



# **Climate Change Hazards Summary Report for Facility Investment Planning**

## **Chesapeake & Ohio Canal National Historical Park February 2021**

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## Introduction

Parks are required to complete a PARK Project Narrative Template for each proposed Great American Outdoors Act Facility Investment Plan (GFIP) project for Legacy Restoration Funding in fiscal years 2023-2025. Information provided in this report is intended to help parks consider climate change related hazards when addressing Question 16 of the narrative template.

*Specifically: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?*

## Step 1: Review summary information for known or potential hazards identified for Chesapeake & Ohio Canal National Historical Park

- Review the list of potential hazards below and decide whether or not they apply to your specific GFIP project. NPS Climate Change Response Program (CCRP) staff attempted to identify potential hazards for the park; however, park staff and project planners have more information about hazards that are likely to be applicable to a specific project.
- The hazards below were selected from a longer list included in Appendix 1, which also indicates CCRP's 'best professional judgement' about the relevance of the hazard for this park. Note both lists serve as a "coarse filter" screening tool to help identify potential climate-related hazards for facility and asset planning.

### Altered rainfall and snowfall

Changing precipitation and humidity conditions can affect flooding, erosion, sediment loads, mold growth, and wood decay. Extreme storms can cause flooding (see below), damaging water and wastewater systems, drainage systems, roads, buildings, and other infrastructure.

From 1901 to 2002, precipitation increased across much of the mid-Atlantic, but showed no statistically significant change in the canal area (Gonzalez et al. 2010). However, seasonal total precipitation in the greater Washington DC area showed a statistically significant increase for autumn,  $48 \pm 21\%$  per century (mean  $\pm$  standard error) from 1950 to 2010, while monthly total precipitation showed a statistically significant decrease during August,  $-76 \pm 29\%$  per century (Gonzalez 2017). Under the highest emissions scenario, climate models project a  $14 \pm 8\%$  average increase of total annual precipitation by 2100, with nearly all climate models projecting precipitation increases (Gonzalez et al. 2018). Projected increases in temperatures, however, could eliminate snowfall from areas along the canal by 2100 under the highest emissions scenario (Ning and Bradley 2015).

Climate change is increasing the frequency of heavy downpours from rainstorms (IPCC 2013). National Oceanic and Atmospheric Administration (NOAA) analyses of weather station data show an increase of heavy storms in the region that includes the 12 northeastern U.S. states and the District of Columbia, with the decade 1991-2000 experienced a 50% increase in five-year storms (a storm with more

precipitation than any other storm in five years), compared to the 1901-1960 average (Walsh et al. 2014). In addition, the heaviest storms in the region became even heavier, with a 71% increase in the amount of precipitation falling in the heaviest 1% of all storm days from 1958 to 2012 (Walsh et al. 2014).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Riverine Flooding

Flood threats to infrastructure include erosion, structural damage from the force of floodwaters, and damage to electrical systems. Post-flooding effects include rot, fungus, insects, mold, and mildew and physical deterioration of building materials.

Many factors influence river flood occurrence in the eastern U.S., including the amount of impervious surface in an urban area, upstream management of dams and reservoirs, and the amount of precipitation and intensity of storms (Yang et al. 2015). In the northeastern U.S., annual high-flow frequency increased in the period 2007-2016 compared to the period 1950-1969 (Dethier et al. 2020).

In addition to potential flooding from sea level rise (section below) in the lower stretches of the Potomac River, climate change could increase flooding upriver from extreme rainstorms. Under the highest emissions scenario, continued climate change could increase three-day peak river flow 10% by 2100 in Washington, DC (Battaglin et al. 2020, Demaria et al. 2016, Naz et al. 2016). Extreme storms in the watershed north and west of Washington, DC, could increase 100-year river flow in the Potomac at Little Falls 11% by 2055 (Van Dusen et al. 2020). Increases in extreme rainstorms could increase flooding along the Chesapeake & Ohio Canal from decreases in green space to absorb stormwater runoff along tributaries.

