Preliminary Design Hydrology, Hydraulics and Scour Report

Mill Hill/Route 15 over Mill Pond Outlet, Bridge # 3063, Deer Isle/Stonington

NORTHSTAR HYDRO

For Kleinfelder, Inc.

And Maine DOT

September 18, 2019

Updated May 13, 2021

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STATE OF MAINE
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5-13-2021

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Executive Summary: Bridge #3063 conveys flow from the Holts/Mill Pond under Route 15 in Deer Isle/Stonington, Maine. The pond outlet is a tidal stream connected to Penobscot Bay. The existing bridge is a 42' Single Span Concrete T-beam Superstructure on concrete and stacked granite abutments which are reported to be set on bedrock. The proposed structure is planned to utilize the existing abutments and provide a replacement span with some modification of approach embankments to support widening.

This bridge conveys flow from the upstream drainage basin of Mill Pond under Route 15 and is subject to daily and storm tide inundation. The bottom of the bridge channel is higher than low tide. The bottom chord is higher than FEMA's 100-year storm surge elevation. Sea Level Rise of up to 4' could inundate the low chord during storm tides, but is not likely to overtop the bridge assuming current estimates of potential rise for 100-years. The proposed bridge provides more than 2' of clearance for the 10-year upland flow coupled with MHW plus 4' of Sea Level Rise (SLR). The proposed bridge also provides more than 2' of clearance above the current 50- and 100-year storm tides.

Drainage Area, square miles	2.3
Design Discharge (Q50), cfs	176
Check Discharge (Q100), cfs	206
Scour Check Discharge (Q500), cfs	271
Ordinary High Water (Q1.1), cfs	20
Flood of Record, cfs	unknown
Mean Lower Low Water, ft NAVD	-5.6
Mean Low Water, ft, NAVD	-5.3
Mean High Water, ft NAVD	4.6
Mean High Water plus 4' SLR, ft, NAVD	8.6
Mean Higher High Water, ft, NAVD	5.0
HOWL	9.3
HAT, 2019	6.5
10-year tidal surge, NAVD	8.4
10-year tidal surge with 4' of sea level rise. NAVD	12.4
50-year tidal surge	9.0
100-year tidal surge, NAVD	9.3
500-year tidal surge, NAVD	9.9
FEMA AE Zone Elevation	10

Summary Table 1. Hydrology Summary for Plans

Hydraulic model HECRAS was run in both steady and unsteady flow modes to simulate flow through this bridge which conveys daily and storm tides inland and upland flows seaward. Existing and proposed bridges were modeled, with geometric changes in the bridge deck, in the width of the bridge and in the embankments built to support the widened bridge.

Model combinations include:

Model Type	Tide Level	Upland Flow Frequency
Steady Flow	MHW	Q1.1-, Q10, Q25, Q50, Q100, Q500
Steady Flow	MHW + 4' SLR	same
Unsteady Flow	Calibration tide	50 cfs
Unsteady Flow	10-year surge tide	1.1-year
Unsteady Flow	100-year surge tide	1.1-year
Unsteady Flow	500-year surge tide	1.1-year

Modeling and onsight measurements indicate that the bridge restricts tidal and upland flows slightly with the following notes:

- At maximum normal tide height, with high upland flows, the upstream level is about 0.2' higher than downstream, likely due to upland flows.
- During a tide cycle, maximum difference in height of tide from up- to downstream is about 1', and maximum difference in height of water from downstream to upstream is about 0.9'.
- A slight lag in time occurs as the basin fills and nearly equilibrates at maximum during typical daily incoming tides.
- Measured high tide at the bridge occurred at very close to the same time as predicted at the Oceanville NOAA tide station.
- Modeling indicates that full tidal surge levels will be propagated upstream during storm tide events.

The bridge meets Maine DOT tidal bridge standards for clearance, using upland Q10 and MHW tide plus 4' leaves 1.7' of clearance for the existing bridge and 4' of clearance for the proposed bridge.

The upland 50-year flow is conveyed with adequate clearance as well. The 50-year tide will have 3.8' of clearance at the proposed bridge.

Hydraulic data is summarized in Summary Table 2.

	Existing	Proposed
Low Chord	10.5-11.9	11.8-12.9
Headwater El. @Q10, ft NAVD MHW/MLW + 4’ SLR	4.8/8.8	4.8/8.8
Headwater El. @ Q50, ft NAVD, MHW/MHW + 4’SLR	4.8/8.8	4.8/8.8
Headwater El. @ Q100, ft NAVD, MHW/MHW + 4’ SLR	4.8/8.8	4.8/8.8
Discharge Velocity @ Q50, fps (At MLW)	4.5	4.4
Discharge Velocity @ Q100, fps (100-year tidal surge)	6.6/-7.7	6.6/-7.0
Headwater, MHW with Q1.1, ft NAVD	4.8	4.8
Discharge Velocity @ typical daily tides (calibration data- 2-18-19), cfs	6.9/-7.1	Not calculated
Clearance @ 50-year tidal surge, ft	1.5	2.8
Clearance @ 10-year upland flow, with MHW +4’ SLR, ft	1.7	3.0
50-year storm tide, ft NAVD	9.0	9.0
100-year storm tide ft, NAVD	9.3	9.3
100-year storm tide with waves, ft, NAVD	10.3	10.3
Approximate Bridge Opening Area, ft^2	544	600

Summary Table 2. Hydraulic Summary for Plans

1.0 Introduction: This report details work related to hydrologic, hydraulic and scour analysis at the Route 15 Bridge over Mill Pond Outlet in Deer Isle and Stonington, Bridge # 3063. The project site is shown in figure 1.

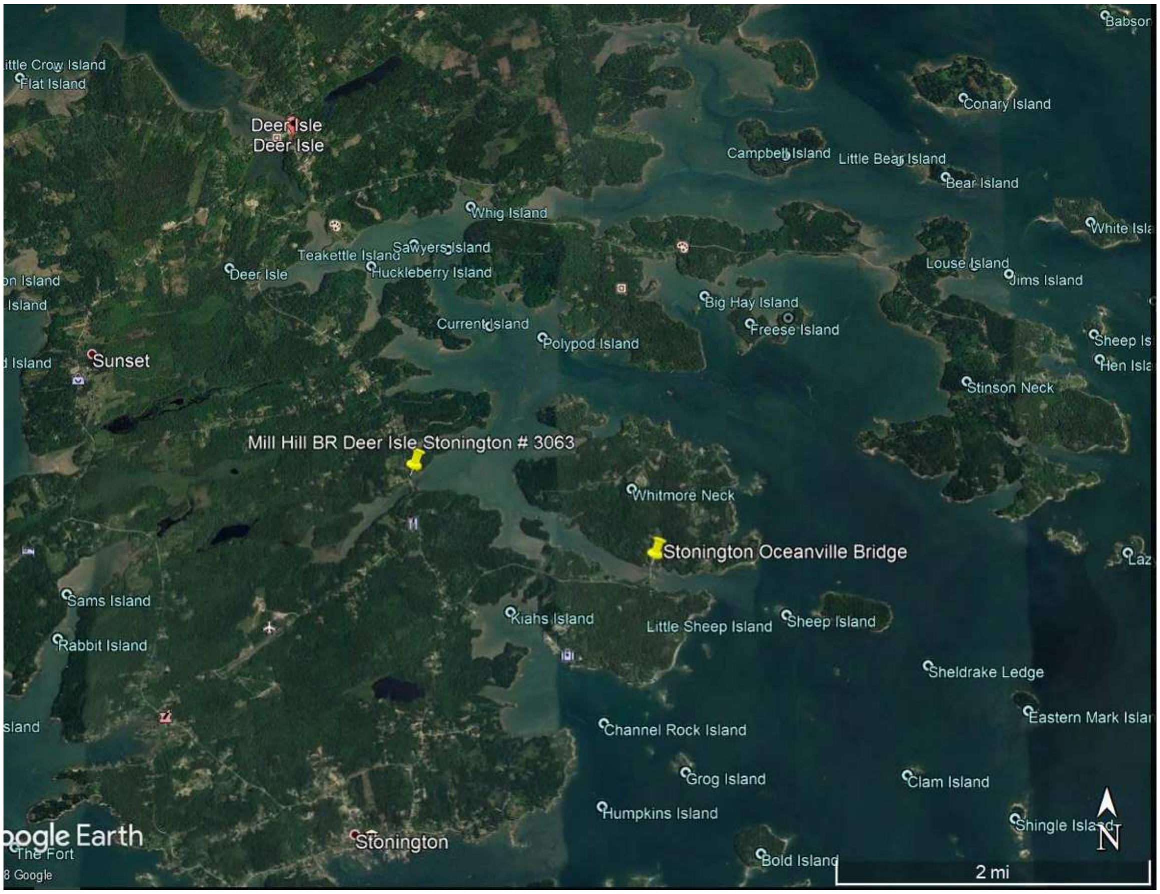

Figure 1. Site Location Route 15 over Mill Pond Outlet #3063.

The bridge crosses over the outlet of Mill Pond, which collects limited amounts of upland runoff and cycles with the tides each day. The bridge site is somewhat protected from large ocean waves due to its location within a cove and behind several islands. Figure 2 shows a closeup aerial view of the bridge location.

Figure 2. Aerial Photo, Mill Pond Outlet (labeled Holt Pond in Google Map data), Stonington/Deer Isle.

According to inspection reports, the existing bridge consists of a 42' span, concrete T beam slab on stone masonry capped abutments. The original bridge was built in 1939. The original bridge plans show a concrete footing/leveling slab on bedrock with dry laid stacked granite blacks capped with concrete. Later reports note that the bridge was widened and rehabilitated in 2005 on the original stone masonry abutments. In inspection reports, the abutments are noted to be in satisfactory condition with some bank erosion. The bridge is noted as stable for scour. The upstream face of the bridge is shown in figure 3.

Figure 3. Upstream face of bridge.

The proposed bridge will be seated on existing foundations, but with wider travel lanes, will be slightly wider perpendicular to flow, will have a shallower superstructure depth (higher low chord), and will have minor modifications to embankments to accommodate the wider superstructure.

In addition to upland flows, this bridge site is subject to flows in both directions due to tidal influx. A goal of the hydraulic analysis is to determine whether this bridge restricts the amount of tidal waters that can travel upstream and fill the basin above the bridge, or whether the bridge allows for the full tidal cycle to fill the pond upstream of the bridge.

Goals for Preliminary Design included:

- Determine flood elevations for bridge profile design based on tidal and upland flood analyses.
- Evaluate up- and down-stream water levels under a variety of tide/streamflow conditions.
- Evaluate rate of flow through bridge under normal and flood tides and due to freshwater flows
- Evaluate whether the bridge restricts flows either from the tidal side to upstream or from the watershed flowing downstream.
- Evaluate scour potential based on predicted and measured velocity, observed bed material and bridge geometry

MaineDOT offers the following guidelines in Chapter 2 of the Bridge Design Guide for bridge design clearance and freeboard:
Riverine:

- All bridges should be designed to safely convey Q50

Tidal Structures:

- *"Bridges on tidal rivers/streams should be designed to protect the bridge structure itself. Most of the surrounding land and the approach roadways may be inundated by relatively frequent tidal storm surges. The minimum design freeboard in these areas is 2 feet above Q10 (based on MHW with sea level rise), including wave heights." (page 2-31)*
- Additional DOT guidance includes: The finished grade of the bridge will be set by considering this requirement, along with navigation clearance, the approach roadways, topography, and good engineering judgment.

Sea Level Rise:

This report considers sea level rise of up to 4' for the project. The May 2018 update to Maine DOT's Bridge Design Guide includes the following:

"2*.3.7 Changes in Sea Level*

Historical data from NOAA shows that the sea level along the Maine coast over the past 80-100 years has risen between 0.5 and 0.75 feet per 100 years relative to local datums. More detailed information is available from the NOAA Tides and Currents website in the Sea Level Trends section. Based on this historical data and NOAA projections, the proposed design should assume 4 feet of sea level rise per 100 years."

Maine DOT provided the following graph from NOAA relative to potential sea level rise. Note that 4' reflects an Intermediate projection for potential rise.

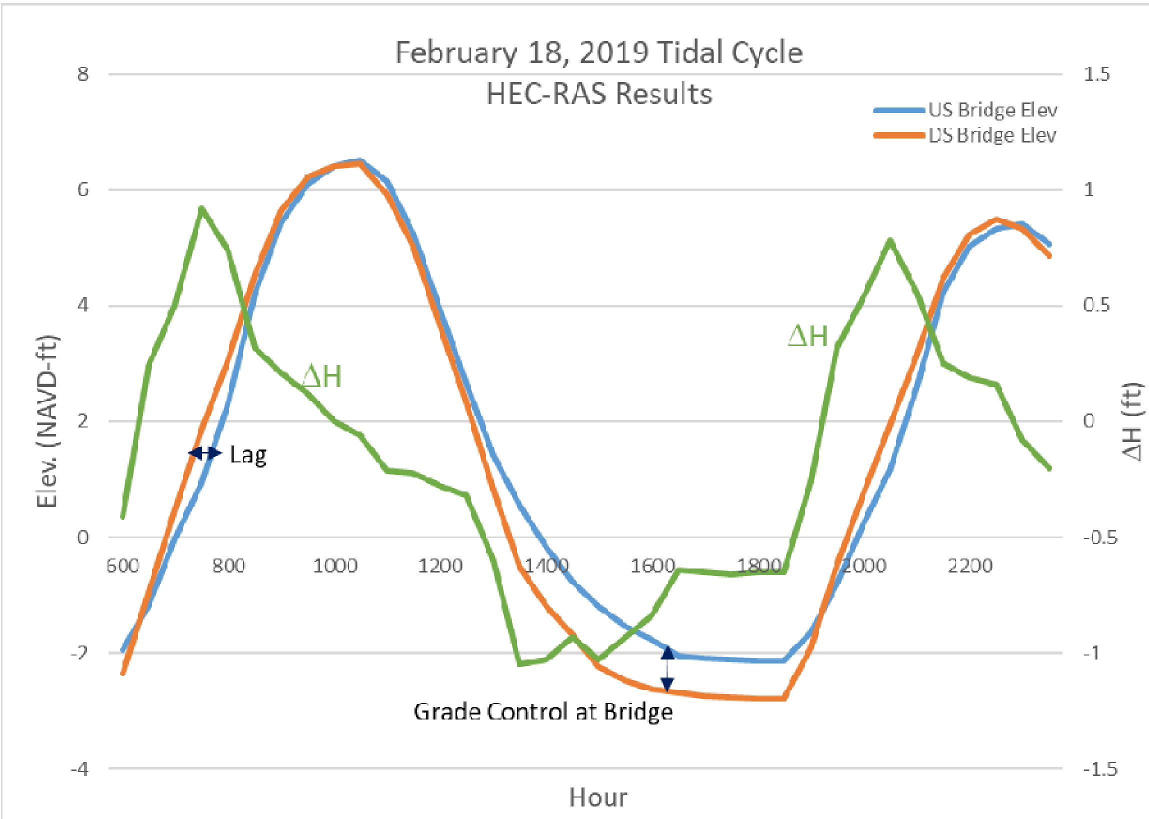

Figure 4. Sea Level Rise Projections for Portland (from NOAA Sea Level Rise Viewer- per Maine DOT).

2.0 Review of Existing Data and Site Visit:

Existing information was gathered and reviewed including:

- FEMA Flood Insurance Studies of Stonington/Deer Isle, including LOMR/LOMA map revisions. Figure 4 shows several panels of the Effective FIS map for Deer Isle and Stonington, with a zone designation of AE 10 feet on the downstream side of the bridge and AE 9 feet upstream of the bridge.

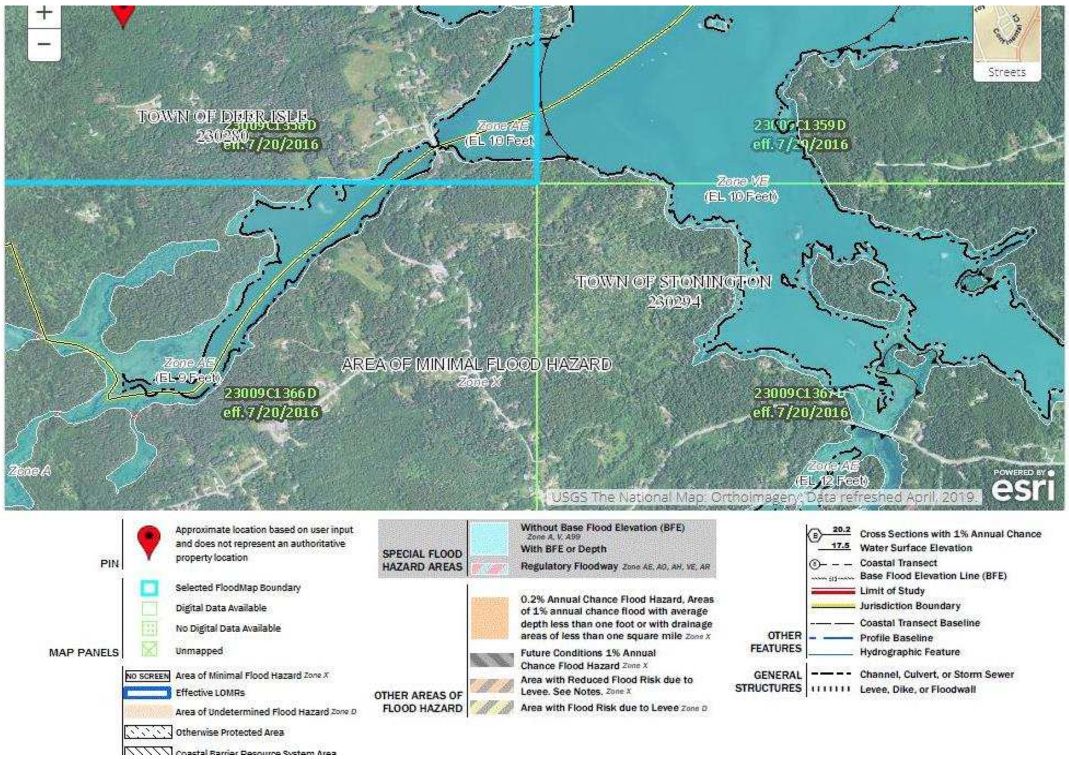

Figure 5. FEMA map panels for Deer Isle and Stonington near project site.

- NOAA tide data and coastal charts

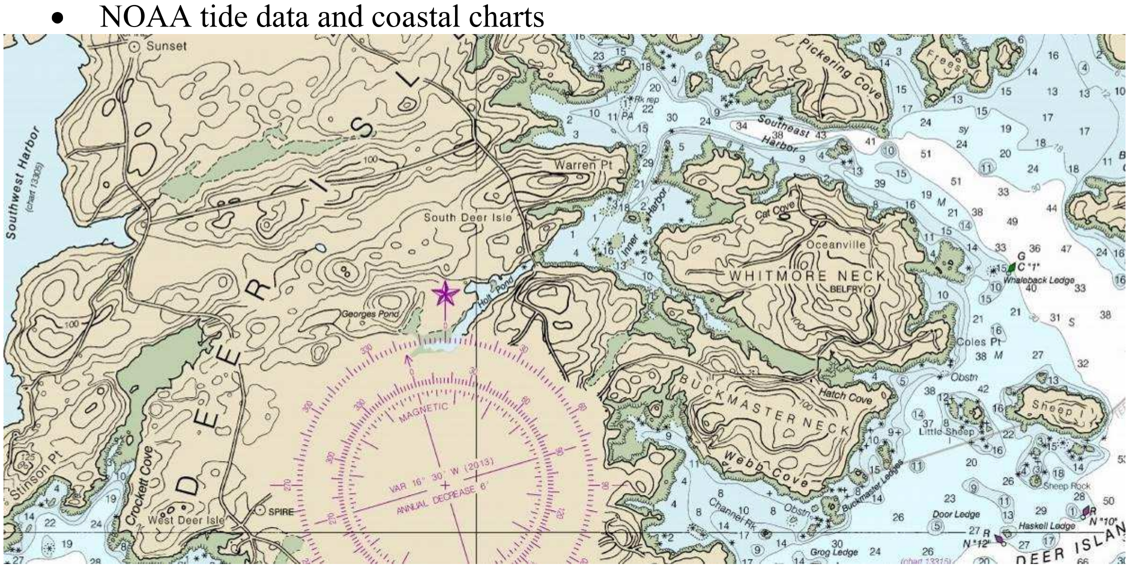

Figure 6. NOAA Chart 13316 near project site. Note that no water depths are given for Mill (Holt) Pond. All depths are shown as MLLW datum, used for navigation.

