Contents

Bear Creek Watershed Association

Draft Report Updated June 24, 2020

Potential Future (2020-2050) Climate Predicts for Middle Bear Creek Watershed

Climate Awareness

Western snowpack has declined drastically over the last 50-years. Multiple scientific studies have shown that between the 1980s and 2010s, there was a 10 to 25 percent loss in the annual maximum amount of water contained in snowpack in the western U.S. These studies also predict that climate change could cause as much as an additional 60 percent decline in snowpack over the next 30 years.

Generally, various climate models predict Colorado will see average annual temperatures increase by 2.5°F, with summers warming by 6°F and winters by 3°F by 2050. Warmer temperatures mean changes in evaporation and soil moisture, reducing snowmelt runoff in each of Colorado's river basins. More precipitation is expected to fall as rain rather than snow, and the state's high-elevation snowpack — the source of much of the state's water supply — could decline by 20 percent and melt earlier than in the past. By 2050, the spring snowmelt runoff could begin up to 17 days earlier than today, while one of Denver's most significant sources of water, the South Platte River, could see a decline in streamflow by up to 35 percent.

The hydrology of a front range watershed like Bear Creek can be very complex under expected conditions. The Bear Creek Watershed Association (BCWA) has available over 100-years of stream flow records. A clear long-term trend of declining flows, shifting weather patterns and earlier spring runoff is evident in the data record. This changing hydrology has a profound influence on water quality within the watershed. The Association also has a 25-year water quality data record. In the past decade, the Bear Creek Watershed has experienced both extreme drought and flood events. These emerging extreme trends don't appear to be predictable, but maybe there is an opportunity for the Association and member water providers to better understand how climate changes may affect the watershed in the near and long-term future. Water providers are also developing source water protection plans to better preserve and protect future water supplies.

These statewide and western U.S. climate model predictions have prompted the BCWA to specifically evaluate potential climate changes within the Bear Creek Watershed. Climate change presents challenges to watershed management, water supply, wastewater and stormwater utilities and the communities in the Bear Creek Watershed. Those water and wastewater utilities that adapt to these changes may need to raise rates to develop new water supplies and adjust their treatment and operations. The BCWA will need to adapt management strategies to protect the watershed water resources. Without adaptation, hydrologic features, infrastructure and operations designed for historical climate conditions could be overwhelmed or damaged. Main breaks, overflows, and service outages would lead to lost local business revenue and public health concerns. Environmental changes and impaired forest resources will alter water quality, supply and biodiversity. Several likely climate changes are predicted for Middle Bear Creek Watershed and each climate future has unique challenges to consider.

BCWA has concerns about water quality changes due to increases in surface water temperatures. BCWA monitors air and water temperatures around the watershed and have seen increases in daily maximum temperatures. BCWA is concerned that increasing temperatures due to changing climate conditions will present new challenges related to temperature-driven water quality changes. Temperatures in March, July, November and December are critical for snowfall and snowmelt, and temperatures in the winter and shoulder seasons are of the highest concern for temperature-driven water quality events. This data can inform the potential severity of future climate change threats.

The watershed is home to different fish species, some of which are sensitive to small increases in temperature. An increase of 1 to 2°F would present issues for the fisheries and may increase existing regulatory and water quality concerns. The fisheries in the watershed are a source of revenue for BCWA; any potential limitations to the operation of the fisheries could have community-wide impacts. Daily maximum instream surface water temperatures are classified by the State of Colorado as days with a peak two-hour average temperature above 70°F in a 24-hour period for the Bear Creek Watershed. A stream violation will occur if air temperature exceeds 90°F. Higher observed temperatures could put parts of the watershed at risk of being listed on the state's 303(d) list.

Water quality impacts from flooding have also been seen in the watershed, particularly following a wildfire. Sediment inflow following a 2013 flooding event reduced capacity in Evergreen Lake and Bear Creek Reservoir. The risk of wildfires is expected to increase in the future due to drier conditions from changing precipitation patterns, higher average temperatures, an increased number of hotter days and changes in watershed health. BCWA is seeing harmful beetles, as well as the migration of other invasive species into the upper portion of the watershed, which can contribute to tree mortality.

Since the watershed is mostly snowpack-fed, BCWA has concerns about drought, increased surface water temperatures, changes in snowmelt timing and the potential impacts to water availability in the future. Multiple studies and reports for Colorado predict average annual temperatures increasing by a minimum of 2.5°F, with summers warming by 5-7°F and winters by 3-5°F by 2050. Warmer temperatures mean changes in evaporation and soil moisture, reducing snowmelt runoff in each of Colorado's river basins. More precipitation is expected to fall as rain rather than snow, and the state's high-elevation snowpack —the source of much of the state's water supply — could decline by 20 percent and melt earlier than in the past.

