



Climate Change Hazards Summary Report for Facility Investment Planning

Lake Meredith National Recreation Area 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?

How to Use this Information for your GFIP Projects

Parks can use information in this report to answer Question 16 as well as to inform other related GFIP questions. The steps to incorporate this information are as follows:

1. Review Section 1.0, Table 1: *Climate-related Hazards Checklist* to identify potential hazards for your project. The checklist is a “coarse filter” screening tool to help identify potential climate-related hazards that need to be addressed at an early stage in facility and asset planning. 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. Additional detail describing ‘known’ or ‘potential’ hazards for the park is provided in Appendix 1.
2. Review Section 2.0, which defines adaptation and resiliency strategies and provides an example answer to Question 16 of the GFIP Project Narrative Template.
3. Develop an answer to Question 16 for your specific project and location, as well as strategies to address each hazard. Language can be adapted from Section 2.0 and Appendix 1 to assist with formulating your answer.
4. If additional assistance is desired, see Section 3.0 for contact information.
5. Appendix 2 provides a map to visualize how climate is changing for the park. The map portrays the present-day location that has a climate similar to that expected by the 2080s for (or near) **Lake Meredith National Recreation Area**.

Section 1.0 Using the Climate-Related Hazard Checklist

This report provides an initial evaluation of climate hazards for **Lake Meredith National Recreation Area** (LAMR) 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. Park and planning staff **must use their knowledge of specific projects, locations, and local conditions** to determine the actual risk posed by a particular hazard, and whether/when to consult subject matter experts to conduct a more detailed assessment.

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
1. 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	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National park historical and projected climate change
2. Melting permafrost/ declining sea and lake ice	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Road and building foundations unstable • Landslides and unstable hillsides • Shoreline erosion	• Global Permafrost Zonation Index Map	• Alaska CASC

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
3. Increased drought 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)	• Drought Monitor • National Integrated Drought Information Center • National Climate Assessment • State Climate Summaries	• Drought Monitor • National Integrated Drought Information Center
4. Increased wildfire 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	• Barbero et al. 2015 International Journal of Wildland Fire (Barbero et al. 2015)	• NIFC • International Wildland-Urban Interface Code
5. Altered precipitation patterns and changing humidity	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National Park historical and projected climate change

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
6. Increased extreme precipitation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils	• National Climate Assessment • State climate summary	• Evaluations are mostly at regional scales
7. 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	• FEMA Flood map service	• FEMA Map Service Center • Floodplain maps for HUD projects • Van Dusen et al. 2020 (for select parks) (Van Dusen et al. 2020) • May require a special flood study
8. Sea/lake 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	• NOAA SLR viewer • NOAA - Great Lakes Environmental Research Laboratory	• IRMA – Coastal reports • GRD SLR viewer • Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects • SLR reports • Great Lakes Dashboard Project

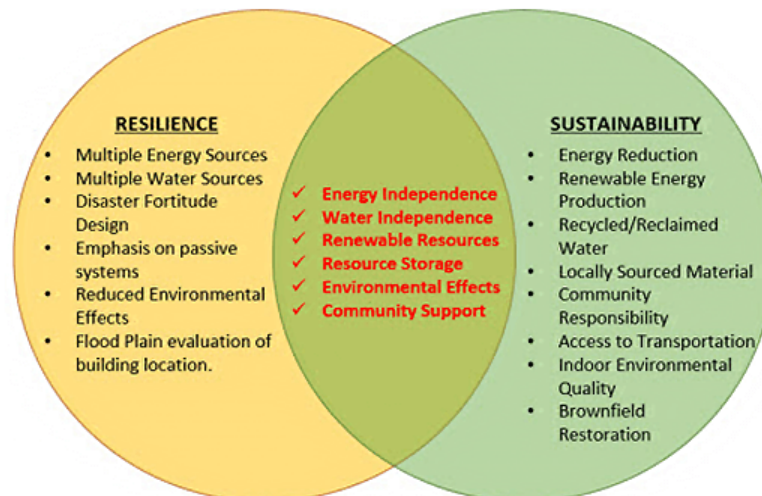
Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
9. Hurricanes and tornadoes	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Building destruction • Flying debris • Storm Surge • Tree fall (see other categories for associated intense rainfall and floods)		• Wind Speed data – from local codes • International Building Code • FEMA Map Service Center • NPS Technical Support
10. Pest infestation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Historic/ Facility Fabric Loss • Vegetation loss • Disease vectors may increase • Termites and other woodboring pests expanding range with warming and increased humidity	• USFS Forest Health Program	• Integrated Pest Management • Fisichelli et al. forest pests (Fisichelli et al. 2014) • USFS maps
11. Invasive species	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Aquatic mussels – water intakes clogged • Vegetation (kudzu, vines) – damage buildings, kill trees, obstruct waterways	• National Invasive Species Council	• Early Detection and Distribution Mapping System (current distribution) • Early Detection and Distribution Mapping System (projected distribution)

Section 2.0 Adaptation and Resiliency Strategies

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, e.g., 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.



