Technical Appendix 7

Air Quality

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
°F	degrees Fahrenheit
CAA	Clean Air Act
CCS	Continued Current Strategies
CH_4	methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRSS	Colorado River Simulation System
DAQ	Department of Air Quality
dv	Deciview
eGrid	Emissions and Generation Resource Integrated Database
EIS	United States Energy Information Administration
EPA	United States Environmental Protection Agency
GHG	Greenhouse gas
H_2S	Hydrogen sulfide
HAP	Hazardous Air Pollutant
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
$\mu g/m^3$	micrograms per cubic meter
MMT	Million Metric Tons
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NDEP	Nevada Division of Environmental Protection
NEI	National Emissions Inventory
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NPS	National Park Service
NLR	National Laboratory of the Rockies
O_3	Ozone

PM	particulate matter
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
Reclamation	Bureau of Reclamation
SO_2	Sulfur dioxide
SF_6	Sulfur hexafluoride
UAC	Utah Air Conservation Act
U.S.	United States
USDI	United States Department of the Interior
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WRCC	Western Regional Climate Center
WY	water year

TA 7. Air Quality

TA 7.1 Affected Environment

This section presents the existing conditions, regulatory framework and applicable laws, and available existing studies and resources pertaining to air quality. The geographic scope consists of Lake Powell to Southerly International Boundary which includes the Arizona counties of Yuma, La Paz, Mohave, Coconino, Yavapai, and Navajo, the Utah counties of Washington, San Juan, Kane, and Clark County, Nevada. These counties encompass the direct, indirect, and cumulative effects associated with air pollutant dispersal into the atmosphere. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and carbon dioxide equivalent (CO_2e) emissions and climate trends would be analyzed for the county, the state, and the United States (U.S.), which would include every major hydropower facility along the Colorado River, from Lake Powell to the Southerly International Boundary. The geographic scope for analysis is referred to as the "analysis area" throughout this section.

TA 7.1.1 Criteria Pollutants

The Clean Air Act (CAA) was implemented to ensure acceptable and nonhazardous air quality for the people of the U.S. Subsequently, the U.S. Environmental Protection Agency (EPA) established the National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment, referred to as criteria pollutants (**Table TA 7-1**). Unlike the rest of the criteria pollutants, ground-level ozone is typically not directly emitted into the atmosphere from an emissions source. Instead, ozone is formed when emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) mix in the presence of sunlight. **Table TA 7-1** shows the current primary and secondary NAAQS and averaging period for each pollutant. Primary standards are set to protect the public health with a margin of safety, and secondary standards are meant to protect environmental concerns such as air quality related values, which are resources that may be adversely affected by a change in air quality (visibility, vegetation, water quality, soils, fish and wildlife, etc.). The applicable NAAQS have fully been adopted by Utah, Arizona, and Nevada (Clark County Division of Air Quality jurisdiction) and are provided in **Table TA 7-1**.

Table TA 7-1
National Ambient Air Quality Standards

Criteria Pollutant	Averaging Period	Primary NAAQS	Secondary NAAQS
Nitrogen Dioxide (NO_2)	1 hour	0.100 ppm[*]	N/A
	Annual	0.053 ppm[†]	0.053 ppm[†]
Sulfur Dioxide (SO_2)	1 hour	0.075 ppm[‡]	N/A
	3 hours	N/A	0.50 ppm[§]
	24 hours	N/A	N/A
	Annual	N/A	10 ppb[††]
Particulate Matter with a diameter of 10 microns or less (PM_{10})	24 hours	150 $\mu g/m^3$ [#]	150 $\mu g/m^3$ [#]
	Annual	N/A	N/A
Particulate Matter with a diameter of 2.5 microns or less ($PM_{2.5}$)	24 hours	35 $\mu g/m^3$ [**]	35 $\mu g/m^3$ [**]
	Annual	9 $\mu g/m^3$ [†, ††]	15 $\mu g/m^3$ [†, ††]
Carbon Monoxide (CO)	1 hour	35 ppm[§]	N/A
	8 hours	9 ppm[§]	N/A
Lead (Pb)	3 months	0.15 $\mu g/m^3$ [¶]	0.15 $\mu g/m^3$ [¶]
Ozone (O3)	8 hours	0.070 ppm[§§]	0.070 ppm[§§]
	1 hour	N/A	N/A
Hydrogen Sulfide (H2S)	1 hour	N/A	N/A
Visibility reducing particles	8 hours	N/A	N/A
Sulfates	24 hours	N/A	N/A
Vinyl Chloride	1 hour	N/A	N/A

Source: EPA 2025a

Note: N/A = not applicable; ppm = parts per million; ppb = parts per billion; $\mu g/m^3$ = micrograms per cubic meter/

[*] The standard is based on the 3-year average of the 98th percentile of the daily maximum 1-hour average.

[†] Annual mean value.

[‡] The standard is based on the 3-year average of the 99th percentile of the daily maximum 1-hour average.

[§] Not to be exceeded more than once per calendar year.

[¶] Not to be exceeded.

[#] Not to be exceeded more than once per calendar year on average over 3 years.

[**] The standard is based on the 3-year average of the 98th percentile of the 24-hour average.

[††] The standard is based on the 3-year average of the weighted annual mean.

[‡‡] The standard is 9 ppm for areas with an elevation less than 5,000 feet above mean sea level.

[§§] The standard is based on the annual fourth-highest daily maximum 8-hour concentration averaged over 3 years.

[¶¶] 30-day average.

In addition, each state implements regulations that further govern fugitive dust. In Arizona, Arizona Administrative Code (Title 18, Chapter 2), enforced by the Arizona Department of Environmental Quality, applies to owners and operators of nonresidential construction sites in designated Dust Visibility Protection Areas and requires dust controls, vehicle speed limits and monitoring and recordings. Utah rules that address fugitive dust and particulate matter include Title R307 of the Utah Administrative Code which applies to all new or existing sources of fugitive dust greater than one fourth acre in size and are also in areas designated as nonattainment or maintenance for the federal PM_{10} and $PM_{2.5}$ standards. Title R307 also applies statewide outside nonattainment or maintenance areas and establishes minimum work practices and emission standards for fugitive dust. Fugitive dust controls for Nevada are outlined in Nevada Administrative Code 445B.22037. These include best practical methods pertaining to fugitive dust and the requirement to obtain a surface disturbance operating permit for disturbance of 5 acres or more of land. These measures are generally adopted by permit conditions or compliance agreements with the Nevada Division of Environmental Protection and apply to regulated activities that can generate dust.

For each criteria pollutant, the EPA classifies areas as in "attainment" if the area is in compliance with NAAQS or as "non-attainment," if one or more NAAQS is exceeded. Areas for which available data are not sufficient to make an attainment status designation are listed as unclassifiable. Air quality within the Arizona counties of La Paz, Mohave, Coconino, Yavapai, and Navajo is considered in "attainment" or "unclassifiable" for Carbon Monoxide (CO), lead, Nitrogen Dioxide (NO_2), ozone (O_3), PM_{10}, $PM_{2.5}$, and Sulfur Dioxide (SO_2). Air quality within the Arizona county of Yuma has been designated as marginal nonattainment for the 2015 eight-hour O_3 standard, moderate nonattainment for PM_{10}, and considered in "attainment" or "unclassifiable" for all other pollutants. Air quality within the Utah counties of Washington, Kane, and San Juan is considered in "attainment" or "unclassifiable" for CO, lead, NO_2, O_3, PM_{10}, $PM_{2.5}$, and SO_2. Clark County, Nevada has been designated as serious nonattainment for the 2015 eight-hour O_3 standard and a maintenance area for CO and PM_{10}, and considered in "attainment" or "unclassifiable" for all other pollutants (EPA 2025b).

Therefore, the General Conformity Rule, which is designed to protect ambient air quality within nonattainment and maintenance areas against further degradation, would apply for O_3, CO, and PM_{10}. The general conformity de minimis thresholds for all pollutants pursuant to 40 CFR 93.153 (b)(1) are presented in **Table TA 7-2**.

Table TA 7-2
General Conformity De Minimis Levels

	Tons/Year	Nonattainment Area	Analysis Area Nonattainment
O_3 (VOCs or NO_x)	100	Other outside an ozone transport region	N/A
O_3 (VOCs or NO_x)	50	Serious	Clark County, NV
O_3 (VOCs or NO_x)	25	Severe	N/A
O_3 (VOCs or NO_x)	10	Extreme	N/A
SO_2 or NO_2	100	All	N/A
CO	100	All Maintenance Areas	Clark County, NV
PM_{10}	100	Moderate	Clark County, NV (maintenance)
PM_{10}	70	Serious	N/A
$PM_{2.5}$ (direct emissions, SO_2, VOCs, NO_x, ammonia)	100	Moderate	N/A
$PM_{2.5}$ (direct emissions, SO_2, VOCs, NO_x, ammonia)	70	Serious	N/A

Source: EPA 2025c
Notes: VOC = volatile organic compound

TA 7.1.2 Hazardous Air Pollutants

CAA regulations also control the release of Hazardous Air Pollutants (HAPs): chemicals that are known or suspected to cause cancer or other serious health effects, such as reproductive effects, birth defects, or adverse environmental effects. EPA currently lists 187 compounds as HAPs, some of which, such as benzene, toluene, and formaldehyde, can be emitted from oil and gas development operations but are minimal in solar development operations. NAAQS have not been set for HAPs; rather HAP emissions are controlled by source type– or industrial sector–specific regulations by developing standards for controlling emissions of air toxics known as maximum achievable control technology standards. There are no project-specific applicable maximum achievable control technology requirements regarding HAPs, as these standards only apply to stationary sources within specific industrial groups.

TA 7.1.3 Existing Conditions

Air Quality Monitors and Design Values

Criteria pollutants are monitored throughout various parts of the country. Monitors measure concentrations of pollutant in the atmosphere and the results are often presented in parts per million (ppm) or micrograms per cubic meter ($\mu g/m^3$). Pursuant to 40 CFR 58.14 (c)(1), the EPA and states periodically analyze and review monitor locations, discontinue monitoring at locations where pollutant concentrations have been well below the standards, and add monitors in areas where pollutant concentrations may be approaching air quality standards. Instantaneous on-demand monitored outdoor air quality data collected from state, local, and tribal monitoring agencies can be obtained from EPA’s Air Data webpage and interactive tool (EPA 2025d).

The EPA uses the criteria pollutant monitoring data to determine a “design value” for each pollutant and associated averaging time. A design value is a statistic representing the monitored concentration of a given pollutant in a given location, expressed in the manner of its standard, which can be compared to the NAAQS. Design values are updated annually and posted to the EPA’s Air Quality Design Value website (EPA 2025d). The most recent available 2024 design values for the analysis area counties in Arizona, Nevada, and Utah are provided in **Table TA 7-5**, **Table TA 7-3**, and **Table TA 7-4**. Rural counties may not have existing monitors; therefore, no data are available, and it is assumed that pollutant concentrations meet ambient air quality standards. Other counties may have monitors that record only certain pollutants. With the exception of Kane and San Juan Counties, criteria pollutant monitoring data are available for at least one criteria air pollutant and available criteria pollutant monitoring data are reported. Design values are typically used to designate and classify nonattainment areas, as well as to assess progress toward meeting the NAAQS. The design value for O_3 for Clark County exceeds the NAAQS for O_3 (0.70 ppm), and the number of exceedances of the PM_{10} NAAQS exceed the standard for Clark County and Yuma County. None of the other design values listed in **Table TA 7-5**, **Table TA 7-3**, and **Table TA 7-4** exceed or approach proximity to the NAAQS (EPA 2025e).

Table TA 7-3
2024 Design Values for Mohave, Coconino, Navajo, and Yavapai Counties, Arizona

Pollutant	Yuma	La Paz	Mohave	Coconino	Navajo	Yavapai	Averaging Time	NAAQS
O_3	0.069	0.068	N/A	0.065	0.064	0.061	8-hour*	0.070 ppm
NO_2	N/A	N/A	N/A	N/A	N/A	N/A	Annual†	53 ppb
NO_2	N/A	N/A	N/A	N/A	N/A	N/A	1-hour¶	100 ppb
CO	N/A	N/A	N/A	N/A	N/A	N/A	8-hour**	9 ppm
CO	N/A	N/A	N/A	N/A	N/A	N/A	1-hour**	35 ppm
SO_2	N/A	N/A	N/A	N/A	N/A	N/A	1-hour†	0.075 ppm
$PM_{2.5}$	8.1	3.5	N/A	N/A	N/A	N/A	Annual§	9 μg/m^3
$PM_{2.5}$	21	11	N/A	N/A	N/A	N/A	24-hour¶	35 μg/m^3
PM_{10}	6.0 2022-2024 Ave. Est. Exceed-ances	0.7 2022-2024 Ave. Est. Exceed-ances	0.7 2022-2024 Ave. Est. Exceed-ances	N/A	N/A	N/A	24-hour††	150 μg/m^3

Source: EPA 2025e

Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. ppb = parts per billion.

* Annual fourth highest daily maximum 8-hour concentration, averaged over 3 years.

† 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.

‡ Annual fourth highest daily maximum 1-hour concentration, averaged over 3 years.

§ Annual mean, averaged over 3 years.

¶ 98th percentile, averaged over 3 years.

** Not to be exceeded more than once per year

†† Not to be exceeded more than once per year on average over 3 years.

Table TA 7-4
2024 Design Values for Washington Counties, Utah

Pollutant	Washington	Averaging Time	NAAQS
O_3	0.065	8-hour*	0.070 ppm
NO_2	4 ppb	Annual†	53 ppb
NO_2	28 ppb	1-hour¶	100 ppb
CO	N/A	8-hour**	9 ppm
CO	N/A	1-hour**	35 ppm
SO_2	N/A	1-hour†	0.075 ppm
$PM_{2.5}$	5.1	Annual§	9 μg/m^3
$PM_{2.5}$	14	24-hour¶	35 μg/m^3
PM_{10}	N/A	24-hour††	150 μg/m^3

Source: EPA 2025e

Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. San Juan and Kane Counties have no monitoring data. ppb = parts per billion.

* Annual fourth highest daily maximum 8-hour concentration, averaged over 3 years.
† 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
‡ Annual fourth highest daily maximum 1-hour concentration, averaged over 3 years.
§ Annual mean, averaged over 3 years.
¶ 98th percentile, averaged over 3 years.
** Not to be exceeded more than once per year
†† Not to be exceeded more than once per year on average over 3 years.

Table TA 7-5
2024 Design Values for Clark County, Nevada

Pollutant	Clark County	Averaging Time	NAAQS
O_3	0.074 ppm	8-hour*	0.070 ppm
NO_2	20 ppb	Annual†	53 ppb
NO_2	51 ppb	1-hour¶	100 ppb
CO	2.4 ppm	8-hour**	9 ppm
CO	2.8 ppm	1-hour**	35 ppm
SO_2	4 ppb	1-hour†	0.075 ppm
$PM_{2.5}$	8.7 μg/m^3	Annual§	9 μg/m^3
$PM_{2.5}$	29 μg/m^3	24-hour¶	35 μg/m^3
PM_{10}	4.0 2022-2024 Average Estimated Exceedances	24-hour††	150 μg/m^3

Source: EPA (2025e).
Note: N/A = not available, monitors do not report. Many rural counties have no monitoring data and are assumed under the CAA to be in attainment. ppb = parts per billion.
* Annual fourth highest daily maximum 8-hour concentration, averaged over 3 years.
† 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
‡ Annual fourth highest daily maximum 1-hour concentration, averaged over 3 years.
§ Annual mean, averaged over 3 years.
¶ 98th percentile, averaged over 3 years.
** Not to be exceeded more than once per year
†† Not to be exceeded more than once per year on average over 3 years.

National Emissions Inventory

Triennially, the EPA publishes a comprehensive summary of air emissions data, known as the National Emissions Inventory (NEI). The most recent NEI data available are from 2020. **Table TA 7-6** through **Table TA 7-10** provides the 2020 emissions for the six criteria air pollutants and HAPs for the U.S.; the State of Arizona; Nevada; and Utah; and all of counties in the analysis area. The EPA uses the NEI to develop and review regulations, conduct air quality modeling, and conduct risk assessments to understand how air pollution may affect the health in communities across the country. Therefore, the non-attainment status for some of the counties in the analysis area indicate the NEI data presented below are only a concern for those pollutants in nonattainment (EPA 2023).

Table TA 7-6
National Emissions Inventory 2020 Emissions Data for United States, Nevada, Arizona, and Utah (tons)

Pollutant	United States	Nevada	Arizona	Utah
NO_x	8,814,608	80,106	147,990	110,291
CO	66,065,689	412,095	1,265,343	862,864
VOC	46,140,059	267,402	680,519	465,409
PM_{10}	16,761,114	117,964	183,742	183,966
$PM_{2.5}$	5,815,036	29,738	80,611	68,285
SO_2	1,838,518	4,807	17,102	12,704
HAPs	5,964,882	57,126	114,811	83,712

Source: EPA 2023

Table TA 7-7
National Emissions Inventory 2020 Emissions Data for Nevada and Clark County (tons)

Pollutant	Nevada	Clark County	% of State
NO_x	80,106	24,426	30.5%
CO	412,095	187,398	45.5%
VOC	267,402	51,867	19.4%
PM_{10}	117,964	15,733	13.3%
$PM_{2.5}$	29,738	5,882	19.8%
SO_2	4,807	404	8.4%
HAPs	57,126	10,138	17.7%

Source: EPA 2023

Table TA 7-8
National Emissions Inventory 2020 Emissions Data for Arizona and Yuma, La Paz and Navajo Counties (tons)

Pollutant	Arizona	Yuma County	% of State	La Paz County	% of State	Navajo County	% of State
NO_x	147,990	5,792	3.9%	3,145	2.1%	8,798	5.9%
CO	1,265,343	27,492	2.1%	12,982	1.0%	21,237	1.7%
VOC	680,519	15,287	2.3%	10,727	1.6%	34,443	5.1%
PM_{10}	183,742	5,324	2.9%	2,626	1.4%	5,910	3.2%
$PM_{2.5}$	80,611	1,407	1.8%	680	0.8%	1,484	1.8%
SO_2	17,102	104	0.6%	16	0.1%	1,887	11.0%
HAPs	114,811	3,000	2.6%	1,924	1.7%	5,806	5.1%

Source: EPA 2023

Table TA 7-9
National Emissions Inventory 2020 Emissions Data for Arizona and Coconino, Mohave and Yavapai Counties (tons)

Pollutant	Arizona	Coconino County	% of State	Mohave County	% of State	Yavapai County	% of State
NO_x	147,990	12,455	8.4%	9,863	6.7%	10,411	7.0%
CO	1,265,343	102,877	8.1%	49,112	3.9%	68,627	5.4%
VOC	680,519	105,740	15.5%	37,626	5.5%	44,088	6.5%
PM_{10}	183,742	14,435	7.9%	6,384	3.5%	12,358	6.7%
$PM_{2.5}$	80,611	7,462	9.3%	2,109	2.6%	4,833	6.0%
SO_2	17,102	651	3.8%	142	0.8%	2,721	15.9%
HAPs	114,811	16,615	14.5%	7,339	6.4%	7,270	6.3%

Source: EPA 2023

Table TA 7-10
National Emissions Inventory 2020 Emissions Data for Utah and Kane, San Juan and Washington Counties (tons)

