Climate Resiliency Checklist

Introduction

Climate change is already manifesting tangible impacts on infrastructure, buildings, and people. Projections suggest that these impacts will only intensify over time, with evidence of rising sea levels, increased coastal and urban flood risks, and extreme heat, all of which bear serious implications for our campus community and operations.

Brown University is deeply committed to mitigating climate impacts and adapting its facilities and buildings to enhance community resilience. To fulfill this commitment, we have developed the Climate Resiliency Checklist, a comprehensive planning tool designed to address climate-related risks. The tool serves to:

(i) evaluate how climate change will impact new constructions and existing buildings, and

(ii) integrate climate resilience and adaptation strategies into our planning and development processes accordingly.

All Category 1 (new projects) and Category 2 (major renovations) initiatives must complete and submit this Climate Resiliency Checklist. The Project Planning and Design Team is required to provide full information on the project, building envelopes, energy loads, and climate change impacts such as extreme heat, precipitation, sea level rise, and extreme wind.

Through this measure, Brown University is taking crucial proactive steps toward building a resilient campus and community that can withstand and thrive amidst present and future challenges. This checklist will be a living document and is intended to be updated at each projects stage.

Please refer to the Appendix section for studies on future climate change-related risks associated with extreme heat, flooding, wind, and hurricanes.

Contents:

Contributors:

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A. Project Information

1. Project Name:	
2. Project Address:	
3. Scope of work:	
4. Project Phase:	☐ Planning ☐ Concept ☐ Schematic Design (SD) ☐ Design Development (DD) ☐ Construction Documentation (CD) ☐ Construction ☐ Certificate of Occupancy

5. Project Team:	
a) Architect:	
b) Construction Manager:	
c) MEP Engineer:	
d) Civil Engineer:	
e) Landscape Architect:	
f) Sustainability Consultant:	
g) Energy Analyst:	
h) Code Consultant:	
i) Other:	

6. Project Description:	
a) List the principal uses/program of the building:	
b) List basement uses / program (if applicable):	
c) List the uses/program of the first floor:	
d) List any critical site infrastructure and/or building uses that may be vulnerable to utility outages, flooding, etc. (Example: vivarium, refrigeration rooms, etc.):	

8. Site and Building:	
a) Site area (sq. ft.):	
b) Building gross area (sq. ft.):	
c) Building height to parapet (ft):	
d) Number of floors:	
e) Existing site elevation – Low (ft. NAVD88):	
f) Existing site elevation – High (ft. NAVD88):	
g) Proposed site elevation – Low (ft. NAVD88):	

h) Proposed site elevation – High (ft. NAVD88):	
h) Proposed first-floor elevation – High (ft. NAVD88):	
h) Below grade levels (number of floors):	

9. Sustainability Benchmarking:	
a) LEED-Equivalent Certification Goal:	
b) LEED-Equivalent version:	
c) LEED- Equivalent Certification status:	
d) Other third-party certifications being pursued (Passive House, ILFI, WELL, WEDG, etc.):	

10. Building Envelope:		
The purpose of collecting building envelope information is to determine the ability of the building to maintain acceptable thermal conditions in the absence of active heating and cooling systems.		
a) Below-grade assemblies and roof: When reporting R-values, differentiate between R-discontinuous and R-continuous. For example, use "R13" to show R13 discontinuous and use R10c.i. to show R10 continuous. When reporting the U value, report the total assembly U value including supports and structural elements.	Foundation wall (R-value):	
	Exposed floor (R-value):	
	Slab edge (at or below) (R-value):	
	Roof (R-value):	

b) Vertical above-grade assemblies: Report percentages of the total vertical area; the total should add up to 100%.	Average overall window-to-wall ratio (WWR):	
	Average overall U-value for glazing assemblies:	
	Average glazing SHGC:	
c) Provide a narrative describing any measures that were / will be pursued to enhance the building's ability to maintain thermally acceptable indoor conditions, during the annual hottest and coldest periods, in the absence of active cooling and heating systems. Describe how the thermally acceptable criteria were determined.:		

11. Energy Loads and Performance:	
This information is requested to determine the building's critical loads and dependencies on district utilities, to identify appropriate alternatives if necessary.	
a) Describe how energy loads & performance were determined:	

b) Annual Energy Usage	1) Annual Total Electricity Demand (MMBtu):	
	2) Annual Total Natural Gas Demand (MMBtu):	
	3)Annual Total Chilled Water Demand (MMBtu):	
	4) Annual Total Steam Demand (MMBtu):	
c) Peak Electric (kW)		
d) Peak Heating (MMBtu)		
e) Peak Cooling (Tons)		
f) Energy Use – Below current RI Code (%):		
g) Have the infrastructure requirements been reviewed and are adequate/available?	☐ RIE ☐ NBC ☐ DIS ☐ DPW	
h) Energy Use Intensity (kBtu/SF)		

12. Emergency and Critical System Loads:	
a) Provide a narrative outlining vulnerable operations/program:	

b) List critical spaces and functions	
c) Critical Electric demand (kW)	
d) Critical heating demand (MMbtu/hr)	
e) Critical Cooling (Tons/hr)	

13. Utility Service Reliability:	
a) Which of the following district utilities are expected to support building operations:	☐ Steam ☐ Chilled Water ☐ Natural Gas ☐ Domestic Water ☐ Electricity ☐ Low Voltage Systems ☐ Municipal Sewers ☐ Municipal Stormwater Drains ☐ Combined Sewers
b) What are the failure risks associated with each applicable utility service based on current conditions and any known failure events in the past? Describe proposed backup alternatives for those utility services, which have a high failure risk:	

14. Proposed Back-up / Emergency Power Systems:	
a) Number of generators	
b) Electrical generation output total (kW)	
c) System type (natural gas vs. diesel) (kW)	
d) Fuel Source	
e) Roll-up generator connection:	☐ Yes ☐ No

B. Extreme Heat Events

Since 1970 average annual temperatures across the Northeast have risen by more than 2°F, and winter temperatures have risen by around 4°F. By the end of the century, the average annual temperature could be 56°F (compared to the current 46°F), and the number of days above 90°F (currently about 10 a year) could rise to as much as 90. These temperature increases are expected to have an impact on occupant health and comfort as well as the design of the space conditioning systems. This section requests information to enable proactive planning to mitigate the anticipated impacts of these future heat risks.