CREAT (Climate Resilience Evaluation and Awareness Tool) provides climate projection data within a risk assessment framework to help the BCWA understand climate change, assess risks from climate-related threats and evaluate potential adaptation options for implementation. Within CREAT, BCWA can assess consequences from climate-related threats that

can impact watershed assets and management. CREAT defines benefits from implementing adaptation options to protect those assets and management alternatives.

BCWA Factsheets

BCWA Factsheet 56 Climate Model UBCW and BCWA Factsheet 71 Climate Model MBCW summarize the two CREAT models. Both models (UBCW Model and MBCW Model) show similar results for the larger scale predictions of having a great potential for hotter and drier conditions with changes in storm frequency and intensity.

MBCW Modeling

MBCW Model Elements

1. Utility - Middle Bear Creek Watershed – Evergreen to BCLP Lakewood
    a. 15600 W Morrison Rd (BCLP Visitor Center)
    b. Lakewood CO 80465
    c. Public
    d. Strong
    e. Combined Water
    f. Population 52725
    g. 4 MGD
2. Utilities West Jefferson County, Kittredge, Genesee, Forest Hills, Morrison
    a. Other – Lakewood, Green Mountain, Bear Creek WS
3. Drainage – Bear Creek mainstem from outlet Evergreen lake to station 90 below Bear Creek Reservoir
4. Weather Stations (BCLP, Lakewood, Foothills south Turkey Creek at Indian Hills). Selected Indian Hills

    Selected Climate Station: INTER CANYON [39.5728, -105.2192]

5. Concerns – Water Supply, Water Quality Management, natural disasters, ecosystem and landscape management, population and demographics
6. Threats – drought, flood, water quality, ecosystem changes (forest health), service demand and use
7. Baseline
    a. All months and annual average. Need shoulder season data for march, April; growing season July-September; shoulder November-December.
    b. 5, 15, 30-year storms for both 2-hr and 72-hr
    c. Hot days over 95 degrees
    d. Planning horizon 2018-2050
8. Model Hotter and drier conditions (highest probability of occurrence). The use of median data could be misleading in decision making but could be good for comparisons. Since warm and wet are not predicted trend for region don't model at this time.
    a. Reduced snowpack and shift in runoff period (earlier)
9. Critical water quality parameters are nitrogen and phosphorus
10. Forest health change could be biggest problem area, includes increased erosion
11. Concept for BCR is forebay
12. Use current set of management strategies

MBCW CREAT Climate Modeling

The CREAT model predictions done by the BCWA for the Middle Bear Creek Watershed show similar results within the 2020-2050 time-period as the UBCW Model. During normal conditions, treated effluent discharges from WWTPs in the Middle Bear Creek drainage account for about 1% of the flow in Bear Creek between Evergreen Lake and Bear Creek Reservoir. During drought conditions, treated wastewater effluent discharges account for 20-25% of the flow. During the 2002 drought, low flow conditions and existing water rights issues resulted in treated wastewater effluent accounting for almost 90% of the flow in portions of this middle reach of Bear Creek.

MBCW Model Predictions

The CREAT model predicts the watershed between 2020 – 2050 will become significantly hotter on average with an increased potential for drier conditions. As with all climate modeling there is an understanding that future conditions can

vary from predictions. However, planning for the expected changes of hotter and drier is a prudent management strategy. The results of a CREAT assessment provide information the BCWA can use for long-term watershed water quality planning processes.

The Climate Resilience Evaluation and Awareness Tool (CREAT) is a risk assessment and scenario-based planning application for water, wastewater, and combined utilities of all sizes. CREAT provides users with access to basic climate science information and a framework to gauge climate-related risk reduction following the implementation of different adaptation strategies. Results can be incorporated into asset planning and water-resource management efforts to build resilience at their utility.

Please review the Climate Change Scenarios and Data chapter in the CREAT Methodology Guide for more information on the climate science data provided in the tool, which incorporates the same models and overall conclusions in the U.S. Global Change Research program's 2014 National Climate Assessment, as well as methods used to provide projections in CREAT.

For more information on CREAT, visit EPA's Creating Resilient Water Utilities initiative.

What if the climate gets significantly hotter?