Under the highest emissions scenario (RCP8.5), models project a 300 to 400% increase in the frequency of 20-year storms in the Mid-Atlantic region (Walsh et al. 2014). If flood frequency also experiences that increase, areas of the Chesapeake & Ohio Canal that had been estimated to experience flooding once in 100 years could experience flooding once every 25 to 30 years.

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Sea level rise and storm surge

Sea level rise poses considerable risks to infrastructure, lighthouses, forts, and other historic structures. Sea level rise could increase the infrastructure costs of nuisance flooding (low level, frequent flooding) above the costs of major floods (high level, infrequent flooding), particularly around the Washington, DC

area (Moftakhari et al. 2017). Higher relative sea level also causes accelerated coastal erosion, landward migration of shorelines, and saltwater intrusion and changes in groundwater, and amplifies flooding caused by higher storm surges (Field et al. 2007).

Global sea level is rising and will continue to increase (Tebaldi et al. 2012), with local variability. Since 1924, sea level has risen 32 cm (13 in.) in Washington, DC, ([https://tidesandcurrents.noaa.gov/sltrends/sltrends\\_station.shtml?id=8594900](https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8594900)). The sea level gauge is currently on a wharf on the Southwest Waterfront. Under the highest emissions scenario, continued climate change could raise sea level 80 cm (3 ft.) at Rock Creek Park by 2100 (Caffrey et al. 2018).

In 2003, Hurricane Isabel caused a storm surge up the Potomac River that reached 2.5 m at the Washington, DC, tidal gauge (Wang et al. 2015). Under high emissions, climate change could cause a 100-year storm surge that could add 3 m (9 ft.) of storm water on top of the increased sea level (Tebaldi et al. 2012). Sea level rise could increase periodic flooding and permanently inundate some land along the Potomac River (Ayyub et al. 2012, Moftakhari et al. 2017, Zhang et al. 2019).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Hurricanes and tornadoes

Sea level rise and storm surges from hurricanes (see section above) can cause severe flooding, including of infrastructure that had no flooding during past storms. Building standard guidance is based on base flood elevations of 0.6-1 m (2-3 ft.) above Federal Emergency Management Agency 100-year flood zones, depending on building criteria. Hurricanes also threaten structures from damage from wind, wind-blown rain, and debris. Large temperature swings stress buildings through sudden thermal expansion and can crack pipes. Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding.

While climate change contributes to hurricane formation by warming sea surface temperatures (IPCC 2013), changes in historical monitoring methods have prevented definitive attribution of past hurricanes trends to climate change (IPCC 2013, USGCRP 2017). For the future, climate models project increases in North Atlantic hurricane intensities and precipitation amounts in the mid-Atlantic region (Kossin et al. 2017, Ting et al. 2019, Stansfield et al. 2020).

Climate change can increase the frequency of severe thunderstorms, which generate tornadoes, with analyses of historical records from 1979 to 2017 showing increases in the midwestern and southeastern U.S., but no statistically significant trend for the mid-Atlantic region (Gensini and Brooks 2018). For the U.S. as a whole, the number of days with over 30 tornadoes (Brooks et al. 2014, Elsner et al. 2015) and the number of tornadoes per tornado outbreak have increased (Moore 2017, Tippet and Cohen 2016).

Moreover, tornado power, a function of wind speed, tornado path area, and air density, has increased  $5\% \pm 1\%$  per year from 1994 to 2016 (Elsner et al. 2019).

Under the highest emissions scenario, continued climate change could increase the number of severe thunderstorm days with tornado conditions by 40% in the Washington, DC, area (Diffenbaugh et al. 2013, Gensini and Mote 2015).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Hotter temperatures

Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems.