- MDOT file information including inspection reports related to scour.
  - Mill Hill Bridge, Survey Plans, Sheets 1-4. Dec 12, 1932. Top of road at bridge datum, 98-99.5'. Stream bottom at approximately 80'.
  - Nov 4, 2005 notes: Bridge widened about 30", new railings, new riprap.
  - Inspection report notes stable for scour and above flood levels, 2012, 2013, 2014, 2015, and 2017.

- Air photos
- Topographic Maps
- Historical Flood Information
- NOAA Tide gage data.
  NOAA publishes predicted tide data for several stations near the site, including station # 8414249 at Oceanville Station in Stonington and #8414348, Deer Isle Station in Stonington. Figure 6 shows the locations of both stations.

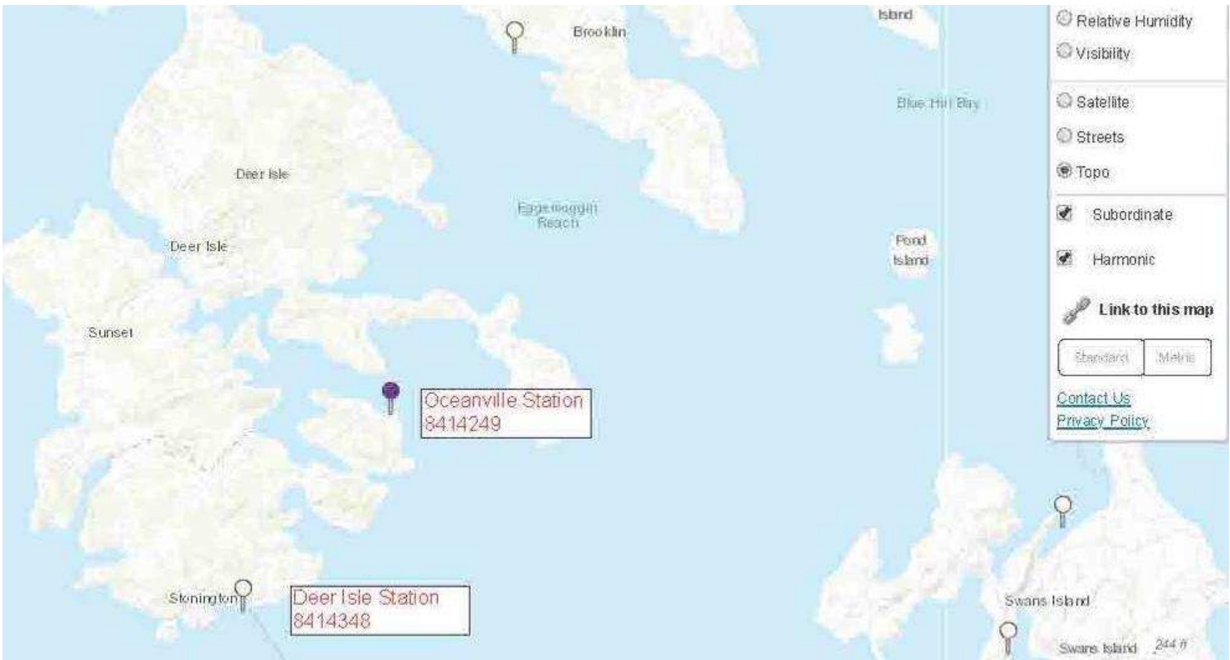

Figure 7. NOAA tidal prediction stations

A table in the appendix summarizes available tidal datum information and table 1 below summarizes values to be used for the project. NHI consulted with the project team and the following set of tidal elevations was selected for the project.

Tidal datums for Bridge # 3063 based on NOAA Tide Station, Oceanville, #8414249, Harmonic Station		
Datum	**MLLW**	**NAVD**
HOWL - 2/7/78		9.3
Highest predicted tide, 2019	12.1	6.49
MHHW	10.63	5.02
MHW	10.21	4.6
NAVD88	5.61	0
MLW	0.35	-5.26
MLLW	0	-5.61
LAT	-1.6	-7.21

Table 1. Summary of Tidal Datums, Deer Isle Bridge # 3063.

2.1 Measure water levels and estimate flow velocities:

NHI measured water levels and estimated flow velocities to determine how the bridge interacts with the complex flows generated by combined tides and upland flows. Tidal elevation and flow data were gathered at the site over an ebbing tide starting at peak tide level. Up- and down-stream water heights at the bridge were measured at selected intervals to assist in evaluating velocity and elevations. Measurements were taken on February 18, 2019 from 10:26 am to 2:38 pm. Measurements were taken from top of rail of bridge at each abutment, at center and at up- and down-stream locations. High tide for that day was predicted to occur at Station 8414249 at 10:17 am. At the project site, the tide continued to come in through the bridge until 10:35 am. High tide was predicted to be 6.14’ NAVD and low tide was predicted to be -6.9’ at 4:47 pm. As discussed below, this high tide elevation is based on measured tides at Bar Harbor adjusted to match the Oceanville gage.

Figure 8. Tide measurement from top of rail.

MEDOT surveyed the bridge. Field measurements of the rail, fascia, and beam depths were made. Kleinfelder combined these measurements with survey data to determine the existing top of rail and associated bottom chord elevations. Top of curb elevations from the survey were used to determine the top of rail elevations by adding the field measured rail height of 27”. The bottom chord elevations were then determined by subtracting the total depth of the structure (rail + curb and deck + beam depth) which is approximately 7’-4” to 7’-6” depending upon the location. Table 2 lists computed bridge elevations.

Location Along Bridge	Side of Bridge	Top of Rail Elevation (ft)	Bottom Chord Elevation (ft)
North End	East	17.84	10.51
	West	17.90	10.48
Middle	East	18.45	11.12
	West	18.63	11.17
South End	East	19.06	11.73
	West	19.36	11.86

Table 2. Bridge elevations.

Field measurement data and elevation conversions are included in the appendix. Tide elevation values calculated from measured data combined with bridge survey data ranged from '6.15' to -1.68' NAVD on the downstream side of the bridge. Field data are graphed in this report in the section on hydraulic analysis and modeling.

2.2 Velocity Estimates:

To assist in calibration of the hydraulic model, tidal flow velocities were estimated by timing a floating object as it passed through the bridge. Each measurement was repeated at least three times and averaged. While this method provides rough estimates of velocity, the comparison to flow meter data has been found to be quite close at other project sites.

Time	Average Velocity, fps	Velocity Head, ft, V^2/2g
10:50 AM	2.2	0.1
11:23 AM	2.6	0.1
11:51 AM	3.7	0.2
12:25 PM	5.3	0.4
12:36 PM	6.2	0.6
12:51 PM	6.9	0.7
1:15 AM	6.3	0.6
2:30 AM	5.7	0.5

Table 3. Summary of calculated velocity measurements. 2/18/19

2.3 Predicted Tides on Day of Measurements:

To assist in calibrating the hydraulic model, measured tide data was compared to predicted tide data. Available tide data was analyzed to determine the best data to use for prediction of tide elevations at the project site. Three NOAA tide gages were evaluated, with the final choice being station #8414249, the Oceanville, Deer Isle Station. Data for the day of tide measurements is shown below. Bar Harbor is the closest recording tide gage. The Deer Isle - Stonington Station (#8144348) allows tide elevation predictions based on the predicted or recorded tides at Bar Harbor. The Oceanville gage provides only predicted tides based on harmonic constants provided by NOAA. To calibrate the hydraulic model, the Oceanville predicted tides were adjusted slightly based on recorded tides at Bar Harbor, which were slightly different than predicted. Since Oceanville is a Harmonic station, the adjustment was calculated at the Deer Isle Stonington Station 8414348 (a station subordinate to the Bar Harbor recording station) and added to the Oceanville predicted tides.

Based on the Bar Harbor and Stonington tidal gages, it was estimated that the actual high tide on the day of measurement was 0.6' higher than predicted at the Oceanville gage. This adjustment is documented in the appendix.

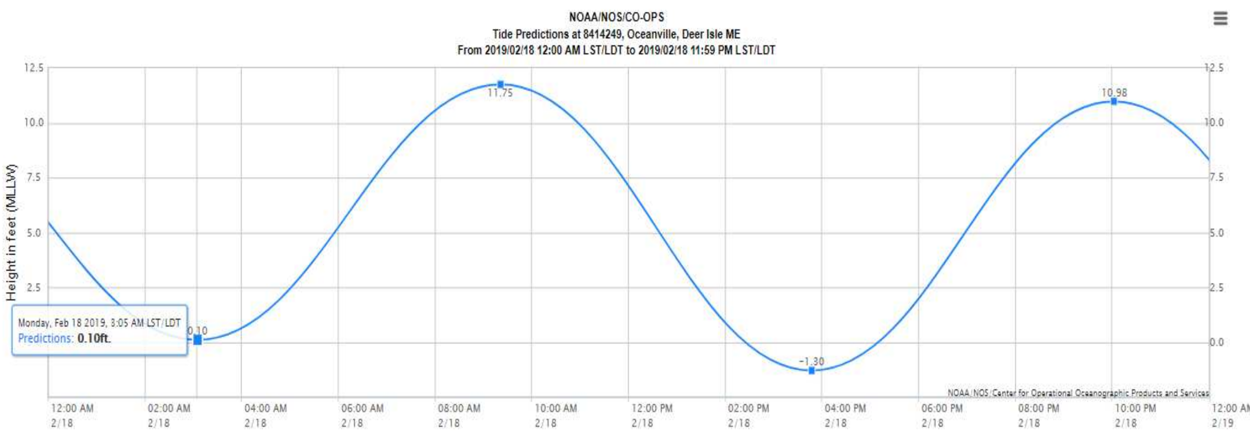

Figure 9. Predicted tides at Station 8414249, Oceanville, Deer Isle, ME. 2/18/19. Harmonic

Predicted Tides, 2/18/19. MLLW/LST/LDT

Time	Time plus 1 hour	MLLW	NAVD
2:05 am	3:05 am	0.10	-5.51
9:21 am	10:21 am	11.75	6.14
3:47 pm	4:47 pm	-1.30	-6.91
10:02 pm	11:02 pm	10.98	5.37

Adding the estimated tidal elevation adjustment described above, the high tide on 2/18/2019 would have been approximately 6.7' NAVD.

2.4 Site Visit Photographs

Photographs were taken on February 18, 2019.

Figure 10. Upstream face at low tide.

Figure 11. Downstream face, high tide.


Figure 12. Looking downstream, high tide.


Figure 13. Downstream of bridge, lower tide.

Figure 14. Looking upstream near low tide.

Figure 15. Downstream face. Note tide has dropped below base of bridge channel.

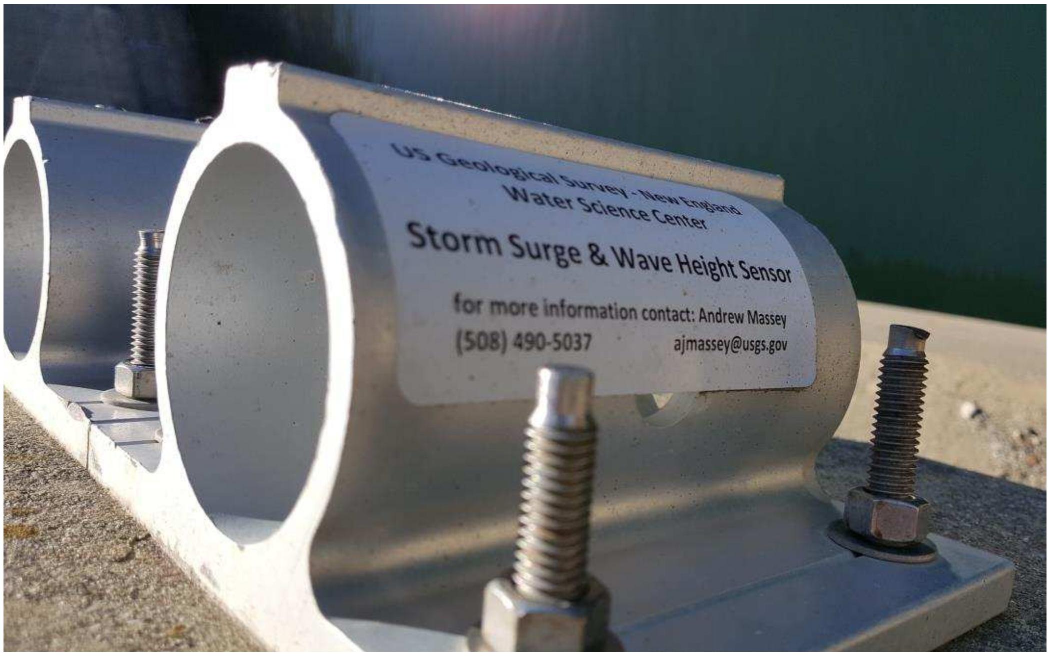

Figure 16. USGS installation for rapid deployment of storm surge measurement equipment.

The project bridge has equipment installed that can be used by USGS for rapid deployment of storm surge sensors. This installation would need to be redone and resurveyed with a new bridge.

3.0 Hydrologic Analysis:

Tidal and upland hydrology were computed at the project site. Upland hydrology for Mill Pond was computed using StreamStats published by USGS. Drainage basin and drainage basin characteristics are shown in figure 16.

StreamStats Report - Mill Pond Outlet Stonington/Deer Isle

Region ID: ME
Workspace ID: ME20180711135547333000
Clicked Point (Latitude, Longitude): 44.18805, -68.66127
Time: 2018-07-11 09:56:04 -0400

Figure 17. Drainage basin to Mill Pond.

Drainage Area, sq. mi.	2.3
1-year, cfs	20
10-year, cfs	118
25-year, cfs	155
50-year, cfs	176
100-year, cfs	206
500-year, cfs	271

Table 4. Summary of Peak upland flows, Mill Pond.

Tidal elevations are based on NOAA tide station 8414249 at Oceanville and FEMA storm surge elevations as published in their July, 2018 county- wide study of Hancock County.

Tide Level	Elevations in Feet at Specified Datum	
Tidal Datum	MLLW	NAVD
FEMA AE Zone		9.3 (US)/10 (DS)
500-year storm (FEMA)		9.9
HOWL- est. based on Bar Harbor gage 8414348		9.3
100-year storm (FEMA)		9.3
50-year storm (FEMA)		9.0
MHW + 4' SLR		8.6
10-year storm (FEMA)		8.4
2-18-19 predicted		6.7
2-18-19 measured at site		6.15
MHHW	10.63	5.02
MHW	10.21	4.60
NAVD	5.61	0.00
MLW	0.35	-5.26
MLLW	0.00	-5.61

Table 5. Summary of Tidal Elevations

4.0 Site Survey and Topography

Survey was collected by Maine DOT for the region approximately 250 feet upstream of the bridge and 350 feet downstream. In this region, site survey was used to build the hydraulic model. Outside the surveyed area a digital elevation model (DEM) based on the LiDAR for the Northeast 2010-2011 was used to obtain elevations above the water surface. Upstream of the site, bathymetry was estimated by reviewing aerial photography. Downstream of the bridge, NOAA navigation chart 13316 and aerial photography were used to estimate bathymetry. These datasets were combined to develop geometry for the hydraulic model.

5.0 Hydraulic Analysis:

Hydraulic analyses for preliminary design included modeling flows through the existing bridge and a planned replacement span. Model HECRAS version 5.06 was used in steady and unsteady flow mode to simulate flow through the bridge using the boundary conditions listed above, with tidal hydrographs forming the downstream border and upland flow as the upstream boundary.

Goals of the preliminary hydraulic analysis include:

- Preliminary assessment of flood elevations for existing and proposed bridges
- Preliminary flow velocity studies for scour analyses under existing and proposed conditions.
- Understanding of interaction of tides, upland flows and bridge structure.

The model consists of a geometric simulation of the bridge and surrounding areas that impact flow, and the boundary conditions of flow and water levels.

Figure 18 shows the geometric model layout with cross sections shown in green and storage area (Mill Pond) shown in blue.

Figure 18. Hydraulic model layout.

Model contours at the bridge are shown in figure 19.

Figure 19. Bottom contours at bridge

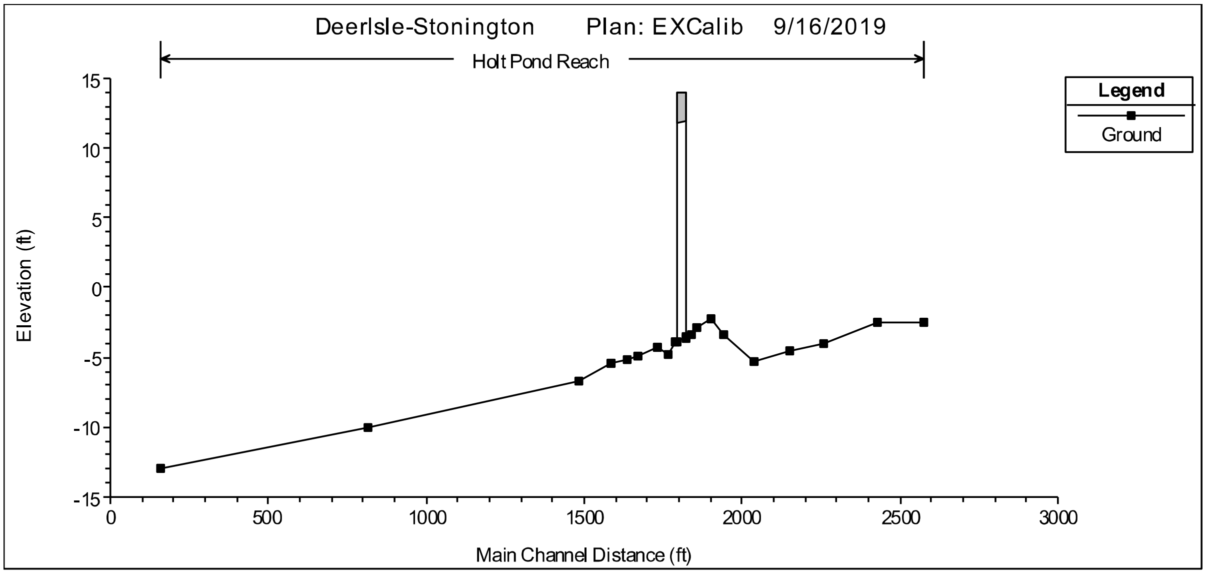

Figure 20. Model profile, left side is downstream, right side is upstream.

