



Climate Change Hazards Summary Report for Facility Investment Planning

Cumberland Gap National Historical Park January 2021

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Executive Summary

A changing climate at Cumberland Gap National Historical Park is projected to lead to both increased temperature and precipitation by the end of the century. Models project annual average temperature increases at the park by as much as 4.7°C, and increased annual average precipitation by as much as 10% (Gonzalez et al. 2018). These future trends are already unfolding within the park with recent decades significantly warmer than the prior century, and trending toward higher rates of precipitation (Monahan and Fisichelli 2014). It is not clear if precipitation will fall more sporadically and intensely, however the science does point in this direction for the Southeast.

A changing climate can alter the needs people have from the built environment and change the risk of damage and expected maintenance requirements for structures and infrastructure. People may have greater need for climate-controlled environments, and heat and humidity exceeding capacity can stress HVAC systems. More moisture can also lead to higher rates of decay and corrosion of materials.

If the increased heat and precipitation are interspersed with dry spells, in a forested park like Cumberland Gap National Historical Park, wildfire can become a threat, especially if a dominant tree species like pitch pine suffers widespread die-off due to climate conditions that both stress the tree and promote the reproduction of a tree pest like the southern pine beetle. Infrastructure located under tree canopies or embedded within dense grassland could be at risk.

Further, if the projected increased heat and precipitation intensifies storms as expected, higher volumes of runoff in a mountainous terrain could result in flash flooding, exceedance of culvert capacity, and road and bridge washouts. More intense storms can also increase the risk of tornados.

These are some of the potential hazards facility planners may want to consider when developing projects for funding through the Great American Outdoors Act and Legacy Restoration Fund. Information provided in this report is intended to help the park consider climate change related hazards when addressing Question 16 of the GFIP project narrative template. The following report details projected changes in climate at Cumberland Gap National Historical Park, describes some ways climate can affect facilities, and describes some potential adaptations. An attempt has been made to provide local climate information and anticipate facilities risk; however, park staff know more about the hazards that might affect specific projects. As such, further dialogue with the Climate Change Response Program and Sustainable Operations and Maintenance Branch may help to uncover additional intersections between climate and risk to facilities.

Introduction & Purpose

Cumberland Gap National Historical Park is developing a facility investment plan and associated projects for funding through the Great American Outdoors Act and Legacy Restoration Fund. Information provided in this report is intended to help the park consider climate change related hazards when addressing Question 16 of the GFIP project narrative template.

Climate change is warming the air and increasing precipitation, the intensity of storms, risk of flooding and subsequent erosion at Cumberland Gap National Historical Park. Climate change may also alter natural systems, pests and invasive species, and affect seasonal use patterns at the park. These increasing risks can be anticipated and addressed in the planning phase of new facilities projects.

The park has significant deferred maintenance and future investment in Cumberland Gap National Historical Park assets can reduce risk due to climate related impacts. This report helps to build awareness of potential hazards to Great American Outdoors Act and Legacy Restoration Funded projects. Further dialogue beyond this report can help to move from awareness to adaptive construction.

Summary Information for Hazards

Hotter average days and more very hot days

Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems. Demand for complex air conditioning systems can add stress to building envelopes and often requires significant alterations to a structure.

Temperature can be used to predict visitation patterns with a 92% accuracy, with peak visitation occurring in the summer (Fisichelli et al. 2015). It's possible heat, combined with humidity can make the park less hospitable to individuals seeking outdoor experiences. In turn, more climate controlled indoor environments may be needed to provide an escape from the elements for park staff and visitors.

