THE Water Research FOUNDATION

PROJECT NO.
4729

Mapping Climate Exposure and Climate Information Needs to Water Utility Business Functions: Appendix E

Water Utility Business Risk and Opportunity Profiles

DENVER WATER

WUCA
Water Utility Climate Alliance

Mapping Climate Exposure and Climate Information Needs to Water Utility Business Functions Appendix E: Water Utility Business Risk and Opportunity Profiles

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Water Utility Climate Alliance

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CLIMATE RISK AND OPPORTUNITY PROFILE

Austin Water

CLIMATE PROJECTIONS

Drought
From 2008 to 2016, the Austin region experienced a historic drought. Higher temperatures will increase naturally occurring droughts.[5]

Heatwaves
Long periods of extreme heat have increased, causing stress to community health and power availability.[1]

Flooding
Extreme flooding events have damaged infrastructure that provides facility access.[3]

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Planning, Modeling, Forecasting, and Analysis
Austin Water has used four planning horizons to assess precipitation, temperature, and evaporation projections.

Business Affairs
The extended drought from 2008 to 2016 reduced water demand and impacted revenue, which resulted in rate structure adjustments.

Treatment
Austin Water's major water and wastewater plants have experienced limited functionality and access during recent large flooding events.

UTILITY OVERVIEW

For more than 100 years, Austin Water has been committed to providing safe, reliable, high-quality, sustainable, and affordable water services. Over the last several years, Austin Water has faced major climate and extreme weather events including drought, extreme and prolonged heat waves, more severe flooding events, shifts in precipitation patterns, and wildfires. Extreme flooding events have impeded treatment plant operations and damaged infrastructure that provides access to key utility facilities.

Austin Water is currently developing plans to expand water supply storage capacity and improve access to facilities, so each facility is more resilient to climate change risks including flooding and drought. Austin Water has also identified funding and strategies to repair and bring systems back more quickly after extreme events, including using FEMA funding sources to repair damaged facilities.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends include the following:

- Mean annual temperature has increased by approximately 1°F since the first half of the 20th century.[2]
- More than 18 million people living in Texas, or 72% of the state's population, are currently living in areas at elevated risk of wildfire.[4]

FUTURE CLIMATE

Projected changes include the following:

- By 2050, the state is projected to see 115 dangerous heat days a year, second only to Florida.[4]
- Higher temperatures will increase soil moisture loss during dry spells, intensifying naturally occurring droughts.[2]
- Texas currently faces the worst threat from widespread summer drought among the lower 48 states. [4]

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

PLANNING, MODELING, FORECASTING, AND ANALYSIS

- **Summary:** Austin Water worked with Dr. Katharine Hayhoe to develop climate change adjusted streamflow projections over the 100-year planning horizon, using 20 Global Climate Models on an 8.5 Representative Concentration Pathway.
- **Current risk:** Austin Water's planning horizons vary depending upon department needs. Financial planning typically considers 1-, 5-, and 10-year horizons, while infrastructure and water supply planning prioritize near and mid-terms needs and consider 100-year and lifespan planning horizons.
- **Climate impacts include:** All climate change impacts (drought, flooding, heatwaves, etc.), even remote to the region, will affect planning, modeling, forecasting, and analysis.
- **Opportunities:** The Water Forward Integrated Water Resource Plan includes strategies for the 2020, 2040, 2070, and 2115 planning horizons, with more detailed implementation plans for the time period between now and 2040.

Climate Stressors and Risks **PLANNING, MODELING, FORECASTING, AND ANALYSIS**	
Stressors	**Risks**
• Increased average temperatures • Increased frequency and intensity in heat waves • Increased incidence of drought • Increased flooding • Increased intensity and frequency of heavy rainfall events	• Much wider range of possible future conditions • Changes in availability of local and regional water supplies • Changes in demand for outdoor irrigation and other water uses

BUSINESS AFFAIRS

- **Summary:** Austin Water has had several severe flooding events that have damaged utility infrastructure, but its catastrophic insurance has provided some reimbursement for damage. The extended drought from 2008 to 2016 impacted Austin Water significantly.
- **Current risks:** Reduced water demand has impacted revenue, which resulted in rate structure adjustments intended to stabilize revenues. Finances were strained to the point that bond rating agencies put the utility on a negative watch, although that has now been removed and finances have stabilized.
- **Climate impacts include:** Extreme events including increases in heat waves, storm intensity, and precipitation linked to droughts and flooding.
- **Opportunities:** Austin Water completed a joint committee process where commissioners from three different city council-appointed commissions convened when drought conditions and accompanying decreased water use led to significant losses in revenue. Austin Water looked at various options for financial planning, such as rate changes, increasing fixed charges, drought rates, and increased reserves, to help the utility absorb some of the financial impacts.

Climate Stressors and Risks **BUSINESS AFFAIRS**	
Stressors	**Risks**
• Increased frequency in heat waves • Increased incidence of drought • Flooding • Increased acres burned and severity of wildfire	• Increase in flood frequency and magnitude • Impeded drinking water production • Flooding of stormwater outfalls • Flood damage to infrastructure

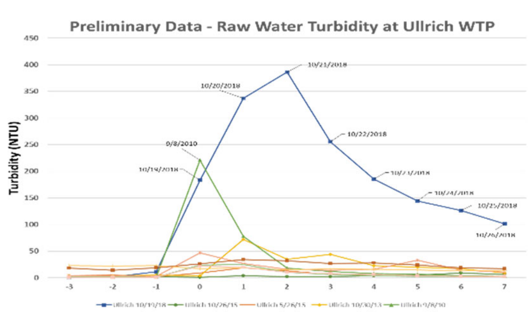
WASTEWATER TREATMENT

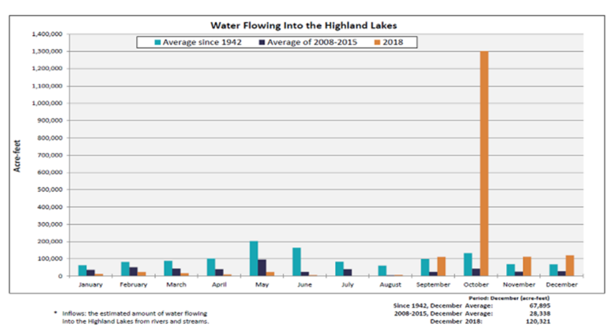
- **Summary:** Several City of Austin departments convened and noted that both of Austin's wastewater treatment plants are near floodplain areas, and one requires bridge access that is maintained by a different entity.
- **Current risks:** One of Austin Water's major wastewater treatment plants have experienced limited access during recent large flooding events.
- **Climate impacts:** Impacts include flooding, shifting precipitation patterns, increased intensity, and frequency of heavy rainfall.
- **Opportunities:** The process of intradepartmental coordination showed that while the bridge for wastewater treatment access may not be a priority for the traffic-related transportation team, it is a priority for Austin Water. Austin Water found it very useful to think about how to prioritize actions across departments and business functions.

DRINKING WATER TREATMENT AND STORAGE CAPACITY

Climate Stressors and Risks **WASTEWATER TREATMENT**	
Stressors	**Risks**
• Increased flooding • Increased intensity and frequency of heavy rainfall • Land use changes • Increased incidence of drought	• Increased challenge accessing wastewater treatment facilities • Flood impacts on wastewater treatment capacity and infrastructure • Stormwater intrusion into wastewater systems • Regulatory issues due to water quality concerns

- **Summary:** A catastrophic upstream flood in October 2018 resulted in dramatic increases in the turbidity of Austin's raw water supply. This reduced drinking water treatment plant production and resulted in emergency conservation measures and a city-wide boil water notice that lasted for seven days.
- **Current risks:** Future flood events could result in a recurrence of this scenario.
- **Climate impacts:** Impacts include flooding, shifting precipitation patterns, increased intensity, and frequency of heavy rainfall.
- **Opportunities:** Austin Water is developing turbidity triggers for issuing future emergency conservation measures. Expanding Austin's drinking water storage capacity has become a higher priority.





Source: Courtesy of Austin Water.

Climate Stressors and Risks **DRINKING WATER TREATMENT AND STORAGE CAPACITY**	
Stressors	**Risks**
• Increased flooding • Increased intensity and frequency of heavy rainfall • Land use changes • Increased incidence of drought	• Increased challenge managing turbidity in raw water supplies • Impacts on drinking water plant production and pressure within the distribution system • Impacts on drinking water storage capacity

Utility Strategies, Plans, and Reports

- Water Forward – (Adopted Nov 2018)
- Climate Change Projections for the City of Austin (2014)
- City of Austin Climate Resilience Action Plan (2018)
- Understanding the Drought (2015)

Sources

[1] Melillo, J. M., T.C. Richmond, and G.W. Yohe, Eds. *Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment.* Prepared for the U.S. Global Change Research Program, p. 148. 2014. Website: https://nca2014.globalchange.gov/highlights

[2] Runkle, J., and K. E. Kunkel. *Texas State Summary*. Prepared for NOAA Technical Report NESDIS 149-TX, p. 4. 2017. Website: https://statesummaries.ncics.org/tx#

[3] U.S. Global Change Research Program. *DRAFT Fourth National Climate Assessment – Southwest Public Review Chapter.* 2017. Website: https://www.globalchange.gov/content/nca4-planning

[4] Climate Central. *States at Risk – Texas*. 2018. Website: http://statesatrisk.org/texas/all

[5] Austin Water. *Understanding the Drought*. 2015. Website: http://www.austintexas.gov/sites/default/files/files/Water/Drought/Understanding_the_Drought_Feb2015.pdf.

CLIMATE RISK AND OPPORTUNITY PROFILE
Fort Collins Utilities

CLIMATE PROJECTIONS

Extreme Temperature
Statewide average temperatures are projected to increase by 2.5°F to 5°F by 2050 under an RCP 4.5 scenario.[3]

Wildfires
Increased warming, drought, and insect outbreaks have increased wildfires and impacts to people and ecosystems.[1]

Seasonality of Precipitation
Annual streamflows in all of Colorado's river basins could decrease and peak streamflows are projected to come earlier in the year.[3]

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Stormwater Management
Intensity of precipitation and the occurrence of drought put the utility's stormwater management systems at risk.

Asset Management
Increased frequency of extreme climate-related events may increase asset maintenance and replacement costs.

Engineering and Design
Failure to consider climate change projections in design and throughout master planning could have serious impacts on critical utility functions and ability to meet demand.

UTILITY OVERVIEW

Fort Collin's first city sewer system was built in 1888, with five sewer districts formed by ordinance in 1891. The city established a public works department in the early 1900s and then obtained senior water rights and built the Poudre Canyon Treatment Plant.

