US Army Corps of Engineers®
New York District

NEW YORK/NEW JERSEY HARBOR & TRIBUTARIES STUDY (HATS) – TO SUPPORT THE DESIGN AND COST OF EARLY ACTIONABLE ELEMENTS

East Riser Channel

Engineering and Design Sub Appendix B3

Attachment B-3B Hydraulics

MARCH 2026

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1. INTRODUCTION

1.1. Area of Study

As shown in Figure 1-1, the East Riser creek is in the Meadowlands area in Bergen County, New Jersey. The basin is a low-lying, space-constricted, and flood-prone urbanized area and is commercially, industrially, and residentially developed. This area is characterized by a heavily urbanized landscape, with a dense concentration of critical infrastructure that plays a vital role in regional transportation and industrial operations. It contains an extensive network of railroad tracks transporting freight for commercial use, as well as major highways that are essential for both local and interstate travel. Despite its commercial and industrial nature, there are residential properties, including two manufactured home communities.

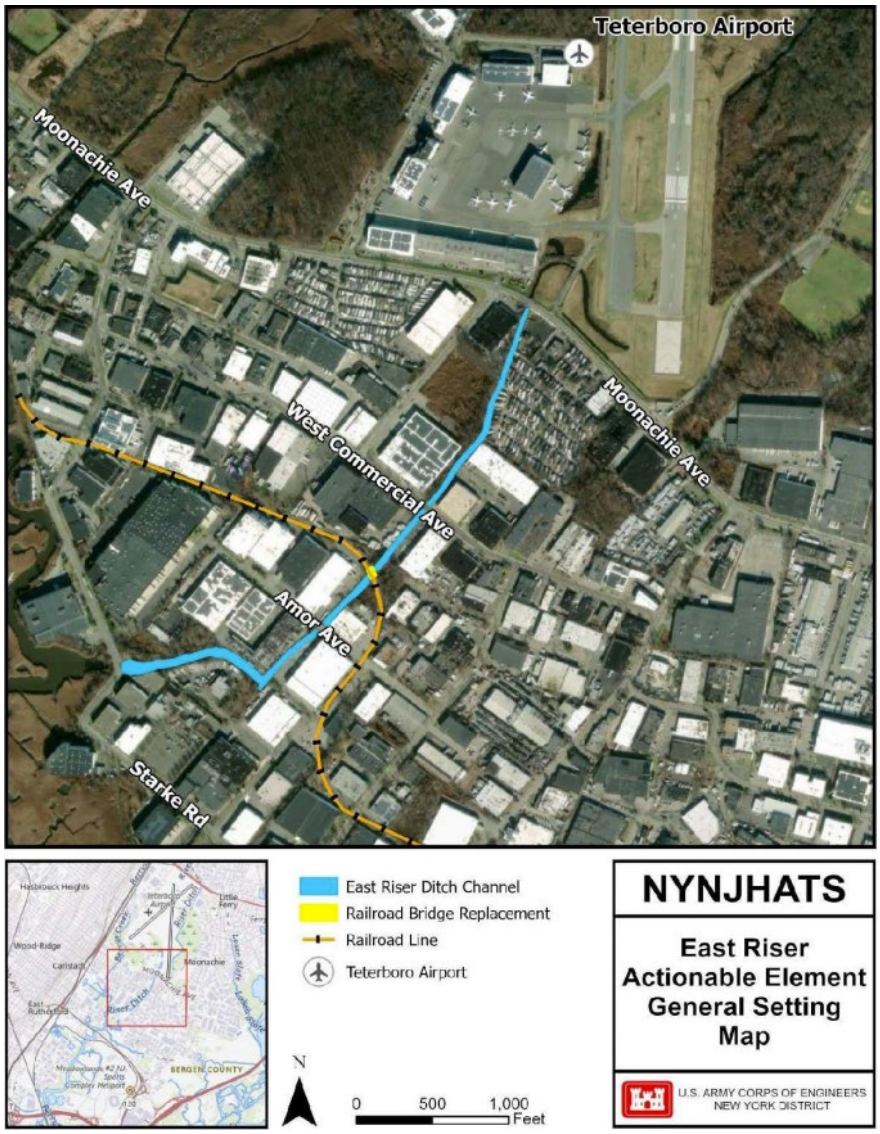

Figure 1-1: East Riser Actionable Element General Setting Map

As depicted in Figure 1-2, both the East and West Riser drain into Berry's Creek and have tide gates to prevent storm tide backflow in all but the largest events. In several locations, the drainage networks and floodplains of the East and West Riser merge, with portions of the flow directed to each waterway. The New Jersey Department of Environmental Protection (NJDEP) Rebuild by Design Meadowlands (RBDM) study recommended the channel modifications of East Riser and the pump station as one project. The intent was for both the channel modifications and pump station to work as a system. The NJDEP is implementing the pump station, and it is expected to be completed prior to end of construction for the East Riser Actionable Element. Without the channel modifications, the pump station would not provide flood risk management benefits at the intended level of performance. Consequently, it is likely that any reductions in water surface elevation provided by the pump station alone would be limited. To capture the true impact of the project, as agreed upon with USACE leadership and non-Federal sponsors and partners, the pump station and channel modifications are being treated as a system for the purposes of reporting project benefits. The with-project scenario includes both the channel modifications and the pump station. Conveyance enhancements between East Riser tide gate and the manufactured home communities downstream of Teterboro Airport will eliminate the impacts from sedimentation in the channel and a lack of bridge and culvert capacity.

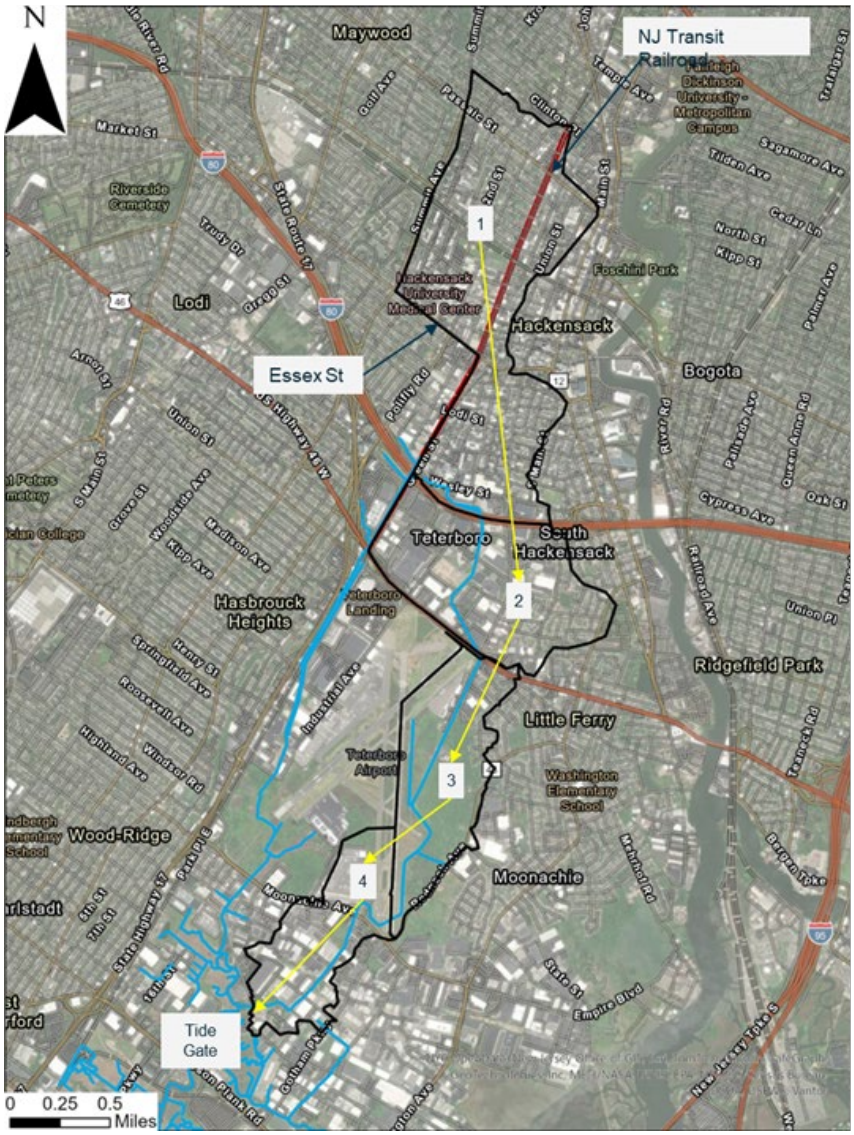

Figure 1-2: East Riser Drainage Area

Upstream of the manufactured home communities, the East and West Riser channels drain the area of Teterboro Airport. Within the airport, there are various drainage culverts, but the primary control of drainage patterns is the elevation of the runways. Upstream of the airport, there is a mix of industrial/warehouse development and some residential development. Drainage patterns in these areas are heavily influenced by the presence of elevated portions of Interstate 80, the New Jersey Transit train tracks, and to a lesser extent, Route 46.

1.1.1. Physical Characteristics

The drainage area of the East Riser (Figure 1-2) is approximately 2.7 square miles. Much of the topography is flat or somewhat flat. Elevations vary from 89 feet (ft) (North American Vertical Datum of 1988 (NAVD 88)) in the upstream of the I-80 drainage area to -2 ft (NAVD 88) at the downstream tide gate in the East Riser South drainage area. The area is urban, consisting of residential, commercial, and industrial establishments. The residential areas are within the City

of Hackensack, Township of South Hackensack, Borough of Moonachie, and Borough of Carlstadt. A portion of the drainage area is occupied by the Teterboro Airport, which has experienced extensive flooding. I-80 and Route 46 cut through the drainage area and run east in the downhill direction. Moonachie Avenue is another major transportation route, which runs roughly parallel to and south of Route 46. These, along with other roads, function as barriers that concentrate surface runoff to channels and closed conduits through the low-lying areas of the drainage area to Berry's Creek.

1.1.2. Sources of Flooding

Flooding in the East Riser (ER) basin can result from either coastal storm surges via Berry's Creek, or rainfall runoff that drains to Berry's Creek but exceeds the capacity of the existing drainage system. The basin is partially protected from storm surges by existing high ground, constructed berms, tide gates, and pump stations. These existing features provide relief from tidal surges during high frequency storm events (e.g., a 20% to 50% Annual Exceedance Probability (AEP) coastal storm event), but for higher surge levels, large and low-lying portions of the inland area become inundated causing extensive property damages and risks to life-safety.

Because the area of East and West Riser (WR) is so flat and intensely developed, the current discharge exceeds the capacity of the bridges and channels. The channel capacity has also been limited by tidal backwater at the tide gate. That source of flooding will be mitigated by the construction of a 500 cubic feet per second (cfs) pump station that will provide fluvial discharge even when tides or storm tides prevent discharge through the tide gates. As discussed in Section 1.1 the pump station and channel modifications are being treated as a system for the purposes of reporting project benefits. The with-project scenario includes both the channel modifications and the pump station. .

Additional constraints on flow are related to limited hydraulic capacity at an undersized rail crossing, the undersized culvert at Commercial Ave, and a general lack of channel capacity. Upstream of Moonachie Ave, (the upstream limit of the proposed channel improvements) extensive flooding occurs within Teterboro Airport. Much of that flooding is due to the lack of capacity at a long culvert on East Riser that runs underneath one of the primary runways. The result is extensive backwater flooding extending north on East Riser. A significant amount of the East Riser flow overtops the runway, with a portion of that flow eventually joining West Riser. The area between the two runways is subject to flooding from a combination of flows overtopping from both the East and West Riser.

Under future modelling scenarios, the frequency of inland inundation will increase as Relative Sea Level Change (RSLC) impacts the frequency and duration that discharge through the tide gates at East and West Riser are blocked by the tides and minor storm surge.

The RBDM Project envisioned that improvements in the East Riser basin would ultimately be paired with Coastal Storm Risk Management (CSRM) project features. The East Riser pump station and channel improvements were defined as the "Build Alternative" of a selected plan that included local CSRM measures. The fluvial flood risk management measures for East Riser are considered a critical component of an overall plan since construction of the CSRM features would not be effective if the area were subject to continued fluvial flooding.

1.2. General Description of the Project Features

Figure 1-3 shows the major components of proposed flow condition improvements along East Riser, a tributary of the Hackensack River in the Meadowlands of northeastern New Jersey. The East Riser Actionable Element Site (Project Area) is within the Hackensack/Passaic Planning Region. The site is a low-lying, space-constricted urbanized area and is commercially, industrially, and residentially developed.

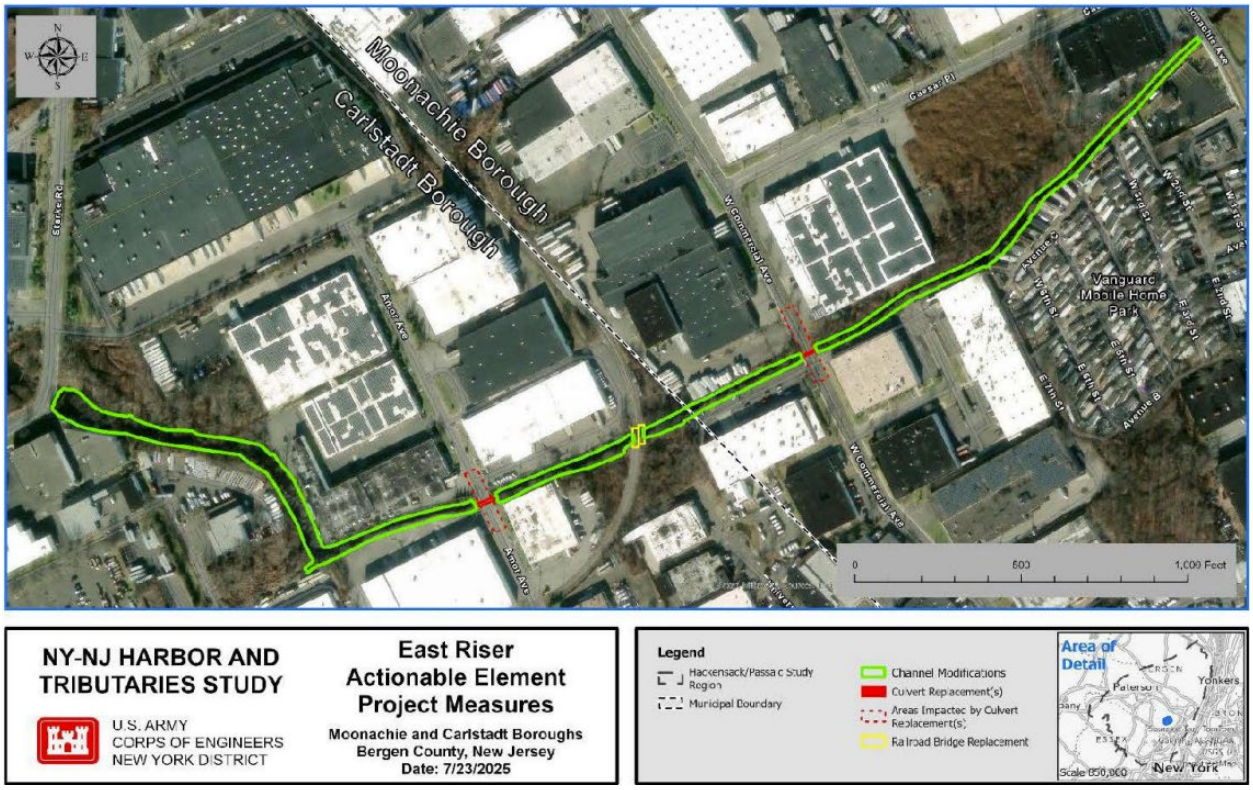

Figure 1-3: East Riser Actionable Element Project Measures

1.2.1. Channel and Bridge Modifications

The proposed channel modifications will consist of bank stabilization, the widening and deepening of the East Riser Channel, and the replanting of vegetation along about 4,150 ft of the lower reach of the channel. The proposed channel generally has a bottom width of 30 ft.

Results from the without project modelling show that the existing channel does not have enough capacity to convey the flows that are created by the higher intensity storms, which causes flooding in the area of interest.

The proposed modifications make the channel deeper and wider. The modifications start at the downstream face of the Moonachie Avenue bridge and continue approximately 4400 feet to the East Riser tide gate. The channel width will be increased an average of 10 ft along the profile. The figure below compares the invert of the channel in the with and without project scenarios.

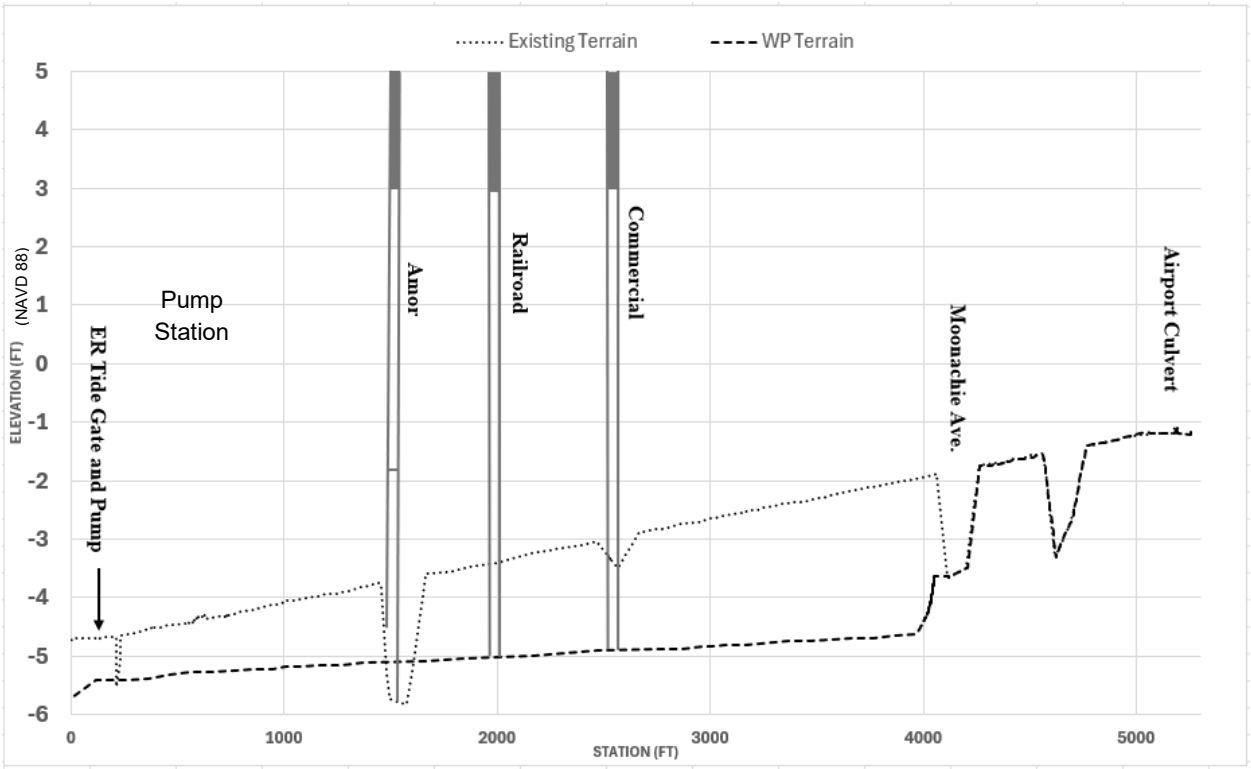

Figure 1-4. Channel inverts along the East riser for with and without project scenarios.

Furthermore, the existing narrow bridge openings are the constraint points along the profile that are causing backwater and flooding upstream of the bridges on East Riser.

The proposed modifications for these bridges are as follows:

- **Commercial Avenue Bridge**

  The existing opening of the Commercial Ave bridge is a 12’ span x 6’ rise elliptical culvert. The project proposes a rectangular opening with 30’ width and 8’ rise.

- **Railroad Bridge**

  The existing opening of the Railroad bridge is a 21’ wide and 6.35’ high rectangular culvert. The project proposes to replace this culvert with a 44’ width and 8’ rise rectangular culvert.

- **Amor Avenue Bridge**

  The existing opening of the Amor Avenue bridge is a dual ellipse culvert with 7.75’ span x 4.25’ rise. The project proposes a rectangular opening of 30’ wide and 8’ height.

1.2.2. Culverts

The proposed 30 ft wide bridges to replace culverts at Amor Ave and West Commercial Ave will dramatically increase conveyance and reduce the likelihood of debris blockage of the opening.

Figure below shows the layout of the bridges in the model for with and without project scenarios:

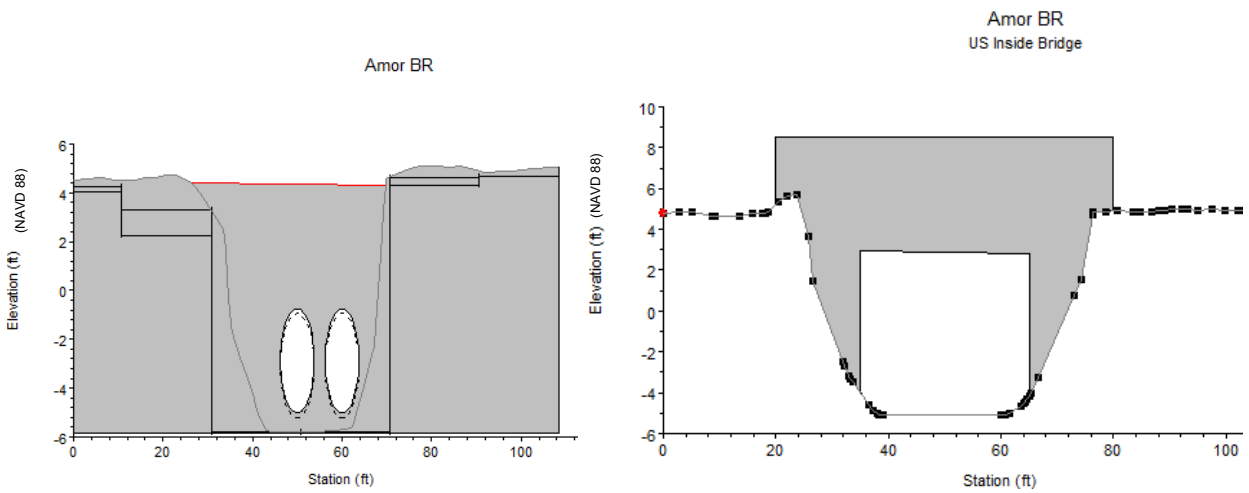

Figure 1-5. Amor Avenue Bridge layout for Without Project (left) and With Project (right),

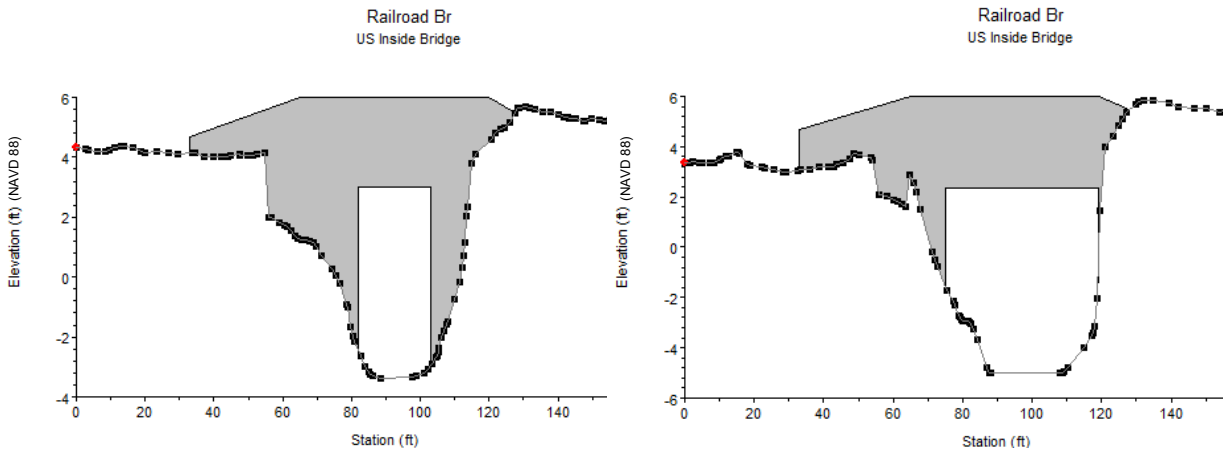

Figure 1-6. Railroad Bridge layout for Without Project (left) and With Project (right)

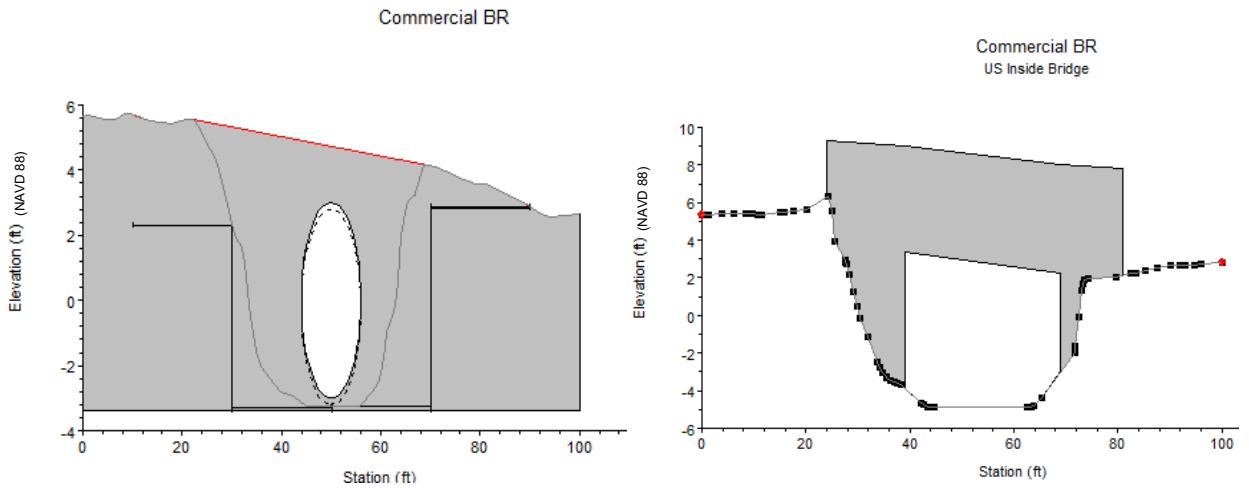

Figure 1-7. Commercial Ave Bridge layout for Without Project (left) and With Project (right).

