Sawmill Brook Restoration Project – Review of Technical Feasibility of Tide Gate Removal

TO: Susan Beckmann, Chair, Manchester-by-the-Sea Board of Selectmen

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Nearly five years of planning has gone into the Sawmill Brook Flood Mitigation/Restoration project. The project has multiple goals including fish passage improvement, wildlife habitat enhancement, public safety, and aesthetics that must be balanced with flood mitigation and resiliency. The multiple goals of the project are necessary to secure regulatory permit approvals and correct historical environmental impacts. Manchester-by-the-Sea (Town) completed a Massachusetts Environmental Trust (MET) grant project to demonstrate the technical feasibility of the restoration of the Central Pond area of Sawmill Brook, including removal of the tide gate at Central Street.

In the fall of 2018, the Town was awarded a Municipal Vulnerability Preparedness (MVP) Action Grant to develop planning level designs for the restoration of Central Pond. The MVP Action Grant is ongoing, and to date a public kickoff meeting, property ownership research along the eastern banks of Central Pond, geotechnical soil borings, and a geotechnical report for wall repairs/improvements have been completed. The two remaining tasks are an alternatives analysis and permit level design for the restoration of Central Pond.

The functionality of the current tide gate was not well understood by many of the attendees at the MVP action grant public kickoff meeting on October 18, 2018. The public meeting emphasized that the tide gate does not function as a barrier to the higher tides, but rather as a fresh water level control. The proposed Central Bridge replacement will include a larger opening to allow upstream flood waters to drain faster after a high tide and during extreme inland precipitation events.

The purpose of this memorandum is to clarify the function of the tide gate at Central Street Bridge, the concerns with fish passage, coastal and inland storm drainage, and physical conditions. The memo also provides a summary of the technical feasibility of the tide gate removal included as part of the Central Street Bridge replacement.

1 Function of the Existing Tide Gate

For over a decade, the Town has recognized that the Central Street tide gate, dam, and related structures must be improved to provide better drainage and allow fish passage. Based on a review of documents available from the Town, our understanding is that the tide gate was originally installed in the early 1900's to create a skating pond in the downtown area. The current function of the tide gate is a control structure to maintain the surface water elevation of Central Pond. Up to the present time, the gate was only opened to release impounded waters if a large storm was predicted and from March-May period to provide an opportunity for fish passage.

The tide gate structure is comprised of two orthogonal concrete walls approximately 9 feet high, a bottom opening gate of cast iron or cast steel (gate and tracks), and an overhead

actuator motor/controller supported by a galvanized steel platform (Photo 1). The tide gate opening is 5.9 feet and the open height of the gate is 2.75 feet, with the invert 10 to 18 inches above the stream bed. The elevation of the top of the tide gate is 4.6 feet Mean Sea Level (MSL) NAVD 88 and regularly overtops during average to high tide events. When the tide gate is closed, the hydrostatic pressure from impounded water causes water to seep through the stone culvert wing wall (Photo 1 and Photo 2). This seepage flow can cause loss of soils under the street through the wall. Attempts to repair the stone surface and culvert have failed, particularly in the tidal zone area.

1.1 Impediments to fish passage

The tide gate and weir design at the Central Street Bridge have been identified by the Massachusetts Division of Marine Fisheries as an impediment to fish passage, notably impacting the state-listed species, rainbow smelt (*Osmerus mordax*). The existing tide gate structure has a top of wall elevation just above mean high water level, making this a significant obstruction to Rainbow Smelt passage on many high tides. Tidal water levels will rise over these walls on spring high tides (full moon or new moon) and during higher than predicted tides associated with atmospheric low pressure or wind setup; and such conditions will periodically allow smelt to swim over the walls when the tide gate is closed. This tide gate is a bottom opening gate (Photo 3), which does not offer a suitable partial opening for smelt passage. When operating the tide gate to maintain upstream impoundment water levels, the

Photo 1: View of tide gate motor on the right and wall seepage on the left.