Today, Fort Collins has not experienced many significant climate-related incidents, which has made it difficult to act on the topic. Fort Collins Utilities has primarily promoted climate change mitigation and has not facilitated much community conversation about adaptation and resilience. However, the utility is in the planning, design, and construction stage of infrastructure development, which is the right time to discuss future risks and opportunities.

Fort Collins Utilities is not using downscaled modeling for its *Water Supply Vulnerability Study;* instead, it is completing the modeling with a range of precipitation and temperature changes. It will map these results against the range of climate model predictions rather than assessing plans against a single climate model.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends include the following:

- Increased warming, drought, and insect outbreaks have increased wildfires and impacts to people and ecosystems.[1]
- Renewable hydropower in the Southwest has declined during drought, due in part to climate change.[2]

FUTURE CLIMATE

Projected changes include the following:

- Statewide average temperatures are projected to increase by 2.5° F to 5° F by 2050 under a medium-low (RCP 4.5) emissions scenario.
- The frequency and extent of wildfires are projected to increase, and that increase will likely lead to more destructive flooding.[1]

The following pages of this risk and opportunity profile outline the relevant climate drivers, both risks and opportunities, mapped to Fort Collins Utilities' key business functions as identified by Fort Collins Utilities in August 2018.

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

Fort Collins Utilities participated in this research project to investigate how the utility's core business functions anticipate climate risks and opportunities. Fort Collins Utilities identified stormwater management, asset management, and engineering and design as the three business functions of highest interest in relation to climate change.

STORMWATER MANAGEMENT

- **Summary:** Fort Collins Utilities' stormwater management includes forecasting, water quality management, design and maintenance of collection and storage infrastructure, floodplain management, land use, and planning, development, and regulation.
- **Current risk:** The utility's water quality management and maintenance of infrastructure are at risk due to precipitation intensity, extreme temperatures, and drought.
- **Barriers to action:** Fort Collins Utilities requires quality climate data to update stormwater management design standards.
- **Opportunities:** For Fort Collins Utilities' Water Supply Vulnerability Study, the utility is completing the modeling with a range of precipitation and temperature changes. This modeling can also inform scenario analysis for stormwater management.

Case Study

Water and Wastewater Utilities Planning for Climate Change

A case study on the climate threats, the planning process, and adaptation efforts by Fort Collins Utilities to mitigate water quality issues caused by flash flooding following wildfires.

Impacts of Climate Drivers and Underlying Conditions

Flooding and Erosion

Climate Drivers	Impacts
Runoff Volume Higher Precipitation Intensity	• Damage to infrastructure and increased insurance risk • Floodplain changes, channel stability, and debris management • Health and safety concerns connected to rain or snow events

Water Quality

Climate Drivers	Impacts
Extreme Temperatures Higher Precipitation Intensity Drought	• Sedimentation of reservoirs and holding facilities • Increase in concentration and volume of pollutants of concern • Increase in disease vectors, growth of algal blooms, and changes to aquatic habitat

Other Impacts

Climate Drivers	Impacts
Drought Extreme Temperatures	• Aesthetic and habitat value reductions in multipurpose facilities • Increase in electric power needs and the need for landscape irrigation and fire prevention around facilities

STORMWATER MANAGEMENT	
Risks	**Opportunities**
• Flooding and erosion from higher intensity precipitation • Damage to private and public property • Increased cost and complexity of flood control projects and programs	• Site design and landscaping to mitigate temperature increases and aesthetic issues • Coordinate with upstream diverters • Expand regulatory floodplain/greenspace • Reconsider flood control operations to maximize water supply benefits

ASSET MANAGMENT

- **Summary:** Fort Collins Utilities asset management includes lifecycle analysis, service levels, reliability, maintenance standards, infrastructure development, mapping, strategic planning, and data collection.
- **Current risk:** Thus far, Fort Collins has not experienced many significant climate-related incidents, so has not yet acted in a major way to adapt assets to climate risks; however, Fort Collins Utilities understands the potential future risks and is approaching this topic with great interest at present.
- **Opportunities:** Fort Collins Utilities has opportunities to maintain larger emergency financial reserves and to enhance communications internally and externally.

Impacts of Climate Drivers and Underlying Conditions

Health and Safety

Drought Temperature Increases Higher Precipitation Intensity	• Outdoor workers are at risk from high heat and reduced air quality • Increased risks of main breaks or dam failure due to drought and increased intensity of precipitation • Increased temperatures lead to increased risks from water quality changes and disease vectors

Infrastructure

Drought Temperature Increases Higher Precipitation Intensity	• Increases in pipeline and road damage due to heat and flooding • Increased potential for failure of major equipment • Decreased reliability of communication, data, analysis, and energy systems

Water Quality

Higher Precipitation Intensity Drought Increased Size and Frequency of Wildfire	• Pretreatment required due to increased sediment loading, pollutants and algae • Aquatic habitat loss • Supply operations shifts from flow reduction

Financial Impact

Drought Increased Size and Frequency of Wildfire	• Higher water treatment costs • Reduced land value from habitat quality changes • Revenue losses due to drought restrictions

ASSET MANAGEMENT	
Risks	Opportunities
• Increased maintenance and replacement costs and increased potential for emergency response • Increased costs and public relation problems associated with infrastructure failure	• Maintain larger emergency financial reserves • Increase rate or emergency rate structure • Ensure reliable water and energy supply to at-risk customers • Implement a more aggressive maintenance and repair program • Enhance communications internally and externally

ENGINEERING AND DESIGN

- **Summary:** Fort Collins Utilities' engineering and design work includes surveying, sizing, layout, and design standard development.
- **Current risk:** Engineers at the utility want clear data indicating a specific trend for the Front Range based on the last 50 years of data to inform design standards. Much of the utility's policy guidance is around specific design criteria (i.e., planning for 100-year flood event). As an institution, Fort Collins Utilities has been unable to quantify the impacts of climate change to systems and fully understand how to prepare for it. The utility is challenged with incorporating climate change into policy documents where there is limited climate information.
- **Opportunities:** There is an opportunity to engage more engineers more frequently in conversations about climate projections and its implications throughout planning process. There is also the opportunity to increase the use of scenario-based planning to determine what could happen rather than trying to predict a specific outcome. Scenario planning will assist the utility with flexible long-term planning for a number of uncertain factors related to climate change.

Impacts of Climate Drivers and Underlying Conditions

Infrastructure

Heat and Heatwaves Drought Increased Wind Speed	• Specific facility failures and potential for cascading failures due to increased wind speed, heat waves, and drought • Inability to meet demand for services in the instance of extreme drought or a heat wave

Health and Safety

Increased Extreme Heat Increased Storm Intensity Drought	• Buildings and infrastructure may not withstand increased stresses and may become hazardous • Increased incidence of extreme heat threatens the health of works in the field who are exposed to outdoor conditions for extended periods

Financial Impacts

Change in Runoff Timing Drought	• Higher repair, construction, and reconstruction costs • Rising energy use and cost for heating and cooling • Potential rate structure shifts to account for seasonality changes

Climate Stressors	Impacts
Heat and Heatwaves Drought Change in Runoff Timing	• Increased stress to water quality, water treatment, and stormwater management • Flood control and reservoir storage challenges due to drought and precipitation intensity increases • Strained diversions and delivery facility capacity

ENGINEERING AND DESIGN	
Risks	**Opportunities**
• Failure to consider climate change projections in design and throughout master planning can have serious effects on critical utility functions and ability to meet demand • Health and safety issues • Increased costs to retrofit and repair	• Take advantage of energy and water conservation potential in utility buildings • Enhance urban tree canopy, cool roofs, and low energy design standards • Design standard improvements

*In August 2018, staff from Fort Collins Utilities collaborated with the research team to map three example water utility business functions, **stormwater management, asset management, and engineering and design**, to five different climate stressors and impacts. Stressors and impacts related to precipitation, temperature, and wildfire were common to both drinking water treatment and delivery and water supply. Each checkmark in Table 1 indicates that the climate stressor and impact has an effect on the relevant business function.*

Table 1. Climate Stressors and Impacts

Business Functions	Climate Stressors and Impacts					
	Drought	Precipitation	Runoff	Storms	Temperature	Wildfire
Asset Management	✓	✓			✓	✓
Engineering and Design	✓	✓	✓	✓	✓	✓
Stormwater Management	✓	✓	✓	✓	✓	

SUMMARY OF CLIMATE INFORMATION SOURCES AND TYPES

Below is a summary of climate information sources and types that were identified to help evaluate risks and opportunities for similar water utilities, organized by the five different climate stressors and impacts identified in Table 1. The sources and types represent a sampled and pragmatic, rather than an exhaustive, list of climate information for these examples as the actual number of potential sources and types is large and continues to expand. The following tables can be used as starting points from which a utility can remove or add climate information sources and types that aid in evaluating climate-related risks and opportunities.

Table Key (Tables 2 – 13)

Climate Stressors and Impacts were classified by the following:

- **Derivative:** sources that provide static or interactive content through predetermined analyses or syntheses in graph, map, or text formats.
- **Data:** sources that require end users to download, analyze, or visualize data to generate climate information

(F) = fine-scale information, higher resolution

(B) = broad-scale information, county level or lower resolution

DROUGHT

Table 2. Drought Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Change in Colorado (B)	✓			✓
Colorado State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA NCEI Weekly Divisional Products (B)		✓		
U.S. Drought Monitor (B,F)	✓	✓		
U.S. Drought Portal (B,F)		✓		
U.S. Monthly Drought Outlook (B)			✓	
U.S. Seasonal Drought Outlook (B)			✓	
West Wide Drought Tracker (B,F)	✓	✓		
Western Water Assessment Climate Extremes (B,F)	✓			

Table 3. Drought Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Colorado State Climate Summary (B)	✓			✓
NOAA NCEI Drought Variability[a] (B)	✓			
U.S. Drought Monitor (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		

[a] Tree-ring reconstructions of two drought indices, see the Precipitation section for more related data sources

PRECIPITATION

Table 4. Precipitation Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		√		
Climate Change in Colorado (B,F)	√			√
Climate Explorer (B,F)	√			√
Colorado State Climate Summary (B)	√			√
Fourth National Climate Assessment (B)	√			√
NOAA CPC ENSO Diagnostic Discussion (B)		√	√	
NOAA CPC Precipitation (B)		√		
NOAA NCEI Climate at a Glance (B,F)	√			
NOAA NCEI Daily Summaries Map (F)	√	√		
NOAA NCEI Weekly Divisional Products (B)		√		
NOAA NWS (B,F)		√	√	
NOAA NWS AHPS Precipitation (F)		√		
NOAA NWS CPC (B)			√	
NOAA NWS CPC U.S. Hazards Outlook (B)			√	
NOAA NWS National Operational Hydrologic Remote Sensing Center (B)	√	√		
NOAA NWS Storm Prediction Center (B)			√	
NOAA NWS WPC Quantitative Precipitation Forecasts (B)			√	
PRISM (B,F)	√	√		
SNOTEL and Snow Course (F)		√		
U.S. Climate Atlas (B)	√			
West Wide Drought Tracker (B,F)	√	√		

