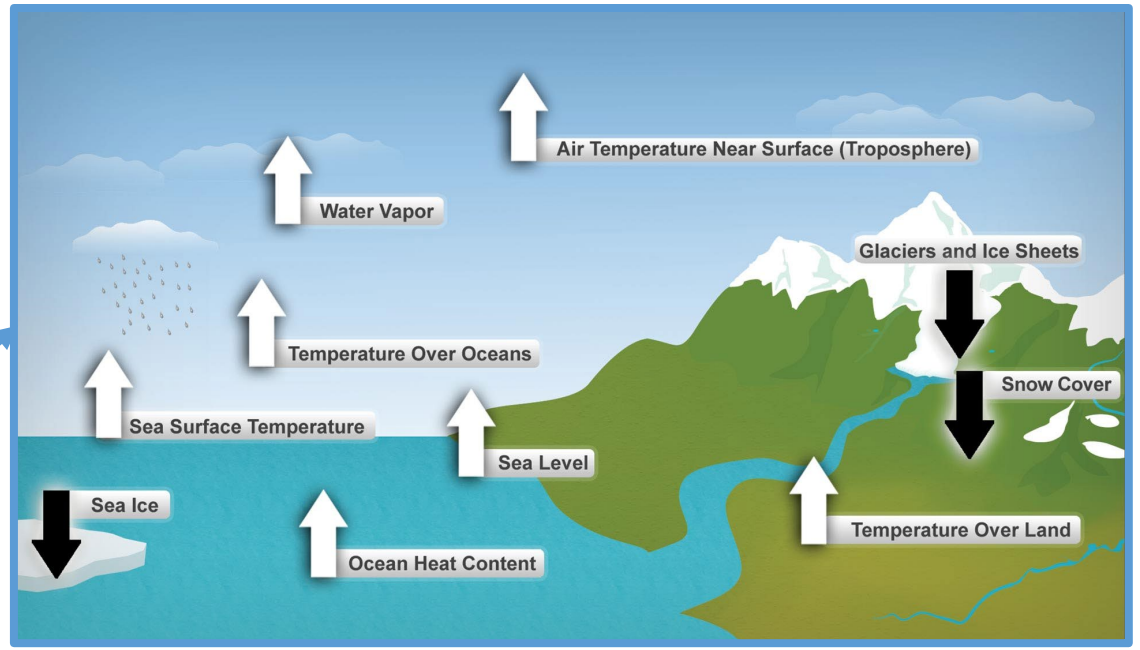
BUREAU OF RECLAMATION

Climate Change and Implications for Hydropower and Water Resources

Midwest Electric Consumers Association – Annual Meeting, December 6, 2022

Climate Change – What is it?

- Earth's Greenhouse Effect and its sensitivity to CO2, CH4, other gases
- Human influence on these gases
- Aligns with the global warming that we have observed
- Atmosphere is well mixed across the planet → good correlation with global to local warming
- Jet stream and "local" (e.g., Missouri Basin) precipitation pattern responses remain uncertain



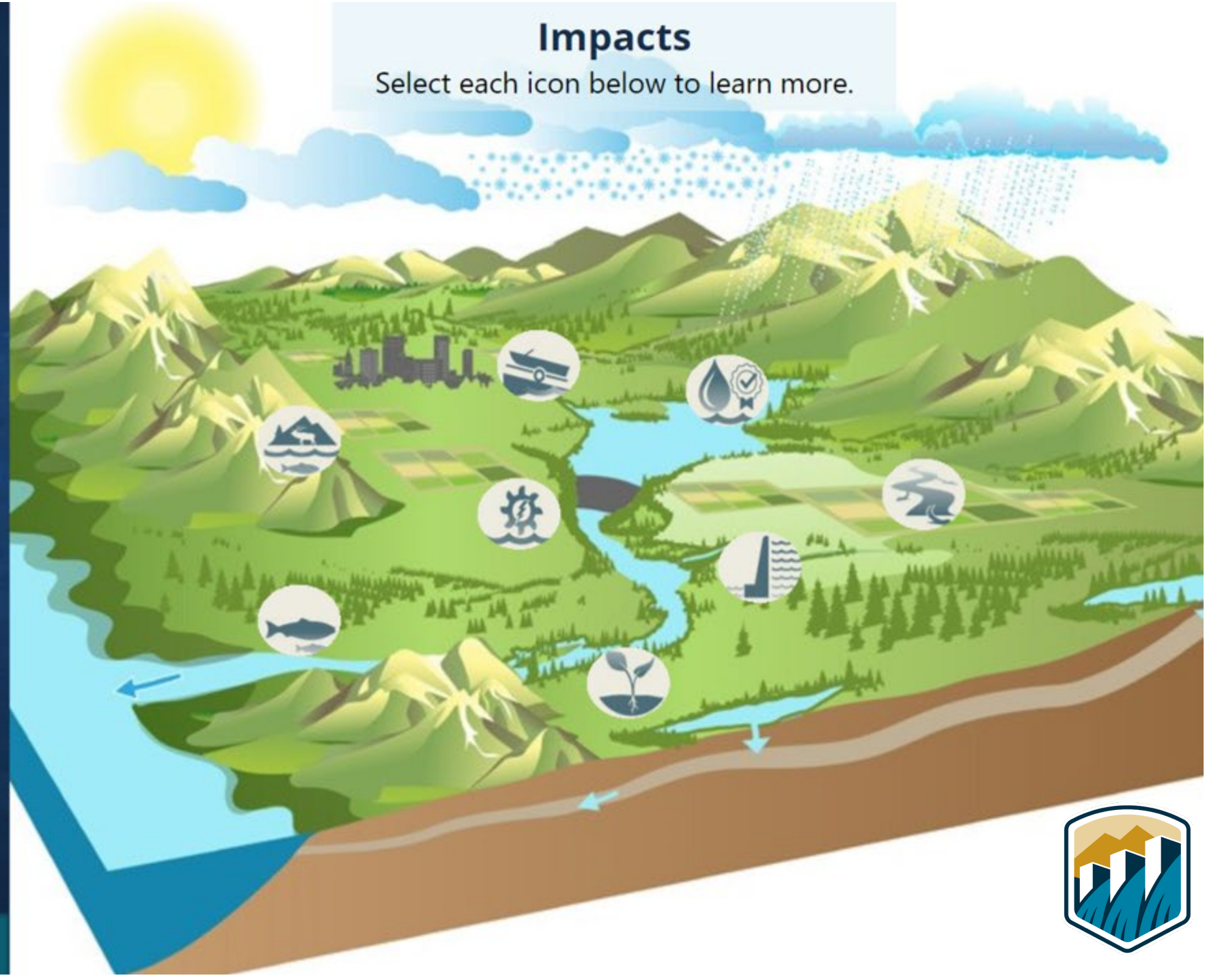
Increasing temperatures, decreasing snowpack, changes to the volume of precipitation, and changes to runoff timing and volume across the west will affect numerous aspects of water management:

- Water Deliveries
- Water Quality
- Recreation
- Fish and Wildlife Habitat
- Hydropower
- Endangered, Threatened, or Candidate Species
- Flood Control
- Ecological Resilience

Conditions

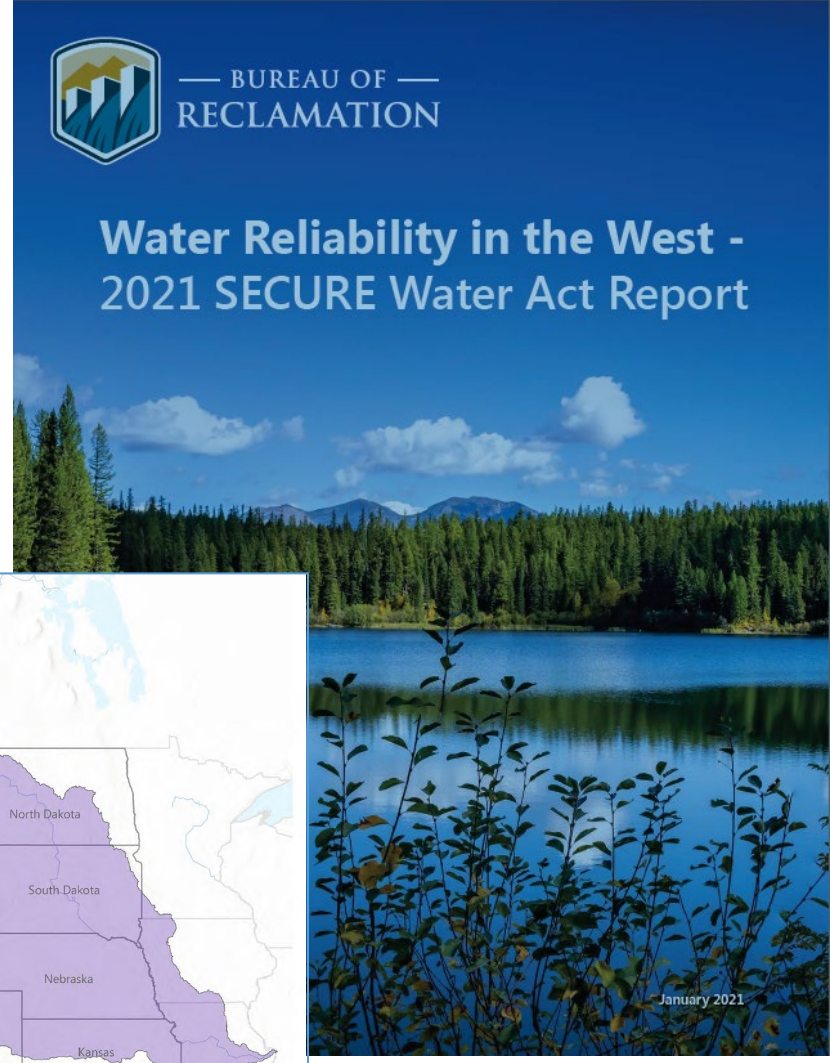
Impacts

Select each icon below to learn more.



