PORT AUTHORITY NY NJ

AIR LAND RAIL SEA

Climate Resilience Design Guidelines

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TABLE OF CONTENTS

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Please reference these guidelines as “PANYNJ Climate Resilience Design Guidelines (v1.2), 2018”.

1.0 INTRODUCTION TO THE PANYNJ CLIMATE RESILIENCE GUIDELINES

1.1 BACKGROUND

In June 1993, the Port Authority formally issued an environmental policy statement recognizing its long-standing commitment to provide transportation, terminal, and other facilities of commerce in an environmentally sound manner. In 2008, the Board of Commissioners reaffirmed its support of the Port Authority's continuing sustainability initiatives and expanded the Authority's environmental policy to include climate change. The Sustainability Policy directs the Authority to "develop strategies that reduce the risk posed by climate change to its facilities and operations and, in collaboration with other regional stakeholders, develop strategies that mitigate the risk to the region posed by climate change in a manner that will promote a sustainable environment."

To help fulfill this policy mandate, the Port Authority Engineering Department responded in 2009 by issuing a Design Memorandum dictating that "the design of all new construction and major rehabilitation projects is to be evaluated based on … climate change variables", including temperature, precipitation, and sea level rise. In 2015, this memorandum was replaced by the first edition of the PANYNJ Climate Resilience Design Guidelines (CRG), Version 1.0, which this document in turn supersedes.

The Guidelines enable the Port Authority to proactively address projected risks during the design process, ensuring that public dollars are spent wisely to keep the region moving, now and in the future.

1.2 2018 CRG UPDATE SUMMARY

The 2018 CRG update incorporates the lessons learned from over three years of implementation, as well as feedback from representatives within the PA Engineering Department and Line Departments. Although the CRG Version 1.1 does not substantially modify the Guidelines' original technical basis, specific updates to the CRG include:

- Simplified presentation of climate change projections;
- Streamlining of the Design Flood Elevation (DFE) determination process;
- Clarification of guidance for projects located outside of the current 1% annual chance floodplain, but which may be situated within the projected future floodplain.

It is anticipated that subsequent editions will contain guidance on additional climate change stressors, including extreme temperatures and intense precipitation events.

1.3 OBJECTIVES

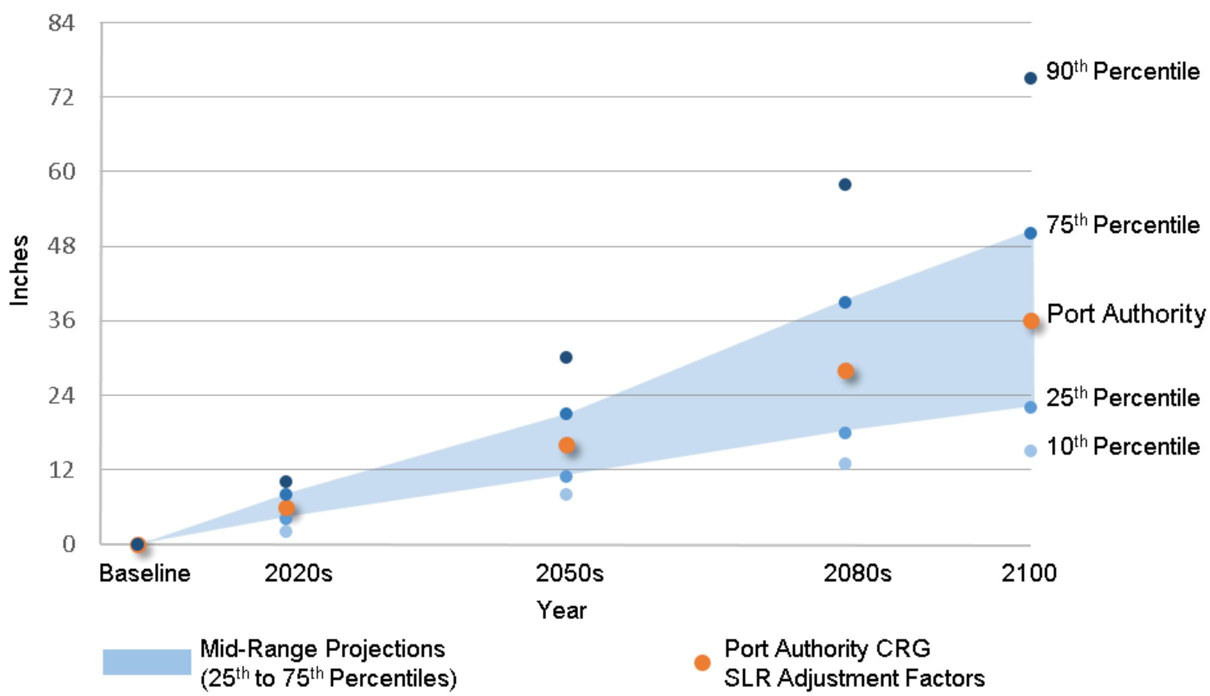
The purpose of the CRG is to maximize the long-term safety, service, and resilience of the Port Authority's assets, now and in the future, as climate conditions change. The specific objectives of the CRG are to:

- Adopt a science-based approach to managing climate-related risks to Port Authority facilities and infrastructure;
- Support the incorporation of climate change projections—particularly sea level rise—into the full range of Port Authority engineering and architectural design standards, as a supplement to applicable building code requirements;
- Provide a clear methodology for factoring projected future sea level rise into project design criteria, while maintaining the flexibility of project teams to develop cost-effective design solutions; and
- Support our Line Departments and Office of Emergency Management to ensure that, when natural disasters inevitably strike, Port Authority facilities and infrastructure are better equipped to withstand the impacts and to recover and restore operations more quickly.

1.4 CLIMATE PROJECTIONS

The New York City Panel on Climate Change (NPCC) has been instrumental in providing a common basis of scientific knowledge for agencies in the region. Climate change projections referenced in this document were obtained from NPCC's *Building the Knowledge Base for Climate Resilience: New York City Panel on Climate Change 2015 Report*[1]. The report provides recently observed trends and projections up to the year 2100[2], applicable to a 100-mile radius around the New York City metropolitan area. Figure 1 displays the NPCC's regional sea level rise projections for the greater New York City area[3]. A summary of the NPCC's current mid-range climate projections (25th to 75th percentile)[4] is included as Appendix A.

Figure 1. NPCC Sea Level Rise Projections, 2015



As of May 2018, the climate change projections cited in this document are complete and accurately transcribed from NPCC. The Port Authority will continue to update the CRG as climate models evolve. As appropriate, design teams may opt additionally to consider customized downscaling or site-specific analyses, subject to approval by the Chief, Resilience & Sustainability.

NPCC's 2015 projections are summarized below, along with potential implications for Port Authority facilities and infrastructure.

[1] References to climate change projections obtained from pages 9-11, 31-32 of the Annals of the New York Academy of Science, Vol. 1336: *Building the Knowledge Base for Climate Resilience: New York City Panel on Climate Change 2015 Report*, Pages 1-150 (http://onlinelibrary.wiley.com/doi/10.1111/nyas.2015.1336.issue-1/issuetoc).

[2] Leveraging the methods and projections produced at a global scale by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[3] Annals of the New York Academy of Science, Vol. 1336: *Building the Knowledge Base for Climate Resilience: New York City Panel on Climate Change 2015 Report*, Page 41.

[4] Percentiles are used by the NPCC to characterize the range of projections from a variety of models. The 25th to 75th percentile range represents the middle 50 percent of projections, meaning that of the total climate model outputs, 25 percent were lower and 25 percent were higher than this range. Consistent with CRG 1.0, PANYNJ uses the mid-point of this range.