Pollutant	Utah	Kane County	% of State	San Juan County	% of State	Washington County	% of State
NO_x	110,291	791	0.7%	1,671	1.5%	3,029	2.7%
CO	862,864	7,224	6.5%	8,619	7.8%	23,078	20.9%
VOC	465,409	15,162	13.7%	20,813	18.9%	14,397	13.1%
PM_{10}	183,966	2,566	2.3%	4,206	3.8%	5,563	5.0%
$PM_{2.5}$	68,285	532	0.5%	720	0.7%	1,314	1.2%
SO_2	12,704	25	0.0%	48	0.0%	61	0.1%
HAPs	83,712	2,813	2.6%	4,025	3.6%	2,513	2.3%

Source: EPA 2023

Air Pollution Associated Diseases

Air pollution is associated with many respiratory diseases. These effects come from inhaling particulate matter, O_3, NO_X, SO_2, and other pollutants. For example, Valley Fever or coccidioidomycosis is a lung disease that is prevalent in the southwestern U.S. The fungus Coccidioides immitis causes Valley Fever, which grows in soils with low rainfall, high summer temperatures, and moderate winter temperatures. When the soil is disturbed by winds, construction, farming, or other activities, these fungal spores become airborne. Infection occurs when a spore is inhaled by a susceptible person or animal. Construction, agriculture, and archaeology workers are at a higher risk of exposure and disease because their jobs cause soil disturbance, which can lead to the presence of fungal spores. The analysis area counties are all areas that may harbor the fungus that causes the disease Valley Fever (CDC 2024). Depending on the level of exposure, breathing O_3 can also trigger a variety of health problems. Effects of O_3 inhalation can include coughing and sore or scratchy throat; difficulty breathing deeply and vigorously and pain when taking deep breaths; inflammation of and damage to the airways; increased susceptibility to lung infections; aggravation of lung diseases such as asthma, emphysema, and chronic bronchitis; and an increase in the frequency of asthma attacks. Some of these effects have been found even in healthy people, but effects are more serious in people with lung diseases such as asthma. O_3 exposure may lead to increased school absences, medication use, visits to doctors and emergency rooms, and hospital admissions. Long-term exposure to O_3 is linked to aggravation of asthma and is likely to be one of many causes of asthma development. Studies in locations with elevated O_3 concentrations also report associations of O_3 with deaths from respiratory causes. Asthma often starts during childhood when the immune system is still developing. Multiple factors may work together to cause asthma. These factors include allergens in the environment that affect babies or young children, including cigarette smoke and certain germs; viral infections that affect breathing; and family history, such as a parent (in particular, a mother) who has asthma. Common triggers for asthma include indoor allergens, such as dust mites, mold, and pet dander or fur; outdoor allergens, such as pollens and mold; emotional stress; physical activity (although with treatment, most individuals can still be active); infections, such as colds, influenza (flu), or COVID-19; certain medicines, such as aspirin, which may cause serious breathing problems in people with severe asthma; poor air quality (such as high levels of O_3); or very cold air (National Heart, Lung, and Blood Institute 2024).

Prevention of Significant Deterioration and Air Quality Related Values

As set forth in the CAA, the Prevention of Significant Deterioration (PSD) regulations were developed and implemented to protect public health and welfare and to preserve, protect, and enhance the air quality in national parks, wilderness areas, monuments, and other areas of special value. The regulations apply to permitting for new or modified *major*[1] stationary sources in attainment areas. As part of the PSD, the EPA classifies airsheds as Class I or Class II. Class I areas are areas of special national or regional natural, scenic, recreational, or historic value for which the PSD regulations provide special protection. All other areas are designated Class II areas, which allow for moderate pollution increases and reasonable growth, while still applying stringent air quality constraints (NPS 2023a). Class I areas are also defined as national parks over 6,000 acres and wilderness areas and memorial parks over 5,000 acres that were established as of 1977. **Table TA 7-11** presents the Class I areas located within the analysis area, as well as those located in counties adjacent to the analysis area. For those Class I areas that are national parks, the U.S. Department of the Interior (USDI) National Park Service (NPS) compiles visibility data which is also provided in **Table TA 7-11**.

Air quality related values were established to address impacts such as acid deposition, regional haze, and the degradation of sensitive species in Class I areas.

[1] Major sources are defined as a source that emits 100 tons per year or more of any criteria pollutant for pollutants specifically listed source categories in 40 CFR 51.166(b)(a)(i)(a) or that emit 250 tons per year of any criteria pollutants and are not specifically listed sources.

Table TA 7-11
Class I Areas

State	Class I Area	Agency	County	NPS Visibility Summary
Utah	Arches National Park	USDI-NPS	Grand	Visibility is fair at Arches National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.3 dv compared to NPS visibility benchmarks. This is 2.3 dv above the estimated natural condition of 3.0 dv. In 2022, the measured visual range is between 88 and 179 miles. Without the effects of pollution estimated visual range would be between 123 to 201 miles.
	Bryce Canyon National Park	USDI-NPS	Garfield and Kane	Visibility is fair at Bryce Canyon National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5 dv compared to NPS visibility benchmarks. This is 2.2 dv above the estimated natural condition of 2.8 dv. In 2022, the measured visual range is between 76 and 187 miles. Without the effects of pollution estimated visual range would be between 120 to 210 miles.
	Canyonlands National Park	USDI-NPS	Wayne, Garfield, San Juan	Visibility is fair at Canyonlands National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.3 dv compared to NPS visibility benchmarks. This is 2.3 dv above the estimated natural condition of 3.0 dv. In 2022, the measured visual range is between 88 and 179 miles. Without the effects of pollution estimated visual range would be between 123 to 201 miles.
	Capitol Reef National Park	USDI-NPS	Wayne, Garfield	Visibility is fair at Capitol Reef National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 5.6 dv compared to NPS visibility benchmarks. This is 2.5 dv above the estimated natural condition of 3.1 dv. In 2022, the measured visual range is between 82 and 171 miles. Without the effects of pollution estimated visual range would be between 127 to 197 miles.

State	Class I Area	Agency	County	NPS Visibility Summary
Utah *(cont.)*	Zion National Park	USDI-NPS	Washington, Iron, and Kane	Visibility is fair at Zion National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 7 dv compared to NPS visibility benchmarks. This is 3.3 dv above the estimated natural condition of 3.7 dv. In 2022, the measured visual range is between 81 and 158 miles. Without the effects of pollution estimated visual range would be between 122 to 203 miles.
Arizona	Petrified Forrest National Park	USDI-NPS	Apache and Navajo	Visibility is fair at Petrified Forest National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 6.4 dv compared to NPS visibility benchmarks. This is 3.5 dv above the estimated natural condition of 2.9 dv. In 2022, the measured visual range is between 86 and 161 miles. Without the effects of pollution estimated visual range would be between 123 to 200 miles.
	Grand Canyon National Park	USDI NPS	Coconino and Mohave	Visibility is good at Grand Canyon National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 4.8 dv compared to NPS visibility benchmarks. This is 1.9 dv above the estimated natural condition of 2.9 dv. In 2022, the measured visual range is between 100 and 194 miles. Without the effects of pollution estimated visual range would be between 117 to 215 miles.
	Sycamore Canyon Wilderness	USDA-Forest Service	Yavapai and Coconino	N/A
	Pine Mountain Wilderness	USDA-Forest Service	Yavapai	N/A
	Mazatzal Wilderness	USDA-Forest Service	Yavapai and Gila	N/A
	Superstition Wilderness	USDA-Forest Service	Maricopa	N/A
	Sierra Ancha Wilderness	USDA-Forest Service	Gila	N/A

State	Class I Area	Agency	County	NPS Visibility Summary
Arizona *(cont.)*	Mount Baldy Wilderness	USDA-Forest Service	Apache	N/A
Nevada	Great Basin National Park	USDI-NPS	White Pine	Visibility is fair at Big Bend National Park based on the 5-year average (2018–2022) measured visibility (haze index) on mid-range days of 9.8 dv compared to NPS visibility benchmarks. This is 6.1 dv above the estimated natural condition of 3.7 dv. In 2022, the measured visual range is between 58 and 140 miles. Without the effects of pollution estimated visual range would be between 120 to 207 miles.

Source: EPA 2025d; NPS 2023a
N/A – Not available as only National Parks have a NPS Visibility Summary
dv – deciviews
USDA – U.S. Department of Agriculture

Visibility is monitored using methodologies established by the Interagency Monitoring of Protected Visual Environments Program. The particulates that contribute to haze are collected on filters at each Interagency Monitoring of Protected Visual Environments site. Samples are then measured to determine how visibility is affected over time and by which pollutants. A deciview is a unit of measurement to quantify human perception of visibility. Because visibility at any one location is highly variable throughout the year, it is characterized by three groupings: the clearest 20 percent days, average 20 percent days, and haziest 20 percent days. Visibility degradation is primarily due to sulfate, nitrate, and PM in the atmosphere, with contributions from both anthropogenic and natural sources. Measuring progress in air pollution control can be challenging, because natural sources beyond human control, such as dust storms and wildfires, can produce significant visibility impairment over large areas for days to weeks at a time. Under the 2017 Regional Haze Rule revisions, the EPA proposed a new visibility tracking metric—"most impaired days"—to better characterize visibility conditions and trends. The most impaired days are those with the most impairment from anthropogenic sources, whereas the haziest grouping now better represents days with haze from natural sources. Total haze on the most impaired days is used to track progress toward Regional Haze Rule goals. Comparing trends in the 20 percent haziest days with the 20 percent most impaired days provides a method to assess impacts from episodic events, like wildfires, which have greatly affected visibility throughout the western U.S. in recent years (Burke et al. 2021).

Visibility information can be found at the Federal Land Managers Environmental Database (FED CIRA 2023). Visibility trends for Class I areas are determined for the clearest, haziest, and most impaired categories. Visibility on the clearest days improved consistently, whereas haziest days have shown little improvement due to many years with large wildfire smoke episodes. The difference between the haziest and most impaired days has increased since the beginning of the monitoring record, indicating that episodic events are now exerting a larger impact on visibility.

Atmospheric deposition occurs when gaseous and particulate air pollutants are deposited on the ground, water bodies, or vegetation. The NPS monitors and evaluates deposition to determine parks that are most at risk and where conditions are declining or improving (NPS 2024). Nitrogen deposition conditions are fair to poor with no trend data available (**Table TA 7-12**). Sulfur deposition conditions are good with trend data unavailable for most locations.

Table TA 7-12
Nitrogen and Sulfur Deposition Conditions at National Parks

State	Class I Area	Nitrogen (Conditions 2018–2022/Trend 2013–2022)	Sulfur (Conditions 2018–2022//Trend 2013–2022)
Utah	Arches National Park	Poor / Trend Not Available	Good / Trend Not Available
	Bryce Canyon National Park	Fair / Relatively Unchanging	Good / Relatively Unchanging
	Canyonlands National Park	Poor / Relatively Unchanging	Good / Improving
	Capitol Reef National Park	Fair / Trend Not Available	Good / Trend Not Available
	Zion National Park	Fair / Trend Not Available	Good / Trend Not Available
Arizona	Petrified Forrest National Park	Poor / Relatively Unchanging	Good / Improving
	Grand Canyon National Park	Poor / Relatively Unchanging	Fair / Improving
Nevada	Great Basin National Park	Poor / Relatively Unchanging	Fair / Improving

Source: NPS 2023b

Regional Modeling and Studies

Lake Powell and Lake Mead Modeling

In 2024, U.S. Geological Survey (USGS) initiated a study in cooperation with NPS to model exposed shoreline area and potential dust emissions at the Lake Mead and Lake Powell (Sankey et al. 2024).

Lake Mead Annual High and Low Elevations

Annual high and low elevations of Lake Mead for years 1935–2024 are available through the Bureau of Reclamation (Reclamation) with the maximum storage capacity at 1,229 feet. For 2024, the high elevation was 1,077 feet and the low was 1,061 feet. In 2014, the high elevation was 1,109 feet and the low was 1,080 feet (Reclamation 2025a).

Lake Powell Annual High and Low Elevations

Annual high and low elevations of Lake Powell for years 1964–2024 are available through the Reclamation with the maximum storage capacity at 3,700 feet. For 2024, the high elevation was 3,587 feet and the low was 3,558 feet. In 2014, the high elevation was 3,609 feet and the low was 3,574 feet (Reclamation 2025b).

Lake Mead Mapping

USGS in cooperation with the Lake Mead/Mohave Research Institute, University of Nevada, Las Vegas completed a detailed geophysical mapping of the floor of Lake Mead during 1999, 2000, and 2001. The 1999 survey covered the Boulder Basin section of the lake, the 2000 survey focused on the northwestern portion of Las Vegas Bay, and the 2001 survey covered the eastern part of the lake. Results from these surveys have been presented in several reports; and in 2003 the three data sets were integrated and presented as a composite of the entire lake in the 'Mapping the floor of Lake Mead (Nevada and Arizona): Preliminary discussion and Geographic Information Systems data release, USGS Open-File Report 03-320'. Also provided is a brief geologic overview of the floor of Lake Mead, and a summary of some of the findings that have resulted from these surveys to provide a geologic perspective for the Geographic Information Systems, which is also provided in this report. Overall, analysis of the seismic-reflection data indicates that a large volume of sediment carried by the Colorado River has accumulated in Lake Mead since impoundment in 1935. The sediment is not uniformly distributed, but rather is concentrated in the deepest parts of the lake and covers the floors of the valleys cut by the Colorado River and the other tributary streams that originally flowed through the area (Twichell and others, 1999; 2001; 2002; 2003). The sediment forms a continuous cover along the entire length of the pre-impoundment Colorado River valley from the eastern extremity of the survey just east of Iceberg Canyon to the Hoover Dam at the west end of the study area. Sediment also covers the floors of the larger tributary valleys that feed the Colorado River (USGS 2003).

Lake Powell Mapping

The USGS, in cooperation with Reclamation, surveyed Lake Powell between fall 2017 and spring 2018 to produce an integrated topobathymetric dataset, which comprises topographic light detection and ranging (lidar) data (land elevation) and multibeam bathymetry (bed elevation of a water body), for the purposes of calculating the elevation-area-capacity relationships in Lake Powell. In 2017 and 2018, the USGS and Reclamation completed extensive surveys of the reservoir utilizing high-resolution multibeam bathymetry and lidar. These data were merged into a seamless topobathymetric dataset, which was subsequently revised to calculate new elevation-area-capacity relationships. This collaborative effort provided a revised and high-resolution estimate of storage capacity in Lake Powell and an updated topobathymetric surface to support water availability studies amidst prolonged drought. The report summarizes the updated elevation-area-capacity relationships, describes the surveying methods and elevation-area-capacity calculations, and provides comparisons of the updated elevation-area-capacity relationships with previous estimates. Storage capacity and areal extent of Lake Powell was determined for a range of elevations from 3,120 to 3,717.20 feet above the North American Vertical Datum of 1988 (NAVD 88). The updated elevation-area-capacity relationships indicate Lake Powell has lost 1,833,000 acre-feet or 6.79 percent of its storage capacity at full pool (3,702.91 feet above NAVD 88) since construction was completed in 1963 through 2018. With consideration to potential error in the topobathymetric dataset, the loss of storage capacity ranges between 1,607,000 and 2,059,000 acre-feet. The reduction in storage capacity is attributed to sedimentation at the deltas of the Colorado and San Juan Rivers. Decreases in storage capacity were largest for the reservoir at elevations above 3,600 feet above NAVD 88, which coincide with frequent reservoir elevations since the 1970s. Historical surveys were limited by comparatively coarser survey techniques than those used for the 2017–18 topobathymetric digital elevation model, though the average annual storage loss between surveys remained similar since impoundment in 1963. With increasing demands on water in the Colorado River Basin amidst a decadal-scale drought, these results provide critical information to support water resource management in Lake Powell and beyond (Root et al. 2022).

Impact of Lost Generation at the Glen Canyon Powerplant

This report was prepared by Argonne National Laboratory and the National Renewable Energy Laboratory (now known as National Laboratory of the Rockies [NLR]) in support of an economic and financial analysis conducted for the United States Department of Energy's Western Area Power Administration of the loss in Glen Canyon power generation due to the environmental requirements for the years 2024 to 2027. This report presents data showing the changes in generation sources for each of the years (2024–2027). These figures show that when there is a reduction in hydropower, the replacement generation from mostly Natural Gas Fired generation (Gas Combined Cycle) generation and Gas Combustion Turbine, with a small portion also coming from coal-fired generation. However, the compensation of natural gas and coal vary by month and year (Argonne et al. 2024).

Research on Emissions from U.S. Reservoirs

EPA scientists are collaborating with researchers at USGS and Department of Energy to measure CH_4 and carbon dioxide (CO_2) emissions from 108 U.S. reservoirs during a four-year survey taking place from 2020 through 2023. The Survey of Reservoir Emissions will inform a greater understanding of the amount of CH_4 and CO_2 emitted from U.S. reservoirs, and the environmental factors that determine the rate of emissions from reservoirs (EPA 2024a).

In addition, a 2021 analysis takes a closer look at reservoirs emissions in arid regions. The analysis presents emission measurements from Lake Powell, reporting CO_2e emissions from the shallow (less than 15 meters) littoral regions of the reservoir that are higher than the global average areal emissions from reservoirs whereas fluxes from the main reservoir were two orders of magnitude lower. They then compared these measurements to modeled CO_2 and CH_4 emissions from the reservoir using four global scale models. Factoring these emissions into hydropower production at Lake Powell yielded low emissions per megawatt-hour as compared to fossil-fuel based energy sources. With the exception of one model, the estimated hydropower emissions for Lake Powell ranged from 10−32 kilograms CO_2e megawatt-hour, compared to ∼400−1000 kilogram CO_2e megawatt-hour for natural gas, oil, and coal. We also estimate that reduced littoral habitat under low water levels leads to ∼50 percent reduction in the CO_2e emissions per megawatt-hour. The sensitivity of emissions to reservoir water levels suggests that the interaction will be an important policy consideration in the design and operation of arid region systems (Waldo et al. 2021).

TA 7.1.4 NAAQS: Regulatory Framework/Applicable Laws, Regulations, Plans, and Policies

As discussed, Section 176 of the federal CAA requires federal agencies that fund, permit, or approve an activity to ensure that the activity complies with the applicable State Implementation Plan adopted to eliminate or reduce air quality violations (42 USC 7506). In order to ensure that air pollutant emissions associated with federally approved or funded activities do not exceed emission budgets established in the applicable State Implementation Plan and do not interfere with the state's ability to attain and maintain the NAAQS in areas working to attain or maintain the standard, the

EPA passed federal conformity rules. The General Conformity Rule applies to all projects that are not related to transportation. According to 40 CFR 51(W), a detailed determination of the General Conformity Rule's applicability is required when federal actions or funding of non-transportation-related activities in nonattainment areas result in emissions that exceed de minimis threshold levels (EPA 2024b). Also discussed, are the PSD regulations that are developed and implemented to protect public health and welfare and to preserve, protect, and enhance the air quality in national parks, wilderness areas, national monuments, and other areas of special value.

