District Department
of Transportation

Climate Change Adaptation Plan

Contents

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TREE EXPERTS

Executive Summary

Changes in climate patterns are becoming an increasingly important phenomenon both globally and in the United States. In particular, the District of Columbia (the District) has experienced several extreme weather events in recent years demonstrated through several days of snow, intense winds, rain, flooding, and storm surge. These events caused extensive disruption to activities and services throughout the city including its transportation system. Research and science indicate that extreme weather events such as these are becoming more intense and common.

Many scientists and experts have indicated that changes in the characteristics of our environment, specifically temperature, precipitation rate, and sea level rise, can cause more intense storms resulting in severe flooding, soil erosion, and several other effects on the built environment. These changing climate conditions play a particularly important role in the planning, design, and maintenance of transportation infrastructure. Our transportation assets, such as roads and bridges, need to withstand the worst weather events and minimize effects that could shorten service life.

Recognizing the need to prepare itself for more intense weather events, the District Department of Transportation (DDOT) has developed a plan to adapt its transportation system to climate change. The plan focuses only on transportation and was developed based on the National Cooperative Highway Research Program (NCHRP) and Federal Highway Administration (FHWA) research and guidance. This document not only outlines the adaptation framework to address climate change impacts on DDOT's transportation assets, it also consists of a series of action items that will enable DDOT to move forward in implementation.


STOP

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Introduction

In the past few years, the District of Columbia (the District), similar to other areas in the United States, has experienced extreme weather events more frequently. These events have resulted in increased snow, intense winds, higher rainfall events, flooding, and storm surges. These recurring extreme weather events are an indication of the changes in climate.

Some of the recent extreme weather events that hit the District in recent history include the snow storm of 2010, hurricanes Irene (2011) and Sandy (2012). These events are a stark reminder of how extreme weather impacts the transportation system of an entire city and even a region. According to the United States Department of Transportation (USDOT), "the climate is changing and the transportation sector needs to prepare for its impacts" (USDOT 2011 Climate Change Policy).

With growing evidence of increased frequency and/or intensity of extreme weather events anticipated to occur in the future, there is a need to review and adapt transportation infrastructure to withstand the detrimental effects that extreme weather events can have on the District's transportation system as a result of climate change.

As a first step to reinforce its ability to respond and adapt to extreme weather events, the District Department of Transportation (DDOT) has developed this Climate Change Adaptation Plan.

Climate Change and Transportation

Weather and climate play prominent roles in the planning, design, and maintenance of the transportation system. When even a light rain can slow down traffic, it's not surprising that extreme weather events, such as hurricanes, floods, and snowstorms, can shut down large parts of the transportation network for extended periods. The storm events that occurred over the past few years have shown us the impacts of extreme weather and the challenges that they pose to transportation infrastructure and the community it serves. Climate considerations play a key role in the delivery and resiliency of transportation services in the face of changing weather patterns.

1 Introduction

Climate Change Adaptation and DDOT

DDOT owns and maintains over 4,000 lane miles of roadways and streets, 240 bridges and tunnels, 68,000 street lights and over 1400 signalized intersections. The design, maintenance, operation, and development of this huge infrastructure requires DDOT to develop ways to ensure that its infrastructure can withstand the worst weather events and minimize effects that could shorten service life.

DDOT started working on climate change issues several years ago and identified climate change adaptation as one of the eight priorities in DDOT's Sustainability Plan. DDOT actively participated in the DC Climate Change Action Plan that was developed by the District Department of the Environment (DDOE). DDOT has also been an active participant of the Transportation and Climate Change Initiative (TCI) for the Mid Atlantic and Northeastern States, and was one of the 12 signatory States on the "Declaration of Intent" to work on climate change issues.

Due to its early work in climate change, in 2011 DDOT was selected by the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) to host one of the early climate change workshops. This workshop provided DDOT an opportunity to facilitate a national dialogue with federal, regional, and local agencies as well as national experts in the field and formulate next steps in the development of climate change adaptation methodologies. The workshop was attended by several agencies including Federal Highway Administration (DC Division and Headquarters), Federal Transit Administration, US Environmental Protection Agency, National Park Service, New York State Department of Transportation, Metropolitan Washington Council of Governments, National Capital Planning Commission, District Department of the Environment, DC Office of Planning, Georgetown Climate Center, and Washington Metropolitan Area Transit Authority.

In October 2012, DDOT held another Climate Change Workshop. The focus of this workshop was to engage national and state experts in developing ideas to integrate climate change adaptation approaches into DDOT's policies and practices, and finalize development of the DDOT Climate Change Adaptation Plan.


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Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC 1992).

According to the US Environmental Protection Agency (EPA), climate change refers to: "any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer" (EPA 2012).

Weather vs. Climate

While weather is focused on short-term occurrences and experiences, climate is the reflection of specific trends developed over a longer period of time (i.e., decades or hundreds of years), and in some cases manifests itself through the changing magnitude and frequency of extreme weather events. The science of climate change requires us to understand the impacts of not only an intense downpour that may occur this week, but also how many intense downpours could occur over the next 25, 50, 100 years and how many inches of rain or sea level change may be occurring.

Climate Change Indicators

There are many climate change indicators or variables such as temperature, precipitation, storms, droughts, heat waves, greenhouse gas emissions, ocean heat, sea level rise, glacier melts, snow cover, length of growing seasons, and leaf and bloom dates. Temperature, sea-level rise, precipitation, and storms are four of the most common climate-related indicators used.

Temperature

Rising temperatures represent the most certain outcome of climate change and drive changes in other climate-related variables like sea levels and precipitation. With increasing amounts of greenhouse gases, the Earth's atmosphere gradually retains more heat from solar radiation. Eventually, this retained heat leads to warmer surface temperatures. Recent studies show a general trend towards warmer weather. According to the EPA, average temperatures have risen across the lower 48 states since 1901, with an increased rate of warming over the past 30 years (EPA 2010). Seven of the top 10 warmest years on record for the lower 48 states have occurred since 1990, and the last 10 five-year periods have been the warmest five-year periods on record. Average global temperatures show a similar trend, and 2000–2009 was the warmest decade on record worldwide. Within the United States, parts of the North, the West, and Alaska have seen the most temperatures increase (EPA 2010).

Figure 1 shows the changes in average air temperatures in different parts of the United States since the early 20th century, including data since 1901 for the lower 48 states (EPA 2010).

Figure 2 presents the projected temperature changes in the United States by the middle and end of this century (USGCRP 2009).

Figure 3 shows that currently rare extreme temperatures are projected to become more commonplace in the future. For instance, it is projected that a day so hot that it is currently experienced every 20 years would occur every other year or more frequently by the end of the century.