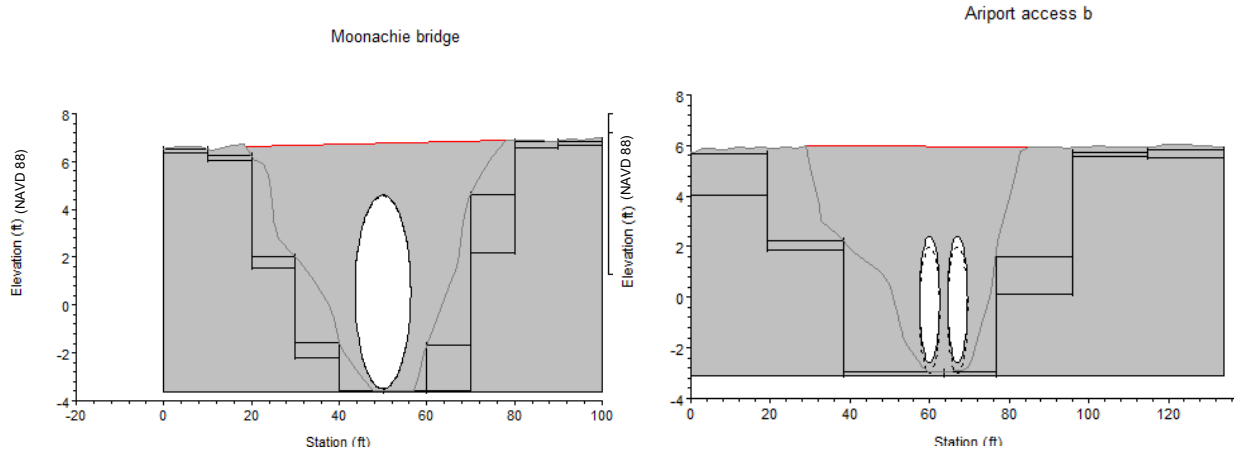

Figure 1-8. Bridge layout of Moonachie Bridge (left) and Airport Access Bridge (right).

2. HYDRAULIC MODELING – HEC-RAS

2.1. Description of Construction of the Model

As described above, the study area is extremely flat and the flow paths between the East and West Riser merge at several locations, most notably within Teterboro Airport. To capture the complex flow paths, diversions between the two basins, and the flood routing impact of flows trapped behind undersized culverts, the model was developed using two-dimensional (2D) HEC-RAS. Prior modelling of the study area included a 2D Infoworks IFM model used in the channel and pump station design for NJDEP, and a 1-dimensional (1D) unsteady state HEC-RAS model specifically developed in accordance with NJDEP Flood Hazard Area rules. A modified version of the unsteady model developed for permitting was used during the initial evaluation of the Actionable Elements evaluation to inform the flood risk and benefit analysis documented in the Draft Feasibility Report.

The 2D model domain boundary was developed to match the East Riser and West Riser watershed boundaries upstream of Teterboro Airport, and along the western edge of the low-lying portions of West Riser that could impact routing of combined East and West Riser flows. These limits correspond with the drainage basins described in Attachment B-3A Hydrology. This was necessary to integrate the boundary inflows developed using the Hydrologic Engineering Center - Hydrologic Modelling System (HEC-HMS) model. The model domain was extended far enough downstream of the tide gates to be representative of the downstream tidal boundary condition. The model domain with tide gate locations is shown in Figure 2.1.

The model geometry uses hydraulic structure dimensions and elevations taken from the previous 1D HEC-RAS model used for the Draft Feasibility Report and the prior Infoworks model. That model was developed using survey data collected specifically for the RBDM analysis and design, while other portions were based on channel and bridge surveys completed as input to other HEC-RAS models developed for permitting actions, including the Flood Hazard Area permits for the new control tower at Teterboro Airport. See Figure 2-1 for extents of the newly surveyed portions of the Study Area, and those taken from prior modelling studies. The 1D cross sections in the portion of the West Riser downstream of the tide gate were developed for this modelling effort and are based on the existing conditions terrain described in Section 2.3.

Figure 2-1: Terrain Model for Detailed HEC-RAS 2D Modelling

The model uses a 100-ft by 100-ft cell size for the 2D flow area, with break-lines being added along roadways, channels, and other important terrain features that would be likely to impact flow conditions.

Land use coverage was based on data acquired from NJDEP, with roadways added based on local parcel data and refinements being made in the open channel regions. Several Manning's n roughness value polygons were added to the domain along steep roadways, with a higher n-value assigned to these areas to reduce model instabilities in these areas. The roughness

values were adapted from the section 6 of the HEC-RAS 2D User's Manual and are presented in Table 1 below.

Table 1. Land use data

ID	Name	ManningsN
0	NoData	0.035
1	RESIDENTIAL, HIGH DENSI...	0.05
2	RESIDENTIAL, SINGLE UNI...	0.05
3	RESIDENTIAL, SINGLE UNI...	0.08
4	COMMERCIAL_SERVICES	0.05
5	INDUSTRIAL	0.05
6	TRANSPORTATION_COMM...	0.05
7	MAJOR ROADWAY	0.04
8	MIXED TRANSPORTATION ...	0.12
9	RAILROADS	0.05
10	AIRPORT FACILITIES	0.06
11	STORMWATER BASIN	0.05
12	INDUSTRIAL AND COMMER...	0.12
13	MIXED URBAN OR BUILT-U...	0.06
14	OTHER URBAN OR BUILT-U...	0.06
15	CEMETERY	0.06
16	MANAGED WETLAND IN M...	0.06
17	RECREATIONAL LAND	0.06
18	ATHLETIC FIELDS (SCHOOLS)	0.05
19	STADIUM, THEATERS, CUL...	0.1
20	CROPLAND AND PASTURE...	0.03
21	DECIDUOUS FOREST (10-50...	0.1
22	DECIDUOUS FOREST (>50%...	0.1
23	OLD FIELD (< 25% BRUSH C...	0.05
24	PHRAGMITES DOMINATE O...	0.08
25	DECIDUOUS BRUSH SHRU...	0.08
26	CONIFEROUS BRUSH SHR...	0.08
27	MIXED DECIDUOUS CONIFE...	0.08
28	SALINE MARSH (LOW MAR...	0.06
29	SALINE MARSH (HIGH MAR...	0.08
30	PHRAGMITES DOMINATE C...	0.1
31	DECIDUOUS WOODED WE...	0.12
32	DECIDUOUS SCRUB SHRU...	0.08
33	MIXED SCRUB SHRUB WET...	0.11
34	HERBACEOUS WETLANDS	0.07
35	PHRAGMITES DOMINATE I...	0.1
36	ALTERED LANDS	0.06
37	DISTURBED WETLANDS (M...	0.06
38	TRANSITIONAL AREAS	0.06
39	TIDAL MUD FLAT	0.035
40	STREAMS AND CANALS	0.035
41	ARTIFICIAL LAKES	0.035
42	BRIDGE OVER WATER	0.035
43	TIDAL RIVERS, INLAND BA...	0.035
44	NATURAL LAKES	0.035

2.2. Scenarios for Analysis

A total of 24 existing conditions scenarios were evaluated. The precipitation input consists of eight rainfall frequency events with a single duration of 48 hours based on present day precipitation data. These rainfall frequencies include: 50% AEP (2-year, 20% AEP (5-year), 10% AEP (10-year), 5% AEP (25-year), 2% AEP (50-year), 1% AEP (100-year), and 0.5% AEP (200-year), and 0.2% AEP (500-year). Each set of precipitation data was analysed with two sets of downstream tidal boundary stage hydrographs, one for “Normal Tide” non-storm conditions, and one for storm

surge conditions. Compared to the base year (2037), the 2087 tidal condition uses a 1.11 ft Relative Sea Level Change (RSLC) based on the intermediate scenario calculated at The Battery tide gauge in New York City using the USACE RSLC calculation tool.

3. MODEL DATA SOURCES

3.1. Terrain

The overbank areas of the model domain are based upon LiDAR data collected in April 2014. The digital elevation model (DEM) added to model as a bare-earth geotiff, with a 1-foot pixel size. Building footprints were removed from the terrain and replaced by raised elevation of 20 ft to replicate the buildings and to function as blocked obstructions in the model. The West Riser and East Riser open channels were represented by creating interpolation surfaces based on 1D HEC-RAS models of USACE RBDM project. The terrain at the culvert and bridges inlets and outlets was adjusted to match or be slightly lower than the structure invert in order to allow HEC-RAS to run successfully.

3.2. Inflows

The outflow of each drainage area from the HEC-HMS model was applied as an internal boundary condition to the HEC-RAS model. (See Attachment B-3A Hydrology for more information.) For better representation of the precipitation in the study area, multiple internal boundary condition points were added throughout each subbasin to inject the flow at different locations. Based on the number of the injection points in each subbasin, a flow multiplier added to the HMS results in the inflow data table. For example, if there was four different injection points considered for a subbasin, the flow multiplier of 0.25 applied to the HMS outputs, and the result inserted as the boundary condition to each of those four injection points.

3.3. Precipitation

Different precipitation scenarios applied to the HEC-RAS model are described in Attachment B-3A Hydrology. The HEC-RAS model was originally tested using a “Rain on Grid” approach, where rainfall excess calculated with HEC-HMS were applied within the HEC-RAS 2D Domain. This approach resulted in model instability. Instead, inflow was applied only at the boundaries (as described in Section 3.2), which resulted in a stable and reliable model.

3.4. Boundary Conditions

At the downstream edge of the model domain, exterior stage (or coastal) hydrographs are specified as the model boundary condition. The coastal boundary conditions are grouped into three categories: *Lower Bound, Most Likely, and Upper Bound.* Additionally, the boundary conditions are adjusted to a “base year” of 2037 and “future year” of 2087.

For the *Lower Bound* scenarios, the tidal boundary condition was set to be the normal tide graph of the Bergen Point, NY gauge with an adjustment of the mean water level to match an intermediate RSLC projection for the base year of 2037 and future year 2087. This translates to a high tide elevation of 3.42 ft (NAVD 88) for the base year and 4.53 ft (NAVD 88) for 2087.

For the *Most Likely* scenarios, a historic data analysis was conducted to understand the connection between precipitation and coastal events. For this analysis, the intermediate RSLC curve was used to adjust the maximum daily tidal water levels (coastal water levels) from the elevation of the original record date to an elevation equivalent to the base year of 2037 and future year of 2087. For the base year, the analysis of the precipitation and water level data indicated that the majority of interior runoff events coincide with an exterior water level (tide plus surge) less than or equal to the 2-year recurrence interval (50% AEP). Similarly, the majority of significant storm surge events are likely to coincide with runoff equivalent to a 2-year (50% AEP) event or less.

The 2-year (50% AEP) was the highest frequency precipitation event that was modelled in this study; therefore, the raw historic data was filtered to exclude the events with frequencies higher than the 2-year (50% AEP) precipitation limit. The distribution of total daily precipitation events (with frequencies higher than 2-year (50% AEP)) compared to the coastal exterior stages (or daily maximum water level) are presented in Figure 3-1. The median and mean values of the daily maximum water level are marked in the graph. The mean value of this distribution is considered the *Most Likely* maximum water elevation for the tailwater condition. This translates to a peak water surface elevation 4.27 ft (NAVD 88) for the base year (2037) and 5.38 ft (NAVD 88) for the future year (2087). The water level incorporates a normal tide as well as a small surge elevation.

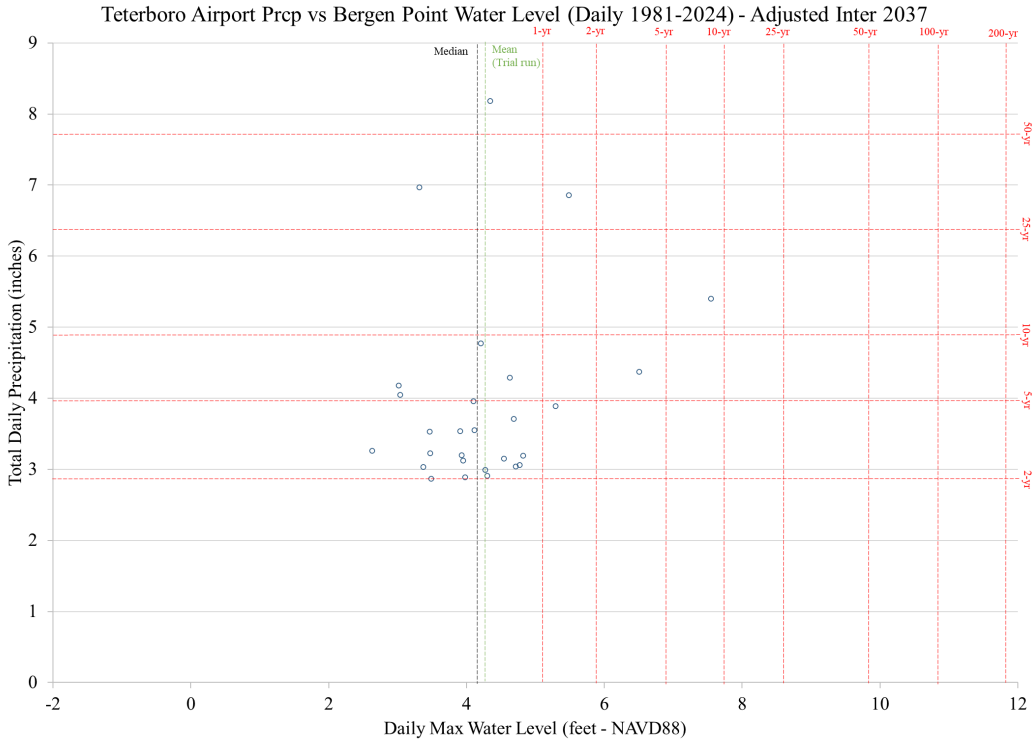

Figure 3-1. Total Daily Precipitation (2-yr and greater) vs Tidal Water Level (Yr 2037)

A comparison of the *Lower Bound* and *Most Likely* boundary condition water levels are shown in Figure 3-2. The upper left panel shows the *Lower Bound* boundary conditions with a normal tide

adjusted to the peak base year elevation (3.42 ft NAVD 88) and the upper right panel shows the *Lower Bound* boundary conditions with a normal tide adjusted to the peak future year elevation (4.53 ft NAVD 88). The lower left panel shows the *Most Likely* boundary conditions for the base year. This includes the normal tide with a small surge incorporated at the start of the time series reaching a peak of 4.27 ft (NAVD 88). The lower right panel shows the *Most Likely* boundary conditions for the future year. This includes the normal tide with a small surge incorporated at the start of the time series reaching a peak of 5.38 ft (NAVD 88).

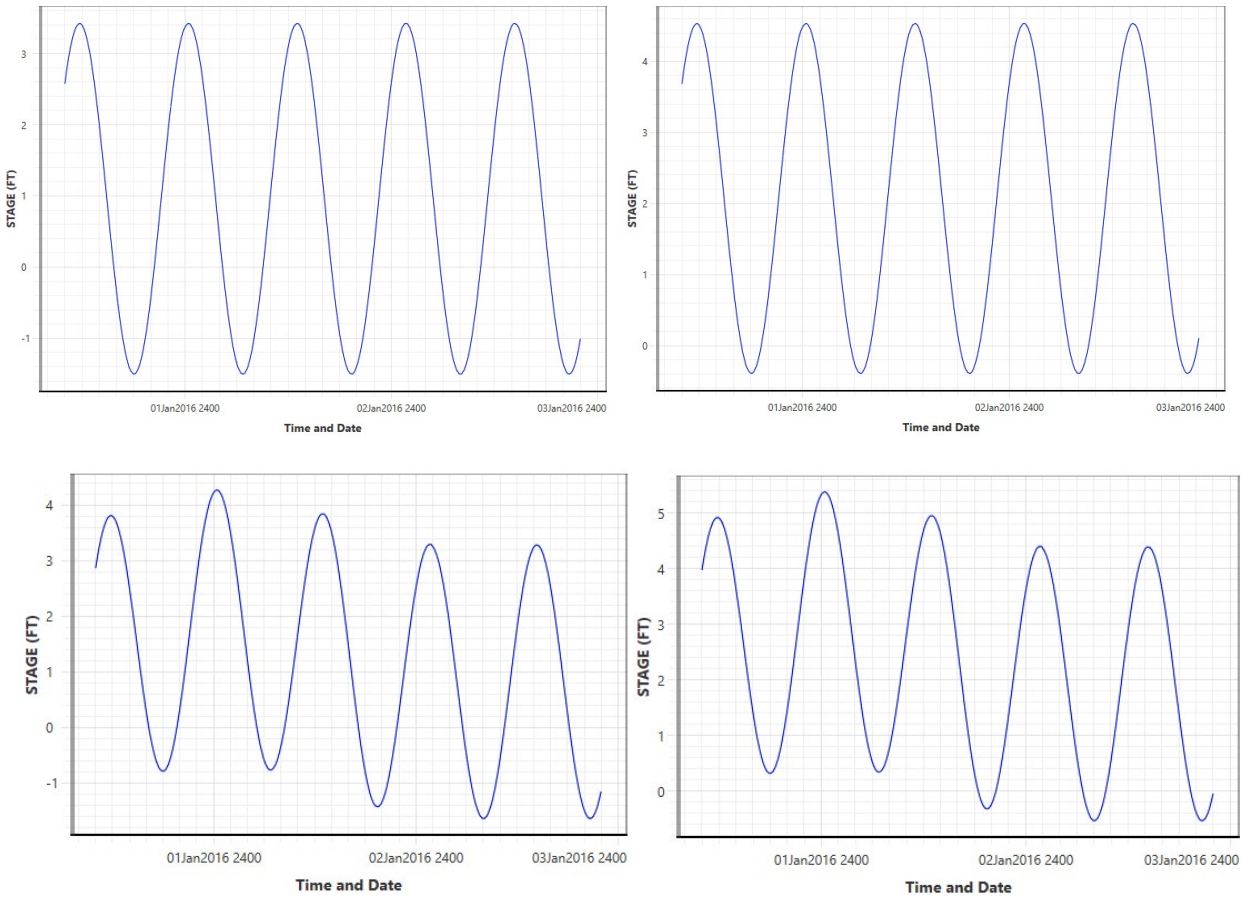

Figure 3-2. Tidal boundary conditions for *Lower Bound* base year (top left), *Lower Bound* future year (top right), *Most Likely* base year (bottom left), and *Most Likely* future year (bottom right).

In addition to the *Lower Bound* and *Most Likely* scenarios, an Upper Bound exterior stage has been defined. For the *Upper Bound* scenarios, the lower frequency tidal boundary conditions were utilized, which incorporate a storm surge on top of the normal tide. To calculate the highest water level elevations for a range of frequencies, the U.S. Army Corps' North Atlantic Coast Comprehensive Study (NACCS) dataset was used. NACCS save point 4281 was selected for consistency with the analysis completed for the NY/NJ Harbor & Tributaries plan. This data was cross-checked against nearby FEMA stage frequency curves and NOAA stage frequency curves

form observed data at the Bergen Point, NY gauge and the NACCS data was determined to be acceptable for use as tailwater boundary conditions.

The NACCS data provides a base condition analysis with no tides and an analysis of 96 random tides. Each analysis also includes a range of confidence limits as well as an “expected value”. The expected value from the 96 random tides analysis was used for this analysis. Data were converted from the Mean Sea Level (MSL) datum to NAVD88 by deducting 0.023 ft and were converted from meters to feet. Data were adjusted to the base year of 2037 by adding 0.61 ft and to the future conditions year of 2087 by adding 1.72 ft.

Table 2. Peak water level elevation (ft NAVD88) for various recurrence intervals using NACCS Save Point #4281 for the base year (2037) and future year (2087)

Annual Exceedance Probability	Frequency	Base Year (2037) Water Level (ft NAVD88)	Future Year (2087) Water Level (ft NAVD88)
50%	2-year	5.88	6.99
20%	5-year	6.89	8.00
10%	10-year	7.75	8.86
4%	25-year	8.6	9.71
2%	50-year	9.82	10.93
1%	100-year	10.84	11.95
0.5%	200-year	11.82	12.93
0.2%	500-year	13	14.11

Because the elevation of berms surrounding the project area of interest is set to 5.5 ft NAVD88, any coastal event higher than 5.5 ft overtops the berm and inundates the project area, regardless of the interior flow. Therefore, no interior flow was included in the modelling for events with coastal tailwater high tide elevations greater than 5.5 ft.

Table 3 lists the boundary conditions included in the analysis. The final exterior stage elevations are different for the base year and future conditions scenarios.

Table 3. Model scenario boundary conditions

Varied Interior Condition		Risk Condition	
Interior Flow	**Exterior Stage Base Year (ft NAVD 88)**	**Exterior Stage Future Year (ft NAVD 88)**	
2-year	Normal tide (3.42 ft)	Normal tide (4.53 ft)	Lower Bound
5-year			Lower Bound
10-year			Lower Bound
25-year			Lower Bound
50-year			Lower Bound
100-year			Lower Bound
200-year			Lower Bound
500-year			Lower Bound
2-year	Most Likely (4.27 ft)	Most Likely (5.38 ft)	Most Likely
5-year			Most Likely
10-year			Most Likely
25-year			Most Likely
50-year			Most Likely
100-year			Most Likely
200-year			Most Likely
500-year			Most Likely
N/A	2-year (5.88 ft)	2-year (6.99 ft)	Upper Bound
	5-year (6.89 ft)	5-year (8.00 ft)	Upper Bound
	10-year (7.75 ft)	10-year (8.86 ft)	Upper Bound
	25-year (8.6 ft)	25-year (9.71 ft)	Upper Bound
	50-year (9.82 ft)	50-year (10.93 ft)	Upper Bound
	100-year (10.84 ft)	100-year (11.95 ft)	Upper Bound
	200-year (11.82 ft)	200-year (12.93 ft)	Upper Bound
	500-year (13.00 ft)	500-year (14.11 ft)	Upper Bound

3.5. Pumps

There are two pump stations currently located in the East Riser and West Riser drainage area:

1) **Existing pump station at Teterboro Airport**: This facility is located near the southwestern edge of the Teterboro Airport and is known as the Vincent Street pump station. The Vincent Street facility pumps from an eastern branch of the West Riser that captures runoff from the Airport and discharges directly into the main channel of West Riser that has a channel invert that is six feet higher. It consists of four pumps with the maximum discharge capacity of 175 cubic feet. The pump station wet well dimensions and pump operating characteristics were extracted from plans and applied to the HEC-RAS 2D model.

