Mayor's Office of
Recovery and Resiliency

#ONENYC

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CLIMATE RESILIENCY DESIGN GUIDELINES

CONTENTS

I. INTRODUCTION

In the coming years and throughout the 21st century, New York City (NYC) will face new challenges from a rapidly changing climate. Many physical infrastructure, landscape and building projects ("facilities") will face new or more severe risks from extreme flooding, precipitation and heat events.[1] At the same time, environmental conditions are also projected to change, posing chronic hazards as some coastal areas are regularly inundated by high tide and average annual temperatures rise. In NYC's *Roadmap to 80 x 50*, the City of New York (the City) committed to reducing emissions of greenhouse gases by 80% by 2050.[2] However, the impacts from climate change are already occurring, and these Guidelines establish how the City can increase its resiliency to unavoidable climate change through design.

Codes and standards that regulate the design of infrastructure and buildings incorporate historic weather data to determine how to build for the future. However, historic conditions do not accurately represent the projected severity and frequency of future storms, sea level rise, heat waves and precipitation. The climate is already changing and will continue to change in significant ways over the entire useful life of facilities designed today, threatening to undermine capital investments and impede critical services. To protect the facilities New Yorkers depend upon, the City will design them using the best available data for future conditions.

The *Climate Resiliency Design Guidelines* ("Guidelines") provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities. Resilient design is intended to become an integral part of the sequential project planning process for agencies and their designers. All new projects should assess their climate change risks in the context of the project's purpose, specific site location and funding, and then determine the appropriate design strategies. These Guidelines apply to all City capital projects except coastal protection projects (e.g. sea walls and levees), for which the City will develop separate guidance. Implementing the Guidelines will result in protection standards that will make the City's built environment more resilient to climate change and promote the health, safety and prosperity of New Yorkers.

The Guidelines provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities.

A. GOALS

The primary goal of the Guidelines is to incorporate forward-looking climate change data in the design of all City capital projects. The Guidelines provide a consistent methodology for engineers, architects, landscape architects and planners to design facilities that are resilient to changing climate conditions. The Guidelines are to be used throughout the design process—during capital planning initiation, as a reference in requests for proposals (RFPs), during a conceptual or study phase, through to final design—for all new construction and substantial improvements of City facilities.

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[1] Though the intensity and frequency of storms is expected to increase, firm projections on future wind conditions have not yet been developed. NYC commenced a study in 2017 to assess projected changes to extreme wind hazards and identify risks to the city's built environment.

[2] To learn more about 80 x 50, visit: http://www1.nyc.gov/site/sustainability/codes/80x50.page.

A successful resiliency strategy is one that provides co-beneficial outcomes, reduces costs over the life of the asset wherever possible and avoids negative indirect impacts to other systems. Resilient design should not exist in a silo, but rather be a well-integrated part of existing processes and address other goals of the City. For example, these resilient design choices should be made in the context of the City’s capital planning, risk management and financial planning. Similarly, resilient design choices should be selected to maximize the efficacy and efficiency of investments. Some ways this can be done include: 1) integrating “soft” resiliency strategies (operational measures or investments in green infrastructure) and “hard” resiliency strategies (built or intensive investments); 2) addressing multiple climate hazards with single interventions; and 3) reducing climate change risk in concert with other goals (e.g., energy efficiency or reduction in greenhouse gas emissions).

These Guidelines were developed by the Mayor’s Office of Recovery and Resiliency (ORR) in close collaboration with City agencies that are involved in the design or management of capital projects. A Design Guidelines Working Group was convened to consult on the development of the Guidelines, which included more than 15 City agencies.[3] A preliminary version (1.0) of these Guidelines was issued in April 2017 and was tested and validated through an extensive review with internal and external climate and design experts. Version 2.0 has been updated to reflect lessons learned through that analysis.

B. CLIMATE CHANGE PROJECTIONS FOR NEW YORK CITY

The New York City Panel on Climate Change (NPCC) provides regional climate change projections that inform City resiliency policy. Composed of leading scientists, the NPCC prepares projections for the metropolitan region which have shown that extreme weather will increase in frequency and severity, and that the climate will become more variable. These projections are divided across future time slices including the 2020s, 2050s, 2080s and 2100. The most NPCC recent climate change projections from 2015 encompass a wide range of possible outcomes, for example:

- Mean annual temperature is projected to increase between 4.1 and 6.6°F by the 2050s and between 5.3 and 10.3°F by the 2080s.[4]
- Frequency of heat waves is projected to triple by the 2050s to 5 to 7 heat waves per year and 5 to 8 heat waves per year by the 2080s.[5]
- Mean annual precipitation is projected to increase between 4 to 13% by the 2050s and between 5 to 19% by the 2080s.[6]
- Sea level is expected to continue rising by another 11 to 21 inches by the 2050s and by 18 to 39 inches by the 2080s.[7]

This document provides specific guidance on how to use the range of climate change projections in design. For more information on climate change projections for the metropolitan region, see Appendix 2. The NPCC continues to study and refine projections for the metropolitan region, and these Guidelines will be updated as new reports are released by the NPCC.

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[3] Representatives from the following City departments and agencies contributed to the creation of this document: Environmental Protection, Transportation, City Planning, Buildings, Design and Construction, Parks and Recreation, Emergency Management, School Construction Authority, City Administrative Services, Health and Hospitals, Information Technology and Telecommunications, Economic Development Corporation, Housing Authority, Public Design Commission, Mayor’s Office of Sustainability, Mayor’s Office of the Chief Technology Officer, Housing Preservation and Development, Office of Management and Budget, Sanitation and Law.

[4] Ranges for heat reflect the middle and high range estimates from the NPCC. See Appendix 2 for more information.

[5] Ibid.

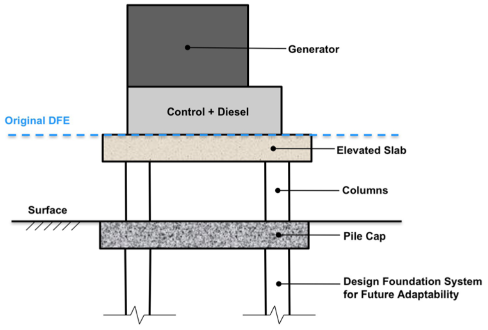
[6] Ranges for precipitation reflect the middle and high range estimates from the NPCC. See Appendix 2 for more information.

[7] Ranges for sea level rise reflect the middle range estimates from the NPCC. See Appendix 2 for more information.

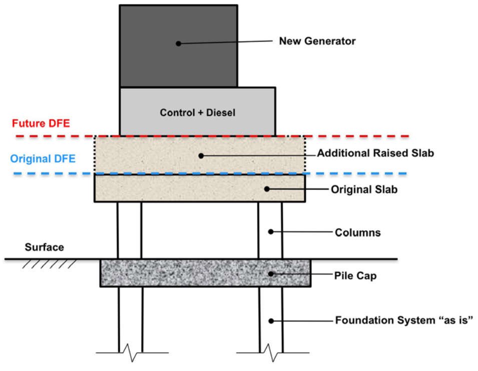
C. PLANNING ACROSS PROJECT USEFUL LIFE

A resilient facility is one built to withstand, or recover quickly from, natural hazards. Climate conditions will continue to change over time, which makes considering the useful life important for choosing the right level of protection.[8] Users should, using professional knowledge and examples from the built environment, estimate the full useful life of the facility to determine necessary design adjustments tied to climate change (useful life starts at the end of construction). The full project useful life of a facility is typically a longer period than the design life, and more accurately represents the extended service life of most types of facilities (assuming regular maintenance). For example, an administrative building may have a design life of 30 years, but in practice such buildings remain in use for 50 years or more when well-maintained. Full useful life is also met through the successful deployment of design strategies that minimize operations and maintenances (O&M) and the need for renovations.

ORR and Department of Design and Construction (DDC), with input from other City agencies, are developing a library of common asset types for buildings, landscapes, infrastructure and equipment, and assessing their typical design and useful lives. This resource will be added as an addendum to the Guidelines by April 2019.



1st USEFUL LIFE



2nd USEFUL LIFE

Figure 1 - Example of a flexible adaptation pathway for an outdoor emergency generator and platform

D. MANAGING UNCERTAINTY

Climate change projections from the NPCC are the product of state-of-the-art modeling and analysis. However, as with all projections, there is uncertainty embedded within them.[9] The NPCC continues to develop, review and synthesize the latest climate data for the metropolitan region, and new findings will be incorporated into future versions of these Guidelines.

Given uncertainty, flexible adaptation pathways provide a useful, iterative approach for managing uncertainty and designing resilient facilities, particularly those with a useful life that extends over 50 years - beyond which the uncertainty of projections increases.[10] Adaptation pathways are particularly useful for expensive, long-lived and highly complex projects. They provide a way to balance uncertainty with cost, as well as manage operational and maintenance constraints. A facility can be engineered with an adaptable protection level which reduces the hazard risk to acceptable levels for part of its useful life and that can be re-evaluated as risk levels change.

An illustrative example of using flexible adaptation

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[8] NIST, Community Resilience Planning Guide for Buildings and Infrastructure Systems, Vol. 1 .NIST Special Publication 1190: US Department of Commerce, 2016.

[9] PlaNYC, A Stronger More Resilient New York, report of the NYC Special Initiative for Rebuilding and Resiliency. Report. June 11, 2013, page 28. From that report: "Like all projections, the NPCC projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities, and the potential for error should be acknowledged."

[10] To learn more, see Chapter 2 in the NPCC 2010 report, Climate Change Adaptation in New York City, available at http://onlinelibrary.wiley.com/doi/10.1111/nyas.2010.1196.issue-1/issuetoc

pathway on a facilities’ component is explained in Figure 1. It shows an emergency generator with an approximate useful life of 25 years located outside a building. In order to incorporate the Guidelines into design, it is recommended that the foundation of the generator structure is designed to match the useful life of the building, which can vary between 50-70 years, that the generator serves. Assuming the generator is subject to flooding risk from sea level rise and coastal surge, it should be built on an elevated concrete slab that matches the future year design flood elevation (DFE) scenario corresponding to the end of the generator’s useful life. The generator must be replaced when it reaches the end of its useful life, which is typically far less than that of the building. When the replacement generator is installed, the concrete slab is further elevated to accommodate the future DFE. The foundation of the generator and the columns are designed to support the additional future load from the concrete slab. Thereby, the initial investment into the foundation can be used to adapt in the future, allowing for future flexibility and avoided costs.

Adaptation pathways may not apply equally to all types of projects or climate change projections. Facility flood defenses, for example, may be more easily developed through an adaptation pathway than heat-vulnerable materials or below grade drainage systems. For this reason, the Guidelines use the middle of the 25th to 75th percentile range projections for sea level rise (see Table 4) and the high-end 90th percentile projections for heat (see Table 1). For precipitation, these Guidelines recommend using the existing 50-year storm data as a proxy for the projected high-end 5-year storm. (see Section III.B and Figure 4 for more details).

Uncertainty can be further addressed through risk management. Some facilities, such as those that are critical or cost more than $50 million for design and construction, will benefit from a full climate change risk assessment (see examples in Appendix 7). This assessment will evaluate protecting the facility to a potentially higher level of sea level rise than the recommended height in these Guidelines. The City plans to develop a process for integrating climate change data into existing risk management processes by April 2019. If engaging in a climate change risk assessment process, please contact ORR at ResilientDesign@cityhall.nyc.gov.

E. PROJECT-SPECIFIC CONSIDERATIONS

Existing information and requirements specific to different kinds of projects must be reviewed on a case-by-case basis when evaluating resiliency design strategies. Refer to Appendix 5 for an example approach of how to make resiliency planning and design decisions, and discuss these considerations as a project team to determine which apply and how to respond:

- **Financing requirements**: if the project is federally-funded or receives recovery funding, discuss with the funding agency if certain protection standards or cost-benefit analyses are required. For example, FEMA requires specific flood protection standards for critical facilities and non-critical facilities.
- **Interdependencies**: consider how hazards impact interdependencies across sectors, as well as the risks from coincident events (e.g. extreme precipitation occurring during an extreme surge event) to specific projects.
- **Existing hazard mitigation projects and risk studies**: evaluate if nearby or associated projects have already been assessed for climate change risks. Identify if

any studies have been conducted that could inform design (e.g. local flood modeling with sea level rise). This may inform the climate change risk assessment or provide insights into site specific conditions and design options. A map that catalogs NYC resiliency projects is located here: https://maps.nyc.gov/resiliency/.

- **Agency-specific resiliency design standards**: refer also to resiliency guidelines provided by various City agencies (e.g., *Park’s Design and Planning for Flood Resiliency*[11]). Agency guidelines build on the climate data provided in these Guidelines by providing specific design alternative and insights relevant to those agencies.
- **Limitations**: the Guidelines do not describe or encompass all City resiliency policies. To learn more about how the City plans for a resilient future, see the latest OneNYC plan as well as the 2013 report *A Stronger, More Resilient New York*. Related resiliency issues are being addressed by the City but are out of the scope of these Guidelines, including neighborhood and regional-level climate change risk management and zoning.
- **Further questions?** Contact ORR at ResilientDesign@cityhall.nyc.gov.

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[11] Available at https://www.nycgovparks.org/planning-and-building/planning/resiliency-plans/flood-resiliency

II. INTERPRETING CLIMATE CHANGE DATA FOR RESILIENT DESIGN ADJUSTMENTS

All City of New York capital projects should be designed to withstand increasing heat and precipitation based on the useful life of the asset, while design interventions for storm surge and sea level rise depend on the project’s proximity to the floodplain, useful life and criticality.

In order to support design team efforts to generate resilient design responses (i.e., adjustments to base projects), these Guidelines provide climate change projections and recommend design adjustments or interventions in response to increasing heat, increasing precipitation and sea level rise. The Guidelines recommend designing to loads beyond the minimum requirements in the prevalent NYC local codes. Design teams should consider project benefits and additional costs to incorporating resilient design standards before finalizing project design.

A. INCREASING HEAT

Use this section to determine how to adjust a facility’s design to account for increasing temperatures and to reduce the facility’s contribution to the Urban Heat Island effect. Heat reduction levels will be determined by the function, location and useful life of the asset.

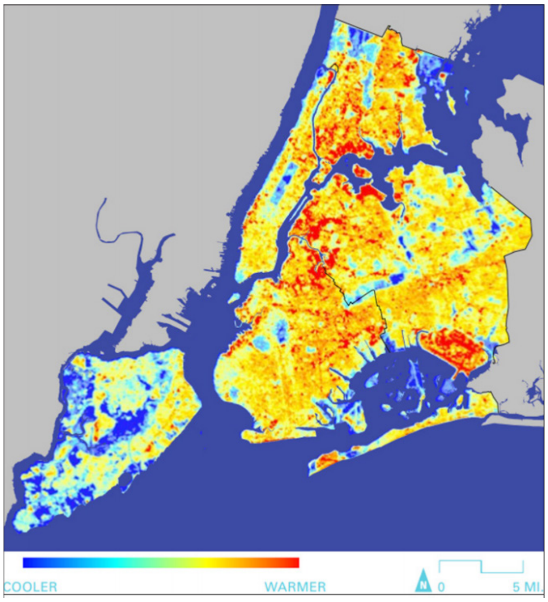

Figure 2 - Thermal imagery of New York City, based on LANDSAT Thermal Data from 8/18/2009[14]

Background

The impacts of heat on NYC are well established. Every summer, over 100 New Yorkers die from causes exacerbated by extreme heat.[12] The region has seen a steady increase in the number of days above 90°F, and temperatures are projected to keep rising, worsening heat-related mortality. By the 2050s, the number of days at or above 90°F is expected to double, and the frequency and length of heat waves will triple to an average 6 heat waves per year.[13] Certain areas of NYC already experience higher temperatures relative to other parts of the city, and these hot spots will be exacerbated by climate change (see Figure 2).

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[12] *OneNYC: The Plan for a Strong and Just City*. (The City of New York, 2015) 228. See also: Madrigano J, Ito K, Johnson S, Kinney PL, Matte T. 2015. A case-only study of vulnerability to heat wave–related mortality in New York City (2000–2011). Environmental Health Perspectives 123:672–678; http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf

[13] Horton et al. New York City Panel on Climate Change 2015 Report Chapter 1: Climate Observations and Projections. Ann. N.Y. Acad. Sci. ISSN 0077-8923: New York, 2015.

[14] LANDSAT Thermal Data from 8/18/2009

Heat can be lethal for all, but its impact on New Yorkers is not equal.

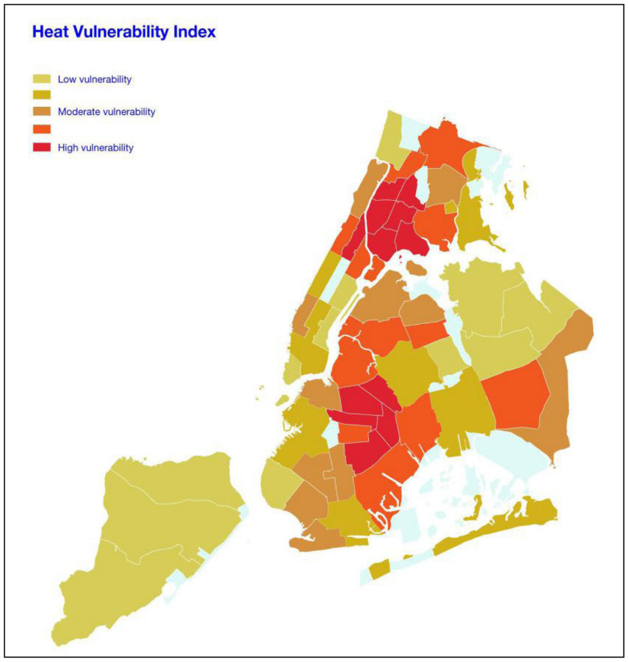

Figure 3 - Heat Vulnerability Index (HVI) for New York City Community Districts (Source: NYC DOHMH 2015). This analysis identifies physical, social and economic factors associated with increased risk of heat-related morbidity and mortality.[17]

In *Cool Neighborhoods NYC*, the City prioritizes strategies to study the Urban Heat Island effect and make targeted investments that benefit communities most vulnerable to heat.[15] New Yorkers are more or less vulnerable to heat based largely upon socio-economic factors, including age, income, location, tree coverage and the percentage of dark surfaces. The NYC Department of Health and Mental Hygiene (DOHMH) developed a Heat Vulnerability Index (HVI) which highlights parts of the city where more residents face an increased risk of heat-related mortality. Their vulnerability is due to their exposure and socio-economic conditions that determine their sensitivity to heat. Community districts in red and orange in Figure 3 are areas of highest vulnerability, and these are particularly concentrated in east Brooklyn, the south Bronx, northern Manhattan and southeast Queens.[16] While all new capital projects should address heat impacts, those sited in moderate to high vulnerable HVI areas should implement multiple strategies to reduce the Urban Heat Island and help address the high vulnerability in these neighborhoods.