Please refer to the Appendix for future climate studies for Providence, RI, which are based on WeatherShift™ data for the year 2060 and include two Representative Concentration Pathway (RCP) scenarios: RCP 4.5 and RCP 8.5. RCPs portray future greenhouse gas emissions; RCP 4.5 scenarios predict a peak in global emissions by 2040 before a decline whereas RCP 8.5 predicts rising emissions till the end of the 21st century.

1. Basis of Design Conditions:	
a) Heating Condition Temperature (Deg.):	
	The above is based on: ☐ ASHRAE 2021: 8.1°F ☐ RCP 4.5 – 2060: 15.3°F ☐ RCP 8.5 – 2060: 16.5°F ☐ Other:
b) Cooling Condition Temperature (Deg.):	
	The above is based on: ☐ ASHRAE 2021: 8.1°F ☐ RCP 4.5 – 2060: 15.3°F ☐ RCP 8.5 – 2060: 16.5°F ☐ Other:

2. What Extreme Heat Event characteristics will be used for project planning:	
a) Estimated number of annual hours above 90°F:	☐ 44 (Typical Meteorological Year- TMY 3) ☐ 112 (RCP 4.5 – 2060) ☐ 166 (RCP 8.5 – 2060) ☐ Other:
b) Number of annual hours above 100°F:	
c) Number of heatwaves per year (a heatwave is a period when the heat index is forecast to reach 95°F for any amount of time on two or more consecutive days or 100°F for any amount of time on a single day):	
d) Average Duration of heatwave (days):	

3. Extreme Heat – Adaption Strategies:	
a) Describe all proposed building and site measures to reduce the heat-island effect at the project site and in the surrounding area:	

b) Describe how the building and its systems will be adapted to efficiently manage future average temperatures, higher extreme temperatures, additional annual heatwaves, and longer heatwaves:	
c) Describe all mechanical and non-mechanical strategies that will support building functionality and use during extended interruptions of utility services and infrastructure including proposed and future adaption measures:	

C. Extreme Precipitation Events

From 1958 to 2010, there was a 70 percent increase in the amount of precipitation that fell on the days with the heaviest precipitation. Currently, the 10-year, 24-hour design storm precipitation level is 4. 9". There is a significant probability that this will approximately increase to at least 6" by the end of the century. This predicted increase in precipitation levels and frequency can cause significant stress on the stormwater management capabilities of the building and municipal systems, which could cause flooding and damage to critical equipment in vulnerable locations. This section seeks information to help plan for future flood risks and reduce anticipated damage.

1. Extreme Precipitation – Design Conditions:	
a) Which 10-year, 24-hour design storm condition will the project be designed for:	☐ Current = 4.9" ☐ Future = 6"
c) Describe all proposed building and site measures for reducing stormwater runoff:	

2. Extreme Precipitation – Adaptation Strategies:	
a) Describe how site and building systems will be adapted to efficiently accommodate future rain events (e.g. rainwater harvesting, on-site stormwater retention, bioswales, green roofs):	

D. Sea Level Rise and Storms

Under any plausible greenhouse gas emissions scenario, sea level in Providence will continue to rise throughout the century. This will increase the number of buildings in Providence susceptible to coastal flooding and the likely frequency of flooding for those already in the floodplain.

a) Is any portion of the site in a FEMA special Flood Hazard Area (SFHA)?	☐ Yes ☐ No	
	What Zone?	
	Current FEMA SFHA Zone Base Flood Elevation:	
b) Is any portion of the site in Providence, RI Sea Level Rise – Flood Hazard Area? Use the STORMTOOLS Design Elevation (SDE), Rhode Island (arcgis.com) online tool to assess the susceptibility of the project site:		

If you answered YES to either of the above questions, please complete the following questions:	
Identify immediate and future adaption strategies for managing the flooding scenario represented on STORMTOOLS Design Elevation (SDE) risk screening tool. The sea level rise – design flood elevation is determined by adding either 24" of freeboard for critical facilities and infrastructure and any ground floor residential units OR 12" of freeboard for other buildings and uses: STORMTOOLS Design Elevation (SDE), Rhode Island (arcgis.com) Advanced STORMTOOLS (arcgis.com)	

a) Sea level Rise – Base Flood Elevation (ft NAVD88):	
b) Sea Level Rise – Design Flood Elevation (ft NAVD88):	
c) First Floor Elevation (ft NAVD88):	
d) Site Elevations at Building (ft NAVD88):	
e) Accessible Route Elevation (ft NAVD88):	
f) Describe site design strategies for adapting to sea level rise including building access during flood events, elevated site areas, hard and soft barriers, wave / velocity breaks, storm water systems, utility services, etc.:	

g) Describe how the proposed building design flood elevation will be achieved including dry/wet floodproofing, critical systems protection (e.g. elevators, generators, switchgear, transformers, basement waterproofing), utility service protection, temporary flood barriers, waste and drain water backflow prevention (backwater valves), etc.:	
h) Describe any potential risks due to the failure of the Fox Point hurricane barrier:	

i) Describe how occupants (including animals) might shelter in place during a flooding event including any emergency power, water, and wastewater provisions and the expected availability of any such measures. A) For research facilities with Vivarium, elaborate on specific resilience measures	
j) Describe any strategies that would support rapid recovery after a weather event:	