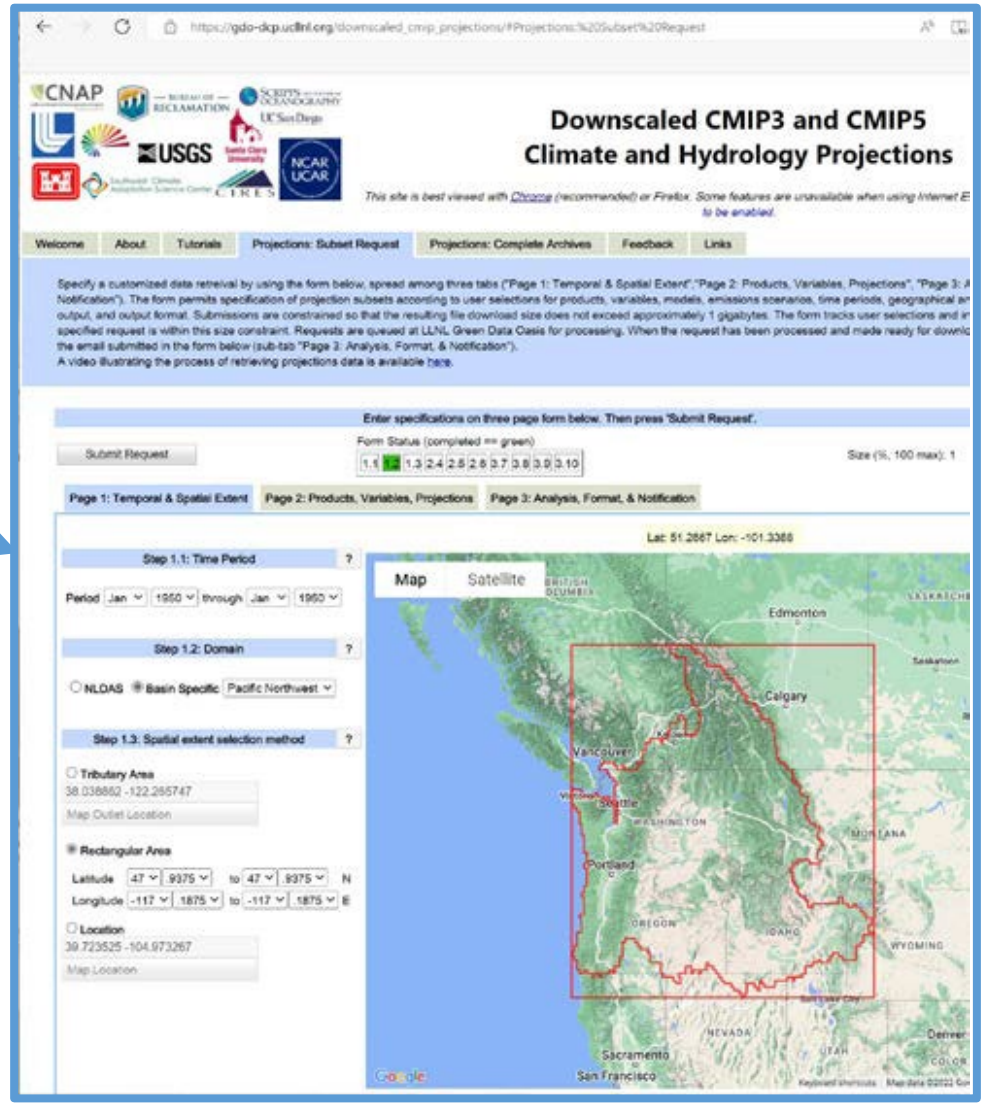
Reclamation Approach to Climate Change

- SECURE Water Act
- WaterSMART Financial Assistance / Basin Studies (Vulnerability Assessments)
- Adaptation / Operationalizing Climate Change
- Community of Practice



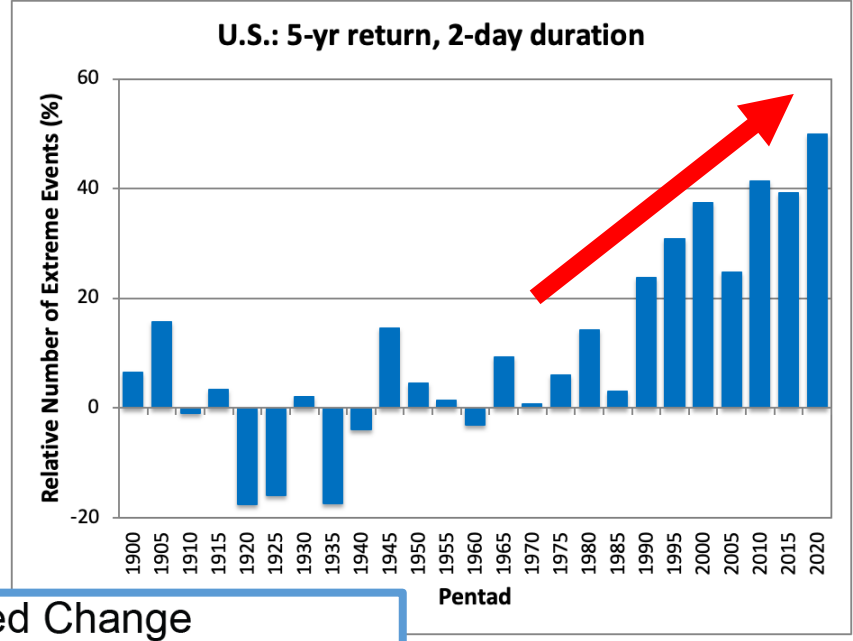
How do we look at climate change?

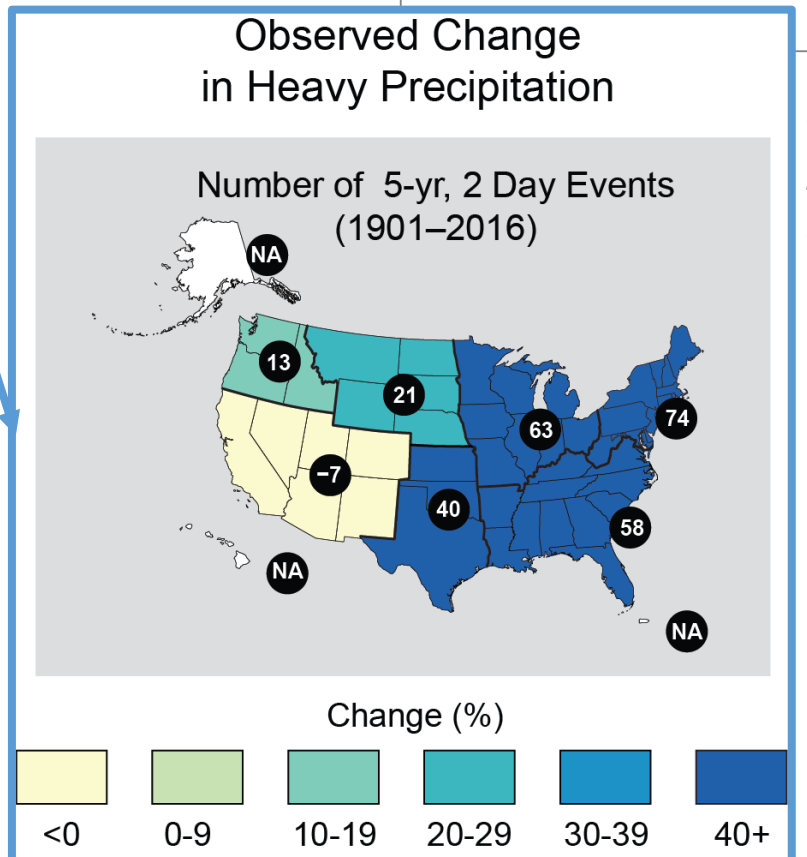
- Consider high-quality climate and hydrology evidence (paleoclimate indicators, observed records, climate and hydrology projections)
- Recognize what information is relevant to a given decision
- Recognize high-quality still means variable reliability and certainty
- Translate into planning assumptions and apply risk management



Where we're more confident

- Warming air and water temperatures
- Rising seas
- Increasing Precipitation Extremes (warmer air holds more moisture)
- Rising rain/snow elevation
- Shrinking mountain snowpack
- Shifting snowmelt timing and runoff seasonality
- Precipitation fate: more evapotranspiration, less runoff





Courtesy: Ken Kunkel, North Carolina State University

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U.S. Department of the Interior

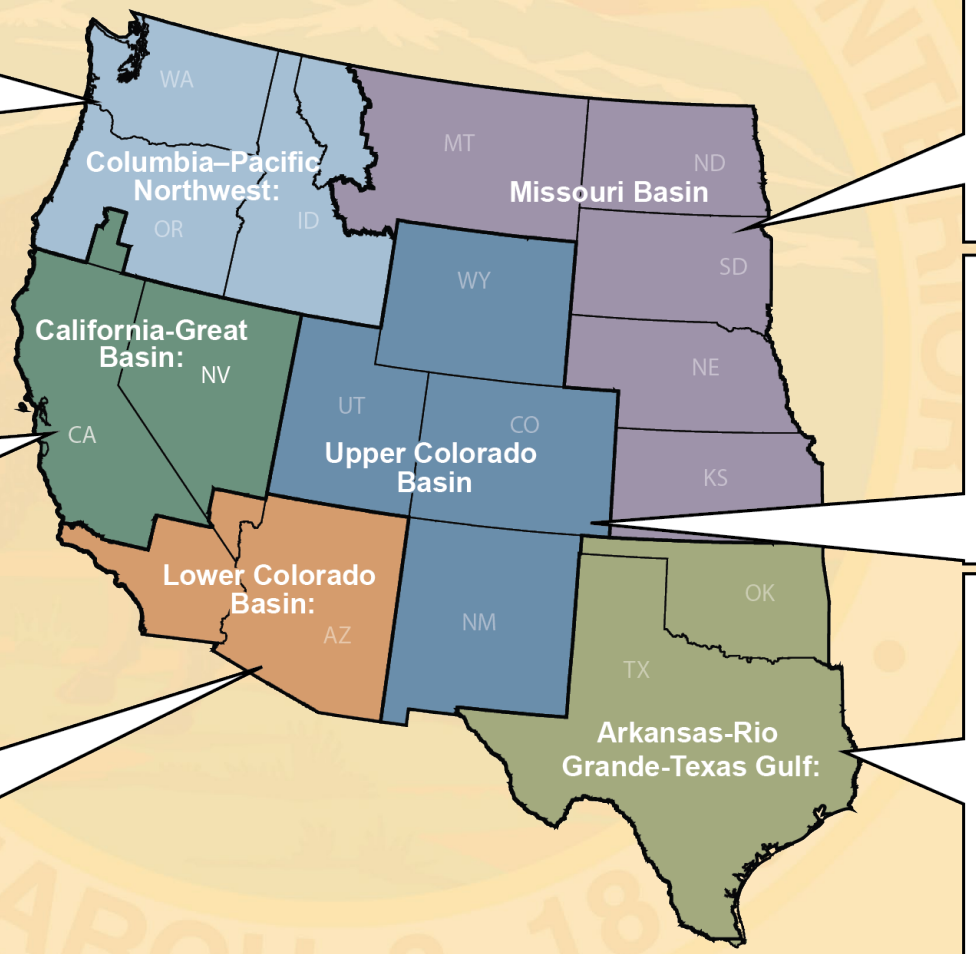
Science and Planning

Climate Change Impacts by Basin

- **Columbia-Pacific Northwest: Increased Variability** Recent years have seen record rainfall, peak runoff, temperatures, and drought throughout the region, stressing operations and ability to meet demands.