Photo 2: Looking upstream at the tide gate and Central St. culvert at low tide.

Photo 3: View of the tide gate from inside culvert

Photo 4: View of stream channel upstream from culvert looking south with dark staining on walls indicating normal high-water level when the gate is closed.

resultant opening creates high head pressures and discharge flow velocities that are unsuitable for fish passage.

1.2 Coastal and Inland Flooding

Coastal flooding due to storm surge and high tides

The tide gate wall regularly overtops on monthly high tides and storm surge tides indicating that **the tide gate is not effective in preventing coastal flooding**.

As part of the MET grant, water level data was collected from pressure transducers above and below the Central Street Bridge from November 2017 to April 2018 to evaluate how high tide periods impacted upstream water levels. This period captured a wide range of conditions, including the record high tides set in January 4, 2018 (see photo 5 for December 3, 2017 high tide). Over the five-month monitoring period 290 high tides were recorded, and 194 (or 67%) of the readings were higher than the tide gate crest wall elevation of 4.6 feet MSL NAVD88.

Photo 5: High Tide on December 3, 2017 the tide is well above the top of the tide gate

Storms with significant wave action can also overtop the roadway, particularly if they are coincident with high tide. Overtopping of the roadway has been observed in the past, and recent topographic survey indicates the pavement elevation at Central Street (10.4 feet) is within about 1 foot of tidal flooding. This can be compared to the January 4, 2018 record high tide elevation 8.9 feet or the Federal Emergency Management Agency (FEMA) 100-year Stillwater flood elevation of 9.9 feet (provided at transect 38 in Table 11 of the FIS report

revised July 2018). The frequency of tidal flooding of the roadway will likely increase over time based on the current sea level rise (SLR) relative to land (including land subsidence) of 0.92 feet per 100 years recorded in Boston (NOAA) and SLR data provided by the Northeast Climate Science Center (NECSC) SLR projections for the Boston area[1].

Inland flooding due to drainage constrictions

During large precipitation events, the tide gate restricts drainage from Sawmill Brook. When the tide gate is closed during high tide, the water elevation in Central Pond will back up, exceeding the height of high water in Manchester Harbor. For example, surface water elevation recorded in Central Pond on January 4, 2018, (at Central Street with a closed gate) exceeded the elevation in Manchester Harbor. This elevation coincided with a record-breaking high tide and a recorded 0.74 includes of precipitation. When the tide gate is open, the narrow opening of the structure restricts discharge from Central Pond, though to a lesser extent than when it is closed.

Photo 6 below shows an example of the Central Pond flooding overtopping the retaining walls along the pond and flooding adjacent properties. The tide gate was closed when this photo was taken. The extent of inland flooding is more widespread with larger storm events. During the May 2016 "Mother's Day Flood" 12 inches of rain was recorded, flooding properties adjacent to Sawmill Brook with up to 6 feet of water and damaging 150 homes. A 2015 local survey of areas prone to flooding, cites extreme precipitation events, stream bank overflow, and culvert backup as the most prevalent causes of flooding in Manchester-by-the-Sea.

Photo 6: Central Pond adjacent to the Manchester Fire Department shown on 1/4/2018. Rising water levels eventually overtopped the wall (elevation 5.4 ft. NAVD88) flooding the parking area and Fire Department basement and garage area despite preventive sand bags across the door.

[1] 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/.

2 Hydrologic Modeling of the Gate Removal

The 2017 MET grant project included detailed hydrologic data collection and hydrologic modeling on the stretch of Sawmill Brook from Norwood Avenue to Central Pond. The purpose was to evaluate the feasibility for removing the tide gate at Central Street and restoring Central Pond into a wetland/riverine system.