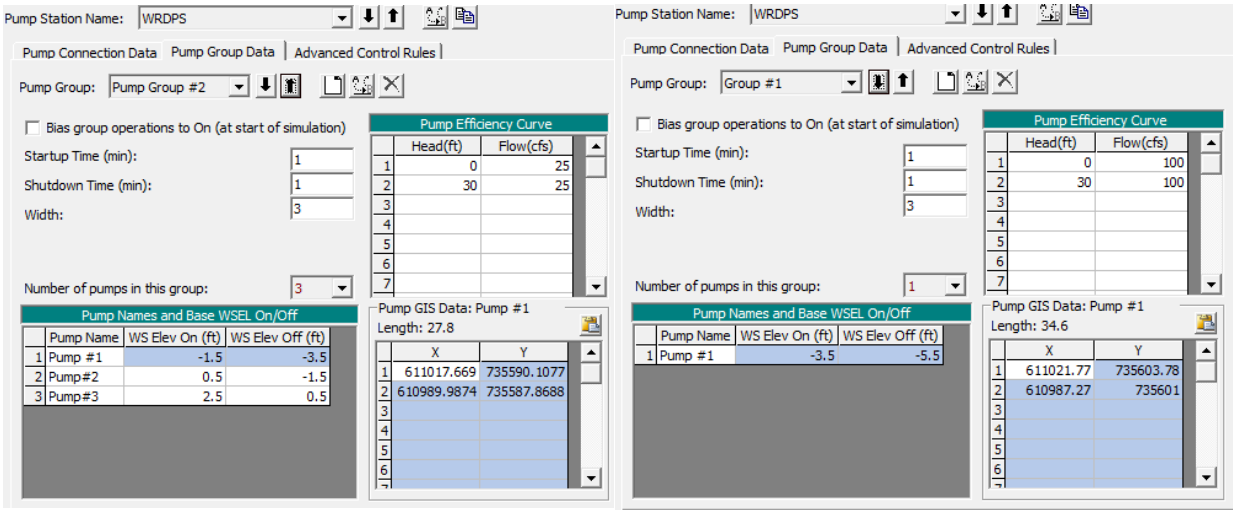

Figure 3-3. Pump characteristics of Vincent pump station.

2) **Existing pump station at Huyler Street**: This pump station is outside of the 2D flow area domain and is not included in the 2D HEC-RAS model. The pump was modelled in the HEC-HMS hydrologic model and its effect captured in the HEC-RAS inflow boundary condition.

In addition, the with-project model includes the new pump station at adjacent to the East Riser tide gate as follow:

3) **East Riser pump station**: Currently under construction, it is located on Starke Road, in vicinity of the East Riser tide gates. The pump station consists of 4 pumps with a total capacity of 500 cfs, which pump the water from East Riser over the tide gate into Berry's Creek. The presence of this pump station effectively limits the impact of tidal tailwater on flood elevations upstream of the tide gate.

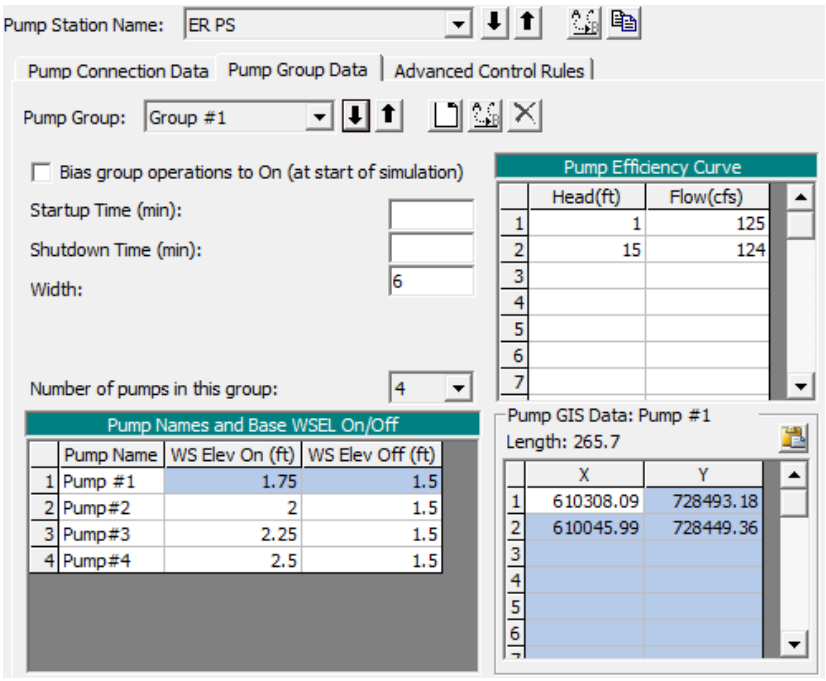

Figure 3-4. Pump characteristics of the East Riser pump station.

3.6. Storm Drains

It is assumed that the amount of water contained in the subsurface storm drainage systems is approximately the same for the with and without project scenarios. Because the 2D HEC-RAS model does not include the subsurface storm drainage system, it is viewed as approximately equivalent to a model whose subsurface system is full of water at the beginning of each storm event and, therefore, it is considered a reasonable approximation of a worst-case scenario regarding inundation conditions.

3.7. Options and Tolerances

The Shallow Water Equations – Eulerian/Lagrangian Advection (SWE-ELM) method was utilized for this modelling effort. This method allows the software to capture the flow contraction or expansions along the bridges and culverts. This method also has a better response for capturing the flow overtopping the barriers and calculating the extent of flooding at higher velocities and flows.

For the time step control options, the variable time step based on the Courant number was used to make sure the model will capture all the abrupt water surface and flow changes at the lower time steps. The maximum and minimum Courant numbers were set to 1 and 0.4.

For the default starting time-step, a parametric study was conducted to compare the percentage error of the model and the total run time for different time-steps. As the result, the initial time-step of 5 seconds appears to be the optimum scenario to run the model the fastest while keeping the model stable with minimum acceptable percentage errors (less than 1%). A maximum iteration of

20 was used for each time step and the water surface elevation tolerance was set to 0.01 ft, while the flow tolerance was 0.1%.

As a result of these methods and calculations, the Overall Volume Accounting Error as percentage was always less than 1% for every scenario.

3.8. Model Validation

Since there was not proper recording of gauges or any accurate water marks, the validation of the model was based on special reports published during and after Hurricane Irene. Figure 3.5 below extracted from one of the reports, shows the extent of the flooding at the Teterboro Airport, with only limited sections of the runways above the water level. This photograph, when compared with the results of the Max WSE for the Without Project scenario at 1% EAP (which was almost matching with Irene return period), validated the accuracy of the model. The water level and sections of the runways staying dry in the results of the model, matches with the aerial images captured during the Irene.

KTEB/Teterboro, NJ – Airport **closed**.Significant flooding of runways and taxiways, and ramps. Flood waters are receding since yesterday but only slowly. An Airport lighting systems check will take place between 1700-1800 this evening, after which a more definite opening time can be given by the Airport Authority. Anticipated reopening is Tuesday am.

Figure 3-5. Aerial photo showing the extent of flooding at Teterboro airport during Irene.

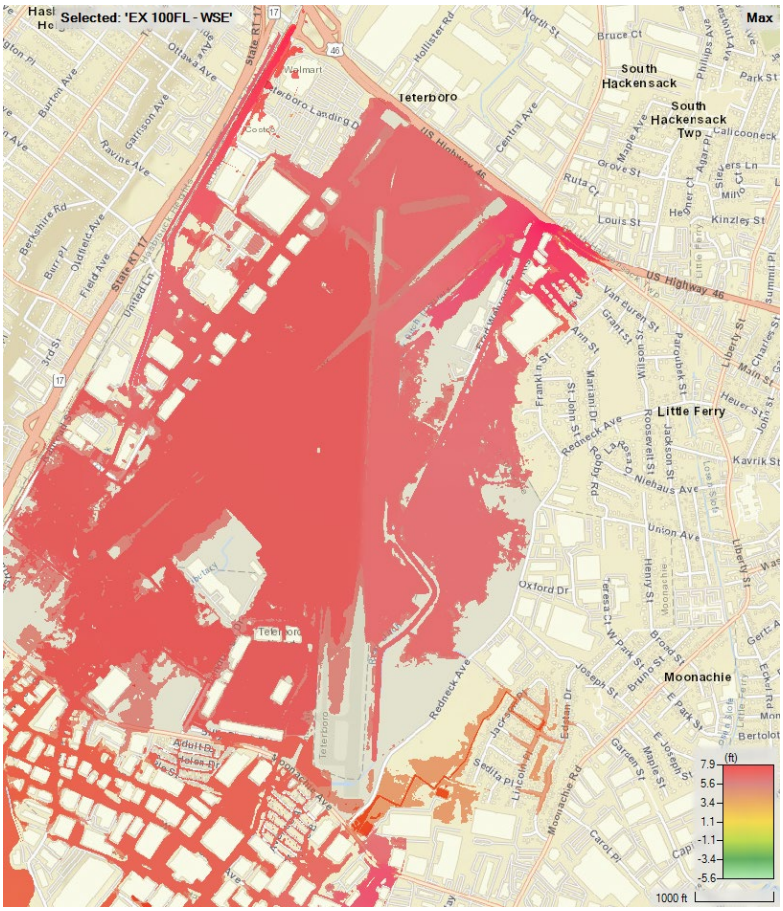

Figure 3-6. Max WSE during a 1% AEP event for the Without Project to be compared with the extend of flooding during Irene.

3.9. Modeling Products

One of the key uses of the updated HEC-RAS modelling results is to generate the inputs to the economic and life safety flood risk analyses used to quantify the benefits of the plan. The outputs from each model run were incorporated into HED-FDA Version 2.0 as HDF files. The modelling team assisted in defining “Impact Areas” and associated stage frequency curves for use in HEC-FDA. Additionally, stage and flow hydrographs were developed to compare the rate of rise and duration of flooding at each of the impact areas. The economic analysis team will use the HEC-RAS results to perform an HEC-FDA benefit-cost analysis for the flood risk management concepts. Figure 3.7 below shows the six impact areas delineated for the study area and the respective extraction point used to develop the stage v frequency curves for each of the impact areas.

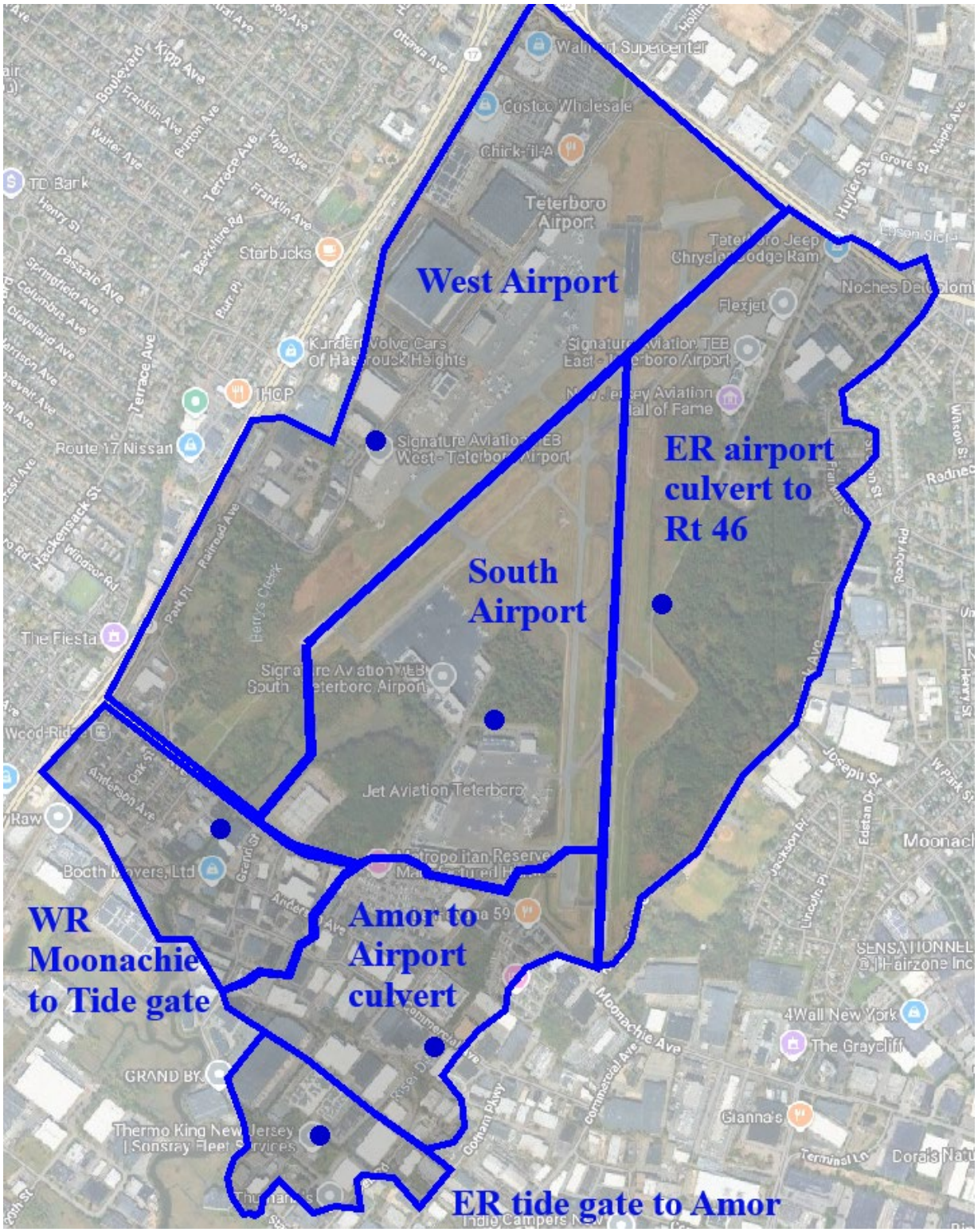

Figure 3-7. Impact areas and their frequency curve extraction points.

4. SUMMARY OF HYDRAULIC MODELLING RESULTS

The 2D HEC-RAS models provide a detailed assessment of the flood impacts for the with- and without- project conditions. Two scenarios have been modelled representing construction completion Base Year (2037) and Future Year (2087) sea levels. The most likely downstream boundary condition is based on a correlation analysis of the historic data, while the lower bound was based on the normal time. Additional details provided in section 3.4. The time series reflects a storm surge hydrograph superimposed over a normal tide adjusted for Relative Sea Level Change at both time scenarios. The project impacts at both the Base Year and Future Year scenarios are similar, so the description of results is focused on the Base Year scenario. In general, the plan provides a reduction in flood depths on East Riser upstream of the tide gate and a reduction in the rate and volume flow diverting from East Riser to West Riser. The modelling results are summarized graphically with a comparison of stages for the Base Year with- and without-project conditions (Figures 4-1 to 4-6) at each of the identified impact areas, followed the Future Year stage comparisons (Figure 4-7 to 4-12) and then by a summary of the flow hydrographs (Figures 4-13 to 4-15) at selected locations.

As seen in Figure 4-1, on East Riser downstream of Amor Avenue, there is a significant decrease in flood elevations associated with the ability of the pump station to discharge East Riser flows downstream of the tide gate when higher downstream elevations block or limit gravity discharge. The pump station capacity is sufficient to provide reduced flood elevations even though the project increases the discharge reaching the pump station. By reducing the flood elevations upstream of the tide gate, the pump station eliminates tidal backwater effects and increases the hydraulic gradient and flow rates in East Riser. In addition, the channel and bridge improvements reduce the upstream flow constraints and contribute to an increase in flow rates. Flow hydrographs at Amor Avenue, presented in Figure 4.7, show the extent of the increased conveyance. The 500 cfs pump station capacity captures most of the increased inflow. Under the without-project conditions, the stages in the impact area upstream of the tide gate are generally between 4.06 NAVD88 for the 50% AEP (2 year) and 5.18 NAVD88 for the .2% AEP (500 year). With the project in place, the range of flood elevations is from 2.56 NAVD88 to 4.80 NAVD66, with the greatest reductions occurring at the high frequency events. For example, the 10% AEP in this area is typically reduced by slightly more than 1 ft, while the 1% AEP reduction is slightly less than 0.5 ft.

As seen in Figure 4-2, the without-project flood elevations on East Riser vary from about 4.1 ft NAVD88 at the 50% AEP (2 year) event to about 5.4 ft NAVD88, in the 0.2% AEP (500-year) event. The proposed plan reduces flood stages in this area of East Riser by between 1.3 ft and 0.3 ft at a point about halfway between Amor Ave. and Moonachie Rd. For a flood elevation of 4.5 NAVD88, the annual exceedance probability changes from 10% AEP in any year to nearly a 1% AEP. Again, the project has the greatest impacts at the higher frequency events.

In the area on East Riser upstream of the culvert at the downstream end of Teterboro Airport, there are relatively minor changes in flooding between the with- and without-project conditions. As seen in Figure 4-3, this difference is only about 0.1 ft for larger events where the capacity of the culvert at the downstream end of the airport limits the effectiveness of the plan conveyance

improvements downstream. As seen in Figure 4-8, in the with-project condition, there is also an increase in flow reaching the culvert, also limiting the effectiveness of the downstream improvements. This increase in flow in East Riser is primarily associated with a reduction in flow diverting from East Riser to the South Airport impact area and to West Riser. Even though the water surface elevation changes are minor, the diverting flow occurs along the length of the airport runway, so the total reduction in diversion is significant.

The area described as the South Airport impact area is located between Teterboro Airport runways and is flooded by flows diverting from both East Riser and West Riser. As seen in Figure 4-4, the with-project flood elevations are lower by around 0.1 ft, reflecting a reduction in flow diversions.

Areas within and adjacent to the airport along West Riser also see a small reduction in flood elevations. As seen in Figure 4-5, these reductions are limited to less than 0.1 ft and are associated with slightly lower flows as seen in Figure 4-15. As seen in Figure 4-6, on West Riser between the tide gate and Moonachie Rd, there is no noticeable change in flood elevations until the 1% AEP or larger events.

The frequency data for each of the impact areas is included in Table 3 for both With and Without project scenarios.

Note that, the results figures and tables in this section, represent the Most Likely scenario runs.

4.1. Impact areas stage frequency curves for Base Year scenario

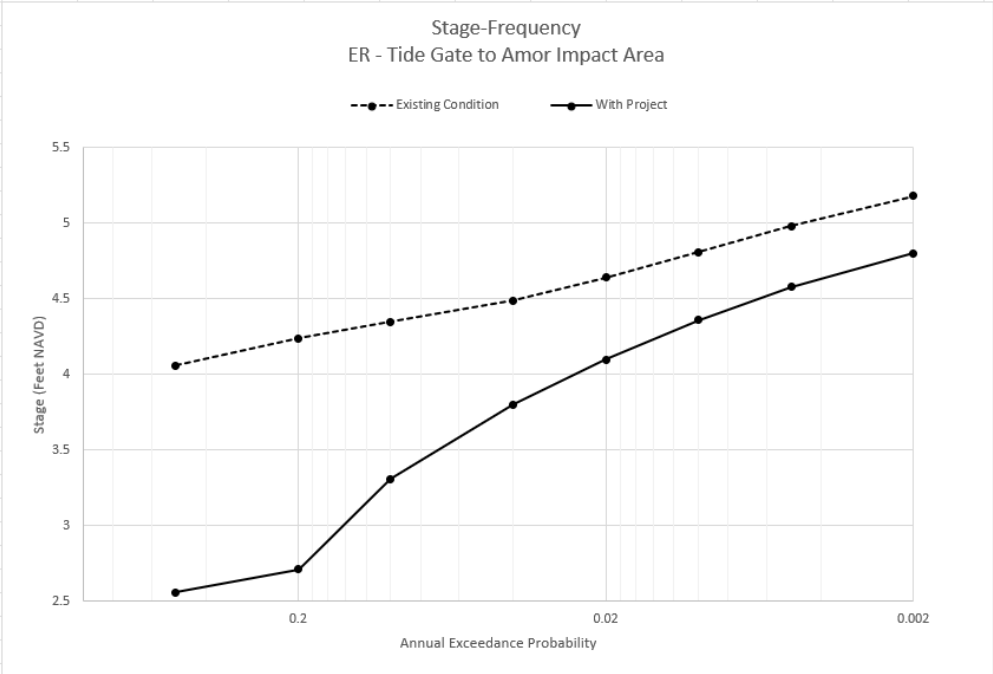

Figure 4-1. Stage Frequency graph for East Riser impact areas between Tide gate and Amor Avenue for Base Year scenario.

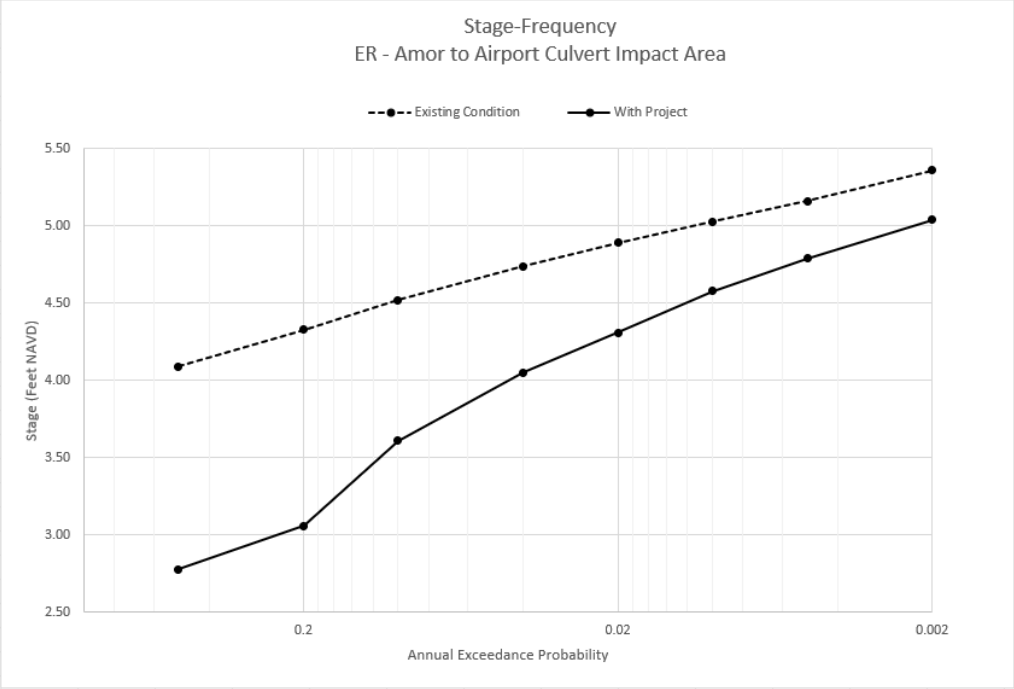

Figure 4-2. Stage Frequency graph for East Riser impact areas between Amor Avenue and airport culvert for Base Year scenario.

