



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

## **Rocky Mountain National Park January 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 Rocky Mountain National 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.

### Hotter average days and more very hot days

Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses on HVAC systems. If not addressed through building design or more efficient temperature control systems, the increased demand for complex air conditioning systems can add stress to building envelopes and can require significant alterations to a structure.

Recent climatic conditions related to temperature at ROMO are already shifting beyond the historical range of variability (Monahan and Fisichelli 2014). Between the timeframe of 1895-2010 the park has experienced a 1.6° F increase in mean annual temperature (Gonzalez et.al. 2018). Looking at the 60-year timeframe from 1960-2010 the park has experienced an increase in mean annual temperature of over 3° F (Gonzalez et.al. 2018, NPS 2017). Minimum (nighttime) temperatures have been rising more rapidly than maximum temperatures (Monahan and Fisichelli 2014). Under the highest greenhouse gas emissions scenario (RCP 8.5), the park can expect to see a continued increase in mean annual temperature of 9.18° F per century (Gonzalez et.al 2018).

ROMOs high elevation tundra habitat contains patchy areas of permafrost that will be impacted as temperatures continue to rise (Janke 2009). Several sections of Trail Ridge Road could potentially be affected by future warming. As the ground warms, localized slumping, loss of soil cohesion from melting ice, or regional subsidence could pose a threat (Isaken et al. 2007; Lantz and Kokelj 2008).

Over the past two decades, average annual temperatures have remained consistently higher than the long-term average (1895-2015). Since 2000, the state has experienced the highest average spring and summer temperatures in the historical record, with temperatures in Colorado having risen about 2°F since the beginning of the 20th century (Frankson et.al. 2017). In addition to warmer mean temperatures and changes in total precipitation, climate change will manifest itself in many other ways. This includes more frequent heat waves, droughts, floods, and an extended frost-free season.

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

### **Altered precipitation patterns, increased extreme precipitation, 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. 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, destabilization of buildings and pipes, erosion of supporting ground around structures, among many other effects.

At higher elevations in ROMO, annual precipitation is more than twice that received at the lower elevations. Seasonality of precipitation also varies with elevation. Most high-elevation precipitation occurs as snow in winter, while at lower elevations most precipitation occurs as rain in summer (Gross 2013). Like Colorado as a whole, annual and seasonal precipitation is naturally variable and projections of changes in precipitation are equally variable. However, it is almost certain that a higher proportion of winter precipitation will fall as rain rather than snow, especially at lower elevations where temperatures are closer to freezing (Mahoney et. al. 2012). Under the highest greenhouse gas emission scenario (RCP 8.5), the park may experience an overall increase in mean annual precipitation of 9% (Gonzales et. al. 2018). Although projections of overall annual precipitation are uncertain, precipitation is projected to increase in the winter and possibly decrease in the summer months (Frankson et.al. 2017). According to the Colorado State Climate Summary, daily precipitation exceeding 2 inches occur on average about once every 3 to 4 years (Frankson et.al. 2017). The trend for increasing frequency of extreme precipitation events is projected to continue through the end of the century (Easterling et al. 2017).

Major weather events in ROMO and the Southern Rockies are caused by flows of air masses that can originate from any direction, and many notable weather events are the result of collision of air masses from more than one direction (Gross 2013; Western Water Assessment 2013). The Front Range location of ROMO makes it particularly susceptible to heavy precipitation events. In the spring, moist air coming up from the Gulf can collide with colder arctic air and result is intense, very wet snowfalls with total snow depth measured in feet, containing inches of snow water equivalent. In the summer, moist upslope air masses can lead to intense orographic precipitation (e.g. microbursts) and violent thunderstorms. Summer precipitation in the mountains is often a result of convection storm (Western

Water Assessment 2013). The park is likely to experience an extreme daily precipitation event by mid-century, with further increased frequency through the end of the century (Easterling et al. 2017).