Greenhouse gas emissions from human activities have increased temperatures globally (IPCC 2013), across the U.S. (USGCRP 2017), and in U.S. national parks (Gonzalez et al. 2018). Temperatures increased across the mid-Atlantic region of the U.S. and showed a statistically significant increase in the area that includes Chesapeake and Ohio Canal National Historical Park (NHP). Taking the Washington DC metro area as an example, annual average temperature in the period 1946-2016 increased at the statistically significant rate of  $1.7 \pm 0.3^\circ\text{C}$  ( $3.1 \pm 0.5^\circ\text{F}$ ) (Gonzalez 2017). Under the highest greenhouse gas emissions scenario, climate models project additional warming of  $4.9 \pm 1^\circ\text{C}$  ( $8.8 \pm 1.8^\circ\text{F}$ ) by 2100. The temperature increase could be kept to  $1.7 \pm 0.7^\circ\text{C}$  ( $3.1 \pm 1.3^\circ\text{F}$ ) under a scenario of reduced emissions (Gonzalez et al. 2018). Under the highest emissions scenario, models project an increase of 30 to 40 more days per year with a maximum temperature  $>32^\circ\text{C}$  ( $90^\circ\text{F}$ ) and an increase of  $3\text{--}4^\circ\text{C}$  ( $6\text{--}8^\circ\text{F}$ ) in the hottest temperature of the year, from 1990 to 2050 (Vose et al. 2017).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Drought

Drought is an extended period of precipitation, surface water, or soil moisture below a long-term average. Drought can affect water supply and water and wastewater systems, water quality (Mosley 2015), and soil stability (Fernandes et al. 2015).

The balance between precipitation and evapotranspiration determines, in large part, the development of drought. In the mid-Atlantic region, projected increases in precipitation under climate change generally outweigh projected increases in evapotranspiration, so climate change does not substantially increase the risk of drought in the region through 2100 (Cook et al. 2015, Wehner et al. 2017). Nevertheless, increases in urban and suburban water use and sedimentation of reservoirs in the upper

parts of the Potomac River watershed could increase the risk of low water supply for the Washington, DC, area (Stagge and Moglen 2017).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Wildfire

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Climate change is intensifying the heat that drives wildfire above natural levels (Jolly et al. 2015) and altering the distribution and density of vegetation that comprises the fuel for wildfires (Gonzalez et al. 2010). These effects combine with the unnatural buildup of coarse woody debris and understory trees from decades of suppression of all fires, even natural ones (Agee and Skinner 2005). For areas where projected climate change increases fire risk, infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

In the northeastern U.S., analyses have not detected a historical change in the area burned by wildfire attributable to human-caused climate change. Fire suppression in eastern U.S. forests has created moister and shadier conditions and less flammable fuel beds that favor moist tree species and disfavor dry fire-adapted species (Nowacki and Abrams 2008). Under continued climate change, increased precipitation would tend to keep wildfire ignition low in the mid-Atlantic region (Clark et al. 2014). For climate change scenarios in which dry periods between storms or evapotranspiration might increase or snowfall is eliminated, the dryness and flammability of coarse woody debris could increase.

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Insect Pests

Pests can directly infest buildings and other infrastructure and indirectly affect infrastructure by increasing risks of tree death and falling branches or trees.

Warmer and moister conditions, which may increase under climate change, tend to favor numerous insect pests, including termites, ants, and hornets (Sims and Appel 2017). Continued climate change under low to high emissions could increase the number of invasive termite species in the mid-Atlantic area (Buczowski and Bertelsmeier 2017).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Invasive species

Terrestrial and aquatic invasive species can damage buildings and water systems. The use of pesticides to combat expanding invasive species may also threaten structures.

Climate change can favor invasive alien plant species, such as kudzu, in temperate zone ecosystems due to increased warmth, humidity, vegetation disturbances, and atmospheric carbon dioxide (Davidson et al. 2011, Hellmann et al. 2008, Liu et al. 2017). Climate change can also exacerbate aquatic invasive species, favored by warmer waters and other altered conditions in freshwater ecosystems (Havel et al. 2015).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