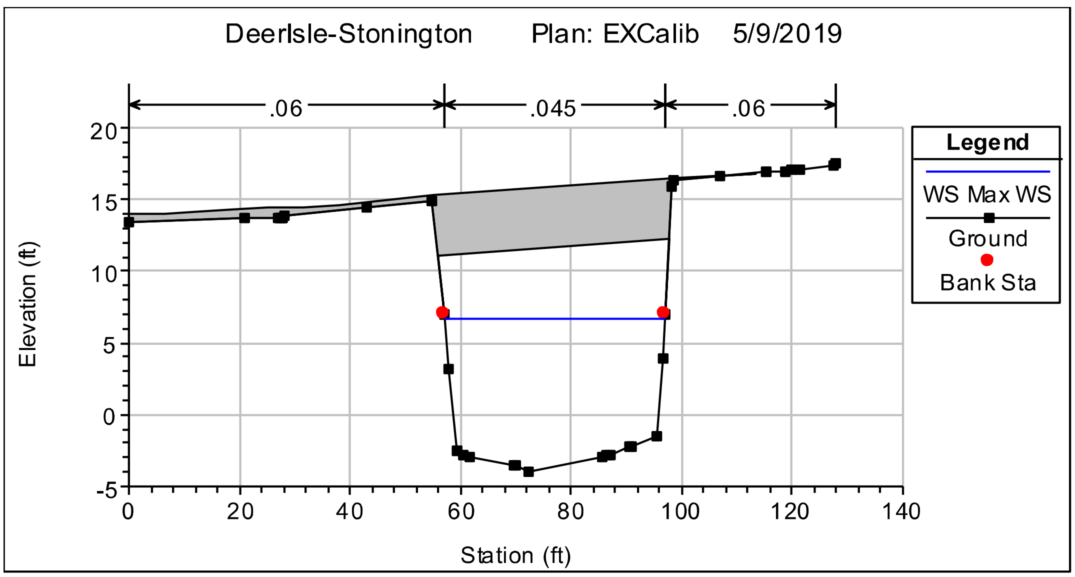

Figure 21. Downstream face of existing bridge, plotted left to right facing downstream.

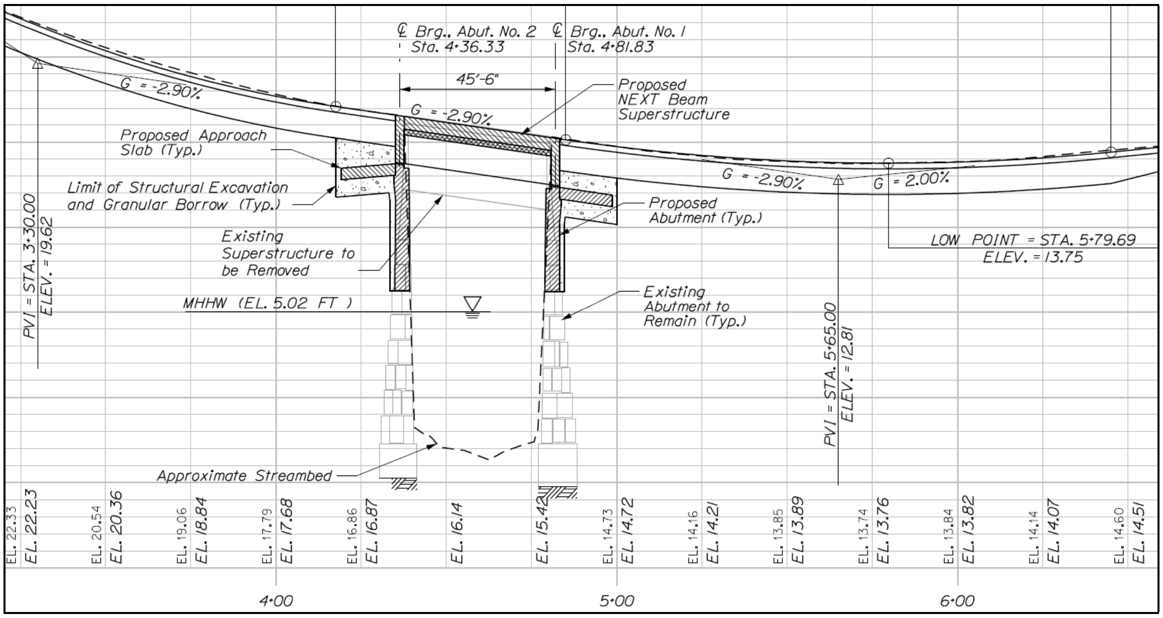

Figure 22: Profile of Proposed Bridge from Kleinfelder's Preliminary Plan dated September 2019.

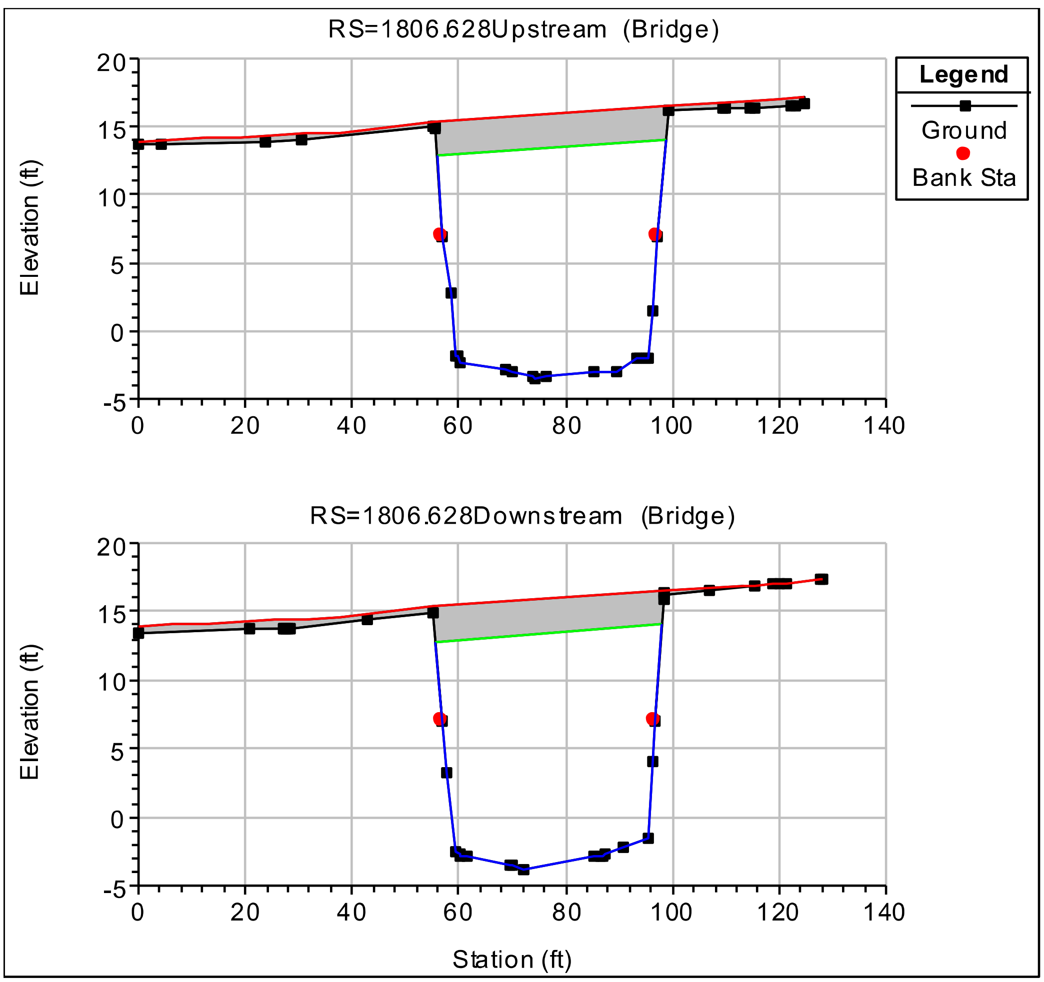

Figure 23. Proposed bridge as modeled in HECRAS. Updated low chords 11.75, 12.92' NAVD

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In addition to the geometry described above, the model includes downstream tidal hydrographs and upstream flows.

Field data was collected to measure a typical incoming tide on February 18, 2019. Predicted tidal hydrographs at Oceanville were compared to field measured data and found to be slightly higher than tides at the project. On the field day, the Bar Harbor tide gage recorded some additional tide height (+0.6') over predicted values. No direct observations of storm surge and/or wave impacts are available for the project site.

The following flow/tide combinations were selected as boundary conditions for analysis in the hydraulic model.

- Steady State:
  - Peak upland flows for Q1-, Q10-, Q25, Q50, Q100 and Q500
  - MHW and MLW tide and MWH plus 4' SLR tide.
- Unsteady flow simulations:
  - Approximately 2-year upland flow (for model stability) coupled with Calibration tides, predicted for 2/18/19
  - 10-year upland flow coupled with MHW-MLW hydrograph (4.6', 118 cfs)
  - 10-year upland flow coupled with MHW-MLW plus 4' of Sea Level Rise hydrograph, (8.6', 118 cfs)
  - 1-year upland flow coupled with 100-year storm surge (elev 9.3', 20 cfs)
  - 1-year upland flow coupled with 500-year storm surge (elev 9.9', 20 cfs)

Estimated storm surge hydrographs and model flow files for the project site were compiled as follows:

1. A tide curve simulating predicted MHW to MLW tides was generated via spreadsheet.
2. MaineDOT provided a suggested method for calculation of storm surge. Surge levels were then added to the MHW/MLW representative tide cycle to produce simulated 10-, 100- and 500-year storm tides.
3. Storm surge plus tide hydrographs were routed through the model as the downstream boundary condition, including the 10-, 100- and 500-year tide levels of 8.4', 9.3', and 9.9', based on FEMA predictions, assuming a 1-year upland flow.
4. Note that these surge levels may be compared to the estimated HOWL of 9.3' of February 7, 1978. This is based on the Bar Harbor gage adjusted to Deer Isle.
5. Velocity estimates were prepared to evaluate potential scour. For tidal systems, fastest velocities occur when tides are changing most rapidly, such as during a surge event and when water levels are near mid-tide. Peak velocities were selected from modeled hydrographs at the proposed bridge at times of highest flow rates.

Calibration data is plotted in figure 24. Data sets include:

- Measured average elevations for seaward (tailwater-TW) and landward (headwater - HW) sides of the bridge – measured at the faces of the bridge
- Measured (verified) tides for Bar Harbor (BH) adjusted to Oceanville (DI)

- Predicted tides at Oceanville (DI)
- HECRAS model elevations using DI predicted tides as the seaward boundary condition.

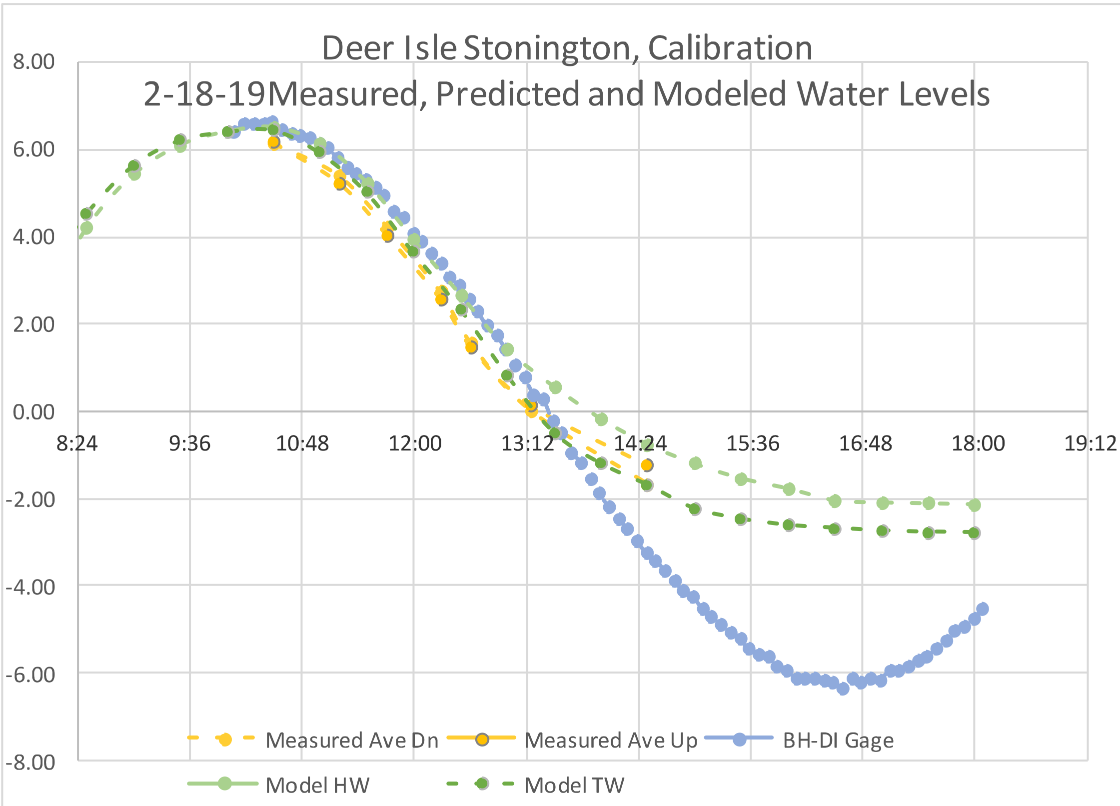


Figure 24. Measured, Predicted and Modeled Tides on 2/18/19

The calibration graph shows that measured water levels were slightly lower than predicted, suggesting that using predicted tide data is likely conservative as far as peak tide levels. Model tailwater elevations reflect elevations near the bridge where bottom elevations are higher than the lowest tide levels. The HECRAS model was run using predicted tide curves rather than the short field measured data set, again building conservative water levels into the model, but reflecting the shape of the tide curve well.

Tables 6 and 7 on the following pages summarize existing and proposed bridge hydraulic data. Additional detailed model output is included in the report appendix for existing conditions. Proposed conditions were nearly identical so detailed output was not included for the proposed model.

Notable in the results is that the new bridge will be nearly identical to the existing bridge in terms of hydraulic function, but will add additional clearance under the bridge for storm tides.

Figure 25 shows the observed February 18, 2019 tidal cycle as modeled in HEC-RAS. The calibrated model provides insight into whether the bridge constricts tidal flow. The figure shows a lag between the US and DS elevations at the bridge and the impact of a grade control in the bridge. This indicates that the bridge restricts flow slightly, which appears to be a function of both the bridge span and the grade control or channel bottom elevation within the bridge.

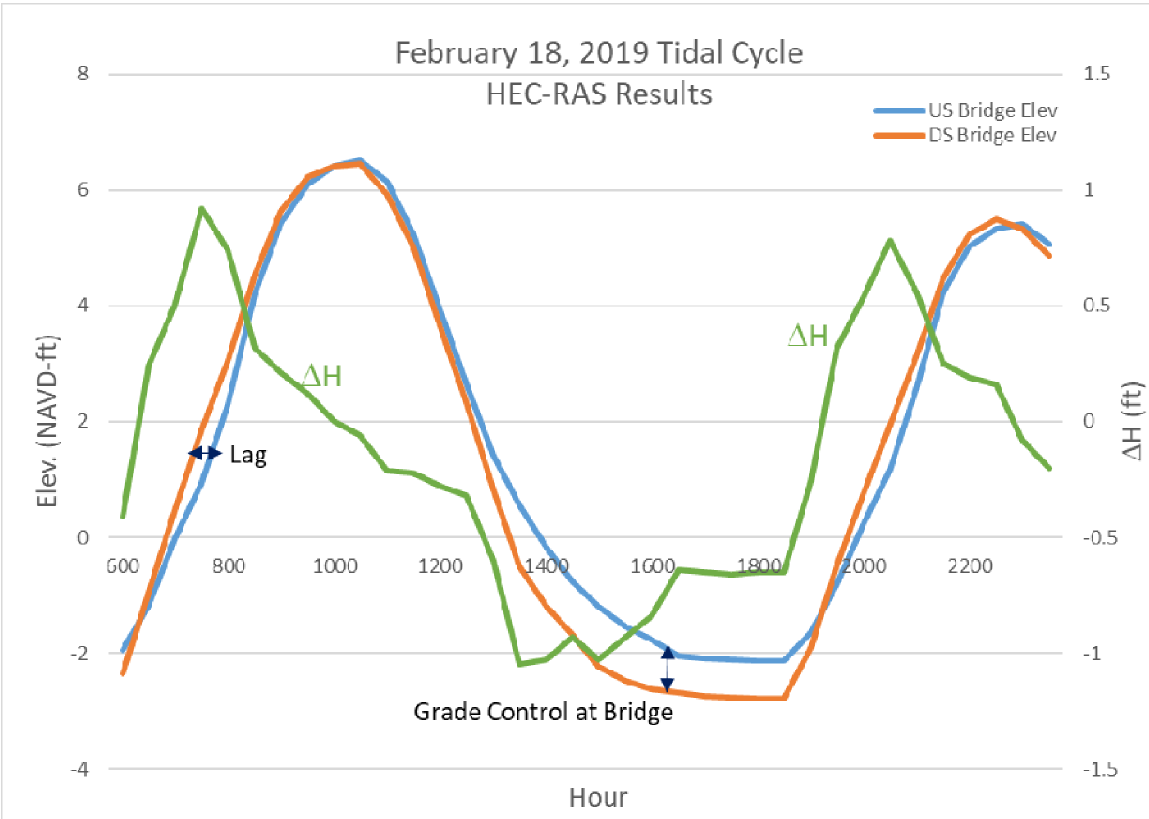


Figure 25. Modeled calibration tides showing difference in water levels on upstream and downstream sides of the bridge.

Modeling and onsite measurements indicate that the bridge restricts tidal and upland flows slightly with the following notes:

- At maximum normal tide height, with high upland flows, the upstream level is about 0.2' higher than downstream, likely due to upland flows.
- During a tide cycle, maximum difference in height of tide from up- to downstream is about 1', and maximum difference in height of water from downstream to upstream is about 0.9'.
- A slight lag in time occurs as the basin fills and nearly equilibrates at maximum during typical daily incoming tides.
- Measured high tide at the bridge occurred at very close to the same time as predicted at the Oceanville NOAA tide station.
- Modeling indicates that full tidal surge levels will be propagated upstream during storm tide events.

The bridge meets Maine DOT tidal bridge standards for clearance, using upland Q10 and MHW tide plus 4’ leaves 1.7’ of clearance for the existing bridge and 3’ of clearance for the proposed bridge.

The upland 50-year flow is conveyed with adequate clearance as well. The 50-year tide will have 3.8’ of clearance at the proposed bridge.

5.2 Wave Heights

The site was reviewed for potential wave heights using methodology described in the U.S. Army Corps of Engineers Shore Protection Manual, Chapter 3. Both deep water and shallow water potential waves were calculated using SPM charts 3-24 and 3-30. Effective fetch length was estimated at 2851’ using google earth air photos and NOAA Nautical Charts. Figure 26 below shows offshore areas and depths. Potential wave height is dependent on available fetch for wind generation of waves, wind speeds, and offshore depths. The deepwater and 20 feet depth charts were used.