*Park staff assessment – relevant to GFIP Project:*

☐ Yes

☐ No

### Increased drought frequency, intensity, magnitude, and duration

Rising air temperatures and changing precipitation patterns are exacerbating drought risk in many parts of the United States (Wehner et al. 2017). Changing drought conditions (frequency, severity, duration) can challenge a variety of infrastructure and operations (Department of Homeland Security 2015) 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).

Colorado frequently experiences droughts. The intensity of droughts is projected to increase. Precipitation varies widely from year to year, but annual and spring precipitation totals have been lower than the long-term average during the most recent 5-year period (2010–2014) due to a severe drought during 2012 and 2013. Fall precipitation has been slightly above average, however, since the 1980s (Frankson et al. 2017).

*Park staff assessment – relevant to GFIP Project:*

☐ Yes

☐ No

### Increased wildfire frequency, intensity, magnitude, and duration

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Excessive fire, however, can damage ecosystems, kill people, and damage infrastructure. Climate change is intensifying the heat that drives wildfire (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). The effects of climate change on wildfire vary across landscapes. For areas where projected climate change increases fire risk, buildings, cultural landscapes, or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

Climate change has had a significant impact on the vegetation and the frequency and intensity of fire at ROMO. Drier and hotter conditions has already increased the risk of wildfire occurrence and severity in at the park and this trend is projected to continue in the future (Liu et al. 2013; Park and Abatzoglou 2020). One consequence of earlier snow melt is a shift in soil water and an increasing summer water deficit, which is associated with fire seasons that begin earlier and end later. Throughout the west, higher temperatures are associated with a longer fire season, more large fires, and more total acres

burned (Westerling et al. 2006). The condition of natural fire in the park warrants moderate concern. The majority of the park is thought to be within the historical range of variability with respect to fire frequency and severity. However, more acres have burned in the park in the last decade than in the preceding 100 years (NPS 2017), and the extreme fire ROMO experienced in 2020 emphasizes wildfire risks associated with drying and increasing temperatures.

Additionally, the warmer winters have resulted in greater winter survival of mountain bark beetles, and the warm temperatures in spring, summer, and fall have facilitated rapid development of mature beetles. These very favorable conditions, in concert with drought in the 2000's, have led to widespread eruptions of mountain pine beetle and massive tree death, increasing risk of wildfire (Bentz et al. 2010, Gross 2013).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

### Riverine flood/Flash flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (Dethier et al. 2020, Tabari 2020). 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.

In ROMO and the surrounding region, the combination of climate trends may increase the frequency of extreme weather events and the likelihood of floods (Gross et al. 2016, Easterling et al. 2017). Along the Colorado Front Range, floods can result from very localized microbursts, rain on snow events, and a combination of unusually warm weather and a very large snowpack. In the past century, ROMO has experienced floods from all three of these causes, and projected climate trends are consistent with an increased risk of floods (Mahoney et al. 2012). Earlier snowmelt due to warmer winter temperatures (especially in heavier snow cover years), and an increase in winter-early spring rain events, may create more severe early season flooding and erosion.

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ N

### Pest infestation

Increased temperatures and CO<sub>2</sub>, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of pests (IPCC 2014). Rooting and burrowing mammals and termites have the potential to cause direct damage to power, water,

transportation, and building facilities (Vissichelli 2018). 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.

In ROMO, the condition of limber pine warrants significant management concern. It is declining due to the interacting effects of recent severe droughts and the climate-exacerbated mountain pine beetle (*Dendroctonus ponderosae*) outbreak (NPS 2017). It is also imminently threatened by the invasion of the nonnative pathogen, *Cronartium ribicola*, which causes the lethal disease white pine blister rust (WPBR) in five-needle white pines. WPBR was confirmed in the park in 2010 and is expected to spread, kill trees, and negatively impact biodiversity, ecosystem processes, and other park resources, compounding the effects of changing climate (Schoettle et al. 2014).

