RARITAN RIVER AND BAY COMMUNITIES

RESILIENT NJ
RARITAN RIVER AND BAY COMMUNITIES

RRBC Modeling & Coastal Flood Mapping Updates

Documentation of Updates and Associated Methodology

RARITAN RIVER AND BAY COMMUNITIES

Contents

1 INTRODUCTION

This document describes a series of updates made to the HEC-HMS hydrologic models, HEC-RAS hydraulic models, and coastal floodplain mapping for the New Jersey Department of Environmental Protection (NJDEP) Resilient New Jersey Study, focusing on the Resilient Raritan River and Bay Community (RRBC) study area.

NJDEP provided the baseline HEC-RAS models for the RRBC study area to the RRBC consulting team (led by Arcadis). In coordination with the Steering Committee and other subject matter experts, Arcadis identified improvements that could be made to the HEC-RAS models for the RRBC study area that would improve the quality of the model output. NJDEP agreed to the proposed changes, and they were implemented jointly by Arcadis and the NJDEP consultant that developed the original models. Table 1 shows the identified improvements and the party responsible for making the changes.

The RRBC study area is spanned by two HEC-RAS models, each covering a USGS HUC 8 watershed. 02030105 covers the Raritan River watershed and the western portion of the RRBC study area. 02030104 covers Sandy Hook and Staten Island and the eastern portion of the RRBC study area. Figure 1 shows the boundaries of the HEC-RAS models relative to the RRBC study area.

The following sections will describe in detail the improvements made to the model and the underlying methodologies used in their implementation. Besides the changes noted in this document, the modeling approach and methodology is identical to that described in the *Resilient New Jersey - Floodplain Mapping Methodology* (2020) report submitted to the NJDEP.

Note that while these model changes improve the model representation of the runoff and flooding in the region, this is still a planning-level study. The modeling is appropriate for use to inform regional planning decisions on the potential level of risk communities face both currently and in the future, but it should not be used for specific engineering design projects. However, the models could be further developed for that purpose.

Table 1 – Overview of identified improvements and implementation responsibilities for RRBC baseline models

APPLICABLE MODEL OR SCENARIO	BASELINE NJDEP MODEL SETUP	IDENTIFIED IMPROVEMENT(S)	IMPLEMENTATION RESPONSIBILITY
All HEC-RAS Modeling	CoNED data, including coastal areas with poor delineation of the shoreline resulted in sudden, unrealistic changes in bathymetry.	Updated with Post-Sandy Lidar for better representation.	NJDEP Consultant
All HEC-RAS Modeling	Limited bathymetry for Raritan River in baseline model terrain	Update DEM with bathymetric data for Raritan River	Arcadis
Current and future 2% and 1% rainfall models	Culvert/bridge openings not modeled (water does not flow through known openings)	Add culverts/bridge openings on FEMA studied streams	NJDEP Consultant & Arcadis
Current and future 2% and 1% rainfall models	Large cell size and no breaklines cause "leaky cells" where discharge can traverse high points in terrain	Add breaklines to the model geometry along major elevated transportation corridors	NJDEP Consultant & Arcadis
Sandy Models	Sandy & Future Sandy modeling based on incorrect high-water mark (HWM), using constant water surface elevation (WSEL) instead of time-varying boundary condition	Revise HWM data for Sandy. Update Raritan River HEC-RAS model to use time-varying boundary condition. Use HWM data to map floodplain in GIS for Sandy Hook / Staten Island model domain.	Arcadis
Future Tidal Models / Current and future 2% and 1% rainfall models	Constant tidal boundary condition used (i.e., 72 hours of high tide)	Adjust boundary condition to include typical tidal variation.	Arcadis
Current and future 2% and 1% rainfall models	Storm sewer drainage system capacity not considered in baseline model methodology	Adjust excess rainfall in HEC-HMS with approximation of storm sewer capacity, including sensitivity analysis to select design storm. Use updated rainfall in HEC-RAS model.	Arcadis

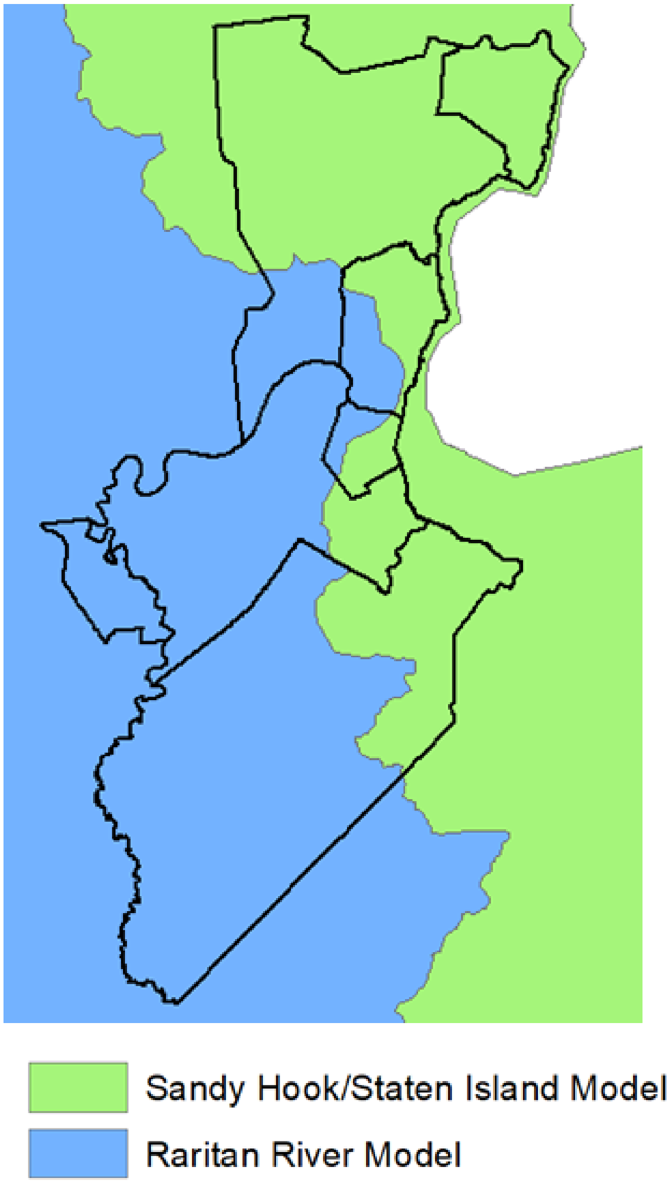


Figure 1 – Map showing the boundaries the two HEC-RAS models relative to the RRBC study area (black outline).

