NOVEMBER 15TH, 2016

CLIMATE ADAPTATION PLAN

CLIMATE CHANGE ADAPTATION PLAN FOR THE DISTRICT OF COLUMBIA

PREPARED FOR

WE ARE WASHINGTON DC

DEPARTMENT OF ENERGY & ENVIRONMENT

SUSTAINABLE DC

PREPARED BY

PERKINS +WILL

KLEINFELDER

ACKNOWLEDGMENTS

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CONTENTS

LIST OF TABLES, MAPS AND FIGURES

TABLES

MAPS

FIGURES

EXECUTIVE SUMMARY

Project Description

The District of Columbia has seen stark examples of the risks posed by climate change including record-breaking heatwaves and flooding driven by heavier rain events and rising sea levels. In 2012, the District narrowly escaped the devastation of Hurricane Sandy. Recognizing the potential negative impacts of climate change, the Sustainable DC Plan, the District's comprehensive sustainability plan adopted in 2013, called for the District to increase its resilience to future climate change through physical adaptation and human preparedness.

In order to evaluate potential climate risks and identify adaptation solutions, in 2014, the District Department of Energy & Environment (DOEE), commissioned a study of the projected climate change impacts for the District, the vulnerabilities stemming from those projections and recommended future adaptation strategies that might begin to address those vulnerabilities. The previously published reports on the climate and its resulting vulnerabilities are the precursors to this report which focuses on climate adaptation strategies. For a detailed explanation of projected changes and the data behind the analysis, see Task 1 Report Climate Projections and Scenario Development[1] and Task 2 Report Vulnerability and Risk Assessment[2]. This report, Task 3 Climate Adaptation Plan, completes the study.

Task 1 Climate Projections and Scenario Development Results

The Task 1 Climate Projections and Scenario Development report shows that the District will experience significant changes in its climate over the next 65 years. Based on the climate projections, the most significant impacts for the District will be increased heat, more frequent and severe heavy precipitation events, and rising sea levels.

The team compared three planning horizons — the 2020s, 2050s, and 2080s — against the baseline conditions of 1981-2000. High and low greenhouse gas emission scenarios were also used. As expected, the higher emission scenario yielded more significant increases in temperatures and precipitation-driven flooding than was observed with the lower emission scenarios, which accounts for the range of results in the following trends:

- Annual average and summer temperatures are expected to increase in future years. Heat waves will become more intense and have a longer duration. In the past, there has been an average of 11 days per year exceeding 95°F. Projections indicate an average of 18-20 days per year by 2020, 30-45 days the 2050, and as much as 40-70 days per year by 2080.
- The frequency and intensity of extreme precipitation events are expected to

1. Task 1 Report - Climate Projections & Scenario Development, September 10, 2015. http://doee.dc.gov/publication/climate-projections-scenario-development
2. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness

increase in future years. This change in precipitation patterns with more intense storms of shorter duration will add stress to infrastructure and increase the likelihood of flooding.

- Sea level rise is expected to continue, and even accelerate in the future due to climate change. Relative sea level rise projections range from 0.6 to 1.9 feet by 2050 and 0.9 to 3.8 feet by 2080.

Task 2 Vulnerability and Risk Assessment Results

With this context in mind, the vulnerability and risk assessment was based on the climate change projections and scenarios established in the Task 1 Climate Projections and Scenario Development Report using increased heat, increased precipitation and sea level rise/ storm surge projections to conduct a "stress test" on the District's infrastructure and resources. The key findings from the Task 2 Vulnerability and Risk Assessment Report are:

- Wards 7 and 8 are home to the largest number of residents with a higher vulnerability to climate change impacts – especially an increase in extreme heat – due to socioeconomic factors that increase sensitivity to heat and limit the ability to adapt including unemployment, age (seniors and young children), level of education and poverty.
- Major infrastructure assets such as electric substations and Metrorail are at-risk to increased heat and flooding by 2020 or 2050; their failure could have significant regional impact as businesses, governments, and residents in a dense urban environment who rely on energy supply and public transportation for day-to-day life.
- Surface flooding from inland precipitation events may pose as much risk as flooding associated with sea level rise and storm surge – especially in the near term.
- Areas of risk to flood and extreme heat are not evenly distributed throughout the District; but instead are concentrated near particular water bodies (i.e., The Watts Branch tributary to the Anacostia River) or areas with a large number of highly vulnerable residents that will not only be more at risk of exposure to climate impacts, but are also likely to have less means to adapt or be resilient to flooding or heat stress.
- Under existing conditions, the District is already vulnerable to flooding along the Potomac and Anacostia Rivers as documented by repetitive flooding of areas (reported by stakeholders) and the Federal Emergency Management Agency's (FEMA) 100-year flood map.

The combined impact of increased precipitation, sea level rise (SLR) and storm surge in the future will require reconsidering the delineation of the current 100-year and 500-year floodplain boundaries to reflect the high probability of increased flooding risks in the future.

- Taking into account the unique geography of the District; as it is bounded by the Potomac River and is bisected by the Anacostia River; bridges provide vital connections within the District and through surrounding states. Their possible failure, due to flooding impacts, would have significant implications on the functioning of the larger regional transportation network. Key bridges have been potentially identified as at risk in this assessment, such as the 14th Street Bridges[3] that span the Potomac River. It is recommended that a more detailed vulnerability assessment be performed for key bridges spanning the Potomac and Anacostia rivers.

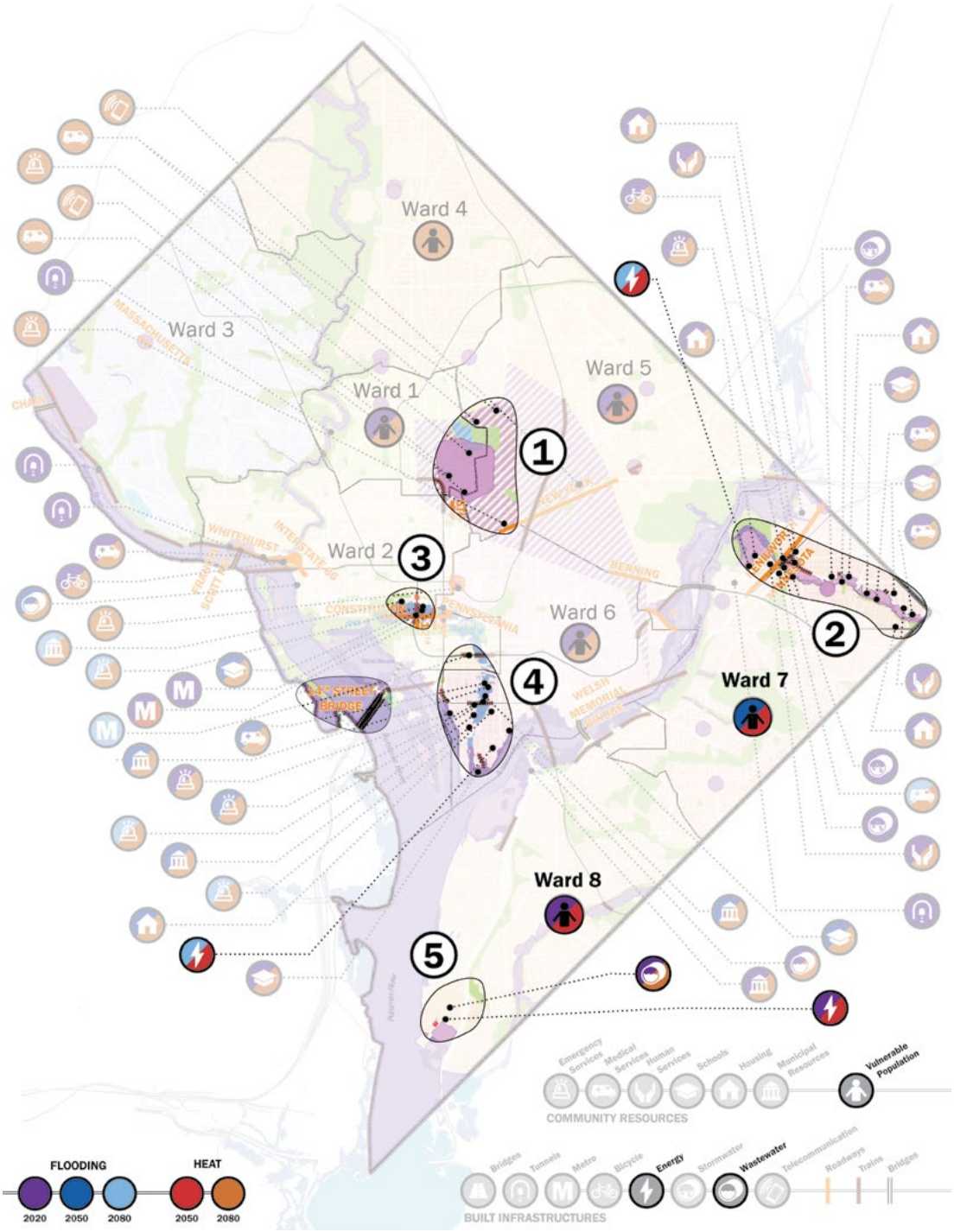
Since many of these risks to regional assets are not limited to the District's jurisdiction, adaptation will require coordination with other states, agencies, and organizations such as regional transportation agencies and energy providers.

The combined outputs of the assessment then drive the planning priority areas across the District. Within each planning priority area, key takeaways from the Task 2 Vulnerability and Risk Assessment Report are:

- **Priority Planning Area 1**: Includes the neighborhoods of Bloomingdale and LeDroit Park. Because this area has already experienced significant flooding due to the limited capacity of the existing stormwater management systems, the projected increase in frequency and severity of extreme precipitation elevates these neighborhoods to a high-risk level. Ongoing efforts to expand the capacity of the stormwater system capacity in the area, including DC Water's Northeast Boundary Tunnel and interim McMillan Stormwater Storage Project will significantly reduce this risk, but not for the most extreme events.
- **Priority Planning Area 2**: This area around the Watts Branch, a tributary to the Anacostia River, is currently at risk of flooding, and is projected to be at increased risk as early as 2020. This area has a significant concentration of community resources at-risk, such as medical services and public housing, including the soon-to-redeveloped Kenilworth Courts development that serve vulnerable populations.

3. The 14th Street Bridge refers to the group of three highway bridges (Rochambeau, George Mason Memorial, Arlan Williams Memorial), a railroad bridge (Long), and a Metrorail Bridge (Fenwick Metro Transit) that span the Potomac.

- **Priority Planning Area 3**: This area includes the District's downtown area centered near the Federal Triangle neighborhood. These areas are already at risk of riverine, coastal and interior flooding which will be exacerbated by 2080. These areas have a significant concentration of built infrastructure, including a large concentration of professional businesses, cultural resources including the Smithsonian and National Mall; as well as Metrorail stations and other community resources, such as the John A. Wilson Building (city hall), and other DC agency headquarters. This area's roadway and transit systems also serve a large number of the District's transient population of commuters and tourists. Actions are already being taken to better protect this area from riverine flooding including upgrades to the 17th Street Levee and the greater Potomac levee system. It will however remain at risk to interior flooding, and by 2080 there will be an increased risk from riverine and coastal flooding due to rising sea level.
- **Planning Priority Area 4**: This area in Southwest DC extends from south of the Capitol to Buzzard Point and is primarily at risk of riverine and coastal flooding. This area is a mix of residential, commercial, government, and several large development projects and planning initiatives (The Wharf, Buzzard Point, DC United Soccer Stadium, etc). The area includes a variety of community resource facilities and infrastructure at risk of flooding, including public safety, public housing, human services, transit, energy and wastewater. Several public housing properties are located in Priority Area 4, including the Greenleaf properties that are scheduled to be redeveloped in the near future, and James Creek. Metrorail lines that cross through this area include the Green Line and Blue/Orange/Silver Lines.
- **Planning Priority Area 5**: This area along the Potomac River is at risk of flooding within 2020, 2050, and 2080 scenarios, which will impact a key electrical sub-station and the Blue Plains Advanced Wastewater Treatment Plant. A planned sea wall at Blue Plains, which is being designed to the current 500-year flood elevation plus three feet to account for sea level rise, will substantially reduce the risk to the plant, but not necessarily the surrounding areas.



MAP 1 Planning Priority Areas [4]

4. Task 1 Report - Climate Projections & Scenario Development, September 10, 2015 - http://doee.dc.gov/publication/climate-projections-scenario-development

Task 3 Climate Adaptation Plan

The District Climate Adaptation Plan follows the goals set out in the Sustainable DC Plan to "... advance physical adaptation and human preparedness to increase the District's resilience to future climate change." (Sustainable DC) The Adaptation Plan builds upon the work of the Task 1 Report which delineated the climate projections and scenario development as well as the Task 2 Report focused on the vulnerability & risk assessment as well as the work of other agencies that have ongoing efforts to develop mitigation and adaptation strategies.

The Task 3 Report Climate Adaptation Plan, establishes a framework around four sectors: Transportation + Utilities (TU), Buildings + Development (BD), Neighborhoods + Communities (NC) and Governance + Implementation (GI). Each of these is further explained below and subsequently acts as organizing principles for each set of actions.

- **Transportation + Utility Infrastructure**: Adapting and hardening energy, transportation, water, and telecommunications systems.
- **Buildings + Development**: Upgrading existing buildings and new construction/ development to address climate risks.
- **Neighborhoods + Communities**: Strengthening emergency preparedness and community, social and economic resilience.
- **Governance + Implementation**: Establishing cross-cutting policies, aligning plans, and monitoring progress.

The Task 3 Report Climate Adaptation Plan, should be read with the Climate Adaptation Master Action List. The narrative in the body of this report provides a high-level summary of the recommended actions, while the Master Action List provides more detail. The Climate Adaptation Master Action List Summary (Table 1) includes all top level recommended actions while the full list can be found in the appendix, the body of the report provides more detail.

	ACTION (SUB-ACTION)
TU – Transportation + Utilities Goal: Improve the transportation and utility infrastructure to maintain viability during periods of extreme heat, extreme weather and flooding.	
TU 1.0	**Develop site-level adaptation plans** for all transportation, energy, water & wastewater, telecommunications + data (internet) facilities, functions and service areas identified as at-risk from sea level rise and flooding based on the Vulnerability Assessment.
TU 2.0	**Increase the resilience of all types energy systems**
TU 3.0	**Increase Resiliency of both Potable and Non-Potable Water Systems**
TU 4.0	**Increase Resilience of Communication Systems**
TU 5.0	**Increase Resilience of Transportation Systems**
BD – Buildings & Development Goal: Upgrade existing buildings and design new buildings and development projects to withstand climate change impacts.	
BD 6.0	**Provide back-up power for emergencies at all indentified critical facilities. Ensure that existing back-up power systems are located above projected flood elevations.**
BD 7.0	**Improve thermal safety + indoor building temperatures to increase resilience to extreme heat, especially in the event of a power outage.**
BD 8.0	**Pursue deep energy and water efficiency for all buildings**
BD 9.0	**Incorporate Climate Resilience into Development Planning and Review Processes**
BD 10.0	**Leverage land-use planning to promote resiliency**
BD 11.0	**Provide incentives to encourage private property owners and developers to implement flood resiliency measures.**
BD 12.0	**ADDITIONAL BD ACTIONS**
NC – Neighborhoods & Communities Goal: Make neighborhoods and communities safer and more prepared by strengthening community, social, and economic resiliency.	
NC 13.0	**Improve emergency preparedness and planning with a particular focus on vulnerable populations.**
NC 14.0	**Reduce risks of extreme heat and the urban heat island**
NC 15.0	**Strengthen Community Cohesion for Safety + Resilience**
NC 16.0	**Develop Eco-Resiliency Districts and Community Resiliency Hubs**
NC 17.0	**ADDITIONAL NC ACTIONS**
GI – Governance & Implementation Goal: Establish the policies, structures, and monitoring and evaluation procedures to ensure successful implementation of the adaptation plan.	
GI 18.0	**Conduct additional analysis of climate vulnerability and adaptation strategies based on gaps identified in the reports associated with this larger study.**
GI 19.0	**Align Climate Adaptation Plan with related planning efforts including Hazard Mitigation, Comprehensive Land-Use, Comprehensive Energy, and Capital Budget Planning.**
GI 20.0	**Establish the necessary structures to ensure successful implementation of the Climate Adaptation Plan**

TABLE 1 Master Adaptation Action List (Short) – See Appendix for full version.

Next Steps

At this point, the DOEE team has engaged in multiple shared stakeholder conversations in order to advance its assessment as well as to contribute to others. These stakeholders include the:

- Architect of the Capitol (AOC)
- DC Housing Authority (DCHA)
- DC Office of Planning (DCOP)
- DC Water
- Department of General Services (DGS)
- Department of Health (DOH)
- Department of Housing and Community Development (DHCD)
- Department of Public Works (DPW)
- District Department of Transportation (DDOT)
- Department of Human Services (DHS)
- Georgetown Climate Center
- Homeland Security and Emergency Management Agency (HSEMA)
- Metropolitan Washington Council of Governments (MWCOG)
- National Capital Planning Commission (NCPC)
- National Park Service (NPS)
- Pepco
- Smithsonian Institution (SI)
- United States General Services Administration (US GSA)
- University of Maryland
- Washington Gas
- Washington Metropolitan Area Transit Authority (WMATA).