By the end of the century, low greenhouse gas scenarios (RCP 2.6) project an annual mean temperature increase of 1.5° C, higher atmospheric concentrations of greenhouse gas (RCP 8.5) projects to an increase of annual mean temperature of 4.7° C (Gonzalez et al. 2018). For this past century, in the three most recent decades, the part of the year with the most precipitation is getting hotter (Monahan and Fisichelli 2014).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Increased drought frequency, intensity, magnitude, and duration

Changing drought conditions (frequency, severity, duration) can challenge a variety of infrastructure and operations in the NPS (e.g., water supply and wastewater systems), impair water quality (Mosley 2015), affect soil heaves and shrinkages (Fernandes et al. 2015), and will enhance other related risks such as wildfire (Halofsky et al. 2020).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Increased wildfire frequency, intensity, magnitude, and duration

There is fire risk to buildings, cultural landscapes, or other infrastructure located under or near tree canopies or dense grasslands. Even though precipitation is projected to increase at CUGA, it's possible that the park could experience dry conditions coincident with mass tree mortality events. Climate change is intensifying the heat that drives wildfire (Jolly et al. 2015) and expected to adversely impact pitch pine and other CUGA trees (Fisichelli et al. 2014), which could result in additional fuel on the ground.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Altered precipitation patterns and changing humidity

Changing precipitation and humidity conditions can result in local flooding, encourage mold growth, wood decay, increase fire risk, and intensify drought conditions, depending on the pattern of change. As temperatures increase, annual average precipitation is projected to increase by 5% to 10% by the end of the century (Gonzalez et al. 2018).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Increased extreme precipitation

Extreme precipitation events present a variety of threats to infrastructure and operations including flooding of sites, sewage backup, accelerated decay of masonry, overcoming drainage systems, road wash out, cracks in building infrastructure, erosion of adobe, destabilization of buildings and pipes, erosion of supporting ground around structures, among many other effects. Additionally, saturated soils can contribute to landslides on unstable slopes. It is believed that precipitation intensity will increase with increasing temperatures (Easterling et al. 2017).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Riverine flood/Flash flood

Floods threaten infrastructure and operations through a variety of mechanisms, including inundation of structures, enhanced erosional forces, road wash out, structural collapse from force of floodwaters,

sewage backup, and damage to utilities, generators, and electrical systems. Post-flooding effects include increased rot, fungal/insect attack, mold and mildew, and physical deterioration of wood, brick and stone building materials. With higher temperatures driving up the intensity of storms in mountainous terrain, flash flood risk could increase.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Severe thunderstorms and tornados

Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding. With continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially (Abell et al. 2007, Diffenbaugh et al. 2013, Gensini and Mote 2015).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Pest infestation

Termites have the potential to cause direct damage to wooden components of structures. Facilities may be impacted indirectly through other mechanisms exacerbated by climate change such as forest insect pest invasions or fluctuating ground water levels leading to increased tree mortality, hazard trees, and treefall. Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of pests (IPCC 2014).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Invasive species

Non-native species that may not currently impact facilities may become harmful due to changes in local climates (NRC 2002, IPCC 2014). Even native species invading new territory can present a risk (i.e. armadillo). Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of invasive species (IPCC 2014).

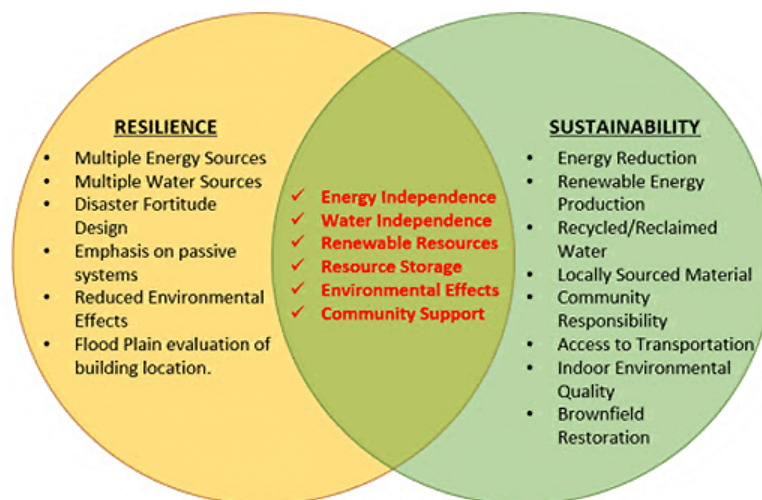
Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Adaptation and Resiliency Strategies

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 using 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](#)).

What Climate Change Risks or Hazards are Likely to Affect a Project at CUGA?