Arizona

Air pollutant sources in Yuma, La Paz, Coconino, Yavapai, Mohave, and Navajo Counties fall under the jurisdiction of the Arizona Department of Environmental Quality Air Quality Division. Arizona Department of Environmental Quality operates a network of ambient air quality monitors throughout Arizona for a variety of federal and state monitoring programs. The primary monitoring objective is to measure criteria pollutants regulated under the CAA for compliance with the NAAQS. In addition, Arizona Department of Environmental Quality Air Quality Division's 'Air Permits and Compliance' section issues air quality permits to industrial facilities that emit significant quantities of air pollutants to ensure that the emissions do not harm public health or cause a significant deterioration in air quality.

Nevada

The Nevada Revised Statutes Chapter 445B focuses on air pollution in Nevada. Under this Nevada Revised Statutes for air pollution, each county in the state with a population equal to or greater than 100,000 people must establish a board of county commissioners to establish and implement an air pollution control program (NRS 445B.500). In 2001, the Clark County Board of County Commissioners established the Division of Air Quality (DAQ) to carry out the mandated program. There are 17 counties in the state of Nevada. All but two counties are overseen by the Nevada Division of Environmental Protection (NDEP) for the implementation of the CAA. Washoe and Clark Counties have a delegated authority by the Governor of the State of Nevada for the implementation of the CAA. The DAQ under the Clark County Department of Environment and Sustainability is responsible for administering the air pollution control program for Clark County under the provisions of the Clark County Air Quality Regulations and the EPA-approved State Implementation Plan for Clark County, Nevada (Clark County Air Quality Regulations Sections 00 through 94 as adopted in 40 CFR 52(DD)). In Nevada, the NDEP Bureau of Air Pollution Control and Air Quality Planning has primary responsibility under Nevada Revised Statutes 445B.100 through 445B.825 for managing air quality through state regulations. Within Clark County, emissions are regulated by the DAQ. Construction activities impacting greater than 0.25 acre in Clark County would require a dust control operating permit from DAQ. Projects larger than 10 acres would also require completion of a Dust Mitigation Plan Supplement for DAQ (Clark County 2023). In addition, Section 12.1 of the Clark County Air Quality Regulations requires the issuance of a Minor Stationary Source Permit for any applicable source located in Clark County that has a potential to emit a regulated pollutant that is equal to or greater than the thresholds listed in that section. Any mechanical equipment (e.g., backup generators, boilers, cooling towers) may trigger air quality "stationary source" permitting in accordance with Clark County Air Quality Regulations Section 12.1. Therefore, stationary source permits are obtained before commencing construction of any emissions unit when collectively (i.e., emissions from all emissions units in aggregate) meeting the thresholds for any of the regulated pollutants. The NDEP Bureau of Air Pollution Control and Air Quality Planning and Clark County DAQ have both been delegated authority by the EPA to implement federal programs of the CAA.

Utah

The EPA has delegated authority to Utah Division of Air Quality, under the Utah Department of Environmental Quality, for regulating air quality in all areas of Utah, with the exception of tribal lands, which remain under the authority of the EPA. The Utah Division of Air Quality has primary responsibility for managing air quality through state regulations. The Utah Division of Air Quality's responsibility is to ensure that the air in Utah meets the health and visibility standards established under the CAA. To fulfill this responsibility, DAQ is required by the federal government to oversee compliance with the NAAQS statewide and visibility standards at Class I airsheds. DAQ enacts rules pertaining to air quality standards, develops plans to meet federal standards, when necessary, administers emissions reductions incentive programs, issues preconstruction and operating permits to stationary sources, and enforces compliance with state and federal air quality rules. The Utah Air Conservation Act (UAC 19-2) delegates rulemaking power to the Utah Air Quality Board to promulgate rules pertaining to air quality issues. As of August 2020, Utah Department of Environmental Quality does not require a fugitive dust control plan for the analysis area. The UAC does not specifically require the development of a fugitive dust control plan in attainment areas. However, the UAC does require that operators take measures to limit PM emissions during construction and demolition activities greater than 0.25 acres in size (UAC R307-205). UAC R307-205 also requires fugitive dust to be controlled (regardless of the size or amount of acreage disturbed) to maintain a specified opacity.

TA 7.1.5 Climate Trends and Applicable Pollutants

Global evidence indicates that the earth's climate is showing increases in ocean temperatures, sea level, and acidity; the melting of glaciers and sea ice; changing temperature and precipitation patterns; changes in the frequency, intensity, and duration of extreme weather events; and shifts in ecosystem characteristics, such as the migration of birds. Climate trends result from several factors, including the release of pollutants, land use management practices, and the albedo effect, or reflectivity of various surfaces (including reflectivity of clouds). These pollutants consist of CO_2, CH_4, N_2O, and several fluorinated species of gas. CO_2 is emitted primarily from the combustion of fossil fuels, with additional contributions from land-use change and industrial processes. CH_4 (methane) is emitted primarily from agricultural activities (especially livestock digestion and manure management), fossil fuel production and distribution, and the decomposition of organic waste in landfills and wetlands. N_2O (nitrous oxide) is emitted primarily from agricultural soil management (use of nitrogen-based fertilizers), manure handling, industrial processes, and the combustion of fossil fuels and biomass. Fluorinated gases, which are synthetic, are emitted from a variety of industrial processes. Effects from these pollutants are mostly indirect in that they do not necessarily have a negative impact on human health near emission sources and/or at the time of release. Rather, they accumulate in the atmosphere and affect weather and climate on a global scale over time. As a result, the analysis area with these potential effects are discussed in terms of global, larger-scale trends developing and changing over time.

The impact of a given pollutant depends both on its radiative forcing, the driver for the buildup of heat within the climate system, and how long it lasts in the atmosphere. Each pollutant varies with respect to its concentration in the atmosphere and the amount of outgoing radiation absorbed by the gas relative to the amount of incoming radiation it allows to pass through (i.e., Radiative Forcing). Different pollutants also have different atmospheric lifetimes. Some, such as CH_4, react in the atmosphere relatively quickly (on the order of 12 years); others, such as CO_2, typically last for hundreds of years or longer. Climate scientists have calculated a factor for each pollutant that accounts for these effects and, when applied, results in CO_2e emissions. This factor is discussed in more detail in the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2022 (EPA 2024c).

Conversion factors for the 20-year time horizon were used to convert these different emissions into CO_2e. CO_2e account for changes in radiative properties, atmospheric lifetimes, and indirect contributions of the different gases. The atmospheric lifetimes and conversion factors over the 100-year time horizons are as follows: CO_2 is one, CH_4 is estimated to be 29.8, meaning that CH_4 would cause 29.8 times as much of an increase in temperature as an equivalent mass of CO_2 over a 100-year time period. The annual average temperature increase potential for N_2O is estimated to be 273 (EPA 2024c).

Existing Conditions

The EPA's provides the most recent accounting of national and state level annual CO_2e emissions (EPA 2024c). NDEP's Air Program prepares a CO_2e emissions inventory for the State of Nevada (NDEP 2024). Arizona does not maintain a statewide CO_2e emissions inventory. **Table TA 7-13** lists the industry sector and total CO_2e emissions for the most recent reporting years for the U.S., and Nevada. U.S. CO_2e emissions from 2005 are also provided to show historical CO_2e emissions for comparison to current emissions.

Table TA 7-13
2005, 2022 Emissions by Sector

Sector	2005 United States CO_2e Emissions (MMT CO_2e)	2022 United States CO_2e Emissions (MMT CO_2e)	2022 Nevada CO_2e Emissions (MMT CO_2e)
Transportation	1,965.9	1,801.5	15.983
Energy	2,457.4	1,577.5	13.254
Industry	1,587.3	1,452.5	7.304
Agriculture	634.3	634.0	1.893
Residential and Commercial	790.1	855.0	5.200
Waste	N/A	N/A	2.100
U.S. Territories	59.7	22.7	
Land use, land use change, and forestry	-907.7	-854.2	-8.274
Total (gross)	**7,494.6**	**6,343.2**	**45.734**
Total (net)	**6,586.9**	**5,589.0**	**37.460**

Sources: EPA 2024c; NDEP 2024

Note: MMT = million metric tons; N/A = not available; Conversion factors values have been applied. The term carbon dioxide equivalent (CO_2e) is used to describe CO_2, CH_4, and N_2O emissions in a common unit. CO_2e is calculated with CO_2, CH_4, and N_2O multiplied by the high-end 100-year conversion factor values (EPA 2024c).

As shown in the table above, total CO_2e emissions for the U.S. have been on the decline over the past decade (EPA 2024c). Also, triennially, the EPA publishes a summary of air emissions data, known as the NEI. The most recent NEI data available are from 2020. **Table TA 7-14** through **Table TA 7-18**. **Table TA 7-17** provides the 2020 CO_2e, CO_2, CH_4, N_2O and SF_6 emissions for the U.S., the State of Nevada, and Arizona. In addition, NEI data is provided for each county in the analysis area (EPA 2023).

Table TA 7-14
National Emissions Inventory 2020 Emissions Data for the United States, Nevada, Arizona and Utah (metric tons)

Pollutant	United States	Nevada	Arizona	Utah
CO_2e	4,567,587,840	52,204,974	89,936,584	52,204,974
Carbon dioxide (CO_2)	4,378,761,025	50,632,841	87,172,460	50,632,841
Methane (CH_4)	5,304,516	46,889	66,792	46,889
Nitrous oxide (N_2O)	108,357	640	2,531	640
Sulfur hexafluoride (SF_6)	49	N/A	4	0

Source: EPA 2023
Note: N/A = not available.

Table TA 7-15
National Emissions Inventory 2020 Emissions Data for the United States, Nevada, and Clark County (metric tons)

Pollutant	Nevada	Clark County	% of State
CO_2e	52,204,974	21,579,558	41.3%
Carbon dioxide (CO_2)	50,632,841	21,244,898	42.0%
Methane (CH_4)	46,889	9,826	21.0%
Nitrous oxide (N_2O)	640	153	23.9%
Sulfur hexafluoride (SF_6)	N/A	N/A	N/A

Source: EPA 2023
Note: N/A = not available.

Table TA 7-16
National Emissions Inventory 2020 Emissions Data for the Utah, and Kane, San Juan and Washington Counties (metric tons)

Pollutant	Utah	Kane County	% of State	San Juan County	% of State	Washington County	% of State
CO_2e	52,204,974	141,671	0.3%	283,797	0.5%	1,373,437	2.6%
Carbon dioxide (CO_2)	50,632,841	137,612	0.3%	276,111	0.5%	1,345,518	2.7%

Pollutant	Utah	Kane County	% of State	San Juan County	% of State	Washington County	% of State
Methane (CH_4)	46,889	128	0.3%	241	0.5%	796	1.7%
Nitrous oxide (N_2O)	640	0.91	0.1%	1.81	0.3%	15	2.3%
Sulfur hexafluoride (SF_6)	0	N/A	N/A	N/A	N/A	N/A	N/A

Source: EPA 2023
Note: N/A = not available.

Table TA 7-17
National Emissions Inventory 2020 Emissions Data for the Arizona, and Kane, San Juan and Washington Counties (metric tons)

Pollutant	Arizona	La Paz County	% of State	Yuma County	% of State	Navajo County	% of State
CO_2e	89,936,584	717,359	0.8%	1,749,399	2.0%	5,291,256	5.9%
Carbon dioxide (CO_2)	87,172,460	660,079	0.7%	1,596,363	1.8%	5,131,004	5.9%
Methane (CH_4)	66,792	1,881	2.8%	4,886	7.3%	4,513	6.8%
Nitrous oxide (N_2O)	2,531	5	0.2%	27	1.1%	94	3.7%
Sulfur hexafluoride (SF_6)	4	N/A	N/A	N/A	N/A	N/A	N/A

Source: EPA 2023
Note: N/A = not available.

Table TA 7-18
National Emissions Inventory 2020 Emissions Data for the Arizona, and Coconino, Mojave and Yavapai Counties (metric tons)

Pollutant	Arizona	Coconino County	% of State	Mohave County	% of State	Navajo County	% of State	Yavapai County	% of State
CO_2e	89,936,584	2,990,940	3.3%	3,081,094	3.4%	5,291,256	5.9%	4,634,763	5.2%
Carbon dioxide (CO_2)	87,172,460	2,774,090	3.2%	3,053,052	3.5%	5,131,004	5.9%	4,489,754	5.2%
Methane (CH_4)	66,792	7,052	10.6%	617	0.9%	4,513	6.8%	4,509	6.8%
Nitrous oxide (N_2O)	2,531	24	0.9%	35	1.4%	94	3.7%	39	1.5%

Pollutant	Arizona	Coconino County	% of State	Mohave County	% of State	Navajo County	% of State	Yavapai County	% of State
Sulfur hexafluoride (SF_6)	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Source: EPA 2023
Note: N/A = not available.

Past and Present, and Projected Climate Trends and Impacts

An analysis of regional climate impacts concluded that the rate of average annual temperature increases in the southwest U.S. was among the most rapid nationally (IPCC 2021). This temperature increase is causing a decline in spring snowpack and reducing flow in the four major southwest rivers. Projections of future climate trends indicate that further increases in average annual temperature could reduce precipitation. Analysis of past records and future projections indicates an overall increase in regional temperatures, including in the analysis area. The observed increase is largely the result of the warmer nights and effectively higher average daily minimum temperatures at many of the measurement sites in the region.

National Oceanic and Atmospheric Administration National Centers for Environmental Information released its climate summaries by state in 2022. The climate summaries for the analysis area states are summarized. More detailed climate discussions for each state can be found through the State Climate Summaries webpage (NOAA 2022).

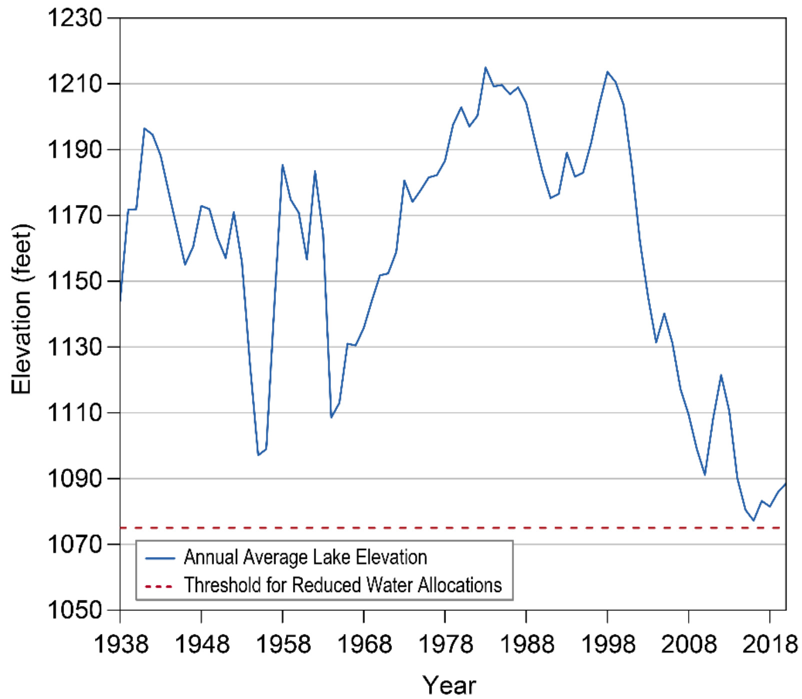
Arizona

Temperatures in Arizona have risen about 2.5 degrees Fahrenheit (°F) since the beginning of the 20th century. The first 21 years of this century have been the warmest period on record for the state. The historical record indicates periodic prolonged wet and dry periods. Arizona is currently in a long-term drought that has lasted more than 20 years. Multiyear periods of high and low precipitation can cause significant variations in reservoir supplies. The latest western U.S. drought has resulted in record-low water levels in Lake Mead, which is a critical water resource for Arizona, as well as southern Nevada, southern California, and northern United Mexican States (Mexico). Since reaching high levels in the late 1990s, water levels have been falling, reaching historic lows in 2015 and 2016 (**Figure TA 7-1**). Long-term droughts also raise the risk of wildfires, already a concern for this arid state.

Figure TA 7-1 shows the time series of the annual average water level (blue line) of Lake Mead at Hoover Dam from 1938 to December 2020. Water levels in Lake Mead have varied widely over the years. Low levels in the 1950s and 1960s were due to drought and the filling of Lake Powell, respectively. Recent years have seen the lowest recorded levels since the original filling of Lake Mead. The red-dashed line indicates the threshold (1,075 feet) below which a federal shortage will be declared, resulting in reduced water allocations for Nevada and Arizona. Unlike many areas of the U.S., Arizona and other southwestern states have not experienced an upward trend in the frequency of extreme precipitation events.

Under the higher and lower emissions pathways, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records.

Figure TA 7-1
Lake Mead Water Levels at Hoover Dam



Source: Reclamation 2025

Although projections of overall annual precipitation are uncertain, there is a risk of decreases in spring precipitation. Additionally, projected rising temperatures will raise the snow line—the average lowest elevation at which snow falls. This will increase the likelihood that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at lower mountain elevations that are now on the margins of reliable snowpack accumulation. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water resources needed for irrigation during the hot summer months.

Naturally occurring droughts are expected to become more intense during the cool season. Even if precipitation does not decrease, higher temperatures will intensify naturally occurring droughts by increasing water evaporation. This will further reduce streamflow, soil moisture, and water supplies. Drought will not only challenge limited agricultural resources but also increase the frequency of dust storms and the frequency of the risk of very large wildfires.

Nevada

Temperatures in Nevada have risen almost 2.4°F since the beginning of the 20th century. After wet conditions in the late 1990s, total annual precipitation has been near or below average since 2000 but shows no overall trend across the 126-year period of record. Seasonal precipitation patterns vary across the state, with most locations receiving the majority of their precipitation during the winter months. However, eastern and southern areas, including Clark County, can experience intense summer rainfall from the North American Monsoon system. Since 2004, the state has received multiple federal disaster declarations for wildfire events.

Drought is a critical climate threat for this arid state. Since 2000, the Colorado River basin, the source of water for the southern part of the state, has experienced drought conditions, with impacts on Lake Mead. In addition, winter precipitation was well below average from the 2011–12 through the 2014–15 water years (WYs; October–September), and all of those years were abnormally warm. This led to a strain on water supplies in agricultural areas that rely on surface water. The majority of the counties in the state have been designated as natural disaster areas due to extreme drought conditions. Lake Mead, the largest man-made reservoir in the U.S., provides water for southern Nevada, as well as Arizona, southern California, and northern Mexico. As of October 25, 2021, water storage in Lake Mead was at 34 percent capacity, and water levels have been dropping since 2000 (**Figure TA 7-1**). Due to aggressive conservation policies, metropolitan areas have been able to manage the reductions in water supplies. Parallel declines in snowpack have been observed over this same time period (**Figure TA 7-1**). Snowpack refills Lake Tahoe every spring, and lake levels slowly decrease throughout the year. Warm and/or dry years lead to low snowpack and associated decreases in the lake's water levels. Since 1900, the lake has fallen below the natural rim 21 times.

Under the higher and lower emissions pathway, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Extreme high temperatures are projected to increase, with potentially large impacts in the very hot southern deserts, particularly the Las Vegas metro area, where 70 percent of the state's population resides.

Projected rising temperatures in Nevada will raise the snow line—the average lowest elevation at which snow falls. This will increase the likelihood that precipitation will fall as rain rather than snow, reducing water storage in the snowpack, particularly at those lower mountain elevations that are now on the margins of reliable snowpack accumulation. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the already dry summer months.