Over the six months of the project data collection, over 259,200 water level measurements were recorded from Manchester Harbor to Norwood Avenue. The measurements were made under various hydrologic conditions, including variable streamflow and tidal conditions, with the Central Street tide gate in open and closed positions. Central Street data graphed in Figure 1 below shows that when the gate is closed (left graph), the tide flows over the top of as soon as it reaches an elevation of 4.6 feet.

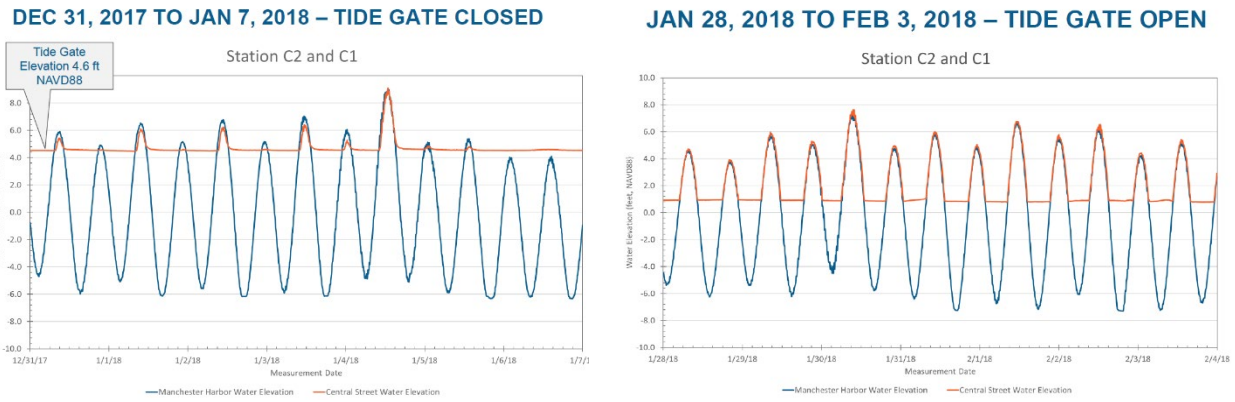


Figure 1: Recorded water levels on either side of Central Street Bridge - Manchester Harbor is in blue and Central Pond in red, with the gate closed (left) and open (right).

For reference, Mean High Water is elevation 4.3 NAVD88 (without storm surge), and Mean Higher High Water (the higher of the two high tides each day) is elevation 4.8 feet NAVD88 feet (NAVD88 based on the NOAA Long Term Tide Water Level Monitoring Station ID: 8443970). Since the tide gate elevation is 4.6 NAVD88, the existing tide gate structure is overtopped on a regular basis, even without storm surge, causing the ocean to back flood the pond even with the existing tide gate closed. The storage volume in the pond is very small and will rapidly fill from ocean overtopping and stream flows. When the gate is open (right graph), the water levels above the bottom of the culvert are identical on either side of Central Street.

The data also showed how the closed control gate impeded stream discharge after a high/tide storm event. Central Pond exceeded the water level in Manchester Harbor during a concurrent record high tide and recorded 0.74 inches of precipitation.

The collected data was also used to update the Sawmill Brook Hydraulic Model. As shown in Figure 2 below, the model output was used to map areas of flooding before and after Central Street Bridge improvements are made under extreme precipitation events and evaluate if the properties upstream from Central Street would benefit from restoration including removal of the tide gate and increasing the size of the Central Street culvert. The model conditions include flooding that would occur during a 24 hour 25-year storm event and mean higher high-water tidal conditions with the tide gate open and closed.

