DROUGHT AND INFRASTRUCTURE

A Planning Guide

OCTOBER 2021

Cybersecurity and Infrastructure Security Agency *with the*
National Drought Resilience Partnership

(U.S. Department of Agriculture, Environmental Protection Agency, National Oceanic and Atmospheric Administration, and Federal Emergency Management Agency)

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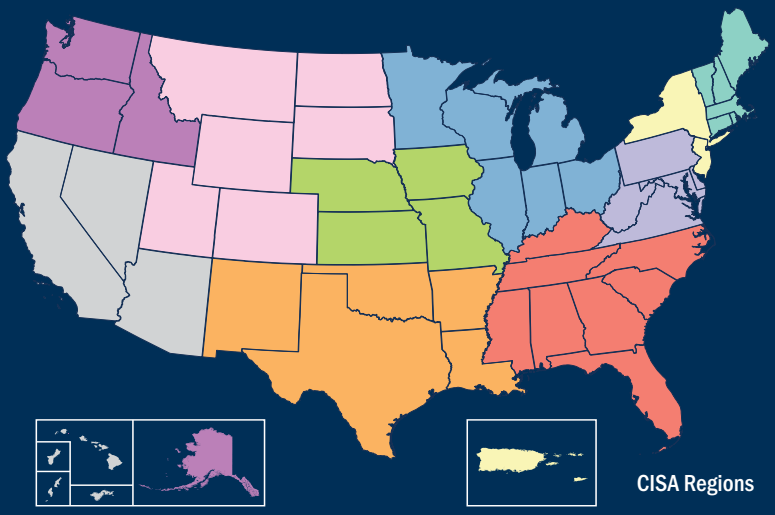

Cybersecurity and Infrastructure Security Agency with the National Drought Resilience Partnership

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October 2021

Introduction

This Drought Guide can be used to **anticipate and prepare for the consequences of drought on infrastructure services**. This guide was developed through the interagency National Drought Resilience Partnership (NDRP). It directs users to the National Integrated Drought Information System (NIDIS) (drought.gov) and other agencies' information and decision tools.[1]

Periodic or sustained drought affects most U.S. regions and territories, potentially disrupting the economy, public health, and the operation of critical infrastructure systems. Changing extremes in precipitation are projected across all seasons, including higher likelihoods of both increasing heavy rain and snow events and more intense droughts. Increased drought frequency and intensity can turn marginal lands into deserts. Water shortages will result in conflicts over priority use and increase the vulnerability of multiple infrastructure systems to primary and secondary disruptions. Federal and state legal requirements mandating water allocations for ecosystems and endangered species add further competition for water resources.

Forecasting Tools for Anticipating Drought

The following drought forecasting tools provide monitoring and predictions for drought by different regions within the U.S., which are important for drought preparedness and mitigation:

- National Integrated Drought Information System (NOAA NIDIS)
- U.S. Drought Monitor
- Climate Prediction Center (NWS)
- Historical Palmer Drought Indices (NOAA)
- Drought Impact Reporter (NDMC)

Unlike hurricanes or other incidents, **drought can be slow-moving and hard to recognize until it is too late to mitigate the impacts**. Drought impacts all facets of our society, from food production to water quality to public health. Communities depend on water for economic and physical survival. If government and private industry fail to anticipate and manage the consequences of drought in advance, conflicts and losses can occur between competing urban, rural, and industrial demands, thus disrupting critical services.

Over the past three decades, 26 major droughts have cost the Nation at least $249 billion, second only to hurricanes.[2] In 2012 alone, approximately two-thirds of the continental U.S. was affected by chronic drought. As such, the need to prepare and protect communities, agriculture, businesses, and individuals threatened by drought is increasingly critical.

