Planning For Water Utility Resilience: Using CREAT 3.0 to Evaluate Adaptive Measures to Climate Stressors

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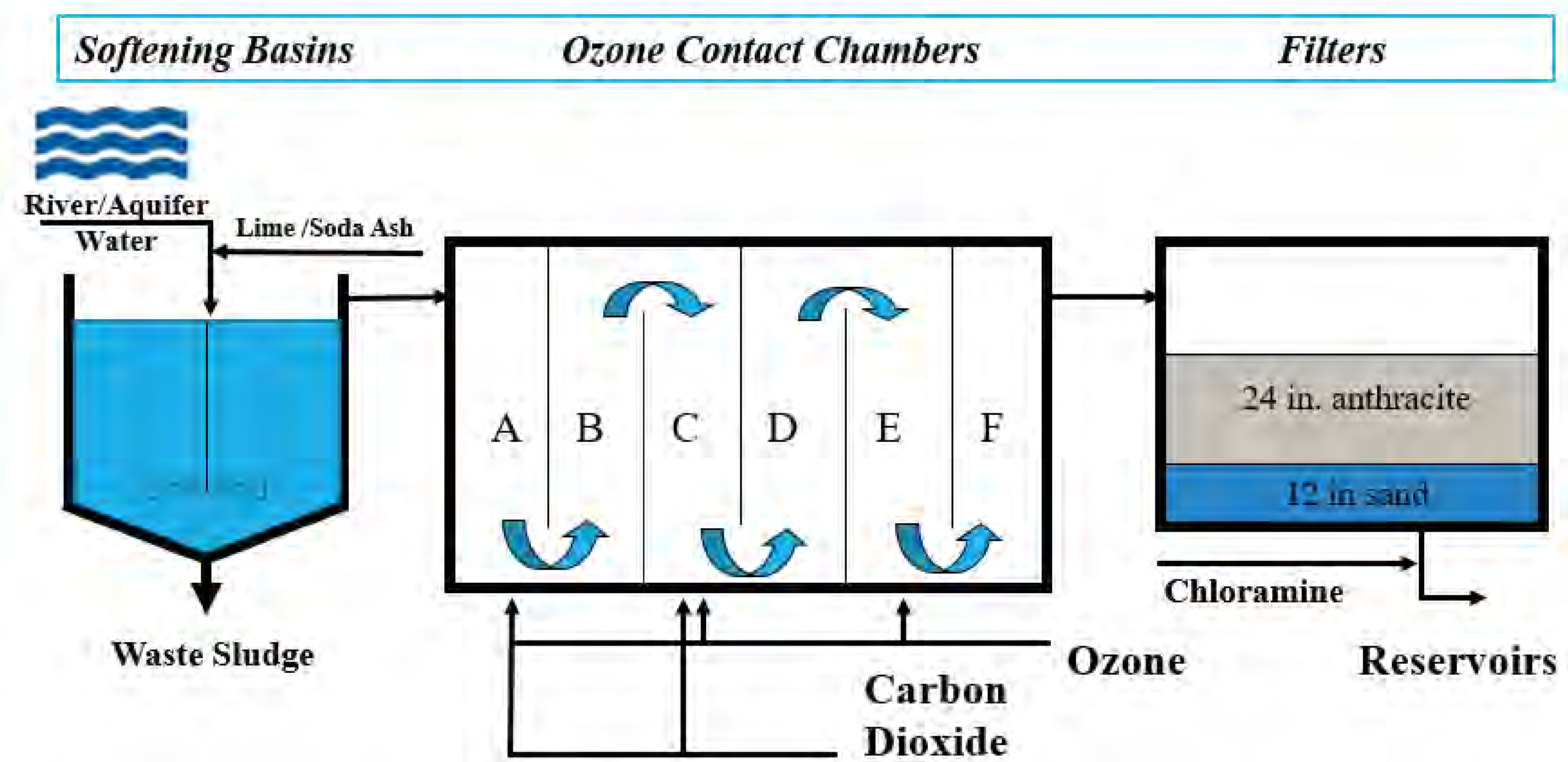
Overview

- CREAT Modules ✓
- Moorhead Public Service Water Supply
- Long-Term Water Supply (Drought) Planning
- Drought Supply Options
  - Buffalo Aquifer Expansion
- MPS CREAT Module Experience
  - Climate Awareness
  - Scenario Development
  - Consequences & Assets
  - Adaptation Planning
  - Risk Assessment

Moorhead Public Service

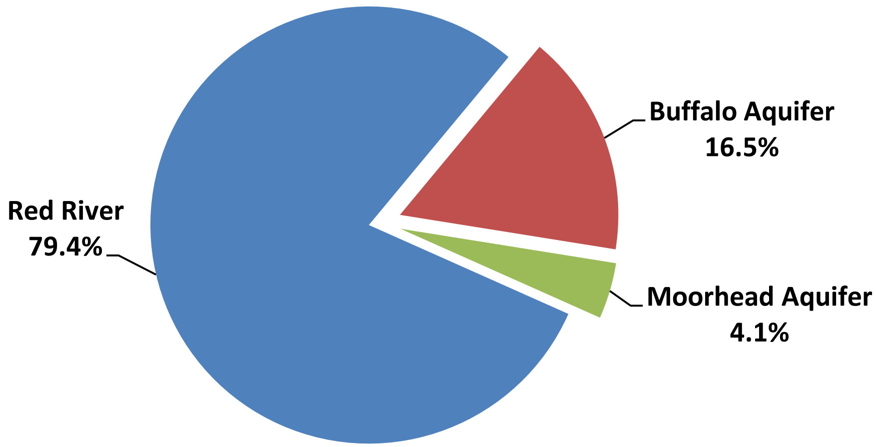
- Moorhead Water Treatment Plant
  - Municipal utility - Public
  - Built in 1994
  - Population served: ~48,000
  - Design capacity: 10 MGD
  - Average 4.52 MGD (2018)
- Source water
  - ~80% - Red River of the North
  - ~20% - Moorhead and Buffalo Aquifers
  - Large variation in water quality
- Treatment process
  - Lime-softening, ozone disinfection, dual-media filtration, chloramination

Moorhead Public Service



MPS Water Supply

- Surface Water – Red River
  - Primary Source
- Groundwater – Buffalo Aquifer and Moorhead Aquifer
  - Supplemental Source



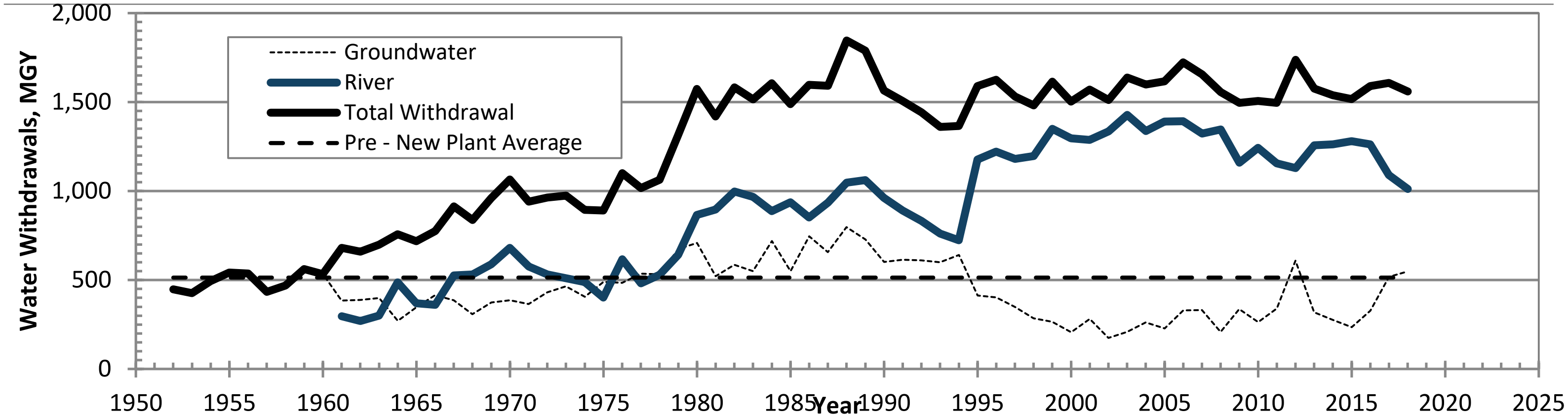
Percent of water supplied to MHD by source (2006-2015)

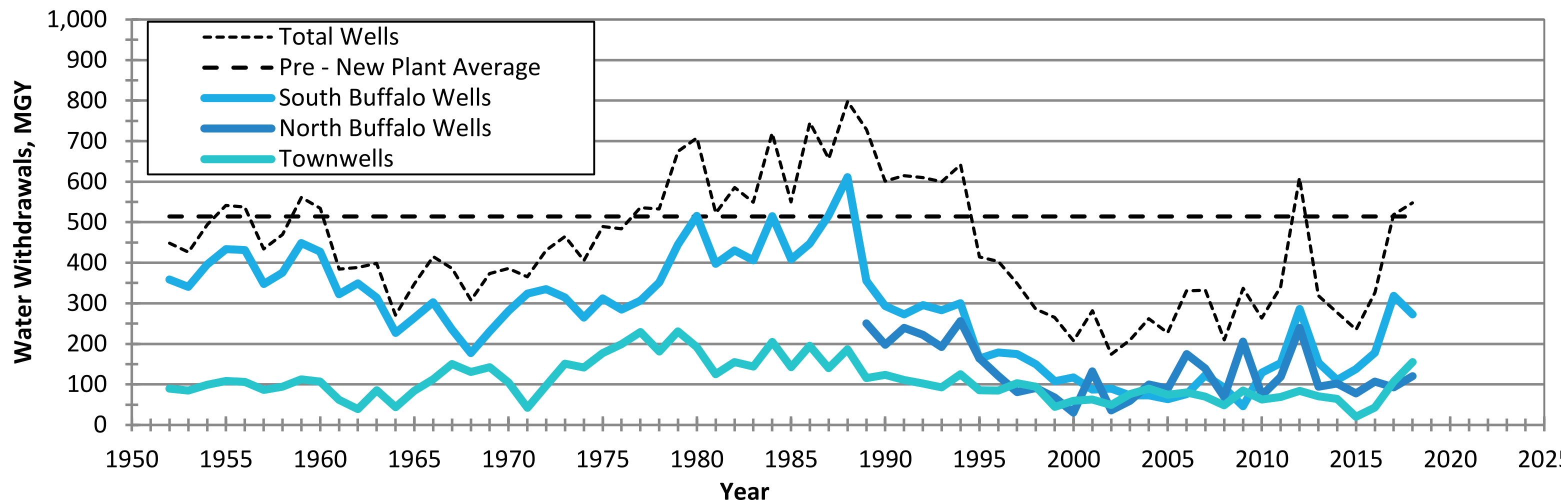
MPS Water Supply

Maintain regular use of all 3 raw water sources for:

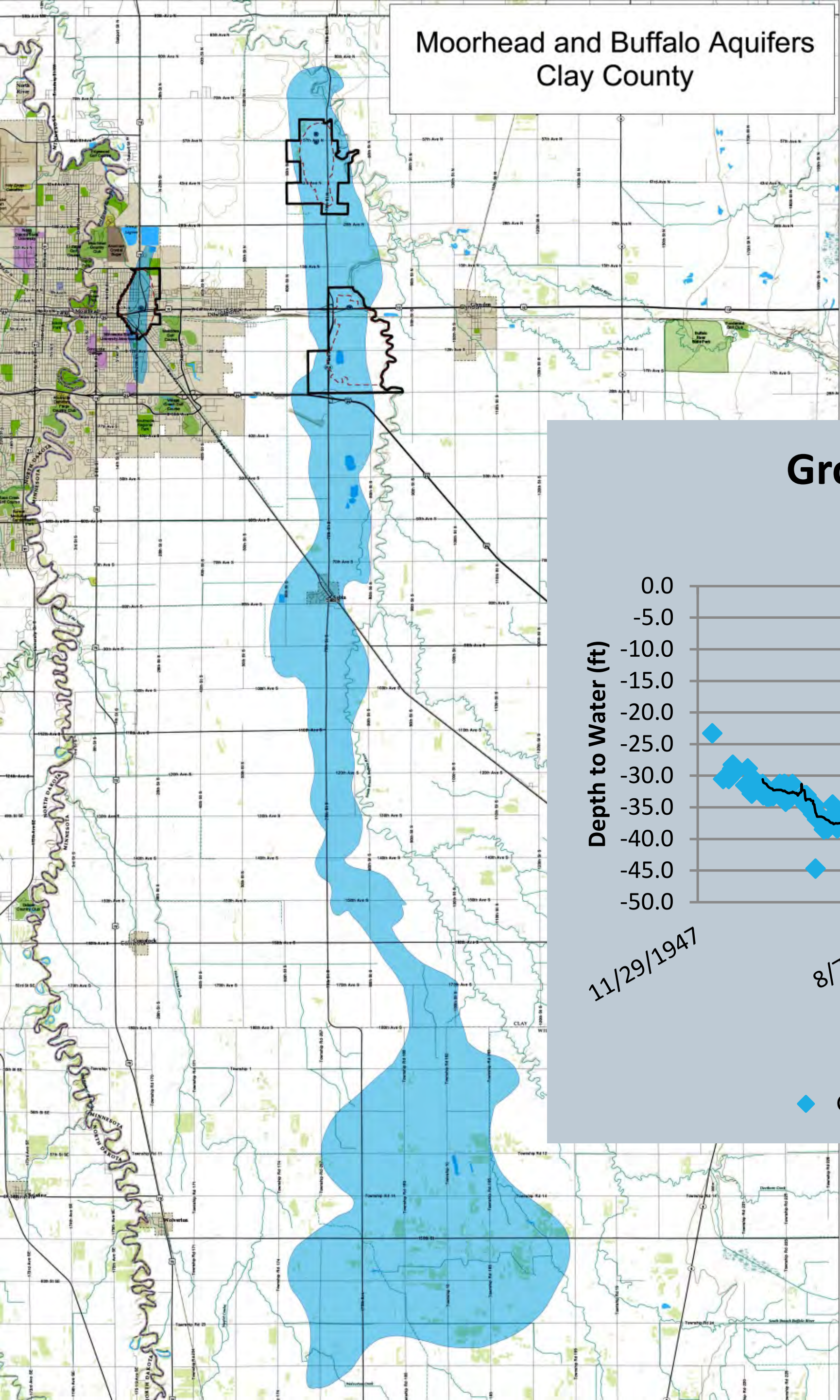
- **Drought and water shortage preparedness**
- Redundancy for Water Quality Variations
- Manage Treatment Operations
- Minimize chemical use and associated costs
- Control taste and odor events