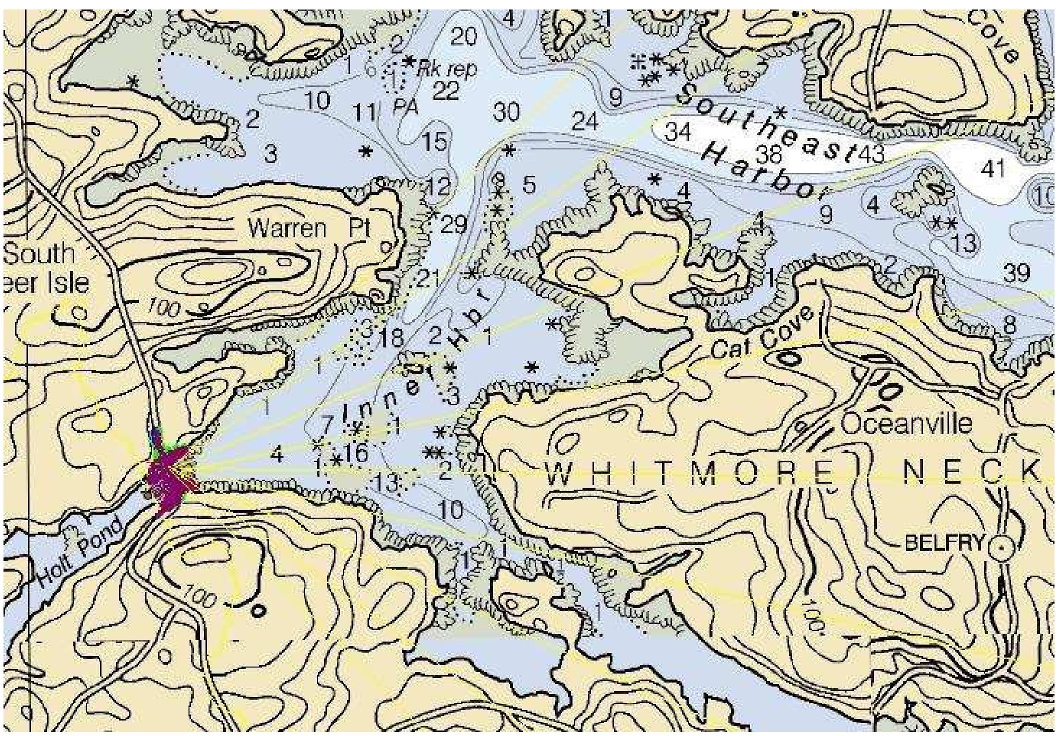


Figure 26. Effective fetch for wave height calculations at project site.

Potential 100-year 1-minute windspeed is 65 and 45 mph from the east and ENE respectively. Potential deepwater maximum wave height is estimated at 1.8’ for the 15 minute wind of 63 mph from the East, with a period of 2 sec. For the shallow water charts, which better represent this location, a wave height of 1.3’ is estimated. These waves are high frequency, small amplitude, small wavelength waves and are smaller than FEMA’s 3’ guideline for waves capable of substantial structural damage.

Deer Isle -Stonginton, Bridge #3063 **Summary of Hydraulic Data**	**Existing Structure**	**Proposed Structure**
Note: DS is seaward, US is landward of bridge		
Low Chord, ft	10.5-11.9	11.8-12.9
Minimum Top of Road	14.0 L, 15.3 on bridge	13.7 L/15.4 on bridge
Calibration Tide Level DS/US	6.5/6.5	Not computed
DS/US Surge Level at 10-year Storm tide , Q1.1	8.4/8.3	8.4/8.3
DS/US Surge Level at 100-year Storm tide, Q1.1	9.3/9.2	9.3/9.2
DS/US Surge Level at 500-year Storm tide, Q1.1	9.9/9.8	9.9/9.8
Maximum Headwater, Upland Q10 and MHW	4.8	4.8
Maximum Headwater, Upland Q10 and MHW plus 4' SLR	8.8	8.8
Maximum Headwater, Upland Q50 and MHW	4.8	4.8
Maximum Headwater, Upland Q100 and MHW	4.8	4.8
Maximum Discharge Velocity, 10-year surge	6.5/-7.5	6.3/-6.8
Maximum Discharge Velocity at Q50, fps MLW	4.5	4.4
Maximum Discharge Velocity at Q100, fps MLW	4.8	4.7
Maximum Discharge Velocity, 100-year surge	6.6/-7.7	6.6/-7.0
Maximum Discharge Velocity at Q500, fps MLW	5.4	5.2
Maximum Discharge Velocity, 500-year surge	6.6/-7.9	6.6/-7.0
Calibration Tide Velocity,	6.9/-7.1	Not computed
Clearance @ Q10, MHW +4'	1.7	3
Clearance @ 10-year surge	2.1	3.4
Clearance @ 50-year surge	1.5	3.8
Clearance @ 100-year surge	1.2	2.5
Bridge Opening Area, ft^2	544	600

Table 6. Summary of Hydraulic Data

Deer Isle Stonington Bridge # 3063

TABLE 7.

Hydraulic Model Results

Model Type	Plan name	Bridge Id	Peak Tide Level	DS WSEL		Q, frequency	Q, cfs	US WSEL		Velocity, fps	
EXISTING				**high**	**low**			**high**	**low**	**inflow**	**outflow**
Steady											
.p09/.p10	EXsteadyQP-MHW/MLW	Existing	MHW/MLW	4.6	-4.9	1	20	4.8	-1.8	NA	2.2
						10	118	4.8	-1.2		3.9
						25	155	4.8	-1		4.3
						50	176	4.8	-0.9		4.5
						100	206	4.8	-0.8		4.8
						500	271	4.8	-0.5		5.4
.p08	EXsteadyQP-MHW+4'SLR	Existing	MHW	8.6	NA	1	20	8.8		NA	0.04
						10	118	8.8			0.27
						25	155	8.8			0.35
						50	176	8.8			0.4
						100	206	8.8			0.46
Unsteady						500	271	8.8			0.61
.p04	EXCalib	Existing	Calibration 2-18-19	6.5	-6.4	2	50	6.5	-1.4	-7.1	6.9
.p02	MHW-Q10EX	Existing	MHW	4.6	-5.2	10	118	4.6	-1.1	-5.3	6.5
.p05	MHW-Q10EX+4'SLR	Existing	MHW +4'SLR	8.6	-1.2	10	118	8.6	-0.6	-1.8	5.2
.p06	EXT100Q1	Existing	100-year surge	9.3	-5.4	1	20	9.2	-1.6	-7.7	6.6
.p01	EXT500Q1	Existing	500-year surge	9.9	-5.4	1	20	9.8	-1.6	-7.9	6.6
PROPOSED											
Steady											
.p12/.p13	PROsteadyQP-MHW/MLW	Proposed	MHW/MLW	4.6	-4.9	1	20	4.8	-1.8	NA	2.2
						10	118	4.8	-1.2		3.8
						25	155	4.8	-1.0		4.2
						50	176	4.8	-0.9		4.4
						100	206	4.8	-0.8		4.7
						500	271	4.8	-0.5		5.2
.p11	PROsteadyQP-MHW+4'SLR	Proposed	MHW	8.6	NA	1	20	8.8			0.05
						10	118	8.8			0.27
						25	155	8.8			0.35
						50	176	8.8			0.4
						100	206	8.8			0.46
Unsteady						500	271	8.8			0.61
.p19	MHW-Q10PRO	Proposed	MHW	4.6	-5.2	10	118	4.6	-1.1	-4.9	6.6
.p17	PROMHW+4-Q10	Proposed	MHW +4'SLR	8.6	-1.2	10	118	8.6	-0.3	-4	5.4
.p15	PRO100Q1	Proposed	100-year surge	9.3	-5.4	1	20	9.2	-1.6	-7	6.6
.p16	PRO500Q1	Proposed	500-year surge	9.9	-5.4	1	20	9.8	-1.6	-7.1	6.6

6.0 Scour

The proposed bridge will be sited on existing abutments which are reported to be seated on bedrock according to the Preliminary Geotechnical Plan Sheets, B-1 (Boring Location Data) and B-2 Interpretive Surface Profile, dated 2019-09-18. Preliminary potential scour depths were evaluated based on bed material, foundations, and computed velocities according to methods recommended in FHWA HEC-18.

The preliminary scour evaluation indicated the potential for up to 10' of contraction scour in unconsolidated bed material. It should be noted that scour equations are conservative at tidal bridges due to flow occurring in two directions, twice daily, such that material that is moved out of the bridge during one tidal direction could be moved back in on the reverse tide.

Plan B-2 shows only about 2' of overburden in the channel with abutment footings seated on rock. Field inspection noted large cobbles/rocks form the bed material.

Figure 27. Bed material of cobbles and rocks downstream of bridge.

It is very likely that scour can occur to bedrock, the recommended scour condition for this stage of design.

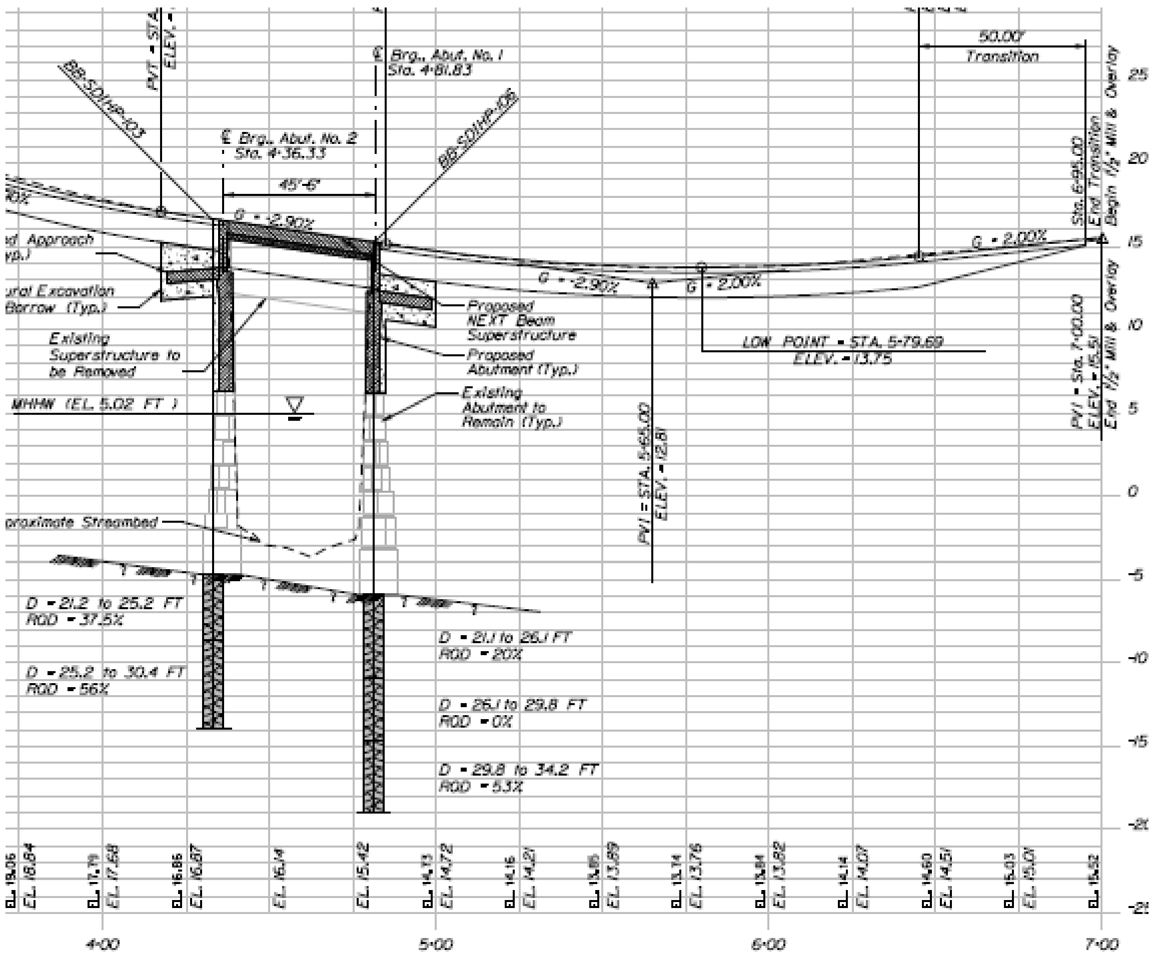


Figure 28. Plan B-2, Interpretive Subsurface Profile, 2019-09-18

Rock of poor quality has the potential for scour during high flows. Rock scour equations generally focus on piers rather than abutments. Generally, potential abutment scour in rock is assumed/computed to be of similar depth as rock that would be cleared for construction on competent rock. The abutments appear to have riprap protection in site photographs.

Figure 29. Downstream face of bridge at low tide. Note riprap.

7.0 References

- ESRI ArcMap, ArcGIS Desktop. Data added from MEGIS website, project plans and ESRI
- Federal Emergency Management Agency. Flood Insurance Study and Flood Hazard Boundary Maps, Hancock County, Maine. July 20, 2016
- Maine Dept. of Transportation. Bridge Design Manual. August 2003, updates to July, 2017
- Maine DOT, Bridge Plans, Mill Hill Bridge # 3063, December 1932
- Maine DOT Bridge Inspection Reports,
- NOAA tide data: Deer Isle/Oceanville Tide Gage # 8414249
- NOAA tide data: Bar Harbor, Primary Gage, Station #8413320
- NOAA Sea Level Trends http://www.co-ops.nos.noaa.gov/sltrends/sltrends.html
- U.S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-RAS River Analysis System. Version 5.06. 2018 Davis, CA
- U.S. Army Corps of Engineers, Updated Tidal Flood Profiles, New England Coastline, March, 2012.
- U.S. Department of Transportation. Federal Highway Administration. Evaluating Scour at Bridges, 5th edition. HEC-18. April 2012, Publication No. FHWA-HIF-12-003
- U.S. Department of Transportation. Federal Highway Administration. Bridge Scour and Stream Instability Countermeasures. HEC-23. Volume 2. September, 2009. FHWA-NHI-09-112. DG 14, Rock Riprap at Bridge Abutments and DG 4, Riprap Revetment
- U. S. Dept. of the Interior, Geological Survey, with Maine Dept. of Transportation. Estimating the Magnitude and Frequency of Peak Flows for Streams in Maine for Selected Recurrence Intervals. Water Resources Investigations Report 99-4008. https://streamstats.usgs.gov/ss/. USGS Streamstats. Beta Version 4.

Appendix.

Notes on Predicted Tidal Data for 2/18/19
Calibration Graphs
Field Data from Tide Measurements
- Water Levels
- Velocity Estimates

Summary of NOAA Tide Data
HECRAS output for existing conditions.
HECRAS steady flow proposed conditions

Notes on Predicted Tides for 2/18/2019

The following steps detail adjustments to NOAA’s Oceanville Harmonic Station predictions based on the difference between predicted and recorded tides at the Bar Harbor tidal recording station.

The closest tide recording station to the project site is Bar Harbor. On the day of field measurements, Bar Harbor recorded tides higher than predicted. To assist in model calibration, predicted, tides near the project were adjusted at the Oceanville, Station 8414249 . Since Oceanville is a Harmonic station, the adjustment was calculated at the Deer Isle Stonington Station 8414348, a station subordinate to the Bar Harbor recording station and added to the Oceanville predicted tides.

1. Tides at Station 8414348, Deer Isle Stonington, Predicted based on Bar Harbor

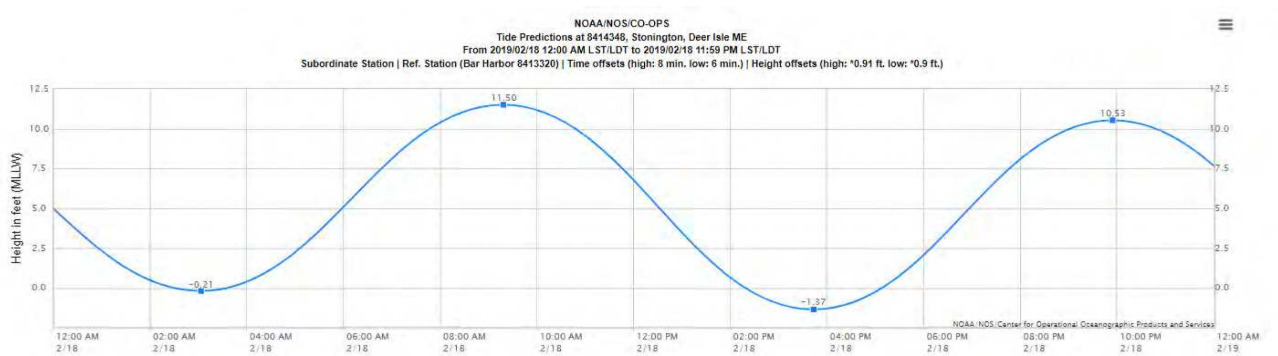


Figure App 1. Predicted tides at Station 8414348, Deer Isle, Stonington, 2/18/19. Based on Bar Harbor * .91 H, .90 L

2. Prediced Tides, Deer Isle: 2/18/19. MLLW, LST/LDT

Time	Time plus 1 hour	MLLW	NAVD
3:03 am	4:03 am	-0.21	-5.67
9:18 am	10:18 am	11.50	6.04
3:43 pm	4:43 pm	-1.37	-6.83
9:54 pm	10:54 pm	10.53	5.07