Projections of annual precipitation for Nevada are uncertain throughout this century, but warmer temperatures are likely to decrease the amount of water in the mountain snowpack and increase the demand for water. Higher temperatures will also increase the evaporation rate, which will reduce streamflow and soil moisture. Thus, the intensity of future droughts is likely to increase, as will the risk of wildfires in some ecosystems. Increases in population and potentially decreased water flow from the Colorado River may lead to future water security issues across the state.

Utah

Temperatures in Utah have risen more than 2.5°F since the beginning of the 20th century. Unlike many areas of the U.S., Utah and other southwestern states have not experienced an upward trend in the frequency of extreme precipitation events. Although floods are rare in the state, both heavy rainfall and snowmelt can result in severe flooding.

Under the higher and lower emissions pathway, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. A large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records.

Climate models are not consistent in their projections of precipitation for Utah, including winter precipitation. However, projected rising temperatures will also raise the snow line—the average lowest elevation at which snow falls. Continuing recent trends, this will increase the likelihood that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at lower elevations that are currently on the margins of reliable snowpack accumulation. In addition, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.

Droughts, a natural part of Utah's climate, are expected to become more intense. Higher temperatures will amplify the effects of naturally occurring dry spells by increasing the rate of loss of soil moisture. Most of Utah's water is supplied by the snowpack; observed trends toward more winter precipitation falling as rain and less as snow could result in less water storage. Additionally, higher spring temperatures can cause early melting of the snowpack, decreasing water availability during the already dry summer months.

TA 7.1.6 Climate Trends and CO_2e: Regulatory Framework/Applicable Laws, Regulations, Plans, and Policies

Through statutes, executive orders, and agency policies, the federal government seeks to ensure a reliable, affordable, and secure energy supply while supporting efficient use of resources and responsible development of energy infrastructure. Federal actions may also consider potential energy use and emissions effects, as appropriate, in order to inform decision-making and evaluate alternatives consistent with applicable laws and regulations.

TA 7.2 Environmental Consequences

This section provides an analysis of the extent and magnitude of potential impacts on air quality resources for the No Action Alternative, four action alternatives, and the Continued Current Strategies (CCS) Comparative Baseline (as described in **Chapter 2**).

TA 7.2.1 Methodology

This section examines potential effects on air quality resources under the action alternatives and the No Action Alternative, compared to the CCS Comparative Baseline. Potential impacts are considered for the following air quality resources: shoreline exposure area, fugitive dust emissions, changes in CO_2e due to hydropower, and climate trends.

The subaerial shoreline area and potential dust emissions within Lake Mead and Lake Powell were modeled for this analysis and methods combined previously published topographic and bathymetric surveys and geologic mapping (Hirschberg and Pitts 2000; Jones and Root 2021, 2022; Ferrari 2001; Root et al. 2019; Root and Jones 2022; Twichell et al. 2003; Twichell and Cross 2009; Wilson et al.

1969) with new predictions of potential dust emissions using the FENGSHA model (Mallia et al. 2017). FENGSHA is an English analog of the Mandarin term for wind-blown dust. Resource modeling predicts: 1) the area of subaerial shoreline exposed as a function of monthly water surface elevations at Lake Powell and Lake Mead (respectively); 2) potential dust emissions (kg/m^2/hr) as a function of monthly water surface elevations at Lake Powell and Lake Mead modeled using FENGSHA with sustained winds for 15 m/s (~35-miles per hour) for 6 hours. The results are presented as Glen Canyon and Lake Mead exposed shoreline area and associated emission rates (Fischella et al. 2026).

Impacts on shoreline exposure area and fugitive dust emissions are described in the following section using conditional box plots and Decision Making under Deep Uncertainty robustness heat maps and vulnerability bar plots. The conditional box plots have been developed based on the CRSS model outputs and are framed using the 5 flow conditions categories for the preceding 3-year average Lees Ferry natural flow, as described above. In a conditional box plot, the bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Refer to **Chapter 3**, **Section 3.2.6**, for an overview of how to interpret the Decision Making under Deep Uncertainty robustness heat maps and vulnerability bar plots.

The increase or decrease in metric tons of CO_2e emissions due to changes in hydropower generation at Canyon Glen Canyon Dam, Hoover Dam, Parker Dam, and Davis Dam are presented in conditional box plots. In a conditional box plot, the bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

The conditional box plot for each dam compares median CCS Comparative Baseline generation to median generation for each alternative and multiple natural flow groups (e.g., dry, moderately dry, and normal hydrology). In each year of every modeled future, the difference in annual hydropower generation between CCS Comparative Baseline and each alternative was computed to determine the change in generation whether that be an increase or decrease. The annual change in generation was multiplied by the 2025 and 2050 Emissions and Generation Resource Integrated Database (eGrid)/NLR emission factor. **Table TA 7-19** and **Table TA 7-20** shows how the 2025 and 2050 emission factors were calculated. This emission factor represents the potential CO_2e from the from each resource type per megawatt hour and the resource mix percentages for the Western Regional Climate Center (WRCC) energy production. As time passes and more alternative resources enter the grid, energy will be produced by a different mix of resources and therefore the 2050 emission factor in **Table TA 7-20** show the projected mix of resources in 2050 from the U.S. Energy Information Administration (EIA) Annual Energy Outlook 2023. These NLR metric tons of CO_2e per megawatt hour and the eGrid 2023 and EIA 2050 WRCC resource mix percentages were utilized to calculate a weighted average emission factor for 2025 and 2050. The weighted emission factors are multiplied by the changes in megawatt hours for each alternative and flow category.

Table TA 7-19
2025 Emission Factor Information

Units	Coal	Natural Gas	Biomass	Oil	Geothermal	Wind	Concentrating Solar Power	Hydro	Nuclear
NLR CO_2e Emission Factors for Comparison of Electrical System Energy Sources									
metric tons CO_2e/MWh	1.00	0.49	0.05	0.84	0.04	0.01	0.04	0.02	0.01
EGrid 2023 WRCC Resource Percentages									
Percentage of the mix	14.00%	35.50%	1.10%	0.10%	2.20%	10.20%	9.50%	19.80%	7.70%
Weighted 2025 Emission Factor (metric tons CO_2e/MWh)	**0.33**								

Sources: EPA 2025f; EIA 2023; NLR 2021
MWh=megawatt hours

Table TA 7-20
2050 Emission Factor Information

Units	Coal	Natural Gas	Biomass	Oil	Geothermal	Wind	Concentrating Solar Power	Hydro	Nuclear
NLR CO_2 Emission Factors for Comparison of Electrical System Energy Sources									
metric tons CO_2e/MWh	1.00	0.49	0.05	0.84	0.04	0.01	0.04	0.02	0.01
EIA 2050 WRCC Resource Percentages									
Percentage of the mix	4.00%	20.00%	1.50%	2.00%	2.50%	22.00%	35.00%	9.00%	4.00%
Weighted 2050 Emission Factor (metric tons CO_2e/MWh)	**0.18**								

Sources: EPA 2025f; EIA 2023; NLR 2021

Impact Analysis Area

The geographic scope of the air quality resources analysis differs for each issue but includes the Lake Powell to Southerly International Boundary which includes the Arizona counties of Mohave, Coconino, Yavapai, and Navajo, the Utah counties of Washington, San Juan, Kane, and Clark County, Nevada. However, air pollutants tend to disperse into the atmosphere, becoming less concentrated as they travel away from a source of pollution, and therefore cannot be confined within defined boundaries, such as county lines. Specifically, the shoreline exposure analysis area includes Lake Mead and Lake Powell. The changes in CO_2e due to hydropower generation analysis areas includes Glen Canyon Glen Canyon Dam, Hoover Dam, Parker Dam, and Davis Dam. The climate trends analysis area is discussed for the western U.S.

Assumptions

- The hydrologic resources results are direct results from the CRSS model. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation.
- NLR publishes life cycle assessments which quantify environmental burdens from "cradle to grave" and based on several different studies, estimates CO_2e emission factors associated with each type of electricity generation. They are provided in grams of CO_2e per kilowatt-hour (g CO_2e/kWh) (NLR 2021).
- The eGrid was utilized to determine the North American Electric Reliability Corporation resource mix (coal, natural gas, oil, nuclear, hydropower, biomass, wind, solar, and geothermal) for the Western Electricity Coordinating Council region which includes the analysis area (EPA 2025f).
- EIA Annual Energy Outlook 2023 (EIA 2023) provide the potential generation mix for year 2050.
- Equivalency Calculator is used to convert emissions into concrete, understandable terms such as the annual CO_2 emissions of cars, households, and power plants (EPA 2025g).

Impact Indicators

Specific impact indicators were selected to help frame the air quality resources analysis for each of the alternatives. The following indicators were used to assess impacts:

- **Shoreline Exposure**: effects on the areas of shoreline exposure due to operational activities
- **Shoreline Dust Emissions**: effects on shoreline dust emissions due to operational activities
- **Change of CO_2e Emissions Due to a Loss of Hydropower Generation:** effects on CO_2e emissions due to operational activities

TA 7.2.2 Issue 1: How would changing flow characteristics affect the potential exposed shoreline, fallowed agricultural lands and fugitive dust?

Changes in water storage in lakes can affect the area of shoreline sediment exposed subaerially and potentially available for aeolian transport. Lake Mead and Lake Powell are two of the largest reservoirs in the US. Both are formed by impoundment of the Colorado River by hydroelectric dams. Lake Mead was closed by Hoover Dam in 1935. Lake Powell was closed by Glen Canyon Dam in 1963. Both reservoirs reached maximum observed water storage (water surface elevation) in 1983. Since 2020, both reservoirs have reached minimums in water storage not observed since filling. This resource modeling evaluates how potential changes in reservoir water storage might affect potential dust emissions from subaerially exposed reservoir sediment. Relationships between potential dust emissions and water storage could be useful to evaluate air quality and related resource impacts associated with Colorado River water management decisions.

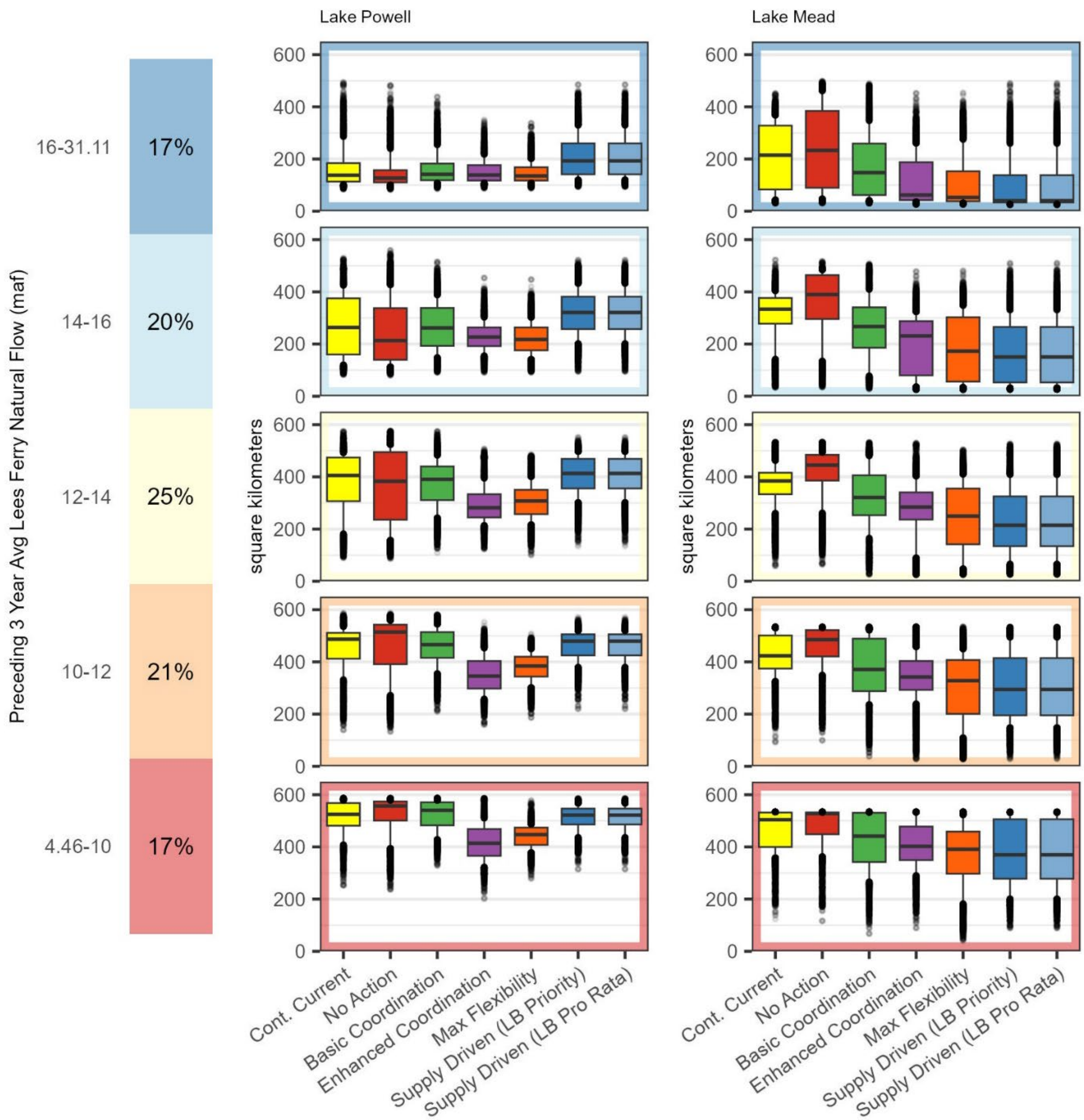
Subaerially exposed shoreline area and potential dust emissions increase as water storage decreases. However, the relationships differ at the two reservoirs due to surficial geology, deposition of reservoir sediment, and topographic and bathymetric terrain; Glen Canyon Dam impounded a deep canyon-bound segment of the Colorado River at Lake Powell, whereas Hoover Dam impounded a comparably broader valley of the river at Lake Mead.

In the Average Flow Category (12–14 maf) for WY minimums, the medians and interquartile ranges for all alternatives for Lake Powell are projected to remain above 200 square kilometers of maximum shoreline exposure. For Lake Mead the medians and interquartile ranges for all alternatives are projected to remain above 125 square kilometers of maximum shoreline exposure. The CCS Comparative Baseline and No Action Alternative do have higher variable results centered around 400 square kilometers of maximum shoreline exposure, while the Supply Driven (both Lower Basin [LB] Priority and LB Pro Rata approaches) and Basic Coordination Alternatives have less variance but are still centered around 400 square kilometers of maximum shoreline exposure. The Maximum Operational Flexibility and Enhanced Coordination Alternatives have lower variable results centered around 300 square kilometers of maximum shoreline exposure. In the Average Flow Category (12–14 maf) for WY minimums, the medians and interquartile ranges for all alternatives for Lake Mead are projected to remain above 125 square kilometers of maximum shoreline exposure. The CCS Comparative Baseline and No Action Alternative have lower variable results but the median for both of these alternatives are higher than all other alternatives. The Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have lower medians than the other alternatives but also have the highest variability. The Basic Coordination and Enhanced Coordination Alternatives are in the middle of the other alternatives and have moderate variability.

As flow categories get drier for Lake Powell WY minimums, the medians for all alternatives are above 400 square kilometers of maximum shoreline exposure and have lower variability. As flow categories get drier for WY minimums, the medians for all Lake Mead alternatives are above 300 square kilometers of maximum shoreline exposure, with higher variability in the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

The Lake Powell maximum shoreline exposure for all alternatives generally perform similarly under wet hydrologic flow conditions. The Lake Mead CCS Comparative Baseline, Basic Coordination, and No Action Alternatives with higher square kilometers of maximum shoreline exposure and higher variability, while the Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Enhanced Coordination Alternatives generally perform similarly with very low shoreline exposure and low variability.

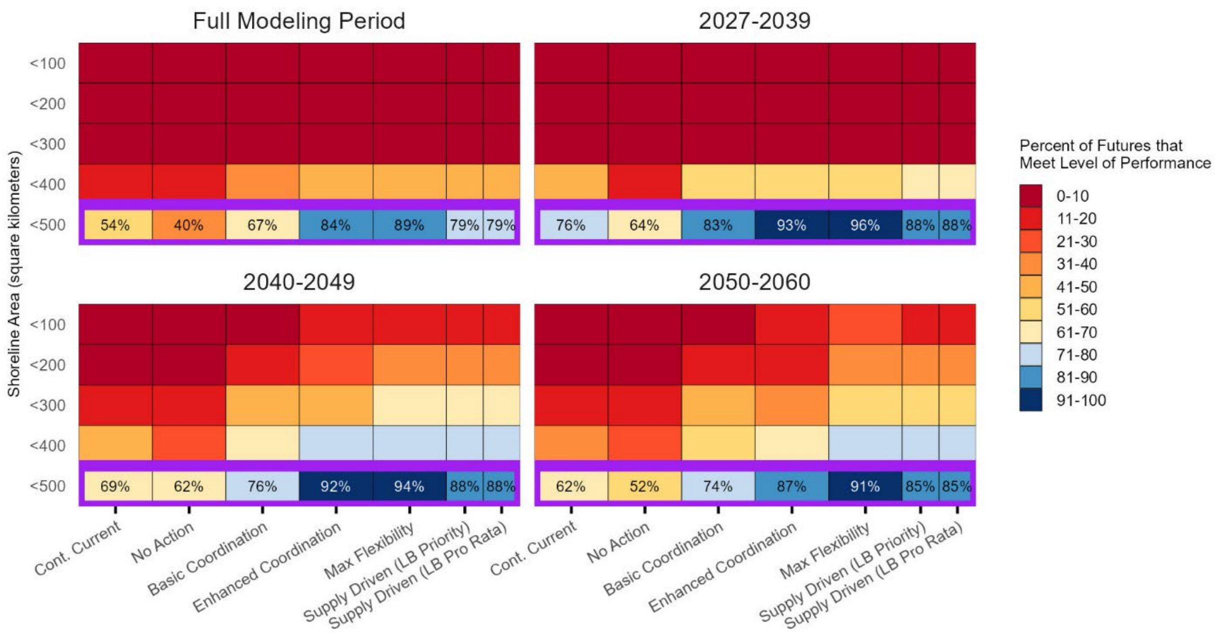
Figure TA 7-2
Water Year Maximum Exposed Shoreline Area for Lake Powell and Lake Mead (square kilometers)



Lake Mead Robustness

Figure TA 7-3 below depicts the performance of each alternative with regard to keeping Lake Mead shoreline exposure area below 500 square kilometers. For Lake Mead, 500 square kilometers is a very rough approximation of the area of shoreline exposed when the reservoir is filled to minimum power pool (950 feet).

Figure TA 7-3
Lake Mead Shoreline Area in Lake Mead National Recreation Area: Robustness. Percent of futures in which the exposed shoreline area is below the value specified in each row in every month



The figure is broken into 4 heat maps, each showing a different time period during the analysis. For example, the top left heat map shows the full modeling period from 2027 through 2060. Rows of the heat map show different frequency ranges (shoreline area) for keeping Lake Mead below this square kilometers; higher rows are associated with lower shoreline exposure. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 100 percent of the months.