Projected Climate Change Hazard	Potential Impacts to Port Authority
Sea Level Rise: - Observed relative sea level rise of about 1.2 inches per decade (which includes factors such as land subsidence) in the greater New York City region has averaged twice the observed global rate. - Sea level rise is very likely (>90% probability of occurrence) to accelerate as the century progresses.	- Amplifies the depth and extent of storm surge, putting more areas at risk of flooding during coastal storm events. - Increasing depth and extent of coastal inundation during extreme and regular high tides. - Increased likelihood of backflow from drainage outfalls. - Progressively greater risk of groundwater flooding in coastally connected areas. - Corrosion of tracks and equipment from saltwater exposure. - Diminishing air draft below bridge spans.
Precipitation: - The number of annual rainfall downpours is very likely (>90% probability of occurrence) to increase.	- Greater volumes of rain in more concentrated downpours could overwhelm drainage systems and cause localized flooding. - Disruption to movement of transit vehicles and freight both during and after significant precipitation events. - Erosion and scour of foundations, pilings, footings, and shorelines from overland flow. - Additional stress on drainage and pumping systems.
Rising Temperatures: - Warmer temperatures are extremely likely (>95% probability of occurrence) - Average number of days per year with temperatures at or above 90°F is projected to more than double to 39-52 days by the 2050s[5]. - Heat waves (3 days or more exceeding 90°F) are projected to occur with greater frequency.	- Impacts to materials, such as expansion and kinking of steel rails. - Increasing summer electricity loads possibly leading to blackouts or brownouts and service disruptions. - Stress on air conditioning systems in vehicles, stations, and operational facilities. - Heat stress on critical mechanical/electrical equipment. - Heat stress on maintenance crews, operators, and passengers.

1.5 Climate Stressors Other Than Sea Level Rise

At this time, the CRG Version 1.1 provides explicit design guidance only for managing the risks of coastal flooding, as amplified by projected sea level rise. As the state of the practice evolves, it is anticipated that future versions of the Guidelines will additionally consider the changing risk profiles of extreme precipitation and heat events. Until then, design teams are encouraged to work with the Resilience & Sustainable Design (RSD) group to develop design criteria for future extreme heat, precipitation, and other stressors as appropriate. PA Line Departments may also request consideration of extreme precipitation and heat events in their Project Initiation Request Forms (PIRF).

[5] 25th to 75th percentile (“mid-range”) projections.

2.0 Stressor: Sea Level Rise and Coastal Inundation

2.1 Codes and Standards

The Port Authority takes a code-plus approach to designing for future sea level rise, meaning that the Climate Resilience Guidelines supplement, but do not supersede, applicable codes and standards[6].

The American Society of Civil Engineers (ASCE) standard *Flood Resistant Design and Construction* (ASCE 24) is fully incorporated into New Jersey Building Code and serves as the basis for New York City Building Code Appendix G (*Flood-Resistant Construction*). ASCE 24 dictates that construction in the FEMA 1% ("100-year") annual chance floodplain is subject to specific, safety-driven requirements, most notably the establishment of a Design Flood Elevation (DFE) comprising:

- **Base Flood Elevation.** The project-specific FEMA Base Flood Elevation (BFE)[7]—the elevation of the 100-year flood including waves—is derived from the FEMA Flood Insurance Rate Map(s); *and*
- **Freeboard**. Freeboard is a factor of safety usually expressed in feet above the BFE, as dictated by the requirements of ASCE 24 or the applicable code.

The Climate Resilience Guidelines supplement ASCE 24 and applicable local codes in two primary ways:

- **Adjustment of the BFE for Sea Level Rise:** The Guidelines augment the applicable FEMA BFE by adding the relative increase in future sea levels (based on the NPCC projections) over the project's expected service life[8].
- **Consideration of future floodplain expansion:** Rising sea levels may also lead to expansion of the 100-year tidal floodplain over time, depending on local conditions. Therefore, the Guidelines apply to projects sited in or proximate to today's 0.2% annual chance ("500-year") floodplain or in the projected future tidal 100-year floodplain, in addition to the current FEMA 100-year floodplain.

2.2 Grant Funding

Projects receiving federal, state or local funding may be required to adhere to specific design criteria. In such instances, the design lead (LE/A or Principal) should contact the Line Department Project Manager early in the process to identify any design requirements stipulated in the grant agreement. If the project is receiving funding from FEMA, FTA, or other entities, the design lead should additionally contact the Climate Resilience Specialist (resilience@panynj.gov) and the Engineering Program Management group during proposal development.