Table 5. Precipitation Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	√			√
Colorado State Climate Summary (B)	√			√
LOCA (F)				√
NOAA NCEI Climate at a Glance (B,F)	√			
NOAA NCEI Climate Data Online (F)	√	√		
NOAA NWS AHPS Precipitation (F)		√		
The North American CORDEX Program (F)				√
PRISM (B,F)	√	√		
SNOTEL and Snow Course (F)	√			
West Wide Drought Tracker (B,F)	√	√		

RUNOFF

Table 6. Runoff Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Change in Colorado (B,F)	√			√
Fourth National Climate Assessment (B)	√			√
Joint Front Range Climate Change Vulnerability Study (B,F)				√
NOAA NWS AHPS Experimental Long-Range River Flood Risk (F)			√	
NOAA NWS AHPS River Forecasts (F)			√	
NOAA NWS AHPS River Observations (F)		√		
TreeFlow (F)	√			
USGS National Water Information System (F)	√	√		
Western Water Assessment Climate Extremes (B,F)	√			

Table 7. Runoff Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
TreeFlow (F)	√			
USGS National Water Information System (F)	√	√		

STORMS

Table 8. Storms Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	√			√
NOAA NWS (B,F)		√	√	
NOAA NWS CPC U.S. Hazards Outlook (B)			√	
NOAA NWS Storm Prediction Center (B)			√	
Western Water Assessment Climate Extremes (B,F)	√			

Table 9. Storms Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Change in Colorado (B,F)	√			√
NOAA Severe Weather Data Inventory (B,F)	√			

TEMPERATURE

Table 10. Temperature Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Climate Change in Colorado (B,F)	✓			✓
Climate Explorer (B,F)	✓			✓
Colorado State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
PRISM (B,F)	✓	✓		
U.S. Climate Atlas (B)	✓			
West Wide Drought Tracker (B,F)	✓	✓		
Western Water Assessment Climate Extremes (B,F)	✓			

Table 11. Temperature Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	✓			✓
Colorado State Climate Summary (B)	✓			✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		

WILDFIRE

Table 12. Wildfire Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
Geospatial Multi-Agency Coordination (F)	✓	✓		
Hazard Mapping System Fire and Smoke Product (B)		✓		
InciWeb: Incident Information System (F)		✓		
National Significant Wildland Fire Potential Outlooks (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
Western Water Assessment Climate Extremes (B,F)	✓			

Table 13. Wildfire Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA NCEI Fire History (F)	✓			

Utility Strategies and Plans

- Fort Collins Climate Action Plan (2016)
- Case Study: Water and Wastewater Utilities Planning for Climate Change (2017)
- Fort Collins Community Resilience Assessment (2016)
- Climate Wise Report on Fort Collins (2014)
- Joint Front Range Climate Change Vulnerability Study (2012)

Sources

1 Melillo, J. M., T.C. Richmond, and G.W. Yohe, Eds. *Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment.* Prepared for the U.S. Global Change Research Program, p. 148. 2014. Website: https://nca2014.globalchange.gov/highlights

2 U.S. Global Change Research Program. *DRAFT Fourth National Climate Assessment – Southwest Public Review Chapter.* 2017. Website: https://www.globalchange.gov/content/nca4-planning

3 Lukas, J. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* Prepared for Colorado Water Conservation Board. 2014. Website: https://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf

Acronyms

AHPS = Advanced Hydrologic Prediction Service
CORDEX = Coordinated Regional Downscaling Experiment
CPC = Climate Prediction Center
ENSO = El Niño-Southern Oscillation
LOCA = Localized Constructed Analogs
NCEI = National Centers for Environmental Information
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
PRISM = Parameter-elevation Regressions on Independent Slopes Model
SNOTEL = Snow Telemetry
USGS = United States Geological Survey
WPC = Weather Prediction Center

Environmental Protection

CLIMATE RISK AND OPPORTUNITY PROFILE

New York City Department of Environmental Protection

CLIMATE PROJECTIONS

Temperature
If emissions continue to increase (A2 scenario), 4.5°F to 10° F warming is projected by the 2080s[1]

Coastal Flooding
New York has 431,000 people at risk from coastal flooding[3]

Drought & Water Supply
Shifting seasonal patterns in streamflow affect the turbidity loads into the Catskill System[4]

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Environmental Monitoring and Management
Increased difficulty balancing Clean Water Act compliance and adaptation measures.

Stormwater Management
Storm surge and sea level rise impact flood mitigation measures and NYC DEP's stormwater portfolio.

External Affairs
Increased need to develop cost benefit analyses and apply for hazard mitigation and resiliency funding.

UTILITY OVERVIEW

New York City Department of Environmental Protection (NYC DEP) manages the city's water supply and provides more than 1.1 billion U.S. gallons of water each day to more than 9 million residents. Hurricane Sandy was a driver in transforming NYC DEP's strategy surrounding climate risks, while Hurricane Irene and Tropical Storm Lee in the upstate area disrupted the city's water supply system by requiring additional water treatment. New York City is sensitive to storm surge, sea level rise, and chronic and extreme rain in combination with sewer overflows.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends over the last two decades include the following:

- Milder winters and earlier spring conditions are already changing habitats, affecting species, and creating irreversible changes to hydrology and wildlife.[2]
- The shifting seasonal pattern in streamflow affects the turbidity loads into the Schoharie Reservoir and impacts Schoharie withdrawals, with increased turbidity in the fall and winter, and decreased turbidity in the spring.[4]

FUTURE CLIMATE

Projected changes include the following:

- If emissions continue to increase, 4.5°F to 10°F warming is projected by the 2080s; however, if global emissions are reduced substantially, projected warming ranges from 3°F to 6°F by the 2080s.[1]
- New York State currently has 100 square miles in the 100-year coastal floodplain. By 2050, this is projected to increase to 150 square miles due to sea level rise.[3]

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

ENVIRONMENTAL MONITORING AND MANAGEMENT

- **Summary:** Most planning and activities undertaken by NYC DEP are guided by environmental regulatory compliance standards, and significant resources go to ensuring that water quality in New York's harbor complies with the Clean Water Act.
- **Current risk:** Hurricane Irene and Tropical Storm Lee in upstate New York had a devastating effect on parts of NYC DEP's water supply system, particularly upstate watershed communities. Both events caused turbidity events that lasted for months and involved major treatment to avoid violating clean water standards.

- **Climate impacts include:** Sea-level rise, salt-water intrusion into freshwater aquifers, higher storm surges, inland flooding, and coastal flooding.
- **Opportunities:** NYC DEP continues to identify synergies where water quality investments can help alleviate flooding.

Climate Stressors and Risks **ENVIRONMENTAL MONITORING AND MANAGEMENT**	
Stressors	**Risks**
• Increased average temperatures • Increased frequency in heat waves • Increased flooding • Increased intensity and frequency of heavy rainfall events • Saline Intrusion	• Monitoring and management of ocean, lake, and stream water quality • Impacts on habitat and endangered species • Environmental compliance implications for the Safe Drinking Water Act, the Endangered Species Act, the Clean Water Act, and the National Environmental Policy Act • Increased costs for watershed management and stream rehabilitation

STORMWATER MANAGEMENT

- **Summary:** Stormwater has been a historic driver for NYC DEP's climate and natural preparedness work. More specifically, compliance with combined sewer overflows and the Clean Water Act have been a focus for stormwater management. Meanwhile, compliance with drinking water regulations and turbidity drive water supply management.
- **Current risks:** Extreme rain events are particularly risky in the Catskills in terms of water planning and quality (turbidity).
- **Climate impacts:** Impacts include inland flooding, coastal flooding, sea-level rise, salt-water intrusion into freshwater aquifers, higher storm surges, inland flooding, and coastal flooding.
- **Opportunities:** NYC DEP has undertaken planning to respond to sea-level rise, storm surge, and flooding events. The utility has begun a contract to prepare its 14 wastewater treatment plants for increased flooding and storm surge. NYC DEP's Wastewater Resilience Plan will be responsible for leading and implementing a wastewater resiliency plan.

Climate Stressors and Risks **STORMWATER MANAGEMENT**	
Stressors	**Risks**
• Inland flooding • Coastal flooding • Sea-level rise • Salt-water intrusion into freshwater aquifer • Higher storm surges	• Increase in flood frequency and magnitude • Combined inland and coastal flooding events • Flooding of stormwater outfalls • Flood damage to infrastructure

EXTERNAL AFFAIRS

- **Summary:** The utility has its own Bureau of Sustainability, which focuses on how to make the utility more sustainable and resilient. Through the bureau's efforts, NYC DEP works with other city agencies to meet the goals and objectives outlined in the OneNYC plan and other citywide sustainability plans.
- **Current risks:** NYC DEP is expected to demonstrate investment in resiliency to system investigators and regulators. Failure to invest would put investor, consumer, and regulator confidence at risk.
- **Climate impacts:** All climate change impacts (i.e., drought, flooding, snowpack, sea-level rise, and air quality), even remote to the region, will affect external affairs.
- **Opportunities:** The utility has identified a need for communication support with regulators to better advocate for revisions to consent orders and regulations that focus on the Clean Water Act and other climate-related risks. This includes working with regulators to synergistically improve water quality and alleviate flooding.

Climate Stressors and Risks **EXTERNAL AFFAIRS**	
Stressors	**Risks**
• Increased temperatures • Increased flooding • Increased intensity and frequency of heavy rainfall • Changes in snowpack • Decline in air quality	• Increased potential for emergency events and disruption of service • Increased need for customer service, public education, and communication • Additional potential for legislative actions that need to be monitored • Increased need for intra- and interagency coordination

Utility Strategies and Plans

- NYC Wastewater Resiliency Plan (2013)
- One New York City: One Water (2015)
- Climate Change Integrated Modeling Project (2013)
- Special Initiative for Rebuilding and Resiliency (2013)
- Climate Change Assessment and Action (2008)

Sources

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CLIMATE RISK AND OPPORTUNITY PROFILE
San Diego Public Utilities

CLIMATE PROJECTIONS

Extreme Temperature
Heat wave intensity and frequency will increase 20% to 50% with a 6°F temperature increase by 2100.[7]

Precipitation Intensity
Short heavy rain events overwhelm conventional water storage systems and post-drought rain can lead to mudslides.[8]

Drought
Drought conditions will increase in intensity and frequency due to lower precipitation and higher temperatures.[9]

Wildfires
Higher temperatures and more intense drought seasons can result in wildfires that will be exacerbated by Santa Ana winds.