- **California-Great Basin: Decreased Snowpack** and lower, summer streamflow and increased water temperatures are impacting habitat for endangered fish

- **Lower Colorado Basin: Record Drought** Prolonged drought has resulted in record-low storage levels on Lake Powell and Lake Mead, key hydropower generators for much of the Southwest.



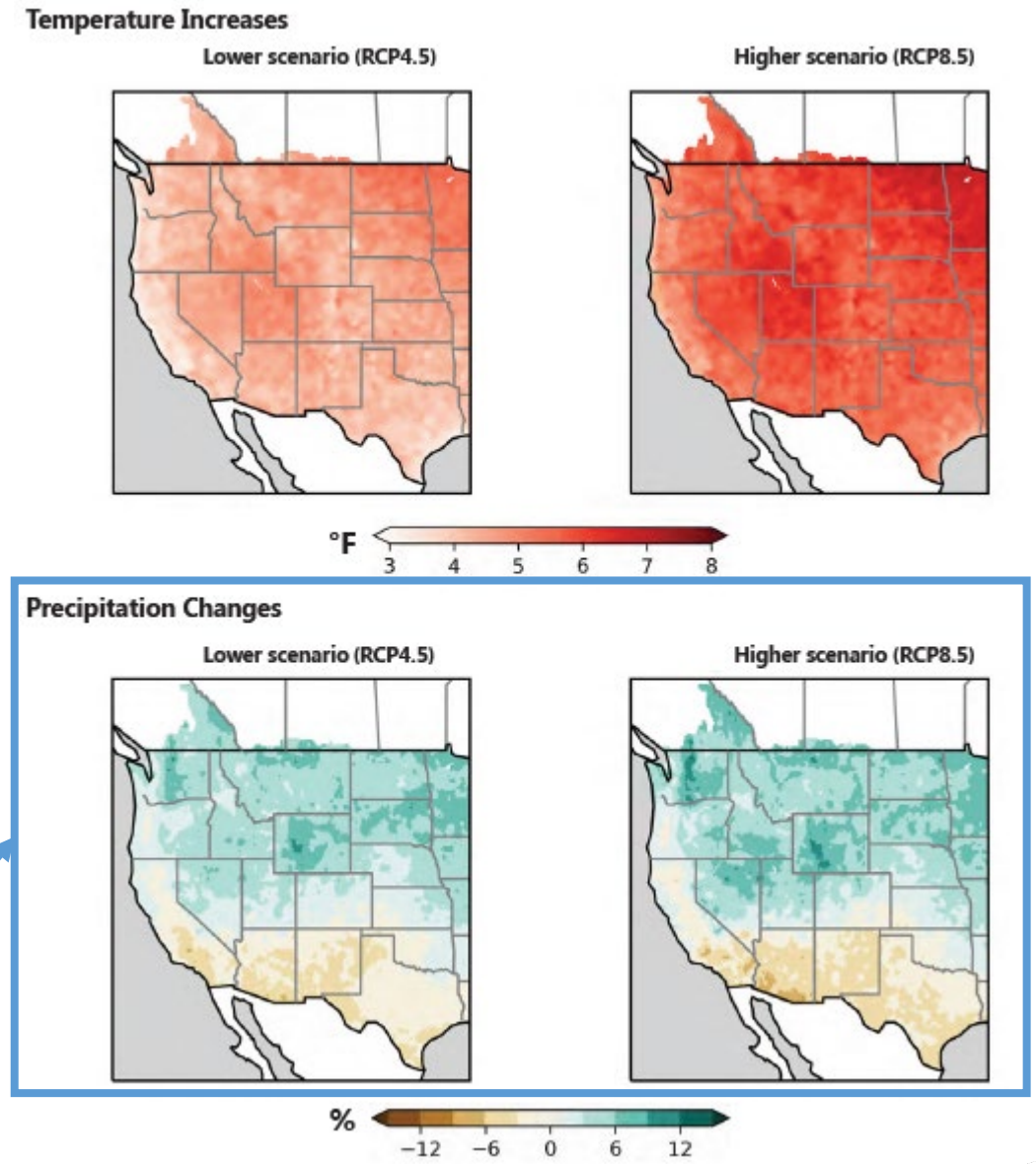
- **Missouri Basin: Increased Flood Events** In June 2022, devastating floods in Montana destroyed homes and transportation infrastructure, including the North Entrance Road to Yellowstone National Park.

- **Upper Colorado Basin: Shifts in Streamflow Regime** Earlier peak streamflow has stressed water supply in summer months, increasing likelihood of water conflicts.

- **Arkansas-Rio Grande-Texas Gulf: Record Temperatures** This area is experiencing high temperatures, which are projected to additionally rise by 4 to 10° F by the end of the 21st century, increasing reservoir evaporation.

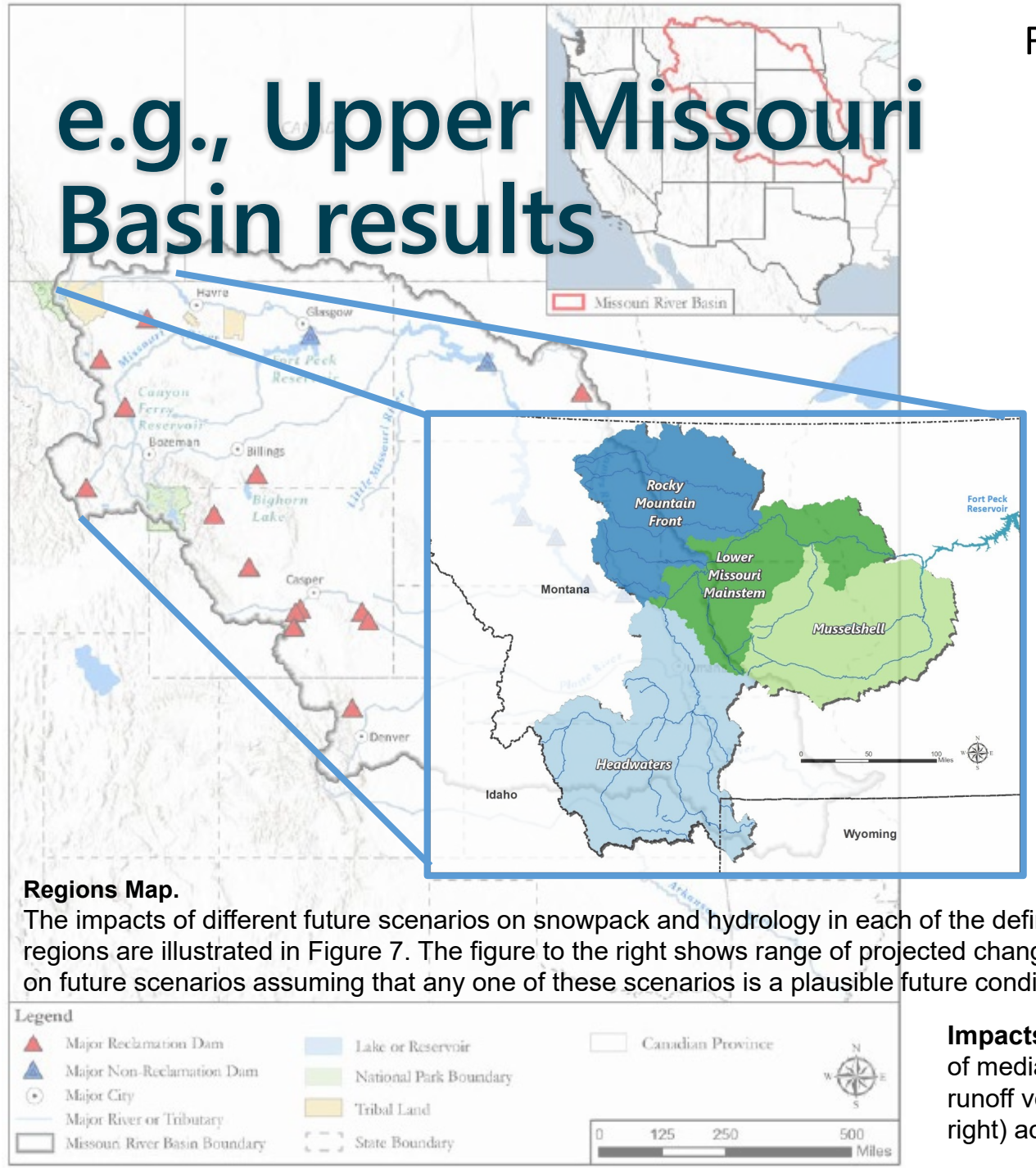
Where we're less confident

- Average-annual precipitation
  - Observed variability is large – hard to detect significant trends
  - Model projections vary a lot – simulating our jet stream response to global warming is difficult and uncertain.
  - Based on models' consensus: bet wetter towards Canada, bet drier towards Mexico…
  - …and remember that given warming, some precipitation increase will be necessary to break even with respect to runoff