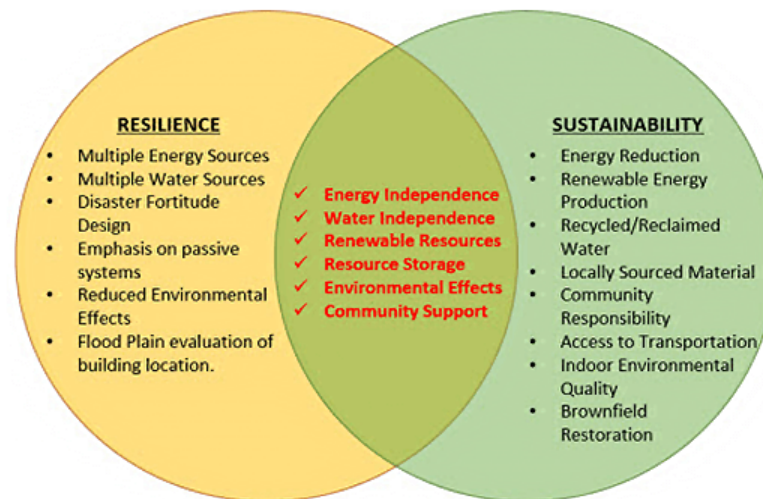
## Step 2: Consider adaptation and resiliency strategies

- Review definitions of resiliency and adaptation strategies.
- Identify adaptation strategies that will help park resources respond to the hazards identified in Step 1.

Question 16 requires a screening for climate hazards followed by a review of adaptation and resiliency strategies that would be put in place to respond to these hazards. For the purposes of this report and investment planning, resilience is a property of a system or asset and generally refers to the ability of the system or asset to maintain its intended purpose following a temporary disturbance.

Adaptation strategies, in the context of built infrastructure, refers to the intentional management decision to identify, prepare for, and respond to observed or expected sustained changes in hazards, including climate change, to adjust to a sustained change in conditions.

It is important to note that resilient park operations can be supported through the use of green infrastructure such as sustainable landscaping, as well as sustainable energy, water, and building envelope solutions. The figure below illustrates this relationship.



Lists of adaptation strategies for different types of infrastructure projects in response to different hazards can be found here: [Incorporating Climate Change Adaptation in Infrastructure Planning and Design](#) (see Chapter 4, Tables 25-34). If used, these adaptation strategies will need to be modified for proposed park projects.

Buildings and assets within national parks may include cultural resources (e.g., historic and pre-historic buildings and structures). The adaptation and resiliency options for cultural resources often overlap with those defined for facilities; however, NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks ([Cultural Resources Climate Change Strategy](#)). “Climate

change poses an especially acute problem for managing cultural resources because they are unique and irreplaceable — once lost, they are lost forever” ([NPS Policy Memorandum 14-02](#)).

### Step 3: Develop an answer to Question 16 for your specific project and location, as well as strategies to address each hazard

- Two example responses to Question 16 are provided below. THESE ARE EXAMPLES FROM OTHER PARKS. You can view other examples here: [Example responses to Q16 on hazards Organized by Park](#).
- You will need to develop park specific answers based on the hazards identified in Step 1 and the adaptation strategies identified in Step 2 for your park and project. The park response should be as project-specific as possible.
- The NPS Climate Change Response Program (CCRP) and Sustainable Operations and Maintenance Branch (SOMB) are available to help evaluate climate change hazards and resiliency strategies for your specific projects. Requests should be sent to the NPS [GFIP Hazards and Risk Assistance email account](#); a member of the team will reply with support.

*Question 16: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?*

#### **Example from Grand Teton National Park: Road improvement project**

Several climate change related hazards have been identified that may affect projects in GRTE, including hotter average days, more extreme heat days, increased drought frequency and intensity, altered precipitation and flooding patterns, increased wildfire, and increased invasive species abundance or distribution. The primary hazard affecting this project is spring runoff and flooding. Projected warmer and wetter spring seasons are likely to result in increased rain on snow events, which lead to higher peak spring runoff volume, flooding, and streambank scour/erosion. Increased flooding along with potential impacts from increased wildfire (erosion and reduced infiltration) will cause the river channel to become even more dynamic and increase the likelihood of road bank failure.

Past weather-related impacts at Gros Ventre Road include:

- The Gros Ventre River is a braided river that is roughly 1,500 feet wide and the active flow channels frequently migrate and avulse across the braided channel. In recent years, unprecedented spring high water flows have caused the main channels of the river to erode the bank adjacent to and undercutting the Gros Ventre Road. In 2017, the road washed out and required \$6M in repairs.