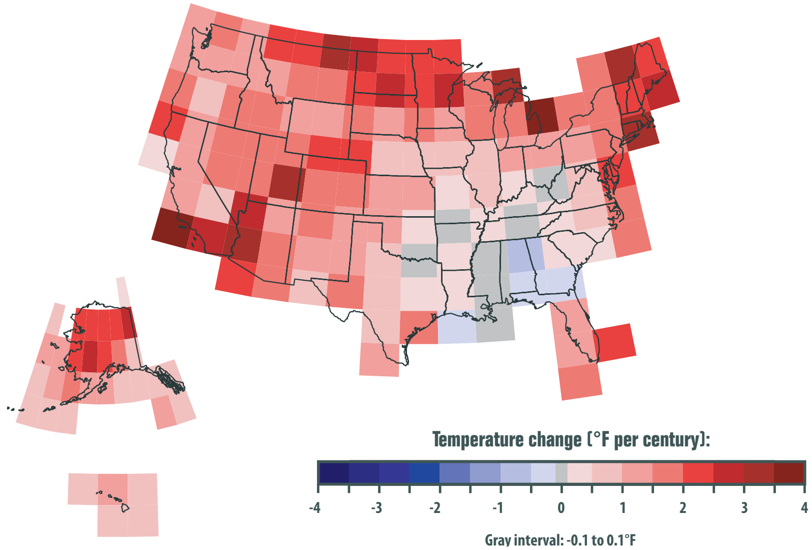


Figure 1
Rate of Temperature Change in the U.S., 1901-2008
Source: EPA 2010

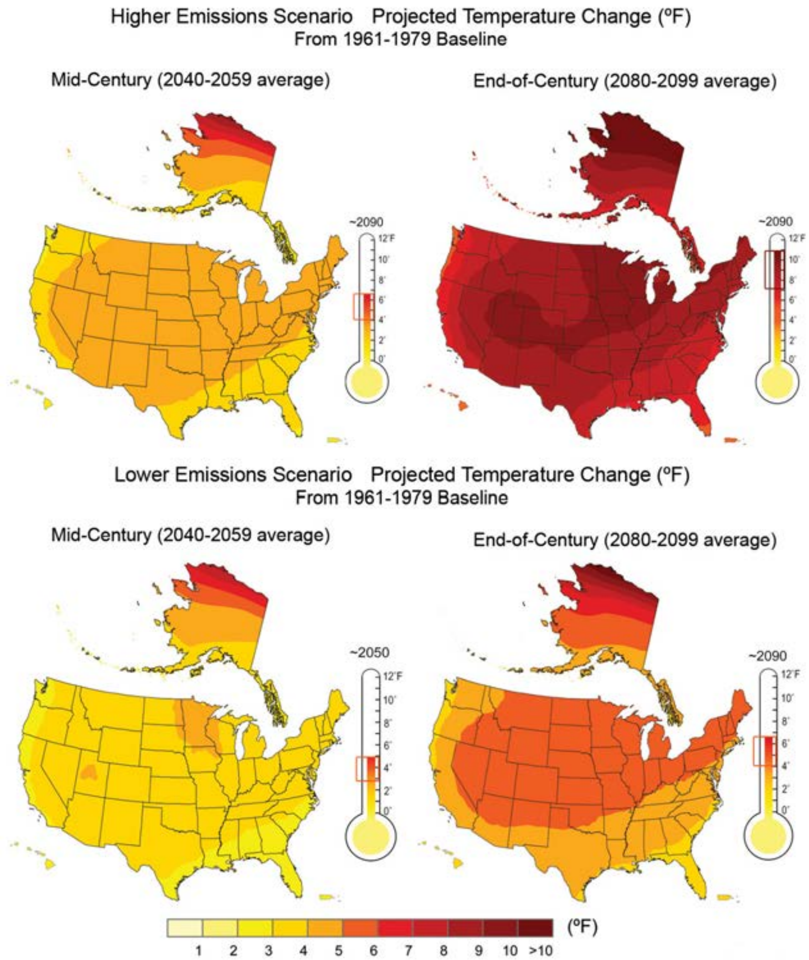
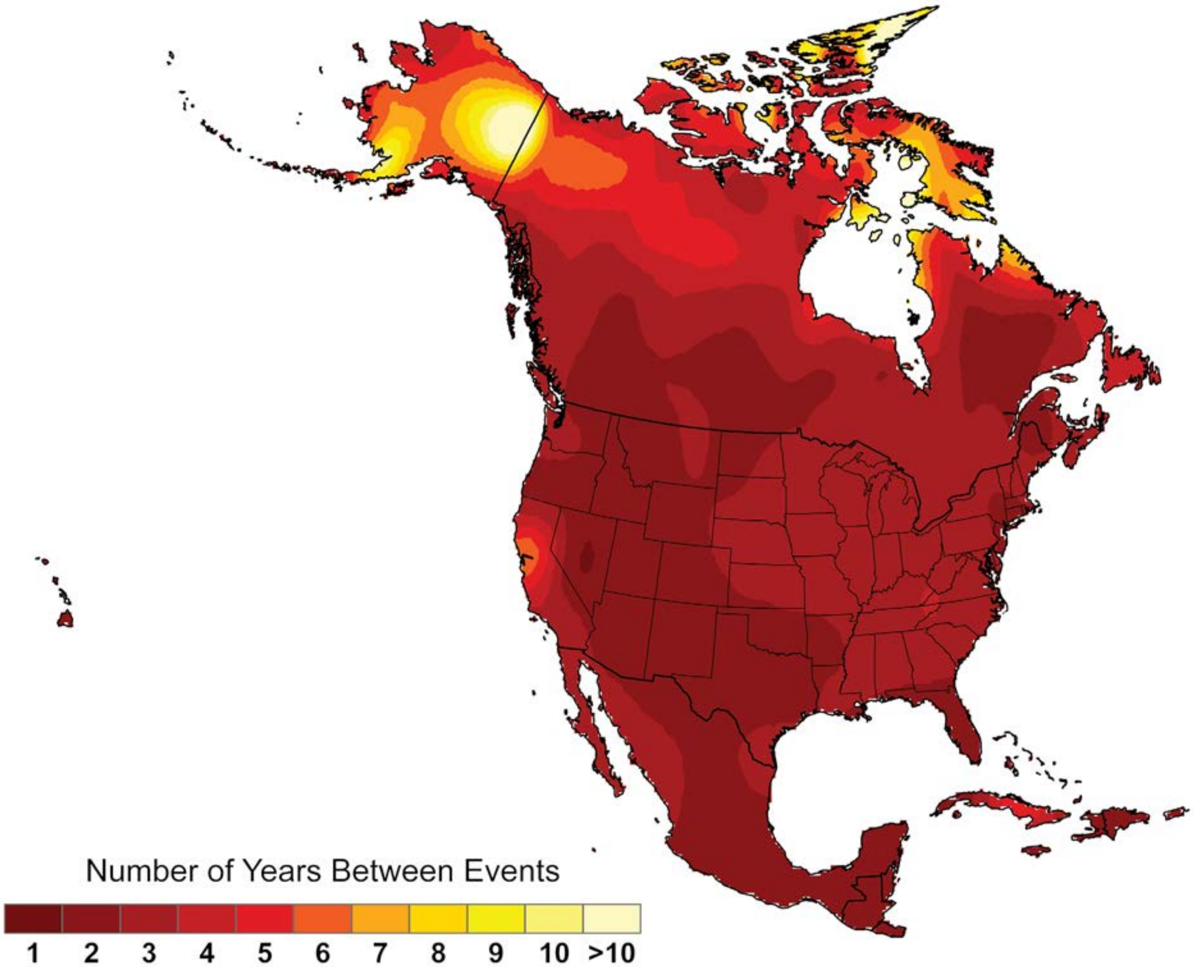