MBCW Model Predicts 6.12°F increase in average annual temperature in Middle Bear Creek Drainage and at Bear Creek Reservoir by 2050

- Adjust treatment processes to warmer waters and altered water quality, and reduced seasonal supplies
- Communities stressed during hotter conditions
- Increased reservoir temperatures will cause more eutrophication
- Altered Forest management to deal with soil moisture loss and invasive species
- Consider regulatory options for compliance with WQCC standards and classifications in watershed where meeting current regulations will be difficult in responding to climate change
- Reduced snowpack and earlier runoff periods with reduced summer water supplies
- Increased seasonal demand during hotter conditions exceeding supply leads to outages and public health risks
- Larger wildfires and damage to infrastructure and water resources under hotter conditions
- Loss of operating revenue and equipment damage, water quality, environmental and health consequences
- Difficult management of dissolved oxygen in water bodies, particularly reservoirs. Some water bodies may experience larger areas or greater frequency of hypoxia due to climate change
- Shifting weather patterns

What if the climate were significantly wetter?

MBCW Model Predicts **6.95%** change in annual precipitation and **28.59%** increase in 100-year storm by 2050

- Strained reservoirs, overwhelmed treatment and flooded facilities during sustained and intense storm events
- Adjust treatment processes to lesser quality inflow due to soil erosion and contaminants from overland flows
- Flooded streets and basements throughout the community following heavy precipitation events
- Health risk from Sanitary Sewer Overflows (SSOs)

What if the climate were significantly drier?

MBCW Model predicts **0.88%** change in annual precipitation by 2050

- Revenue loss from reduced usage during voluntary or mandatory conservation actions in response to drought
- Operational changes to increase efficiency, conserve and access alternate supplies during intense drought
- Disrupted historical storage cycles in aquifers, reservoirs and snowpack
- Larger wildfires and damage to infrastructure and water resources under hotter conditions

- Drought Plans could include the adoption of water use restrictions for households, businesses and other water users
- Stressed or loss of fisheries
- Greater fluctuations in Bear Creek Reservoir with impaired water quality
- Declined forest health

Climate Data and Predictions for Middle Bear Creek Watershed

Measurement	Baseline	Hotter and Drier Climate Influence on Middle Bear Creek Watershed Quality	Moderate Climate Influence on Middle Bear Creek Watershed Quality
Annual Average Temperature (Fahrenheit)	46.26	--	--
January Average Temperature (Fahrenheit)	28.64	--	--
February Average Temperature (Fahrenheit)	30.87	--	--
March Average Temperature (Fahrenheit)	35.49	--	--
April Average Temperature (Fahrenheit)	43.12	--	--
May Average Temperature (Fahrenheit)	51.98	--	--
June Average Temperature (Fahrenheit)	61.10	--	--
July Average Temperature (Fahrenheit)	67.40	--	--
August Average Temperature (Fahrenheit)	65.40	--	--
September Average Temperature (Fahrenheit)	57.63	--	--
October Average Temperature (Fahrenheit)	47.61	--	--
November Average Temperature (Fahrenheit)	36.03	--	--
December Average Temperature (Fahrenheit)	29.82	--	--
Annual Degree Change in temperature (Fahrenheit)	--	6.12	5.18
January Degree Change in temperature (Fahrenheit)	--	5.82	4.26
February Degree Change in temperature (Fahrenheit)	--	5.95	4.79
March Degree Change in temperature (Fahrenheit)	--	6.03	4.64
April Degree Change in temperature (Fahrenheit)	--	6.80	4.19
May Degree Change in temperature (Fahrenheit)	--	6.62	4.86
June Degree Change in temperature (Fahrenheit)	--	6.14	5.79
July Degree Change in temperature (Fahrenheit)	--	5.88	5.75
August Degree Change in temperature (Fahrenheit)	--	5.71	5.96
September Degree Change in temperature (Fahrenheit)	--	6.38	5.99
October Degree Change in temperature (Fahrenheit)	--	6.37	6.17
November Degree Change in temperature (Fahrenheit)	--	5.80	5.37
December Degree Change in temperature (Fahrenheit)	--	5.96	4.39
Annual Total Precipitation (Inches)	19.27	--	--
January Total Precipitation (Inches)	0.65	--	--
February Total Precipitation (Inches)	0.68	--	--
March Total Precipitation (Inches)	1.85	--	--
April Total Precipitation (Inches)	2.48	--	--
May Total Precipitation (Inches)	2.95	--	--
June Total Precipitation (Inches)	1.96	--	--
July Total Precipitation (Inches)	2.04	--	--
August Total Precipitation (Inches)	2.08	--	--
September Total Precipitation (Inches)	1.41	--	--
October Total Precipitation (Inches)	1.15	--	--
November Total Precipitation (Inches)	1.21	--	--
December Total Precipitation (Inches)	0.82	--	--
Annual % Change in precipitation (%)	--	0.88	3.68
January % Change in precipitation (%)	--	11.21	-0.04