The color of a heat map square corresponds with the percent of futures that meet this level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Mead shoreline exposure area below the specified value on the left axis in every month (least robust) to a dark blue color representing greater than 91 percent of futures keeping the Lake Mead shoreline exposure area below the specified value on the left axis in every month (most robust). The higher the percentage, the more likely Lake Mead shoreline exposure will remain below the specified square kilometers under most future hydrologic scenarios. Keeping the Lake Mead shoreline exposure below 500 square kilometers ensures that fugitive dust will be minimized.

The Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 square kilometers of shoreline exposure in 90 percent of months over the full modeling period (shown in the top row), doing so in 89 percent and 84 percent of the futures, respectively. Over the full modeling period, the Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives perform slightly better than the CCS Comparative Baseline succeeding in 67 percent and 79 percent of futures, respectively. This is slightly more robust than the CCS Comparative Baseline Alternative, which stays below 500 square kilometers of shoreline exposure in 54 percent of months over the full modeling period (shown in the top row). The No Action Alternative has the worst performance at 40 percent success rate over the full analysis period.

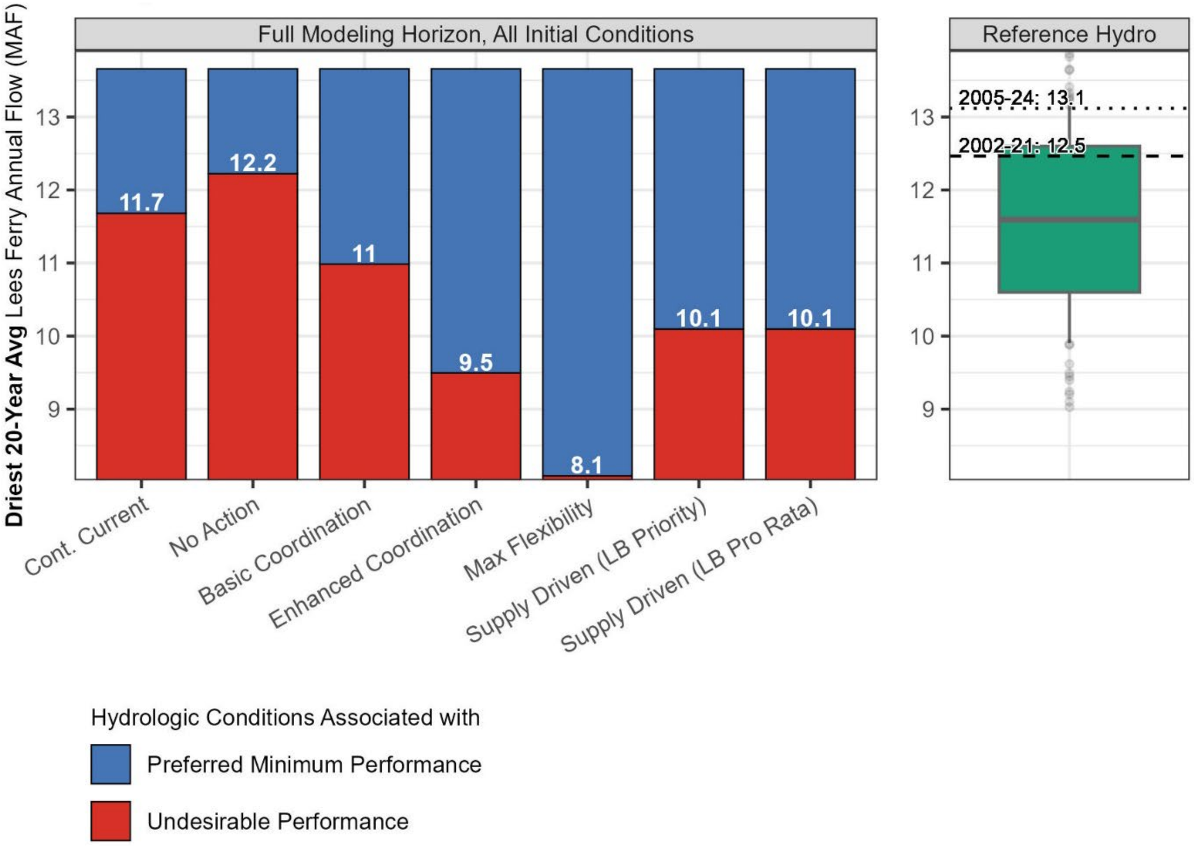
The 2040-2049 modeling period has the most futures performing over 61 percent. For example, the Maximum Operational Flexibility and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives stay below 300 square kilometers of shoreline exposure, doing so in 61-70 percent of the futures.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently achieve 81-100 percent robustness (two darkest blues), while the No Action Alternative only reach a maximum of 64 percent robustness at even the lowest levels of performance for the 500 square kilometers of shoreline exposure category.

Figure TA 7-4 below looks at flow conditions that could cause the Lake Mead shoreline exposure area to be above 500 square kilometers in one or more months. This definition of undesirable performance (shown in the figure as the red region of the bar plot) is based on the highlighted row in the above **Figure TA 7-4**, which qualifies a future as successful in meeting the preferred minimum performance when an alternative kept Lake Mead below this critical buffer shoreline exposure area of 500 square kilometers 100 percent of the time.

For this vulnerability analysis, the driest 20-year average of Lees Ferry annual flow during the full modeling period was used as the reference hydrology, and is shown in the box plot to the right of the vulnerability bar plot. The reference hydrology shows the distribution of driest 20-year averages included in the reference ensemble, with the median 20-year average Lees Ferry flow being around 11.6 maf. Also included in the reference hydrology box plot are the driest observed 20-year average flow from 2002–2021 (12.5 maf) and the most recent observed 20-year average from 2005–2024 (13.1 maf) as dashed lines, for comparison.

Figure TA 7-4
Lake Mead Shoreline Area in Lake Mead National Recreation Area: Vulnerability. Conditions that Could Cause Lake Mead Exposed Shoreline Area Above 500 Square Kilometers in One or More Months

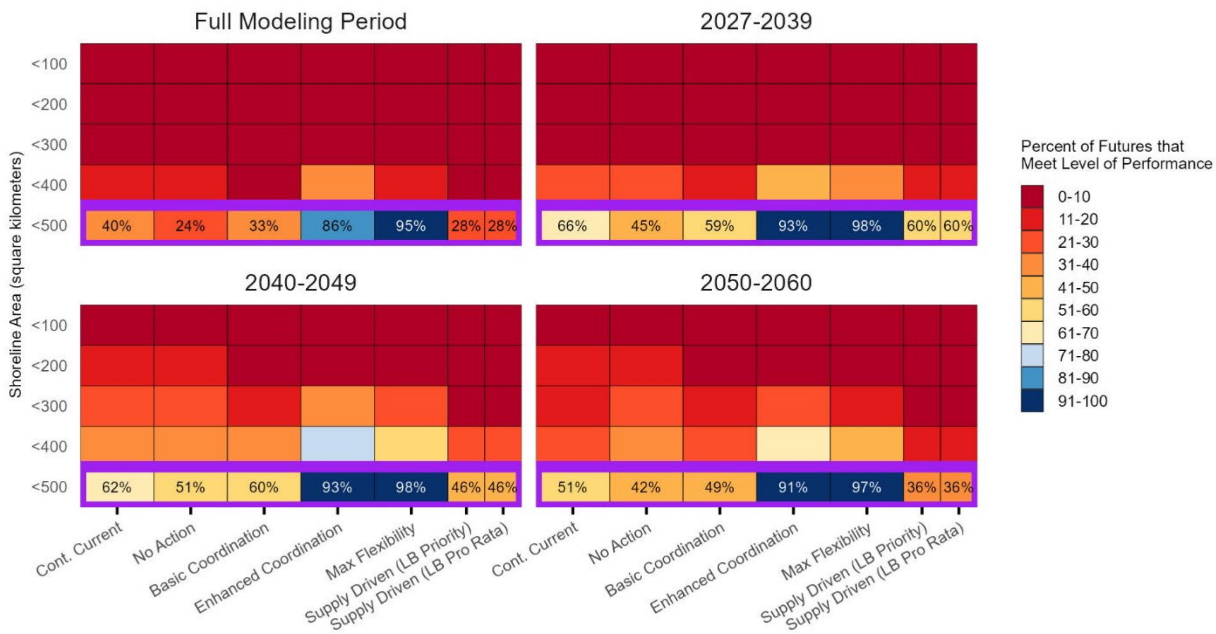


The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions: 20-year droughts of 9.5 maf, 8.1 maf, and 10.1 maf, respectively. These conditions are near the 10th percentile of the reference hydrology ensemble, so only about 10 percent of the traces include droughts this dry or drier. The Basic Coordination Alternative is vulnerable to 20-year droughts with an average flow of 11.0 maf, which is slightly above the 25th percentile of the reference hydrology ensemble. The CCS Continued Baseline Alternative is more vulnerable, with a 20-year drought of 11.7 maf likely to cause undesirable performance. The No Action Alternative is the most vulnerable; Lake Mead is likely to go below 1,000 feet elevation in a 20-year drought averaging 12.2 maf. From 2002 to 2021, the 20-year average was 12.4 maf, so the No Action Alternative is just below the vulnerability of conditions that have already occurred.

Lake Powell Robustness

Figure TA 7-5 below depicts the performance of each alternative with regard to keeping Lake Powell shoreline exposure area below 500 square kilometers. For Lake Powell, 500 square kilometers is a very rough approximation of the area of shoreline exposed when the reservoir is filled to minimum power pool (3,490 feet).

Figure TA 7-5
Lake Powell Shoreline Area in Glen Canyon National Recreation Area: Robustness. Percent of futures in which the exposed shoreline area is below the value specified in each row in every month



The figure is broken into 4 heat maps, each showing a different time period during the analysis. For example, the top left heat map shows the full modeling period from 2027 through 2060. Rows of the heat map show different frequency ranges (shoreline area) for keeping Lake Powell below this square kilometers; higher rows are associated with lower shoreline exposure. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 100 percent of the months.

The color of a heat map square corresponds with the percent of futures that meet this level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Powell shoreline exposure area below the specified value on the left axis in every month (least robust) to a dark blue color representing greater than 91 percent of futures keeping the Lake Powell shoreline exposure area below the specified value on the left axis in every month (most robust). The higher the percentage, the more likely Lake Powell shoreline exposure will remain below the specified square kilometers under most future hydrologic scenarios. Keeping the Lake Powell shoreline exposure below 500 square kilometers ensures that fugitive dust will be minimized.

The Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying below 500 square kilometers of shoreline exposure in 85 percent of months over the full modeling period (shown in the bottom row), doing so in 95 percent and 86 percent of the futures, respectively. The Basic Coordination and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives perform similarly to the CCS Comparative Baseline, if not slightly worse, succeeding in 33 percent and 28 percent of futures, respectively, over the full analysis period. The No Action Alternative has the worst performance at a 24 percent success rate over the full analysis period.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently achieve 86-100 percent robustness (two darkest blues), while the No Action Alternative only reaching a maximum of 51 percent robustness at even the lowest levels of performance for the 500 square kilometers of shoreline exposure category.

Figure TA 7-6 below looks at flow conditions that could cause the Lake Powell shoreline exposure area to be above 500 square kilometers in one or more months. This definition of undesirable performance (shown in the figure as the red region of the bar plot) is based on the highlighted row in **Figure TA 7-5**, which qualifies a future as successful in meeting the preferred minimum performance when an alternative kept Lake Powell below this critical buffer shoreline exposure area of 500 square kilometers 100 percent of the time.

For this vulnerability analysis, the driest 20-year average of Lees Ferry annual flow during the full modeling period was used as the reference hydrology and is shown in the box plot to the right of the vulnerability bar plot. This drought reference hydrology shows the distribution of driest 20-year averages in the reference ensemble with a median 20-year average Lees Ferry flow of around 11.6 maf. Also included on the reference hydrology box plot are the averages for 2005–2024 (13.1 maf) and 2002–2021 (12.5 maf) as dashed lines, for comparison.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to similar conditions: 20-year droughts of 9.2 maf and 8.0 maf, respectively. These conditions are below the 10th percentile of the reference hydrology ensemble, so less than 10 percent of the traces include droughts this dry or drier. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have 20-year droughts of 12.3, 12.9, 12.7 and 12.7, respectively which are all near or above the 2002–2021 average (12.5 maf). Therefore, these alternatives are all more vulnerable and likely to cause undesirable performance.

Figure TA 7-6
Lake Powell Shoreline Area in Glen Canyon National Recreation Area: Vulnerability. Conditions that Could Cause Lake Powell Exposed Shoreline Area Above 500 Square Kilometers in One or More Months

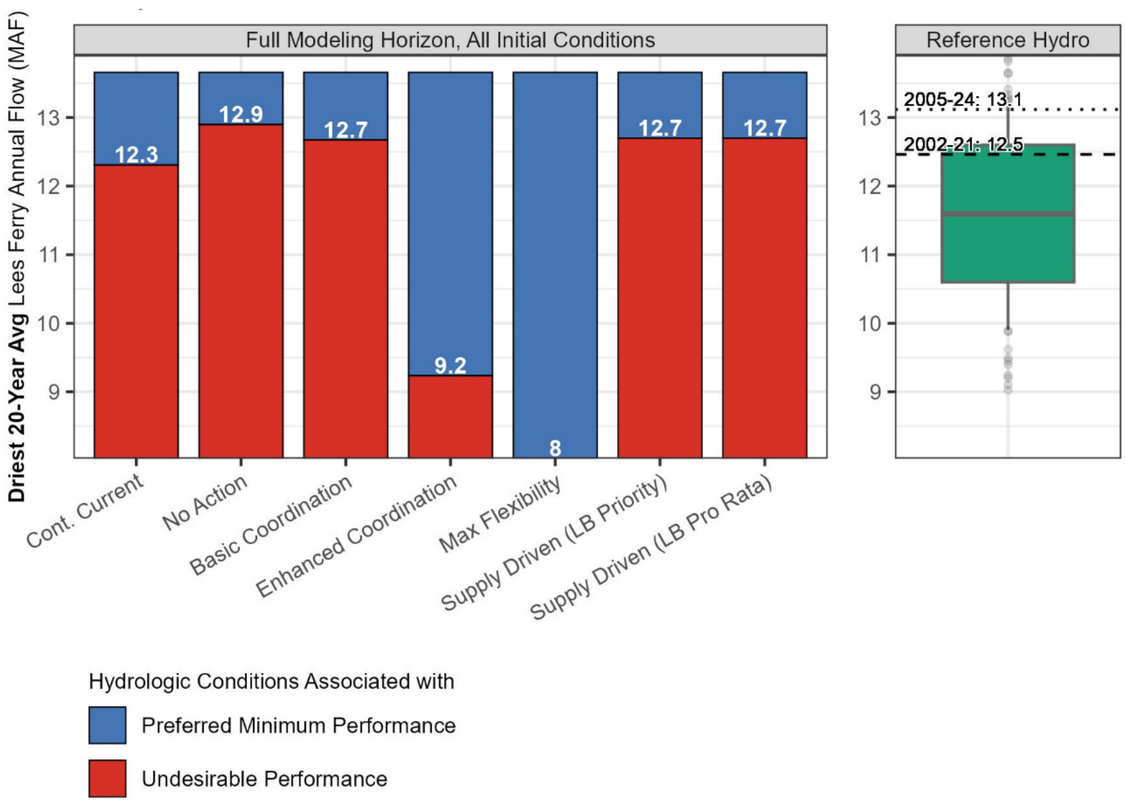
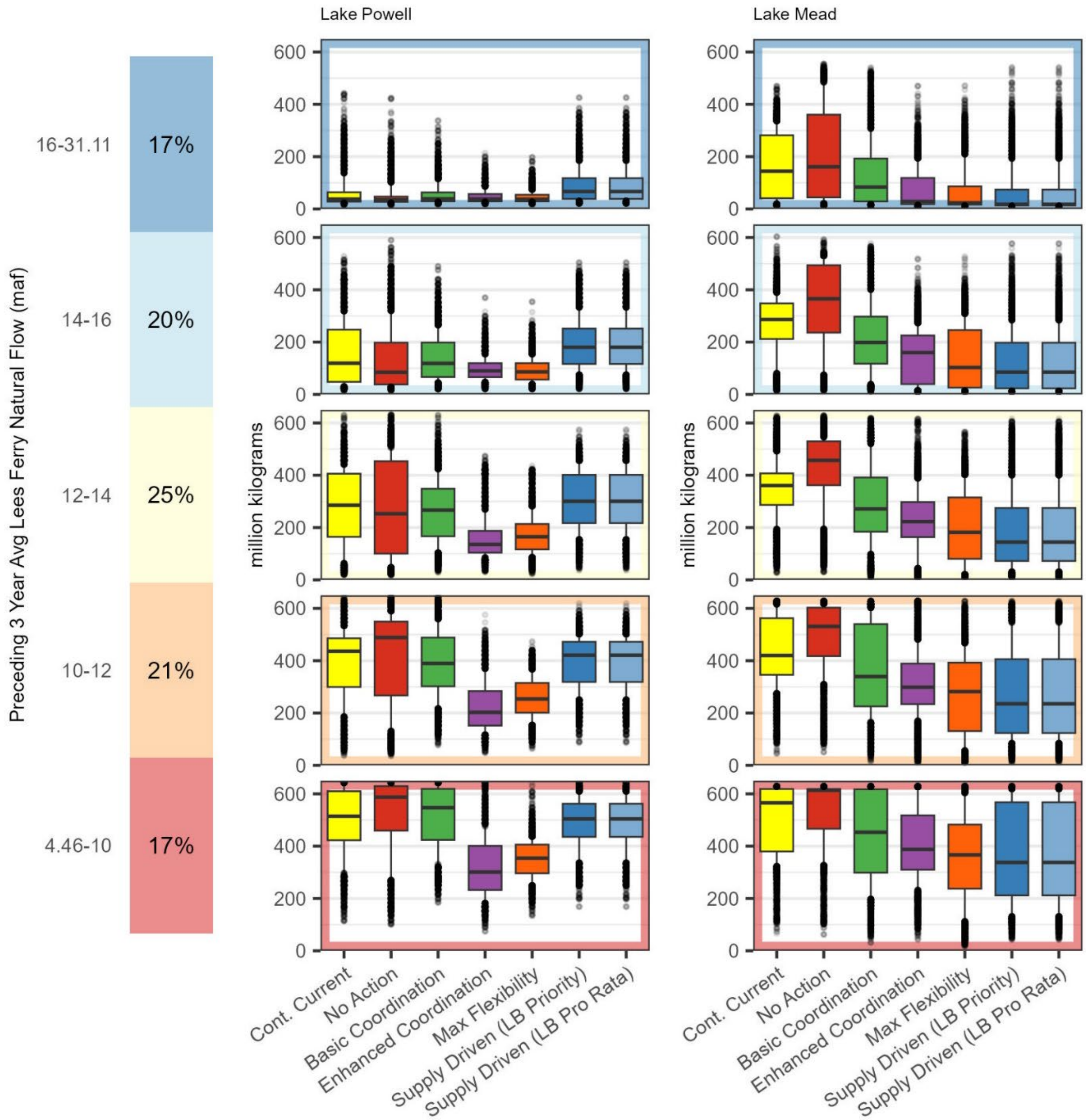


Figure TA 7-7
Water Year Maximum Monthly Shoreline Dust Emissions for Lake Powell and Lake Mead (million kilograms)