The Guidelines recommend that project designers consider two aspects of the relationship between their project and increasing heat: the way their project reduces the Urban Heat Island effect and the impact that increasing heat will have on the physical components of their project itself:

- **Reduce Urban Heat Island effect**: materials in the built environment absorb the sun’s heat throughout the day and re-radiate it back into the atmosphere, driving localized temperatures higher and increasing demands on cooling systems. Air conditioning and ventilation equipment also push extra heat into the air, contributing to a feedback loop that increases localized ambient temperatures and impacts the health of heat-vulnerable New Yorkers. This section provides guidance on how new capital construction can reduce the contribution to ambient heat in the city.
- **Minimize impact from increasing heat**: increasing heat can physically impact components of buildings and infrastructure, damaging or stressing materials, electrical systems and mechanical systems. Rising temperatures will also stress energy and communications networks that buildings and other infrastructure rely upon.[18] This section provides climate data to be used to adjust and adapt heat-vulnerable components of assets.

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[15] OneNYC, 228.

[16] To learn more about Heat Vulnerability Index, see page 229 of OneNYC at http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf

[17] See page 229 in the OneNYC plan to learn more about HVI

[18] Damiano, H. et al. *NYC’s Risk Landscape: A Guide to Hazard Mitigation.* (NYC Emergency Management, 2014), 103.

1. Urban Heat Island reduction

New capital construction should minimize its contribution to the Urban Heat Island effect. The design interventions provided below offer benefits to the community and the facility through reduced heat loading, reduced energy costs and/or improved occupant health and thermal comfort. The appropriate combination of design interventions will vary dependent on the project scope.

a) **Increase the solar reflectance of surfaces by utilizing light-colored pavement, coatings and materials, in combination with shading, with a minimum target of 50% of the non-structure areas of facility sites.[19]**
Lighter, reflective surfaces help reduce the Urban Heat Island effect, heat loading and internal building temperatures, and extend the lifespan of rooftops and heating, ventilation and air conditioning (HVAC) equipment. The City has taken steps towards reducing ambient temperatures, such as implementing the NYC Cool Roofs program.[20] New buildings, as well as existing buildings with roofs going through significant repairs, are required by law to paint their roofs white. This program intervention reduces a building's contribution to Urban Heat Island effect and provides energy savings by coating the normally dark, concrete roof surface with white paint, allowing the roof to reflect solar radiation.

b) **Increase the shading of surfaces by planting trees or other vegetation, in combination with cool pavements, with a minimum target of 50% of the non-structure areas of facility sites.**
Shady areas with heat- and, in coastal areas, salt-tolerant vegetative species can help keep buildings cool and provide energy savings, as well as lower temperatures.

c) **Meet Climate Zone 6 standards for fenestration and insulation (See Section ECC C402 in Chapter C4 of the 2016 NYC Energy Code) to improve efficiency of building envelopes.**
NYC is currently in Climate Zone 4. NYC already requires that small residential building envelopes are designed to meet higher insulation and fenestration requirements to improve energy efficiency.[21] All City capital projects, including non-residential facilities, should meet this standard.

d) **Select green/blue roofs and/or other appropriate landscape elements that maximize cooling with help of landscape architects.**
The City already encourages the use of green and blue roofs on buildings to reduce the Urban Heat Island effect,[22] provide stormwater management and increase the useful life of the roof. Besides replacing dark roof surfaces, green roofs and vegetation also provide shade and keep the air cool through evapotranspiration by releasing moisture into the atmosphere. Blue roofs, coupled with light colored roofing material, can provide stormwater management and rooftop cooling.
Some of these designs support the shading and solar reflectance goal in Step a) above. Additionally, City capital projects are subject to Leadership in Energy and Environmental Design (LEED) certification, and green roofs can earn LEED credits.[23]
Projects should integrate cooling strategies listed below based on project scope and a balance between costs and benefits:

- Green roofs or blue roofs on a broader range of facilities (including industrial buildings, storage, garages, administration buildings, etc.).

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[19] Urban Green Council (2010). *Green Codes Task Force*. Proposed code "EF 12: Reduce Summer Heat with Cool, Shady Building Lots".

[20] Local Law No. 21 (2011) amended Chapter 12 of the NYC Building Code to update roof coating standards. Also, see Cool and Green Roofing Manual (DDC) 2007 for more information on NYC standards for cool and green roofs: http://www.nyc.gov/html/ddc/downloads/pdf/cool_green_roof_man.pdf

[21] Read more about the code here https://www1.nyc.gov/site/buildings/codes/2016-energy-conservation-code.page

[22] See *Cool and Green Roofing Manual* (DDC) 2007 for more information on NYC standards for cool and green roofs: http://www.nyc.gov html/ddc/downloads/pdf/cool_green_roof_man.pdf

[23] See Local Law No. 32 (2016) for more information.

- Vegetated structures such as shade trees and planters (to reduce heat loading on horizontal or vertical surfaces).
- Bioswales, rain gardens and bioretention.[24]
- Maximize planted permeable surfaces.
- Other permeable surfaces (used for stormwater management, these retain moisture that evaporates as surface temperatures rise).[25]
- Open-grid pavement system (at least 50% unbound).[26]
- Evaluate site planning and building massing with regard to solar gain.
- Solar panels for shading and to generate energy.

2. Minimize impact from increasing heat

This section provides information to support making design adjustments to capital projects to reduce impacts to equipment, structures, landscapes and materials from rising average temperatures and increasing extreme heat events.

a) **Review forward-looking climate data provided in Table 1 and Table 2.** Select heat projections according to the useful life of the facility and its primary components, then evaluate and address impacts in the steps below. Table 1 provides design criteria for average temperatures and incidents of extreme heat events projected to different time periods across the 21st century. Table 2 provides guidance on future 1% Dry Bulb Temperature and Cooling Degree Days for the NYC area. The 1% Dry Bulb Temperature represents the ambient air temperature.

Table 1 – Baseline and projected extreme heat events[27]

End of useful life	**# heat waves per year** *(3 or more consecutive days with max temperatures at or above 90°F)*	# days above 90°F	Annual average temperature
Baseline (1971-2000)	2	18	54°F
Through to 2039	4	33	57.2°F
2040-2069	7	57	60.6°F
2070-2099	9	87	64.3°F

Table 2 – Projections for 1% Dry Bulb temperature and Cooling Degree Days

		Change in projected value for 2050s		
Variable	Baseline for Central Park (1971-2000)	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
1% Dry Bulb temperature	91°F	+3°F	+4-6°F	+7°F
Cooling Degree Days *(base = 65°F)*	1,149	+37%	+46-73%	+87%

Note: Due to HVAC system typical useful life of 25 years or less, only projections for the 2050s are shown. Projections for the 2020s are not shown because it is anticipated that enough of a safety margin is employed already in current systems to withstand the temperature rise expected through the 2020s. The NPCC is currently working on projections of 1% Wet Bulb temperatures, which are expected to increase and may require systems to have higher moisture reducing capacity in addition to the enhanced cooling capacity.

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[24] When siting bioswales, consider groundwater levels and soil permeability and ensure that the site is not contaminated from past or present land uses. A high water table may prohibit some applications.

[25] Urban Green Council (2010). *Green Codes Task Force.* Proposed code "SW 1: REDUCE EXCESSIVE PAVING OF SITES"

[26] LEED Neighborhood Development v4 "Heat island reduction" credit.

[27] Projected estimates for average temperatures are based upon 90th percentile change factor added to the baseline average annual temperature from New York City Panel on Climate Change (2015).

b) **Evaluate potential impacts on systems and materials.**
Heat impacts on a facility are highly contingent on the facility type and should be reviewed on a case-by-case basis.[28] A decrease in the useful life or operational capacity of a facility, or components of a facility, may occur due to rising temperatures. Interventions will also vary depending on whether the project is a new capital investment or a substantial improvement to an existing facility. Factors to evaluate, as applicable to project scope, include but are not limited to:

- Thermal expansion, warping, softening, or other forms of material change or degradation of structural integrity occurring at an accelerated rate by excessive heat;
- Health and safety impacts on occupants vulnerable to heat;
- Increased failure or reduced efficiency of electrical or mechanical systems;
- Prioritization of critical loads for systems and components at the facility; and
- Moisture control needs for buildings with a higher standard for fenestration and insulation.

The results of this evaluation will inform steps taken in the step below.

c) **Reduce heat impacts.**
Review and implement specific changes to the facility design based on assessments above. Develop a strategy based on the specific type of facility, its operational profile and its useful life. A Design Strategies Checklist is available for use in Appendix 6 as a resource to track design approaches. Specific areas of focus are:

- **Electricity outages:** High temperatures drive demand for air conditioning and can increase the risk of facility equipment failure, potentially broader grid disruptions, or brownouts.[29,30] To manage this risk, design City buildings and infrastructure to withstand periods without electricity using the following approaches, in particular if they provide critical or essential services:
    - Identify and assess how much of the facility's load is critical (e.g., "critical load"), including the necessary duration of the backup power supply (e.g., is backup power needed for 8 hours or multiple days?). Determining what loads are critical and how long they should be powered for is essential for a facility's operations and what the role of the facility will have in an emergency situation.[31]
    - Depending on the size of the critical load and budget, different backup power supply options could range from backup generators (e.g. diesel, natural gas) to hybrid systems (e.g., solar + battery storage + appropriately sized generator). Each option has different trade-offs that should be considered in terms of cost, feasibility and environmental impacts. For shorter duration needs and/or smaller critical loads, buildings with existing solar systems should consider adding storage to provide a resiliency benefit. In some cases, co-generation systems may make sense from an economic and resiliency perspective, especially if there

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[28] Sector- and facility-specific impacts vary greatly. For examples of sector-specific impacts and design responses, see *Flooded Bus Barns and Buckled Rails* (FTA 2011) and *Ready to Respond: Strategies for Multifamily Building Resilience* (Enterprise Green Communities 2015).

[29] McGregor et al. (2013) *Two Degrees: The Built Environment and Our Changing Climate.* Routledge Press.

[30] High temperatures also increase energy demand, which can increase fossil fuel based greenhouse gas emissions.

[31] The key roles of the facility that need to be identified are operational hours, number of occupants and electrical loads needed for the desired operations. Electrical equipment and appliances for the desired operations may include - but are not limited to - safety lighting, life-supporting systems, fire protection systems, telecommunications equipment, mechanical systems to mitigate extreme temperatures and computing equipment. Every facility is unique. Operational characteristics and load profiles need to be established prior to sizing the equipment required to keep the facility in operational mode.

    is a significant heating and/or cooling load in addition to electricity demand.[32]
  - Depending on the option, assess need to invest in internal electricity rewiring and building energy management systems (e.g., switches, reconfiguration of distribution infrastructure to isolate critical loads from non-critical loads and the ability to island from the broader grid during the event of a larger disruption, software and hardware to manage the deployment of hybrid systems) and/or need for external hookups for temporary generators and boilers.[33]

- **Failure in facility ventilation, electrical and air conditioning systems**: Some systems designed to meet the requirements of past climate may overheat and fail during extreme events. Some design interventions include:[34]
  - Selecting systems with higher heat tolerance.
  - Adding Energy Recovery Ventilation systems.
  - Providing additional or redundant ventilation systems, either mechanical or natural, to cool electrical equipment.
  - Optimizing building layout by:
    - segregating temperature sensitive electronics and computer control system from other systems;
    - placing heat generating equipment like transformers and switchgear outdoors, where permitted; and
    - splitting the facility cooling loads among different HVAC systems in facility for redundancy and better zone control.

- **Passive solar cooling and ventilation**: There are numerous design features that provide passive solar cooling for buildings to help maintain lower internal ambient temperatures with less air conditioning. These features also help keep facilities habitable during extended grid failures when generators fail or must be reserved for critical functions. Some design features include:[35]
  - Appropriate east-west orientation.
  - Passive ventilation design.
  - Vertically stacked double skin facades.
  - Exterior window shades.
  - Light colored exteriors.
  - Shaded arcades.
  - Thermally massive materials.
  - High performance glazing.
  - Operable windows.

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[32] To learn more, see the *Building Resiliency Task Force* report from Urban Green Council (2013).

[33] Ibid.

[34] *Flooded Bus Barns and Buckled Rails.* FTA Office of Budget and Policy, 2011.

[35] These and other examples are found in McGregor et al. (2013) *Two Degrees: The Built Environment and Our Changing Climate.* Routledge Press. Also see, *Flooded Bus Barns and Buckled Rails.* FTA Office of Budget and Policy, 2011.

B. INCREASING PRECIPITATION

The intensity and frequency of precipitation events are projected to increase with climate change, creating new challenges for stormwater management and impacts to the built environment, such as:

- The potential for greater frequency of stormwater management systems being overwhelmed;[36]
- More frequent and severe flooding of buildings and infrastructure in areas across the city; and
- Greater variability in rainfall events annually, including the chance of drought.

The goal for this section is to guide stormwater management approaches including infiltration, increases in on-site storage volume and, where possible, increases in sewer capacity to account for precipitation increases associated with climate change. Designers should develop and consider design interventions that would decrease site contribution to sewer in-flows beyond the existing NYC Building Code requirements. Given its complexity, the Department of Environmental Protection (DEP) is also evaluating climate impacts to the sewer system on a drainage-wide level. Proactive design, such as increasing on-site infiltration and storm water retention can contribute to system resiliency on a site-specific basis.

Background

NYC's drainage systems are designed to handle approximately the current 3-year intensity-duration-frequency (IDF) event in most areas of the city where sewers were built prior to 1970. In locations with sewers built after 1970, the capacity was built to handle the 5-year event. NYC's network of drainage systems can experience flooding above those thresholds due to widespread precipitation events or by localized, intense storms (sometimes called "cloudbursts"), causing flooding and backups. Climate change projections indicate that flooding, resulting from multiple types of precipitation events, may increase in frequency. This increasing probability is forecast for all types of precipitation events in NYC, although there is greater uncertainty around future short duration events.

Relying on sewers alone to manage extreme precipitation events will not be sufficient in a changing climate. The City plans to reduce impervious areas and provide additional storage capacity to reduce flood damage. For managing stormwater from larger storms such as at the 50- and 100-year recurrence intervals, DEP is increasingly considering the role of streets and open space in managing flow; this is referred to as a dual drainage design approach. The City is piloting projects to test this dual drainage approach.

Another set of interventions include Bluebelt best management practices (BMPs), such as constructed wetlands, storm water ponds and stream restorations that emulate pre-development conditions to manage large volumes of water, and green infrastructure,[37] which in NYC have generally been designed to reduce flooding and combined sewer overflow, respectively. They are not typically sized to manage precipitation events of the same magnitude as sewers, which serve as primary drainage conveyance. However, Bluebelt BMPs, green infrastructure and other stormwater management tools may provide an additional buffer for larger storm events by temporarily storing and/or infiltrating runoff that would otherwise be directed into the sewer system. For instance, areas of open space commonly found in NYC may not provide adequate environments for trees and other plantings. However, in these cases other types of green infrastructure, like permeable surfaces and subsurface detention and retention installations, would still be considered feasible.

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[36] NYC is already taking steps to address this problem, which will worsen with climate change. To learn more about how NYC is using green and gray infrastructure to manage stormwater, visit http://www.nyc.gov/html/dep/html/stormwater/index.shtml.

[37] NYC DEP. NYC Green Infrastructure Program.

The City, led by DEP, continues to develop its options for managing heavier storm events due to climate change. DEP is examining approaches to evaluate sea level rise and rainfall intensity for stormwater management and, where possible, sewer capacity. These efforts will integrate forward-looking climate data into the design of these capital assets, and the compounding factors of heavier rain storms and sea level rise will likely require greater infiltration and on-site storm water retention capacity. Agencies and consultants should work directly with DEP to develop strategies on a given site necessary to meet expected increases in rainfall intensities and frequencies.