February % Change in precipitation (%)	--	7.50	12.75
March % Change in precipitation (%)	--	15.77	13.89
April % Change in precipitation (%)	--	-0.70	11.51
May % Change in precipitation (%)	--	-10.99	-3.48
June % Change in precipitation (%)	--	-1.94	-4.74
July % Change in precipitation (%)	--	0.93	-4.69
August % Change in precipitation (%)	--	-7.05	-3.87
September % Change in precipitation (%)	--	2.84	-1.92
October % Change in precipitation (%)	--	-11.47	-0.52
November % Change in precipitation (%)	--	-2.62	7.10
December % Change in precipitation (%)	--	5.48	18.04
5-year storm event (Inches/24hr)	2.06	--	--
15-year storm event (Inches/24hr)	2.56	--	--
30-year storm event (Inches/24hr)	2.85	--	--
5-year storm event (Inches/72hr)	3.08	--	--
15-year storm event (Inches/72hr)	3.96	--	--
30-year storm event (Inches/72hr)	4.49	--	--
5-year storm event (%)	--	13.63	13.63
15-year storm event (%)	--	17.90	17.90
30-year storm event (%)	--	21.32	21.32

* Baseline relative sea-level rise (SLR) is typically a rate based on vertical land movement (VLM), if available

Current Measures Plan

This captures some of BCWA existing adaptive measures, both implemented and ongoing, that help to mitigate the consequences from a threat occurring to critical assets. Relevant threats include: Floods, Water Quality Degradation, Ecosystem Changes, Drought

Existing BCWA Adaptive Measures

Riparian Corridors For Flood Protection - Promote management of riparian corridors for flood protection. Flood protection from protection of riparian corridor can provide many additional benefits where environmental conditions are favorable and property is available. Consider the types of floods expected to ensure proper managed to provide flood protection. Additional benefits from protection and maintenance of riparian corridors (for example, water quality, species habitat, development trade-off, interconnected wetlands) should be accounted for in costs and benefits and rationale for selecting this measure.

Wastewater or Water Treatment Alternatives - Research alternative treatment technologies for projected climate conditions. These technologies should be tested for the ability to integrate into current operations and their suitability for performance under current conditions. Possible future conditions for these processes to address include higher ambient temperatures, changing influent flows or particulate loading and higher dissolved solids.

Temperature Monitoring and Models - Monitor air and water temperature trends in region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions. Model air and water temperature change relationships.

Stakeholder Engagement - Continue outreach programs and develop outreach materials, Newsletter, Training, Education. Develop and maintain strategies for stakeholder dialogues, relationships, trust and shared decision-making tools to improve responses to events. Stakeholders should include other water-dependent sectors, communities, government agencies and watershed public.

Sediment Management and Controls - Monitor sedimentation of reservoirs, and identify strategies to improve ability to manage reservoir quality and stored water quality. Reducing sediment inputs also attains similar benefits and could be done in concert with removal operations. County and road erosion controls.

Regulatory Flexibility Water Quality -Consider regulatory options for compliance with WQCC standards and classifications in watershed where meeting current regulations will be difficult in responding to climate change. Plans should document the projected challenges to meeting regulations due to changing ambient conditions, water quality and availability, and other impacts on the ability of the utility to meet its mission goals. Regulatory compliance being met while enacting adaptive measures should also be considered in any plans. Rulemaking hearings, site specific standards, on-going monitoring. Assessment reports

Rainwater Collection / Use - Rain Barrels/ Rain Gardens - Promote the implement local rainwater harvesting program by encouraging or providing rain barrels (limited to 40 to 80 gallons) to residential customers for small-scale irrigation or gardening purposes. This type of program should be coupled with models to assess the impact of reduced influent volumes from different precipitation events to ensure performance is not detrimentally impacted by program. Homeowner incur majority of costs, depending on program. Promote green infrastructure and demonstration rain gardens.

Public Communication Plans - Raise public awareness of what Bear Creek Watershed Association planning and the potential for changes in levels of service during events. Notifications balance information on hazards with details of prepared response strategies, including opportunities for the public to assist in preparing and responding to water shortages, contamination, or other events related to climate change. Newsletter, fact-sheets, annual report, stakeholder response.

Public Advisory System - Establish public advisory communication system to alert consumers of events when they occur. This system can also disseminate information during periods of normal information. Media outlets, mobile devices, internet services, and social media can all be utilized to reach the broadest audience.

Nutrient Management Monitoring and Reservoir Models - Build and use models for nutrients, sediment, and other relevant water quality parameters to predict changes attributable to projected climate conditions and design schemes for mitigation of impacts. Beyond many current hydrologic and sediment-transport models, these models should ensure that perturbations in transport and nutrient transformations associated with climate change are accommodated in models.