2. Sea Level Rise and Storms – Adaptation Strategies:	
1) Describe future site design and or infrastructure adaptation strategies for responding to sea level rise including future elevating of site areas and access routes, barriers, wave/velocity breaks, stormwater systems, utility services, etc.:	
2) Describe future building adaption strategies for raising the Sea Level Rise Design Flood Elevation and further protecting critical systems, including permanent and temporary measures:	

E. Wind Risks

The increasing severity of hurricanes and winds could pose severe safety risks to the building and its occupants.

a) Identify potential vulnerabilities due to high winds (uprooted trees, unsecured signage and canopies, unsecured railings, doors or windows, envelope risks, etc.):	
b) Provide a narrative on safety measures to address these vulnerabilities	

Appendix:

1. Extreme heat

This section includes future climate studies for Providence, RI, which are based on WeatherShift™ data for the year 2060 and include two Representative Concentration Pathway (RCP) scenarios: RCP 4.5 and RCP 8.5. RCPs portray future greenhouse gas emissions; RCP 4.5 scenarios predict a peak in global emissions by 2040 before a decline whereas RCP 8.5 predicts rising emissions till the end of the 21st century.

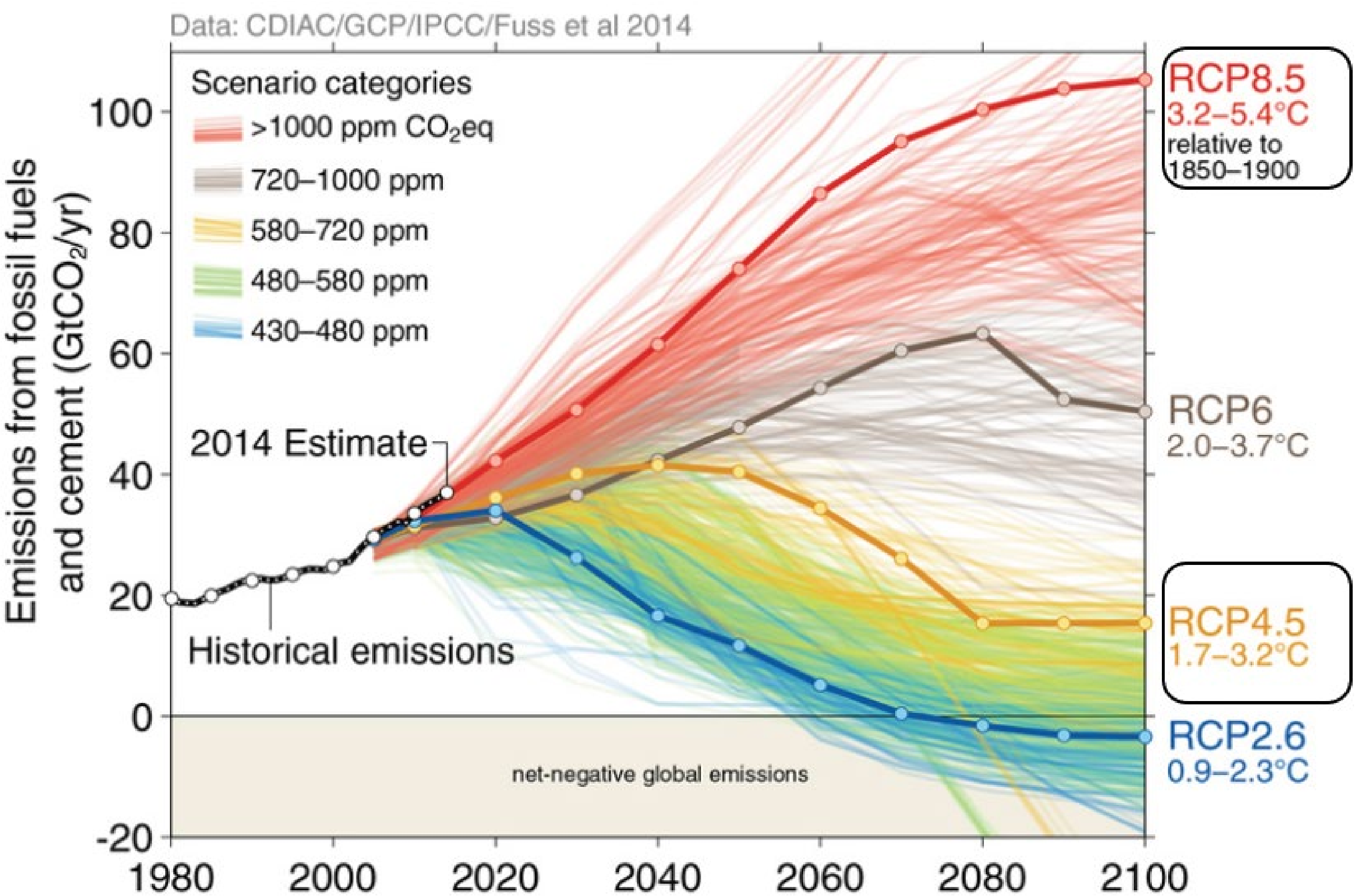

Figure 1: Representative Concentration Pathways (RCPs)