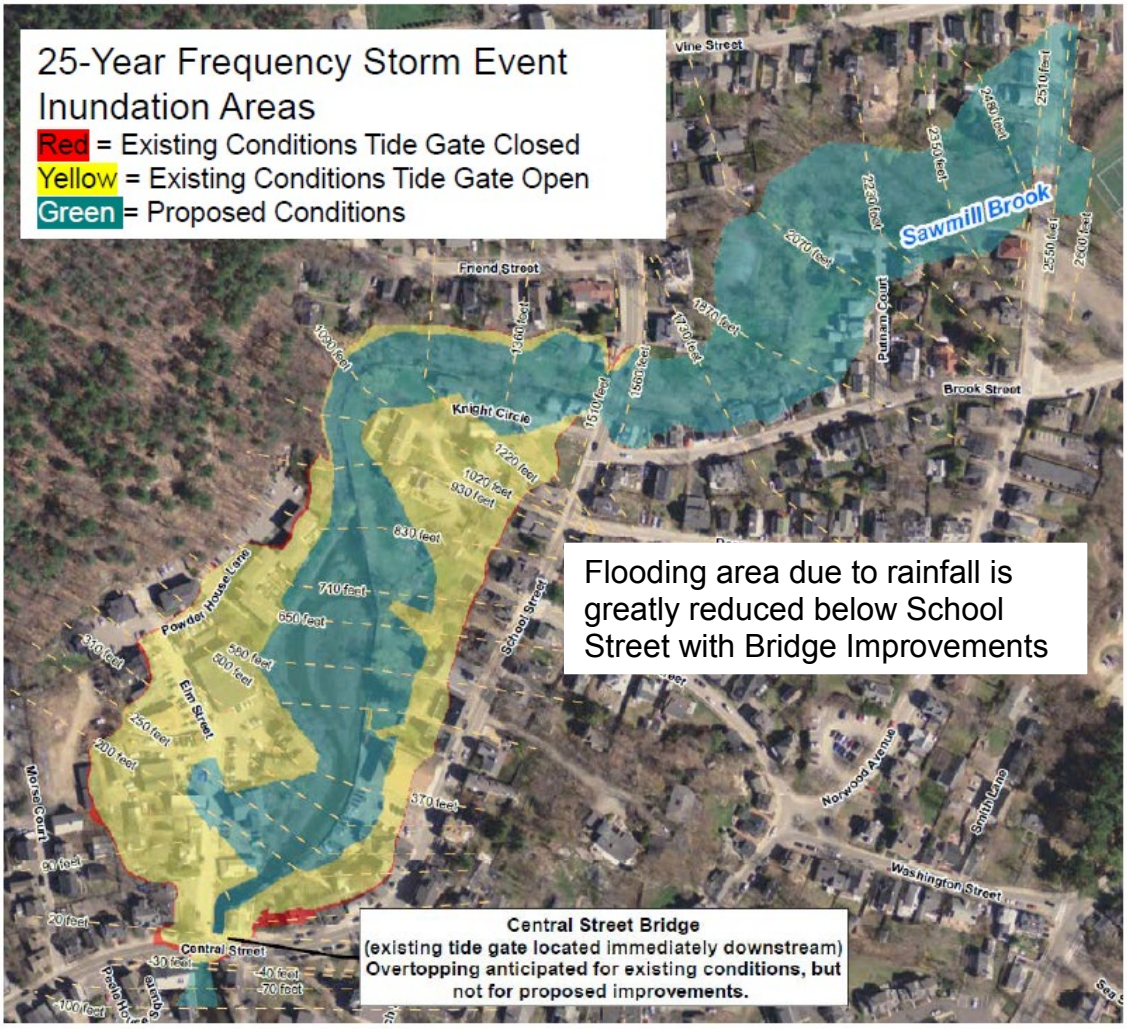


Figure 2. Sawmill Brook Model showing areas of flood inundation from a large storm event (heavy rainfall and storm surge) before and after the Central Street Bridge improvements.

