001251	4.92	533.6	222.46	0.32
1	2594.622	2015_025yr(Surge	Design_12'	1228	6.84	15.0804		15.33	0.001226	4.88	538.99	223.13	0.32
1	2594.622	2015_025yr(Surge	Design_in-kind	1228	6.84	15.1098		15.35	0.001196	4.83	545.55	223.93	0.32
1	2594.622	2015_025yr(Surge	Design_Exist	1228	6.84	15.1247		15.37	0.001181	4.81	548.89	224.34	0.31
1	2594.622	2018_050yr(Surge	Design_20'	1565	6.84	15.5679		15.84	0.001336	5.32	651.03	236.53	0.34
1	2594.622	2015_050yr(Surge	Design_12'	1565	6.84	15.577		15.85	0.001327	5.3	653.18	236.78	0.34
1	2594.622	2015_050yr(Surge	Design_in-kind	1565	6.84	15.6069		15.88	0.001296	5.25	660.28	237.6	0.33
1	2594.622	2015_050yr(Surge	Design_Exist	1565	6.84	15.613		15.88	0.00129	5.24	661.71	237.77	0.33
1	2594.622	015_100yr(Surge)	Design_20'	2000	6.84	16.1147		16.42	0.001433	5.76	785.36	259.6	0.35
1	2594.622	015_100yr(Surge)	Design_12'	2000	6.84	16.1064		16.41	0.001442	5.78	783.21	259.38	0.35
1	2594.622	015_100yr(Surge)	Design_in-kind	2000	6.84	16.1313		16.43	0.001415	5.73	789.68	260.07	0.35
1	2594.622	015_100yr(Surge)	Design_Exist	2000	6.84	16.1329		16.43	0.001413	5.73	790.09	260.11	0.35
1	2470.57	2018_002yr	Design_20'	232	6.6	10.9721		11.09	0.001394	3.04	138.47	98.95	0.29

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2470.57	2018_002yr	Design_12'	232	6.6	10.9721		11.09	0.001394	3.04	138.47	98.95	0.29
1	2470.57	2018_002yr	Design_in-kind	232	6.6	10.9721		11.09	0.001394	3.04	138.47	98.95	0.29
1	2470.57	2018_002yr	Design_Exist	232	6.6	10.9721		11.09	0.001394	3.04	138.47	98.95	0.29
1	2470.57	2018_010yr	Design_20'	845	6.6	14.3316		14.4	0.000523	2.94	668.24	227.03	0.2
1	2470.57	2018_010yr	Design_12'	845	6.6	14.3316		14.4	0.000523	2.94	668.24	227.03	0.2
1	2470.57	2018_010yr	Design_in-kind	845	6.6	14.3604		14.42	0.00051	2.91	674.79	227.73	0.2
1	2470.57	2018_010yr	Design_Exist	845	6.6	14.3953		14.46	0.000495	2.88	682.74	228.57	0.19
1	2470.57	2018_025y	Design_20'	1228	6.6	15.0728		15.15	0.000604	3.39	843.19	245.05	0.22
1	2470.57	2018_025y	Design_12'	1228	6.6	15.0691		15.15	0.000606	3.39	842.28	244.96	0.22
1	2470.57	2018_025y	Design_in-kind	1228	6.6	15.1147		15.19	0.000585	3.34	853.46	246.06	0.21
1	2470.57	2018_025y	Design_Exist	1228	6.6	15.1249		15.2	0.00058	3.33	855.99	246.31	0.21
1	2470.57	2018_050yr	Design_20'	1565	6.6	15.5858		15.68	0.00067	3.73	972.08	257.4	0.23
1	2470.57	2018_050yr	Design_12'	1565	6.6	15.5827		15.67	0.000672	3.73	971.27	257.33	0.23
1	2470.57	2018_050yr	Design_in-kind	1565	6.6	15.5979		15.69	0.000665	3.72	975.18	257.69	0.23
1	2470.57	2018_050yr	Design_Exist	1565	6.6	15.622		15.71	0.000653	3.69	981.41	258.27	0.23
1	2470.57	2018_100yr	Design_20'	2000	6.6	16.1007		16.21	0.000768	4.16	1107.77	269.68	0.25
1	2470.57	2018_100yr	Design_12'	2000	6.6	16.1049		16.21	0.000766	4.15	1108.92	269.77	0.25
1	2470.57	2018_100yr	Design_in-kind	2000	6.6	16.1176		16.22	0.000759	4.14	1112.35	270.07	0.25
1	2470.57	2018_100yr	Design_Exist	2000	6.6	16.1381		16.24	0.000749	4.12	1117.87	270.52	0.25
1	2470.57	2018_500yr	Design_20'	2671	6.6	16.7966		16.93	0.00088	4.69	1300.9	285.62	0.27
1	2470.57	2018_500yr	Design_12'	2671	6.6	16.7919		16.92	0.000882	4.69	1299.57	285.51	0.27
1	2470.57	2018_500yr	Design_in-kind	2671	6.6	16.8048		16.94	0.000875	4.68	1303.26	285.82	0.27
1	2470.57	2018_500yr	Design_Exist	2671	6.6	16.7999		16.93	0.000878	4.69	1301.85	285.7	0.27
1	2470.57	2018_25yr_MHHW_M	Design_20'	1228	6.6	15.0728		15.15	0.000604	3.39	843.19	245.05	0.22
1	2470.57	2018_25yr_MHHW_M	Design_12'	1228	6.6	15.0734		15.15	0.000604	3.38	843.34	245.06	0.22
1	2470.57	2018_25yr_MHHW_M	Design_in-kind	1228	6.6	15.1166		15.19	0.000584	3.34	853.93	246.11	0.21
1	2470.57	2018_25yr_MHHW_M	Design_Exist	1228	6.6	15.134		15.21	0.000576	3.32	858.23	246.53	0.21
1	2470.57	2018_25yr_MSL_Ma	Design_20'	1228	6.6	15.0728		15.15	0.000604	3.39	843.19	245.05	0.22
1	2470.57	2018_25yr_MSL_Ma	Design_12'	1228	6.6	15.0729		15.15	0.000604	3.39	843.2	245.05	0.22
1	2470.57	2018_25yr_MSL_Ma	Design_in-kind	1228	6.6	15.122		15.2	0.000582	3.34	855.26	246.24	0.21
1	2470.57	2018_25yr_MSL_Ma	Design_Exist	1228	6.6	15.1236		15.2	0.000581	3.33	855.67	246.28	0.21
1	2470.57	2100_025yr_Ab1	Design_20'	1706	6.6	15.7473		15.84	0.000711	3.89	1013.97	261.26	0.24
1	2470.57	2100_025yr_Ab1	Design_12'	1706	6.6	15.7748		15.87	0.000697	3.86	1021.15	261.92	0.24
1	2470.57	2100_025yr_Ab1	Design_in-kind	1706	6.6	15.7837		15.88	0.000693	3.85	1023.47	262.13	0.24
1	2470.57	2100_025yr_Ab1	Design_Exist	1706	6.6	15.7855		15.88	0.000692	3.85	1023.94	262.17	0.24
1	2470.57	2100_050yr_Ab1	Design_20'	1717	6.6	15.7722		15.87	0.000708	3.89	1020.47	261.86	0.24
1	2470.57	2100_050yr_Ab1	Design_12'	1717	6.6	15.782		15.88	0.000703	3.88	1023.02	262.09	0.24
1	2470.57	2100_050yr_Ab1	Design_in-kind	1717	6.6	15.8008		15.9	0.000694	3.86	1027.96	262.54	0.24
1	2470.57	2100_050yr_Ab1	Design_Exist	1717	6.6	15.8053		15.9	0.000692	3.85	1029.14	262.65	0.24
1	2470.57	2100_100yr_Ab1	Design_20'	2562	6.6	16.6774		16.81	0.00087	4.62	1267.05	282.79	0.27
1	2470.57	2100_100yr_Ab1	Design_12'	2562	6.6	16.6886		16.82	0.000864	4.61	1270.21	283.06	0.27
1	2470.57	2100_100yr_Ab1	Design_in-kind	2562	6.6	16.7003		16.83	0.000858	4.6	1273.53	283.34	0.27
1	2470.57	2100_100yr_Ab1	Design_Exist	2562	6.6	16.6876		16.81	0.000865	4.61	1269.91	283.03	0.27
1	2470.57	2018_025yr(Surge	Design_20'	1228	6.6	15.0691		15.15	0.000606	3.39	842.28	244.96	0.22
1	2470.57	2015_025yr(Surge	Design_12'	1228	6.6	15.0928		15.17	0.000595	3.37	848.09	245.53	0.22
1	2470.57	2015_025yr(Surge	Design_in-kind	1228	6.6	15.1215		15.2	0.000582	3.34	855.14	246.23	0.21
1	2470.57	2015_025yr(Surge	Design_Exist	1228	6.6	15.1361		15.21	0.000575	3.32	858.73	246.58	0.21
1	2470.57	2018_050yr(Surge	Design_20'	1565	6.6	15.5755		15.67	0.000675	3.74	969.43	257.16	0.23
1	2470.57	2015_050yr(Surge	Design_12'	1565	6.6	15.5845		15.67	0.000671	3.73	971.74	257.37	0.23
1	2470.57	2015_050yr(Surge	Design_in-kind	1565	6.6	15.6139		15.7	0.000657	3.7	979.31	258.07	0.23
1	2470.57	2015_050yr(Surge	Design_Exist	1565	6.6	15.6198		15.71	0.000654	3.69	980.84	258.21	0.23
1	2470.57	015_100yr(Surge)	Design_20'	2000	6.6	16.1154		16.22	0.00076	4.14	1111.74	270.01	0.25
1	2470.57	015_100yr(Surge)	Design_12'	2000	6.6	16.1073		16.21	0.000765	4.15	1109.55	269.83	0.25
1	2470.57	015_100yr(Surge)	Design_in-kind	2000	6.6	16.1317		16.24	0.000752	4.12	1116.15	270.38	0.25
1	2470.57	015_100yr(Surge)	Design_Exist	2000	6.6	16.1333		16.24	0.000751	4.12	1116.57	270.42	0.25
1	2308.278	2018_002yr	Design_20'	232	5.87	10.8477		10.91	0.000699	2.33	151.21	90.82	0.21
1	2308.278	2018_002yr	Design_12'	232	5.87	10.8477		10.91	0.000699	2.33	151.21	90.82	0.21
1	2308.278	2018_002yr	Design_in-kind	232	5.87	10.8477		10.91	0.000699	2.33	151.21	90.82	0.21
1	2308.278	2018_002yr	Design_Exist	232	5.87	10.8477		10.91	0.000699	2.33	151.21	90.82	0.21
1	2308.278	2018_010yr	Design_20'	845	5.87	14.2854		14.32	0.000283	2.28	719.06	240.4	0.15
1	2308.278	2018_010yr	Design_12'	845	5.87	14.2854		14.32	0.000283	2.28	719.06	240.4	0.15
1	2308.278	2018_010yr	Design_in-kind	845	5.87	14.3154		14.35	0.000275	2.26	726.29	241.22	0.15
1	2308.278	2018_010yr	Design_Exist	845	5.87	14.3516		14.39	0.000267	2.23	735.05	242.21	0.15
1	2308.278	2018_025y	Design_20'	1228	5.87	15.0189		15.07	0.000329	2.63	902.75	260.43	0.16
1	2308.278	2018_025y	Design_12'	1228	5.87	15.0151		15.06	0.00033	2.63	901.75	260.33	0.16
1	2308.278	2018_025y	Design_in-kind	1228	5.87	15.0625		15.11	0.000319	2.59	914.13	261.62	0.16
1	2308.278	2018_025y	Design_Exist	1228	5.87	15.0732		15.12	0.000316	2.59	916.93	261.91	0.16
1	2308.278	2018_050yr	Design_20'	1565	5.87	15.5252		15.58	0.00037	2.9	1038.12	274.5	0.18
1	2308.278	2018_050yr	Design_12'	1565	5.87	15.5219		15.58	0.000371	2.91	1037.21	274.4	0.18
1	2308.278	2018_050yr	Design_in-kind	1565	5.87	15.5378		15.59	0.000367	2.89	1041.57	274.86	0.18
1	2308.278	2018_050yr	Design_Exist	1565	5.87	15.563		15.62	0.000361	2.87	1048.51	275.59	0.17

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2308.278	2018_100yr	Design_20'	2000	5.87	16.03		16.1	0.000432	3.26	1180.4	289.33	0.19
1	2308.278	2018_100yr	Design_12'	2000	5.87	16.0344		16.1	0.000431	3.25	1181.69	289.48	0.19
1	2308.278	2018_100yr	Design_in-kind	2000	5.87	16.0477		16.12	0.000427	3.24	1185.54	289.9	0.19
1	2308.278	2018_100yr	Design_Exist	2000	5.87	16.0692		16.14	0.000421	3.23	1191.76	290.58	0.19
1	2308.278	2018_500yr	Design_20'	2671	5.87	16.715		16.8	0.000502	3.69	1386.04	311.69	0.21
1	2308.278	2018_500yr	Design_12'	2671	5.87	16.7101		16.8	0.000503	3.69	1384.52	311.51	0.21
1	2308.278	2018_500yr	Design_in-kind	2671	5.87	16.7237		16.81	0.000499	3.68	1388.75	312.02	0.21
1	2308.278	2018_500yr	Design_Exist	2671	5.87	16.7185		16.8	0.000501	3.69	1387.13	311.82	0.21
1	2308.278	2018_25yr_MHHW_M	Design_20'	1228	5.87	15.0189		15.07	0.000329	2.63	902.75	260.43	0.16
1	2308.278	2018_25yr_MHHW_M	Design_12'	1228	5.87	15.0196		15.07	0.000329	2.63	902.91	260.45	0.16
1	2308.278	2018_25yr_MHHW_M	Design_in-kind	1228	5.87	15.0645		15.11	0.000318	2.59	914.65	261.68	0.16
1	2308.278	2018_25yr_MHHW_M	Design_Exist	1228	5.87	15.0827		15.13	0.000314	2.58	919.42	262.17	0.16
1	2308.278	2018_25yr_MSL_Ma	Design_20'	1228	5.87	15.0189		15.07	0.000329	2.63	902.75	260.43	0.16
1	2308.278	2018_25yr_MSL_Ma	Design_12'	1228	5.87	15.019		15.07	0.000329	2.63	902.77	260.43	0.16
1	2308.278	2018_25yr_MSL_Ma	Design_in-kind	1228	5.87	15.0701		15.12	0.000317	2.59	916.12	261.83	0.16
1	2308.278	2018_25yr_MSL_Ma	Design_Exist	1228	5.87	15.0719		15.12	0.000317	2.59	916.58	261.88	0.16
1	2308.278	2100_025yr_Ab1	Design_20'	1706	5.87	15.6826		15.74	0.000395	3.04	1081.69	279.07	0.18
1	2308.278	2100_025yr_Ab1	Design_12'	1706	5.87	15.7114		15.77	0.000388	3.01	1089.72	279.92	0.18
1	2308.278	2100_025yr_Ab1	Design_in-kind	1706	5.87	15.7206		15.78	0.000385	3.01	1092.32	280.19	0.18
1	2308.278	2100_025yr_Ab1	Design_Exist	1706	5.87	15.7225		15.78	0.000385	3	1092.84	280.24	0.18
1	2308.278	2100_050yr_Ab1	Design_20'	1717	5.87	15.7078		15.77	0.000394	3.04	1088.72	279.81	0.18
1	2308.278	2100_050yr_Ab1	Design_12'	1717	5.87	15.718		15.78	0.000391	3.03	1091.57	280.11	0.18
1	2308.278	2100_050yr_Ab1	Design_in-kind	1717	5.87	15.7376		15.8	0.000386	3.01	1097.09	280.69	0.18
1	2308.278	2100_050yr_Ab1	Design_Exist	1717	5.87	15.7423		15.8	0.000385	3.01	1098.41	280.82	0.18
1	2308.278	2100_100yr_Ab1	Design_20'	2562	5.87	16.5969		16.68	0.000495	3.63	1349.49	307.28	0.21
1	2308.278	2100_100yr_Ab1	Design_12'	2562	5.87	16.6086		16.69	0.000491	3.62	1353.11	307.72	0.21
1	2308.278	2100_100yr_Ab1	Design_in-kind	2562	5.87	16.621		16.7	0.000488	3.61	1356.91	308.18	0.21
1	2308.278	2100_100yr_Ab1	Design_Exist	2562	5.87	16.6075		16.69	0.000492	3.62	1352.77	307.67	0.21
1	2308.278	2018_025yr(Surge	Design_20'	1228	5.87	15.0151		15.06	0.00033	2.63	901.75	260.33	0.16
1	2308.278	2015_025yr(Surge	Design_12'	1228	5.87	15.0397		15.09	0.000324	2.61	908.18	261	0.16
1	2308.278	2015_025yr(Surge	Design_in-kind	1228	5.87	15.0697		15.11	0.000317	2.59	916	261.82	0.16
1	2308.278	2015_025yr(Surge	Design_Exist	1228	5.87	15.0848		15.13	0.000314	2.58	919.97	262.23	0.16
1	2308.278	2018_050yr(Surge	Design_20'	1565	5.87	15.5145		15.57	0.000373	2.91	1035.17	274.18	0.18
1	2308.278	2015_050yr(Surge	Design_12'	1565	5.87	15.5238		15.58	0.000371	2.9	1037.73	274.46	0.18
1	2308.278	2015_050yr(Surge	Design_in-kind	1565	5.87	15.5545		15.61	0.000363	2.88	1046.17	275.35	0.17
1	2308.278	2015_050yr(Surge	Design_Exist	1565	5.87	15.5607		15.62	0.000361	2.88	1047.87	275.53	0.17
1	2308.278	015_100yr(Surge)	Design_20'	2000	5.87	16.0454		16.11	0.000428	3.25	1184.86	289.82	0.19
1	2308.278	015_100yr(Surge)	Design_12'	2000	5.87	16.0369		16.11	0.00043	3.25	1182.39	289.55	0.19
1	2308.278	015_100yr(Surge)	Design_in-kind	2000	5.87	16.0625		16.13	0.000423	3.23	1189.82	290.37	0.19
1	2308.278	015_100yr(Surge)	Design_Exist	2000	5.87	16.0641		16.13	0.000423	3.23	1190.29	290.42	0.19
1	2105.615	2018_002yr	Design_20'	232	6.26	10.6379		10.73	0.000972	2.68	135.69	96.83	0.26
1	2105.615	2018_002yr	Design_12'	232	6.26	10.6379		10.73	0.000972	2.68	135.69	96.83	0.26
1	2105.615	2018_002yr	Design_in-kind	232	6.26	10.6379		10.73	0.000972	2.68	135.69	96.83	0.26
1	2105.615	2018_002yr	Design_Exist	232	6.26	10.6379		10.73	0.000972	2.68	135.69	96.83	0.26
1	2105.615	2018_010yr	Design_20'	845	6.26	14.2039		14.26	0.000328	2.52	706.26	222.97	0.17
1	2105.615	2018_010yr	Design_12'	845	6.26	14.2039		14.26	0.000328	2.52	706.26	222.97	0.17
1	2105.615	2018_010yr	Design_in-kind	845	6.26	14.236		14.29	0.000319	2.49	713.43	223.93	0.17
1	2105.615	2018_010yr	Design_Exist	845	6.26	14.2746		14.32	0.00031	2.46	722.11	225.09	0.16
1	2105.615	2018_025y	Design_20'	1228	6.26	14.9184		14.99	0.000398	2.96	873.25	244.32	0.19
1	2105.615	2018_025y	Design_12'	1228	6.26	14.9143		14.98	0.000399	2.96	872.24	244.22	0.19
1	2105.615	2018_025y	Design_in-kind	1228	6.26	14.9654		15.03	0.000385	2.92	884.74	245.47	0.19
1	2105.615	2018_025y	Design_Exist	1228	6.26	14.9768		15.04	0.000381	2.91	887.56	245.75	0.18
1	2105.615	2018_050yr	Design_20'	1565	6.26	15.4086		15.49	0.000457	3.31	995.97	256.81	0.2
1	2105.615	2018_050yr	Design_12'	1565	6.26	15.405		15.49	0.000458	3.31	995.05	256.7	0.2
1	2105.615	2018_050yr	Design_in-kind	1565	6.26	15.4222		15.5	0.000453	3.3	999.46	257.21	0.2
1	2105.615	2018_050yr	Design_Exist	1565	6.26	15.4495		15.53	0.000445	3.27	1006.5	258.03	0.2
1	2105.615	2018_100yr	Design_20'	2000	6.26	15.8913		15.99	0.000538	3.73	1122.82	268.44	0.22
1	2105.615	2018_100yr	Design_12'	2000	6.26	15.8962		16	0.000536	3.72	1124.14	268.55	0.22
1	2105.615	2018_100yr	Design_in-kind	2000	6.26	15.9108		16.01	0.000531	3.71	1128.07	268.89	0.22
1	2105.615	2018_100yr	Design_Exist	2000	6.26	15.9344		16.03	0.000522	3.69	1134.41	269.44	0.22
1	2105.615	2018_500yr	Design_20'	2671	6.26	16.5509		16.68	0.000624	4.22	1304.71	282.91	0.24
1	2105.615	2018_500yr	Design_12'	2671	6.26	16.5455		16.67	0.000626	4.22	1303.18	282.79	0.24
1	2105.615	2018_500yr	Design_in-kind	2671	6.26	16.5605		16.69	0.00062	4.21	1307.44	283.11	0.24
1	2105.615	2018_500yr	Design_Exist	2671	6.26	16.5548		16.68	0.000623	4.21	1305.81	282.99	0.24
1	2105.615	2018_25yr_MHHW_M	Design_20'	1228	6.26	14.9184		14.99	0.000398	2.96	873.25	244.32	0.19
1	2105.615	2018_25yr_MHHW_M	Design_12'	1228	6.26	14.9191		14.99	0.000398	2.96	873.42	244.34	0.19
1	2105.615	2018_25yr_MHHW_M	Design_in-kind	1228	6.26	14.9675		15.03	0.000384	2.92	885.26	245.52	0.19
1	2105.615	2018_25yr_MHHW_M	Design_Exist	1228	6.26	14.987		15.05	0.000379	2.91	890.06	246	0.18
1	2105.615	2018_25yr_MSL_Ma	Design_20'	1228	6.26	14.9184		14.99	0.000398	2.96	873.25	244.32	0.19
1	2105.615	2018_25yr_MSL_Ma	Design_12'	1228	6.26	14.9185		14.99	0.000398	2.96	873.27	244.33	0.19
1	2105.615	2018_25yr_MSL_Ma	Design_in-kind	1228	6.26	14.9735		15.04	0.000382	2.92	886.75	245.67	0.19

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	2105.615	2018_25yr_MSL_Ma	Design_Exist	1228	6.26	14.9754		15.04	0.000382	2.91	887.21	245.72	0.18
1	2105.615	2100_025yr_Ab1	Design_20'	1706	6.26	15.5568		15.65	0.000492	3.47	1034.35	260.66	0.21
1	2105.615	2100_025yr_Ab1	Design_12'	1706	6.26	15.5881		15.68	0.000482	3.44	1042.5	261.39	0.21
1	2105.615	2100_025yr_Ab1	Design_in-kind	1706	6.26	15.5982		15.69	0.000478	3.44	1045.14	261.63	0.21
1	2105.615	2100_025yr_Ab1	Design_Exist	1706	6.26	15.6002		15.69	0.000478	3.43	1045.68	261.68	0.21
1	2105.615	2100_050yr_Ab1	Design_20'	1717	6.26	15.5825		15.67	0.00049	3.47	1041.03	261.26	0.21
1	2105.615	2100_050yr_Ab1	Design_12'	1717	6.26	15.5936		15.68	0.000486	3.46	1043.93	261.52	0.21
1	2105.615	2100_050yr_Ab1	Design_in-kind	1717	6.26	15.6149		15.7	0.000479	3.44	1049.53	262.02	0.21
1	2105.615	2100_050yr_Ab1	Design_Exist	1717	6.26	15.6201		15.71	0.000477	3.44	1050.87	262.14	0.21
1	2105.615	2100_100yr_Ab1	Design_20'	2562	6.26	16.4352		16.56	0.000617	4.16	1272.12	280.4	0.24
1	2105.615	2100_100yr_Ab1	Design_12'	2562	6.26	16.4482		16.57	0.000612	4.15	1275.77	280.68	0.24
1	2105.615	2100_100yr_Ab1	Design_in-kind	2562	6.26	16.4619		16.58	0.000607	4.13	1279.61	280.98	0.24
1	2105.615	2100_100yr_Ab1	Design_Exist	2562	6.26	16.447		16.57	0.000613	4.15	1275.43	280.66	0.24
1	2105.615	2018_025yr(Surge	Design_20'	1228	6.26	14.9143		14.98	0.000399	2.96	872.24	244.22	0.19
1	2105.615	2015_025yr(Surge	Design_12'	1228	6.26	14.9409		15.01	0.000392	2.94	878.74	244.87	0.19
1	2105.615	2015_025yr(Surge	Design_in-kind	1228	6.26	14.973		15.04	0.000383	2.92	886.62	245.66	0.19
1	2105.615	2015_025yr(Surge	Design_Exist	1228	6.26	14.9893		15.05	0.000378	2.9	890.62	246.06	0.18
1	2105.615	2018_050yr(Surge	Design_20'	1565	6.26	15.3969		15.48	0.000461	3.32	992.97	256.46	0.2
1	2105.615	2015_050yr(Surge	Design_12'	1565	6.26	15.4071		15.49	0.000458	3.31	995.58	256.77	0.2
1	2105.615	2015_050yr(Surge	Design_in-kind	1565	6.26	15.4403		15.52	0.000448	3.28	1004.13	257.75	0.2
1	2105.615	2015_050yr(Surge	Design_Exist	1565	6.26	15.447		15.53	0.000446	3.28	1005.85	257.95	0.2
1	2105.615	015_100yr(Surge)	Design_20'	2000	6.26	15.9082		16.01	0.000532	3.71	1127.38	268.83	0.22
1	2105.615	015_100yr(Surge)	Design_12'	2000	6.26	15.8989		16	0.000535	3.72	1124.86	268.62	0.22
1	2105.615	015_100yr(Surge)	Design_in-kind	2000	6.26	15.927		16.03	0.000525	3.69	1132.44	269.27	0.22
1	2105.615	015_100yr(Surge)	Design_Exist	2000	6.26	15.9288		16.03	0.000524	3.69	1132.92	269.31	0.22
1	1967.196	2018_002yr	Design_20'	232	5.6	9.691	9.69	10.35	0.011412	6.91	45.17	41.27	0.67
1	1967.196	2018_002yr	Design_12'	232	5.6	9.691	9.69	10.35	0.011412	6.91	45.17	41.27	0.67
1	1967.196	2018_002yr	Design_in-kind	232	5.6	9.691	9.69	10.35	0.011412	6.91	45.17	41.27	0.67
1	1967.196	2018_002yr	Design_Exist	232	5.6	9.691	9.69	10.35	0.011412	6.91	45.17	41.27	0.67
1	1967.196	2018_010yr	Design_20'	845	5.6	14.1055		14.19	0.000772	3.17	441.44	140.83	0.2
1	1967.196	2018_010yr	Design_12'	845	5.6	14.1055		14.19	0.000772	3.17	441.44	140.83	0.2
1	1967.196	2018_010yr	Design_in-kind	845	5.6	14.1401		14.22	0.000751	3.14	446.31	141.4	0.2
1	1967.196	2018_010yr	Design_Exist	845	5.6	14.1815		14.26	0.000727	3.1	452.19	142.08	0.2
1	1967.196	2018_025y	Design_20'	1228	5.6	14.7881		14.9	0.00097	3.77	541.4	152.08	0.23
1	1967.196	2018_025y	Design_12'	1228	5.6	14.7836		14.9	0.000973	3.77	540.71	152.01	0.23
1	1967.196	2018_025y	Design_in-kind	1228	5.6	14.8394		14.95	0.000935	3.71	549.22	152.92	0.23
1	1967.196	2018_025y	Design_Exist	1228	5.6	14.8518		14.96	0.000927	3.7	551.13	153.13	0.22
1	1967.196	2018_050yr	Design_20'	1565	5.6	15.25		15.39	0.001141	4.23	613.44	159.86	0.25
1	1967.196	2018_050yr	Design_12'	1565	5.6	15.246		15.39	0.001144	4.24	612.8	159.8	0.25
1	1967.196	2018_050yr	Design_in-kind	1565	5.6	15.265		15.4	0.001129	4.21	615.85	160.11	0.25
1	1967.196	2018_050yr	Design_Exist	1565	5.6	15.2952		15.43	0.001106	4.18	620.69	160.61	0.25
1	1967.196	2018_100yr	Design_20'	2000	5.6	15.691		15.87	0.001392	4.83	685.54	167.13	0.28
1	1967.196	2018_100yr	Design_12'	2000	5.6	15.6965		15.88	0.001387	4.82	686.47	167.23	0.28
1	1967.196	2018_100yr	Design_in-kind	2000	5.6	15.7131		15.89	0.001373	4.8	689.24	167.5	0.28
1	1967.196	2018_100yr	Design_Exist	2000	5.6	15.7396		15.92	0.00135	4.77	693.69	167.94	0.28
1	1967.196	2018_500yr	Design_20'	2671	5.6	16.2941		16.53	0.001771	5.68	792.31	192.57	0.32
1	1967.196	2018_500yr	Design_12'	2671	5.6	16.2877		16.53	0.001778	5.69	791.09	192.23	0.32
1	1967.196	2018_500yr	Design_in-kind	2671	5.6	16.3054		16.54	0.00176	5.67	794.49	193.17	0.32
1	1967.196	2018_500yr	Design_Exist	2671	5.6	16.2986		16.53	0.001767	5.67	793.19	192.81	0.32
1	1967.196	2018_25yr_MHHW_M	Design_20'	1228	5.6	14.7881		14.9	0.00097	3.77	541.4	152.08	0.23
1	1967.196	2018_25yr_MHHW_M	Design_12'	1228	5.6	14.7889		14.9	0.00097	3.76	541.52	152.09	0.23
1	1967.196	2018_25yr_MHHW_M	Design_in-kind	1228	5.6	14.8417		14.95	0.000933	3.71	549.57	152.96	0.23
1	1967.196	2018_25yr_MHHW_M	Design_Exist	1228	5.6	14.8629		14.97	0.000919	3.69	552.83	153.31	0.22
1	1967.196	2018_25yr_MSL_Ma	Design_20'	1228	5.6	14.7881		14.9	0.00097	3.77	541.4	152.08	0.23
1	1967.196	2018_25yr_MSL_Ma	Design_12'	1228	5.6	14.7882		14.9	0.00097	3.77	541.42	152.08	0.23
1	1967.196	2018_25yr_MSL_Ma	Design_in-kind	1228	5.6	14.8483		14.96	0.000929	3.7	550.58	153.07	0.22
1	1967.196	2018_25yr_MSL_Ma	Design_Exist	1228	5.6	14.8503		14.96	0.000928	3.7	550.89	153.1	0.22
1	1967.196	2100_025yr_Ab1	Design_20'	1706	5.6	15.3827		15.54	0.00124	4.45	634.8	162.05	0.26
1	1967.196	2100_025yr_Ab1	Design_12'	1706	5.6	15.4176		15.57	0.001211	4.41	640.46	162.63	0.26
1	1967.196	2100_025yr_Ab1	Design_in-kind	1706	5.6	15.4288		15.58	0.001202	4.4	642.29	162.81	0.26
1	1967.196	2100_025yr_Ab1	Design_Exist	1706	5.6	15.4311		15.58	0.0012	4.4	642.66	162.85	0.26
1	1967.196	2100_050yr_Ab1	Design_20'	1717	5.6	15.4088		15.56	0.001234	4.45	639.03	162.48	0.26
1	1967.196	2100_050yr_Ab1	Design_12'	1717	5.6	15.4212		15.57	0.001224	4.44	641.05	162.69	0.26
1	1967.196	2100_050yr_Ab1	Design_in-kind	1717	5.6	15.445		15.6	0.001205	4.41	644.93	163.08	0.26
1	1967.196	2100_050yr_Ab1	Design_Exist	1717	5.6	15.4507		15.6	0.0012	4.41	645.86	163.17	0.26
1	1967.196	2100_100yr_Ab1	Design_20'	2562	5.6	16.1839		16.41	0.001731	5.57	771.41	186.71	0.31
1	1967.196	2100_100yr_Ab1	Design_12'	2562	5.6	16.1991		16.43	0.001717	5.56	774.25	187.51	0.31
1	1967.196	2100_100yr_Ab1	Design_in-kind	2562	5.6	16.215		16.44	0.001702	5.54	777.24	188.36	0.31
1	1967.196	2100_100yr_Ab1	Design_Exist	2562	5.6	16.1977		16.43	0.001718	5.56	773.99	187.44	0.31
1	1967.196	2018_025yr(Surge	Design_20'	1228	5.6	14.7836		14.9	0.000973	3.77	540.71	152.01	0.23
1	1967.196	2015_025yr(Surge	Design_12'	1228	5.6	14.8126		14.92	0.000953	3.74	545.14	152.48	0.23

