MEMO

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August 18, 2020

Arcadis Project No.:

00186150.0000

Subject:

Beaver Street Interceptor Alternatives Analysis – Hydraulic Model and Capacity Assessment – Internal Technical Memorandum

INTRODUCTION

This technical memorandum summarizes the modeling methodology and assumptions used in the development of the Beaver Street Interceptor hydraulic model. This model is being developed as part of the Beaver Street Interceptor Alternatives Analysis. A system-wide hydraulic model is a valuable tool for future master planning, capacity assessments, build-out/development analyses and wet weather overflow abatement evaluations.

This hydraulic model will be used to evaluate the current and future available capacity of the BSI in support of the renewal/replacement alternatives analysis. The model will support evaluation of the sewer system as the community grows and changes over the next several decades, and it can be used to identify current and future collection system needs.

The hydraulic model was developed using the following tools and software:

- Time Series Analyzer (TSA)
- EPA Sanitary Sewer Overflow Analysis Planning Toolkit (SSOAP)
- The Town’s existing GIS
- PCSWMM (Windows implementation of EPA Stormwater Management Model with a graphical user interface)

MONITORING DATA

Existing flow metering data was reviewed and utilized as part of development of the hydraulic model. Eighteen flow meters were installed in 2017 and data reviewed for the period between 3/23/17 and 6/6/2017 as part of the Town's collection system master plan. A permanent meter at the downstream end of the BSI was installed in 2011 and data for the same time period used in the model.

Rainfall data pulled from the permanent rainfall gauge installed at the Franklin Department of Public Works. Rain events including duration, depth, peak intensity and return period are summarized in Table 1 below. Storm events with a return period greater than 2 months are shaded in gray.

Table 1 – Franklin Rain Gauge – 3/23/17 – 6/6/2017

Franklin Rain Gage						
Start Date	**Duration (hours)**	**Time between events (hours)**	**Total Depth (inches)**	**Peak (5 min.) Intensity**	**Time of Peak Intensity**	**Return Period**
3/24/2017	0.02	n/a	0.01	0.01	3/24/17 12:30	<2 mo
3/25/2017	1.02	17.25	0.03	0.01	3/25/17 5:45	<2 mo
3/25/2017	1.77	7.00	0.04	0.02	3/25/17 15:15	<2 mo
3/27/2017	**8.27**	**38.00**	**0.49**	**0.06**	**3/27/17 11:15**	**2-3 mo**
3/28/2017	**14.02**	**24.50**	**0.53**	**0.04**	**3/28/17 20:15**	**~2 mo**
3/31/2017	**34.27**	**50.75**	**2.10**	**0.07**	**3/31/17 22:45**	**6-9 mo**
4/4/2017	**20.02**	**56.25**	**0.78**	**0.06**	**4/4/17 6:15**	**2-3 mo**
4/6/2017	**13.27**	**34.00**	**0.82**	**0.08**	**4/6/17 13:45**	**~3 mo**
4/15/2017	0.02	215.25	0.01	0.01	4/15/17 20:00	<2 mo
4/19/2017	2.77	97.75	0.06	0.02	4/20/17 0:00	<2 mo
4/21/2017	**25.77**	**23.50**	**0.53**	**0.04**	**4/21/17 4:00**	**2-3 mo**
4/22/2017	2.52	8.25	0.06	0.02	4/22/17 12:00	<2 mo
4/25/2017	**39.52**	**65.75**	**1.55**	**0.12**	**4/26/17 3:00**	**4-6 mo**
4/28/2017	0.02	32.00	0.01	0.01	4/28/17 5:45	<2 mo
4/30/2017	**0.77**	**54.75**	**0.17**	**0.07**	**4/30/17 12:30**	**~2 mo**
5/2/2017	12.77	35.75	0.34	0.07	5/2/17 3:45	<2 mo
5/5/2017	**11.02**	**69.25**	**1.27**	**0.16**	**5/5/17 16:00**	**4-6 mo**
5/6/2017	14.52	6.75	0.18	0.05	5/6/17 10:30	<2 mo
5/13/2017	**15.52**	**168.00**	**1.33**	**0.08**	**5/14/17 1:45**	**4-6 mo**
5/14/2017	16.52	6.75	0.34	0.03	5/15/17 2:45	<2 mo
5/19/2017	0.52	86.00	0.09	0.06	5/19/17 0:00	<2 mo
5/22/2017	0.02	76.75	0.01	0.01	5/22/17 5:15	<2 mo
5/22/2017	6.02	13.75	0.09	0.01	5/22/17 19:00	<2 mo
5/25/2017	**33.02**	**54.50**	**1.36**	**0.22**	**5/25/17 23:30**	**4-6 mo**
5/27/2017	0.02	11.75	0.01	0.01	5/27/17 4:15	<2 mo
5/29/2017	2.77	57.25	0.04	0.01	5/29/17 13:30	<2 mo
5/31/2017	0.02	43.00	0.01	0.01	5/31/17 11:15	<2 mo
5/31/2017	3.52	9.25	0.07	0.02	5/31/17 20:30	<2 mo
6/1/2017	0.02	14.00	0.04	0.04	6/1/17 14:00	<2 mo
6/3/2017	0.27	46.50	0.02	0.01	6/3/17 12:30	<2 mo
6/4/2017	4.27	28.25	0.08	0.02	6/4/17 20:30	<2 mo
6/5/2017	**2.58**	**6.50**	**0.22**	**0.05**	**6/5/17 5:45**	**2 mo**
6/5/2017	**28.08**	**13.5**	**1.77**	**0.06**	**6/6/17 2:30**	**~6 mo**

Note: Design Storm Depths developed using NOAA Atlas 14, Vol 2(2004)

MODEL DEVELOPMENT

The extent of the model was determined by including any pipelines greater than 12-inches in diameter contributing significant tributary flow to the BSI. A figure showing the extents of the model is included as an attachment to this memo. Due to the ongoing and maintenance and rehabilitation of the BSI and surrounding tributary areas, much of the system is recorded and available in ArcGIS. Tributary areas, or sub areas, were previously developed as part of the Collection System Master Plan and will be utilized in the development of the model. Additional components to model development are summarized below:

- Sub Areas 9, 10, 11, 12, 13, 14, 16, 19 and 20 determined to be tributary and upstream of the BSI.
- Required system data for pipeline, manholes, and force mains include pipe diameter, length, inlet and outlet invert elevations, and material as well as manhole invert and rim elevations. This data was taken from the Town's GIS and available record drawings.
- Data Gap Analysis: Gaps in the data, specifically in sub areas 9 and 19, 20 and 14, were filled in with further field survey efforts. Rim elevations of the manholes missing data determined using 2011 LiDAR in ArcGIS with a vertical accuracy of +/-6inches.
- Once hydraulic data was incorporated into the model, the system was reviewed for any inconsistencies and irregular profiles. Some inverts were adjusted assuming a constant slope.
- The Manning's n values shown in Table 2 were used in the development of the model:

Table 2 – Manning's n Values

Type of Conduit and Description	Manning's N
CI: Cast Iron	0.014
DI: Ductile Iron	0.015
AC: Cement	0.013
RCP: Reinforced Concrete Pipe	0.015
VC: Vitrified Clay	0.015
BRK: Brick	0.015
PVC: Polyvinyl Chloride	0.010
CONC: Concrete	0.013

Source:

Manning's n for Closed Conduits Flowing Partly Full (Chow, 1959).

PVC: Neale, L.C. and R.E. Price. Flow characteristics of PVC sewer pipe. Journal of the Sanitary Engineering Division, Div. Proc 90SA3, ASCE. pp. 109-129. 1964.

Bishop, R.R. and R.W. Jeppson. Hydraulic characteristics of PVC sewer pipe in sanitary sewers. Utah State University. Logan, Utah. September 1975.

Pump Station Analysis

- The Milliken Ave Pump Station is within the modeling extents and conveys flow from subareas 12, 13 and a portion of subarea 20 to the downstream collection system. The manufacturers pump curve was utilized to model the pumpstation. The Milliken Ave Pump Station has three pumps with VFDs with two running regularly at 700-900 gpm.
- Public Works Pump was station determined to provide negligible flow to the BSI as the station runs during off peak hours.

Hydrology

Dry weather flow patterns were developed using TSA and the EPA SSOAP toolkit. To incorporate a 50-year population projection, the following analysis was conducted:

- Population tab block data was pulled from the 2010 census in Franklin, MA of Norfolk county.
- Population was distributed throughout the system based on population density. Areas observed in ArcGIS arial imagery to be void of population, such as parks, undeveloped areas, and water bodies, were removed for accuracy.
- The percentage of population at each manhole was developed for the distribution of dry weather flow within the subareas.

The dry weather flow and subsequent average values were determined in TSA and applied to each manhole in proportion to the population distribution. Flow meter 20 and the permanent meter are adjusted to be incremental as they are downstream of other meters.