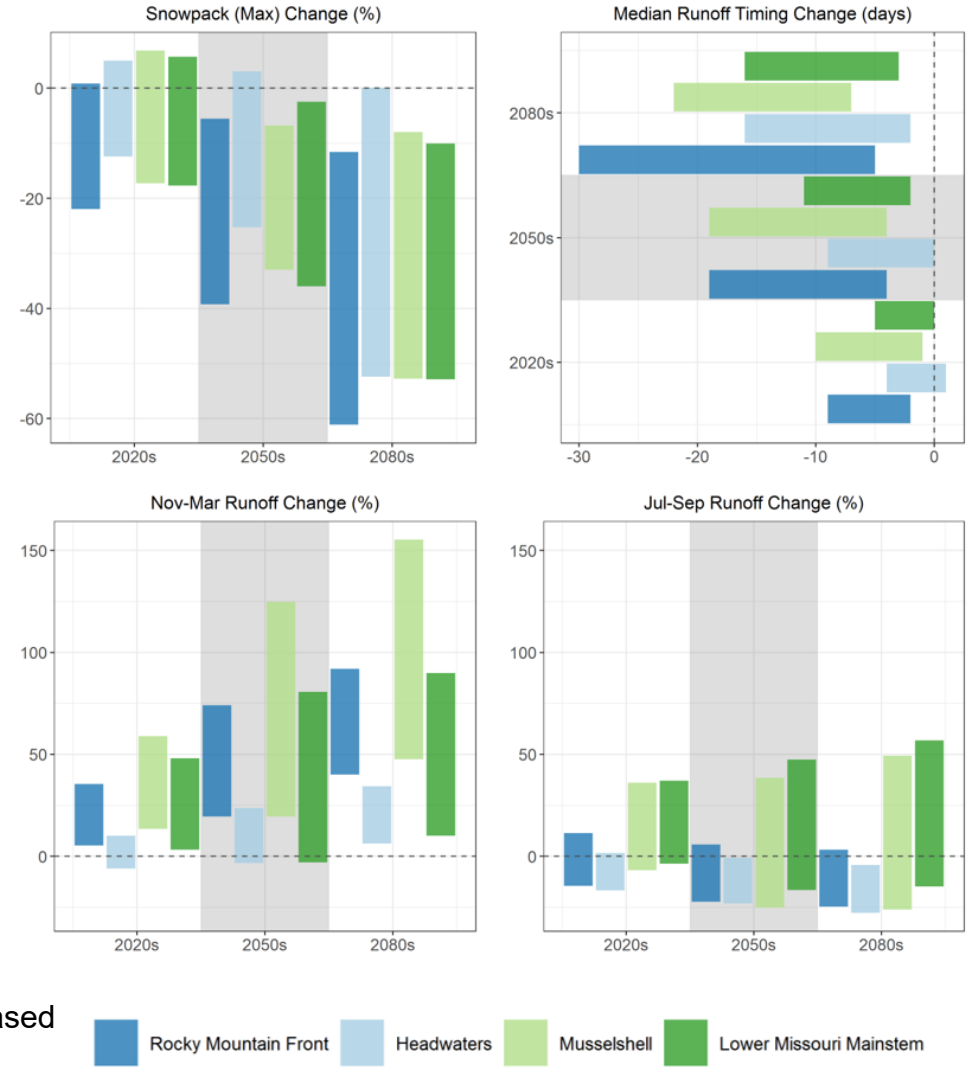
Changes in average annual condition from 1970-1999 to 2040-2069

e.g., Upper Missouri Basin results



Regions Map.
The impacts of different future scenarios on snowpack and hydrology in each of the defined regions are illustrated in Figure 7. The figure to the right shows range of projected changes based on future scenarios assuming that any one of these scenarios is a plausible future condition.

From 2019 Upper Missouri Basin Impacts Assessment & 2021 Missouri Headwaters Basin Study



Impacts. Range of projected change in peak (max) snowpack (%, top left), timing of median annual natural streamflow (days, top right), November - March natural runoff volume (%, bottom left), and July - September runoff volume (%, bottom right) across four regions within the study area.

Warming Implications for Hydropower

- Generation reliability: Warmer air → more rainfall goes to evapotranspiration from the landscape rather than runoff → droughts occur more often → stress on hydropower generation

- Infrastructure O&M: Warmer air → warmer water temperatures → O&M impacts (e.g., warmer "cooling water" for power plants) … but droughts may provide opportunity to realign outages to potentially reduce outage impacts during times when hydrology is more favorable
  - Warmer "cooling" water also has efficiency implications for Thermal electricity generation

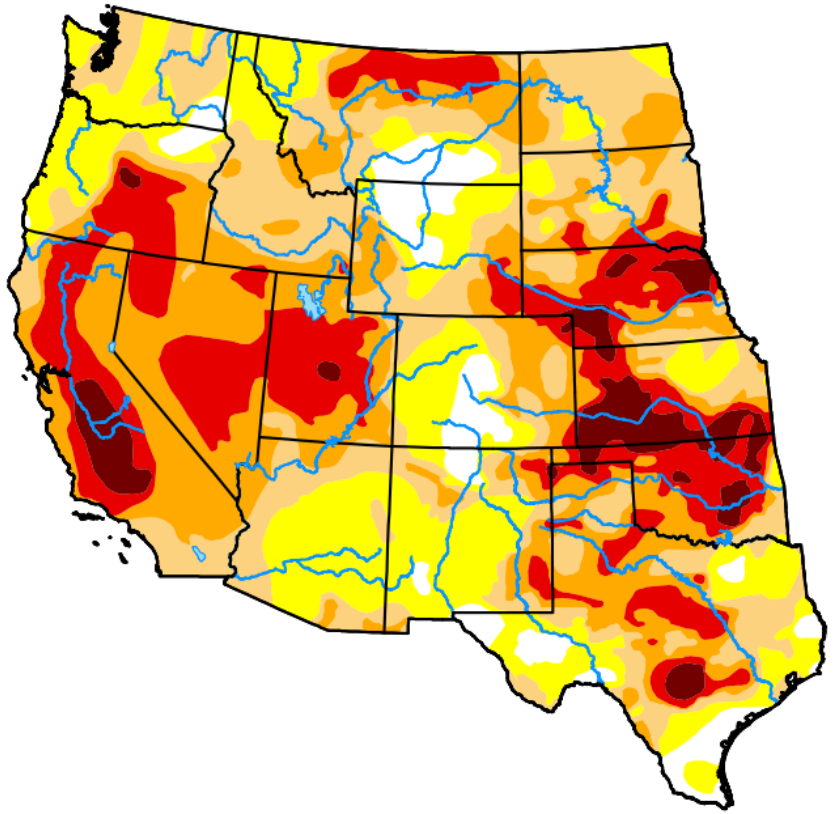
Warming Implications for Water Resources

- Water Delivery Reliability:
  - Water Supply Decreases: Warmer air → more rainfall goes to evapotranspiration from the landscape rather than runoff → droughts occur more often → more frequent water use restrictions
  - Water Demand Increase(?): Warmer air → opportunities to grow warmer-climate crops and/or farm through longer growing seasons → increased irrigation water demands
- Environmental Compliance:
  - Ecosystem Impacts: Warmer air → warmer water → impacts on aquatic habitats and species sensitive to water temperature increases
- … Combined impacts could affect water & power scheduling

Current Drought and Reservoir Conditions

U.S. Drought Monitor

Bureau of Reclamation



November 22, 2022

(Released Wednesday, Nov. 23, 2022)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	5.77	94.23	73.03	47.76	22.23	4.70
Last Week *11-15-2022*	5.35	94.65	73.20	47.91	22.18	4.65
3 Months Ago *08-23-2022*	14.23	85.77	68.81	50.73	23.77	4.27
Start of Calendar Year *01-04-2022*	7.26	92.74	80.24	55.04	19.99	2.56
Start of Water Year *09-27-2022*	5.09	94.91	73.72	46.57	20.12	4.14
One Year Ago *11-23-2021*	12.01	87.99	74.39	52.83	28.21	8.76

Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

Author:

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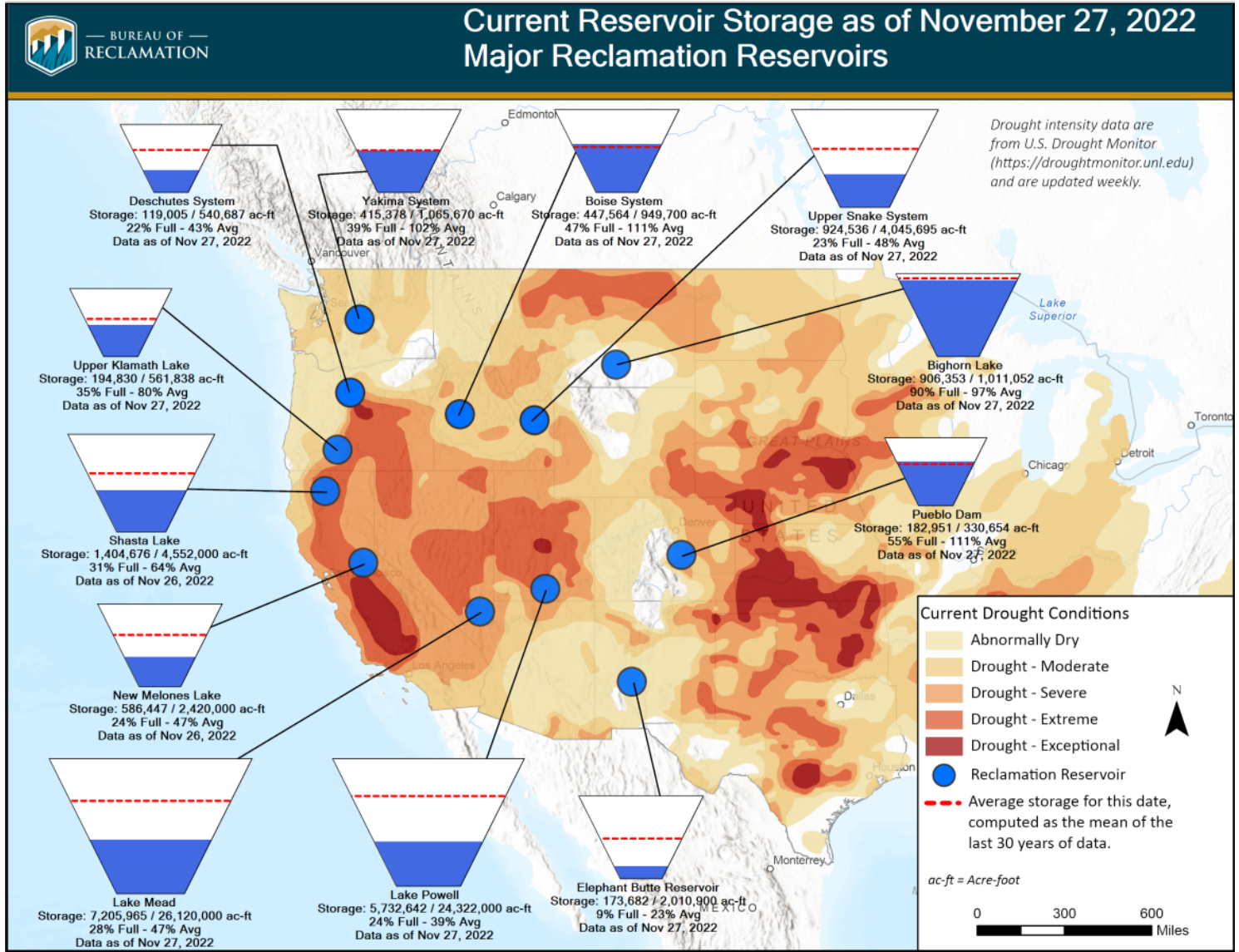
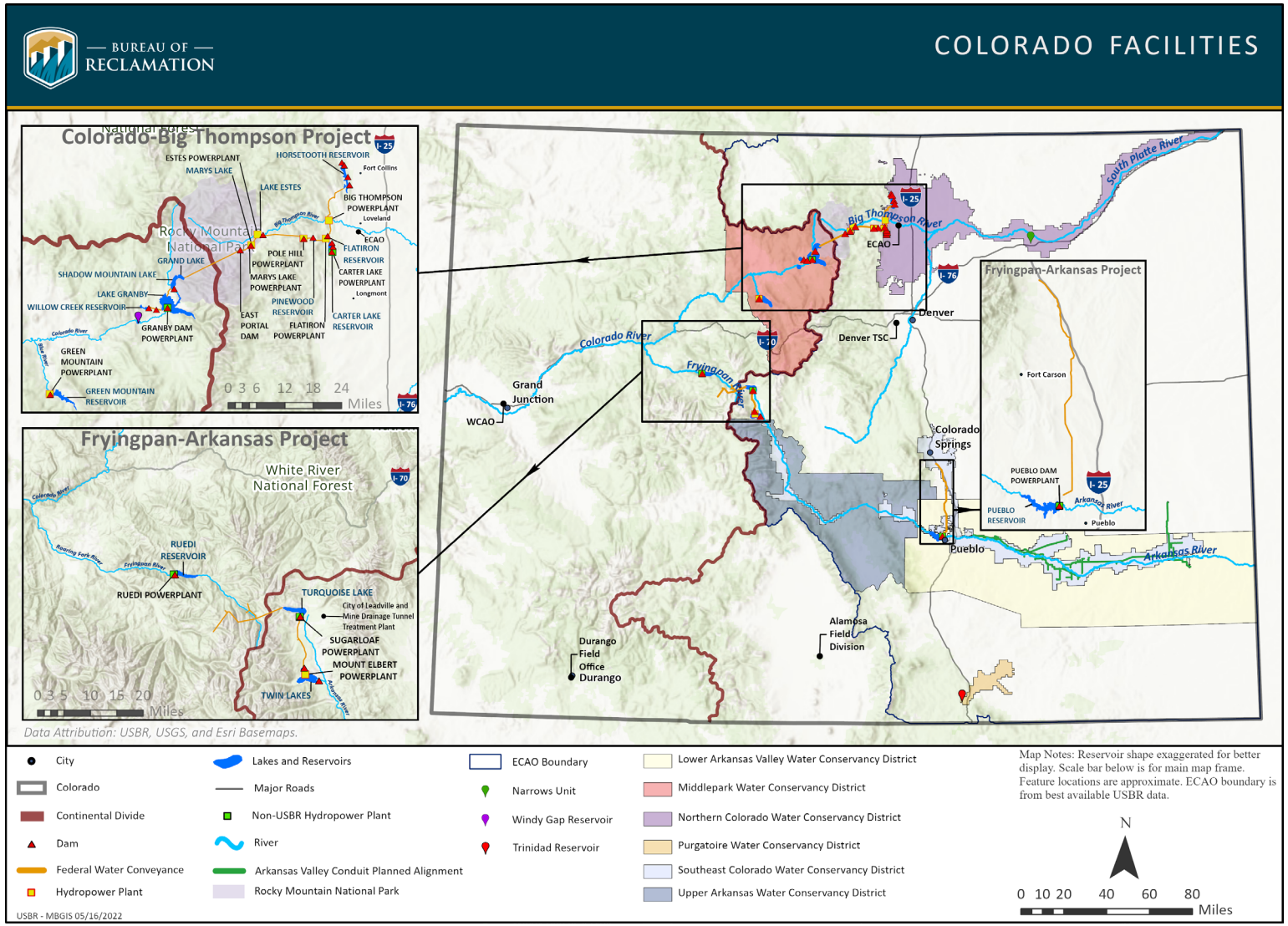
U.S. Department of Agriculture