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1967.196	2015_025yr(Surge	Design_in-kind	1228	5.6	14.8477		14.96	0.000929	3.7	550.49	153.06	0.22
1	1967.196	2015_025yr(Surge	Design_Exist	1228	5.6	14.8654		14.97	0.000918	3.68	553.2	153.35	0.22
1	1967.196	2018_050yr(Surge	Design_20'	1565	5.6	15.237		15.38	0.001151	4.25	611.37	159.65	0.25
1	1967.196	2015_050yr(Surge	Design_12'	1565	5.6	15.2483		15.39	0.001142	4.23	613.17	159.83	0.25
1	1967.196	2015_050yr(Surge	Design_in-kind	1565	5.6	15.2851		15.42	0.001114	4.19	619.06	160.44	0.25
1	1967.196	2015_050yr(Surge	Design_Exist	1565	5.6	15.2925		15.43	0.001108	4.18	620.25	160.56	0.25
1	1967.196	015_100yr(Surge)	Design_20'	2000	5.6	15.7102		15.89	0.001375	4.81	688.75	167.45	0.28
1	1967.196	015_100yr(Surge)	Design_12'	2000	5.6	15.6996		15.88	0.001385	4.82	686.98	167.28	0.28
1	1967.196	015_100yr(Surge)	Design_in-kind	2000	5.6	15.7314		15.91	0.001357	4.78	692.31	167.8	0.28
1	1967.196	015_100yr(Surge)	Design_Exist	2000	5.6	15.7334		15.91	0.001355	4.78	692.65	167.83	0.28
1	1801.551	2018_002yr	Design_20'	232	4	8.6655	5.83	8.78	0.001011	2.74	84.8	20.21	0.24
1	1801.551	2018_002yr	Design_12'	232	4	8.6664	5.83	8.78	0.00101	2.74	84.82	20.21	0.24
1	1801.551	2018_002yr	Design_in-kind	232	4	8.6716	5.83	8.79	0.001006	2.73	84.92	20.21	0.23
1	1801.551	2018_002yr	Design_Exist	232	4	8.7535	5.83	8.87	0.000952	2.68	86.58	20.28	0.23
1	1801.551	2018_010yr	Design_20'	845	4	13.9181	8.23	14.07	0.000575	3.44	392.35	142.79	0.2
1	1801.551	2018_010yr	Design_12'	845	4	13.9181	8.23	14.07	0.000575	3.44	392.35	142.79	0.2
1	1801.551	2018_010yr	Design_in-kind	845	4	13.957	8.23	14.1	0.000561	3.41	397.95	145.2	0.2
1	1801.551	2018_010yr	Design_Exist	845	4	14.0033	8.23	14.14	0.000547	3.38	404.74	148.61	0.19
1	1801.551	2018_025y	Design_20'	1228	4	14.5094	9.37	14.73	0.000853	4.37	486.41	173.18	0.24
1	1801.551	2018_025y	Design_12'	1228	4	14.5039	9.37	14.73	0.000856	4.37	485.45	172.9	0.25
1	1801.551	2018_025y	Design_in-kind	1228	4	14.5716	9.37	14.79	0.000822	4.3	497.27	176.32	0.24
1	1801.551	2018_025y	Design_Exist	1228	4	14.5867	9.37	14.8	0.000814	4.29	499.94	177.08	0.24
1	1801.551	2018_050yr	Design_20'	1565	4	14.8952	10.42	15.18	0.001095	5.08	557	193.23	0.28
1	1801.551	2018_050yr	Design_12'	1565	4	14.8901	10.42	15.18	0.001098	5.08	555.99	192.93	0.28
1	1801.551	2018_050yr	Design_in-kind	1565	4	14.9149	10.42	15.2	0.001082	5.05	560.8	194.42	0.28
1	1801.551	2018_050yr	Design_Exist	1565	4	14.954	10.42	15.23	0.001057	5.01	568.45	196.79	0.27
1	1801.551	2018_100yr	Design_20'	2000	4	15.2204	11.67	15.61	0.001465	5.99	623.1	212.67	0.32
1	1801.551	2018_100yr	Design_12'	2000	4	15.2288	11.67	15.61	0.001457	5.98	624.89	213.07	0.32
1	1801.551	2018_100yr	Design_in-kind	2000	4	15.2536	11.67	15.63	0.001434	5.94	630.19	214.25	0.32
1	1801.551	2018_100yr	Design_Exist	2000	4	15.293	11.67	15.66	0.001398	5.88	638.67	216.12	0.32
1	1801.551	2018_500yr	Design_20'	2671	4	15.6648	12.82	16.18	0.001973	7.15	722.98	238.05	0.38
1	1801.551	2018_500yr	Design_12'	2671	4	15.6535	12.82	16.17	0.001988	7.17	720.28	237.35	0.38
1	1801.551	2018_500yr	Design_in-kind	2671	4	15.6848	12.82	16.19	0.001949	7.12	727.75	239.29	0.38
1	1801.551	2018_500yr	Design_Exist	2671	4	15.6729	12.82	16.19	0.001963	7.14	724.9	238.55	0.38
1	1801.551	2018_25yr_MHHW_M	Design_20'	1228	4	14.5094	9.37	14.73	0.000853	4.37	486.41	173.18	0.24
1	1801.551	2018_25yr_MHHW_M	Design_12'	1228	4	14.5103	9.37	14.73	0.000853	4.37	486.56	173.22	0.24
1	1801.551	2018_25yr_MHHW_M	Design_in-kind	1228	4	14.5744	9.37	14.79	0.00082	4.3	497.76	176.46	0.24
1	1801.551	2018_25yr_MHHW_M	Design_Exist	1228	4	14.6001	9.37	14.81	0.000808	4.28	502.31	177.76	0.24
1	1801.551	2018_25yr_MSL_Ma	Design_20'	1228	4	14.5094	9.37	14.73	0.000853	4.37	486.41	173.18	0.24
1	1801.551	2018_25yr_MSL_Ma	Design_12'	1228	4	14.5095	9.37	14.73	0.000853	4.37	486.42	173.18	0.24
1	1801.551	2018_25yr_MSL_Ma	Design_in-kind	1228	4	14.5823	9.37	14.8	0.000816	4.29	499.17	176.86	0.24
1	1801.551	2018_25yr_MSL_Ma	Design_Exist	1228	4	14.5848	9.37	14.8	0.000815	4.29	499.61	176.98	0.24
1	1801.551	2100_025yr_Ab1	Design_20'	1706	4	14.9836	11.03	15.31	0.001233	5.42	574.31	198.54	0.3
1	1801.551	2100_025yr_Ab1	Design_12'	1706	4	15.0306	11.03	15.35	0.001199	5.36	583.71	201.59	0.29
1	1801.551	2100_025yr_Ab1	Design_in-kind	1706	4	15.0456	11.03	15.36	0.001188	5.34	586.75	202.56	0.29
1	1801.551	2100_025yr_Ab1	Design_Exist	1706	4	15.0487	11.03	15.36	0.001186	5.34	587.37	202.76	0.29
1	1801.551	2100_050yr_Ab1	Design_20'	1717	4	15.0118	11.05	15.33	0.001228	5.42	579.93	200.37	0.3
1	1801.551	2100_050yr_Ab1	Design_12'	1717	4	15.0285	11.05	15.35	0.001216	5.4	583.29	201.45	0.29
1	1801.551	2100_050yr_Ab1	Design_in-kind	1717	4	15.0606	11.05	15.37	0.001192	5.35	589.78	203.53	0.29
1	1801.551	2100_050yr_Ab1	Design_Exist	1717	4	15.0682	11.05	15.38	0.001187	5.34	591.34	204.03	0.29
1	1801.551	2100_100yr_Ab1	Design_20'	2562	4	15.5663	12.65	16.07	0.001932	7.03	699.82	231.97	0.37
1	1801.551	2100_100yr_Ab1	Design_12'	2562	4	15.5926	12.65	16.09	0.0019	6.99	705.95	233.59	0.37
1	1801.551	2100_100yr_Ab1	Design_in-kind	2562	4	15.6199	12.65	16.11	0.001868	6.94	712.34	235.28	0.37
1	1801.551	2100_100yr_Ab1	Design_Exist	2562	4	15.5902	12.65	16.09	0.001903	6.99	705.38	233.44	0.37
1	1801.551	2018_025yr(Surge	Design_20'	1228	4	14.5039	9.37	14.73	0.000856	4.37	485.45	172.9	0.25
1	1801.551	2015_025yr(Surge	Design_12'	1228	4	14.5392	9.37	14.76	0.000838	4.34	491.59	174.68	0.24
1	1801.551	2015_025yr(Surge	Design_in-kind	1228	4	14.5816	9.37	14.8	0.000817	4.29	499.05	176.83	0.24
1	1801.551	2015_025yr(Surge	Design_Exist	1228	4	14.603	9.37	14.81	0.000806	4.27	502.84	177.91	0.24
1	1801.551	2018_050yr(Surge	Design_20'	1565	4	14.8783	10.42	15.17	0.001106	5.1	553.73	192.24	0.28
1	1801.551	2015_050yr(Surge	Design_12'	1565	4	14.893	10.42	15.18	0.001096	5.08	556.57	193.1	0.28
1	1801.551	2015_050yr(Surge	Design_in-kind	1565	4	14.9409	10.42	15.22	0.001065	5.02	565.88	196.01	0.28
1	1801.551	2015_050yr(Surge	Design_Exist	1565	4	14.9504	10.42	15.23	0.001059	5.01	567.75	196.59	0.27
1	1801.551	015_100yr(Surge)	Design_20'	2000	4	15.2493	11.67	15.63	0.001438	5.95	629.26	214.04	0.32
1	1801.551	015_100yr(Surge)	Design_12'	2000	4	15.2334	11.67	15.62	0.001453	5.97	625.86	213.29	0.32
1	1801.551	015_100yr(Surge)	Design_in-kind	2000	4	15.2809	11.67	15.65	0.001409	5.9	636.04	215.54	0.32
1	1801.551	015_100yr(Surge)	Design_Exist	2000	4	15.2838	11.67	15.65	0.001406	5.9	636.68	215.68	0.32
1	1776			Culvert									
1	1748.775	2018_002yr	Design_20'	232	4.1	8.1271	6.61	8.33	0.002331	3.59	64.58	22.76	0.38
1	1748.775	2018_002yr	Design_12'	232	4.1	8.1283	6.61	8.33	0.002328	3.59	64.61	22.76	0.38

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1748.775	2018_002yr	Design_in-kind	232	4.1	8.1363	6.61	8.34	0.002309	3.58	64.79	22.77	0.37
1	1748.775	2018_002yr	Design_Exist	232	4.1	8.2363	6.84	8.45	0.002613	3.7	62.74	22.96	0.39
1	1748.775	2018_010yr	Design_20'	845	4.1	11.1604	8.83	11.67	0.002783	5.82	152.96	52.94	0.43
1	1748.775	2018_010yr	Design_12'	845	4.1	11.1604	8.83	11.67	0.002783	5.82	152.96	52.94	0.43
1	1748.775	2018_010yr	Design_in-kind	845	4.1	11.341	8.83	11.81	0.002497	5.61	158.82	55.47	0.41
1	1748.775	2018_010yr	Design_Exist	845	4.1	11.5198	9.03	11.98	0.002497	5.56	160.32	58.54	0.41
1	1748.775	2018_025y	Design_20'	1228	4.1	11.5151	9.97	12.44	0.004805	7.88	164.51	58.46	0.57
1	1748.775	2018_025y	Design_12'	1228	4.1	11.5154	9.97	12.44	0.004804	7.88	164.52	58.46	0.57
1	1748.775	2018_025y	Design_in-kind	1228	4.1	12.0361	9.97	12.77	0.003931	7.05	183.31	72.51	0.53
1	1748.775	2018_025y	Design_Exist	1228	4.1	12.1524	10.14	12.89	0.003969	7.05	183.33	81.13	0.53
1	1748.775	2018_050yr	Design_20'	1565	4.1	11.8487	10.7	13.14	0.007213	9.33	176.29	68.03	0.71
1	1748.775	2018_050yr	Design_12'	1565	4.1	11.8462	10.7	13.14	0.007225	9.34	176.2	67.99	0.71
1	1748.775	2018_050yr	Design_in-kind	1565	4.1	12.3167	10.7	13.39	0.005357	8.5	193.84	104.53	0.62
1	1748.775	2018_050yr	Design_Exist	1565	4.1	12.5304	10.85	13.56	0.005095	8.35	197.51	111.42	0.6
1	1748.775	2018_100yr	Design_20'	2000	4.1	11.8844	11.74	13.96	0.011506	11.84	177.63	68.62	0.9
1	1748.775	2018_100yr	Design_12'	2000	4.1	11.9987	11.74	13.98	0.01068	11.57	181.91	70.44	0.87
1	1748.775	2018_100yr	Design_in-kind	2000	4.1	12.3637	11.74	14.08	0.008503	10.77	195.6	106.89	0.78
1	1748.775	2018_100yr	Design_Exist	2000	4.1	12.5114	11.79	14.2	0.008417	10.7	196.8	110.92	0.78
1	1748.775	2018_500yr	Design_20'	2671	4.1	13.4089	13.21	14.61	0.005842	9.95	389.58	162.4	0.66
1	1748.775	2018_500yr	Design_12'	2671	4.1	13.4089	13.21	14.61	0.005842	9.95	389.58	162.4	0.66
1	1748.775	2018_500yr	Design_in-kind	2671	4.1	13.2068	13.21	14.6	0.006846	10.56	361.53	149.64	0.72
1	1748.775	2018_500yr	Design_Exist	2671	4.1	13.3591	13.26	14.63	0.006424	10.22	378.21	159.25	0.69
1	1748.775	2018_25yr_MHHW_M	Design_20'	1228	4.1	11.5151	9.97	12.44	0.004805	7.88	164.51	58.46	0.57
1	1748.775	2018_25yr_MHHW_M	Design_12'	1228	4.1	11.5153	9.97	12.44	0.004804	7.88	164.52	58.46	0.57
1	1748.775	2018_25yr_MHHW_M	Design_in-kind	1228	4.1	12.0407	9.97	12.78	0.003919	7.04	183.49	72.63	0.53
1	1748.775	2018_25yr_MHHW_M	Design_Exist	1228	4.1	12.1632	10.14	12.89	0.003942	7.03	183.74	82.53	0.53
1	1748.775	2018_25yr_MSL_Ma	Design_20'	1228	4.1	11.5151	9.97	12.44	0.004805	7.88	164.51	58.46	0.57
1	1748.775	2018_25yr_MSL_Ma	Design_12'	1228	4.1	11.5153	9.97	12.44	0.004804	7.88	164.52	58.46	0.57
1	1748.775	2018_25yr_MSL_Ma	Design_in-kind	1228	4.1	12.0434	9.97	12.78	0.003912	7.04	183.59	72.68	0.52
1	1748.775	2018_25yr_MSL_Ma	Design_Exist	1228	4.1	12.1467	10.14	12.88	0.003983	7.06	183.12	80.4	0.53
1	1748.775	2100_025yr_Ab1	Design_20'	1706	4.1	11.915	10.97	13.41	0.008205	10.04	178.77	69.13	0.76
1	1748.775	2100_025yr_Ab1	Design_12'	1706	4.1	12.0332	10.97	13.46	0.0076	9.8	183.2	72.44	0.73
1	1748.775	2100_025yr_Ab1	Design_in-kind	1706	4.1	12.3918	10.97	13.63	0.006083	9.14	196.65	107.75	0.66
1	1748.775	2100_025yr_Ab1	Design_Exist	1706	4.1	12.4038	11.11	13.69	0.006539	9.32	192.76	108.07	0.68
1	1748.775	2100_050yr_Ab1	Design_20'	1717	4.1	11.9196	10.99	13.43	0.008287	10.09	178.94	69.21	0.76
1	1748.775	2100_050yr_Ab1	Design_12'	1717	4.1	12.0359	10.99	13.47	0.007686	9.86	183.3	72.51	0.74
1	1748.775	2100_050yr_Ab1	Design_in-kind	1717	4.1	12.4274	10.99	13.66	0.006032	9.13	197.99	108.72	0.66
1	1748.775	2100_050yr_Ab1	Design_Exist	1717	4.1	12.3852	11.14	13.69	0.0067	9.41	192.06	107.57	0.69
1	1748.775	2100_100yr_Ab1	Design_20'	2562	4.1	13.2217	13.11	14.49	0.006224	10.08	363.56	150.55	0.68
1	1748.775	2100_100yr_Ab1	Design_12'	2562	4.1	13.2213	13.11	14.49	0.006226	10.09	363.51	150.52	0.68
1	1748.775	2100_100yr_Ab1	Design_in-kind	2562	4.1	13.1583	13.11	14.48	0.006549	10.28	354.95	146.69	0.7
1	1748.775	2100_100yr_Ab1	Design_Exist	2562	4.1	13.3003	13.15	14.52	0.006191	9.98	370.03	155.33	0.68
1	1748.775	2018_025yr(Surge	Design_20'	1228	4.1	11.5154	9.97	12.44	0.004804	7.88	164.52	58.46	0.57
1	1748.775	2015_025yr(Surge	Design_12'	1228	4.1	11.7163	9.97	12.56	0.004771	7.53	171.39	64.77	0.57
1	1748.775	2015_025yr(Surge	Design_in-kind	1228	4.1	12.1769	9.97	12.87	0.003596	6.85	188.59	84.3	0.5
1	1748.775	2015_025yr(Surge	Design_Exist	1228	4.1	12.1569	10.14	12.89	0.003958	7.04	183.5	81.71	0.53
1	1748.775	2018_050yr(Surge	Design_20'	1565	4.1	11.7979	10.7	13.12	0.007461	9.43	174.4	67.19	0.72
1	1748.775	2015_050yr(Surge	Design_12'	1565	4.1	12.0782	10.7	13.25	0.006215	8.91	184.89	74.14	0.66
1	1748.775	2015_050yr(Surge	Design_in-kind	1565	4.1	12.4034	10.7	13.44	0.005084	8.36	197.09	108.06	0.6
1	1748.775	2015_050yr(Surge	Design_Exist	1565	4.1	12.5332	10.85	13.56	0.005087	8.34	197.62	111.49	0.6
1	1748.775	015_100yr(Surge)	Design_20'	2000	4.1	11.9251	11.74	13.97	0.011202	11.74	179.15	69.3	0.88
1	1748.775	015_100yr(Surge)	Design_12'	2000	4.1	12.1579	11.74	14.02	0.009652	11.21	187.88	81.85	0.83
1	1748.775	015_100yr(Surge)	Design_in-kind	2000	4.1	12.4512	11.74	14.11	0.008069	10.59	198.88	109.36	0.76
1	1748.775	015_100yr(Surge)	Design_Exist	2000	4.1	12.5093	11.79	14.2	0.008428	10.71	196.72	110.87	0.78
1	1600.008	2018_002yr	Design_20'	232	4.45	7.148		7.69	0.008013	5.9	39.31	15.31	0.65
1	1600.008	2018_002yr	Design_12'	232	4.45	7.1532		7.69	0.007965	5.89	39.39	15.31	0.65
1	1600.008	2018_002yr	Design_in-kind	232	4.45	7.1856		7.71	0.007675	5.82	39.89	15.33	0.64
1	1600.008	2018_002yr	Design_Exist	232	4.45	7.3782		7.83	0.00621	5.41	42.85	15.44	0.57
1	1600.008	2018_010yr	Design_20'	845	4.45	9.6979	9.7	10.89	0.009119	9.29	117.11	61.29	0.74
1	1600.008	2018_010yr	Design_12'	845	4.45	9.6979	9.7	10.89	0.009119	9.29	117.11	61.29	0.74
1	1600.008	2018_010yr	Design_in-kind	845	4.45	11.1984		11.43	0.001695	4.78	314.67	181.55	0.33
1	1600.008	2018_010yr	Design_Exist	845	4.45	11.4627		11.63	0.001248	4.21	364.44	195.09	0.29
1	1600.008	2018_025y	Design_20'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_025y	Design_12'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_025y	Design_in-kind	1228	4.45	12.0711		12.26	0.001448	4.81	498.78	266.44	0.31
1	1600.008	2018_025y	Design_Exist	1228	4.45	12.2616		12.41	0.00115	4.36	549.96	270.99	0.28
1	1600.008	2018_050yr	Design_20'	1565	4.45	11.1437	11.14	11.98	0.006203	9.09	304.81	178.81	0.63
1	1600.008	2018_050yr	Design_12'	1565	4.45	11.7834		12.19	0.003034	6.77	430.39	218.49	0.45
1	1600.008	2018_050yr	Design_in-kind	1565	4.45	12.5901		12.76	0.001284	4.74	640.38	279.38	0.3
1	1600.008	2018_050yr	Design_Exist	1565	4.45	12.877		13	0.000946	4.16	721.57	286.61	0.26
1	1600.008	2018_100yr	Design_20'	2000	4.45	11.9277		12.49	0.004268	8.14	462.79	230.7	0.54