2 HEC-RAS GEOMETRY IMPROVEMENTS

2.1 BATHYMETRY UPDATES

The baseline RRBC HEC-RAS models had limited bathymetry for the Raritan River, Arthur Kill and Raritan Bay. Arcadis updated the bathymetry with improved data so that the conveyance capacity of Raritan

River would be better represented in the model. Table 2 provides an overview of the bathymetric data used to update the model geometry.

Table 2 – Overview of sources of bathymetry data used to update the HEC-RAS model geometry

BATHYMETRY SOURCE	COVERAGE AREA	COMMENTS
NCEI Continuously Updated DEM (DEM)[1]	Raritan Bay, Arthur Kill	Also used to supplement existing bathymetry in the SHSI model domain.
NCEI Hydrographic Surveys / Sounding Data[2]	Western portion of Raritan Bay, Mouth of the Raritan River	NOS Survey IDs: • H11399 (2008) • H12587 (2014) • H12586 (2014)
Rutgers Raritan River Basin Bathymetry[3]	Inland areas of the Raritan River	Compilation of a variety of topobathymetric data sources—see reference for documentation.

2.2 MODEL GEOMETRY UPDATES

The baseline RRBC HEC-RAS models did not have any breaklines in the study area. Breaklines are used in HEC-RAS 2D to align the grid cell faces along elevation features in the topography to ensure that they are captured in the model geometry. Without breaklines, the coarse grid cell size (200-ft) of the RRBC model causes some grid cells to straddle high points in the terrain, which allows water in the model to traverse the elevated. This behavior is known as "leaky cells" and results in water not pooling behind impediments in the terrain, which can lead to areas not being identified as at risk to flooding. To reduce the impact of "leaky cells," breaklines were added along transportation corridors (roadways, freeways, and railroads) throughout the RRBC study area.

The baseline RRBC HEC-RAS models also lacked culvert and bridge openings at some major crossings. Streamlines had been burned into the baseline model terrain; however, in some cases, the burned crossings provided limited conveyance compared to the actual structure. To address this, FEMA structures were added to the model geometry were breaklines crossed FEMA-studied streams. The structures were modeled as storage area/2D connections. Figure 2 is a screenshot showing some example culverts in the 2D model domain and Figure 3 shows a profile view of an example culvert.

[1] https://chs.coast.noaa.gov/htdata/raster2/elevation/NCEI_ninth_Topobathy_2014_8483/

[2] Bathymetric Data Viewer (noaa.gov)

[3] http://raritan.rutgers.edu/generating-an-elevation-grid-for-the-raritan-river-basin/