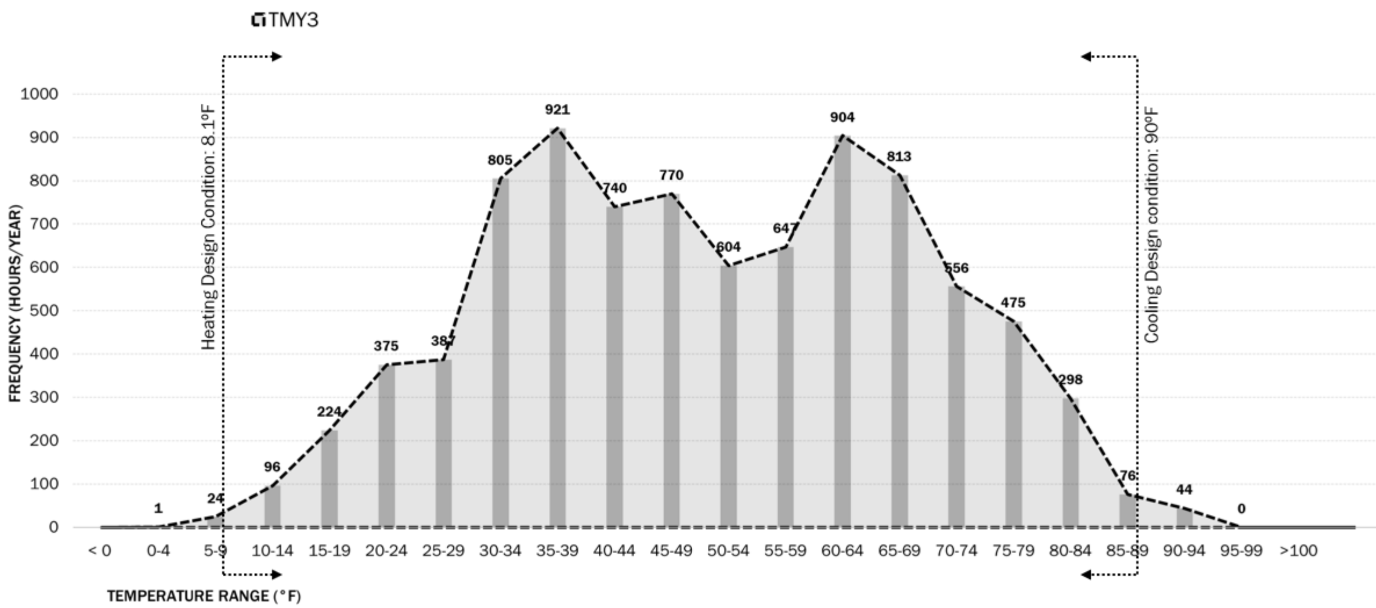

Figure 2: Current frequency of annual hours within specific temperature ranges.

- This is based on the Typical Meteorological Year (TMY3) weather file for Providence, RI.

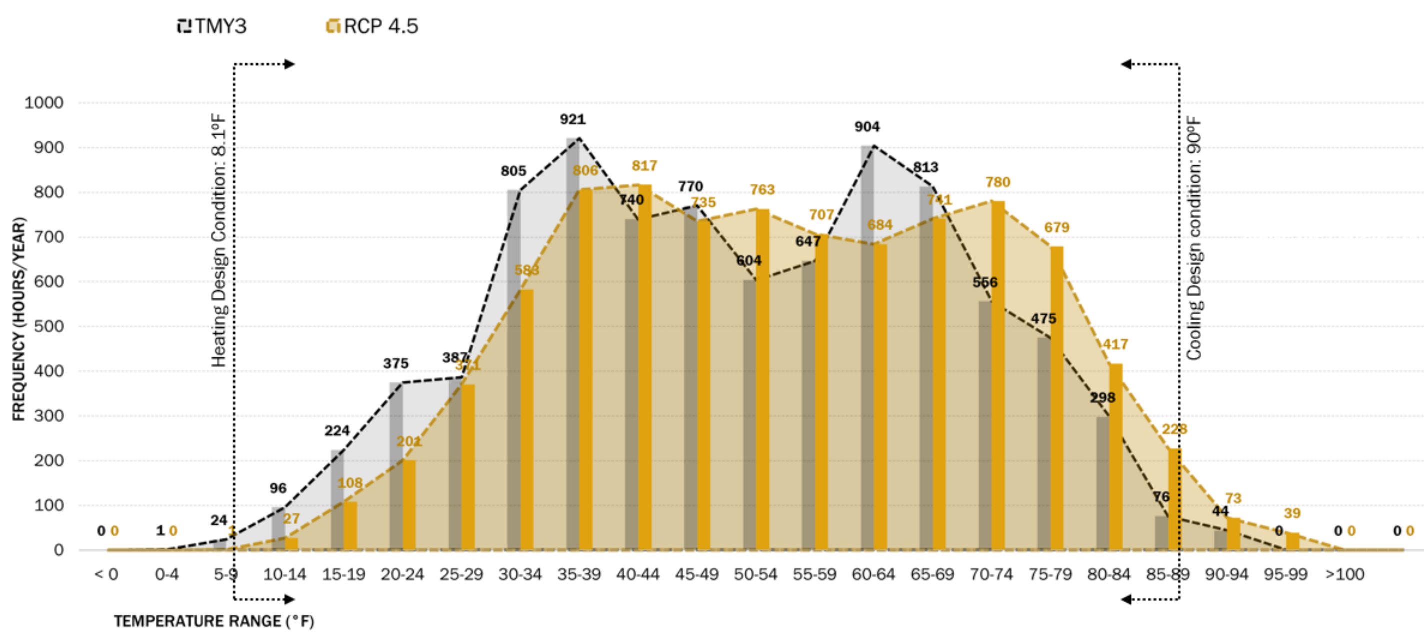

Figure 3: Frequency of annual hours within specific temperature ranges in the year 2060.