[6] In the unlikely instance that these Guidelines are found to be less stringent than code in a particular application, code prevails.
[7] FEMA Region 2 defines Base Flood Elevation (BFE) as the elevation shown on the Flood Insurance Rate Map (FIRM) for Zones AE, AH, A1-30, or VE that indicates the water surface elevation resulting from a flood that has a 1% chance of occurring in any given year.
[8] Where it is necessary or useful to differentiate between code-required design flood elevations and the DFEs derived from these Guidelines, use "SLR DFE" in drawings, notes, and narratives to indicate that the DFE has been adjusted for projected future sea level rise.

2.3 DESIGN CRITERIA

There are five principal steps for developing the sea-level rise adjusted project DFE (SLR DFE). For questions about this process, please contact the Climate Resilience Specialist at resilience@panynj.gov.

Step 1: Determine CRG Applicability

These Guidelines apply to Port Authority projects where at least one of the following criteria is true:

1) The project is located in or is potentially hydrologically or hydraulically connected[9] to a federally delineated tidal floodplain (Effective or Preliminary);
2) (Advisory) The project is located in a projected future tidal floodplain, as defined by the Future Flood Risk Mapper[10], an application created by the City of New York and adapted for portions of northern New Jersey[11] by the Port Authority.

Please contact the Climate Resilience Specialist with questions concerning the applicability of the CRG to your project, or email resilience@panynj.gov.

Step 2: Include Climate Resilience in Project Documents

Early integration of the CRG criteria into the project delivery process is essential to ensuring an effective and cost-conscious outcome. Consequently, the CRG must be referenced in the following documents, if applicable:

- The project Proposal;
- The Attachment A for consultant services;
- Design Criteria/Performance Criteria/Basis of Design documents;
- Requirements and Provisions for Work;

Further, invite the Climate Resilience Specialist to the kick-off meeting.

Interdependent Risks

As part of Step 2, consider whether there may be an opportunity to address critical interdependencies (for example, shared risks to essential electrical, telecommunications, fueling, or surface access infrastructure) within the project scope.

Step 3: Establish Project DFE (SLR DFE)

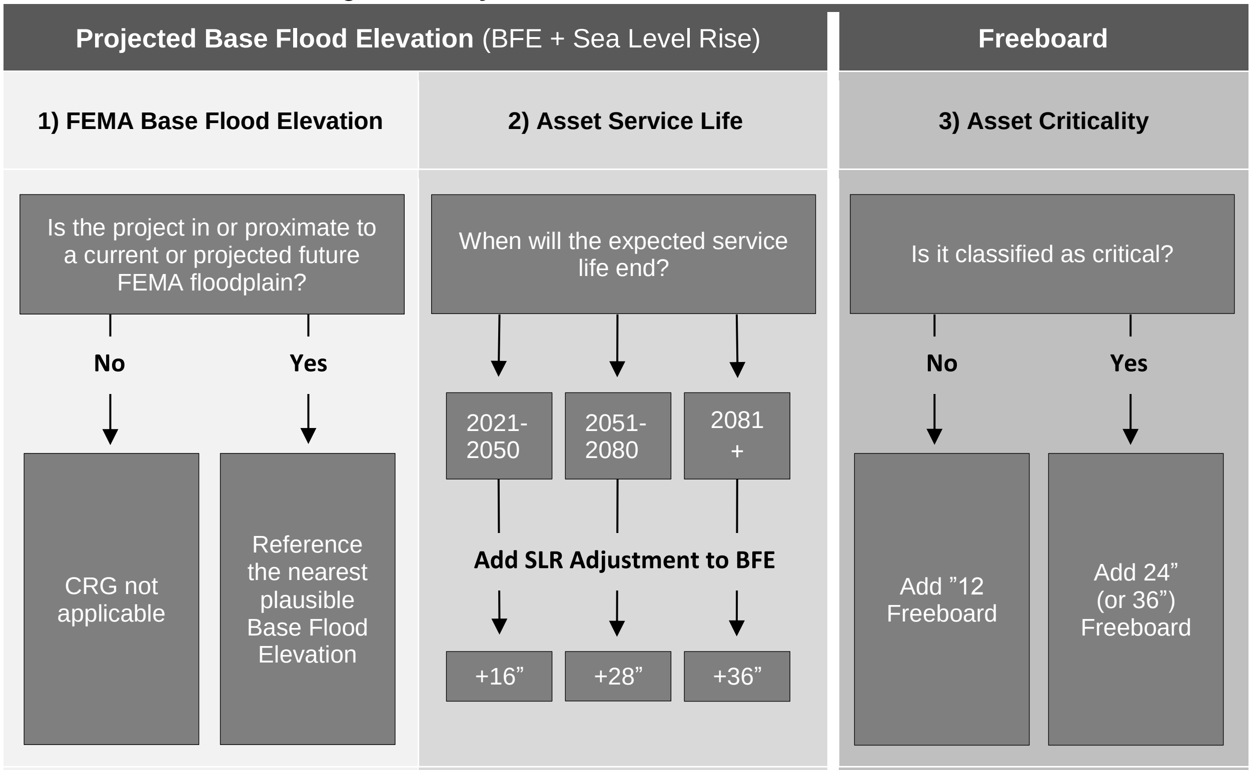
The design team must assemble three sources of information to compute the project's sea level rise adjusted Design Flood Elevation:

1. FEMA Base Flood Elevation (BFE)
2. Asset Service Life
3. Asset Criticality

The key informational requirements for determining the project DFE are summarized in Figure 2, below, followed by detailed guidance.

[9] Via storm drain, channel, or ditch, for example.
[10] http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page
[11] PA staff may access this resource from the RSD SharePoint site. Consultants may request access through the project Lead Engineer/Architect.

Figure 2: Key Information for DFE Determination



Source: Access FEMA’s Effective Flood Insurance Rate Maps (FIRMs) online here.[12] Preliminary FIRMs can be viewed using FEMA’s Preliminary FIRM Viewer.[13]

Source: Use the PA Asset Class Reference Manual[14] for guidance, complemented by best engineering judgment and Line Department consultation.

Source: Refer to applicable building code to determine the Flood Design Class, or reference critical infrastructure types in Step 3.3 of this document.

3.1 FEMA Base Flood Elevation (BFE)

Overlay the project footprint on the applicable Preliminary and Effective FEMA Flood Insurance Rate Maps (FIRM) and, consistent with local building codes, select the *more conservative* (higher) Base Flood Elevation among the two. Convert the BFE into the North American Vertical Datum of 1988 (NAVD88), if necessary[15].

For CRG-applicable projects outside of the current 1% annual chance floodplain (e.g., in the 0.2% annual chance floodplain or in a projected future 1% annual chance floodplain, per the applicability criteria in Step 1), select the nearest plausible Base Flood Elevation, accounting for subsurface (e.g., drainage and/or seepage) connectivities and/or structurally-sound obstructions to overland flows.

FEMA FIRMs are available online (as of May 2018):

- Effective FIRMs (2007): https://msc.fema.gov/portal/advanceSearch
- Preliminary FIRMs (2013/2015): www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/

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[12] https://msc.fema.gov/portal/advanceSearch
[13] http://www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/
[14] https://panynj.sharepoint.com/sites/Engineering/_layouts/15/DocIdRedir.aspx?ID=ENGDEPT-1823177521-14
[15] Note that the Effective FIRM references the outdated NGVD29 datum, whereas the Preliminary FIRM references the required NAVD88 datum. For guidance on conversion, consult Central Survey or visit: www.region2coastal.com/view-flood-maps-data/understanding-vertical-datums

Contact the Climate Resilience Specialist (resilience@panynj.gov) for information on pending FEMA flood map appeals, revisions, or amendments, if applicable.

In instances where higher resolution or more up-to-date flood risk information is available, as validated by the Climate Resilience Specialist, these additional sources should be factored into determination of the project DFE (unless the alternative information results in an DFE less stringent than applicable codes and standards). Such sources may include:

- NOAA's Hurricane SLOSH maps;
- Hurricane Sandy inundation maps;
- USACE's North Atlantic Coast Comprehensive Study maps;
- Site-specific flood hazard analyses.