Average dry weather flow patterns developed in TSA and the EPA Sanitary Sewer Overflow Analysis Planning (SSOAP) toolbox from imported incremental flow meter data and converted to a multiplier pattern. The weekday and weekend multiplier pattern was then added to PCSWMM for each sub area and applied to each manhole depending on its location.

Daily multiplier patterns were developed and included in PCSWMM to adjust the ADWF pattern for weekdays and weekends. Also added a monthly multiplier to account for seasonal changes in infiltration rates, groundwater levels

WET WEATHER FLOW

To model wet weather flows, the RTK method was applied for modeling inflows into the system that were directly related to rainfall. The RTK is a unit hydrograph method that simulates inflow in response to rainfall as a function of multiple triangular hydrographs where:

R =fraction of runoff that enters the collection system as inflow;

T =time to peak of the hydrograph, and

K = ratio of recession time to peak (T)

RTK values were developed and calibrated for the following storms:

- March 31, 2017-April 8, 2017 (back-to-back storm events)

- April 26, 2017
- May 5, 2017
- May 15, 2017

A sample output from TSA showing RTK input values, a calibration curve, and legend are shown as Figures 2 and 3 below:

Figure 2 – RTK Input Values

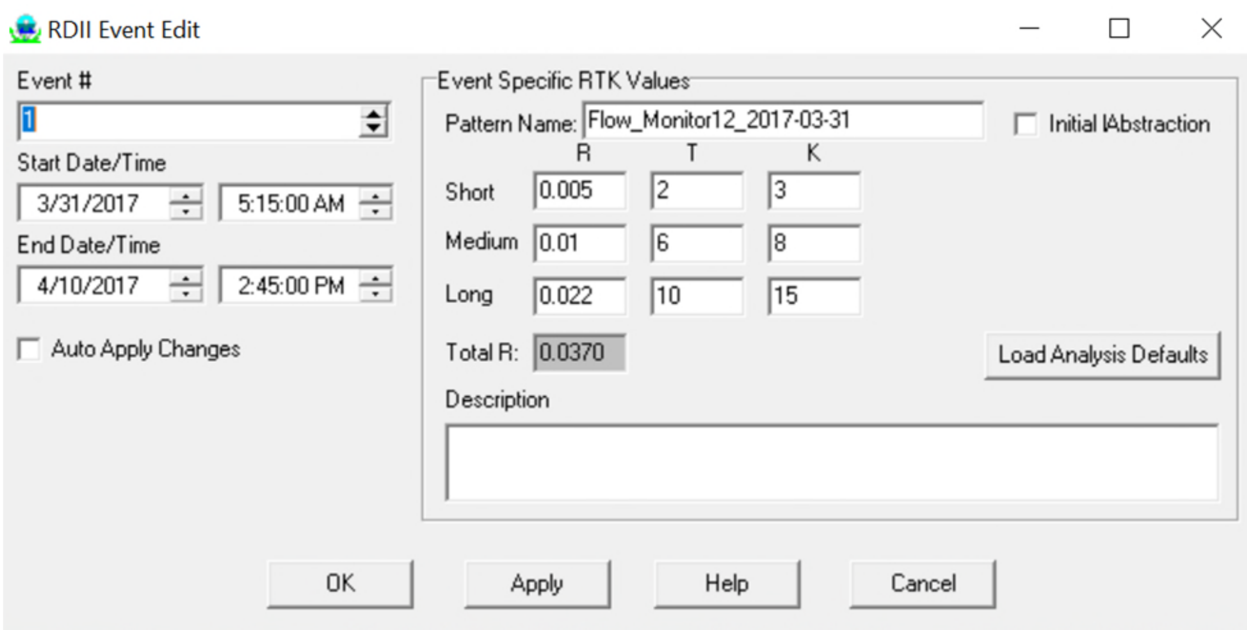
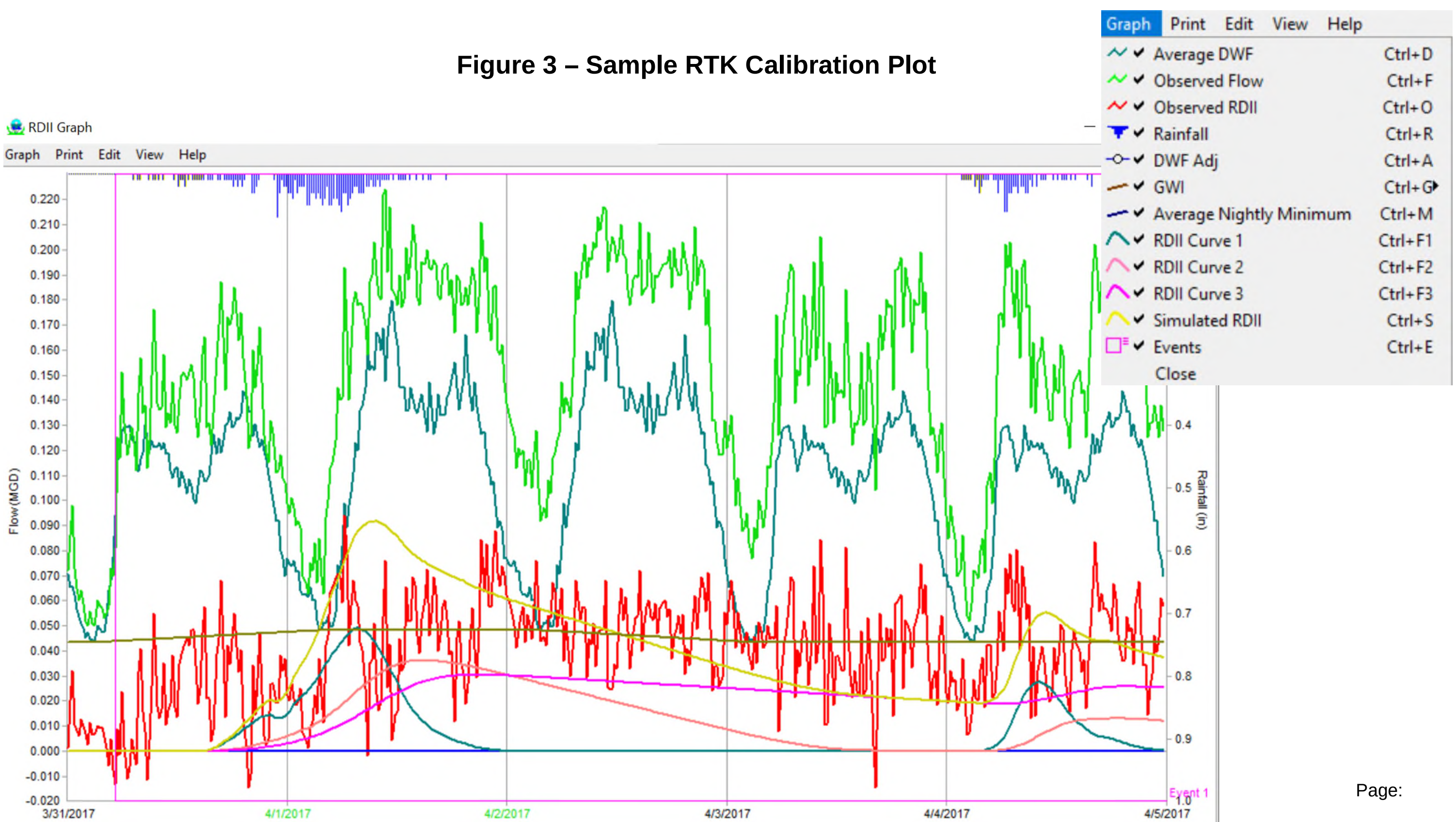


Figure 3 – Sample RTK Calibration Plot



MODEL CALIBRATION

Several adjustments were made during the calibration process to improve calibration results. The 2018 calibration results are included as an attachment to this memo. These improvements are summarized below:

- Adjust the ADWF value – monitoring period lacked a sufficient duration of time without wet-weather events.
- Added sediment to the pipe network to improve depth match where flows matched
- Some of the events were not consistently represented across the collection system specifically the 5/25 event.
- Some of the metered data inconsistent: spatial variability and issues with metering