- This is based on the WeatherShift™ data for the RCP 4.5 scenario for Providence, RI.
- A 154% increase in the number of hours above the current ASHRAE 2021 cooling design condition is observed.

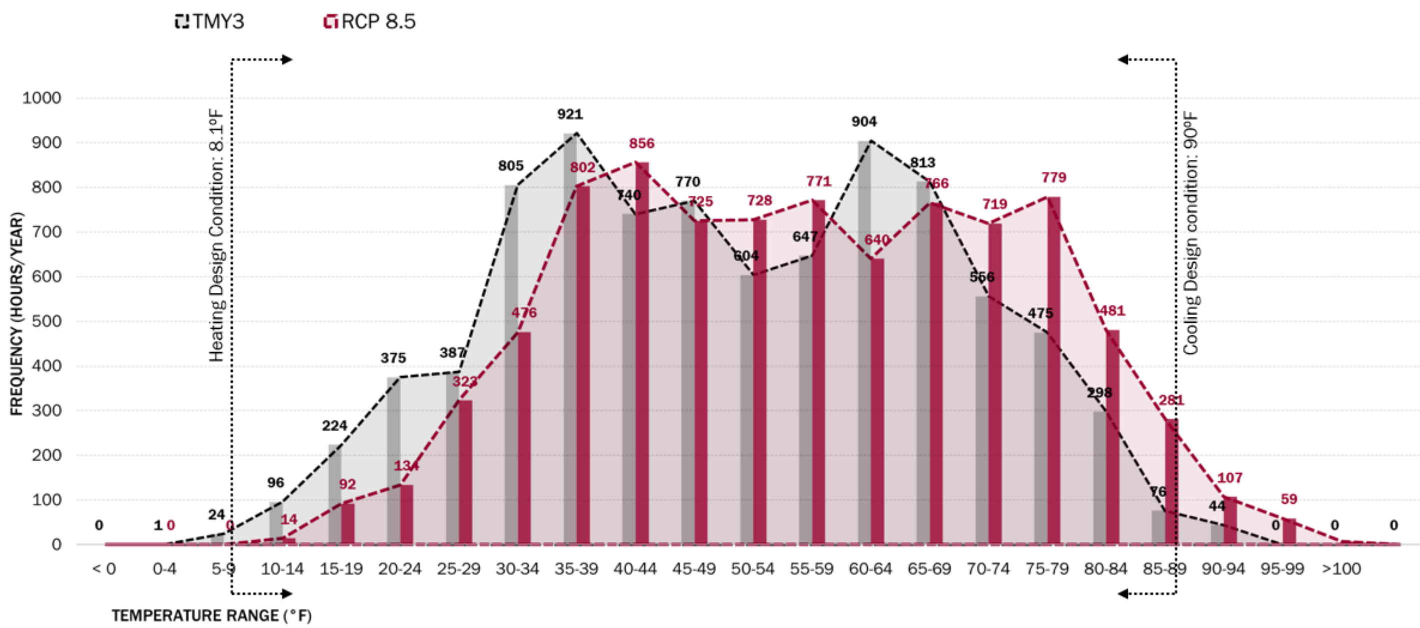

Figure 4: Frequency of annual hours within specific temperature ranges in the year 2060.

- This is based on the WeatherShift™ data for the RCP 8.5 scenario for Providence, RI.
- A 277% increase in the number of hours above the current ASHRAE 2021 cooling design condition is observed.