Figure 2
Projected Temperature Change in the U.S.
Source: USGCRP 2009



Source: USGCRP 2009

Projected Temperature Change in the U.S.

Figure 3

Sea Level Rise

The rise in temperatures can have impacts beyond more uncomfortable heat waves. At the global level, higher temperatures will also melt arctic ice sheets and lead to thermal expansion of the oceans. Together, these processes will lead to significantly higher sea levels by the end of this century. Sometimes rising sea levels are made even more complex as land in some areas is sinking at the same time due to independent geologic processes. Higher sea levels can have three effects: (1) inundation of some low-lying riverside areas; (2) higher storm surges in areas currently at risk of surge; and (3) expansion of areas being exposed to storm surges.

When averaged over all the world's oceans, sea level has increased at a rate of roughly six-tenths of an inch per decade since 1870. The rate of increase has accelerated in recent years to more than an inch per decade. Changes in sea level relative to the height of the land vary widely because the land itself moves. Along the U.S. coastline, sea level has risen the most relative to the land along the Mid-Atlantic coast and parts of the Gulf Coast. Sea level has decreased relative to the land in parts of Alaska and the Northwest (EPA 2010). Figures 5 and 6 show the change in sea level for the United States for the past century, while Figure 4 shows the sea level change trend for the District. Both the Potomac and Anacostia Rivers are tidal rivers and the areas bordering them can expect to experience the effects of these sea level changes, including increased flooding.

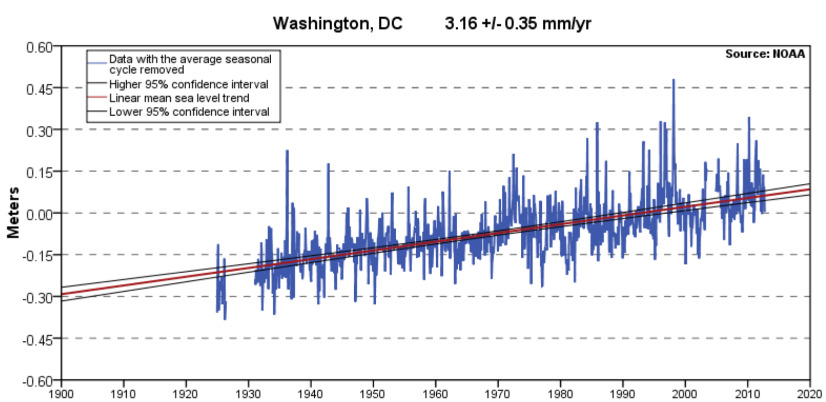
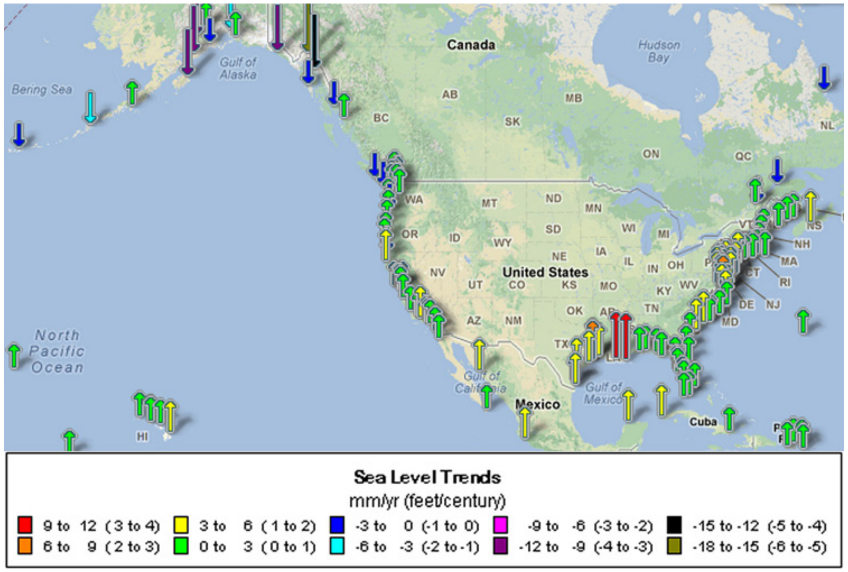