The modeling shows that increasing the size of the Central Street culvert and removing the tide gate would result in a significant increase in discharge flow capacity (oceanward), that would be anticipated to reduce pond overbank flooding. The proposed improvements (removing the tide gate and replacing the existing culvert with a 20-foot wide arch culvert) would be anticipated to reduce the water surface elevation upstream of Central Street during a 24-hour duration 25-year frequency storm event occurring with mean higher high-water tidal conditions from 11.8 feet to 5.6 feet. Similarly, the water surface elevation upstream of Central Street would be anticipated to decrease from 12.5 feet to 7.7 feet if a 24-hour duration 50-year frequency storm event occurred during mean higher high-water tidal conditions. See Figure 3 and Tables 1 and 2 for the stream discharge and surface water elevations. To further

demonstrate the differences, Figure 4 and Figure 5 provide cross sections at the Central Street Bridge and Central Pond before and after the improvements are made during mean higher high water and mean lower low water tide conditions.

The January 4, 2018 King Tide was also modeled for existing conditions with the tide gate open; existing conditions with the tide gate closed; and proposed conditions with the tide gate open and a larger culvert. The inundation areas for the three conditions were approximately the same, suggesting that removing the tide gate would not alter upstream water surface elevations during extreme high tides. This is also shown in the water level measurements, as the Central Pond water surface elevations exceeded the Manchester Harbor tide level during the January 4, 2018 storm event when the tide gate was closed.

3 Technical Feasibility Conclusions

Local observations indicate that the Central Street tide gate acts as an impediment to drainage and fish passage. Data and survey results demonstrate that the tide gate does not provide protection from high tide impacts or storm surge; and that the impoundment restricts drainage from Central Pond; causing upstream surface waters to back up. The collected data supplemented the existing Sawmill Brook Hydrologic Model and the modeling demonstrated that removal of the tide gate would improve, not worsen, flooding impacts to abutting properties upstream of Central Street.

Hydrologic modeling reinforced the observed similarity in high tide impacts to Central Pond whether tide gate is open or closed, concluding that the tide gate does not restrict high tide volumes. For example, the modeled maximum water surface elevation calibrated for the January 4, 2018 record high tide conditions were approximately the same, whether the tide gate was open or whether the proposed improvements had taken place. The 25-year inundation area during mean higher high water is highest for existing conditions when the tide gate is closed, though similar to the inundation area if the tide gate were open. The proposed Central Street Bridge improvements (with the tide gate removed and the culvert enlarged) are projected to reduce the 25-year inundation area due to increased hydraulic capacity through the Central Street Bridge.

The improvements will not eliminate all flooding. Extreme precipitation events will overwhelm the channel carrying capacity of Sawmill Brook and continue to flood low lying properties, even after the improvements. Widening culverts upstream of Central Street and modifications to the stream channel above and below the culverts will be needed in the future to improve mitigation of the upstream flooding impacts.

It is still possible that extreme high tide/storm surge events can overtop Central Street and inundate properties upstream; however, if flooding does occur due to extreme high tide or storm surge it will be anticipated to recede faster with the proposed improvements than for existing conditions due to the increased hydraulic capacity. Sawmill Brook water control structures will not protect the properties from extreme high coastal flooding due to the low-lying topography of many properties; coastal flooding protection must be provided through other methods such as a hurricane barrier installed at the harbor entrance.