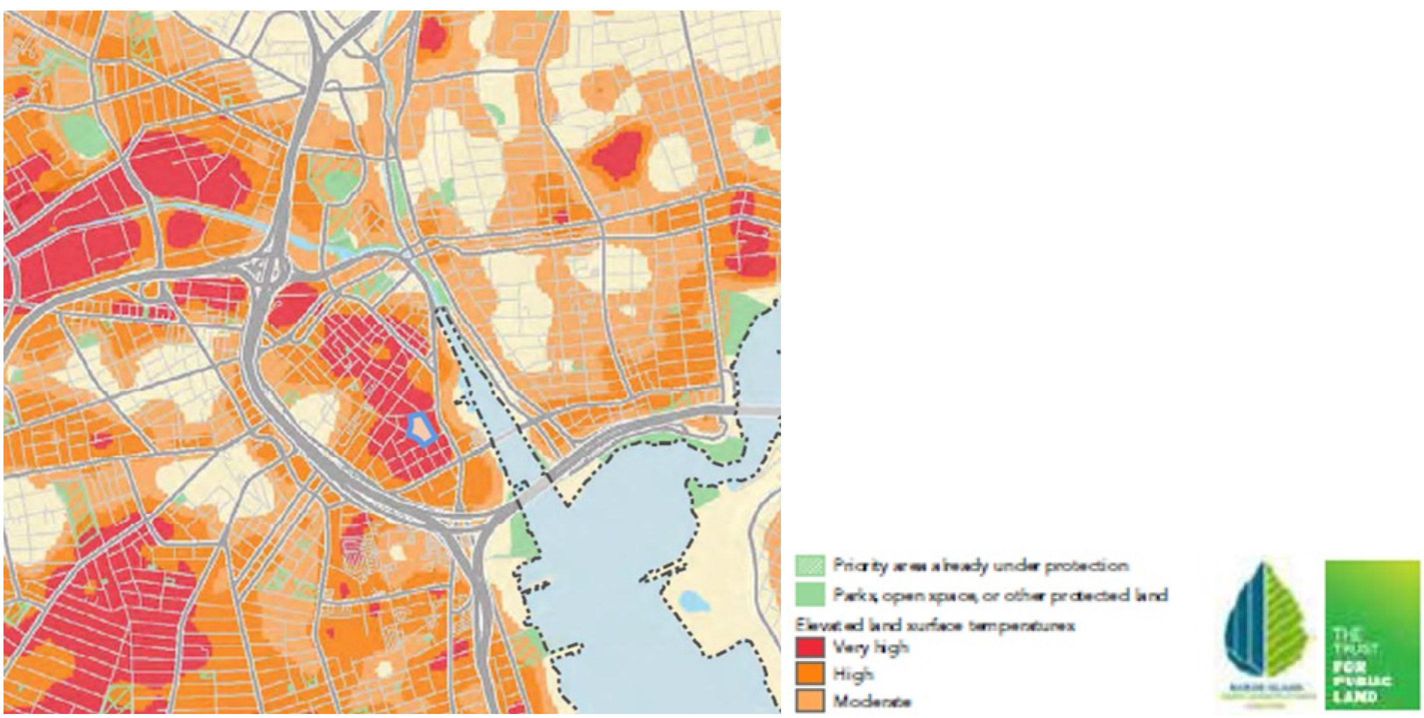

Figure 5: Urban Heat Island Effect, Providence, RI

2. Flooding and Sea-Level Rise

As part of the National Flood Insurance Program (NFIP), the federal government provides Flood Insurance Rate Maps (FIRM) to municipalities that agree to regulate development in high-risk flood areas. The maps identify flood-prone areas that form the basis for the federally backed flood insurance rates. A FIRM is an official map on which FEMA has delineated both the special flood hazard areas (SFHA) and the lower risk premium zones applicable to the community. SFHAs depict areas subject to the 1% annual chance flood (or base flood). The A and V zones are designated as SFHAs on the maps. Lower risk areas, 0.2% annual chance flood, are displayed to demonstrate the extent of potential flooding.

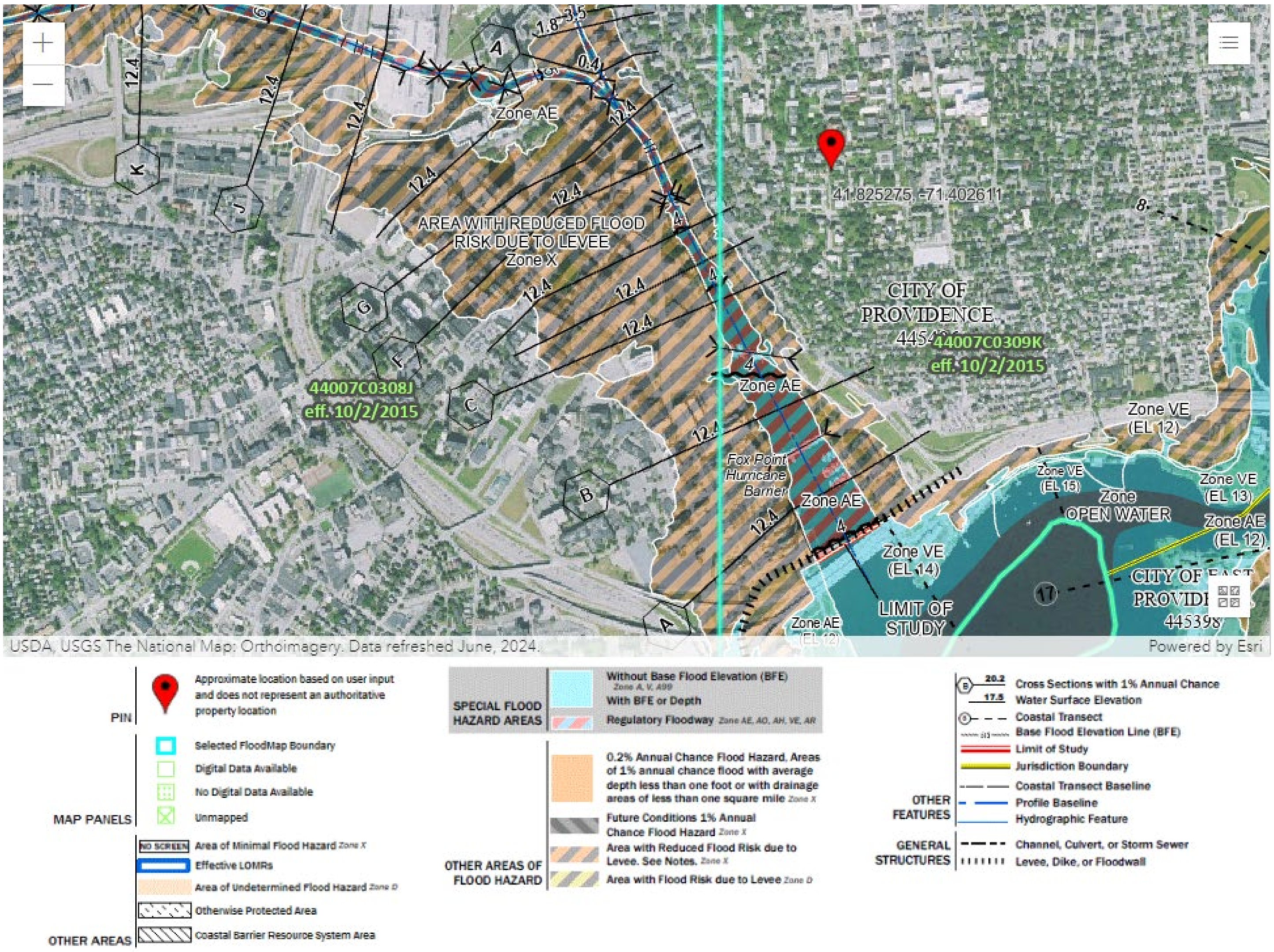

Figure 6: FIRM for Providence, RI.