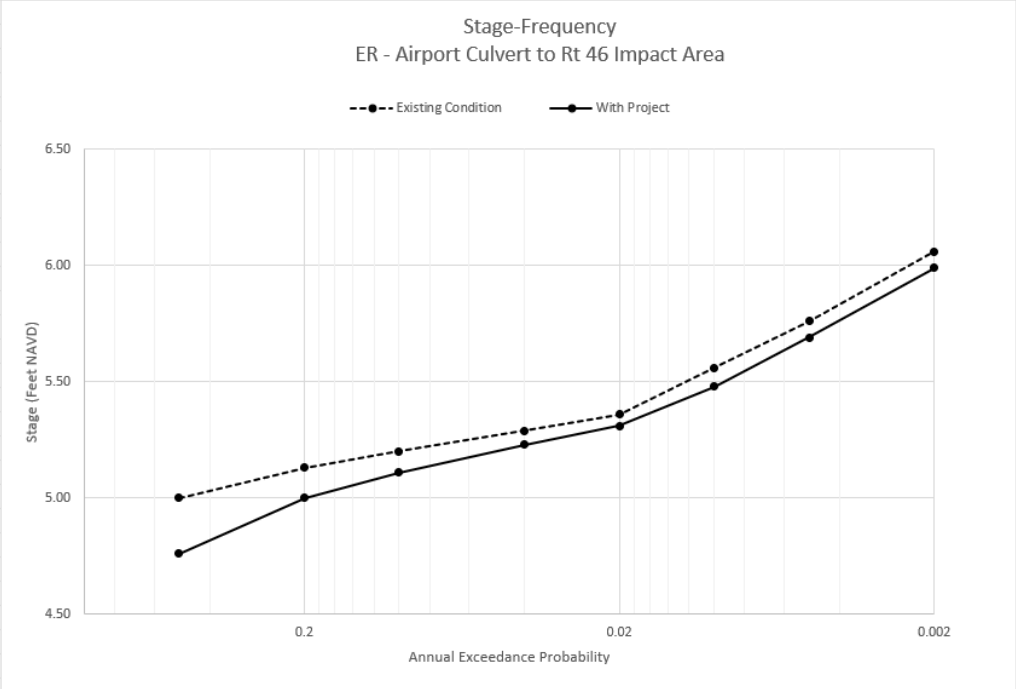

Figure 4-3. Stage Frequency graph for East Riser impact areas between airport culvert and Rt 46 for Base Year scenario.

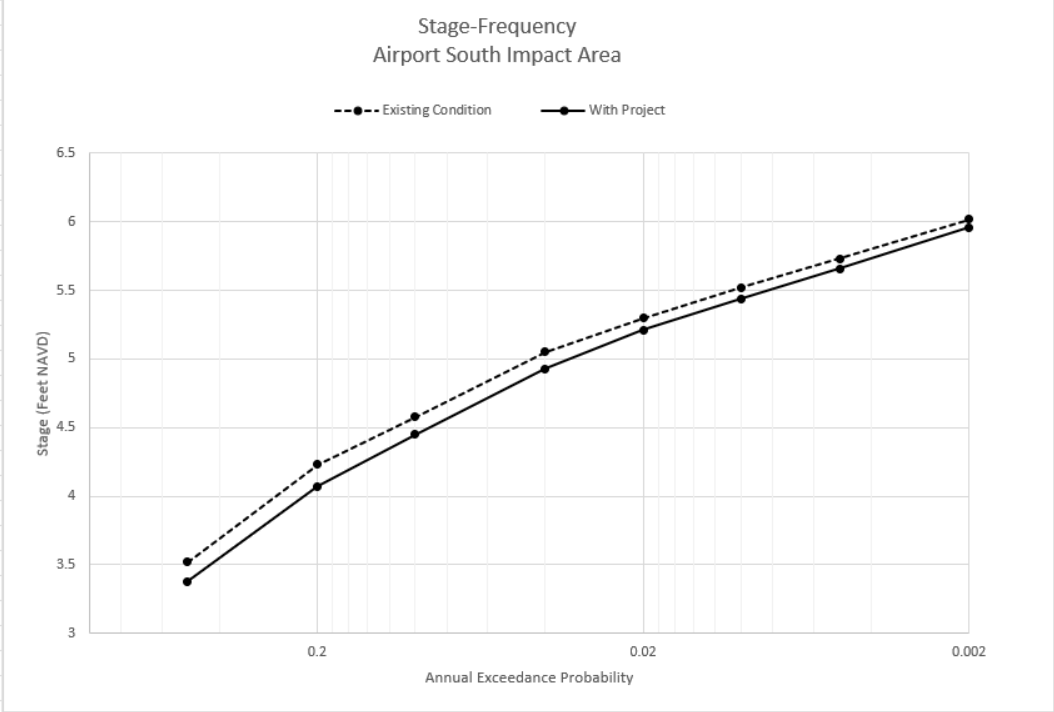

Figure 4-4. Stage Frequency graph for Airport South Impact area for Base Year scenario.

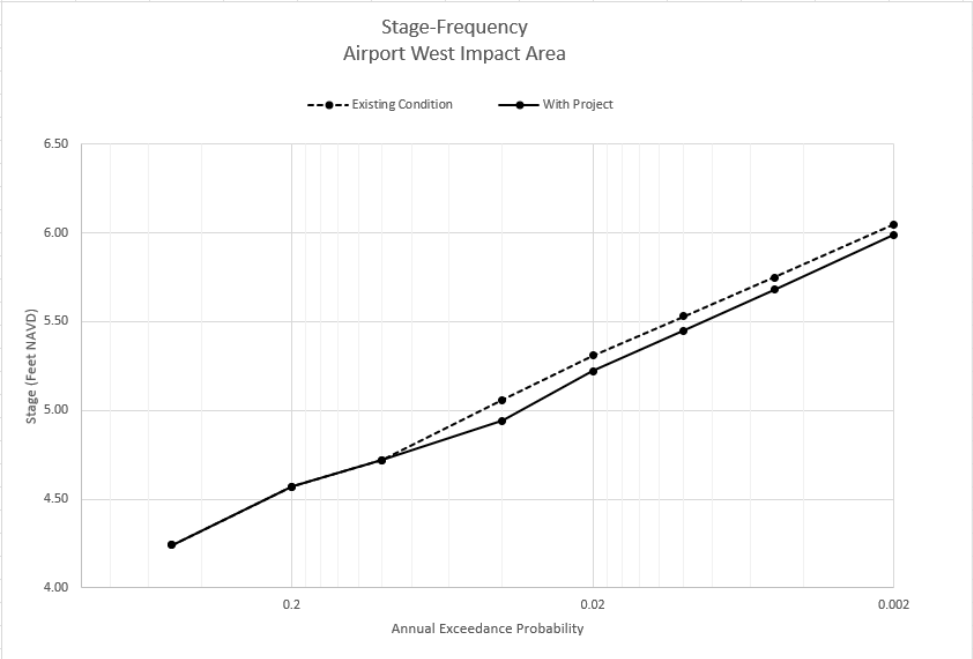

Figure 4-5. Stage Frequency graph for Airport West Impact area for Base Year scenario.

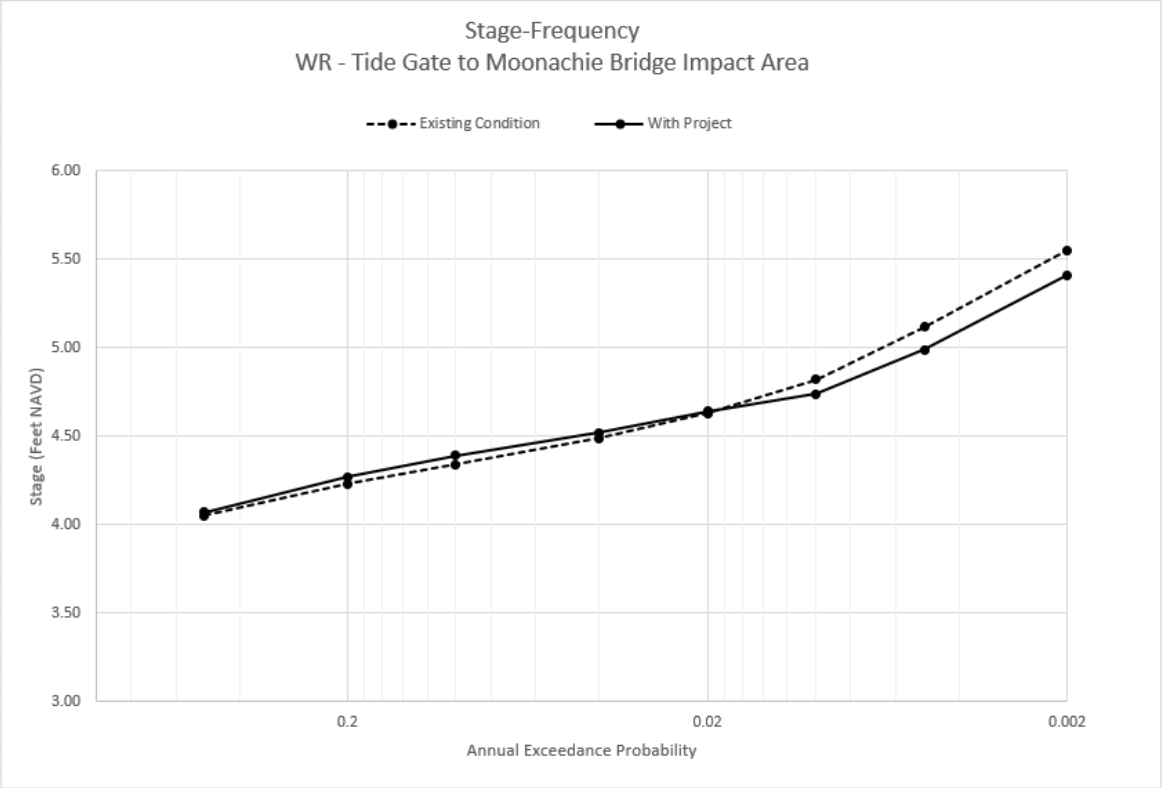

Figure 4-6. Stage Frequency graph for West Riser impact area between Moonachie and tide gate for Base Year scenario.

Table 4. Frequency curve data for the impact areas for WP and WOP scenarios in the base year (2037) (ft NAVD 88).

Base SLC		WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP
Storm Event	Frequency	ER Tide gate to Amor		ER - Amor to Airport Culvert		ER- Culvert to Rt 46		Airport South		Ariport West		WR - Tide gate to Moonachie Bridge	
2	0.5	4.06	2.56	4.09	2.78	5.00	4.76	3.52	3.38	4.24	4.24	4.05	4.07
5	0.2	4.24	2.71	4.33	3.06	5.13	5.00	4.23	4.07	4.57	4.57	4.23	4.27
10	0.1	4.35	3.31	4.52	3.61	5.20	5.11	4.58	4.45	4.72	4.72	4.34	4.39
25	0.04	4.49	3.80	4.74	4.05	5.29	5.23	5.05	4.93	5.06	4.94	4.49	4.52
50	0.02	4.64	4.10	4.89	4.31	5.36	5.31	5.3	5.21	5.31	5.22	4.63	4.64
100	0.01	4.81	4.36	5.03	4.58	5.56	5.48	5.52	5.44	5.53	5.45	4.82	4.74
200	0.005	4.98	4.58	5.16	4.79	5.76	5.69	5.73	5.66	5.75	5.68	5.12	4.99
500	0.002	5.18	4.80	5.36	5.04	6.06	5.99	6.02	5.96	6.05	5.99	5.55	5.41

4.2. Impact areas stage frequency curves for Future Year scenario

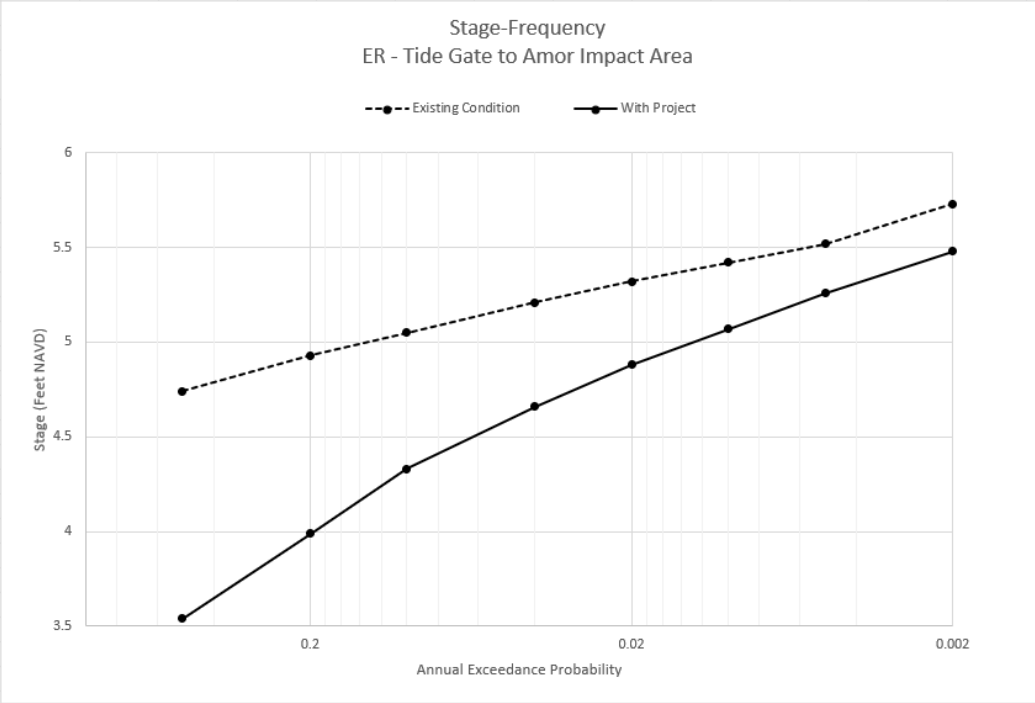

Figure 4-7. Stage Frequency graph for East Riser impact areas between Tide gate and Amor Avenue for Future Year scenario.

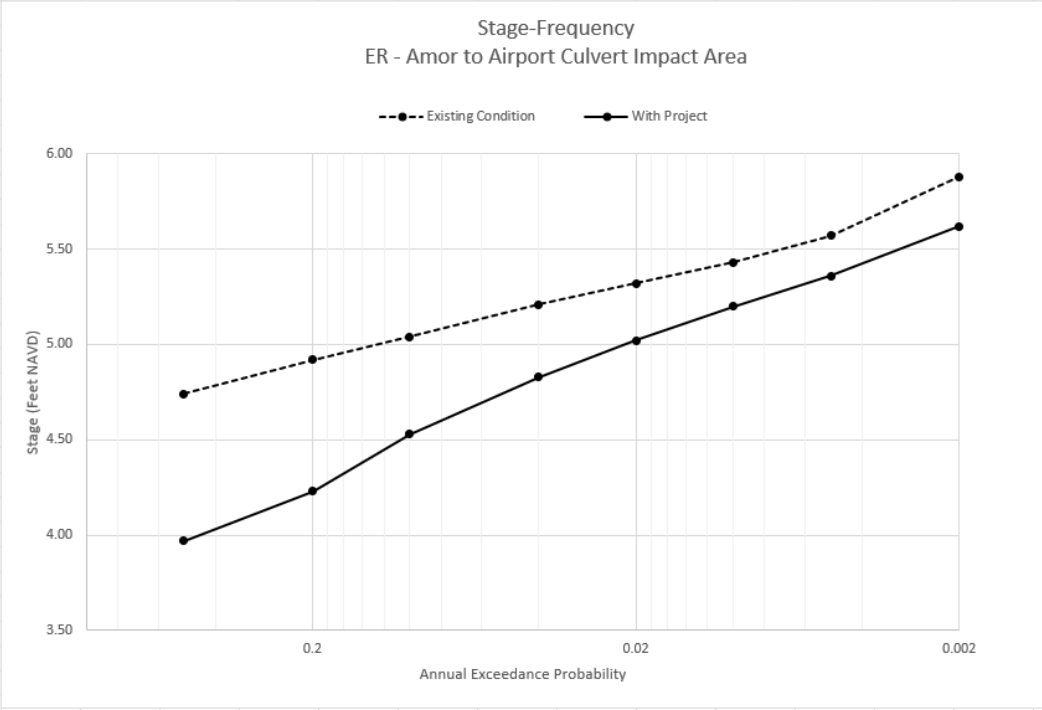

Figure 4-8. Stage Frequency graph for East Riser impact areas between Amor Avenue and airport culvert for Future Year scenario.

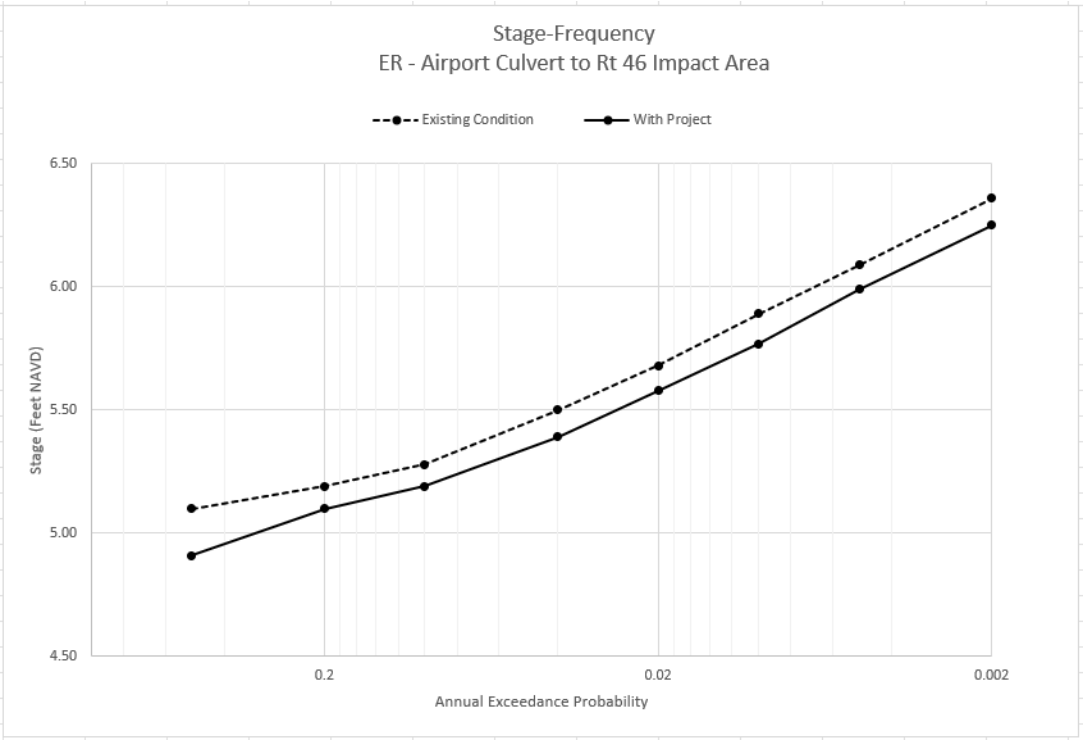

Figure 4-9. Stage Frequency graph for East Riser impact areas between airport culvert and Rt 46 for Future Year scenario.

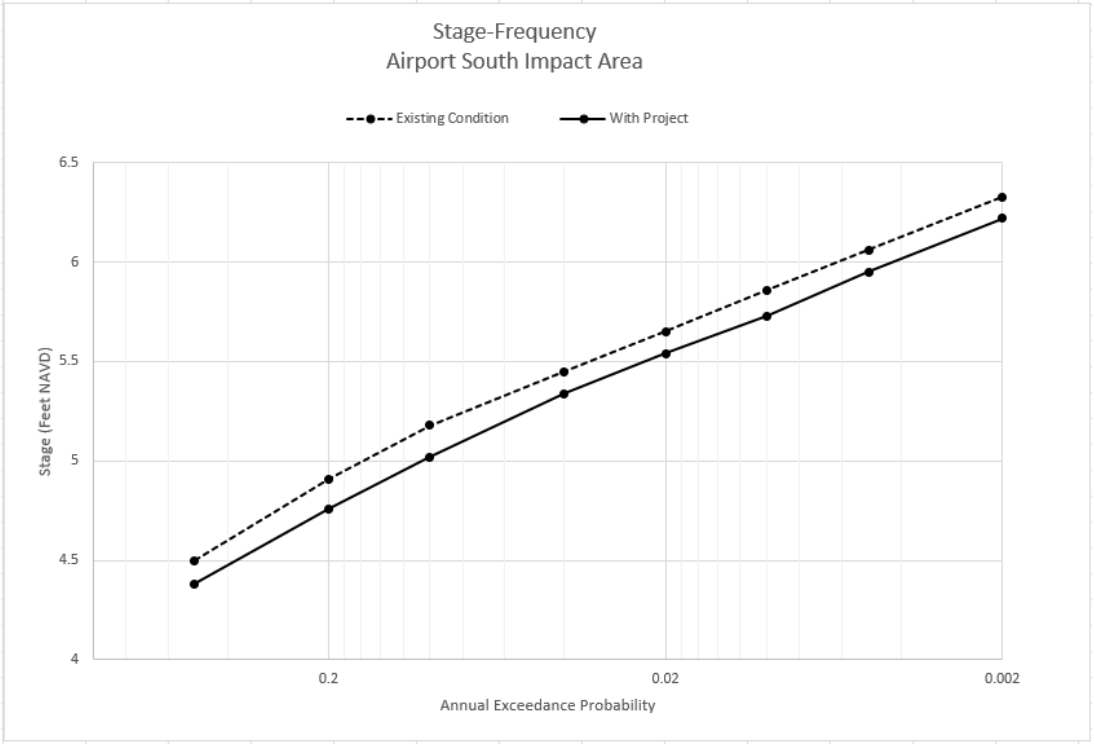

Figure 4-10. Stage Frequency graph for East Riser impact areas airport south for Future Year scenario.

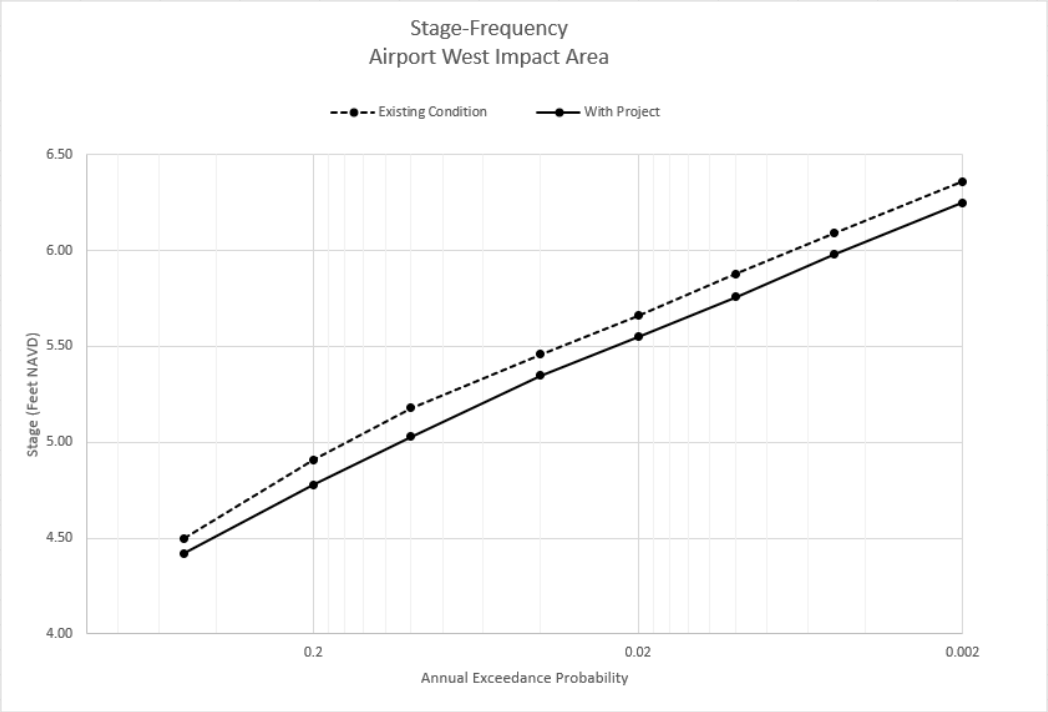

Figure 4-11. Stage Frequency graph for East Riser impact areas Airport West for Future Year scenario.