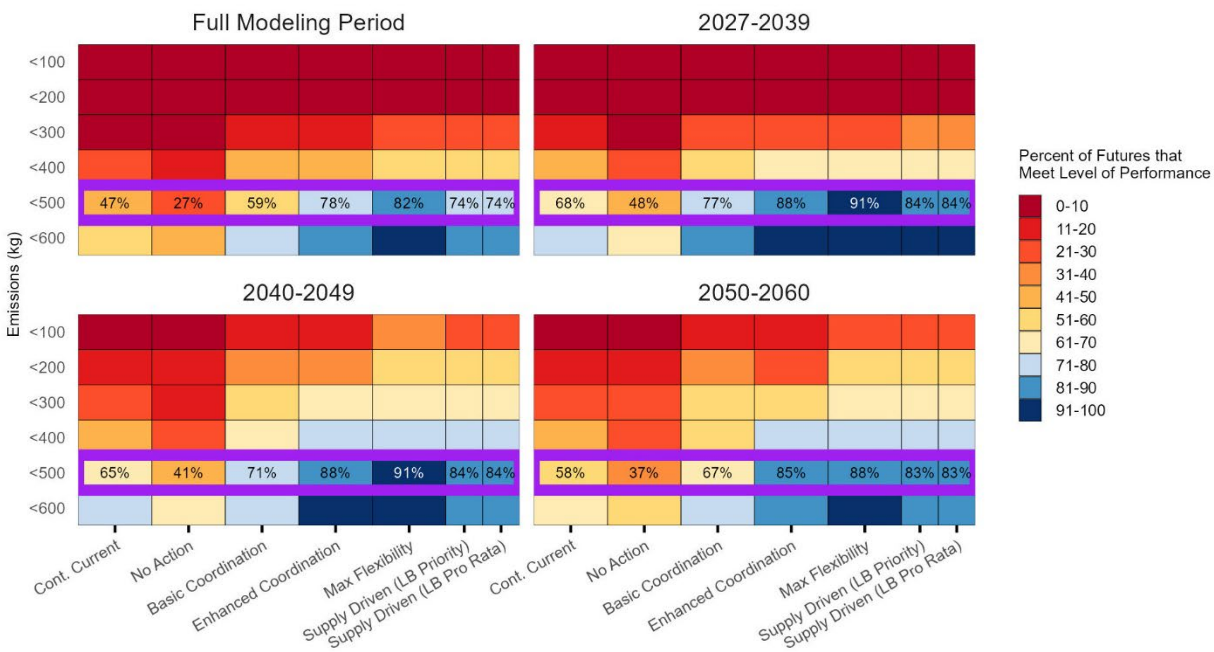
In the Average Flow Category (12–14 maf) for WY minimums, the medians and interquartile ranges for all alternatives for Lake Powell are projected to remain above 100 million kilograms of $PM_{2.5}$ as a result of shoreline exposure. For Lake Mead the medians and interquartile ranges for all alternatives are projected to remain above 70 million kilograms of $PM_{2.5}$ as a result of shoreline exposure. The Lake Powell CCS Comparative Baseline and the Supply Driven (both LB Priority and LB Pro Rata approaches), Basic Coordination, and No Action Alternatives all have similar medians and higher variabilities. The Enhance Coordination and Maximum Operational Flexibility Alternatives have lower medians and small variabilities. Therefore, these two alternatives would result in less $PM_{2.5}$ than the other four alternatives.

The Lake Mead No Action Alternative has the highest median and 75th percentile and therefore is the alternative with the largest amount of $PM_{2.5}$ as a result of shoreline exposure. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Maximum Operational Flexibility Alternatives have the lowest medians and higher variability. As flow categories get drier for WY minimums, the medians for all Lake Powell and Lake Mead alternatives are increase the million kilograms of $PM_{2.5}$. As flow categories get more wet for WY minimums the potential $PM_{2.5}$ decreases.

Lake Mead Robustness

Figure TA 7-8 below depicts the performance of each alternative with regard to keeping Lake Mead $PM_{2.5}$ from shoreline exposure area below 600 million kilograms.

Figure TA 7-8
Lake Mead Shoreline Dust (PM 2.5) Emissions in Lake Mead National Recreation Area: Robustness.
Percent of futures in which emissions are less than the value specified in each row in every month



The figure is broken into 4 heat maps, each showing a different time period during the analysis. For example, the top left heat map shows the full modeling period from 2027 through 2060. Rows of the heat map show different frequency ranges ($PM_{2.5}$ emissions) for keeping Lake Mead below these million kilograms; higher rows show less $PM_{2.5}$ emissions. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 100 percent of the months.

The color of a heat map square corresponds with the percent of futures that meet this level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Mead emissions below 100 million kilograms (least robust) to a dark blue color representing greater than 91 percent of futures keeping the Lake Mead emissions above 500 million kilograms (most robust). The higher the percentage, the more likely Lake Mead will remain above the minimum power pool (950 feet) under most future hydrologic scenarios. Keeping the Lake Mead emissions below 500 million kilograms ensures that fugitive dust would be minimized protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power.

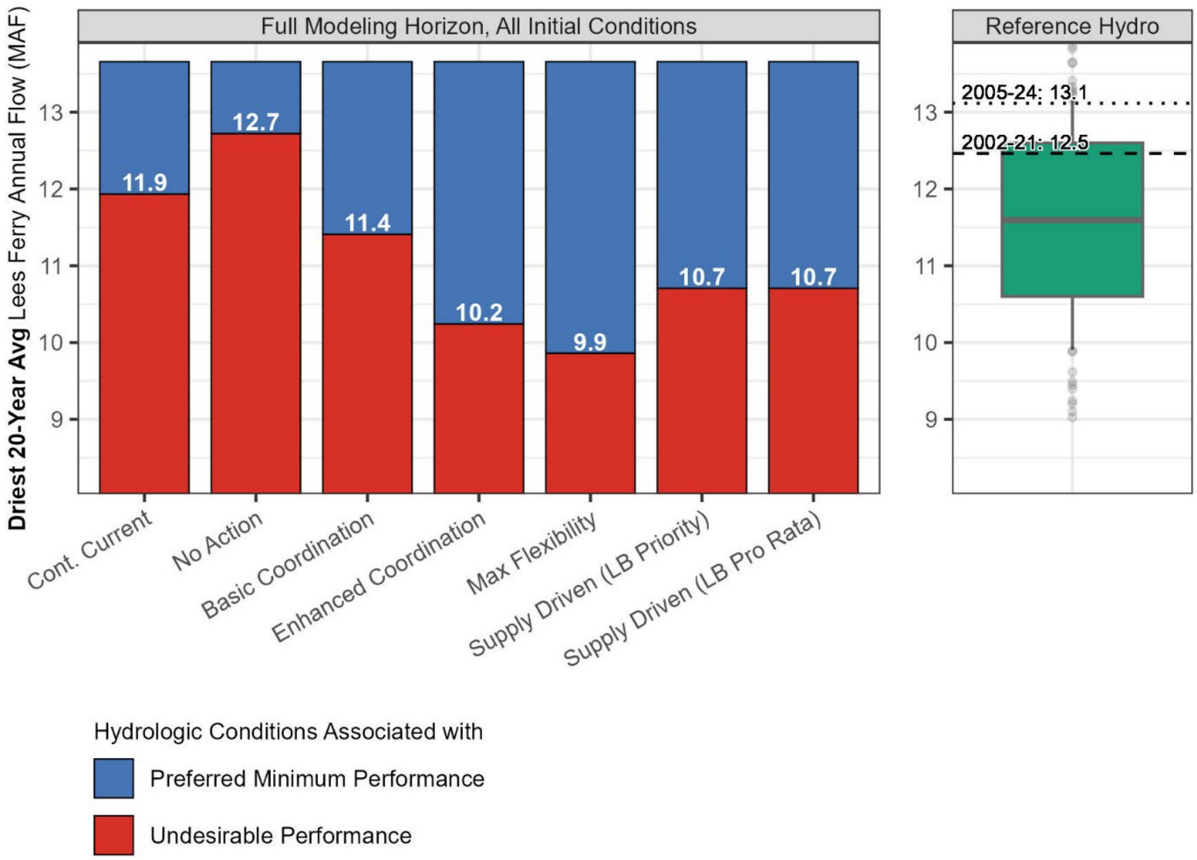
The Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Enhanced Coordination Alternatives are the most robust at staying below 500 million kilograms in 80 percent of months over the full modeling period, doing so in 82 percent and 78 percent of the futures, respectively. The Basic Coordination Alternative performs similarly to the CCS Comparative Baseline, if not slightly better, succeeding in 59 percent of futures over the full analysis period. The No Action Alternative has the worst performance at a 27 percent success rate over the full analysis period.

The Enhanced Coordination, Supply Driven (both LB Priority and LB Pro Rata approaches), and Maximum Operational Flexibility Alternatives consistently achieve 71-100 percent robustness (three darkest blues in color), while the other alternatives only reach a maximum of 77 percent robustness at even the lowest levels of performance (e.g., greater than or equal to 60 percent of months).

Figure TA 7-9 below looks at flow conditions that could cause the Lake Mead emissions above 500 million kilograms during at least one or more months. This definition of undesirable performance (shown in the figure as the red region of the bar plot) is based on the highlighted row in the above **Figure TA 7-8**, which qualifies a future as successful in meeting the preferred minimum performance when an alternative kept Lake Mead below 500 million kilograms 100 percent of the time.

For this vulnerability analysis, the driest 20-year average of Lees Ferry annual flow during the full modeling period was used as the reference hydrology, and is shown in the box plot to the right of the vulnerability bar plot. The reference hydrology shows the distribution of driest 20-year averages included in the reference ensemble, with the median 20-year average Lees Ferry flow being around 11.6 maf. Also included in the reference hydrology box plot are the driest observed 20-year average flow from 2002-2021 (12.5 maf) and the most recent observed 20-year average from 2005-2024 (13.1 maf) as dashed lines, for comparison.

Figure TA 7-9
Lake Mead Shoreline Dust (PM 2.5) Emissions in Lake Mead National Recreation Area: Vulnerability.
Conditions that Could Cause Lake Mead Emissions Above 500 million kg in One or More Months

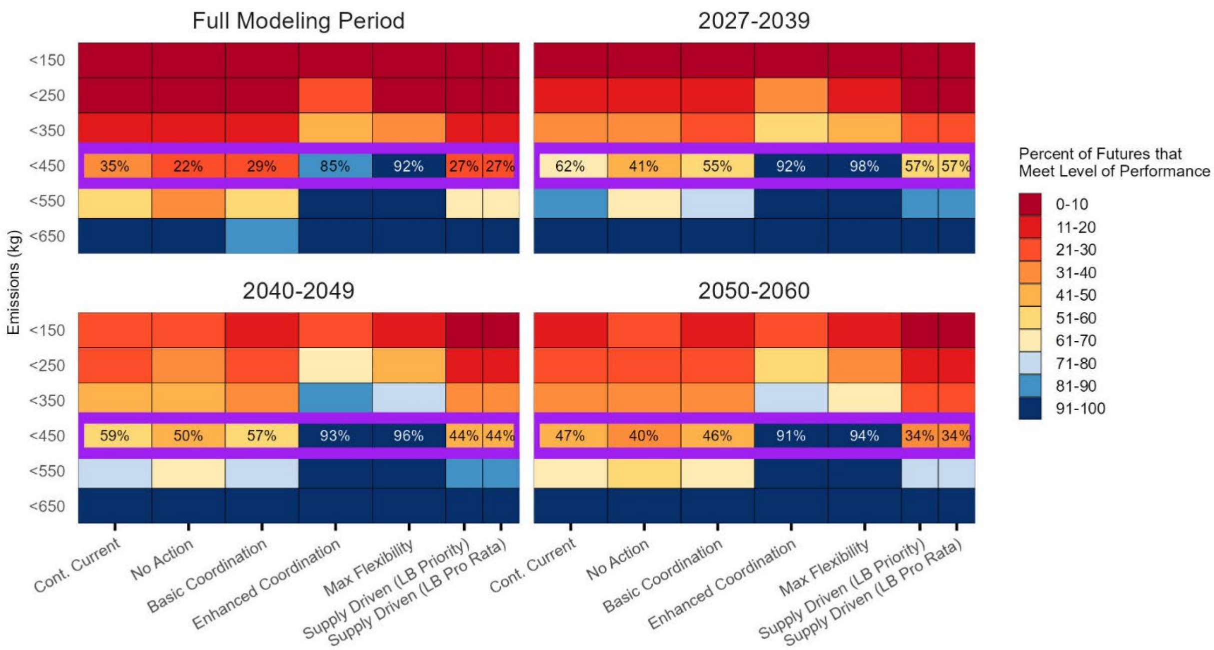


The Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions: 20-year droughts of 10.2 maf, 9.9 maf, and 10.7 maf, respectively. These conditions are near the 10th percentile of the reference hydrology ensemble, so only about 10 percent of the traces include droughts this dry or drier. The Basic Coordination Alternative is vulnerable to 20-year droughts with an average flow of 11.4 maf, which is slightly above the 25th percentile of the reference hydrology ensemble. The CCS Continued Baseline Alternative is more vulnerable, with a 20-year drought of 11.9 maf likely to cause undesirable performance. The No Action Alternative is the most vulnerable; Lake Mead is likely to go below 1,000 feet elevation in a 20-year drought averaging 12.7 maf. From 2002 to 2021, the 20-year average was 12.4 maf, so the No Action Alternative is just above the vulnerability of conditions that have already occurred.

Lake Powell Robustness

Figure TA 7-10 below depicts the performance of each alternative with regard to keeping Lake Powell $PM_{2.5}$ from shoreline exposure area below 650 million kilograms.

Figure TA 7-10
Lake Powell Shoreline Dust (PM 2.5) Emissions in Glen Canyon National Recreation Area: Robustness.
Percent of futures in which emissions are less than the value specified in each row in every month



The figure is broken into 4 heat maps, each showing a different time period during the analysis. For example, the top left heat map shows the full modeling period from 2027 through 2060. Rows of the heat map show different frequency ranges ($PM_{2.5}$ emissions) for keeping Lake Powell below these million kilograms; higher rows show less $PM_{2.5}$ emissions. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 100 percent of the months.

The color of a heat map square corresponds with the percent of futures that meet this level of performance, which increases from a red color representing less than 10 percent of futures keeping the Lake Powell emissions below 150 million kilograms (least robust) to a dark blue color representing greater than 91 percent of futures keeping the Lake Powell emissions above 450 million kilograms (most robust). Keeping the Lake Powell emissions below 450 million kilograms ensures that fugitive dust would be minimized protecting air quality in the area and represents the reasonable approximation of the emission value that would occur when the lake is full enough with water to operate the dam to generate power.

The Maximum Operational Flexibility and Enhanced Coordination Alternatives are the most robust at staying above elevation 3,500 feet in 100 percent of months over the full modeling period (shown in the top row), doing so in 87 percent and 82 percent of the futures, respectively. The Basic Coordination, Supply Driven (LB Priority approach), and Supply Driven (LB Pro Rata approach) Alternatives perform similarly to the CCS Comparative Baseline, if not slightly worse, succeeding in 25 percent, 24 percent, and 24 percent of futures, respectively, over the full analysis period. The No Action Alternative has the worst performance at a 20 percent success rate over the full analysis period.

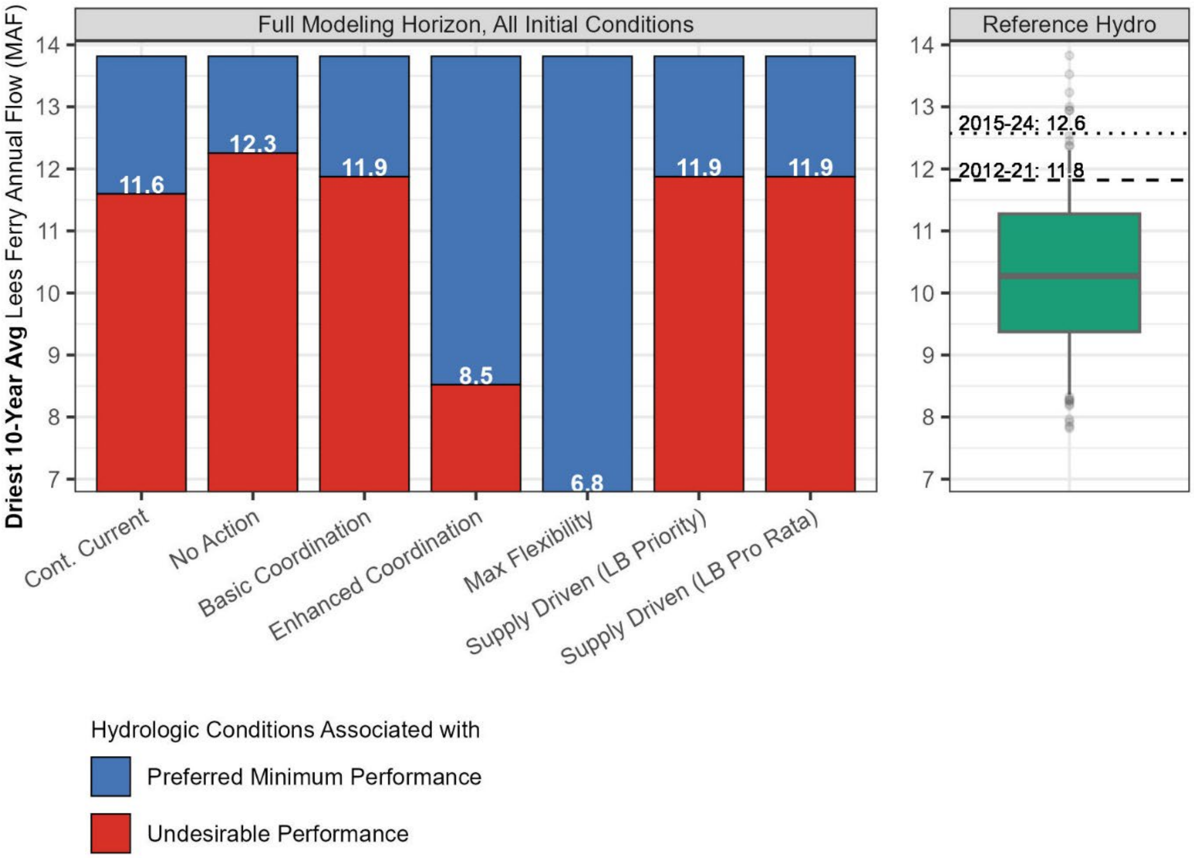
The Enhanced Coordination and Maximum Operational Flexibility Alternatives consistently achieve 91-100 percent robustness (dark blue in color), while the other alternatives only reach a maximum of 80 percent robustness at even the lowest levels of performance (e.g., greater than or equal to 60 percent of months).

Figure TA 7-11 below shows the streamflow conditions associated with Lake Powell shoreline dust ($PM_{2.5}$) emissions exceeding 450 million kilograms in one or more months. This definition of undesirable performance (shown in the figure as the red region of the bar plot) is based on the highlighted row in the above **Figure TA 7-10**, which qualifies a future as successful in meeting the preferred minimum performance when an alternative maintained shoreline dust emissions below 450 million kilograms in every month.