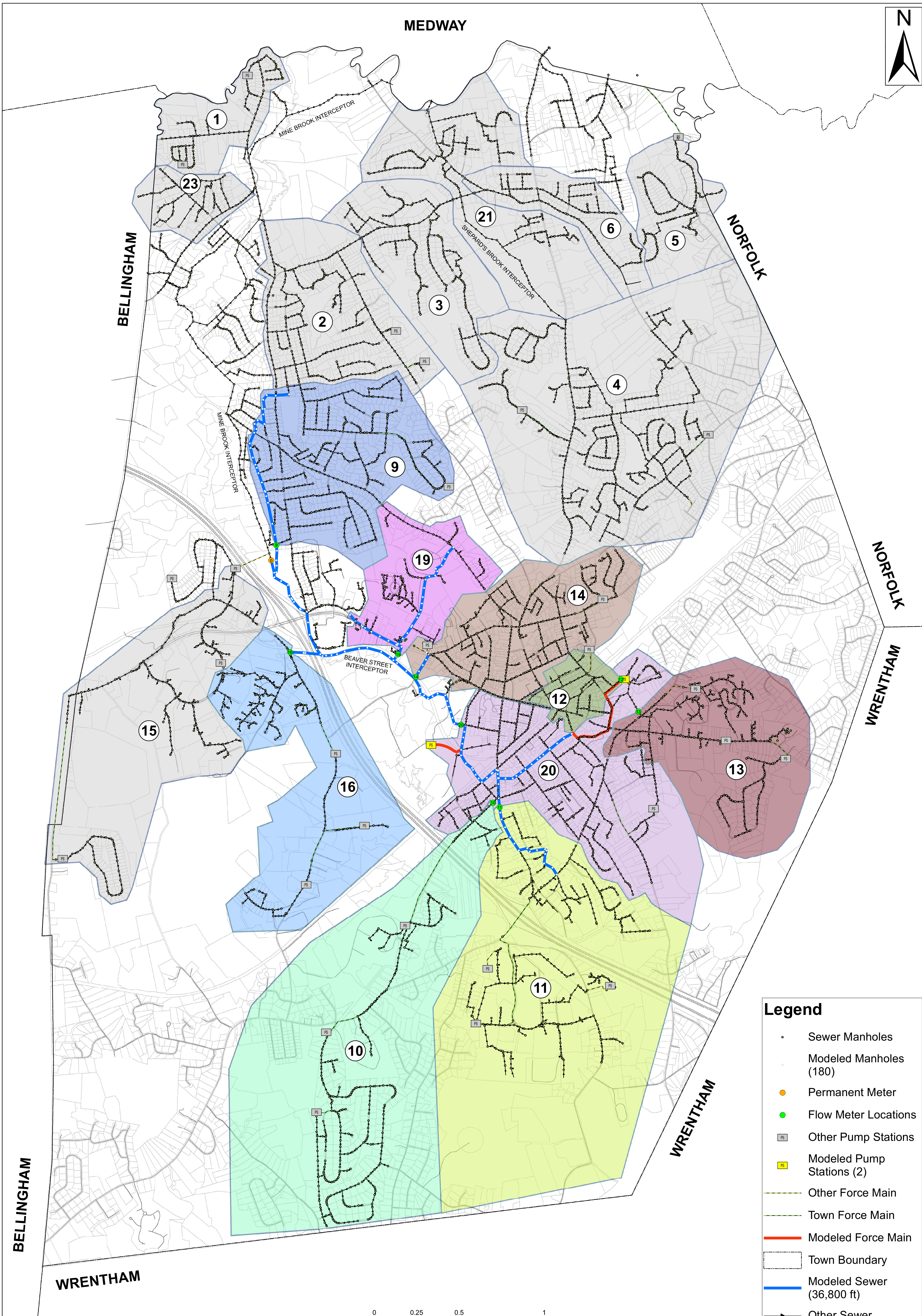
MODEL RUNS AND RESULTS

The hydraulic model was run to simulate a 10-year, 24-hour storm event, a 25-year, 24 hour storm event, and a 100-year, 24-hour storm event for the 50 year projected flows. Results of the baseline hydraulic model showed the existing BSI has the necessary capacity to convey the existing sanitary flow under the 25-year, 24-hour design storm. The model shows several locations where the hydraulic grade line is above the crown of the pipe, indicating surcharging within the manholes, however it did not indicate any sanitary sewer overflows (SSOs). Hydraulic grade line profiles are included as an attachment to this memo.

Additional data incorporated and calibrated into the projected 50-year hydraulic model included:

- Additional flows from planned new connections
- Additional 15% flows based on the population projection
- Design Storm Depths developed using NOAA Atlas 14, Vol 2 (2004).

Results of the projected 50-year hydraulic model showed the existing BSI is at its full capacity under the 10-year, 24-hour storm event and above capacity under the 25-year, 24-hour storm event, with an SSO indicated at manhole MH9 and the hydraulic grade line above the crown of the pipe from Cottage Street to manhole MH46 off of Pond Street. The 25-year, 24-hour storm event was run through three alternatives developed as part of the Beaver Street Interceptor Analysis and the results are summarized in Section 4 of that report. Hydraulic grade line profiles for each alternative are included as an attachment to this memo.



Town of Franklin, Massachusetts

Collection System Master Plan

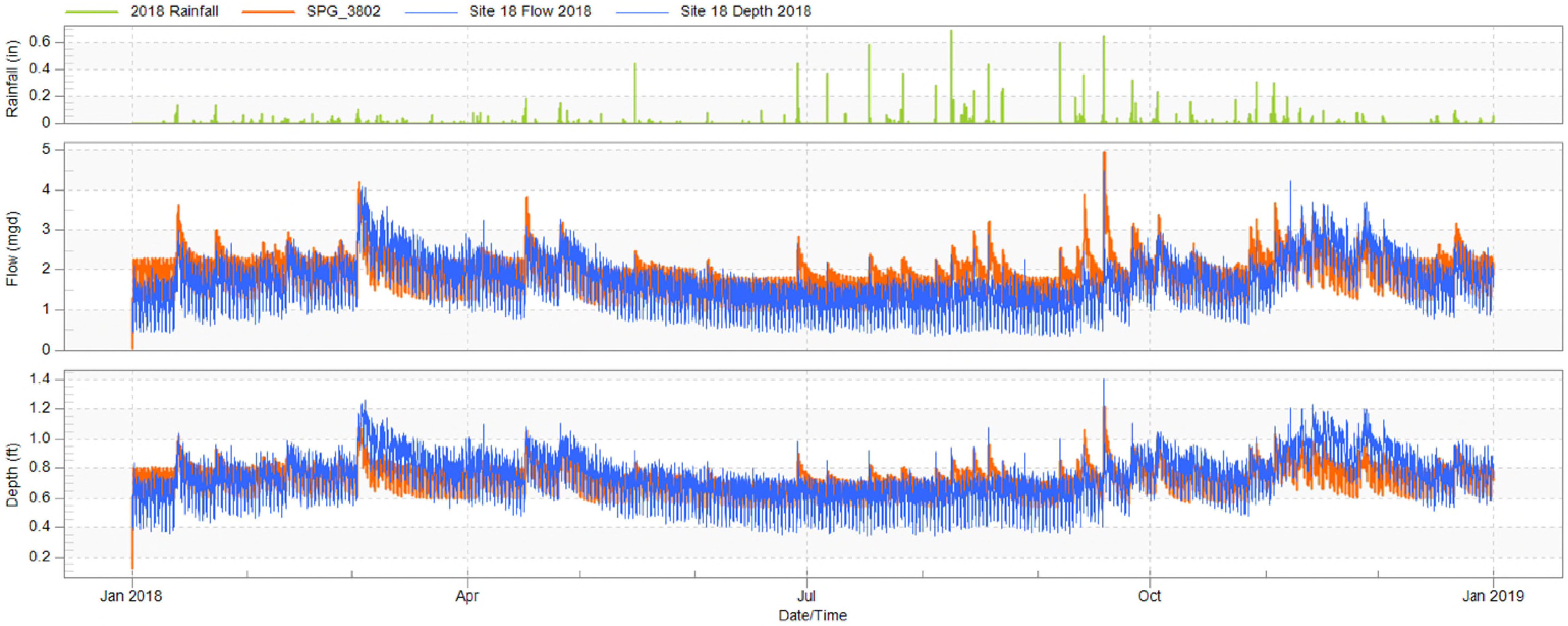
Model Extents

ARCADIS

February 2020

Model Calibration Results:

2018 – Relatively good match between metered and modeled results. Model slightly overpredicts which proves that the model is slightly conservative.