The next step is for DOEE to collaborate with the Lead and Partner agencies as identified per category in the Master Action List to:

- Develop the governance structure and partnerships with Lead and Partner agencies as well as stakeholders who have parallel climate adaptation efforts ongoing as well as infrastructure owners and operators.
- Establish a schedule for completion of remaining assessments noted herein while establishing metrics + evaluation approaches.
- Identify funding sources and Lead agencies for remaining assessments.
- Begin discussions regarding public/public-private financing and detailed implementation strategies.

PHOTO CREDIT: VICTORIA PICKERING. SUSTAINABLE DC, CLIMATE CHANGE PHOTO CONTEST

01

INTRODUCTION

The District of Columbia has seen stark examples of the risks posed by climate change including record-breaking heatwaves and flooding driven by heavier rain events and rising sea levels. In 2012, the District narrowly escaped the devastation of Hurricane Sandy. Recognizing the potential negative impacts of climate change, the Sustainable DC Plan, the District's comprehensive sustainability plan adopted in 2013, called for the District to increase its resilience to future climate change through physical adaptation and human preparedness.

In order to evaluate potential climate risks and identify adaptation solutions, in 2014, the District Department of Energy & Environment (DOEE), commissioned a study of the projected climate change impacts for the District, the vulnerabilities stemming from those projections and recommended future adaptation strategies that might begin to address those vulnerabilities. The previously published reports on the climate and its resulting vulnerabilities are the precursors to this report which focuses on climate adaptation strategies. For a detailed explanation of projected changes and the data behind the analysis, see Task 1 Comprehensive Climate Projections[5] and Task 2 Vulnerability and Risk Assessment[6]. This report, Climate Adaptation Plan, completes the study.

Report Organization

This report is organized to capture the results of the earlier work in Task 1 and Task 2 as well as to present the results of Task 3. To begin, it summarizes the climate projections and potential impacts from Task 1 by risk area. Within each risk, it then includes examples of the types of impacts to be expected with the risk and specific references to the District. These examples were drawn from both the results of Task 1 as well as the broader resources comparisons previously described. The Plan then summarizes the Vulnerabilities identified in Task 2. Following this, the Plan proper, Task 3, is organized by four sectors of recommended actions. Within each sector, there are tables identifying primary and supporting actions, referencing materials and Lead and Partner agencies. These tables comprise the Climate Adaptation Plan Master Action List.

5. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015. http://doee.dc.gov/publication/climate-projections-scenario-development
6. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness

PHOTO CREDIT: VICTORIA PICKERING. SUSTAINABLE DC, CLIMATE CHANGE PHOTO CONTEST

02

CLIMATE PROJECTIONS AND POTENTIAL IMPACTS

CLIMATE PROJECTIONS & POTENTIAL IMPACTS SUMMARY

Results from the Task 1 report include projections of the likely impacts of climate change for the District and recommended planning scenarios for the 2020s, 2050s, and 2080s. The District will experience significant changes in its climate over the next 65 years. Based on the climate projections, the most significant impacts for the District will be **increased heat, more frequent and severe heavy precipitation events, and rising sea levels**.

The team compared three planning horizons — the 2020s, 2050s, and 2080s — against the baseline conditions of 1981-2000 and two scenarios for this study: the higher RCP 8.5 scenario, where human emissions of carbon dioxide and other heat-trapping gases continue to rise, and the lower RCP 4.5 scenario, where emissions peak and then begin to decline by mid-century.[7] As expected, the higher emission scenario yielded more significant increases in temperatures and precipitation-driven flooding than was observed with the lower emission scenarios, which accounts for the range of results in the following impacts:

- **Impact #1**: Annual average and summer temperatures are expected to increase in future years. Heat waves will become more intense and have a longer duration. In the past, there has been an average of 11 days per year exceeding 95°F. Projections indicate an average of 18-20 days per year by 2020, 30-45 days the 2050, and as much as 40-70 days per year by 2080.
- **Impact #2**: The frequency and intensity of extreme precipitation events are expected to increase in future years. This

7. Greenhouse Gas Emission Scenarios– Scientific consensus is that climate change, caused by human activities, is occurring and will accelerate if GHG emissions continue to increase. There is still uncertainty, however in projecting the magnitude of future climate change. The primary drivers of these uncertainties at the global scale can be attributed to: (1) uncertainties in future greenhouse gas levels and other climate drivers which alter the global energy balance, such as aerosols and land-use changes, and (2) uncertainties in how sensitive the climate system, as reflected in the global climate models, will be to greenhouse gas concentrations and other climate drivers. In this assessment, the team addresses these uncertainties by relying on projections corresponding to a higher (RCP 8.5) and lower (RCP 4.5) scenario, based on simulations from nine different GCMs with different levels of sensitivity to carbon dioxide and other climate drivers. However, the actual emissions, and hence atmospheric carbon dioxide levels and global temperature, could rise above the higher scenario (if carbon emissions continue to increase at the rate they have since 2000, for example) or be cut to below the lower scenario (if carbon-free energy solutions are implemented rapidly at the global scale, for example). To help mitigate the uncertainties at a local scale the outputs from multiple weather stations were used in this study.

change in precipitation patterns with more intense storms of shorter duration will add stress to existing infrastructure and increase the likelihood of flooding.

- **Impact #3**: Sea level rise is expected to continue, and even accelerate in the future due to climate change. Relative sea level rise projections range from 0.6 to 1.9 feet by 2050 and 0.9 to 3.8 feet by 2080.

For detailed understanding of each of these impacts, see the Task 1 report[8].

For the development of the Climate Adaptation Plan and to contextualize these impacts more directly, the potential risks associated with of each impact are included in the following sections. These initial descriptors are drawn from previous work in a variety of sources.[9]

8. Task 1 Report - Climate Projections & Scenario Development, September 10, 2015. http://doee.dc.gov/publication/climate-projections-scenario-development
9. These initial descriptors are drawn from previous work in a variety of sources including Sustainable DC, the National Climate Assessment, the American Association for the Advancement of Science, the Lancet and Adapting for Climate Change – Draft A for City of Sydney.

Impact #1: Increased heat

Climate change will cause temperatures to rise in the District resulting in more frequent extreme heat days and longer, more frequent heat waves. Heat has been the largest single weather-related cause of death in the US since the National Oceanic and Atmospheric Administration (NOAA) began reporting data for heat in 1988. Due to climate change, the annual average, as well as summer temperatures, are expected to increase in future years in the District.

Impact #1: Increased Heat
The baseline, or historic conditions used are the years 1981-2000 which for summer daytime maximum temperatures average 87°F with nighttime minimum temperatures averaging around 66°F. These values are projected to increase 2.5-3°F by the 2020s, 5-7°F by the 2050s, and as much as 6-10°F by the 2080s.

In the past, as documented from 1991-2010, the District has been an average of 11 days per year when air temperatures exceeded 95°F. Projections indicate an average of 18-20 days with temperature exceeding 95°F by the 2020s, 30-45 days by the 2050s, and 40-70 days per year by the 2080s.

Extreme heat events are also projected to increase. A threshold of 95°F was chosen as the indicator of extreme temperature based on the District's Heat Emergency Plan. Heat waves, defined by the District as three or more consecutive days with daily maximum heat index values exceeding 95°F, will also become hotter and last longer.

This increase in dangerous heat events will impact infrastructure as well as people. Those most vulnerable to heat include the elderly, young children, those with respiratory issues, as well as outdoor workers and residents who do not have or cannot afford to operate air conditioning.

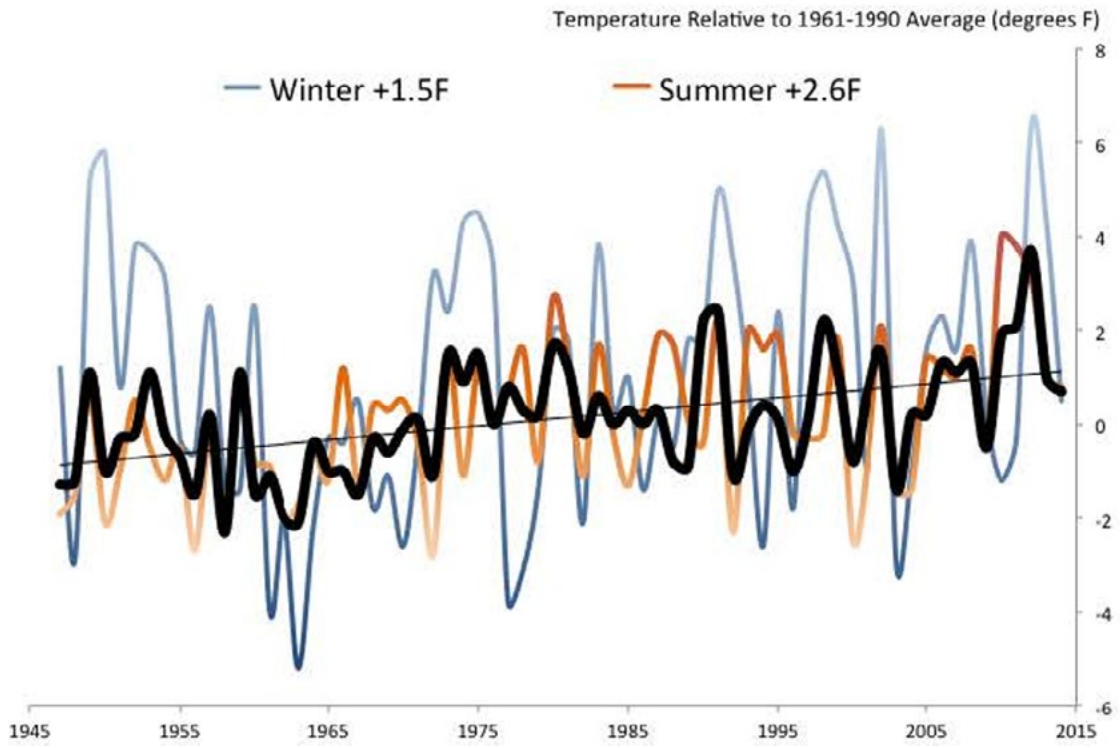


FIGURE 1 Observed change in average temperatures (in degrees F relative to the 1961-1990 average) for winter (blue), summer (orange) and annually (black) at Reagan Airport from 1947-2014.[10]

10. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015; Appendix A. http://doee.dc.gov/publication/climate-projections-scenario-development

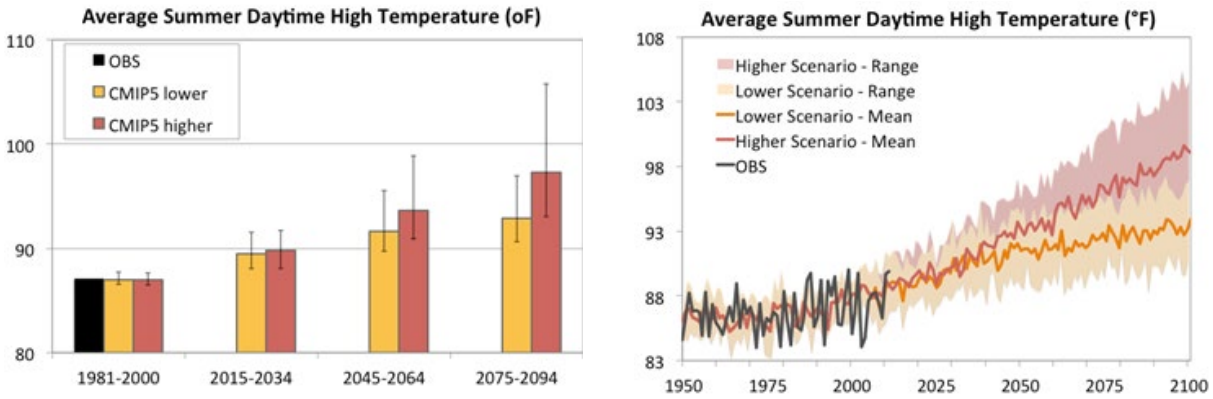


FIGURE 2 Historical and projected summer maximum or high temps used in this analysis under higher (red) and lower (orange) future scenarios.[11]

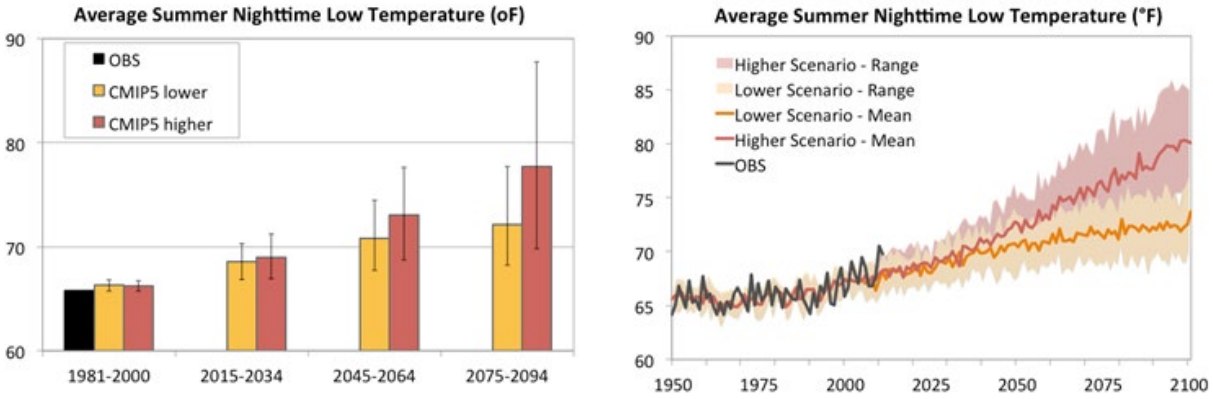


FIGURE 3 Historical and projected summer average nighttime minimum or low temps used in this analysis under higher (red) and lower (orange) future scenarios.[12]

11. For the bar charts, the uncertainty range, indicated by the thin vertical lines above and below each bar, encompasses the range of projections from the nine different global climate models used in this analysis. Each colored bar represents the average of 180 years of simulations, while each bar represents the average of 20 years of observations. For the time series plots, the solid colored lines indicate the multi-model average for each year while the shaded range encompasses the range of projections from the nine different global climate models. The solid black line indicates the single annual value for observations that year. As such, the black line is similar to the shaded range (which shows year to year values) rather than the colored lines (which average across nine model-year).
12. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015; Appendix A. http://doee.dc.gov/publication/climate-projections-scenario-development

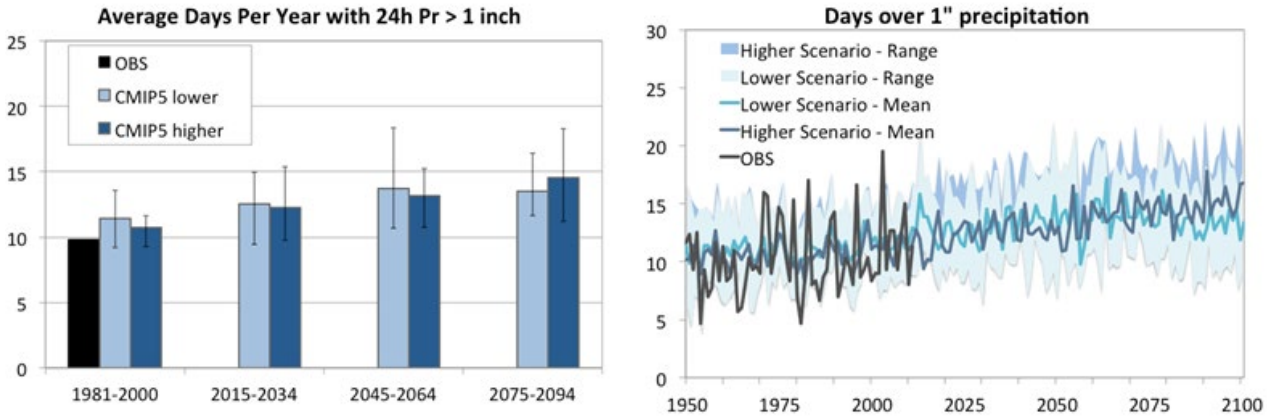


FIGURE 4 Number of days per year with more than 1" of precipitation in 24hr period. Values are averaged across the three weather stations used in this analysis under higher (dark blue) and lower (light blue) future scenarios.[13]