Future climate changes that may impact this project could include:

#### **Precipitation changes**

- Expected warmer and wetter spring seasons are likely to result in rain over snow events, which lead to higher peak spring runoff volume and water velocity. It is predicted that the temporary fixes have a limited lifespan if runoff and higher than average spring flows continue to increase, and the river does not change course.
- If precipitation increases or changes, this too may cause increased soil moisture which may affect the structural integrity of the roads and slopes.

**Increased temperatures** may contribute to pavement degradation. Crack/heave damage occurs in drier soils.

The park will consider the following measures to improve resilience to these hazards:

- Design and Engineering Enhancements:
  - This project will either armor the bank or relocate the roadway away from the river (onto a nearby bench away from the highly eroded riverbank allowing the river to maintain a more natural course), depending on future studies (archeological, hydrologic, engineering, etc.), environmental analysis, and potential lifecycle costs of both options taking into account the future potential hazard of increased flows and the river changing course.
  - Slopes may need to be adjusted and properly placed culverts installed.
- Planning
  - Revegetation will be a vital component to increase resilience to precipitation changes and increased temperatures. Design and maintenance are vital.

This project will advance sustainability through the following strategies:

- The 2006 Transportation Plan which analyzed 22.5 miles of multiuse pathways and 18.8 miles widened shoulders to be used as a bike lane, including this segment of the Gros Ventre Road. These pathways and widened shoulders are not only used by park visitors recreationally, but also for local residents commuting to and from work in the park and the town of Jackson, providing enhanced recreational and transportation opportunities that are low carbon output.

#### [New River Gorge National Park and Preserve - Project 1](#)

NERI will leverage GAOA funding opportunities to address potential resiliency and climate change vulnerabilities. Climate change hazards and stressors that may affect facility projects include hotter average days, more high temperature days, more extreme precipitation events, more high-humidity days, flooding, landslides, pest infestations, and invasive species.

Assets that are vulnerable to these changes include historic structures, cultural landscapes, and single-point visitor access routes and destinations.

##### *Historic structures and landscapes*

Historic structures, such as the National Bank of Thurmond, would open for visitor access, house historic artifacts, provide office space, or be made available for commercial leasing. To prepare for hotter average days, more extreme heat days, and higher humidity, the proposed project includes:

- Installation of high efficiency, variable speed HVAC with enhanced humidity control
- Energy-efficient building envelopes
- Photovoltaic and hot water solar for resilient and renewable energy sources
- Demolishing structures to eliminate future O&M costs, particularly those in vulnerable landscape positions, such as floodplains.

To address the more frequent and severe precipitation volumes which increase rot and infestation potential, the proposed improvements include:

- Stormwater BMP's to address runoff from buildings and impervious surfaces
- Enhanced, resilient building envelopes as part of any historic building restoration project to address more frequent severe weather.

Tree mortality, along with warmer temperatures and higher precipitation, would favor some non-native invasive trees and vines, including kudzu, which already threatens park assets. Mitigation will include:

- Hazard tree management
- Aggressive invasive plant management around priority assets
- Redesign of grounds and landscapes at Thurmond, Grandview, and others.

#### *Roads and trails*

Higher precipitation and stronger storms could cause greater stormwater runoff, increasing washouts and erosion on roads and trails. Adaptations would include:

- Larger culverts and additional water control features
- Reducing risk of massive failures that would cut off visitors and commercial rafting from linchpin river access areas
- Re-engineering river access routes to handle maximum water runoff and saturation. Trails within the gorge, such as the Rend Trail, would be rerouted away from high-risk zone or stabilize the upslope side by installing strengthening measures such as a wall or gabion baskets.

#### *River access locations*

Recreation assets within the floodplain, including twenty boat launch sites and eight campgrounds, are very susceptible to flooding and require significant annual maintenance, including replacing large volumes of gravel. The park would increase resilience of these sites by:

- Hardening with stable surfaces
- Enhancing drainage systems
- Relocating campsites to less vulnerable locations.