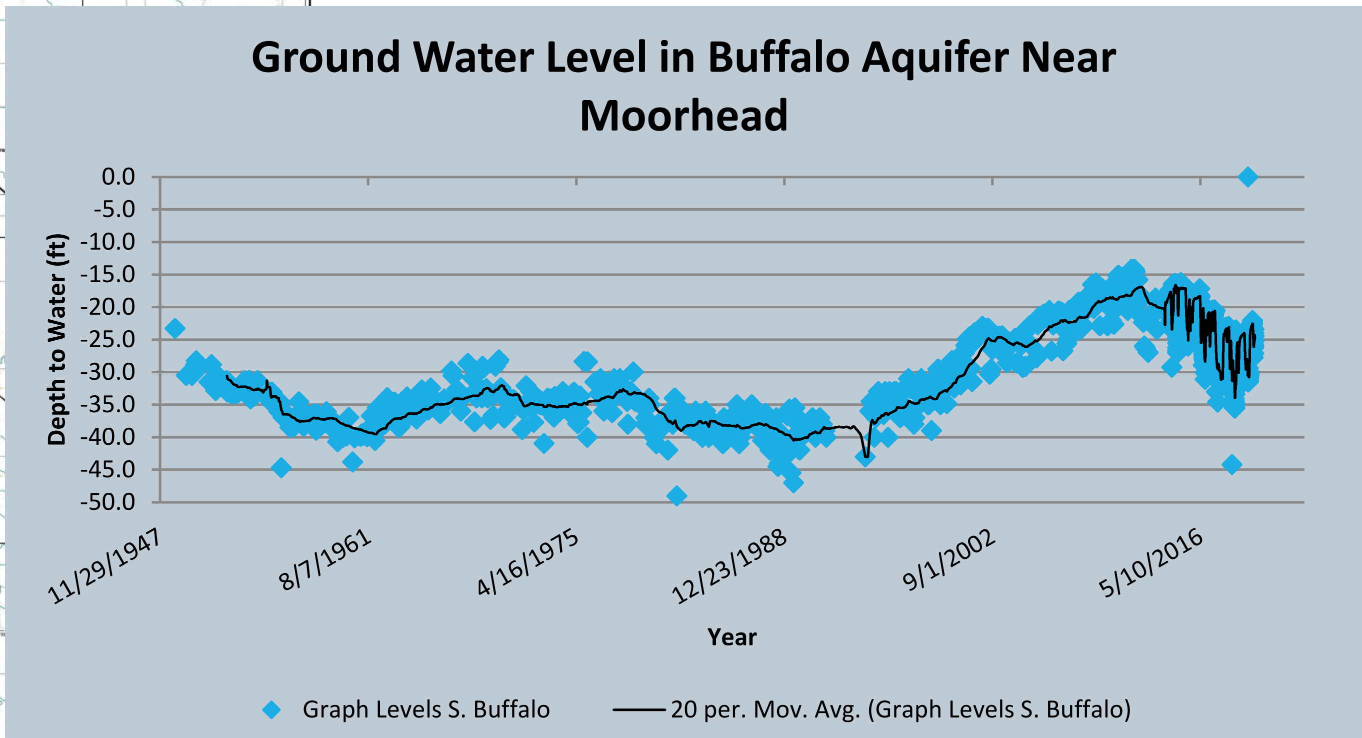
MPS Water Supply



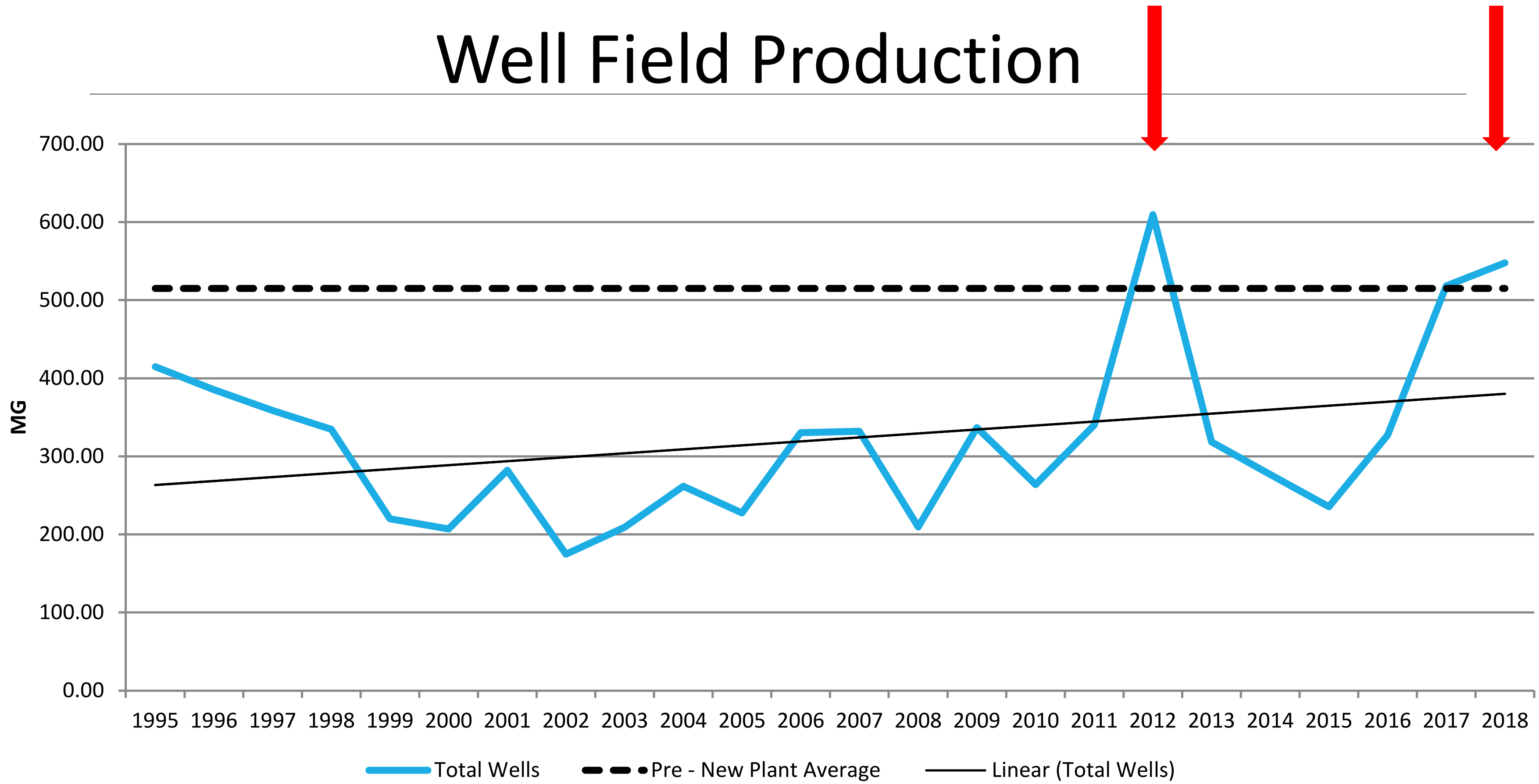


Sustainable Utilization of the Buffalo Aquifer





Well Field Production

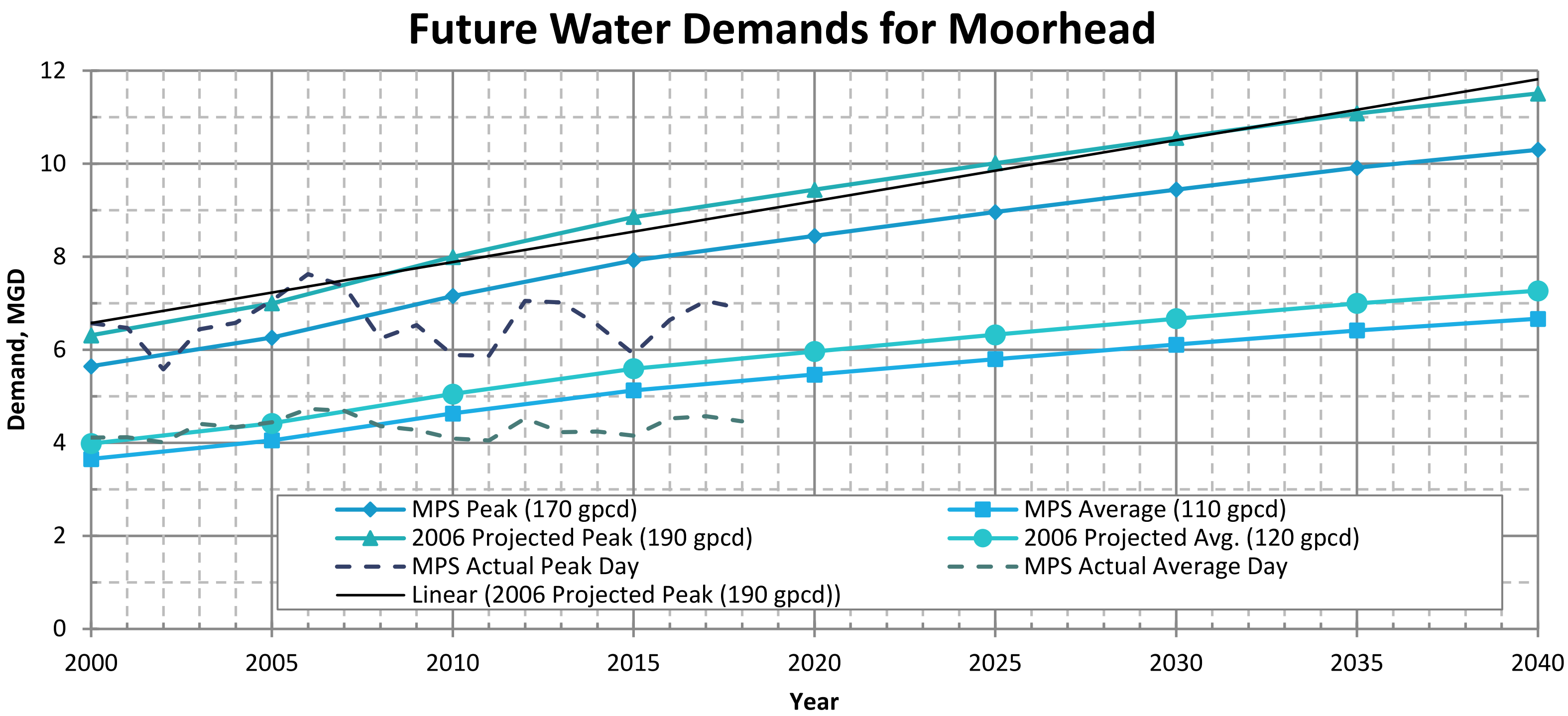


MPS Raw Water Summary

- Total Capacity = 12.78 MGD
- Firm Capacity = 10.53 MGD
  - (largest pump out of service)
  - Current Well Capacity of 5.5 MGD
- MN DNR has permitted 25.6 MGDe for Moorhead
  - Buffalo Aquifer wells and Red River could be expanded to provide additional water from existing sources
  - MPS is determining where additional water supply will be provided

Moorhead Water Demand projections

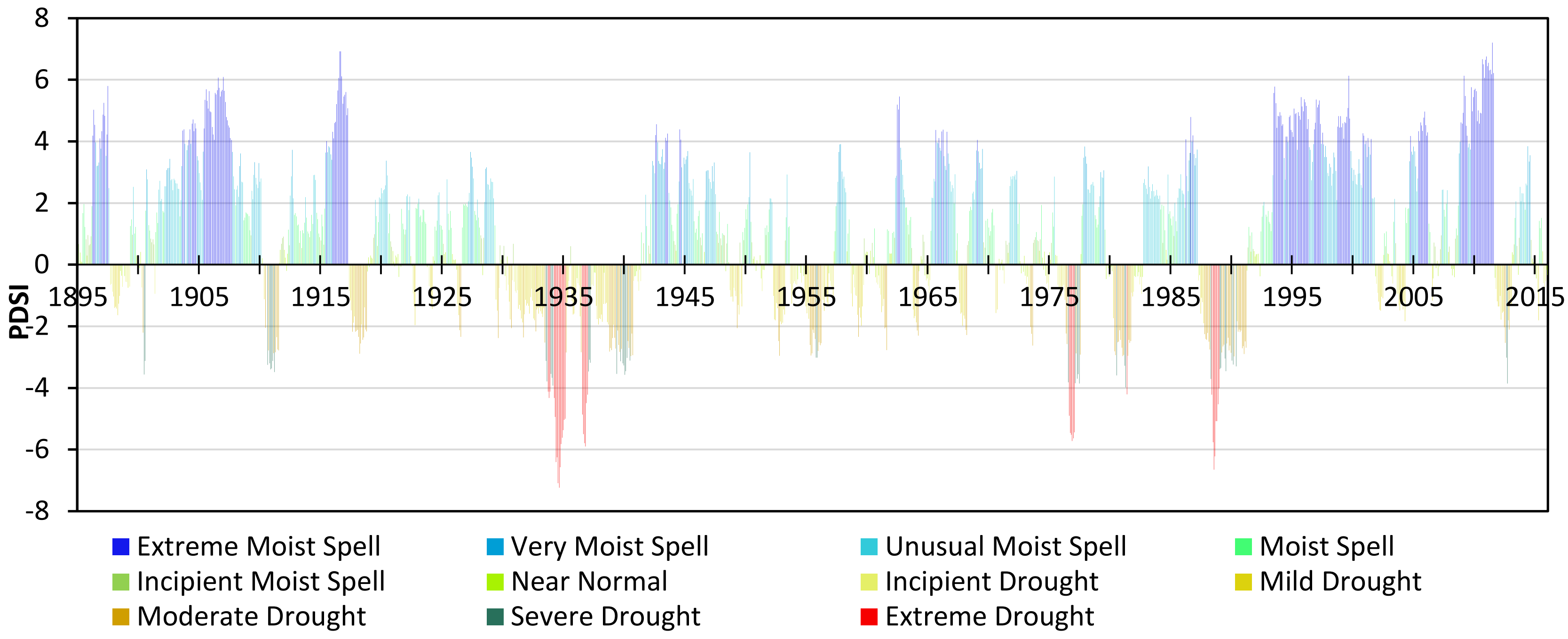
MPS’ peak demand is projected to surpass the current firm capacity in approximately 2040



Defining Climate Threats

Lower surface water (Red River) levels driving need for increased groundwater use from Buffalo Aquifer

Lower groundwater recharge (Buffalo Aquifer)