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Drinking Water Treatment and Delivery
San Diego PUD identified sea level rise as a threat to water quality and existing delivery structures.

Water Supply
Water imports from California and Colorado are increasingly exposed to pollutants from wildfires and high temperatures.

Employee Education
Climate uncertainty impairs San Diego PUD's ability to implement large-scale climate risk planning.

UTILITY OVERVIEW

San Diego Water Company's first well was dug in 1873 to serve roughly 2,000 inhabitants.[1] Today, San Diego Public Utilities Department (PUD) serves 1.4 million inhabitants.[2] Due to its semi-arid desert climate, San Diego is dependent upon water imports from Northern California and the Colorado River for 80-90% of its water. San Diego PUD has over 3,300 miles of water lines, nearly 50 water pumping plants, and potable water storage capacity of 200 million gallons. Despite its current water management and hazard mitigation planning, San Diego PUD faces major climate and extreme weather events including higher temperatures, increased precipitation intensity, increased wildfires, and exacerbated drought years. San Diego's 70 miles of coastline is vulnerable to sea level rise, which threatens San Diego's tourism, real estate prices, and public infrastructure.[3]

San Diego PUD collaborates with local research institutions, including UC San Diego's Scripps Institution of Oceanography, to model and monitor imported water projections and climate-related risks and opportunities. San Diego PUD's hazard mitigation plan includes water shortage contingency plans and the utility now coordinates with the City's new Department of Sustainability and is compliant with the City's Climate Action Plan.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends include the following:

- From 1961 to 1990, California's annual mean temperature was 74.2°F.[4]
- Each year of the 1970s, roughly 133,000 acres of U.S. Forest Service land was burned by wildfire.[5]

FUTURE CLIMATE

Projected changes include the following:

- California's annual mean temperature is projected to be 79.8°F by 2070.[4]
- By 2050, California is projected to experience more than 140 days a year with high wildfire potential—a 14% increase in days with high wildfire potential from 2000.[5]
- By 2050, San Diego's 100-year flood events are 100 times more likely, which will result in the current 100-year flood event occurring every year.[6]

The following pages of this risk and opportunity profile outline the relevant climate drivers, both risks and opportunities, mapped to San Diego PUD's key business functions as identified in consultation with San Diego PUD in August 2018.

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

San Diego PUD staff were interviewed in this research project to investigate how the utility's core business functions anticipate climate risks and opportunities. San Diego PUD identified drinking water treatment and delivery, water supply, and employee education as the three business functions of highest interest in relation to climate change.

DRINKING WATER TREATMENT AND DELIVERY

- **Summary:** San Diego PUD works with local and national research institutions and consultants to model supply and demand in the face of climate change and explore imported water projections and county growth.
- **Current risk:** Operational costs and demand for potable water are expected to increase as the availability of water resources decrease. Water delivery is interrupted by reduced flows and imported water supply shortages.
- **Opportunities:** The San Diego PUD has made important strides in implementing long-range and climate focused projects with Capital Improvement Plans (CIPs). San Diego PUD's Water Sustainability Report will include water supply forecasting for its portfolio risks; when published, it will be incorporated into the Water Demand Forecast and inform the 2020 Long-Range Water Resources Plan.

Collaborative Partners

- U.S. Bureau of Reclamation
- UC San Diego's Scripps Institution of Oceanography
- The Association of Metropolitan Water Agencies
- San Diego County Water Authority
- Integrated Regional Water Management
- U.S. Geological Survey

Impacts of Climate Drivers and Underlying Conditions

Health and Safety

Climate Drivers	Impacts
Extreme Temperatures/Heatwaves Higher Precipitation Intensity	• Rising temperatures increase algal blooms, microbes, and waterborne agents, leading to water quality issues [9] • Water polluted by flooded sewers requires chemical treatment

Water Quality

Climate Drivers	Impacts
Extreme Temperatures/Heatwaves Higher Precipitation Intensity More Frequent/Intense Wildfires	• The concentration of pollutants in water increases with extreme heat because water evaporates faster • Coastal species are impaired by erosion and sedimentation • Rising temperatures increase algal blooms, microbes, and waterborne agents, leading to water quality issues[9]

Infrastructure Impacts

Climate Drivers	Impacts
More Frequent/Intense Wildfires Underlying: Aging Infrastructure	• Existing reservoir and delivery infrastructure have fixed capacities, possibly causing problems in emergencies

Regulatory Impacts

Climate Drivers	Impacts
More Frequent/Intense Wildfires Underlying: Aging Infrastructures	• Potential violations of the Safe Drinking Water Act from fire debris and sedimentation • Potential violations of California's numerous environmental laws

EFFECTS OF CLIMATE CHANGE ON DRINKING WATER TREATMENT AND DELIVERY	
Risks	**Opportunities**
• Potentially less production capacity • Increased energy and water demand and reduced ability to meet sustainability objectives • Increased cost of operations • Increased likelihood of system failures	• Increased emphasis on upgrading mitigation systems to reduce risk • Interdepartmental assessments of potential for climate impacts • Potential for research development and educational resources for the public

WATER SUPPLY

- **Summary:** San Diego PUD is dependent upon imported water for up to 80-90% of its water supply.[17] Imported water is at risk due to water delivery contracts, ecological harm to Northern California delta habitats from over-pumping, water quality, and distance (hundreds of miles away).
- **Current risk:** Increasing mean annual temperatures threaten San Diego PUD's water imported sources, including the Colorado River and Northern California, jeopardizing existing water rights, prioritization processes, and imported water prices.
- **Opportunities:** 1) Pure Water, 2) San Diego PUD is investigating and potentially expanding groundwater basins within the San Diego River Valley Groundwater Basin.

San Diego PUD Water Sources

- The Colorado River
- Northern California, origins at the Sacramento-San Joaquin River Delta (Delta)
- Nine local reservoirs
- San Diego recycled water
- Groundwater

Impacts of Climate Drivers and Underlying Conditions

Water Availability

Underlying: Invasive Species & Demand

- To protect fisheries, courts restricted Delta water exports[10]
- Invasive species (giant reed and Quagga mussel) reduce availability[10]
- Greater demands from population growth and land development result in less flexibility across water sources

Water Quality

Extreme Heat/Humidity/Heatwaves

Higher Precipitation Intensity

More Frequent/Intense Wildfires

Underlying: Invasive Species & Demand

- The concentration of pollutants in water increases with extreme heat because water evaporates faster
- Rising temperatures increase algal blooms, microbes, and waterborne agents, leading to water quality issues[12]
- Storm surges cause flooding, which may result in sewer spills that could corrupt San Diego PUD's water quality[14]

Water Demand

Extreme Heat/Humidity/Heatwaves

Drought

Underlying: Invasive Species & Demand

- San Diego County's population is projected to reach 4 million by 2050[13]
- High heat and low precipitation will extend drought seasons requiring greater quantities of water
- Existing abilities to transport water to treatment plants are limited by pipeline capacity

Flooding

Higher Precipitation Intensity

Underlying: Invasive Species & Demand

- Storm surges cause flooding and may result in sewer spills that could corrupt the quality of San Diego PUD's water supply[14]
- Flash floods can overwhelm dam structures and may cause dam failure if flood management is not appropriately incorporated

Electric Power Disruption

More Frequent/Intense Wildfires

Underlying: Invasive Species & Demand

- Climate events disrupting power lines may inhibit San Diego PUD's ability to pump imported water into San Diego[15]
- Service continuity lost when power outages halt water treatment

EFFECTS OF CLIMATE CHANGE ON WATER SUPPLY	
Risks	**Opportunities**
• Less water available • Additional operational and regulatory constraints • Misleading appearance of unlimited water supply due to wholesale water purchasing model • Local reliable sources impacted by physical climate	• Improve water storage and reservoir capacity and facility interconnectedness • Evaluate extended drought scenarios and potential for additional emergency storage capacity, with reevaluation every five years • The Pure Water program will source local water[16]

Climate Data and Information

*In August 2018, staff from San Diego PUD collaborated with the research team to map two example water utility business functions, **drinking water treatment and delivery and water supply**, to five different climate stressors and impacts. Climate stressors and impacts related to temperature, precipitation, and wildfire were common to both drinking water treatment and delivery and water supply. Each checkmark in Table 1 indicates that the climate stressor and impact influence the relevant business function.*

Table 1. Climate Stressors and Impacts

Water Utility Business Functions	Climate Stressors and Impacts				
	Drought	Humidity	Precipitation	Temperature	Wildfire
Drinking water treatment and delivery			✓	✓	✓
Water supply	✓	✓	✓	✓	✓

SUMMARY OF CLIMATE INFORMATION SOURCES AND TYPES

Below is a summary of climate information sources and types that were identified to help evaluate risks and opportunities for similar water utilities, organized by the five different climate stressors and impacts identified Table 1. The sources and types represent a sampled and pragmatic, rather than an exhaustive, list of climate information for these examples, as the actual number of potential sources and types is large and continues to expand. The following tables can be used as starting points from which a utility can remove or add climate information sources and types that aid in evaluating climate-related risks and opportunities.