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1600.008	2018_100yr	Design_12'	2000	4.45	12.5355		12.83	0.002228	6.21	625.14	277.99	0.39
1	1600.008	2018_100yr	Design_in-kind	2000	4.45	13.0157		13.19	0.001342	5.02	761.55	290.06	0.31
1	1600.008	2018_100yr	Design_Exist	2000	4.45	13.2293		13.38	0.001089	4.6	824.08	295.37	0.28
1	1600.008	2018_500yr	Design_20'	2671	4.45	13.7936		13.96	0.001168	4.97	994.74	309.41	0.29
1	1600.008	2018_500yr	Design_12'	2671	4.45	13.7936		13.96	0.001168	4.97	994.73	309.41	0.29
1	1600.008	2018_500yr	Design_in-kind	2671	4.45	13.6547	11.89	13.84	0.001317	5.22	951.98	305.95	0.31
1	1600.008	2018_500yr	Design_Exist	2671	4.45	13.7746		13.94	0.001187	5	988.86	308.93	0.29
1	1600.008	2018_25yr_MHHW_M	Design_20'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_25yr_MHHW_M	Design_12'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_25yr_MHHW_M	Design_in-kind	1228	4.45	12.0783		12.27	0.001435	4.79	500.72	266.6	0.31
1	1600.008	2018_25yr_MHHW_M	Design_Exist	1228	4.45	12.2759		12.43	0.00113	4.32	553.85	271.36	0.28
1	1600.008	2018_25yr_MSL_Ma	Design_20'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_25yr_MSL_Ma	Design_12'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2018_25yr_MSL_Ma	Design_in-kind	1228	4.45	12.0825		12.27	0.001428	4.78	501.83	266.7	0.31
1	1600.008	2018_25yr_MSL_Ma	Design_Exist	1228	4.45	12.254		12.41	0.00116	4.37	547.92	270.8	0.28
1	1600.008	2100_025yr_Ab1	Design_20'	1706	4.45	11.2939	11.29	12.12	0.006178	9.21	332.23	186.44	0.63
1	1600.008	2100_025yr_Ab1	Design_12'	1706	4.45	12.2124		12.52	0.002352	6.2	536.67	269.74	0.4
1	1600.008	2100_025yr_Ab1	Design_in-kind	1706	4.45	12.7738		12.94	0.001252	4.75	692.12	284.04	0.3
1	1600.008	2100_025yr_Ab1	Design_Exist	1706	4.45	12.8335		12.99	0.001176	4.63	709.14	285.53	0.29
1	1600.008	2100_050yr_Ab1	Design_20'	1717	4.45	11.3042	11.3	12.13	0.006183	9.23	334.17	186.97	0.63
1	1600.008	2100_050yr_Ab1	Design_12'	1717	4.45	12.2277		12.54	0.002339	6.2	540.79	270.13	0.4
1	1600.008	2100_050yr_Ab1	Design_in-kind	1717	4.45	12.8238		12.98	0.001204	4.68	706.36	285.29	0.29
1	1600.008	2100_050yr_Ab1	Design_Exist	1717	4.45	12.8255		12.98	0.001202	4.67	706.85	285.33	0.29
1	1600.008	2100_100yr_Ab1	Design_20'	2562	4.45	13.6183		13.79	0.001251	5.08	940.85	305.05	0.3
1	1600.008	2100_100yr_Ab1	Design_12'	2562	4.45	13.618		13.79	0.001251	5.08	940.76	305.04	0.3
1	1600.008	2100_100yr_Ab1	Design_in-kind	2562	4.45	13.5759		13.75	0.001299	5.15	927.97	303.99	0.31
1	1600.008	2100_100yr_Ab1	Design_Exist	2562	4.45	13.6876		13.85	0.001177	4.95	962.08	306.77	0.29
1	1600.008	2018_025yr(Surge	Design_20'	1228	4.45	10.7924	10.79	11.59	0.005839	8.49	245.07	161.31	0.61
1	1600.008	2015_025yr(Surge	Design_12'	1228	4.45	11.6168		11.91	0.002222	5.71	395.15	204.47	0.38
1	1600.008	2015_025yr(Surge	Design_in-kind	1228	4.45	12.2726		12.42	0.001135	4.33	552.96	271.28	0.28
1	1600.008	2015_025yr(Surge	Design_Exist	1228	4.45	12.2675		12.42	0.001141	4.34	551.58	271.15	0.28
1	1600.008	2018_050yr(Surge	Design_20'	1565	4.45	11.3366	11.15	12	0.004947	8.28	340.25	188.63	0.57
1	1600.008	2015_050yr(Surge	Design_12'	1565	4.45	12.23		12.49	0.001938	5.64	541.42	270.19	0.36
1	1600.008	2015_050yr(Surge	Design_in-kind	1565	4.45	12.6977		12.85	0.001143	4.51	670.57	282.11	0.28
1	1600.008	2015_050yr(Surge	Design_Exist	1565	4.45	12.8801		13	0.000943	4.16	722.46	286.69	0.26
1	1600.008	015_100yr(Surge)	Design_20'	2000	4.45	12.1647		12.62	0.003424	7.45	523.83	268.6	0.48
1	1600.008	015_100yr(Surge)	Design_12'	2000	4.45	12.7795		13	0.001711	5.56	693.76	284.19	0.35
1	1600.008	015_100yr(Surge)	Design_in-kind	2000	4.45	13.1061		13.27	0.001227	4.83	787.88	292.31	0.29
1	1600.008	015_100yr(Surge)	Design_Exist	2000	4.45	13.2273		13.37	0.001091	4.6	823.51	295.32	0.28
1	1456.522	2018_002yr	Design_20'	232	3.05	6.4314		6.79	0.004281	4.78	48.52	16.66	0.49
1	1456.522	2018_002yr	Design_12'	232	3.05	6.4483		6.8	0.004209	4.75	48.8	16.67	0.49
1	1456.522	2018_002yr	Design_in-kind	232	3.05	6.543		6.87	0.003835	4.6	50.38	16.74	0.47
1	1456.522	2018_002yr	Design_Exist	232	3.05	6.9401		7.2	0.002672	4.06	57.08	17.01	0.39
1	1456.522	2018_010yr	Design_20'	845	3.05	9.0051	8.25	9.61	0.004367	6.96	162.88	65.28	0.53
1	1456.522	2018_010yr	Design_12'	845	3.05	9.0051	8.25	9.61	0.004367	6.96	162.88	65.28	0.53
1	1456.522	2018_010yr	Design_in-kind	845	3.05	11.1957		11.26	0.000448	2.8	586.74	304.9	0.18
1	1456.522	2018_010yr	Design_Exist	845	3.05	11.4584		11.51	0.000337	2.49	669.12	322.48	0.16
1	1456.522	2018_025y	Design_20'	1228	3.05	9.8078	8.98	10.49	0.004464	7.72	236.09	126.8	0.55
1	1456.522	2018_025y	Design_12'	1228	3.05	10.3116	8.98	10.73	0.002703	6.33	340.81	256.8	0.43
1	1456.522	2018_025y	Design_in-kind	1228	3.05	12.0675		12.12	0.000388	2.8	878.71	371.9	0.17
1	1456.522	2018_025y	Design_Exist	1228	3.05	12.2549		12.3	0.000318	2.58	948.66	374.88	0.16
1	1456.522	2018_050yr	Design_20'	1565	3.05	10.9522	9.69	11.25	0.002024	5.83	514.46	288.56	0.38
1	1456.522	2018_050yr	Design_12'	1565	3.05	11.7673		11.89	0.000837	4.02	771.93	343.14	0.25
1	1456.522	2018_050yr	Design_in-kind	1565	3.05	12.5762		12.63	0.000376	2.87	1069.93	379.87	0.17
1	1456.522	2018_050yr	Design_Exist	1565	3.05	12.8638		12.91	0.000288	2.57	1179.83	384.32	0.15
1	1456.522	2018_100yr	Design_20'	2000	3.05	11.9027		12.07	0.001192	4.85	819.02	352.2	0.3
1	1456.522	2018_100yr	Design_12'	2000	3.05	12.5108		12.61	0.000654	3.77	1045.12	378.85	0.22
1	1456.522	2018_100yr	Design_in-kind	2000	3.05	12.9945		13.06	0.000418	3.12	1230.19	386.35	0.18
1	1456.522	2018_100yr	Design_Exist	2000	3.05	13.2104		13.26	0.000348	2.89	1313.97	389.82	0.17
1	1456.522	2018_500yr	Design_20'	2671	3.05	13.7691		13.83	0.000399	3.22	1534.37	399.15	0.18
1	1456.522	2018_500yr	Design_12'	2671	3.05	13.7691		13.83	0.000399	3.22	1534.37	399.15	0.18
1	1456.522	2018_500yr	Design_in-kind	2671	3.05	13.6277		13.7	0.000445	3.36	1478.09	396.79	0.19
1	1456.522	2018_500yr	Design_Exist	2671	3.05	13.7498		13.81	0.000405	3.24	1526.66	398.82	0.18
1	1456.522	2018_25yr_MHHW_M	Design_20'	1228	3.05	9.8078	8.98	10.49	0.004464	7.72	236.09	126.8	0.55
1	1456.522	2018_25yr_MHHW_M	Design_12'	1228	3.05	10.6418	8.98	10.91	0.001799	5.34	427.93	270.88	0.36
1	1456.522	2018_25yr_MHHW_M	Design_in-kind	1228	3.05	12.0746		12.13	0.000385	2.8	881.35	372.02	0.17
1	1456.522	2018_25yr_MHHW_M	Design_Exist	1228	3.05	12.269		12.31	0.000314	2.56	953.97	375.1	0.15
1	1456.522	2018_25yr_MSL_Ma	Design_20'	1228	3.05	9.8078	8.98	10.49	0.004464	7.72	236.09	126.8	0.55
1	1456.522	2018_25yr_MSL_Ma	Design_12'	1228	3.05	10.6278	8.98	10.9	0.00183	5.38	424.15	270.28	0.36
1	1456.522	2018_25yr_MSL_Ma	Design_in-kind	1228	3.05	12.0787		12.13	0.000383	2.79	882.86	372.08	0.17
1	1456.522	2018_25yr_MSL_Ma	Design_Exist	1228	3.05	12.2474		12.29	0.000321	2.59	945.85	374.76	0.16

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1456.522	2100_025yr_Ab1	Design_20'	1706	3.05	11.1824	9.78	11.45	0.001854	5.7	582.69	304.01	0.37
1	1456.522	2100_025yr_Ab1	Design_12'	1706	3.05	12.1987		12.29	0.000651	3.67	927.64	374.01	0.22
1	1456.522	2100_025yr_Ab1	Design_in-kind	1706	3.05	12.7574		12.81	0.000377	2.91	1139.01	382.67	0.17
1	1456.522	2100_025yr_Ab1	Design_Exist	1706	3.05	12.8174		12.87	0.000357	2.85	1162.01	383.6	0.17
1	1456.522	2100_050yr_Ab1	Design_20'	1717	3.05	11.2118	9.79	11.48	0.001818	5.65	591.64	305.97	0.36
1	1456.522	2100_050yr_Ab1	Design_12'	1717	3.05	12.2134		12.31	0.00065	3.67	933.14	374.24	0.22
1	1456.522	2100_050yr_Ab1	Design_in-kind	1717	3.05	12.8074		12.86	0.000364	2.88	1158.18	383.45	0.17
1	1456.522	2100_050yr_Ab1	Design_Exist	1717	3.05	12.8092		12.86	0.000364	2.88	1158.83	383.47	0.17
1	1456.522	2100_100yr_Ab1	Design_20'	2562	3.05	13.593		13.66	0.00042	3.26	1464.33	396.21	0.18
1	1456.522	2100_100yr_Ab1	Design_12'	2562	3.05	13.5927		13.66	0.00042	3.26	1464.21	396.2	0.18
1	1456.522	2100_100yr_Ab1	Design_in-kind	2562	3.05	13.55		13.62	0.000434	3.31	1447.29	395.49	0.19
1	1456.522	2100_100yr_Ab1	Design_Exist	2562	3.05	13.6636		13.73	0.000398	3.19	1492.33	397.39	0.18
1	1456.522	2018_025yr(Surge	Design_20'	1228	3.05	10.3252	8.98	10.74	0.002658	6.29	344.32	257.38	0.43
1	1456.522	2015_025yr(Surge	Design_12'	1228	3.05	11.6064		11.69	0.000608	3.38	717.59	332.38	0.21
1	1456.522	2015_025yr(Surge	Design_in-kind	1228	3.05	12.2658		12.31	0.000315	2.57	952.76	375.05	0.15
1	1456.522	2015_025yr(Surge	Design_Exist	1228	3.05	12.2608		12.31	0.000316	2.57	950.87	374.97	0.15
1	1456.522	2018_050yr(Surge	Design_20'	1565	3.05	11.3181		11.51	0.001344	4.91	624.54	313.09	0.31
1	1456.522	2015_050yr(Surge	Design_12'	1565	3.05	12.2188		12.3	0.000537	3.34	935.13	374.32	0.2
1	1456.522	2015_050yr(Surge	Design_in-kind	1565	3.05	12.6839		12.73	0.000339	2.75	1110.92	381.53	0.16
1	1456.522	2015_050yr(Surge	Design_Exist	1565	3.05	12.867		12.91	0.000287	2.56	1181.03	384.37	0.15
1	1456.522	015_100yr(Surge)	Design_20'	2000	3.05	12.1446		12.28	0.000947	4.41	907.41	373.14	0.27
1	1456.522	015_100yr(Surge)	Design_12'	2000	3.05	12.7562		12.83	0.000518	3.42	1138.53	382.65	0.2
1	1456.522	015_100yr(Surge)	Design_in-kind	2000	3.05	13.0859		13.14	0.000387	3.02	1265.56	387.76	0.17
1	1456.522	015_100yr(Surge)	Design_Exist	2000	3.05	13.2085		13.26	0.000349	2.9	1313.2	389.79	0.17
1	1331.074	2018_002yr	Design_20'	232	1.92	6.0011		6.29	0.003158	4.34	53.45	15.56	0.41
1	1331.074	2018_002yr	Design_12'	232	1.92	6.0277		6.32	0.003086	4.31	53.87	15.86	0.4
1	1331.074	2018_002yr	Design_in-kind	232	1.92	6.1647		6.43	0.002807	4.14	56.55	23.38	0.38
1	1331.074	2018_002yr	Design_Exist	232	1.92	6.7325		6.91	0.001596	3.44	78.09	52.57	0.3
1	1331.074	2018_010yr	Design_20'	845	1.92	8.8162		9.12	0.002262	5.37	237.73	97.05	0.38
1	1331.074	2018_010yr	Design_12'	845	1.92	8.8162		9.12	0.002262	5.37	237.73	97.05	0.38
1	1331.074	2018_010yr	Design_in-kind	845	1.92	11.1799		11.21	0.000223	2.09	757.18	356.78	0.13
1	1331.074	2018_010yr	Design_Exist	845	1.92	11.4455		11.47	0.000171	1.87	854.03	372.49	0.11
1	1331.074	2018_025y	Design_20'	1228	1.92	9.6956		10	0.002064	5.6	336.13	127.69	0.37
1	1331.074	2018_025y	Design_12'	1228	1.92	10.2451		10.43	0.001259	4.6	449.79	299.61	0.29
1	1331.074	2018_025y	Design_in-kind	1228	1.92	12.0509		12.08	0.000205	2.13	1090.31	405.93	0.12
1	1331.074	2018_025y	Design_Exist	1228	1.92	12.2403		12.27	0.000172	1.98	1167.41	408.29	0.11
1	1331.074	2018_050yr	Design_20'	1565	1.92	10.8743		11.02	0.001051	4.42	650.91	338.7	0.27
1	1331.074	2018_050yr	Design_12'	1565	1.92	11.7306		11.79	0.000447	3.08	962.61	389.36	0.18
1	1331.074	2018_050yr	Design_in-kind	1565	1.92	12.5571		12.59	0.000211	2.24	1297.38	412.21	0.13
1	1331.074	2018_050yr	Design_Exist	1565	1.92	12.8483		12.87	0.000166	2.03	1417.96	415.82	0.11
1	1331.074	2018_100yr	Design_20'	2000	1.92	11.8465		11.94	0.000655	3.76	1008.14	396.22	0.22
1	1331.074	2018_100yr	Design_12'	2000	1.92	12.4772		12.53	0.000369	2.95	1264.49	411.22	0.17
1	1331.074	2018_100yr	Design_in-kind	2000	1.92	12.9712		13.01	0.000246	2.49	1469.12	417.34	0.14
1	1331.074	2018_100yr	Design_Exist	2000	1.92	13.1904		13.22	0.000208	2.32	1560.93	420.06	0.13
1	1331.074	2018_500yr	Design_20'	2671	1.92	13.7446		13.79	0.000249	2.62	1795.51	426.42	0.14
1	1331.074	2018_500yr	Design_12'	2671	1.92	13.7446		13.79	0.000249	2.62	1795.51	426.42	0.14
1	1331.074	2018_500yr	Design_in-kind	2671	1.92	13.6007		13.65	0.000275	2.73	1734.26	424.83	0.15
1	1331.074	2018_500yr	Design_Exist	2671	1.92	13.7249		13.77	0.000252	2.64	1787.13	426.2	0.14
1	1331.074	2018_25yr_MHHW_M	Design_20'	1228	1.92	9.6956		10	0.002064	5.6	336.13	127.69	0.37
1	1331.074	2018_25yr_MHHW_M	Design_12'	1228	1.92	10.5865		10.71	0.000877	3.95	555.87	321.66	0.25
1	1331.074	2018_25yr_MHHW_M	Design_in-kind	1228	1.92	12.0581		12.09	0.000203	2.13	1093.23	406.02	0.12
1	1331.074	2018_25yr_MHHW_M	Design_Exist	1228	1.92	12.2546		12.28	0.00017	1.97	1173.25	408.47	0.11
1	1331.074	2018_25yr_MSL_Ma	Design_20'	1228	1.92	9.6956		10	0.002064	5.6	336.13	127.69	0.37
1	1331.074	2018_25yr_MSL_Ma	Design_12'	1228	1.92	10.572		10.7	0.000891	3.98	551.21	320.81	0.25
1	1331.074	2018_25yr_MSL_Ma	Design_in-kind	1228	1.92	12.0622		12.09	0.000202	2.12	1094.9	406.07	0.12
1	1331.074	2018_25yr_MSL_Ma	Design_Exist	1228	1.92	12.2327		12.26	0.000173	1.99	1164.32	408.19	0.11
1	1331.074	2100_025yr_Ab1	Design_20'	1706	1.92	11.1059		11.24	0.000982	4.36	730.94	352.4	0.26
1	1331.074	2100_025yr_Ab1	Design_12'	1706	1.92	12.1685		12.22	0.000354	2.83	1138.11	407.39	0.16
1	1331.074	2100_025yr_Ab1	Design_in-kind	1706	1.92	12.7374		12.77	0.000216	2.3	1371.9	414.45	0.13
1	1331.074	2100_025yr_Ab1	Design_Exist	1706	1.92	12.7983		12.83	0.000205	2.25	1397.17	415.2	0.12
1	1331.074	2100_050yr_Ab1	Design_20'	1717	1.92	11.1363		11.27	0.000964	4.33	741.68	354.2	0.26
1	1331.074	2100_050yr_Ab1	Design_12'	1717	1.92	12.1831		12.23	0.000354	2.83	1144.07	407.58	0.16
1	1331.074	2100_050yr_Ab1	Design_in-kind	1717	1.92	12.7879		12.82	0.00021	2.27	1392.85	415.07	0.13
1	1331.074	2100_050yr_Ab1	Design_Exist	1717	1.92	12.7897		12.82	0.00021	2.27	1393.57	415.09	0.13
1	1331.074	2100_100yr_Ab1	Design_20'	2562	1.92	13.5676		13.61	0.000259	2.65	1720.21	424.46	0.14
1	1331.074	2100_100yr_Ab1	Design_12'	2562	1.92	13.5673		13.61	0.000259	2.65	1720.08	424.46	0.14
1	1331.074	2100_100yr_Ab1	Design_in-kind	2562	1.92	13.5238		13.57	0.000267	2.68	1701.62	423.98	0.14
1	1331.074	2100_100yr_Ab1	Design_Exist	2562	1.92	13.6394		13.68	0.000246	2.59	1750.7	425.26	0.14
1	1331.074	2018_025yr(Surge	Design_20'	1228	1.92	10.2591		10.44	0.001241	4.57	454	300.52	0.29
1	1331.074	2015_025yr(Surge	Design_12'	1228	1.92	11.5815		11.63	0.000317	2.57	905.2	380.53	0.15
1	1331.074	2015_025yr(Surge	Design_in-kind	1228	1.92	12.2513		12.28	0.00017	1.97	1171.92	408.43	0.11

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1331.074	2015_025yr(Surge	Design_Exist	1228	1.92	12.2463		12.27	0.000171	1.98	1169.84	408.36	0.11
1	1331.074	2018_050yr(Surge	Design_20'	1565	1.92	11.2625		11.36	0.000705	3.74	786.86	361.67	0.22
1	1331.074	2015_050yr(Surge	Design_12'	1565	1.92	12.1939		12.24	0.000291	2.57	1148.49	407.71	0.15
1	1331.074	2015_050yr(Surge	Design_in-kind	1565	1.92	12.6662		12.7	0.000193	2.16	1342.43	413.57	0.12
1	1331.074	2015_050yr(Surge	Design_Exist	1565	1.92	12.8515		12.88	0.000166	2.02	1419.28	415.86	0.11
1	1331.074	015_100yr(Surge)	Design_20'	2000	1.92	12.1		12.17	0.000518	3.41	1110.23	406.54	0.19
1	1331.074	015_100yr(Surge)	Design_12'	2000	1.92	12.7283		12.77	0.000299	2.7	1368.12	414.33	0.15
1	1331.074	015_100yr(Surge)	Design_in-kind	2000	1.92	13.0641		13.1	0.000229	2.41	1507.95	418.49	0.13
1	1331.074	015_100yr(Surge)	Design_Exist	2000	1.92	13.1885		13.22	0.000208	2.32	1560.1	420.03	0.13
1	1255.24	2018_002yr	Design_20'	232	1.66	5.3612		5.91	0.007194	5.95	39.02	12.34	0.59
1	1255.24	2018_002yr	Design_12'	232	1.66	5.4142		5.95	0.006875	5.85	39.68	12.41	0.58
1	1255.24	2018_002yr	Design_in-kind	232	1.66	5.6513		6.11	0.005653	5.43	42.94	16.57	0.53
1	1255.24	2018_002yr	Design_Exist	232	1.66	6.5411		6.76	0.002164	3.92	72.53	48.23	0.34
1	1255.24	2018_010yr	Design_20'	845	1.66	8.4464		8.9	0.003527	6.44	188.99	71.54	0.46
1	1255.24	2018_010yr	Design_12'	845	1.66	8.4464		8.9	0.003527	6.44	188.99	71.54	0.46
1	1255.24	2018_010yr	Design_in-kind	845	1.66	11.1422		11.19	0.000345	2.57	682.82	352.4	0.15
1	1255.24	2018_010yr	Design_Exist	845	1.66	11.4201		11.45	0.000248	2.23	782.2	362.05	0.13
1	1255.24	2018_025y	Design_20'	1228	1.66	9.2539		9.77	0.003655	7.12	248.86	76.79	0.48
1	1255.24	2018_025y	Design_12'	1228	1.66	9.9634	8.23	10.29	0.002125	5.8	305.34	82.43	0.37
1	1255.24	2018_025y	Design_in-kind	1228	1.66	12.025		12.06	0.000273	2.44	1006.92	380.3	0.14
1	1255.24	2018_025y	Design_Exist	1228	1.66	12.2193		12.25	0.000225	2.25	1081.05	382.78	0.13
1	1255.24	2018_050yr	Design_20'	1565	1.66	10.327	8.67	10.85	0.003471	7.65	409.63	315	0.48
1	1255.24	2018_050yr	Design_12'	1565	1.66	11.665		11.75	0.000647	3.66	871.84	369.86	0.21
1	1255.24	2018_050yr	Design_in-kind	1565	1.66	12.5319		12.57	0.000272	2.52	1201.35	386.78	0.14
1	1255.24	2018_050yr	Design_Exist	1565	1.66	12.8291		12.86	0.00021	2.26	1316.88	390.58	0.12
1	1255.24	2018_100yr	Design_20'	2000	1.66	11.7475		11.88	0.000966	4.5	902.44	372.35	0.26
1	1255.24	2018_100yr	Design_12'	2000	1.66	12.4313		12.5	0.000487	3.35	1162.49	385.5	0.19
1	1255.24	2018_100yr	Design_in-kind	2000	1.66	12.9425		12.99	0.000311	2.77	1361.23	392.03	0.15
1	1255.24	2018_100yr	Design_Exist	2000	1.66	13.1666		13.21	0.00026	2.56	1449.43	394.9	0.14
1	1255.24	2018_500yr	Design_20'	2671	1.66	13.7162		13.77	0.000307	2.88	1668.46	402.64	0.15
1	1255.24	2018_500yr	Design_12'	2671	1.66	13.7162		13.77	0.000307	2.88	1668.46	402.64	0.15
1	1255.24	2018_500yr	Design_in-kind	2671	1.66	13.5691		13.62	0.000341	3.01	1609.43	400.29	0.16
1	1255.24	2018_500yr	Design_Exist	2671	1.66	13.6961		13.75	0.000311	2.9	1660.39	402.21	0.15
1	1255.24	2018_25yr_MHHW_M	Design_20'	1228	1.66	9.2539		9.77	0.003655	7.12	248.86	76.79	0.48
1	1255.24	2018_25yr_MHHW_M	Design_12'	1228	1.66	10.1237	8.23	10.57	0.002831	6.79	346.75	303.78	0.43
1	1255.24	2018_25yr_MHHW_M	Design_in-kind	1228	1.66	12.0324		12.07	0.000271	2.43	1009.73	380.39	0.14
1	1255.24	2018_25yr_MHHW_M	Design_Exist	1228	1.66	12.2339		12.26	0.000222	2.23	1086.65	382.97	0.13
1	1255.24	2018_25yr_MSL_Ma	Design_20'	1228	1.66	9.2539		9.77	0.003655	7.12	248.86	76.79	0.48
1	1255.24	2018_25yr_MSL_Ma	Design_12'	1228	1.66	10.0133	8.23	10.54	0.003286	7.25	313.58	293.86	0.46
1	1255.24	2018_25yr_MSL_Ma	Design_in-kind	1228	1.66	12.0366		12.07	0.00027	2.43	1011.35	380.45	0.14
1	1255.24	2018_25yr_MSL_Ma	Design_Exist	1228	1.66	12.2115		12.24	0.000227	2.25	1078.09	382.69	0.13
1	1255.24	2100_025yr_Ab1	Design_20'	1706	1.66	10.8371		11.12	0.002068	6.15	577.31	340.33	0.37
1	1255.24	2100_025yr_Ab1	Design_12'	1706	1.66	12.1227		12.19	0.000478	3.25	1044.16	381.55	0.18
1	1255.24	2100_025yr_Ab1	Design_in-kind	1706	1.66	12.712		12.75	0.000275	2.57	1271.22	389.09	0.14
1	1255.24	2100_025yr_Ab1	Design_Exist	1706	1.66	12.7743		12.81	0.000261	2.51	1295.48	389.88	0.14
1	1255.24	2100_050yr_Ab1	Design_20'	1717	1.66	10.8822		11.16	0.001975	6.04	592.71	341.82	0.37
1	1255.24	2100_050yr_Ab1	Design_12'	1717	1.66	12.1375		12.2	0.000477	3.25	1049.79	381.74	0.18
1	1255.24	2100_050yr_Ab1	Design_in-kind	1717	1.66	12.7633		12.8	0.000267	2.54	1291.21	389.74	0.14
1	1255.24	2100_050yr_Ab1	Design_Exist	1717	1.66	12.7651		12.8	0.000266	2.53	1291.9	389.76	0.14
1	1255.24	2100_100yr_Ab1	Design_20'	2562	1.66	13.5379		13.59	0.000321	2.92	1596.95	399.85	0.15
1	1255.24	2100_100yr_Ab1	Design_12'	2562	1.66	13.5376		13.59	0.000321	2.92	1596.83	399.84	0.15
1	1255.24	2100_100yr_Ab1	Design_in-kind	2562	1.66	13.4931		13.55	0.000332	2.96	1579.05	399.21	0.16
1	1255.24	2100_100yr_Ab1	Design_Exist	2562	1.66	13.6113		13.66	0.000304	2.85	1626.31	400.89	0.15
1	1255.24	2018_025yr(Surge	Design_20'	1228	1.66	9.9791	8.23	10.3	0.002101	5.78	306.64	82.56	0.37
1	1255.24	2015_025yr(Surge	Design_12'	1228	1.66	11.5345		11.6	0.00046	3.06	823.83	365.72	0.18
1	1255.24	2015_025yr(Surge	Design_in-kind	1228	1.66	12.2306		12.26	0.000222	2.24	1085.38	382.93	0.13
1	1255.24	2015_025yr(Surge	Design_Exist	1228	1.66	12.2254		12.26	0.000224	2.24	1083.38	382.86	0.13
1	1255.24	2018_050yr(Surge	Design_20'	1565	1.66	11.1215		11.29	0.001214	4.82	675.51	351.42	0.29
1	1255.24	2015_050yr(Surge	Design_12'	1565	1.66	12.1571		12.21	0.000388	2.94	1057.26	381.99	0.17
1	1255.24	2015_050yr(Surge	Design_in-kind	1565	1.66	12.6435		12.68	0.000246	2.42	1244.61	388.21	0.13
1	1255.24	2015_050yr(Surge	Design_Exist	1565	1.66	12.8324		12.86	0.000209	2.25	1318.14	390.62	0.12
1	1255.24	015_100yr(Surge)	Design_20'	2000	1.66	12.0292		12.13	0.000721	3.97	1008.54	380.35	0.23
1	1255.24	015_100yr(Surge)	Design_12'	2000	1.66	12.6925		12.75	0.000385	3.03	1263.63	388.84	0.17
1	1255.24	015_100yr(Surge)	Design_in-kind	2000	1.66	13.0376		13.08	0.000288	2.68	1398.58	393.25	0.14
1	1255.24	015_100yr(Surge)	Design_Exist	2000	1.66	13.1646		13.2	0.00026	2.57	1448.62	394.87	0.14
1	1169.738	2018_002yr	Design_20'	232	1	4.792		5.3	0.006351	5.73	40.47	13.3	0.57
1	1169.738	2018_002yr	Design_12'	232	1	4.8937		5.37	0.005811	5.55	41.88	14.19	0.54
1	1169.738	2018_002yr	Design_in-kind	232	1	5.2839		5.66	0.004144	4.93	47.89	16.34	0.46
1	1169.738	2018_002yr	Design_Exist	232	1	6.3998		6.58	0.001697	3.53	78.18	45.88	0.3
1	1169.738	2018_010yr	Design_20'	845	1	7.2412	7.24	8.36	0.009238	9.27	122.07	58.46	0.72