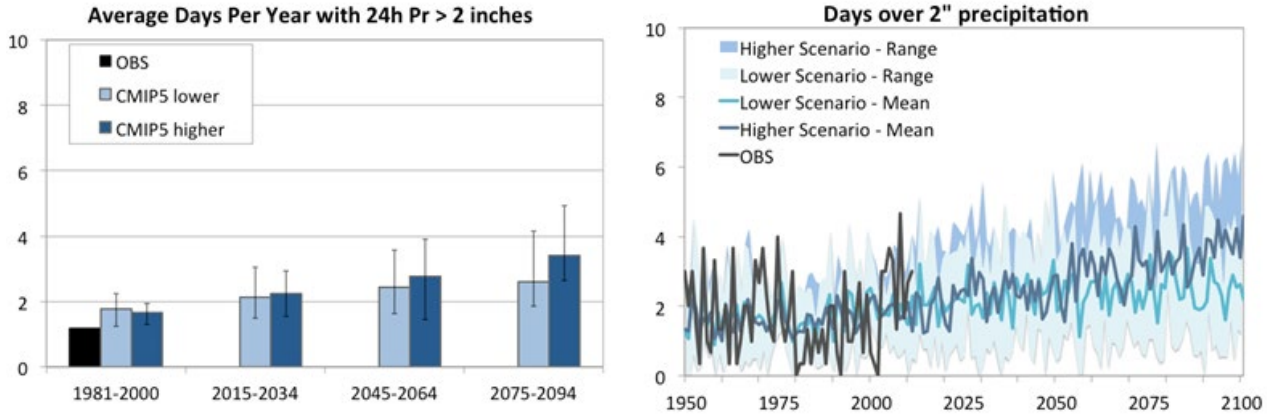


FIGURE 5 Number of days per year with more than 2" of precipitation in 24hr period. Values are averaged across the three weather stations used in this analysis under higher (dark blue) and lower (light blue) future scenarios. Source: "Climate Change Projections for the District of Columbia."[14]

13. For the bar charts, the uncertainty, range, indicated by the thin vertical lines above and below each bar, encompasses the range of projections from the nine different global climate models used in this analysis. Each colored bar represents the average of 180 simulations, while each black bar represents the average of 20 years of observations. For the time series plots, the solid colored lines indicate the multi-mode average for each year while the shaded range encompasses the range of projections from the nine different global climate models. The solid black line indicated the single annual value for observations that year. As such, the black line is similar to the shaded range (which shows year to year values) rather than the colored lines (which average across nine model-years).
14. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015; Appendix A. http://doee.dc.gov/publication/climate-projections-scenario-development

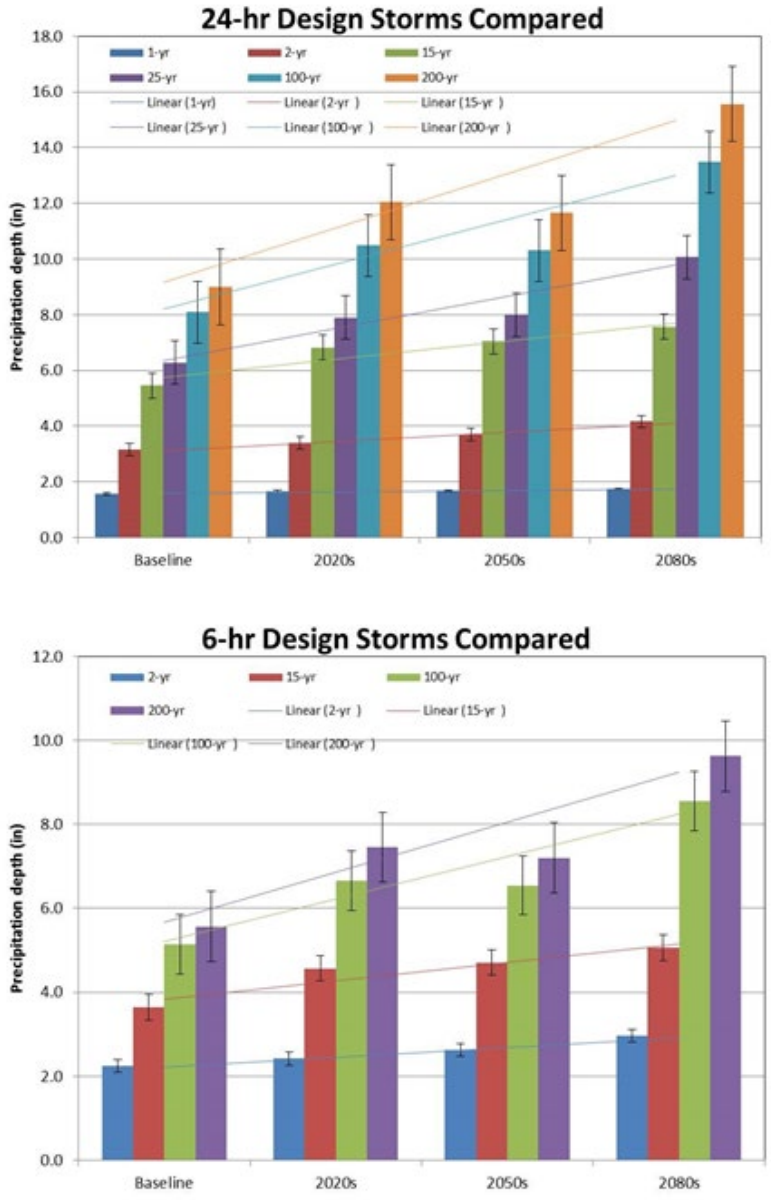


FIGURE 6 Bar charts compare 24-hour & 6-hour design storms for each of the planning horizons (Baseline [1981-2000], 2020s, 2050s, and 2080s). Values shown on the bar charts are the averages of Dalecarlia & National Arboretum stations.[15]

15. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015; Appendix A. http://doee.dc.gov/publication/climate-projections-scenario-development

PREVIOUS STUDIES

Examples of the risks associated with Increased Heat
Previous analyses from the District heat island study[16] and in the 2015 District of Columbia Wildlife Action Plan, identified a number of increased risks that accompany increased heat. These include increased urban heat island impact, increased negative impacts on health, increased heat shifts in natural systems and greater strain on energy and transportation systems as well as District resources. Each of these risks is further explained below.

Increased heat compounds the urban heat island
An urban heat island, or UHI, is an urban area that's warmer than the areas surrounding it. Heat is created by energy from people, transportation, industries and exacerbated by the hard surfaces typically comprising the urban fabric. Areas that already experience urban heat island effects within the District will be exacerbated as more frequent heat waves occur, leading to areas that are too hot, too often. As the District's urban heat island increases, it in turn may harm some species in the existing tree canopy. The likely outcome is either a reduction of protective flora and increased urban heat island impact or the need to consider heat-tolerant species in the canopy investments identified in the Sustainable DC plan. Consideration of species replacement strategies in advance of growing heat concerns will be critical. The District will also need to identify other ways to reduce impacts such as through cool roofs or green roofs programs.[17]

Increased heat has negative impacts on health
With increased heat, population health risks also increase. Coupled with increased risks to the energy infrastructure, which in turn is necessary to mitigate heat impacts in most traditional construction, increased heat is a significant health risk for the District. Examples of population health risks include:

- **Heat stress**: Higher incidents of heat stress and other related illnesses among the community will result in a decrease in comfort levels and an increase in hospital admissions, pressure on social services and morbidity. This is particularly true for the most vulnerable populations who respond differently to increased heat. With population forecasts predicting an aging District population, those at risk will increase in relative percentage.
- **Air Quality**: Increased heat will exacerbate the conditions for the formation of ground-level ozone. This deterioration of air quality will cause an increase in incidents of respiratory distress, resulting in an increase in hospital admissions and morbidity. Similarly, changing cycles will extend the period of plant pollen and in turn have negative consequences on community health.[18]
- **Reduced workforce productivity**: As conditions become too hot for people to work outside during parts of the day, and indoor thermal comfort is affected by pressures on cooling, workforce productivity will be impacted. Where outside labor is required to maintain parks and facilities, or for construction activities, workers will necessarily work alternative hours to avoid heat peaks and also will likely require more frequent breaks to manage heat impacts.

16. For further reading, see Assessing the Health Impacts of Urban Heat Island Reduction Strategies in the District of Columbia by Kalkstein et al, 2013
17. Kalkstein et al, 2013
18. For further information, see the National Resources Defense Council's "Sneezing and Wheezing: How Climate Change Could Increase Ragweed Allergies, Air Pollution, and Asthma: 2007 with 2015 Update."

- **Behavior change**: Negative changes in behavior may result, in particular increases in violence and antisocial behavior, in turn leading to increased demand for emergency and social services.[19]
- **Reduced outdoor activity**: The increased risk of heat stress and dehydration associated with outdoor exercise, along with reduced air quality, may result in reduced appeal for outdoor physical activities such as walking and cycling. For the District where the monuments and National Mall draw millions of tourists annually, there may be shifts in visitation patterns and resulting impacts on business that rely on tourism.
- **Disease**: Increased temperatures will allow longer gestation periods for disease carriers or vectors such as ticks, mosquitoes, rodents and bacteria. Migration suggests that tropical climate infestations such seen with the spread of Chikungunya into more northerly regions may spread in the District within the study projection horizon. These vectors may increase transmission of West Nile virus, equine encephalitis, Lyme disease and Rocky Mountain Spotted Fever[20] Algae blooms and reduction in general aquatic life conditions due to rising water temperatures will further threaten existing ecosystems.

Increased heat shifts natural systems

DOEE recently completed a climate change vulnerability assessment as part of the update to the District of Columbia Wildlife Action Plan in 2015. The assessment found that climate change poses serious threats to wildlife and habitat in the District.

- Climate shifts that increase the temperature in the District will in turn shift the natural environment. Warmer temperatures will shift the aquatic plant life and potentially the loss of fisheries due to oxygen depletion. Loss of plant life and the disposition of fresh and saltwater patterns will in turn shift wildlife migration patterns. These are fundamental changes to the way that the natural environment functions in the District.
- Increased temperatures may lead to heat stress for species, decreased water quality and dissolved oxygen content as well as changes to food availability.[21] Temperature increases may also be problematic for species at the edge of their ranges. For example, if species are at the more southern end of their range and unable to migrate, they may not survive significant increases in temperature that are greater than they can withstand.[22] Warmer temperatures may also result in warmer waters, which could favor parasites and other pests in aquatic environments.[23]
- Warming temperatures will also lead to changes in plant phenology, as has already been observed.[24] These changes may have significant impacts on ecosystems by changing existing natural land cover types and by allowing for the spread of pests into previously unaffected regions.[25]
- Species migration and/or extinction in turn will disrupt businesses that rely on those species, such as fisheries, agricultural and aquaponics farms. Reduced food production in turn will have negative impacts on food affordability and availability. Increased heat (and precipitation) will likely shift growing seasons and crop composition in the region. As recently as 2012, the District and its surrounding area was remapped into the warmer Zone 7 region of the US Department of Agriculture

19. For further information, see "Climate change and mental health: a causal pathways framework" by Berry et al, 2010 and "Quantifying the Influence of Climate on Human Conflict" by Hsiang et al, 2013.
20. See AAAS, 2015.
21. See Anderegg et al, 2013.
22. See Pyke et al, 2008.
23. See Pyke et al, 2009, Najjar et al, 2010.
24. See Primack et al, 2004, Miller-Rushing and Primack, 2008.
25. See Wildlife Action Plan, 2015.

(USDA) Agricultural Zone Maps. Historically the District was categorized as Zone 6 with much cooler winter temperatures and shorter growing seasons. Warmer zones comparatively have longer growing seasons, milder winters and have flora and fauna that work within that climate accordingly.

- While the District is not recognized as a major food production area, it is in the process of developing more urban agriculture to further stabilize access to fresh food choices for many vulnerable populations as well as to increase awareness of the ways for individuals to have more sustainable food choices. Notably these are small steps, as the District is dependent on supply from other regions to meet the food demands of its populations. This dependency in turn ties to its dependency on having the transportation necessary to obtain food and the energy necessary to maintain the food once received. As both the transportation systems and energy systems have some degree of vulnerability, there is a cascading consequence to the District's food dependency.

Increased heat strains and sometimes disrupts energy systems

- Extreme heat will place strain on energy systems decreasing system efficiency and the performance of energy networks. Electricity consumption will also increase due to a surge in peak demand for air conditioning. Higher electricity demands, particularly for cooling, will further stress these systems and increase their likelihood of failure.

- Increased heat overall will likely change summertime peak demand, and the increasing frequency, intensity and duration of heat waves could lead to more brownouts and blackouts. Individual building cooling capacity may not be sufficient if the period of high heat days is lengthy.[26] Significant investment will be required for their upgrade or replacement.

- Critical energy infrastructure might also be vulnerable to prolonged periods of extreme heat. Substations are designed to run for a limited time using emergency response measures, and prevent customer outages should one component fail. However, running at emergency ratings reduces equipment lifetime, so repeated extreme heat events would affect equipment durability.

Increased heat strains and sometimes disrupts transportation systems

- Extreme heat will lead to increases in heat impacts to transportation infrastructure, resulting in congestion, major delays and mass transit disruption with the potential stranding of commuters. It is assumed that the District's roadway infrastructure is not highly vulnerable to heat today; however in the future with the projected rise in high heat days and heat waves, the infrastructure could become compromised. This is primarily due to the low sensitivity of roadways to heat. However, taking into consideration that by 2080 there could be heatwaves lasting from 9.5 - 12 days, current standards might need to be revised to prevent buckling. However, extreme heat could lead to the degradation of concrete structures and softening of pavements not previously observed in DC.

- For transit it is assumed that current design standards might not be sufficient to prevent buckling of rail lines as heat stress is likely to increase significantly by 2080. Most of the Metrorail segments and stations in the District are underground and have cooling systems, making them less sensitive and more able to adapt to increasing heat. The aboveground segments that could be more vulnerable to heat impacts are the Yellow Line from L'Enfant Plaza to Pentagon (this segment also crosses the Potomac River via the Yellow Line bridge), the Orange Line from Stadium Armory to Deanwood, and the Red Line from NOMA/Gallaudet University to Brookland / CUA. Many of the above ground stations are in Maryland and Virginia, outside of Washington, DC's boundaries. However, when there are failures at these stations there are almost always service disruptions to the lines as they travel through Washington, DC. This further highlights the need for cooperation among jurisdictions for future planning in the adaptation phase.

26. Horton et al, 2015

- Extreme heat can cause major disruptions to flights arriving and departing from local airports beyond the District, but a dependency of the District due to reduced safe operating conditions from asphalt softening.
- Commuters may opt to use private vehicles rather than public transport to access the District to avoid potential delays and discomfort, resulting in increased congestion; and deterioration of air quality.

Increased heat strains District resources

- Demand for heat refuge areas for respite will increase, putting strain on available resources.[27] For example, existing cooling center programs may need to increase the amount of days that they provide service or the need to increase the capacity of existing centers. The District may also need to add cooling centers beyond those currently available in public buildings.
- As the demand for cooling centers increases, the District will need to look beyond government or housing authority resources and partner with trusted community assets such as churches, businesses, and community organizations to provide cooling services.

27. Cooling centers are currently located at District government or housing authority properties. For a map of all locations see: http://hsema.dc.gov/sites/default/files/dc/sites/hsema/page_content/attachments/Cooling%20Centers.pdf

Impact #2: Increased Extreme Precipitation

Climate change is expected to result in an increase in the frequency and severity of extreme precipitation events. While the District currently receives an average of 10 days per year with greater than 1 inch of rain in a given 24-hour period, and an average of 1 day per year with greater than 2 inches of rain in a given 24-hour period, projections show increases in days per year with more than 1 inch of rainfall and days per year with more than 2 inches of rainfall.

Impact #2: Increased Extreme Precipitation

By the 2020s, the number of days per year with more than 1 inch of rainfall per 24-hour period is expected to be 11 days. That number is projected to increase to 12 days by the 2050s and 13 days by the 2080s. The number of days per year with more than 2 inches of rainfall per 24-hour period is expected to increase to 3 days per year by the 2020s, an average of 3.5 days per year by the 2050s, and between 3.5 to 4.5 days per year by the 2080s.