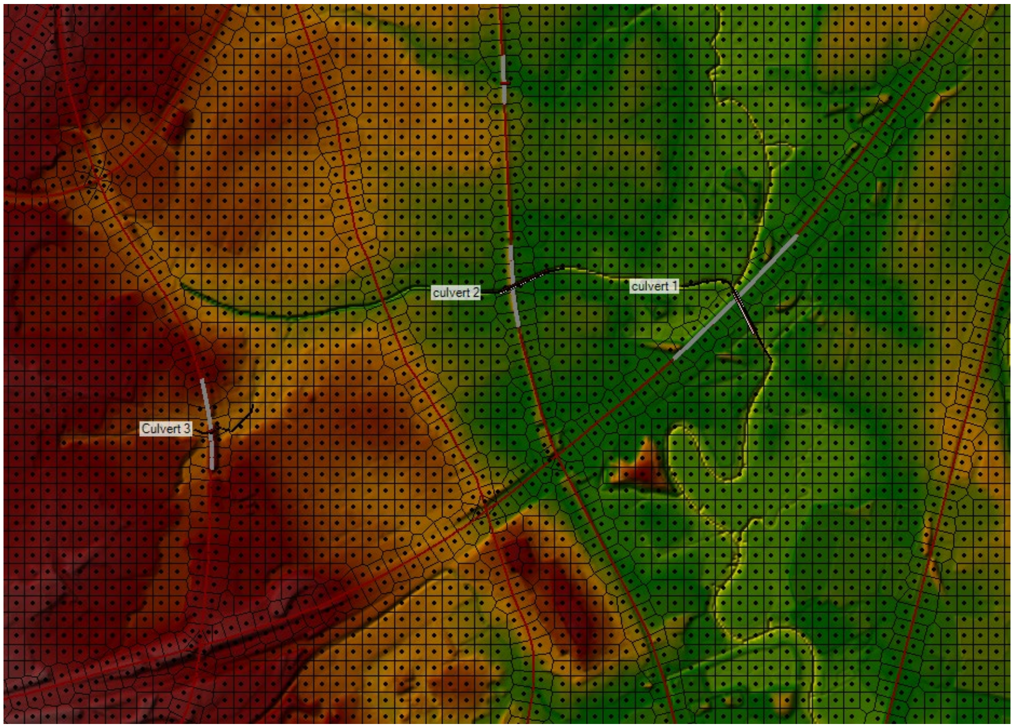


Figure 2 – Culverts and bridges added to the HEC-RAS 2D domain

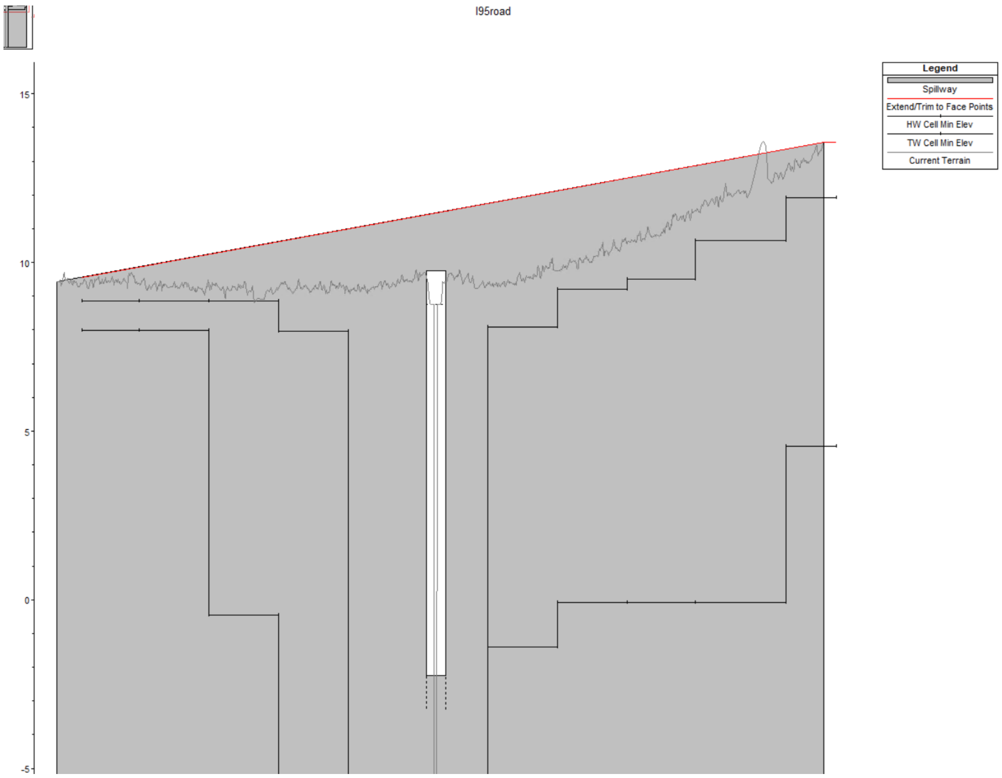


Figure 3 – Profile view showing an example culvert in the HEC-RAS model

3 SANDY & TIDAL UPDATES

3.1 SANDY UPDATES

The baseline HEC-RAS models used a single flood elevation in the study area to map the flooding from Hurricane Sandy. This approach did not accurately capture the spatial variation in the storm surge elevation observed during the event, particularly in the RRBC study area. Two approaches were used to address this. In the Raritan River model (HUC8 – 02030105), Sandy was modeled using a time series water surface elevation boundary at the mouth of the Raritan River, using observed data from three gauges in the vicinity of the river mouth to accommodate gauge failures during the storm. A plot of the resulting hydrograph is shown in Figure 4. For the 2070 scenario, the storm hydrograph was adjusted to future sea level rise conditions by adding 2.4 feet to the hydrograph. Running the model with transient boundary condition better represents the upstream propagation of storm surge than a steady-state value, which can overestimate the inland extent of flooding. Additional documentation of the hydrograph boundary condition development is included as Attachment A to this report.

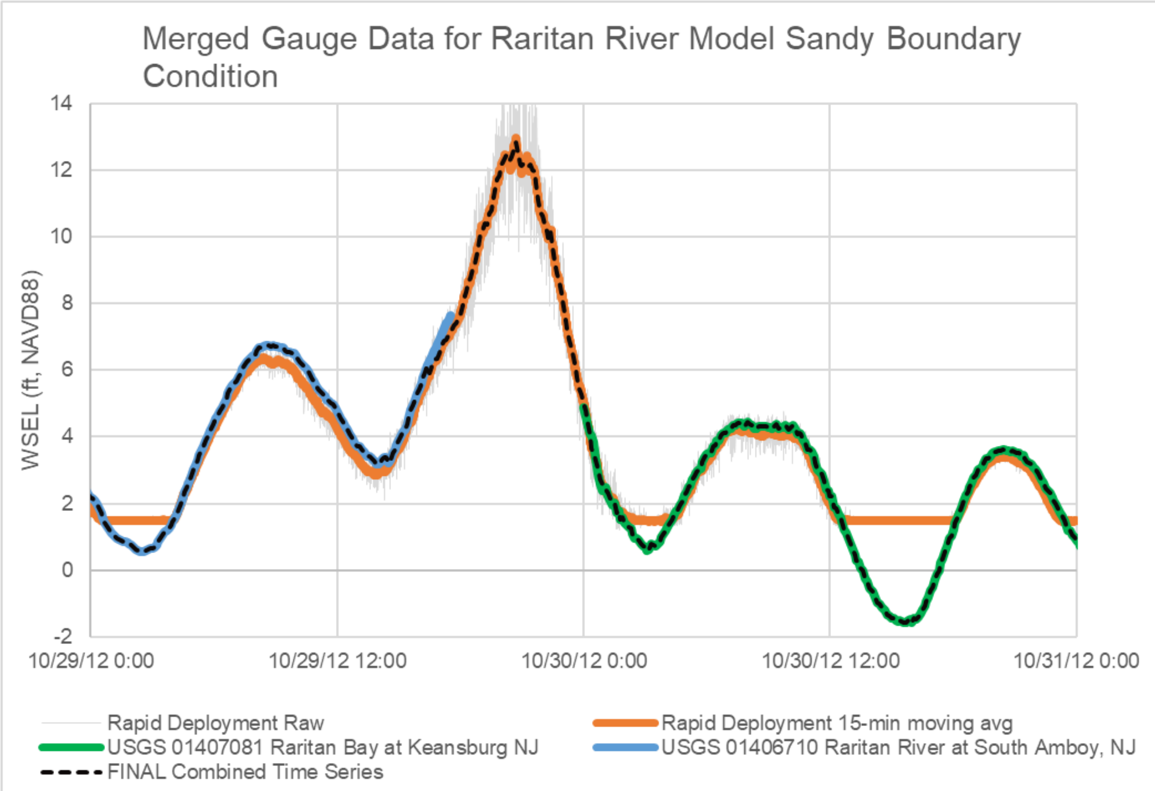


Figure 4 - Hurricane Sandy boundary condition developed for the Raritan River model