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1169.738	2018_010yr	Design_12'	845	1	7.2412	7.24	8.36	0.009238	9.27	122.07	58.46	0.72
1	1169.738	2018_010yr	Design_in-kind	845	1	11.1197		11.16	0.000279	2.34	684.25	332.43	0.14
1	1169.738	2018_010yr	Design_Exist	845	1	11.4022		11.43	0.000211	2.08	779.82	344.16	0.12
1	1169.738	2018_025y	Design_20'	1228	1	8.6155		9.36	0.005344	8.26	216.13	77.74	0.57
1	1169.738	2018_025y	Design_12'	1228	1	9.7611		10.1	0.002176	5.87	313.71	93.37	0.37
1	1169.738	2018_025y	Design_in-kind	1228	1	12.0016		12.04	0.000256	2.39	993.58	369.05	0.13
1	1169.738	2018_025y	Design_Exist	1228	1	12.1992		12.23	0.000215	2.22	1067.22	376.8	0.12
1	1169.738	2018_050yr	Design_20'	1565	1	10.1498		10.55	0.002586	6.61	381.61	292.15	0.41
1	1169.738	2018_050yr	Design_12'	1565	1	11.6118		11.7	0.000593	3.54	852.87	352.87	0.2
1	1169.738	2018_050yr	Design_in-kind	1565	1	12.5059		12.55	0.00027	2.53	1184.61	388.77	0.14
1	1169.738	2018_050yr	Design_Exist	1565	1	12.8084		12.84	0.000212	2.29	1304	400.55	0.12
1	1169.738	2018_100yr	Design_20'	2000	1	11.6603		11.79	0.000925	4.43	870.03	354.88	0.25
1	1169.738	2018_100yr	Design_12'	2000	1	12.3837		12.46	0.000487	3.38	1137.39	384.05	0.19
1	1169.738	2018_100yr	Design_in-kind	2000	1	12.9107		12.96	0.00032	2.83	1345.2	404.83	0.15
1	1169.738	2018_100yr	Design_Exist	2000	1	13.1397		13.18	0.000269	2.63	1438.98	414.09	0.14
1	1169.738	2018_500yr	Design_20'	2671	1	13.6829		13.74	0.000328	3	1669.82	435.96	0.16
1	1169.738	2018_500yr	Design_12'	2671	1	13.6829		13.74	0.000328	3	1669.81	435.96	0.16
1	1169.738	2018_500yr	Design_in-kind	2671	1	13.5323		13.59	0.000363	3.13	1604.57	429.85	0.16
1	1169.738	2018_500yr	Design_Exist	2671	1	13.6624		13.72	0.000332	3.01	1660.87	435.21	0.16
1	1169.738	2018_25yr_MHHW_M	Design_20'	1228	1	8.6155		9.36	0.005344	8.26	216.13	77.74	0.57
1	1169.738	2018_25yr_MHHW_M	Design_12'	1228	1	10.0469		10.33	0.00175	5.39	351.71	289.23	0.34
1	1169.738	2018_25yr_MHHW_M	Design_in-kind	1228	1	12.0091		12.05	0.000254	2.38	996.36	369.32	0.13
1	1169.738	2018_25yr_MHHW_M	Design_Exist	1228	1	12.2141		12.25	0.000212	2.2	1072.82	377.39	0.12
1	1169.738	2018_25yr_MSL_Ma	Design_20'	1228	1	8.6155		9.36	0.005344	8.26	216.13	77.74	0.57
1	1169.738	2018_25yr_MSL_Ma	Design_12'	1228	1	9.8204		10.15	0.00209	5.78	319.39	98.18	0.37
1	1169.738	2018_25yr_MSL_Ma	Design_in-kind	1228	1	12.0135		12.05	0.000253	2.37	997.96	369.47	0.13
1	1169.738	2018_25yr_MSL_Ma	Design_Exist	1228	1	12.1913		12.22	0.000216	2.22	1064.26	376.42	0.12
1	1169.738	2100_025yr_Ab1	Design_20'	1706	1	10.6882		10.95	0.001778	5.72	544.67	314.47	0.34
1	1169.738	2100_025yr_Ab1	Design_12'	1706	1	12.0792		12.15	0.000461	3.22	1022.32	371.84	0.18
1	1169.738	2100_025yr_Ab1	Design_in-kind	1706	1	12.6849		12.73	0.000277	2.6	1254.82	395.7	0.14
1	1169.738	2100_025yr_Ab1	Design_Exist	1706	1	12.7484		12.79	0.000264	2.54	1280.05	398.16	0.14
1	1169.738	2100_050yr_Ab1	Design_20'	1717	1	10.7379		10.99	0.00171	5.63	560.35	316.56	0.34
1	1169.738	2100_050yr_Ab1	Design_12'	1717	1	12.0939		12.16	0.000461	3.22	1027.78	372.37	0.18
1	1169.738	2100_050yr_Ab1	Design_in-kind	1717	1	12.7369		12.78	0.00027	2.57	1275.46	397.72	0.14
1	1169.738	2100_050yr_Ab1	Design_Exist	1717	1	12.7387		12.78	0.000269	2.57	1276.18	397.79	0.14
1	1169.738	2100_100yr_Ab1	Design_20'	2562	1	13.5034		13.56	0.000341	3.02	1592.19	428.65	0.16
1	1169.738	2100_100yr_Ab1	Design_12'	2562	1	13.5031		13.56	0.000341	3.02	1592.05	428.64	0.16
1	1169.738	2100_100yr_Ab1	Design_in-kind	2562	1	13.4575		13.51	0.000352	3.06	1572.54	426.74	0.16
1	1169.738	2100_100yr_Ab1	Design_Exist	2562	1	13.5785		13.63	0.000324	2.96	1624.48	431.77	0.15
1	1169.738	2018_025yr(Surge	Design_20'	1228	1	9.9189		10.23	0.001942	5.62	329.24	100.92	0.35
1	1169.738	2015_025yr(Surge	Design_12'	1228	1	11.499		11.56	0.000406	2.9	813.33	348.18	0.17
1	1169.738	2015_025yr(Surge	Design_in-kind	1228	1	12.2107		12.24	0.000213	2.21	1071.54	377.26	0.12
1	1169.738	2015_025yr(Surge	Design_Exist	1228	1	12.2054		12.24	0.000214	2.21	1069.55	377.05	0.12
1	1169.738	2018_050yr(Surge	Design_20'	1565	1	11.0316		11.18	0.001048	4.51	655.12	328.77	0.27
1	1169.738	2015_050yr(Surge	Design_12'	1565	1	12.1219		12.18	0.000373	2.9	1038.24	373.38	0.16
1	1169.738	2015_050yr(Surge	Design_in-kind	1565	1	12.6196		12.66	0.000246	2.43	1229.1	393.17	0.13
1	1169.738	2015_050yr(Surge	Design_Exist	1565	1	12.8117		12.84	0.000211	2.28	1305.31	400.68	0.12
1	1169.738	015_100yr(Surge)	Design_20'	2000	1	11.962		12.06	0.000702	3.94	978.99	367.41	0.22
1	1169.738	015_100yr(Surge)	Design_12'	2000	1	12.6539		12.71	0.000391	3.08	1242.61	394.5	0.17
1	1169.738	015_100yr(Surge)	Design_in-kind	2000	1	13.008		13.05	0.000297	2.74	1384.79	408.76	0.15
1	1169.738	015_100yr(Surge)	Design_Exist	2000	1	13.1377		13.18	0.00027	2.63	1438.12	414.01	0.14
1	1065.804	2018_002yr	Design_20'	232	1.11	4.9233		5	0.000725	2.19	105.71	34.28	0.22
1	1065.804	2018_002yr	Design_12'	232	1.11	5.0219		5.09	0.000657	2.13	109.09	34.28	0.21
1	1065.804	2018_002yr	Design_in-kind	232	1.11	5.3909		5.45	0.000495	1.9	122.32	36.82	0.18
1	1065.804	2018_002yr	Design_Exist	232	1.11	6.4568		6.49	0.000206	1.43	164.78	63.41	0.12
1	1065.804	2018_010yr	Design_20'	845	1.11	7.0333	4.49	7.33	0.001688	4.44	213.79	96.96	0.36
1	1065.804	2018_010yr	Design_12'	845	1.11	7.3521	4.49	7.59	0.001289	4.05	246.73	109.84	0.32
1	1065.804	2018_010yr	Design_in-kind	845	1.11	11.1206		11.14	0.000073	1.39	1019.03	319.03	0.08
1	1065.804	2018_010yr	Design_Exist	845	1.11	11.4013		11.42	0.00006	1.28	1109.79	327.48	0.07
1	1065.804	2018_025y	Design_20'	1228	1.11	8.8213		9.01	0.000828	3.84	452.07	168.27	0.26
1	1065.804	2018_025y	Design_12'	1228	1.11	9.8504		9.95	0.000389	2.9	648.29	212.68	0.18
1	1065.804	2018_025y	Design_in-kind	1228	1.11	11.9969		12.02	0.000084	1.59	1310.39	346.04	0.09
1	1065.804	2018_025y	Design_Exist	1228	1.11	12.1942		12.21	0.000074	1.51	1379.68	356.49	0.08
1	1065.804	2018_050yr	Design_20'	1565	1.11	10.2402		10.37	0.000496	3.38	750.14	291.7	0.21
1	1065.804	2018_050yr	Design_12'	1565	1.11	11.6061		11.65	0.000177	2.24	1177.52	333.91	0.13
1	1065.804	2018_050yr	Design_in-kind	1565	1.11	12.4978		12.53	0.0001	1.79	1490.35	372.44	0.1
1	1065.804	2018_050yr	Design_Exist	1565	1.11	12.8009		12.82	0.000083	1.67	1605.53	387.46	0.09
1	1065.804	2018_100yr	Design_20'	2000	1.11	11.6501		11.72	0.00028	2.83	1192.24	335.29	0.16
1	1065.804	2018_100yr	Design_12'	2000	1.11	12.3702		12.42	0.000176	2.36	1443.26	365.88	0.13
1	1065.804	2018_100yr	Design_in-kind	2000	1.11	12.8987		12.94	0.000128	2.08	1643.68	392.08	0.11
1	1065.804	2018_100yr	Design_Exist	2000	1.11	13.1287		13.16	0.000112	1.98	1735.09	402.93	0.11

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	1065.804	2018_500yr	Design_20'	2671	1.11	13.6671		13.71	0.000148	2.35	1958.88	428.33	0.12
1	1065.804	2018_500yr	Design_12'	2671	1.11	13.6671		13.71	0.000148	2.35	1958.88	428.33	0.12
1	1065.804	2018_500yr	Design_in-kind	2671	1.11	13.5154		13.56	0.000161	2.42	1894.42	421.17	0.13
1	1065.804	2018_500yr	Design_Exist	2671	1.11	13.6465		13.69	0.00015	2.36	1950.04	427.36	0.12
1	1065.804	2018_25yr_MHHW_M	Design_20'	1228	1.11	8.8213		9.01	0.000828	3.84	452.08	168.27	0.26
1	1065.804	2018_25yr_MHHW_M	Design_12'	1228	1.11	10.1108		10.2	0.00034	2.77	712.64	287.62	0.17
1	1065.804	2018_25yr_MHHW_M	Design_in-kind	1228	1.11	12.0045		12.03	0.000083	1.58	1312.99	346.37	0.09
1	1065.804	2018_25yr_MHHW_M	Design_Exist	1228	1.11	12.2091		12.23	0.000073	1.51	1384.98	357.29	0.08
1	1065.804	2018_25yr_MSL_Ma	Design_20'	1228	1.11	8.8213		9.01	0.000828	3.84	452.07	168.27	0.26
1	1065.804	2018_25yr_MSL_Ma	Design_12'	1228	1.11	9.9074		10	0.000373	2.85	660.47	215.11	0.18
1	1065.804	2018_25yr_MSL_Ma	Design_in-kind	1228	1.11	12.0088		12.03	0.000083	1.58	1314.49	346.6	0.09
1	1065.804	2018_25yr_MSL_Ma	Design_Exist	1228	1.11	12.1864		12.21	0.000074	1.51	1376.89	356.08	0.08
1	1065.804	2100_025yr_Ab1	Design_20'	1706	1.11	10.7189		10.82	0.000403	3.17	893.36	306.65	0.19
1	1065.804	2100_025yr_Ab1	Design_12'	1706	1.11	12.0698		12.11	0.000154	2.16	1335.74	349.85	0.12
1	1065.804	2100_025yr_Ab1	Design_in-kind	1706	1.11	12.6756		12.71	0.000107	1.87	1557.37	381.46	0.1
1	1065.804	2100_025yr_Ab1	Design_Exist	1706	1.11	12.7393		12.77	0.000103	1.84	1581.77	384.56	0.1
1	1065.804	2100_050yr_Ab1	Design_20'	1717	1.11	10.7646		10.87	0.000394	3.14	907.43	308.05	0.19
1	1065.804	2100_050yr_Ab1	Design_12'	1717	1.11	12.0843		12.13	0.000155	2.17	1340.82	350.63	0.12
1	1065.804	2100_050yr_Ab1	Design_in-kind	1717	1.11	12.7276		12.76	0.000105	1.86	1577.28	384.01	0.1
1	1065.804	2100_050yr_Ab1	Design_Exist	1717	1.11	12.7294		12.76	0.000105	1.86	1577.98	384.09	0.1
1	1065.804	2100_100yr_Ab1	Design_20'	2562	1.11	13.4877		13.53	0.000151	2.34	1882.78	419.87	0.12
1	1065.804	2100_100yr_Ab1	Design_12'	2562	1.11	13.4874		13.53	0.000151	2.34	1882.64	419.85	0.12
1	1065.804	2100_100yr_Ab1	Design_in-kind	2562	1.11	13.4414		13.49	0.000155	2.36	1863.41	417.68	0.12
1	1065.804	2100_100yr_Ab1	Design_Exist	2562	1.11	13.5632		13.61	0.000145	2.3	1914.64	423.43	0.12
1	1065.804	2018_025yr(Surge	Design_20'	1228	1.11	9.9915		10.09	0.000375	2.88	678.79	255.55	0.18
1	1065.804	2015_025yr(Surge	Design_12'	1228	1.11	11.4963		11.53	0.000118	1.82	1141.03	330.46	0.11
1	1065.804	2015_025yr(Surge	Design_in-kind	1228	1.11	12.2057		12.23	0.000074	1.51	1383.77	357.11	0.08
1	1065.804	2015_025yr(Surge	Design_Exist	1228	1.11	12.2004		12.22	0.000074	1.51	1381.89	356.82	0.08
1	1065.804	2018_050yr(Surge	Design_20'	1565	1.11	11.0377		11.11	0.000266	2.64	992.68	316.46	0.16
1	1065.804	2015_050yr(Surge	Design_12'	1565	1.11	12.114		12.15	0.000126	1.96	1351.23	352.21	0.11
1	1065.804	2015_050yr(Surge	Design_in-kind	1565	1.11	12.6117		12.64	0.000093	1.74	1533.11	378.22	0.1
1	1065.804	2015_050yr(Surge	Design_Exist	1565	1.11	12.8041		12.83	0.000083	1.67	1606.8	387.62	0.09
1	1065.804	015_100yr(Surge)	Design_20'	2000	1.11	11.9495		12.01	0.000229	2.62	1294.01	344.57	0.15
1	1065.804	015_100yr(Surge)	Design_12'	2000	1.11	12.6411		12.68	0.00015	2.21	1544.23	379.71	0.12
1	1065.804	015_100yr(Surge)	Design_in-kind	2000	1.11	12.9964		13.03	0.000121	2.04	1682.21	396.69	0.11
1	1065.804	015_100yr(Surge)	Design_Exist	2000	1.11	13.1266		13.16	0.000113	1.98	1734.25	402.83	0.11
1	950.2366	2018_002yr	Design_20'	232	1.6	4.9548		4.96	0.000056	0.65	359.38	116.19	0.06
1	950.2366	2018_002yr	Design_12'	232	1.6	5.052		5.06	0.000051	0.63	370.68	116.34	0.06
1	950.2366	2018_002yr	Design_in-kind	232	1.6	5.4158		5.42	0.000036	0.56	413.1	116.86	0.05
1	950.2366	2018_002yr	Design_Exist	232	1.6	6.4723		6.48	0.000015	0.43	545.75	147.09	0.04
1	950.2366	2018_010yr	Design_20'	845	1.6	7.1863		7.21	0.000121	1.34	663.77	179.93	0.1
1	950.2366	2018_010yr	Design_12'	845	1.6	7.475		7.5	0.0001	1.26	717.19	190.15	0.09
1	950.2366	2018_010yr	Design_in-kind	845	1.6	11.127		11.13	0.000013	0.64	1708.77	349.67	0.04
1	950.2366	2018_010yr	Design_Exist	845	1.6	11.4062		11.41	0.000012	0.61	1807.97	361.49	0.04
1	950.2366	2018_025y	Design_20'	1228	1.6	8.909		8.94	0.000088	1.38	1034.05	252.88	0.09
1	950.2366	2018_025y	Design_12'	1228	1.6	9.8912		9.91	0.000052	1.16	1304.93	296.1	0.07
1	950.2366	2018_025y	Design_in-kind	1228	1.6	12.0028		12.01	0.000019	0.81	2029.12	423.07	0.05
1	950.2366	2018_025y	Design_Exist	1228	1.6	12.1992		12.21	0.000017	0.79	2112.81	428.94	0.04
1	950.2366	2018_050yr	Design_20'	1565	1.6	10.293		10.32	0.000069	1.37	1429.75	320.2	0.08
1	950.2366	2018_050yr	Design_12'	1565	1.6	11.6201		11.64	0.000036	1.09	1885.99	368.02	0.06
1	950.2366	2018_050yr	Design_in-kind	1565	1.6	12.5041		12.52	0.000024	0.96	2244.97	438	0.05
1	950.2366	2018_050yr	Design_Exist	1565	1.6	12.8058		12.82	0.000021	0.91	2378.45	446.93	0.05
1	950.2366	2018_100yr	Design_20'	2000	1.6	11.672		11.7	0.000057	1.39	1905.13	369.57	0.08
1	950.2366	2018_100yr	Design_12'	2000	1.6	12.3817		12.4	0.000042	1.25	2191.6	434.36	0.07
1	950.2366	2018_100yr	Design_in-kind	2000	1.6	12.9062		12.92	0.000033	1.15	2423.5	449.92	0.06
1	950.2366	2018_100yr	Design_Exist	2000	1.6	13.1348		13.15	0.00003	1.11	2527.13	456.77	0.06
1	950.2366	2018_500yr	Design_20'	2671	1.6	13.6742		13.7	0.000043	1.37	2777.97	473.43	0.07
1	950.2366	2018_500yr	Design_12'	2671	1.6	13.6742		13.7	0.000043	1.37	2777.97	473.43	0.07
1	950.2366	2018_500yr	Design_in-kind	2671	1.6	13.5234		13.55	0.000046	1.4	2706.93	468.61	0.07
1	950.2366	2018_500yr	Design_Exist	2671	1.6	13.6537		13.68	0.000044	1.37	2768.24	472.78	0.07
1	950.2366	2018_25yr_MHHW_M	Design_20'	1228	1.6	8.909		8.94	0.000088	1.38	1034.05	252.88	0.09
1	950.2366	2018_25yr_MHHW_M	Design_12'	1228	1.6	10.1476		10.16	0.000046	1.11	1383.54	315.34	0.07
1	950.2366	2018_25yr_MHHW_M	Design_in-kind	1228	1.6	12.0102		12.02	0.000019	0.81	2032.29	423.3	0.05
1	950.2366	2018_25yr_MHHW_M	Design_Exist	1228	1.6	12.214		12.22	0.000017	0.79	2119.16	429.38	0.04
1	950.2366	2018_25yr_MSL_Ma	Design_20'	1228	1.6	8.909		8.94	0.000088	1.38	1034.05	252.88	0.09
1	950.2366	2018_25yr_MSL_Ma	Design_12'	1228	1.6	9.9465		9.96	0.00005	1.14	1321.36	298.05	0.07
1	950.2366	2018_25yr_MSL_Ma	Design_in-kind	1228	1.6	12.0145		12.02	0.000019	0.81	2034.11	423.43	0.05
1	950.2366	2018_25yr_MSL_Ma	Design_Exist	1228	1.6	12.1914		12.2	0.000017	0.79	2109.46	428.71	0.04
1	950.2366	2100_025yr_Ab1	Design_20'	1706	1.6	10.7579		10.78	0.000064	1.38	1582.25	336.02	0.08
1	950.2366	2100_025yr_Ab1	Design_12'	1706	1.6	12.0805		12.1	0.000035	1.12	2062.09	425.41	0.06
1	950.2366	2100_025yr_Ab1	Design_in-kind	1706	1.6	12.6821		12.69	0.000027	1.02	2323.39	443.27	0.05

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	950.2366	2100_025yr_Ab1	Design_Exist	1706	1.6	12.7454		12.76	0.000026	1.01	2351.54	445.14	0.05
1	950.2366	2100_050yr_Ab1	Design_20'	1717	1.6	10.8024		10.83	0.000064	1.38	1597.25	337.58	0.08
1	950.2366	2100_050yr_Ab1	Design_12'	1717	1.6	12.095		12.11	0.000035	1.12	2068.27	425.84	0.06
1	950.2366	2100_050yr_Ab1	Design_in-kind	1717	1.6	12.7339		12.75	0.000027	1.01	2346.41	444.8	0.05
1	950.2366	2100_050yr_Ab1	Design_Exist	1717	1.6	12.7357		12.75	0.000027	1.01	2347.21	444.86	0.05
1	950.2366	2100_100yr_Ab1	Design_20'	2562	1.6	13.4953		13.52	0.000043	1.35	2693.75	467.74	0.07
1	950.2366	2100_100yr_Ab1	Design_12'	2562	1.6	13.495		13.52	0.000043	1.35	2693.6	467.73	0.07
1	950.2366	2100_100yr_Ab1	Design_in-kind	2562	1.6	13.4493		13.47	0.000044	1.36	2672.28	466.34	0.07
1	950.2366	2100_100yr_Ab1	Design_Exist	2562	1.6	13.5704		13.59	0.000042	1.33	2728.96	470.12	0.07
1	950.2366	2018_025yr(Surge	Design_20'	1228	1.6	10.0284		10.05	0.000049	1.13	1346.2	311.49	0.07
1	950.2366	2015_025yr(Surge	Design_12'	1228	1.6	11.5058		11.52	0.000023	0.87	1844.12	364.61	0.05
1	950.2366	2015_025yr(Surge	Design_in-kind	1228	1.6	12.2106		12.22	0.000017	0.79	2117.71	429.28	0.04
1	950.2366	2015_025yr(Surge	Design_Exist	1228	1.6	12.2054		12.21	0.000017	0.79	2115.45	429.12	0.04
1	950.2366	2018_050yr(Surge	Design_20'	1565	1.6	11.0614		11.08	0.000047	1.2	1685.9	347.4	0.07
1	950.2366	2015_050yr(Surge	Design_12'	1565	1.6	12.1226		12.14	0.000029	1.02	2080.04	426.67	0.06
1	950.2366	2015_050yr(Surge	Design_in-kind	1565	1.6	12.6175		12.63	0.000023	0.94	2294.82	441.36	0.05
1	950.2366	2015_050yr(Surge	Design_Exist	1565	1.6	12.809		12.82	0.000021	0.91	2379.92	447.03	0.05
1	950.2366	015_100yr(Surge)	Design_20'	2000	1.6	11.9662		11.99	0.00005	1.32	2015.16	378.32	0.07
1	950.2366	015_100yr(Surge)	Design_12'	2000	1.6	12.6503		12.67	0.000037	1.2	2309.32	442.33	0.06
1	950.2366	015_100yr(Surge)	Design_in-kind	2000	1.6	13.0033		13.02	0.000032	1.13	2467.33	452.8	0.06
1	950.2366	015_100yr(Surge)	Design_Exist	2000	1.6	13.1328		13.15	0.00003	1.11	2526.18	456.71	0.06
1	892.5984	2018_002yr	Design_20'	232	1.22	4.953		4.96	0.000047	0.55	422.07	154.09	0.06
1	892.5984	2018_002yr	Design_12'	232	1.22	5.0505		5.05	0.000042	0.53	437.09	154.23	0.06
1	892.5984	2018_002yr	Design_in-kind	232	1.22	5.4149		5.42	0.000028	0.47	493.4	154.73	0.05
1	892.5984	2018_002yr	Design_Exist	232	1.22	6.4722		6.47	0.000011	0.35	657.87	156.72	0.03
1	892.5984	2018_010yr	Design_20'	845	1.22	7.1864		7.21	0.000087	1.1	779.41	190.7	0.09
1	892.5984	2018_010yr	Design_12'	845	1.22	7.4753		7.49	0.000072	1.03	836.65	205.47	0.08
1	892.5984	2018_010yr	Design_in-kind	845	1.22	11.1269		11.13	0.000011	0.56	1774.46	352.53	0.03
1	892.5984	2018_010yr	Design_Exist	845	1.22	11.4061		11.41	0.000009	0.54	1874.11	361	0.03
1	892.5984	2018_025y	Design_20'	1228	1.22	8.9099		8.93	0.000065	1.15	1153.76	227.39	0.08
1	892.5984	2018_025y	Design_12'	1228	1.22	9.8915		9.91	0.000039	0.98	1380.48	238.68	0.06
1	892.5984	2018_025y	Design_in-kind	1228	1.22	12.0025		12.01	0.000015	0.72	2094.76	457.21	0.04
1	892.5984	2018_025y	Design_Exist	1228	1.22	12.1989		12.21	0.000014	0.7	2184.93	460.77	0.04
1	892.5984	2018_050yr	Design_20'	1565	1.22	10.2931		10.31	0.000053	1.18	1497.11	307.88	0.07
1	892.5984	2018_050yr	Design_12'	1565	1.22	11.6196		11.63	0.000029	0.97	1951.88	367.32	0.06
1	892.5984	2018_050yr	Design_in-kind	1565	1.22	12.5037		12.51	0.00002	0.86	2326.19	466.3	0.05
1	892.5984	2018_050yr	Design_Exist	1565	1.22	12.8054		12.81	0.000018	0.82	2467.71	471.77	0.04
1	892.5984	2018_100yr	Design_20'	2000	1.22	11.6713		11.69	0.000046	1.23	1970.88	368.7	0.07
1	892.5984	2018_100yr	Design_12'	2000	1.22	12.3811		12.4	0.000035	1.12	2269.15	464.08	0.06
1	892.5984	2018_100yr	Design_in-kind	2000	1.22	12.9056		12.92	0.000028	1.03	2515.08	473.59	0.06
1	892.5984	2018_100yr	Design_Exist	2000	1.22	13.1343		13.15	0.000025	1	2623.84	477.77	0.05
1	892.5984	2018_500yr	Design_20'	2671	1.22	13.6734		13.69	0.000036	1.23	2884.16	487.88	0.06
1	892.5984	2018_500yr	Design_12'	2671	1.22	13.6734		13.69	0.000036	1.23	2884.15	487.88	0.06
1	892.5984	2018_500yr	Design_in-kind	2671	1.22	13.5226		13.54	0.000038	1.26	2810.76	485.05	0.07
1	892.5984	2018_500yr	Design_Exist	2671	1.22	13.6529		13.67	0.000036	1.24	2874.13	487.5	0.06
1	892.5984	2018_25yr_MHHW_M	Design_20'	1228	1.22	8.9099		8.93	0.000065	1.15	1153.77	227.39	0.08
1	892.5984	2018_25yr_MHHW_M	Design_12'	1228	1.22	10.1477		10.16	0.000035	0.95	1452.95	299.28	0.06
1	892.5984	2018_25yr_MHHW_M	Design_in-kind	1228	1.22	12.01		12.02	0.000015	0.72	2098.18	457.34	0.04
1	892.5984	2018_25yr_MHHW_M	Design_Exist	1228	1.22	12.2137		12.22	0.000014	0.7	2191.75	461.04	0.04
1	892.5984	2018_25yr_MSL_Ma	Design_20'	1228	1.22	8.9099		8.93	0.000065	1.15	1153.76	227.39	0.08
1	892.5984	2018_25yr_MSL_Ma	Design_12'	1228	1.22	9.9467		9.96	0.000038	0.98	1394.4	273.4	0.06
1	892.5984	2018_25yr_MSL_Ma	Design_in-kind	1228	1.22	12.0143		12.02	0.000015	0.72	2100.15	457.42	0.04
1	892.5984	2018_25yr_MSL_Ma	Design_Exist	1228	1.22	12.1911		12.2	0.000014	0.7	2181.33	460.63	0.04
1	892.5984	2100_025yr_Ab1	Design_20'	1706	1.22	10.7575		10.78	0.000051	1.2	1646.83	336.77	0.07
1	892.5984	2100_025yr_Ab1	Design_12'	1706	1.22	12.08		12.09	0.000029	1	2130.24	458.61	0.06
1	892.5984	2100_025yr_Ab1	Design_in-kind	1706	1.22	12.6816		12.69	0.000022	0.91	2409.44	469.53	0.05
1	892.5984	2100_025yr_Ab1	Design_Exist	1706	1.22	12.745		12.76	0.000022	0.9	2439.24	470.68	0.05
1	892.5984	2100_050yr_Ab1	Design_20'	1717	1.22	10.802		10.82	0.00005	1.2	1661.88	339.31	0.07
1	892.5984	2100_050yr_Ab1	Design_12'	1717	1.22	12.0945		12.11	0.000029	1	2136.9	458.88	0.06
1	892.5984	2100_050yr_Ab1	Design_in-kind	1717	1.22	12.7334		12.74	0.000022	0.91	2433.81	470.47	0.05
1	892.5984	2100_050yr_Ab1	Design_Exist	1717	1.22	12.7353		12.75	0.000022	0.91	2434.66	470.5	0.05
1	892.5984	2100_100yr_Ab1	Design_20'	2562	1.22	13.4945		13.51	0.000036	1.21	2797.15	484.53	0.06
1	892.5984	2100_100yr_Ab1	Design_12'	2562	1.22	13.4941		13.51	0.000036	1.21	2796.99	484.52	0.06
1	892.5984	2100_100yr_Ab1	Design_in-kind	2562	1.22	13.4485		13.47	0.000036	1.22	2774.89	483.66	0.06
1	892.5984	2100_100yr_Ab1	Design_Exist	2562	1.22	13.5696		13.59	0.000035	1.2	2833.59	485.94	0.06
1	892.5984	2018_025yr(Surge	Design_20'	1228	1.22	10.0286		10.04	0.000037	0.97	1417.76	291.83	0.06
1	892.5984	2015_025yr(Surge	Design_12'	1228	1.22	11.5055		11.51	0.000019	0.77	1910.14	364.13	0.04
1	892.5984	2015_025yr(Surge	Design_in-kind	1228	1.22	12.2104		12.22	0.000014	0.7	2190.19	460.98	0.04
1	892.5984	2015_025yr(Surge	Design_Exist	1228	1.22	12.2051		12.21	0.000014	0.7	2187.77	460.89	0.04
1	892.5984	2018_050yr(Surge	Design_20'	1565	1.22	11.061		11.08	0.000037	1.05	1751.31	350.44	0.06
1	892.5984	2015_050yr(Surge	Design_12'	1565	1.22	12.1222		12.13	0.000024	0.91	2149.61	459.38	0.05