- Some areas within the Brown University campus are within regions identified with reduced flood risk, while most of the campus does not have major flood risks.
- It is observed that the Fox Point Hurricane Barries (levee) reduces the flood risk along the Providence River.

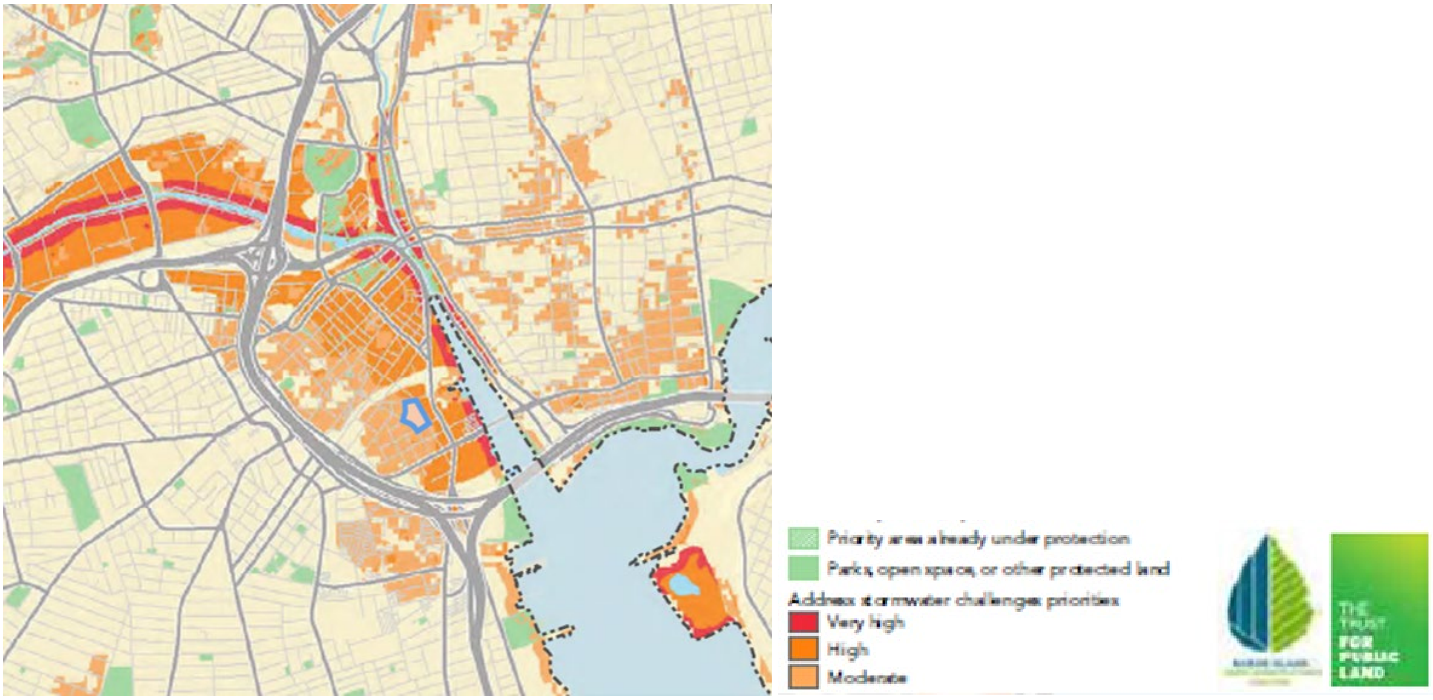

Figure 7: Stormwater burden map.

3. Wind

It is observed that portions of the Brown University campus lie in a Hurricane inundation zone for worst-case hurricanes (category 4: 130-156 mph wind speed), striking the coast of Rhode Island.