3. Predicted and Measured Tides 2/18/19 at Bar Harbor, MLLW/NAVD

		Predicted	Measured
9:18 am	10:18 am	12.6	13.3
		6.6	7.3

BH Measured adjusted to Station 8414348

13.3’ X .91 = 12.1’ MLLW = 6.64’ NAVD estimated, or 0.6’ higher than predicted

4. Predicted Tides at Oceanville, Deer Isle (selected station for project) on 2/18/19

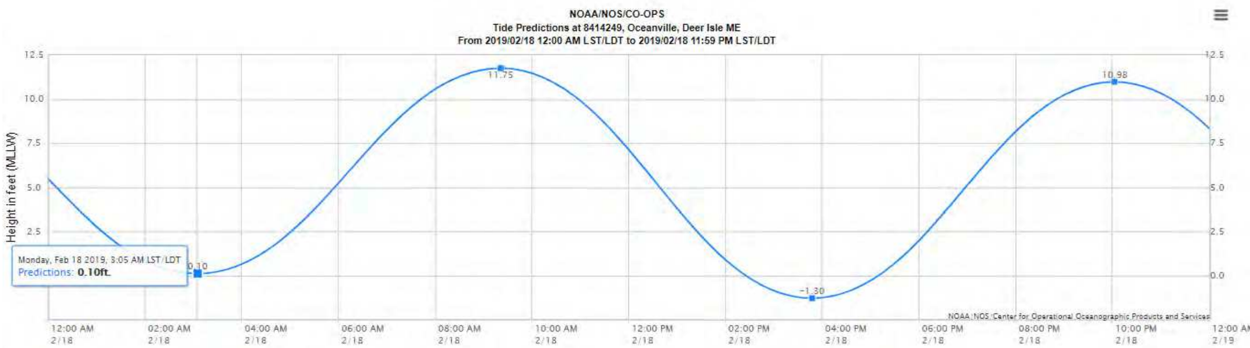


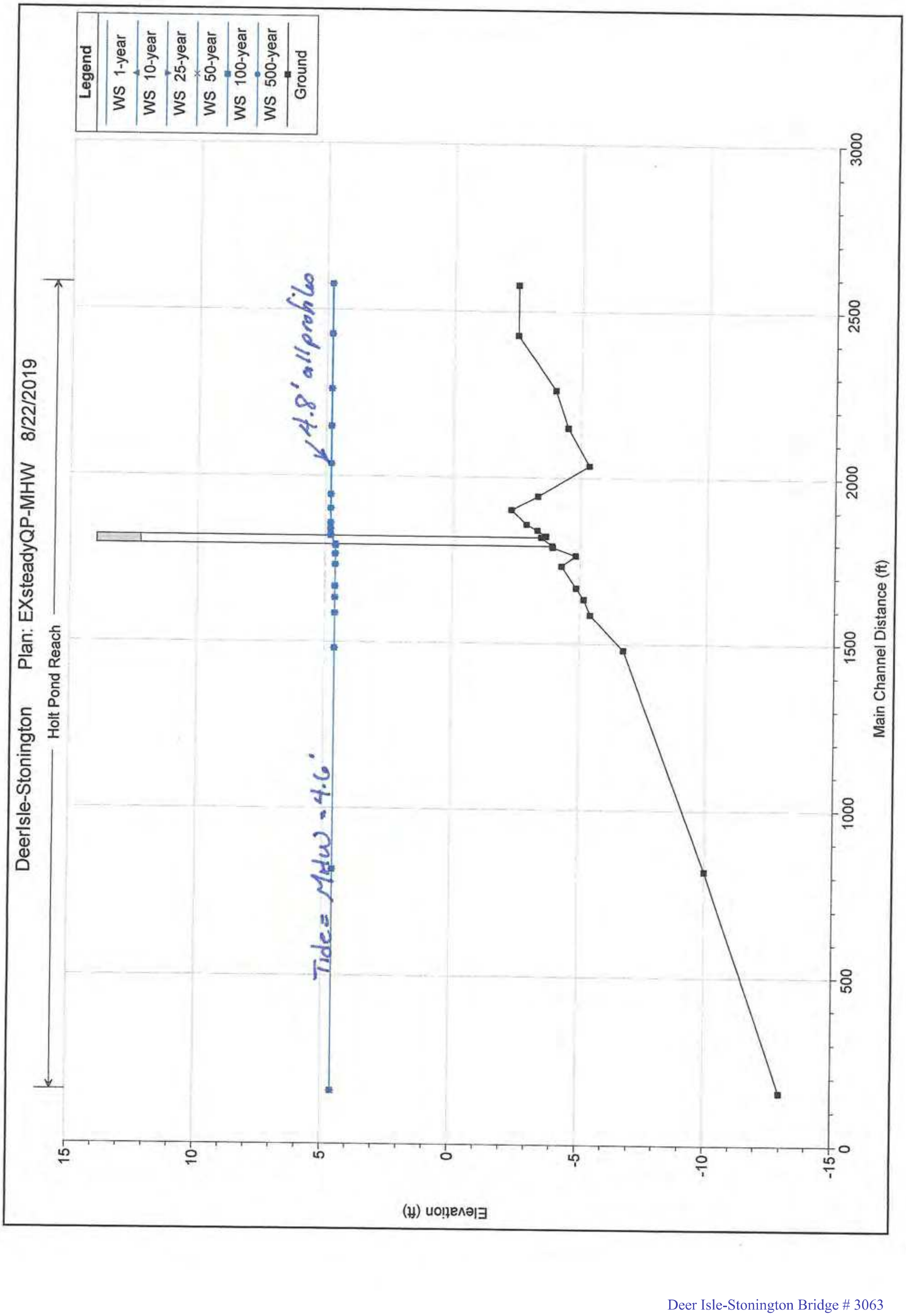
Figure App2. Predicted tides at Station 8414249, Oceanville, Deer Isle, ME. 2/181/19. Harmonic

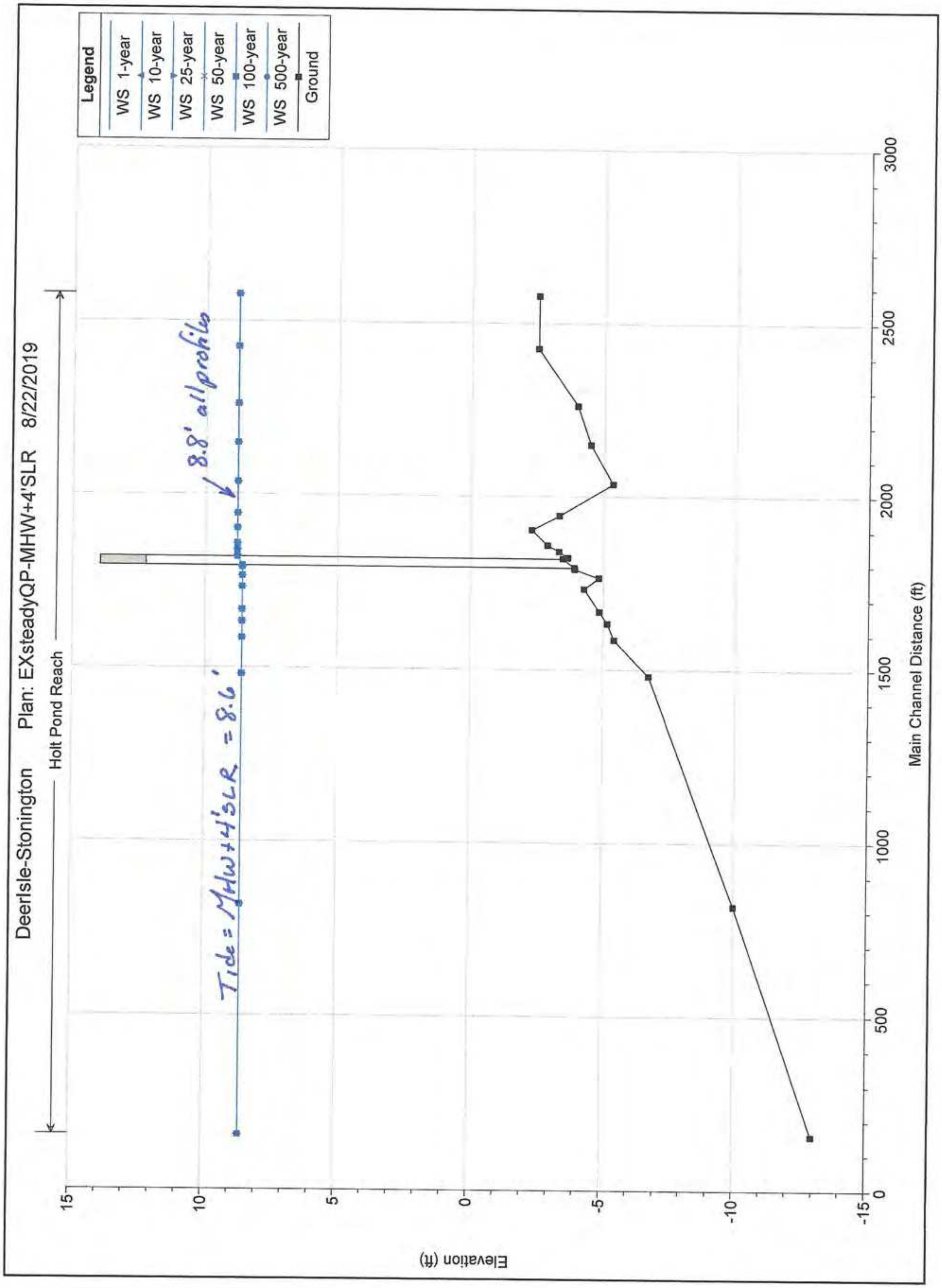
Predicted Tides, 2/18/19. MLLW/LST/LDT

Time	Time plus 1 hour	MLLW	NAVD
2:05 am	3:05 am	0.10	-5.51
9:21 am	10:21 am	11.75	6.14
3:47 pm	4:47 pm	-1.30	-6.91
10:02 pm	11:02 pm	10.98	5.37

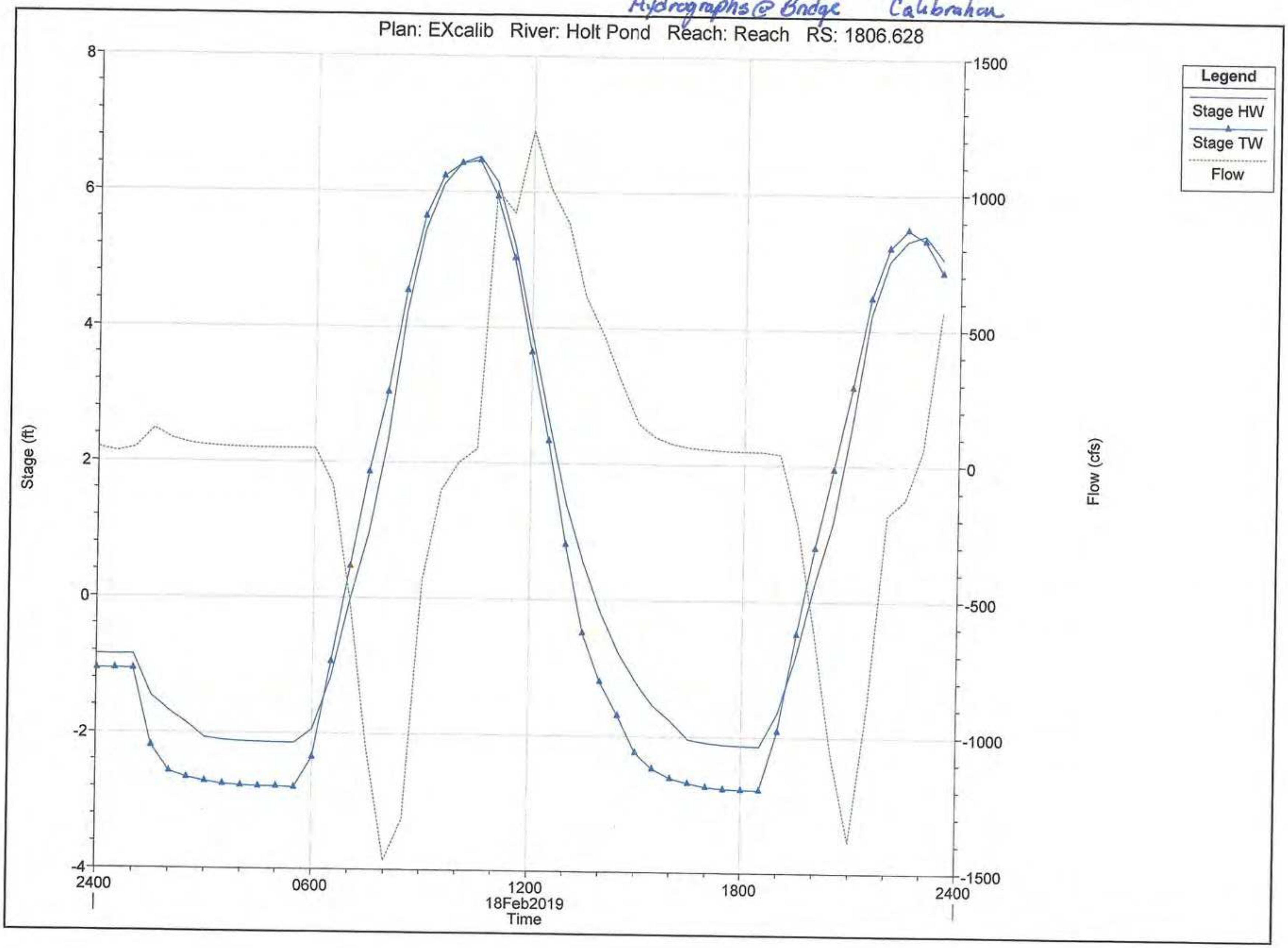
5. Adjust Station 8414348 predicted to account for measured at Bar Harbor on 2/18/19.

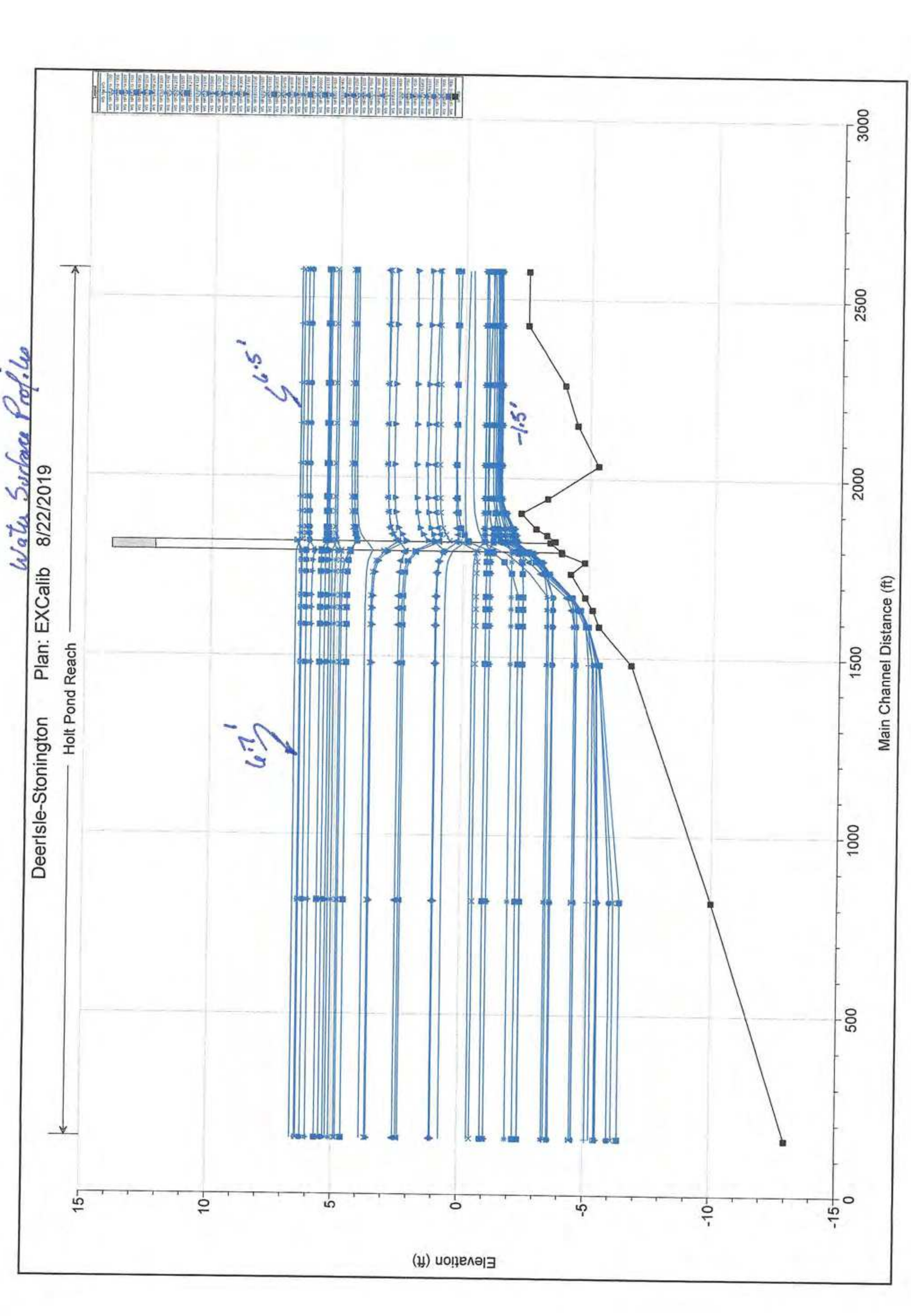
6.14’ plus 0.6’ = 6.7’ NAVD, estimated high at Oceanville on day of measurement.


DeerIsle-Stonington Plan: EXsteadyQP-MHW 8/22/2019
Holt Pond Reach
Legend
WS 1-year
WS 10-year
WS 25-year
WS 50-year
WS 100-year
WS 500-year
Ground
Tide= MHW =4.6'
4.8' all profiles
Elevation (ft)
Main Channel Distance (ft)
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
3000

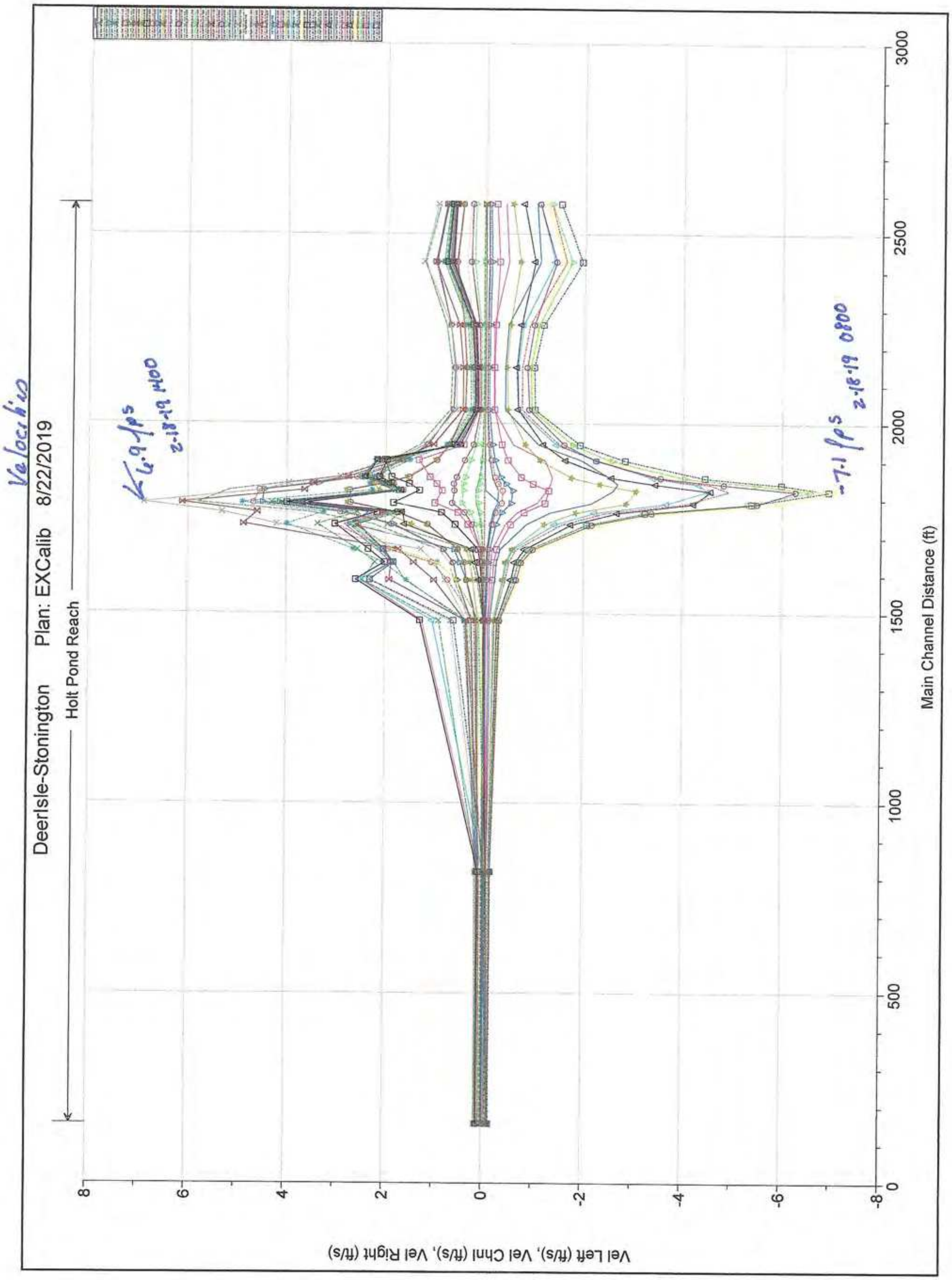

DeerIsle-Stonington Plan: EXsteadyQP-MHW+4'SLR 8/22/2019
Holt Pond Reach
Legend
WS 1-year
WS 10-year
WS 25-year
WS 50-year
WS 100-year
WS 500-year
Ground
Tide = MHW+4'SLR = 8.6'
8.8' all profiles
Elevation (ft)
Main Channel Distance (ft)
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
3000