For this vulnerability analysis, the driest 10-year average of Lees Ferry annual flow during the full modeling period was used as the reference hydrology and is shown in the box plot to the right of the vulnerability bar plot. This drought reference hydrology shows the distribution of driest 10-year averages in the reference ensemble with a median 10-year average Lees Ferry flow of around 10.3 maf. Also included on the reference hydrology box plot are the averages for 2012–2021 (11.8 maf) and 2015–2024 (12.6 maf) as dashed lines, for comparison.

The Enhanced Coordination and Maximum Operational Flexibility Alternatives are only vulnerable to very dry conditions: 10-year droughts of 8.5 maf and 6.8 maf, respectively. These conditions are near or below the 10th percentile of the reference hydrology ensemble, so only about 10 percent of the traces include droughts this dry or drier. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives have 10-year droughts of 11.6, 12.3, 11.9 and 11.9, respectively which are all above the reference hydrology box plot averages for 2012–2021 (11.8 maf) and 2015–2024 (12.6 maf). Therefore, these alternatives are all more vulnerable and likely to cause undesirable performance.

Figure TA 7-11
Lake Powell Shoreline Dust (PM 2.5) Emissions in Glen Canyon National Recreation Area: Vulnerability.
Conditions that Could Cause Lake Powell Emissions Above 450 million kg in One or More Months



When reservoir elevations are low and there is more dust mobilization and potential acceleration of runoff, and snow in locations like the Rockies could be subject to dust on snow effects. Dust darkens the snow surface, reducing its albedo (reflectivity). Clean snow reflects up to 90 percent of sunlight, but when dust is present, more sunlight is absorbed instead of reflected. As a result, snow melts faster, even if temperatures remain low. This effect is especially pronounced in spring, when the sun is stronger. This has the potential to alter water timing in the watersheds. Because snow melts earlier and faster due to dust, the rivers and streams may experience earlier peak flows. This can lead to less water availability in summer when it is most needed (e.g., for agriculture, ecosystems, and human consumption).

Changing flow characteristics can affect the fallowing of agricultural lands, especially in regions that rely on consistent irrigation from reservoirs. If the changing flows result in reduced dam releases, there could be less irrigation water available to downstream farmers. Reduced dam releases could also result in forced fallowing which occurs when water is insufficient and farmers fallow (intentionally leave idle) some or all of their fields to conserve water for high-value crops and avoid costs associated with planting and irrigation they cannot support.

Clark County, Nevada is the only county in the analysis area that has been designated as serious nonattainment for the 2015 eight-hour O_3 standard and a maintenance area for CO and PM_{10} (EPA 2025b). In addition, the design value for O_3 for Clark County exceeds the NAAQS for O_3 (0.70 ppm) and the Clark County number of exceedances of the PM_{10} NAAQS exceeds the standard (EPA 2024b). Therefore, shoreline exposure which has the potential to increase particulate matter could further exacerbate the current PM_{10} issue in Clark County.

TA 7.2.3 Issue 2: How would lake reservoir elevations and releases impact power generation and CO_2e emissions?

Issue 2 addresses how operational activities for the various alternatives affect reservoir elevations and therefore impact hydropower generation. When there is a reduction of hydropower, there would be a potential increase of CO_2e emissions due to more emissive alternative energy generation compensating for this reduction (Argonne et al. 2024). There will be a comparison of the four action alternatives and the No Action Alternative to the CCS Comparative Baseline. Power generation is dependent on the same factors as power capacity but generation reflects the amount of power created over a certain period. The power generation is more dependent on plant operations through scheduled releases as these releases, along with other natural factors like rainfall and water availability, determine how much water flows through the turbines over a given amount of time. These models simulate releases and lake reservoir elevations to calculate an estimated generation.

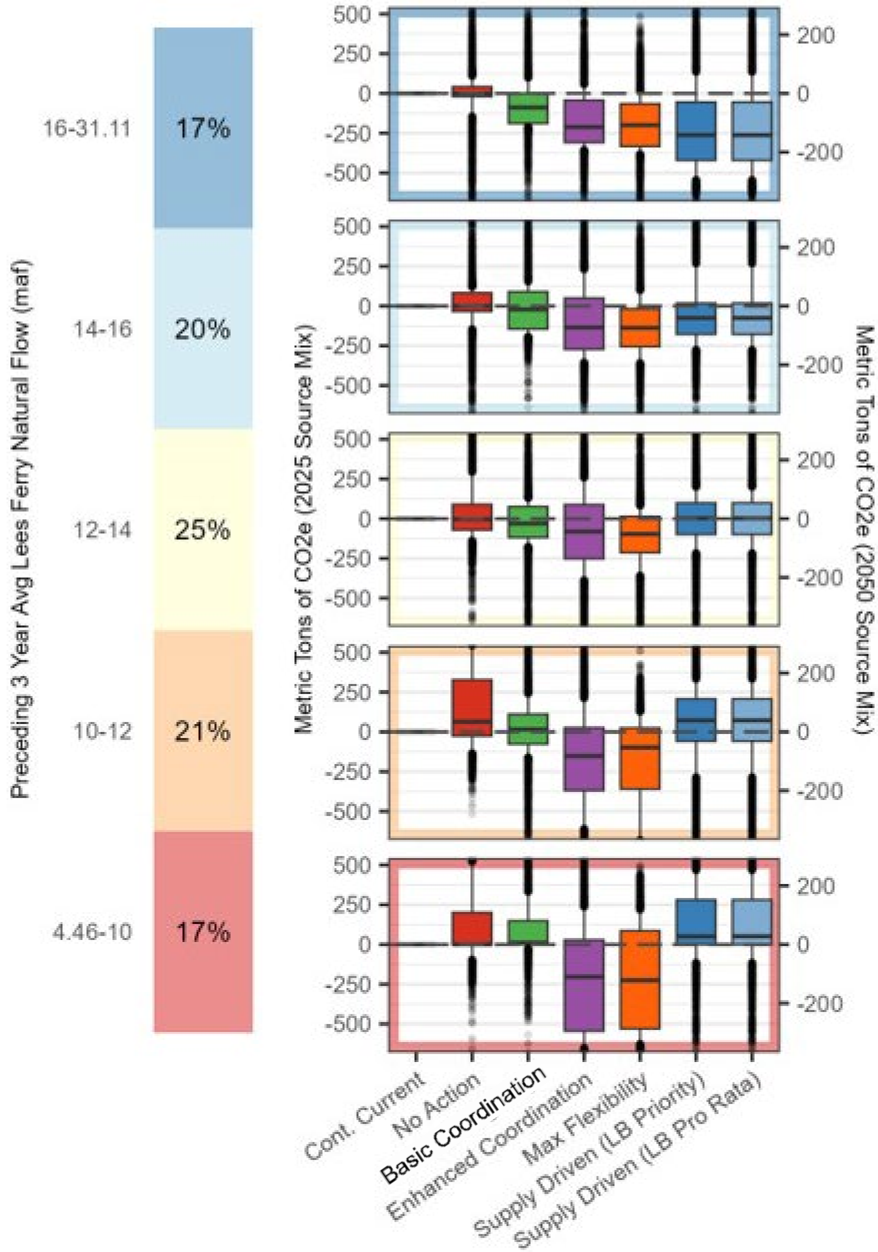
Energy capacity is the maximum possible electric output at a given time. Installed hydropower plant capacity is dependent on generator capacity and turbine efficiency, but the actual capacity is also dependent on the flow rate of water moving through the system. Therefore, the reservoir storage and lake elevation impact capacity for hydropower. Capacity for hydropower is dependent on the time of year as well as water availability differs between the summer and winter months. Lake elevation impacts the head, and a larger head leads to greater potential energy. The maximum capacity of hydropower will be the most instantaneous power generated in a second with the highest water flow possible through the turbines of a hydropower plant. The critical elevations for Lake Mead and Lake Powell are presented in tables in **TA 15**, Dams and Electrical Power Resources. At Lake Powell the minimum power pool is 3,490 feet and when water elevations go below this, Glen Canyon Dam is no longer able to produce hydropower. At Lake Mead the minimum power pool is 950 feet and when water elevations go below this, Hoover Dam is no longer able to produce hydropower. This is typically measured in megawatts. This section will consider how the different alternatives impact the generation capacities of the hydropower plants at the Glen Canyon, Hoover, Davis, and Parker Dams.

The box plots below report metric tons of CO_2e based on the 2025 resource mix emission factor on the left axis and the 2050 resource mix emission factor on the right axis, utilizing the megawatt hour increase or decrease for each alternative and flow category. Only the 2025 resource mix is discussed in detail, as the 2050 resource mix results would have lower metric tons of CO_2e as the emission factor includes more alternative energy resources.

For **Figure TA 7-12**, in the Average Flow Category (12–14 maf), the alternatives are projected to result in a range of behavior, in terms of medians and variability of metric tons of CO_2e. The Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) Alternatives have the highest medians of 2.3 metric tons of CO_2e and similar variability. The positive CO_2e value indicates an increase in CO_2e compared to the CCS Comparative Baseline. The No Action Alternative also has a median close to zero (which is the CCS Comparative Baseline), with a median resulting in a 3.5 metric ton decrease in CO_2e and a smaller interquartile range indicating less variability. The Enhanced Coordination and Maximum Operational Flexibility Alternatives have similar medians, which both result in a decrease in CO_2e, with the Maximum Operational Flexibility Alternative having similar variability to the other Alternatives and the Enhanced Coordination Alternative having the highest variability of all the Alternatives. The Enhanced Coordination Alternative variability ranges from a 251.8 metric ton decrease in CO_2e at the 25th percentile to an 88.2 metric ton increase in CO_2e. The Basic Coordination Alternative has a median of 30.2 metric tons of CO_2e and a similar level of variability Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) Alternatives.

For **Figure TA 7-12**, in the Critically Dry Flow Category (4.46–10 maf), all of the alternatives except the Enhanced Coordination and Maximum Operational Flexibility Alternatives, are projected to result in similar behavior, in terms of medians and variability since they were all above zero metric tons of CO_2e, indicating a potential increase of CO_2e compared to the CCS Comparative Baseline. The Enhanced Coordination and Maximum Operational Flexibility Alternatives both have medians far below the CCS Comparative Baseline and both would potentially result in a 200 metric ton decrease or more in CO_2e. The variability for both these alternatives is similar and have a larger interquartile range indicating more variability, ranging from 86 metric ton increase to a 545 metric ton decrease in CO_2e. The interquartile ranges for the Supply Driven (LB Priority approach), Supply Driven (LB Pro Rata approach), Enhanced Coordination, and Maximum Operational Flexibility are all wider in this flow category, indicating more variability than in the Average Flow Category, while the variability in the Basic Coordination and No Action Alternatives is similar to the range in the Average Flow Category. The No Action Alternative is the most reliable as it stays equal to or above the CCS Comparative Baseline under each flow category, and therefore performs consistently the worst. The Average Flow Category (12–14 maf) 75th percentile variance results in no more than a 100 metric ton increase in CO_2e (Supply Driven [LB Pro Rata approach] and Supply Driven [LB Priority approach] Alternative) which is equivalent to 23.3 gasoline powered passenger vehicles driven for one year or 20.8 homes' electricity for one year. The Critically Dry Flow Category (4.46–10 maf) 75th percentile variance results in no more than a 281 metric ton increase in CO_2e (Supply Driven [LB Pro Rata approach] and Supply Driven [LB Priority approach] Alternative) which is equivalent to 65.5 gasoline powered passenger vehicles driven for one year or 58.6 homes' electricity for one year.

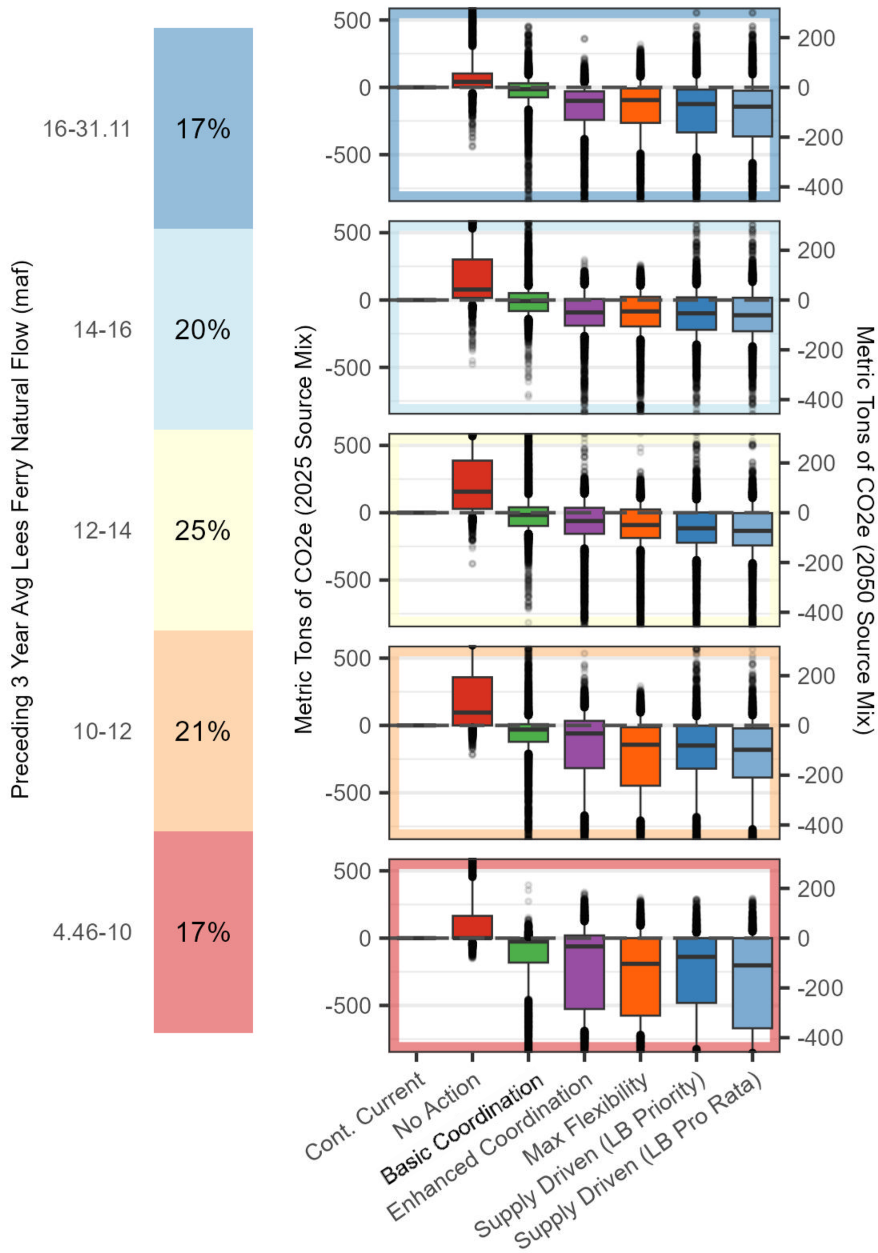
Figure TA 7-12
Change of CO2e Emissions Due to a Loss of Hydropower Generation at Glen Canyon



For **Figure TA 7-13**, in the Average Flow Category (12–14 maf), the alternatives are projected to result in a range of behavior, in terms of medians and variability. The No Action Alternative has the highest median with a 156.8 metric ton increase in CO_2e, and the largest variability, with the 25th percentile at 28.9 metric tons and the 75th percentile at 387.4 metric tons of CO_2e. All other alternatives have medians below zero (which is the CCS Comparative Baseline) and therefore result in a decrease in CO_2e. The Basic Coordination Alternative has the lowest variability for all alternatives, with the 25th percentile resulting in a 98.0 metric tons decrease and the 75th percentile resulting in a 40.6 metric tons increase in CO_2e. The Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) Alternatives have increasing variabilities. The Supply Drive Alternative (LB Pro Rata approach) median and the 25th and 75th percentile variability results in a decrease in CO_2e, with the 25th percentile at 2.9 metric tons and the 75th percentile at 242.8 metric ton of CO_2e.

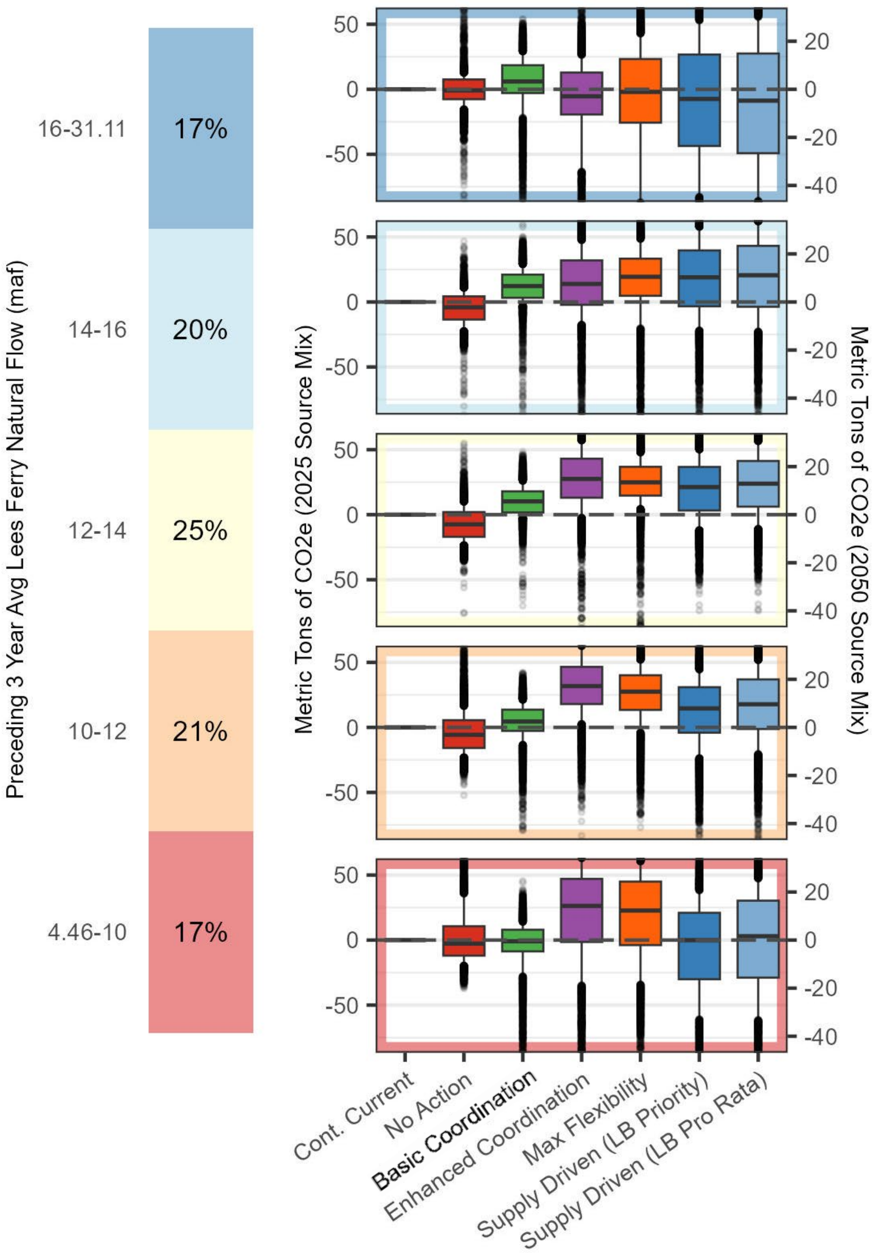
For **Figure TA 7-13**, in the Critically Dry Flow Category (4.46–10 maf), the alternatives are also projected to result in a range of behavior, in terms of medians and variability. The No Action Alternative median is zero (which is equal to the CCS Comparative Baseline) and it is the only Alternative with the 25th to 75th percentile variability resulting in an increase in CO_2e. The Basic Coordination Alternative 75th percentile variable is zero, with the median and 25th percentile variable resulting in a decrease in CO_2e, 25.3 and 181.7 metric tons, respectively. The Supply Driven (LB Priority approach), Supply Driven (LB Pro Rata approach), and Maximum Operational Flexibility Alternatives all have 75th percentile variables at zero, with the Supply Driven (LB Pro Rata approach) having the largest variability (with a 669.5 metric ton decrease for the 25th percentile). The interquartile ranges for all the Alternatives, except No Action, are all wider in this flow category, indicating more variability than in the Average Flow Category. The No Action Alternative is the most reliable as it stays equal to or above the CCS Comparative Baseline under each flow category, and therefore performs consistently the worst. The Average Flow Category (12–14 maf) 75th percentile variance results in no more than 387 metric ton increase in CO_2e (No Action Alternative) which is equivalent to 90.3 gasoline powered passenger vehicles driven for one year or 80.6 homes' electricity for one year. The Critically Dry Flow Category (4.46–10 maf) 75th percentile variance results in no more than a 165 metric ton increase in CO_2e (No Action Alternative) which is equivalent to 38.5 gasoline powered passenger vehicles driven for one year or 34.4 homes' electricity for one year.