Defining Climate Threats

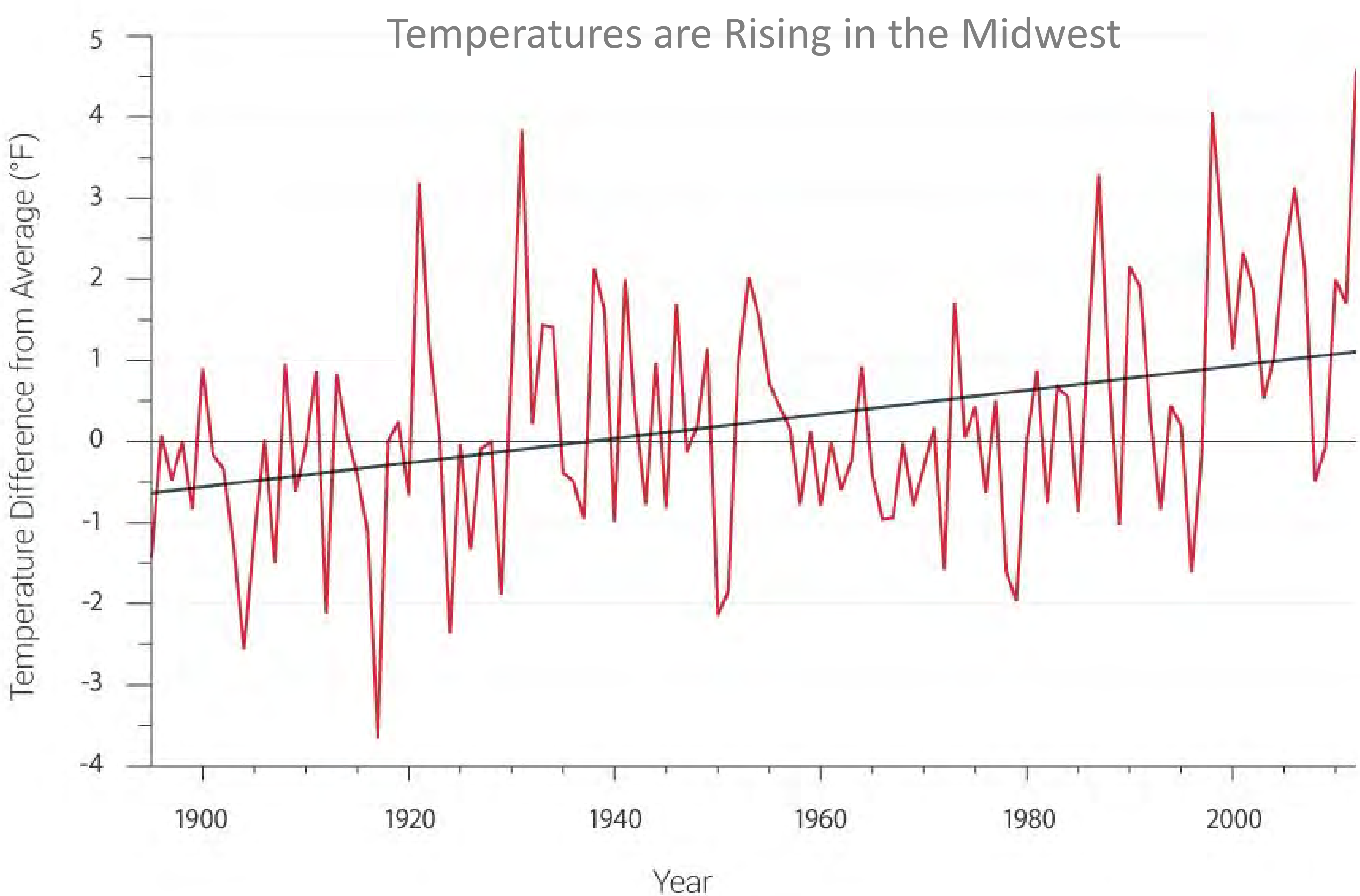


Figure 18.1: Annual average temperatures (red line) across the Midwest show a trend towards increasing temperature. The trend (heavy black line) calculated over the period 1895-2012 is equal to an increase of 1.5°F. (Figure source: updated from Kunkel et al. 2013).

Public Health Issues

- Drought
  - Reduced soil moisture, groundwater, lakes, rivers, wetlands and stream flows
  - Potential concentration of pollutants
  - Decreased water supply for drinking water and agriculture
  - Fire
- Increased Water Temperature
  - Fish populations
  - Mercury biomagnification in predatory fish
  - Harmful Algal Blooms (HABs)
  - Invasive species
  - Increased vector born diseases (West Nile Virus, etc.)

Extreme Heat Records

- 2011
  - 5 extreme heat advisories in MN
    - June 6-7
    - June 30-July 1
    - July 16-20
    - July 23
    - August 1
  - July 19, 2011
    - State Record Heat Index of 130 degrees F set in Moorhead, MN
    - 88 degree dew point with 93 degree f air temp
  - Extreme heat events Increasingly driven by high dew point, not high temperature – MN Weather Almanac
    - More evaporation occurs – warm air is less dense, so there is more room for water vapor
    - Water holding capacity of air increases 7% per degree C – part of the reason for higher statistical likelihood of higher intense storms with more precipitation overall, but less source water recharge
    - Humidity – function of temp and water vapor in atmosphere → affects skin's ability to evaporate moisture (sweat) to cool the body

Extreme Heat Events

HEAT INDEX (HI): A measure of how hot it really feels when relative humidity is factored in with the actual air temperature.

NOAA's National Weather Service Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	[illegible]	[illegible]
45	80	82	84	87	89	93	96	100	104	109	114	119	124	[illegible]	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	[illegible]	[illegible]		
55	81	84	86	89	93	97	101	106	112	117	124	[illegible]	[illegible]			
60	82	84	88	91	95	100	105	110	116	123	[illegible]	[illegible]				
65	82	85	89	93	98	103	108	114	121	[illegible]	[illegible]					
70	83	86	90	95	100	105	112	119	[illegible]	134						
75	84	88	92	97	103	109	116	124	[illegible]							
80	84	89	94	100	106	113	121	[illegible]								
85	85	90	96	102	110	117	[illegible]	[illegible]								
90	86	91	98	105	113	122	[illegible]									
95	86	93	100	108	117	[illegible]										
100	87	95	103	112	121	[illegible]										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

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These storms started out producing large hail and a few funnel clouds, then transitioned to bow echoes and 60 to 70 mph winds. These strong winds hit the Fargo-Moorhead area as well as the Fergus Falls, Minnesota area.


SKY TRAK

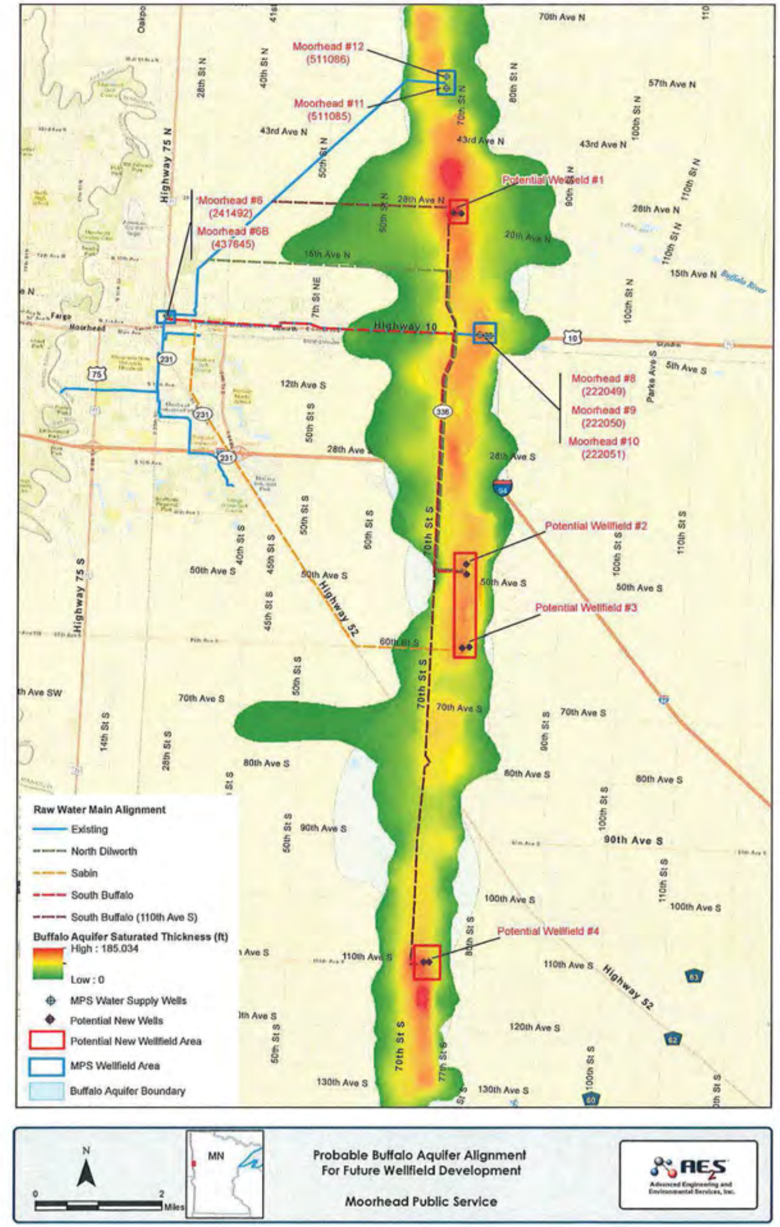
A Resilient Utility

- To prepare for potential drought conditions and the corresponding climate impacts, MPS initiated the development of a Buffalo Aquifer Management Plan to develop drought management strategies and evaluate the feasibility of a **Buffalo Aquifer Expansion Project** for the sustainable usage of the aquifer during a drought.

- The operational strategy used at the current WTP has helped MPS reserve groundwater supplies for extended drought conditions in the Red River Valley and periods of contaminated water quality conditions on the Red River.

CREAT Experience

- Series of computer modules designed to compare risks to costs of adaptive measures
- Can evaluate specified threats a utility can face to operational resiliency
- MPS’ modules centered around the **Buffalo Aquifer Expansion Project** as outlined in the **Buffalo Aquifer Management Plan**
- Focused on source waters and pumping and conveyance systems in CREAT