Figure 4

Sea Level Change for Washington DC

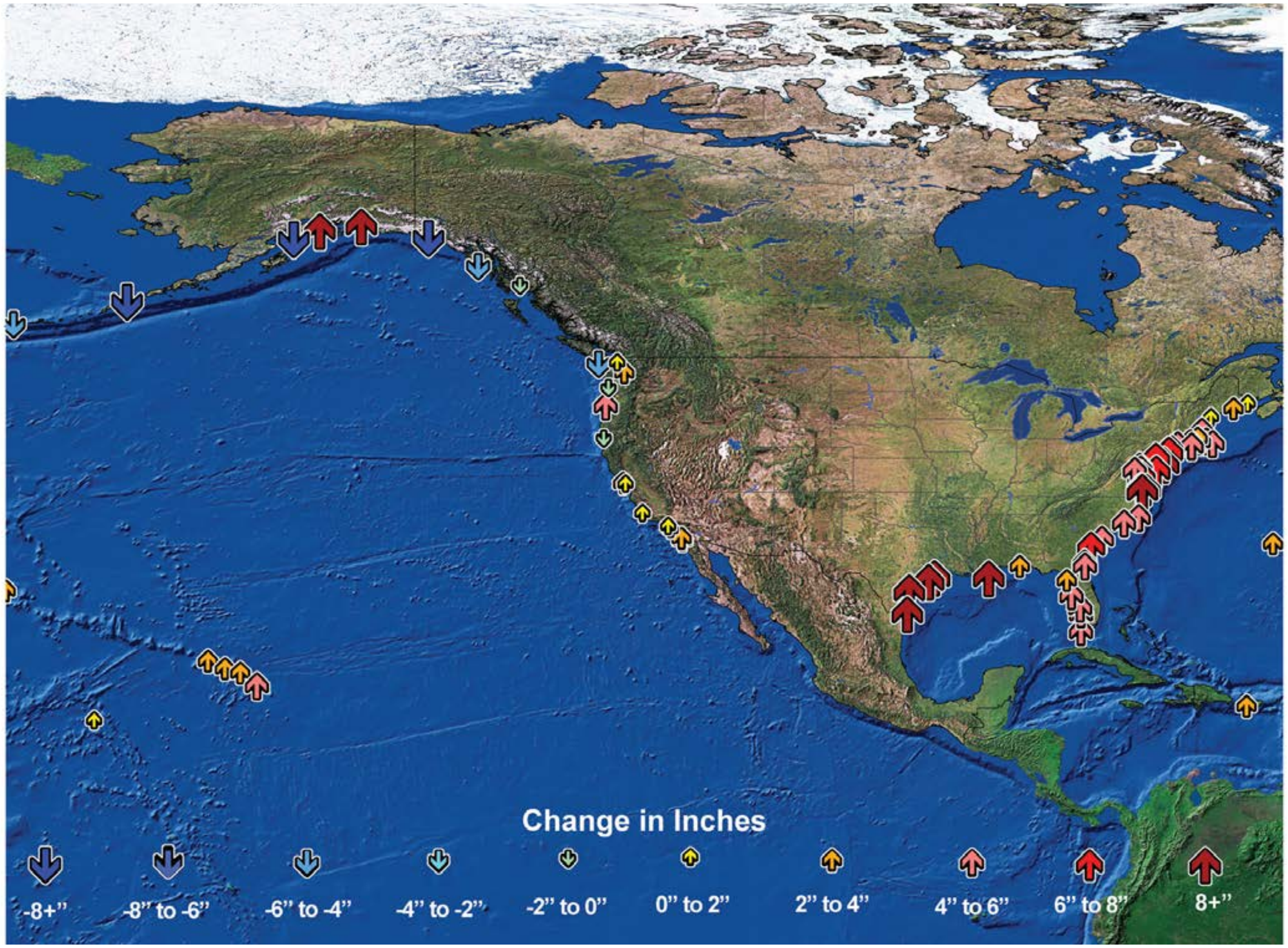
Source: NOAA/CO-OPS 2012



Sea Level Change in the U.S.

Source: NOAA/CO-OPS 2012

Figure 5



Source: USGCRP 2009

Projected Temperature Change in the U.S.

Figure 6

Precipitation

Changes in precipitation are another important indicator of climate change. There has been an increase in average precipitation globally as well as in the United States. Since 1901, global precipitation has increased at an average rate of 1.9 percent per century, while precipitation in the lower 48 states of the United States has increased at a rate of 6.4 percent per century (EPA 2010). Another important phenomenon that has been observed in recent years in the United States is the higher percentage of precipitation being recorded in the form of intense single-day events. Figure 7 shows the changes in precipitation trends in the United States over the past 50 years, while Figure 9 projects future changes in precipitation relative to the season.

On average, much of the United States including the District is expected to get wetter throughout the 21st century; although, the wet weather events may be spaced out by periods of intense dry spells. Figure 8 shows the projected percentage change in average seasonal precipitation for the District region. The changes expected to occur during the summers are likely to be less intense than those that would occur in the winters. Winter conditions are expected to be far wetter, which may be intensified by higher greenhouse gas emissions.

With these projected percent changes in precipitation, the frequency and intensity of extreme precipitation events may also be affected. Consequently, flooding and landslides caused by these intense rain storms can be expected to increase accordingly.