3.2 Asset Service Life

Sea level rise is already impacting the Port District, with over 14 inches of increase in mean sea level observed at the Battery since the year 1900[16], an average rise of 1.2 inches per decade. The rate of increase is projected to accelerate as the 21st century progresses, likely leading to a significant rise in both the frequency and magnitude of coastal flooding. To help mitigate these risks, the Authority supplements the applicable FEMA Base Flood Elevation with projected sea level rise, commensurate with the expected service life of the asset(s) being designed.

For guidance on determining an asset's expected service life, refer to the Port Authority Asset Class Reference Manual. This reference should be complemented by the engineering judgment of the design team, in consultation with the appropriate Line Department or facility. A conservative estimate is recommended, as the *service* life of a given asset may vastly exceed its original *design* life.

Based on the anticipated end year of a given asset's expected service life, use Table 1, below, to determine the appropriate sea level rise adjustment factor to be added to the Base Flood Elevation established in Step 3.1. No SLR adjustment is required if a given project's service life will terminate prior to January 1, 2021.

Table 1. Sea Level Rise Adjustment Factors

End of Anticipated Asset Service Life	Sea Level Rise Adjustment
2021-2050	+16"
2051-2080	+28"
2081+	+36"

[16] https://www1.nyc.gov/assets/planning/download/pdf/applicants/wrp/wrp-2016/nyc-wrp-appendixd.pdf

3.3 Asset Criticality

An asset's classification as *Critical* or *Non-Critical* determines the level of code-required freeboard, a safety factor added to the BFE. Freeboard typically adds 1 foot (non-critical) or 2 feet (critical) to the BFE, but can be as high as 3 feet in certain circumstances.

The determination of asset criticality is driven primarily by the following local codes and national standards, depending on the host jurisdiction:

- New Jersey: New Jersey Building Code (IBC), which points to ASCE-24, *Table 1-1 Flood Design Class of Buildings and Structures*; or
- New York City: New York City Building Code, which points to Appendix G, *Table 1-1 Classification of Structures for Flood-Resistant Design and Construction*.

Under both building codes, Flood Design Classes 1 and 2 are considered "Non-critical," while Classes 3 and 4 are considered "Critical."

Calculation of Flood Loads

Flood load calculations must incorporate projected future sea level rise for all applicable projects. To calculate flood loads, augment the Base Flood Elevation by the appropriate SLR adjustment factor (see Steps 3.1 and 3.2). Where SLR is likely to result in landward migration of the VE Zone, factor in breaking wave loads as appropriate.

Consistent with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, freeboard should be omitted from flood load calculations.

In addition, the following Port Authority infrastructure types follow ASCE-24 freeboard requirements for Category 4 structures:

- PATH Tunnels (e.g., entrances, penetrations, vent buildings);
- Vehicular Tunnels (e.g., entrances, penetrations, vent buildings);
- Power distribution facilities (e.g., electrical substations, switch houses, transformers);
- Emergency generators;
- Fire Protection Systems; and
- Aircraft Fueling Systems.

Additions or subtractions of assets to the list above require agreement between the respective Line Department Director and the Chief Engineer.

3.4 Sea Level Rise Adjusted DFE

Based on the information collected in Steps 3.1 through 3.3, calculate the sea level rise-adjusted DFE (SLR DFE) for the project. Refer to Table 2 for *non-critical* assets and Table 3 for *critical* assets.

Table 2. SLR DFE for *Non-Critical* Assets

1) FEMA Base Flood Elevation (BFE)	2) Sea Level Rise Adjustment based on Asset Design Life		3) Freeboard (code-required)	DESIGN FLOOD ELEVATION (SLR DFE)
Project specific (see Step 3.1 for guidance)	2021-2050	+16"	+12"	**= FEMA BFE + 28"**
	2051-2080	+28"	+12"	**= FEMA BFE + 40"**
	2081+	+36"	+12"	**= FEMA BFE + 48"**