Table Key (Tables 2 – 11)

Climate Stressors and Impacts were classified by the following

- **Derivative:** sources that provide static or interactive content through predetermined analyses or syntheses in graph, map, or text formats.
- **Data:** sources that require end users to download, analyze, or visualize data to generate climate information

(F) = fine-scale information, higher resolution

(B) = broad-scale information, county level or lower resolution

DROUGHT

Table 2. Drought Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Cal-Adapt Extended Drought Scenarios (F)				✓
California State Climate Summary (B)	✓			✓
California's Fourth Climate Change Assessment (B,F)				✓
CNAP Drought Tracker (B,F)		✓	✓	
Fourth National Climate Assessment (B)	✓			✓
NOAA NCEI Weekly Divisional Products (B)		✓		
U.S. Drought Monitor (B,F)	✓	✓		
U.S. Drought Portal (B,F)		✓		
U.S. Monthly Drought Outlook (B)			✓	
U.S. Seasonal Drought Outlook (B)			✓	
West Wide Drought Tracker (B,F)	✓	✓		

Table 3. Drought Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
California State Climate Summary (B)	✓			✓
NOAA NCEI Drought Variability[a] (B)	✓			
U.S. Drought Monitor (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		

[a] Tree-ring reconstructions of two drought indices, see PRECIPITATION below for more related data sources

HUMIDITY

Table 4. Humidity Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA NWS (B,F)		✓	✓	

Table 5. Humidity Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Cal-Adapt Additional VIC Variables (F)				✓
NOAA NCEI Climate Data Online (F)	✓	✓		

PRECIPITATION

Table 6. Precipitation Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Cal-Adapt (F)				✓
California State Climate Summary (B)				✓
California's Fourth Climate Change Assessment (B,F)				✓
Climate Explorer (B,F)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA CPC Precipitation (B)		✓		
NOAA CPC ENSO Diagnostic Discussion (B)		✓	✓	
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS AHPS Precipitation (F)		✓		
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS National Operational Hydrologic Remote Sensing Center (B)	✓	✓		
NOAA NWS Storm Prediction Center (B)			✓	
NOAA NWS WPC Quantitative Precipitation Forecasts (B)			✓	
PRISM (B,F)	✓	✓		
SNOTEL and Snow Course (F)		✓		
TreeFlow (F)	✓			
U.S. Climate Atlas (B)	✓			
West Wide Drought Tracker (B,F)	✓	✓		

Table 7. Precipitation Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Cal-Adapt (F)				✓
California State Climate Summary (B)	✓			✓
Climate Explorer (B,F)	✓			✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
NOAA NWS AHPS Precipitation (F)		✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		
SNOTEL and Snow Course (F)	✓			
TreeFlow (F)	✓			
West Wide Drought Tracker (B,F)	✓	✓		

TEMPERATURE

Table 8. Temperature Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Cal-Adapt (F)				✓
California State Climate Summary (B)	✓			✓
California's Fourth Climate Change Assessment (B,F)				✓
Climate Explorer (B,F)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
PRISM (B,F)	✓	✓		
U.S. Climate Atlas (B)	✓			
West Wide Drought Tracker (B,F)	✓	✓		

Table 9. Temperature Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Cal-Adapt (F)				✓
California Heat Assessment Tool (B,F)				✓
California State Climate Summary (B)	✓			✓
Climate Explorer (B,F)				✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		

WILDFIRE

Table 10. Wildfire Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
CAL FIRE Incident Information (F)		✓		
Cal-Adapt Wildfire (F)				✓
California's Fourth Climate Change Assessment (B,F)				✓
Fourth National Climate Assessment (B)	✓			✓
Geospatial Multi-Agency Coordination (F)	✓	✓		
Hazard Mapping System Fire and Smoke Product (B)		✓		
InciWeb: Incident Information System (F)		✓		
National Significant Wildland Fire Potential Outlooks (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	

Table 11. Wildfire Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Cal-Adapt Wildfire (F)				✓
NOAA NCEI Fire History (F)	✓			

Utility Strategies and Plans

- City of San Diego Urban Water Management Plan (2016)
- City of San Diego Public Utility Department: 2012 Long-Range Water Resources Plan (2013)
- Pure Water San Diego (Ongoing)
- Customer Outreach (Ongoing)

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[16] City of San Diego Public Utilities Department: *Water Purification Demonstration Project*. Website: https://www.sandiego.gov/sites/default/files/legacy/water/pdf/wpdpspeakers.pdf

[17] San Diego Public Utilities Department. "Water Supply." Accessed October 10, 2018. Website: https://www.sandiego.gov/public-utilities/sustainability/water-supply

Acronyms

AHPS = Advanced Hydrologic Prediction Service
CNAP = California-Nevada Climate Applications Program
CORDEX = Coordinated Regional Downscaling Experiment
CPC = Climate Prediction Center
ENSO = El Niño-Southern Oscillation
LOCA = Localized Constructed Analogs
NCEI = National Centers for Environmental Information
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
PRISM = Parameter-elevation Regressions on Independent Slopes Model
SNOTEL = Snow Telemetry
VIC = Variable Infiltration Capacity
WPC = Weather Prediction Center

CLIMATE RISK AND OPPORTUNITY PROFILE

Salt Lake City Department of Public Utilities

CLIMATE PROJECTIONS

Temperature
Projected regional temperature increases, combined with the way cities amplify heat, will pose increased threats and costs.[1]

Wildfire and Flooding
The frequency and extent of wildfires are projected to increase, which will likely lead to more destructive flooding.[1]

Drought & Water Supply
The intensity of naturally occurring future droughts are projected to increase in Utah.[3]

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Operations
Cascading impacts from flooding and algal blooms have affected operations as infrastructure has required extensive repairs.

Procurement
Major events spur a rush to procure disaster clean up services to respond to infrastructure challenges.

External Affairs
Following major events, external affairs is called upon communicate to the public including state, Federal, and municipal decision-makers.

UTILITY OVERVIEW

Established in 1876, the Salt Lake City Department of Public Utilities (Public Utilities) is the oldest retail water provider in the western United States. Public Utilities provides drinking water to more than 350,000 people in Salt Lake City and portions of Salt Lake County, conducts flood control and stormwater management, collects and treats wastewater, and maintains public street lighting. It also protects source waters in the Central Wasatch Mountain watersheds and promotes conservation through efficient water use.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends over the last two decades include the following:

- Average annual temperature has increased about 2°F since the early 20th century. Warming is particularly evident as an increase in very warm nights and a below average occurrence of extremely cold nights over the past two decades.[3]
- Increased warming, drought, and insect outbreaks have increased wildfires and impacts to people and ecosystems.[1]

FUTURE CLIMATE

Projected changes include the following:

- The frequency and extent of wildfires are projected to increase, and that increase will likely lead to more destructive flooding as burned areas are more susceptible to flooding and runoff of sedimentation and debris.[1]
- Snowpack and streamflow amounts are projected to decline in parts of the U.S. Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems.[1]
- Projected changes in winter precipitation include an increase in the fraction falling as rain rather than snow, potentially decreasing snowpack water storage.[3]

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

OPERATIONS

- **Summary:** Public Utilities' operations include source protection, water treatment and distribution, and infrastructure operations and maintenance. Major climate events impacted operations in 2016 and 2017.
- **Current risk:** Major flooding events, drought, and algal blooms impacted the utility's operations. Cascading impacts from a 2017 200-year storm event led to the need for infrastructure repair and assessment. Following a 2016 algal bloom, the operations team temporarily replaced irrigation secondary water with culinary sources as needed.
- **Climate impacts:** Impacts include drought, inland flooding, shifts in snowpack, wildfires, and algal blooms.
- **Opportunities:** Multi-hazard training for all operations staff can lead to potential co-benefits and better emergency preparedness, improved health and safety records, and better employee morale.

Climate Stressors and Risks **OPERATIONS**	
Stressors	**Risks**
• Utility infrastructure size, complexity, and condition • Increased frequency in heat waves • Increased flooding • Increased intensity and frequency of heavy rainfall events	• Direct exposure of operations staff to climate risks in the field • Heatwaves, storms, floods, and wildfires may be life threatening • Increased costs for infrastructure repairs and water resource/source management

PROCUREMENT

- **Summary:** Increased incidence of disasters can lead to a need to procure disaster clean-up, engineering design, and construction services quickly.
- **Current risks:** Extreme rain events and algal blooms posed risks to the utility's procurement functions in 2016 and 2017.
- **Climate impacts:** Impacts include heat waves, increased intensity of winter storms, intense or prolonged freezing periods, droughts, and flooding, and local and distant climate events impacting supply chains.
- **Opportunities:** Actions to mitigate risks include intra- and interagency hazard and emergency preparedness training, on-site storage of infrastructure repair supplies, and facilitated contracting procedures for emergency response conditions.

Climate Stressors and Risks **PROCUREMENT**	
Stressors	**Risks**
• Inland flooding • Increased algal blooms • Severity of wildfire and post-fire flooding • Land cover change • Intensity of winter storms	• Increased energy costs • Additional emergency procurement and contracting issues to recover from extreme events • Challenges with global, national, and regional supply chains/transportation of products • Need for emergency procurement of disaster clean-up, engineering, and construction services

EXTERNAL AFFAIRS

- **Summary:** Increased incidence of extreme events will cause the utility to communicate more frequently with the public and with external stakeholders.
- **Current risks:** Following a 200-year storm event, the utility's communications team was engaged, and the utility did 14 interviews to communicate to the public. The external affairs team also ran weekly situational phone calls with 62 parties from the state, federal, and municipal levels following a 2016 algal bloom.
- **Climate impacts:** Impacts include all climate change impacts (i.e., drought, flooding, snowpack, and air quality), even remote to the region, will affect external affairs.
- **Opportunities:** Well-structured and targeted communications, external affairs plans, and programs can have co-benefits across all aspects of utility management such as higher customer satisfaction, reduced potential for lawsuits, more ability to affect policy and legislation, community-level standing agreements, mutual assistance efforts, and hazard mitigation command structures.

Climate Stressors and Risks **EXTERNAL AFFAIRS**	
Stressors	**Risks**
• Increased temperatures • Increased flooding • Increased intensity and frequency of heavy rainfall • Decline in water quality • Decline in air quality	• Increased potential for emergency events and disruption of service • Increased need for customer service, public education, and communication • Additional potential for legislative actions that need to be monitored • Increased need for intra- and interagency coordination

Utility Strategies and Plans

- Planning for an Uncertain Future: Climate Change Sensitivity Assessment toward Adaptation Planning for Public Water Supply (2013)
- Incorporating Potential Severity into Vulnerability Assessment of Water Supply Systems under Climate Change Conditions (2016)

Sources

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[2] U.S. Global Change Research Program. *DRAFT Fourth National Climate Assessment – Southwest Public Review Chapter.* 2017. Website: https://www.globalchange.gov/content/nca4-planning

[3] Frankson, R., K. E. Kunkel, L. Stevens, and D. Easterling. *Utah State Climate Summary*. Prepared for NOAA Technical Report NESDIS 149-UT, p. 4. 2017. Website: https://statesummaries.ncics.org/ut

SOUTHERN NEVADA WATER AUTHORITY

CLIMATE RISK AND OPPORTUNITY PROFILE

Southern Nevada Water Authority

CLIMATE PROJECTIONS

Extreme Heat
Heat waves above 110 °F will become 5 times more frequent, while average annual temperatures will increase between 5°F and 10 °F by 2100.[5]

Drought
Streamflow in the Colorado River is expected to decline by about 20% by midcentury from warming temperatures alone.[8]

Storm Intensity
Extreme rainfall events and storm intensity may increase in the future.[5]

Wildfires
Increased warming, drought, and insect outbreaks have increased wildfires and impacts to people and ecosystems.

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Administration
Intensity of heat and flood events from extreme storms put SNWA's employees and communication systems at risk.

Engineering Operations
Wildfires, extreme heat, and drought require more energy and costs to pump and treat water before distribution to customers.

Finance
Increased conservation and lower water demand in response to drought, along with financial downturns and increasing costs of living, have the potential to disrupt SNWA's current funding streams.