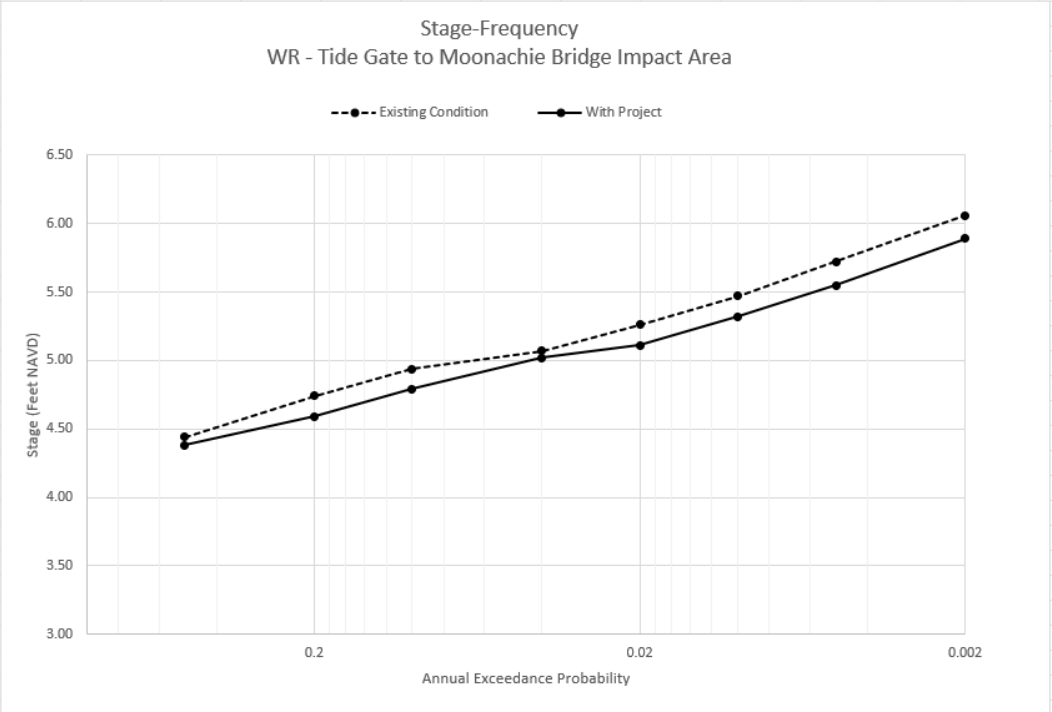

Figure 4-12. Stage Frequency graph for West Riser impact areas between Tide gate to Moonachie bridge for Future Year scenario.

Table 5. Frequency curve data for the impact areas for WP and WOP scenarios in the year (2087) intermediate RSLC (ft NAVD 88).

Future SLC		WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP	WOP	WP
Storm Event	Frequency	ER Tide gate to Amor		ER - Amor to Airport Culvert		ER- Culvert to Rt 46		Airport South		Ariport West		WR - Tide gate to Moonachie Bridge	
2	0.5	4.74	3.54	4.74	3.97	5.10	4.91	4.5	4.38	4.50	4.42	4.44	4.38
5	0.2	4.93	3.99	4.92	4.23	5.19	5.10	4.91	4.76	4.91	4.78	4.74	4.59
10	0.1	5.05	4.33	5.04	4.53	5.28	5.19	5.18	5.02	5.18	5.03	4.94	4.79
25	0.04	5.21	4.66	5.21	4.83	5.50	5.39	5.45	5.34	5.46	5.35	5.07	5.02
50	0.02	5.32	4.88	5.32	5.02	5.68	5.58	5.65	5.54	5.66	5.55	5.26	5.11
100	0.01	5.42	5.07	5.43	5.20	5.89	5.77	5.86	5.73	5.88	5.76	5.47	5.32
200	0.005	5.52	5.26	5.57	5.36	6.09	5.99	6.06	5.95	6.09	5.98	5.72	5.55
500	0.002	5.73	5.48	5.88	5.62	6.36	6.25	6.33	6.22	6.36	6.25	6.06	5.89

4.3. Flow Hydrographs

Apart from the effects of the project on the stage frequency curves, significant improvements were observed in the flow discharges in the project area. Three points were chosen to represent the flow changes in different locations of the channels in with- and without-project scenarios. The results were extracted for the 1% and 10% AEP, but similar behaviors were observed in other scenarios as well.

The biggest improvement was observed in East Riser in the areas downstream of the airport culvert. Widening the channel and bridge openings increased the discharge in these areas by approximately 50% depending on the AEP scenarios. Figures 4-13 to 4-15 show the project impact on the flow discharge.

These improvements were significant at East Riser in the areas upstream of the airport culvert as well. However, the increases in the discharges were not as significant as the downstream impact area due to the constraints in the airport culvert. The discharge increases of approximately 25% are reported for the different AEPs.

The third extraction point was chosen in West Riser, and the results do not show any significant impact on the discharges in West Riser.

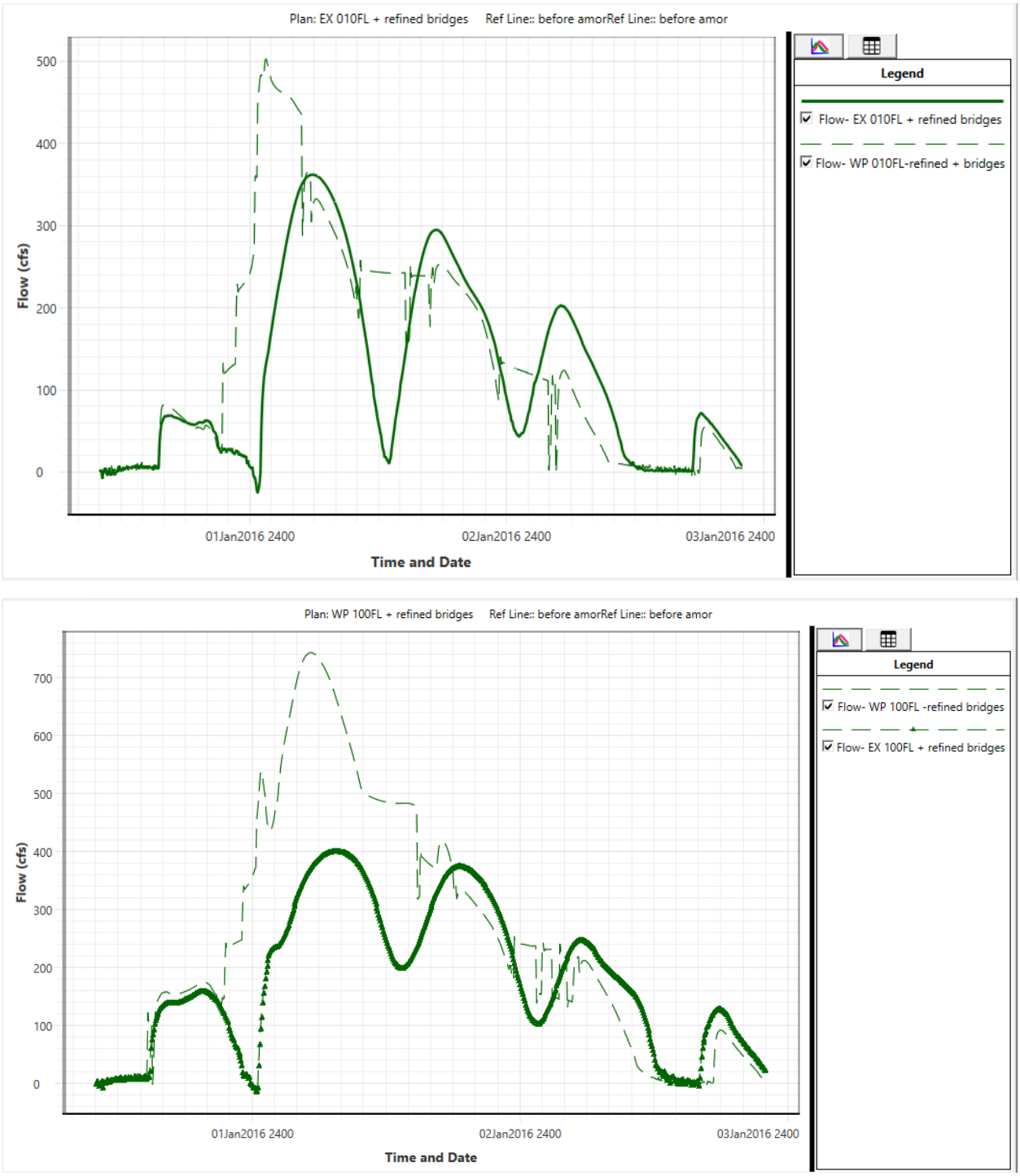

Figure 4-13. East Riser Flow hydrographs upstream of Amor Avenue Bridge for with- and without-project in 10-year (top) and 100-year (bottom) scenarios.

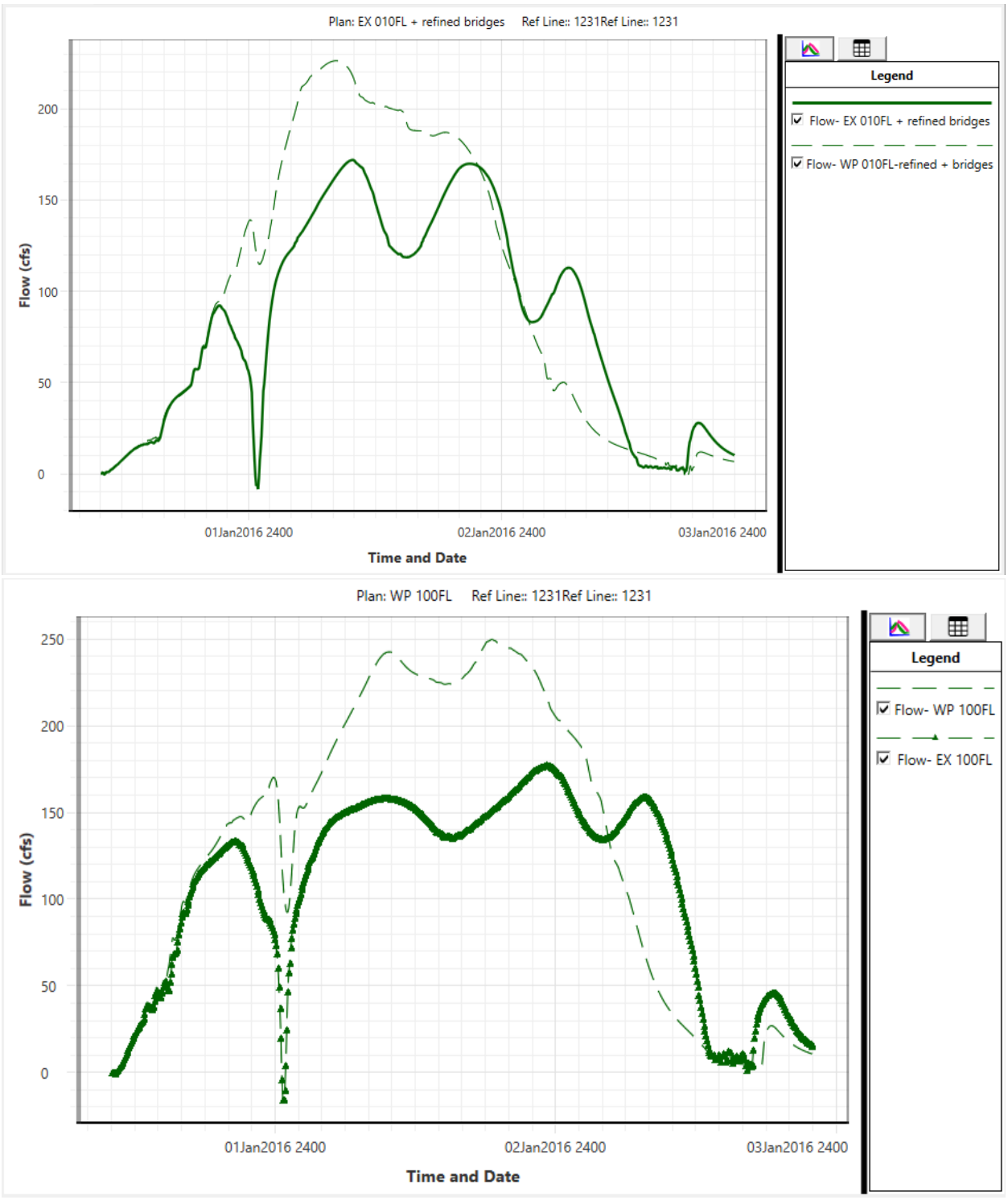

Figure 4-14. East Riser Flow hydrographs upstream of Airport culvert for with- and without-project in 10-year (top) and 100-year (bottom) scenarios.

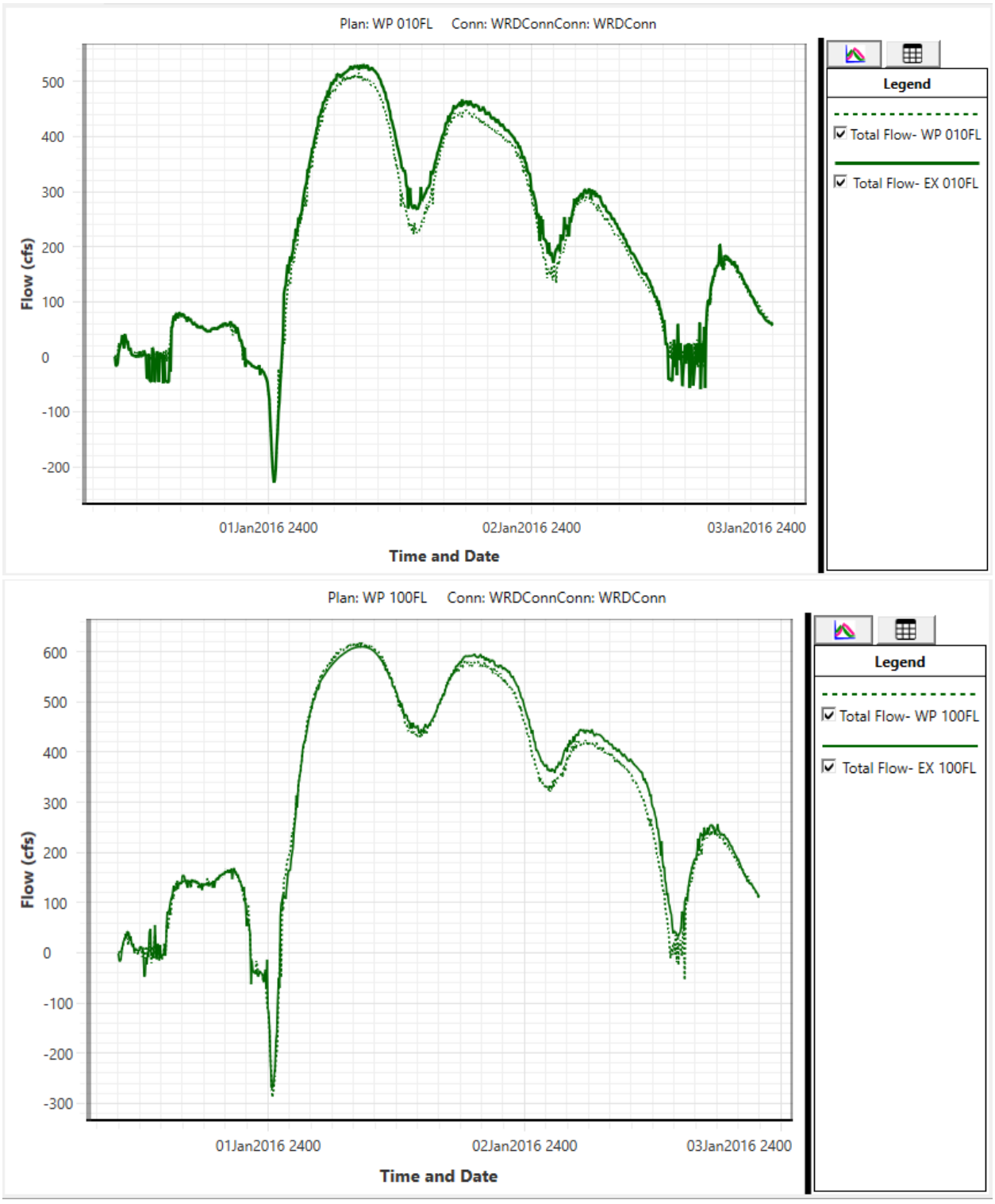

Figure 4-15. West Riser Flow hydrographs upstream of Moonachie Rd for with- and without-project in 10-year (top) and 100-year (bottom) scenarios.

4.4. Flow diversion across the airport

As noted in the earlier discussions of flooding sources, there is a substantial diversion of flow from East Riser to West Riser. The time series plots in Figures 4-16 and 4-17 show the flow toward West Riser and the Airport South impact area for 10% and 1% AEP scenarios. With improvements in place, the reduction in water surface elevations at East Riser results in a reduction in the rate and volume of flow diversion. As noted above, the reduction in flooding in West Riser is relatively minor, but the proposed plan for East Riser clearly influences flows and flooding on both East and West Riser.

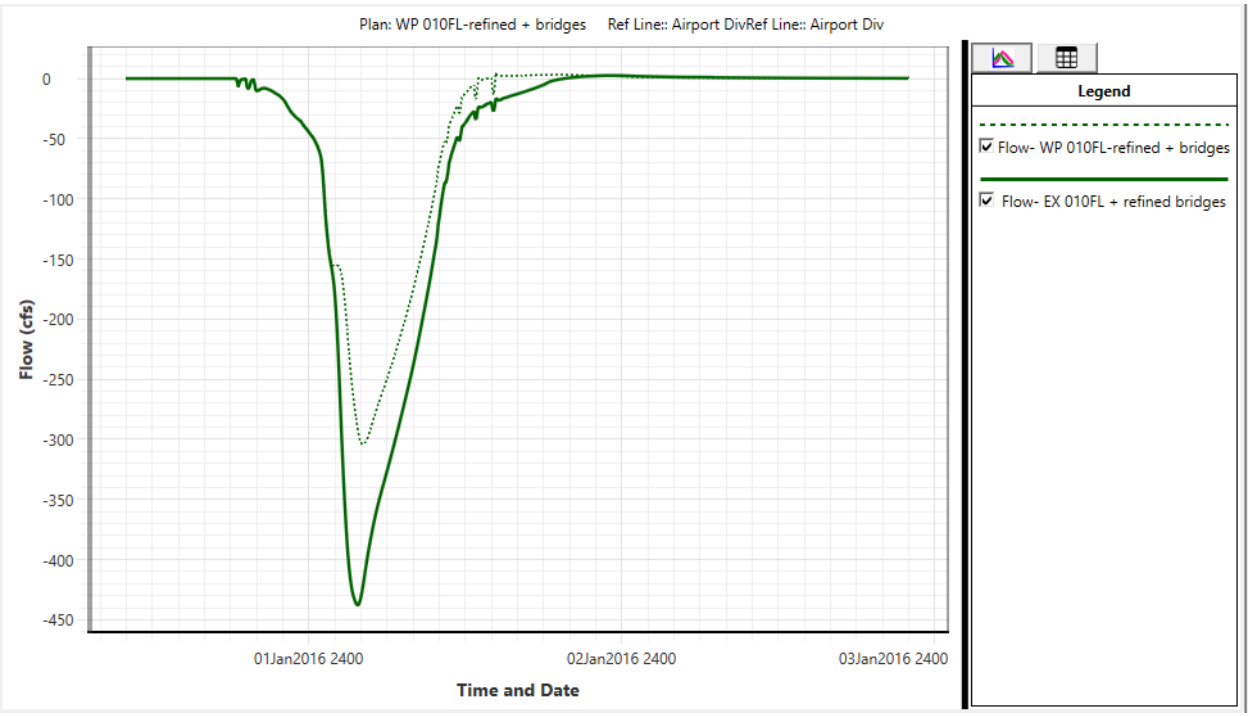

Figure 4-16. Flow diversion from ER to WR along the airport for 10-year Event in WP and WOP scenarios

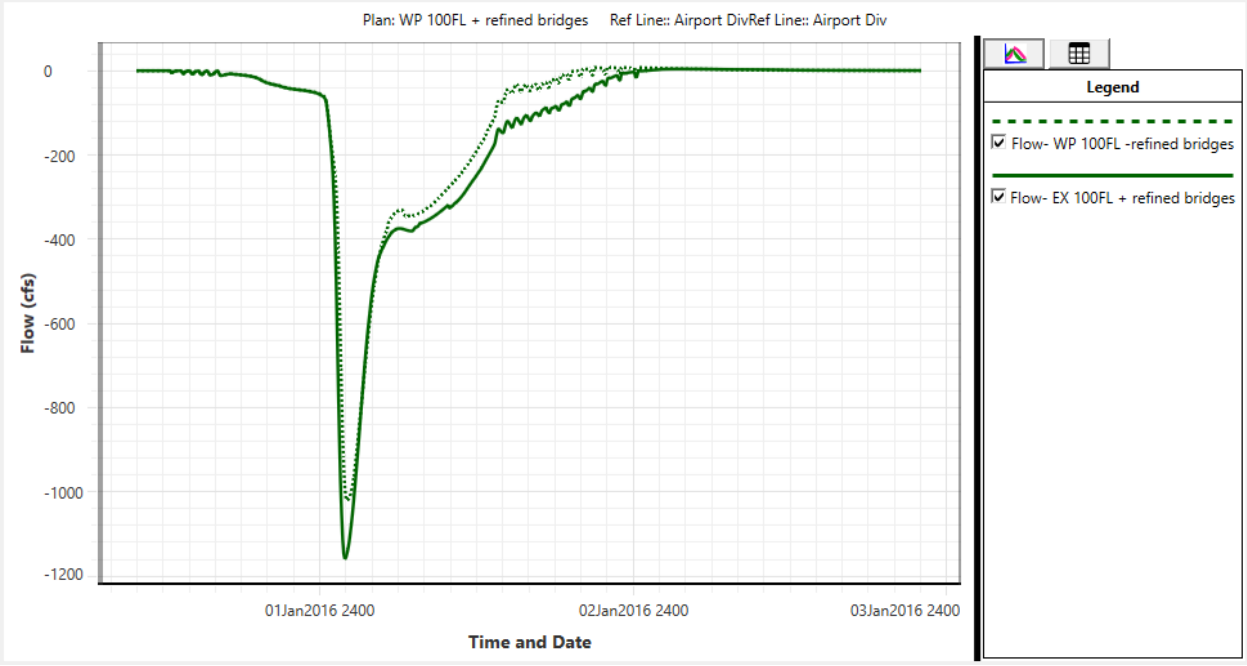

Figure 4-17. Flow diversion from ER to WR along the airport for 100-year Event in With Project and Without Project scenarios.

4.5. Floodplain Mapping and East Riser Flood Profile

To provide a spatial comparison of the reduction in flooding with the project, the flood depths at each point in the 2D HEC RAS model were compared and the difference in flood depths was calculated. Figures displaying the reductions in flood depths from the project were developed for the 10% AEP and 1% AEP under the Base Year and Future scenarios. The change in Water Surface Elevations are presented in Figures 4-18 to 4-25. The maps also show the extent of the different impact areas that were used in the economic modelling discussed above. It should be noted that the flood mapping does not show inundation within the footprints of buildings.

The most significant differences in water surface elevations are the reductions in the impact areas on East Riser within the vicinity of the plan improvements. Figures 4-26 to 4-29 provide a profile view of the changes in the channel inverts and flood elevations in the immediate project area.