droughtmonitor.unl.edu

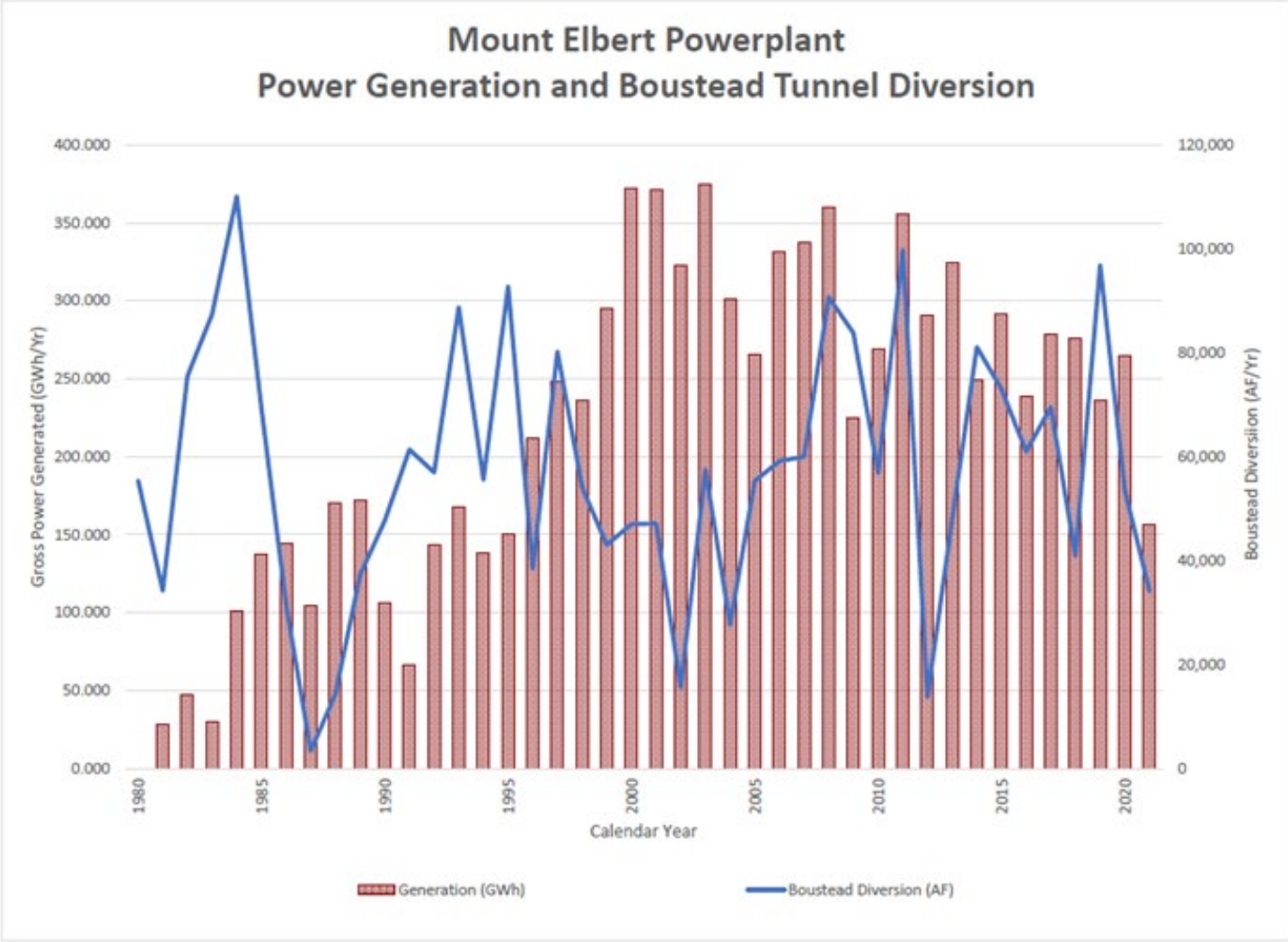
Current Drought and Reservoir Conditions



East Slope Water Conditions

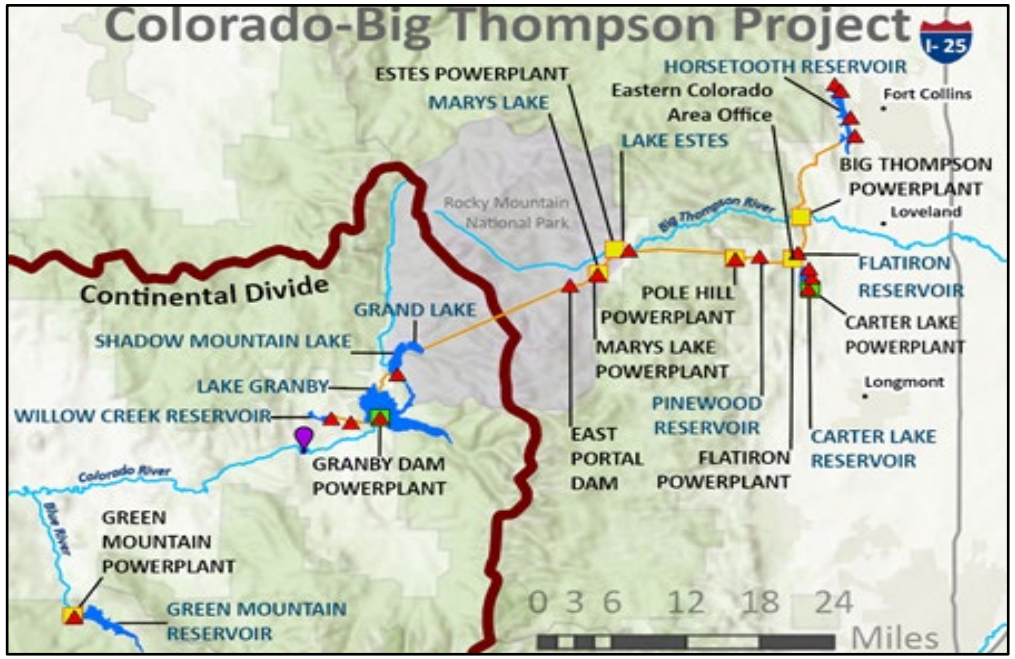


Fryingpan-Arkansas Power Generation



3 of the largest wildfires in Colorado history have occurred in 2020

Experts say climate change and a buildup of dead and parched wildland vegetation have contributed to this year's fires in the West.