Table 3. SLR DFE for *Critical* Assets

1) FEMA Base Flood Elevation (BFE)	2) Sea Level Rise Adjustment based on Asset Design Life		3) Freeboard[17] (code-required)	DESIGN FLOOD ELEVATION (SLR DFE)
Project specific (see Step 3.1 for guidance)	2021-2050	+16”	+24”	**= FEMA BFE + 40”**
	2051-2080	+28”	+24”	**= FEMA BFE + 52”**
	2081+	+36”	+24”	**= FEMA BFE + 60”**

Step 4: Develop Resilient Design Strategies

This Guideline sets out the methodology for incorporating projected sea level rise into project design criteria, but preserves the flexibility of project teams to develop packages of flood mitigation solutions that best satisfy broader design objectives in a cost-effective and co-beneficial manner[18].

Approaches to increasing the resilience of an asset to flood damage and/or operational disruption generally fall into the basic categories of a) elevate, b) relocate, c) protect, or d) accommodate. These approaches include, but are not limited to:

- Coastal protection, including wave attenuation (placement of levees, berms, or living shorelines)[19];
- Site selection and relocation (placement of structures on higher ground or within flood protected areas);
- Perimeter protection (placement of flood walls and/or deployable protection measures to limit flood risk within a defined perimeter);
- Elevation (raising an entire structure above the DFE);
- Elevation of utilities and critical equipment such as controls, outlets, generators, etc.;
- Wet floodproofing (allowing floodwaters to enter and exit certain non-critical, generally unoccupied portions of a structure to equalize flood loads, subject to code restrictions);
- Dry floodproofing (placement of permanent, deployable, and/or temporary mitigation measures to prevent intrusion of flood waters into a structure);
- Pumps (to prevent build-up of incidental leakage in a dry floodproofed structure or perimeter protected site);
- Backflow prevention (the installation of devices to prevent surge intrusion through storm or sanitary sewers).

[17] See New York City Building Code, Appendix G for circumstances in which 3 feet of freeboard are required, which must be reflected in the SLR DFE.
[18] Subject to the restrictions of applicable codes, standards, and PANYNJ Engineering Guidelines.
[19] In certain instances, the elevation of coastal/perimeter protection structures may be lower than the SLR DFE as long as all applicable landward/perimeter-enclosed assets are designed in accordance with these Guidelines, subject to the restrictions of codes, standards, and other PANYNJ Guidelines.

Flood Mitigation Product Library

To support design teams in identifying potential flood mitigation products and systems, the Port Authority Resilience & Sustainable Design unit offers an extensive product library of flood mitigation products (for informational use only). PA staff may access this resource from the RSD SharePoint site. Consultants may request access through the project Lead Engineer/Architect.

A viable flood protection system may incorporate several of the preceding strategies. For the most critical assets—for which loss of operation for <u>any</u> period of time would be unacceptable—multiple layers of redundant protection may be preferable.

The PANYNJ Climate Resilience Specialist is available to meet with project teams to discuss flood mitigation approaches and product options.

Step 5: (If Applicable) Conduct A Climate Risk-Enhanced Benefit-Cost Analysis (BCA)

At the request of the Line Department or if required for a given funding source, Benefit-Cost Analysis (BCA) can be employed to inform design decision-making. Climate risk-enhanced BCA considers the incremental capital and/or operating costs of designing for resilience (i.e., only the portion of Total Project Cost attributed directly to the additional consideration of sea level rise) in balance with projected avoided losses over time due to flood-related failures.

Climate risk-enhanced BCA has at least two potential applications in the context of climate resilient design:

- Typically, to support selection of the most cost-effective flood mitigation alternative during Stage I design services;
- Selectively, to determine whether a Stage III flood mitigation design to the required DFE is appropriately cost effective. If the BCA definitively demonstrates that design to the full DFE is not cost beneficial, the design team may pursue a flexible adaptation pathway[20] approach, in consultation with the Climate Resilience Specialist.

The Resilience & Sustainable Design unit and the Economics unit of the PANYNJ Office of Planning and Regional Development collaborate to perform the climate-risk enhanced BCA, on request. This service should be specified in the project Proposal and Attachment A, if applicable. Contact the Climate Resilience Specialist with questions pertaining to the BCA process at resilience@panynj.gov.