1. Precipitation design adjustment for on-site stormwater systems

Based upon the design storm required for the City facility in design, follow the steps below and review recommended design interventions.

a) **Identify the duration of the design event required.**
The current 50-year IDF can be used as a proxy for the future 5-year storm (projected for the 2080s). Design on-site detention/retention systems to retain the volume associated with the current 50-year IDF curve (see Figure 4 below). Design the on-site system to release at the maximum rate as specified in 15 Rules of the City of NY (RCNY) Chapter 31.[38]

b) **Conduct sensitivity analysis.**
Compare the retention/detention required for the current 5-year IDF versus the

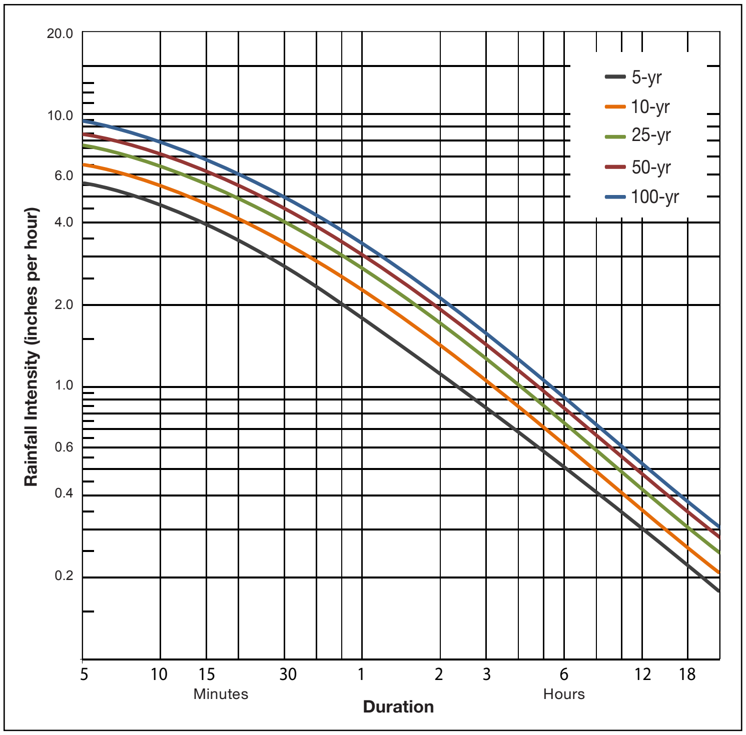

Figure 4 - Current Intensity-Duration-Frequency Precipitation Curve for NYC, adapted from U.S. Department of Commerce Weather Bureau Technical Paper 25.

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[38] Refer to existing codes and standards as well when determining the existing required storm, as NYC requires different sizes of design storms for infrastructure and buildings. For example, NYC Plumbing Code Chapter 11, and Title 15 of the Rules of the City of New York Chapter 31.

current 50 year IDF to determine the cost and benefits associated with complying with these Guidelines. Use the Evaluation of Project Benefits section below and Appendix 4 for guidance on how to identify and assess benefits. Given the results of the cost/benefit analyses, review the added benefit of designing retention/detention using greater magnitude storms (e.g. 100-year) or lower (e.g. 25-year). The goal is to maximize retention/detention capacity given site and cost constraints as well as through an evaluation of the benefit of adding capacity to detain/retain water for larger storm events.

c) **Identify design interventions for managing increased precipitation.[40]**
There are different ways to manage stormwater better and avoid urban flooding after intense rain. Choose the right combination of interventions after considering the site location, operational requirements, cost, benefits and useful life of the intervention. Some examples of design interventions are:

- Minimize increases in impervious surface;
- Utilize strategies that infiltrate, evaporate or reuse rainwater to achieve storm water volume reductions. Then choose strategies that detain (delay drainage) to manage the rate of the storm water flow into the City's drainage system;
- Install stormwater infiltration, detention and storage (e.g. bioswales,[41] green roofs, blue roofs, and other blue or green infrastructure; storage basins or tanks);
- Protect areas below grade from flooding;
- Keep catch basin grates clear;
- When implementing perimeter protections, ensure that interior water management is also accounted for; and
- Explore interventions to protect underground utility and telecommunications infrastructure from water damage.

d) **Use appropriate DEP guidelines to perform the above tasks using the higher design storm.**
The three currently prescribed DEP guidelines are as follows:

- Guidelines for the Design and Construction of Stormwater Management Systems, July 2012.[42]
- Criteria for Detention Facility Design, November 2012.[43]
- DEP Site Connection Proposal Application and Guidelines.[44]

***Note on stormwater standards**: As DEP updates stormwater standards and develops specific tools to evaluate impacts of increased precipitation and drainage strategies for on-site storm water management, these changes will be reflected in future versions of these Guidelines. However, it is recommended that the designer should develop and consider design interventions that would increase the on-site storage beyond the existing requirements. Also, a methodology is under development that will establish a consistent, citywide process for addressing legal grade, which will have further implications for how extreme precipitation is managed.*

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[39] NYC DEP Standards for Stormwater Release Rates, available at http://www.nyc.gov/html/dep/html/environmental_reviews/stormwater_release_rates.shtml

[40] Also see: DEP Guide to Rain Event Preparedness at: http://www.nyc.gov/html/dep/pdf/brochures/flood-preparedness-flyer.pdf and Ready to Respond: Strategies for Multifamily Building Resilience at: http://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356

[41] When siting bioswales, consider groundwater levels and soil permeability and ensure that the site is not contaminated from past or present land uses. A high water table may prohibit some applications.

[42] Available at http://www.nyc.gov/html/dep/html/stormwater/stormwater_management_construction.shtml

[43] Available at http://www.nyc.gov/html/dep/pdf/water_sewer/30_criteria_for_detention_facility_design_06062012.pdf

[44] Available at http://www.nyc.gov/html/dep/pdf/water_sewer/24.pdf

2. Incorporating climate change projections into DEP drainage planning

The first line of defense for managing intense precipitation events does not require changes to the sewer system, as described above. For drainage and wastewater infrastructure planning in a changing climate, the sewer network and wastewater infrastructure should be qualitatively evaluated, from the upstream pipes to the regulator chambers, pump stations, interceptors and ultimately to the downstream outfall, to determine the feasibility of incorporating climate change projections into the system design. For DEP storm sewer projects FY 2021 or later in separately sewered drainage areas where the design is in the early stages and there is free discharge, the agency will evaluate the feasibility of revising the design to incorporate climate projections into the design. If the project (including the prescribed changes) passes the cost/benefit analysis, then DEP will consider incorporating climate change projections into the sizing. However, changes in one part of the system must be carefully evaluated. For example, any upsizing of the regulator chamber or the high point of the system can negatively impact the design and operation of the wastewater infrastructure and residences/businesses on the system and can lead to a diminished the level of service.

DEP is in the process of developing a hydrologic and hydraulic (H&H) model to estimate runoff flow for future climate scenarios, and is evaluating rainfall hyetographs for the existing and future rainfall scenarios to be included in the drainage planning process. In addition, DEP currently coordinates with ORR for drainage planning as a part of coastal resiliency projects. A more detailed methodology to incorporate climate change projections into drainage planning will be developed for version 3.0 of the Climate Resiliency Design Guidelines to be released in April 2019.

C. SEA LEVEL RISE

This section provides tools to 1) determine if the project will be subject to tidal inundation during its useful life due to sea level rise and 2) incorporate sea level rise into flood protection levels of capital projects. For projects in the current and future 1% annual chance floodplains, sea level rise-adjusted design flood elevations (DFE) are provided and reflect the criticality of the asset and its useful life.

Background

NYC has experienced the devastation of coastal storms, most recently during Hurricane Sandy. Sea level rise is projected to increase the depth, extent and frequency of flooding from storm surge.[45] Sea level rise will also regularly inundate some low-lying areas during high tides. Current flood protection heights are determined by using the base flood elevation established by the FEMA Preliminary Flood Insurance Rate Map (PFIRM) 2015[46] and the standard of protection for buildings in the floodplain in Appendix G of the NYC Building Code.[47] These Guidelines augment existing requirements for two primary purposes: ensuring City facilities built today incorporate sea level rise and critical assets (as defined in Table 4) are protected to a higher level. It is important to note that all projects and design interventions must comply with NYC Building Code.

Critical components essential to the facility's functionality should be protected to the higher standard for criticality, even if the facility itself is non-critical.

Designers should differentiate between critical and non-critical components within a larger facility or campus (e.g. at a maintenance yard differentiate between structures and equipment). Critical components essential to the facility's functionality should be protected to the higher standard for criticality even if the facility itself may be non-critical. Some examples of critical components include: electrical distribution and switching areas, motor-control centers, chemical feed equipment, boilers, communications systems, monitoring and safety equipment, HVAC units, fire alarms and suppression equipment, furnaces, elevators, emergency fuel supplies, emergency generators and hazardous material storage. Component protection should also be evaluated if a facility is expected to be fully operational during a flood event, or if it is expected to quickly resume full operations after an event.

For buildings and infrastructure with a long useful life, it is not always cost effective or operationally feasible to design a facility to be resilient to hazards faced at the end of its useful life. In these cases, the most resilient design will be one that provides extra protection against hazards in the initial decades while also leaving open design alternatives for updating resiliency measures as new data is provided or new risk assessments are completed. This flexible adaptation pathways approach builds in options to protect assets later in life, as demonstrated in an example shown in Figure 1 (in Section I).

Other considerations to keep in mind include:

- These Guidelines apply to all City capital projects except coastal flood protection systems, which are designed to different standards than those provided here for

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[45] New York City Panel on Climate Change Report Chapter 2: Sea Level Rise and Coastal Storms (2015).

[46] However, NYC Building code G102.2.2 requires that designers review both the PFIRM and the effective FIRM and use the more restrictive of the two.

[47] For information on the differences between FEMA FIRM, PFIRM and the City's forward-looking flood maps, see Appendix 3.

buildings and other physical infrastructure. Many of NYC’s coastal flood protection systems are currently being developed to comply with FEMA accreditation for flood levee systems.[48] The City plans to develop further guidance for designing coastal protection projects;

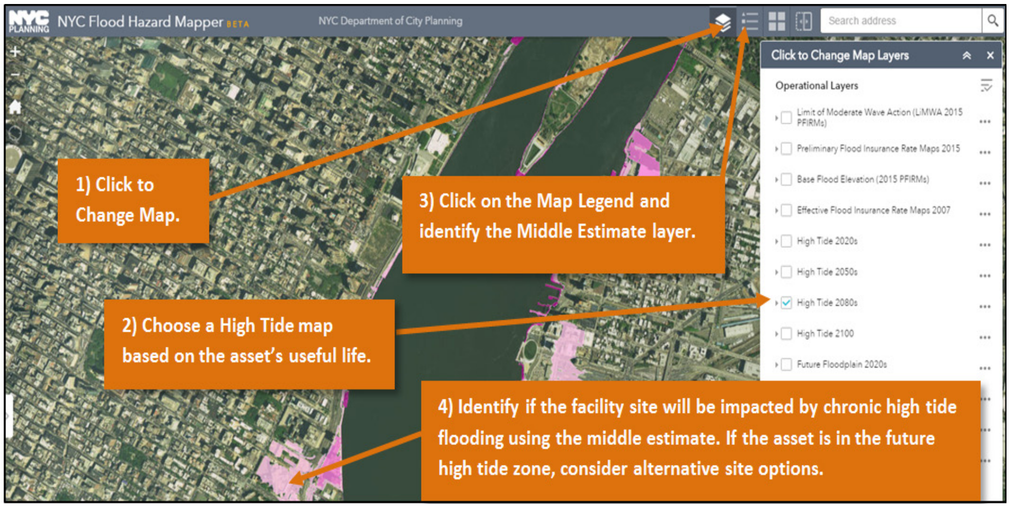
- For information on the differences between FEMA FIRM, PFIRM and the City’s forward-looking flood maps, see Appendix 3;
- Coincident stressors from sea level rise should also be considered. For example, bridge scour may increase as sea levels rise. Similarly, flooding during heavy rainfall events can be worsened due to higher tailwater conditions associated with high sea levels. Be aware of how different risks may interact, and how different interventions can be deployed to address multiple hazards or provide other co-benefits;
- Note projects that require discretionary approval are required to incorporate sea level rise projections as part of the NYC Waterfront Revitalization Program;[49] and
- A methodology is under development that will establish a consistent, citywide process for addressing legal grade, which will have further implications for how sea level rise and precipitation are managed.

For more information see Section I.E. Designers should use the resources and methods described in this section to: 1) assess tidal inundation due to sea level rise and 2) address risks in the current and future floodplains.

1. Assessing tidal inundation due to sea level rise

Tidal flooding currently affects parts of NYC and is projected to worsen as sea levels rise and inundate low-lying coastal sites during high tides. When determining a site location or establishing scope of substantial improvements for other types of coastal facilities, the project team will consider alternative sites outside of zones threatened with regular inundation if resiliency actions are not taken. Some facilities, such as wastewater treatment plants and harbor facilities, need to be near the coast for operational purposes.

a) **Determine tidal inundation risk from sea level rise.**
Use the Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper)[50] to see if your site is in an area inundated from high tide plus sea level rise within the project’s useful life. For example, if the useful life ends between 2040 and 2069, choose the 2050s High Tide map). Determine risk only from high tide and sea level rise, separate from flood events. Follow the instructions in Figure 5 and refer to the example in Figure 6 to review inundation at the end of an asset’s useful life.



1) Click to Change Map.

2) Choose a High Tide map based on the asset’s useful life.

3) Click on the Map Legend and identify the Middle Estimate layer.

4) Identify if the facility site will be impacted by chronic high tide flooding using the middle estimate. If the asset is in the future high tide zone, consider alternative site options.

Figure 5 - Flood Hazard Mapper high tide plus sea level rise at http://www.nyc.gov/floodhazardmapper

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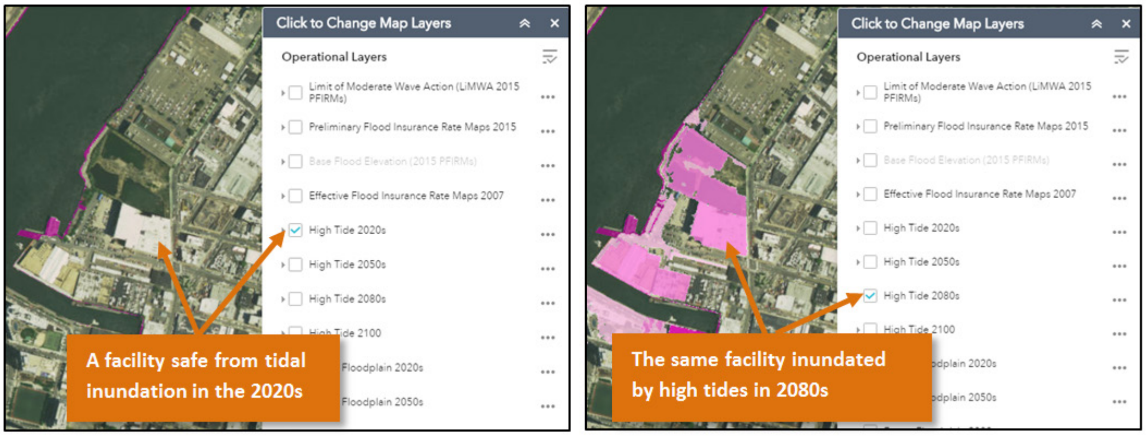
[48] For more information, please visit: http://www.fema.gov/fema-levee-resources-library

[49] For more information, visit http://www.nyc.gov/wrp

[50] The Flood Hazard Mapper relies on publicly available data to present these map resources. Users should also refer to FEMA and the NPCC for official information.



A facility safe from tidal inundation in the 2020s

The same facility inundated by high tides in 2080s

Figure 6 - Flood Hazard Mapper with high tide in the 2020s (left) and in the 2080s (right) at http://www.nyc.gov/floodhazardmapper

b) **Address flood risk.**
If the Flood Hazard Mapper shows that the facility is expected to be inundated by high tides within its useful life or if primary access roads are at risk of inundation, consider alternative site options.

- OR -

If the site is not expected to be regularly inundated by tides, proceed to the next section, 2. Addressing Risks in the Current Floodplain.

Note on calculating tidal inundations with sea level rise: *if a project team is interested in understanding the depth of tidal inundation given climate change projections, follow these steps. First, determine the Mean Higher High Water (MHHW) elevation in feet-NAVD 88[51] datum nearest to the site. If the MHHW data is unavailable from a site specific survey, refer to http://www.nyc.gov/wrp for a list of MHHW elevations (NAVD88) at tide stations across the city.[52] Second, add the high estimate (90th percentile) of expected sea level rise (see Table 8 in Appendix 2) for the year corresponding to the facility’s useful life to the MHHW to determine the projected depth of tidal inundation with sea level rise.*

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[51] North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum of orthometric height established for vertical control surveying in the U.S. based upon the General Adjustment of the North American Datum of 1988. https://www.ngs.noaa.gov/datums/vertical/

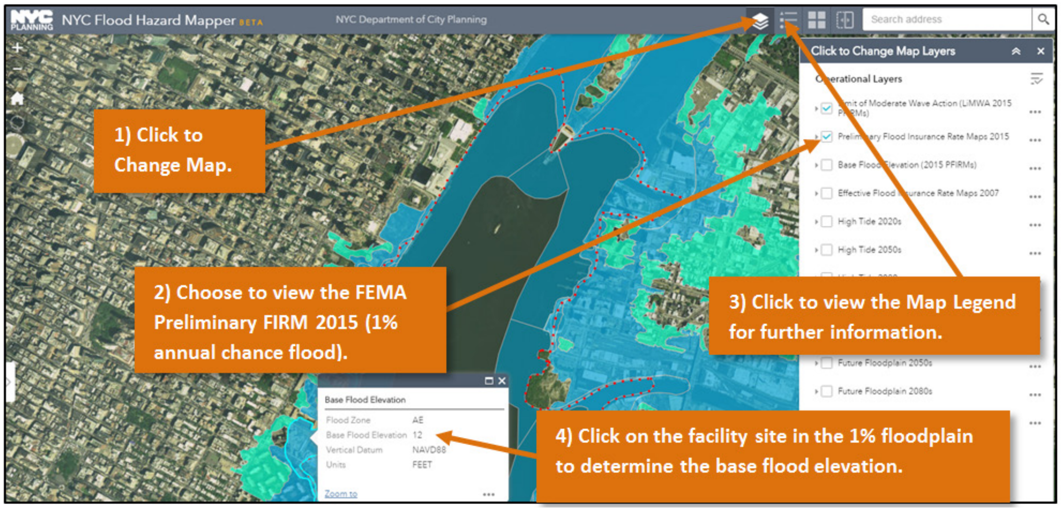
[52] SLR elevations at http://www.nyc.gov/wrp are adjusted to account for sea level rise since the last tidal epoch. If no other resource is available to determine MHHW, use the NOAA Online Vertical Datum Transformation tool to calculate the MHHW in feet-NAVD.