Although population densities of mountain pine beetle have decreased in the park, populations of other bark beetles are increasing in Colorado. These species include Douglas fir beetles (*Dendroctonus pseudotsugae*), spruce beetles (*Dendroctonus rufipennis*), and western balsam bark beetles (*Dryocoetes confusus*). These beetles are native to the southern Rockies; however, the extent of recent beetle activity is without historical precedent. Additionally, climate change is expected to intensify the impacts of future beetle activity (NPS 2017).

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

## Invasive species

Increased temperatures and CO<sub>2</sub>, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of invasive species (IPCC 2014). Weeds and aquatic mussels have the potential to cause direct damage to power, water, transportation, and building facilities (Vissichelli 2018). Non-native species that may not currently impact facilities may become harmful due to changes in local climates (NRC 2002, IPCC 2014).

Previous work at ROMO has specifically identified the continued success of cheatgrass (*Bromus tectorum*) establishment, even at high elevations within the park (NPS 2017). The expected conditions created by climate change. This invasive grass can easily be spread with disturbance and serves as a highly flashy fuel for the spread of wildfire.

*Park staff assessment – relevant to GFIP Project:*

- ☐ Yes
- ☐ No

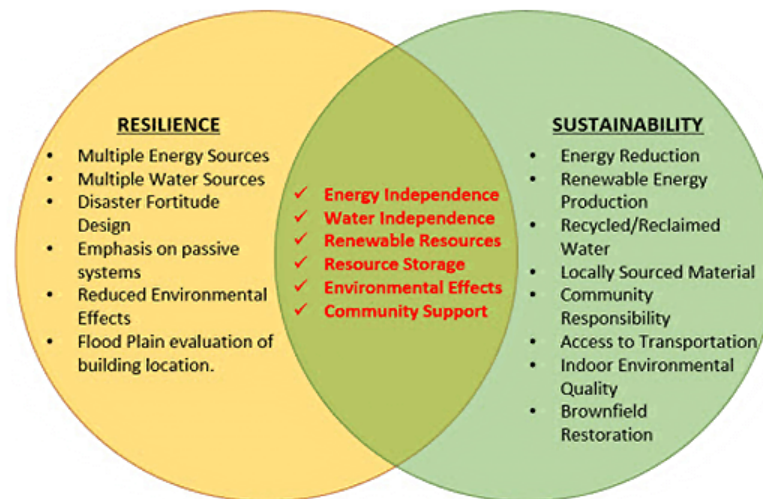
## Step 2: Consider adaptation and resiliency strategies

- 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

- Three example responses to Question 16 are provided below. THESE ARE GENERIC EXAMPLES FROM OTHER PARKS.
- 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 Minute Man National Historic Park: Restoring historic structures***

Several climate change hazards may affect building-related projects at MIMA, including hotter average days, more extreme heat days, increased hurricane impacts from wind and flooding, altered precipitation patterns, and increased extreme precipitation. Adaptation and resiliency strategies for the expected hazards are described below:

- Hotter average days and more extreme heat days will increase demand and requirements for higher capacity air conditioning systems unless accommodated through modified building designs or other systems.
- Extreme heat and humidity can stress the building envelope and will require significant humidity control alterations for structures.
- Changes in building design or post-flooding dehumidification systems, in coordination with the NPS Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center, to avoid any increase in energy use.
- Hurricane force wind and wind-blown rain as well as damage from wind-blown debris or treefall will require wind resistant fortification of the structure. Addressing hazardous trees and retrofitting roof structures to be more wind resistant may also be required.
- Flooding from increased hurricane 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 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 Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center regarding alternatives and maintenance for historic structures.

***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 hazards affecting this project are altered precipitation patterns and related changes to spring runoff. 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. The Gros Ventre River is a wide, braided river with active flow channels that frequently migrate. In recent years, unprecedented spring high water flows caused the main channels of the river to erode the bank adjacent to the Gros Ventre Road, and resulting in partial road collapse in 2017. Temporary fixes have a limited lifespan, particularly if spring runoff levels continue to change as predicted.