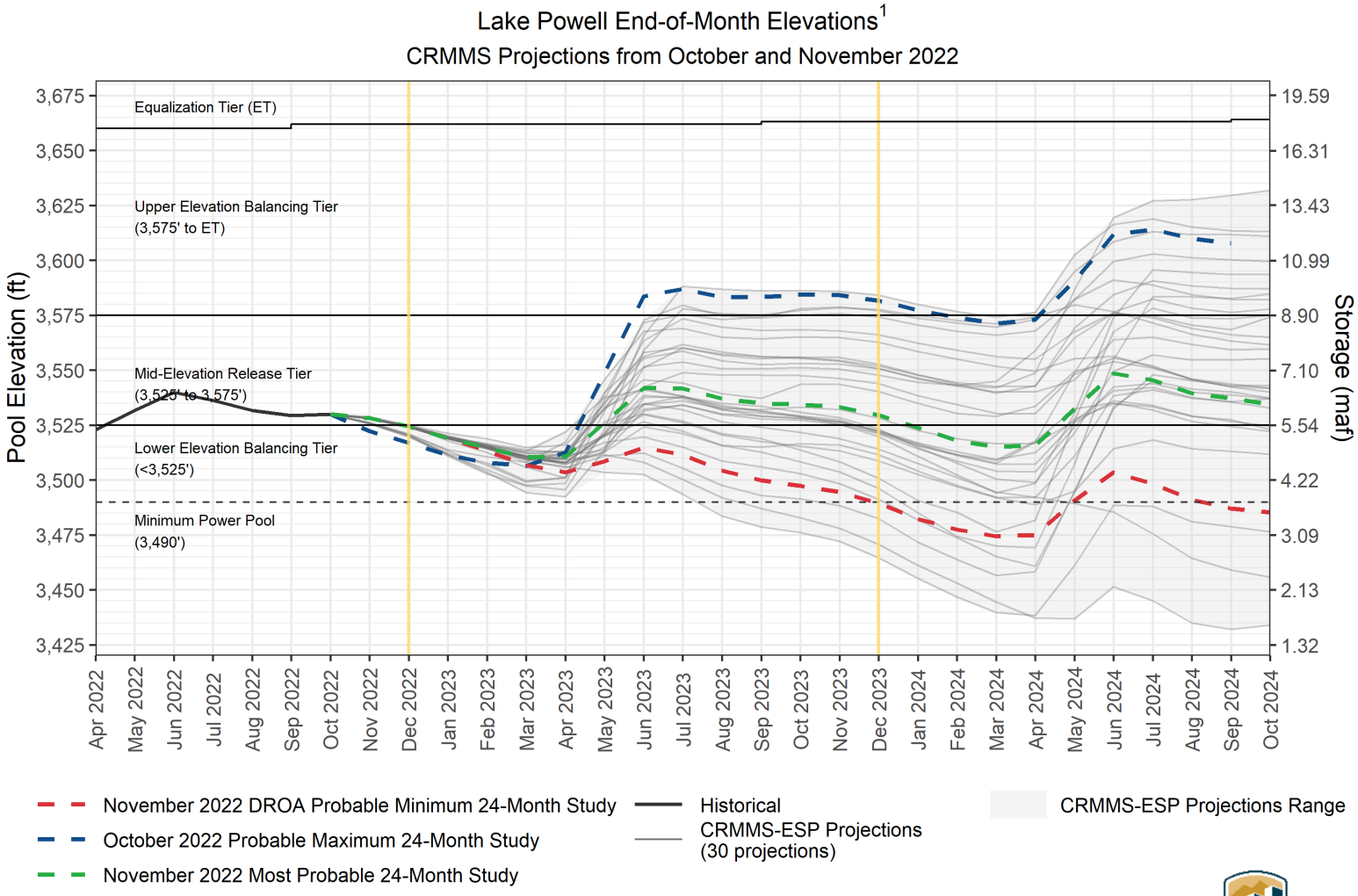


Colorado River Drought

Lake Powell Full, 2000

Lake Powell 31% Capacity, August 2021
(24% Capacity on November 27, 2022)

Colorado River 24-Month Study



[1] Projected Lake Powell end-of-month physical elevations from the latest CRMMS-ESP and 24-Month Study inflow scenarios.

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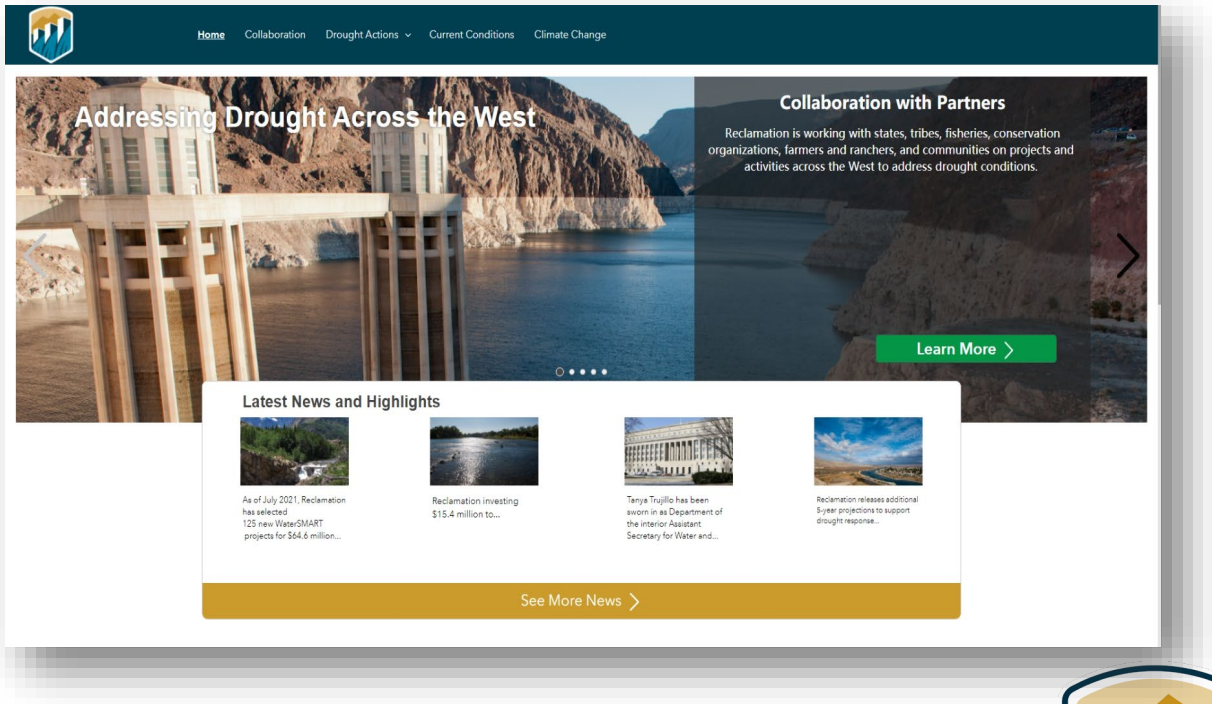
Reclamation Approach to Drought

We are leveraging multiple tools to address drought in the West, including:

- New water supplies
- Improved reservoir operations
- Hydropower optimization
- Water management improvements
- Water reuse
- Planning and science



Progress Report

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WaterSMART - Data Visualization Tool

over $940 million in Federal funds with over $3 billion in non-Federal cost share for 887 water resources planning and on-the-ground improvement projects in the Western U.S.

Click the blue colored button below to interact with WaterSMART projects funded since 2010.

Time Slider Visualization

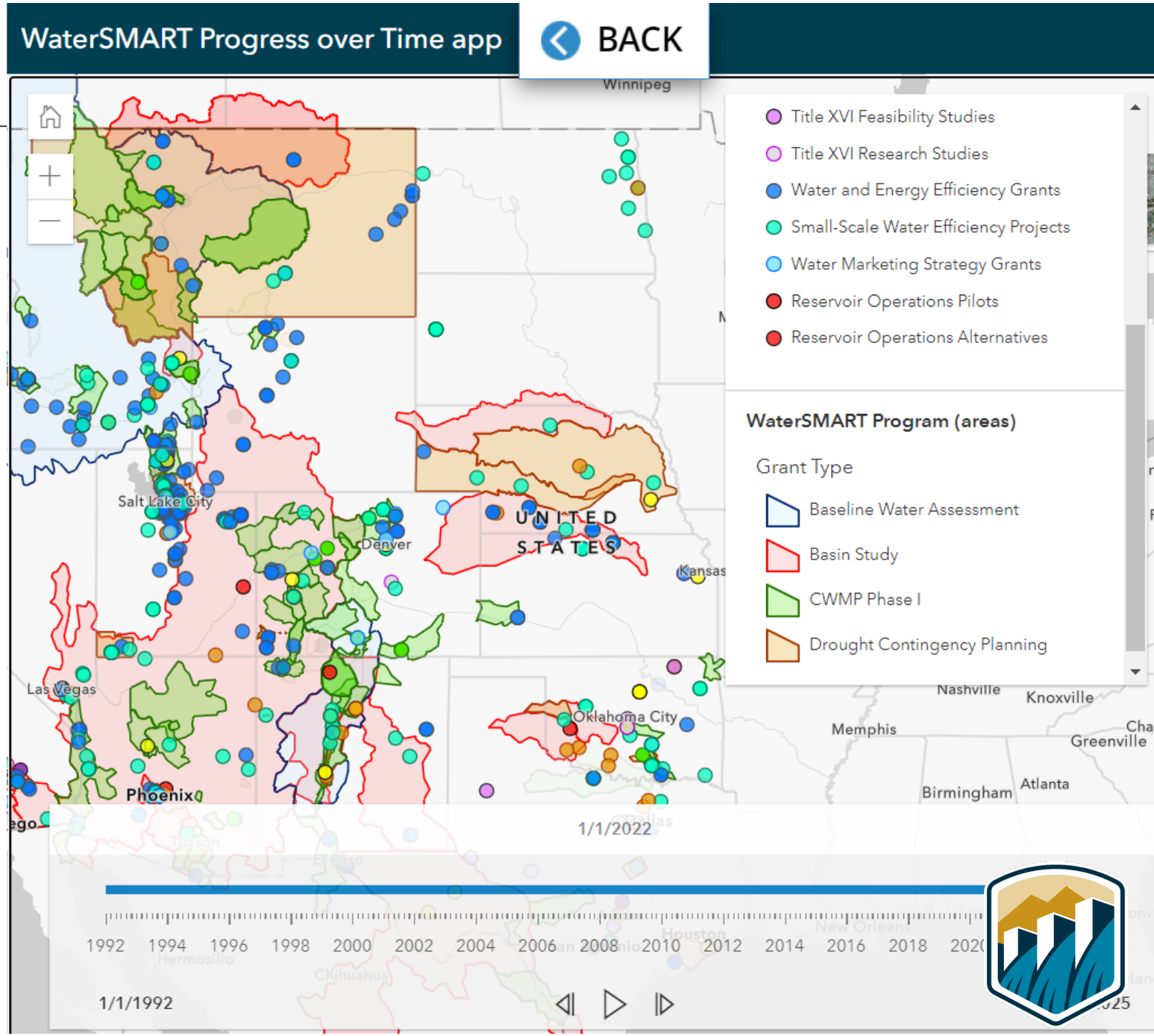
WaterSMART Programs

(Click links to navigate)