1 *This Drought Guide aligns with the National Preparedness Goal and the National Infrastructure Protection Plan and draws on materials produced for the 2018 National Drought Resilience Partnership Goal 2, Communicating Drought Risk to Critical Infrastructure. Although not cited in each section separately, this document references drought risk and impact reports available through other federal agency members of the NDRP including the National Drought Information System (NDIS); the University of Nebraska's National Drought Mitigation Center (NDMC); When Every Drop Counts, published by the National Center for Disease Control; and Drought Response and Recovery: A Basic Guide for Water Utilities, published by EPA Water Security Division Products and Lists. Users should seek out these source sites and documents, which are also listed in the Supplemental Resources section of this guide.*

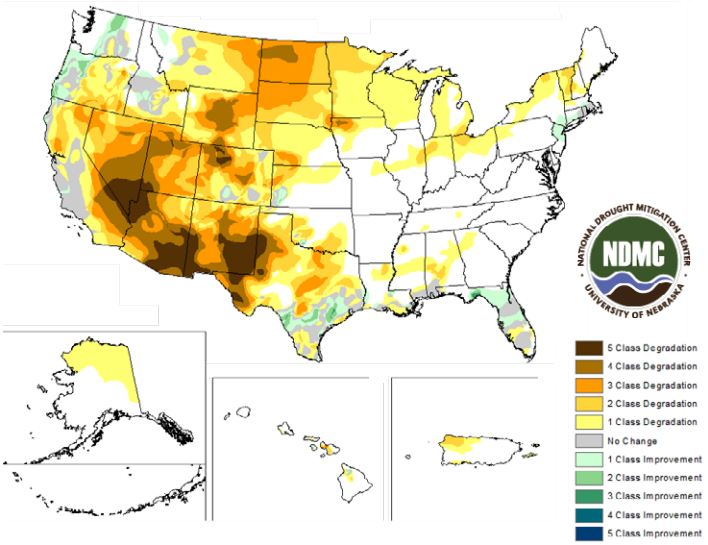
2 *Smith, A. (2020, January 8). 2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters. Retrieved January 4, 2021, from NOAA Climate.gov website.*

Drought Overview

Changing extremes in precipitation are projected across all seasons, including higher likelihoods of more intense droughts and heavy rain and snow events. **Drought conditions can impact several critical infrastructure sectors within a region** including: Water & Wastewater, Energy, Agriculture & Food, and Healthcare & Public Health. Urban infrastructures are especially vulnerable because of their interdependencies; strains in one system can cause disruptions in others.

According to the U.S. Drought Monitor (USDM) and historical Palmer Drought Index, both drought and rainfall are becoming more extreme during decades of increased average heat indexes. Compared to the wetter 1980s and 1990s, the first two decades of the 2000s saw extensive drought and extensive wetness with more than 27% of the U.S. experiencing moderate to exceptional drought in mid-summer 2020. Drought across the West and southern High Plains expanded and intensified long-term dry conditions. Short-term drought in the Southeast, Iowa, and western Ohio Valley and southern Great Lakes reduced or pushed back long-term wet areas. The short-term drought in the Northeast began to have areas of long-term drought while the central Plains and Ohio Valley became wetter. When annual water loss from transpiration by plants and from evaporation is higher than annual precipitation, water supply for critical infrastructure operations can be affected. (See NCDC NOAA State of the Climate).

The U.S. Drought Monitor provides maps, updates, and projections of drought conditions as illustrated below.



U.S. Drought Monitor Class Change
Start of Water Year, March 16, 2021
compared to March 17, 2020
via droughtmonitor.unl.edu

Drought Types and Hazards

The climatological community has defined four **primary types of drought** that present direct and secondary hazards, listed below:

1. **Meteorological drought:** Occurs when dry weather patterns dominate an area and can begin and end rapidly.
2. **Hydrological drought:** Occurs when low water supply becomes evident, especially in streams, reservoirs, and groundwater levels, usually after many months of meteorological drought and takes time to develop and then recover.
3. **Agricultural drought:** Occurs when soil moisture is insufficient and results in the lack of crop growth and production, which is primarily concerned with short-term drought situations.
4. **Socioeconomic drought:** Occurs when the demand for an economic good exceeds supply as a result of a weather-related deficit in water supply.

Each drought type threatens disruption of goods and services produced by critical infrastructure sectors.

Direct hazards resulting from drought that threaten critical infrastructure sectors include:

- **Raw water availability:** Decreased supply, increased demand, and competition between water dependent sectors and community needs.
- **Raw water quality degradation:** Increased concentration levels of contaminants, pollutants, sediments, and solid waste as raw water volumes diminish.