“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](#)).

A significant amount of the infrastructure within national parks are 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 infrastructure, although NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks. ([Cultural Resources Climate Change Strategy](#)).

Section 2.1 Example Answer to the PARK Project Narrative Template Question

A hypothetical response to Question 16 is provided below for a project at Lake Meredith National Recreation Area that includes building assets.

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?

Several climate change hazards have been identified that may affect this project, including hotter average days, more extreme heat days, increased tornado impacts, 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 appropriately sized air conditioning systems.
- Extreme heat and humidity can stress the building envelope and will require significant humidity control alterations for structures.
- With continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially. Consider wind resistant fortification of the structures. Addressing hazardous trees and retrofitting roof structures to be more wind resistant may also be required.
- Hotter and drier conditions will worsen declines in the water level within the High Plains Aquifer. New water sources might need to be identified and water conservation measures will need to be put in place.
- Hotter and drier conditions will lead to an increase in wildfires. It will be important to maintain or increase the park's prescribed fire program and design any structures susceptible to wildfire damage with fire-resistant materials.
- Winter and spring precipitation is projected to increasingly fall in the form of very heavy precipitation events, which can increase flooding and runoff. Road construction may require larger culverts to accommodate heavy runoff. Buildings, infrastructure, and roads in existing flood zones may need additional mitigation.
- The potential for increased invasive species should be mitigated. Measures include mitigation during construction (e.g., using weed-free gravel and cleaning construction equipment) and increased weed treatment post construction.

Section 3.0 Additional Assistance

The hypothetical response to Question 16 in Section 2.1 is provided as an example; 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 for assistance in evaluation of climate change hazards and resiliency strategies as they relate to specific infrastructure 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.

Additional resources can be found at the [NPS Facility Planning Branch Strategic Facility Investment Planning SharePoint site](#). This folder 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.

Appendix 1. Summary Information for Known or Potential Hazards Identified for Lake Meredith National Recreation Area

Most park specific details related to hazards were directly extracted from Fisichelli (2013). Numbering relates to Potential Climate Hazard* presented in Table 1.

1. Hotter average days and more very hot days

Climate change is already driving observable increases in average and extreme temperatures, and this trend is projected to continue, with record setting years becoming more common in the future (U.S. Global Change Research Program et al. 2017). The annual average temperature in the United States is expected to increase by 2.3 to 11°F by the end of the century depending on greenhouse gas emissions, relative to 1986-2015 (U.S. Global Change Research Program et al. 2018). 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.

Historical climate trends for LAMR are based on climate data from a nearby long-term weather station in Stratford, TX. Over the 111-year instrumental record (1901-2011) mean annual temperature showed a slight increasing trend (+0.13 °F per decade). Seasonal temperature changes were strongest in spring (+0.23 °F per decade). Mean annual temperature, compared with the 1971-2000 average, is projected to increase roughly 4-5 °F by mid-century and 6-8 °F by the end of the century, depending on the greenhouse gas emissions scenario. Warming by mid-century is projected for all seasons, with the greatest increase likely in summer. There is wide agreement among individual climate models in the direction and magnitude of warming over the coming decades.

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. Small changes in total annual precipitation may mask large shifts in the precipitation regime and associated impacts to ecosystems. For example, fewer but larger rain events will lead to both more frequent droughts and more severe flooding and erosion.

3. 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).

Since the creation of the United States Drought Monitor Map in 2000, Texas has been completely drought-free for only approximately 8% of the time (2000–2014), and at least half of the state has been under drought conditions for approximately 42% of this time period. Higher temperatures in combination with drought conditions are likely to increase the severity, frequency, and extent of wildfires in the future posing significant harm to property, human health, and the livelihood of residents (Runkle et al. 2017). Furthermore, even if average precipitation does not change, higher temperatures will increase the rate of soil moisture loss and thus naturally occurring droughts will likely be more intense. Longer dry spells are also projected (Runkle et al. 2017).

Long-term declines in the water level within the High Plains Aquifer have resulted from greater water discharge than recharge (McGuire 2013). Climate change will worsen this situation by causing drier conditions and increasing the need for irrigation.

4. 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 debris and small 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 or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

In Texas, analyses have not detected a historical change in the area burned by wildfire attributable to human-caused climate change. In the high plains grasslands of the Texas panhandle, climate change under medium greenhouse gas emissions could increase fire probability 50% to 100% (a doubling) by 2100 (Stambaugh et al. 2018).

5. Altered precipitation patterns and changing humidity

Changing precipitation patterns have been observed in many regions of the United States as result of climate change and changes are expected to continue. Depending on the region in the United States, increases or decreases in precipitation have been experienced (U.S. Global Change Research Program et al. 2018). 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.