2. *Addressing risks in the current floodplain*[53]

A facility located in the current 1% annual chance floodplain (PFIRM 2015)[54] will face increasing risk of flooding during its useful life due to sea level rise increasing the depth of coastal storms. This section provides a process for adjusting the design flood elevation required by code to account for sea level rise.

a) **Find the location of the facility using the Flood Hazard Mapper** (http://www.nyc.gov/floodhazardmapper)**, and follow the instructions in Figure 7.**

- Choose to view the layer "FEMA Preliminary FIRM 2015."
- Click on the facility site in the 1% floodplain to view the base flood elevation.



1) Click to Change Map.

2) Choose to view the FEMA Preliminary FIRM 2015 (1% annual chance flood).

3) Click to view the Map Legend for further information.

4) Click on the facility site in the 1% floodplain to determine the base flood elevation.

Base Flood Elevation

Flood Zone AE
Base Flood Elevation 12
Vertical Datum NAVD88
Units FEET

Figure 7 - Flood Hazard Mapper with FEMA PFIRM (2015) at www.nyc.gov/floodhazardmapper

b) **If the facility is not in the current 1% annual chance floodplain (PFIRM 2015),** proceed to the next section: "3. Addressing risks in the future floodplain."

- OR -

If the facility is in the current 1% annual chance floodplain (PFIRM 2015), note the base flood elevation (BFE) and proceed to Step c) below. Please note, if a facility has multiple BFEs, or if the site is partially in the 1% annual chance floodplain, it is recommended to use the highest BFE as the current BFE for the entire site.

c) **Establish a sea level rise-adjusted DFE.**
Use the current base flood elevation at your site, the facility's useful life and its criticality level to determine the design flood elevation using Table 4 (on the next page) as a basis of design.

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[53] This process for adjusting the design flood elevation to account for sea level rise satisfies the criteria of the climate-informed science approach described at the state and federal level.

[54] FEMA updates its flood maps periodically. As of April 2018, the most recent maps are the Preliminary Flood Insurance Rate Maps (PFIRM) available at DCP's Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper). Also note that NYC Building Code requires developers to use the PFIRM (2015) or the FIRM (2007), whichever is more restrictive. For more information on these requirements, please refer to Appendix G of the NYC Building Code. Please note that the DCP maps are not official and all site locations should be confirmed with the official FEMA PFIRM. NYC will provide information on the latest flood maps as they are updated.

Table 4 - Determine the sea level rise-adjusted design flood elevation for critical and non-critical facilities[55]

Critical* facilities

End of useful life	Base Flood Elevation (BFE)[56] in NAVD 88	+ Freeboard[57]	+ Sea Level Rise Adjustment[58]	= Design Flood Elevation (DFE) in NAVD 88
Through 2039	FEMA 1% (PFIRM)	24”	6”	= FEMA 1% + 30”
2040-2069	FEMA 1% (PFIRM)	24”	16”	= FEMA 1% + 40”
2070-2099	FEMA 1% (PFIRM)	24”	28”	= FEMA 1% + 52”
2100+	FEMA 1% (PFIRM)	24”	36”	= FEMA 1% + 60”

Non-critical facilities

End of useful life	Base Flood Elevation (BFE) in NAVD 88	+ Freeboard	+ Sea Level Rise Adjustment	= Design Flood Elevation (DFE) in NAVD 88
Through 2039	FEMA 1% (PFIRM)	12”	6”	= FEMA 1% + 18”
2040-2069	FEMA 1% (PFIRM)	12”	16”	= FEMA 1% + 28”
2070-2099	FEMA 1% (PFIRM)	12”	28”	= FEMA 1% + 40”
2100+	FEMA 1% (PFIRM)	12”	36”	= FEMA 1% + 48”

Additional analysis should be conducted to incorporate wave action and wave run-up in DFE calculations especially in areas that are located within the FEMA’s 1% annual chance Limit of Moderate Wave Action (LiMWA) zone. Wave run up is the maximum vertical extent of wave uprush above surge.

***Definition of critical buildings and infrastructure for determining DFE in Table 4**

The criticality definitions below are for use in the application of the Guidelines only. All items identified as critical in NYC Building Code Appendix G are critical in these guidelines; however, this list includes additional facilities that are not listed in Appendix G.[59] If a facility is not listed here, it is considered non-critical for the purposes of determining freeboard.

- Hospitals and health care facilities;
- Fire, rescue, ambulance and police stations and emergency vehicle garages;
- Jails, correctional facilities and detention facilities;
- Facilities used in emergency response, including emergency shelters, emergency preparedness, communication, operation centers, communication towers, electrical substations, back-up generators, fuel or water storage tanks, power generating stations and other public utility facilities;
- Critical aviation facilities such as control towers, air traffic control centers and hangars for aircraft used in emergency response;
- Major food distribution centers (with an annual expected volume of greater than 170,000,000 pounds);[60]
- Buildings and other structures that manufacture, process, handle, store, dispose,\ or use toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released;[61]
- Infrastructure in transportation, telecommunications or power networks including bridges, tunnels (vehicular and rail), traffic signals, (and other right of way elements including street lights and utilities), power transmission facilities, substations, circuit breaker houses, city gate stations, arterial roadways, telecommunications central offices, switching facilities, etc.;
- Ventilation buildings and fan plants;
- Operations centers;
- Pumping stations (sanitary and stormwater);
- Train and transit maintenance yards and shops;
- Wastewater treatment plants;
- Water supply infrastructure;
- Combined-sewer overflow (CSO) retention tanks;
- Fueling stations;
- Waste transfer stations; and
- Facilities where residents have limited mobility or ability, including care facilities and nursing homes.

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[55] If an industry standard does not include freeboard in its flood protection standards for particular infrastructure assets, then only consider the sea level rise adjustment when determining flood protection levels.

[56] Note that NYC Building Code requires developers to use the PFIRM (2015) or the FIRM (2007), whichever is more restrictive. For more information on these requirements please refer to Appendix G of the NYC Building Code.

[57] These freeboard values reflect NYC Building Code Appendix G Table 2-1, which establishes the minimum elevation of the top of lowest floor. Appendix G requires other freeboard values for other parts of structures and in different parts of the floodplain. Refer to Appendix G for the appropriate freeboard and use that value in Table 4 above.

[58] The sea level rise figures provided are for the middle of the 25th-75th percentile range projections from the NPCC. These values do not necessarily indicate the average of all models.

[59] The structural occupancy categories outlined in Appendix G of the NYC Building Code are the same as ASCE 7 used for structural design. For critical buildings, structural design should comply with ASCE 7 and 24 for design class IV.

[60] This threshold represents the median volume of main food distributors in NYC according to statistics collected as part of the Five Borough Food Flow study in 2016, available at: https://www.nycedc.com/system/files/files/resource/2016_food_supply-resiliency_study_results.pdf .

[61] The threshold quantity for hazardous materials is established by Chapter 7 of Title 24 of the NYC Administrative Code.

CASE STUDY: Adjusting the DFE for Sea Level Rise

This case study provides an example of how to calculate a sea level rise-adjusted DFE based on the useful life of a hypothetical critical services building and its primary component.

Step 1. Organize the site by various critical or primary components and their year of construction. Determine their useful life along with the associated future year scenario for flood risk assessment. In this example, the building structure and the outside emergency generator are the most at-risk components from combined sea level rise and coastal storm surge.

Step 2. Overlay the site footprint area over the effective current PFIRM or FIRM and the corresponding future year scenario FEMA 1% to identify flood risk to the site. From overlaying the 2015 preliminary FEMA floodplain over the site, it was determined that the site has a 1% annual chance of flooding, with a base flood elevation of 13’ NAVD.

Step 3. Evaluate the criticality of each primary component of the facility based on the Guidelines’ definition for critical infrastructure. (Table 4). This (hypothetical) building is critical.

Step 4. Use Table 4 to determine the sea level rise adjustment and freeboard requirements for each component and calculate the DFE for each that corresponds to its useful life period.

Step 5. Compare the DFE of each component and the associated Guidelines’ recommended DFE to calculate anticipated flood depth.

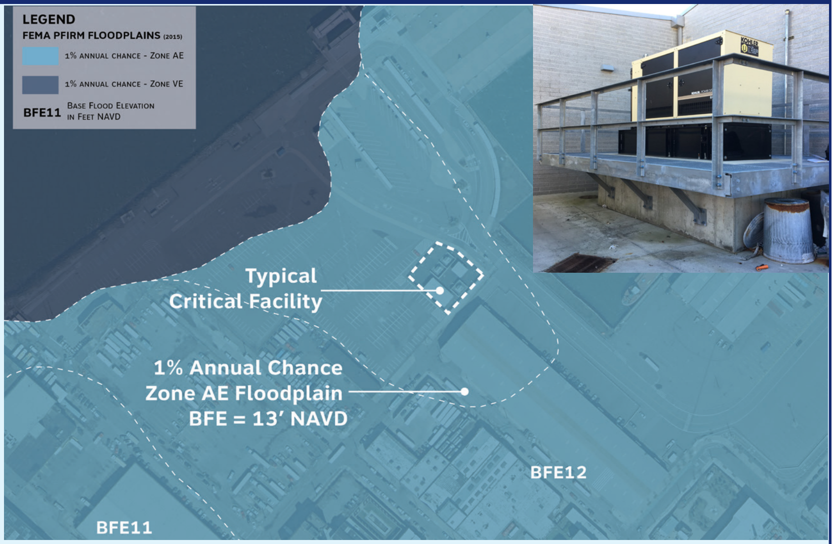


Figure 8 - Example of how to locate a facility within the current floodplain and determine the BFE. Figure 9 (inset) - Outdoor emergency generator at the facility.

Table 5 – Example of how to calculate a sea level rise-adjusted DFE for a critical facility

Construction year	Components	Useful Life	Future Year Scenario [Useful Life + Const. Year]	BFE in NAVD 88 (feet)	Freeboard + Sea Level Rise Adjustment (feet)	Adjusted DFE in NAVD 88 (feet)
2010	Building Structure	70 years	2070-2099	13.0’	2’+2.3’	17.3’
2010	Outdoor Emergency Generator	25 years	Through 2039	13.0’	2’+0.5’	15.5’

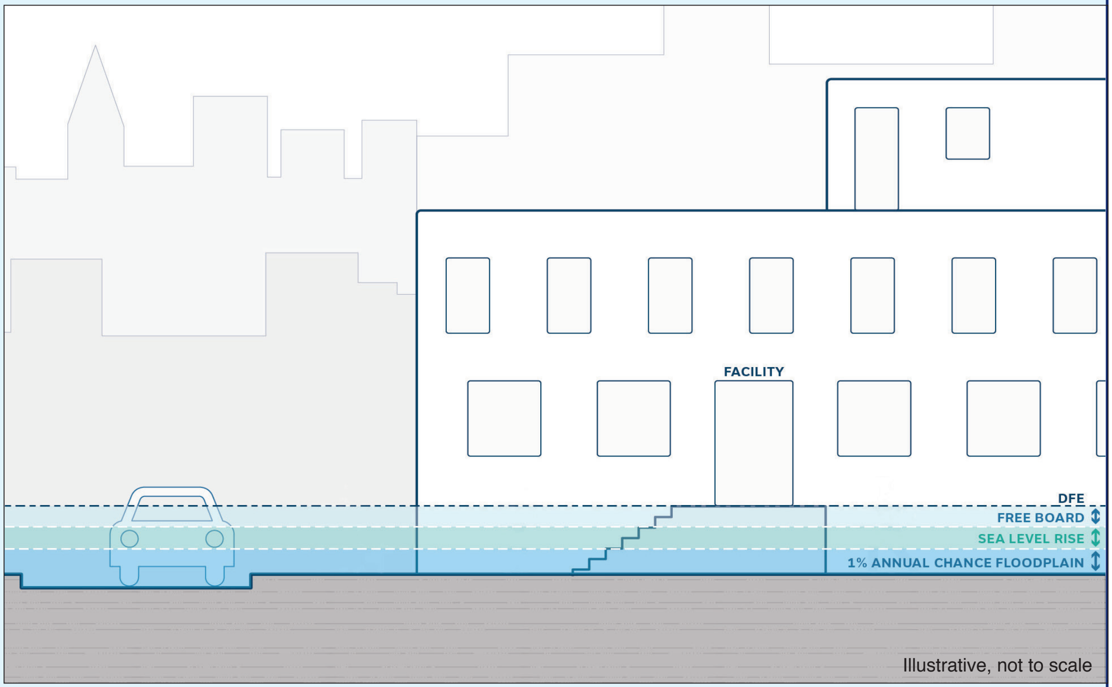
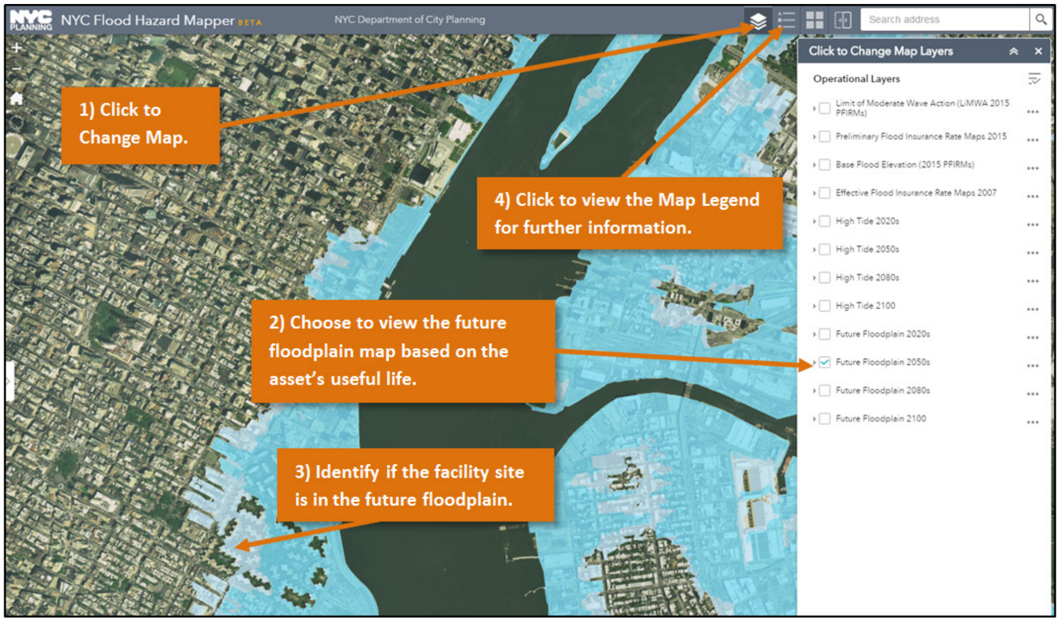


Figure 10 - This schematic shows how to determine the design flood elevation of a facility within the current 1% floodplain.

3. Addressing risks in the future floodplain

If the facility is not in the current 1% annual chance floodplain (PFIRM 2015), it may still be at risk in the future from flooding as sea level rise increases the extent of the floodplain. Follow the steps below to determine if your facility is located in the future floodplain and, if so, what sea level rise-adjusted DFE to use.

a) **Use the Flood Hazard Mapper** (http://www.nyc.gov/floodhazardmapper) **to determine if the facility site will be in the future 1% annual chance floodplain.** Assess if, by the end of the facility’s useful life, the floodplain is projected to increase to encompass all or part of the project site. For example, if the useful life ends between 2040 and 2069, choose the 2050s floodplain map. Refer to the steps in Figure 11 below:



1) Click to Change Map.

2) Choose to view the future floodplain map based on the asset’s useful life.

3) Identify if the facility site is in the future floodplain.

4) Click to view the Map Legend for further information.

Figure 11 - Flood Hazard Mapper with future 1% annual chance floodplain (adjusted for sea level rise) at http://www.nyc.gov/floodhazardmapper

b) **If the site <u>is not</u> in the future floodplain,** no flood protection is required for this facility.

- OR -

If the site <u>is</u> in the future floodplain, identify the nearest adjacent base flood elevation at the project site in the current 1% annual chance floodplain (PFIRM 2015) using the Flood Hazard Mapper.[62]

c) **Use Table 4 to determine the DFE.**
Add freeboard and the sea level rise-adjustment to the nearest adjacent BFE on the current 1% annual chance floodplain (PFIRM 2015) to determine the DFE.

d) **Apply the DFE calculation from Table 4 to the protected facility.**
See Figures 12 and 13 for an illustration of how to calculate the DFE.

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[62] Maps of future floodplains show the impacts of sea level rise alone, and do not consider how changes in storms’ climatology might also affect wave action and the full extent of the floodplain.