[20] A Flexible Adaptation Pathway is one or more "[r]esilience-building strategies that can evolve or be adapted over time …" as better information becomes available. *NYC Climate Resiliency Design Guidelines, Version 2.0* (April 2018). http://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf

3.0 Integration of Climate Resilience in Other PANYNJ Engineering Discipline Guidelines

There are a number of intersections between the CRG and the design guidelines of other Port Authority Engineering disciplines. Provided below is a basic summary of how climate resilience is explicitly integrated into other Engineering design guidelines at PANYNJ, as of the issuance date of this document.

Table 4. PANYNJ Engineering Design Guidelines, references to Climate Resilience

ARCHITECTURE Consideration of: • Site selection, placement, and elevation for storm resilience • Wet and dry floodproofing for storm resilience • Higher roof albedo and better building insulation for extreme heat resilience • Higher wind rated roofs	**CIVIL** Consideration of: • Vertical alignment of roadways and railways to accommodate sea level rise • Drainage capacity to manage increases in precipitation and/or sea level rise • Adjustment of hydraulic grade line to accommodate sea level rise • Watertight manhole covers and alternate venting for flooding/sea level rise
LANDSCAPE ARCHITECTURE Consideration of: • Salt and floodwater tolerant plantings for storm resilience • Absorbent landscapes for storm resilience • Plant selection and locations for temperature increases • Preservation/expansion of tree canopies for temperature increases • Increased irrigation for extreme heat days • Water tolerant plants for increase in precipitation	**MECHANICAL** Consideration of: • Equipment elevation to accommodate sea level rise • System redundancy for increasing frequency of extreme weather • Stronger equipment supports for wind loads • Submersible pumping systems for flooding/sea level rise • Adaptation for water supply pressure drop during power outages • Drain sizing to manage increased precipitation
ELECTRICAL Consideration of: • Elevation of switch houses and equipment to accommodate flooding/sea level rise • Watertight sealing of ductbanks, conduits, or other penetrations to a structure below the SLR DFE, whether vacant, occupied, or abandoned, for storm resilience to mitigate pathways for floodwater intrusion	**STRUCTURAL** Consideration of: • Flood design loads to accommodate sea level rise **GEOTECHNICAL** Consideration of: • Groundwater levels including sea level rise

APPENDIX A - NEW YORK CITY PANEL ON CLIMATE CHANGE (NPCC) CLIMATE CHANGE PROJECTIONS, 2015

This table is provided for reference only. SLR adjustments should be sourced from Table 1 (Step 3) of this document.

Climate Variables*	Baseline	Mid-Range Projections**		
	1971-2000	2020s	2050s	2080s
Average temperatures	54°F	+ 2.0° to 2.9°F	+ 4.1° to 5.7°F	+ 5.3° to 8.8°F
Days per year with max temperatures ≥ 90°F	18 days	26 to 31 days	39 to 52 days	44 to 76 days
Heat waves per year	2 events	3 to 4 events	5 to 7 events	6 to 9 events
Average duration of heat waves	4 days	5 days	5 to 6 days	5 to 7 days
Annual precipitation	50.1 in.	+ 1% to 8%	+ 4% to 11%	+ 5% to 13%
Days per year with rainfall > 2 in.	3 to 4 days	3 to 4 days	4 days	4 to 5 days
Sea level rise	-	See Table 1		
Future annual chance of today's 1% annual chance flood (100-year flood)	1%	1.1% to 1.4%	1.6% to 2.4%	2.0% to 5.4%
Flood heights associated with 100-year flood	11.3 ft.	11.6 to 12.0 ft.	12.2 to 13.1 ft.	12.8 to 14.6 ft.

* Temperatures and precipitation observations are taken at Central Park. Coastal flooding observations are taken at The Battery.

** Mid-Range refers to the 25th to 75th percentile of model-based outcomes.

Source: Annals of the New York Academy of Science, Vol. 1336: Building the Knowledge Base for Climate Resilience: New York City Panel on Climate Change 2015 Report, Pages 1-150.