The proposed project would directly address these hazards by either armoring the riverbank or moving the roadway away from the river. Future studies (e.g. archeological, hydrologic, engineering, etc.), environmental analyses, and potential lifecycle cost analyses will take higher spring runoff levels into account in determining the preferred alternative. One noted benefit of moving the road away from the highly eroded river bank would be allowing the river to maintain a more natural course.

Other hazards that will be considered in future studies include:

- Increased temperatures and crack/heave damage in drier soils, which may contribute to pavement degradation.
- Precipitation increases or changes, which may cause increased soil moisture and affect the structural integrity of the roads and slopes. Slopes may need to be adjusted accordingly, as well as the installation of additional culverts.

***Example from San Francisco Maritime National Historic Park: pier repair, historic building restoration, road repair, or water system project***

Several climate change hazards may affect a (pier repair, historic building restoration, road repair, or water system) project at San Francisco Maritime National Historical Park, including sea level rise, storm surge, more frequent storms, San Francisco Bay flooding, increased street stormwater runoff, hotter temperatures, and increased insect pests. Possible adaptation and resiliency strategies include:

- Adoption of sea-level rise adaptation measures developed by Golden Gate National Recreation Area in a plan for Crissy Field ([CMG Landscape Architecture 2016](#)) that covers an area up to the western boundary of San Francisco Maritime National Historical Park.
- Natural shoreline features along Aquatic Park Beach to handle some inundation from sea level rise.
- Vegetated catch basins for urban street stormwater runoff.
- Drainage systems and culverts that could handle greater water flows.
- Relocation of any infrastructure from an area where a hazard cannot be avoided.

- Water conservation measures to reduce water use during droughts.
- Strengthening structures to prevent damage from extreme storms or treefall.
- Changes in building design or post-flooding dehumidification systems, coordinating with the NPS Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center and avoiding any increase in energy use, which would increase greenhouse gas emissions and exacerbate climate change.
- Changes in building design or building systems to maintain appropriate temperatures and humidity without increasing energy use, which would increase greenhouse gas emissions and exacerbate climate change. Energy conservation and renewable energy systems to prevent any increase in fossil fuel energy use.
- Early detection and removal of termites or other pests or hazards.

## 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.
  - Appendix 2 below, which provides a map to visualize how climate is changing for the park.
  - 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 **Rocky Mountain National 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                                                                                                                                                                                                        |
|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hotter average days and more very hot days | Known Hazard<br><input checked="" type="checkbox"/><br><br>Potential Hazard<br><input type="checkbox"/><br><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> |

| Potential Climate Hazard                                         | Best Professional Judgment                                                                                                                                          | Examples of risk or secondary hazard                                                                                                                                                                                                                                                                                                | Sources of General Non-site specific Data                                                                                                                                                                                                                             | Sources for Site Specific Data                                                                                                                                |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Increased drought frequency, intensity, magnitude, and duration  | <p>Known Hazard<br/><input type="checkbox"/></p> <p>Potential Hazard<br/><input checked="" type="checkbox"/></p> <p>Not Applicable<br/><input type="checkbox"/></p> | <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 | <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 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> <li>• <a href="#">Parks and Abatzoglou 2020.</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                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Altered precipitation patterns, increased extreme precipitation, and changing humidity | <p>Known Hazard<br/><input type="checkbox"/></p> <p>Potential Hazard<br/><input checked="" type="checkbox"/></p> <p>Not Applicable<br/><input type="checkbox"/></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> |
| 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>                       |