CASE STUDY: Identifying a Base Flood Elevation (BFE) in the Future Floodplain

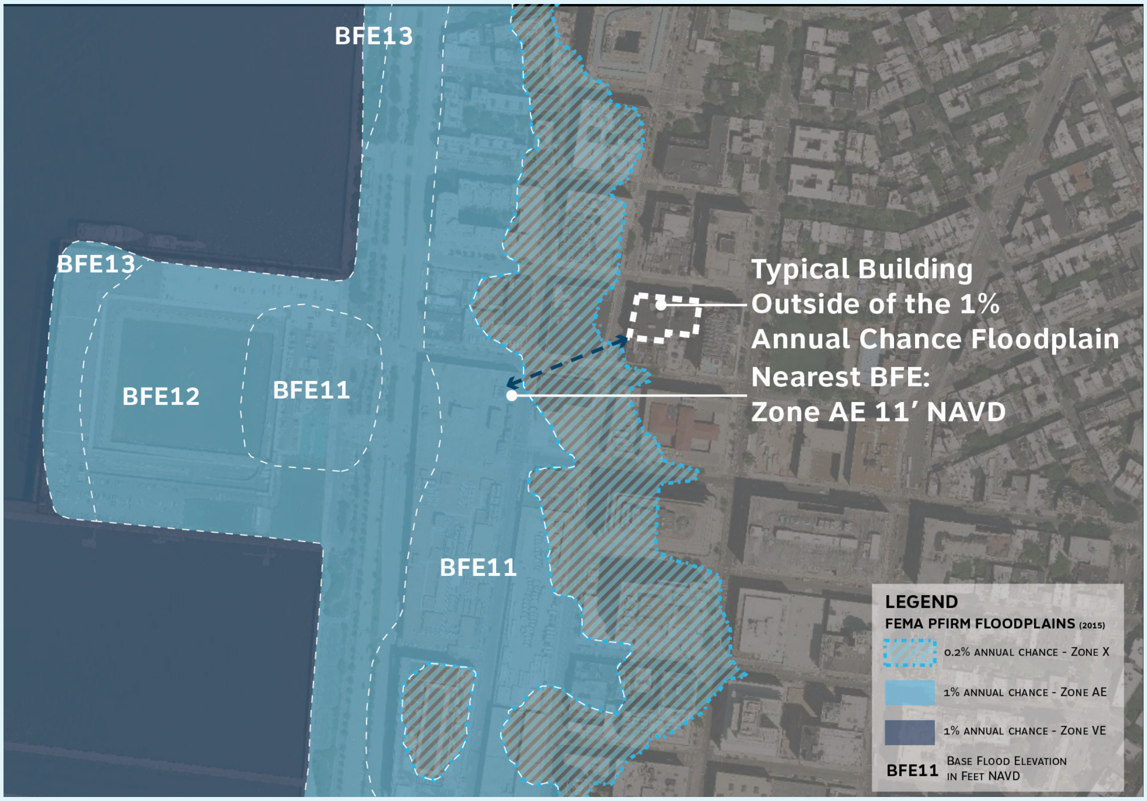

Figure 12 - This schematic map shows how to locate the nearest adjacent 1% floodplain elevation.

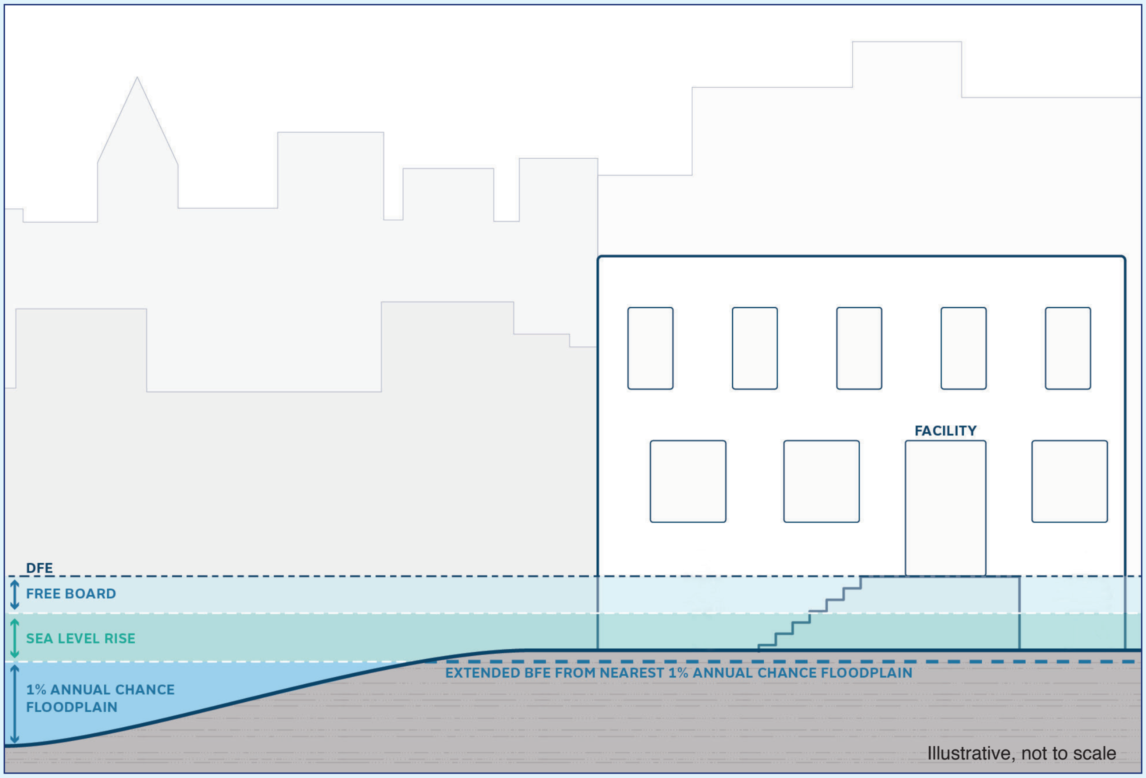

Figure 13 -This schematic shows how to determine the design flood elevation of a facility that is outside of the current 1% floodplain.

4. Identify appropriate design interventions

For all projects at risk of current or future flooding, select protections that meet the project's design flood elevation. Consider project-specific factors including the site location, operational requirements, existing continuity planning and cost.[63] A Design Strategies Checklist in Appendix 6 is available for use as a resource to track possible design approaches. Some examples of design alternatives are:

- Site relocation: where feasible, conduct alternative site analysis.
- Permanent barriers at a site (e.g. floodwalls).
- Deployable flood barriers (e.g. stop logs, flood doors/gates, inflatable barriers).
- Natural systems-based approaches (e.g. living shorelines, restored wetlands).[64]
- Prioritized protection of electrical, mechanical and other critical or costly-to-replace equipment above the design flood elevation (e.g. motors and controller, boilers and furnaces, fuel storage tanks, duct work, alarm systems and suppression equipment, electrical panels, electrical distribution and switching areas, gas and electric meters, telecommunications equipment, chemical feed equipment, HVAC units and emergency generators).[65]
- Dry floodproofing: design a facility to prevent water from entering.
- Wet floodproofing: design a facility to permit floodwaters to flow in and out of the structure without causing significant damage (e.g. elevate or protect critical equipment, use water-resistant building materials below the design flood elevation, include flood vents and pumps).
- Design redundant telecommunications conduit entrances for multiple carrier entry. Telecom conduit should run to diverse manholes when possible.
- Install backup power for telecom equipment with design consideration for such equipment (e.g., installation above DFE).
- Install outdoor-rated disconnect switch for telecommunications equipment on the roof.
- Explore interventions to protect underground utilities and other telecommunications facilities from water damage.
- Install backflow preventers, backwater valves and sump pumps for all buildings and infrastructure in the floodplain, as well as behind flood barriers.
- Shoreline improvements that reduce the height of waves or attenuate waves, where feasible.

Operational requirements and continuity plans can inform the selection of appropriate design interventions, particularly in terms of how quickly a site needs to be up and running after a flood event. Some examples of how functional uses can pair with interventions include:

- A facility that needs to be operating during or immediately after a flood event may need to be dry floodproofed using permanent barriers or designed for passive survivability (such as a police or fire station).
- A facility that needs to recover quickly after an event could elevate prioritized equipment and have deployable barriers.
- A site that can recover over a longer duration of time could be temporarily inundated during an event (such as parks or plazas). The use of resilient materials and strategies can reduce costly damage caused by temporary inundation.

Different design interventions should be chosen based on the specific operational requirements of the project, however these must meet the ASCE 24 design requirements for Coastal VE Zones.

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[63] Additional resources for identifying adaptive strategies: *Urban Waterfront Adaptive Strategies* (NYC Department of City Planning https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf *Floodproofing Non-Residential Buildings* (FEMA) at: https://www.fema.gov/media-library/assets/documents/34270 *Ready to Respond: Strategies for Multifamily Building Resilience* (Enterprise Green Community) at: http://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356

[64] While natural systems-based approaches ameliorate flooding, their use for storm surge or wave mitigation would need to be quantified before contributing towards the design flood elevation.

[65] For more information, see FEMA's *Floodproofing Non-Residential Buildings* at: https://www.fema.gov/media-library/assets/documents/34270

III. EVALUATION OF PROJECT BENEFITS

Designing and constructing facilities to handle the future climate loads above the current NYC codes and standards, based on projected useful life of the components, provides resiliency benefits. The incremental costs to implement the Guidelines’ recommended design interventions should be compared with the incremental benefits to aid agencies in making decisions about resilient design strategies. The project design team should evaluate benefits of the interventions designed to meet Guidelines’ recommended criteria for all the climate stressors qualitatively and/or quantitatively. For projects with construction costs below $50 million, the project design team is recommended to perform a qualitative benefits assessment on the interventions that meet the Guidelines’ recommendations for all applicable climate stressors. For critical facilities or projects with construction costs over $50 million, the project design team is recommended to perform quantitative benefit calculations to identify the optimal interventions that meet Guidelines’ recommended design criteria.

A. GENERAL METHODOLOGY TO ESTIMATE PROJECT BENEFITS

This general methodology to perform qualitative and quantitative benefit calculations is recommended for use by project design teams at the beginning of and during the design process. This methodology enables estimation of project benefits for a high-level benefit-cost analysis (BCA) that can be applied to evaluate and compare resiliency features designed to address sea level rise with coastal storm surge, increased precipitation and extreme heat events. The type of benefits provided by interventions designed to meet the Guidelines’ design criteria can vary by climate stressors and typology of the facilities. The main guiding principle in development of the high-level BCA methodologies included in these Guidelines was to balance simplicity with accuracy. The project benefits categories identified within the methodology may not cover all the potential benefits provided by every facility type within NYC. In particular, the benefits of planning for increased precipitation are difficult to quantify. Hence, the project design team should use their discretion to modify this general benefit calculation methodology as needed to meet their project goals and objectives. The project design team should develop appropriate input data, whether quantitative or qualitative, needed to estimate project benefits.

B. CATEGORIES OF PROJECT BENEFITS

There are three types of project benefit categories - direct benefits, indirect benefits, and other benefits - that can be used to perform qualitative assessments and develop quantitative estimates of monetary benefits for intervention alternatives designed to meet the Guidelines’ recommendations. These project benefit categories will help to perform a high-level benefit-cost analysis that balances accuracy with an appropriate level of effort.

- **Direct Benefits** include reduced or avoided physical damages to facilities and contents, reduced or avoided displacements for residential structures and reduced life cycle or O&M costs that can be quantified as a primary result of implementing a specific hazard mitigation measure. Table 12 in Appendix 4 provides a list of direct benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards. Note that given the current state of practice, it is not possible to quantify reduced or avoided physical damages or residential displacements that result from a specific extreme heat mitigation measures. Therefore, direct benefits applicable to extreme heat hazards are limited to reduced life cycle costs applicable to certain measures, such as green roofs. Refer to Table 15 for details on direct benefits for extreme heat hazards.

- **Indirect Benefits** include reduced or avoided service losses for non-residential buildings, public facilities and/or infrastructure (utilities, roads and bridges) based on the value of service continuity and/or emergency services to New Yorkers that can be quantified as a secondary result of implementing a specific hazard mitigation measure. Table 13 in Appendix 4 provides a list of indirect benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards. Note that given the current state of practice on extreme heat, it is not possible to quantify reduced or avoided service losses that result from a specific extreme heat mitigation measures. Therefore, indirect benefits applicable to extreme heat hazards are limited to reduced energy costs such as cool roofs, green roofs, or shade trees. Refer to Table 15 in Appendix 4 for details on indirect benefits for extreme heat hazards.

- **Other Benefits** where applicable, other potential benefits may include social benefits for residents such as avoided stress and anxiety, avoided lost productivity, environmental/ecosystem service benefits, avoided need for emergency services and other potential benefits that can be estimated as a result of implementing a specific hazard mitigation measure. Table 14 in Appendix 4 provides a list of other potential benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards.

Note on the ecosystem service benefit category: *in Table 14, the stormwater management benefits of green infrastructure should be distributed between the extreme heat and increased precipitation hazards since these measures provide both significant reductions in rainfall runoff as well as Urban Heat Island mitigation through evapotranspiration. However, there is currently limited data available to quantify the actual distribution of stormwater management benefits between the two hazards. For various dual-benefit providing interventions, careful considerations should be given to identify the appropriate benefits category provided by the intervention with a goal to avoid duplication of quantified benefits. In this methodology, the stormwater management benefits of green infrastructure are applied to the increased precipitation hazard in order to avoid a duplication of benefits.*

Note on real estate and quality of life benefits: *additionally, it is important to note that two potential benefit categories shown in Table 14 - real estate and quality of life/health/avoided casualties - were not included in the current BCA methodology for sea level rise or increased precipitation hazards. Although these categories could increase project benefits for sea level rise and increased precipitation hazards, they were only applied to measures that address extreme heat hazards such as green roofs, trees and other plantings. Refer to Table 15 for a detailed summary of other benefit categories quantified as unit benefits for extreme heat hazards.*

C. WHICH METHODOLOGY TO USE?

Projects with total costs below $50 million: recommended to conduct a qualitative assessment to identify the optimal interventions that meet Guidelines' design criteria using the "*D) BCA methodology for projects under $50 million*" methodology below.

Projects with a total cost above $50 million, or are highly complex or critical facilities: recommended to conduct both a qualitative and quantitative benefit calculation to identify the optimal interventions that meet Guideline's design criteria using the "*E) BCA methodology for projects above $50 million*" below. A quantitative BCA also must include qualitative factors.

D. BCA methodology for projects under $50 million

The project design team should develop design alternatives to meet the Guidelines' criteria which may be in excess of NYC code and standards requirements (baseline conditions). It is assumed that the project design team will develop alternatives to address each of the following applicable climate stressors - sea level rise/coastal storm surge, increased precipitation and extreme heat - separately. Tables 12-15 in Appendix 4 provides a list of typical direct, indirect and other benefits provided by various intervention typologies to reduce impacts from climate stressors. During the qualitative assessment, the project design team should consider that intervention strategies will have varying levels of reliability, effectiveness, benefits and cost implications during the qualitative assessment.

The project design team is recommended to develop appropriate evaluation criteria and metrics for each of the applicable project benefit categories. For each alternative, the project design team could use either a scoring, weighting, ranking or other type of qualitative assessment framework to assess each applicable project benefit categories with the developed evaluation criteria and metrics. Table 6 provides an example template to evaluate alternatives using a set of general evaluation criteria and metrics using a color-coded rating system (and see Table 7 for an example of how to complete the template). The project design team can utilize a similar template customized to their project goals and objectives. This assessment allows agencies to screen the qualitative benefits for various alternatives that would then lead to development of final project components to match the available budget and goals of the project.

Table 6 – Evaluation matrix for comparison of mitigation alternatives across the useful life of a project

Project title:____

Evaluation Criteria	**Baseline Condition (Designed to NYC Building Code and Standards)**	**Resilient Design Alternatives for Managing__________________**		
		Alternative 1 __________ __________	**Alternative 2** __________ __________	**Alternative 3** __________ __________
First Costs				
Constructability/Ease of Implementation				
Environmental Impacts/Co-Benefits/Permitting				
Operation and Maintenance (O&M)				
Reliability and Durability				
Risk Reduction Benefits				
Quality of Life Benefits/Visual Aesthetics				

Qualitative Color Scale: Green=Least resource intensive alternative; Purple=most resource intensive; yellow=medium level of resource intensity.

Qualitative Evaluation Factors	**Description**	**Relative Color Rating System**
First Costs	Additional construction costs needed to incorporate Guidelines’ recommended resilient design over the baseline project costs	Highest cost ($$$) rated as Purple, whereas lowest cost ($) rated as Green
Constructability/Ease of Implementation	Construction techniques and site conditions such as presence of major utilities conflicts and other conditions which dictate the level of constructability required for each alternative	Difficult to construct rated as Purple, whereas easiest to construct rated as Green
Environmental Impacts/Co-Benefits/Permitting	Impacts to the built and natural environment such as circulation, noise and hazardous waste plus the level of effort required for permitting (e.g. interventions in water require highest level of permitting requirement) from each alternative in addition to the baseline project condition	Highest environmental impacts and highest level of effort required for permitting rated as Purple, whereas the least impact and level of effort rated as Green
Operation and Maintenance (O&M)	Level of effort of additional manpower and cost of O&M for the alternatives over the baseline project O&M requirements	Highest level of effort and cost for O&M rated as Purple, whereas the lowest is rated as Green
Reliability and Durability	Interventions that do not require human involvement or a facility’s ability to withstand all the forces during a storm event (e.g. permanent solutions with higher reliability than deployable solution)	Interventions requiring human involvement (active measures) rated as Purple, whereas interventions with minimal or no human involvement (passive measures) rated as Green
Risk Reduction Benefits	Monetary benefits provided by each intervention alternative in avoided damages over the baseline condition	Lowest potential monetary benefit rated as Purple, whereas as highest potential monetary benefit rated as Green
Quality of Life Benefits/Visual Aesthetics	Benefits either to the community, such as recreation or safety, or serve the community during emergency situations	Lowest potential quality of life benefits rated as Purple, whereas as highest potential benefits rated as Green

CASE STUDY: Example of How to Use the Evaluation Matrix

A new, non-critical facility with a building structure is proposed on a site that is currently in the 2015 Preliminary FEMA 1% annual chance floodplain with a BFE of 10’ (NAVD 88). The baseline conditions DFE to meet existing NYC codes and standards is 11’ (NAVD 88). Using the Guidelines recommended design criteria, the facility’s DFE is 13.3’ (NAVD 88). and existing grade is around 6’ (NAVD 88). The project design team develops three alternatives to meet the Guidelines’ recommended DFE design for the facility. Table 7 offers an example of how a qualitative assessment can be used to compare three resilient design alternatives using the evaluation criteria and metrics.