Habitat Improvements & Management - Develop strategies and procedures. Address stream habitat problems. Apply watershed management practices to maintain or improve stream habitat. Develop cooperative programs with other agencies and community. Promote green infrastructure, stream restoration and riparian corridor protection.

General Watershed Monitoring - Continue monitoring surface water quality trends (nutrients), biological parameters (e.g., macroinvertebrate) in upper watershed from Mt Evans to EGL. Track changes in biodiversity. Incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions. Model water quality change relationships.

Fire Management and Water Quality - Promote and support fire management plans to reduce fire risk. Consider implications of fire management on water quality. Develop strategies to address water quality degradation caused by wildfire and promote mitigation measures such as containment ponds. Obtain pre-fire permitting for development of emergency sedimentation ponds. Support controlled burns, thinning, and weed and invasive plant control help to reduce the frequency and severity of wildfires in fire-prone areas. Update fire risk maps and strategies.

Water Quality Monitoring - Monitor stream, watershed and reservoir conditions and incorporate results into overall performance monitoring and assessment. Data collection supports projections of how watershed, streams and reservoir respond to spatial and temporal changes in annual climate.

Dam / Flood Control Inspection and BCR Operations - Conduct inspections of structures designed to control floods or store water within system. Inspections should be part of any assessment of failure risk under projected flow conditions.

Emergency Response Plan - Community - Local and county emergency response and recovery plans in coordination with local hospitals and first responders. These plans focus on events that may become more frequent under projected future climate conditions, especially those that the community has limited experience dealing with. Plans should be coupled with other measures to limit consequences when possible.

BCR Dissolved Oxygen Management - Implement practices to manage dissolved oxygen in BCR, or other reservoirs. Operation and maintenance aeration system BCR. Some water bodies may experience larger areas or greater frequency of hypoxia due to climate change. Measures including sluices, pumps, or injections of gases into these reservoirs could mitigate impacts of low oxygen water. Ongoing monitoring, site specific standards, annual reporting. Risk and fishery assessments.

Ecosystem and Watershed Management For Water Quality - Indirectly manage ecosystems that influence water quality. Both wetlands and forested lands can provide benefits to surface water quality management. Benefits include reduced sediment and nutrient loading, flood control, temperature regulation, and increased ecological diversity. Carefully consider the location of any managed land to ensure water quality benefits can be realized. Develop strategies and procedures. Address nonpoint source loadings. Apply watershed management practices to maintain or improve surface water quality and riparian corridor integrity by mimicking natural watershed hydrology, reducing pollutant runoff, and increasing groundwater recharge. Promote integration of this management with other priorities and resources in the watershed.

Ecological (Vegetation) Monitoring and Riparian Corridor Monitoring - Monitor changes in ecosystems within the watershed with ground cover surveys, aerial photography, water quality monitoring or with research from local conservation groups, Denver and universities. Changes in vegetation can be indicators of other important changes that impact water resources.

Drought Contingency Plans - Develop or update plans for drought to prepare for possible reductions in water supply. Plans could include the adoption of water use restrictions for households, businesses and other water users. These plans should be updated regularly to remain consistent with current operations and assets.

Drought and Stormwater Runoff Monitoring & Management - Monitor runoff to inform flood risk management, water quality models, and stormwater collection. Data may include rates, nutrient or contaminant concentrations, and erosion or sediment loading rate. Develop, practice, and regularly update management plans to reduce drought and stromwater runoff risk. Provide tools, strategies and procedures to reduce water quality and riparian corridor impacts from low flow or high flow conditions.

Coldwater and Warmwater Management - Develop or alter policies, strategies and procedures for cold and warm water stream/watershed management. Continue to collect baseline data on water quality and biological components in watershed. Establish data trends. Collect new weather data at up-stream stations. Compare air and water temperature trends and associations. Changing conditions may necessitate changes in management for species or ecosystem protection. Current practices for balancing ecological and water supply priorities may be challenged more often and plans should address this issue.

Climate Training & Awareness For Personnel/ Watershed Membership - Develop policies or procedures to address climate change and watershed management. Conduct climate-related training (for example, tabletop exercises, knowledge building) for utility personnel and emergency response community. Draw from resources provided by associations and government agencies to provide information regarding the potential impacts of climate change and effectiveness of response actions.

Bioretention Facilities and Urban Drainage Measures - Promote green infrastructure in the community or at facilities. Green infrastructure is a sustainable approach to wet weather management. Green Infrastructure approaches maintain or restore natural hydrology by improving stormwater infiltration or capturing water for re-use. Bioretention can include infiltration basins, rain gardens, infiltration trenches and bioswales. Promote Urban Drainage and Flood Control Manual. Coyote Gulch.