- Hotter average days and more extreme heat days will increase demand and requirements for appropriately sized air conditioning systems.
- Extreme heat and humidity can stress the building envelope and will require significant humidity control alterations for structures.
- Flooding from increased intensity storm events, increased extreme precipitation, or in conjunction with altered precipitation patterns may require modifications to building infrastructure location and landscape drainage systems.
- Post-flooding effects and more warm humid days may include increased rot, mold and mildew, and physical deterioration of wood, brick and stone building materials. Adaptation actions will include identifying appropriate dehumidification and air handling systems and coordinating with the NPS National Center for Preservation Technology and Training regarding alternatives and maintenance for historic structures.
- Early detection, monitoring, and eradication, if possible, will help protect historic structures and other buildings from termite damage.
- There is some chance that wildfire risk will increase. If possible, consider landscaping options that will reduce fuels around structures.

Additional Assistance

- Additional resources for answering question 16 and other questions related to the GFIP process 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 at:

GFIPHazardsandRiskAssistance@doimspp.onmicrosoft.com and a member of that team will reply with support.

Appendix 1: Climate-Related Natural Hazards Checklist

The following checklist is an expert-opinion based screening tool that illustrates the hazards that were considered in the development of this report. Knowledge of how climate change will unfold is developing rapidly and new hazards may become evident in the future. Only hazards believed to be affected by a changing climate are included in this report.

Potential Hazard	Best Professional Judgment	Potential Risk or Secondary Hazard
Air Temperature: Hotter Average Days and More Very Hot Days	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Inadequate HVAC • Road surface degradation • Lack of water due to increased water for irrigation • Increased humidity • Danger to staff and visitors
Drought: Increased Frequency, Intensity, Magnitude, and Duration	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Limited water supply for cooling, landscaping, other equipment • Increased competition for available water and water rights conflicts • Crack/heave damage in drier soils • Increased vulnerability to wildfire (below)
Wildfire: Increased Frequency, Intensity, Magnitude, and Duration	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Damage to facilities and contents • Smoke damage • Air quality dangerous to staff and visitors • Increased runoff • Increased erosion • Damage to water treatment plants

Precipitation: Altered Patterns and Changing Humidity	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change
Precipitation: Increased Extreme Events	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils
Riverine Flood/ Flash Flood	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Damage or destruction of infrastructure • Stream channel migration • Stream bank erosion/extreme erosion • Safety • Water quality diminished • Damage to water source and delivery infrastructure • Changing requirements for culvert flow capacity
Sea Level Change and Coastal Storm Surge	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Rising sea and lake levels • Rising water – wind driven (e.g., hurricane, nor'easter) • Saltwater intrusion • Vegetation damage • Need to elevate or relocate coastal facilities

Hurricanes, Tornadoes, and Other High Wind Events	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Building destruction • Flying debris • Storm Surge • Tree fall (see other categories for associated intense rainfall, floods)
Pest Infestation	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Historic fabric and facility damage • Vegetation loss • Disease vectors may increase. • Termites and other woodboring pests are expanding range with warming and increased humidity.
Invasive Species	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Vegetation (e.g., kudzu, vines, Brazilian pepper) can damage buildings, kill trees, obstruct waterways. • Marine and aquatic invasive species
Subsurface Hazards Cave/Karst (Sinkholes)	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Surface collapse • Contamination • May affect freshwater availability, drainage, and drought potential • Abandoned Mineral Lands (AML) features

Shrink/ Swell Soils	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Damage to structure • “Heaving” of ground beneath structure • Increased landslide susceptibility
Landslide/ Rockfall/ Avalanche	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Rockfall • Mud or debris slides or flows onto structures • Mud or debris slides or flows from under structures • Snow avalanche
Tsunami	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Coastal area inundation associated with earthquakes or undersea landslides • May be triggered by mass wasting events
Volcanic Eruption	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Lava Flows • Fire • Toxic gas releases • Ash

Hydrothermal Activity (e.g., Geysers)	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Toxic gas release • Explosion • Boiling water • Steam • Surface collapse into void
Earthquake	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Falling objects • Collapsing structures • Inoperability of major building systems e.g. power, sewer, water • Liquefaction; loss of strength to foundations, silt deposition, standing water • Trigger to other hazards e.g. landslides, debris flows

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