Table 7 – Evaluation matrix for comparison of mitigation alternatives across the useful life of a project - COMPLETED EXAMPLE

Evaluation Criteria	Baseline Condition (Designed to NYC Building Code and Standards)	Resilient Design Alternatives for Managing *Coastal Surge/SLR*		
		Alternative 1 *Flood proof building built on grade to Guidelines DFE*	**Alternative 2** *Elevate building structure above Guidelines’ DFE on columns*	**Alternative 3** *Raise site grade by filing the building site footprint to Guidelines’ DFE*
First Costs	*Baseline cost for building structure is $15 million*	🟩 *Incremental costs are within 5% over the baseline costs*	🟨 *Incremental costs are between 5-10% over baseline costs*	🟪 *Incremental costs are 20% and more over baseline costs*
Constructability/Ease of Implementation	*Relatively easy to construct within site constraints*	🟩 *Similar to baseline conditions since construction requires additional flood proofing only*	🟨 *Moderate challenges to construct foundation structure for columns within site constraints*	🟪 *Extremely challenging to construct within the site constraints. Potentially fatal flaw.*
Environmental Impacts/ Co-Benefits/Permitting	*No major impacts but may require additional effort to obtain DOB permits with flood proofing and deployable systems*	🟨 *No major impacts but may require additional effort to obtain DOB permits with flood proofing and deployable systems*	🟩 *No major impacts and relatively easy to permit*	🟪 *Potential drainage, circulation impacts and challenges to obtain clean fill material for the site*
Operation and Maintenance (O&M)	*Major O&M costs associated with deployable systems*	🟪 *Major O&M costs associated with deployable systems*	🟨 *Moderate O&M costs associated with proposed elevator for access*	🟩 *Minimal O&M costs since deployable and elevators not required*
Reliability and Durability	*Least reliability with highest potential risk from flooding during to failure of deployable systems*	🟪 *Least reliability with highest potential risk from flooding during to failure of deployable systems*	🟨 *Moderate reliability with potential risk from flooding limited to elevator shaft only*	🟩 *Highest reliability since deployable are not required to protect building from flooding*
Risk Reduction Benefits	*Maximum flood risk reduction benefits assuming deployable and flood proofing is effective*	🟨 *Maximum flood risk reduction benefits assuming deployable and flood proofing is effective*	🟩 *Maximum flood risk reduction benefits*	🟩 *Maximum flood risk reduction benefits*
Quality of Life Benefits/ Visual Aesthetics	*Facility may not be operational during the storm event*	🟨 *Facility may not be operational during the storm event*	🟩 *Facility can be potentially operational during the storm event*	🟩 *Facility can be potentially operational during the storm event*

Qualitative Color Scale: Green=Least resource intensive alternative; Purple=most resource intensive; yellow=medium level of resource intensity.

E. BCA methodology for projects over $50 million

In order for a project to be considered cost-effective, a benefit-cost analysis (BCA) assesses if the benefits of a project outweigh its costs, or in other words, the benefit-cost ratio (BCR) is greater than 1.0, as illustrated in Equation 1.

Equation 1. Benefit-Cost Ratio Formula

$$\mathbf{BCR} = \frac{\mathbf{BENEFITS}}{\mathbf{COSTS}}$$

Where: BCR = Benefit-Cost Ratio

BENEFITS = Total project benefits

COSTS = Total project costs

These estimated project benefits are combined with the project costs, which are defined as the differential construction and long-term operation and maintenance costs associated with constructing a proposed project to the Guidelines’ recommended design level. It is assumed that the baseline project will be designed to the most prevalent NYC codes and standards. This benefit methodology should be used to determine the additional project benefit that the Guidelines’ recommended design would provide over the baseline project benefit. It is assumed that the project design team will develop alternatives to address each of the following applicable climate stressors - sea level rise/coastal storm surge; increased precipitation and extreme heat - separately. For each alternative, the project design team should use the following steps to determine the Benefit-Cost Ratio (BCR).

a) Determine project useful life for design interventions

Determining the useful life of the proposed project is an important first step in the detailed BCA assessment methodologies for two reasons. First, the project useful life determines what values must be used from the Guidelines to establish the future climate design conditions. The various hazard tables in the Guidelines establish design requirements based on useful life ranges: through 2039, 2040-2069, 2070-2099 and 2100+ (2100+ projections are only available for sea level rise). A review of these tables show that the design requirements needed to meet the projected climate hazards increase as the end of useful life range increases. Second, the useful life determines how long the project will need to be operated and maintained in order to remain technically sound and effective at reducing future damages and losses.

b) Determine discount rate for project benefits calculation

The cost-effectiveness of projects assessed using the BCR must be done on a net present value basis, meaning the present value of the benefits is compared to the present value of the costs. Most project costs are computed for present value based on current cost estimates, bids or cost guidance. However, project benefits - as well as project costs for operation and maintenance - accrue over time into the future and are computed on an annualized basis. To address this issue, the Present Value Coefficient (PVC) is used to bring these annualized project benefits and O&M costs into the present value. As indicated by the formula in Equation 2, the PVC is a function of the Project Useful Life (PUL) and the Discount Rate (DR).

Equation 2. Present Value Coefficient (PVC) Formula

$$\mathbf{PVC} = \frac{[1 - (1 + DR)^{-(PUL)}]}{DR}$$

Where: PVC = Present Value Coefficient

PUL = BCA Project Useful Life based on project type

DR = Discount Rate

The project design team should coordinate with agencies and NYC OMB if needed to determine appropriate discount rates based on funding source, project type and other factors. This coordination should take place during project initiation phase where total project costs (design and construction) are over $50 million.[66]

c) Develop input data to perform benefit calculations

Tables 16 and 17 in Appendix 4 provide a list of typical input data by each climate stressor needed to perform benefit analysis quantitatively on variety of facilities.[67] The project design team should use these tables as a reference to identify appropriate input data categories and/or additional input data needed to perform benefit analysis on the project.

d) Identify applicable project benefit categories to estimate benefits

Tables 16 and 17 in Appendix 4 provide a list of typical project benefits by each climate stressor needed to perform benefit analysis quantitatively on various types of projects. The project design team should use these tables as a reference to identify appropriate project benefit categories for each climate stressor to perform benefit analysis on the project.

e) Calculate benefits of recommended design interventions for each climate stressor

The input data and applicable project benefits can be assembled along with incremental project cost data to analyze cost-effectiveness using the FEMA BCA Tool Damage-Frequency Assessment (DFA) module or similar software. This analysis will provide a BCR for each alternative, which can then be used to compare the alternatives that were developed to mitigate effects from applicable climate stressors. The project design team can then use the results from this analysis to identify optimal interventions that provides a balanced solution that provides resiliency benefits within the available project budget.

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[66] For example, a NYC OMB March 2015 memorandum recommends using an annually updated DR as published each year in Appendix C of OMB Circular A-94. The current OMB-recommended discount rates from OMB A-94 Appendix C vary by project useful life and are as follows: 2.1% DR for useful lives of 10 to 19 years, 2.5% DR for useful lives of 20 to 29 years, and 2.8% DR for useful lives of 30 years or greater. By contrast, FEMA hazard mitigation grants use a DR of 7.0% for all projects based on the Federal OMB A-94 rate for federally-funded mitigation measures. Since these DRs will impact the PVC and the project benefits, the project team must ensure that BCA results prepared using an OMB-recommended DR (2.1% to 2.8%) be updated to reflect the Federal DR (7.0%) when applying for FEMA mitigation grant funds.

[67] Note the data requirements for the sea level rise and increased precipitation hazards in Table 16 are more detailed than the requirements for the extreme heat hazards, due to the less detailed level of analysis available for extreme heat.

APPENDICES

APPENDIX 1 - KEY TERMS[68]

100-year flood (1% annual chance flood)	A flood that has a 1% probability of occurring in any given year. The 100-year floodplain is the extent of the area of a flood that has a 1% chance of occurring or being exceeded in any given year.
500-year flood (0.2% annual chance flood)	A flood that has a 0.2% probability of occurring in any given year. The 500-year floodplain is the extent of the area of a flood that has a 0.2% chance of occurring or being exceeded in any given year.
Adaptation	Adjustment in natural or human systems to a new or changing environment that seeks to maximize beneficial opportunities or moderate negative effects. Successful adaptations contribute to resiliency.
Base flood elevation (BFE)	The elevation of surface water resulting from a flood that has a 1% annual chance of occurring or being exceeded in any given year. The BFE is shown on the Flood Insurance Rate Map (FIRM).[69]
Bluebelt	Reference to the Department of Environmental Protection's (DEP) Bluebelt program to preserve natural drainage corridors, including streams, ponds and other wetland areas. Preservation of these wetland systems allows them to perform their functions of conveying, storing and filtering storm water.
Climate	The average weather (or more rigorously, a statistical description of the average in terms of the mean and variability) over a period of time, usually 30 years. These quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.[70]
Climate change	Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events and changes to other variables of the climate system.
Climate change risk	The chance that investments (such as in capital projects) can be affected by the physical impacts of climate change.[71] Risks are evaluated as a product of the probability of occurrence and the magnitude of damages or impacts, including socioeconomic factors that would result if they did occur (consequences).
Climate change risk assessment	This assessment involves a detailed, project-specific analysis that includes a vulnerability and risk assessment, often followed by cost-benefit analysis, to assess and select investments in climate change risk mitigation. Risk is assessed as a function of the magnitude and probability of a given climate change hazard. Examples resources are included in Appendix 7.
Climate vulnerability	The degree to which systems and populations are affected by adverse impacts. It is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.[72]
Cloudburst	An extreme amount of rain in a short period of time, often over a small geographic area.[73]
Cooling Degree Day (CDD)	A form of degree-day used to estimate the energy requirements for air conditioning or refrigeration when the daily mean temperature is above 65°F.

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[68] All terms are from the U.S. Global Change Research Program (USGCRP) glossary unless otherwise noted. The USGCRP glossary is available at: http://www.globalchange.gov/climate-change/glossary

[69] "Definitions," FEMA, last modified March 1, 2017. https://www.fema.gov/national-flood-insurance-program/definitions

[70] UKCIP Glossary http://www.ukcip.org.uk/glossary/

[71] "Account for Climate Risk," International Finance Corporation

[72] UKCIP Glossary http://www.ukcip.org.uk/glossary/

[73] New York City Environmental Protection "Cloudburst Resiliency Planning Study," 2017. Available at: http://www.nyc.gov/html/dep/pdf/climate/nyc-cloudburst-study.pdf

Design life	The life expectancy of an asset or product as determined during design.[74] As opposed to useful life (see below).
Dry Bulb temperature	The ambient air temperature measured by a thermometer.
Extreme event	Unexpected, unusual or unpredictable weather or flooding compared to historical or future projected distribution. Extreme events include, for example, heat waves, cold waves, heavy rains, periods of drought and flooding and severe storms.
Facilities	For the purposes of this document, "facilities" refers to all types of buildings, housing, infrastructure, structures and landscape features designed by or for the City of New York.
Flexible adaptation pathway	Resilience-building strategies that can evolve or be adapted over time as climate change risk assessments, evaluations of adaptation strategies and monitoring continue.[75]
Flood Insurance Rate Maps (FIRM)	Official flood map of a community on which FEMA has delineated the 1% annual chance floodplain and the base flood elevations (BFEs) applicable to the community.[76] The FIRM also includes the 0.2% floodplain annual chance floodplain and differentiates between special flood hazard areas (V, A Coast A zones) and floodways. The official FIRM is from the year 2007, while the 2015 PFIRM is currently required by NYC Building Code to calculate design flood elevations. NYC DOB references the more restrictive of the two maps in both base flood elevation and flood hazard area (i.e., V versus A zone). Refer to Appendix 3 for more information.
Freeboard	An additional amount of height above the base flood elevation used as a factor of safety (e.g., two feet above the base flood) in determining the level at which a facility's lowest floor must be elevated or floodproofed to be in accordance with state or community floodplain management regulations.[77]
Future time slices	Future periods, defined by the NPCC, for when climate change projections are available. In this document, the following decadal projections are associated with specific time spans: 2020s projection = present to 2039 2050s projection = 2040 to 2059 2080s projection = 2070 to 2099 2100s projection = end of century and beyond
Green infrastructure	An array of practices that use or mimic natural systems to manage urban stormwater runoff. Water is either directed to engineered systems for infiltration or detained for longer periods before it enters the sewer system.
Heat Vulnerability Index (HVI)	Summarizes relative risk of adverse health effects from heat due to social and environmental factors. Used to identify neighborhoods at higher risk during and after extreme heat events.
Heat wave	A period of three consecutive days where temperatures rise above 90°F or two consecutive days over 95 degrees.[78]
New York City Panel on Climate Change (NPCC)	The body of leading climate and social scientists charged with making climate change projections for the metropolitan region.[79]

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[74] Sustainable Infrastructure Management Program Learning Environment. http://simple.werf.org/
[75] Rosenzweig, C. et al. Climate Change Adaptation in New York City: Building a Risk Management Response.
[76] "Definitions," FEMA.
[77] Ibid.
[78] Horton, R. et al. New York City Panel on Climate Change 2015 Report: Chapter 1: Climate Observations and Projections. Ann. N.Y. Acad. Sci. ISSN 0077-8923. (New York, 2015) 25.
[79] For more information on the NPCC, visit www1.nyc.gov/site/orr/challenges/nyc-panel-on-climate-change.page

Open-grid pavement system	Pavements that consist of loose substrates supported by a grid of a more structurally sound grid or webbing. Unbounded, loose substrates in these systems transfer and store less heat than bound and compacted pavements and aid permeability. Pavement is 50% pervious and contains vegetation in the open cells designed to allow percolation or infiltration of storm water through the surface into the soil below.[80]
Preliminary Flood Insurance Rate Map (PFIRM)	Preliminary flood map developed by FEMA in 2015 for New York City that provides projected risks for flood hazards.[81] Refer to Appendix 3 for more information.
Project useful life (PUL)	The period over which an asset or component is expected to be available for use by an entity. This depends on regular and adequate maintenance. This period of time typically exceeds the design life (see above). The combined effect of operational requirements and useful life is practical in assessing an investment in improving resilience.[82]
Rain garden	Also called "bioswale." Planted areas designed to collect and manage stormwater that runs off streets, sidewalks, commercial and residential rooftops and other sources when it rains.
Resiliency	The ability to bounce back after change or adversity. The capability of preparing for, responding to and recovering from difficult conditions.[83]
Sea level rise-adjusted design flood elevation	As defined in these Guidelines, the increased height of the base flood elevation due to sea level rise, plus freeboard depending on the criticality of the facility. The sea level rise adjustment depends on the useful life of the facility.
Storm surge	An abnormal rise of water generated by a storm, over and above predicted astronomical tides.[84]
Substantial improvement	Any repair, reconstruction, rehabilitation, addition, or improvement of a building or structure, the cost which equals or exceeds 50% of the market value of the structure before the improvement or repairs started. For more information, see Appendix G of the NYC Building Code and 1 RCNY §3606-01.[85]
Tidal inundation	Flooding which occurs at high tides due to climate-related sea level rise, land subsidence and/or the loss of natural barriers.[86]
Urban Heat Island (UHI) effect	The tendency for higher air temperatures to persist in urban areas as a result of heat absorbed and emitted by buildings and asphalt, tending to make cities warmer than the surrounding suburban and rural areas.
Weather	The state of the atmosphere at a given time with regard to temperature, cloudiness, precipitation, wind and other meteorological conditions.[87]
Wet Bulb temperature	The temperature indicated when a thermometer bulb is covered with a water-saturated wick over which air is caused to flow at approximately 4.5 m/s (900 ft/min) to reach the equilibrium temperature of water evaporating into the air when the heat of vaporization is supplied by the sensible heat of the air.[88]

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[80] "Glossary," US Green Building Council (2017). Available at: http://www.usgbc.org/glossary/term/5525

[81] "Preliminary FEMA Map Products," FEMA Map Service Center. Available at: https://hazards.fema.gov/femaportal/prelimdownload/

[82] "Glossary," International Infrastructure Management Manual (2011).

[83] *A Stronger, More Resilient New York* (2013), 1.

[84] "Storm Surge Overview," National Hurricane Center. NOAA. Available at: https://www.nhc.noaa.gov/surge/

[85] "Flood Resistant Construction," Appendix G, New York City Building Code (2008), and 1 RCNY §3606-01 available at: https://www1.nyc.gov/assets/buildings/rules/1_RCNY_3606-01.pdf

[86] "Ocean Facts," National Ocean Service. NOAA. Available at: http://oceanservice.noaa.gov/facts/nuisance-flooding.html.

[87] UKCIP Glossary http://www.ukcip.org.uk/glossary/

[88] "ASHRAE Terminology," ASHRAE. Available at: https://www.ashrae.org/technical-resources/authoring-tools/terminology

APPENDIX 2 - CLIMATE CHANGE PROJECTIONS

Climate change projections are provided by the New York City Panel on Climate Change (NPCC). The full NPCC report is available from the New York Academy of Sciences.[89] Tables 8-10 (below) were reproduced directly from the NPCC report, while Table 2 (see Section II.A) was developed using the data underlying the NPCC report to inform the design of HVAC systems under warmer conditions.

Table 8 – NYC sea level rise projections[90]

Baseline (2000-2004) 0 in	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	2 in	4-8 in	10 in
2050s	8 in	11-21 in	30 in
2080s	13 in	18-39 in	58 in
2100	15 in	22-50 in	75 in

Note: Projections are based on six-component approach that incorporates both local and global factors. The model-based components are from 24 global climate models and two representative concentration pathways. Projections are relative to the 2000-2004 base period.