Secondary hazards resulting from drought that threaten critical infrastructure sectors include:

- **Land subsidence exacerbation:** Shrink-and-swell periods, less moisture and reduced stability of soil, contributing to soil erosion. Can result in increased risk of damage to infrastructure assets and structures due to shifts in soil/foundation.
- **Wildfires:** Reduced moisture in vegetation, air, and ground. Vegetation becomes less resilient to combustion, thus enabling fire to spread more quickly. Can increase risk of fire damage to exposed critical infrastructure.
- **Flooding:** Reduced moisture in vegetation and ground, hardened top soils and soil erosion, and increased volume of rain during drought periods, when rain does occur. Can increase risk of flooding and saltwater intrusion due to lower water levels.
- **Dust storms:** Reduced moisture in air and soil, longer periods between precipitation periods. Can result in increased coating of dust and other contaminants, mainly impacting electrical transmission lines.

Potential Impacts to Critical Infrastructure

In addition to known agricultural impacts, the Cybersecurity and Infrastructure Security Agency (CISA) has identified potential impacts of drought to the operation of other critical infrastructure sectors. These effects are illustrated in the Supplemental Resources section of this Guide.

Water & Wastewater

Water supply and demand is influenced by many changing factors, including climate, population, and land use. Decreased water availability, exacerbated by population growth and land-use change, will continue to **increase competition for water**. This will impact both the region's economy (agriculture, energy, and tourism) and its unique ecosystems. Increasing population and continued development of urbanized areas will increase water demand and will exacerbate conflicts between urban, agricultural, and industrial uses. Saltwater intrusion into freshwater aquifers threatens supplies and environmentally sensitive wetlands and wildlife habitats that must be protected by federal and state law. Increased groundwater withdrawals could accelerate ongoing aquifer depletion and limit the ability to irrigate, turning marginal lands into deserts.

Although average household water use has declined with conservation efforts, these are insufficient to mitigate sustained drought in the face of increasing populations and demands. Large water utilities must evaluate how water supply may change in conjunction with climate change, and which adaptation options are most viable.

The filtration components in surface water treatment facilities are designed based on historical water quality data. Systems are not designed to address the increased concentration of pollutants, chemicals, heavy metals, or sediment that can result from reduced water supplies. Wildfire and loss of vegetation can result in sediment that clogs water intake systems.

Energy

Significant amounts of water are used to produce hydroelectric energy and to drive turbines and higher temperatures during drought affect electric lines. Water purification and distribution, and wastewater pumping and treatment are also dependent on the supply of electricity. The trend toward more dry days and higher temperatures will increase evaporation, decrease water supplies, reduce electricity transmission capacity, and increase cooling demands.

The U.S. Department of Energy (DOE) is developing shared systems modeling frameworks to show the relationship between conservation and utility cost savings and to quantify the relationship between energy, water, and food sectors, markets, and regulatory changes (See Capturing the Benefits of Integrated Resource Management for Water & Electricity Utilities and their Partners).

Health

Projected regional temperature increases, combined with the way cities amplify heat, will pose increased threats and costs to public health. Heat stress, a recurrent health problem for vulnerable residents, has been the leading weather-related cause of death in the United States since 1986, when record keeping began. Residential and Commercial heating, ventilation, and air conditioning (HVAC) systems can malfunction from water shortages due to drought, exposing vulnerable populations to extreme heat. Disruptions to urban electricity and water supplies will exacerbate these health problems, as documented by the Centers for Disease Control and Prevention (CDC).

Drought Impact Examples

California
In 2017, a long period of drought led to a fire-damaged landscape in Northern California. An extremely wet winter resulted in rapid runoffs that damaged the Oroville Dam spillway forcing more than 180,000 people to be evacuated.

Columbia Watershed
Reduced water levels caused by drought affected:

- hydroelectric power production for the Northwest Region;
- crop irrigation;
- migration for salmon and steelhead fish as part of the fishing industry; and
- barge navigation on waterways.

Utah
Drought conditions have led to the lowest snowpack level in 30 years, changing the availability and timing of water supplies and substantially affecting the ski and tourism industry.