Figure 3. Stream Discharge Rating Curve for Existing and Proposed Conditions

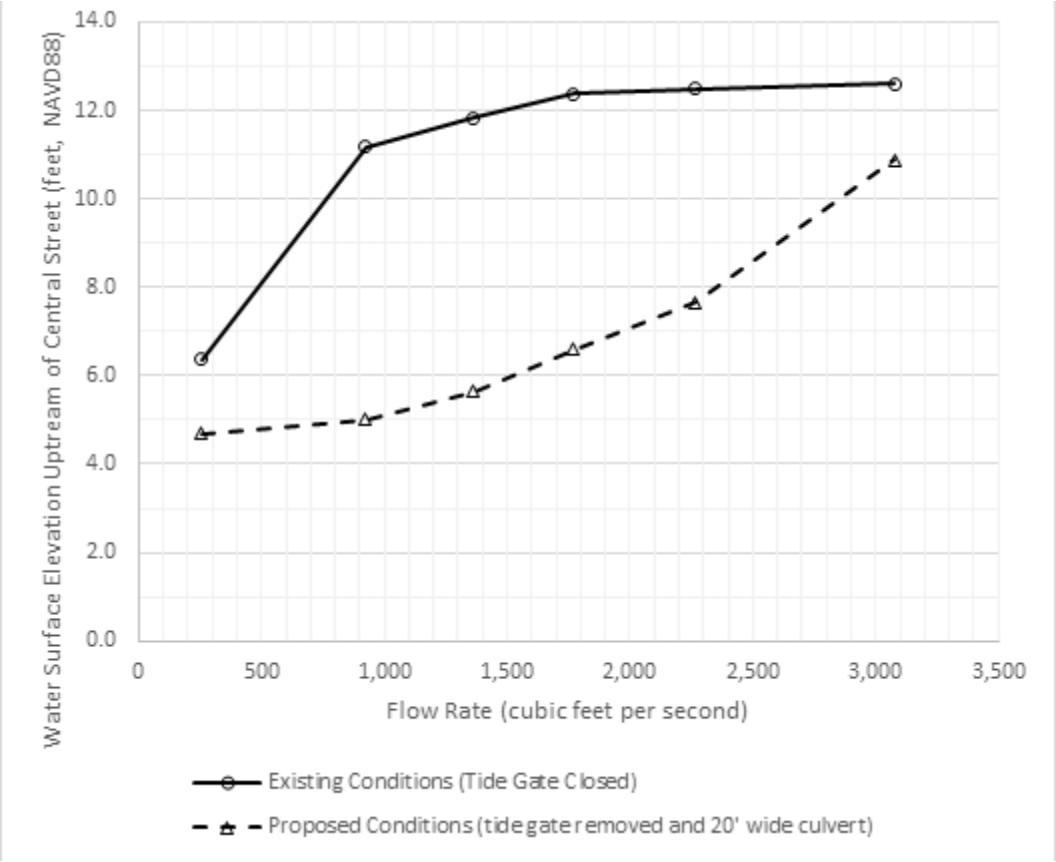


Table 1

Existing Conditions Closed (current conditions, MHHW)

Storm Event	Flow (cfs)	WSEL (feet)
2-year	254	6.4
10-year	924	11.2
25-year	1,363	11.8
50-year	1,772	12.4
100-year	2,267	12.5
500-year	3,078	12.6

Table 2

Proposed Conditions (current conditions, MHHW)

Storm Event	Flow (cfs)	WSEL (feet)
2-year	254	4.7
10-year	924	5
25-year	1,363	5.6
50-year	1,772	6.6
100-year	2,267	7.7
500-year	3,078	10.9