Table 9 – Mean annual changes[91]

a. Temperature Baseline (1971-2000) 54°F	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	+ 1.5°F	+2.0-2.9°F	+3.2°F
2050s	+3.1°F	+4.1-5.7°F	+6.6°F
2080s	+3.8°F	+5.3-8.8°F	+10.3°F
2100	+4.2°F	+5.8-10.4°F	+12.1F
b. Precipitation Baseline (1971-2000) 50.1 in	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	-1 percent	+1-8%	+10%
2050s	+1 percent	+4-11%	+13%
2080s	+2 percent	+5-13%	+19%
2100	-6 percent	-1% to +19%	+25%

Note: Based on 35 global climate models (GCMs) and two RCPs. Baseline data cover the 1971–2000 base period and are from the NOAA National Climatic Data Center (NCDC). Shown are the low estimate (10th percentile), middle range (25th percentile to 75th percentile), and high estimate (90th percentile). These estimates are based on a ranking (from most to least) of the 70 (35 GCMs times 2 RCPs) projections. The 90th percentile is defined as the value that 90 percent of the outcomes (or 63 of the 70 values) are the same or lower than. Like all projections, the NPCC climate change projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities and the potential for error should be acknowledged.

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[89] The NPCC 2015 report is available at: http://onlinelibrary.wiley.com/doi/10.1111/nyas.2015.1336.issue-1/issuetoc.

[90] From New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections, page 41.

[91] From New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections, page 30.

Table 10 – Extreme events[92]

2020s	Baseline (1971-2000)	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
Numbers of heat waves per year	2	3	3-4	4
Average heat wave duration (days)	4	5	5	5
Number of days per year with:				
Maximum temperature at or above 90°F	18	24	26-31	33
Maximum temperature at or above 100°F	0.4	0.7	1-2	2
Minimum temperature at or below 32°F	71	50	52-58	60
Rainfall at or above 1 inch	13	13	14-15	16
Rainfall at or above 2 inches	3	3	3-4	5
Rainfall at or above 4 inches	0.3	0.2	0.3–0.4	0.5
2050s	Baseline (1971-2000)	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
Numbers of heat waves per year	2	4	5-7	7
Average heat wave duration (days)	4	5	5-6	6
Number of days per year with:				
Maximum temperature at or above 90°F	18	32	39-52	57
Maximum temperature at or above 100°F	0.4	2	3-5	7
Minimum temperature at or below 32°F	71	37	42-48	52
Rainfall at or above 1 inch	13	13	14-16	17
Rainfall at or above 2 inches	3	3	4-4	5
Rainfall at or above 4 inches	0.3	0.3	0.3-0.4	0.5
2080s	Baseline (1971-2000)	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
Numbers of heat waves per year	2	5	6-9	9
Average heat wave duration (days)	4	5	5-7	8
Number of days per year with:				
Maximum temperature at or above 90°F	18	38	44-76	87
Maximum temperature at or above 100°F	0.4	2	4-14	20
Minimum temperature at or below 32°F	71	25	30-42	49
Rainfall at or above 1 inch	13	14	15-17	18
Rainfall at or above 2 inches	3	3	4-5	5
Rainfall at or above 4 inches	0.3	0.2	0.3-0.5	0.7

Note: Projections for temperature and precipitation are based on 35 GCMs and 2 RCPs. Baseline data are for the 1971 to 2000 base period and are from the NOAA National Climatic Data Center (NCDC). Shown are the low estimate (10th percentile), middle range (25th to 75th percentile) and high estimate (90th percentile) 30-year mean values from model-based outcomes. Decimal places are shown for values less than one, although this does not indicate higher precision/certainty. Heat waves are defined as three or more consecutive days with maximum temperatures at or above 90°F. Like all projections, the NPCC climate change projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities and the potential for error should be acknowledged.

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[92] From New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections, page 31.

APPENDIX 3 - DIFFERENTIATION OF FLOOD MAPS

These Guidelines reference several different kinds of flood maps and sources of design flood elevations. These maps are described and differentiated below.

Table 11 - Differentiation of flood maps used in NYC

Reference Title	Data Source	Information Provided	Referenced By	Link
2007 FIRM	FEMA	Based on historical data from before 1983, identifies the current base flood (extent and elevation) as the flood that has a 1% chance of occurring in any given year, also known as a 100-year flood. The NYC Building Code requires that either the 2007 FIRM or 2015 PFIRM elevation be used, whichever is higher.	2014 NYC Building Code Appendix G Climate Resiliency Design Guidelines	https://msc.fema.gov/portal
2015 PFIRM	FEMA	Based on historical data, identifies the current base flood (extents and elevation) as the flood that has a 1% chance of occurring in any given year, also known as a 100-year flood. The NYC Building Code requires that either the 2007 FIRM or 2015 PFIRM elevation be used, whichever is higher. The 2015 PFIRM is currently being reassessed by FEMA.	2014 NYC Building Code Appendix G Climate Resiliency Design Guidelines	https://hazards.fema.gov/femaportal/prelimdownload/ http://www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/
NYC Flood Hazard Mapper	NYC Department of City Planning	Maps current and future flood hazards in NYC including the following data layers: 2007 FIRM and 2015 PFIRM, high tide with sea level rise and PFIRM with sea level rise through 2100.	Climate Resiliency Design Guidelines Waterfront Revitalization Plan	http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page
"Table 4 – Determine the sea level rise-adjusted design flood elevation for critical and non-critical facilities"	ORR & NPCC	Provides data to use when adding sea level rise to a given 2015 PFIRM or 2007 FIRM Base Flood Elevation (BFE) to calculate a Design Flood Elevation (DFE). Based on the criticality and expected useful life of a facility.	Climate Resiliency Design Guidelines	See Section II on "Sea Level Rise" above.

APPENDIX 4 - PROJECT BENEFITS CATEGORIES

This appendix provides guidance on how to identify and assess benefits as a supplement to Sections III.D and III.E.

Table 12 lists typical direct benefits for reducing impacts from climate stressors and basic guidance for how to estimate them. See Section III.D for more information.

Table 12 – Direct benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Direct Benefit	Basic Guidance for Estimating Values
Physical Damages (Structure, Contents)	• For flood-damaged buildings, use depth damage functions developed by FEMA and USACE for structures and contents. • Use depth damage functions in conjunction with Building Replacement Values (BRVs) and not market values; BRVs typically range between $100 to $325/SF for residential buildings and $120 to $450/SF for commercial/ public buildings. • For more complex structures or facilities, use engineering estimates of flood damages; or review historic flood damages documented from insurance claims, repair records, or FEMA Public Assistance claims from recent flood disasters.
Residential Displacements	• For flood-damaged buildings, use depth damage functions developed by FEMA and USACE for residential displacements.
Reduced Life Cycle/ Operation and Maintenance (O&M) Costs[93]	• Applicable only to projects that reduce overall life cycle costs or net annual O&M costs from baseline conditions. • Input reduced annual O&M costs as a project benefit at a 1-year recurrence interval. • Reduced overall life cycle costs can be input as a longer project useful life.

Table 13 lists typical indirect benefits for reducing impacts from climate stressors, and basic guidance for how to estimate them. See Section III.D for more information.

Table 13 – Indirect benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Indirect Benefit	Basic Guidance for Estimating Values
Non-Residential Building Service Losses	• Estimate service loss values and durations for non-residential buildings, public buildings, critical facilities and parks/natural features based on FEMA BCA guidance and standard values based on building use.
Utility Service Losses[94]	• Estimate utility service losses for water, wastewater and electrical facilities based on the number of impacted customers, FEMA per capita standard values for utility service ($105/person/day for potable water; $49/person/day for wastewater; $148/person/day for electrical).[95] • Estimate utility service loss durations based on engineering estimates; or review historic flood damages losses documented from utility company records. • This benefit can also apply to measures that increase energy efficiency.
Road/Bridge Service Losses	• Estimate road/bridge service losses based on the average daily traffic (ADT), detour time and additional travel distance and FEMA and GSA standard values for road service ($33.44/vehicle/hour of delay; $0.545/mile).[96] • Estimate road/bridge service loss durations; or review historic flood damages losses.
Emergency Service Losses	• Applicable only to projects that reduce or eliminate documented emergency service costs from baseline conditions. • Examples of avoided emergency services costs include NYPD staffing to monitor barricades for flooded roads or NFDY staffing for water rescues of residents from flooded buildings or streets.

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[93] Reduced life cycle costs may be applicable to some measures that provide extreme heat benefits such as green roofs that can last longer than a standard roof if properly maintained.

[94] Reduced utility service costs may be applicable to some measures that provide extreme heat benefits such as cool roofs, green roofs and shade trees.

[95] FEMA per capita standard values taken from FEMA BCA Toolkit Version 5.3.0 (Build Date 12/22/2016) and developed in FEMA’s Baseline Standard Economic Value Methodology Report (July 28, 2016). Consider updating FEMA standard per capita values to reflect current New York City utility rates.

[96] Consider updating FEMA and GSA standard values to reflect current New York City area labor rates and fuel costs.

Table 14 lists other typical benefits for reducing impacts from climate stressors, and basic guidance for how to estimate them. See Section III.D for more information.

Table 14 – Other potential benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Other Benefit	Basic Guidance for Estimating Values
Avoided Stress and Anxiety	• Applicable only for projects that directly benefit occupants of residential structures. • Use FEMA standard value for avoided mental stress and anxiety treatment costs of $2,443/person to estimate benefit for all impacted residents.[97]
Avoided Lost Productivity	• Applicable only for projects that directly benefit occupants of residential structures. • Use FEMA standard value for avoided lost worker productivity costs of $8,736/household to estimate benefit for all impacted workers (conservatively assuming one worker per household).
Environmental Open Space	• Applicable only for projects that create or acquire open space areas by acquisition. • Use FEMA standard value for environmental open space based on the type of land acquired ($8,308/Acre/year for Green open space; $39,545/Acre/year for Riparian; $6,010/Acre/year for Wetlands; $554/Acre/year for Forests; $1,799/Year for Marine and estuary).[97]
CSO Volume Reduction	• Applicable only for projects that provide Combined Sewer Overflow (CSO) abatement by reducing the volume of rainfall runoff. • Use CSO abatement cost of $0.015/gallons/year applied to increased precipitation hazard runoff volume for 5-year design storm.[98]
Ecosystem Service[99]	• Add stormwater management benefits of green infrastructure projects to increased precipitation hazards where avoided damages and service losses are not quantified. • Unit benefits applicable to increased precipitation hazard include: o Green roofs: $0.133/SF/year (PUL 40 years) o Bioswale/Rain Garden/Meadow Mix: $0.020/SF/year (PUL 30 years) o Permeable Grass Pavers: $0.020/SF/year (PUL 30 years) o Tree Plantings: $303/Tree/year (PUL 30 years) o Planter Box Trees: $101/Tree/year (PUL 15 years)
Real Estate[99]	• Potential real estate benefits from increased resilience of residential and/or commercial properties/streetscapes/neighborhoods included within the project scope. • Benefit applied to extreme heat hazard for green infrastructure projects directly impacting residential or commercial properties.
Quality of Life/Health Benefits[99]	• Potential quality of life benefits related to improved public health from the resilience measures included within the project scope. • Benefit applied to extreme heat hazard for green infrastructure projects directly impacting residential or commercial properties.

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[97] FEMA standard values for avoided mental stress and anxiety and environmental open space values taken from FEMA BCA Toolkit Version 5.3.0 (Build Date 12/22/2016)

[98] CSO abatement cost taken from APG1 Report for NYC "Technical Approaches for Benefit-Cost Analysis of Hazard Mitigation Projects in Urban and Coastal Environments" (April 2016)

[99] Ecosystem Services, Real Estate and Quality of Life/Health benefits tend to be more applicable to green infrastructure measures that provide extreme heat benefits such as green roofs, trees and other plantings.

Table 15 lists potential benefits for reducing impacts from heat, and basic guidance for how to estimate them. See Section III.D for more information.

Table 15 – Potential benefits for extreme heat (Urban Heat Island) reduction measures

Category	Benefit	Basic Guidance for Estimating Values
Direct Benefit	Reduced Life Cycle Cost	• Applicable only to measures such as green roofs that are expected to last longer than standard roofs. • Compute total cost savings including annual O&M costs.
Indirect Benefit	Energy Savings	• Applicable to measures that reduce energy costs by providing cooling through increased shading and/or evapotranspiration. • Use New York Power Authority rates of $0.148/kWh for electricity and $0.810/Therm for natural gas.
Other Potential Benefits	Air Quality	• Applicable to measures that absorb pollutants and/or reduce carbon dioxide emissions.
	Acoustics	• Applicable to measures such as green roof or walls that reduce noise transfer.
	Quality of Life/Health	• Potential quality of life benefits and related to improved public health.
	Real Estate	• Applicable to measures that provide residential real estate benefits from increased resilience of properties/streetscapes/neighborhoods.
	Retail Sales/ Marketing	• Applicable to measures that provide commercial property benefits from increased aesthetics resulting in increased marketing and sales for streetscapes/neighborhoods.
	Tax Credits/ Incentives	• Applicable to resilience or green infrastructure measures such as green roofs that have accompanying Federal, State or City tax credits or other incentives.

Table 16 provides general guidance on how to quantitatively calculate benefits from efforts to address from climate stressors. See Section III.E for more information.

Table 16 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	**General Guidance – Basic Description**	**Applicable Benefit Category**			**Applicable Typical Facility Typology***			
		Direct Benefits	**Indirect Benefits**	**Other Potential Benefits**	**Building Structures**	**Complex Facilities**	**Transportation/ Streetscapes/ Plazas**	**Park Features**
First Floor Elevation (FFE)	• The elevation of the first finished floor of the structure, excluding basements. • FFE measured from top of lowest floor (riverine/non-coastal high hazard areas) or bottom of lowest horizontal structural member (coastal high hazard areas).	**Y**			**Y**	**Y**	**Y**	
Building Replacement Value (BRV)	• The unit cost to rebuild a structure of the same quality of construction. • Not the same as market value.	**Y**			**Y**	**Y**	**Y**	
Building Size	• The total floor area of the building in square feet. • Total Building Value = BRV x Building Size • Typical BRVs for NYC range between $100 to $325/SF for residential buildings and $120 to $450/SF for commercial/public buildings.	**Y**			**Y**	**Y**	**Y**	
Structure Description	• The type of building, number of stories and foundation type (full basement, partial basement, no basement). • Collect more detailed foundation data for coastal flood zones.	**Y**			**Y**	**Y**	**Y**	
Building Use	• Details related to residential housing, commercial business and public use.	**Y**	**Y**		**Y**	**Y**	**Y**	
Building Type	• The primary use of building – residential, commercial, public and others.	**Y**	**Y**		**Y**	**Y**	**Y**	
Depth Damage Function (DDF)	• Curves used to estimate structure damage, contents damage and displacement of residential buildings based on flood depth. • DDFs selection based on Structure Description, Building Type, Building Use. • Structure DDFs based on percentage of Total Building Value. • Contents DDFs based on percentage of Total Contents Value. • Displacement DDFs based on number of displacement days x Displacement Cost.	**Y**	**Y**		**Y**	**Y**	**Y**	
Contents Value	• The cost to replace structure contents (furnishings, equipment). • Residential building Contents Values typically 50% BRV (FEMA DDFs) or 100% BRV (USACE DDFs). • Non-residential building Contents Values between 18% to over 100% depending on building use (USACE DDFs). • Total Contents Value = %BRV x Building Size.	**Y**	**Y**		**Y**	**Y**	**Y**	

Table 16 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Number of Residents (Residential)	• Total number of occupants in a residential building. • Typically estimated based on number of residential units x average number of individuals per household (based on current US Census data or use 2.5 individuals per household as a default).	Y		Y	Y	Y	Y	
Displacement Cost (Residential)	• The unit cost to lodge and feed displaced residents while flood damage is repaired. • Average unit displacement cost of $415/ residential unit/day recommended based on current FY2018 GSA Per Diem rates for New York City.	Y		Y	Y	Y	Y	
Value of Service (Non-Residential and Public)	• The unit cost of service disruption and rental of temporary facilities while flood damage is repaired. • Disruption costs for non-residential buildings typically range from $0.95 to $1.36/SF/month and rental costs range from $0.20 to $1.36/ SF/month depending on building use. • Value of service for public buildings ($/day) is typically based on the annual operating budget for the City agency using the building prorated based on building size or population served by the building, then divided by 365 days/year.		Y		Y		Y	Y
Value of Service (Critical Facilities)	• The unit cost of critical facilities (police, fire, emergency medical services) lost or delayed while flood damage is repaired.		Y		Y		Y	
Value of Service Duration	• The duration of service disruption and rental of temporary facilities for non-residential buildings and critical facilities while flood damage is repaired. • For non-residential buildings: o Value of Service Durations vary from 4 months to over 30 months based on building use and the depth of flooding. o Total Value of Service Loss = (Disruption Cost x Building Area) = (Rental Cost x Building Area x Value of Service Duration) • For public buildings and critical facilities: o Value of Service Durations vary from 0 days to 720 months based on building use and the depth of flooding from FEMA FIA or USACE DDFs. o Total Value of Service Loss = (Value of Service) x (Service Loss Duration)		Y		Y		Y	

Table 16 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Engineering Estimates for Damages	• Engineered estimate models of physical damages and service losses at the project site based on the Guidelines event recurrence interval(s) and flood depth(s).	Y	Y		Y	Y	Y	Y
Historic Damages and Service Losses	• Historic physical damages and service losses at the project site documented from previous flood events. • Do not use routine maintenance. • The historic damage event recurrence interval (RIs) and/or flood depths must be determined, updated for inflation to the present value, and adjusted to match the Guidelines event RIs/ flood depths.	Y	Y		Y	Y	Y	Y
Facility Replacement Value	• The unit cost to rebuild the facility.							
Impacted Area	• The geographic area impacted by the facility in the event of failure in acres.		Y	Y		Y	Y	
Facility Capacity	• The design capacity of the facility. • For example - facility capacity expressed in millions of gallons per day (MGD) for water and wastewater facilities or megawatts (MW) for electrical facilities.		Y	Y		Y	Y	
Service Population	• The number of impacted residents served by the facility. • Typically estimated based on number of impacted residential customers x average number of individuals per household (based on current US Census data or use 2.5 individuals per household as a default). • Facilities serving mostly non-residential/ public buildings and/or critical facilities should focus on service losses rather than service population.		Y			Y	Y	

Table 16 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Value of Service	• Unit value of service provided by the facility. • Example of FEMA standard values for complete loss of utility service: $105/person/day for potable water $49/person/day for wastewater $148/person/day for electrical • Consider updating FEMA standard per capita values to reflect current The New York City utility rates.		Y			Y		
Roadway Elevations	• Roadway Elevations.	Y					Y	
Roadway Replacement Value	• Roadway Replacement Value.	Y					Y	
Inundation Area Map	• Inundation Area Map developed by FEMA or through modeling by project design team.	Y	Y				Y	
Building Inventory of Inundation Area	• The number and type of buildings within the streetscape and neighborhood inundated by the Guideline’s flood events.	Y	Y				Y	
Average Daily Traffic (ADT)	• The average number of one-way traffic trips per day along the roadway(s) within the streetscape/neighborhood inundated by the Guideline’s flood events.		Y				Y	
Additional Travel Time	• The additional travel time needed to detour around a flooded roadway expressed in minutes. • In the unlikely event there is no detour available, use a 12-hour travel time per one-way trap but provide a detailed area street map as supporting documentation.		Y				Y	
Value of Traffic Delay	• The value of service associated with lost time in traffic. • For example - FEMA standard average value of $33.44/vehicle/hour of delay. • Consider updating FEMA and GSA standard values to reflect current New York City area labor rates and fuel costs.		Y				Y	

Table 17 provides general guidance on how to quantitatively calculate benefits from efforts to address climate stressors. See Section III.E for more information.