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	892.5984	2015_050yr(Surge	Design_in-kind	1565	1.22	12.6171		12.63	0.000019	0.84	2379.19	468.36	0.05
1	892.5984	2015_050yr(Surge	Design_Exist	1565	1.22	12.8087		12.82	0.000018	0.82	2469.25	471.83	0.04
1	892.5984	015_100yr(Surge)	Design_20'	2000	1.22	11.9654		11.98	0.000041	1.18	2080.48	376.36	0.07
1	892.5984	015_100yr(Surge)	Design_12'	2000	1.22	12.6497		12.67	0.000031	1.07	2394.46	468.95	0.06
1	892.5984	015_100yr(Surge)	Design_in-kind	2000	1.22	13.0028		13.02	0.000027	1.02	2561.17	475.35	0.05
1	892.5984	015_100yr(Surge)	Design_Exist	2000	1.22	13.1322		13.15	0.000025	1	2622.85	477.73	0.05
1	816.2677	2018_002yr	Design_20'	232	1.23	4.9512		4.95	0.00003	0.44	522.64	185.84	0.05
1	816.2677	2018_002yr	Design_12'	232	1.23	5.0489		5.05	0.000027	0.43	540.81	186.11	0.04
1	816.2677	2018_002yr	Design_in-kind	232	1.23	5.414		5.42	0.000018	0.38	608.94	187.12	0.04
1	816.2677	2018_002yr	Design_Exist	232	1.23	6.472		6.47	0.000007	0.29	808.22	190.56	0.02
1	816.2677	2018_010yr	Design_20'	845	1.23	7.1853		7.2	0.000057	0.89	956.05	225.69	0.07
1	816.2677	2018_010yr	Design_12'	845	1.23	7.4746		7.49	0.000047	0.84	1022.42	233.07	0.07
1	816.2677	2018_010yr	Design_in-kind	845	1.23	11.1272		11.13	0.000007	0.46	2110.23	386.77	0.03
1	816.2677	2018_010yr	Design_Exist	845	1.23	11.4064		11.41	0.000006	0.45	2220.56	403.63	0.03
1	816.2677	2018_025y	Design_20'	1228	1.23	8.9103		8.92	0.000043	0.94	1387.42	278.46	0.06
1	816.2677	2018_025y	Design_12'	1228	1.23	9.8922		9.9	0.000026	0.81	1677.28	313.63	0.05
1	816.2677	2018_025y	Design_in-kind	1228	1.23	12.0031		12.01	0.00001	0.6	2478.17	481.56	0.03
1	816.2677	2018_025y	Design_Exist	1228	1.23	12.1995		12.2	0.00001	0.58	2573.18	485.96	0.03
1	816.2677	2018_050yr	Design_20'	1565	1.23	10.2944		10.31	0.000035	0.97	1808.9	337.93	0.06
1	816.2677	2018_050yr	Design_12'	1565	1.23	11.6206		11.63	0.00002	0.8	2308.59	423.42	0.05
1	816.2677	2018_050yr	Design_in-kind	1565	1.23	12.5046		12.51	0.000014	0.71	2722.46	492.78	0.04
1	816.2677	2018_050yr	Design_Exist	1565	1.23	12.8062		12.81	0.000012	0.68	2872.11	499.53	0.04
1	816.2677	2018_100yr	Design_20'	2000	1.23	11.6728		11.69	0.000032	1.02	2330.84	428.79	0.06
1	816.2677	2018_100yr	Design_12'	2000	1.23	12.3825		12.39	0.000024	0.92	2662.49	490.05	0.05
1	816.2677	2018_100yr	Design_in-kind	2000	1.23	12.9069		12.92	0.000019	0.85	2922.52	501.79	0.05
1	816.2677	2018_100yr	Design_Exist	2000	1.23	13.1354		13.14	0.000017	0.83	3037.8	506.92	0.04
1	816.2677	2018_500yr	Design_20'	2671	1.23	13.6751		13.69	0.000025	1.03	3314.66	519.03	0.05
1	816.2677	2018_500yr	Design_12'	2671	1.23	13.6751		13.69	0.000025	1.03	3314.65	519.03	0.05
1	816.2677	2018_500yr	Design_in-kind	2671	1.23	13.5244		13.54	0.000026	1.05	3236.65	515.65	0.06
1	816.2677	2018_500yr	Design_Exist	2671	1.23	13.6546		13.67	0.000025	1.03	3304	518.57	0.05
1	816.2677	2018_25yr_MHHW_M	Design_20'	1228	1.23	8.9103		8.92	0.000043	0.94	1387.43	278.46	0.06
1	816.2677	2018_25yr_MHHW_M	Design_12'	1228	1.23	10.1485		10.16	0.000023	0.78	1760.07	331.67	0.05
1	816.2677	2018_25yr_MHHW_M	Design_in-kind	1228	1.23	12.0106		12.02	0.00001	0.6	2481.77	481.73	0.03
1	816.2677	2018_25yr_MHHW_M	Design_Exist	1228	1.23	12.2143		12.22	0.00001	0.58	2580.37	486.29	0.03
1	816.2677	2018_25yr_MSL_Ma	Design_20'	1228	1.23	8.9103		8.92	0.000043	0.94	1387.42	278.46	0.06
1	816.2677	2018_25yr_MSL_Ma	Design_12'	1228	1.23	9.9475		9.96	0.000026	0.8	1694.68	315.54	0.05
1	816.2677	2018_25yr_MSL_Ma	Design_in-kind	1228	1.23	12.0149		12.02	0.00001	0.6	2483.84	481.82	0.03
1	816.2677	2018_25yr_MSL_Ma	Design_Exist	1228	1.23	12.1917		12.2	0.00001	0.58	2569.39	485.78	0.03
1	816.2677	2100_025yr_Ab1	Design_20'	1706	1.23	10.759		10.77	0.000034	0.99	1971.89	364.67	0.06
1	816.2677	2100_025yr_Ab1	Design_12'	1706	1.23	12.0811		12.09	0.000019	0.82	2515.8	483.31	0.05
1	816.2677	2100_025yr_Ab1	Design_in-kind	1706	1.23	12.6826		12.69	0.000015	0.75	2810.54	496.77	0.04
1	816.2677	2100_025yr_Ab1	Design_Exist	1706	1.23	12.7459		12.75	0.000015	0.75	2842.06	498.18	0.04
1	816.2677	2100_050yr_Ab1	Design_20'	1717	1.23	10.8035		10.82	0.000034	0.99	1988.18	367.34	0.06
1	816.2677	2100_050yr_Ab1	Design_12'	1717	1.23	12.0956		12.11	0.00002	0.83	2522.83	483.63	0.05
1	816.2677	2100_050yr_Ab1	Design_in-kind	1717	1.23	12.7344		12.74	0.000015	0.75	2836.32	497.93	0.04
1	816.2677	2100_050yr_Ab1	Design_Exist	1717	1.23	12.7362		12.74	0.000015	0.75	2837.22	497.97	0.04
1	816.2677	2100_100yr_Ab1	Design_20'	2562	1.23	13.4961		13.51	0.000025	1.01	3222.11	515.02	0.05
1	816.2677	2100_100yr_Ab1	Design_12'	2562	1.23	13.4958		13.51	0.000025	1.01	3221.95	515.01	0.05
1	816.2677	2100_100yr_Ab1	Design_in-kind	2562	1.23	13.4502		13.46	0.000025	1.02	3198.47	513.99	0.05
1	816.2677	2100_100yr_Ab1	Design_Exist	2562	1.23	13.5712		13.58	0.000024	1	3260.84	516.7	0.05
1	816.2677	2018_025yr(Surge	Design_20'	1228	1.23	10.0294		10.04	0.000025	0.79	1720.89	326.22	0.05
1	816.2677	2015_025yr(Surge	Design_12'	1228	1.23	11.5061		11.51	0.000013	0.64	2261.13	409.99	0.04
1	816.2677	2015_025yr(Surge	Design_in-kind	1228	1.23	12.2109		12.22	0.00001	0.58	2578.73	486.21	0.03
1	816.2677	2015_025yr(Surge	Design_Exist	1228	1.23	12.2057		12.21	0.00001	0.58	2576.18	486.09	0.03
1	816.2677	2018_050yr(Surge	Design_20'	1565	1.23	11.0622		11.07	0.000025	0.87	2085.2	382.87	0.05
1	816.2677	2015_050yr(Surge	Design_12'	1565	1.23	12.1231		12.13	0.000016	0.75	2536.13	484.25	0.04
1	816.2677	2015_050yr(Surge	Design_in-kind	1565	1.23	12.6179		12.62	0.000013	0.7	2778.46	495.32	0.04
1	816.2677	2015_050yr(Surge	Design_Exist	1565	1.23	12.8095		12.82	0.000012	0.68	2873.75	499.61	0.04
1	816.2677	015_100yr(Surge)	Design_20'	2000	1.23	11.9669		11.98	0.000028	0.98	2461.36	458.71	0.06
1	816.2677	015_100yr(Surge)	Design_12'	2000	1.23	12.651		12.66	0.000021	0.89	2794.87	496.06	0.05
1	816.2677	015_100yr(Surge)	Design_in-kind	2000	1.23	13.004		13.01	0.000018	0.84	2971.35	503.96	0.05
1	816.2677	015_100yr(Surge)	Design_Exist	2000	1.23	13.1334		13.14	0.000017	0.83	3036.75	506.87	0.04
1	742.3986	2018_002yr	Design_20'	232	0.93	4.9462		4.95	0.000044	0.58	402.92	128.34	0.06
1	742.3986	2018_002yr	Design_12'	232	0.93	5.0443		5.05	0.00004	0.56	415.51	128.53	0.05
1	742.3986	2018_002yr	Design_in-kind	232	0.93	5.4105		5.41	0.000028	0.5	462.75	129.68	0.05
1	742.3986	2018_002yr	Design_Exist	232	0.93	6.4702		6.47	0.000012	0.38	603.02	135.08	0.03
1	742.3986	2018_010yr	Design_20'	845	0.93	7.1682		7.19	0.000103	1.21	704.04	158.75	0.09
1	742.3986	2018_010yr	Design_12'	845	0.93	7.4598		7.48	0.000086	1.14	751.7	168.19	0.09
1	742.3986	2018_010yr	Design_in-kind	845	0.93	11.1246		11.13	0.000012	0.6	1792.94	467.96	0.03
1	742.3986	2018_010yr	Design_Exist	845	0.93	11.4042		11.41	0.00001	0.57	1927.53	493.8	0.03

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	742.3986	2018_025y	Design_20'	1228	0.93	8.8934		8.92	0.000079	1.28	1029.43	225.22	0.09
1	742.3986	2018_025y	Design_12'	1228	0.93	9.8812		9.9	0.000047	1.08	1285.28	294.8	0.07
1	742.3986	2018_025y	Design_in-kind	1228	0.93	12.0001		12.01	0.000016	0.73	2230.09	521.49	0.04
1	742.3986	2018_025y	Design_Exist	1228	0.93	12.1969		12.2	0.000014	0.71	2333.09	525.29	0.04
1	742.3986	2018_050yr	Design_20'	1565	0.93	10.2794		10.3	0.000063	1.29	1429.69	402.77	0.08
1	742.3986	2018_050yr	Design_12'	1565	0.93	11.6141		11.63	0.000031	1.01	2032.21	503.85	0.06
1	742.3986	2018_050yr	Design_in-kind	1565	0.93	12.5011		12.51	0.00002	0.85	2493.79	531.15	0.05
1	742.3986	2018_050yr	Design_Exist	1565	0.93	12.8034		12.81	0.000017	0.8	2655.24	536.99	0.04
1	742.3986	2018_100yr	Design_20'	2000	0.93	11.6625		11.68	0.000049	1.27	2056.66	506.06	0.07
1	742.3986	2018_100yr	Design_12'	2000	0.93	12.3764		12.39	0.000034	1.11	2427.69	528.74	0.06
1	742.3986	2018_100yr	Design_in-kind	2000	0.93	12.9026		12.92	0.000026	1	2708.62	538.91	0.05
1	742.3986	2018_100yr	Design_Exist	2000	0.93	13.1318		13.14	0.000023	0.96	2832.64	543.33	0.05
1	742.3986	2018_500yr	Design_20'	2671	0.93	13.6708		13.69	0.000032	1.17	3128.48	554.9	0.06
1	742.3986	2018_500yr	Design_12'	2671	0.93	13.6707		13.69	0.000032	1.17	3128.47	554.9	0.06
1	742.3986	2018_500yr	Design_in-kind	2671	0.93	13.5195		13.54	0.000035	1.2	3044.79	551.53	0.06
1	742.3986	2018_500yr	Design_Exist	2671	0.93	13.6501		13.67	0.000033	1.18	3117.04	554.44	0.06
1	742.3986	2018_25yr_MHHW_M	Design_20'	1228	0.93	8.8934		8.92	0.000079	1.28	1029.43	225.22	0.09
1	742.3986	2018_25yr_MHHW_M	Design_12'	1228	0.93	10.1385		10.15	0.000042	1.04	1373.51	395.04	0.06
1	742.3986	2018_25yr_MHHW_M	Design_in-kind	1228	0.93	12.0076		12.01	0.000016	0.73	2233.99	521.64	0.04
1	742.3986	2018_25yr_MHHW_M	Design_Exist	1228	0.93	12.2117		12.22	0.000014	0.7	2340.88	525.57	0.04
1	742.3986	2018_25yr_MSL_Ma	Design_20'	1228	0.93	8.8934		8.92	0.000079	1.28	1029.43	225.22	0.09
1	742.3986	2018_25yr_MSL_Ma	Design_12'	1228	0.93	9.9368		9.95	0.000046	1.07	1301.76	298.53	0.07
1	742.3986	2018_25yr_MSL_Ma	Design_in-kind	1228	0.93	12.0119		12.02	0.000015	0.73	2236.24	521.72	0.04
1	742.3986	2018_25yr_MSL_Ma	Design_Exist	1228	0.93	12.1891		12.2	0.000014	0.71	2328.98	525.13	0.04
1	742.3986	2100_025yr_Ab1	Design_20'	1706	0.93	10.7455		10.77	0.000058	1.29	1623.56	429.29	0.08
1	742.3986	2100_025yr_Ab1	Design_12'	1706	0.93	12.0756		12.09	0.000029	1	2269.51	522.95	0.06
1	742.3986	2100_025yr_Ab1	Design_in-kind	1706	0.93	12.679		12.69	0.000021	0.89	2588.57	534.58	0.05
1	742.3986	2100_025yr_Ab1	Design_Exist	1706	0.93	12.7425		12.75	0.000021	0.88	2622.56	535.81	0.05
1	742.3986	2100_050yr_Ab1	Design_20'	1717	0.93	10.7902		10.81	0.000057	1.29	1642.81	431.86	0.08
1	742.3986	2100_050yr_Ab1	Design_12'	1717	0.93	12.0901		12.1	0.000029	1.01	2277.1	523.23	0.06
1	742.3986	2100_050yr_Ab1	Design_in-kind	1717	0.93	12.7309		12.74	0.000021	0.89	2616.35	535.59	0.05
1	742.3986	2100_050yr_Ab1	Design_Exist	1717	0.93	12.7327		12.74	0.000021	0.89	2617.32	535.62	0.05
1	742.3986	2100_100yr_Ab1	Design_20'	2562	0.93	13.4916		13.51	0.000032	1.16	3029.4	550.91	0.06
1	742.3986	2100_100yr_Ab1	Design_12'	2562	0.93	13.4912		13.51	0.000032	1.16	3029.23	550.9	0.06
1	742.3986	2100_100yr_Ab1	Design_in-kind	2562	0.93	13.4455		13.46	0.000033	1.17	3004.03	549.88	0.06
1	742.3986	2100_100yr_Ab1	Design_Exist	2562	0.93	13.5669		13.58	0.000031	1.14	3070.96	552.59	0.06
1	742.3986	2018_025yr(Surge	Design_20'	1228	0.93	10.0191		10.04	0.000044	1.06	1327.32	353.23	0.07
1	742.3986	2015_025yr(Surge	Design_12'	1228	0.93	11.5018		11.51	0.00002	0.81	1975.94	498.47	0.05
1	742.3986	2015_025yr(Surge	Design_in-kind	1228	0.93	12.2083		12.21	0.000014	0.7	2339.11	525.51	0.04
1	742.3986	2015_025yr(Surge	Design_Exist	1228	0.93	12.2031		12.21	0.000014	0.7	2336.34	525.4	0.04
1	742.3986	2018_050yr(Surge	Design_20'	1565	0.93	11.0527		11.07	0.000042	1.12	1759.56	460.88	0.07
1	742.3986	2015_050yr(Surge	Design_12'	1565	0.93	12.1186		12.13	0.000024	0.91	2292.04	523.78	0.05
1	742.3986	2015_050yr(Surge	Design_in-kind	1565	0.93	12.6148		12.62	0.000018	0.83	2554.27	533.34	0.05
1	742.3986	2015_050yr(Surge	Design_Exist	1565	0.93	12.8067		12.81	0.000017	0.8	2657	537.05	0.04
1	742.3986	015_100yr(Surge)	Design_20'	2000	0.93	11.9585		11.98	0.000042	1.2	2208.45	519.7	0.07
1	742.3986	015_100yr(Surge)	Design_12'	2000	0.93	12.6459		12.66	0.00003	1.05	2570.92	533.94	0.06
1	742.3986	015_100yr(Surge)	Design_in-kind	2000	0.93	13		13.01	0.000025	0.99	2761.19	540.8	0.05
1	742.3986	015_100yr(Surge)	Design_Exist	2000	0.93	13.1298		13.14	0.000023	0.96	2831.51	543.29	0.05
1	607.5615	2018_002yr	Design_20'	232	0.79	4.917	2.16	4.94	0.000176	1.19	195.67	57.77	0.11
1	607.5615	2018_002yr	Design_12'	232	0.79	5.0171	2.16	5.04	0.000161	1.15	201.46	57.96	0.11
1	607.5615	2018_002yr	Design_in-kind	232	0.79	5.3893	2.16	5.41	0.000117	1.04	223.16	58.66	0.09
1	607.5615	2018_002yr	Design_Exist	232	0.79	6.4584	2.16	6.47	0.000053	0.81	287.36	63	0.07
1	607.5615	2018_010yr	Design_20'	845	0.79	7.0496	3.34	7.16	0.000486	2.61	327.87	84.18	0.2
1	607.5615	2018_010yr	Design_12'	845	0.79	7.3569	3.34	7.45	0.000399	2.46	355.85	95.16	0.18
1	607.5615	2018_010yr	Design_in-kind	845	0.79	11.1034	3.34	11.12	0.000053	1.26	884.97	400.59	0.07
1	607.5615	2018_010yr	Design_Exist	845	0.79	11.3851	3.34	11.4	0.000047	1.21	935.47	429.37	0.07
1	607.5615	2018_025y	Design_20'	1228	0.79	8.7781	3.89	8.89	0.000366	2.74	515.4	129.62	0.18
1	607.5615	2018_025y	Design_12'	1228	0.79	9.8061	3.89	9.88	0.000213	2.29	664.15	159.74	0.14
1	607.5615	2018_025y	Design_in-kind	1228	0.79	11.9669	3.89	12	0.000077	1.6	1042.9	514.83	0.09
1	607.5615	2018_025y	Design_Exist	1228	0.79	12.1658	3.89	12.2	0.00007	1.56	1080.7	554.6	0.08
1	607.5615	2018_050yr	Design_20'	1565	0.79	10.1745	4.34	10.28	0.000287	2.73	724.72	303.89	0.17
1	607.5615	2018_050yr	Design_12'	1565	0.79	11.552	4.34	11.61	0.000149	2.18	965.85	446.91	0.12
1	607.5615	2018_050yr	Design_in-kind	1565	0.79	12.4789	4.34	12.5	0.000066	1.54	1745.35	565.89	0.08
1	607.5615	2018_050yr	Design_Exist	1565	0.79	12.7861	4.34	12.81	0.000053	1.41	1920.86	576.69	0.07
1	607.5615	2018_100yr	Design_20'	2000	0.79	11.5613	4.87	11.66	0.000242	2.78	967.54	447.89	0.16
1	607.5615	2018_100yr	Design_12'	2000	0.79	12.3354	4.87	12.38	0.00012	2.05	1664.53	560.85	0.11
1	607.5615	2018_100yr	Design_in-kind	2000	0.79	12.8763	4.87	12.91	0.000082	1.76	1973.01	579.87	0.09
1	607.5615	2018_100yr	Design_Exist	2000	0.79	13.1099	4.87	13.14	0.00007	1.65	2109.44	588.11	0.09
1	607.5615	2018_500yr	Design_20'	2671	0.79	13.6445	5.6	13.68	0.000089	1.91	2428.36	604.9	0.1
1	607.5615	2018_500yr	Design_12'	2671	0.79	13.6445	5.6	13.68	0.000089	1.91	2428.35	604.9	0.1
1	607.5615	2018_500yr	Design_in-kind	2671	0.79	13.4901	5.6	13.53	0.000098	1.99	2335.31	600.05	0.1

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1	607.5615	2018_500yr	Design_Exist	2671	0.79	13.6235	5.6	13.66	0.00009	1.92	2415.65	604.24	0.1
1	607.5615	2018_25yr_MHHW_M	Design_20'	1228	0.79	8.7781	3.89	8.89	0.000366	2.74	515.4	129.62	0.18
1	607.5615	2018_25yr_MHHW_M	Design_12'	1228	0.79	10.0713	3.89	10.14	0.000187	2.18	707.5	293.82	0.13
1	607.5615	2018_25yr_MHHW_M	Design_in-kind	1228	0.79	11.9745	3.89	12.01	0.000076	1.6	1044.33	518.35	0.09
1	607.5615	2018_25yr_MHHW_M	Design_Exist	1228	0.79	12.1808	3.89	12.21	0.00007	1.55	1083.58	555.53	0.08
1	607.5615	2018_25yr_MSL_Ma	Design_20'	1228	0.79	8.7781	3.89	8.89	0.000366	2.74	515.4	129.62	0.18
1	607.5615	2018_25yr_MSL_Ma	Design_12'	1228	0.79	9.8633	3.89	9.94	0.000207	2.26	673.35	161.41	0.14
1	607.5615	2018_25yr_MSL_Ma	Design_in-kind	1228	0.79	11.9789	3.89	12.01	0.000076	1.6	1045.15	519.31	0.09
1	607.5615	2018_25yr_MSL_Ma	Design_Exist	1228	0.79	12.1579	3.89	12.19	0.000071	1.56	1079.18	553.56	0.09
1	607.5615	2100_025yr_Ab1	Design_20'	1706	0.79	10.6421	4.52	10.75	0.000271	2.75	804.19	352.51	0.16
1	607.5615	2100_025yr_Ab1	Design_12'	1706	0.79	12.0125	4.52	12.08	0.000145	2.21	1051.5	535.14	0.12
1	607.5615	2100_025yr_Ab1	Design_in-kind	1706	0.79	12.6561	4.52	12.68	0.000069	1.6	1846.19	572.12	0.08
1	607.5615	2100_025yr_Ab1	Design_Exist	1706	0.79	12.7208	4.52	12.75	0.000066	1.57	1883.27	574.4	0.08
1	607.5615	2100_050yr_Ab1	Design_20'	1717	0.79	10.6873	4.53	10.79	0.000268	2.75	812	357.25	0.16
1	607.5615	2100_050yr_Ab1	Design_12'	1717	0.79	12.0265	4.53	12.09	0.000146	2.22	1054.15	537.14	0.12
1	607.5615	2100_050yr_Ab1	Design_in-kind	1717	0.79	12.7087	4.53	12.73	0.000068	1.58	1876.33	573.97	0.08
1	607.5615	2100_050yr_Ab1	Design_Exist	1717	0.79	12.7105	4.53	12.74	0.000068	1.58	1877.39	574.03	0.08
1	607.5615	2100_100yr_Ab1	Design_20'	2562	0.79	13.464	5.49	13.5	0.000091	1.92	2319.67	599.23	0.1
1	607.5615	2100_100yr_Ab1	Design_12'	2562	0.79	13.4637	5.49	13.5	0.000091	1.92	2319.47	599.22	0.1
1	607.5615	2100_100yr_Ab1	Design_in-kind	2562	0.79	13.4169	5.49	13.45	0.000094	1.94	2291.49	597.75	0.1
1	607.5615	2100_100yr_Ab1	Design_Exist	2562	0.79	13.5408	5.49	13.57	0.000087	1.88	2365.81	601.65	0.1
1	607.5615	2018_025yr(Surge	Design_20'	1228	0.79	9.9482	3.89	10.02	0.000199	2.23	687.15	163.88	0.14
1	607.5615	2015_025yr(Surge	Design_12'	1228	0.79	11.4624	3.89	11.5	0.000095	1.73	949.5	437.5	0.1
1	607.5615	2015_025yr(Surge	Design_in-kind	1228	0.79	12.1774	3.89	12.21	0.00007	1.56	1082.92	555.41	0.08
1	607.5615	2015_025yr(Surge	Design_Exist	1228	0.79	12.172	3.89	12.2	0.00007	1.56	1081.9	555.22	0.08
1	607.5615	2018_050yr(Surge	Design_20'	1565	0.79	10.9763	4.34	11.05	0.000194	2.39	862.48	387.4	0.14
1	607.5615	2015_050yr(Surge	Design_12'	1565	0.79	12.0665	4.34	12.12	0.000119	2.01	1061.74	541.94	0.11
1	607.5615	2015_050yr(Surge	Design_in-kind	1565	0.79	12.5945	4.34	12.62	0.000061	1.49	1811.03	569.96	0.08
1	607.5615	2015_050yr(Surge	Design_Exist	1565	0.79	12.7894	4.34	12.81	0.000053	1.41	1922.78	576.81	0.07
1	607.5615	015_100yr(Surge)	Design_20'	2000	0.79	11.8674	4.87	11.96	0.000212	2.65	1024.2	490.94	0.15
1	607.5615	015_100yr(Surge)	Design_12'	2000	0.79	12.6134	4.87	12.65	0.000098	1.89	1821.77	570.62	0.1
1	607.5615	015_100yr(Surge)	Design_in-kind	2000	0.79	12.9757	4.87	13	0.000077	1.71	2030.81	583.39	0.09
1	607.5615	015_100yr(Surge)	Design_Exist	2000	0.79	13.1078	4.87	13.13	0.00007	1.65	2108.2	588.04	0.09
1	550.7734	2018_002yr	Design_20'	232	0.88	4.9164	2.06	4.93	0.000099	0.87	266.23	82.51	0.09
1	550.7734	2018_002yr	Design_12'	232	0.88	5.0168	2.06	5.03	0.000089	0.85	274.52	82.73	0.08
1	550.7734	2018_002yr	Design_in-kind	232	0.88	5.3898	2.06	5.4	0.000064	0.76	305.53	83.55	0.07
1	550.7734	2018_002yr	Design_Exist	232	0.88	6.4595	2.06	6.46	0.000028	0.59	399.36	98.47	0.05
1	550.7734	2018_010yr	Design_20'	845	0.88	7.0661	3.1	7.12	0.000251	1.87	463.37	117.91	0.15
1	550.7734	2018_010yr	Design_12'	845	0.88	7.373	3.1	7.42	0.000204	1.75	503.44	140.19	0.13
1	550.7734	2018_010yr	Design_in-kind	845	0.88	11.1111	3.1	11.12	0.000021	0.79	1498.46	482.66	0.05
1	550.7734	2018_010yr	Design_Exist	845	0.88	11.3925	3.1	11.4	0.000017	0.74	1635.91	493.52	0.04
1	550.7734	2018_025y	Design_20'	1228	0.88	8.8059	3.55	8.86	0.000172	1.88	741.68	190.46	0.13
1	550.7734	2018_025y	Design_12'	1228	0.88	9.8275	3.55	9.86	0.000095	1.53	953.75	290.34	0.1
1	550.7734	2018_025y	Design_in-kind	1228	0.88	11.9811	3.55	11.99	0.000025	0.92	1932.07	512.82	0.05
1	550.7734	2018_025y	Design_Exist	1228	0.88	12.1795	3.55	12.19	0.000022	0.88	2034.5	520.23	0.05
1	550.7734	2018_050yr	Design_20'	1565	0.88	10.2062	3.89	10.25	0.000125	1.81	1040.92	386.78	0.11
1	550.7734	2018_050yr	Design_12'	1565	0.88	11.5769	3.89	11.6	0.000053	1.3	1727.45	499.48	0.07
1	550.7734	2018_050yr	Design_in-kind	1565	0.88	12.4856	3.89	12.5	0.00003	1.05	2195.68	533.11	0.06
1	550.7734	2018_050yr	Design_Exist	1565	0.88	12.791	3.89	12.8	0.000025	0.98	2360.76	548.28	0.05
1	550.7734	2018_100yr	Design_20'	2000	0.88	11.6022	4.3	11.63	0.000085	1.65	1740.13	500.3	0.09
1	550.7734	2018_100yr	Design_12'	2000	0.88	12.3481	4.3	12.37	0.000053	1.38	2122.78	527.09	0.08
1	550.7734	2018_100yr	Design_in-kind	2000	0.88	12.8836	4.3	12.9	0.000039	1.22	2411.77	553.37	0.07
1	550.7734	2018_100yr	Design_Exist	2000	0.88	13.1157	4.3	13.13	0.000035	1.17	2542.17	571.42	0.06
1	550.7734	2018_500yr	Design_20'	2671	0.88	13.6507	4.89	13.67	0.000046	1.39	2865.59	627.43	0.07
1	550.7734	2018_500yr	Design_12'	2671	0.88	13.6507	4.89	13.67	0.000046	1.39	2865.59	627.42	0.07
1	550.7734	2018_500yr	Design_in-kind	2671	0.88	13.4972	4.89	13.52	0.00005	1.44	2769.99	617.69	0.07
1	550.7734	2018_500yr	Design_Exist	2671	0.88	13.6298	4.89	13.65	0.000047	1.4	2852.49	626.13	0.07
1	550.7734	2018_25yr_MHHW_M	Design_20'	1228	0.88	8.8059	3.55	8.86	0.000172	1.88	741.68	190.46	0.13
1	550.7734	2018_25yr_MHHW_M	Design_12'	1228	0.88	10.0912	3.55	10.12	0.000082	1.46	1014.04	372.4	0.09
1	550.7734	2018_25yr_MHHW_M	Design_in-kind	1228	0.88	11.9887	3.55	12	0.000025	0.92	1935.95	513.05	0.05
1	550.7734	2018_25yr_MHHW_M	Design_Exist	1228	0.88	12.1944	3.55	12.2	0.000022	0.88	2042.27	520.8	0.05
1	550.7734	2018_25yr_MSL_Ma	Design_20'	1228	0.88	8.8059	3.55	8.86	0.000172	1.88	741.68	190.46	0.13
1	550.7734	2018_25yr_MSL_Ma	Design_12'	1228	0.88	9.8845	3.55	9.92	0.000092	1.52	966.58	300.02	0.09
1	550.7734	2018_25yr_MSL_Ma	Design_in-kind	1228	0.88	11.993	3.55	12	0.000025	0.92	1938.18	513.18	0.05
1	550.7734	2018_25yr_MSL_Ma	Design_Exist	1228	0.88	12.1716	3.55	12.18	0.000022	0.88	2030.4	519.93	0.05
1	550.7734	2100_025yr_Ab1	Design_20'	1706	0.88	10.6747	4.03	10.72	0.000115	1.81	1153.33	443.61	0.11
1	550.7734	2100_025yr_Ab1	Design_12'	1706	0.88	12.0396	4.03	12.06	0.000047	1.27	1962.14	514.9	0.07
1	550.7734	2100_025yr_Ab1	Design_in-kind	1706	0.88	12.6628	4.03	12.68	0.000032	1.1	2290.88	541.71	0.06
1	550.7734	2100_025yr_Ab1	Design_Exist	1706	0.88	12.727	4.03	12.74	0.000031	1.08	2325.79	544.91	0.06
1	550.7734	2100_050yr_Ab1	Design_20'	1717	0.88	10.7198	4.04	10.76	0.000114	1.8	1164.41	448.63	0.11
1	550.7734	2100_050yr_Ab1	Design_12'	1717	0.88	12.0539	4.04	12.07	0.000047	1.27	1969.49	515.44	0.07