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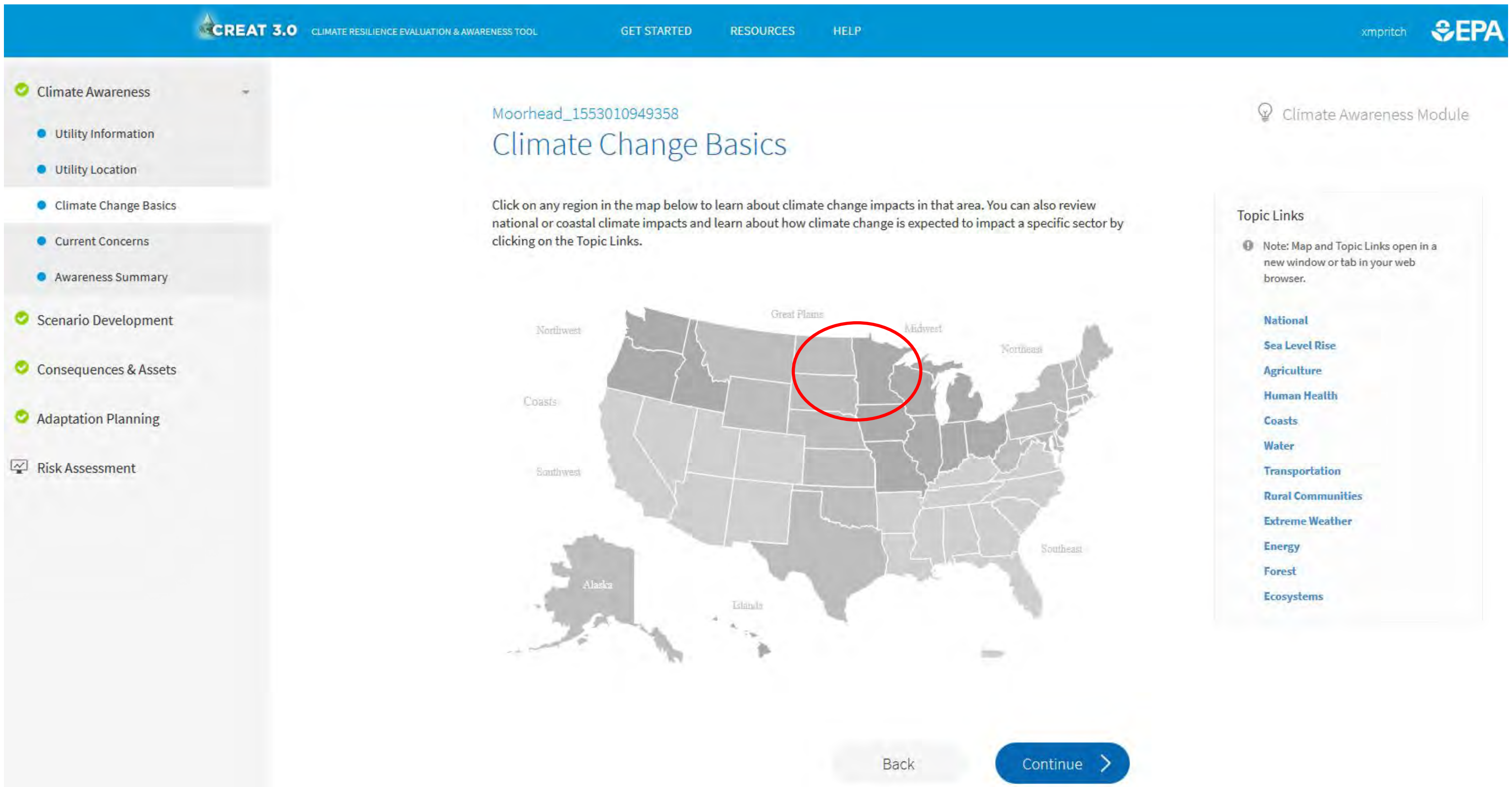
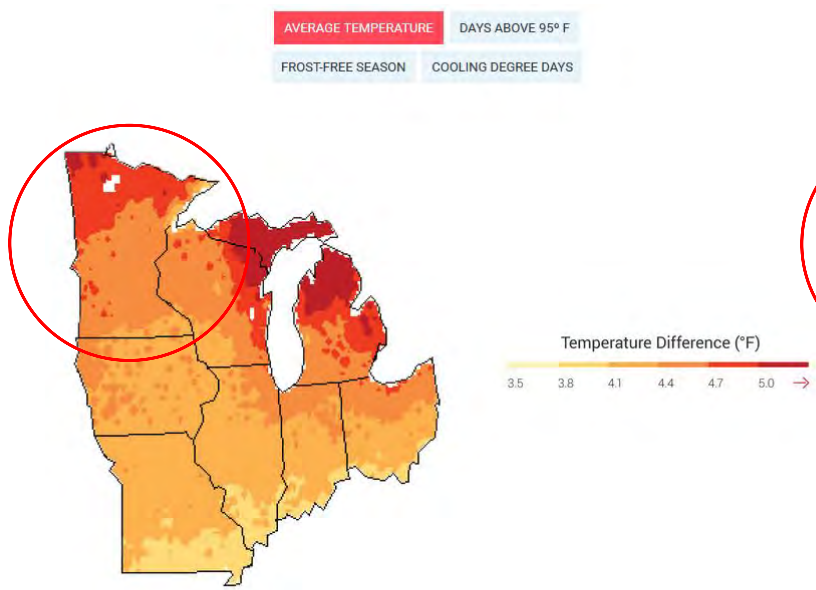
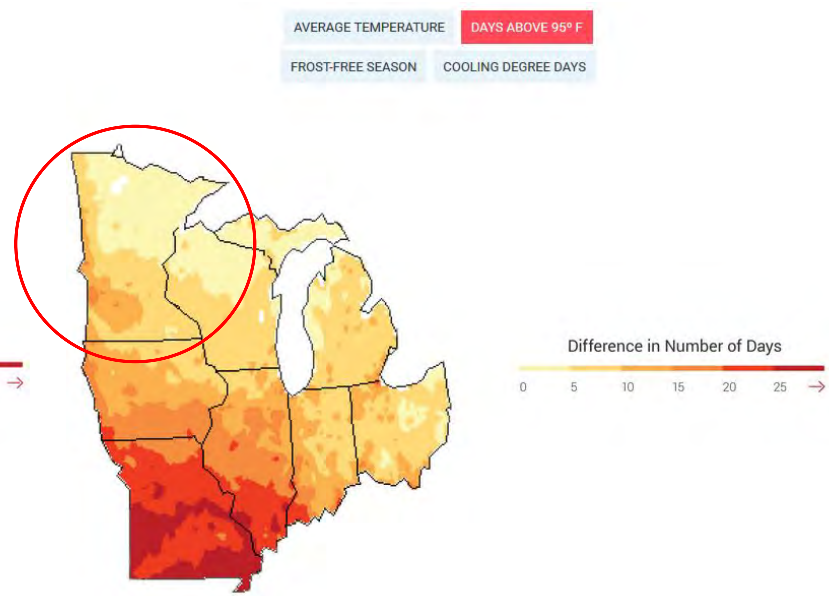
Climate Issues by Region



Climate Issues by Region
Projected Climate Changes





- Generally, annual precipitation increased during the past century (by up to 20% in some locations), with much of the increase driven by intensification of the heaviest rainfalls (Pryor et al. 2009). This tendency towards more intense precipitation events is projected to continue in the future (Schoof et al. 2010). **Precipitation is projected to increase in winter, spring and fall, but decrease in the summer, and the average number of days each year without precipitation is expected to increase.**
- Heat waves are anticipated to be more frequent, more severe and longer in duration

Figure 18.2: Projected increase in annual average temperatures by mid-century (2041-2070) as compared to the 1971-2000 period tell only part of the climate change story. Maps also show annual projected increases in the number of the hottest days (days over 95°F), longer frost-free seasons, and an increase in cooling degree days, defined as the number of degrees that a day's average temperature is above 65°F, which generally leads to an increase in energy use for air conditioning. Projections are from global climate models that assume emissions of heat-trapping gases continue to rise (A2 scenario). (Figure source: NOAA NCDC / CICS-NC).

Temperature and Precipitation Distribution in the Great Plains

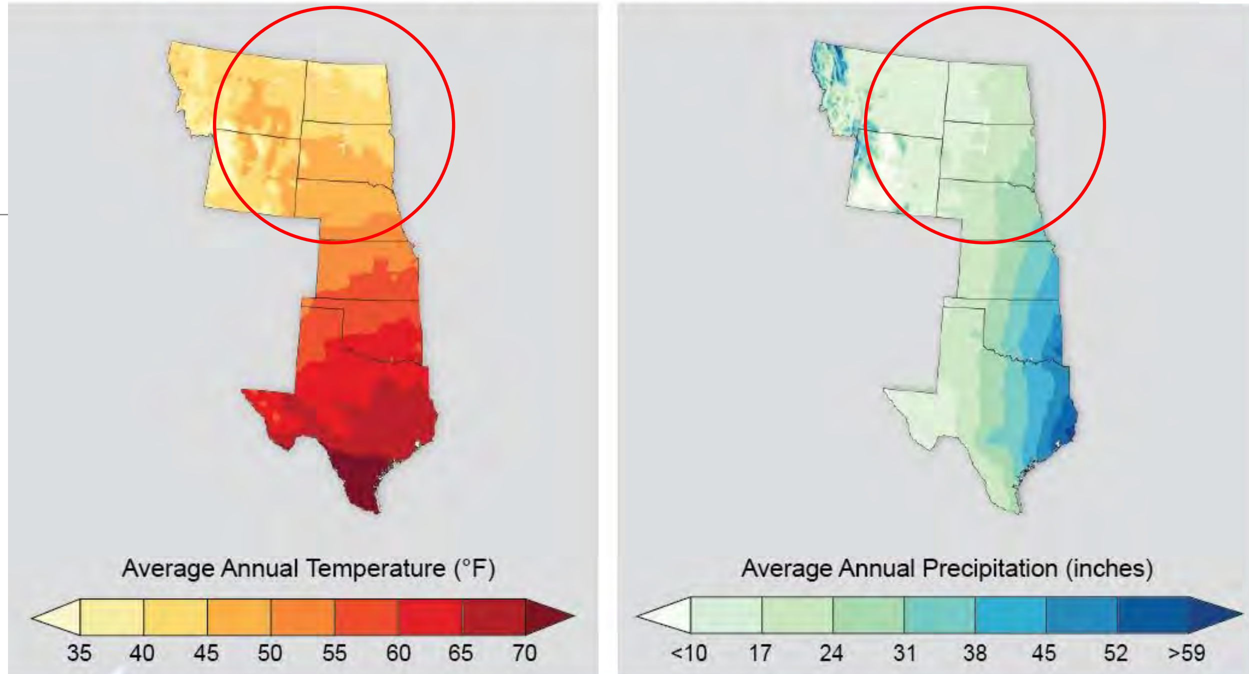


Figure 19.1: The region has a distinct north-south gradient in average temperature patterns (left), with a hotter south and colder north. For precipitation (right), the regional gradient runs west-east, with a wetter east and a much drier west. Averages shown here are for the period 1981-2010. (Figure source: adapted from Kunkel et al. 2013[1]).

- Projections of increasing temperatures, faster evaporation rates and more sustained droughts brought on by climate change will only add **more stress to overtaxed water sources**.
- Projected **increases in precipitation are unlikely to be sufficient to offset decreasing soil moisture** and water availability in the Great Plains, due to rising temperatures and aquifer depletion.
- **More frequent extreme events, such as heat waves, droughts, snow and heavy rainfall are projected to occur.**
- North Dakota's increase in annual temperature over the past 130 years is the fastest in the contiguous U.S. and is mainly driven by warming winters.

Figure 19.1: The region has a distinct north-south gradient in average temperature patterns (left), with a hotter south and colder north. For precipitation (right), the regional gradient runs west-east, with a wetter east and a much drier west. Averages shown here are for the period 1981-2010. (Figure source: adapted from Kunkel et al. 2013[1]).