Table 17 – Guidance on quantitative unit benefit calculations for extreme heat hazard measures

Measure	General Guidance – Unit Benefit Information and Data Requirements	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Green Roof	• Unit benefit range over PUL = $4.70/SF to $373/SF of green roof area ($7.19/SF standard value). • Assumed PUL = 40 years • Apply standard value unit benefit to green roof area to estimate measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.	Y	Y	Y	Y	Y	Y	
Bioswale/ Rain Garden/ Meadow Mix	• Unit benefit range over PUL = $3.96/SF to $211/SF of area ($7.30/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to bioswale/ rain garden/meadow mix area to estimate total measure benefit.		Y	Y	Y	Y	Y	Y
Cool Roof	• Unit benefit range over PUL = $1.17 to $31.51/SF of material area ($1.44/SF standard value). • Assumed PUL = 20 years • Apply standard value unit benefit to cool roof area to estimate total measure benefit. • Higher range values more applicable to residential building streetscape projects.		Y	Y	Y	Y	Y	
Light-Colored Pavers/ Light-Colored Materials	• Unit benefit range over PUL = $0.774 to $2.04/SF of material area ($0.866/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to material area to estimate total measure benefit.			Y	Y	Y	Y	

Table 17 – Guidance on quantitative unit benefit calculations for extreme heat hazard measures

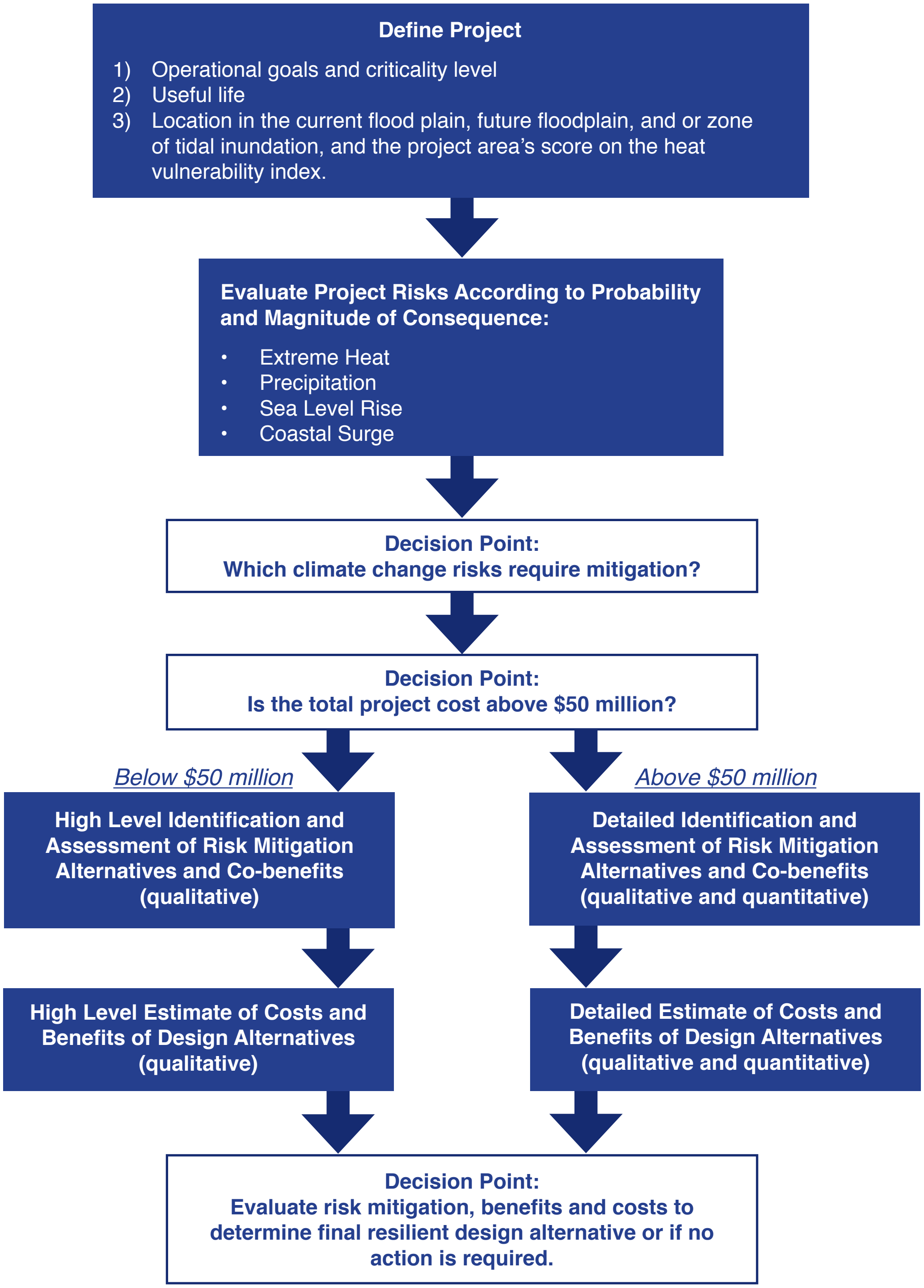
Measure	General Guidance – Unit Benefit Information and Data Requirements	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Tree Planting	• Unit benefit range over PUL = $1,005 to $77,154/Tree ($1.855/Tree standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to number of trees to estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.		Y	Y	Y	Y	Y	Y
Planter Box Tree	• Unit benefit range over PUL = $212 to 16,304/ Tree ($392/Tree standard value). • Assumed PUL = 15 years • Apply standard value unit benefit to number of trees to estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.		Y	Y	Y	Y	Y	
Shade Canopy	• Unit benefit range over PUL = $0.363 to $3.96/SF ($0.458/SF standard value) • Assumed PUL = 15 years • Apply standard value unit benefit to area of shade canopy estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.		Y		Y	Y	Y	
Permeable Grass Pavers	• Unit benefit range over PUL = $0.258/SF to $0.521/SF of pavers ($0.363/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to paver area to estimate total measure benefit.		Y	Y	Y	Y	Y	

* For the purposes of the BCA, refer to the following facility typologies:

- “Building Structures” include critical small building sites such as EMS or FDNY stations, and non-critical small building sites such as libraries or comfort stations.
- “Complex Facilities” include critical infrastructure such as wastewater treatment sites, pump stations, water filtration plants and similar large or complex facilities.
- “Transportation/Streetscape/Plazas” include roadway reconstruction, streetscape improvements, street raising, plazas and other transportation-related infrastructure.
- “Park Features” include parks and similar public recreational facility with natural landscape features.

APPENDIX 5 - EXAMPLE PLANNING DECISION TREE

This decision tree provides a summarized, example approach for how to implement these Guidelines. Projects with a total cost greater than $50 million are recommended to conduct a full, qualitative and quantitative climate change risk assessment and BCA, while projects below $50 million are recommended to conduct a qualitative risk assessment and BCA.



Define Project

1) Operational goals and criticality level
2) Useful life
3) Location in the current flood plain, future floodplain, and or zone of tidal inundation, and the project area’s score on the heat vulnerability index.

Evaluate Project Risks According to Probability and Magnitude of Consequence:

- Extreme Heat
- Precipitation
- Sea Level Rise
- Coastal Surge

Decision Point:
Which climate change risks require mitigation?

Decision Point:
Is the total project cost above $50 million?

Below $50 million

High Level Identification and Assessment of Risk Mitigation Alternatives and Co-benefits (qualitative)

High Level Estimate of Costs and Benefits of Design Alternatives (qualitative)

Above $50 million

Detailed Identification and Assessment of Risk Mitigation Alternatives and Co-benefits (qualitative and quantitative)

Detailed Estimate of Costs and Benefits of Design Alternatives (qualitative and quantitative)

Decision Point:
Evaluate risk mitigation, benefits and costs to determine final resilient design alternative or if no action is required.

APPENDIX 6 - DESIGN STRATEGIES CHECKLIST

This appendix provides a template for identifying possible design strategies to address climate change risks, as described throughout the Guidelines.

Project Title:

Design Strategies Checklist (not exhaustive)

Extreme Heat		Comments	Extreme Precipitation		Comments	Sea Level Rise & Storm Surge		Comments
☐	Select Site in Low Heat Vulnerability Index area		☐	Select High Elevation Site		☐	Select High Elevation Site	
☐	Minimize East-West Building Orientation		☐	Green Roof		☐	Raise Building Floor Elevation	
☐	Passive Solar Cooling and Ventilation Systems		☐	Protect Below Grade Areas from Flooding		☐	Waterproof Building Envelope	
☐	Cool Roof (SRI appropriate)		☐	On-site Stormwater Management (gray)		☐	Elevate Critical Building Functions	
☐	Green Roof (extensive)		☐	Reduce Impervious Areas		☐	Elevate Critical Equipment	
☐	Vegetative Structures		☐	Permeable Pavement		☐	Perimeter Floodwall[100]/ Levee (passive or active)	
☐	Enhanced HVAC System, including space layout optimization and system scalability		☐	Increase Green Spaces and Planted Areas		☐	Dry/Wet Floodproofing	
☐	More Efficient Building Envelope		☐	Other:		☐	Utility Redundancy Design[101]	
☐	Parking Lot Shading		☐			☐	Resilient Materials & Landscape Treatments	
☐	Light Colored Pavements (appropriate SRI)		☐			☐	Design for Storm Surge Outflow	
☐	Increase Planted Areas		☐			☐	Install Backwater Flow Prevention	
☐	Permeable Surfaces		☐			☐	Design for Scour	
☐	Open-grid Pavement		☐			☐	Raise Road Elevation	
☐	Other:		☐			☐	Other:	

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[100] Permanent perimeter flood walls are not permitted to meet floodproofing requirements in buildings with substantial improvements and/or damages.

[101] Utility redundancy design should be pursued for critical systems, not all building systems.

APPENDIX 7 - CLIMATE CHANGE RISK ASSESSMENT RESOURCES

These Guidelines provide data on climate change hazards and recommend how that data can inform resilient design. A risk assessment is a tool to help project managers and designers evaluate risk levels, as well as select and prioritize resilient design strategies. A high level risk assessment is recommended for all City capital projects with a total cost of under $50 million. Projects above $50 million are recommended to conduct an in-depth assessment.

Risk assessments use quantified estimates of the probability and magnitude of consequence of an event occurring to prioritize responses. "Probability" is an assessment of the likelihood of a hazard occurring, while "magnitude" describes the hazard's potential impact. Risk assessment tools, such as the examples listed below, can be used to define and score these categories. Projects that score higher across both probability and magnitude can be prioritized for investment and risk mitigation action. Projects that score lower across both criteria may require no action beyond meeting code. The results are typically charted on a risk matrix, and an example is provided on the next page.

The climate change risk management frameworks below offer templates for how to integrate climate change projections into a risk assessment process. Refer to these resources for examples and further information:

- ***Vulnerability Assessment and Adaptation Framework*** is prepared by the Federal Highway Administration (FHWA). While developed for transportation planning, this risk assessment framework has broad applicability for evaluating asset vulnerability to climate change. Available at: https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/

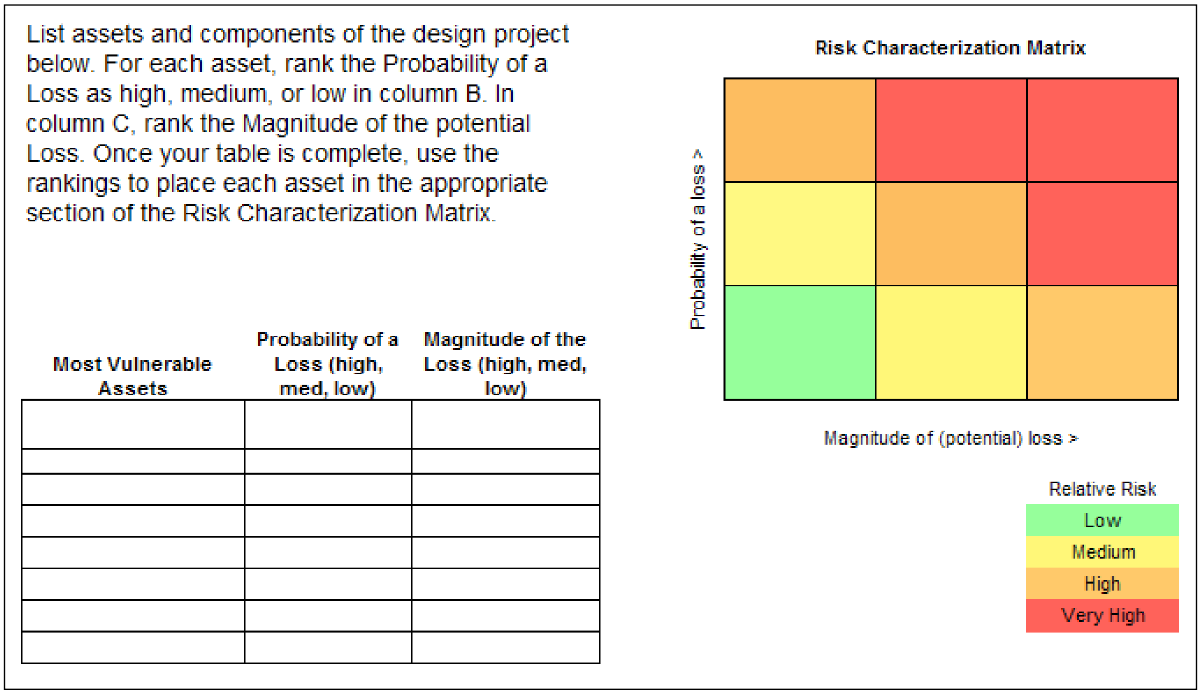
- ***U.S. Climate Resilience Toolkit***
  The U.S. Global Change Research Program offers a step by step risk assessment framework including tools and case studies at: https://toolkit.climate.gov/#steps (see example on next page)

- ***Coast Adapt: Guidance on undertaking a risk assessment***
  High level assessment:
  https://coastadapt.com.au/sites/default/files/factsheets/T3M4_2_2nd_pass_risk_assessment.pdf
  Detailed assessment:
  https://coastadapt.com.au/sites/default/files/factsheets/T3M4_3_3rd_pass_risk_assessment.pdf

- ***Climate adaptation: Risk, uncertainty and decision-making***
  Download the report here: https://www.ukcip.org.uk/publications/#Risk

The City plans to develop a NYC-specific process for integrating climate change data into existing risk management processes by April 2019.

The Risk Characterization Matrix below is an example from the U.S. Climate Resilience Toolkit. This tool can be used to assess the probability and magnitude of impact for identified risks. The risk of coincident climate stressors/risks (such as storm surge plus increased precipitation) can also be assessed, as applicable.



List assets and components of the design project below. For each asset, rank the Probability of a Loss as high, medium, or low in column B. In column C, rank the Magnitude of the potential Loss. Once your table is complete, use the rankings to place each asset in the appropriate section of the Risk Characterization Matrix.

Most Vulnerable Assets	**Probability of a Loss (high, med, low)**	**Magnitude of the Loss (high, med, low)**

Risk Characterization Matrix

Probability of a loss >

🟧	🟥	🟥
🟨	🟧	🟥
🟩	🟨	🟧

Magnitude of (potential) loss >

Relative Risk
🟩 Low
🟨 Medium
🟧 High
🟥 Very High

Figure 14 - Example of a climate change risk matrix (adapted from U.S. Climate Resilience Toolkit)

Project teams can determine the magnitude of the impact (along the horizontal scale of 1 through 3, with 3 being the most severe) and the probability/likelihood of occurrence for each specific risk (along the vertical scale, with 3 being the most likely). A score is typically assigned for each risk (Probability x Magnitude) and then charted on the matrix. Based on the estimated probability and magnitude of consequence above, the risks are ranked and prioritized for mitigation. Factors to bear in mind include:

- Not all facility typologies have the same level of functional and operational importance during events or tolerance for disruption.
- Not all climate stressors and risks have the same level of impact on each project site.
- Not all identified risks can or should be mitigated fully.

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