Serial No.	Precipitation Indicator	Baseline 1981-2000	2015-2034 (2020s)	2045-2064 (2050s)	2080s
1	# of days/year with rainfall at or above 1 in	10	12 (10 – 15)	13 (11 – 18)	14 (12 – 18)
2	# of days/year with rainfall at or above 2 in	1	1.5 (1 – 2)	2 (1 – 3)	3 (2 -5)
3	1-yr 24 hr. storm (in)	1.6	1.7 (1.5 - 1.8)	1.7 (1.5 - 1.8)	2 (±<1)
4	2-yr 24 hr. storm (in)	3.2	3.4 (3.2 - 3.7)	3.7 (3.5 - 3.9)	4 (4 - 5)
5	15-yr 24 hr. storm (in)	5.5	6.8 (6.0 - 7.3)	7.1 (6.7 - 7.6)	8 (4 - 9)
6	25-yr 24 hr. storm (in)	6.3	7.9 (6.8 - 8.6)	8 (7.5 - 8.8)	10 (8 - 12)
7	100-yr 24 hr. storm (in)	8.1	10.5 (8.9 - 12.4)	10.3 (9.0 - 11.9)	14 (10 - 16)
8	200-yr 24 hr. storm (in)	9	12 (10.1 - 14.7)	11.7 (9.8 - 13.6)	16 (11 - 19)
9	2-yr 6 hr. storm (in)	2.3	2.4 (±<0.1)	2.6 (2.6 - 2.7)	3 (±<1)
10	15-yr 6 hr. storm (in)	3.6	4.6 (4.3 - 4.8)	4.7 (4.6 - 4.8)	5 (4 - 6)
11	100-yr 6 hr. storm (in)	5.1	6.7 (6.5 - 6.8)	6.5 (6.4 - 6.7)	9 (7 - 10)
12	200-yr 6 hr. storm (in)	5.6	7.5 (7.2 - 7.7)	7.2 (±<0.1)	10 (8 - 11)
13	80th Percentile storm (in)	0.8	0.9 (0.1)	0.9 (0.1)	0.95 (0.1-0.15)
14	90th Percentile storm (in)	1.14	1.24 (0.1)	1.24 – 1.34 (0.1-0.2)	1.24 – 1.39 (0.1-0.25)
15	95th Percentile storm (in)	1.5	1.6 – 1.65 (0.1-0.15)	1.6 – 1.75 (0.1-0.25)	1.75 – 1.85 (0.15-0.35)

TABLE 2 Table of Precipitation Indicators. Ranges of indicators are shown in parentheses. Results in Serial Numbers 3-12 are averages of projections for Dalecarlia & the National Arboretum weather stations and ranges shown are representative of the median for the upper (RCP 8.5) and lower (RCP 4.5) projections.[28]

28. Task 1 Report – Climate Projections & Scenario Development, September 10, 2015; Appendix A. http://doee.dc.gov/publication/climate-projections-scenario-development

IMPACT #2: INCREASED EXTREME PRECIPITATION — PREVIOUS STUDIES

Examples of the risks from **Increased Extreme Precipitation** include the increase in likelihood of damage to property and infrastructure, service disruption, displacement, greater flooding and greater public health risks:

Increased extreme precipitation increases likelihood of flooding

- **Due to its location at the confluence** of two tidally-influenced rivers, the District is influenced by three primary types of flooding: interior (inland drainage), riverine and coastal. Different storm events will result in various combinations of flooding – some resulting in more inland impacts, while others may be more coastally influenced. It is interesting to note that storm surge has the potential to turn drainage outlets into inlets with the potential for causing flooding miles away from the coast as it travels through the piped infrastructure and surfaces in remote, interior sections.
- **Flash flooding**: Heavy rainfall can cause stormwater drainage systems to back up and cause localized flash flooding of roads, public spaces and property. This may result in an increase in property damage, localized traffic congestion, and vehicular and pedestrian accidents, as well as the loss of parking spaces in low-lying areas and basements. It will also disrupt commuter patterns and in turn impact the ability of employees to earn income. The District has established patterns on this issue and should expect those patterns to be exacerbated given the increased precipitation expected.
- **Flood Insurance**: Flood insurance costs will continue to rise as exposures to increased precipitation will likely outpace the infrastructure upgrades necessary to manage it. This likely will include increased exposure beyond current policy holders, putting those unfamiliar with their increased risks at even greater exposure. These will be coupled with increased risk due to sea level rise, reducing values of properties in areas of greatest risks and with histories of persistent flooding. See Impact #3: Sea Level Rise/Storm Surge risks below as it relates to economic impact of limiting development in flood prone areas.

Increased extreme precipitation increases damage to property and infrastructure

- **Property/infrastructure damage**: An increase in intense rainfall events may result in extensive damage from flooding to property and infrastructure including street lights and embankments, buildings and trees. This will increase cleanup efforts, disposal and maintenance costs.
- **Localized power infrastructure damage**: An increase in intense rainfall may result in damage or inundation of electricity and gas powered infrastructure and vital equipment, resulting in energy interruptions. Powerful storm activity can bring down powerlines and flood power substations and vital equipment located in basements, potentially causing extensive blackouts and service interruptions across the city, including to transport. This risk extends beyond the District to where the power is sourced and transmitted.

Increased extreme precipitation increases likelihood of service disruption

- **Increased storms causing disruption to travel infrastructure**: An increase in the frequency and intensity of rainfall could damage assets and disrupt services in the District. This includes disruptions to flight patterns, flight frequency, passenger rail travel and commutation.[29]
- **Communication disruption**: An increase in the frequency and intensity of storms may lead to IT and communications equipment disruptions, resulting in the loss of vital equipment and

29. See DDOT's Climate Change Adaptation Plan for more details. https://comp.ddot.dc.gov/Documents/Climate%20Adaptation%20Plan.pdf

telecommunications. This includes signaling for passenger rail as Amtrak currently experiences disruptions with heavy precipitation and high heat.

Increased extreme precipitation increases likelihood of displacement

- **Displacement**: An increase in intense rainfall events may result in more frequent damage to properties, causing displacement and disruption to community, business and other activities while clean-up and recovery occurs. In the short term, this may increase the need for and cost of emergency housing or shelter, rebuilding skills, disaster relief, and social services. In the longer term, this may impact productivity and damage the reputations of communities that frequently flood. This in turn may also result in greater devaluation of investments, triggering market shifts in development. This will put greater development pressures on the remaining areas outside of the higher risks zones, likely increasing prices and decreasing affordability.

Increased extreme precipitation threatens public health

- **Water Quality**: An increase in intense rainfall has the potential to cause an overflow of the combined sewer and stormwater system (2/3 of the District is on separate systems + 1/3 is combined), releasing contaminants and creating hazardous water quality conditions downstream causing a risk to public health, further degradation of the watershed and resulting species impact. General run-off also increases, moving contaminants from roadways into waterways and into the Potomac and Anacostia Rivers.

- **Community health**: With increased flooding, there will likely be increased cases of mold and the resulting respiratory illnesses that stem from mold exposure.

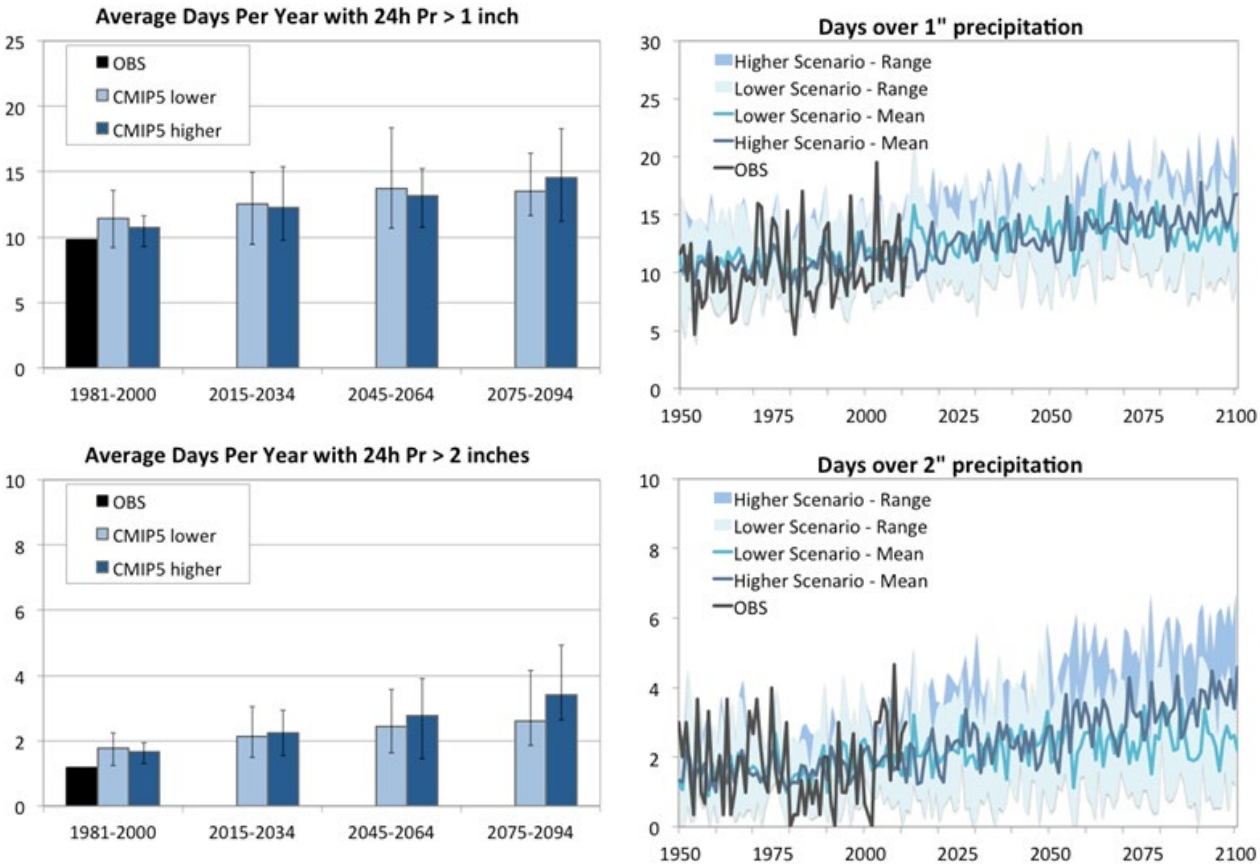


FIGURE 7 Amount of precipitation falling in the wettest 24 hour period in 1 (top) and 2 (bottom) years, averaged across the three weather stations used in this analysis under higher (dark blue) and lower (Light blue) future scenarios.[30]

30. For the bar charts, the uncertainty range, indicted by the thin vertical lines above and below each bar, encompasses the range of projections from the nine different global climate models used in this analysis. Each blue bar represents the average of 180 years of simulations, while each black bar represents the average of 20 years of observations. For the time series plots, the solid blue line indicates the multi-model average for each year while the shaded range encompasses the range of projections from the nine different global climate models. The solid black line indicates the single annual value for observations that year. As such, the black line is similar to the shaded range (which shows year to year vales) rather than the blue lines (which average across nine model years). There is no time series plot for the 2-year storm since, by definition, this indicator does not have annual values.
Task 1 Report - Climate Projections & Scenario Development, September 10, 2015; Appendix A - http://doee.dc.gov/publication/climate-projections-scenario-development

Impact #3: Sea Level Rise/ Storm Surge

Sea level rise refers to the increase in base sea level of the rivers and water bodies in the District. Storm surge acts as a compounding impact on the newer sea levels. As sea levels increase, approaching storms literally have more water to move inland.

Impact #3: Sea Level Rise/Storm Surge
Historical average on the District waterfront from 1924 to 2013 is 3.2 mm/year (0.125 in/year), with a total RSLR of 11 inches during this period. This has resulted in a more than 300% increase in nuisance flooding in the Distract in the last 90 years.

Over the past century, sea levels have been rising as a result of climate change. Oceans have warmed causing their volumes to expand, and glaciers and land-based ice have melted contributing additional fresh water to the oceans' volumes, resulting in global sea level rise (GSLR). The estimated long-term rate of GSLR is 1.7 mm/year (0.065 in/year).[31] Relative sea level rise (RSLR) in the District area has been higher than GSLR because the local landmass in the region has been sinking as the result of long-term geological processes, known as land subsidence. Sea level rise is expected to continue, and even accelerate in the future due to climate change. In fact, there may be some evidence that the average annual rate from 1993 to 2012 is 3.2 mm/year, nearly double the long-term rate.[32]

Risks include increased financial burdens, interruptions in transportation systems and infrastructure backups due to outfalls that may experience flooding or storm surge.

Scenarios for Sea Level Rise for the District

- 2020 – 100-year flood = base flood elevation
- 2050 – 100 year flood + 3 feet = base flood elevations + 3 feet
- 2080 – FEMA 500-year flood = base flood elevation + 4 feet.

31. USACE, 2013
32. See Church et al, 2013.

CASCADING CONSEQUENCES

Each risk introduces cascading consequences for the District to consider. For example, increased precipitation increases likely flooding. Sea Level Rise also increases likely flooding. Both when considered in tandem significantly increase likely flooding. Increased flooding from both sources increases likely impact on transportation infrastructure, introducing closures and other unexpected delays. Closures and delays negatively impact business continuity and access to critical services or the ability for employees to use transit to get to their jobs. Loss of workdays may result in loss of housing or the ability to feed a family. Loss of either may escalate to homelessness or losing custody of children.

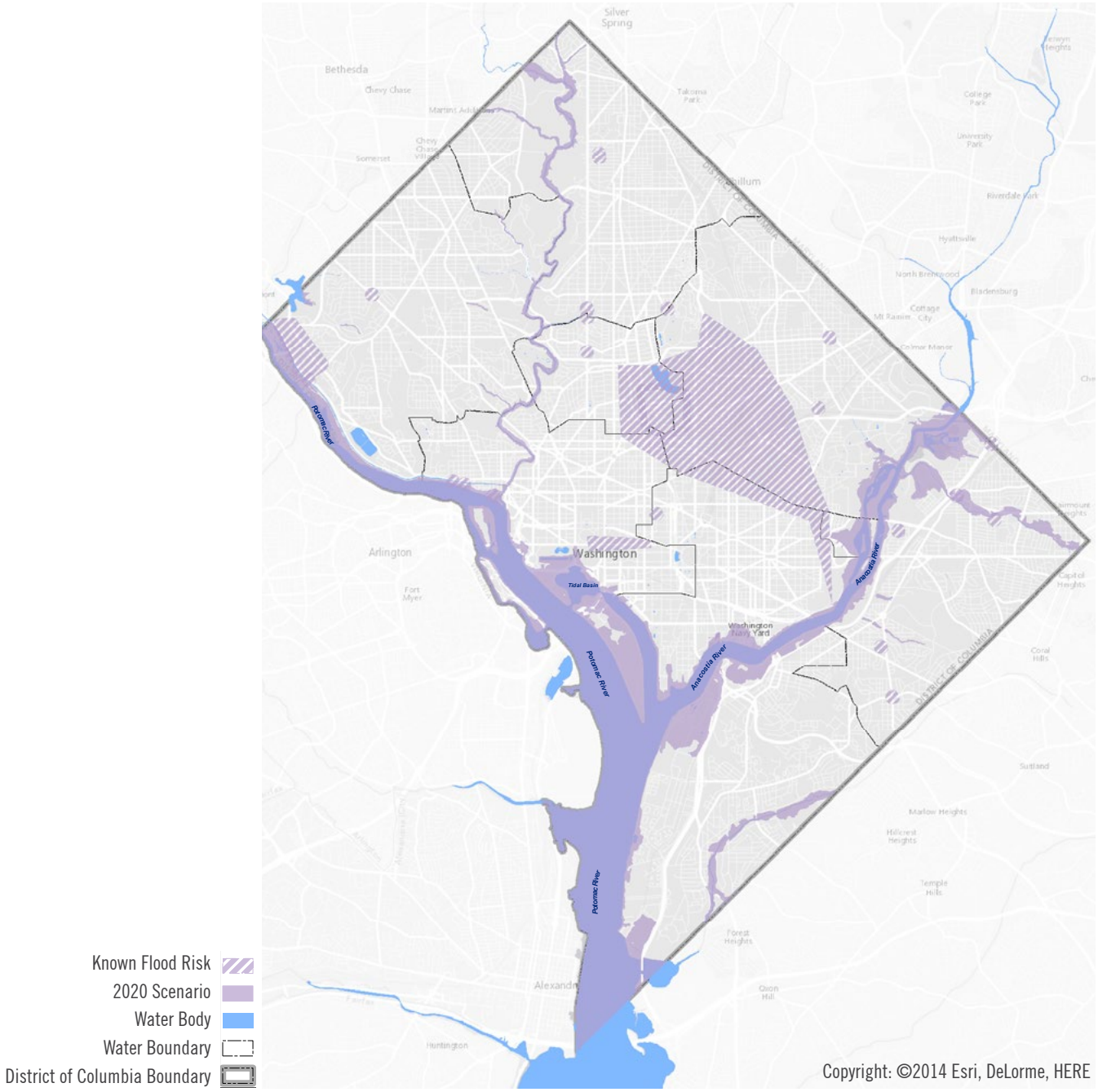
IMPACT #3: SEA LEVEL RISE/STORM SURGE — PREVIOUS STUDIES

Examples of the risks from **Sea Level Rise/Storm Surge** include:

Sea Level Rise/Storm Surge will increase financial burdens
Rising sea levels, coastal inundation and saltwater intrusion could increase the financial burden for maintenance and protection, and threaten the financial value and viability of properties and infrastructure along the coast. This in turn suggests the need to consider potential economic impact of limiting development in these areas. This is a challenging question without significant modeling in place.