The western portion of the RRBC study area, which falls in the Sandy Hook / Staten Island model (HUC8 – 02030104), has a large coastline with a lot of variation in storm surge elevation. Because of this, it was not realistic to represent Sandy in HEC-RAS with a single boundary condition since the model would not be able to capture the spatial variation. To address this, it was decided that it would be better map Sandy using observed high water mark data obtained from the USGS Flood Event Viewer. The mapping was performed by creating a TIN using the observed high water mark data and then comparing it to the ground elevation to map the resulting floodplain. The same process was performed for the 2070 timeframe scenario with 2.4 ft of SLR added to the Sandy high water marks. Figure 5 shows the updated Sandy mapping.

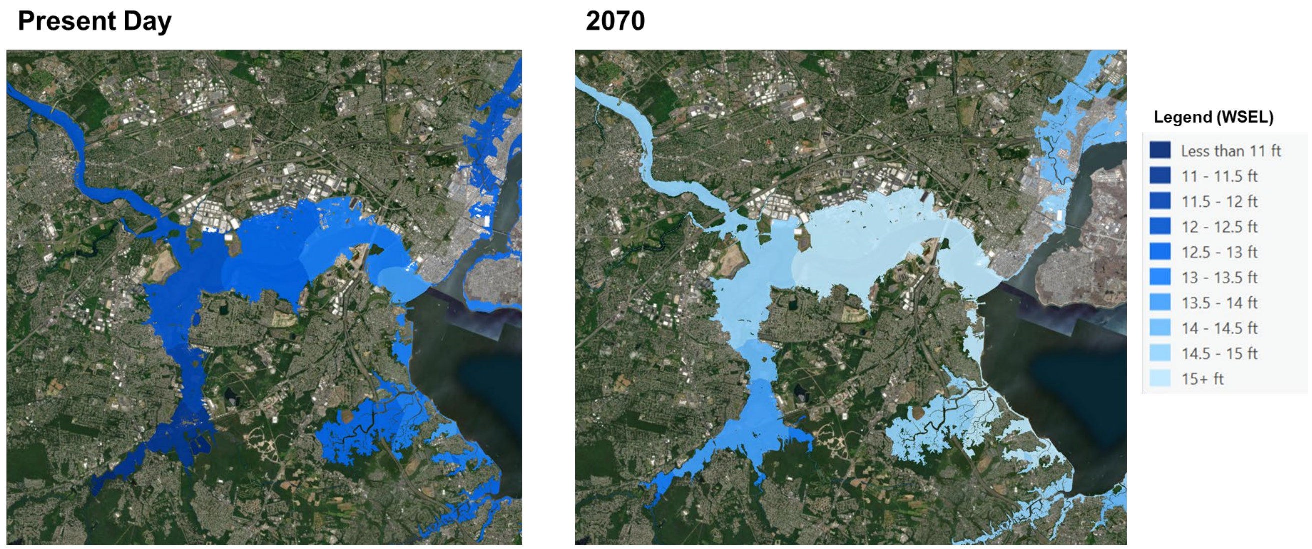


Figure 5 – Updated Sandy WSEL mapping in the study area

3.2 TIDAL UPDATES

For the rainfall event modeling and the 2070 mean higher high water (MHHW) scenario, the model was updated to use a transient tidal boundary instead of a constant water elevation. This change was made to allow floodwater to drain from inland areas during the low point of the tidal cycle, which could result in lower inland flood elevations than the baseline models. Additional documentation of how the tidal boundary conditions were developed is included as Attachment A to this report.

4 STORM SEWER CAPACITY ADJUSTMENTS

The baseline HEC-RAS model uses the rain-on-grid capability of HEC-RAS 2D to transform rainfall into rainfall runoff. The baseline HEC-RAS models use HEC-HMS to perform the loss calculations and then use the precipitation excess as the input to the model. This accounts for the infiltration capacity of the soil as well as other losses, but it omits the capacity of the storm sewer. The RRBC study area is largely urbanized, so not accounting for the storm sewer capacity in the modeling process likely leads an overestimation of flooding from a given storm event.

To account for the conveyance capacity provided by the storm sewer system in the model, Arcadis developed an approach to adjust the rainfall excess by a constant rainfall intensity. To identify a representative intensity value to act as a proxy for the storm sewer capacity, Arcadis performed a sensitivity analysis using a PC-SWMM model of the Jersey City stormwater drainage system that was readily available. Several design storms and constant rainfall intensities were tested in the model and the system outfalls were observed to see when they would reach capacity – or when the discharge value would reach a constant value that was sustained even when a more intense rainfall was run in the model.

Figure 6 is a plot showing some of the results from the sensitivity analysis. As shown on the chart, the smaller outfalls in the Jersey City system began reaching capacity with about 1-in/hr of constant rainfall intensity, which is close to the peak 1-hr intensity for the 1-year design storm. Based on this observation, and after receiving feedback from local municipalities in the study area, the 1-in/hr intensity value was selected as a reasonable estimate, conservatively low, estimate of the storm sewer capacity.