#### *Other adaptations*

Warmer temperatures would extend shoulder seasons and increase demand on visitor access and facilities beyond traditional high-use periods; the park will adapt by designing assets and systems for higher capacity and extended use.

## Step 4: Seek additional assistance if desired

Additional resources for answering question 16 and related questions can be found in:

- Appendix 1 below, which includes a full hazards checklist, providing additional links for supporting information related to each hazard.
- The [GFIP Guidance and Logistics](#) folder under the [Resources to Assess Risks and Hazards tab](#) includes:
  - An Excel workbook labeled [T75 Parks GFIP NRSS Supporting Materials](#) that provides links to information for natural resources to be considered during project design and construction.
  - A [FAQs – Assessing Risks and Hazards](#) document that provides detailed guidance for answering Question 16.

- A [Natural Hazard Assessment Webinar](#) recording that provides key information, definitions, and guidance for understanding natural hazards and related resources.

The NPS Climate Change Response Program (CCRP) and Sustainable Operations and Maintenance Branch (SOMB) are also available for assistance in evaluation of climate change hazards and resiliency strategies as they relate to specific projects. Questions can be sent to the NPS [GFIP Hazards and Risk Assistance email account](#) and a member of that team will reply with support.

## Appendix 1: The Climate-Related Hazard Checklist

This appendix provides an initial evaluation of climate hazards for **Chesapeake & Ohio Canal National Historical Park** according to the hazard ratings identified below. The information used to identify hazards in the checklist is mostly from regional assessments. Park and project specific information was generally not available when assessing these hazards. NPS Climate Change Response Program (CCRP) staff made an initial attempt to identify potential hazards for the park broadly (see 'Best Professional Judgement' column); however, park staff and project planners have more information about hazards that are likely to be applicable to a specific project.

### Explanation of Hazard Ratings

**Known hazard:** Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

**Potential hazard:** Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

**Not applicable:** No evidence *was identified* showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

**Table 1. Climate-related Hazards Checklist**

| Potential Climate Hazard                                                               | Best Professional Judgment                                                          | Examples of risk or secondary hazard                                                                                                                                                                                                                                                                                                 | Sources of General Non-site specific Data                                                                                                        | Sources for Site Specific Data                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Altered precipitation patterns, increased extreme precipitation, and changing humidity | <p>Known Hazard<br/>☒</p> <p>Potential Hazard<br/>☐</p> <p>Not Applicable<br/>☐</p> | <ul style="list-style-type: none"> <li>• Local flooding</li> <li>• Mold growth</li> <li>• Wood decay</li> <li>• Drought</li> <li>• Fire</li> <li>• Groundwater change</li> <li>• Surface erosion</li> <li>• Floods (see below)</li> <li>• Water damage to structures from driven rain</li> <li>• Unstable saturated soils</li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">National Climate Assessment</a></li> <li>• <a href="#">State climate summary</a></li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">National Climatic Data Center</a></li> <li>• <a href="#">DAYMet gridded climate data</a></li> <li>• <a href="#">National Park historical and projected climate change</a></li> <li>• Evaluations are mostly at regional scales</li> </ul> |