FIGURE 4 CENTRAL STREET
BEFORE AND AFTER TIDE GATE REMOVAL

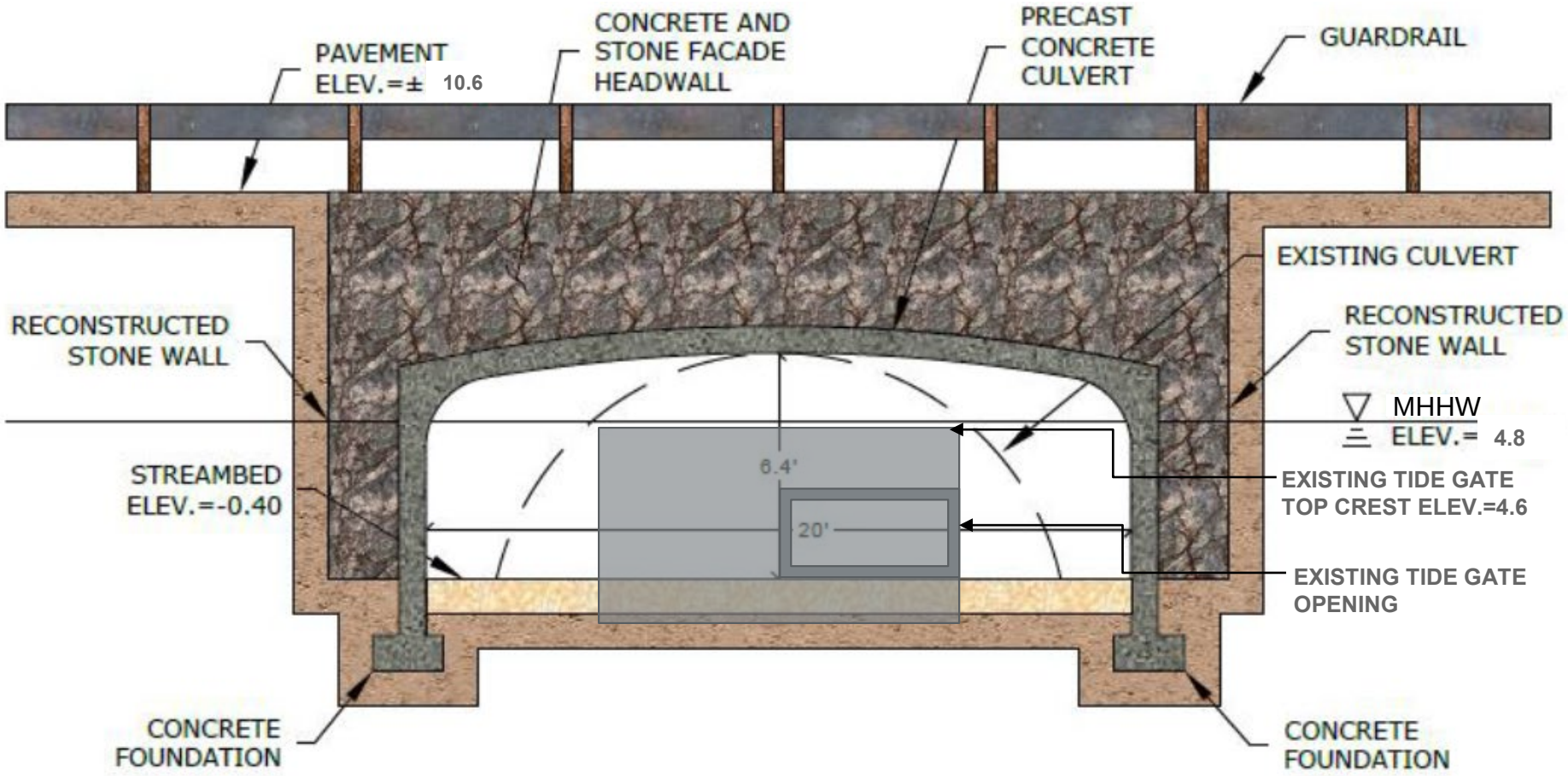
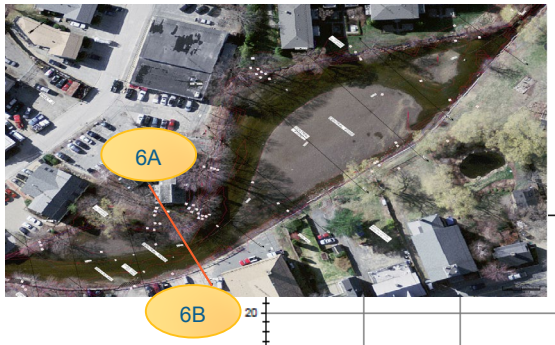
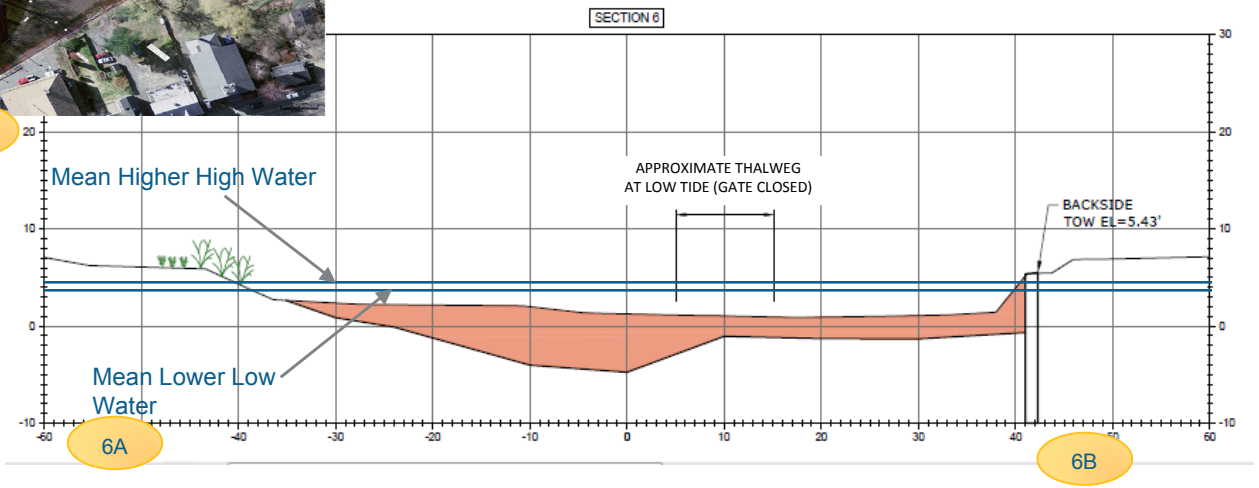