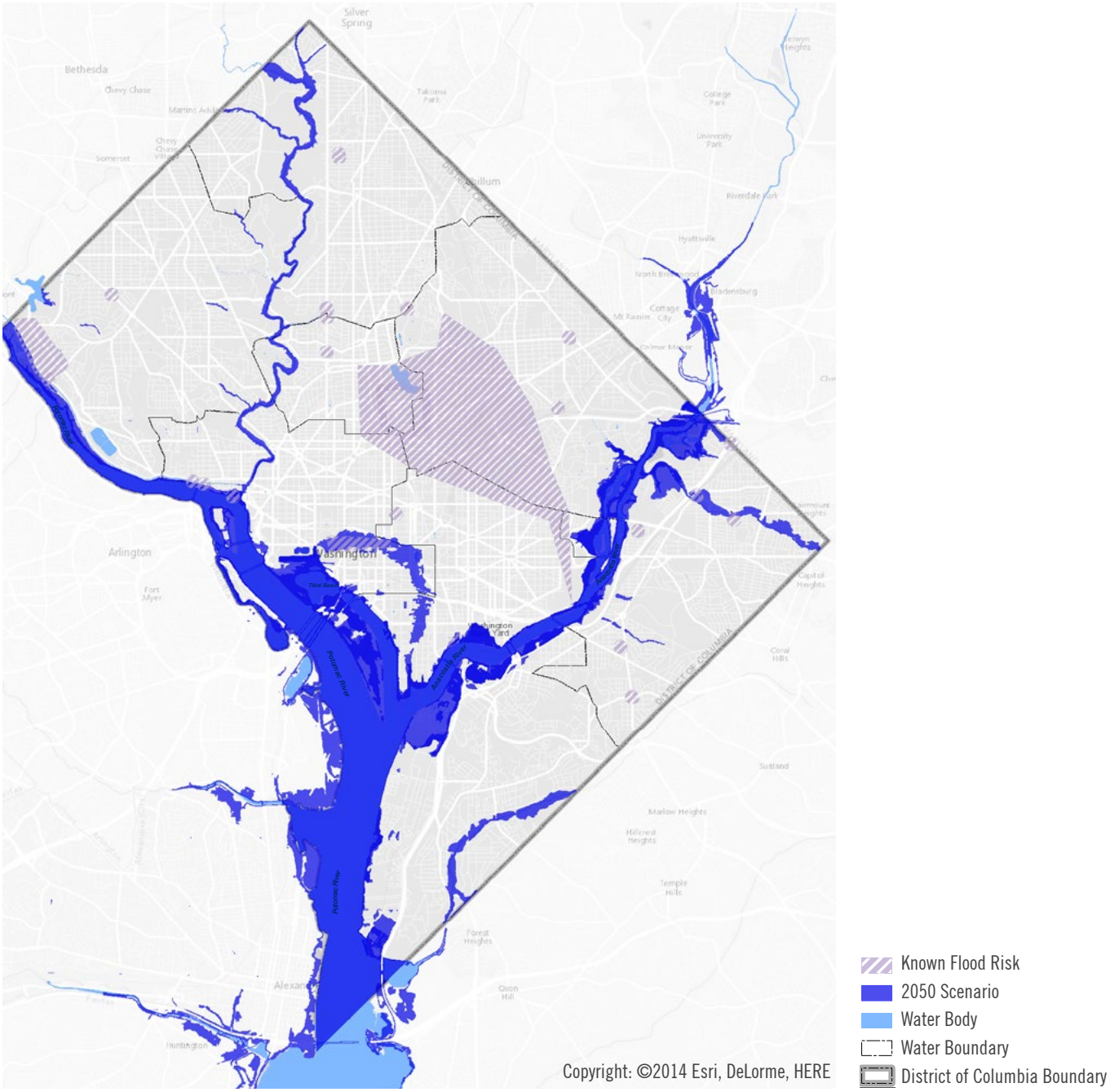
Sea Level Rise/Storm Surge will disrupt Transportation
Rising sea levels and coastal inundation could limit transport access and egress both directly along waterfront areas and across the wider transport network.

Sea Level Rise/Storm Surge will have negative impact on Outfalls
Rising sea levels and coastal inundation may impact proper function of outfalls at lower elevations, resulting in backups at catchment areas throughout the District. While the Vulnerability Assessment did not identify strategic outfalls at risk, it did note the need for further evaluation given the contributing drainage to those outfalls.



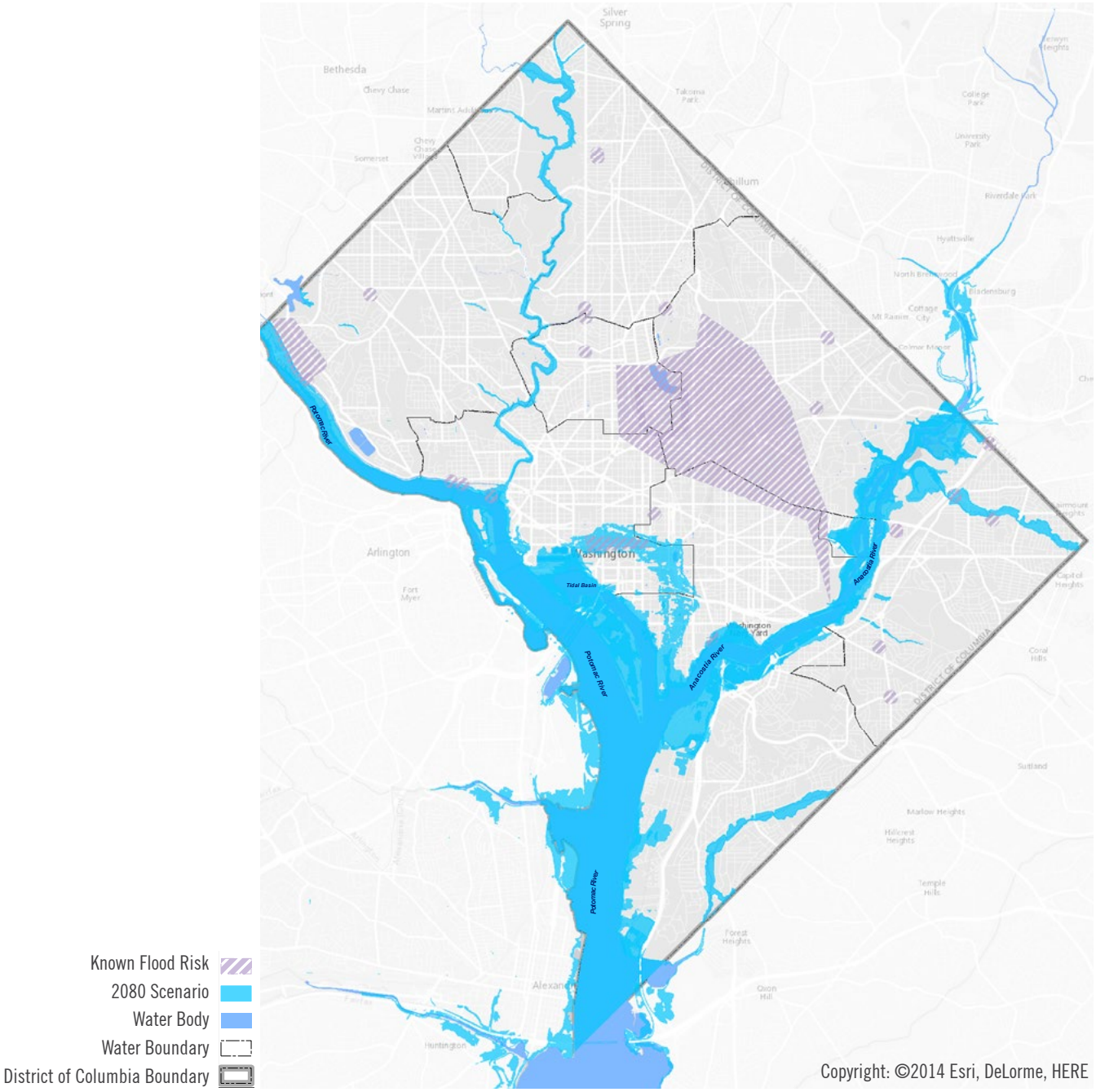
MAP 2 2020 Scenario for flooding: areas of known flood risk and the current FEMA 100-year floodplain.[33]

33. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness



MAP 3 2050 Scenario based on NACCS SLOSH hurricane storm surge inundation mapping for present day Category 2 hurricane as a proxy for the current FEMA 100-year base flood elevation + 3 feet of sea level rise.[34]

34. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness



MAP 4 2080 Scenario based on current FEMA 500-year floodplain as a proxy for the current FEMA 100-year base flood elevation + 4 feet of sea level rise.[35]

35. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness

It is also true that these projections are not independent, but rather codependent, and create larger impacts when taken cumulatively rather than individual events. Flooding from precipitation coupled with expected sea level rise means that flooding may occur more frequently with less extreme events. For example, most planning in DC is around 100-year storms, or typical annual storms. However, these storms now create more damage as storm surge is greater when coupled with SLR.

CASCADING CONSEQUENCES — EXAMPLES

A recent example in the District was the Derecho which occurred in July of 2012. The Derecho caused extended power outages in the District. As the Derecho was followed by a record-breaking heatwave, this power outage led to cascading consequences for health and other facilities which did not have adequate backup power to provide cooling and strained the resources of major hospitals that were able to keep operating.

Examples of the risks from **cascading consequences** include:

Urban heat island
Exacerbated by increases in temperature in general and overall negative impact on health, morbidity in ecologies and failures in energy systems.

Heat stress
Exacerbated health risks due to increased temperatures compounded with urban heat islands and reduction in air quality.

Community health
Impacted by increased temperatures, exposure to pollutants from flooding, ecological and epidemiological shifts as well as long-term exposure to stress itself.

Reduce workforce productivity

Exacerbated by heat stress and disruptions to systems such as transport and power as well as community health.

Behavior change
Stressed by increased temperatures, risks from flooding and extreme weather events as well as long-term exposure to stress itself.

Reduced outdoor activity
Exacerbated by increased temperature, pervasive flooding and extreme weather events and cascading to negative health impacts.

Ecological impacts
Exacerbated by increased temperature and pervasive flooding as well as sea level rise/storm surge, cascading to epidemiological shifts and negative health impacts.

Epidemiological shifts
Exacerbated by increased temperature and pervasive flooding, cascading to negative health and ecological impacts.

Energy system strain
Exacerbated by increased temperature as well as compounding systems failure in flood prone areas, cascading to disruptions in work, transport and building systems.

Power disruptions
Exacerbated by increased temperature and energy system strain as well as compounding systems failure in flood prone areas, cascading to disruptions in work, transport and building systems.

Transport disruption
Exacerbated by systems failure in flood prone areas, cascading to disruptions in work and increasing congestion.

Congestion
Exacerbated by systems failure in transport systems as well as pervasive flooding on major roadways.

Strain on District resources
Exacerbated by compounding systems failures and emergency response required.

Infrastructure degradation
Exacerbated by compounding systems failure in areas prone to inland flooding and/or flooding from sea level rise and storm surge.

VULNERABILITY & RISK ASSESSMENT SUMMARY

With this context in mind, the vulnerability and risk assessment was based on the climate change projections and scenarios established in the Climate Projections and Scenario Development Report using increased heat, increased precipitation and sea level rise/ storm surge projections to conduct a "stress test" on the District's infrastructure and resources.

In order to assess the impacts of climate change on the District of Columbia, the team inventoried key infrastructure and community resources and ranked them based on their vulnerability to climate change and the risk associated with their failure. Assets were determined to be critical or key based on their contribution to the overall functionality of the District as a whole and the consequences if they were to fail.

Examples of critical infrastructure include electrical substations and roadways. Key community resources include facilities that support the well-being of the community, such as affordable housing and human services. The table below represents the critical infrastructure and key community resources that were included in this analysis. A detailed discussion of each is available in the Task 2 Report.

BUILT INFRASTRUCTURES[36]

Energy

Transportation

Water

Telecommunication

COMMUNITY RESOURCES

Municipal Resources

Emergency Services

Medical Services

Human Services

Schools

Public Housing

In addition to threats to the built environment, we considered the vulnerability of the District's residents, recognizing that some residents will be less able to adapt to the risks of climate change. Social aspects of vulnerability to climate change impacts are more challenging to measure than those in the built environment as they are defined by a complex set of demographic, economic, and health factors. In order to identify the wards with the largest share of vulnerable residents, a vulnerable population index was developed using demographic and socioeconomic indicators of both sensitivity to climate change impacts and ability adapt.

36. There are some infrastructure types and community resources that were not included in this study due to a lack of publicly available geospatial data for the resource.

Indicators include the following:

- Income: poverty is associated with poor nutrition, and less access to medical care. Low-income individuals also have fewer financial resources to cope with and recover from disasters and disruptions such as damage to housing, disruption to work schedules.
- Age: seniors and young children are more sensitive to extreme heat. Seniors may also be less able to cope with flooding and other disasters due to poor health, disabilities or other functional needs, or limited financial resources.

The data used for the index were derived from demographic and place-based indicators as reported in the Sustainable DC Plan (2013). This vulnerability assessment also considered populations within the District, such as the tourist population, commuters or outdoor workers, which are also likely to be impacted by climate change related events, such as flooding and heat waves.

The team did not explicitly assess the vulnerability of natural systems, because those analyses are covered elsewhere. In the 2015 Wildlife Action Plan, DOEE assessed the vulnerability of the District's wildlife and habitat to climate change and identified priority habitat restoration and protection actions.

Finally, many of the District's infrastructure and natural systems extend beyond the city's boundaries, or are outside of its direct jurisdiction, so the impacts of climate change on the District at-large are codependent upon regional conditions and actions.

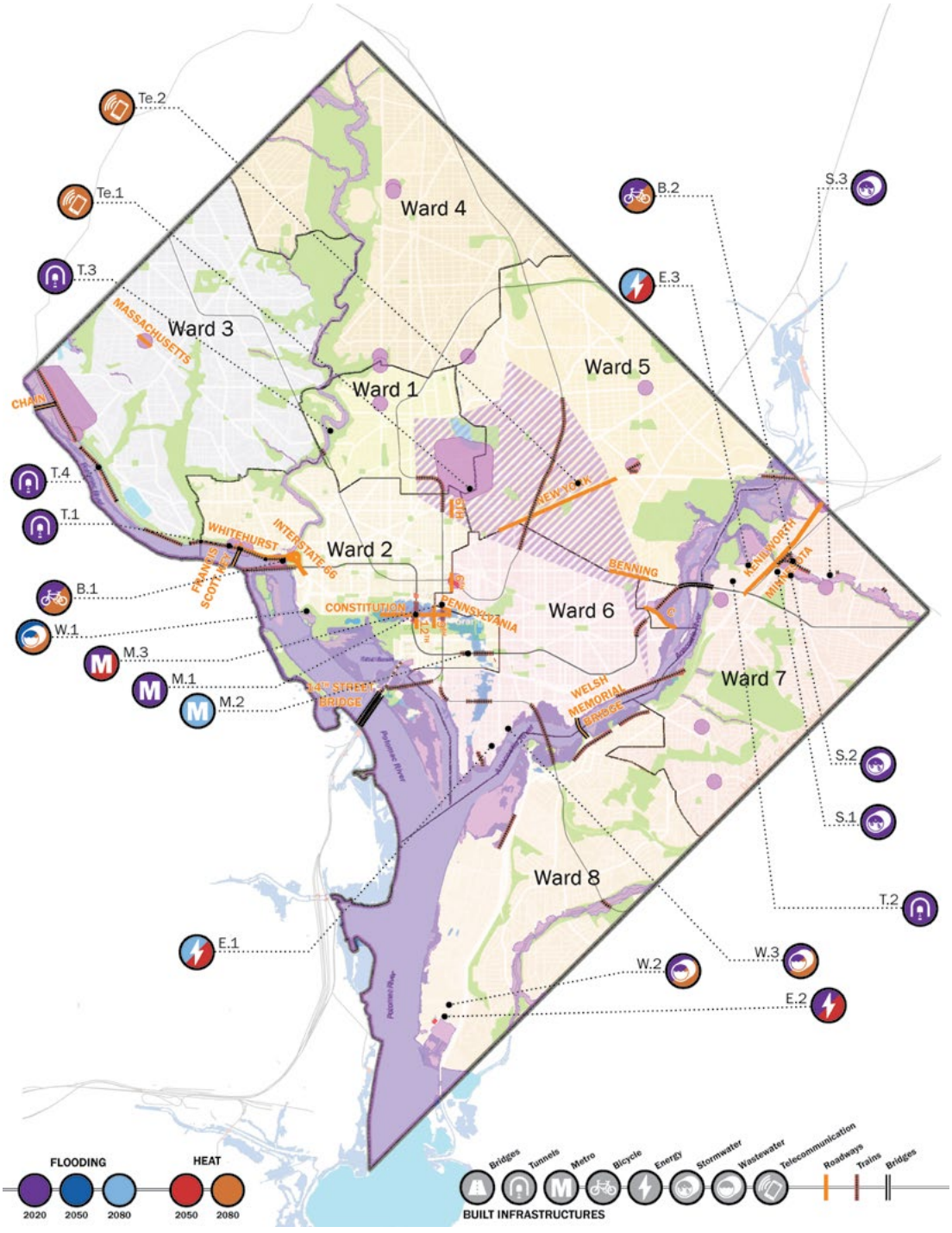
The key findings from the Task 2 Report Vulnerability and Risk Assessment[37] are as follows:

- Wards 7 and 8 are home to the largest number of residents with a higher vulnerability to climate change impacts – especially an increase in extreme heat – due to socioeconomic factors that increase sensitivity to heat and limit the ability to adapt including unemployment, age (seniors and young children), and poverty. These Wards are those housing the majority of vulnerable community resources such as schools and human services and also having larger vulnerable populations with the highest concentrations of population with unemployment, low level of education and poverty prevalence.
- Major infrastructure assets such as electric substations and Metrorail are at-risk of being affected by increased heat and flooding by 2020 or 2050; their failure could have significant regional impact as businesses, governments, and residents in a dense urban environment rely on energy supply and public transportation for day-to-day life.

37. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness

- Surface flooding from inland precipitation events may pose as much risk as flooding associated with sea level rise and storm surge – especially in the near term.
- Areas of risk to flooding and extreme heat are not evenly distributed throughout the District; but instead are concentrated near particular water bodies (i.e., The Watts Branch tributary to the Anacostia River) or areas with a large number of highly vulnerable residents that will not only be more at risk of exposure to climate impacts, but are also likely to have less means to adapt or be resilient to flooding or heat stress.
- Under existing conditions, the District is already vulnerable to flooding along the Potomac and Anacostia Rivers as documented by repetitive flooding of areas (reported by stakeholders) and FEMA's 100 year flood map. The combined impact of increased precipitation, sea level rise and storm surge in the future will require reconsidering the delineation of the current 100 year and 500 year flood plain boundaries to reflect the high probability of changed flooding risks in the future.
- Taking into account the unique geography of the District, as it is bounded by the Potomac River and bisected by the Anacostia River; bridges provide vital connections within the District and to surrounding areas. Their possible failure, due to flooding impacts, would have significant implications for the functioning of the larger regional transportation network. Key bridges have been potentially identified as at risk in this assessment, such as the 14th Street Bridges[38] that span the Potomac. It is recommended that a more detailed vulnerability assessment be performed on key bridges spanning the Potomac and Anacostia Rivers.

38. The 14th Streets Bridges refers to the group of three highway bridges (Rochambeau, George Mason Memorial, and Arland Williams Memorial), a railroad bridge (Long), and a Metrorail bridge (Fenwick Metro Transit) that span the Potomac.



MAP 5 Compilation of Infrastructure Most at Risk [39]

39. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness

Since many of these risks to regional assets are not limited to the District's jurisdiction, adaptation will require coordination with other states, agencies, and organizations such as regional transportation agencies and energy providers. Suggested lead and partner agencies for each adaptation strategy are included in the Climate Adaptation Master Action List.

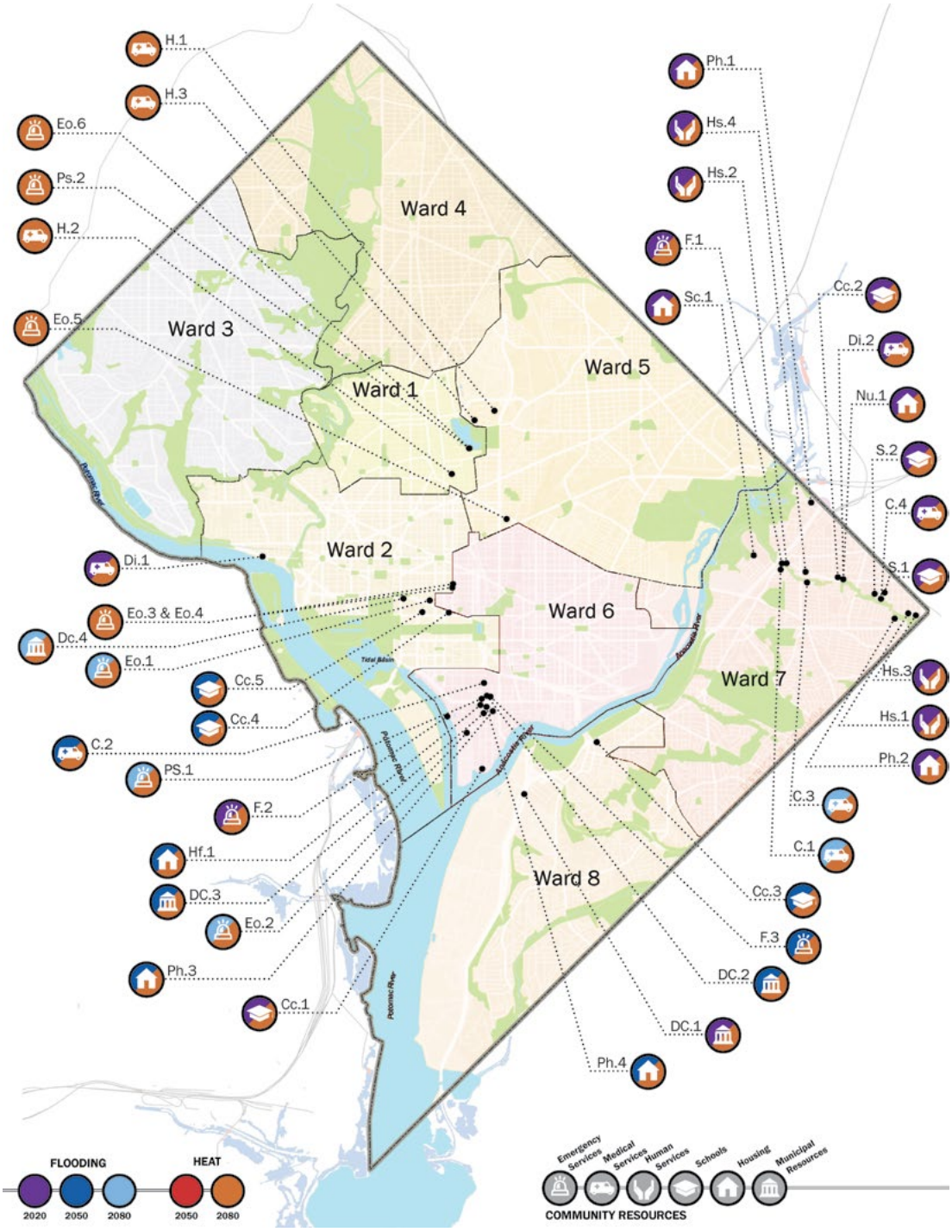
The combined outputs of the assessment then drove the identification of priority planning areas across the District. Within each planning priority area, key takeaways are:

- **Priority Planning Area 1**: Includes the neighborhoods of Bloomingdale and LeDroit Park. Because this area has already experienced significant flooding due to the limited capacity of the existing stormwater management systems, the projected increase in frequency and severity of extreme precipitation elevates these neighborhoods to a high-risk level. Ongoing efforts to expand the capacity of the stormwater system capacity in the area, including DC Water's Northeast Boundary Tunnel and interim McMillan Stormwater Storage Project will significantly reduce this risk, but not for the most extreme events.
- **Priority Planning Area 2**: This area around the Watts Branch, a tributary to the Anacostia River, is currently at risk of flooding, and is projected to be at increased risk as early as 2020. This area has a significant concentration of community resources at-risk, such as medical services and public housing, including the soon-to-redeveloped Kenilworth Courts development that serve vulnerable populations.
- **Priority Planning Area 3**: This area includes the District's downtown area centered near the Federal Triangle neighborhood. These areas are already at risk of riverine, coastal and interior flooding which will be exacerbated by 2080. These areas have a significant concentration of built infrastructure, including a large concentration of professional businesses, cultural resources including the Smithsonian and National Mall; as well as Metrorail stations and other community resources, such as the John A. Wilson Building (city hall), and other DC agency headquarters. This area's roadway and transit systems also serve a large number of the District's transient population of commuters and tourists. Actions are already being taken to better protect this area from riverine flooding including upgrades to the 17th Street Levee and the greater Potomac levee system. It will however remain at risk to interior flooding, and by 2080 there will be an increased risk from riverine and coastal flooding due to rising sea level.

- **Priority Planning Area 4**: This area in Southwest DC extends from south of the Capitol to Buzzard Point and is primarily at risk of riverine and coastal flooding. This area is a mix of residential, commercial, government, and several large development projects and planning initiatives (The Wharf, Buzzard Point, DC United Soccer Stadium, etc). The area includes a variety of community resource facilities and infrastructure at risk of flooding, including public safety, public housing, human services, transit, energy and wastewater. Several public housing properties are located in Priority Area 4, including the Greenleaf properties that are scheduled to be redeveloped in the near future and James Creek. Metrorail lines that cross through this area include the Green Line and Blue/Orange/Silver Line.
- **Priority Planning Area 5**: This area along the Potomac River is at risk of flooding within 2020, 2050, and 2080 scenarios, which will impact a key electrical sub-station and the Blue Plains Advanced Wastewater Treatment Plant. A planned sea wall at Blue Plains, which is being designed to the current 500-year flood elevation plus three feet to account for sea level rise, will substantially reduce the risk to the plant, but not necessarily the surrounding areas.

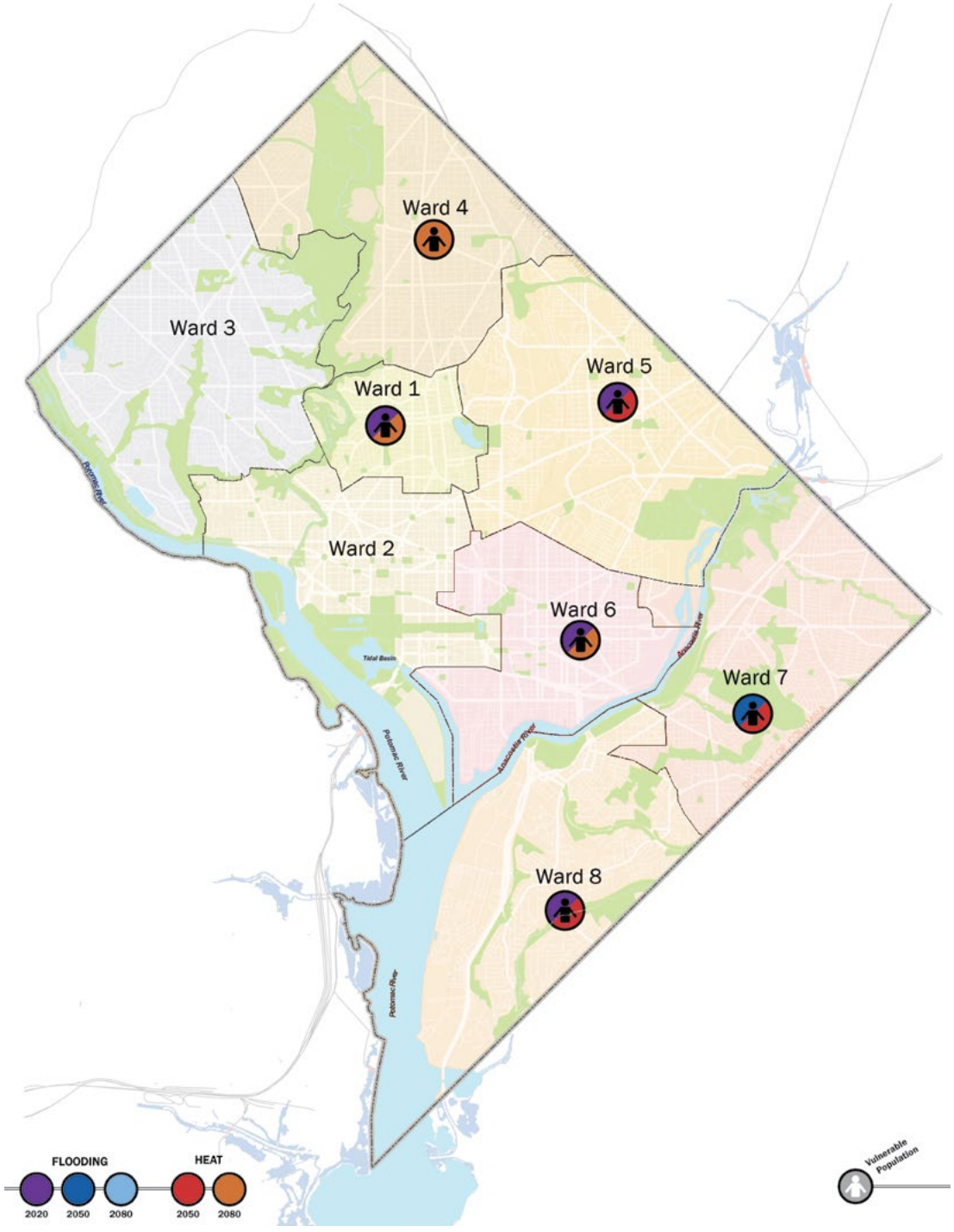
The Planning Priority Areas Map shows the most at-risk resources, populations, and assets with respect to climate change within the boundaries of DC. It represents the results of an assessment that compares seemingly unrelated resources, such as public health infrastructure (e.g. emergency services) and the transportation system and makes a comparison between the risks within each as well as between them (e.g. how does the risk of an overheated school rate against the risk of a flooded Metro station). These prioritizations focus the recommended actions to those areas at greatest risk in the three planning scenarios. In some cases these may serve to prioritize smaller scale activities while in others these may act as central nodes for organizing a larger set of adaptation studies or implementations.

The cascading impact of one system failing and interdependencies of the infrastructure systems and critical resources has also been factored in. For example, flooding could impact lifeline systems such as energy and telecommunications, without which some roadway infrastructure (e.g. traffic signals, lighting) may not be able to properly function. Emergency services, such as police stations and emergency medical services are also vulnerable to flooding, given their reliance on operational roadways to ensure public safety before, during, or after an event.



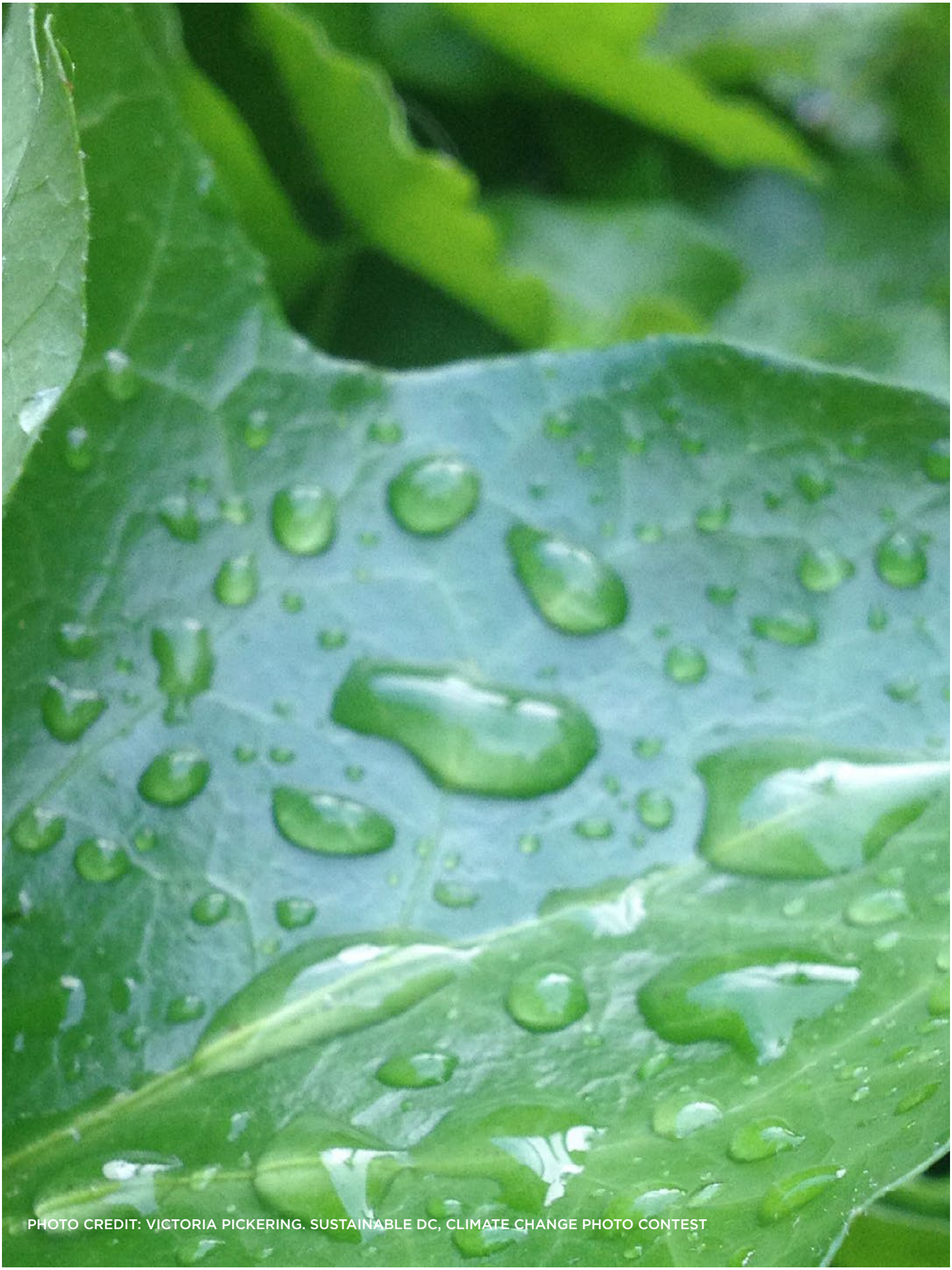
MAP 6 Compilation of Community Resources Most at Risk.[40]

40. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness



MAP 7 Vulnerable Populations per Ward.[41]

41. Task 2 Report – Vulnerability& Risk Assessment, March 2016. http://doee.dc.gov/service/climate-adaptation-and-preparedness



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03

CLIMATE ADAPTATION PLAN FRAMEWORK

The Climate Adaptation Plan, Task 3 Report, is the result of assessing the Task 1 and Task 2 outcomes against best practices from other jurisdictions, to additional scientific literature that further contextualized the risks, and to broadly adopted evaluation frameworks, such as Envision[42], for dealing with the types of risks associated with climate change. This effort sought to establish the breadth of adaptations necessary given the risks and vulnerabilities identified. These resources are listed in the Reference section of this report.