| Potential Climate Hazard                 | Best Professional Judgment                                                                                                                                          | Examples of risk or secondary hazard                                                                                                                                                                                                                                                                                                                          | Sources of General Non-site specific Data                                                                                                                           | Sources for Site Specific Data                                                                                                                                                                                                                                                                                                                                        |
|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Riverine flood/flash flood               | <p>Known Hazard<br/><input checked="" type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input type="checkbox"/></p> | <ul style="list-style-type: none"> <li>• Damage or destruction of infrastructure</li> <li>• Stream channel migration</li> <li>• Stream bank erosion/extreme erosion</li> <li>• Safety</li> <li>• Water quality diminished</li> <li>• Damage to water source and delivery infrastructure</li> <li>• Changing requirements for culvert flow capacity</li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">FEMA Flood map service</a></li> </ul>                                                                          | <ul style="list-style-type: none"> <li>• <a href="#">FEMA Map Service Center</a></li> <li>• <a href="#">Floodplain maps for HUD projects</a></li> <li>• <a href="#">Van Dusen et al. 2020</a> (for select parks)</li> <li>• May require a special flood study</li> </ul>                                                                                              |
| Sea level change and coastal storm surge | <p>Known Hazard<br/><input checked="" type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input type="checkbox"/></p> | <ul style="list-style-type: none"> <li>• Rising sea and lake levels</li> <li>• Rising water – wind driven (e.g. hurricane, nor'easter)</li> <li>• Saltwater intrusion</li> <li>• Vegetation damage</li> </ul>                                                                                                                                                 | <ul style="list-style-type: none"> <li>• <a href="#">NOAA SLR viewer</a></li> <li>• <a href="#">NOAA - Great Lakes Environmental Research Laboratory</a></li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">IRMA – Coastal reports</a></li> <li>• <a href="#">NPS SLR viewer</a></li> <li>• <a href="#">Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects</a> (requires VPN connection)</li> <li>• <a href="#">SLR reports</a></li> <li>• <a href="#">Great Lakes Dashboard Project</a></li> </ul> |
| Hurricanes and tornadoes                 | <p>Known Hazard<br/><input checked="" type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input type="checkbox"/></p> | <ul style="list-style-type: none"> <li>• Building destruction</li> <li>• Flying debris</li> <li>• Storm surge</li> <li>• Tree fall</li> </ul> <p>(see other categories for associated intense rainfall and floods)</p>                                                                                                                                        |                                                                                                                                                                     | <ul style="list-style-type: none"> <li>• Wind speed data – from local codes</li> <li>• International Building Code</li> <li>• <a href="#">FEMA Map Service Center</a></li> </ul>                                                                                                                                                                                      |

| Potential Climate Hazard                                         | Best Professional Judgment                                                                                                                        | Examples of risk or secondary hazard                                                                                                                                                                                                                                                                                                | Sources of General Non-site specific Data                                                                                                                                                                                                                             | Sources for Site Specific Data                                                                                                                                                                                                            |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hotter average days and more very hot days                       | Known Hazard<br><input checked="" type="checkbox"/><br>Potential Hazard<br><input type="checkbox"/><br>Not Applicable<br><input type="checkbox"/> | <ul style="list-style-type: none"> <li>• Inadequate HVAC</li> <li>• Road surface degradation</li> <li>• Lack of water due to increased water for irrigation</li> <li>• Increased humidity</li> <li>• Danger to staff</li> </ul>                                                                                                     | <ul style="list-style-type: none"> <li>• <a href="#">National Climate Assessment</a></li> <li>• <a href="#">State climate summary</a></li> </ul>                                                                                                                      | <ul style="list-style-type: none"> <li>• <a href="#">National Climatic Data Center</a></li> <li>• <a href="#">DAYMet gridded climate data</a></li> <li>• <a href="#">National park historical and projected climate change</a></li> </ul> |
| Increased drought frequency, intensity, magnitude, and duration  | Known Hazard<br><input type="checkbox"/><br>Potential Hazard<br><input checked="" type="checkbox"/><br>Not Applicable<br><input type="checkbox"/> | <ul style="list-style-type: none"> <li>• Limited water supply for cooling, landscaping, structural fire suppression, other equipment</li> <li>• Increased competition for available water and water rights conflicts</li> <li>• Crack/heave damage in drier soils</li> <li>• Increased vulnerability to wildfire (below)</li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">Drought Monitor</a></li> <li>• <a href="#">National Integrated Drought Information Center</a></li> <li>• <a href="#">National Climate Assessment</a></li> <li>• <a href="#">State climate summary</a></li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">Drought Monitor</a></li> <li>• <a href="#">National Integrated Drought Information Center</a></li> </ul>                                                                             |
| Increased wildfire frequency, intensity, magnitude, and duration | Known Hazard<br><input type="checkbox"/><br>Potential Hazard<br><input checked="" type="checkbox"/><br>Not Applicable<br><input type="checkbox"/> | <ul style="list-style-type: none"> <li>• Damage to facilities and contents</li> <li>• Smoke damage</li> <li>• Air quality dangerous to staff and visitors</li> <li>• Increased runoff</li> <li>• Increased erosion</li> <li>• Damage to water treatment plants</li> </ul>                                                           | <ul style="list-style-type: none"> <li>• <a href="#">Barbero et al. 2015 International Journal of Wildland Fire</a></li> </ul>                                                                                                                                        | <ul style="list-style-type: none"> <li>• <a href="#">NIFC</a></li> <li>• <a href="#">International Wildland-Urban Interface Code</a></li> </ul>                                                                                           |