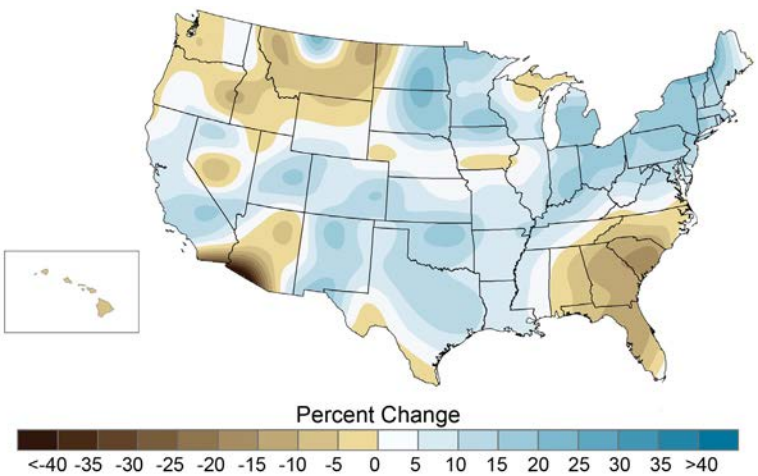


Figure 7

Change in Precipitation Trends in the U.S.
Source: USGCRP 2009

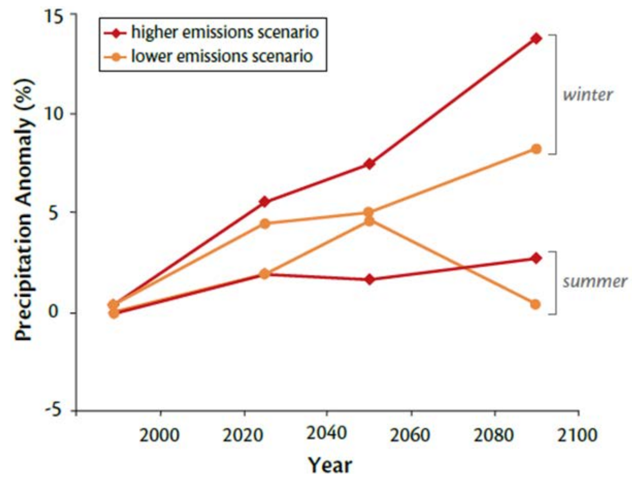
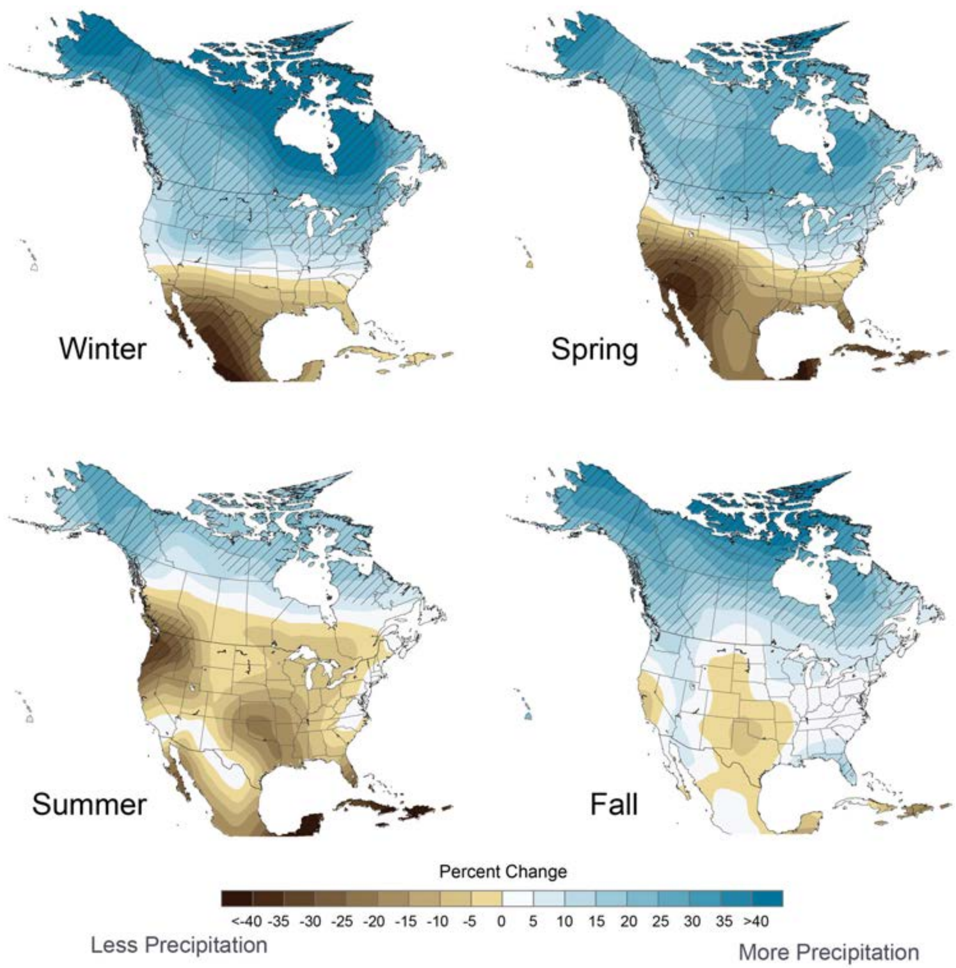


Figure 8

Projected Percentage Change in Summer and Winter Precipitation
Source: UMCES 2008



Source: USGCRP 2009

Future Changes in Precipitation Trends

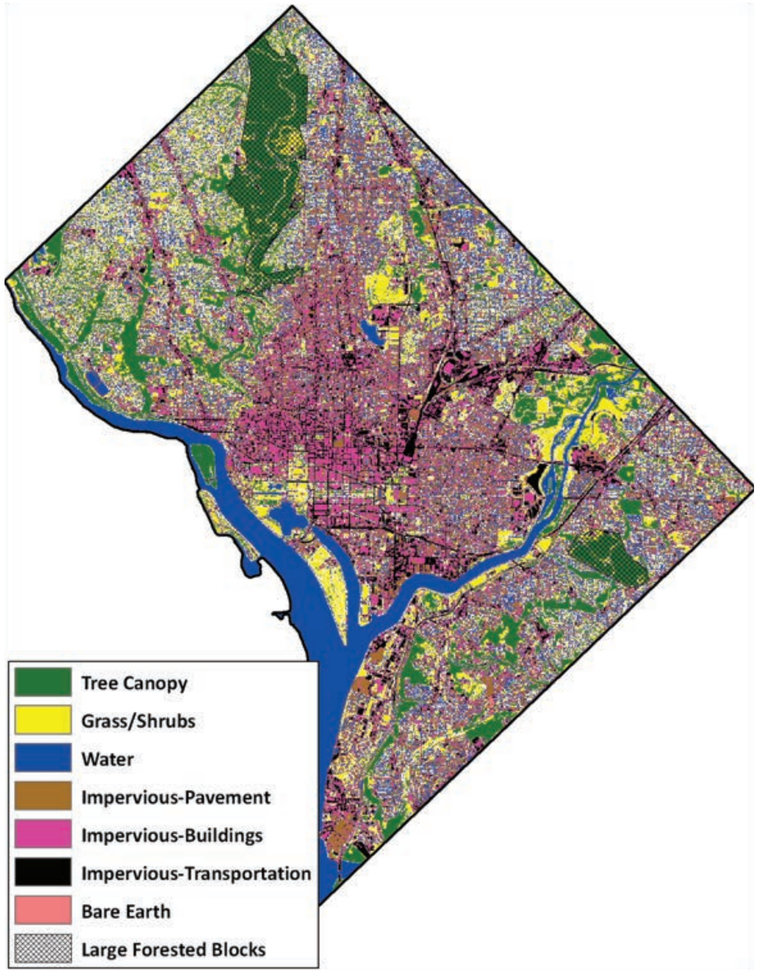
Figure 9

Storms

The EPA reports that the intensity and frequency of tropical storms in the Atlantic Ocean, Caribbean, and Gulf of Mexico have risen noticeably over the past 20 years, with six of the 10 most active hurricane seasons occurring since the mid-1990s. These trends are closely related to variations in sea surface temperature in the tropical Atlantic (EPA, 2010), leading the U.S. Global Change Research Program to conclude that hurricane activity has "increased substantially since the 1950s and '60s in association with warmer Atlantic sea surface temperatures."

The Washington DC area has been affected by severe weather conditions such as hurricanes and blizzards, with more frequency and intensity. These storms that affect the Washington area get their energy from both the warm waters of the tropics (e.g., Hurricane Irene) and the jet stream from cold fronts from the north and warm fronts from the south (e.g. extreme snow events of 2010). These storms produced intense rain and high winds that resulted in property damage, flooding, and downed trees, negatively impacting tree canopy and urban forest restoration efforts.

The trees in the District are one of DDOT's most important assets. Typically, trees in full leaf-out more effectively shade and help protect buildings during heat waves. Additional benefits of urban trees include capturing rainfall, absorbing pollutants, reducing stormwater runoff, and reducing heat island effects. DDOT's Urban Forestry Administration (DDOT Trees) reported that during Hurricane Sandy, 224 trees were lost and the largest fallen tree being 12 feet in diameter. Additionally, the June 2012 derecho caused more tree damage in the District than Hurricane Sandy.