Using these resources the team then developed a comprehensive evaluation to illustrate the range of potential adaptations. Through stakeholder engagement, the team collected feedback on the District's ongoing efforts across various agencies in the process of developing or implementing adaptation measures. Combining the inputs of the comprehensive evaluation and the stakeholders' ongoing efforts, the team then developed a sector-based organizing principle and the recommended actions per sector.

The organizing principle captures likely ways of structuring District recommendations based on the expected agency involvement. Infrastructure issues, renovation and construction of buildings, neighborhood preparedness and governance were clearly differentiated sectors.

Specifically these sectors are:

- **Transportation + Utility Infrastructure**: Adapting and hardening energy, transportation, water, and telecommunications systems.
- **Buildings + Development**: Upgrading existing buildings and new construction/ development to address climate risks.
- **Neighborhoods + Communities**: Strengthening emergency preparedness and community, social and economic resilience.
- **Governance + Implementation**: Establishing cross-cutting policies, aligning plans, and monitoring progress.

Recognizing that actions will necessarily cross sectors, recommendations situate actions with the Lead agency most likely to take responsibility for the work required. However, Partner agencies are expected to be involved and are identified in the Master Action List. Using this sector-based organizing principle, the team then clustered sector-specific recommendations including Lead and Partner agencies as well as necessary reference to ongoing work.

To organize these categories of effort, the team developed an overall Action List based on the RELi[43] framework, a comprehensive

42. http://sustainableinfrastructure.org/envision/
43. http://c3livingdesign.org/?page_id=5110

listing of resilient design criteria with the latest in proven integrative process for developing next generation communities, neighborhoods, buildings, homes and infrastructure. It is structured similar to LEED® with a lens on resiliency. The Action List + Credit Catalog are resources included in the RELi Green + Resilient Property Underwriting and Finance Standard. RELi was developed through an American National Standards Institute (ANSI) accredited process as a National Consensus Standard. Additional resources used include Envision, LEED ND V4, LEED BD+C V4, Fortified, NYC Urban Green Building Resiliency Proposal, the 2030 Challenge, the Living Building Challenge and other similar sources.

With impacts identified from Task 1, and priority planning areas identified from Task 2, the team developed this framework to connect the range of actions to be addressed in the larger plan. The Master Action List itemizes the actions within each of the four categories, the references or sources of the recommendation and the Lead and Partner agencies involved. Lead refers to the lead agency or non-governmental entity recommended to take the lead on implementing the action. Partner refers to a supporting agency or non-governmental entity.

The Climate Adaptation Plan, Task 3 Report, should be read with the Climate Adaptation Master Action List in hand. The report provides an overall framework for the process and outcomes and provides narrative structure to set broader context within each of the issues. The Master Action List provides more detailed recommendations related to each climate risk and each of the areas above. A summary of these recommendations follows at the end of this section.

This plan builds on and leverages a larger set of climate adaptation and related planning efforts led by various District agencies, including:

- **The Department of Energy & Environment (DOEE)**: In addition to citywide climate adaptation planning efforts, DOEE leads several related efforts including the Floodplain Management Program which coordinates the District's participation in the National Flood Insurance Program, updating the District's Comprehensive Energy Plan, and implementation of the Sustainable DC Plan.
- **The District Department of Transportation (DDOT)**: In 2013, DDOT released a climate change adaptation plan for the District's transportation that outlined a framework to address

climate change impacts on DDOT's transportation assets including roadways, bridges, and tunnels.

- **The District Homeland Security, Emergency Management Agency (HSEMA)**: As the lead agency for emergency management efforts, HSEMA develops emergency preparedness plans including the District's All-Hazard Mitigation Plan, which when updated in 2016 will incorporate climate related hazards and mitigation actions.
- **The District Office of Planning (OP)**: In 2016, OP will update the District's Comprehensive Plan which provides guidance for future land-use planning and development. The update will include a new goals, objectives, and policies for resilience.
- **The Department of Health (DOH)**: Resilient DC is a collaborative project led by DOH to bring together residents, community partners, businesses, and District and Federal agencies to strengthen the District's ability to bounce back from disasters.

There is necessarily overlap across these sectors, so while an action may fall within the infrastructure sector, it will also likely impact buildings and neighborhoods.

TRANSPORTATION + UTILITY INFRASTRUCTURE

For transportation and utility infrastructure, these actions include the development of site-level adaptation plans for all transportation, energy, water & wastewater, telecommunications + data (internet) facilities, functions and service areas identified as at-risk from sea level rise and flooding based on the Vulnerability Assessment Priority Planning Areas. More broadly, there is a need to increase the resiliency of all energy, water, communication and transportation systems.

BUILDINGS + DEVELOPMENT

For buildings and development, these actions include various means to reduce demand and increase likelihood of ability shelter in place through improved back-up power and greater thermal safety. Paramount to these are increases in energy and water efficiency. These actions as well as broader land use planning to promote resiliency must be incorporated into development planning and review processes. This includes incentivizing private owners and developers to implement resiliency measures and developing agency protocols and sequencing for evaluating compliance with resiliency measures.

NEIGHBORHOODS + COMMUNITIES

For neighborhoods and communities, these actions include improving awareness of areas at greatest risk as well as improving readiness from emergency responders and community members. Special attention must be made to vulnerable populations. Response however is only one side of the equation.

Reducing risks from extreme heat through mitigation measures as well as improving access to cooling centers are equally important. For neighborhoods and communities, these adaptation measures must be complemented by improved community cohesion, a key indicator for greater community resilience. This includes encouraging healthier lifestyles, increasing opportunities for community engagement, proactive citizen response planning with community organizations and the development of neighborhood-scale systems such as district cooling to alleviate the dependency on the larger grid system. Each of these activities requires risk assessments by owners and occupants as well as work to implement projects identified in these assessments. These activities in turn open opportunities for workforce development within the communities of greatest risk.

GOVERNANCE + IMPLEMENTATION

For governance and implementation, these actions include additional analysis given gaps identified in this initial study. They also include the development of an organizational strategy that links all of the related adaptation efforts in the District with these findings.

A summary of actions within each category is provided in the following summary table, as well as which agencies are anticipated to lead the effort and which will provide support. Additional District agencies (outside of those above) are included where appropriate, as well as non-District agencies that may have jurisdiction over certain elements.

TABLE 3 Master Action List Transportation + Utilities Actions. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
TRANSPORTATION + UTILITIES					
Goal: Improve the transportation and utility infrastructure to maintain viability during periods of extreme heat, severe weather and flooding.					
TU 1.0	*Develop site-level adaptation plans for all facilities and service areas identified as at-risk from sea level rise and flooding.*				
TU 1.1	Identify at-risk facilities and develop adaptation or retirement plans for those facilities, prioritizing upgrades based on the age and criticality of the assets as well as their vulnerability.	Sea Level Rise Flooding	HSEMA	Infrastructure owners and operators (DDOT, WMATA, DC Water, Pepco, Washington Gas, etc.).	Short
TU 1.2	Conduct near-term (2020s) and long-term flooding (2050s+) evaluations for at-risk facilities based on projected increases in extreme precipitation and storm surges as well as permanent inundation due to sea level rise.	Sea Level Rise Flooding	HSEMA	Infrastructure owners and operators (DDOT, WMATA, DC Water, Pepco, Washington Gas, etc.).	Short
TU 2.0	*Increase the resilience of energy systems.*				
TU 2.1	Conduct distribution system planning in order to identify the best strategies for stabilizing the power grid with distributed energy resources including storage, renewable energy and micro-grids capable of islanding. Prioritize locations that could provide backup power to critical facilities, or alleviate congestion on the distribution grid.	Extreme Heat Flooding Extreme Weather	DOEE	DC SEU, Pepco, DC PSC, Washington Gas	Long
TU 2.2	Ensure that climate risks are considered in utility rate cases for investments in new and upgraded infrastructure. Flood proof and/or elevate electric infrastructure including, but not limited to, substations, transformers, switch gear, etc.	Sea Level Rise Flooding	DC PSC	Pepco, DOEE	Medium
TU 2.3	Ensure that climate risks are considered in utility rate cases for investments in new and upgraded infrastructure. Flood proof and/or elevate natural gas infrastructure including, but not limited to, pressure regulating stations, odorization equipment, tanks, controls, electric components, etc.	Sea Level Rise Flooding	Washington Gas	DC PSC, DOEE	Medium
TU 2.4	Conduct site-level studies of extreme heat risk to electric grid infrastructure including transformers and overhead transmission and distribution lines. Identify necessary upgrades and mitigation strategies.	Extreme Heat	Pepco	DC PSC, DOEE	Short-Medium
TU 3.0	*Increase resilience of drinking water, wastewater, and stormwater systems.*				
TU 3.1	Update design standards for water and drainage infrastructure to address the projected increase in intensity of precipitation.	Extreme Precipitation	DOEE	DDOT, DC Water	Medium
TU 3.2	Increase combined sewer and separate stormwater system capacity with green and grey infrastructure including raingardens, green roofs, trees, cisterns, and pervious pavement. Focus first on areas that flood regularly, have steep topography, or have known drainage capacity issues.	Flooding, Extreme Precipitation	DOEE	DC Water, DDOT	Long
TU 3.3	In order to prevent hazardous water pollution in the event of flooding, identify facilities with hazardous materials, hazardous wastes and brownfield sites in flood risk areas. Work with owners to develop prevention and response plans for potential flooding risks.	Extreme Precipitation	DOEE	HSEMA, FEMS	Medium

Table 3, Continued— Master Action List Transportation + Utilities Actions. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
TU 3.4	Reduce water demand and increase combined sewer system capacity with water recycling and reuse. Explore the use of distributed rainwater harvesting and grey/black water recycling to reduce demand on potable water systems during shortages or disruptions.	"Extreme Heat Drought	DOEE	DC Water	Long
TU 3.5	Flood proof critical components of drinking water infrastructure including, but not limited to, pumping stations, raw water reservoirs, finished water storage, waste treatment facilities, building infrastructure, access roads, etc. Implement backflow prevention techniques.	Sea Level Rise Flooding	DC Water	USACE	Medium
TU 3.6	Flood proof critical stormwater and combined sewer infrastructure including, but not limited to, pumping stations, inlets and outlets. Implement backflow prevention techniques.	Sea Level Rise Flooding	DOEE DC Water	DDOT	Medium
TU 4.0	*Increase resilience of communication systems.*				
TU 4.1	Expand the initial findings and recommendations of this report with a comprehensive vulnerability assessment of the AM/FM, TV, cellular communication and internet systems.	All	DC PSC	OCTO, Telecommunications Companies, HSEMA	Short
TU 5.0	*Increase resilience of transportation systems.*				
TU 5.1	Continue and expand efforts to mitigate flooding of the Metrorail system.	Flooding, Extreme Precipitation	WMATA	DDOT, DOEE	Medium
TU 5.2	Identify alternate evacuation routes for roads and bridges identified as vulnerable to flooding and/or sea level rise.	Sea Level Rise Flooding	DDOT	HSEMA	Short
TU 5.3	Update design standards for roads and transit infrastructure to account for projected extreme temperatures and extreme precipitation events. Ensure all street tree boxes are filled and that large shade trees are planted in tree boxes where possible.	Extreme Heat Extreme Precipitation	DDOT	WMATA, Amtrak, CSX, MARC, VRE	Long
TU 5.4	Evaluate existing bridges' expansion joints and design for resilience to extreme temperatures.	Extreme Heat/Cold	DDOT	FHWA	Medium
TU 5.5	Evaluate vertical clearance for bridges on waterways based on sea level rise projections.	Sea Level Rise	DDOT	FHWA	Medium

TABLE 4 Master Action List Buildings + Development. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
BUILDINGS + DEVELOPMENT					
Goal: Upgrade existing buildings and design new buildings and development projects to withstand climate change impacts.					
BD 6.0	*Provide back-up power for emergencies at all identified critical facilities. Ensure that existing back-up power systems are located above projected flood elevations.*				
BD 6.1	Evaluate the most critical facilities to identify those with or without existing back-up power systems; determine if they are above flood elevations, in good working order, and provide the appropriate capacity for that facility type.	All	HSEMA	DGS, DOEE	Medium
BD 6.2	Flood proof the most critical facilities to protect against future events accounting for sea level rise and increasingly severe precipitation events.	Flooding Sea Level Rise	DGS	HSEMA, DOEE	Long
BD 7.0	*Improve thermal safety + indoor building temperatures to increase resilience to extreme heat, especially in the event of a power outage.*				
BD 7.1	Incorporate recommendations/requirements for improving thermal safety in residential and building codes through the use of passive cooling strategies.	Extreme Heat	DCRA	DOEE, DOH	Short
BD 7.2	Identify existing residential building typologies (e.g. high rises, garden style) where residents are at highest-risk during extreme heat events and develop policies to support and encourage retrofits and upgrades.	Extreme Heat	DOEE	DHCD, DCHA, DCRA	Medium
BD 7.3	Expand existing incentive programs to include thermal safety and urban heat island mitigation measures such as cool roofs, solar shading, and shade trees.	Extreme Heat	DOEE	DCSEU	Short
BD 7.4	Evaluate the public housing portfolio for vulnerability to extreme heat and flooding and incorporate resilience in future capital improvement plans.	Extreme Heat, Flooding, Extreme Precipitation	DCHA	DOEE	Short
BD 8.0	*Pursue deep energy and water efficiency for all buildings.*				
BD 8.1	Continue to pursue energy efficiency for all commercial and residential buildings through incentive programs, building codes, and financing to increase grid stability by reducing energy demand at peak periods and during extreme events.	Extreme Heat	DCRA	DOEE, DCSEU	Short
BD 8.2	Consider developing a post occupancy energy optimization and retro-commissioning program for new and existing buildings to provide training and incentives to ensure the actual efficiency potential constructed into buildings is realized.	Extreme Heat	DOEE	DCRA, DCSEU	Medium
BD 8.3	Develop incentives, training and technical assistance programs for significant water use reductions including rainwater and greywater harvesting and onsite blackwater treatment.	Extreme Precipitation	DOEE	DC Water, DCRA, DDOT	Medium
BD 9.0	*Incorporate climate resilience into development planning and review processes.*				
BD 9.1	Develop climate resilience guidelines for new development projects.	All	DOEE	OP, DMPED, DCRA	Short
BD 9.2	Evaluate sequencing of agency approvals for new building development projects to determine the best point at which to incorporate flood review.	All	DCRA	DOEE, OP	Short