Scenario Development

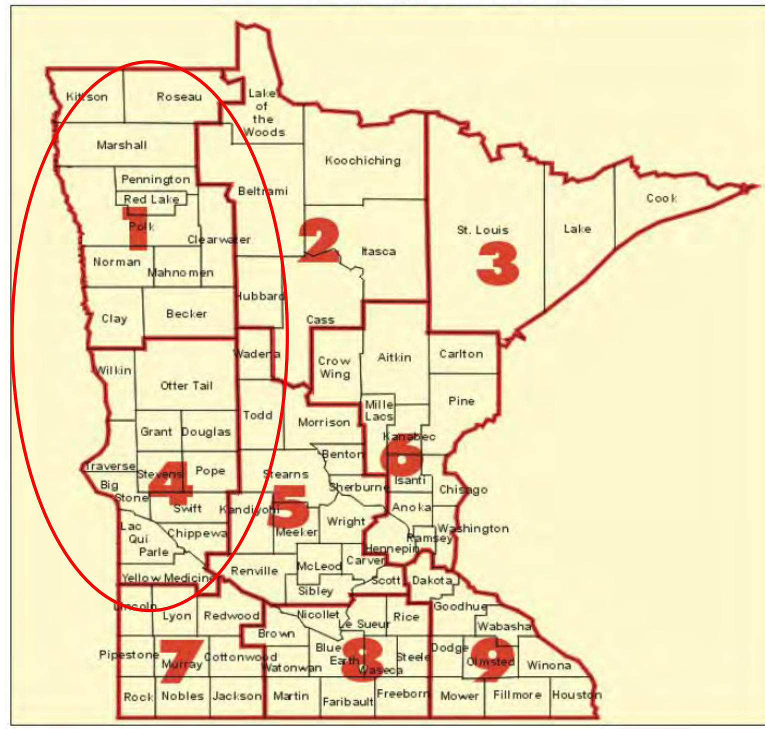
- Goal is to identify and define climate threats you want to consider based on the current concerns identified in the Climate Awareness module
- Review historical climate conditions provided by CREAT for your location, such as temperature, precipitation and storm events (stock data)
- Stock data helps you to understand how these conditions drive selected threats. This historical climate data is used to build a Baseline Scenario for comparison with scenarios of future climate conditions.
- MPS used *customized location – specific data from Buffalo AMP* for drought scenario development
  - CREAT (PRISM data from 1981-2010) vs MPS Drought Model data
  - Used CREAT default values for the 100-year intense precipitation event and annual number of hot days for analysis

Scenario Development: Buffalo AMP Data Regions

North Dakota (Regions 6 and 9):

South Dakota (Region 3):

Minnesota (Regions 1 and 4):



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Scenarios Identified

- ***Baseline Scenario***
  - **Reduced groundwater recharge of the Buffalo Aquifer and streamflow for the Red River and Buffalo River.**
  - Decreased surface water supplies and groundwater recharge
- MPS compared their climate records with the default CREAT data (PRISM data from 1981-2010)
  - Custom data used for Baseline Scenario
  - Default CREAT values used for the intense precipitation event and a range of metrics for annual number of hot days.

- ***Hotter & Drier Scenario***
  - **Reduced groundwater recharge for the Buffalo Aquifer and reduced streamflow for the Red River and Buffalo River.**
  - Decreases in summer-month precipitation will decrease surface water supplies and groundwater recharge. Related potential factors include:
    - increased reliance on groundwater to meet demand;
    - increased demand due to increasing temperatures;
    - increased strain on groundwater resources due to increased agriculture increases; and
- decreased ability to meet peak demand due to insufficient groundwater pumping capacity.

- Note: Both scenarios baseline and hot & dry required monthly temperature, precipitation, 100-year intense precipitation events (inches in 24 hrs), number of hot days above 90, 95, & 100 (annually, degrees F)

Scenario: Custom Baseline (2019-2060)

Baseline Scenario

Baseline Scenario

CREAT TIP

The Baseline Scenario is composed of historical climate variables based on observations from near your location, like average temperature, total precipitation and extreme events. These climate conditions define the threats you may be experiencing today and will continue to face even with minimal climate change. Understanding your baseline climate conditions will help you consider how projected future changes in these conditions might alter your threats and ultimately place your assets and water resources at risk.

Review the **Baseline Scenario** for your location below. Click "Edit Scenario" to update the values seen in the table or add additional measurements for consideration. If you do not wish to change the data, click "Continue."

If you do not see the Number of Hot Days in the table below, the default or currently selected climate station does not have this data available. To add this data, edit the Baseline Scenario and either change the Climate Station or add the data based on your records or other data sources under Other Conditions. To review stations that have Hot Days data, visit the **CREAT Projection Map**.

Baseline Scenario

Baseline Scenario: Historical Data — VIEW SCENARIO

MEASUREMENT	VALUE	UNITS	SOURCE
Average Annual Temperature	40.63	Fahrenheit	Custom
Average January Temperature	7.03	Fahrenheit	Custom
Average February Temperature	11.65	Fahrenheit	Custom

Scenario:
Hotter & Drier (2019-2060)

Hotter & Drier

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Scenario Development Module

Projected Scenarios

Click "Add Scenario" to build a new scenario. You should include at least one scenario, in addition to the Baseline Scenario, to continue your assessment.

As you develop scenarios, consider the projection data provided in CREAT as a basis for your threat definitions. **Each value shown as a projection in the table below is based on an average of those climate model results that represent each of the possible climate futures provided.** These projections are provided to illustrate the future range of potential changes in climate; no single scenario is more likely to occur than any other.

Add Scenario

Baseline Scenario

Hotter & Drier

Hotter & Drier (2060):
Hotter And Drier Future Conditions

VIEW SCENARIO

MEASUREMENT	VALUE	UNITS	SOURCE
Annual Change In Temperature	7.43	Fahrenheit	CREAT
January Change In Temperature	9.07	Fahrenheit	CREAT
February Change In Temperature	8.93	Fahrenheit	CREAT
March Change In Temperature	6.88	Fahrenheit	CREAT
April Change In Temperature	6.03	Fahrenheit	CREAT

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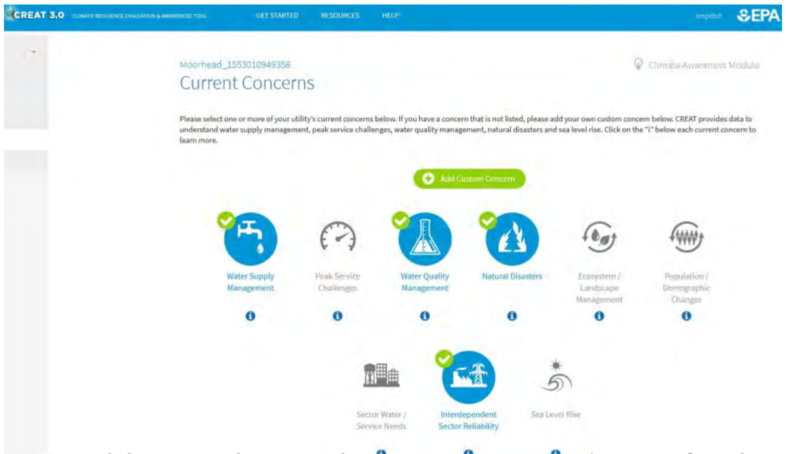
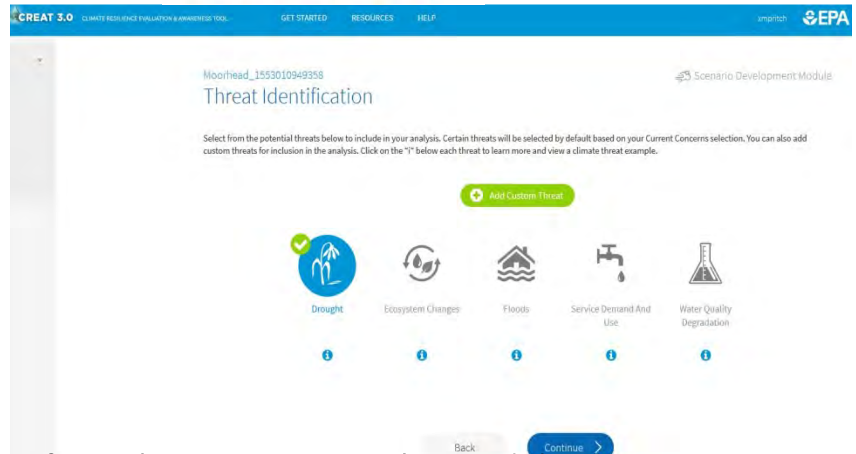
Scenario Development - Selections

Threat Selected





- Able to select utility concerns and specific threats for Risk Assessment in the Module
- Used customized location – specific data in place of baseline historical data provided by CREAT
  - Purpose was to more closely align efforts with completed MPS Drought Model

Scenario Summary

- **Hotter & Drier**
- Decreases in summer-month precipitation will decrease surface water supplies and groundwater recharge, especially impacting utilities that rely on groundwater supplies.
- Related potential factors include:
  - increased reliance on groundwater to meet demand;
  - increased demand due to increasing temperatures;
  - increased strain on groundwater resources due to increased agriculture increases; and
  - decreased ability to meet peak demand due to insufficient groundwater pumping capacity.