Land Cover and Tree Canopy in the District
Source: USDA Forest Service 2009

Figure 10

Source: flickr user Ben H. Rome

Climate Change Adaptation Plan Framework and Scope

Historically, transportation infrastructure has been developed under the assumption that climate and weather patterns remain constant through its service life. With growing climate change impacts, a better understanding of these changes and impacts is needed such as: climate projections and uncertainties in these projections; vulnerabilities of the infrastructure; and steps needed to adapt the infrastructure to address these changes. Based on this information an adaptation plan can be developed for an organization to prepare and adapt its assets for changes in climate.

There are various climate change adaptation frameworks available. The two most notable are developed by National Cooperative Highway Research Program (NCHRP) and FHWA.

Adaptation Framework

A process to address weather and climate change as part of agency operations was developed for NCHRP, 20-83 (05) Climate Change and the Highway System. This framework provides a basis for decisions that can be modeled and integrated into regular agency processes. The framework is further outlined in Figure 11.

In November 2012, FHWA released a draft of the "Climate Change & Extreme Weather Vulnerability Assessment Framework." According to FHWA, the vulnerability assessment framework consists of three primary components:

1. Defining Objective and Scope
2. Assessing Vulnerability
3. Integrating Vulnerability into Decision-making

Figure 12 illustrates this framework in detail. DDOT's Climate Change Adaptation Framework is focused on the three vulnerability assessment components of the FHWA framework. The scope of the DDOT Climate Adaptation Plan is provided below. DDOT's approach and strategies for assessing vulnerability and integrating vulnerability considerations into the planning process are discussed in the next chapter.

Scope

The purpose of DDOT's Climate Change Adaptation Plan is to develop and identify strategies to ensure DDOT's transportation infrastructure can withstand the changes in climate and extreme weather conditions. The target audience for this framework plan is decision makers, engineers, designers, planners, and other transportation professionals in DDOT. Based on research and expert opinion, temperature, sea level rise, precipitation, and storms were identified as the key climate variables to affect the District transportation system.

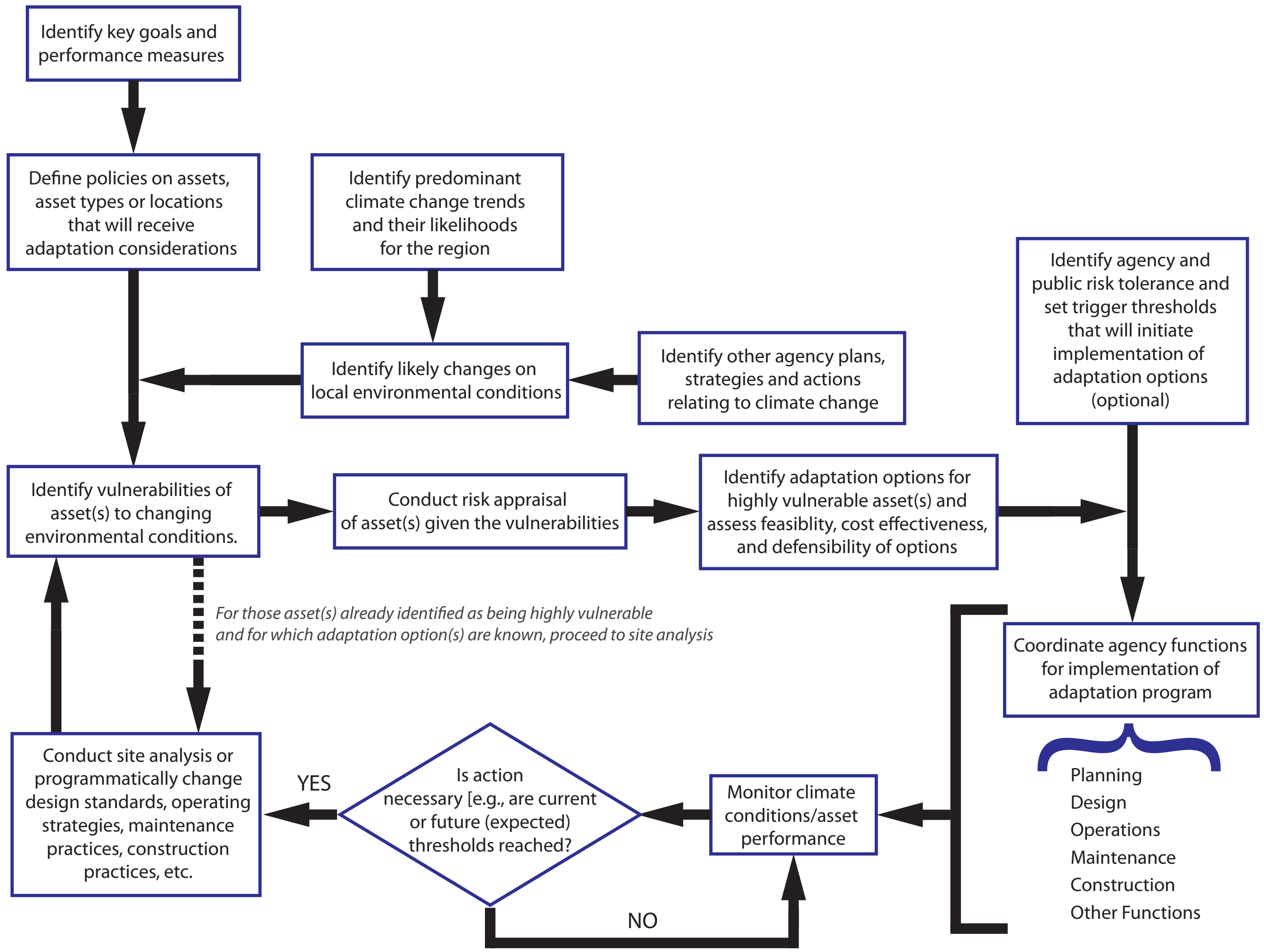
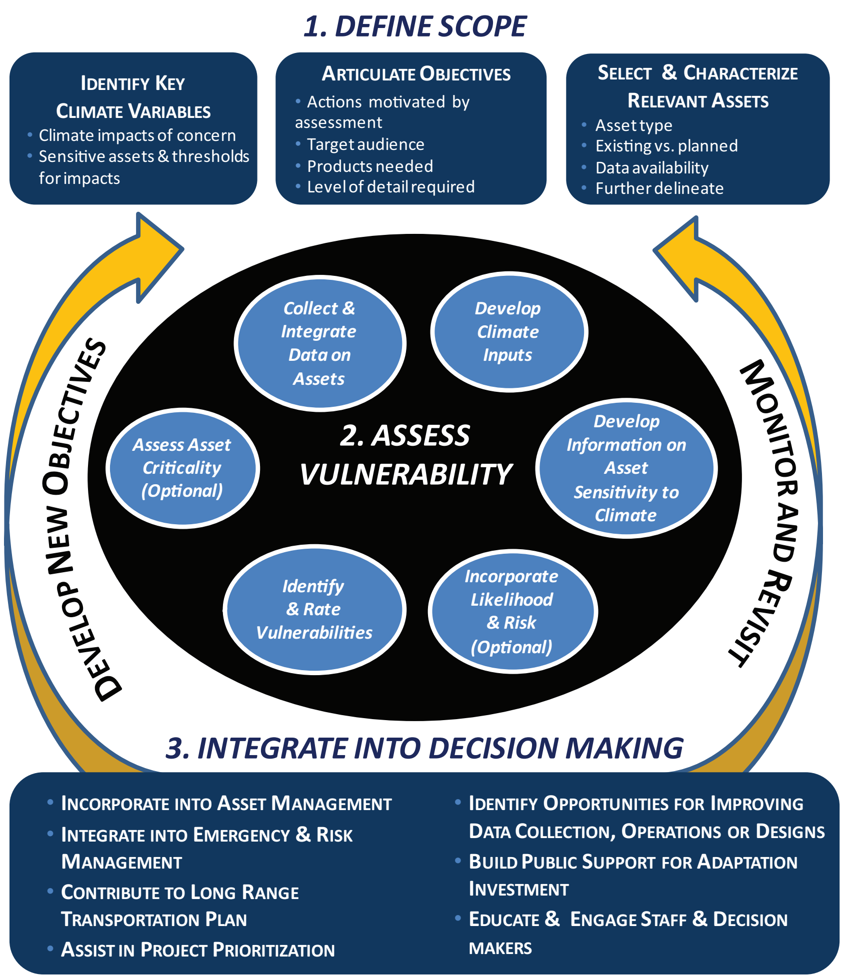