Table 4, Continued— Master Action List Buildings + Development. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
BD 9.3	Assess feasibility of district energy and/or micro grids and district stormwater management for all large development projects.	All	DOEE	OP, DMPED	Medium
BD 9.4	Require all planned unit developments, large tract review, and publicly financed projects to complete an adaptation checklist based on BD 9.1.	All	OP	DMPED, Zoning Commission, DDOT, OCFO, DOEE	Medium
BD 10.0	*Leverage land-use planning to promote resilience.*				
BD 10.1	Conduct a citywide analysis of flood zones to understand the impact of setbacks, buffers, and zoning and land use policies on existing and future developments.	Extreme Precipitation, Sea Level Rise, Flooding	DOEE	OP	Short
BD 10.2	Incorporate climate resilience into the District's Comprehensive Plan.	All	OP	DOEE, HSEMA	Short
BD 10.3	Propose amendments to floodplain regulations and zoning and land use policies to ensure that waterfront setbacks and buffers allow for future sea-level rise, changes in precipitation patterns, sustainable landscaping practices, erosion, and reduce flood risks.	Sea Level Rise, Flooding	DOEE	OP, DCRA	Medium
BD 10.4	Develop a set of flood resilience guidelines for the 500-year floodplain in addition to those existing for the 100-year floodplain for new development and substantial improvements.	Sea Level Rise, Flooding	DOEE	DCRA, OP	Medium
BD 10.5	Propose regulations that limit the development of new critical facilities including hospitals, emergency services, shelter facilities and critical infrastructure systems within the 500-year floodplain.	Sea Level Rise, Flooding	DOEE	OP, HSEMA	Medium
BD 10.6	Identify buildings in the current 500-year floodplain and create design guidelines for retrofitting the various typologies of buildings.	Sea Level Rise, Flooding	DOEE	DCRA	Medium
BD 11.0	*Provide incentives to encourage private property owners and developers to implement flood resiliency measures.*				
BD 11.1	Increase public awareness of flood risks and flood insurance. Offer rebates or grants for flood-resilience measures such as removable flood barriers, dry and wet flood proofing (for nonresidential buildings), elevation (for residential buildings) in vulnerable areas, and wastewater backup valves.	Flooding, Extreme Precipitation	DOEE	HSEMA	Medium
BD 11.2	Explore the use of buyouts and relocation for flood-prone properties in order to minimize flooding threats to residents and to facilitate the restoration of natural floodplains, as well as to account for future sea level rise. As a first step, assess potential areas through the update of the District's All Hazard Mitigation Plan.	Flooding	DOEE	FEMA, HSEMA	Medium
BD 11.3	Explore the use of tax credits for conservation of floodplains and natural buffers, such as wetlands and riverbank tree planting, in vulnerable areas.	Flooding	DOEE	OCFO, DISB	Medium
BD 11.4	Provide guidelines and encourage developers to consider resilience measures as community benefits for planned unit developments, large tract developments, and similar projects.	All	OP	DOEE	Short

TABLE 5 Master Action List Neighborhoods + Communities. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
NEIGHBORHOODS + COMMUNITIES					
Goal: Make neighborhoods and communities safer and more prepared by strengthening community, social, and economic resilience					
NC 12.0	*Improve emergency preparedness and planning with a particular focus on those most vulnerable.*				
NC 12.1	Encourage active participation by residents and businesses in disaster preparedness, response, and recovery training programs including the Community Emergency Response Team volunteer program.	All	HSEMA	Serve DC	Short
NC 12.2	Continue and expand efforts to identify and reach residents with greater vulnerability to climate change impacts including heat and flooding. Provide training to home healthcare, homeless service,and other service providers that engage directly with vulnerable residents.	All	DOH	HSEMA, Office on Aging, DHS, DOEE, ODR, DBH	Short
NC 12.3	Identify opportunities to reduce the economic impacts of severe weather and heat related events on vulnerable residents through existing programs and new partnerships to reduce utility bills and make homes more resilient.	All	DOEE	DOH, Office on Aging, DHCD	Short
NC 12.4	Evaluate health risks that are exacerbated by projected climate shifts as well as the cascading consequences of those shifts including impacts to air quality. Provide training and capacity-building to public health officials to address increased cases of heat stress as well as the potential for increased prevalence of disease-carrying specimens and infectious diseases.	All	DOH	DOEE	Medium
NC 12.5	Improve public awareness of health risks associated with climate change, and strategies for dealing with extreme heat and natural disasters.	All	DOH	DOEE, HSEMA	Medium
NC 12.6	Create a more in-depth assessment of vulnerable populations at the neighborhood level (where they live, what their needs are) to build upon ward-level assessments completed for this study.	All	HSEMA	DOEE, DOH, OP	Short
NC 13.0	*Reduce risks of extreme heat and the urban heat island.*				
NC 13.1	Develop thermal mapping of the District to identify urban heat-island hot-spots, vulnerable residents, and areas with the greatest potential for cooling.	Extreme Heat	DOEE	OCTO	Short
NC 13.2	Reduce the heat-island effect and related increase in outside air temperatures with cool and living roofs, expanded green space, tree planting and tree protection efforts, prioritizing hotspots and those areas with the greatest number of heat vulnerable residents. Incorporate heat-island mitigation into planning for green infrastructure, tree canopy, and public space initiatives.	Extreme Heat	DOEE	OP, DDOT, DPR	Medium
NC 13.3	Evaluate existing cooling centers based on location, accessibility and needs of vulnerable residents. Consider areas for pets, security, sign-language interpreters, child friendly amenities, accessible restrooms, medical assistance, back-up power, sleeping areas, drinking water, and proximity to transit.	Extreme Heat	HSEMA	DOH, DOEE	Short
NC 13.4	Evaluate and revise existing heat-emergency plan and warning system with community input. Leverage health and temperature data from past events to determine the best activation and warning thresholds. Consider implementing a tiered warning system to account for the increasing severity and duration of heat events.	Extreme Heat	DOH	HSEMA, DOEE	Medium

Table 5, Continued— Master Action List Neighborhoods + Communities. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
NC 14.0	*Strengthen community cohesion for safety and resilience.*				
NC 14.1	Assess walkability, bikeability, and public transit access in the District in order to reduce the dependence on personal cars and diversify transportation and evacuation options in the event of an emergency. Use Walk Score or Walkability Index as a tool to evaluate priority planning areas and their dependency on transit systems that may be at greater risk due to climate impacts. Prioritize improvement of walkability and connectivity to those areas as part of the update to the Comprehensive Plan.	All	DDOT	OP	Short
NC 14.2	Develop or maintain planning policies to support neighborhoods with easy access to fundamental resources including, but not limited to, a mix of food, emergency and health services, basic business services, housing types and cost ranges and community spaces such as meeting rooms, community gardens + tool share, park space, libraries and schools.	All	OP	DOH, DGS, DCPL, DHCD, DPR, DSLBD,	Long
NC 14.3	Strengthen and encourage active participation in community-based organizations and expand opportunities for civic engagement and volunteerism. Provide capacity-building and training for community level emergency preparedness and resiliency planning. An example is the Evacuteer Program in New Orleans. See www.evacuteer.org.	All	DMGEO	Serve DC, HSEMA	Medium
NC 14.4	Encourage healthy lifestyles through the built environment and neighborhood planning. Apply active design to buildings. Encourage walking and biking for transportation. Provide green space that supports community activities and serves as a rain garden to capture slow precipitation runoff. Provide public spaces that encourage the community to come together to pro-actively foster a culture of resilience. Assess health profiles of priority planning areas to determine where the greatest needs are for lifestyle improvements and prioritize activities to support those areas.	All	OP	DOH	Medium
NC 14.5	Leverage climate adaptation implementation projects to advance workforce development objectives and to promote business continuity planning.	All	DOES	DOEE, DDOT, DSLBD	Medium
NC 15.0	*Develop eco-resilience districts and community resilience hubs.*				
NC 15.1	Leverage ongoing work with neighborhood planning to begin to implement neighborhood-scale resilience solutions including district energy and micro grids, and district stormwater and water reuse systems.	All	OP, DOEE	OP	Medium
NC 15.2	Explore the creation of Community Resilience Hubs which would locate emergency preparedness and response supplies and training in resilient community facilities, be they privately or publicly owned (e.g., churches, community centers, etc.). An example is the Evacuteer Program in New Orleans. See www.evacuteer.org.	All	DMGEO, HSEMA	DOH	Medium
NC 15.3	Provide technical and financial assistance to private entities that provide essential services, including universities, hospitals and affordable housing so that these entities may conduct their own risk assessments. Work with these entities to integrate their risk assessments into the larger plan for the District.	All	HSEMA	Private entities hosting critical District facilities	Medium

TABLE 6 Master Action List Governance + Implementation. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
GOVERNANCE + IMPLEMENTATION					
Goal: Establish the policies, structures, and monitoring and evaluation procedures to ensure successful implementation of the adaptation plan.					
GI 16.0	*Conduct additional analysis of climate vulnerability and adaptation strategies based on current gaps and to account for the latest climate science.*				
GI 16.1	Develop and periodically update comprehensive flood modeling for the District that translates the projections for future sea level rise and extreme precipitation into updated flooding extents and depths for riverine, coastal, and interior flooding.	All	HSEMA	DOEE, DC Water	Short
GI 16.2	Monitor annually the current climate change science regarding impacts that were not comprehensively addressed by the climate change projections, including extreme cold, wind/storms, drought, and groundwater.	Extreme Cold, Extreme Wind, Drought	DOEE	HSEMA	Short
GI 16.3	Support efforts by infrastructure owners including WMATA, DC Water, Pepco, Washington Gas, and telecommunication providers to conduct more in-depth climate vulnerability assessments of their systems.	All	DOEE	HSEMA	Medium
GI 17.0	*Align Climate Ready DC with related planning efforts including hazard mitigation, comprehensive land-use, comprehensive energy, and capital budget planning.*				
GI 17.1	Incorporate long-term energy resilience planning into the five-year Comprehensive Energy Plan.	All	DOEE	OP	Short
GI 17.2	Integrate climate change adaptation into the District's Hazard Mitigation Plan and related emergency planning efforts.	All	HSEMA	DOEE	Short
GI 17.3	Develop climate change resilience guidelines for all capital projects t o ensure that public facilities are resilient to extreme heat, floods, and severe weather. Incorporate climate impact assessments into the planning, design, and engineering of capital projects.	All	EOM	DOEE, DGS	Short
GI 17.4	Add resilience as an element to the Comprehensive Plan for the National Capital: District Elements.	All	OP	DOEE	Short
GI 17.5	Revise engineering and building standards and codes to address climate change.	All	DCRA	DOEE	Short-Medium
GI 17.6	Engage with the Historic Preservation Review Board, Zoning Commissioning, and Public Service Commission, etc. to ensure that projects are allowed/ encouraged to incorporate greater resilience during design and permitting.	All	DOEE	HPRB, Zoning Commission, PSC, NCPC, OP	Short
GI 17.7	Incorporate climate risks and adaptation strategies into natural resource and ecosystem planning including the Wildlife Action Plan, Wetland Conservation Plan, and tree canopy planning.	All	DOEE	DDOT	Short
GI 18.0	*Establish the necessary structures to ensure successful implementation of Climate Ready DC.*				
GI 18.1	Develop a supporting implementation plan for the strategy that identifies lead agencies, timelines, and potential funding sources.	All	DOEE	OCA	Short
GI 18.2	Identify potential sources of funding and financing including emerging financing tools like green/climate bonds. Leverage existing capital budgets (for public and private infrastructure) to implement upgrades over time.	Sea Level Rise, Flooding	OCFO	OCA	Short

Table 6, Continued— Master Action List Governance + Implementation. *All = Sea Level Rise, Flooding, Extreme Heat, Extreme Weather, Extreme Precipitation, Extreme Cold, Extreme Wind, Drought

#	Action (sub-action)	Climate Risks	Lead(s)	Partners	Timeframe
GI 18.3	Develop a plan for monitoring and evaluation including the identification of key indicators of climate vulnerability and successful adaptation. Integrate monitoring and evaluation into existing performance management processes.	All	DOEE	OCA	Short
GI 18.4	Establish a public-private task force with key stakeholders including community organizations, businesses, and infrastructure owners and operators to oversee and coordinate implementation of the plan, identify funding opportunities, and develop cross-cutting policy recommendations and design guidelines.	All	EOM	DOEE	Short
GI 18.5	Require climate change training for staff responsible for capital infrastructure and large development projects to educate them about climate risks and how to manage them.	All	EOM	DOEE	Medium
GI 18.6	Use existing cross-agency, inter-governmental, and regional networks like the DC Silver Jackets to share technical resources and best practices. Establish an ongoing best practices/lessons learned forum that brings together key representatives from each collaborating agency.	All	EOM	DOEE	Short
GI 18.7	Develop a system to regularly evaluate sea level rise and changes in the 100-year and 500-year flood plain in order to provide clear guidance to developers and regulators.	All	DOEE	OP, DCRA	Medium
GI 18.8	Incorporate health impact analysis in prioritization of transportation projects.	All	DDOT, DOH	OP, DOEE	Short

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04

NEXT STEPS

At this point, the DOEE team has engaged in multiple shared stakeholder conversations in order to advance its assessment as well as to contribute to others. These stakeholders include:

- Architect of the Capitol (AOC)
- DC Housing Authority (DCHA)
- DC Office of Planning (DCOP)
- DC Water
- Department of General Services (DGS)
- Department of Health (DOH)
- Department of Housing and Community Development (DHCD)
- Department of Public Works (DPW)
- District Department of Transportation (DDOT)
- Department of Human Services (DHS)
- Georgetown Climate Center
- Homeland Security and Emergency Management Agency (HSEMA)
- Metropolitan Washington Council of Governments (MWCOG)
- National Capital Planning Commission (NCPC)
- National Park Service (NPS)
- Pepco
- Smithsonian Institution (SI)
- United States General Services Administration (US GSA)
- University of Maryland
- Washington Gas
- Washington Metropolitan Area Transit Authority (WMATA)

The next step is for DOEE to collaborate with the Lead and Partner agencies as identified in the Master Action List to:

- Develop the governance structure and partnerships with Lead and Partner agencies as well as stakeholders who have parallel climate adaptation efforts ongoing.
- Establish a schedule for completion of remaining assessments noted herein while establishing metrics + evaluation approaches.
- Identify funding sources and Lead agencies for remaining assessments.
- Begin discussions regarding public/ public-private financing and detailed implementation strategies.

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APPENDICES

Task 1 Report - Climate Projections & Scenario Development Report

Task 2 Report - Vulnerability and Risk Assessment

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GLOSSARY

2030 Challenge

'Architecture 2030 is a non-profit organization established in response to the climate change crisis in 2002. Architecture 2030's mission is to rapidly transform the built environment from the major contributor of greenhouse gas (GHG) emissions to a central part of the solution to the climate crisis. Within this mission, 'all new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70% below the regional (or country) average/median for that building type.' http://architecture2030.org

Envision

'A product of a joint collaboration between the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure. Envision® provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle.' https://www.sustainableinfrastructure.org/rating/.

Epidemiological

The study of the distribution and determinants of health-related states or events (including disease), and the application of this study to the control of diseases and other health problems [World Health Organization]

Fortified

A set of standards developed by the Insurance Institute for Business & Home Safety (IBHS), an independent, nonprofit, scientific research and communications organization supported solely by property insurers and reinsurers.' It is a 'code-plus new construction program that offers a package of improvements that greatly increase a new light commercial building's durability and resilience to natural hazards.' https://disastersafety.org/

For the 2020s, there is no statistically significant difference between the magnitudes of climate change projected under a higher scenario as compared to a lower one. This is due to the unlikelihood that a change in human behavior will have a noticeable impact on present trends in climate, due to the inertia of both the climate system and effects of historical human impacts. Climate projections for the 2050s and 2080s, on the other hand, are scenario-dependent. Therefore, projections must be considered separately for the higher and the lower scenarios. Therefore, the vulnerability assessment will depend on the scenarios used for future projections, and the eventual proposed adaptation plan strategies will be preliminary for the 2080s. Source: Task 1 Climate Projections Report:

Living Building Challenge

A building certification program, advocacy tool and philosophy comprised of seven performance categories called Petals: Place, Water, Energy, Health & Happiness, Materials, Equity and Beauty. Petals are subdivided into a total of twenty Imperatives, each of which focuses on a specific sphere of influence. This compilation of Imperatives can be applied to almost every conceivable building project, of any scale and any location—be it a new building or an existing structure. http://living-future.org/lbc/about

Micro-grid

Localized grids that can disconnect from the traditional grid to operate autonomously and help mitigate grid disturbances to strengthen grid resilience [Energy.gov]

National Climate Assessment

The National Climate Assessment summarizes the impacts of climate change on the United States, now and in the future. nca2014.globalchange.gov

NYC Urban Green Building Resiliency Report - The Building Resiliency Task Force Report provides 33 actionable proposals for making New York buildings and residents better prepared for the next extreme weather event. Convened in 2013 at the request of the City of New York following Superstorm Sandy, 200-plus task force members led by Urban Green were charged with making recommendations to improve building resiliency and maximize preparedness for future weather emergencies. http://urbangreencouncil.org/content/projects/building-resiliency-task-force#sthash.Y1LMFuXg.dpuf

Phenology

Key seasonal changes in plants and animals from year to year—such as flowering, emergence of insects and migration of birds—especially their timing and relationship with weather and climate [US National Phenology Network]

RELi

A systems-based Green + Resilient Property Underwriting and Finance Standard that provides a structured approach to assessing resiliency across social, economic and environmental issues. www.c3livingdesign.org

Sustainable DC Plan

A long-term sustainability vision and action plan for the District of Columbia. www.sustainable.dc.gov

United States Green Building Council

An organization established ‘in 1993 to promote sustainability in the building and construction industry. LEED, or Leadership in Energy & Environmental Design, is a green building certification program administered by USGBC. To receive LEED certification, building projects satisfy prerequisites and earn points to achieve different levels of certification. Prerequisites and credits differ for each rating system, and teams choose the best fit for their project.’ Standards referenced for the District Climate Adaptation plan include: LEED ND V4, LEED BD+C V4. Accessed (2015) www.usgbc.org

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