UTILITY OVERVIEW

Southern Nevada Water Authority (SNWA) was founded in 1991 as the regional wholesale water provider to seven member agencies in one of the driest states of the country. SNWA treats, delivers, and manages water resources, for more than 2.1 million residents - 90% of which is pumped from Lake Mead and the Colorado River.[1] To achieve its mission of providing "sustainable, adaptable and responsible" water services, SNWA uses an integrated resource planning approach to ensure demands are met today and into the future.[2] To ensure continued reliability in the face of climate change and extreme events, a large workforce - one half of whom work outside - must maintain Lake Mead water intakes, two water treatment facilities, nearly 7,000 miles of waterlines, reservoirs, pumping stations, and production wells.

To prepare for declining Lake Mead reservoir elevations, SNWA's steps for adaptive management include conservation, water banking, and integrated resource and infrastructure planning. SNWA is now beginning to explore potential impacts and solutions to personnel and infrastructure.

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends include the following:

- From 1980 to 2015, the average dew point temperature in Las Vegas increased from 44°F to 50°F, thereby making it more challenging for the body to cool itself.[3]
- Between 1970 and 2016, Clark County, Nevada has warmed 2.6°F.[4]

FUTURE CLIMATE

Projected changes include the following:

- By 2100, average annual temperatures in Clark County will warm between 5 °F and 10 °F.[5]
- Under present conditions, Lake Mead is projected to decline below 1,075 feet above sea level by 2020, triggering a reduction in water deliveries to NV and AZ.[6]
- Las Vegas may experience 106 days per year with a Heat Index above 105°F by 2050.[7]

The following pages of this risk and opportunity profile outline the relevant climate drivers, both risks and opportunities, mapped to SNWA's key business functions as identified by SNWA in August 2018.

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

SNWA participated in this research project to investigate how the utility's core business functions anticipate climate risks and opportunities. SNWA identified administration, engineering operations, and finance as the three business functions of highest interest in relation to climate change.

ADMINISTRATION

- **Summary:** SNWA personnel live and work in one of the hottest and driest states in the country. Climate change and extreme weather events could increase risks to personnel.
- **Current risk:** SNWA employees are exposed to public health and water quality stressors, such as extreme temperature, wildfires, and storm events, that will likely increase in intensity and frequency as a result of climate change.
- **Barriers to action:** State and local politicians within Southern Nevada are hesitant to include the concepts of climate-related events in assessments. Evaluating impacts to personnel is a new area of study and there is limited information in the water sector to draw on to develop solutions.
- **Opportunities:** SNWA is currently conducting an enterprise risk management assessment to include climate conditions grounded in historical hydrological variability and climate events. To take on a global perspective on risk, SNWA's assessment interviewed 183 individuals to discuss risk.

Impacts of Climate Drivers and Underlying Conditions

Worker Health and Safety

Extreme Heat Vector-borne Disease Wildfires Storm Intensity	• Increased health impacts on outdoor workers including heat stroke, heat stress, storm exposure, and mental health disorders • Warmer climates are exposed to increased vector-bone diseases that threaten worker health and contaminate water sources • Wildfires increase toxic particulate matter in the air • Wildfires increase the amount of ozone in the atmosphere close to the earth's surface, which is harmful to crops and humans

Power Continuity

Extreme Heat	• Power outages from extreme heat have cascading effects that cause AC outages, heat stress, and water monitoring disruptions

Transit Impacts

Wildfires Storm Intensity	• Roads, bridges, and railways are damaged from heat due to heat-intolerant materials • Intense flooding and erosion inhibit employee access to facilities

Communication and Technology Impacts

Extreme Heat Wildfires	• Technology cannot operate beyond a certain heat threshold • Field technology and communication systems are sensitive to heat and may not function during extreme heat events

ADMINISTRATION	
Risks	**Opportunities**
• Inadequate Business Continuity Plan (loss of electric power—indoor workers' reliance on AC) • Declining overall productivity of the work force • Cascading risks of power loss: communications, operations, and operational challenges • Risk communications and monitoring technology does not function beyond certain heat thresholds • Increased incidence of worker's compensation claims and injuries • Impacts to reputation and brand associated with lack of preparedness for events	• Investment in heat-resistant communications technology (i.e., radios) • Shifting work schedules to adapt to increasing summer heat or increasing rest cycles • Training for recognizing various heat-related stresses • Monitor absenteeism and worker comp claims • Develop procedures and criteria halting work above certain heat indexes and other air-quality thresholds • Incorporate climate considerations into preparedness for natural hazards (e.g., wildfires) • Ensure proactive communication and disaster preparedness messaging

ENGINEERING/OPERATIONS

- **Summary:** Due to extreme climate risks that currently take place in Southern Nevada, SNWA's safety engineers have participated in training courses about climate change impacts on engineering.
- **Current risk:** Increasing mean annual temperatures and changing source water conditions threaten critical infrastructure used in water treatment and distribution
  Opportunities: SNWA is already facing climate impacts due to its extreme environment; as a result, SNWA has an opportunity to be a leader in the water utility industry for sustainable water use and resilience planning.

SNWA Water Sources

- Colorado River via Lake Mead
- Local Groundwater
- Recycled Water

Impacts of Climate Drivers and Underlying Conditions

Water Quality

Climate Drivers	Impacts
Drought Storm Intensity Extreme Heat Wildfires	• Drought reduces freshwater inputs to surface reservoirs, groundwater recharge, and ability to meet water demand • Higher water temperatures in Lake Mead increase contaminant levels • Turbidity impairs water quality during storm events and floods • Wildfires introduce pollutants to exposed water resources

Efficiency of Operations

Climate Drivers	Impacts
Drought Storm Intensity Extreme Heat	• Low lake levels require increased pumping efficiency to meet demand • Warmer water requires more extensive and costly treatment • Generator and energy storage is needed during power outages

Power Continuity

Climate Drivers	Impacts
Extreme Heat Storm Intensity Drought	• Power outages cause cascading effects including the inability to treat and transport water • Without power, SNWA is unable to effectively communicate to its staff to recover systems or to its customers to indicate when water will be restored

Distribution Challenges

Climate Drivers	Impacts
Drought Extreme Heat	• Warm water limits distribution by pressure rated pipes • Maintenance demand would increase with pipe and road damage from extreme heat and flood events

ENGINEERING/OPERATIONS	
Risks	**Opportunities**
• Potential inoperability of intake pumping stations 1 and 2 if Lake Mead's surface level declines • Increase in THM MCL exceedances • Declining efficiency of operations impacted by low lake levels and higher water temperature • Higher energy costs • Potential loss of function in control devices could lead to system failure • Increase in small system failures due to lack of redundancy	• Building new pumping stations to preserve SNWA access to Lake Mead as lake levels decline • Lower frequency of facilities freezing at higher elevations if winter temperatures increase • Engage engineers in planning conversations about extreme heat, extreme events, water temperature and quality concerns, and lake levels

FINANCE

- **Summary:** Since the financial downturn in 2008, SNWA has brought in financial experts, completed stress tests, and made a concerted effort to realign revenue streams to make the utility more resilient to change and external impacts.
- **Current risk:** Facility and/or personnel impacts from climate change and extreme events could result in unbudgeted financial expenditures. Increased conservation and lower water demand in response to drought and climate change has the potential to reduce SNWA's current funding streams.
  Opportunities: SNWA has established internal and external citizen-based advisory committees to guide long-term investment decisions when current economic and environmental futures are uncertain.

Impacts of Climate Drivers and Underlying Conditions

Damage to Facilities

Climate Drivers	Impacts
Extreme Heat Storm Intensity Wildfires Drought	• Extreme storms make pumping stations and exposed facilities unusable if damaged • Exposed facilities endure more wear and tear from climate events • Heat and flooding damage pipe infrastructure and roads • HVAC units experience frequent outages during storms • Costs increase due to demands for comprehensive insurance • Increased financial and credit risks due to loss of revenue from more frequent climate-related service interruptions

Water Quality and Quantity Implications

Climate Drivers	Impacts
Wildfires Storm Intensity	• Higher water treatment costs • Potential revenue losses from drought restrictions • Potential for impacts on both the water demand and water supply side of the equation (longer peak demand season) • Health risks associated with changes in raw water quality and treatment approaches

FINANCE	
Risks	**Opportunities**
• Facilities may become uninsurable or very expensive to insure given increased incidence of extreme weather events • Increased risk of impacts to credit rating due to uncertainty in future planning and the impacts of extreme heat and storms • Incurring unplanned capital expenditures in the event of damaged infrastructure and facilities • Lack of available funding for upfront costs to prepare for damages or impacts from climate drivers in advance of the events • Drought restrictions potentially result in revenue loss	• Opportunity to pursue creative financing strategies for infrastructure improvements • Maintain larger emergency financial reserves • Implement preparatory maintenance and repair program (evaluate current design standards against future projections) • Modify existing capital improvement planning process to include evaluating climate change risks • Redundancy in systems can be planned • Policy changes such no longer constructing above-ground steel reservoirs or changing pipe materials (no more polyethylene pipes as they are shown to have much higher failure rate when water is warm)

*In September 2018, staff from Southern Nevada Water Authority's representatives mapped three example water utility business functions, **administration, engineering/operations, and finance**, to four different climate stressors and impacts. Stressors and impacts related to storms (including extreme winds, lightning, heavy precipitation, and flooding), temperature, and wildfire were common to all three business functions. A checkmark in Table 1 indicates which climate stressors and impacts affect individual business functions.*

Table 1. Climate Stressors and Impacts

Business Functions	Climate Stressors and Impacts			
	Drought	Storms	Temperature	Wildfires
Administration		✓	✓	✓
Engineering / Operations	✓	✓	✓	✓
Finance	✓	✓	✓	✓

SUMMARY OF CLIMATE INFORMATION SOURCES AND TYPES

Below is a summary of climate information sources and types that were identified to help evaluate risks and opportunities for similar water utilities, organized by the different climate stressors and impacts identified Table 1. The sources and types represent a pragmatic, rather than an exhaustive, list of climate information for these examples, because the actual number of potential sources and types is large and continues to increase. The following tables can be used as starting points from which a utility can remove or add climate information sources and types that aid in evaluating climate-related risks and opportunities.