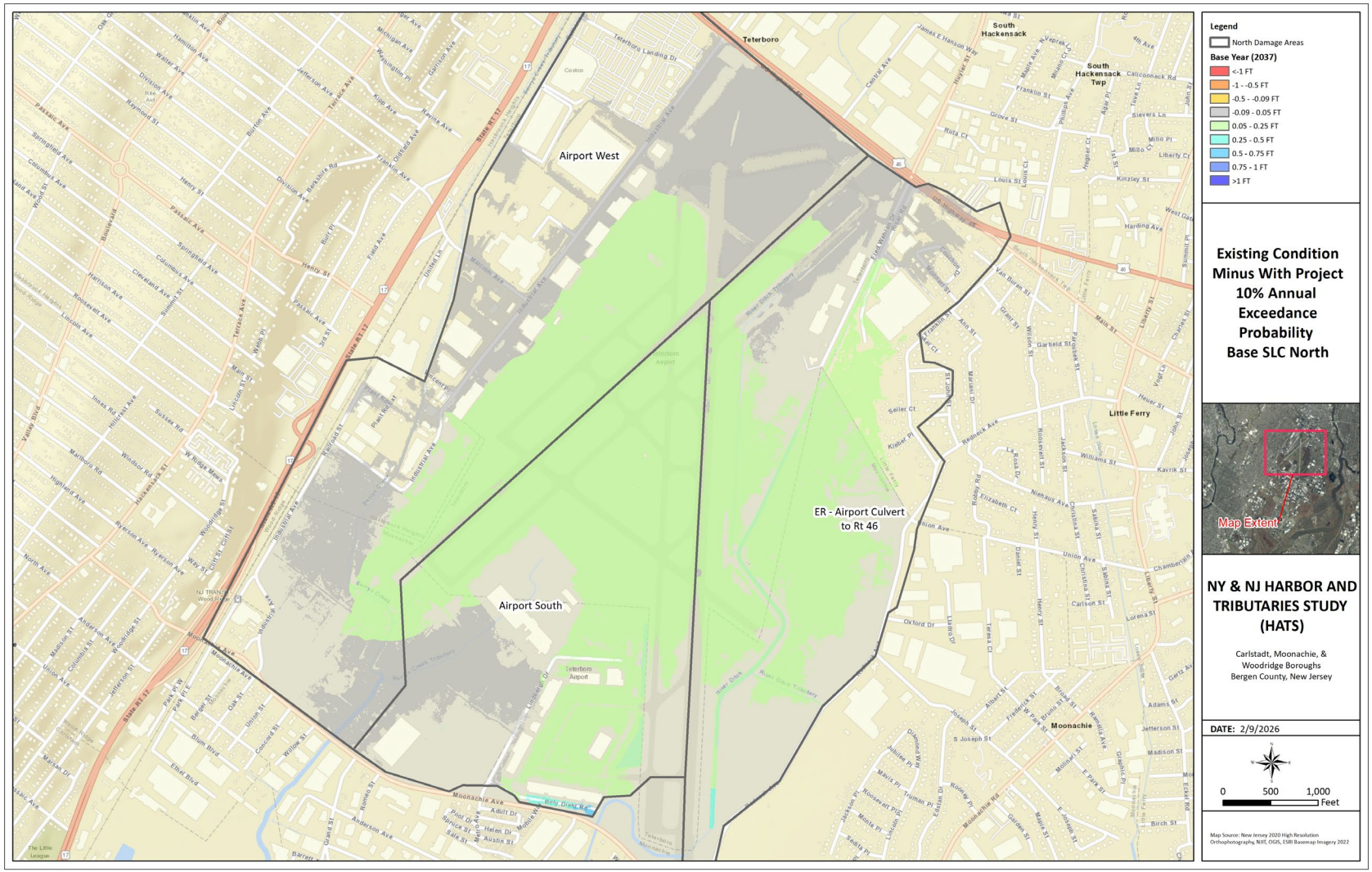

Figure 4-18. Floodplain mapping showing the Without-Project condition minus the With-Project condition for the 10% AEP in the Base Year for the north part of the model.

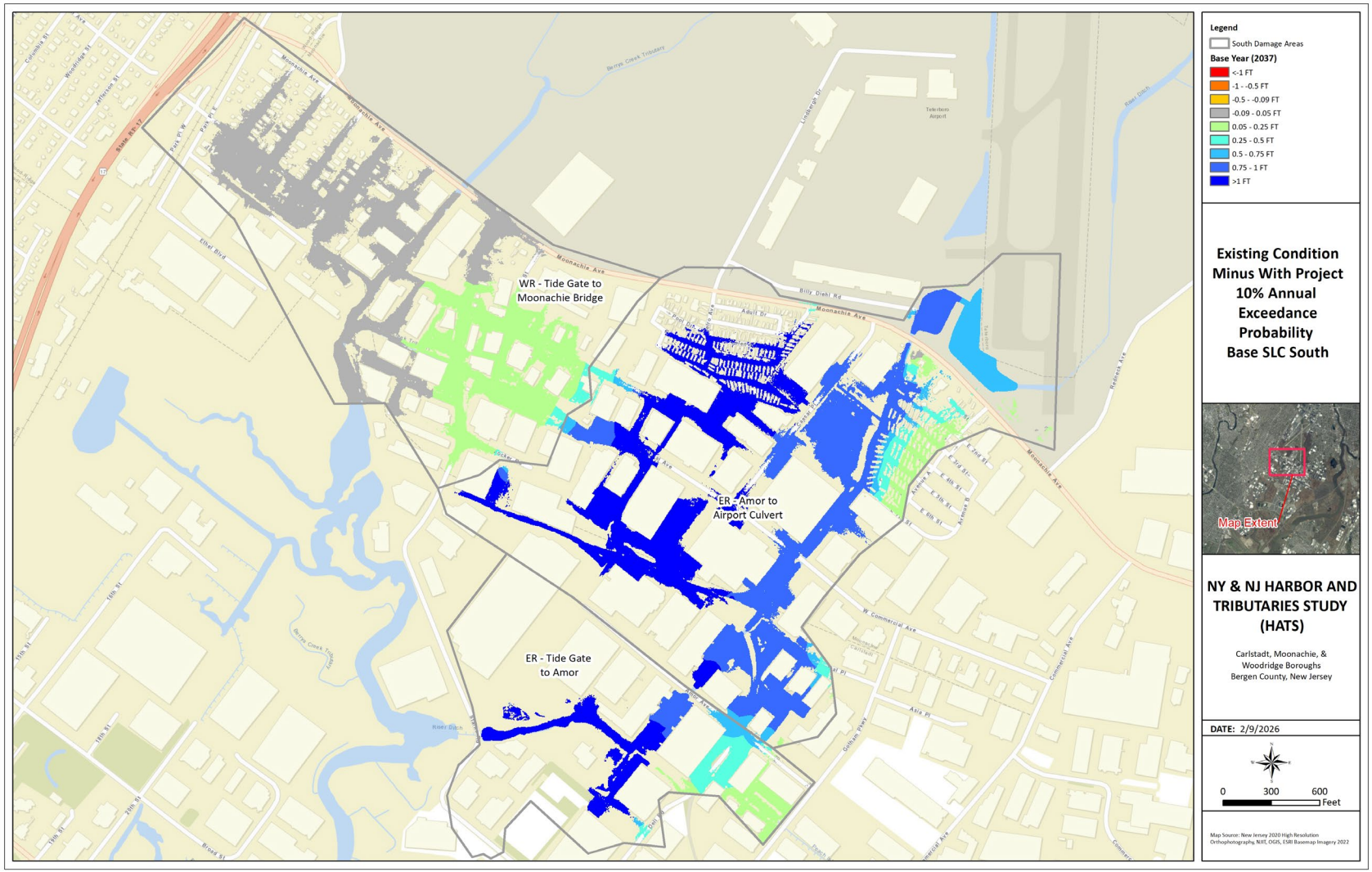

Figure 4-19. Floodplain mapping showing the Without Project condition minus the With project Condition for the 10% AEP in the Base Year for the south part of the model.

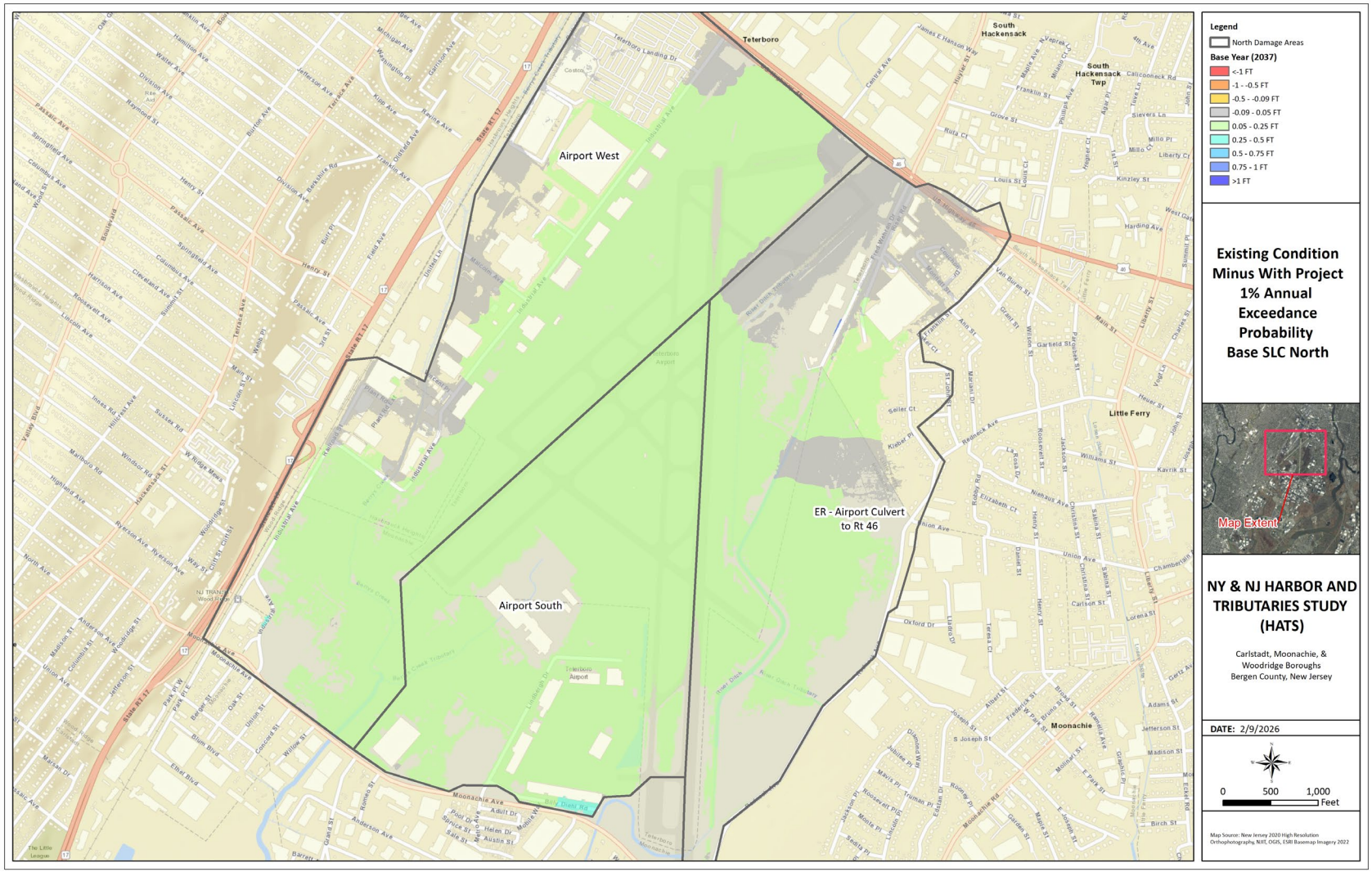

Figure 4-20. Floodplain mapping showing the Without Project condition minus the With project Condition for the 1% AEP in the Base Year for the north part of the model.

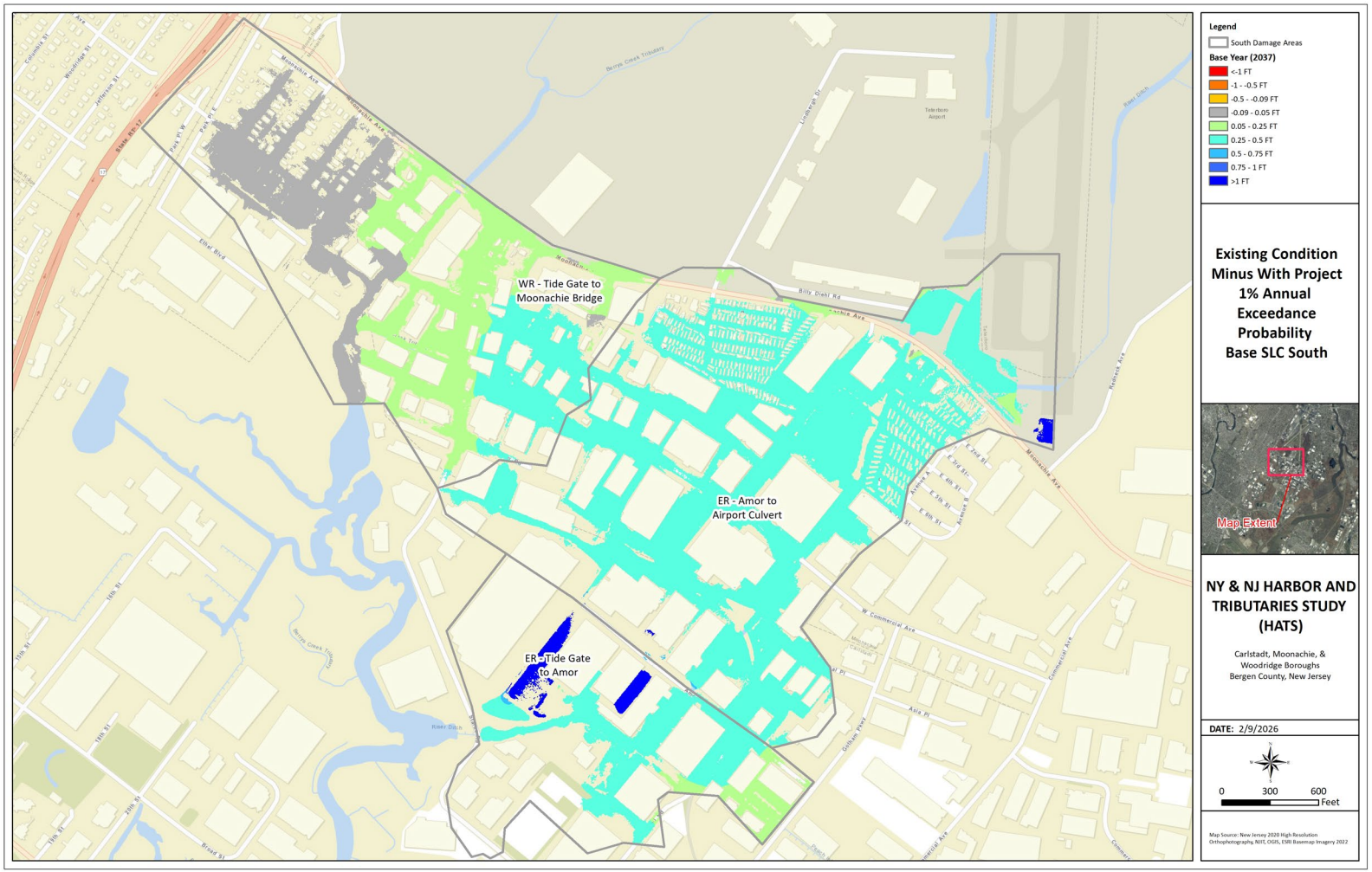

Figure 4-21. Floodplain mapping showing the Without Project condition minus the With Project condition for the 1% AEP in the Base Year for the south part of the model.

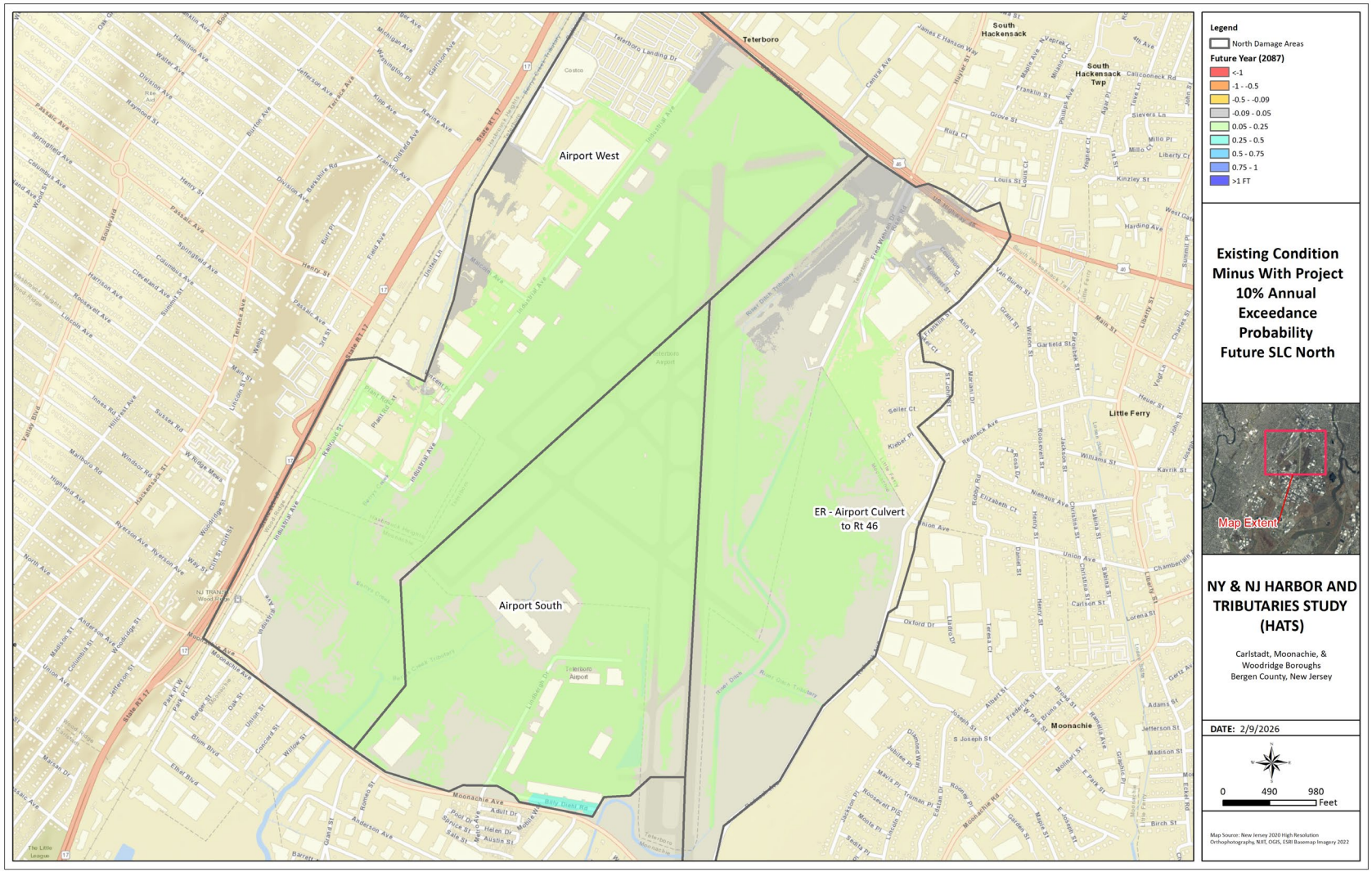

Figure 4-22. Floodplain mapping showing the Without Project condition minus the With project Condition for the 10% AEP in the Future Year for the north part of the model.

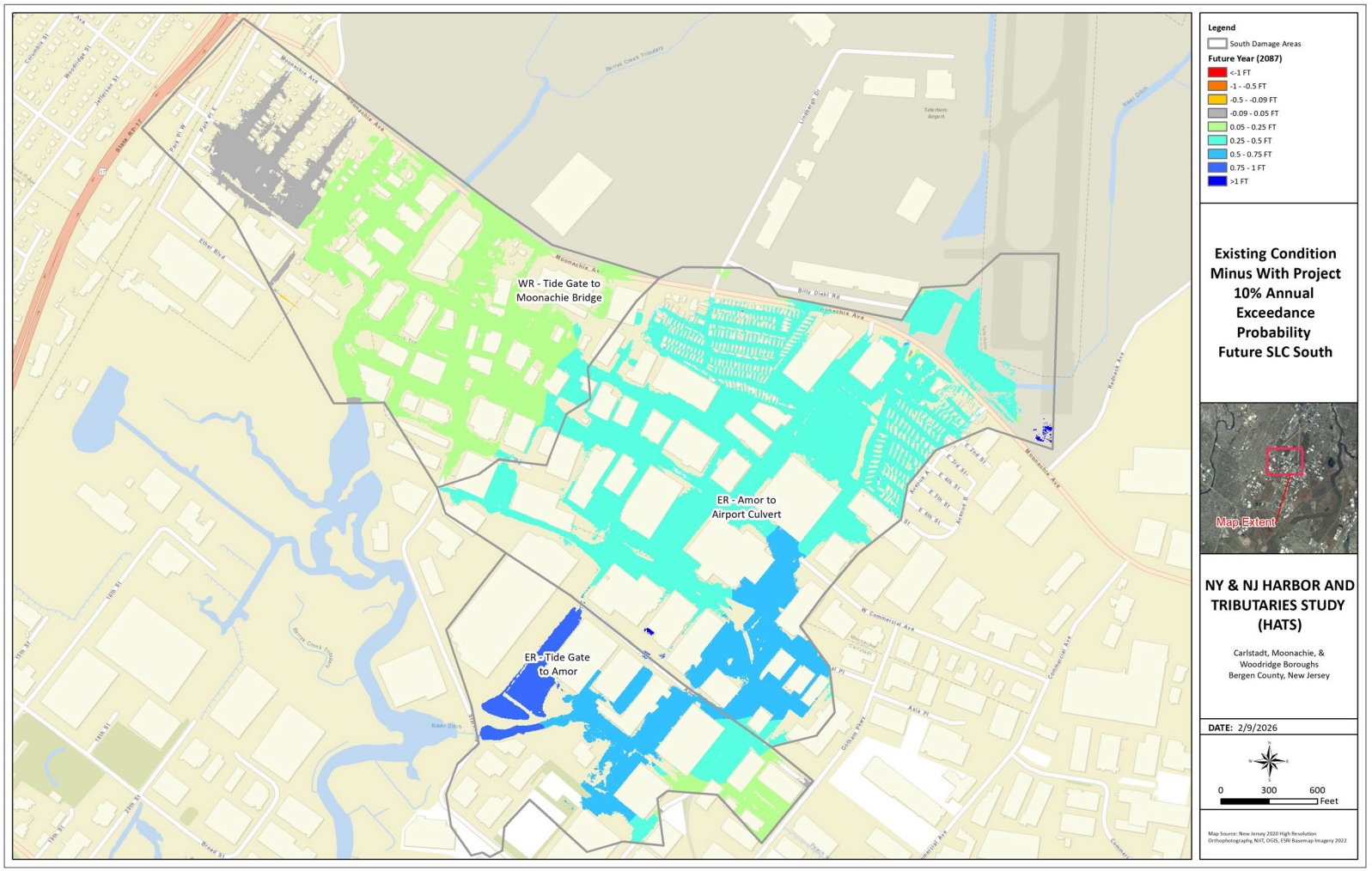

Figure 4-23. Floodplain mapping showing the Without Project condition minus the With project Condition for the 10% AEP in the Future Year for the south part of the model.