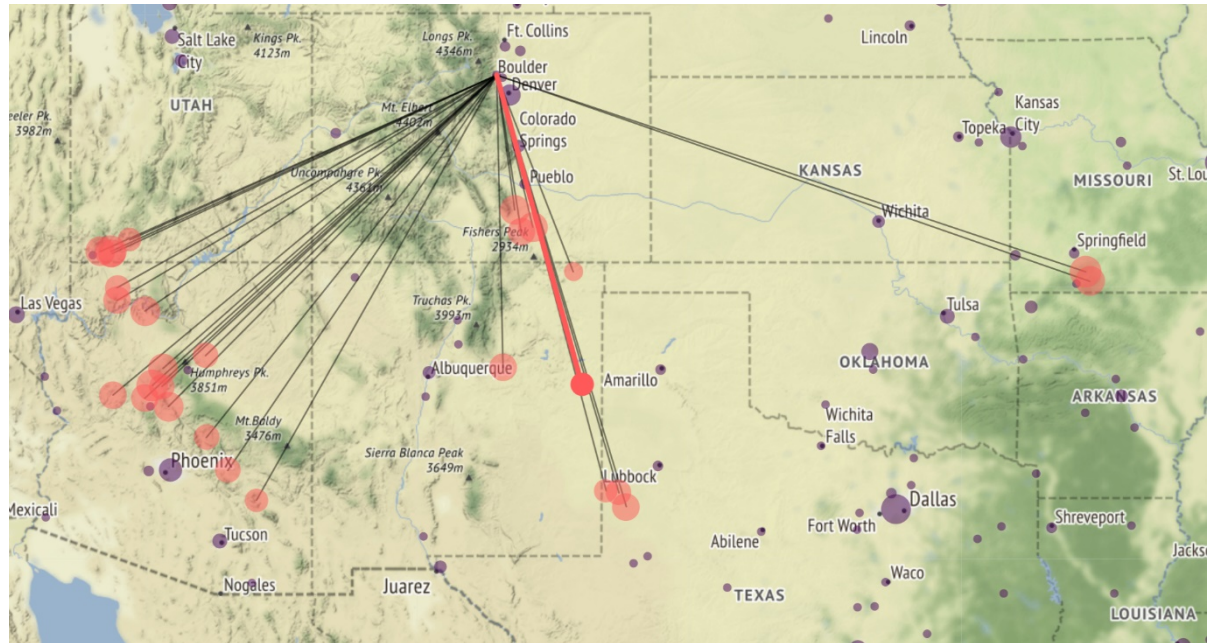
| Potential Climate Hazard                 | Best Professional Judgment                                                                                                                                          | Examples of risk or secondary hazard                                                                                                                                                                                   | Sources of General Non-site specific Data                                                                                                                           | Sources for Site Specific Data                                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sea level change and coastal storm surge | <p>Known Hazard<br/><input type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input checked="" 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> |
| Lake and reservoir level change          | <p>Known Hazard<br/><input type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input checked="" type="checkbox"/></p> |                                                                                                                                                                                                                        |                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                      |
| Hurricanes and tornadoes                 | <p>Known Hazard<br/><input type="checkbox"/></p> <p>Potential Hazard<br/><input type="checkbox"/></p> <p>Not Applicable<br/><input checked="" 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                                                                                                                                                                                                                                                                                              |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pest infestation         | 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>• Historic/facility fabric loss</li> <li>• Vegetation loss</li> <li>• Disease vectors may increase</li> <li>• Termites and other woodboring pests expanding range with warming and increased humidity</li> </ul> | <ul style="list-style-type: none"> <li>• <a href="#">USFS Forest Health Program</a></li> </ul>        | <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 checked="" type="checkbox"/><br>Potential Hazard<br><input 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> |

## Appendix 2. What Will the Park Climate Feel Like in 60 Years?

The map below is intended to help visualize how the present-day climate in the region of **Rocky Mountain National Park** is projected to change as a result of climate change (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, Boulder, Colorado's climate in 2080 may feel like today's climate near Clovis, New Mexico. The typical summer in Clovis, New Mexico is 9.2°F (5.1°C) warmer and 46.9% wetter than summer in Boulder, Colorado. The red line shows the average of the 27 climate models; the black lines show the 27 individual projections assuming continued high emissions, providing a sense of the plausible range of future climates. Circle size gives a sense of how good of a match that location is, with larger circles indicating poorer matches; all circles (red or purple) denote cities used in the analysis. The analysis is based on twelve climate metrics, including minimum and

maximum temperature and precipitation by season (spring, summer, fall, winter). More details are available in the reference cited above and the website <https://fitzlab.shinyapps.io/cityapp/>.



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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.