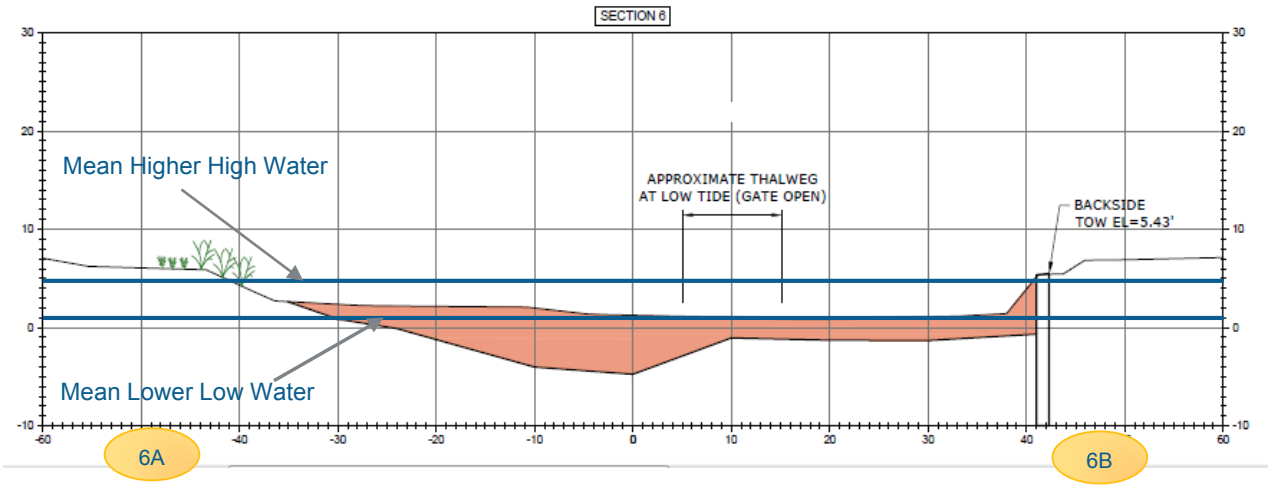


FIGURE 5 CENTRAL POND
BEFORE AND AFTER TIDE GATE REMOVAL





Pond Level with
Gate Closed



Pond Levels with
Gate Removed

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