- WaterSMART Grants
- Title XVI Water Reclamation and Reuse
- Drought Response Program
- Basin Study Program
- Cooperative Watershed Management Program
- Working with Partners to Increase Water Supply Reliability

WaterSMART Funding Opportunities

WaterSMART Program funding opportunities are typically offered




Questions?
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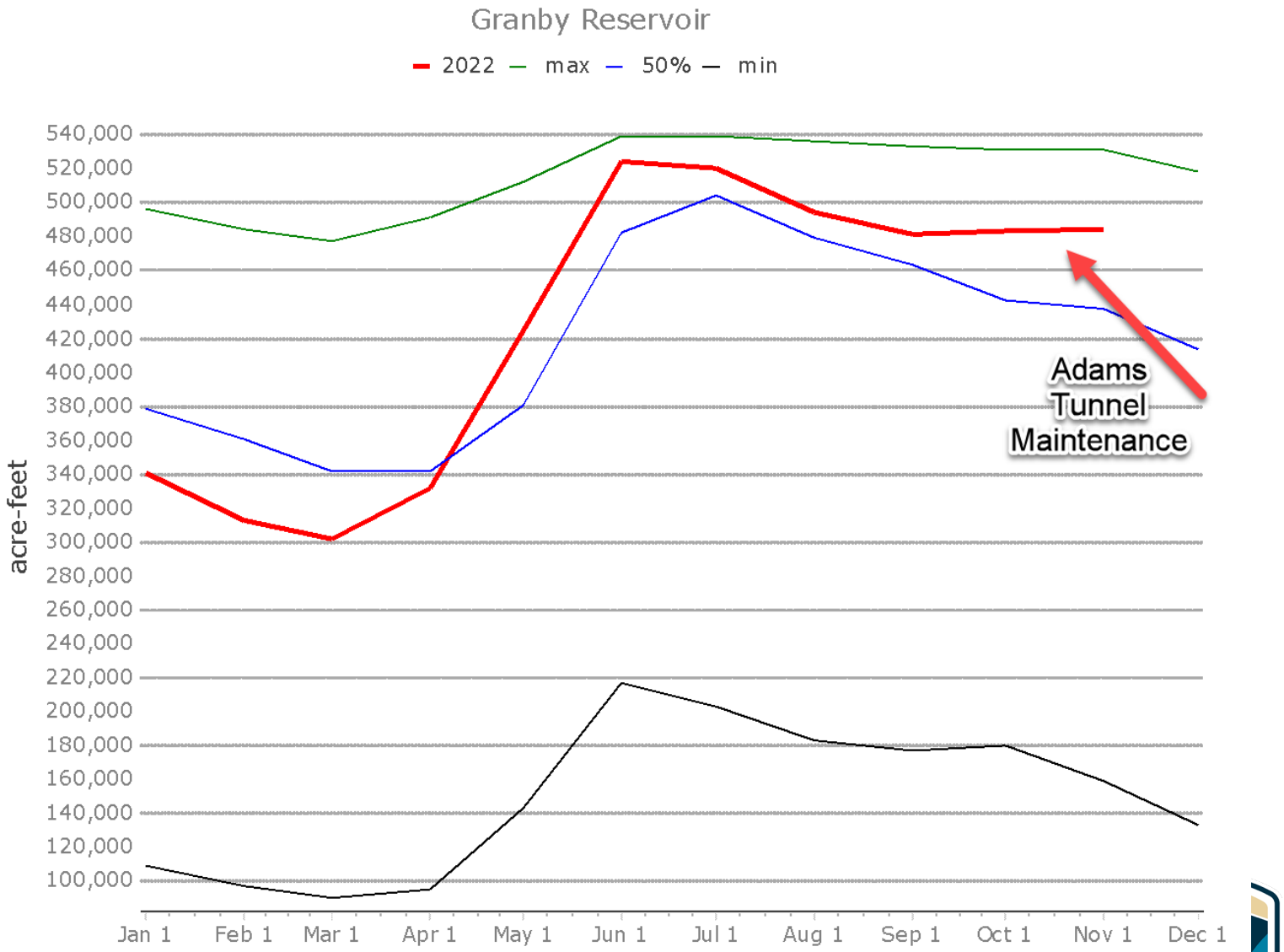
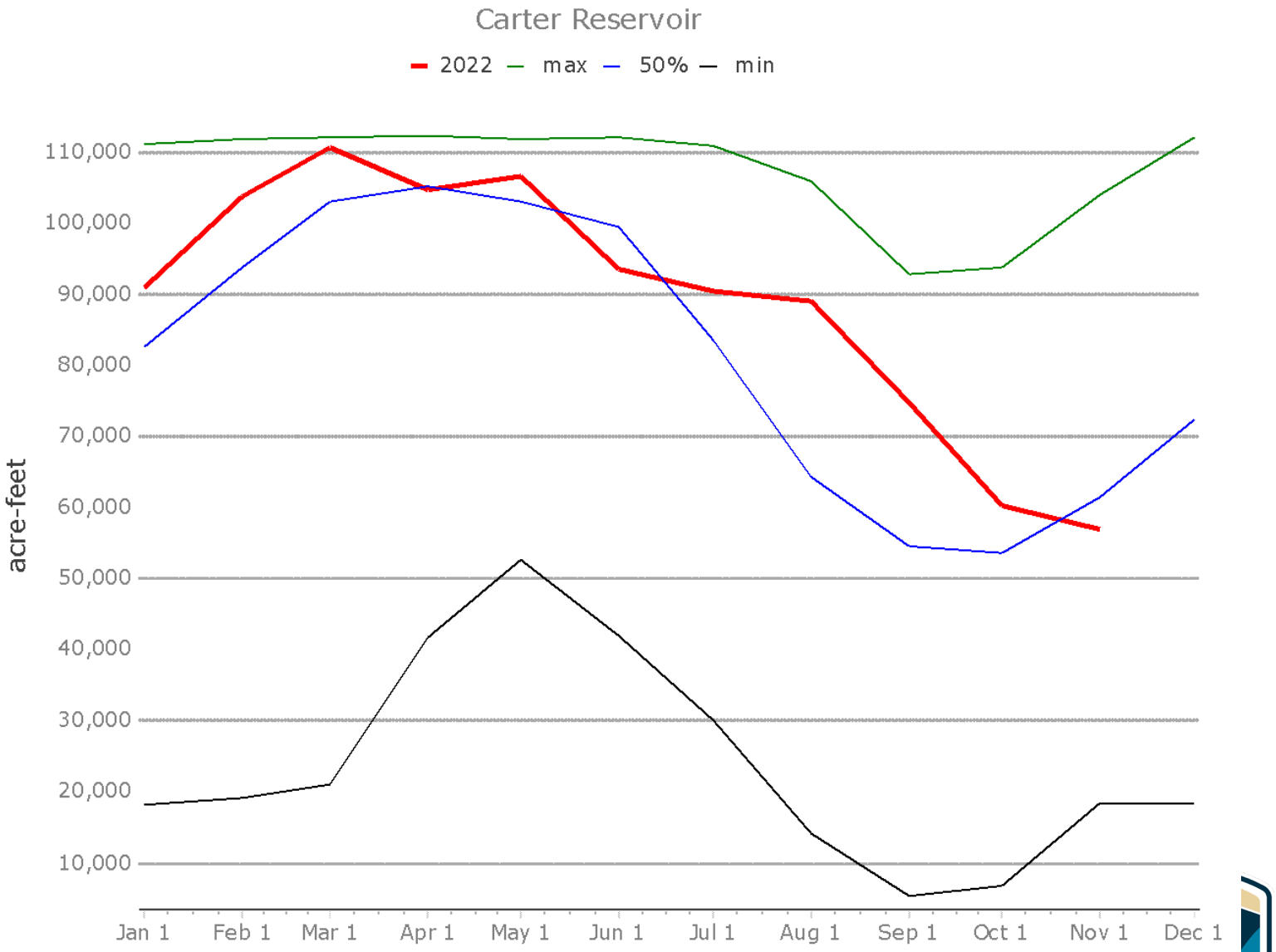
Granby Reservoir Water Storage 2022

- More water is being stored in Granby Reservoir due to the Adams Tunnel Maintenance and other related projects.