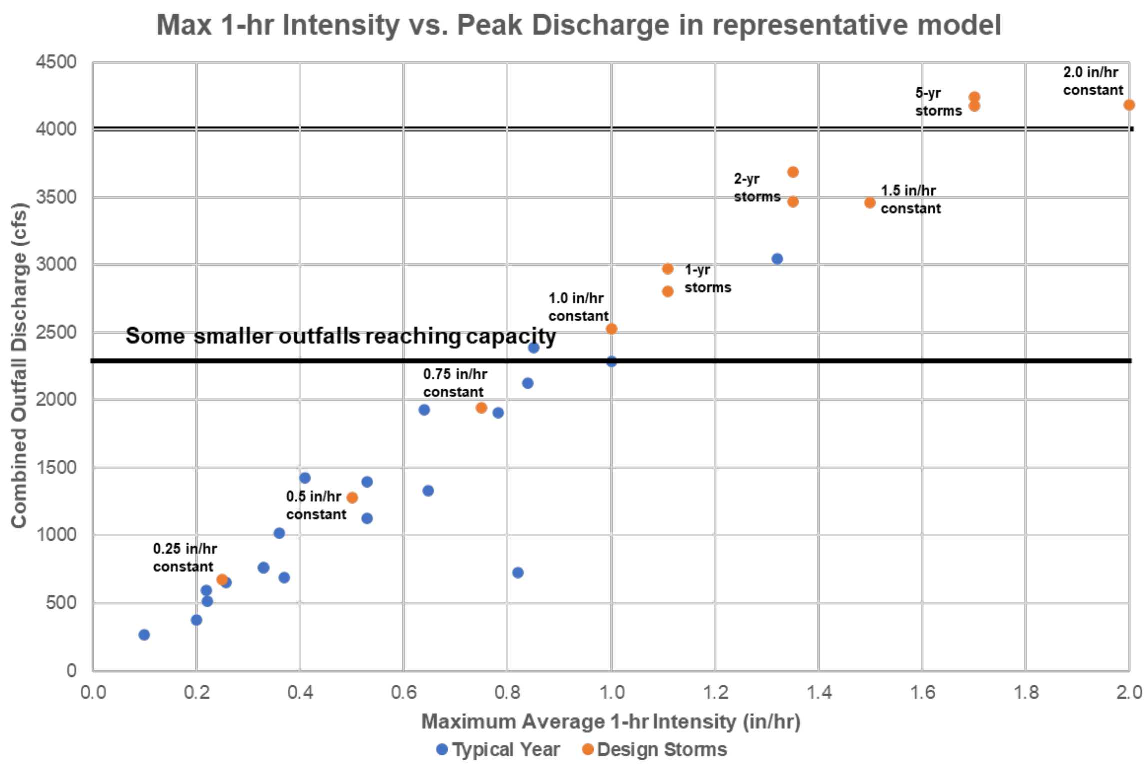


Figure 6 – Max 1-hr rainfall intensity vs. combined outfall discharge for the storm water system sensitivity analysis used estimate the drainage system capacity.

The 1-in/hr adjustment was reduced to 0.75 in/hr for the western portion of model that falls in the Raritan River model (HUC8 – 02030105). This was because the Raritan River HEC-HMS model used a much lower composite curve number to compute the losses than the eastern portion of the study area in the other model domain. This was because the Raritan River model includes a lot of undeveloped areas to the west of the study area; however, a low curve number is not representative the land uses in the portion of the watershed in the RRBC study area. Assuming a 0.75 in/hr capacity instead of a 1.0

in/hr capacity helps mitigate the difference in infiltration caused by the curve number discrepancy and have more consistent results across the model boundary.

The rainfall excess in the HEC-RAS model was updated to reflect the storm sewer capacity by subtracting either 0.75 in/hr or 1.0 in/hr from the rainfall excess for the modeled rainfall scenarios in HEC-HMS. The storm sewer adjustment was only applied to developed areas within the study area – other parts of the model domain as well as undeveloped areas were modeled with the original rainfall excess. This was modeled using the new spatial rainfall feature in HEC-RAS version 6.1. Rain gauges with the storm sewer adjustment were added to the model around developed areas, and rain gauges without the adjustment were used around undeveloped areas as well as the perimeter of the study area. Figure 7 shows the rain gauges used to create the spatially varying rainfall in HEC-RAS and the resulting rainfall distribution in the model.