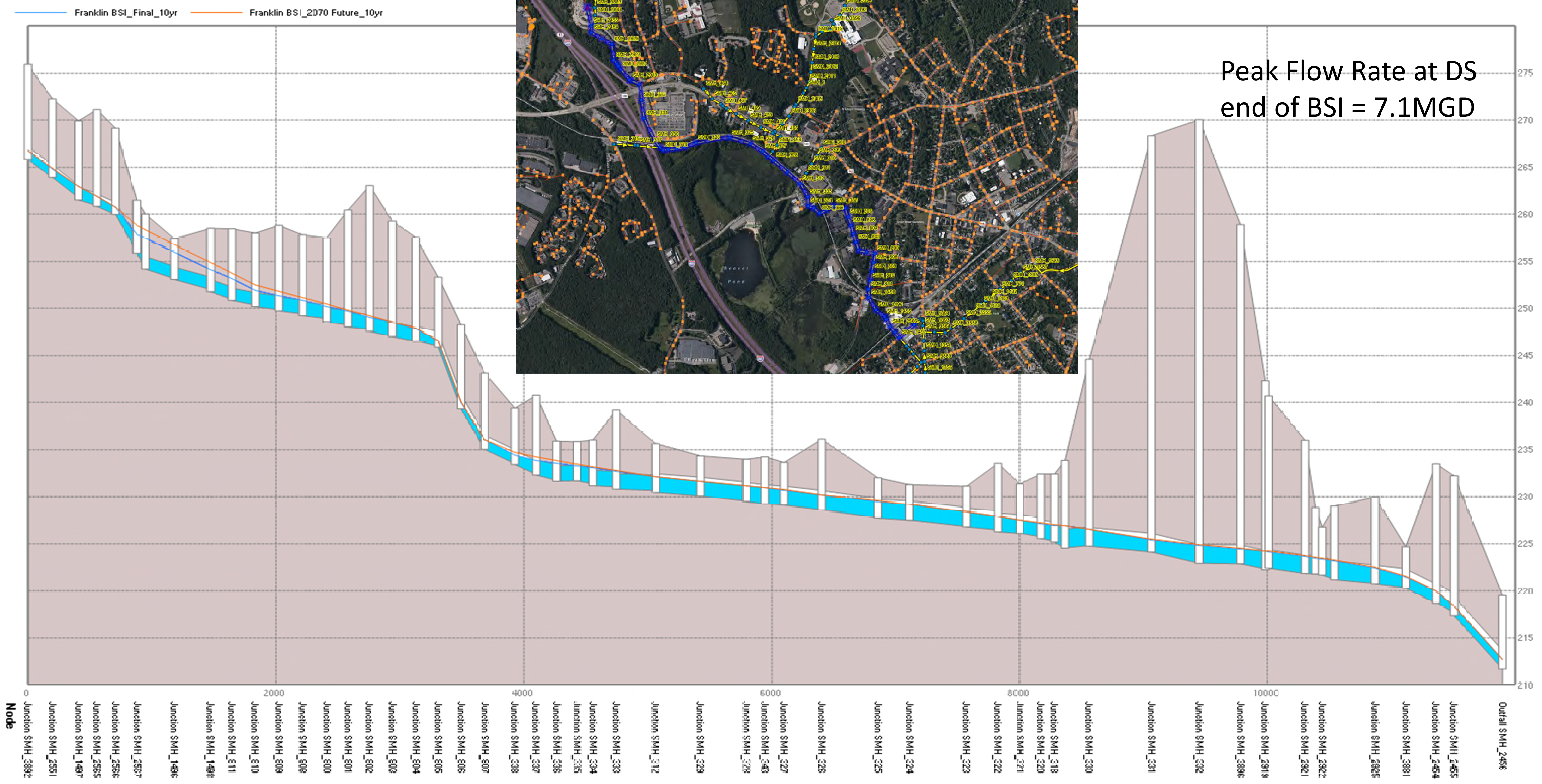


BSI Existing Conditions VS Future Conditions

September 1, 2020

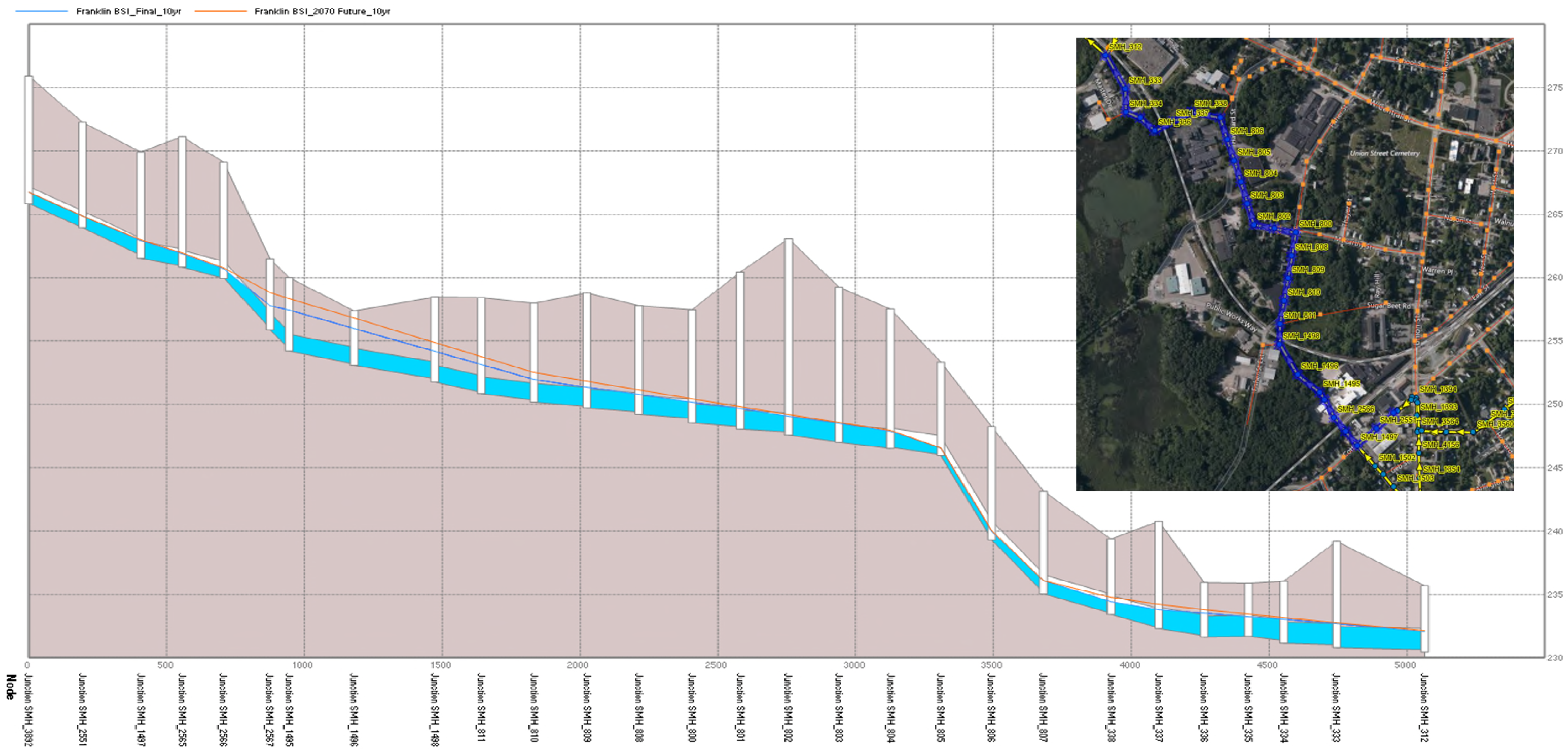
Future Flows increased the BSF 14.85% from 2.27MGD to 2.61MGD (0.337MGD increase)