Table Key (Tables 2 – 13)

Climate Stressors and Impacts were classified by the following:

- **Derivative:** sources that provide static or interactive content through predetermined analyses or syntheses in graph, map, or text formats.
- **Data:** sources that require end users to download, analyze, or visualize data to generate climate information

(F) = fine-scale information, higher resolution

(B) = broad-scale information, county level or lower resolution

DROUGHT

Table 2. Drought Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
CNAP Drought Tracker (B,F)		✓	✓	
Colorado River System 5-Year Projected Future Conditions (F)		✓	✓	
Fourth National Climate Assessment (B)	✓			✓
Nevada State Climate Summary (B)	✓			✓
NOAA NCEI Weekly Divisional Products (B)		✓		
U.S. Bureau of Reclamation (F)	✓	✓		
U.S. Drought Monitor (B,F)	✓	✓		
U.S. Drought Portal (B,F)		✓		
U.S. Monthly Drought Outlook (B)			✓	
U.S. Seasonal Drought Outlook (B)			✓	
West Wide Drought Tracker (B,F)	✓	✓		

Table 3. Drought Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Nevada State Climate Summary (B)	✓			✓
NOAA NCEI Drought Variability[a] (B)	✓			
U.S. Bureau of Reclamation (F)	✓	✓		
U.S. Drought Monitor (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		
Nevada State Climate Summary (B)	✓	✓		

[a] Tree-ring reconstructions of two drought indices, see the Precipitation section for more related data sources

FLOODING

Table 4. Flooding Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS AHPS Experimental Long-Range River Flood Risk (F)			✓	
NOAA NWS AHPS River Forecasts (F)			✓	
NOAA NWS AHPS River Observations (F)		✓		
USGS National Water Information System (F)	✓	✓		

Table 5. Flooding Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short-Term	Long-Term
USGS National Water Information System (F)	✓	✓		

PRECIPITATION

Table 6. Precipitation Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Climate Conditions in Clark County, NV (B,F)	✓			✓
Climate Explorer (B,F)	✓			✓
Nevada State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA CPC ENSO Diagnostic Discussion (B)		✓	✓	
NOAA CPC Precipitation (B)		✓		
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS AHPS Precipitation (F)		✓		
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS National Operational Hydrologic Remote Sensing Center (B)	✓	✓		
NOAA NWS Storm Prediction Center (B)			✓	
NOAA NWS WPC Quantitative Precipitation Forecasts (B)			✓	
PRISM (B,F)	✓	✓		
SNOTEL and Snow Course (F)		✓		
U.S. Climate Atlas (B)	✓			
West Wide Drought Tracker (B,F)	✓	✓		

Table 7. Precipitation Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	✓			✓
Nevada State Climate Summary (B)	✓			✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
NOAA NWS AHPS Precipitation (F)		✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		
SNOTEL and Snow Course (F)	✓			
West Wide Drought Tracker (B,F)	✓	✓		

STORMS (INCLUDING EXTREME WIND AND LIGHTNING)

Table 8. Storm Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	

Table 9. Storm Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA Severe Weather Data Inventory (B,F)	✓			

TEMPERATURE

Table 10. Temperature Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Climate Conditions in Clark County, NV (B,F)	✓			✓
Climate Explorer (B,F)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
Nevada State Climate Summary (B)	✓			✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
PRISM (B,F)	✓	✓		
U.S. Climate Atlas (B)	✓			
West Wide Drought Tracker (B,F)	✓	✓		
Western Water Assessment Climate Extremes (B,F)	✓			

Table 11. Temperature Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	✓			✓
LOCA (F)				✓
Nevada State Climate Summary (B)	✓			✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		
West Wide Drought Tracker (B,F)	✓	✓		

WILDFIRE

Table 12. Wildfire Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
Geospatial Multi-Agency Coordination (F)	✓	✓		
Hazard Mapping System Fire and Smoke Product (B)		✓		
InciWeb: Incident Information System (F)		✓		
National Significant Wildland Fire Potential Outlooks (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	

Table 13. Wildfire Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA NCEI Fire History (F)	✓			

Utility Strategies and Plans

- 2017 Water Resource Plan (2017)
- SNWA Sustainability in Action
- SNWA Water Conservation Plan 2014-2018 (2014)

Sources

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[8] Udall, B., and J. Overpeck (2017), The twenty-first century Colorado River hot drought and implications for the future, Water Resour. Res., 53, doi:10.1002/2016WR019638.

Acronyms

AHPS = Advanced Hydrologic Prediction Service
CNAP = California-Nevada Climate Applications Program
CORDEX = Coordinated Regional Downscaling Experiment
CPC = Climate Prediction Center
ENSO = El Niño-Southern Oscillation
LOCA = Localized Constructed Analogs
NCEI = National Centers for Environmental Information
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
PRISM = Parameter-elevation Regressions on Independent Slopes Model
SNOTEL = Snow Telemetry
USGS = United States Geological Survey
WPC = Weather Prediction Center

CLIMATE RISK AND OPPORTUNITY PROFILE

Tampa Bay Water

CLIMATE PROJECTIONS

Extreme Temperature
Temperatures across the Southeast are expected to increase during this century, with projected increases in the range of 4°F to 8°F.[15]

Precipitation Intensity
Extreme rainfall events and storm intensity are increasing flood frequencies, making the Southeast highly vulnerable.[16]

Sea Level Rise
Rising sea levels will cause daily coastal floods during high tides if adaptation measures are not implemented.[16]

Storm Intensity
Warming oceans from increasing atmospheric temperatures can increase hurricane wind intensity and cause more damage.[17]

KEY BUSINESS FUNCTIONS IMPACTED BY CLIMATE CHANGE

Drinking Water Treatment and Distribution
Water quality and delivery is increasingly risk-prone as temperatures and storms become more intense.

Physical & Cyber Security
Tampa Bay Water's field electronics and servers are sensitive to increased heat, humidity, and precipitation.

Engineering, Design, and Construction
Cost-effective management of Tampa Bay Water's equipment requires robust material analyses as climate-related uncertainties persist.

UTILITY OVERVIEW

Tampa Bay Water was created in 1998 as an alliance between six west-central Florida governments. Tampa Bay Water supplies wholesale drinking water to more than 2.5 million Floridians, is a national leader in reliable water supply and best practices, and is an advocate for local public water resources.[1] To diversify water supply sources, Tampa Bay Water has invested in surface water from the Tampa Bypass Canal and Seawater Desalination. Additionally, Tampa Bay Water's Seawater Desalination facility is capable of processing 25 million gallons of water per day.

Updated in 2016, the first goal of Tampa Bay Water's Strategic Plan is to "maintain water supply and delivery system reliability and sustainability." Through partnerships with Florida State University, the University of Florida, and local Water Utility Climate Alliance (WUCA) members, Tampa Bay Water works to incorporate climate into its risk management framework.


The City of Tampa, Florida and the Bay[14]

CLIMATE SUMMARY

HISTORICAL CLIMATE

Climate trends include the following:

- Over the past 40 years the Gulf of Mexico has warmed 1°F to 2°F, and the Atlantic Ocean has warmed up to 4°F.[2]
- Florida has experienced one severe drought every decade since 1900.[3]
- Since 1970, Miami has experienced an average of 72.5 more days per year above 90°F.[4]

FUTURE CLIMATE

Projected changes include the following:

- Miami is projected to experience an average of 126 days per year with a heat index above 105°F by 2030 and 151 days per year by 2050.[4]
- By 2100, sea level is projected to rise one to four feet, threatening 20% of Tampa Bay's population.[5]

The following pages of this risk and opportunity profile outline the relevant climate drivers, both risks and opportunities, mapped to Tampa Bay Water's key business functions as identified by Tampa Bay Water in August 2018.

BUSINESS FUNCTION RISKS AND OPPORTUNITIES

Tampa Bay Water participated in this research project to investigate how the utility's core business functions anticipate climate risks and opportunities. Tampa Bay Water identified drinking water treatment and distribution, physical and cyber security, and engineering, design, and construction as the three business functions of highest interest in relation to climate change.

DRINKING WATER TREATMENT AND DISTRIBUTION

- **Summary:** Tampa Bay Water has partnered with local universities and other WUCA members to investigate climate impacts on water supply, demand, and the infrastructure in place to ensure reliable water delivery. Looking forward, Tampa Bay Water aims to develop new design standards for its outdoor assets to increase resilience against extreme temperatures and humidity.
- **Current risk:** Tampa Bay is exposed to variable and intense precipitation, temperatures, and storm events as a result of climate change threatening water quality and distribution infrastructure.
- **Barriers to action:** Community members and customers are hesitant to embrace climate change, which ultimately inhibits political support for climate-related policy and planning.
- **Opportunities:** Tampa Bay Water recognizes climate change as an opportunity to develop innovative solutions to water treatment and distribution issues.

Impacts of Climate Drivers and Underlying Conditions

Climate Drivers	Impacts
Precipitation Intensity Extreme Temperature Storm Intensity Sea Level Rise	• Heavy rains cause inland flooding and sewer overflows that contaminate surface water sources[6] • Water taste and color are tainted by algal blooms and bacterial growths from excess nutrient runoff and warming waters[7] • Tampa Bay Water's Seawater Desalination facility is at sea level; as sea levels rise the facility's ability to continue operating is in question

Saltwater Intrusion

Climate Drivers	Impacts
Sea Level Rise	• Saltwater will increasingly affect coastal rivers and aquifers as sea levels rise[8]

Increased Demand and Reduced Supply

Climate Drivers	Impacts
Extreme Temperature Drought	• Water pollutant concentrations increase with extreme heat • From 2012 to 2013, severe drought in Florida required water providers to diversify water sources to meet consumer demands

Facility Infrastructure

Climate Drivers	Impacts
Extreme Temperature Drought	• Increased heat and humidity damage outdoor equipment and inhibits water distribution • Droughts reduce water storage and increase demand

Energy Reliability

Climate Drivers	Impacts
Sea Level Rise Storm Intensity	• Water treatment and desalination facilities go offline in Category 3 hurricanes, reducing Tampa's supply of clean water to distribute • Employees cannot repair or access damaged assets during storms

DRINKING WATER TREATMENT AND DISTRIBUTION	
Risks	**Opportunities**
• Increased costs of operations and maintenance • Loss of continuity of service • Possible system failure • Potential water shortage and water use permit violation	• Investment in treatment facilities to reduce risks and increase capacity • Slightly higher temperatures improve desalination treatment efficiency (up to a threshold) • More aggressive maintenance may reduce risks

PHYSICAL AND CYBER SECURITY

- **Summary:** Tampa Bay Water's treatment and distribution network is dependent upon physical and cyber infrastructure, including a water treatment plant, desalination plant, a 15.5-billion-gallon reservoir, and an extensive groundwater well network.
- **Current risk:** Extreme temperatures, precipitation, and sea level rise threaten Tampa Bay Water's physical and cyber security as electronic grid communications and infrastructure may fail during climate events. In Tallahassee, Florida's capital, 96% of customers lost power during Hurricane Michael.[10]
- **Opportunities:** Tampa Bay Water is working to increase its physical and cyber resilience, which will result in increased energy efficiency, innovative design, and reliable water delivery.