| Potential Climate Hazard | Best Professional Judgment                                                                                                                        | Examples of risk or secondary hazard                                                                                                                                                                                                         | Sources of General Non-site specific Data                                                             | Sources for Site Specific Data                                                                                                                                                                                                                                                                                              |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pest infestation         | Known Hazard<br><input type="checkbox"/><br>Potential Hazard<br><input checked="" type="checkbox"/><br>Not Applicable<br><input type="checkbox"/> | <ul style="list-style-type: none"> <li>• Historic/facility fabric loss</li> <li>• Vegetation loss</li> <li>• Disease vectors may increase</li> </ul> Termites and other woodboring pests expanding range with warming and increased humidity | <a href="#">USFS Forest Health Advisory System</a>                                                    | <ul style="list-style-type: none"> <li>• <a href="#">NPS Pest and Invasive Species Management Contacts</a></li> <li>• <a href="#">Fisichelli et al. forest pests</a></li> <li>• <a href="#">USFS maps</a></li> </ul>                                                                                                        |
| Invasive species         | Known Hazard<br><input type="checkbox"/><br>Potential Hazard<br><input checked="" type="checkbox"/><br>Not Applicable<br><input type="checkbox"/> | <ul style="list-style-type: none"> <li>• Aquatic mussels – water intakes clogged</li> <li>• Vegetation (kudzu, vines) – damage buildings, kill trees, obstruct waterways</li> </ul>                                                          | <ul style="list-style-type: none"> <li>• <a href="#">National Invasive Species Council</a></li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">NPS Pest and Invasive Species Management Contacts</a></li> <li>• <a href="#">Early Detection and Distribution Mapping System</a> (current distribution)</li> <li>• <a href="#">Early Detection and Distribution Mapping System</a> (projected distribution)</li> </ul> |

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## Disclaimer

### Report Purpose and Scope:

Parks identified for Legacy Restoration Funding in fiscal years 2023-2025 are required to develop a Great American Outdoors Act Facility Investment Plan (GFIP). The intended use of this series of park-specific reports is to help parks address Question 16 of the narrative template: *What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?*

Each report compiled and summarized published information on a suite of climate change hazards. Each report included an analysis of each hazard, for which the report author assigned a 'hazard rating' as follows:

**Known hazard:** Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

**Potential hazard:** Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

**Not applicable:** No evidence was identified showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

As articulated within the report (in an appendix of the hazard ratings) those ratings constitute the author's 'best professional judgement' about the relevance of the hazard for that park based on the reviewed literature (cited in the narrative text for the hazard & provided in the report bibliography).

The intended use of each report is to inform decisions for facility investment planning related to (i) potential hazards that a suggested facility investment concept would need to appropriately consider and avoid or mitigate and (ii) identifying facilities possibly at greater relative vulnerability due to the identified hazards. The level of information quality in the report was calibrated to those purposes, i.e. to inform development of questions for a facility investment scoping process to further explore.

### Peer Review Process:

Each report was based on a template, which heavily relied on boilerplate text for the non-park specific elements. The boilerplate text underwent multiple rounds of informal peer review by assorted CCRP staff, including members of the Climate Science and Adaptation Team, the Communications Team, the Regional Climate Change Liaisons, and the Climate Change Liaison to Facilities and Planning. Each report was peer-reviewed by a member of CCRP to check interpretation, consistency in hazard ratings, improve narrative coherence, and flag priority additions/modifications. In situations where revisions were required, the peer reviewer then re-reviewed the final revised report to assure adequate resolution of the identified issues.