Climate Station: MOORHEAD Custom Baseline Scenario				Climate Station: MOORHEAD Hotter & Drier			
Ave Annual Temp	40.63	Fahrenheit	Custom	Annual Change in temp	7.43	Fahrenheit	CREAT
Ave May Temp	54.8	Fahrenheit	Custom	May Change in temp	5.93	Fahrenheit	CREAT
Ave June Temp	64.48	Fahrenheit	Custom	June Change in temp	6.58	Fahrenheit	CREAT
Ave July Temp	69.99	Fahrenheit	Custom	July Change in temp	8.14	Fahrenheit	CREAT
Ave August Temp	67.76	Fahrenheit	Custom	August Change in temp	7.64	Fahrenheit	CREAT
Ave September Temp	57.73	Fahrenheit	Custom	September Change in temp	7.22	Fahrenheit	CREAT
Total Annual Precipitation	21.21	Inches	Custom	Annual Change in precip	1.56	%	CREAT
Total May Precip	2.68	Inches	Custom	May Change in precip	4.49	%	CREAT
Total June Precip	3.74	Inches	Custom	June Change in precip	-8.13	%	CREAT
Total July Precip	3.06	Inches	Custom	July Change in precip	-17.41	%	CREAT
Total August Precip	2.7	Inches	Custom	August Change in precip	-15.82	%	CREAT
Total September Precip	2.16	Inches	Custom	September Change in precip	-0.81	%	CREAT
100-year Intense Precipitation Event	7.23	Inches/24hr	CREAT	Change in 100-year Intense Precipitation	25.75	%	CREAT
Annual Number of hot days over 90 °F	7.4	Days	CREAT	Annual Number of hot days over 90 °F	43.73	Days	CREAT
Annual Number of hot days over 95 °F	0.93	Days	CREAT	Annual Number of hot days over 95 °F	16.47	Days	CREAT
Annual Number of hot days over 100 °F	0	Days	CREAT	Annual Number of hot days over 100 °F	3.87	Days	CREAT

Consequences and Assets

- Identified the types of threats that may impact MPS and selected data that defines scenarios of threats based on different changes in climate conditions at your location. Next, you need to determine which types of consequences you might expect if these threats were to occur.
- Utility Business Impacts
- Utility Equipment Damage
- Environmental Impacts
- Source/Receiving Water Impacts

Economic Consequence Matrix for Moorhead Public Service

Levels	Utility Business Impacts Operating revenue loss evaluated in terms of the magnitude and recurrence of service interruptions. Consequences range from long-term loss of expected operating revenue to minimal potential for any loss.	Utility Equipment Damage Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of the magnitude of damage and financial impacts. Consequences range from complete loss of the asset to minimal damage to the equipment.	Environmental Impacts Evaluated in terms of environmental damage or loss, aside from water resources, and compliance with environmental regulations. Consequences range from significant environmental damage to minimal impact or damage.	Source/Receiving Water Impacts Degradation or loss of source or receiving water quality or quantity evaluated in terms of recurrence. Consequences range from long-term compromise to no more than minimal changes to water quality or quantity.
Very High	Long-term or significant loss of expected revenue or operating income	Complete loss of raw water pumps and transmission mains	Significant environmental damage	Long-term compromise of source water quality or quantity
	> $1,246,500	**> $120,000**	**> $173,880**	**> $1,181,280**
High	Seasonal or episodic compromise of expected revenue or operating income	Significant wear to raw water pumps and transmission mains	Persistent environmental damage	Seasonal or episodic compromise of source water quality or quantity
	$832,500 - $1,246,500	**$80,000 - $120,000**	**$72,680 - $173,880**	**$492,200 - $1,181,280**
Medium	Minor and short-term reductions in expected revenue	Minor wear to raw water pumps and transmission mains	Short-term damage, compliance can be quickly restored	Temporary impact on source water quality or quantity
	$414,000 - $832,500	**$40,000 - $80,000**	**$28,980 - $72,680**	**$196,880 - $492,200**
Low	Minimal potential for loss of revenue or operating income	Minimal wear to raw water pumps and transmission mains	No impact or environmental damage	No more than minimal changes to water quality
	$0 - $414,000	**$0 - $40,000**	**$0 - $28,980**	**$0 - $196,880**

Note: values based on water sector survey data and calculated using the utility type, population served, total daily flow, public vs private ownership, and financial condition, with input and adjustment by MPS

MOORHEAD PUBLIC SERVICE

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Consequences and Assets Module

Public Health Consequences

Do you wish to consider public health consequences for this analysis file?

Yes No

CREAT provides defaults for the Value of Statistical Life (VSL) and the Value of Statistical Injury (VSI) toanalyze public health impacts. You can customize these values, if desired.

Value of statistical life: $7,900,000

VSL is the value attributed to each fatality assessed due to the occurrence of a threat to a particular asset. A default value of $7,900,000 is provided based on Guidelines for Preparing Economic Analyses.

Value of statistical injury: $79,000

VSI is the value attributed to each injury assessed due to the occurrence of a threat to a particular asset. A default value of $79,000 is provided based on Guidelines for Preparing Economic Analyses.

Back Continue

Asset Definition

- Prioritize those assets that are particularly vulnerable to the threats you have defined. Think about your assets and how you might group them together based on their thresholds for specific impacts.
  - Surface Water – Red River of the North
  - Ground Water – **Buffalo Aquifer**
  - Pumps and Conveyance Systems for Transport and Treatment

Adaptive Measures

Existing

- Multiple Well Fields along Buffalo Aquifer
- Identified Drought Management Stages corresponding to Water Supply Plan Action Levels
- New River Pump Station (2013)
- Limited storage of Surface Water
- Full Maintenance and Rehabilitation of All Well Houses Complete in 2018

Potential

- Increase Buffalo Aquifer Capacity (Included in Assessment)
- Replace existing raw groundwater transmission mains
- Regular inspection and annual statistical analysis of individual well production and performance (specific capacity)
- Concerted Public Outreach Efforts

PLAN NAME	RELEVANT THREATS	TOTAL COST
Current Measures	Drought	$3,600,000
Increase capacity & storage	Drought	$22,760,000 - $22,790,000

Table D-1. Existing Adaptive Measures at MPS

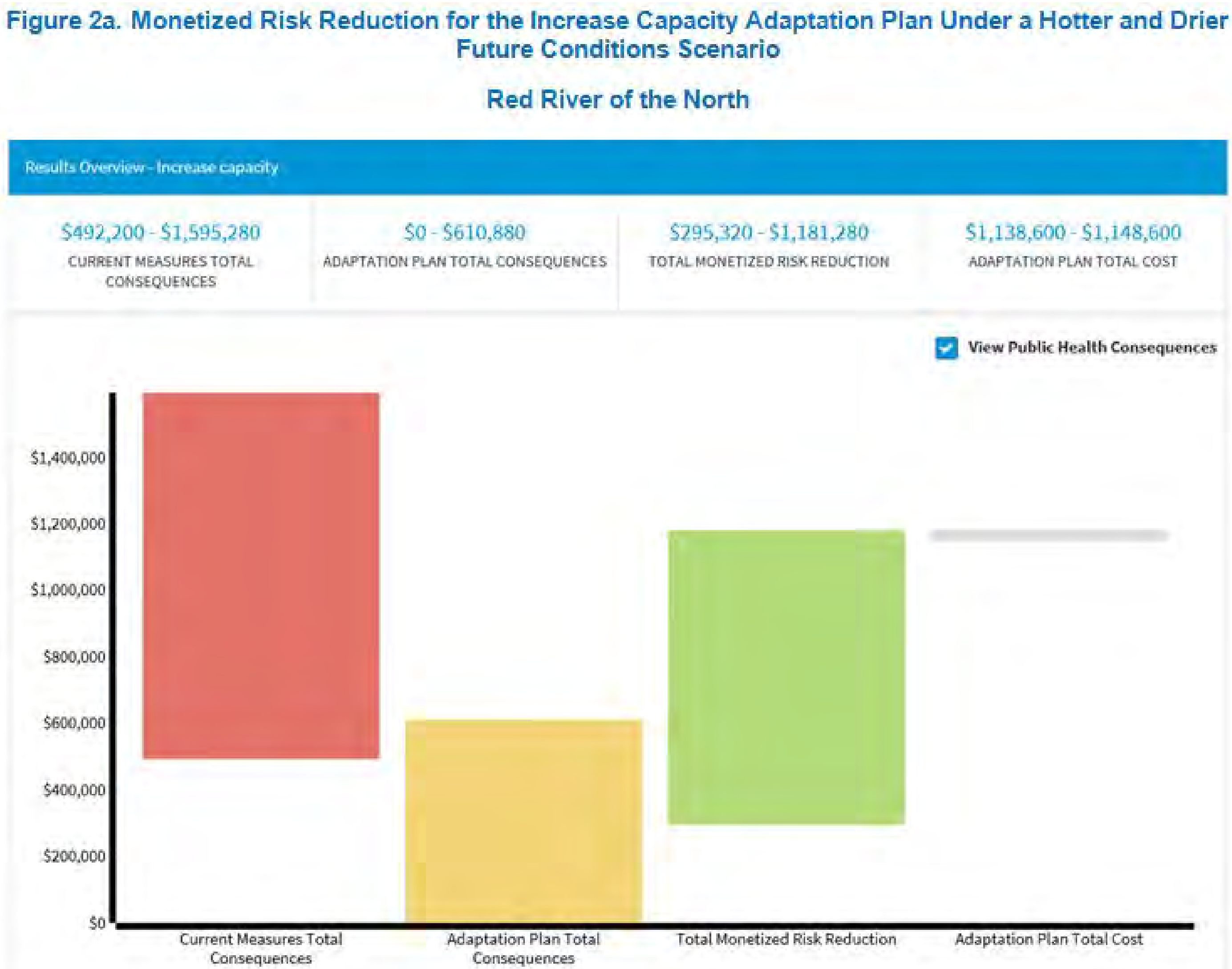
EXISTING ADAPTIVE MEASURE	DESCRIPTION	TOTAL COST
Buffalo Aquifer	The Buffalo Aquifer was developed to augment and supplement water supply when water availability decreased from the Red River. Currently, there are 2 separate well fields (North Buffalo and South Buffalo).	$0
Demand Management	MPS has documented Drought Stages and corresponding drought management actions.	$0
Lime Sludge Storage Ponds	Currently 3-5 weeks of supply are stored in the ponds, considering a raw water pumping rate of 290 gpm; storage capacity decreases as lime sludge volumes increase. There are 12 storage ponds.	$0
New Intake Construction	A new intake and complete river pumping station were constructed 2012-2013; they are resilient to a 500-year flood level (~45 ft). The intake has been relocated from the river bank to the channel at the center of the river. This will allow water to be withdrawn even under low flow conditions seen during drought. MPS used FEMA funds (pre-disaster mitigation funds) for the project.	$3,600,000

PLAN NAME	RELEVANT THREATS	TOTAL COST
Current Measures	Drought	$3,600,000
Increase capacity & storage	Drought	$22,760,000 - $22,790,000

Table D-2. Potential Adaptive Measures at MPS

POTENTIAL ADAPTIVE MEASURE	DESCRIPTION	ESTIMATED COST
Improve Buffalo Aquifer Capacity – Construct Potential Wellfield #2	Buffalo Aquifer developed to augment and supplement water supply when availability decreased from the Red River. 2 Separate wellfields (North and South) Construct Potential Wellfield #2 Total cost = $20,400,000 Annualized Cost (not including Annual O&M) = $1,108,600	$1,108,600
Annual O&M of New Well Field on Southern Buffalo Aquifer	Once constructed, annual Operation and Maintenance costs for the Southern Buffalo Aquifer (New Well Field #2) are estimated.	$30,000 - $40,000
Improvement of Lime Sludge Storage Ponds – Add De-Watering Facility	Construct de-watering facility $6.4-6.8 million (total cost). Could then move water directly from the river to the ponds; increases total capacity to store water. Based on cost/benefit calculated, MPS opted to construct the facility rather than pay for dredging, de-watering, and disposal costs every three years (around $1.2 million per pond each time).	$410,000 - $440,000