BCWA Watershed Plan - Develop and maintain an electronic watershed plan. Develop a climate change policy and strategies. This plan should account for climate-related changes in the watershed.

Bear Creek Reservoir Management and Operations - Flood control infrastructure, aeration system, shore line protection, vegetative management, flow monitoring, water quality assessment and monitoring, adaptive strategies,

control regulation. Invasive species management. Boating and water activities. Phytoplankton monitoring and management. (Sediment forebays concept)

Recreation Uses - Fishery, trails, access, swimming, beach, picnic, other recreation (e.g., riding bicycle, horses)

Climate Modeling - Development and maintenance of CREAT climate model for upper Bear Creek, MBC and Turkey Creek Drainages

Habitat and Stream Indices for Stream Sites and Segments - Develop and update habitat and stream site indices to track changes to stream conditions both spatially and temporally. Maintain set of protocols and methods for stream characterizations. Maintain set of reference pictures of sites.

Annual and Data Reports, Master Data Sheets - Maintain long-term record of information and data characterizing watershed and changes to quality.

Consequences & Assets for Middle Bear Creek Watershed

Changing climate conditions may impact utility assets that can have a number of different consequences, including loss of operating revenue and equipment damage, water quality, environmental and health consequences. The assets and consequences listed below were identified by Middle Bear Creek Watershed – Evergreen to BCLP Lakewood for consideration in assessing the potential impacts from climate change.

Asset Name	Assigned Threat
Collection And Treated Wastewater Conveyance Systems	Floods, Service Demand and Use
Distribution System	Floods, Water Quality Degradation
Drinking Water Treatment Plant	Drought, Service Demand and Use, Water Quality Degradation
Forested Lands	Drought, Ecosystem Changes, Water Quality Degradation
Managed Species	Ecosystem Changes
Wetlands, Flood Plain	Floods
Aquifers	Drought, Ecosystem Changes, Floods, Water Quality Degradation
Watershed/Snowpack	Drought, Service Demand and Use, Water Quality Degradation
Lakes And Reservoirs	Drought, Ecosystem Changes, Floods, Water Quality Degradation
Streams And Rivers	Drought, Ecosystem Changes, Floods, Water Quality Degradation
Wastewater Treatment Plant	Drought, Floods, Service Demand and Use
Recreational uses	Drought, Ecosystem Changes, Floods, Water Quality Degradation

Scenarios and Threats for Middle Bear Creek Watershed

Changing climate conditions are expected to impact a utility's ability to meet its basic goals. The scenarios presented below capture current and future risk profiles for specific threat(s) to Middle Bear Creek Watershed. These scenarios will inform decision-making and planning to mitigate potential future climate impacts.

Baseline

Baseline Scenario - The Baseline Scenario captures historical data for the analysis location to assist in defining Middle Bear Creek Watershed – Evergreen to BCLP Lakewood's current risk profile.

THREAT(S) IDENTIFIED AND DEFINED FOR THIS SCENARIO:

Drought: Lower lake and reservoir levels with reduced stream flows
Definition: Decreases in annual precipitation will lead to lower lake and reservoir levels and stream flows that water utilities rely on for surface water supplies. In addition, evaporation rates and water loss from vegetation will be higher due to increasing temperatures. These lower levels may make it difficult to meet water demands, especially in summer months and may drop water levels below intake infrastructure. Drought conditions reduce soil moist in forested areas and increase erosion potential. Reduced stream flows stresses fisheries. Increases in temperature occur during low flow periods.

Ecosystem Changes: Altered vegetation / wildfire risk/ changes in biodiversity
Definition: Increasing temperature and changing precipitation patterns can contribute to vegetation changes or persistence of pests or disease. Shifts in biodiversity and potentially drier conditions also increase the risks of wildfire. Water resources and facilities can be damaged by these shifts, depending on the rate of change, extent of impacted ecosystems and frequency of fire events.

Floods: High flow events
Definition: Changes in precipitation patterns, particularly greater storm intensities, may generate additional floods associated with high flow events. These flooding events may challenge current infrastructure for water management and flood control. When these protections fail, inundation may damage infrastructure such as water treatment plants, intake facilities and water conveyance and distribution systems, bridges and roads. More extreme events can lead to sewer overflows and reduce the capacity of sewer systems already impacted by inflow and infiltration. Floods cause extensive erosion and sediment deposition, reducing reservoir capacity. Increased nutrient loading.

Service Demand and Use: Changes in influent flow & temperature
Definition: Increasing temperature and changing precipitation patterns both alter influent conditions. Changes in temperature and flow may have important ramifications on the effectiveness of treatment and capacity of the system.