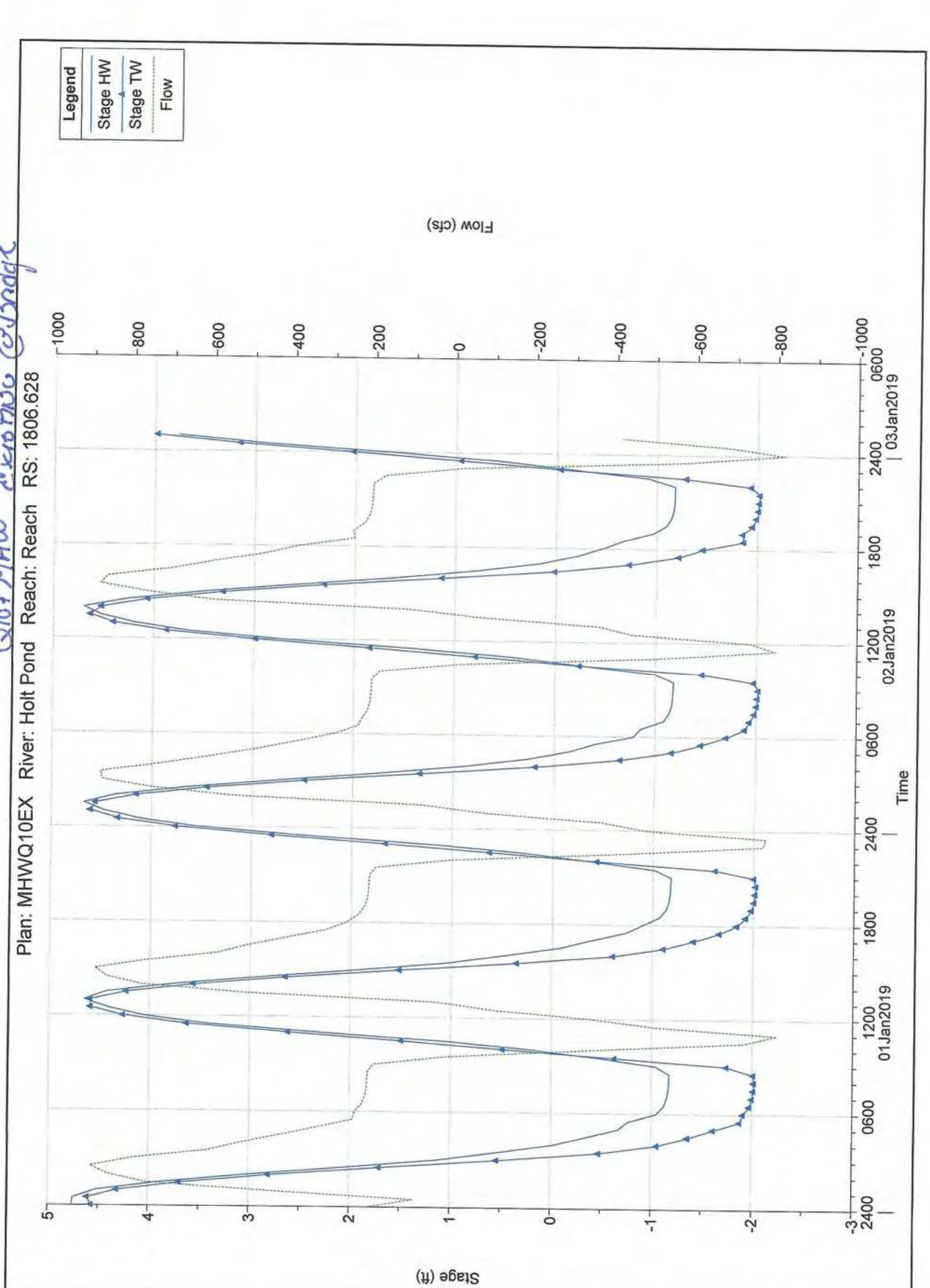
Hydrographs @ Bridge   Calibration

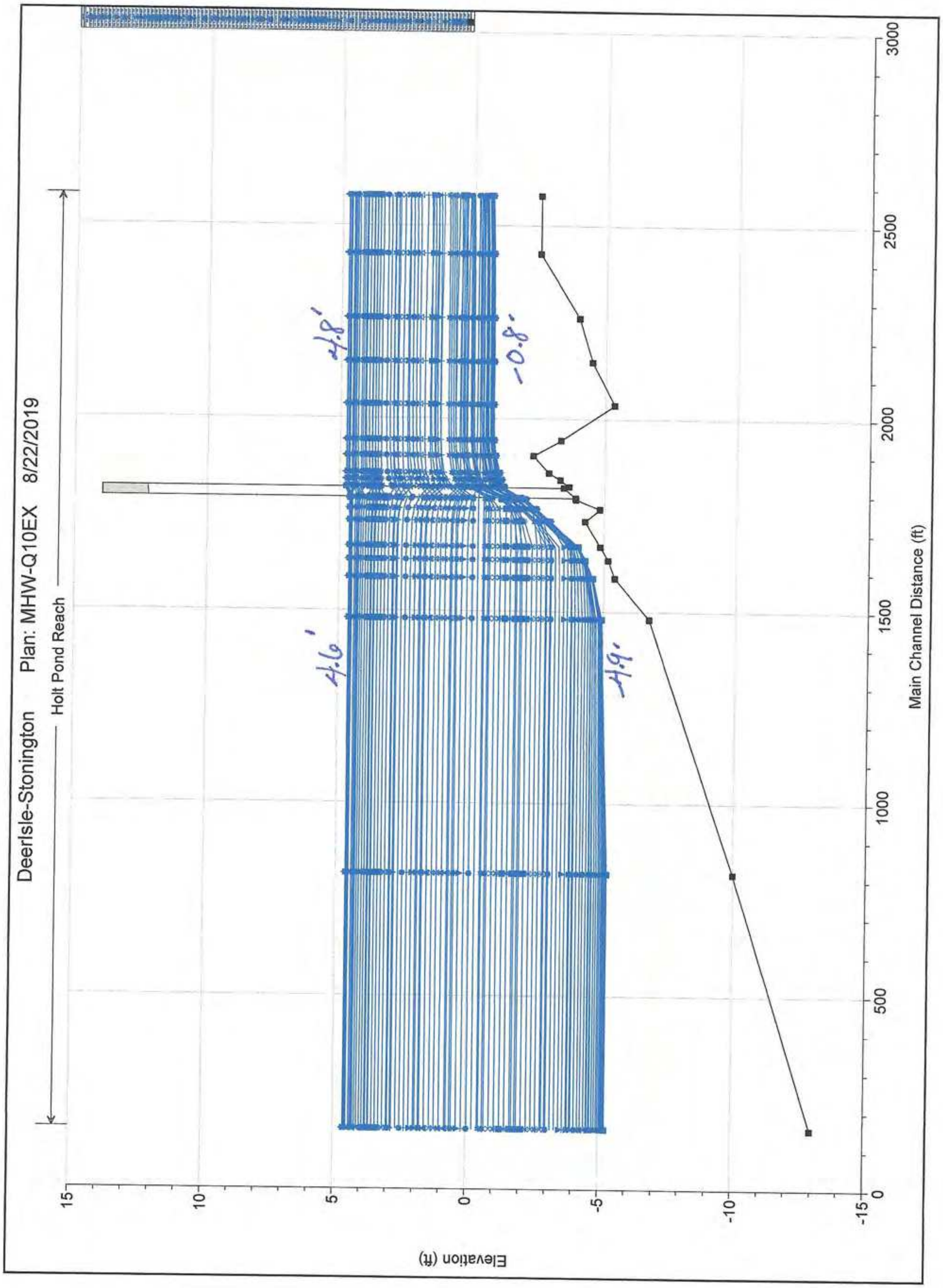




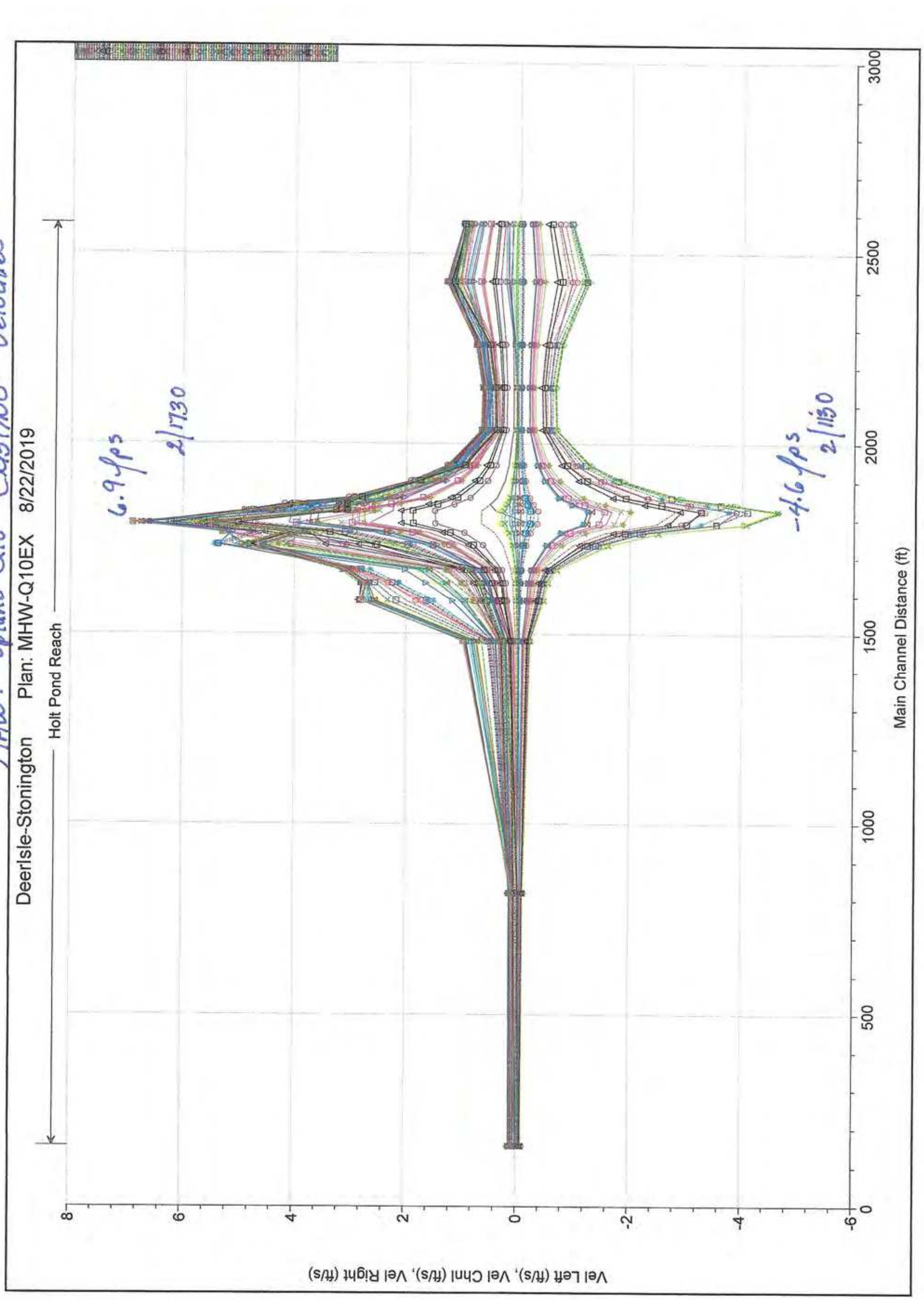
Water Surface Profile
DeerIsle-Stonington Plan: EXCalib 8/22/2019
Holt Pond Reach
6.7'
6.5'
-1.5'
Elevation (ft)
Main Channel Distance (ft)
0
500
1000
1500
2000
2500
3000
15
10
5
0
-5
-10
-15

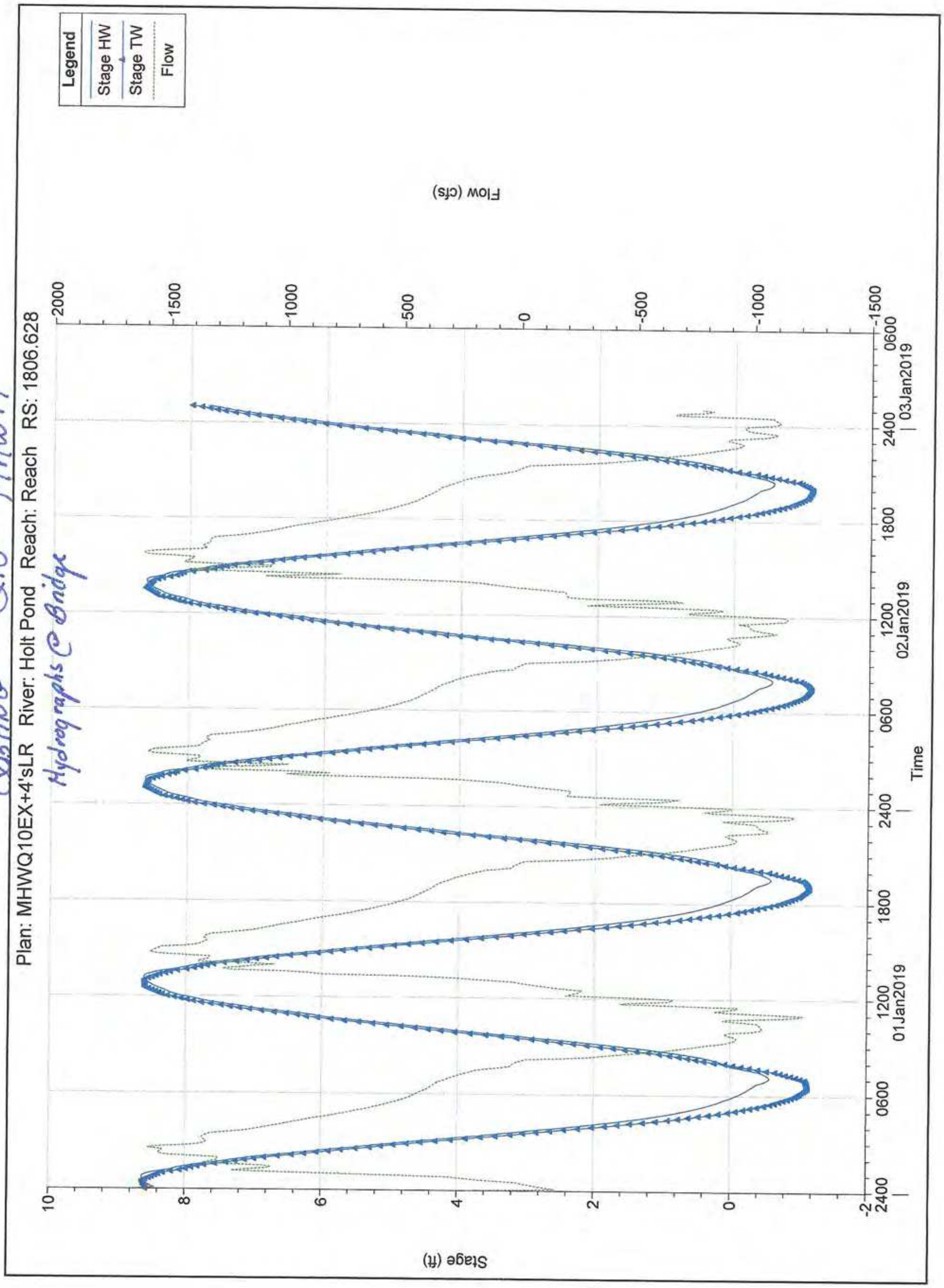

DeerIsle-Stonington Plan: EXCalib 8/22/2019
Holt Pond Reach
Velocities
6.9 fps 2-18-19 1400
-7.1 fps 2-18-19 0800
Main Channel Distance (ft)
Vel Left (ft/s), Vel Chnl (ft/s), Vel Right (ft/s)
0
500
1000
1500
2000
2500
3000
8
6
4
2
0
-2
-4
-6
-8

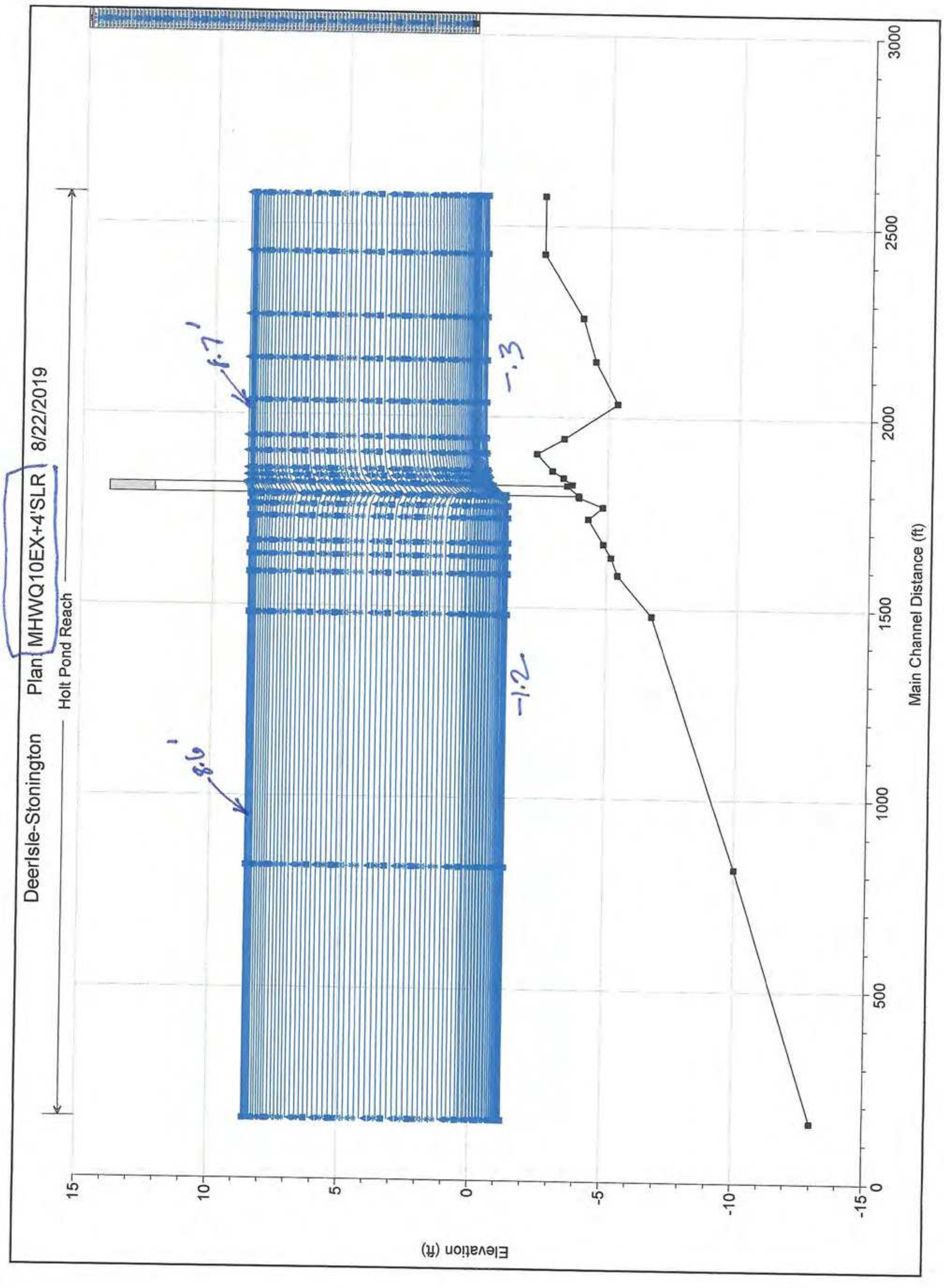

Q10+MHW Existing @ Bridge
Plan: MHWQ10EX River: Holt Pond Reach: Reach RS: 1806.628
Legend
Stage HW
Stage TW
Flow
Stage (ft)
Flow (cfs)
Time
01Jan2019
02Jan2019
03Jan2019