BSI Peak HGL 10yr-24hr Design Storm

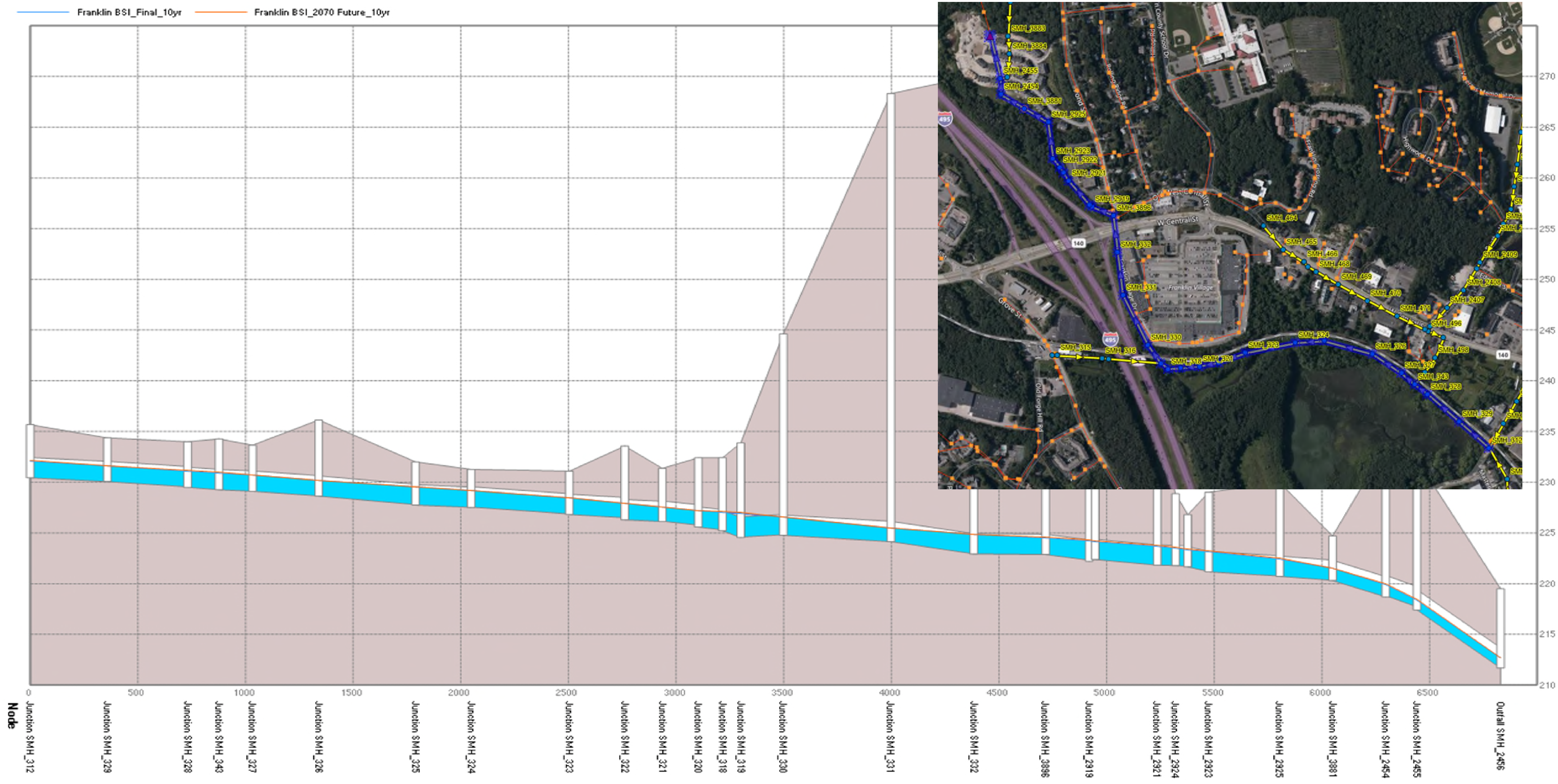


Peak Flow Rate at DS end of BSI = 7.1MGD

Upstream BSI Peak HGL 10yr-24hr Design Storm



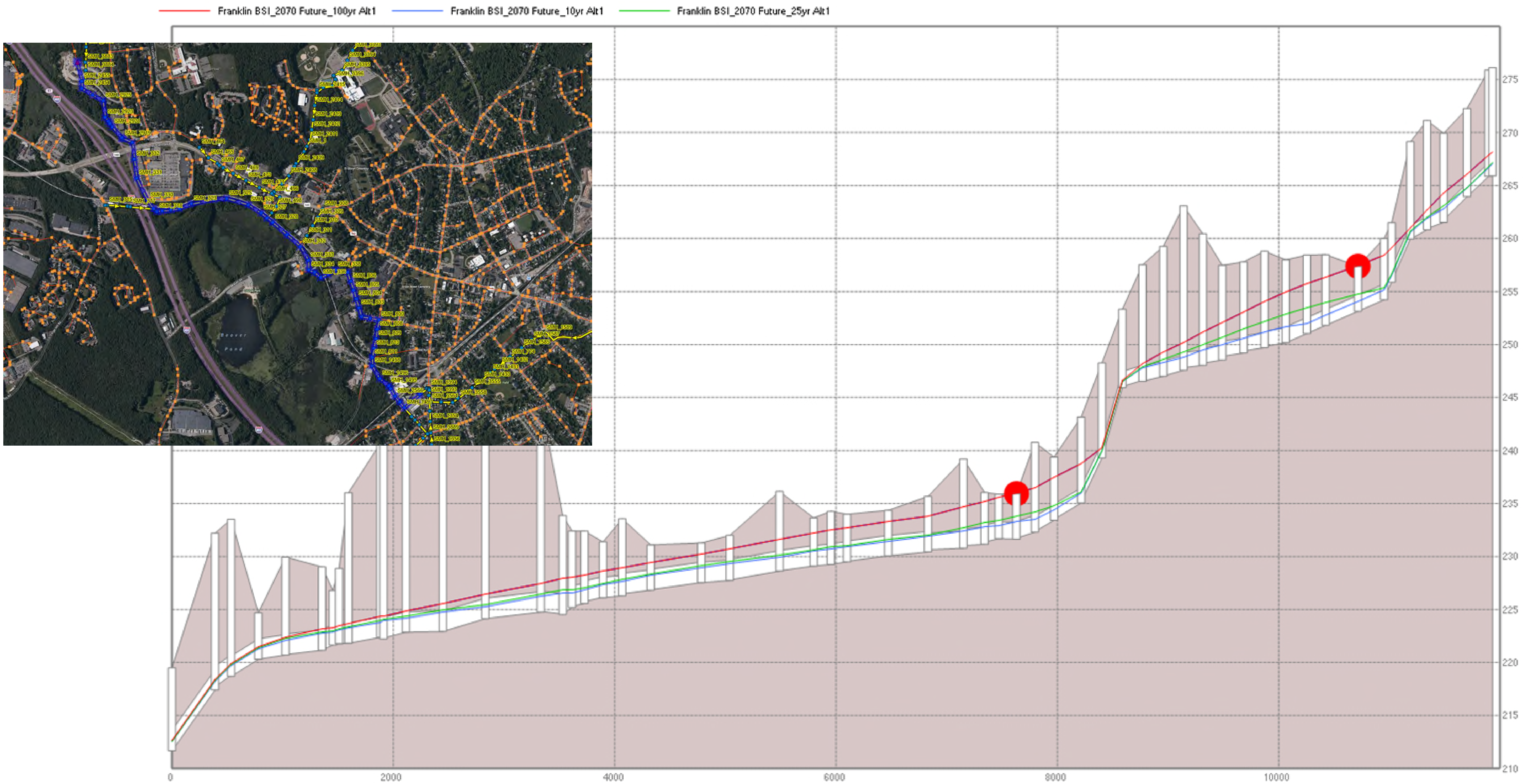
Downstream BSI Peak HGL 10yr-24hr Design Storm



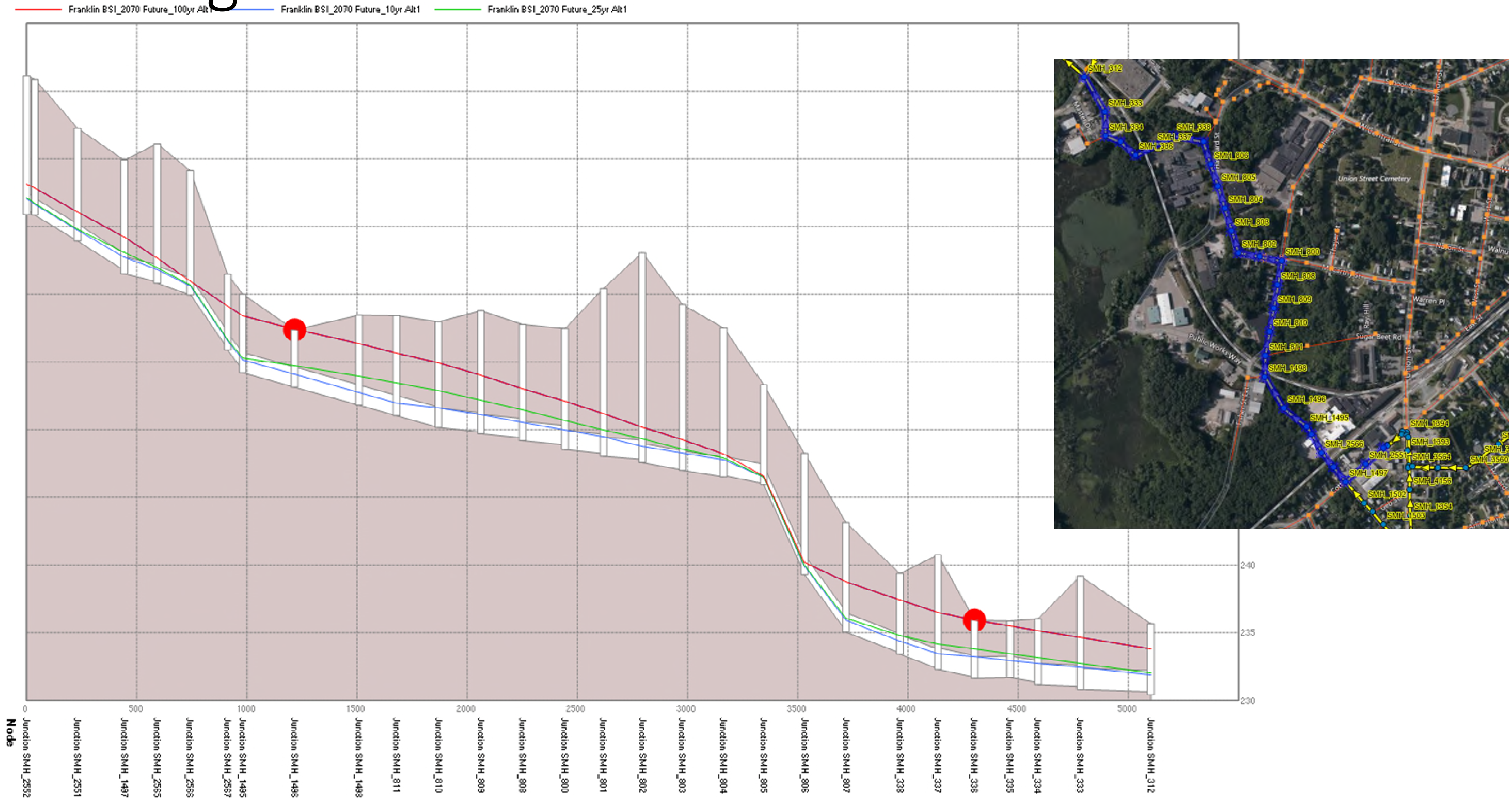
BSI Future Conditions: Alt 1 10yr-24hr/25yr-24hr/100yr-24hr Design Storm