Central Texas
While droughts are a cyclical phenomenon, the State of Texas has been in a record-breaking drought during most of the current decade. In February 2015, the Lower Colorado River Authority declared that the drought conditions were worse than assumed.

- A number of public water systems experienced water shortages that triggered mandatory water reductions.
- One community required trucking water for more than 2 years at a cost of $400K until new water systems (wells) were brought online.
- Three natural gas steam turbines were taken offline due to water levels below plant cooling water intakes.

Cascading Infrastructure Consequences

The economic impacts of drought affect many sectors of the economy and reach well beyond the area experiencing physical drought. Direct economic impacts of drought affect industries including agriculture, recreation, energy, tourism, timber, fisheries, and others that rely heavily on water. Indirect economic impacts of drought can be just as severe and damaging as direct impacts. Indirect impacts include job losses, business failures, lost investments, economic uncertainty, and changed development and consumption patterns.

Drought often correlates with large wildfire events and changes to soil that increase cyclical flooding and/or result in land subsidence. Wildfires affect human health through reduced air quality and direct injuries. In addition to fire damage to buildings, smoke and ash can harm human health and damage HVAC systems in affected areas. Fires and flooding are increasing across the U.S., causing extreme stress to historic water management infrastructure. Increased extreme weather events lead to alternating drought and flood cycles that can stress dams and other infrastructure that was designed for different trends, as noted by FEMA (Fourth National Climate Assessment Volume II - Chapter 3: Water) and the U.S. Global Change Research Program (USGCRP) Climate Science Special Report (Chapter 8: Droughts, Floods, and Wildfire).

Photo by **Marcus Kauffman** on Unsplash.

Planning, Mitigation and Adaptation Strategies

A region's economy, natural systems, and many infrastructure systems vital to critical services all face important drought-related risks. Dominant adaptation strategies for the agriculture sector include altering local planting choices to better match new climate conditions and developing heat-tolerant crop varieties and breeds of livestock. Most critical for effective adaptation is the **delivery of climate risk information to decision-makers at appropriate temporal and spatial scales** and a focus on cropping systems that increase water-use efficiency, shifts toward irrigation, and more precise control of irrigation delivery. Drought preparedness and recovery require an iterative risk management approach to protect a region's economy, infrastructure, natural systems, public health, and important agriculture and energy sectors.

Also, the key is planning for drought resilience and building proactive partnerships between water, electric, and other infrastructure providers and federal, state, local, tribal, and territorial partners within the region.

Drought Resilience Measures Example

A CISA Regional Resiliency Assessment Project (RRAP) report for Central Texas, for example, identified the following drought resilience enhancement options:

- Organize a **state water summit** to discuss lessons learned, new technologies, and new data sources to support planning
- Include **public messages about the importance of water conservation** strategies at all times, not just during periods of drought
- Incorporate the **potential effects of climate change** on precipitation and temperatures into water and wastewater and energy infrastructure planning
- Develop a shared set of **surface and groundwater planning tools** that any public water system can use

Table 1, below, includes key drought considerations and example mitigation actions/resources to help counties, local governments, tribal and territorial governments, and federal regional offices work with other stakeholders to reduce vulnerabilities to drought. The table is organized by standardized planning steps reflected in the CISA Infrastructure Resilience Planning Framework and other agencies' planning guidelines. Informational resources are also identified within the table as a starting point for those planning for drought.

Table 1: Drought Planning and Adaptation Considerations and Resource[3]