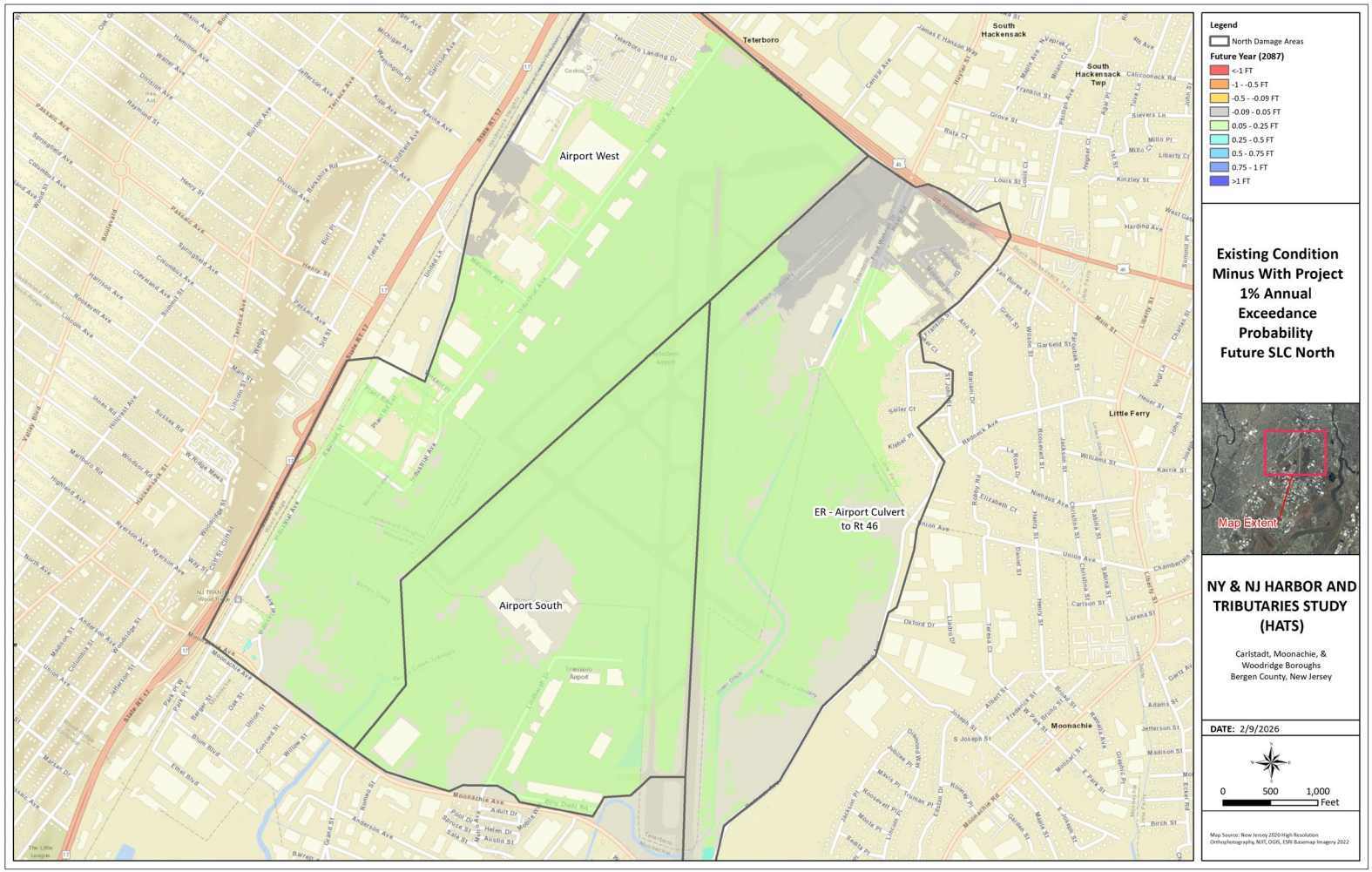

Figure 4-24. Floodplain mapping showing the Without project condition minus the With project condition for the 1% AEP in the Future Year for the north part of the model.

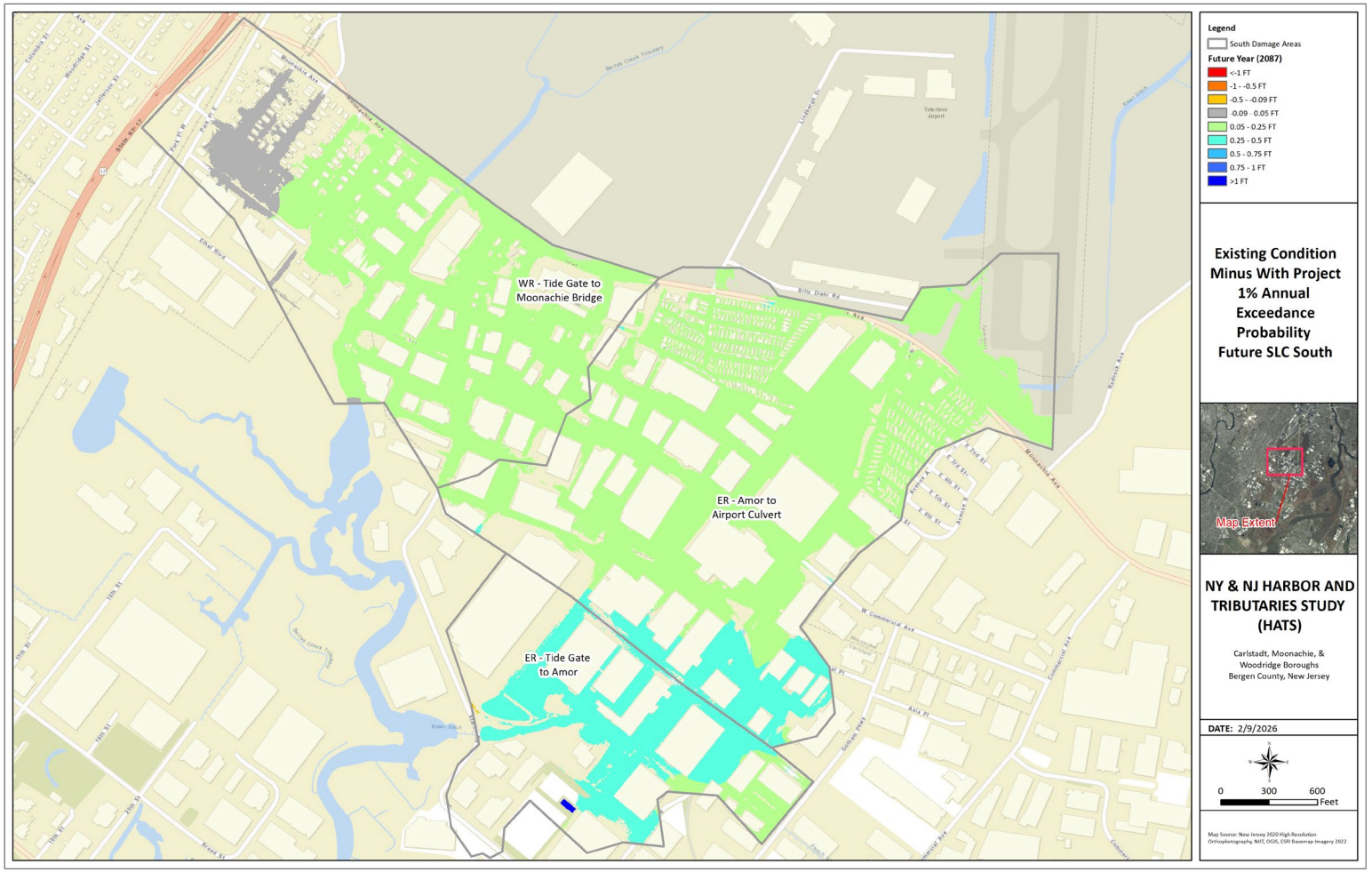

Figure 4-25. Floodplain mapping showing the Without project condition minus the With project for condition the 1% AEP in the Future Year for the south part of the model.

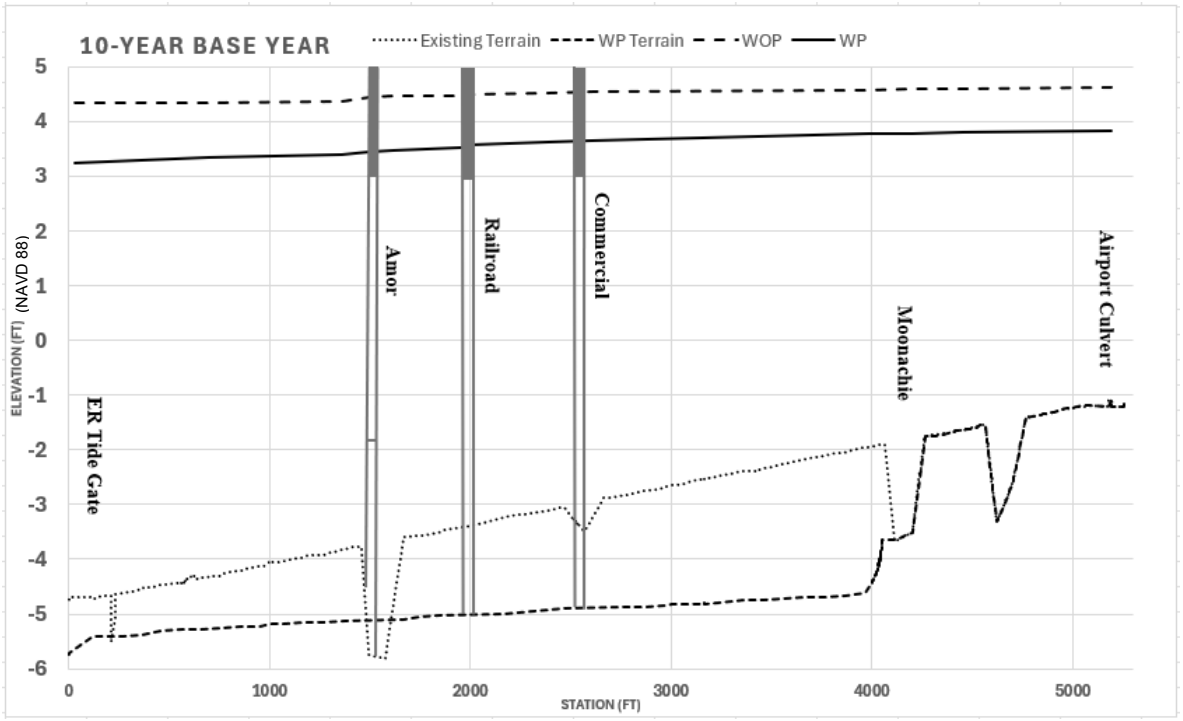

Figure 4-26. WSE comparison between with and without project Scenarios for base year 10% AEP.

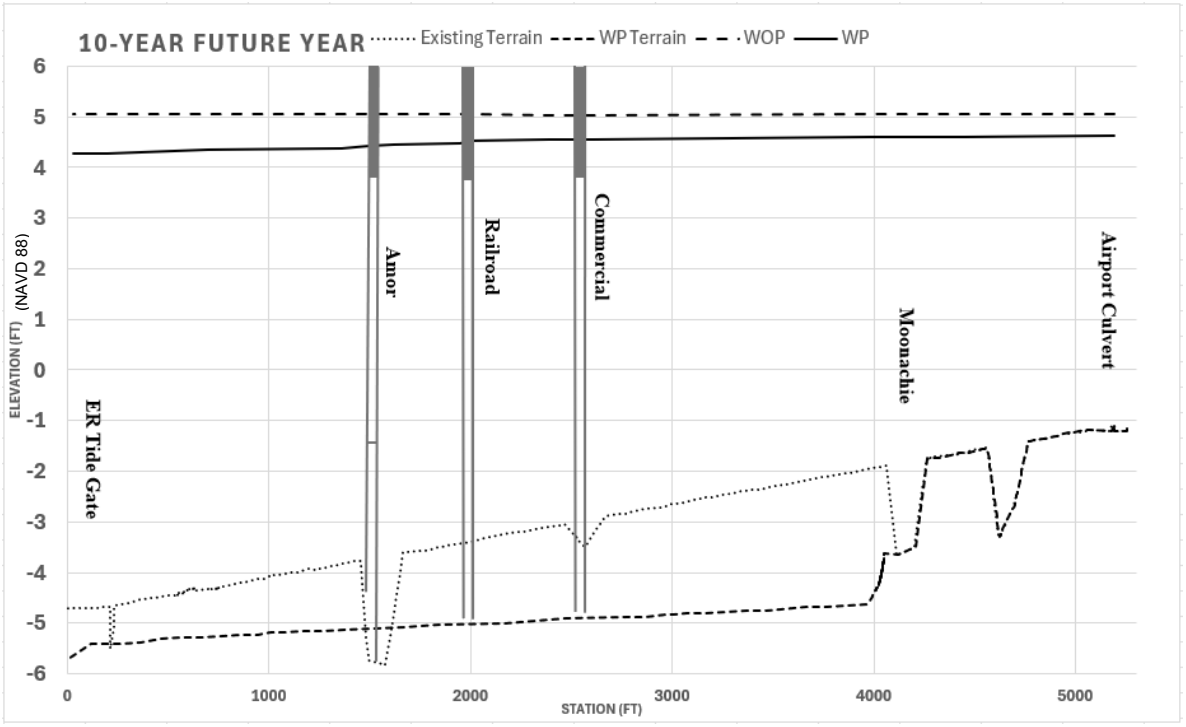

Figure 4-27. WSE comparison between with and without project Scenarios for future year 10% AEP.

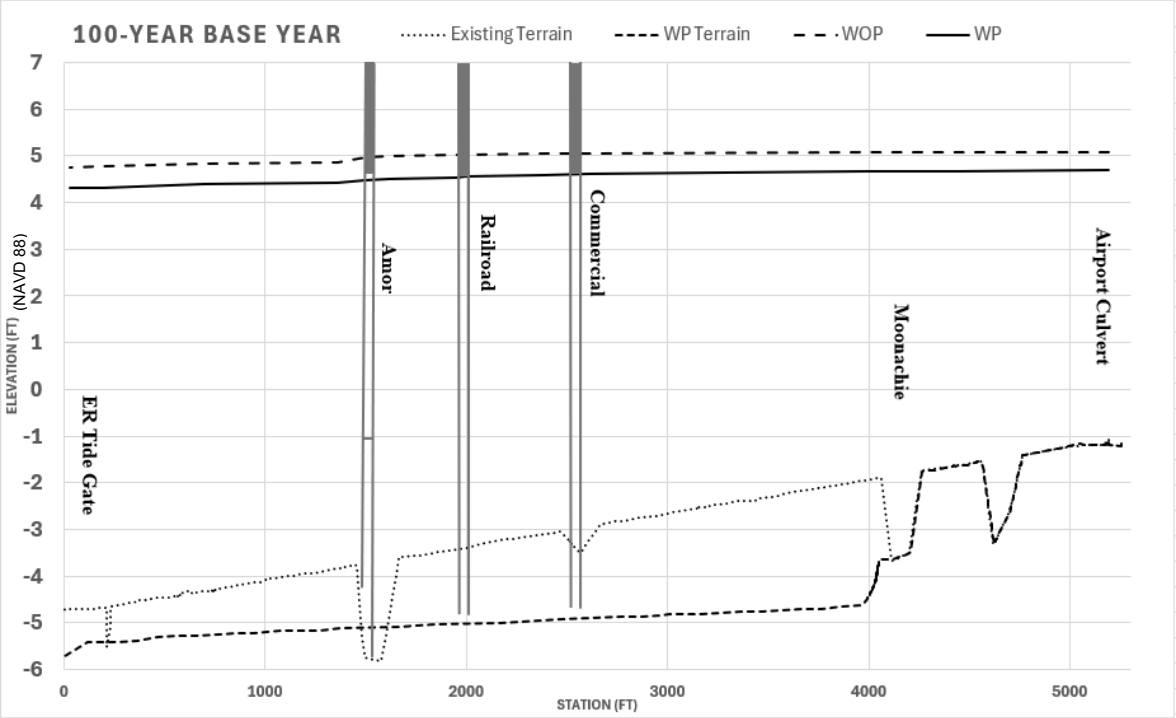

Figure 4-28. WSE comparison between with and without project Scenarios for base year 1% AEP.

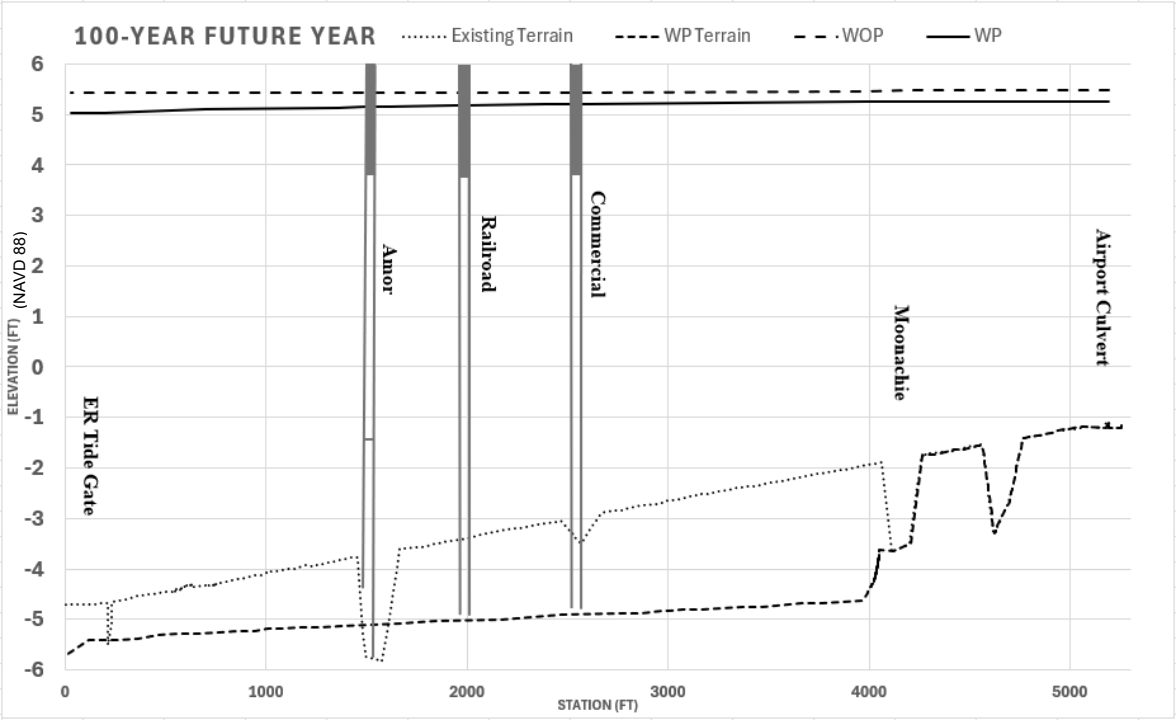

Figure 4-29. WSE comparison between with and without project Scenarios for future year 1% AEP.

4.6. Probability scenario results

The model runs for the lower bound (normal tide), most likely (4.27 ft NAVD 88), and upper bound (lower frequency tidal events). Results of the stages and flow for each of the damage areas included in the tables below:

Asterisks (*) adjacent to values in Tables 6 through 29 denote flows or stages for which minor adjustments were made based on engineering judgement to ensure that key inputs to models used for the economic analysis meet data requirements by increasing monotonically.

Table 6. Base year WOP for ER tide gate to Amor

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.56	Lower Bound
5-year	Normal		3.67	Lower Bound
10-year	Normal		3.76	Lower Bound
25-year	Normal		3.89	Lower Bound
50-year	Normal		4.02	Lower Bound
100-year	Normal		4.16	Lower Bound
200-year	Normal		4.33	Lower Bound
500-year	Normal		4.55	Lower Bound
2-year	4.27 ft	328	4.06	Most Likely
5-year	4.27 ft	357	4.24	Most Likely
10-year	4.27 ft	366	4.35	Most Likely
25-year	4.27 ft	377	4.49	Most Likely
50-year	4.27 ft	390	4.64	Most Likely
100-year	4.27 ft	397	4.81	Most Likely
200-year	4.27 ft	407	4.98	Most Likely
500-year	4.27 ft	425	5.18	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 7. Base year WP – ER Tide gate to Amor

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		2.58	Lower Bound
5-year	Normal		2.71	Lower Bound
10-year	Normal		3.27	Lower Bound
25-year	Normal		3.82	Lower Bound
50-year	Normal		4.02	Lower Bound
100-year	Normal		4.18	Lower Bound
200-year	Normal		4.33	Lower Bound
500-year	Normal		4.51	Lower Bound
2-year	4.27 ft	451	2.59*	Most Likely
5-year	4.27 ft	458	2.72*	Most Likely
10-year	4.27 ft	470	3.31	Most Likely
25-year	4.27 ft	537	3.83*	Most Likely
50-year	4.27 ft	610	4.10	Most Likely
100-year	4.27 ft	710	4.36	Most Likely
200-year	4.27 ft	802	4.58	Most Likely
500-year	4.27 ft	850	4.80	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 8. Future year WOP– ER Tide gate to Amor

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.33	Lower Bound
5-year	Normal		4.49	Lower Bound
10-year	Normal		4.59	Lower Bound
25-year	Normal		4.68	Lower Bound
50-year	Normal		4.76	Lower Bound
100-year	Normal		4.91	Lower Bound
200-year	Normal		5.05	Lower Bound
500-year	Normal		5.23	Lower Bound
2-year	5.38 ft	350	4.74	Most Likely
5-year	5.38 ft	358	4.93	Most Likely
10-year	5.38 ft	365	5.05	Most Likely
25-year	5.38 ft	372	5.21	Most Likely
50-year	5.38 ft	380	5.32	Most Likely
100-year	5.38 ft	393	5.42	Most Likely
200-year	5.38 ft	408	5.52	Most Likely
500-year	5.38 ft	450	5.73	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 9. Future year WP – ER Tide gate to Amor

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		2.60	Lower Bound
5-year	Normal		3.26	Lower Bound
10-year	Normal		3.66	Lower Bound
25-year	Normal		4.12	Lower Bound
50-year	Normal		4.41	Lower Bound
100-year	Normal		4.62	Lower Bound
200-year	Normal		4.80	Lower Bound
500-year	Normal		5.02	Lower Bound
2-year	5.38 ft	466	3.54	Most Likely
5-year	5.38 ft	544	3.99	Most Likely
10-year	5.38 ft	606	4.33	Most Likely
25-year	5.38 ft	692	4.66	Most Likely
50-year	5.38 ft	756	4.88	Most Likely
100-year	5.38 ft	798	5.07	Most Likely
200-year	5.38 ft	813	5.26	Most Likely
500-year	5.38 ft	884	5.48	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 10. Base year WOP – ER - Amor to Airport Culvert

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.85	Lower Bound
5-year	Normal		4.13	Lower Bound
10-year	Normal		4.31	Lower Bound
25-year	Normal		4.53	Lower Bound
50-year	Normal		4.71	Lower Bound
100-year	Normal		4.86	Lower Bound
200-year	Normal		4.99	Lower Bound
500-year	Normal		5.21	Lower Bound
2-year	4.27 ft	212*	4.09	Most Likely
5-year	4.27 ft	213*	4.33	Most Likely
10-year	4.27 ft	214*	4.52	Most Likely
25-year	4.27 ft	215*	4.74	Most Likely
50-year	4.27 ft	216*	4.89	Most Likely
100-year	4.27 ft	217*	5.03	Most Likely
200-year	4.27 ft	218*	5.16	Most Likely
500-year	4.27 ft	219*	5.36	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 11. Base year WP – ER - Amor to Airport Culvert

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		2.76	Lower Bound
5-year	Normal		3.00	Lower Bound
10-year	Normal		3.51	Lower Bound
25-year	Normal		4.03	Lower Bound
50-year	Normal		4.26	Lower Bound
100-year	Normal		4.43	Lower Bound
200-year	Normal		4.59	Lower Bound
500-year	Normal		4.82	Lower Bound
2-year	4.27 ft	325	2.78	Most Likely
5-year	4.27 ft	337	3.06	Most Likely
10-year	4.27 ft	360	3.61	Most Likely
25-year	4.27 ft	417	4.05	Most Likely
50-year	4.27 ft	426	4.31	Most Likely
100-year	4.27 ft	511	4.58	Most Likely
200-year	4.27 ft	550	4.79	Most Likely
500-year	4.27 ft	551*	5.04	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 12. Future year WOP – ER - Amor to Airport Culvert