Hurricane-driven Grid Outages[11]

- Hurricane Hermine = 323,505 accounts
- Hurricane Matthew = 1.13 million accounts
- Hurricane Irma = 6.52 million accounts
- Hurricane Nate = 13,539 accounts
- Hurricane Michael = 400,000 accounts[9]

Impacts of Climate Drivers and Underlying Conditions

Device/Equipment Damage

Extreme Temperature
Precipitation Intensity
Sea Level Rise
Air: Humidity and Salinity

- Costs to maintain facilities, indoors and outdoors, will increase as temperatures rise, requiring more intensive cooling systems
- Sea level rise and intense storm debris hinder access to assets
- Tampa Bay Water's server rooms are not protected against Category 5 hurricanes
- Humidity and salinity damage electronics by disrupting circuitry

Flooding and Wind Damage

Sea Level Rise
Storm Intensity

- Physical damage to Tampa Bay Water's treatment plants, groundwater wells, and water pumps increase with storm intensity (electrical circuits are corrupted if exposed to water)

Grid and Communication Failure

Extreme Temperature
Storm Intensity

- Internal and external communications are disrupted by storms
- Blackouts due to excessive electric demand during high-temperature days threatens water purification and delivery systems

CLIMATE AND CYBER SECURITY

Computer systems and backup systems are likely to be affected by grid outages caused by more frequent and more intense climate events, ultimately halting continuity of service.

PHYSICAL AND CYBER SECURITY	
Risks	**Opportunities**
• System failure (local or regional) • Electric grid and communications failures • Increased maintenance and replacement costs	• Design facilities for higher energy storms • Increase energy efficiency initiatives • Include redundant systems and facilities and additional sensors in new parts of the system • Implement more aggressive maintenance

ENGINEERING, DESIGN, AND CONSTRUCTION

- **Summary:** Tampa Bay Water has prioritized the health and safety of its water as well as the health and safety of its employees. According to Tampa Bay Water's 2016 Strategic Plan, over $1 billion was invested in distribution infrastructure. The agency will also formalize its employee Health and Safety Program.
- **Current risk:** Tampa Bay Water's ability to provide clean and reliable water to its customers depends on the integrity of its infrastructure and productivity of its employees. Aging infrastructure is increasingly vulnerable to climate events and new engineering solutions are required so that new infrastructure can meet the demands of a variable climate.
- **Opportunities:** Tampa Bay Water has diversified its water portfolio to increase resilience against climate variability. Looking forward, Tampa Bay Water plans to include climate in its engineering risk assessments and modify existing standards to meet climate-related standards.

Tampa Bay Water's Sources[13]

- Floridan Aquifer
- Alafia River, Hillsborough River, and the Tampa Bypass Canal
- Seawater desalination

Impacts of Climate Drivers and Underlying Conditions

Employee Well-Being

Climate Drivers	Impacts
Extreme Temperature Storm Intensity	• Extreme heat is unsafe for outdoor workers and altering working hours may not be acceptable to all employees[9,12] • Intense storms events uproot homes and cars and threaten lives

Equipment and Materials

Climate Drivers	Impacts
Extreme Temperature Storm Intensity Water Supply Variability	• Increasing temperatures require more insulation and energy for cooling Tampa Bay Water's facilities • Investment in more robust equipment that can withstand additional water and heat may be required • Future water supplies may be more costly

Enhanced Engineering Requirements

Climate Drivers	Impacts
Storm Intensity Water Supply Variability	• If Tampa's water demand increases, further engineering may be required to bolster existing infrastructure and develop new delivery methods that can withstand supply variability and intense storms

Tampa Bay Water Map and Resources[14]

ENGINEERING, DESIGN, AND CONSTRUCTION	
Risks	**Opportunities**
• Higher costs for engineering, construction, energy and maintenance • Reduced field crew efficiency • System failure and continuity of service problems	• Training for engineers on changing risks • Modified or new design standards to address risks • Changes in planning assumptions and construction timing

Climate Data and Information

In August 2018, staff from Tampa Bay Water collaborated with the research team to map three example water utility business functions, ***drinking water treatment and distribution, engineering, design, and construction, and physical and cyber security****, to eight different climate stressors and impacts. Stressors and impacts related to drought, flooding, sea-level rise, storms, and temperature were common for at least two of the three business functions identified. Each checkmark in Table 1 indicates that the climate stressor and impact influence the relevant business function.*

Table 1. Climate Stressors and Impacts

Water Utility Business Functions	Climate Stressors and Impacts							
	Air Humidity and Salinity	Drought	Flooding	Precipitation	Sea Level Rise/ Storm Surge	Storm Intensity	Extreme Temper-ature	Tropical Cyclones
Drinking water treatment and distribution		✓	✓	✓	✓		✓	✓
Engineering, design, and construction		✓	✓			✓	✓	
Physical and cyber security	✓				✓	✓	✓	

SUMMARY OF CLIMATE INFORMATION SOURCES AND TYPES

Below is a summary of climate information sources and types that were identified to help evaluate risks and opportunities for similar water utilities, organized by the eight different Climate Stressors and Impacts identified Table 1. The sources and types represent a pragmatic, rather than an exhaustive, list of climate information for *these examples. The actual number of potential sources and types is large and continues to expand. The following tables can be used as starting points from which a utility can remove or add climate information sources and types that aid in evaluating climate-related risks and opportunities.*

Table Key (Tables 2 – 17)

Climate Stressors and Impacts were classified by the following:

Derivative: sources that provide static or interactive content through predetermined analyses or syntheses in graph, map, or text formats.

- **Data:** sources that require end users to download, analyze, or visualize data to generate climate information

(F) = fine-scale information, higher resolution

(B) = broad-scale information, county level or lower resolution

AIR (INCLUDING HUMIDITY AND SALINITY)

Table 2. Air Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA NWS (B,F)		✓	✓	
NOAA National Data Buoy Center (F)	✓	✓		
NOAA Tides & Currents (F)		✓	✓	

Table 3. Air Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA National Data Buoy Center (F)	✓	✓		
NOAA NCEI Climate Data Online (F)	✓	✓		

DROUGHT

Table 4. Drought Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Florida State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			
NOAA NCEI Weekly Divisional Products (B)		✓		
U.S. Drought Monitor (B,F)	✓	✓		
U.S. Drought Portal (B,F)		✓		
U.S. Monthly Drought Outlook (B)			✓	
U.S. Seasonal Drought Outlook (B)			✓	

Table 5. Drought Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA NCEI Drought Variability[a] (B)	✓			
U.S. Drought Monitor (B,F)	✓	✓		

[a] Tree-ring reconstructions of two drought indices, see the Precipitation section for more related data sources

FLOODING

Table 6. Flooding Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS AHPS Experimental Long-Range River Flood Risk (F)			✓	
NOAA NWS AHPS River Forecasts (F)			✓	
NOAA NWS AHPS River Observations (F)		✓		
USGS National Water Information System (F)	✓	✓		

Table 7. Flooding Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
USGS National Water Information System (F)	✓	✓		

PRECIPITATION

Table 8. Precipitation Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Climate Explorer (B,F)	✓			✓
Florida State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
Implications of Climate Change on Florida's Water Resources (B)				✓
NOAA CPC ENSO Diagnostic Discussion (B)		✓	✓	
NOAA CPC Precipitation (B)		✓		
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS AHPS Precipitation (F)		✓		
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
NOAA NWS WPC Quantitative Precipitation Forecasts (B)			✓	
PRISM (B,F)	✓	✓		
U.S. Climate Atlas (B)	✓			

Table 9. Precipitation Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	✓			✓
Florida State Climate Summary (B)	✓			✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
NOAA NWS AHPS Precipitation (F)		✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		

SEA-LEVEL RISE/STORM SURGE

Table 10. Sea Level Rise/Storm Surge Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Florida State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS National Hurricane Center (B)		✓	✓	
NOAA OCM Digital Coast Historical Hurricane Tracks (B)	✓			
NOAA Sea Level Rise Viewer (B,F)			✓	✓
NOAA Tides & Currents (F)		✓	✓	
Scenarios for the National Climate Assessment (B)				✓

Table 11. Sea Level Rise/Storm Surge Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA OCM Digital Coast Historical Hurricane Tracks (B)	✓			✓
NOAA Sea Level Rise Viewer (B,F)			✓	✓
NOAA Severe Weather Data Inventory (B,F)	✓			

STORM INTENSITY

Table 12. Sea Level Rise/Storm Surge Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	

Table 13. Sea Level Rise/Storm Surge Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
NOAA Severe Weather Data Inventory (B,F)	✓			

TEMPERATURE

Table 14. Temperature Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Applied Climate Information System Maps (B,F)		✓		
Climate Explorer (B,F)	✓			✓
Florida State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
Implications of Climate Change on Florida's Water Resources (B)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Daily Summaries Map (F)	✓	✓		
NOAA NCEI Weekly Divisional Products (B)		✓		
NOAA NWS (B,F)		✓	✓	
NOAA NWS CPC (B)			✓	
NOAA NWS CPC U.S. Hazards Outlook (B)			✓	
NOAA NWS Storm Prediction Center (B)			✓	
PRISM (B,F)	✓	✓		
U.S. Climate Atlas (B)	✓			

Table 15. Temperature Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Climate Explorer (B,F)	✓			✓
Florida State Climate Summary (B)	✓			✓
LOCA (F)				✓
NOAA NCEI Climate at a Glance (B,F)	✓			
NOAA NCEI Climate Data Online (F)	✓	✓		
The North American CORDEX Program (F)				✓
PRISM (B,F)	✓	✓		

TROPICAL CYCLONES

Table 16. Sea Level Rise/Storm Surge Derivative

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
Florida State Climate Summary (B)	✓			✓
Fourth National Climate Assessment (B)	✓			✓
NOAA NWS CPC Atlantic Hurricane Season Outlook (B)			✓	
NOAA NWS National Hurricane Center (B)		✓	✓	

Table 17. Sea Level Rise/Storm Surge Data

Source (spatial scale)	Timeframes			
	Historical	Recent	Short Term	Long Term
IBTrACS (B)	✓			
NOAA Severe Weather Data Inventory (B,F)	✓			

Utility Strategies and Plans

- Tampa Bay Water Strategic Plan (2016)
- Tampa Bay Water Regulatory Plan (2018- 2019)
- Tampa Bay Water Special District Public Facilities Report (2018)

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Acronyms

AHPS = Advanced Hydrologic Prediction Service
CORDEX = Coordinated Regional Downscaling Experiment
CPC = Climate Prediction Center
ENSO = El Niño-Southern Oscillation
IBTrACS = International Best Track Archive for Climate Stewardship
LOCA = Localized Constructed Analogs
NCEI = National Centers for Environmental Information
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
OCM = Office for Coastal Management
PRISM= Parameter-elevation Regressions on Independent Slopes Model
USGS = United States Geological Survey
WPC = Weather Prediction Center

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