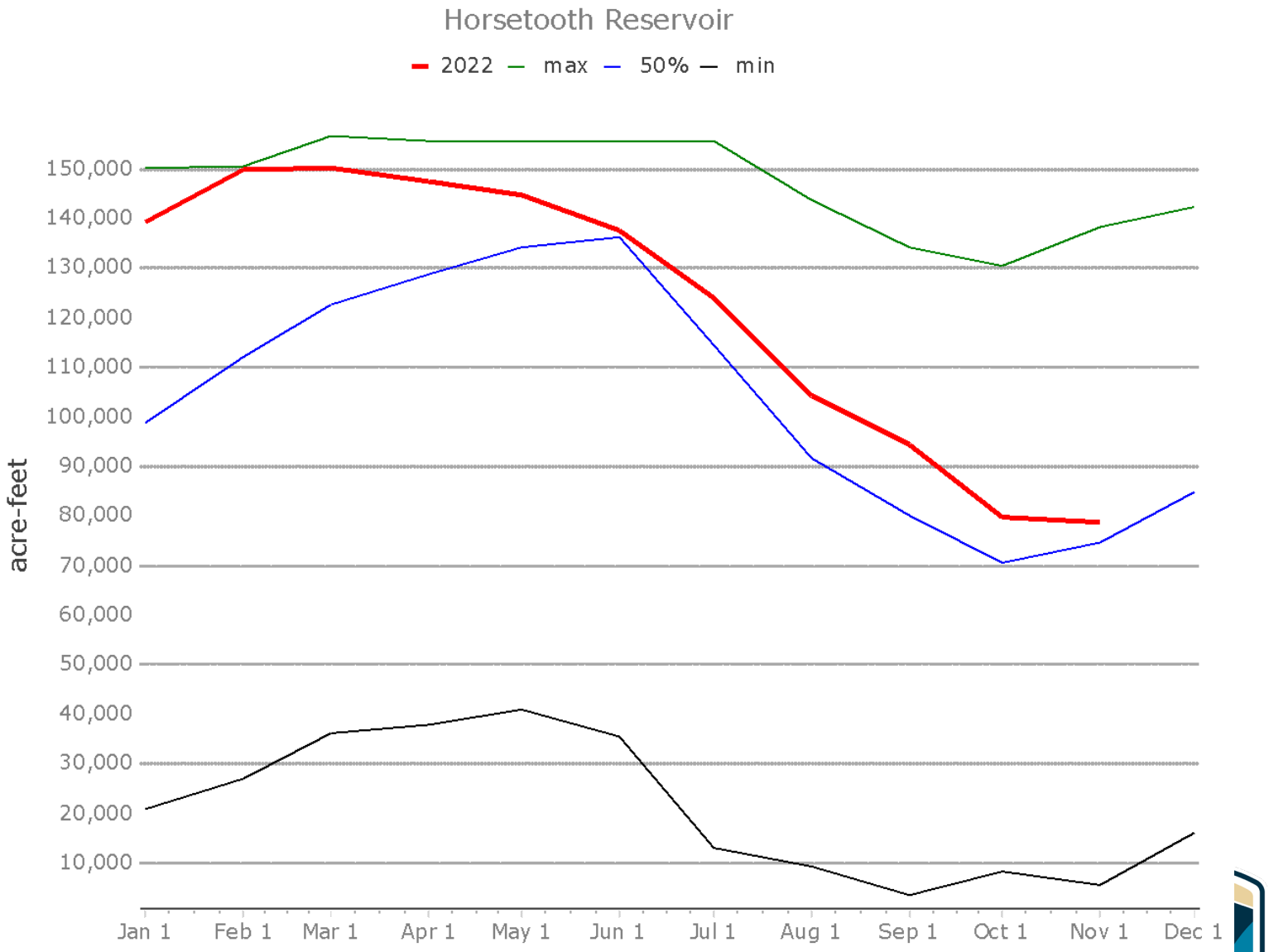


Carter Reservoir Water Storage 2022

- Extra water was stored in Carter Reservoir in anticipation of maintenance work starting in August.



Horsetooth Reservoir Water Storage 2022

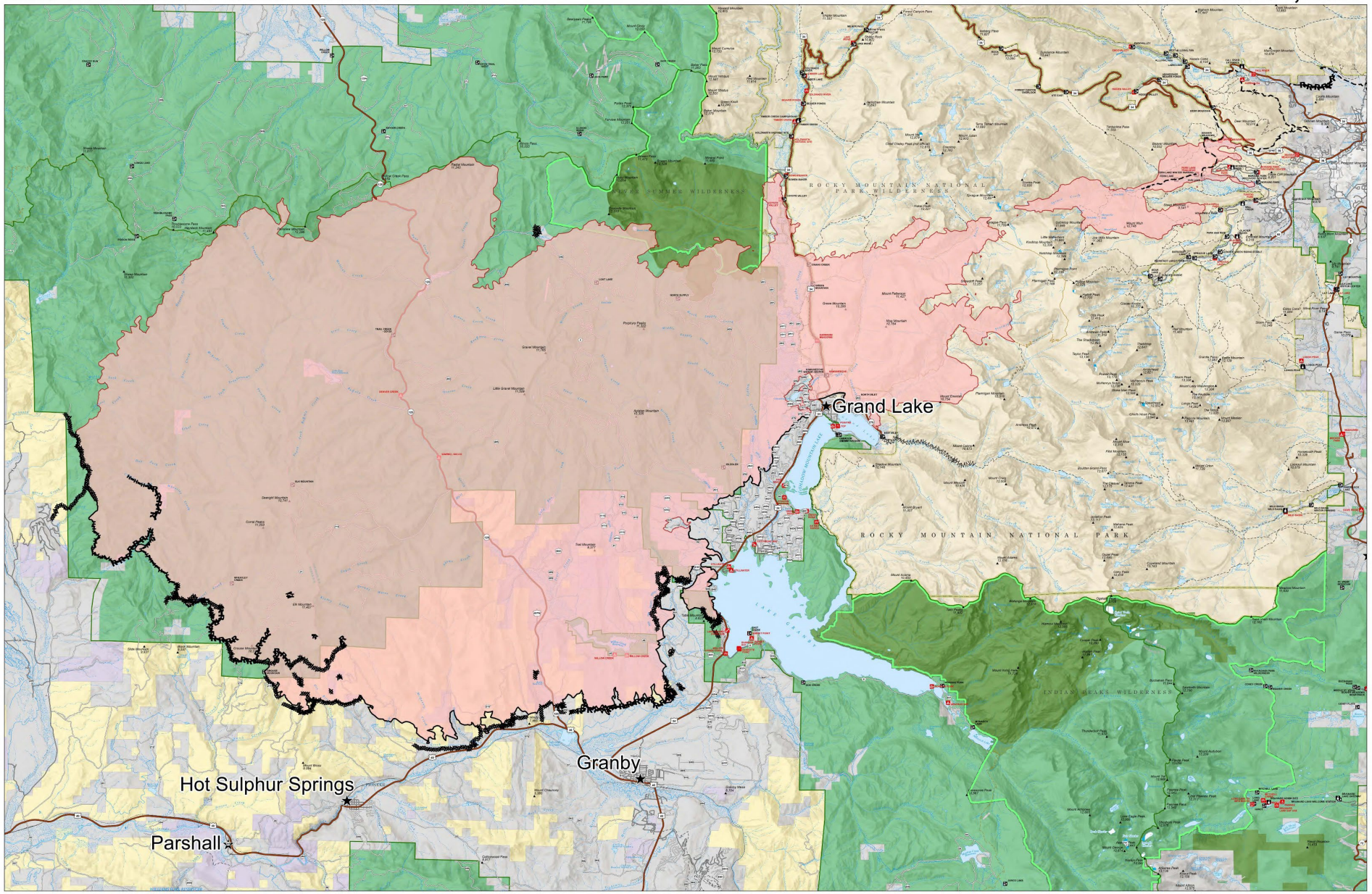


- Not as affected by the maintenance operations.
- Reasons:

1. 70% quota
2. Demands have been normal
3. Some rain occurred in the system.

East Troublesome Creek - Grand Zone

October 30, 2020



10/27/20 1354 hrs
193,774 Total Acres
188,910 Grand Zone
4,864 Thompson Zone

- Fire Perimeter
- Contained Line
- Completed Dozer Line
- Completed Hand Line
- Road as Completed Line
- Line Break Completed
- Proposed Dozer Line
- Planned Fire Line
- Fraser Experimental Forest
- Forest Service
- Bureau of Land Management
- Federal|National Park Service|National Park
- State|Other or Unknown State Land|State Other or Unknown
- State
- Wilderness
- Wilderness Area, National Park Service
- World Hillshade

N

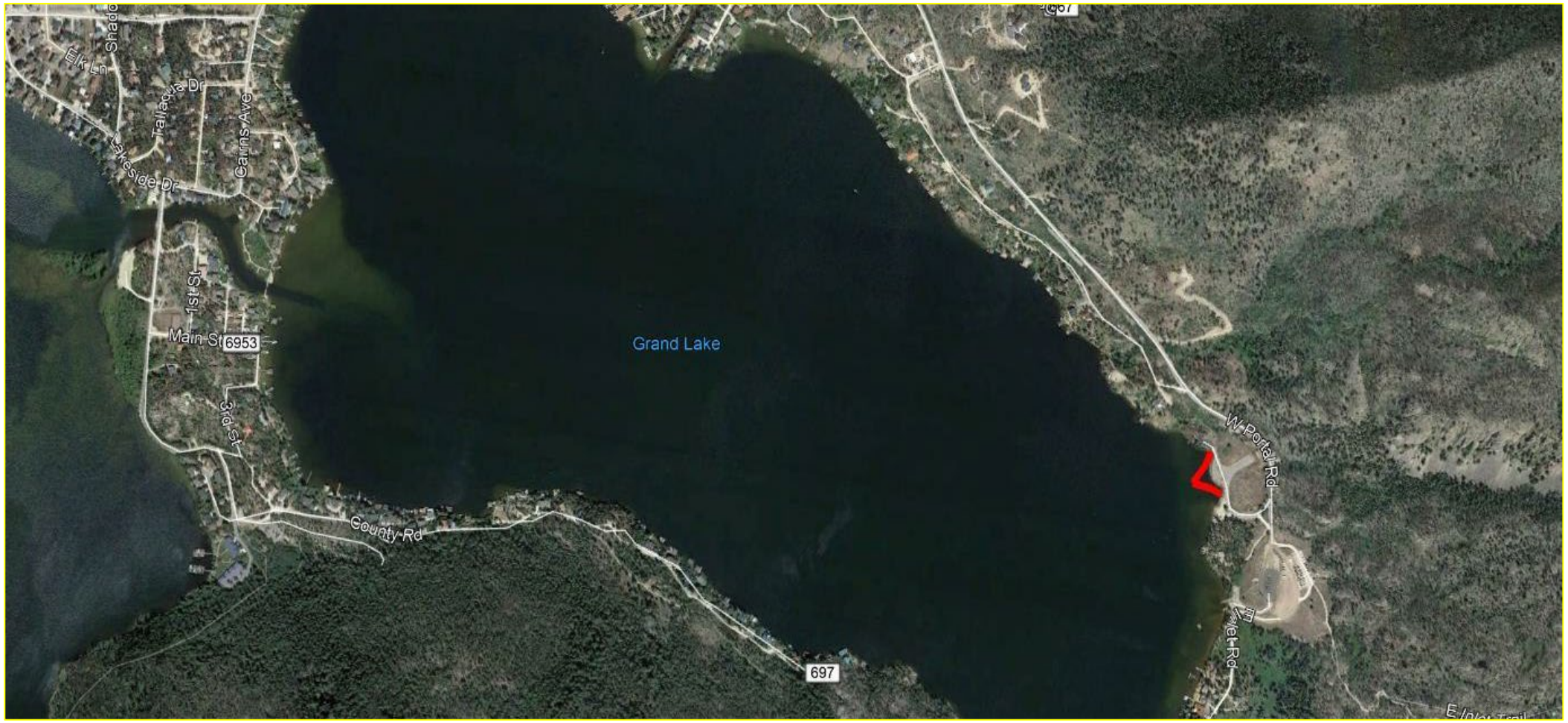
0 1 2 Miles

East Troublesome Fire Recovery Efforts

- Pre-existing Debris Removal
- (next slides) Boom placement at Willow Creek and West Portal
- Sediment basins
- Hillslope Erosion Control – Aerial mulching and seeding, contour falling of trees, waddles
- Streambank Stabilization and Overflow Channels
- Road & Bridge Protection
- Flood Control

Willow Creek Reservoir Debris Boom Installations

- Debris boom locations



West Portal Debris Boom Installation

- Debris boom location