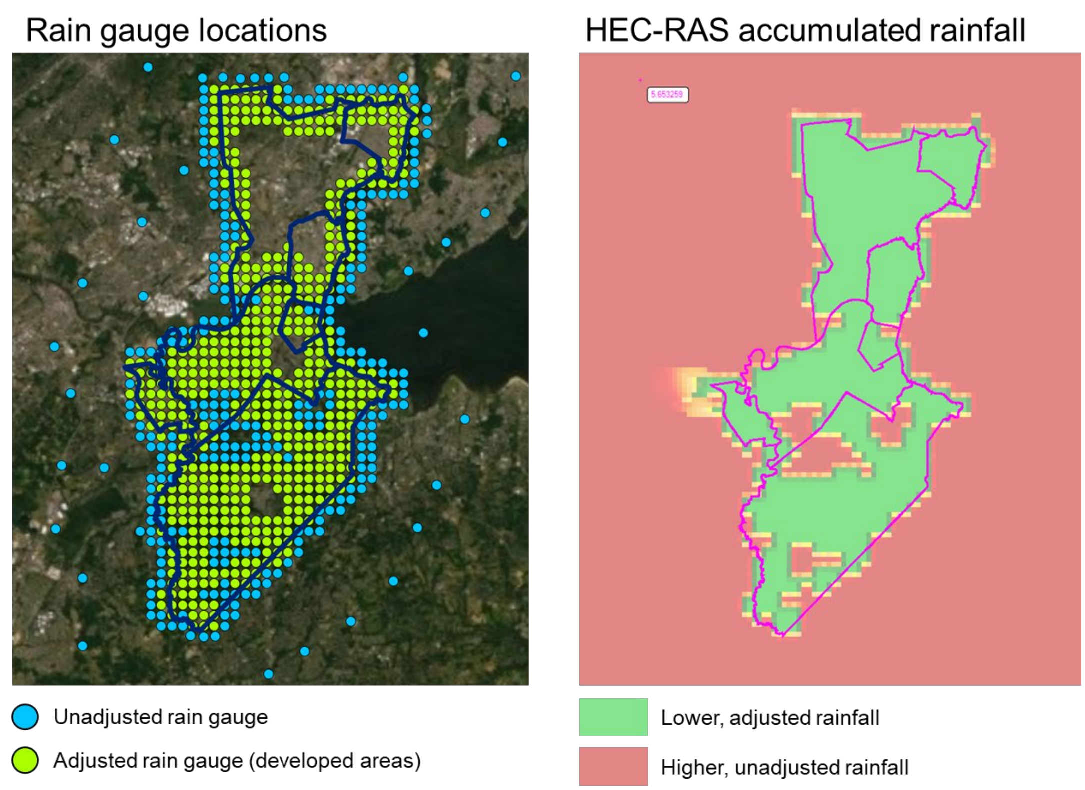


Figure 7 – (Left) Rain gauges used to create the spatially-varying rainfall input in HEC-RAS; (Right) Resulting rainfall distribution computed in the model.

Figure 8 shows the change in the 100-year, 24-hr floodplain for a section of the study area with and without the storm sewer capacity adjustment. As shown in the figure, there is a noticeable, but minor decrease in the extent of flooding when the storm sewer capacity is considered. However, as shown in Figure 9, the change in flood depth when the storm sewer capacity appears more substantial. Flood depths decreased by as much as 2 feet in a large portion of the study area. This has the potential to have a large impact on the risk assessment, as even small changes in flood elevation can have a big impact on flood damage, particularly when the water elevation is close to the finished floor of the structure.

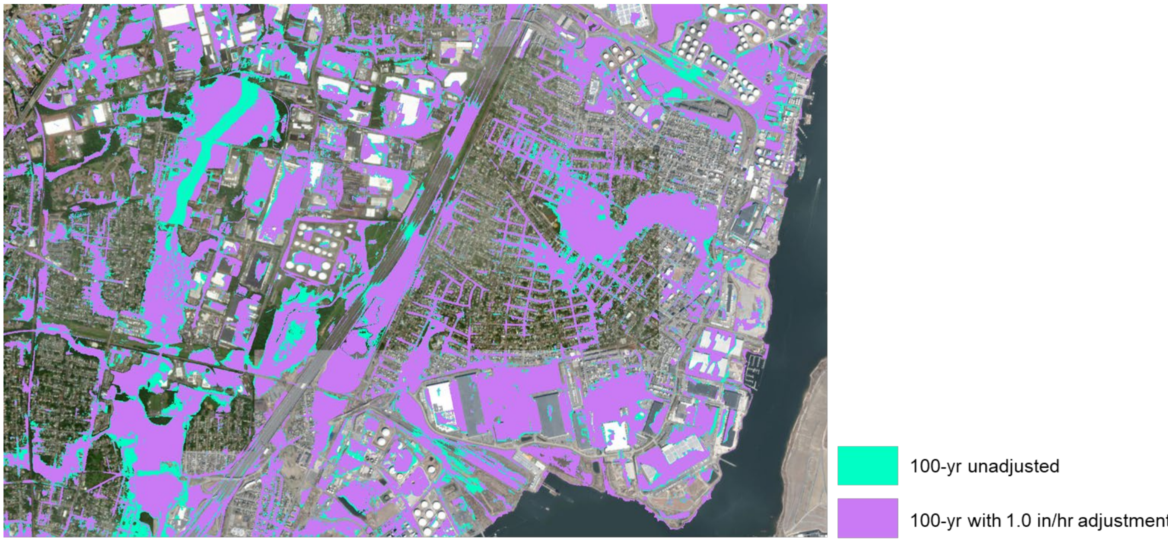


Figure 8 – Change in the 100-year, 24-hr floodplain extents with and without the storm sewer capacity rainfall adjustment

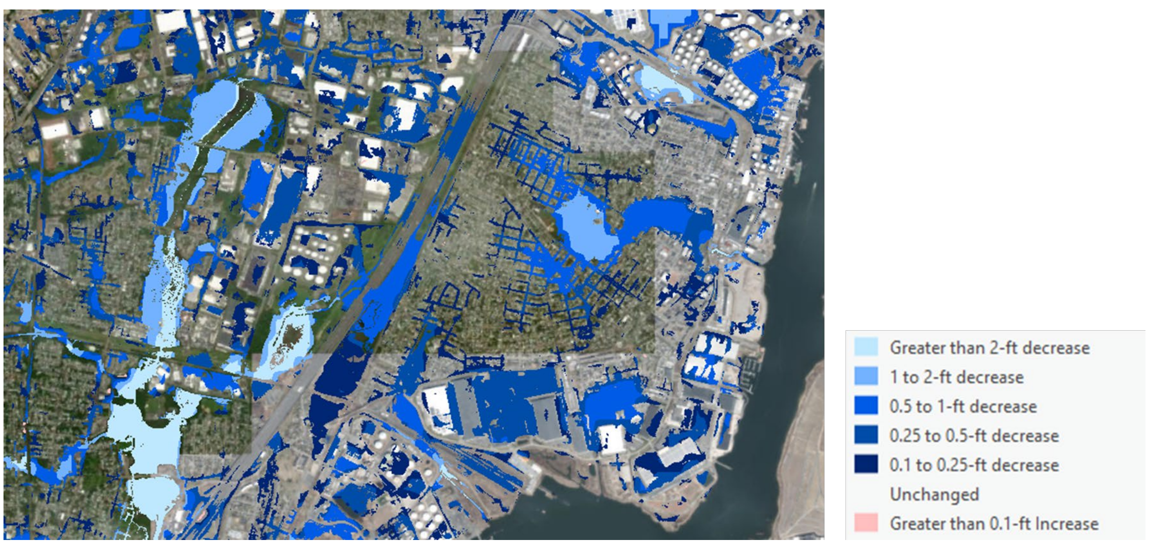


Figure 9 – Change in the 100-year, 24-hr flood depth with and without the storm sewer capacity adjustment