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	550.7734	2100_050yr_Ab1	Design_in-kind	1717	0.88	12.7151	4.04	12.73	0.000032	1.09	2319.29	544.28	0.06
1	550.7734	2100_050yr_Ab1	Design_Exist	1717	0.88	12.7169	4.04	12.73	0.000032	1.09	2320.29	544.37	0.06
1	550.7734	2100_100yr_Ab1	Design_20'	2562	0.88	13.4707	4.79	13.49	0.000047	1.39	2753.65	615.78	0.07
1	550.7734	2100_100yr_Ab1	Design_12'	2562	0.88	13.4704	4.79	13.49	0.000047	1.39	2753.45	615.76	0.07
1	550.7734	2100_100yr_Ab1	Design_in-kind	2562	0.88	13.4239	4.79	13.44	0.000048	1.4	2724.92	612.41	0.07
1	550.7734	2100_100yr_Ab1	Design_Exist	2562	0.88	13.5471	4.79	13.57	0.000045	1.37	2800.9	621.01	0.07
1	550.7734	2018_025yr(Surge	Design_20'	1228	0.88	9.9688	3.55	10	0.000088	1.49	985.78	323.15	0.09
1	550.7734	2015_025yr(Surge	Design_12'	1228	0.88	11.4779	3.55	11.49	0.000035	1.05	1678.19	496.28	0.06
1	550.7734	2015_025yr(Surge	Design_in-kind	1228	0.88	12.191	3.55	12.2	0.000022	0.88	2040.5	520.67	0.05
1	550.7734	2015_025yr(Surge	Design_Exist	1228	0.88	12.1857	3.55	12.19	0.000022	0.88	2037.74	520.46	0.05
1	550.7734	2018_050yr(Surge	Design_20'	1565	0.88	11.0032	3.89	11.03	0.000077	1.51	1446.64	478.04	0.09
1	550.7734	2015_050yr(Surge	Design_12'	1565	0.88	12.0891	3.89	12.1	0.000038	1.15	1987.65	516.78	0.06
1	550.7734	2015_050yr(Surge	Design_in-kind	1565	0.88	12.6005	3.89	12.61	0.000028	1.02	2257.23	538.52	0.06
1	550.7734	2015_050yr(Surge	Design_Exist	1565	0.88	12.7943	3.89	12.8	0.000025	0.98	2362.57	548.46	0.05
1	550.7734	015_100yr(Surge)	Design_20'	2000	0.88	11.9061	4.3	11.93	0.00007	1.53	1893.69	510.53	0.09
1	550.7734	015_100yr(Surge)	Design_12'	2000	0.88	12.6229	4.3	12.64	0.000045	1.3	2269.33	539.89	0.07
1	550.7734	015_100yr(Surge)	Design_in-kind	2000	0.88	12.9823	4.3	13	0.000037	1.2	2466.67	559.41	0.06
1	550.7734	015_100yr(Surge)	Design_Exist	2000	0.88	13.1136	4.3	13.13	0.000035	1.17	2540.97	571.25	0.06
1	487.0596	2018_002yr	Design_20'	232	0.59	4.9109		4.92	0.000089	0.84	276.14	83.58	0.08
1	487.0596	2018_002yr	Design_12'	232	0.59	5.0118		5.02	0.000081	0.82	284.58	83.69	0.08
1	487.0596	2018_002yr	Design_in-kind	232	0.59	5.3862		5.39	0.000058	0.73	315.98	84.08	0.07
1	487.0596	2018_002yr	Design_Exist	232	0.59	6.458		6.46	0.000026	0.57	406.76	85.78	0.05
1	487.0596	2018_010yr	Design_20'	845	0.59	7.0506		7.1	0.000239	1.84	459.9	106.05	0.14
1	487.0596	2018_010yr	Design_12'	845	0.59	7.3601		7.41	0.000196	1.73	499.33	151.06	0.13
1	487.0596	2018_010yr	Design_in-kind	845	0.59	11.1115		11.12	0.000016	0.69	1747.88	517.24	0.04
1	487.0596	2018_010yr	Design_Exist	845	0.59	11.3929		11.4	0.000013	0.64	1895.04	528.38	0.04
1	487.0596	2018_025y	Design_20'	1228	0.59	8.7969		8.85	0.000161	1.84	795.93	291.05	0.12
1	487.0596	2018_025y	Design_12'	1228	0.59	9.8257		9.85	0.000081	1.43	1142.13	374.42	0.09
1	487.0596	2018_025y	Design_in-kind	1228	0.59	11.9816		11.99	0.000019	0.81	2211.69	549.31	0.04
1	487.0596	2018_025y	Design_Exist	1228	0.59	12.1799		12.19	0.000017	0.77	2321.24	555.04	0.04
1	487.0596	2018_050yr	Design_20'	1565	0.59	10.2058		10.24	0.000103	1.65	1302.14	463.93	0.1
1	487.0596	2018_050yr	Design_12'	1565	0.59	11.578		11.59	0.00004	1.14	1993.39	534.26	0.06
1	487.0596	2018_050yr	Design_in-kind	1565	0.59	12.4862		12.49	0.000023	0.92	2492.39	562.46	0.05
1	487.0596	2018_050yr	Design_Exist	1565	0.59	12.7915		12.8	0.000019	0.86	2665.25	569.86	0.05
1	487.0596	2018_100yr	Design_20'	2000	0.59	11.604		11.63	0.000064	1.45	2007.3	535.09	0.08
1	487.0596	2018_100yr	Design_12'	2000	0.59	12.3491		12.36	0.00004	1.21	2415.53	559.14	0.07
1	487.0596	2018_100yr	Design_in-kind	2000	0.59	12.8844		12.9	0.00003	1.07	2718.29	572.12	0.06
1	487.0596	2018_100yr	Design_Exist	2000	0.59	13.1164		13.13	0.000026	1.02	2851.67	577.75	0.05
1	487.0596	2018_500yr	Design_20'	2671	0.59	13.6516		13.67	0.000035	1.22	3164.39	590.85	0.06
1	487.0596	2018_500yr	Design_12'	2671	0.59	13.6515		13.67	0.000035	1.22	3164.39	590.85	0.06
1	487.0596	2018_500yr	Design_in-kind	2671	0.59	13.4982		13.51	0.000038	1.26	3074.05	587.16	0.06
1	487.0596	2018_500yr	Design_Exist	2671	0.59	13.6307		13.65	0.000036	1.23	3152.06	590.35	0.06
1	487.0596	2018_25yr_MHHW_M	Design_20'	1228	0.59	8.7969		8.85	0.000161	1.84	795.93	291.05	0.12
1	487.0596	2018_25yr_MHHW_M	Design_12'	1228	0.59	10.0904		10.11	0.000069	1.34	1248.96	457.2	0.08
1	487.0596	2018_25yr_MHHW_M	Design_in-kind	1228	0.59	11.9892		12	0.000019	0.81	2215.84	549.55	0.04
1	487.0596	2018_25yr_MHHW_M	Design_Exist	1228	0.59	12.1948		12.2	0.000017	0.77	2329.53	555.4	0.04
1	487.0596	2018_25yr_MSL_Ma	Design_20'	1228	0.59	8.7969		8.85	0.000161	1.84	795.93	291.05	0.12
1	487.0596	2018_25yr_MSL_Ma	Design_12'	1228	0.59	9.883		9.91	0.000078	1.41	1163.68	378.81	0.09
1	487.0596	2018_25yr_MSL_Ma	Design_in-kind	1228	0.59	11.9935		12	0.000019	0.81	2218.22	549.96	0.04
1	487.0596	2018_25yr_MSL_Ma	Design_Exist	1228	0.59	12.172		12.18	0.000017	0.77	2316.87	554.85	0.04
1	487.0596	2100_025yr_Ab1	Design_20'	1706	0.59	10.6776		10.71	0.000087	1.58	1528.22	494.16	0.09
1	487.0596	2100_025yr_Ab1	Design_12'	1706	0.59	12.0406		12.05	0.000035	1.11	2244.15	551.66	0.06
1	487.0596	2100_025yr_Ab1	Design_in-kind	1706	0.59	12.6634		12.67	0.000024	0.96	2592.45	566.76	0.05
1	487.0596	2100_025yr_Ab1	Design_Exist	1706	0.59	12.7277		12.74	0.000024	0.95	2628.91	568.32	0.05
1	487.0596	2100_050yr_Ab1	Design_20'	1717	0.59	10.723		10.75	0.000085	1.57	1550.71	496.3	0.09
1	487.0596	2100_050yr_Ab1	Design_12'	1717	0.59	12.0548		12.07	0.000035	1.11	2252.03	552.01	0.06
1	487.0596	2100_050yr_Ab1	Design_in-kind	1717	0.59	12.7157		12.72	0.000024	0.95	2622.14	568.03	0.05
1	487.0596	2100_050yr_Ab1	Design_Exist	1717	0.59	12.7176		12.73	0.000024	0.95	2623.18	568.07	0.05
1	487.0596	2100_100yr_Ab1	Design_20'	2562	0.59	13.4716		13.49	0.000036	1.21	3058.47	586.52	0.06
1	487.0596	2100_100yr_Ab1	Design_12'	2562	0.59	13.4713		13.49	0.000036	1.21	3058.28	586.51	0.06
1	487.0596	2100_100yr_Ab1	Design_in-kind	2562	0.59	13.4249		13.44	0.000036	1.23	3031.08	585.4	0.06
1	487.0596	2100_100yr_Ab1	Design_Exist	2562	0.59	13.5479		13.56	0.000034	1.2	3103.31	588.36	0.06
1	487.0596	2018_025yr(Surge	Design_20'	1228	0.59	9.9677		9.99	0.000074	1.38	1196.05	385.32	0.09
1	487.0596	2015_025yr(Surge	Design_12'	1228	0.59	11.4786		11.49	0.000026	0.92	1940.48	531.1	0.05
1	487.0596	2015_025yr(Surge	Design_in-kind	1228	0.59	12.1914		12.2	0.000017	0.77	2327.64	555.32	0.04
1	487.0596	2015_025yr(Surge	Design_Exist	1228	0.59	12.1861		12.19	0.000017	0.77	2324.7	555.19	0.04
1	487.0596	2018_050yr(Surge	Design_20'	1565	0.59	11.0048		11.02	0.000058	1.32	1692.91	512.77	0.08
1	487.0596	2015_050yr(Surge	Design_12'	1565	0.59	12.0899		12.1	0.000029	1	2271.37	552.86	0.06
1	487.0596	2015_050yr(Surge	Design_in-kind	1565	0.59	12.6011		12.61	0.000021	0.89	2557.16	565.25	0.05
1	487.0596	2015_050yr(Surge	Design_Exist	1565	0.59	12.7948		12.8	0.000019	0.85	2667.14	569.94	0.05
1	487.0596	015_100yr(Surge)	Design_20'	2000	0.59	11.9075		11.93	0.000053	1.34	2171.19	544.74	0.07

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	487.0596	015_100yr(Surge)	Design_12'	2000	0.59	12.6238		12.64	0.000034	1.13	2570.04	565.8	0.06
1	487.0596	015_100yr(Surge)	Design_in-kind	2000	0.59	12.983		12.99	0.000028	1.05	2774.84	574.51	0.06
1	487.0596	015_100yr(Surge)	Design_Exist	2000	0.59	13.1143		13.12	0.000026	1.02	2850.45	577.7	0.05
1	441.3088	2018_002yr	Design_20'	232	0.55	4.8933		4.92	0.000158	1.19	195.07	55.14	0.11
1	441.3088	2018_002yr	Design_12'	232	0.55	4.9953		5.02	0.000145	1.16	200.71	55.42	0.11
1	441.3088	2018_002yr	Design_in-kind	232	0.55	5.3731		5.39	0.000106	1.05	221.78	55.89	0.09
1	441.3088	2018_002yr	Design_Exist	232	0.55	6.4503		6.46	0.00005	0.82	282.04	55.99	0.06
1	441.3088	2018_010yr	Design_20'	845	0.55	6.9668		7.08	0.000492	2.72	311.03	57.28	0.2
1	441.3088	2018_010yr	Design_12'	845	0.55	7.2856		7.39	0.000422	2.57	330.1	65.88	0.19
1	441.3088	2018_010yr	Design_in-kind	845	0.55	11.1066		11.12	0.000028	0.94	1490.7	553.99	0.05
1	441.3088	2018_010yr	Design_Exist	845	0.55	11.3892		11.4	0.000022	0.85	1648.22	560.49	0.05
1	441.3088	2018_025y	Design_20'	1228	0.55	8.7139		8.83	0.00037	2.79	532.39	225.05	0.18
1	441.3088	2018_025y	Design_12'	1228	0.55	9.7887		9.84	0.00017	2.08	826.35	312.5	0.13
1	441.3088	2018_025y	Design_in-kind	1228	0.55	11.9775		11.99	0.00003	1.02	1981.59	572.92	0.06
1	441.3088	2018_025y	Design_Exist	1228	0.55	12.1765		12.18	0.000026	0.96	2096.16	578.68	0.05
1	441.3088	2018_050yr	Design_20'	1565	0.55	10.1533		10.23	0.000227	2.47	973.72	529.87	0.15
1	441.3088	2018_050yr	Design_12'	1565	0.55	11.5677		11.59	0.000066	1.48	1748.56	564.3	0.08
1	441.3088	2018_050yr	Design_in-kind	1565	0.55	12.482		12.49	0.000034	1.12	2274.29	587.45	0.06
1	441.3088	2018_050yr	Design_Exist	1565	0.55	12.7883		12.8	0.000028	1.03	2455.59	596.25	0.05
1	441.3088	2018_100yr	Design_20'	2000	0.55	11.5874		11.62	0.000107	1.88	1759.72	564.71	0.1
1	441.3088	2018_100yr	Design_12'	2000	0.55	12.3413		12.36	0.000061	1.49	2191.93	583.41	0.08
1	441.3088	2018_100yr	Design_in-kind	2000	0.55	12.8795		12.89	0.000042	1.28	2510.1	598.87	0.07
1	441.3088	2018_100yr	Design_Exist	2000	0.55	13.1123		13.13	0.000037	1.21	2650.23	605	0.06
1	441.3088	2018_500yr	Design_20'	2671	0.55	13.6467		13.66	0.000047	1.42	2977.45	619.64	0.07
1	441.3088	2018_500yr	Design_12'	2671	0.55	13.6467		13.66	0.000047	1.42	2977.45	619.64	0.07
1	441.3088	2018_500yr	Design_in-kind	2671	0.55	13.4928		13.51	0.000052	1.47	2882.38	615.42	0.08
1	441.3088	2018_500yr	Design_Exist	2671	0.55	13.6258		13.64	0.000048	1.43	2964.47	619.07	0.07
1	441.3088	2018_25yr_MHHW_M	Design_20'	1228	0.55	8.7139		8.83	0.00037	2.79	532.39	225.05	0.18
1	441.3088	2018_25yr_MHHW_M	Design_12'	1228	0.55	10.0544		10.11	0.000153	2.01	921.41	527.22	0.12
1	441.3088	2018_25yr_MHHW_M	Design_in-kind	1228	0.55	11.9851		11.99	0.00003	1.02	1985.94	573.08	0.06
1	441.3088	2018_25yr_MHHW_M	Design_Exist	1228	0.55	12.1914		12.2	0.000025	0.96	2104.83	579.11	0.05
1	441.3088	2018_25yr_MSL_Ma	Design_20'	1228	0.55	8.7139		8.83	0.00037	2.79	532.39	225.05	0.18
1	441.3088	2018_25yr_MSL_Ma	Design_12'	1228	0.55	9.8476		9.9	0.000163	2.04	844.88	316.43	0.13
1	441.3088	2018_25yr_MSL_Ma	Design_in-kind	1228	0.55	11.9894		12	0.00003	1.01	1988.43	573.17	0.06
1	441.3088	2018_25yr_MSL_Ma	Design_Exist	1228	0.55	12.1686		12.18	0.000026	0.96	2091.59	578.45	0.05
1	441.3088	2100_025yr_Ab1	Design_20'	1706	0.55	10.6425		10.7	0.000173	2.24	1236.11	543.01	0.13
1	441.3088	2100_025yr_Ab1	Design_12'	1706	0.55	12.033		12.05	0.000055	1.39	2013.42	574.49	0.08
1	441.3088	2100_025yr_Ab1	Design_in-kind	1706	0.55	12.6591		12.67	0.000036	1.16	2378.81	592.54	0.06
1	441.3088	2100_025yr_Ab1	Design_Exist	1706	0.55	12.7236		12.74	0.000034	1.14	2417.07	594.39	0.06
1	441.3088	2100_050yr_Ab1	Design_20'	1717	0.55	10.6894		10.74	0.000168	2.21	1261.58	544.28	0.13
1	441.3088	2100_050yr_Ab1	Design_12'	1717	0.55	12.0472		12.07	0.000055	1.39	2021.62	574.96	0.08
1	441.3088	2100_050yr_Ab1	Design_in-kind	1717	0.55	12.7116		12.72	0.000035	1.15	2409.93	594.05	0.06
1	441.3088	2100_050yr_Ab1	Design_Exist	1717	0.55	12.7134		12.73	0.000035	1.15	2411.03	594.1	0.06
1	441.3088	2100_100yr_Ab1	Design_20'	2562	0.55	13.4666		13.48	0.000048	1.42	2866.25	614.7	0.07
1	441.3088	2100_100yr_Ab1	Design_12'	2562	0.55	13.4662		13.48	0.000048	1.42	2866.06	614.69	0.07
1	441.3088	2100_100yr_Ab1	Design_in-kind	2562	0.55	13.4196		13.44	0.00005	1.44	2837.44	613.42	0.07
1	441.3088	2100_100yr_Ab1	Design_Exist	2562	0.55	13.5432		13.56	0.000046	1.4	2913.42	616.8	0.07
1	441.3088	2018_025yr(Surge	Design_20'	1228	0.55	9.9346		9.98	0.000153	1.99	872.67	322.22	0.12
1	441.3088	2015_025yr(Surge	Design_12'	1228	0.55	11.4716		11.49	0.000044	1.2	1694.47	562.28	0.07
1	441.3088	2015_025yr(Surge	Design_in-kind	1228	0.55	12.188		12.2	0.000026	0.96	2102.86	579.01	0.05
1	441.3088	2015_025yr(Surge	Design_Exist	1228	0.55	12.1827		12.19	0.000026	0.96	2099.77	578.86	0.05
1	441.3088	2018_050yr(Surge	Design_20'	1565	0.55	10.9851		11.02	0.000107	1.81	1423.6	551.18	0.1
1	441.3088	2015_050yr(Surge	Design_12'	1565	0.55	12.0838		12.1	0.000045	1.26	2042.64	576.05	0.07
1	441.3088	2015_050yr(Surge	Design_in-kind	1565	0.55	12.5972		12.61	0.000031	1.08	2342.2	590.77	0.06
1	441.3088	2015_050yr(Surge	Design_Exist	1565	0.55	12.7916		12.8	0.000027	1.03	2457.57	596.35	0.05
1	441.3088	015_100yr(Surge)	Design_20'	2000	0.55	11.8955		11.92	0.000084	1.7	1934.69	571.19	0.09
1	441.3088	015_100yr(Surge)	Design_12'	2000	0.55	12.6177		12.63	0.00005	1.38	2354.29	591.35	0.07
1	441.3088	015_100yr(Surge)	Design_in-kind	2000	0.55	12.9785		12.99	0.00004	1.25	2569.52	601.38	0.07
1	441.3088	015_100yr(Surge)	Design_Exist	2000	0.55	13.1102		13.12	0.000037	1.21	2648.96	604.94	0.06
1	328.7169	2018_002yr	Design_20'	254	0.01	4.8034		4.88	0.000506	2.2	115.25	25.85	0.18
1	328.7169	2018_002yr	Design_12'	254	0.01	4.9103		4.98	0.000472	2.15	118.02	25.86	0.18
1	328.7169	2018_002yr	Design_in-kind	254	0.01	5.3031		5.36	0.000369	1.98	128.18	25.88	0.16
1	328.7169	2018_002yr	Design_Exist	254	0.01	6.4051		6.45	0.000211	1.64	155.1	25.96	0.12
1	328.7169	2018_010yr	Design_20'	924	0.01	6.376		6.92	0.002746	5.92	155.99	25.95	0.43
1	328.7169	2018_010yr	Design_12'	924	0.01	6.7706		7.25	0.002283	5.56	166.23	25.98	0.39
1	328.7169	2018_010yr	Design_in-kind	924	0.01	11.0405		11.1	0.000223	2.33	637.95	266.64	0.13
1	328.7169	2018_010yr	Design_Exist	924	0.01	11.3377		11.39	0.000178	2.11	717.43	279.22	0.11
1	328.7169	2018_025y	Design_20'	1363	0.01	7.9416		8.67	0.002951	6.86	204.32	38.09	0.44
1	328.7169	2018_025y	Design_12'	1363	0.01	9.2922		9.76	0.001627	5.58	272.34	109.25	0.33
1	328.7169	2018_025y	Design_in-kind	1363	0.01	11.9072		11.97	0.000246	2.58	884.87	303.06	0.14

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	328.7169	2018_025y	Design_Exist	1363	0.01	12.1155		12.17	0.000217	2.45	956.24	407.58	0.13
1	328.7169	2018_050yr	Design_20'	1772	0.01	9.3149		10.09	0.00272	7.22	274.93	117.46	0.43
1	328.7169	2018_050yr	Design_12'	1772	0.01	11.3838		11.56	0.000624	3.98	731.99	281.15	0.21
1	328.7169	2018_050yr	Design_in-kind	1772	0.01	12.4017		12.48	0.000289	2.88	1079.19	445.26	0.15
1	328.7169	2018_050yr	Design_Exist	1772	0.01	12.7283		12.79	0.000223	2.57	1230.15	481.42	0.13
1	328.7169	2018_100yr	Design_20'	2267	0.01	11.248		11.56	0.001137	5.33	694.19	275.45	0.29
1	328.7169	2018_100yr	Design_12'	2267	0.01	12.1812		12.33	0.000565	3.97	984.89	414.4	0.21
1	328.7169	2018_100yr	Design_in-kind	2267	0.01	12.786		12.87	0.000346	3.21	1259.67	483.85	0.16
1	328.7169	2018_100yr	Design_Exist	2267	0.01	13.0371		13.11	0.000284	2.95	1380.83	496.47	0.15
1	328.7169	2018_500yr	Design_20'	3078	0.01	13.5558		13.64	0.000348	3.36	1649.4	530.17	0.16
1	328.7169	2018_500yr	Design_12'	3078	0.01	13.5558		13.64	0.000348	3.36	1649.39	530.17	0.16
1	328.7169	2018_500yr	Design_in-kind	3078	0.01	13.3886		13.49	0.000396	3.55	1561.52	521.25	0.17
1	328.7169	2018_500yr	Design_Exist	3078	0.01	13.5332		13.62	0.000356	3.39	1635.8	528.94	0.17
1	328.7169	2018_25yr_MHHW_M	Design_20'	1363.01	0.01	7.9416		8.67	0.002951	6.86	204.32	38.09	0.44
1	328.7169	2018_25yr_MHHW_M	Design_12'	1363.01	0.01	9.6365		10.03	0.001347	5.21	319.38	155.04	0.3
1	328.7169	2018_25yr_MHHW_M	Design_in-kind	1363.01	0.01	11.9153		11.98	0.000245	2.58	887.31	303.4	0.13
1	328.7169	2018_25yr_MHHW_M	Design_Exist	1363.01	0.01	12.1313		12.19	0.000214	2.43	962.71	409.23	0.13
1	328.7169	2018_25yr_MSL_Ma	Design_20'	1363	0.01	7.9416		8.67	0.002951	6.86	204.32	38.09	0.44
1	328.7169	2018_25yr_MSL_Ma	Design_12'	1363	0.01	9.3661		9.82	0.001567	5.5	281.14	124.87	0.33
1	328.7169	2018_25yr_MSL_Ma	Design_in-kind	1363	0.01	11.9199		11.99	0.000244	2.57	888.71	303.6	0.13
1	328.7169	2018_25yr_MSL_Ma	Design_Exist	1363	0.01	12.1071		12.17	0.000219	2.46	952.84	406.72	0.13
1	328.7169	2100_025yr_Ab1	Design_20'	1930	0.01	9.914		10.58	0.002277	6.9	367.05	187.14	0.4
1	328.7169	2100_025yr_Ab1	Design_12'	1930	0.01	11.889		12.02	0.000501	3.68	879.37	302.27	0.19
1	328.7169	2100_025yr_Ab1	Design_in-kind	1930	0.01	12.5778		12.65	0.000297	2.94	1159.85	474.17	0.15
1	328.7169	2100_025yr_Ab1	Design_Exist	1930	0.01	12.6471		12.72	0.000282	2.88	1191.19	477.66	0.15
1	328.7169	2100_050yr_Ab1	Design_20'	1946	0.01	9.9802		10.63	0.002216	6.84	379.55	190.64	0.39
1	328.7169	2100_050yr_Ab1	Design_12'	1946	0.01	11.9025		12.04	0.000504	3.69	883.43	302.85	0.19
1	328.7169	2100_050yr_Ab1	Design_in-kind	1946	0.01	12.6328		12.71	0.000288	2.91	1186.02	476.94	0.15
1	328.7169	2100_050yr_Ab1	Design_Exist	1946	0.01	12.6347		12.71	0.00029	2.91	1185.3	477.04	0.15
1	328.7169	2100_100yr_Ab1	Design_20'	2943	0.01	13.37	8.11	13.46	0.000367	3.42	1551.82	520.36	0.17
1	328.7169	2100_100yr_Ab1	Design_12'	2943	0.01	13.3696	8.11	13.46	0.000367	3.42	1551.64	520.33	0.17
1	328.7169	2100_100yr_Ab1	Design_in-kind	2943	0.01	13.3189		13.42	0.000382	3.48	1525.34	516.33	0.17
1	328.7169	2100_100yr_Ab1	Design_Exist	2943	0.01	13.453		13.54	0.000346	3.33	1593.53	524.59	0.16
1	328.7169	2018_025yr(Surge	Design_20'	1363	0.01	9.4772		9.9	0.001476	5.38	295.91	139.47	0.32
1	328.7169	2015_025yr(Surge	Design_12'	1363	0.01	11.3615		11.46	0.000376	3.09	725.74	280.22	0.17
1	328.7169	2015_025yr(Surge	Design_in-kind	1363	0.01	12.1278		12.18	0.000213	2.43	962.92	408.86	0.13
1	328.7169	2015_025yr(Surge	Design_Exist	1363	0.01	12.1221		12.18	0.000216	2.44	958.93	408.27	0.13
1	328.7169	2018_050yr(Surge	Design_20'	1772	0.01	10.6347		10.96	0.001131	5.11	533.28	249.29	0.28
1	328.7169	2015_050yr(Surge	Design_12'	1772	0.01	11.9703		12.08	0.000397	3.29	904.08	305.77	0.17
1	328.7169	2015_050yr(Surge	Design_in-kind	1772	0.01	12.5254		12.59	0.000261	2.75	1135.33	462.37	0.14
1	328.7169	2015_050yr(Surge	Design_Exist	1772	0.01	12.7318		12.79	0.000222	2.56	1231.83	481.57	0.13
1	328.7169	015_100yr(Surge)	Design_20'	2267	0.01	11.6546	6.54	11.88	0.000827	4.66	809.65	292.47	0.25
1	328.7169	015_100yr(Surge)	Design_12'	2267	0.01	12.4969		12.61	0.000437	3.56	1122.15	460.14	0.18
1	328.7169	015_100yr(Surge)	Design_in-kind	2267	0.01	12.8934		12.97	0.000317	3.1	1311.87	488.35	0.16
1	328.7169	015_100yr(Surge)	Design_Exist	2267	0.01	13.0349		13.11	0.000285	2.95	1379.71	496.17	0.15
1	260.5812	2018_002yr	Design_20'	254	-0.2	4.6954	2.24	4.83	0.000934	2.9	87.59	21.8	0.26
1	260.5812	2018_002yr	Design_12'	254	-0.2	4.8098	2.24	4.93	0.000859	2.82	90.08	21.83	0.24
1	260.5812	2018_002yr	Design_in-kind	254	-0.2	5.255	1.64	5.33	0.00043	2.26	112.43	21.95	0.18
1	260.5812	2018_002yr	Design_Exist	254	-0.91	6.3728	1.63	6.43	0.000231	1.91	132.69	22.26	0.13
1	260.5812	2018_010yr	Design_20'	924	-0.2	4.496	4.5	6.41	0.014363	11.1	83.25	21.74	1
1	260.5812	2018_010yr	Design_12'	924	-0.2	5.9672	4.49	6.96	0.005506	8	115.53	22.15	0.62
1	260.5812	2018_010yr	Design_in-kind	924	-0.2	10.8603	3.9	11.06	0.00064	3.69	291.78	81.9	0.2
1	260.5812	2018_010yr	Design_Exist	924	-0.91	11.1727	3.93	11.35	0.00059	3.51	319.69	105.64	0.19
1	260.5812	2018_025y	Design_20'	1363	-0.2	5.6405	5.64	8.1	0.014438	12.58	108.31	22.06	1
1	260.5812	2018_025y	Design_12'	1363	-0.2	8.5928	5.64	9.54	0.003737	7.81	174.46	22.62	0.5
1	260.5812	2018_025y	Design_in-kind	1363	-0.2	11.5917	5.06	11.92	0.000992	4.8	375.57	156.86	0.25
1	260.5812	2018_025y	Design_Exist	1363	-0.91	11.8407	5.1	12.12	0.00091	4.54	416.7	178.02	0.24
1	260.5812	2018_050yr	Design_20'	1772	-0.2	6.5976	6.6	9.51	0.014584	13.68	129.55	22.32	1
1	260.5812	2018_050yr	Design_12'	1772	-0.2	10.4006	6.61	11.39	0.003416	8.05	243.61	73.16	0.46
1	260.5812	2018_050yr	Design_in-kind	1772	-0.2	11.9504	6.02	12.4	0.001376	5.77	436.99	197.04	0.3
1	260.5812	2018_050yr	Design_Exist	1772	-0.91	12.3794	6.08	12.72	0.001128	5.21	544.48	287.98	0.27
1	260.5812	2018_100yr	Design_20'	2267	-0.2	7.6504	7.65	11.05	0.014856	14.8	153.18	22.53	1
1	260.5812	2018_100yr	Design_12'	2267	-0.2	10.6315	7.65	12.11	0.005052	9.91	260.98	77.35	0.57
1	260.5812	2018_100yr	Design_in-kind	2267	-0.2	12.0725	7.09	12.76	0.00211	7.2	463.78	242.04	0.37
1	260.5812	2018_100yr	Design_Exist	2267	-0.91	12.5024	7.17	13.02	0.001708	6.45	581.56	310.3	0.33
1	260.5812	2018_500yr	Design_20'	3078	-0.2	10.884	10.88	13.34	0.008315	12.88	281.13	82.54	0.73
1	260.5812	2018_500yr	Design_12'	3078	-0.2	10.884	10.88	13.34	0.008315	12.88	281.13	82.54	0.73
1	260.5812	2018_500yr	Design_in-kind	3078	-0.2	11.8859	8.64	13.29	0.004297	10.16	424.82	181.27	0.53
1	260.5812	2018_500yr	Design_Exist	3078	-0.91	12.6126	8.79	13.49	0.002903	8.47	616.5	323.41	0.43
1	260.5812	2018_25yr_MHHW_M	Design_20'	1363.01	-0.2	5.6408	5.64	8.1	0.014436	12.58	108.32	22.06	1
1	260.5812	2018_25yr_MHHW_M	Design_12'	1363.01	-0.2	8.9845	5.64	9.84	0.003258	7.43	183.33	22.66	0.46