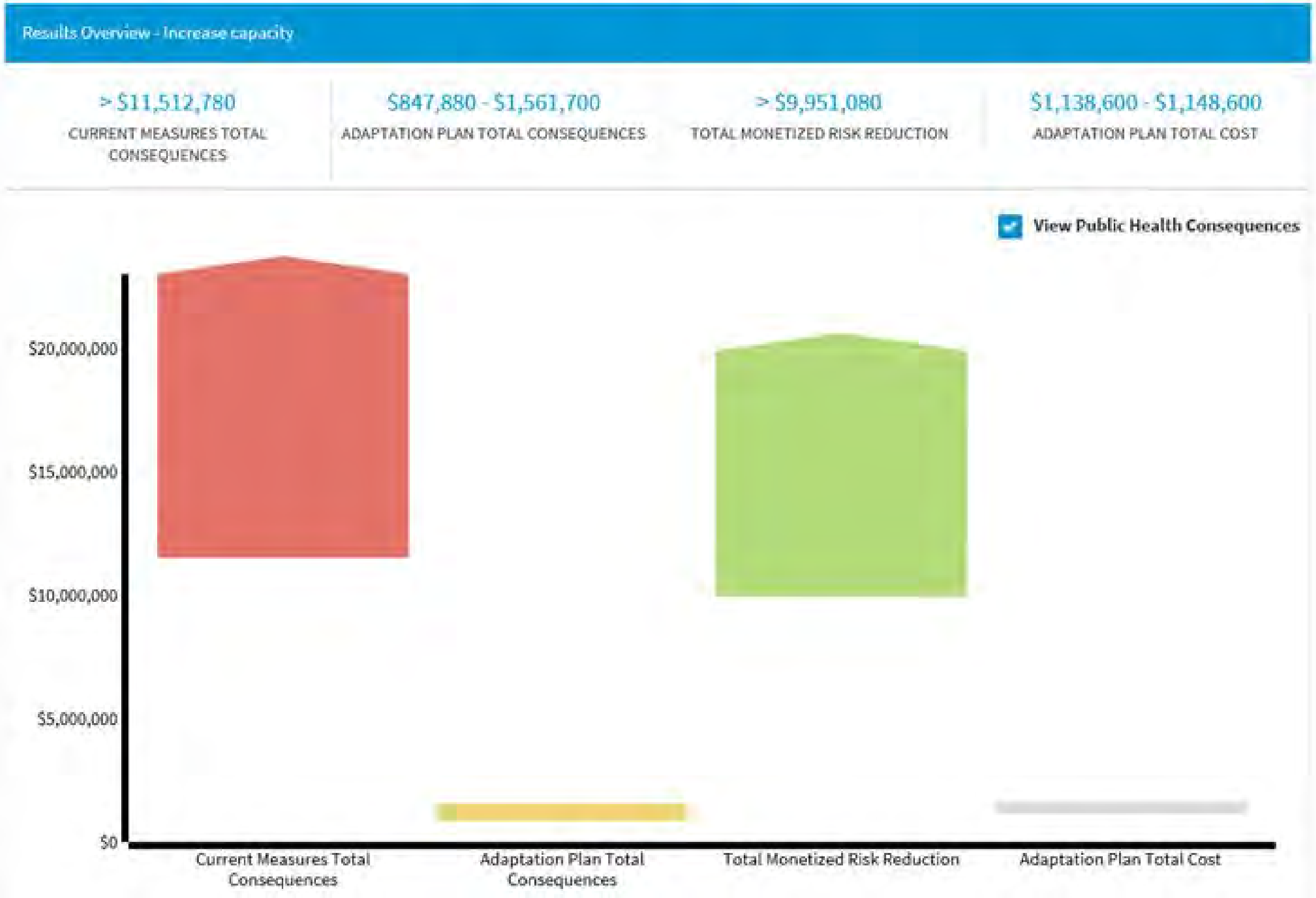
Risk Assessment Results



Risk Assessment Results

Figure 2b. Monetized Risk Reduction for the Increase Capacity Adaptation Plan Under a Hotter and Drier Future Conditions Scenario

Buffalo Aquifer



Likelihood Sensitivity

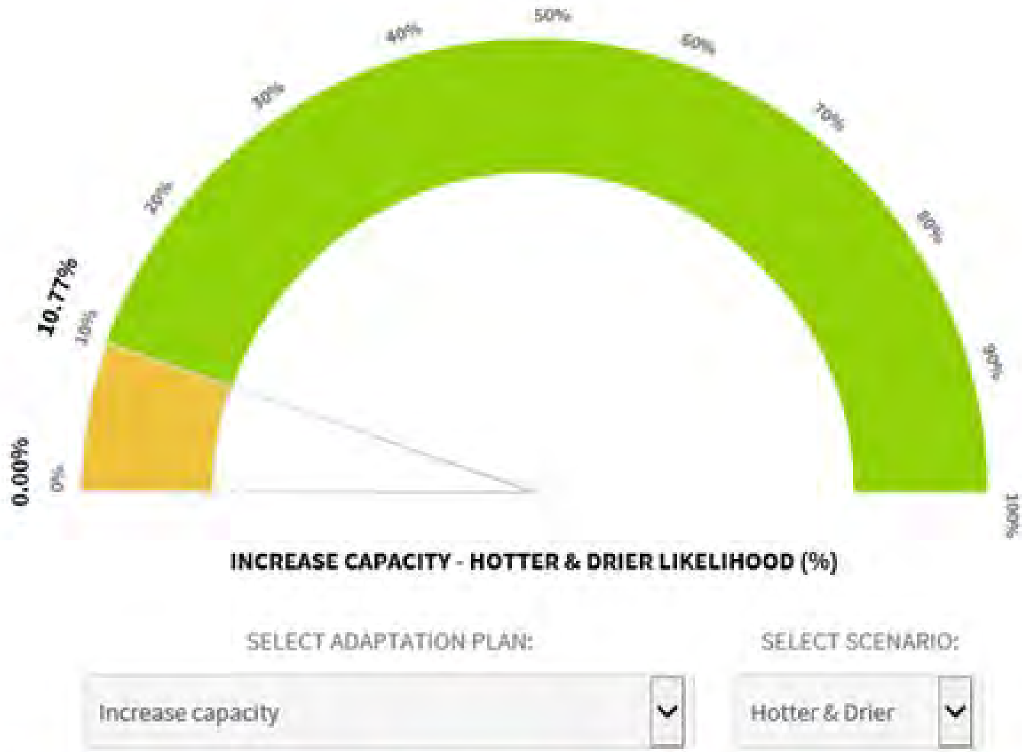


Figure 3. Likelihood Range for Analysis of Adaptation Plan Cost Effectiveness: Hotter and Drier Future Conditions Scenario

The Value of Redundant Supply

Safeguard Public Health

Improve Flexibility and Reliability

Risk Reduction

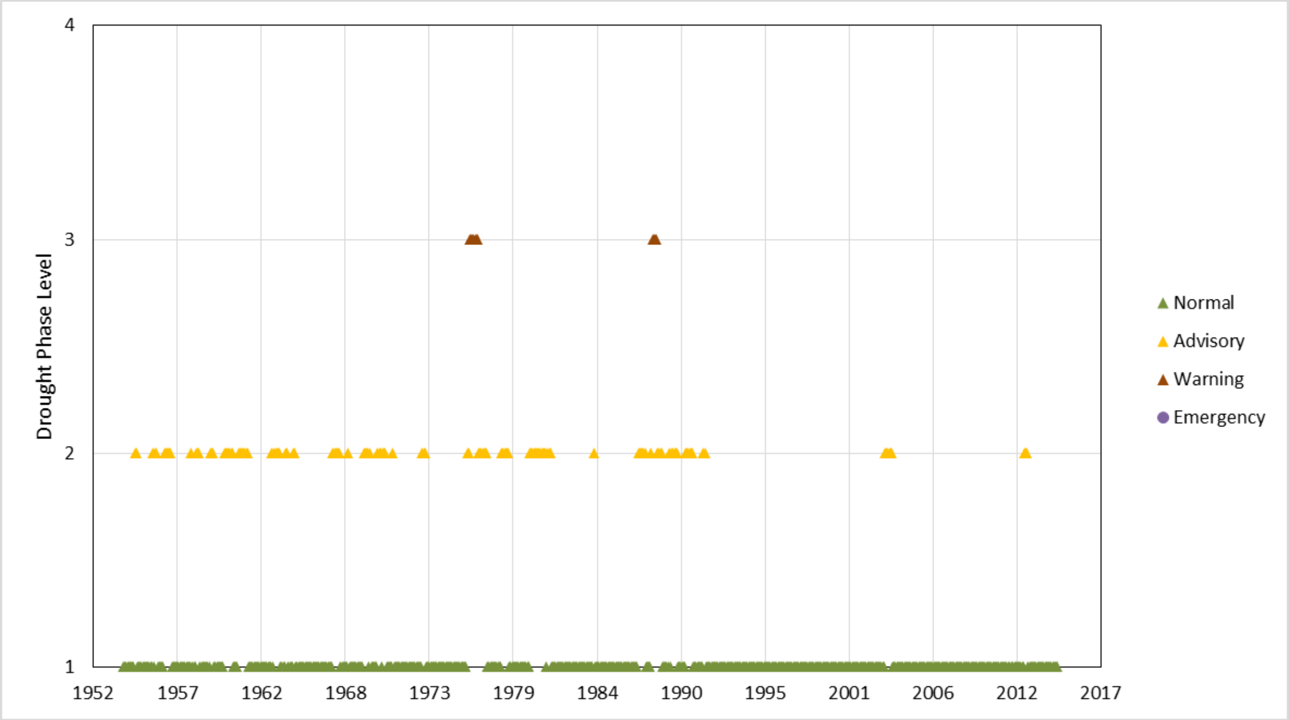
Seamless transfer to redundant systems without service disruptions

Reduce stress on Buffalo Aquifer during heavy withdrawal

How to quantify in CREAT?

Future Work

- Incorporate climate projections data from CREAT into MPS' Drought Model
- Quantify the value of redundancy of supply in subsequent CREAT Modules
- Adaptation of module data for flood analysis



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