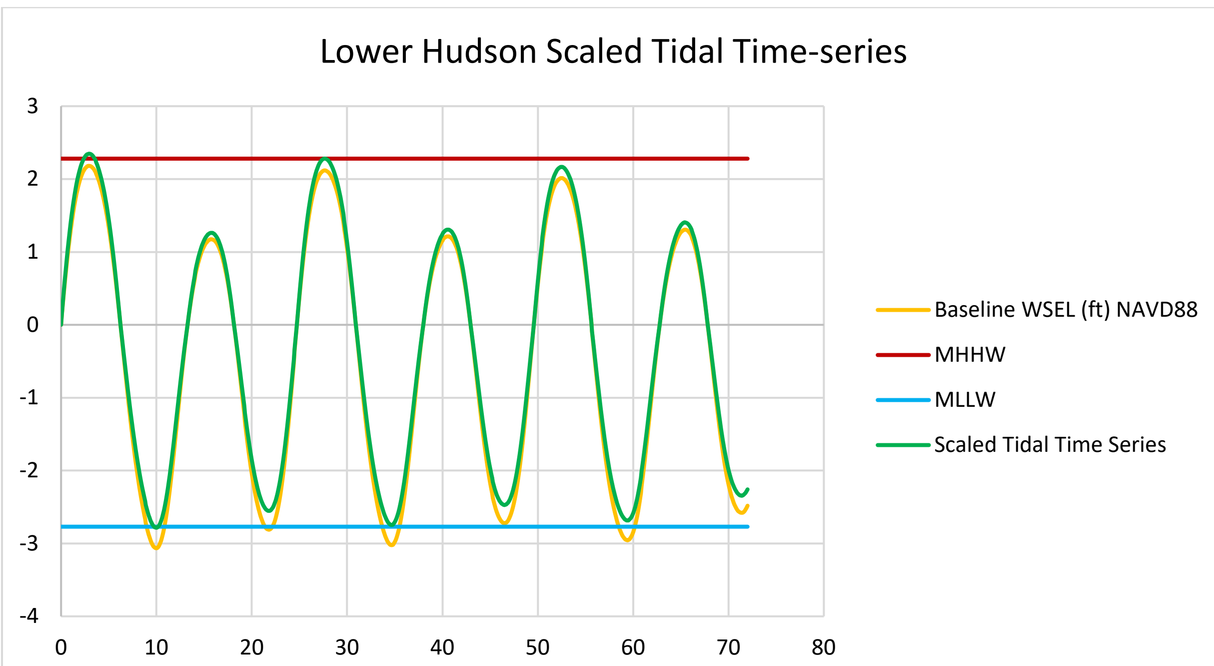
Finally, since the storm sewer adjustment eliminates the water volume from the floodplain and doesn't allow the stormwater to return to downstream bodies of water via outfalls, the unadjusted model output was used in the FEMA 500-year floodplain to retain the water volume that would have been discharged back into local streams from the storm sewer system. This approach includes the benefit of the storm sewer infrastructure in reducing the flood depths in the developed, upstream areas, while still accurately representing the floodplain in downstream receiving streams.

Attachment A:

Tidal Documentation for Resilient New Jersey (NENJ and RRBC)

Tidal Time-series Data

- A separate tidal time-series boundary condition is provided for each model domain. Each time-series has a unique MHHW and a MLLW for the model domain based off different NOAA tidal gauges and harmonic constituent sites, as well as MHHW and MLLW values obtained from VDATUM.
- The tidal time-series were developed by scaling a representative tidal time-series at a NOAA gauge or harmonic constituent site to span MHHW to MLLW based on the percent difference between the maximum of the second highest peak and second lowest trough in the baseline tidal cycle. See graph below for an example of the scaled tidal time-series for the Lower Hudson model.
- The 2070 tidal time-series were created by adding 2.4 ft to each model's present day scaled tidal time-series.



- **Lower Hudson**
  - Representative tidal time-series obtained from NOAA station: The Battery, NY - Station ID: 8518750 (tidal gauge)
  - Baseline tidal time-series data range: 01/01/21 to 04/01/21
  - Start date used for the beginning of baseline tidal cycle 01/01/21 06:12 EST
  - MHHW: 2.28 ft, NAVD88, MLLW: -2.77 ft, NAVD88
    - Source: NOAA Battery Gauge datums

- **Hackensack, Passaic**
  - Representative tidal time-series obtained from NOAA station: Bergen Point West Reach, NY - Station ID: 8519483 (tidal gauge)
  - Baseline tidal time-series data range: 01/01/21 to 04/01/21
  - Start date used for the beginning of baseline tidal cycle 01/01/21 06:18 EST
  - Baseline tidal time-series converted from MSL to NAVD88 by adding -0.176 ft, according to VDATUM
  - MHHW: 2.73 ft, NAVD88, MLLW: -3.04 ft, NAVD88
    - Source: VDATUM at model boundary condition location

- **Raritan River**
  - Representative tidal time-series obtained from NOAA station: KEASBEY, RARITAN RIVER, NJ - Station ID: 8531262 (station with harmonic constituents)
  - Baseline tidal time-series data range: 01/01/21 to 04Ba/01/21
  - Start date used for the beginning of baseline tidal cycle 01/01/21 06:18 EST
  - Baseline tidal time-series converted from MSL to NAVD88 by adding -0.243 ft, according to VDATUM
  - MHHW: 2.65 ft, NAVD88, MLLW: -3.06 ft, NAVD88
    - Source: VDATUM at model boundary condition location