Figure 11 Climate Change Adaptation Decision Framework

Source: NCHRP 2009



Source: FHWA 2012

Climate Change Adaptation Framework

Figure 12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Vulnerability Assessment

For this adaptation plan, a qualitative vulnerability assessment of DDOT's infrastructure was performed by identifying the elements and areas of the transportation system that are most sensitive to projected climate changes by identifying climate inputs, assessing the likelihood of the elements of the infrastructure impacted, and determining the vulnerability of asset(s) within those areas determined as sensitive.

Identifying Potentially Vulnerable Assets

Identifying asset types (e.g., bridges, culverts, roadways, storm water infrastructure, etc.) that are in locations, which are more sensitive to climate variables (e.g., low lying areas already subject to flooding) is an important prerequisite to conducting a risk analysis.

While it is impossible to precisely determine site specific vulnerabilities without conducting a thorough analysis, the map in Figure 13 illustrates sensitive areas such as floodplains and steep slopes in the District, where potential vulnerabilities may be heightened by climate change. Transportation assets in these areas are likely to be focal points for analysis. The floodplain areas shaded in blue are likely to experience deeper and more frequent flooding due to increased sea levels and/or heavier precipitation events.

Vulnerability Assessment

After the assets in climate-sensitive areas have been identified, the next step of the process is to determine the likelihood that the individual asset would be impacted by a specific climate change indicator. The concept of vulnerability entails the following three components:

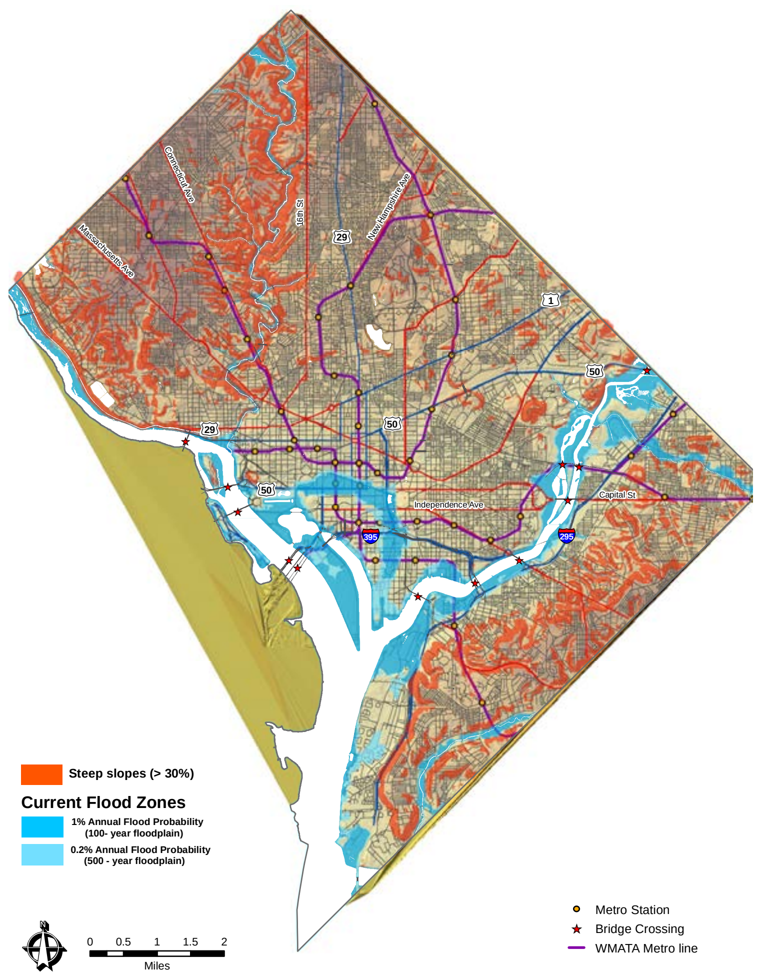
1. The probability of a climate change occurring.
2. The probability that the asset can withstand the changes.
3. The magnitude of the consequences.

4 Vulnerability Assessment

Assets are considered more vulnerable if there is a heightened chance of a climate change that would adversely affect the asset, a low chance that the change can be withstood by the asset, or a severe consequence if the asset fails. Consequences include impacts and severity of the impacts including asset replacement/repair costs, safety, the costs to users of the detour and travel delays, and any damage caused to the surrounding community by the failure. The ultimate goal of this step is to develop a relative ranking (low, medium, and high) of each assets' climate change vulnerability level, so that the most vulnerable assets can be identified.

Bridges and culverts may require an evaluation of their designs to determine if they can survive expected future storm events. Steep slopes are also a concern as higher average precipitation and heavier precipitation events may combine to increase landslide hazards at these locations. Roads traversing these areas may require the addition of slope stabilization measures and other actions.

DDOT conducted a high level, qualitative vulnerability assessment of its infrastructure based on the FHWA "Climate Change & Extreme Weather Vulnerability Assessment Framework". Table 1 lists the type of DDOT assets located in the sensitive areas shown in Figure 13. This table also lists the potential impacts that would be expected to affect each asset type and the vulnerability ranking for each potential impact.