September 21, 2020

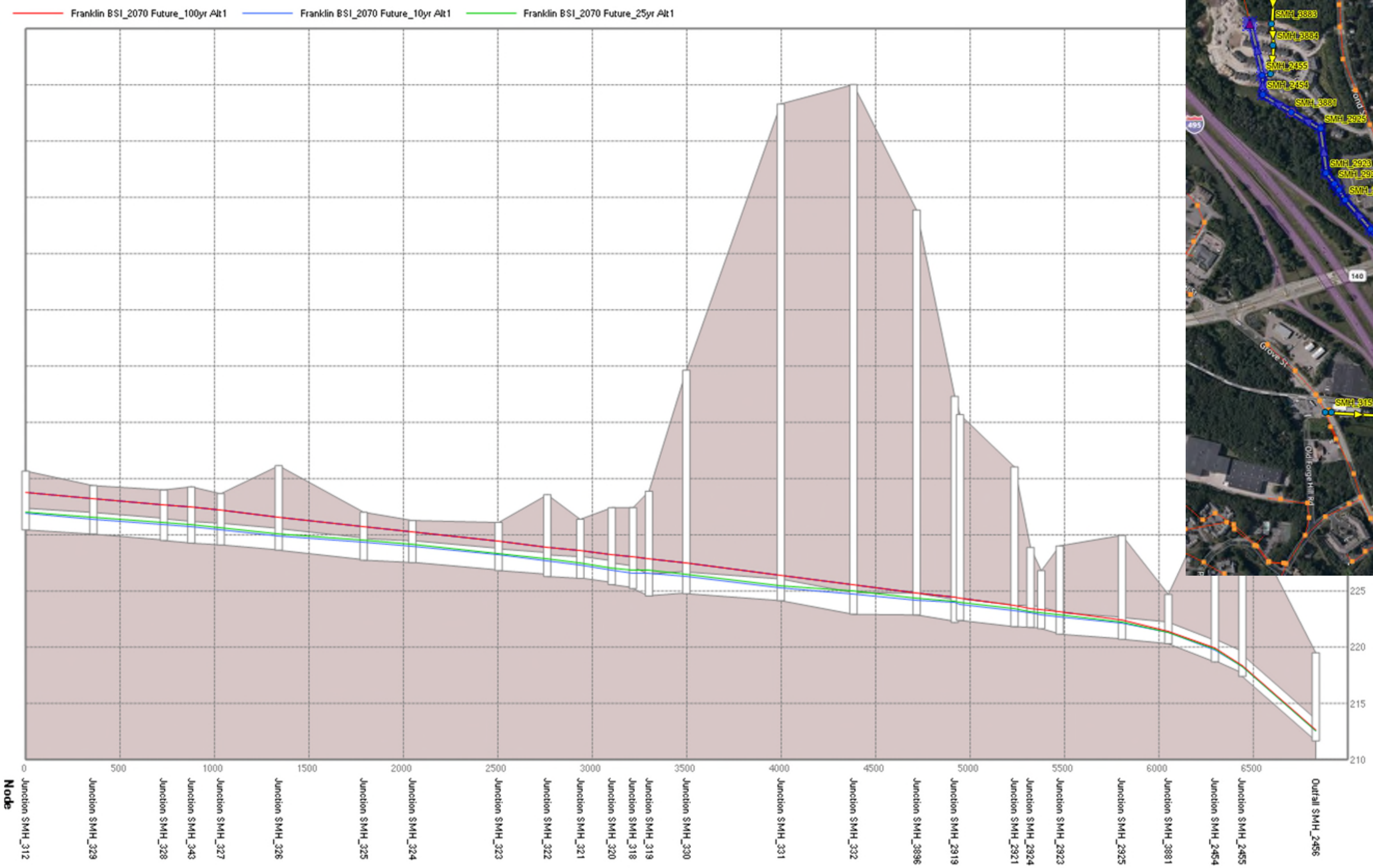
BSI Peak HGL 10yr-24hr/25yr-24hr/100yr-24hr Design Storm – Alternative 1

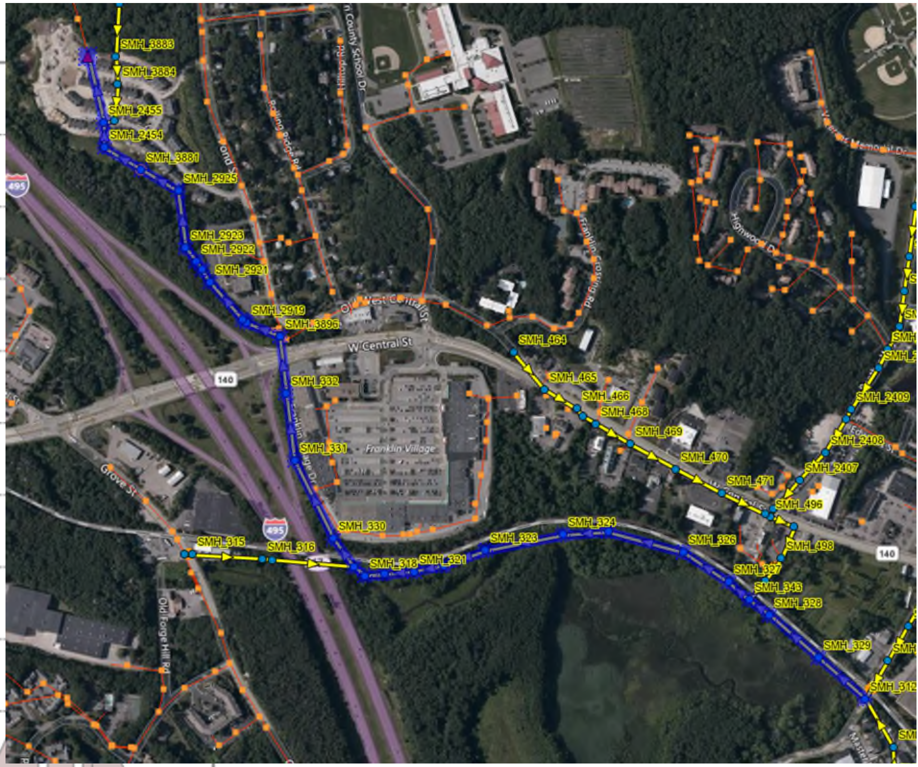


Upstream BSI Peak HGL 10yr-24hr/25yr-24hr/100yr-24hr Design Storm – Alternative 1



Downstream BSI Peak HGL 10yr-24hr/25yr-24hr/100yr-24hr Design Storm – Alternative 1