Water Quality Degradation: Altered surface water quality
Definition: Surface water quality is affected by changes in temperature, precipitation patterns and the number of extreme hot days. Examples of water quality degradation include harmful algal blooms, nutrient (nitrogen and phosphorus) or sediment runoff from storm events and eutrophication of reservoirs. Temerature increases increases biological activity and productivity.

Hotter and Drier

Hotter and Drier Climate Influence on Middle Bear Creek Watershed Quality (2050) - The Hotter and Drier Climate Influence on Middle Bear Creek Watershed Quality uses projected climate data for the utility's time period (2019 – 2050) to assist in defining Middle Bear Creek Watershed – Evergreen to BCLP Lakewood's potential future risk profile.

THREAT(S) IDENTIFIED AND DEFINED FOR THIS SCENARIO:

Drought: Reduced snowpack and earlier runoff, reduced summer storage
Definition: Increasing temperature and changing precipitation patterns combine to decrease the depth and extent of snowpack; often considered a reservoir of source water. Changes in precipitation timing, rain rather than snow, and earlier snowmelt will change the amount and timing of water supply, as well as impact receiving water quality in downstream waterways.

Ecosystem Changes: Altered vegetation, Declining forest health, increased wildfire risk, invasive species
Definition: Increasing temperature and changing precipitation patterns can contribute to vegetation changes or persistence of pests or disease. Shifts in biodiversity and potentially drier conditions also increase the risks of wildfire. Water resources and facilities can be damaged by these shifts, depending on the rate of change, extent of impacted ecosystems and frequency of fire events.

Floods: High flow events, more frequent storms, intense runoff
Definition: Changes in precipitation patterns, particularly greater storm intensities, may generate additional floods associated with high flow events. These flooding events may challenge current infrastructure for water management and flood control. When these protections fail, inundation may damage infrastructure such as water treatment plants, intake facilities and water conveyance and distribution systems. More extreme events can lead to combined sewer overflows and reduce the capacity of sewer systems already impacted by inflow and infiltration.

Service Demand and Use: Changes in residential use, outdoor water restrictions, shift from groundwater to providers
Definition: Residential demand for water is strongly linked to seasonal temperatures. Changes in future temperatures will challenge the ability of utilities to provide adequate levels of water supply, wastewater and stormwater services. Reduced groundwater in alluvial wells could cause demand for water service, hauling.

Water Quality Degradation: Altered stream and reservoir water quality
Definition: Surface water quality is affected by changes in temperature, precipitation patterns and the number of extreme hot days. Examples of water quality degradation include harmful algal blooms, nutrient or sediment runoff from storm events and saline intrusion into historically freshwater bodies. BCR eutrophication, increased nitrogen and phosphorus loads. Expensive treamnt options. Exceeding standards.

Moderate Climate Influence

Moderate Climate Influence on Middle Bear Creek Watershed Quality (2050) - The Moderate Climate Influence on Middle Bear Creek Watershed Quality uses projected climate data for the utility's time period (2019 – 2050) to assist in defining Middle Bear Creek Watershed – Evergreen to BCLP Lakewood's potential future risk profile.

THREAT(S) IDENTIFIED AND DEFINED FOR THIS SCENARIO:

Drought: Reduced groundwater recharge
Definition: Decreases in annual precipitation will decrease surface water supplies and groundwater recharge, especially impacting utilities that rely on groundwater supplies. In addition, evaporation rates and water loss from vegetation will be higher due to increasing temperatures.

Ecosystem Changes: Altered vegetation / wildfire risk
Definition: Increasing temperature and changing precipitation patterns can contribute to vegetation changes or persistence of pests or disease. Shifts in biodiversity and potentially drier conditions also increase the risks of wildfire. Water resources and facilities can be damaged by these shifts, depending on the rate of change, extent of impacted ecosystems and frequency of fire events.

Floods: High flow events
Definition: Changes in precipitation patterns, particularly greater storm intensities, may generate additional floods associated with high flow events. These flooding events may challenge current infrastructure for water management and flood control. When these protections fail, inundation may damage infrastructure such as water treatment plants, intake facilities and water conveyance and distribution systems. More extreme events can lead to combined sewer

overflows and reduce the capacity of sewer systems already impacted by inflow and infiltration.

Service Demand and Use: Changes in influent flow & temperature
Definition: Increasing temperature and changing precipitation patterns both alter influent conditions. Changes in temperature and flow may have important ramifications on the effectiveness of treatment and capacity of the system.