Drought Considerations	Resources
1 LAY THE FOUNDATION • Identify drought threats and hazards in the region • Identify stakeholders and establish a working group to prepare for drought and monitor mitigation and adaptation outcomes	▸ Tools to help identify drought hazards are located on page one of this primer. ▸ FEMA – Planning for Drought Resilience: Fact Sheet ▸ U.S. Climate Resilience Toolkit U.S. Climate Resilience Toolkit ▸ The United States Department of Agriculture (USDA), Department of Interior and other federal regional offices, regional planning and development councils, State Climatologist, State Water Board and state regulatory agencies and policy makers, watershed districts, Resource Conservation and Development Districts, county or city managers and public works directors, infrastructure owners and operators, and decision makers.
2 CRITICAL INFRASTRUCTURE IDENTIFICATION • Identify potential critical infrastructure disruptions across sectors • Prioritize infrastructure services and facilities for action	▸ CISA Protective Security Advisors ▸ CISA Critical Infrastructure Information Sources ▸ U.S. Department of Interior WaterSMART ▸ U.S. Army Corps of Engineers: Institute for Water Resources
3 RISK AND VULNERABILITY ASSESSMENT • Identify potential primary, secondary or cascading consequences for operations and services • Consider secondary impacts to the economy, health, and vulnerable populations • Identify priorities and potential conflicts that must be addressed by the working group	▸ EPA – Climate Resilience Evaluation and Awareness Tool – includes an assessment tool for drought ▸ CISA – Infrastructure Assessments and Analysis products ▸ CDC – When Every Drop Counts – Provides guidance on drought related impacts to public health. ▸ EPA - Drought Response and Recovery for Water Utilities
4 DEVELOP ACTIONS • Work with different authorities on mitigation, adaptation plans, and strategies • Identify public and private actions needed • Reduce water loss in aging pipes through replacement • Develop rate incentives with state regulators • Educate citizens on how to use water efficiently • Establish emergency interconnections with nearby water or power utilities • Work with federal agencies overseeing major facilities • Work with owners and operators to create back-up plans and identify new technologies • Identify and negotiate demands to reduce conflicts	▸ U.S. Department of Interior WaterSMART ▸ FEMA –"Drought Mitigation Ideas" in Mitigation Ideas – A Resource for Reducing Risk to Natural Hazards ▸ Climate Program Office –"Success Stories" ▸ EPA – "Water efficiency & aging infrastructure" in Drought Resilience & Water Conservation ▸ EPA - Drought Response and Recovery: A Basic Guide for Water Utilities ▸ EPA – WaterSense Program – Identifies water-efficient products and practices, and educates the public ▸ DHS/DOE – Dams and Energy Sectors Interdependency Study, pp. 11-12.
5 PLAN IMPLEMENTATION AND MONITORING • Identify technical and financial resources • Revise local capital improvement program(s) • Consider temporary or long-term water use policies • Identify state, federal, and private funding • Review codes to promote green infrastructure • Work with state, federal, and non-profit agencies to identify new laws, research or measures • Incorporate drought measures into the hazard mitigation and comprehensive local and regional plans	▸ EPA – Federal Funding for Water and Wastewater Utilities in National Disasters (Fed FUNDS) ▸ EPA – Water Infrastructure and Resilience Finance Center and the Water Finance Clearinghouse ▸ International Water Association and other NGOs ▸ National Institute of Standards and Technology (NIST) Building Codes and Standards ▸ USDA – Drought Programs and Assistance ▸ National Association of Development Organizations

3 *Inputs to the planning process and considerations highlighted in Table 1 can be found in the CISA Infrastructure Resilience Planning Framework, FEMA Hazard Mitigation Planning policies and resources (fema.gov/emergency-managers/risk-management/hazard-mitigation-planning); Drought-Ready Communities, A Guide to Community Drought Preparedness (drought.gov/documents/drought-ready-communities-guide-community-drought-preparedness-0), Drought Planning National Drought Mitigation Center (NDMC) (drought.unl.edu/droughtplanning/PlanningHome.aspx)*

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Supplemental Resources

Supplemental resources are being developed by CISA and partner agencies to help regions, counties, and local governments work with stakeholders to mitigate, prepare for, respond to, and recover from drought. Such as, the National Drought Resilience Partnership (drought.gov/about/partners) the following resource is included at the end of this Guide:

- Infographic: **Critical Infrastructure Impacts Due to Drought Hazards**

The following resources are accessed separately and can be obtained by contacting CISA Infrastructure Development and Recovery at IDR@cisa.dhs.gov:

- Infographic: **Dams Sector Drought Hazards**
- Infographic: **Critical Manufacturing Sector Drought Hazards**
- **Consequences of Drought to Infrastructure Services: A Workbook**

For additional resources related to drought and critical infrastructure, please contact the Infrastructure Development and Recovery Program at IDR@cisa.dhs.gov.