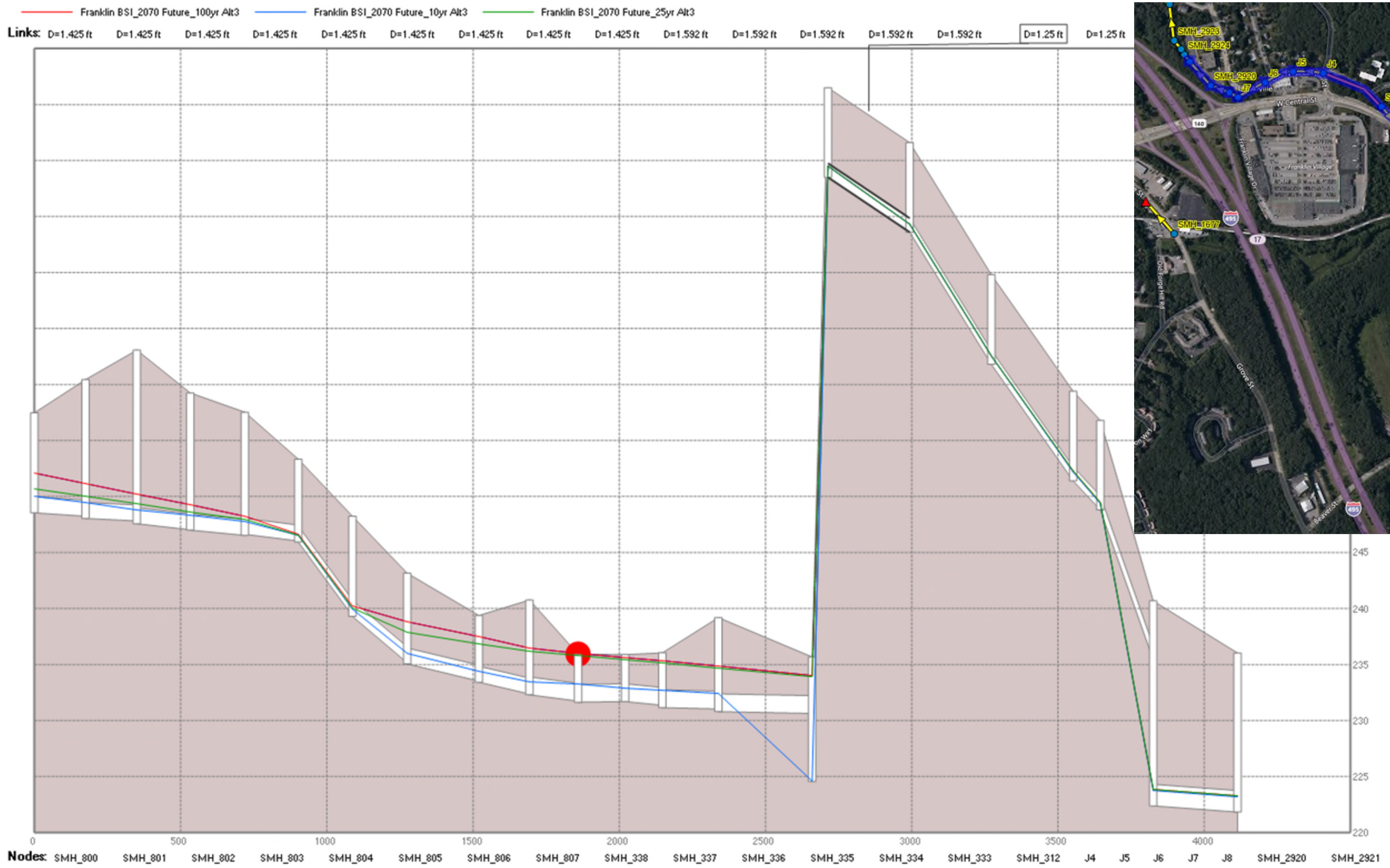


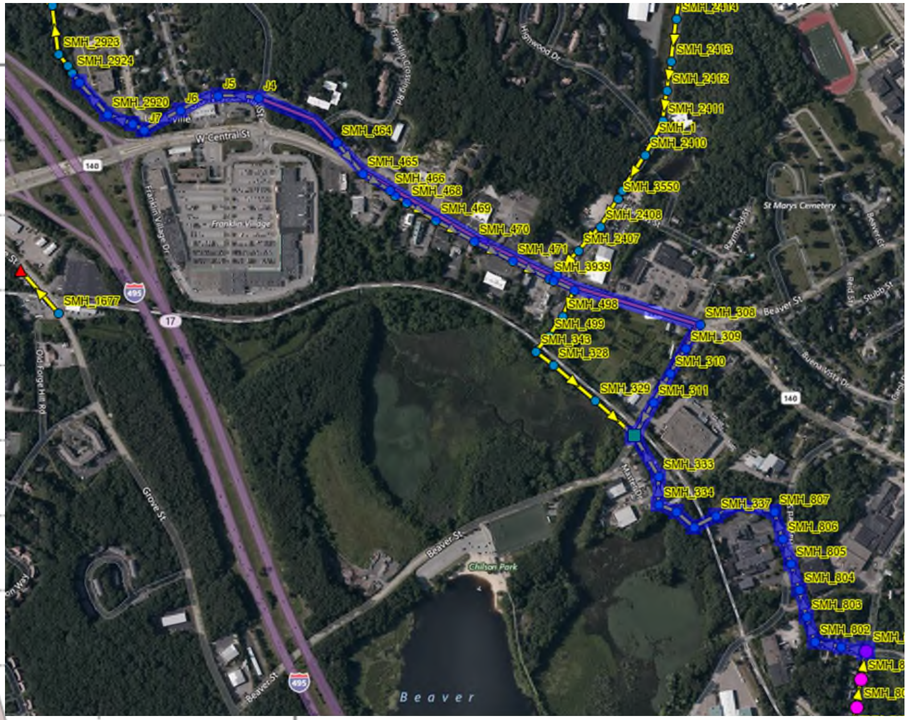


BSI Future Conditions: Alt 3 10yr-24hr/25yr-24hr/100yr-24hr Design Storm

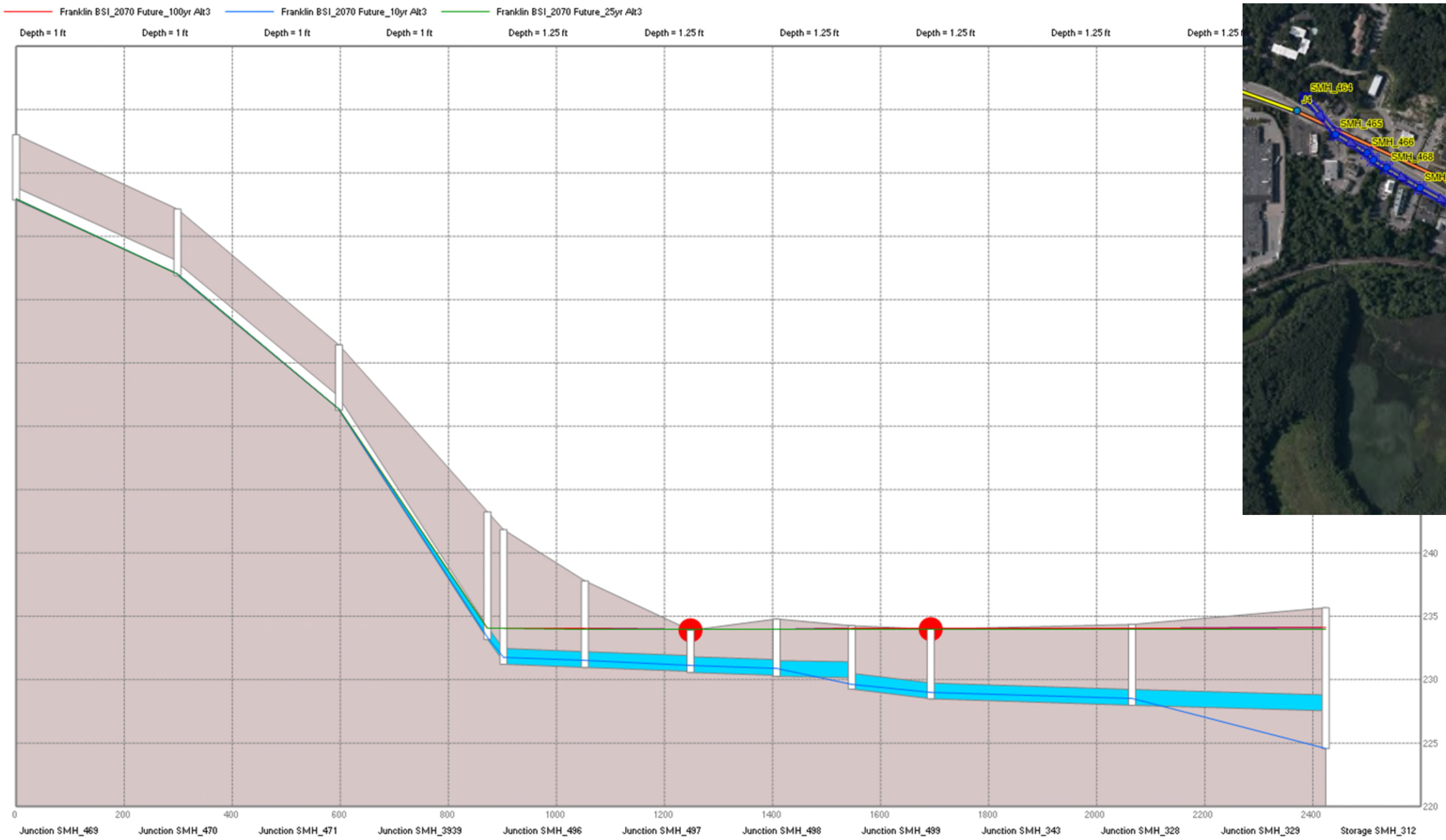
September 21, 2020

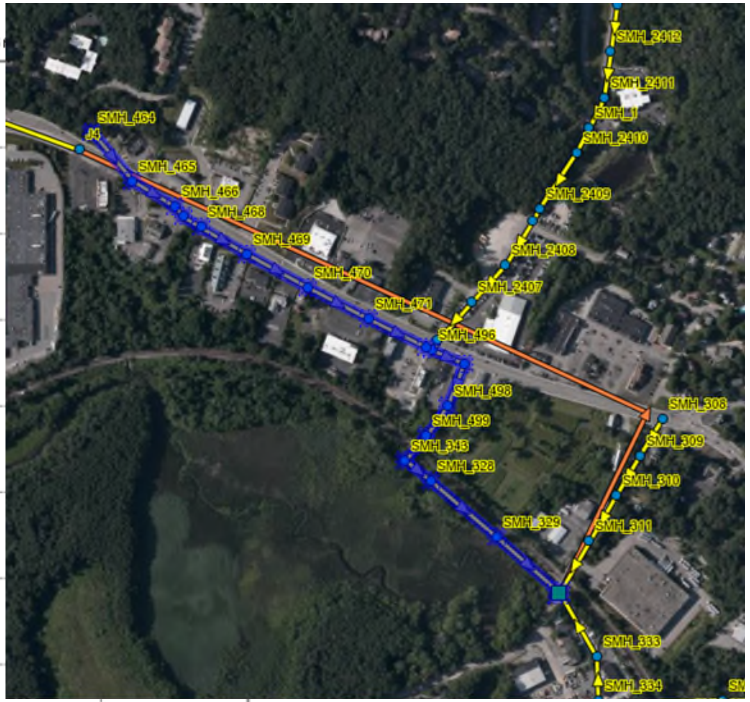
New Beaver Street Pump Station and Sewer
Peak HGL 10yr-24hr/25yr-24hr/100yr-24hr Design Storm