Annual precipitation and seasonal precipitation did not exhibit strong directional trends over the 111-year instrumental record period (1901-2011). Precipitation projections indicate small to moderate decreases in the annual total and divergent patterns among seasons. Annual precipitation by mid-century may decrease slightly (0% to -3%), while seasonally, an increase is projected for winter (+6 to +9%) and a decrease in summer (-10% to -20%), compared with 1971-2000 values (Kunkel et al. 2013).

Annual and seasonal precipitation variability is likely to remain large over the coming decades, and there is greater uncertainty in precipitation than temperature projections (Kunkel et al. 2013).

6. Increased extreme precipitation

Increased frequency and intensity of extreme precipitation events has been attributed to climate change within some regions of the United States and such increases are projected to continue over the next century (U.S. Global Change Research Program et al. 2018). Furthermore, the intensity of extreme precipitation events increase with increasing temperatures (Easterling et al. 2017). 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.

Future changes in annual average precipitation are uncertain, but an increase in intense rainfall is likely (Kunkle et al. 2017). With climate change, precipitation in the winter and spring is projected to increasingly fall in the form of very heavy precipitation events, which can increase flooding and runoff that reduce water quality and cause soil erosion (Shafer et al. 2014).

7. Riverine flood/Flash Flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (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.

9. Tornadoes

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). Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding.

10. Pest infestation

Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of pests (Intergovernmental Panel on Climate Change et al. 2014). Rooting and burrowing mammals and termites have the potential to cause direct damage to power, water, transportation, and building facilities (Vissicelli 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.

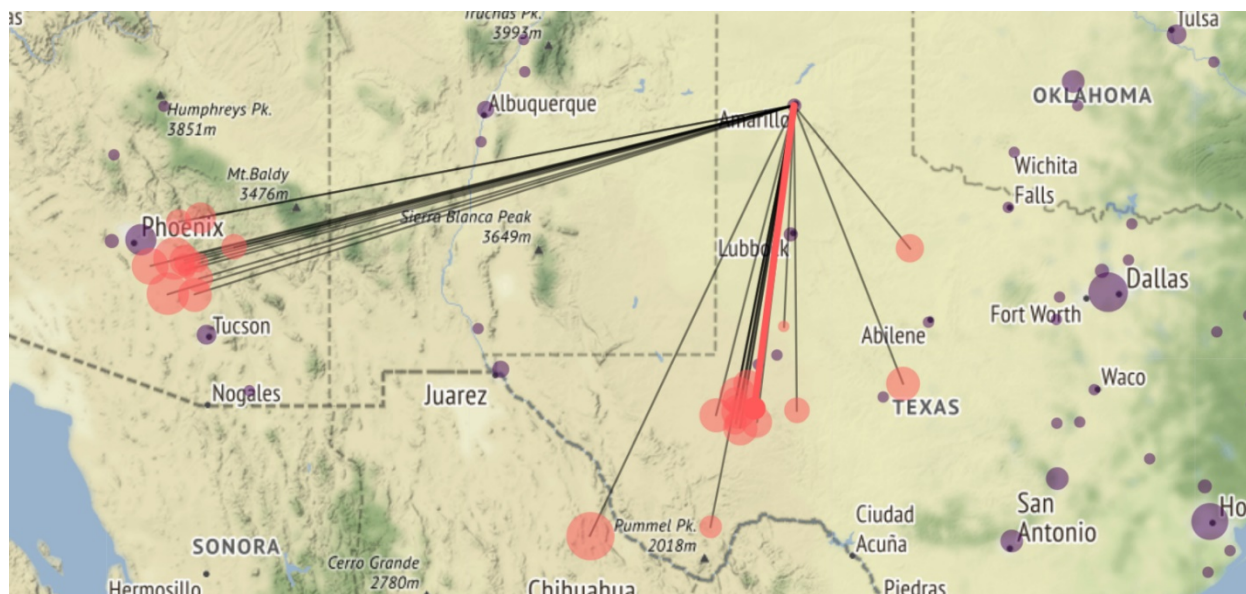
11. Invasive species

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 (Intergovernmental Panel on Climate Change et al. 2014). Weeds and aquatic mussels have the potential to cause direct damage to power, water, transportation, and building facilities (Vissicelli 2018) and may require parks to develop updated integrated pest management plans to account for newly arriving species. Non-native species that may not currently impact facilities may become harmful due to changes in local climates (National Research Council 2002, Intergovernmental Panel on Climate Change et al. 2014).

Invasive species are expected to shift their ranges to track preferred environments as climate changes. Cheatgrass (*Bromus tectorum*) is expected, with high certainty, to expand its range in the Texas panhandle by mid-century (2040-2060) (EDDMapS 2018).

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 **Lake Meredith National Recreation Area** is projected to change as a result of climate change (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, Amarillo's climate in 2080 will feel most like today's climate near West Odessa, Texas. The typical summer in West Odessa, Texas is 6.5°F (3.6°C) warmer and 51.2% drier than summer in Amarillo. 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 at 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.