CRITICAL INFRASTRUCTURE SECTOR IMPACTS DUE TO DROUGHT HAZARDS

Cybersecurity and Infrastructure Security Agency, Infrastructure Security Division | August 2020

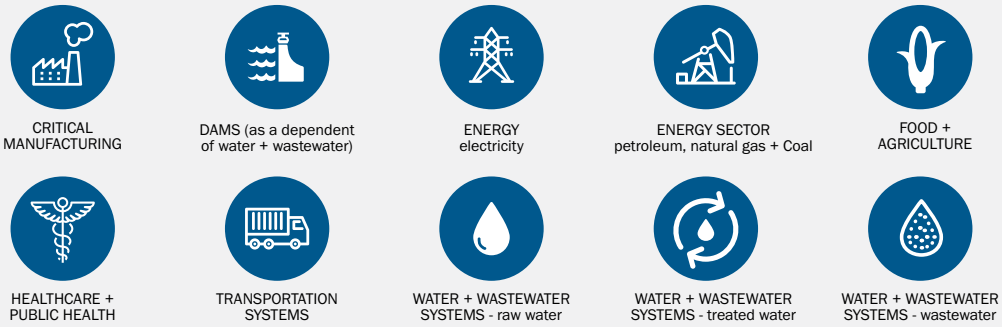
SCOPE

Critical Infrastructure Sector Impacts Due to Drought Hazard

Existing resources from NIDIS, EPA, USDA, DOI, DHS, FEMA, HHS-CDC, and other sources were compiled to create a risk analysis of drought hazard impacts to critical infrastructure sectors. The analysis reflects summaries of identified vulnerabilities of critical infrastructure sectors to direct exposure of drought hazards, operational impacts to each sector that contributes to slow down or stoppage of essential goods and services to meet demand needs, and indirect/cumulative impacts of dependent sectors and communities when supply needs cannot be met. Ten critical infrastructure sectors and subsectors were investigated in the context of five drought hazards.

Drought Hazards

Critical Infrastructure Sectors + Subsectors



KEY FINDINGS

Direct Impacts to Critical Infrastructure from Drought Hazards

Service Provider Critical Infrastructure Sector	Raw Water Availability	Raw Water Quality Degradation	Dust Storms	Flooding	Land Subsidence Exacerbation	Wild Fires
	DROUGHT HAZARDS, DIRECT IMPACTS					
Critical Manufacturing	●	●		○	○	●
Dams						
Energy - Electricity	●	●	●	●		●
Energy - Petroleum, Natural Gas + Coal	●	●		●		●
Food + Agriculture	●	●		●	○	●
Healthcare + Public Health		●		○		●
Transportation Systems	●	●		●	●	●
Water + Wastewater Systems - Raw Water		●	●	●	●	●
Water + Wastewater Systems - Treated Water	●	●	●	●	●	●
Water + Wastewater Systems - Wastewater		●	●	●	●	●

Critical Infrastructure Dependencies + Interdependences

Service Provider Critical Infrastructure Sector	Critical Manuf.	Dams	Energy – Electricity	Energy - Petro, NG, Coal	Food + Ag.	HC + Public Health	Trans.	Raw Water	Treated Water	Waste Water
	SERVICE RECEIVER (DEPENDENT) CRITICAL INFRASTRUCTURE SECTOR									
Critical Manufacturing	●	○	●	●	●		●	●	●	●
Dams	○	–	●	●	●		●	●	●	●
Energy - Electricity	●	●	–	●	●	●	●	●	●	●
Energy - Petroleum, Natural Gas + Coal	●	●	●	–	●	●	●	●	●	●
Food + Agriculture	●	○		●	–	●	●	●	●	●
Healthcare + Public Health	●	●	●	●	●	–	●	●	●	●
Transportation Systems	●	●	●	●		●	●	●	●	●
Water + Wastewater Systems - Raw Water	●	●	●	●	●		●	–	●	○
Water + Wastewater Systems - Treated Water	●		●	●		●	●		–	
Water + Wastewater Systems - Wastewater	●	●	●	●	●	●	●	●		–

○ *Dependency understood but not identified specifically by reference*

Generated by assessments from CISA