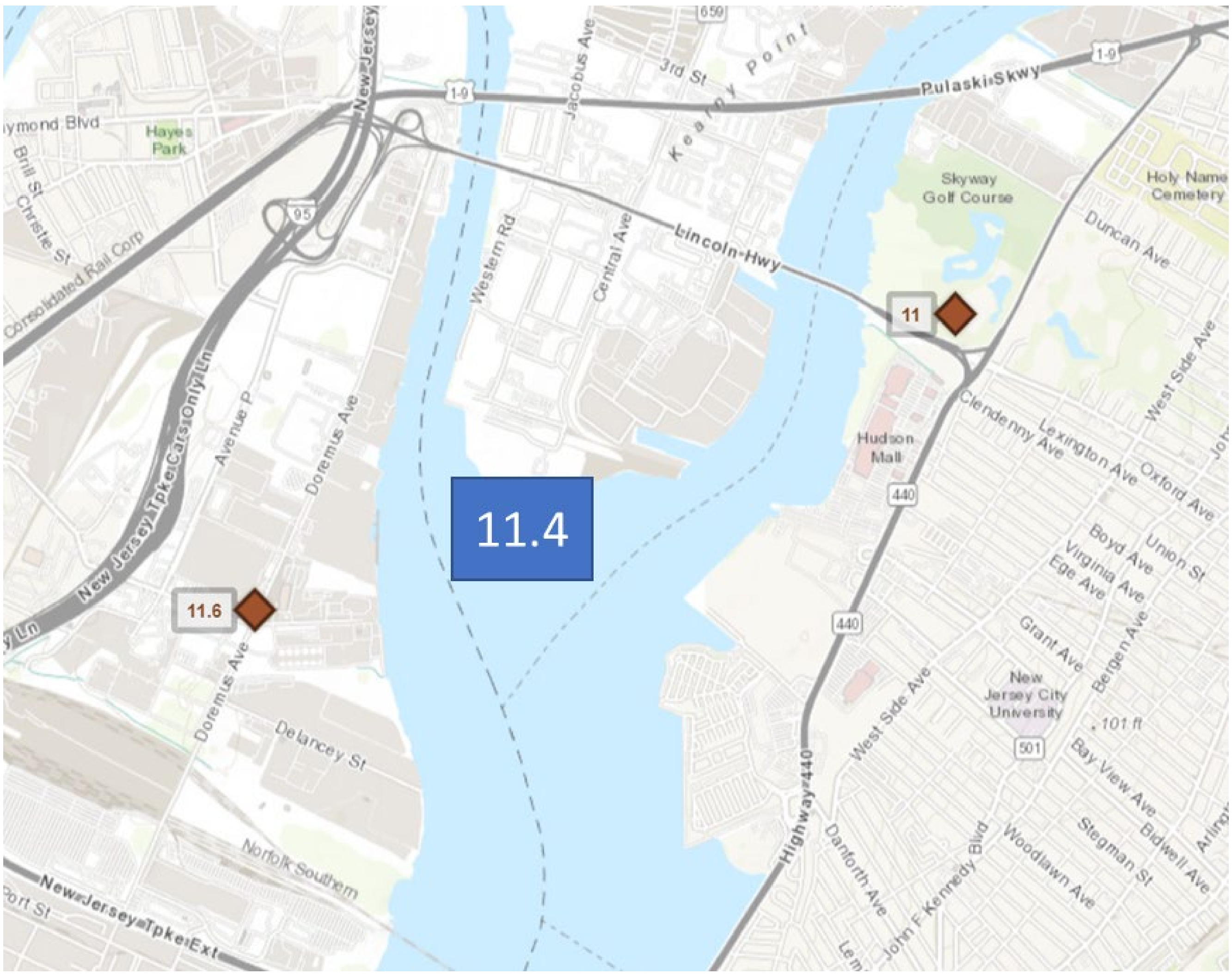
- **Sandy Hook Staten Island**
  - Representative tidal time-series obtained from NOAA station: Sandy Hook, NJ - Station ID: 8531680
  - Baseline tidal time-series data range: 01/01/21 to 04/01/21
  - Start date used for the beginning of baseline tidal cycle 01/01/21 05:54 EST
  - MHHW: 2.41 ft, NAVD88, MLLW: -2.82 ft, NAVD88
    - Source: NOAA Sandy Hook Gauge datums

Sandy Time-series Data

- Hurricane Sandy time-series boundary conditions were developed for the Hackensack/Passaic and the Raritan River using observed WSEL data from temporary storm tide gauges as well as permanent locations. For the Lower Hudson and the Sandy Hook Staten Island domains, Sandy's inundation will be mapped using observed highwater mark data, so no Sandy time-series boundary conditions were developed.
- The 2070 Sandy time-series were created by adding 2.4 ft to the present-day Sandy time-series.
- Both Sandy time-series span from 10/29/12 00:00 to 10/30/12 23:54

- **Hackensack, Passaic**

- Baseline Sandy storm tide time-series obtained from NOAA station: Bergen Point West Reach, NY - Station ID: 8519483 (tidal gauge)
- Baseline time-series converted from MSL to NAVD88 by adding -0.176 ft, according to VDATUM
- The time series was then scaled down from the peak at the Bergen Point Gauge of 11.6 ft, NAVD88 to 11.4 ft, NAVD88 on a percent difference basis. 11.4 ft, NAVD88 is the estimated height of Sandy's storm surge at the Hackensack/Passaic confluence with Newark Bay (see figure below.)



Nearest USGS Sandy high water marks to the Hackensack/Passaic confluence are shown as brown diamonds. The two values were spatially interpolated to approximate the elevation during Hurricane Sandy at the confluence of 11.4 ft, NAVD88 (blue rectangle).

- **Raritan River**

- Composite of three data sources to account for gauge limitations and failures (see plot below):
  - USGS 01406710 Raritan River at South Amboy, NJ
  - USGS Temporary Surge Gauge: SSS-NY-RIC-003WL
  - USGS 01407081 Raritan Bay at Keansburg NJ
- Temporary surge gauge data were filtered with a 15-minute moving average to smooth wave action oscillations
- Composite surge hydrograph scaled on a percentage difference basis to a peak WSEL of 13.6 ft, NAVD88 to match USGS high-water mark near model boundary condition location