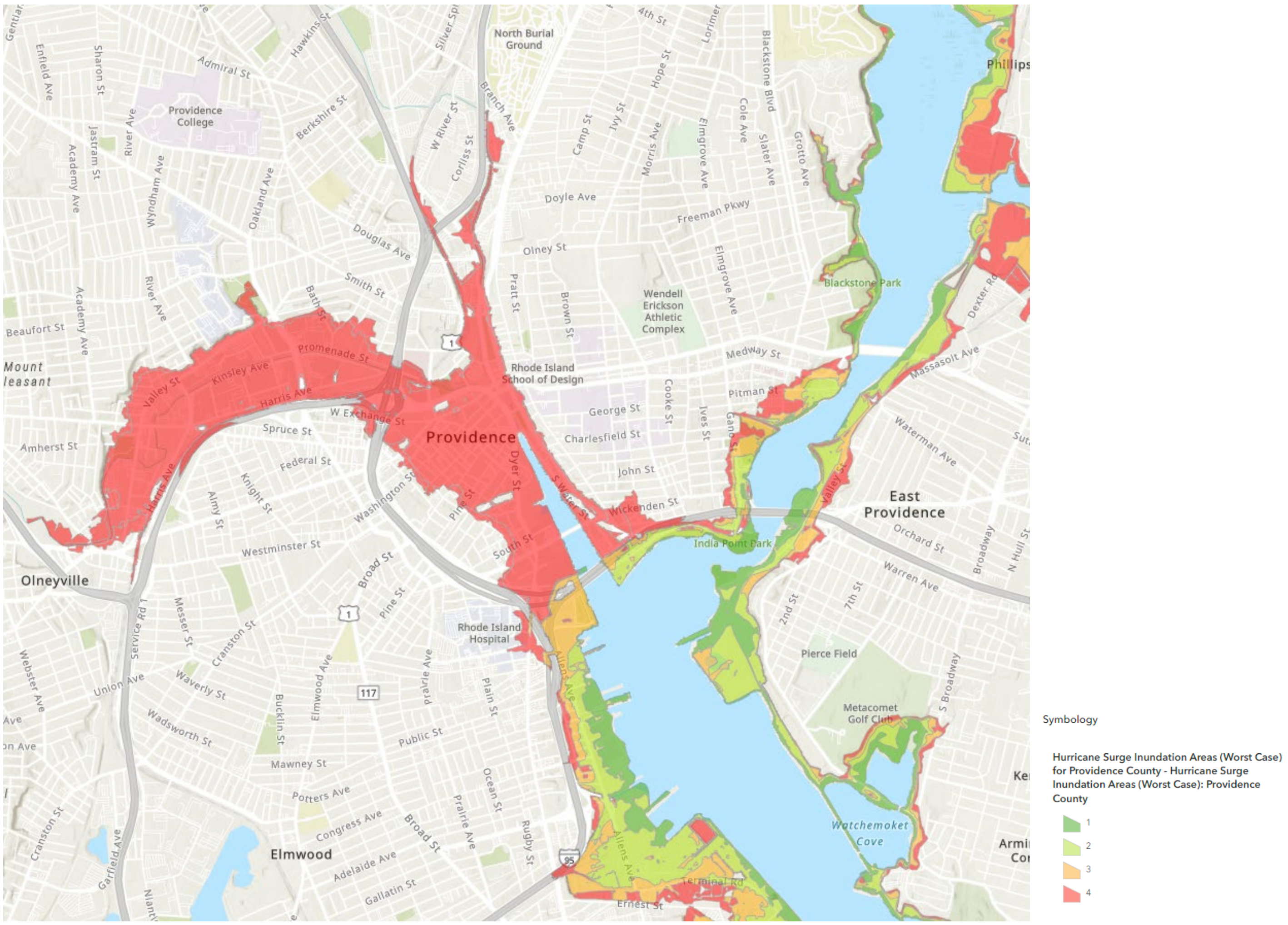

Figure 6: Hurricane Surge Inundation Areas in Providence, RI

4. Glossary

1. 1% Annual Chance Flood: also known as the 100-Year Flood and the Base Flood. Defined by FEMA as a flood with a 1% annual chance of occurring or being exceeded. FEMA Flood Insurance Rate Maps delineate the horizontal extent of the Base Flood, along with its corresponding Base Flood Elevations.
2. 100-Year Floodplain: the boundary of a flood that has a 1% annual chance of occurring or being exceeded. Also referred to as Special Flood Hazard Areas (SFHA) on FEMA Flood Insurance Rate Maps.
3. Adaptation: changes that respond to anticipated environmental risks.
4. Base Flood Elevation (BFE): defined by FEMA as the top of water elevation projected for a specified flooding scenario. BFEs listed on FEMA Flood Insurance Rate Maps are based on the 1% Annual Chance Flood.
5. Building Flood Proof Elevation: a BPDA term for the height below which water will not enter the building, including above and below grade building conditions.
6. Critical Facilities and Infrastructure: defined by FEMA as a facility where even a low risk of disruption would constitute a severe threat. FEMA includes hospitals, fire stations, police stations, critical record storage facilities, and similar structures within this scope. The American Society of Civil Engineers also includes facilities related to energy, water, transportation, communication systems, and natural and virtual resources within their definition of critical facilities.
7. Design Flood Elevation (DFE): defined by FEMA as the height of the lowest occupiable floor (when wet floodproofing), or the height of the lowest structural member of an inhabitable floor (when elevating a building). The DFE is separated from the BFE by freeboard.
8. Federal Emergency Management Agency (FEMA): manages the federal government's response to natural and manmade disasters. FEMA also manages the NFIP and produces Flood Insurance Rate Maps (FIRM).
9. Flood Insurance Rate Map (FIRM): maps produced by FEMA that delineate the borders of the 100-year floodplain and corresponding Base Flood Elevations. The flood projections shown on FIRMs are based on historic data, and do not include factors related to future sea level rise.
10. Floodproofing: defined by FEMA as structural or non-structural interventions that reduce flood damage to a space or a building.
11. Freeboard: defined by FEMA as a factor of safety, or a buffer between predicted flood levels and a building's lowest occupiable floor. In other words, the distance between the SLR-BFE and the SLR-DFE.
12. North American Vertical Datum of 1988 (NAVD88): an elevation datum created by the National Geodetic Survey typically used for coastal water heights.
13. Resilience: the ability of a system to prepare for, withstand, and recover quickly from a disaster. Ideally, resilient systems should recover from an event by becoming stronger than they were prior to the stress.
14. Sustainability: Meeting the needs of the present without compromising the ability of future generations to meet their own needs. UN Brundtland Commission