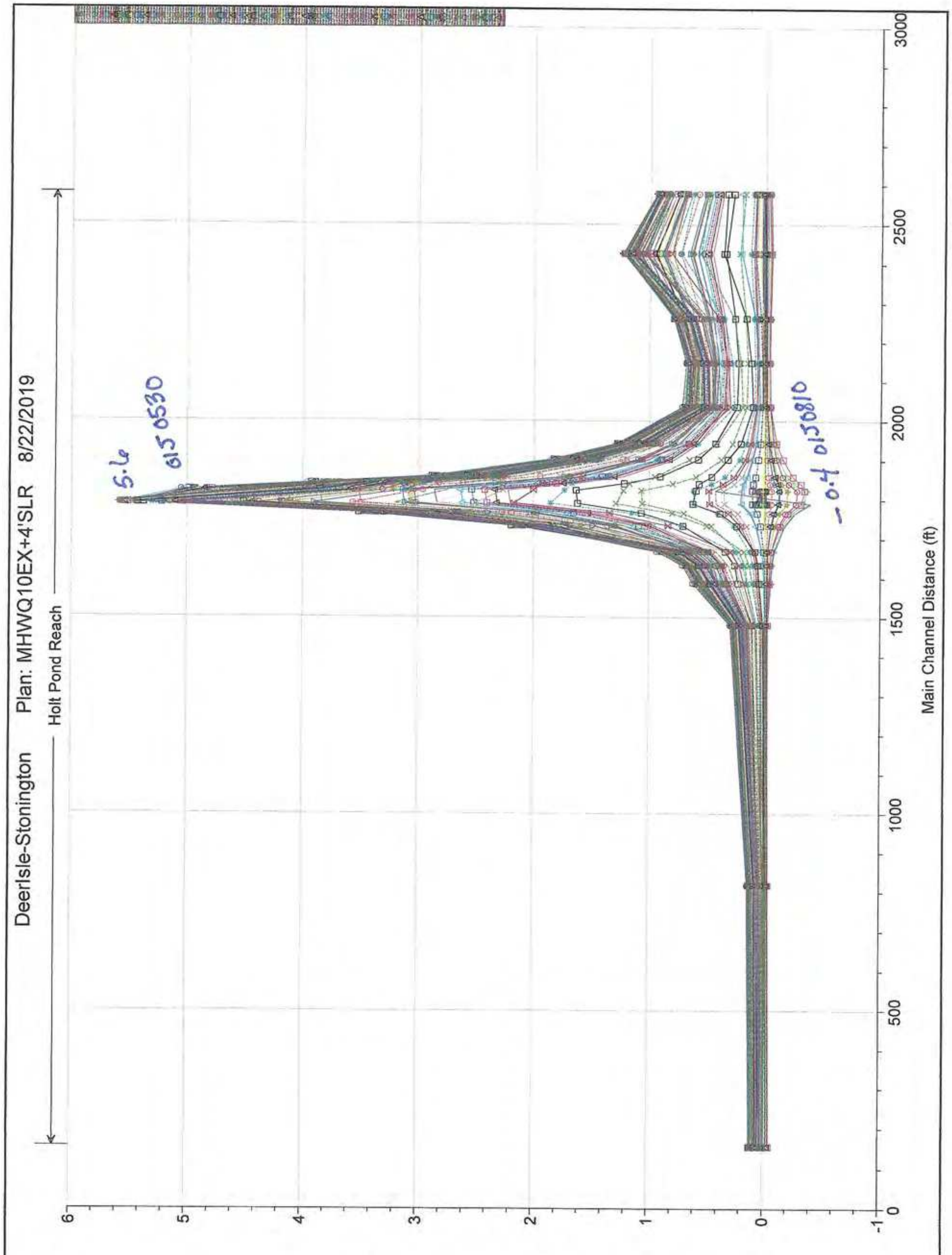


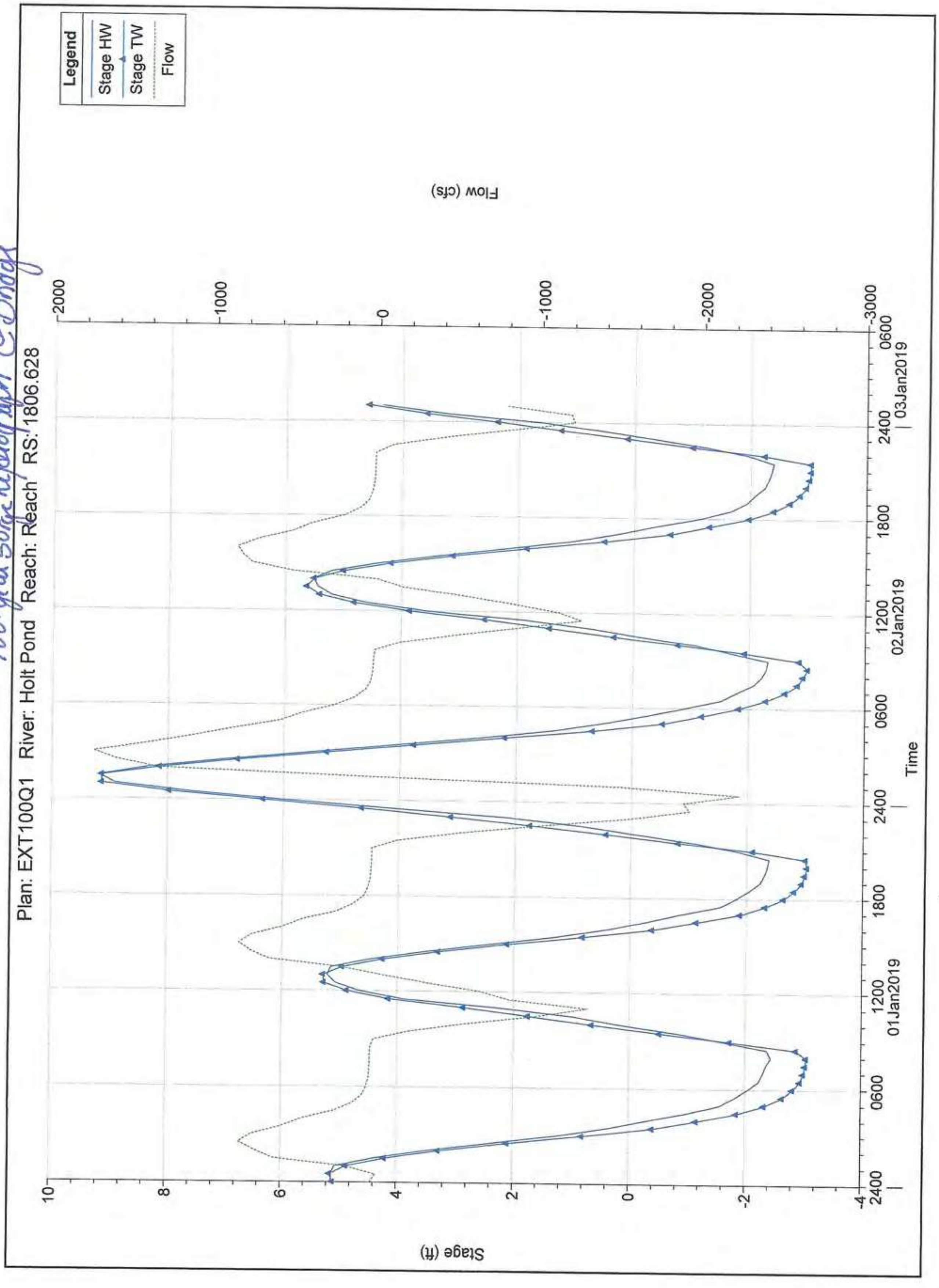
DeerIsle-Stonington Plan: MHW-Q10EX 8/22/2019
Holt Pond Reach
Main Channel Distance (ft)
Elevation (ft)

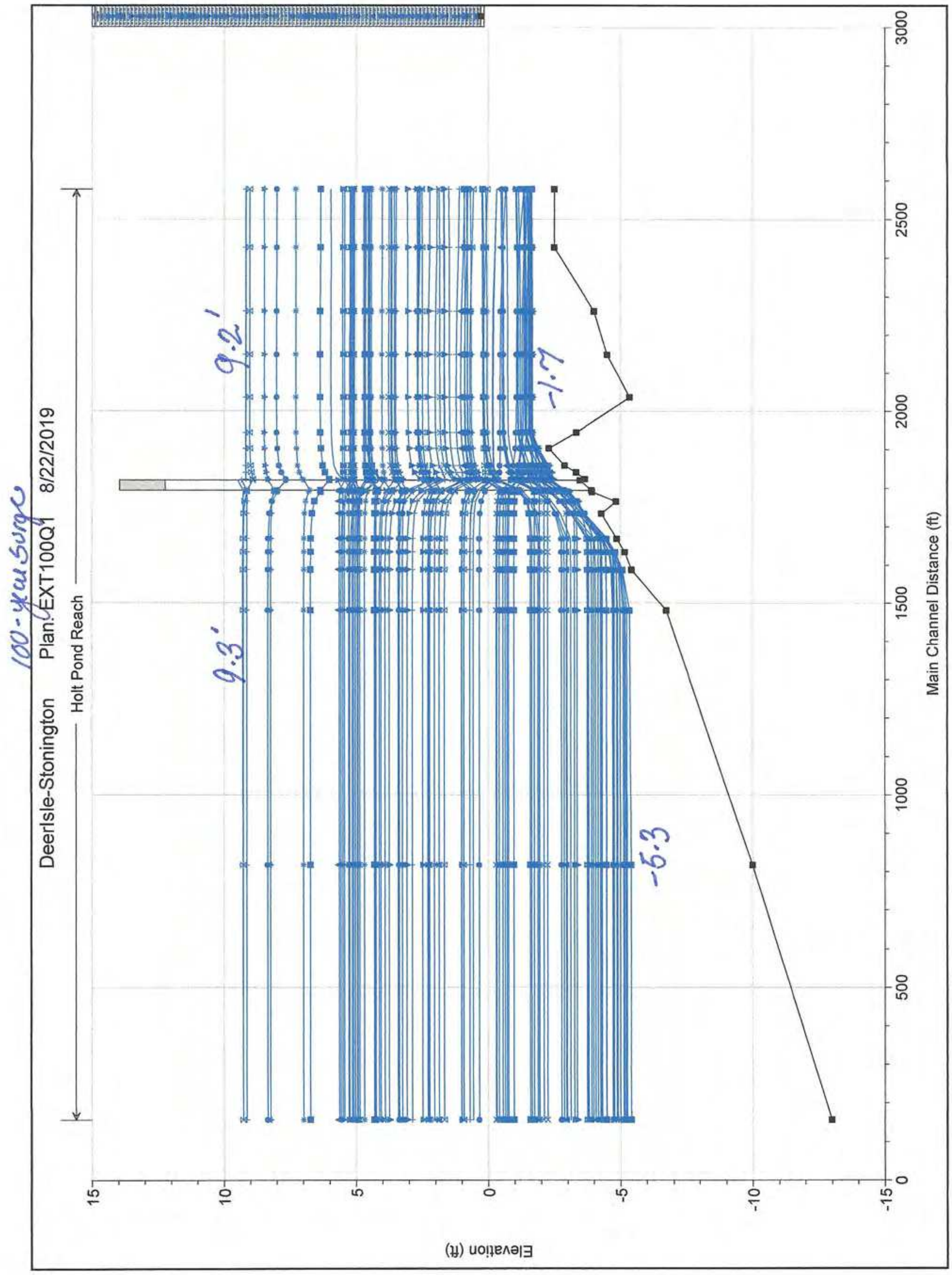

MHW+ upland Q10 Existing Velocities
DeerIsle-Stonington Plan: MHW-Q10EX 8/22/2019
Holt Pond Reach
6.9 fps
2/1730
-4.6 fps
2/1130
Vel Left (ft/s), Vel Chnl (ft/s), Vel Right (ft/s)
Main Channel Distance (ft)
8
6
4
2
0
-2
-4
-6
0
500
1000
1500
2000
2500
3000

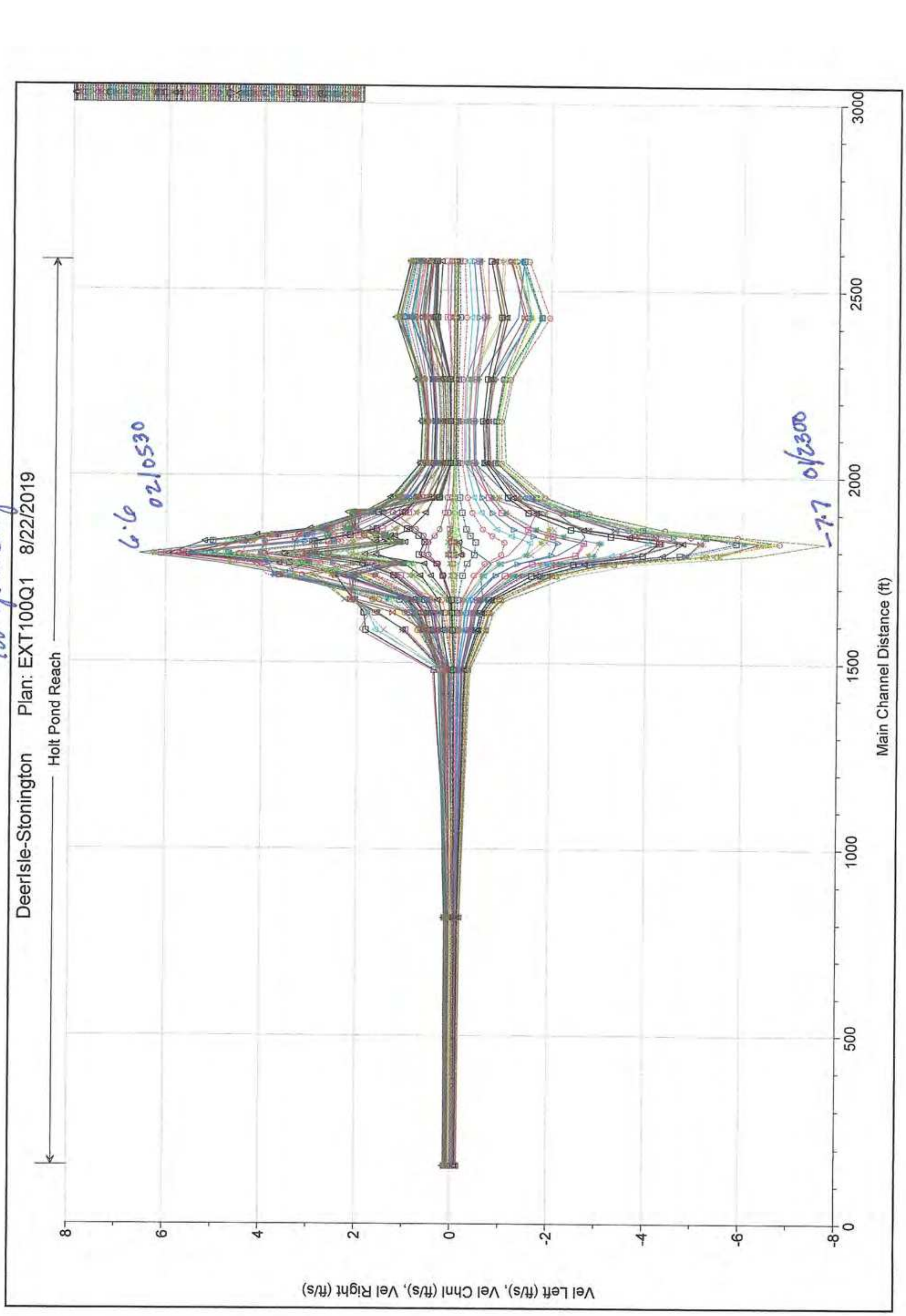

Existing Q10 MHW+4'
Hydrographs @ Bridge
Plan: MHWQ10EX+4'sLR River: Holt Pond Reach: Reach RS: 1806.628
Legend
Stage HW
Stage TW
Flow
Stage (ft)
Flow (cfs)
Time
01Jan2019
02Jan2019
03Jan2019

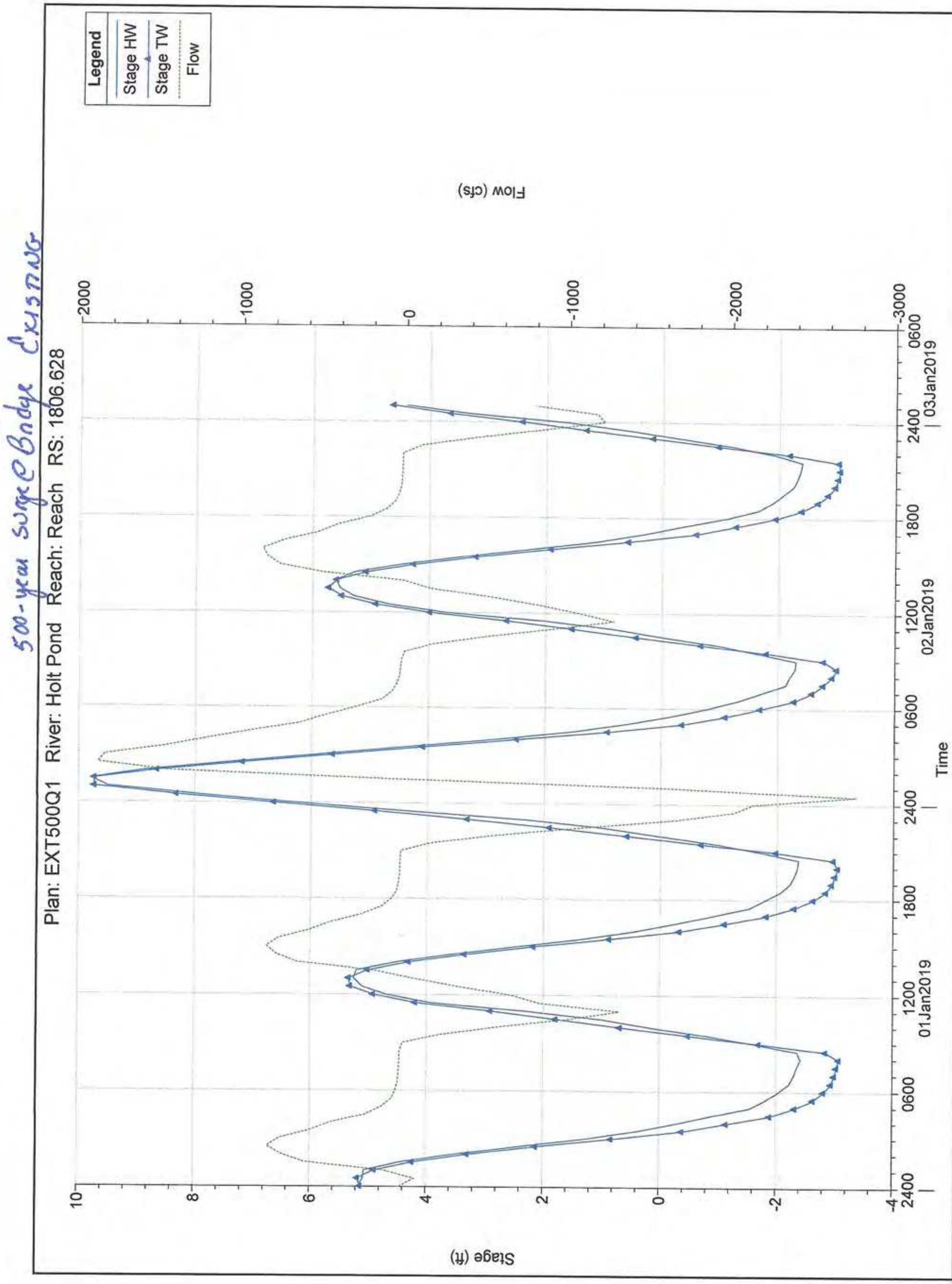

DeerIsle-Stonington Plan: MHWQ10EX+4'SLR 8/22/2019
Holt Pond Reach
Elevation (ft)
Main Channel Distance (ft)
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
3000
8.6'
-1.2
-.3