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.35	Lower Bound
5-year	Normal		4.57	Lower Bound
10-year	Normal		4.73	Lower Bound
25-year	Normal		4.90	Lower Bound
50-year	Normal		5.03	Lower Bound
100-year	Normal		5.15	Lower Bound
200-year	Normal		5.26	Lower Bound
500-year	Normal		5.55	Lower Bound
2-year	5.38 ft	200*	4.74	Most Likely
5-year	5.38 ft	201*	4.92	Most Likely
10-year	5.38 ft	202*	5.04	Most Likely
25-year	5.38 ft	203*	5.21	Most Likely
50-year	5.38 ft	204*	5.32	Most Likely
100-year	5.38 ft	205*	5.43	Most Likely
200-year	5.38 ft	206*	5.57	Most Likely
500-year	5.38 ft	207	5.88	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 13. Future year WP – ER - Amor to Airport Culvert

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		2.89	Lower Bound
5-year	Normal		3.51	Lower Bound
10-year	Normal		3.88	Lower Bound
25-year	Normal		4.33	Lower Bound
50-year	Normal		4.60	Lower Bound
100-year	Normal		4.81	Lower Bound
200-year	Normal		5.00	Lower Bound
500-year	Normal		5.29	Lower Bound
2-year	5.38 ft	313	3.97	Most Likely
5-year	5.38 ft	356	4.23	Most Likely
10-year	5.38 ft	391	4.53	Most Likely
25-year	5.38 ft	463	4.83	Most Likely
50-year	5.38 ft	508	5.02	Most Likely
100-year	5.38 ft	511*	5.20	Most Likely
200-year	5.38 ft	513*	5.36	Most Likely
500-year	5.38 ft	515*	5.62	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 14. Base year WOP – ER - ER- Culvert to Rt 46

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		5.02	Lower Bound
5-year	Normal		5.13	Lower Bound
10-year	Normal		5.20	Lower Bound
25-year	Normal		5.28	Lower Bound
50-year	Normal		5.35	Lower Bound
100-year	Normal		5.50	Lower Bound
200-year	Normal		5.70	Lower Bound
500-year	Normal		6.00	Lower Bound
2-year	4.27 ft	338	5.03*	Most Likely
5-year	4.27 ft	371	5.14*	Most Likely
10-year	4.27 ft	393	5.21*	Most Likely
25-year	4.27 ft	417	5.29	Most Likely
50-year	4.27 ft	437	5.36	Most Likely
100-year	4.27 ft	459	5.56	Most Likely
200-year	4.27 ft	479	5.76	Most Likely
500-year	4.27 ft	504	6.06	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 15. Base year WP – ER - ER- Culvert to Rt 46

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.87	Lower Bound
5-year	Normal		5.06	Lower Bound
10-year	Normal		5.15	Lower Bound
25-year	Normal		5.25	Lower Bound
50-year	Normal		5.32	Lower Bound
100-year	Normal		5.44	Lower Bound
200-year	Normal		5.65	Lower Bound
500-year	Normal		5.94	Lower Bound
2-year	4.27 ft	349	4.88*	Most Likely
5-year	4.27 ft	385	5.07*	Most Likely
10-year	4.27 ft	409	5.16*	Most Likely
25-year	4.27 ft	436	5.26*	Most Likely
50-year	4.27 ft	455	5.33*	Most Likely
100-year	4.27 ft	475	5.48	Most Likely
200-year	4.27 ft	498	5.69	Most Likely
500-year	4.27 ft	517	5.99	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 16. Future year WOP – ER - ER- Culvert to Rt 46

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		5.07	Lower Bound
5-year	Normal		5.16	Lower Bound
10-year	Normal		5.23	Lower Bound
25-year	Normal		5.36	Lower Bound
50-year	Normal		5.55	Lower Bound
100-year	Normal		5.73	Lower Bound
200-year	Normal		5.95	Lower Bound
500-year	Normal		6.21	Lower Bound
2-year	5.38 ft	156	5.10	Most Likely
5-year	5.38 ft	157	5.19	Most Likely
10-year	5.38 ft	160*	5.28	Most Likely
25-year	5.38 ft	162*	5.50	Most Likely
50-year	5.38 ft	165*	5.68	Most Likely
100-year	5.38 ft	170*	5.89	Most Likely
200-year	5.38 ft	173	6.09	Most Likely
500-year	5.38 ft	226	6.36	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 17. Future year WP – ER - ER- Culvert to Rt 46

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.90	Lower Bound
5-year	Normal		5.07	Lower Bound
10-year	Normal		5.17	Lower Bound
25-year	Normal		5.30	Lower Bound
50-year	Normal		5.47	Lower Bound
100-year	Normal		5.66	Lower Bound
200-year	Normal		5.87	Lower Bound
500-year	Normal		6.14	Lower Bound
2-year	5.38 ft	349	4.91	Most Likely
5-year	5.38 ft	384	5.10	Most Likely
10-year	5.38 ft	407	5.19	Most Likely
25-year	5.38 ft	434	5.39	Most Likely
50-year	5.38 ft	451	5.58	Most Likely
100-year	5.38 ft	472	5.77	Most Likely
200-year	5.38 ft	493	5.99	Most Likely
500-year	5.38 ft	511	6.25	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 18. Base year WOP –Airport South

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.32	Lower Bound
5-year	Normal		4.13	Lower Bound
10-year	Normal		4.48	Lower Bound
25-year	Normal		4.96	Lower Bound
50-year	Normal		5.23	Lower Bound
100-year	Normal		5.44	Lower Bound
200-year	Normal		5.66	Lower Bound
500-year	Normal		5.96	Lower Bound
2-year	4.27 ft	338	3.52	Most Likely
5-year	4.27 ft	371	4.23	Most Likely
10-year	4.27 ft	393	4.58	Most Likely
25-year	4.27 ft	417	5.05	Most Likely
50-year	4.27 ft	437	5.3	Most Likely
100-year	4.27 ft	459	5.52	Most Likely
200-year	4.27 ft	479	5.73	Most Likely
500-year	4.27 ft	504	6.02	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 19. Base year WP – Airport South

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.14	Lower Bound
5-year	Normal		4.00	Lower Bound
10-year	Normal		4.38	Lower Bound
25-year	Normal		4.87	Lower Bound
50-year	Normal		5.16	Lower Bound
100-year	Normal		5.39	Lower Bound
200-year	Normal		5.60	Lower Bound
500-year	Normal		5.90	Lower Bound
2-year	4.27 ft	349	3.38	Most Likely
5-year	4.27 ft	385	4.07	Most Likely
10-year	4.27 ft	409	4.45	Most Likely
25-year	4.27 ft	436	4.93	Most Likely
50-year	4.27 ft	455	5.21	Most Likely
100-year	4.27 ft	475	5.44	Most Likely
200-year	4.27 ft	498	5.66	Most Likely
500-year	4.27 ft	517	5.96	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 20. Future year WOP –Airport South

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.24	Lower Bound
5-year	Normal		4.65	Lower Bound
10-year	Normal		4.97	Lower Bound
25-year	Normal		5.29	Lower Bound
50-year	Normal		5.51	Lower Bound
100-year	Normal		5.7	Lower Bound
200-year	Normal		5.91	Lower Bound
500-year	Normal		6.18	Lower Bound
2-year	5.38 ft	156	4.5	Most Likely
5-year	5.38 ft	157	4.91	Most Likely
10-year	5.38 ft	160*	5.18	Most Likely
25-year	5.38 ft	162*	5.45	Most Likely
50-year	5.38 ft	165*	5.65	Most Likely
100-year	5.38 ft	170*	5.86	Most Likely
200-year	5.38 ft	173	6.06	Most Likely
500-year	5.38 ft	226	6.33	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 21. Future year WP –Airport South

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.17	Lower Bound
5-year	Normal		4.54	Lower Bound
10-year	Normal		4.86	Lower Bound
25-year	Normal		5.22	Lower Bound
50-year	Normal		5.42	Lower Bound
100-year	Normal		5.62	Lower Bound
200-year	Normal		5.84	Lower Bound
500-year	Normal		6.11	Lower Bound
2-year	5.38 ft	349	4.38	Most Likely
5-year	5.38 ft	384	4.76	Most Likely
10-year	5.38 ft	407	5.02	Most Likely
25-year	5.38 ft	434	5.34	Most Likely
50-year	5.38 ft	451	5.54	Most Likely
100-year	5.38 ft	472	5.73	Most Likely
200-year	5.38 ft	493	5.95	Most Likely
500-year	5.38 ft	511	6.22	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 22. Base year WOP –Airport West

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.22	Lower Bound
5-year	Normal		4.56	Lower Bound
10-year	Normal		4.71	Lower Bound
25-year	Normal		4.96	Lower Bound
50-year	Normal		5.23	Lower Bound
100-year	Normal		5.45	Lower Bound
200-year	Normal		5.68	Lower Bound
500-year	Normal		5.99	Lower Bound
2-year	4.27 ft	360	4.24	Most Likely
5-year	4.27 ft	413	4.57	Most Likely
10-year	4.27 ft	424	4.72	Most Likely
25-year	4.27 ft	442	5.06	Most Likely
50-year	4.27 ft	444*	5.31	Most Likely
100-year	4.27 ft	445	5.53	Most Likely
200-year	4.27 ft	446	5.75	Most Likely
500-year	4.27 ft	452	6.05	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 23. Base year WP –Airport West

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.20	Lower Bound
5-year	Normal		4.55	Lower Bound
10-year	Normal		4.71	Lower Bound
25-year	Normal		4.87	Lower Bound
50-year	Normal		5.16	Lower Bound
100-year	Normal		5.40	Lower Bound
200-year	Normal		5.62	Lower Bound
500-year	Normal		5.94	Lower Bound
2-year	4.27 ft	360	4.24	Most Likely
5-year	4.27 ft	413	4.57	Most Likely
10-year	4.27 ft	424	4.72	Most Likely
25-year	4.27 ft	440	4.94	Most Likely
50-year	4.27 ft	441	5.22	Most Likely
100-year	4.27 ft	444	5.45	Most Likely
200-year	4.27 ft	448	5.68	Most Likely
500-year	4.27 ft	451	5.99	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 24. Future year WOP –Airport West

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.33	Lower Bound
5-year	Normal		4.65	Lower Bound
10-year	Normal		4.97	Lower Bound
25-year	Normal		5.30	Lower Bound
50-year	Normal		5.52	Lower Bound
100-year	Normal		5.72	Lower Bound
200-year	Normal		5.94	Lower Bound
500-year	Normal		6.21	Lower Bound
2-year	5.38 ft	335	4.50	Most Likely
5-year	5.38 ft	382	4.91	Most Likely
10-year	5.38 ft	398	5.18	Most Likely
25-year	5.38 ft	413	5.46	Most Likely
50-year	5.38 ft	414*	5.66	Most Likely
100-year	5.38 ft	415*	5.88	Most Likely
200-year	5.38 ft	416*	6.09	Most Likely
500-year	5.38 ft	417*	6.36	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 25. Future year WP –Airport West

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.33	Lower Bound
5-year	Normal		4.62	Lower Bound
10-year	Normal		4.87	Lower Bound
25-year	Normal		5.23	Lower Bound
50-year	Normal		5.43	Lower Bound
100-year	Normal		5.64	Lower Bound
200-year	Normal		5.86	Lower Bound
500-year	Normal		6.14	Lower Bound
2-year	5.38 ft	335	4.42	Most Likely
5-year	5.38 ft	383	4.78	Most Likely
10-year	5.38 ft	398	5.03	Most Likely
25-year	5.38 ft	410	5.35	Most Likely
50-year	5.38 ft	411*	5.55	Most Likely
100-year	5.38 ft	412*	5.76	Most Likely
200-year	5.38 ft	413*	5.98	Most Likely
500-year	5.38 ft	414*	6.25	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 26. Base year WOP – WR - Tide gate to Moonachie Bridge

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.68	Lower Bound
5-year	Normal		3.88	Lower Bound
10-year	Normal		4.01	Lower Bound
25-year	Normal		4.21	Lower Bound
50-year	Normal		4.44	Lower Bound
100-year	Normal		4.63	Lower Bound
200-year	Normal		4.95	Lower Bound
500-year	Normal		5.42	Lower Bound
2-year	4.27 ft		4.07	Most Likely
5-year	4.27 ft	458	4.27	Most Likely
10-year	4.27 ft	540	4.40	Most Likely
25-year	4.27 ft	607	4.52	Most Likely
50-year	4.27 ft	609	4.63	Most Likely
100-year	4.27 ft	610	4.82	Most Likely
200-year	4.27 ft	611*	5.12	Most Likely
500-year	4.27 ft	613	5.55	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 27. Base year WP – WR - Tide gate to Moonachie Bridge

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		3.68	Lower Bound
5-year	Normal		3.88	Lower Bound
10-year	Normal		4.01	Lower Bound
25-year	Normal		4.21	Lower Bound
50-year	Normal		4.37	Lower Bound
100-year	Normal		4.54	Lower Bound
200-year	Normal		4.83	Lower Bound
500-year	Normal		5.29	Lower Bound
2-year	4.27 ft	402	4.07	Most Likely
5-year	4.27 ft	445	4.27	Most Likely
10-year	4.27 ft	524	4.40	Most Likely
25-year	4.27 ft	595	4.52	Most Likely
50-year	4.27 ft	608*	4.63	Most Likely
100-year	4.27 ft	609	4.74	Most Likely
200-year	4.27 ft	610	4.99	Most Likely
500-year	4.27 ft	618	5.41	Most Likely
N/A	2-year		5.88	Upper Bound
N/A	5-year		6.89	Upper Bound
N/A	10-year		7.75	Upper Bound
N/A	25-year		8.6	Upper Bound
N/A	50-year		9.82	Upper Bound
N/A	100-year		10.84	Upper Bound
N/A	200-year		11.82	Upper Bound
N/A	500-year		13	Upper Bound

Table 28. Future year WOP – WR - Tide gate to Moonachie Bridge

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.22	Lower Bound
5-year	Normal		4.49	Lower Bound
10-year	Normal		4.64	Lower Bound
25-year	Normal		4.81	Lower Bound
50-year	Normal		4.94	Lower Bound
100-year	Normal		5.16	Lower Bound
200-year	Normal		5.44	Lower Bound
500-year	Normal		5.80	Lower Bound
2-year	5.38 ft	500	4.44	Most Likely
5-year	5.38 ft	573	4.74	Most Likely
10-year	5.38 ft	680*	4.94	Most Likely
25-year	5.38 ft	585*	5.07	Most Likely
50-year	5.38 ft	589*	5.26	Most Likely
100-year	5.38 ft	591*	5.47	Most Likely
200-year	5.38 ft	592*	5.72	Most Likely
500-year	5.38 ft	593	6.06	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

Table 29. Future year WP – WR - Tide gate to Moonachie Bridge

Varied Interior Condition		Results		Risk Condition
Interior Flow	Exterior Stage (ft NAVD 88)	Flow	Stage (ft NAVD 88)	
2-year	Normal		4.22	Lower Bound
5-year	Normal		4.42	Lower Bound
10-year	Normal		4.61	Lower Bound
25-year	Normal		4.75	Lower Bound
50-year	Normal		4.86	Lower Bound
100-year	Normal		5.02	Lower Bound
200-year	Normal		5.29	Lower Bound
500-year	Normal		5.67	Lower Bound
2-year	5.38 ft	480	4.38	Most Likely
5-year	5.38 ft	553	4.59	Most Likely
10-year	5.38 ft	590	4.79	Most Likely
25-year	5.38 ft	592	5.02	Most Likely
50-year	5.38 ft	595*	5.11	Most Likely
100-year	5.38 ft	597	5.32	Most Likely
200-year	5.38 ft	600	5.55	Most Likely
500-year	5.38 ft	601*	5.89	Most Likely
N/A	2-year		6.99	Upper Bound
N/A	5-year		8	Upper Bound
N/A	10-year		8.86	Upper Bound
N/A	25-year		9.71	Upper Bound
N/A	50-year		10.93	Upper Bound
N/A	100-year		11.95	Upper Bound
N/A	200-year		12.93	Upper Bound
N/A	500-year		14.11	Upper Bound

4.7. Model Continuity

Volume continuity tracking is a parameter that is used to assess the level of error occurring within a given HEC-RAS model. Currently, the volume error within the model results is low, with all model plans reporting continuity error less than 1%. Model stability varies throughout the domain. Some structures within the model show rapid variation in flow, indicating some level of model instability, but stage hydrographs for these structures are generally stable.

Originally, many of the instability issues seen in the model results were due to very shallow overland flow resulting from precipitation being applied to a very low slope terrain. Although these conditions are realistic, given the extremely low slopes seen in these drainage channels, they were causing instabilities in the model. Numerous efforts were made to reduce the model instabilities observed, but not all instabilities could be eliminated. Finally, the decision was made to change the method from the rain-on-grid model, and instead, inject the flows as internal boundary condition lines in the lowest elevation of the channels in each drainage area. Furthermore, the stability of the model drastically increased by adding the variable Manning values to each cell face, changing the calculation method to Shallow Water Equation, and adding more break lines along the roads, buildings, and flow paths.

The topographic data was based on LiDAR data, with only limited channel bathymetry available to supplement the channel regions of the terrain.

The model includes two geometries labelled “Existing” and “With project.” The goal was to duplicate the geometries to confirm all the terrain features and modifications, boundary lines, 2D flow cells, and land covers are identical in both geometries. The differences were the East Riser channel bathymetry from ER tide gate to Moonachie Ave., and the proposed improvement on the three bridges of East Riser. These models are intended to produce results that would represent the impacts of the Proposed Project features being simulated, and Figures 4-1 to 4-8 show all the improvements in the discharges and water surface elevation in the With and Without project scenarios.

5. INDUCED FLOODING ANALYSIS

The East Riser plan includes a pump station, channel improvements, and bridge replacements to reduce flood risks in the area upstream of the East Riser tide gate. The plan increases conveyance through the bridges and within the channel, resulting in a higher peak flow rate reaching the East Riser tide gate. For the areas upstream of the tide gate, the pump station provides sufficient capacity to prevent any increase in flood elevations associated with the increased flow in the channel.

The impacts of increased flow and the potential for induced flooding were evaluated as part of the NJDEP Flood Hazard Permit submittal using a 1D unsteady state HEC-RAS model developed in accordance with New Jersey Flood Hazard Area permit rules. This assessment covered extensive combinations of flow and tidal tailwater conditions and identified any increases in water surface elevations. The largest increases in water levels were associated high discharge and lower tidal conditions. Increases in water levels were generally contained within the channels or the adjacent berms and the analysis did not identify any unacceptable induced flooding. Permit number 0200-19-0004.4 LUP240001 was issued on September 25, 2024, and expires on September 25, 2029.

The current hydraulic modelling effort utilized 2D HEC-RAS and considered a full range of discharges in conjunction with a 50% AEP storm tide. As seen in Figures 5-1 and 5-2, stage hydrographs extracted from that model indicate minor increases in peak stages of less than 0.1 ft at a point downstream of the East Riser tide gate. For the 10% AEP event, the increase in flood stage was calculated to be 0.07 feet. For the 1% AEP event, the increase was calculated to be 0.09 ft. It should be noted that flooding in the area downstream of the tide gate is primarily controlled by storm surge and that the plan would have no impact on regulatory flood levels.

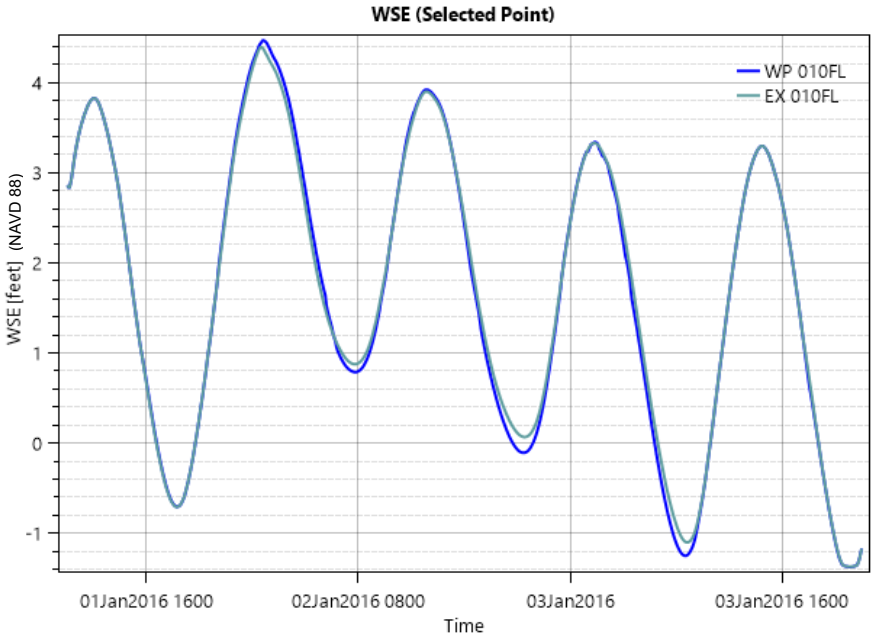

Figure 5-1. Comparison between the WSE downstream of the ER tide gate for With and Without project at 10% AEP.

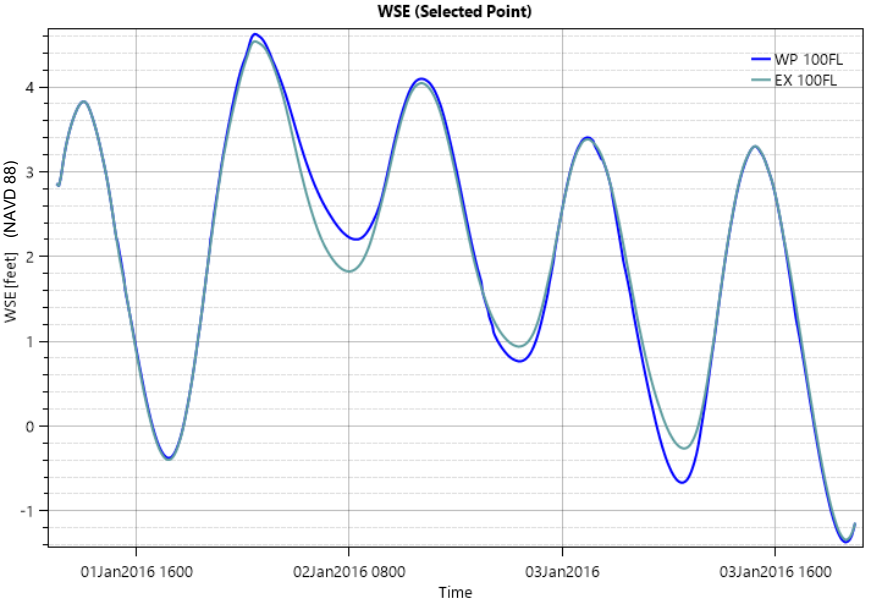

Figure 5-2. Comparison between the WSE downstream of the ER tide gate for With and Without project at 1% AEP.

6. REFERENCES

Horsburgh, K. J., and C. Wilson. "Tide-surge interaction and its role in the distribution of surge residuals in the North Sea." Journal of Geophysical Research: Oceans, 2007: 112.C8.

Horton, Radley, Christopher Little, Vivien Gornitz, Daniel Bader, and Michael Oppenheimer. "Chapter 2: Sea Level Rise and Coastal Storms." February 16, 2015. http://onlinelibrary.wiley.com/doi/10.1111/nyas.12593/epdf.

Mockus, V. (1961). Watershed lag. U.S. Dept. of Agriculture, Soil Conservation Service, ES-1015, Washington, DC

NJDEP Bureau of GIS. NJDEP Bureau of GIS. October 15, 2025. http://www.nj.gov/dep/gis.

NJGIN. New Jersey Geographic Information Network. n.d. njgin.state.nj.us.

NOAA. Estimating vertical land motion from long-term tide gauge records. Silver Spring, MD: National Oceanic and Atmospheric Administration, Center for Operational Oceanographic Products and Services, 2013.

NOAA. "Global and regional sea level rise scenarios for the United States." 2017.

NRCS. "Urban Hydrology for Small Watersheds, TR-55." June 1986. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.

Rossiter, James R. "Interaction between tide and surge in the Thames." Geophysical Journal International, 1961: 6.1: 29-53.

—. Web Soil Survey. August 21, 2017. websoilsurvey.nrcs.usda.gov.