Areas of Special Concern

Figure 13

4 Vulnerability Assessment

Table 1 Vulnerability Assessment of Transportation Infrastructure

Climate Indicator	Transportation Assets	Impact to Infrastructure	Vulnerability Ranking
Temperature	Bridges, Roadways, Trees, and Vegetation	• Asphalt pavement deterioration and pavement buckling • Increased thermal expansion of joints on bridges • Premature deterioration of infrastructure • Deterioration of structures, sealants, paints • Changes in leaf and blooming periods • Increase in invasive species and diseases	Low Low Low Low Low Medium
Precipitation	Slopes, Bridges, Culverts, Roadways, Drainage System, Trees, Vegetation, Tunnels, and Signs	• Erosion • Slope and roadway flooding and washout • Roadway subsurface deterioration • Tunnel flooding • Road embankment failures • Scouring of bridge and culvert abutments • Culvert failures • Drainage overloading and failure • Tree and vegetation damage • Power and other utility failures	Medium Medium Low Low Medium Medium Medium Medium Medium Medium
Sea Level Rise	Bridges, Culverts, Roadways, and Tunnels	• Erosion of roadway subsurface • Bridge scouring • Embankment failures • Reduced vertical clearance for bridges • Flooding of roadways in low lying areas • Changes in floodplains • Increased tunnel flooding	Low Low Low Low Medium Medium Low
Storms	Trees, Bridges, and Culverts	• Loss of trees • Culvert failures • Power failures • Tree growing conditions	High Low High Low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Approach and Adaptation Action Items

An organization's capacity to adapt to the impacts of extreme weather conditions on the delivery of transportation services depends on its ability to respond to the physical needs of the system and to plan for future contingencies. DDOT is actively working to maintain and repair the infrastructure of its transportation system. Assets that are in a state of good repair are better able to withstand the strains caused by extreme weather events, whether they are clean culverts, sturdy bridge piers, stable slopes, or secure traffic signals.

DDOT has developed a set of potential adaptation strategies to help reduce the vulnerability of its assets to the effects of extreme weather conditions and climate change. These strategies are listed in Table 2. In addition, DDOT has also developed a list of action items to help adapt its system to climate change. These action items are provided in Table 3.

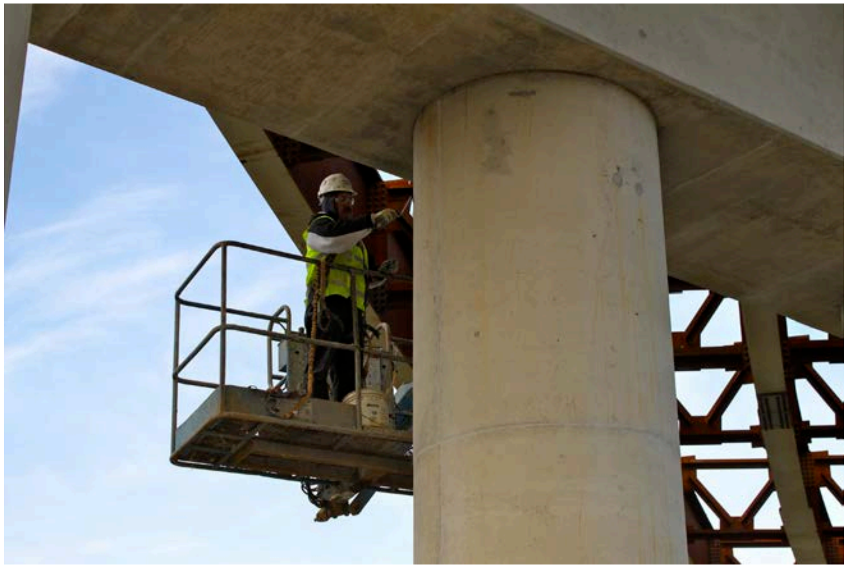

Table 2 Adaptation Strategies

Climate Indicator	Transportation Assets	Potential Adaptation Strategy
Temperature	Bridges, Roadways, Trees, and Vegetation	• Consider climate change in planning and design • Evaluate bridge expansion joints and design • Evaluate pavement design • Monitor and evaluate pavement conditions
Precipitation	Slopes, Bridges, Culverts, Roadways, Drainage System, Trees, Vegetation, Tunnels, and Signs	• Consider climate change in planning and design • Improve storm water management practices • Adapt changes to hydraulic openings for culverts and bridges • Stabilize stream banks • Improve pumping capacity of drainage systems • Improve erosion control systems
Sea Level Rise	Bridges, Culverts, Roadways, and Tunnels	• Consider climate change in planning and design • Improve hydraulic openings for culverts and bridges • Evaluate and improve flood zone data and flood maps • Stabilize stream banks • Improve erosion control systems • Evaluate vertical clearance for bridges on waterways • Evaluate bridge scouring • Improve pumping capacity of drainage systems for tunnels
Storms	Bridges, Signs, Street Lights, and Trees	• Consider climate change in planning and design • Evaluate sign conditions • Evaluate conditions of trees and those that may have impact on transportation facilities • Evaluate wind design issues in street lights, structures, etc

Table 3

Climate Change Adaptation Plan Action Items

Climate Change Adaptation Plan Action Items	
1.	Develop DDOT climate projections (climate models, downscaling technique, and emissions scenarios to use), and study the climate change effects on DDOT infrastructure through the year 2100.
2.	Perform detailed vulnerability and risk assessments for most critical DDOT assets.
3.	Train and update agency staff on climate change issues.
4.	Adjust design parameters based on detailed asset-specific vulnerability analyses for the most critical assets, and layout the possible effects on the transportation system.
5.	Update design standards, specifications, and policies as needed.
6.	Develop a menu of possible adaptation solutions minimizing risk posed by climate change.
7.	Incorporate climate adaptation needs as a criterion for project selection and investment decisions during system planning and capital program development.
8.	Incorporate climate change adaptation into all stages of the project development process.
9.	Flag all future projects lying in potentially climate change sensitive areas and prioritize them for incorporation of specific climate change adaptation strategies.
10.	Consider climate change in planning and design such as improved storm water management, adapting hydraulic openings for culverts and bridges, stabilization of stream banks, pumping capacity of drainage systems, protection against scouring for bridges, improved erosion control systems.
11.	Coordinate with other local and regional agencies to ensure that wide reaching impacts from extreme weather events are minimized and share best practices.
12.	Seek funding for climate change adaptation.
13.	Develop detailed Climate Change Adaptation Plan.

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STANDING
WATER

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Climate Change Adaptation Plan

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