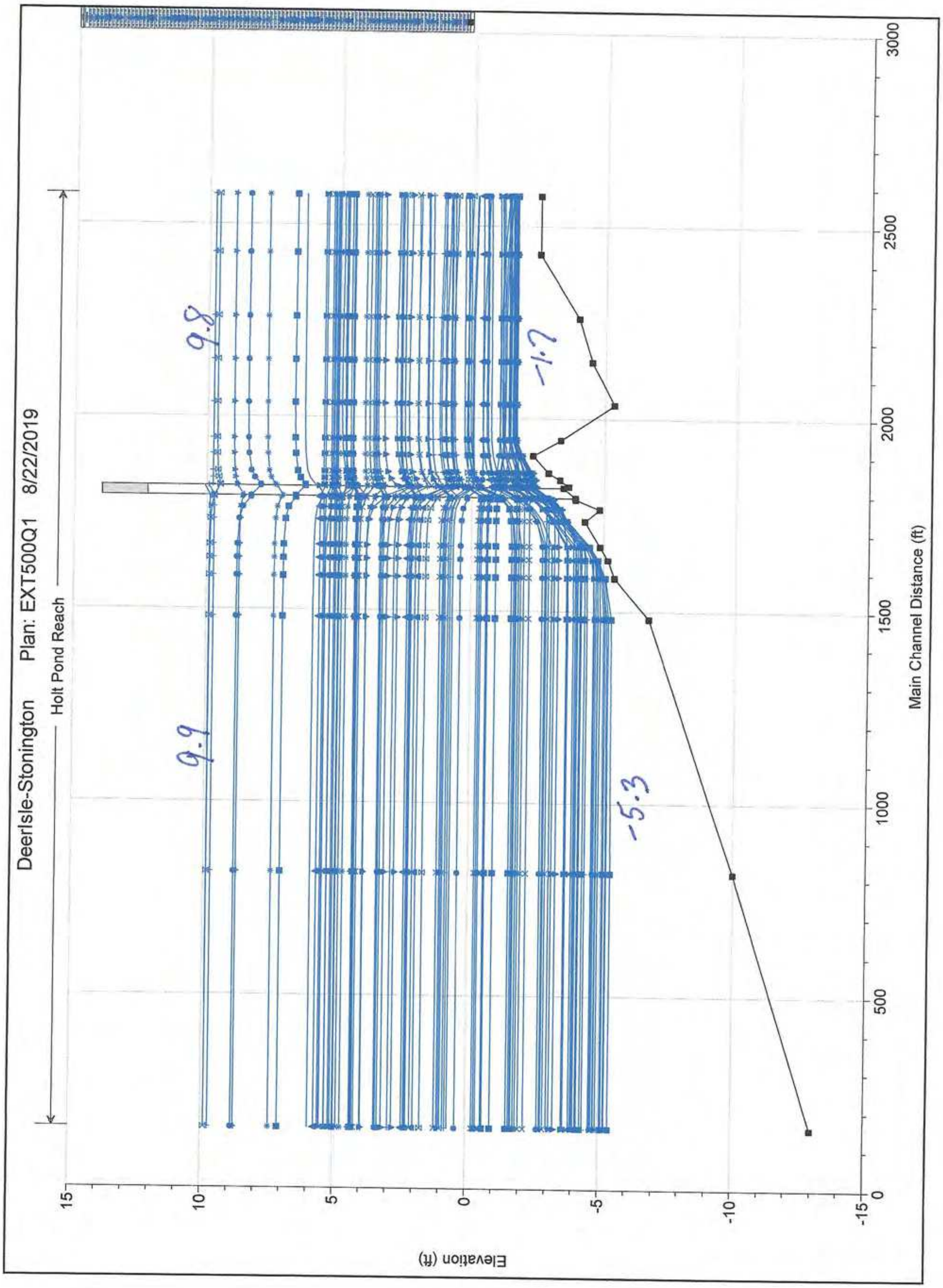

DeerIsle-Stonington Plan: MHWQ10EX+4'SLR 8/22/2019
Holt Pond Reach
5.6
015 0530
-0.4
015 0810
Main Channel Distance (ft)
Vel Left (ft/s), Vel Chnl (ft/s), Vel Right (ft/s)

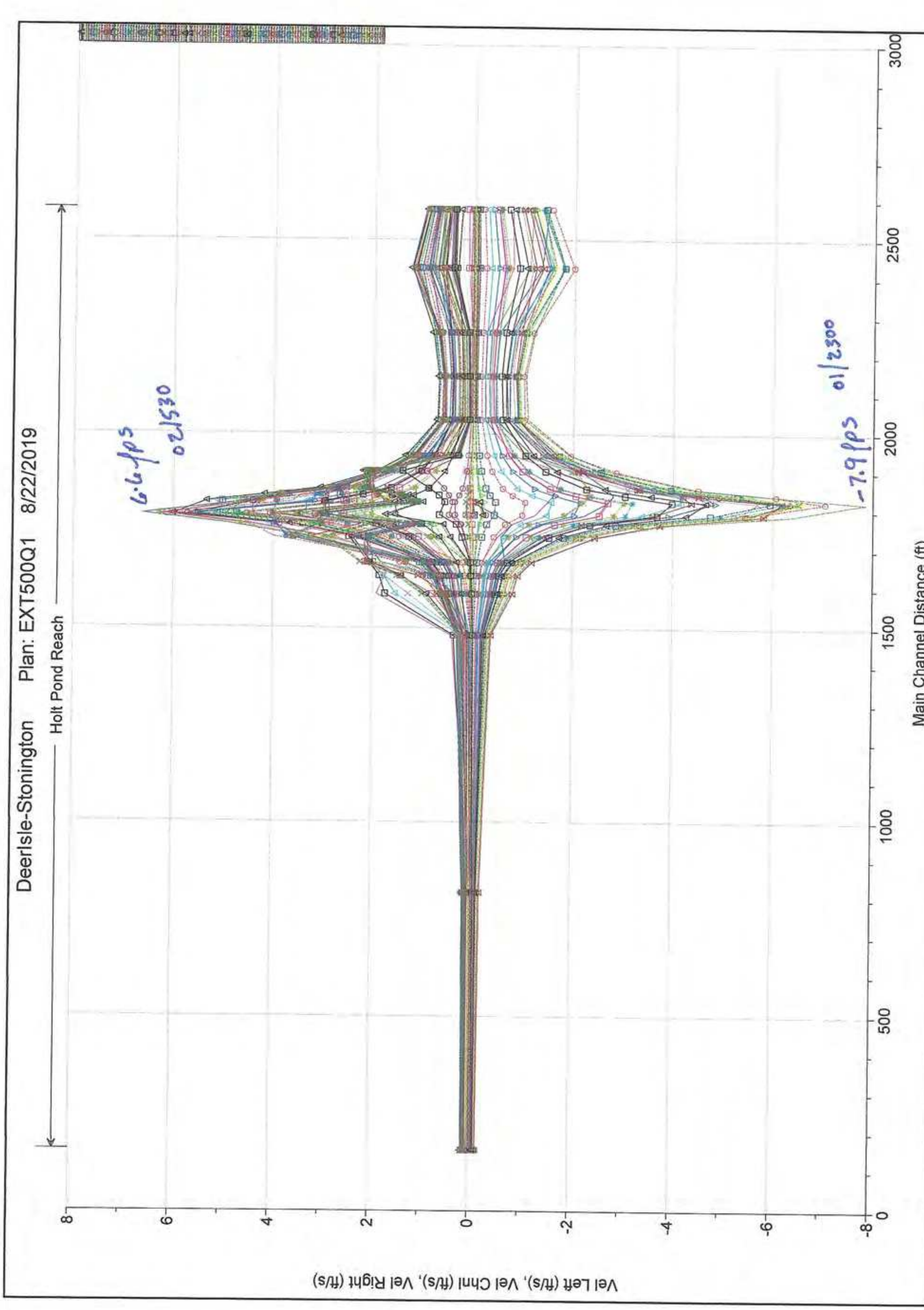

100-year surge hydrograph @ Bridge
Plan: EXT100Q1 River: Holt Pond Reach: Reach RS: 1806.628
Legend
Stage HW
Stage TW
Flow
Stage (ft)
Flow (cfs)
Time
01Jan2019
02Jan2019
03Jan2019


100-year surge
DeerIsle-Stonington Plan: EXT100Q1 8/22/2019
Holt Pond Reach
9.3'
9.2'
-1.7
-6.3
Elevation (ft)
15
10
5
0
-5
-10
-15
Main Channel Distance (ft)
0
500
1000
1500
2000
2500
3000

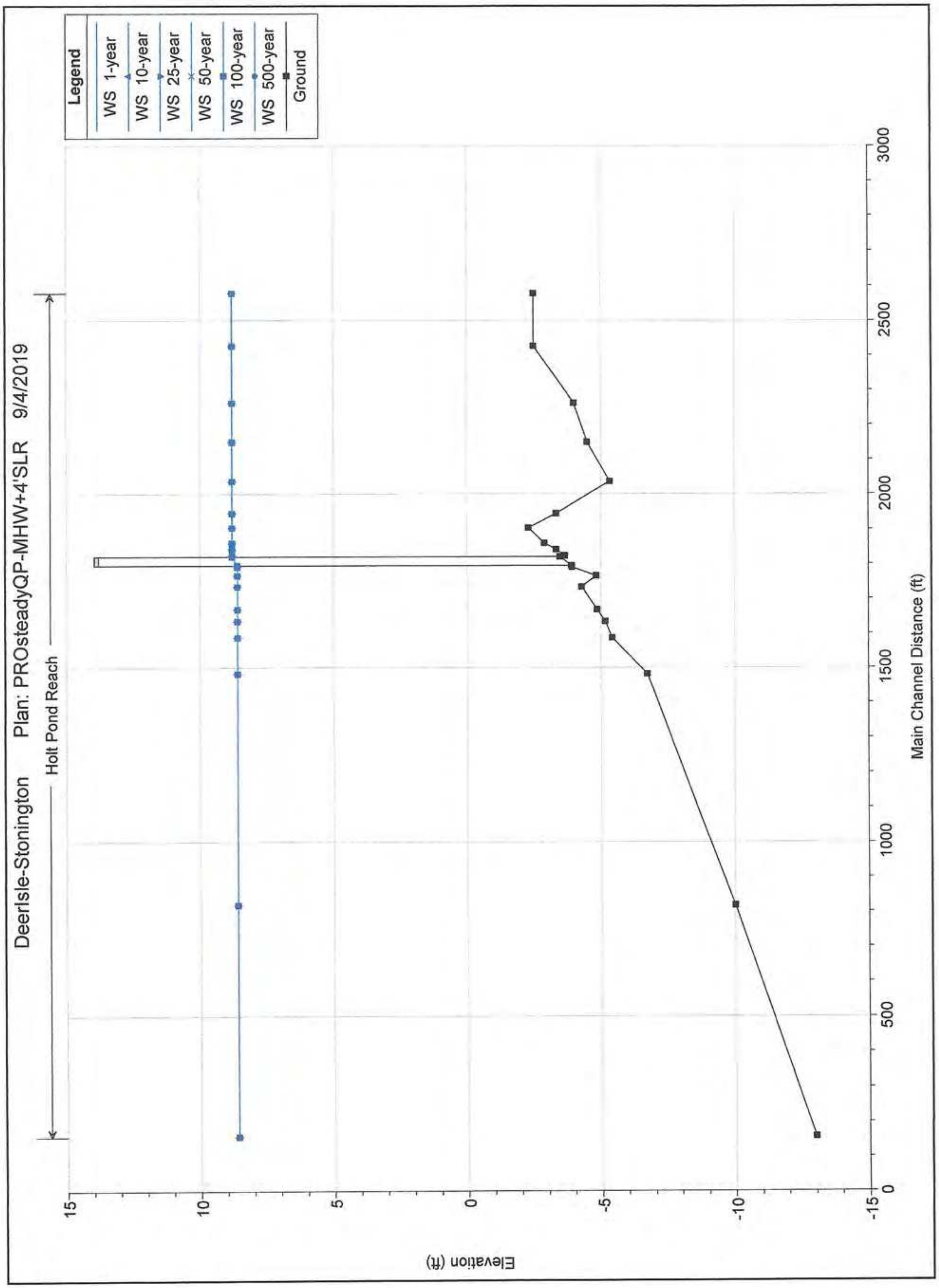

100-year surge
DeerIsle-Stonington Plan: EXT100Q1 8/22/2019
Holt Pond Reach
6.6
02/0530
-7.7
01/2300
Main Channel Distance (ft)
Vel Left (ft/s), Vel Chnl (ft/s), Vel Right (ft/s)
0
500
1000
1500
2000
2500
3000
8
6
4
2
0
-2
-4
-6
-8

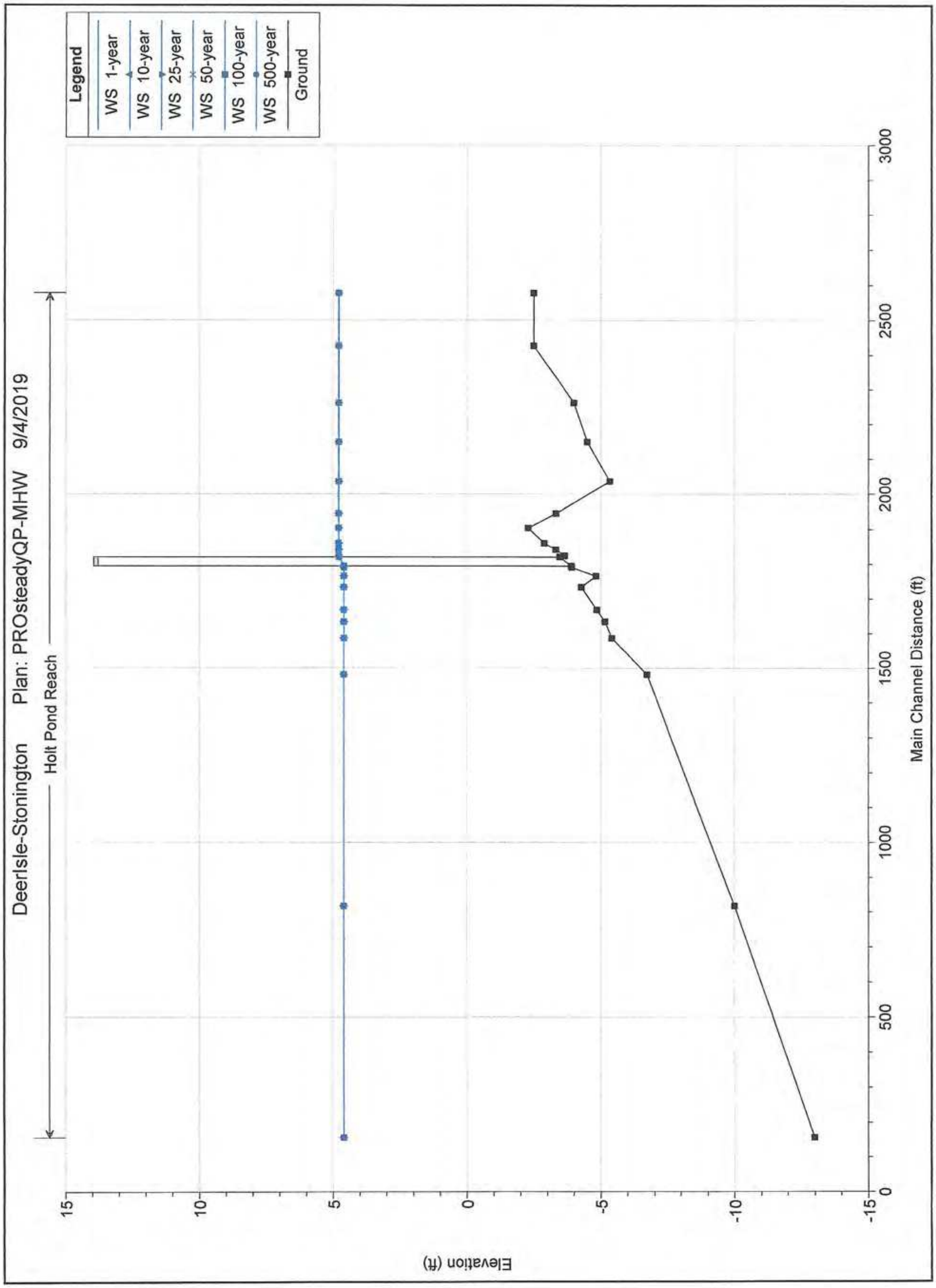

500-year surge @ Bridge Existing
Plan: EXT500Q1 River: Holt Pond Reach: Reach RS: 1806.628
Legend
Stage HW
Stage TW
Flow
Stage (ft)
Flow (cfs)
Time
2400
0600
1200
01Jan2019
1800
02Jan2019
03Jan2019


DeerIsle-Stonington Plan: EXT500Q1 8/22/2019
Holt Pond Reach
Elevation (ft)
Main Channel Distance (ft)
0
500
1000
1500
2000
2500
3000
15
10
5
0
-5
-10
-15
9.9
9.8
-5.3
-1.7



DeerIsle-Stonington Plan: EXT500Q1 8/22/2019
Holt Pond Reach
Main Channel Distance (ft)
Vel Left (ft/s), Vel Chnl (ft/s), Vel Right (ft/s)
6.6 fps
02/1530
-7.9 fps
01/2300


DeerIsle-Stonington Plan: PROsteadyQP-MHW+4'SLR 9/4/2019
Holt Pond Reach
Legend
WS 1-year
WS 10-year
WS 25-year
WS 50-year
WS 100-year
WS 500-year
Ground
Elevation (ft)
Main Channel Distance (ft)
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
3000


DeerIsle-Stonington Plan: PROsteadyQP-MHW 9/4/2019
Holt Pond Reach
Legend
WS 1-year
WS 10-year
WS 25-year
WS 50-year
WS 100-year
WS 500-year
Ground
Elevation (ft)
Main Channel Distance (ft)
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
3000