Figure TA 7-13
Change of CO2e Emissions Due to a Loss of Hydropower Generation at Hoover Dam



For **Figure TA 7-14**, in the Average Flow Category (12–14 maf), the alternatives are projected to result in similar behavior, in terms of medians and variability of metric tons of CO_2e. The No Action Alternative is the only alternative with a median and 25th percentile below zero, resulting in a slight decrease in CO_2e. The 25th percentile results in a 2.0 metric tons increase in CO_2e. All the other alternatives have medians and 25th to 75th percentiles that result in an increase in CO_2e, with the Basic Coordination Alternative having the smallest variability.

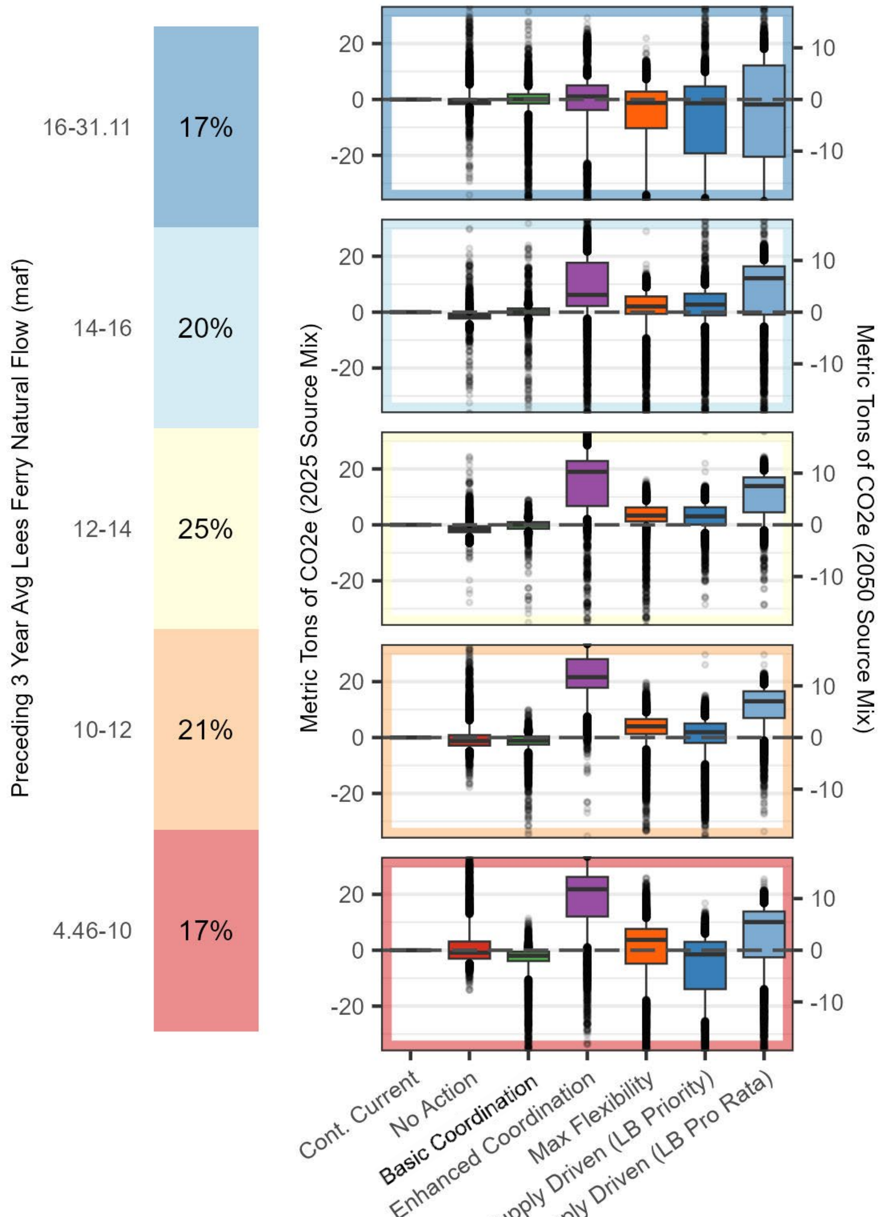
Figure TA 7-14
Change of CO2e Emissions Due to a Loss of Hydropower Generation at Davis Dam



For **Figure TA 7-14**, in the Critically Dry Flow Category (4.46–10 maf), all of the alternatives are projected to result in similar behavior in terms of medians and variability. The Enhanced Coordination and Maximum Operational Flexibility Alternatives both have medians above the CCS Comparative Baseline, around 20 metric tons of CO_2e. The No Action, Basic Coordination, and Supply Driven (LB Priority approach) Alternatives all have medians just below the CCS Comparative Baseline. The No Action and Basic Coordination Alternatives have the lowest variability and the Supply Driven (LB Priority approach), Supply Driven (LB Pro Rata approach) Alternatives have the largest variabilities. The interquartile ranges for the Supply Driven (LB Priority approach), Supply Driven (LB Pro Rata approach), Enhanced Coordination, and Maximum Operational Flexibility Alternatives are all wider in this flow category, indicating more variability than in the Average Flow Category, while the variability in the Basic Coordination and No Action Alternatives is similar to the range in the Average Flow Category. The Maximum Operational Flexibility and Enhanced Coordination are the most reliable as it stays equal to or above the CCS Comparative Baseline under each Flow Category, except the High Flow Category (16–31 maf), and therefore performs consistently the worst. The Average Flow Category (12–14 maf) 75th percentile variance results in no more than a 43 metric ton increase in CO_2e (Enhanced Coordination Alternative) which is equivalent to 10 gasoline powered passenger vehicles driven for one year or 9 homes' electricity for one year. The Critically Dry Flow Category (4.46–10 maf) 75th percentile variance results in no more than a 47 metric ton increase in CO_2e (Enhanced Coordination Alternative) which is equivalent to 11 gasoline powered passenger vehicles driven for one year or 9.8 homes' electricity for one year.

For **Figure TA 7-15**, in the Average Flow Category (12–14 maf), the alternatives are projected to result in similar behavior, in terms of medians and variability of metric tons of CO_2e. However, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have the highest medians and larger interquartile ranges, all resulting in a small increase in metric tons of CO_2e. Only the No Action and Basic Coordination Alternatives have medians that result in a decrease in CO_2e but the 25th percentile are under a 3 metric ton decrease of CO_2e.

Figure TA 7-15
Change of CO2e Emissions Due to a Loss of Hydropower Generation at Parker Dam



For **Figure TA 7-15**, in the Critically Dry Flow Category (4.46–10 maf), the alternatives are also projected to result in similar behavior, in terms of medians and variability of metric tons of CO_2e. However, the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives have the highest medians and larger interquartile ranges. Enhanced Coordination Alternative is the only alternative with a median and a 75th and 25th percentile variance resulting in a small increase in metric tons of CO_2e. No Action and Basic Coordination Alternatives have medians just below zero and very small interquartile ranges. The Maximum Operational Flexibility and Supply Driven (LB Priority approach) Alternatives, are projected to result in similar behavior, in terms of medians but with slightly larger variability. The interquartile ranges for all the alternatives are all slightly wider in this flow category, indicating more variability than in the Average Flow Category. The Enhanced Coordination is the most reliable as it stays equal to or above the CCS Comparative Baseline under each Flow Category, and therefore consistently performs the worst. The Average Flow Category (12–14 maf) 75th percentile variance results in no more than a 23 metric ton increase in CO_2e (Enhanced Coordination Alternative) which is equivalent to 5.4 gasoline powered passenger vehicles driven for one year or 4.8 homes' electricity for one year. The Critically Dry Flow Category (4.46–10 maf) 75th percentile variance results in no more than a 26 metric ton increase in CO_2e (Enhanced Coordination Alternative) which is equivalent to 6.1 gasoline powered passenger vehicles driven for one year or 5.4 homes' electricity for one year.

TA 7.2.4 Issue 3: How would climate trends affect lake reservoir elevations?

Climate trends affects lake reservoir elevations in several interrelated ways, driven largely by changes in temperature, precipitation patterns, and hydrological cycles. Climate trends typically results in more variability and extremes in lake reservoir elevations—lower lows during droughts, higher highs during storm events, and greater management complexity overall.

Reduced Snowpack and Earlier Snowmelt

In many regions, especially mountainous areas, snowpack acts as a natural reservoir, slowly releasing water into rivers and lakes as it melts. Climate trends may cause warmer temperatures which can result in less snow accumulation and earlier snowmelt, shifting the timing of runoff. Reservoirs may fill earlier in the season, but levels drop later in summer when demand (especially for irrigation and cooling) is highest.

Increased Evaporation

Potentially higher temperatures increase evaporation rates from both lake surfaces and surrounding land. As a result, greater water loss from reservoirs, especially in arid and semi-arid regions, leads to lower water levels.

Changes in Precipitation Patterns

Climate trends show potential disruption of rainfall patterns with some areas experience more intense storms, while others face prolonged droughts. The intense rainstorms may cause runoff that does not efficiently recharge reservoirs and the droughts reduce inflow from rivers and streams, lowering reservoir levels over time.

Increased Water Demand

Hotter temperatures and more extreme weather increase demand for agricultural irrigation, municipal use, and power generation (cooling). Reservoir drawdown increases, reducing water levels faster, especially in peak summer months.

Decreased Hydropower

As discussed in Issue 2, hydropower may be affected by climate trends. Any reduction in hydropower would require other power generation sources to increase to compensate. The regional power mix can be analyzed to determine the region's potential capacity to replace hydropower with other alternative energy sources. The eGrid is a comprehensive inventory of environmental attributes of electric power systems. eGrid is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. It provides the generation resource mix for the North American Electric Reliability Corporation regions. The project is located in the Western Electricity Coordinating Council North American Electric Reliability Corporation region. The latest version of eGrid (eGrid 2023) was released in January of 2025 with data from 2023 (EPA 2025f). **Table TA 7-21** shows that renewables such as hydropower, biomass, wind, solar and geothermal are 42.8 percent of the Western Electricity Coordinating Council resource mix compared to non-renewables such as coal, oil, nuclear and gas totaling 57.3 percent. If the 19.8 percent hydropower is reduced it is likely that both renewable and non-renewable resources would compensate. However, as discussed a recent Argonne National Laboratory study shows that when there is a reduction in hydropower at Glen Canyon Powerplant, the replacement generation from mostly Natural Gas Fired generation (Gas Combined Cycle) generation and Gas Combustion Turbine, with a small portion also coming from coal-fired generation for 2024 through 2027 (Argonne et al. 2024).

In addition, as climate trends are further observed and monitored, Reclamation has opportunity to discuss any strategies to increase management flexibility, enhance climate adaptation planning and improve infrastructure resilience.

Table TA 7-21
EGrid 2023 WRCC Resources Mix Percentages

Resource	Generation Percentage
Coal	14.0%
Oil	0.1%
Gas	35.5%
Nuclear	7.7%
Hydropower	19.8%
Biomass	1.1%
Wind	10.2%
Solar	9.5%
Geothermal	2.2%

Sources: EPA (2025f).

TA 7.2.5 Summary of Comparison of Alternatives

Potential impacts on air quality resources for the No Action, the four action alternatives, and the CCS Comparative Baseline vary depending on the shoreline exposure area and the reduction of hydropower for each alternative.

Issue 1: How would changing flow characteristics affect the potential exposed shoreline, fallowed agricultural lands and fugitive dust?

For the Lake Powell WY maximum exposed shoreline area Average Flow Category (12–14), the alternatives all have similar medians and small variabilities, except the Enhanced Coordination and Maximum Operational Flexibility Alternatives which has the lowest median square kilometers of exposed shoreline and the smallest variability.

For the Lake Mead WY maximum exposed shoreline area Average Flow Category (12–14), the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the least shoreline exposure area. The CCS Comparative Baseline and No Action Alternative perform the worst and have the smallest variability. The Basic Coordination Alternative performs in the middle.

For the full modeling period, the Lake Mead shoreline area robustness figures show that the No Action Alternative performs the worst, with only 40 percent of the futures below 500 square kilometers of shoreline area. The CCS Comparative Baseline performs slightly better at 54 percent, then the Basic Coordination Alternative at 67 percent, and then the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) at 79 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 80 percent of the futures below 500 square kilometers of shoreline area. These same trends were seen for the 2027-2039, 2040-2049, and 2050-2060 modeling periods with higher percentages. For the 2027-2039 modeling period and 2040-2049 modeling period, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have over 90 percent of the futures below 500 square kilometers of shoreline area.

The Lake Mead vulnerability plots show that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions and only about 10 percent of the traces include droughts this dry or drier. The Basic Coordination Alternative is just below the median 20-year average Lees Ferry flow, and the CCS Comparative Baseline and No Action Alternative are the most vulnerable with a 20-year drought of 11.7 maf and 12.2 maf, respectively, likely to cause undesirable performance.

For the full modeling period, the Lake Powell shoreline area robustness figures show that the No Action Alternative performs the worst, with only 24 percent of the futures below 500 square kilometers of shoreline area. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) performs slightly better at 28 percent, then Basic Coordination at 33 percent, and then CCS Comparative Baseline at 40 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 80 percent of the futures below 500 square kilometers of shoreline area. These same trends were seen for the 2027-2039 with higher percentages. The 2040-2049 and 2050-2060 modeling periods show that the Supply Driven

Alternatives (both LB Priority and LB Pro Rata approaches) perform the worst, then No Action Alternative. For the 2027-2039, 2040-2049 and 2050-2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have over 90 percent of the futures below 500 square kilometers of shoreline area.

The Lake Powell vulnerability plots show that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to similar conditions and only about 10 percent of the traces include droughts this dry or drier, therefore the least vulnerable. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are above the median 10-year average Lees Ferry flow and are the most vulnerable with a 10-year drought.

For the Lake Powell WY maximum shoreline dust emissions Average Flow Category (12–14), the alternatives all have similar medians, with the Enhanced Coordination and Maximum Operational Flexibility Alternatives having the lowest median square kilometers of exposed shoreline and a smallest variability.

For the Lake Mead WY maximum shoreline dust emissions Average Flow Category (12–14), the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives performed the best, with the least shoreline dust emissions. The CCS Comparative Baseline and No Action Alternative perform the worst, with the highest shoreline dust emissions. The Basic Coordination Alternative performs in the middle.

For the full modeling period, the Lake Mead shoreline dust emissions robustness figures show that the No Action Alternative performs the worst, with only 27 percent of the futures below 500 million kilograms of $PM_{2.5}$. The CCS Comparative Baseline performs slightly better at 47 percent, then Basic Coordination Alternative at 59 percent, and then Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) at 74 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 82 percent and 78 percent, respectively, of the futures below 500 million kilograms of $PM_{2.5}$. These same trends were seen for the 2027-2039, 2040-2049, and 2050-2060 modeling periods with higher percentages and the Maximum Operational Flexibility and Enhanced Coordination Alternatives have over 80 percent of the futures below 500 million kilograms of $PM_{2.5}$.

The Lake Mead vulnerability plots show that the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are vulnerable to similar conditions and only about 10 percent of the traces include droughts this dry or drier, therefore the least vulnerable. The CCS Comparative Baseline, Basic Coordination, and No Action Alternatives are the most vulnerable with a 20-year drought of 11.9 maf, 11.4 maf, and 12.7 maf, respectively, which is over the 20-year average Lees Ferry flow of 11.6 maf and likely to cause undesirable performance.

For the full modeling period, the Lake Powell shoreline dust emissions robustness figures show that the No Action Alternative performs the worst, with only 22 percent of the futures below 450 million kilograms of $PM_{2.5}$. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) performs slightly better at 27 percent, then Basic Coordination at 29 percent, and then CCS

Comparative Baseline at 35 percent. The Maximum Operational Flexibility and Enhanced Coordination Alternatives perform the best with over 80 percent of the futures below 500 million kilograms of $PM_{2.5}$. These same trends were seen for the 2027-2039 with higher percentages. The 2040-2049 and 2050-2060 modeling periods show that the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) performs the worst, then No Action Alternative. For the 2027-2039, 2040-2049 and 2050-2060 modeling periods, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have over 90 percent of the futures below 500 million kilograms of $PM_{2.5}$.

The Lake Powell vulnerability plots show that the Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to similar conditions and only about 10 percent of the traces include droughts this dry or drier, therefore the least vulnerable. The CCS Comparative Baseline, No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives are above the median 10-year average Lees Ferry flow and are the most vulnerable with a 10-year drought.

Issue 2: How would lake reservoir elevations and releases impact power generation and CO_2e emissions?

For the Average Flow Category (12–14), Davis Dam and Parker Dam, perform similarly with the Enhanced Coordination, Maximum Operational Flexibility, Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) perform the worst and have the highest variability. The No Action and Basic Coordination Alternatives perform the best for the Davis Dam and Parker Dam. For Glen Canyon Dam and Hoover Dam Average Flow Category shows the No Action and Basic Coordination Alternatives perform the worst and the No Action has the highest variability. The Supply Driven (LB Priority approach) and Supply Driven (LB Pro Rata approach) Alternatives perform the best.

Issue 3: How would climate trends affect lake reservoir elevations?

Climate trends affects lake reservoir elevations in several interrelated ways, driven largely by changes in temperature, precipitation patterns, and hydrological cycles. Climate trends typically result in more variability and extremes in lake reservoir elevations which may not be captured specifically in the modeling, but the 5 flow conditions categories help to visualize the different potential states of the system throughout the 34-year period of analysis. Dry flow conditions could represent the lower lows present during droughts and the wet flow conditions could represent the higher highs during storm events. General discussion of the effects of climate trends on lake reservoirs is discussed but due to uncertainty these effects cannot be determined for each specific alternative. In addition, **TA 3**, Hydrologic Resources, details the lake reservoir elevations for flow category and alternative.

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