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	260.5812	2018_25yr_MHHW_M	Design_in-kind	1363.01	-0.2	11.6013	5.06	11.92	0.000987	4.79	377.07	157.48	0.25
1	260.5812	2018_25yr_MHHW_M	Design_Exist	1363.01	-0.91	11.8593	5.1	12.14	0.0009	4.52	420.03	179.36	0.24
1	260.5812	2018_25yr_MSL_Ma	Design_20'	1363	-0.2	5.6405	5.64	8.1	0.014438	12.58	108.31	22.06	1
1	260.5812	2018_25yr_MSL_Ma	Design_12'	1363	-0.2	8.6803	5.64	9.61	0.003622	7.72	176.44	22.63	0.49
1	260.5812	2018_25yr_MSL_Ma	Design_in-kind	1363	-0.2	11.6068	5.06	11.93	0.000984	4.78	377.94	157.83	0.25
1	260.5812	2018_25yr_MSL_Ma	Design_Exist	1363	-0.91	11.8317	5.1	12.11	0.000913	4.54	415.11	176.78	0.24
1	260.5812	2100_025yr_Ab1	Design_20'	1930	-0.2	6.9498	6.95	10.01	0.014627	14.04	137.43	22.42	1
1	260.5812	2100_025yr_Ab1	Design_12'	1930	-0.2	10.9144	6.95	11.87	0.003225	8.04	283.65	83.38	0.45
1	260.5812	2100_025yr_Ab1	Design_in-kind	1930	-0.2	12.0684	6.37	12.57	0.001533	6.13	462.8	241.51	0.32
1	260.5812	2100_025yr_Ab1	Design_Exist	1930	-0.91	12.1724	6.45	12.64	0.001515	5.97	488.61	255.06	0.31
1	260.5812	2100_050yr_Ab1	Design_20'	1946	-0.2	6.9836	6.98	10.07	0.01464	14.08	138.19	22.42	1
1	260.5812	2100_050yr_Ab1	Design_12'	1946	-0.2	10.9074	6.98	11.88	0.003289	8.11	283.07	83.18	0.46
1	260.5812	2100_050yr_Ab1	Design_in-kind	1946	-0.2	12.1367	6.4	12.63	0.001495	6.08	479.59	250.41	0.32
1	260.5812	2100_050yr_Ab1	Design_Exist	1946	-0.91	12.1422	6.48	12.63	0.001569	6.06	480.97	251.13	0.31
1	260.5812	2100_100yr_Ab1	Design_20'	2943	-0.2	8.9563	8.96	12.99	0.015337	16.11	182.69	22.66	1
1	260.5812	2100_100yr_Ab1	Design_12'	2943	-0.2	8.9594	8.96	12.99	0.01532	16.1	182.76	22.66	1
1	260.5812	2100_100yr_Ab1	Design_in-kind	2943	-0.2	12.121	8.4	13.25	0.003453	9.23	475.66	248.36	0.48
1	260.5812	2100_100yr_Ab1	Design_Exist	2943	-0.91	12.6217	8.53	13.41	0.002635	8.07	619.47	324.3	0.41
1	260.5812	2018_025yr(Surge	Design_20'	1363	-0.2	8.8079	5.64	9.71	0.003463	7.6	179.33	22.65	0.48
1	260.5812	2015_025yr(Surge	Design_12'	1363	-0.2	10.9	5.64	11.38	0.001619	5.69	282.45	82.98	0.32
1	260.5812	2015_025yr(Surge	Design_in-kind	1363	-0.2	11.8538	5.06	12.13	0.000858	4.53	419.04	178.96	0.24
1	260.5812	2015_025yr(Surge	Design_Exist	1363	-0.91	11.8484	5.1	12.13	0.000906	4.53	418.09	178.57	0.24
1	260.5812	2018_050yr(Surge	Design_20'	1772	-0.2	9.403	6.6	10.72	0.004794	9.19	192.82	22.7	0.56
1	260.5812	2015_050yr(Surge	Design_12'	1772	-0.2	11.2628	6.61	11.96	0.002316	6.95	317.04	117.62	0.38
1	260.5812	2015_050yr(Surge	Design_in-kind	1772	-0.2	12.111	6.02	12.52	0.00126	5.57	473.19	247.06	0.29
1	260.5812	2015_050yr(Surge	Design_Exist	1772	-0.91	12.3835	6.08	12.73	0.001126	5.21	545.67	289.14	0.27
1	260.5812	015_100yr(Surge)	Design_20'	2267	-0.2	9.4031	7.65	11.55	0.007846	11.76	192.83	22.7	0.71
1	260.5812	015_100yr(Surge)	Design_12'	2267	-0.2	11.3383	7.65	12.44	0.003651	8.77	326.33	128.69	0.48
1	260.5812	015_100yr(Surge)	Design_in-kind	2267	-0.2	12.2671	7.09	12.88	0.001871	6.85	513.37	268.13	0.35
1	260.5812	015_100yr(Surge)	Design_Exist	2267	-0.91	12.4982	7.17	13.02	0.001713	6.46	580.23	309.87	0.33
1	239.34			Culvert									
1	212.9068	2018_002yr	Design_20'	254	-5.32	4.7664	-3.84	4.77	0.00002	0.7	361.07	47.07	0.04
1	212.9068	2018_002yr	Design_12'	254	-5.32	4.7664	-3.84	4.77	0.00002	0.7	361.07	47.07	0.04
1	212.9068	2018_002yr	Design_in-kind	254	-5.32	4.7664	-3.84	4.77	0.00002	0.7	361.07	47.07	0.04
1	212.9068	2018_002yr	Design_Exist	254	-5.32	6.0515	-0.9	6.12	0.000298	2.14	118.55	48.92	0.12
1	212.9068	2018_010yr	Design_20'	924	-5.32	4.7217	-2.17	4.82	0.000264	2.57	358.97	47.01	0.16
1	212.9068	2018_010yr	Design_12'	924	-5.32	4.7217	-2.17	4.82	0.000264	2.57	358.97	47.01	0.16
1	212.9068	2018_010yr	Design_in-kind	924	-5.32	4.7217	-2.17	4.82	0.000264	2.57	358.97	47.01	0.16
1	212.9068	2018_010yr	Design_Exist	924	-5.32	7.8034	2.24	8.47	0.002385	6.55	141	51.44	0.35
1	212.9068	2018_025y	Design_20'	1363	-5.32	4.6627	-1.35	4.89	0.000588	3.83	356.2	46.92	0.24
1	212.9068	2018_025y	Design_12'	1363	-5.32	4.6627	-1.35	4.89	0.000588	3.83	356.2	46.92	0.24
1	212.9068	2018_025y	Design_in-kind	1363	-5.32	4.6627	-1.35	4.89	0.000588	3.83	356.2	46.92	0.24
1	212.9068	2018_025y	Design_Exist	1363	-5.32	8.4896	3.86	9.78	0.004365	9.1	149.79	52.43	0.47
1	212.9068	2018_050yr	Design_20'	1772	-5.32	4.5834	-0.67	4.98	0.001024	5.03	352.48	46.81	0.32
1	212.9068	2018_050yr	Design_12'	1772	-5.32	4.5834	-0.67	4.98	0.001024	5.03	352.48	46.81	0.32
1	212.9068	2018_050yr	Design_in-kind	1772	-5.32	4.5834	-0.67	4.98	0.001024	5.03	352.48	46.81	0.32
1	212.9068	2018_050yr	Design_Exist	1772	-5.32	10.979	5.2	11.08	0.000214	2.62	758.43	205.62	0.13
1	212.9068	2018_100yr	Design_20'	2267	-5.32	4.4494	0.09	5.12	0.001754	6.55	346.22	46.62	0.42
1	212.9068	2018_100yr	Design_12'	2267	-5.32	4.4494	0.09	5.12	0.001754	6.55	346.22	46.62	0.42
1	212.9068	2018_100yr	Design_in-kind	2267	-5.32	4.4494	0.09	5.12	0.001754	6.55	346.22	46.62	0.42
1	212.9068	2018_100yr	Design_Exist	2267	-5.32	10.6487	6.71	10.84	0.000391	3.49	699.08	150.47	0.18
1	212.9068	2018_500yr	Design_20'	3078	-5.32	4.0975	1.22	5.45	0.003743	9.33	329.9	46.12	0.61
1	212.9068	2018_500yr	Design_12'	3078	-5.32	4.0975	1.22	5.45	0.003743	9.33	329.9	46.12	0.61
1	212.9068	2018_500yr	Design_in-kind	3078	-5.32	4.0975	1.22	5.45	0.003743	9.33	329.9	46.12	0.61
1	212.9068	2018_500yr	Design_Exist	3078	-5.32	11.3172	9.04	11.6	0.000574	4.37	832.81	232.41	0.22
1	212.9068	2018_25yr_MHHW_M	Design_20'	1363.01	-5.32	5.6671	-1.35	5.84	0.000409	3.37	404.05	48.37	0.21
1	212.9068	2018_25yr_MHHW_M	Design_12'	1363.01	-5.32	5.6671	-1.35	5.84	0.000409	3.37	404.05	48.37	0.21
1	212.9068	2018_25yr_MHHW_M	Design_in-kind	1363.01	-5.32	5.6671	-1.35	5.84	0.000409	3.37	404.05	48.37	0.21
1	212.9068	2018_25yr_MHHW_M	Design_Exist	1363.01	-5.32	8.4889	3.86	9.78	0.004366	9.1	149.78	52.43	0.47
1	212.9068	2018_25yr_MSL_Ma	Design_20'	1363	-5.32	0.297	-1.35	1.13	0.003222	7.3	186.69	36.03	0.57
1	212.9068	2018_25yr_MSL_Ma	Design_12'	1363	-5.32	0.297	-1.35	1.13	0.003222	7.3	186.69	36.03	0.57
1	212.9068	2018_25yr_MSL_Ma	Design_in-kind	1363	-5.32	0.297	-1.35	1.13	0.003222	7.3	186.69	36.03	0.57
1	212.9068	2018_25yr_MSL_Ma	Design_Exist	1363	-5.32	8.4845	3.86	9.77	0.00437	9.1	149.72	52.42	0.47
1	212.9068	2100_025yr_Ab1	Design_20'	1930	-5.32	6.6364	-0.42	6.92	0.000594	4.27	451.6	49.76	0.25
1	212.9068	2100_025yr_Ab1	Design_12'	1930	-5.32	6.6364	-0.42	6.92	0.000594	4.27	451.6	49.76	0.25
1	212.9068	2100_025yr_Ab1	Design_in-kind	1930	-5.32	6.6364	-0.42	6.92	0.000594	4.27	451.6	49.76	0.25
1	212.9068	2100_025yr_Ab1	Design_Exist	1930	-5.32	8.5991	5.7	11.13	0.008522	12.77	151.19	52.58	0.66
1	212.9068	2100_050yr_Ab1	Design_20'	1946	-5.32	6.634	-0.4	6.92	0.000604	4.31	451.49	49.76	0.25
1	212.9068	2100_050yr_Ab1	Design_12'	1946	-5.32	6.634	-0.4	6.92	0.000604	4.31	451.49	49.76	0.25
1	212.9068	2100_050yr_Ab1	Design_in-kind	1946	-5.32	6.634	-0.4	6.92	0.000604	4.31	451.49	49.76	0.25

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	212.9068	2100_050yr_Ab1	Design_Exist	1946	-5.32	8.5817	5.74	11.16	0.008701	12.89	150.97	52.56	0.66
1	212.9068	2100_100yr_Ab1	Design_20'	2943	-5.32	6.4399	1.04	7.13	0.001475	6.66	441.86	49.48	0.39
1	212.9068	2100_100yr_Ab1	Design_12'	2943	-5.32	6.4399	1.04	7.13	0.001475	6.66	441.86	49.48	0.39
1	212.9068	2100_100yr_Ab1	Design_in-kind	2943	-5.32	6.4399	1.04	7.13	0.001475	6.66	441.86	49.48	0.39
1	212.9068	2100_100yr_Ab1	Design_Exist	2943	-5.32	11.2239	8.69	11.49	0.000543	4.23	811.38	227.36	0.21
1	212.9068	2018_025yr(Surge	Design_20'	1363	-5.32	8.1518	-1.35	8.26	0.00019	2.58	528.66	51.94	0.14
1	212.9068	2015_025yr(Surge	Design_12'	1363	-5.32	8.1518	-1.35	8.26	0.00019	2.58	528.66	51.94	0.14
1	212.9068	2015_025yr(Surge	Design_in-kind	1363	-5.32	8.1518	-1.35	8.26	0.00019	2.58	528.66	51.94	0.14
1	212.9068	2015_025yr(Surge	Design_Exist	1363	-5.32	8.5017	3.86	9.79	0.004352	9.09	149.94	52.44	0.47
1	212.9068	2018_050yr(Surge	Design_20'	1772	-5.32	8.1177	-0.67	8.29	0.000324	3.36	526.89	51.89	0.19
1	212.9068	2015_050yr(Surge	Design_12'	1772	-5.32	8.1177	-0.67	8.29	0.000324	3.36	526.89	51.89	0.19
1	212.9068	2015_050yr(Surge	Design_in-kind	1772	-5.32	8.1177	-0.67	8.29	0.000324	3.36	526.89	51.89	0.19
1	212.9068	2015_050yr(Surge	Design_Exist	1772	-5.32	10.9854	5.2	11.09	0.000214	2.62	759.75	206.15	0.13
1	212.9068	015_100yr(Surge)	Design_20'	2267	-5.32	8.0632	0.09	8.35	0.000538	4.33	524.07	51.81	0.24
1	212.9068	015_100yr(Surge)	Design_12'	2267	-5.32	8.0632	0.09	8.35	0.000538	4.33	524.07	51.81	0.24
1	212.9068	015_100yr(Surge)	Design_in-kind	2267	-5.32	8.0632	0.09	8.35	0.000538	4.33	524.07	51.81	0.24
1	212.9068	015_100yr(Surge)	Design_Exist	2267	-5.32	10.6528	6.71	10.84	0.000391	3.49	699.71	150.79	0.18
1	208.0453	2018_002yr	Design_Exist	254	-5.32	6.0415	-0.81	6.12	0.00034	2.25	112.66	49.15	0.13
1	208.0453	2018_010yr	Design_Exist	924	-5.32	7.7022	2.47	8.45	0.002773	6.94	133.21	51.59	0.37
1	208.0453	2018_025y	Design_Exist	1363	-5.32	8.2652	4.14	9.73	0.005214	9.72	140.19	52.41	0.51
1	208.0453	2018_050yr	Design_Exist	1772	-5.32	8.4445	5.54	10.85	0.008426	12.44	142.42	52.68	0.65
1	208.0453	2018_100yr	Design_Exist	2267	-5.32	10.6431	7.07	10.83	0.0004	3.52	691.88	154.61	0.18
1	208.0453	2018_500yr	Design_Exist	3078	-5.32	11.3072	9.39	11.6	0.000589	4.41	814.53	219.19	0.22
1	208.0453	2018_25yr_MHHW_M	Design_Exist	1363.01	-5.32	8.2644	4.14	9.73	0.005216	9.72	140.18	52.41	0.51
1	208.0453	2018_25yr_MSL_Ma	Design_Exist	1363	-5.32	8.2597	4.14	9.73	0.005222	9.73	140.13	52.41	0.51
1	208.0453	2100_025yr_Ab1	Design_Exist	1930	-5.32	10.2611	6.04	10.41	0.000328	3.12	638.1	129.12	0.16
1	208.0453	2100_050yr_Ab1	Design_Exist	1946	-5.32	10.277	6.1	10.43	0.000331	3.14	640.17	129.48	0.17
1	208.0453	2100_100yr_Ab1	Design_Exist	2943	-5.32	11.2148	9.01	11.49	0.000556	4.27	794.57	212.82	0.22
1	208.0453	2015_025yr(Surge	Design_Exist	1363	-5.32	8.2781	4.14	9.74	0.005197	9.71	140.35	52.43	0.51
1	208.0453	2015_050yr(Surge	Design_Exist	1772	-5.32	8.4561	5.54	10.86	0.008402	12.43	142.56	52.69	0.65
1	208.0453	015_100yr(Surge)	Design_Exist	2267	-5.32	10.6473	7.07	10.84	0.000399	3.52	692.52	154.88	0.18
1	203.1735	2018_002yr	Design_Exist	254	-5.32	6.0921	-0.8	6.1	0.000021	0.64	398.09	49.23	0.04
1	203.1735	2018_010yr	Design_Exist	924	-5.32	8.1871	2.47	8.24	0.000137	1.83	504.44	52.3	0.1
1	203.1735	2018_025y	Design_Exist	1363	-5.32	9.2244	4.14	9.32	0.00022	2.44	559.48	53.81	0.13
1	203.1735	2018_050yr	Design_Exist	1772	-5.32	10.0302	4.6	10.16	0.000296	2.94	606.8	125.18	0.16
1	203.1735	2018_100yr	Design_Exist	2267	-5.32	10.6405	4.6	10.83	0.0004	3.52	692.46	159.73	0.18
1	203.1735	2018_500yr	Design_Exist	3078	-5.32	11.3039	4.6	11.6	0.000588	4.41	818.44	222.15	0.22
1	203.1735	2018_25yr_MHHW_M	Design_Exist	1363.01	-5.32	9.2238	4.14	9.32	0.00022	2.44	559.44	53.81	0.13
1	203.1735	2018_25yr_MSL_Ma	Design_Exist	1363	-5.32	9.2199	4.14	9.31	0.00022	2.44	559.23	53.81	0.13
1	203.1735	2100_025yr_Ab1	Design_Exist	1930	-5.32	10.2589	4.6	10.41	0.000328	3.13	636.02	134.49	0.16
1	203.1735	2100_050yr_Ab1	Design_Exist	1946	-5.32	10.2748	4.6	10.43	0.000332	3.15	638.18	136.18	0.17
1	203.1735	2100_100yr_Ab1	Design_Exist	2943	-5.32	11.2116	4.6	11.49	0.000556	4.27	798.16	217.13	0.22
1	203.1735	2015_025yr(Surge	Design_Exist	1363	-5.32	9.2352	4.14	9.33	0.000219	2.43	560.05	53.83	0.13
1	203.1735	2015_050yr(Surge	Design_Exist	1772	-5.32	10.0385	4.6	10.17	0.000296	2.93	607.84	125.36	0.16
1	203.1735	015_100yr(Surge)	Design_Exist	2267	-5.32	10.6446	4.6	10.84	0.000399	3.52	693.13	159.99	0.18
1	170.7372	2018_002yr	Design_20'	254	-5.32	4.769		4.77	0.000006	0.47	545.48	69.44	0.03
1	170.7372	2018_002yr	Design_12'	254	-5.32	4.769		4.77	0.000006	0.47	545.48	69.44	0.03
1	170.7372	2018_002yr	Design_in-kind	254	-5.32	4.769		4.77	0.000006	0.47	545.48	69.44	0.03
1	170.7372	2018_002yr	Design_Exist	254	-5.32	4.769		4.77	0.000006	0.47	545.48	69.44	0.03
1	170.7372	2018_010yr	Design_20'	924	-5.32	4.7565		4.8	0.000085	1.7	544.61	69.4	0.11
1	170.7372	2018_010yr	Design_12'	924	-5.32	4.7565		4.8	0.000085	1.7	544.61	69.4	0.11
1	170.7372	2018_010yr	Design_in-kind	924	-5.32	4.7565		4.8	0.000085	1.7	544.61	69.4	0.11
1	170.7372	2018_010yr	Design_Exist	924	-5.32	4.7565		4.8	0.000085	1.7	544.61	69.4	0.11
1	170.7372	2018_025y	Design_20'	1363	-5.32	4.7403		4.84	0.000186	2.51	543.49	69.36	0.16
1	170.7372	2018_025y	Design_12'	1363	-5.32	4.7403		4.84	0.000186	2.51	543.49	69.36	0.16
1	170.7372	2018_025y	Design_in-kind	1363	-5.32	4.7403		4.84	0.000186	2.51	543.49	69.36	0.16
1	170.7372	2018_025y	Design_Exist	1363	-5.32	4.7403		4.84	0.000186	2.51	543.49	69.36	0.16
1	170.7372	2018_050yr	Design_20'	1772	-5.32	4.7193		4.89	0.000317	3.27	542.03	69.29	0.21
1	170.7372	2018_050yr	Design_12'	1772	-5.32	4.7193		4.89	0.000317	3.27	542.03	69.29	0.21
1	170.7372	2018_050yr	Design_in-kind	1772	-5.32	4.7193		4.89	0.000317	3.27	542.03	69.29	0.21
1	170.7372	2018_050yr	Design_Exist	1772	-5.32	4.7193		4.89	0.000317	3.27	542.03	69.29	0.21
1	170.7372	2018_100yr	Design_20'	2267	-5.32	4.6856		4.96	0.000525	4.2	539.7	69.19	0.27
1	170.7372	2018_100yr	Design_12'	2267	-5.32	4.6856		4.96	0.000525	4.2	539.7	69.19	0.27
1	170.7372	2018_100yr	Design_in-kind	2267	-5.32	4.6856		4.96	0.000525	4.2	539.7	69.19	0.27
1	170.7372	2018_100yr	Design_Exist	2267	-5.32	4.6856		4.96	0.000525	4.2	539.7	69.19	0.27
1	170.7372	2018_500yr	Design_20'	3078	-5.32	4.6065		5.12	0.000996	5.76	534.23	68.95	0.36
1	170.7372	2018_500yr	Design_12'	3078	-5.32	4.6065		5.12	0.000996	5.76	534.23	68.95	0.36
1	170.7372	2018_500yr	Design_in-kind	3078	-5.32	4.6065		5.12	0.000996	5.76	534.23	68.95	0.36
1	170.7372	2018_500yr	Design_Exist	3078	-5.32	4.6065		5.12	0.000996	5.76	534.23	68.95	0.36