Redirected Sewer to new Beaver Street PS
Peak HGL 10yr-24hr/25yr-24hr/100yr-24hr Design Storm

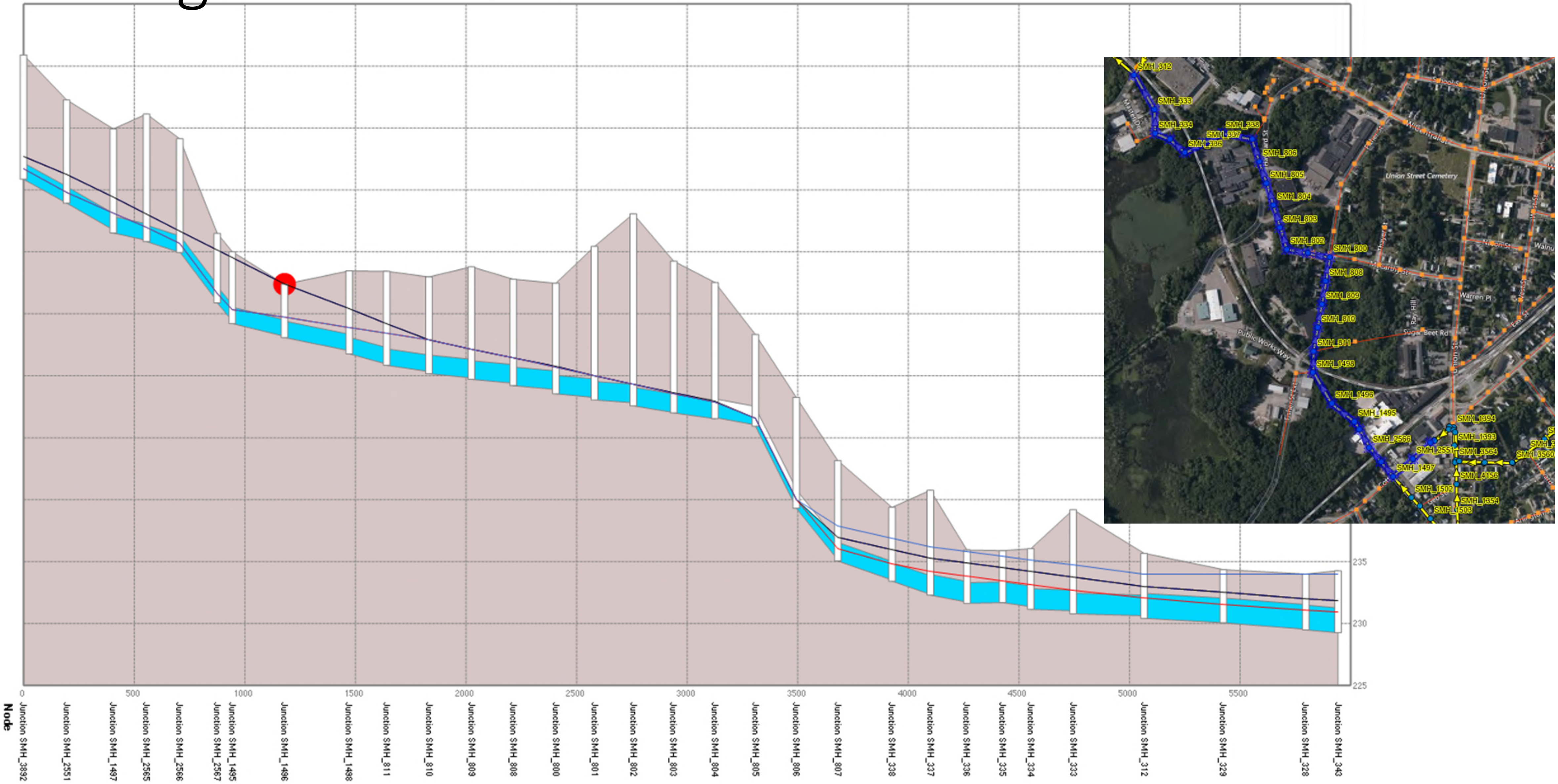




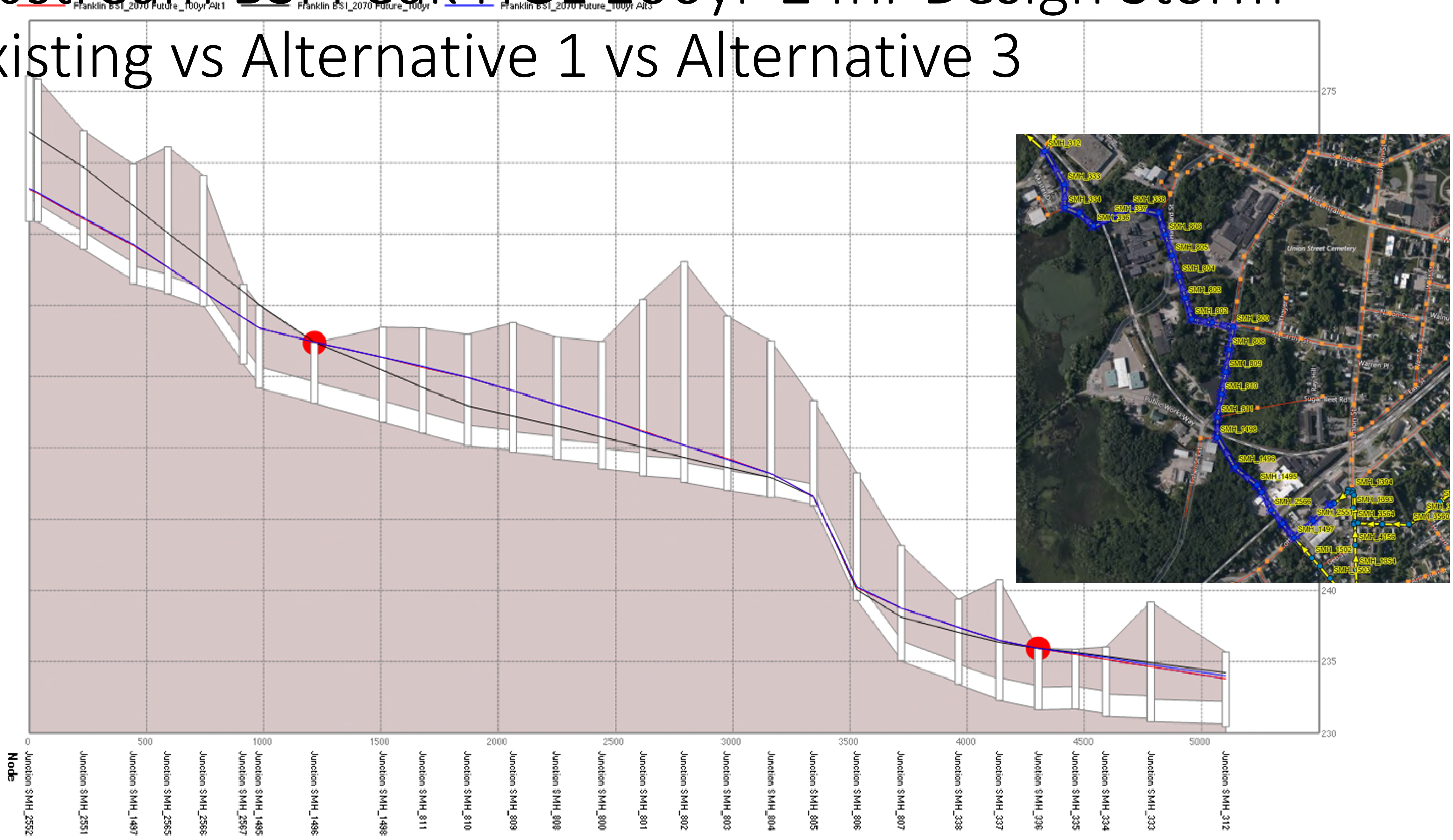
BSI Future Conditions: Existing vs Alt1 vs Alt 3 25yr-24hr/100yr-24hr Design Storm

September 21, 2020

Upstream BSI Peak HGL 25yr-24hr Design Storm – Existing vs Alternative 1 vs Alternative 3



Upstream BSI Peak HGL 100yr-24hr Design Storm – Existing vs Alternative 1 vs Alternative 3



Downstream BSI Peak HGL 100yr-24hr Design Storm – Existing vs Alternative 1