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	170.7372	2018_25yr_MHHW_M	Design_20'	1363.01	-5.32	5.7279		5.8	0.00013	2.22	613.47	72.37	0.13
1	170.7372	2018_25yr_MHHW_M	Design_12'	1363.01	-5.32	5.7279		5.8	0.00013	2.22	613.47	72.37	0.13
1	170.7372	2018_25yr_MHHW_M	Design_in-kind	1363.01	-5.32	5.7279		5.8	0.00013	2.22	613.47	72.37	0.13
1	170.7372	2018_25yr_MHHW_M	Design_Exist	1363.01	-5.32	5.7279		5.8	0.00013	2.22	613.47	72.37	0.13
1	170.7372	2018_25yr_MSL_Ma	Design_20'	1363	-5.32	0.5328		0.9	0.001269	4.89	278.65	56.53	0.39
1	170.7372	2018_25yr_MSL_Ma	Design_12'	1363	-5.32	0.5328		0.9	0.001269	4.89	278.65	56.53	0.39
1	170.7372	2018_25yr_MSL_Ma	Design_in-kind	1363	-5.32	0.5328		0.9	0.001269	4.89	278.65	56.53	0.39
1	170.7372	2018_25yr_MSL_Ma	Design_Exist	1363	-5.32	0.5328		0.9	0.001269	4.89	278.65	56.53	0.39
1	170.7372	2100_025yr_Ab1	Design_20'	1930	-5.32	6.736		6.86	0.00018	2.81	693.42	88.16	0.16
1	170.7372	2100_025yr_Ab1	Design_12'	1930	-5.32	6.736		6.86	0.00018	2.81	693.42	88.16	0.16
1	170.7372	2100_025yr_Ab1	Design_in-kind	1930	-5.32	6.736		6.86	0.00018	2.81	693.42	88.16	0.16
1	170.7372	2100_025yr_Ab1	Design_Exist	1930	-5.32	6.736		6.86	0.00018	2.81	693.42	88.16	0.16
1	170.7372	2100_050yr_Ab1	Design_20'	1946	-5.32	6.7354		6.86	0.000183	2.84	693.37	88.15	0.16
1	170.7372	2100_050yr_Ab1	Design_12'	1946	-5.32	6.7354		6.86	0.000183	2.84	693.37	88.15	0.16
1	170.7372	2100_050yr_Ab1	Design_in-kind	1946	-5.32	6.7354		6.86	0.000183	2.84	693.37	88.15	0.16
1	170.7372	2100_050yr_Ab1	Design_Exist	1946	-5.32	6.7354		6.86	0.000183	2.84	693.37	88.15	0.16
1	170.7372	2100_100yr_Ab1	Design_20'	2943	-5.32	6.6891		6.98	0.000425	4.31	689.3	87.47	0.25
1	170.7372	2100_100yr_Ab1	Design_12'	2943	-5.32	6.6891		6.98	0.000425	4.31	689.3	87.47	0.25
1	170.7372	2100_100yr_Ab1	Design_in-kind	2943	-5.32	6.6891		6.98	0.000425	4.31	689.3	87.47	0.25
1	170.7372	2100_100yr_Ab1	Design_Exist	2943	-5.32	6.6891		6.98	0.000425	4.31	689.3	87.47	0.25
1	170.7372	2018_025yr(Surge	Design_20'	1363	-5.32	8.1886		8.23	0.000055	1.71	840.3	120.18	0.09
1	170.7372	2015_025yr(Surge	Design_12'	1363	-5.32	8.1886		8.23	0.000055	1.71	840.3	120.18	0.09
1	170.7372	2015_025yr(Surge	Design_in-kind	1363	-5.32	8.1886		8.23	0.000055	1.71	840.3	120.18	0.09
1	170.7372	2015_025yr(Surge	Design_Exist	1363	-5.32	8.1886		8.23	0.000055	1.71	840.3	120.18	0.09
1	170.7372	2018_050yr(Surge	Design_20'	1772	-5.32	8.1806		8.26	0.000093	2.22	839.35	120	0.12
1	170.7372	2015_050yr(Surge	Design_12'	1772	-5.32	8.1806		8.26	0.000093	2.22	839.35	120	0.12
1	170.7372	2015_050yr(Surge	Design_in-kind	1772	-5.32	8.1806		8.26	0.000093	2.22	839.35	120	0.12
1	170.7372	2015_050yr(Surge	Design_Exist	1772	-5.32	8.1806		8.26	0.000093	2.22	839.35	120	0.12
1	170.7372	015_100yr(Surge)	Design_20'	2267	-5.32	8.168		8.29	0.000153	2.85	837.84	119.73	0.15
1	170.7372	015_100yr(Surge)	Design_12'	2267	-5.32	8.168		8.29	0.000153	2.85	837.84	119.73	0.15
1	170.7372	015_100yr(Surge)	Design_in-kind	2267	-5.32	8.168		8.29	0.000153	2.85	837.84	119.73	0.15
1	170.7372	015_100yr(Surge)	Design_Exist	2267	-5.32	8.168		8.29	0.000153	2.85	837.84	119.73	0.15
1	136.7287	2018_002yr	Design_20'	254	-7.5	4.77	-6.55	4.77	0.000002	0.34	793.66	96.66	0.02
1	136.7287	2018_002yr	Design_12'	254	-7.5	4.77	-6.55	4.77	0.000002	0.34	793.66	96.66	0.02
1	136.7287	2018_002yr	Design_in-kind	254	-7.5	4.77	-6.55	4.77	0.000002	0.34	793.66	96.66	0.02
1	136.7287	2018_002yr	Design_Exist	254	-7.5	4.77	-6.55	4.77	0.000002	0.34	793.66	96.66	0.02
1	136.7287	2018_010yr	Design_20'	924	-7.5	4.77	-5.29	4.79	0.000028	1.23	793.66	96.66	0.07
1	136.7287	2018_010yr	Design_12'	924	-7.5	4.77	-5.29	4.79	0.000028	1.23	793.66	96.66	0.07
1	136.7287	2018_010yr	Design_in-kind	924	-7.5	4.77	-5.29	4.79	0.000028	1.23	793.66	96.66	0.07
1	136.7287	2018_010yr	Design_Exist	924	-7.5	4.77	-5.29	4.79	0.000028	1.23	793.66	96.66	0.07
1	136.7287	2018_025y	Design_20'	1363	-7.5	4.77	-4.65	4.82	0.000061	1.81	793.66	96.66	0.1
1	136.7287	2018_025y	Design_12'	1363	-7.5	4.77	-4.65	4.82	0.000061	1.81	793.66	96.66	0.1
1	136.7287	2018_025y	Design_in-kind	1363	-7.5	4.77	-4.65	4.82	0.000061	1.81	793.66	96.66	0.1
1	136.7287	2018_025y	Design_Exist	1363	-7.5	4.77	-4.65	4.82	0.000061	1.81	793.66	96.66	0.1
1	136.7287	2018_050yr	Design_20'	1772	-7.5	4.77	-4.12	4.86	0.000104	2.35	793.66	96.66	0.13
1	136.7287	2018_050yr	Design_12'	1772	-7.5	4.77	-4.12	4.86	0.000104	2.35	793.66	96.66	0.13
1	136.7287	2018_050yr	Design_in-kind	1772	-7.5	4.77	-4.12	4.86	0.000104	2.35	793.66	96.66	0.13
1	136.7287	2018_050yr	Design_Exist	1772	-7.5	4.77	-4.12	4.86	0.000104	2.35	793.66	96.66	0.13
1	136.7287	2018_100yr	Design_20'	2267	-7.5	4.77	-3.54	4.91	0.00017	3.01	793.66	96.66	0.16
1	136.7287	2018_100yr	Design_12'	2267	-7.5	4.77	-3.52	4.91	0.00017	3.01	793.66	96.66	0.16
1	136.7287	2018_100yr	Design_in-kind	2267	-7.5	4.77	-3.52	4.91	0.00017	3.01	793.66	96.66	0.16
1	136.7287	2018_100yr	Design_Exist	2267	-7.5	4.77	-3.52	4.91	0.00017	3.01	793.66	96.66	0.16
1	136.7287	2018_500yr	Design_20'	3078	-7.5	4.77	-2.66	5.03	0.000313	4.08	793.66	96.66	0.22
1	136.7287	2018_500yr	Design_12'	3078	-7.5	4.77	-2.66	5.03	0.000313	4.08	793.66	96.66	0.22
1	136.7287	2018_500yr	Design_in-kind	3078	-7.5	4.77	-2.66	5.03	0.000313	4.08	793.66	96.66	0.22
1	136.7287	2018_500yr	Design_Exist	3078	-7.5	4.77	-2.66	5.03	0.000313	4.08	793.66	96.66	0.22
1	136.7287	2018_25yr_MHHW_M	Design_20'	1363.01	-7.5	5.75	-4.65	5.79	0.000046	1.65	893.87	107.84	0.08
1	136.7287	2018_25yr_MHHW_M	Design_12'	1363.01	-7.5	5.75	-4.65	5.79	0.000046	1.65	893.87	107.84	0.08
1	136.7287	2018_25yr_MHHW_M	Design_in-kind	1363.01	-7.5	5.75	-4.65	5.79	0.000046	1.65	893.87	107.84	0.08
1	136.7287	2018_25yr_MHHW_M	Design_Exist	1363.01	-7.5	5.75	-4.65	5.79	0.000046	1.65	893.87	107.84	0.08
1	136.7287	2018_25yr_MSL_Ma	Design_20'	1363	-7.5	0.684	-4.65	0.81	0.000273	2.89	473.24	68.64	0.19
1	136.7287	2018_25yr_MSL_Ma	Design_12'	1363	-7.5	0.684	-4.65	0.81	0.000273	2.89	473.24	68.64	0.19
1	136.7287	2018_25yr_MSL_Ma	Design_in-kind	1363	-7.5	0.684	-4.65	0.81	0.000273	2.89	473.24	68.64	0.19
1	136.7287	2018_25yr_MSL_Ma	Design_Exist	1363	-7.5	0.684	-4.65	0.81	0.000273	2.89	473.24	68.64	0.19
1	136.7287	2100_025yr_Ab1	Design_20'	1930	-7.5	6.77	-3.93	6.84	0.000068	2.13	1009.81	119.48	0.1
1	136.7287	2100_025yr_Ab1	Design_12'	1930	-7.5	6.77	-3.93	6.84	0.000068	2.13	1009.81	119.48	0.1
1	136.7287	2100_025yr_Ab1	Design_in-kind	1930	-7.5	6.77	-3.93	6.84	0.000068	2.13	1009.81	119.48	0.1
1	136.7287	2100_025yr_Ab1	Design_Exist	1930	-7.5	6.77	-3.93	6.84	0.000068	2.13	1009.81	119.48	0.1
1	136.7287	2100_050yr_Ab1	Design_20'	1946	-7.5	6.77	-3.91	6.84	0.00007	2.15	1009.81	119.48	0.11
1	136.7287	2100_050yr_Ab1	Design_12'	1946	-7.5	6.77	-3.91	6.84	0.00007	2.15	1009.81	119.48	0.11
1	136.7287	2100_050yr_Ab1	Design_in-kind	1946	-7.5	6.77	-3.91	6.84	0.00007	2.15	1009.81	119.48	0.11

Reach	River Sta	Profile	Plan	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	136.7287	2100_050yr_Ab1	Design_Exist	1946	-7.5	6.77	-3.91	6.84	0.00007	2.15	1009.81	119.48	0.11
1	136.7287	2100_100yr_Ab1	Design_20'	2943	-7.5	6.77	-2.8	6.93	0.000159	3.25	1009.81	119.48	0.16
1	136.7287	2100_100yr_Ab1	Design_12'	2943	-7.5	6.77	-2.8	6.93	0.000159	3.25	1009.81	119.48	0.16
1	136.7287	2100_100yr_Ab1	Design_in-kind	2943	-7.5	6.77	-2.8	6.93	0.000159	3.25	1009.81	119.48	0.16
1	136.7287	2100_100yr_Ab1	Design_Exist	2943	-7.5	6.77	-2.8	6.93	0.000159	3.25	1009.81	119.48	0.16
1	136.7287	2018_025yr(Surge	Design_20'	1363	-7.5	8.2	-4.65	8.23	0.000023	1.34	1199.56	147.66	0.06
1	136.7287	2015_025yr(Surge	Design_12'	1363	-7.5	8.2	-4.65	8.23	0.000023	1.34	1199.56	147.66	0.06
1	136.7287	2015_025yr(Surge	Design_in-kind	1363	-7.5	8.2	-4.65	8.23	0.000023	1.34	1199.56	147.66	0.06
1	136.7287	2015_025yr(Surge	Design_Exist	1363	-7.5	8.2	-4.65	8.23	0.000023	1.34	1199.56	147.66	0.06
1	136.7287	2018_050yr(Surge	Design_20'	1772	-7.5	8.2	-4.12	8.25	0.00004	1.74	1199.56	147.66	0.08
1	136.7287	2015_050yr(Surge	Design_12'	1772	-7.5	8.2	-4.12	8.25	0.00004	1.74	1199.56	147.66	0.08
1	136.7287	2015_050yr(Surge	Design_in-kind	1772	-7.5	8.2	-4.12	8.25	0.00004	1.74	1199.56	147.66	0.08
1	136.7287	2015_050yr(Surge	Design_Exist	1772	-7.5	8.2	-4.12	8.25	0.00004	1.74	1199.56	147.66	0.08
1	136.7287	015_100yr(Surge)	Design_20'	2267	-7.5	8.2	-3.52	8.27	0.000065	2.23	1199.56	147.66	0.1
1	136.7287	015_100yr(Surge)	Design_12'	2267	-7.5	8.2	-3.52	8.27	0.000065	2.23	1199.56	147.66	0.1
1	136.7287	015_100yr(Surge)	Design_in-kind	2267	-7.5	8.2	-3.52	8.27	0.000065	2.23	1199.56	147.66	0.1
1	136.7287	015_100yr(Surge)	Design_Exist	2267	-7.5	8.2	-3.52	8.27	0.000065	2.23	1199.56	147.66	0.1

ATTACHMENT D

Scour Results

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Modified Laursen's Equation (1960), Laursens (1963), and NCHRP

Tighe&Bond

Bridge/Culvert Name: MBTS Central Street Bridge - Proposed 20-Foot Concrete Arch Culvert
Town Manhcester by the Sea (MBTS)
Lat: 42.575253
Long: -70.77288

Storm Size: 50-Year
HEC-RAS Proj: SawmillBrookDownstream
HEC-RAS Geom: SawmillBrk_Design20'
HEC-RAS XS1 328.7
HEC-RAS XS2 260.6 (just upstream of culvert)

Notes
(1) Governing storms are 50-year for Scour Design and 100-Year for Scour Check (based on Table 1.3.4-1 in the MassDOT LRFD Bridge Manual.
(2) for scour at open-bottom culverts, refer to HEC-18 for equations
(3) left bank and right bank defined from looking downstream

Data Input

Description	Item	LOB	CHANNEL	ROB
Constant for Critical Velocity Calculation (English Units)	Ku (crit)	11.17	11.17	11.17
Constant for Clear-Water Scour Calculations (English Units)	Ku (CW-cont)	0.0077	0.0077	0.0077
Constant for Open Bottom Culvert Contraction Scour Calc	Ku (Open-Bottom)	0.84	0.84	0.84
Hydraulic Depth at XS 1	y_1 (ft)	1.37	8.78	0.16
Hydraulic Depth at XS 1 (for Critical Velocity Calculation)	y (ft)	**1.37**	**8.78**	**0.16**
Hydraulic Depth at XS 2 Prior to Scour	y_0 (ft)		5.8	
Flow at XS 1	Q_1 (ft^3/s)	79.23	1686.97	5.8
Flow at XS 2	Q_2 (ft^3/s)		1772	
Top Width at XS1	W_1 (ft)	22.24	26.6	68.62
Top Width at XS2	W_2 (ft)		22.32	
Unit Discharge at XS1	q_1 (ft^2/s)	**3.56**	**63.42**	**0.08**
Unit Discharge at XS2	q_2 (ft^2/s)		**79.39**	
Velocity at XS1	V_1 (ft/s)	2.61	7.22	0.53
Velocity at XS1 (For Critical Scour Equation V is V1)	V (ft/s)	**2.61**	**7.22**	**0.53**
Energy Grade Line at XS1	S_1	0.002722	0.002722	0.002722
D50 from Sieve Analysis	D50 (mm)	0.275	0.275	0.275
D50 from Sieve Analysis with Convesrion from mm to ft	D50 (ft)	0.000902	0.000902	0.000902

Critical Velocity

$$V_c = K_u y^{1/6} D^{1/3}$$

Input:

	LOB	CHANNEL	ROB	
Ku (crit)	11.17	11.17	11.17	<- constant English units
y (ft)	1.37	8.78	0.16	<- hydraulic depth from HEC-RAS upstream cross section
D50 (ft)	0.000902	0.000902	0.000902	<- based on sieve analysis
V (ft/s)	2.61	7.22	0.53	<- mean channel velocity in HEC-RAS

Output:

Vc (ft/s)	**1.137**	**1.550**	**0.795**
Clear-Water ??	NO	NO	YES
Live-Bed ??	YES	YES	NO
Construction Scour	**Live-Bed**	**Live-Bed**	**Clear-Water**

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Modified Laursen's Equation (1960), Laursens (1963), and NCHRP

Tighe&Bond

Live-Bed Contraction Scour

$$y_2 = y_1 \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \qquad y_s = y_2 - y_0$$

Input:

	LOB	CHANNEL	ROB	
y1 (ft)	1.37	8.78		
y0 (ft)	0	5.8		<- assumed that this is the same approx. as y1
Q_1 (ft^3/s)	79.23	1686.97		<- flow for design storm assuming all going into channel
Q_2 (ft^3/s)	0	1772		<- assuming no overtopping, all flow goes through
W1 (ft)	22.24	26.6		<- based on upstream cross section top width HEC-RAS at design stor
W2 (ft)	0	22.32		<- based on proposed structure clear span HEC-RAS at design storm
S1	0.002722	0.002722		<- from HEC-RAS
V* (ft/s)	0.347	0.877		<- calculated
D50 (mm)	0.275	0.275		
T (ft/s)	0.036123	0.036123		<- input from figure 6.8 (estimated using polynomial best fit)

Intermediate Calcs:

k1	0.69	0.69	
y2	N/A No Flow	9.500761239	

Output:

ys (ft)	N/A No Flow	3.700761239		<- predicted scour depth for Live-Bed

Clear-Water Contraction Scour

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7} \qquad y_s = y_2 - y_0$$

Input:

	LOB	CHANNEL	ROB	
Q_2 (ft^3/s)			0	
D50 (ft)			0.000902	<- assumed about 0.25"
Dm (ft)	-	-	0.0011275	<- calculated based on D50
W_2 (ft)			0	<- based on HEC-RAS
y0 (ft)			0	<- based on HEC-RAS
Ku (CW-cont)			0.0077	<- constant

Intermediate Calcs:

y2 (ft)			N/A No Flow

Output:

ys (ft)			N/A No Flow

Take Live-Bed where applicable and Contraction Scour where applicable.

TOTAL CONTRACTION SCOUR ESTIMATED: (feet)

Left Bank	Channel	Right Bank
N/A No Flow	3.701	N/A No Flow

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Tighe&Bond

Modified Laursen's Equation (1960), Laursens (1963), and NCHRP

Clear-Water Scour Equation for Open-Bottom Culverts (with WingWall)

$$y_{max}=K_u Q_{BI}^{0.28}\left(\frac{Q}{W_C D_{50}^{1/3}}\right)^{0.26}$$

$$y_s=y_2-y_0$$

		CHANNEL	
Input:	Ku (Open-Bottom)	0.84	<- 0.84 english units; 1.16 SI units
	QBI (cfs)	8.19	<- Discharge blocked by road embankment on one side of culvert (estimated using HEC-RAS Flow Tubes)
	Q_2 (ft^3/s)	1772	
	Wc (ft)	20	<- Culvert Width
	D50 (ft)	0.001	
	y0 (ft)	5.800	
	ymax (ft)	8.917	
	ys (ft)	3.117	

CONTRACTION SCOUR ESTIMATE FOR OPEN BOTTOM CULVERT (feet)	Open Bottom Culvert Scour
	3.117

Abutment Scour

$$y_{max}=\propto_A y_c$$

$$y_s=y_{max}-y_0$$

Input:

		LOB	CHANNEL	ROB	
	q_1 (ft^2/s)	3.5625	63.41992481	0.084523463	<- Unit Discharge at XS1
	q_2 (ft^2/s)		79.390681		<- Unit Discharge at XS2
	q_2/q_1		1.25182553		
	y0 (ft)		5.8		<- based on HEC-RAS
	NCHRP Figure		Figure 8.10		<- based on HEC-RAS
	yc		9.501		<- flow depth including scour (maximum y_{max} or y_2)
	α_A		1.75		<- From NCHRP Figures
Intermediate Calcs:					
	ymax		16.63		
Output:					
	ys (ft)	N/A No Flow	10.8	N/A No Flow	<- abutment scour

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Modified Laursen's Equation (1960) and Laursens (1963)

Tighe&Bond

Bridge/Culvert Name: MBTS Central Street Bridge - Proposed 20-Foot Concrete Arch Culvert
Town Manhcester by the Sea (MBTS)
Lat: 42.575253
Long: -70.77288

Storm Size: 100-Year
HEC-RAS Proj: SawmillBrookDownstream
HEC-RAS Geom: SawmillBrk_Design20'
HEC-RAS XS1 328.7
HEC-RAS XS2 260.6 (just upstream of culvert)

Notes
(1) Governing storms are 50-year for Scour Design and 100-Year for Scour Check (based on Table 1.3.4-1 in the MassDOT LRFD Bridge Manual.
(2) for scour at open-bottom culverts, refer to HEC-18 for equations
(3) left bank and right bank defined from looking downstream

Data Input

Description	Item	LOB	CHANNEL	ROB
Constant for Critical Velocity Calculation (English Units)	Ku (crit)	11.17	11.17	11.17
Constant for Clear-Water Scour Calculations (English Units)	Ku (CW-cont.)	0.0077	0.0077	0.0077
Constant for Open Bottom Culvert Contraction Scour Calc	Ku (Open-Bottom)	0.84	0.84	0.84
Hydraulic Depth at XS 1	y_1 (ft)	2.08	10.72	1.55
Hydraulic Depth at XS 1 (for Critical Velocity Calculation)	y (ft)	**2.08**	**10.72**	**1.55**
Hydraulic Depth at XS 2 Prior to Scour	y_0 (ft)		6.8	
Flow at XS 1	Q_1 (ft^3/s)	218.41	1519.41	529.18
Flow at XS 2	Q_2 (ft^3/s)		2267	
Top Width at XS1	W_1 (ft)	44.42	26.6	204.43
Top Width at XS2	W_2 (ft)		22.53	
Unit Discharge at XS1	q_1 (ft^2/s)	**4.92**	**57.12**	**2.59**
Unit Discharge at XS2	q_2 (ft^2/s)		**100.62**	
Velocity at XS1	V_1 (ft/s)	2.36	5.33	1.67
Velocity at XS1 (For Critical Scour Equation V is V1)	V (ft/s)	**2.36**	**5.33**	**1.67**
Energy Grade Line at XS1	S_1	0.00427	0.00427	0.00427
D50 from Sieve Analysis	D50 (mm)	0.275	0.275	0.275
D50 from Sieve Analysis with Conversion from mm to ft	D50 (ft)	0.000902	0.000902	0.000902

Critical Velocity

$$V_c = K_u y^{1/6} D^{1/3}$$

Input:

	LOB	CHANNEL	ROB	
Ku (crit)	11.17	11.17	11.17	<- constant English units
y (ft)	2.08	10.72	1.55	<- hydraulic depth from HEC-RAS upstream cross section
D50 (ft)	0.000902	0.000902	0.000902	<- based on sieve analysis
V (ft/s)	2.36	5.33	1.67	<- mean channel velocity in HEC-RAS

Output:

Vc (ft/s)	**1.219**	**1.603**	**1.161**
Clear-Water ??	NO	NO	NO
Live-Bed ??	YES	YES	YES
Construction Scour	**Live-Bed**	**Live-Bed**	**Live-Bed**

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Modified Laursen's Equation (1960) and Laursens (1963)

Tighe&Bond

Live-Bed Contraction Scour

$$y_2 = y_1 \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \qquad y_s = y_2 - y_0$$

Input:

	LOB	CHANNEL	ROB	
y1 (ft)	2.08	10.72	1.55	
y0 (ft)	0	6.8	0	<- assumed that this is the same approx. as y1
Q_1 (ft^3/s)	218.41	1519.41	529.18	<- flow for design storm assuming all going into channel
Q_2 (ft^3/s)	0	2267	0	<- assuming no overtopping, all flow goes through
W1 (ft)	44.42	26.6	204.43	<- based on upstream cross section top width HEC-RAS at design stor
W2 (ft)	0	22.53	0	<- based on proposed structure clear span HEC-RAS at design storm
S1	0.00427	0.00427	0.00427	<- from HEC-RAS
V* (ft/s)	0.535	1.214	0.462	<- calculated
D50 (mm)	0.275	0.275	0.275	
T (ft/s)	0.036123	0.036123	0.036123	<- input from figure 6.8 (estimated using polynomial best fit)

Intermediate Calcs:

k1	0.69	0.69	0.69
y2	N/A No Flow	8.531130248	N/A No Flow

Output:

ys (ft)	N/A No Flow	1.731130248	N/A No Flow	<- predicted scour depth for Live-Bed

Clear-Water Contraction Scour

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7} \qquad y_s = y_2 - y_0$$

Input:

	LOB	CHANNEL	ROB	
Q_2 (ft^3/s)				
D50 (ft)				<- assumed about 0.25"
Dm (ft)	-	-	-	<- calculated based on D50
W_2 (ft)				<- based on HEC-RAS
y0 (ft)				<- based on HEC-RAS
Ku (CW-cont)				<- constant

Intermediate Calcs:

y2 (ft)			

Output:

ys (ft)			

Take Live-Bed where applicable and Contraction Scour where applicable.

	Left Bank	Channel	Right Bank
TOTAL CONTRACTION SCOUR ESTIMATED: (feet)	N/A No Flow	1.731	N/A No Flow

SCOUR ANALYSIS - CONTRACTION SCOUR & ABUTMENT SCOUR

Tighe&Bond

Modified Laursen's Equation (1960) and Laursens (1963)

Clear-Water Scour Equation for Open-Bottom Culverts (with WingWall)

$$y_{max}=K_u Q_{BI}^{0.28}\left(\frac{Q}{W_C D_{50}^{1/3}}\right)^{0.26}$$

$$y_s=y_2-y_0$$

		CHANNEL	
Input:	Ku (Open-Bottom)	0.84	<- 0.84 english units; 1.16 SI units
	QBI (cfs)	13.29	<- Discharge blocked by road embankement on one side of culvert (estimated using HEC-RAS Flow Tubes)
	Q_2 (ft^3/s)	2267	
	Wc (ft)	20	<- Culvert Width
	D50 (ft)	0.001	
	y0 (ft)	6.800	
	ymax (ft)	10.887	
	ys (ft)	4.087	

CONTRACTION SCOUR ESTIMATE FOR OPEN BOTTOM CULVERT (feet)	Open Bottom Culvert Scour
	4.087

Abutment Scour

$$y_{max}=\propto_A y_c$$

$$y_s=y_{max}-y_0$$

Input:

	LOB	CHANNEL	ROB	
q_1 (ft^2/s)	4.916929311	57.12067669	2.588563322	<- Unit Discharge at XS1
q_2 (ft^2/s)		100.6213937		<- Unit Discharge at XS2
q_2/q_1		1.761558152		
y0 (ft)	0	6.8	0	<- based on HEC-RAS
NCHRP Figure		Figure 8.10		<- based on HEC-RAS
yc		10.887		<- flow depth including scour (maximum y_{max} or y_2)
α_A		1.25		<- From NCHRP Figures

Intermediate Calcs:

ymax	13.61

ABUTMENT SCOUR	LOB	CHANNEL	ROB	
ys (ft)	N/A No Flow	6.8	N/A No Flow	<- abutment scour

SCOUR ANALYSIS - LONG-TERM AGGREGATION/DEGRADATION

QUALITATIVE AND QUANTITATIVE APPROACHES

Tighe&Bond

Bridge/Culvert Name:	MBTS Central Street Bridge - Proposed 20-Foot Concrete Arch
Town	Manchester by the Sea (MBTS)
Lat:	42.575253
Long:	-70.77288

Notes
(1) Governing storms are 50-year for Scour Design and 100-Year for Scour Check (based on Table 1.3.4-1 in the MassDOT LRFD Bridge
(2) Qualitative and Quantitative analyses below reference HEC-20 FHWA approach

HEC-20 (6.26) Level 1 (Qualitative Geomorphic Analyses)

Direct Evidence	
Land-Use Change?	Not significant (based on historical imagery from 1995
Exposed Utility Crossings	(No Data)
Exposed Bridge Foundations	No, existing bridge founded on bedrock.
Channel Banks Failing Due to Excessive Height	Not Observed
Comparison of Reference Reach Cross sections	U/S reach channelized D/S reach currently impacted by tide gate (to be
Dams/Reservoirs Upstream/Downstream ?	Tide gate located downstream (to be removed)
Changes in Watershed Land-Use ?	
Urbanization	Not Significant
Deforestation	Not Significant
Increased Impervious	Not Significant
Channelization	The pond and channel leading to the bridge is channelized with vertical walls.
Cutoffs of Meander Bends (natural or manmade)	The channel has some slight meanders but is generally straight. There is an ogee shaped bend upstream of the bridge.
Changes in Downstream Hydraulic Control	
Rocks	(Assumed None)
Dams	Tide gate to be removed; however, the tide gate
Culvert	Not Significant
Diversions of Water In/Out of Stream	None known within project area

HEC-20 (6.26) Level 2 (Basic Engineering Analyses)

Watershed Sediment Yield	Based on sediment transport analysis sediment is anticipated to settle into the pond upstream of the bridge during high tide, and tend to flow out during low tide.
Incipient Motion	Yes (See Below)
Armoring	No (See Below)
Rating Curve Shifts	No Data Available

HEC-20 (6.26) Level 3 (Mathematical or Physical Modeling Studies)

A sediment transport analysis was completed in the area in 2018 as part of Sediment Characterization and Flushing Studies - Sawmill Brook Flood Mitigation and Restoration Project completed in 2018 by Tighe & Bond using HEC-RAS. The analysis evaluated the effects of a bank full "channel forming flow" occurring doing mean higher high water (MHHW) tide conditions and mean lower low water (MLLW) tide conditions.

Sediment Transport/Routing Modeling

Incipient Diameter Analysis

Input:

	LOB	CHANNEL	ROB	
Q (cfs)		1772		
V (f/s)		13.68		
y (ft)		5.8		<- hydraulic depth from HEC-RAS
R (ft)		3.99		<- area / wetted perimeter (HEC-RAS)
D50 (ft)		0.0009		
D84 (ft)		0.0044		
Ku		1.486		<- constant
n		0.033		<- manually enter here, or use the calc below

Intermediate Calcs:

ks	**0.01546**	
n	**0.01243**	<- est of Manning's n based on D50 , Sturm 2001
n	**0.01620**	<- est of Manning's n based on 3.5D84, Sturm 2001
τ_0	**3.633**	

Output:

Dc (ft)	**1.2**	Ks=0.03 λ=62.4 λs=(2.65*62.4)

>During design flood, hydraulic forces are adequate to transport bed material up to Dc in diameter. The gradation curve indicates the percentage of bed material that is less than or equal to this particle diameter, therefor, 100 - (this percentage) is coarser than the Dc

>If more than 5% of the bed material is coarser than Dc, then armoring is possible. See section below

Armoring Analysis

(No armoring is anticipated to occur)

Conclusions: Based on the qualitative and quantitative analysis above, the long term aggregation and degradation potential for this reach suggests that there may be potential for both sediment aggradation and degradation over time. It is anticipated that storm events occurring during higher tides will cause sediment to aggregate, while storm events during low tides will tend to cause sediment to degenerate. The shallow bedrock (within 0 to 2 feet of the channel bottom) is anticipated to act as a functional vertical control for degradation. The existing walls on either end of the channel and the pond upstream are anticipated to prevent channel migration.