Water Quality Degradation: Altered surface water quality
Definition: Surface water quality is affected by changes in temperature, precipitation patterns and the number of extreme hot days. Examples of water quality degradation include harmful algal blooms, nutrient or sediment runoff from storm events and saline intrusion into historically freshwater bodies.

Minimum Proactive Plan 30-Years

Measures that could be done over 30-years to minimize water quality degradation. Relevant threats for this plan include: Drought, Ecosystem Changes, Water Quality Degradation, Floods, Recreation uses, Reservoir Management, Infrastructure protection, Source Water Protection. In addition to continuation of the existing Association adaptive measures, strategies and operations, the BCWA may explore including the following new or expanded adaptive measures as part of the 2020-2050 watershed management plan.

Possible New or Expanded Adaptive Measures

Improvement of Temperature Monitoring
Add additional monitoring of water and air temperature trends in the region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions and stricter standards. Add air temperature stations at areas within middle Bear Creek Watershed. Additional water temperature probes into tributaries. Develop mitigation strategies. Model temperature trends. Evaluate site-specific temperature standards. Develop or identify practices to mitigate stream temperature rises.

Improvement of Public Communication (Plans)
Raise public awareness of what Bear Creek Watershed Association is planning and the potential for changes in levels of service during events. These notifications should balance information on hazards with details of prepared response strategies, including opportunities for the public to assist in preparing and responding to water shortages, contamination, or other events related to climate change. Use other social media methods to reach broader audience and stakeholders. Develop fund raising programs and establish funding support mechanisms.

Improvement of Fire Management
Develop, practice, and regularly update management plans to reduce fire risk. Controlled burns, thinning, and weed and invasive plant control help to reduce the frequency and severity of wildfires in fire-prone areas. Pre-permitting and Installation of additional sedimentation catch basins will be required. This is primarily other stakeholders with water quality support from Association.

Improvement of Climate Modeling/ Training For Personnel, Decision Makers & Watershed Members
Expand and run climate models. Improve data inputs. Outreach climate data results. Conduct climate-related training (for example, tabletop exercises, knowledge building) for utility personnel and emergency response community. Draw from resources provided by associations and government agencies to provide information regarding the potential impacts of climate change and effectiveness of response actions.

Improvement of Bioretention Facilities and Green Infrastructure Projects
Promote green infrastructure in the community or at facilities. Promote Urban Drainage practices and programs. Develop green infrastructure projects and demonstration. Green infrastructure is a sustainable approach to wet weather management. Green Infrastructure approaches maintain or restore natural hydrology by improving stormwater infiltration or capturing water for re-use. Bioretention can include infiltration basins, rain gardens, infiltration trenches and bioswales. Promote rain gardens.

Storm-related Excessive Erosion Mitigation
Add engineered control structures to restore and maintain stream bank integrity from excessive storm runoff. Improved storm sewer sizing and implementation of best management practices, including Low Impact Development or green infrastructure

Improvement of Coldwater and Warmwater Management
Develop or alter policies and procedures for cold water management. Adding structure and depth to the stream for species or ecosystem protection. Current practices for balancing ecological and water supply priorities may be challenged more often and plans should address this issue.

Expanded Water Quality Monitoring
Add additional monitoring of water quality trends in the region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions and stricter standards. Add water quality stations in Bear Creek Watershed. Increase monitoring parameters.

Decision Models That Incorporate Uncertainty
Adapt water quality and environmental decision-making frameworks for investments at your utility and watershed to incorporate uncertainty. This uncertainty can be handled in quantitative or qualitative fashion, depending on the amount of information known regarding uncertainty. Elements of decision-making framework that may be uncertain include budgets, climate change, supply-demand, and land use.

Bear Creek Reservoir
Maintain reservoir model. Evaluate effectiveness of aeration system to address dissolved oxygen and temperature issues. Develop assessment of site-specific temperature standard. Involvement in the proposed reservoir expansion. Phytoplankton bloom management strategy. Identify mechanism to minimize phytoplankton blooms. Adaptive monitoring. Implementation of reservoir TMDL. Reduction strategies for both total phosphorus and total nitrogen. Evaluate use of forebays. Shoreline protection. Change to outlet structure.

Recreation Uses
Evaluate recreational users' impact to water quality. Changes to recreational uses with changes to reservoir expansion. Trails and erosion control. Establish an erosion pin monitoring network for trails and shoreline.

Estimated Cost Adaptive Measures

Adaptive Measure Name	Description	Total Cost
Bear Creek Reservoir	Maintain reservoir model. Evaluate effectiveness of aeration system to address dissolved oxygen and temperature issues. Develop assessment of site-specific temperature standard. Involvement in the proposed reservoir expansion. Phytoplankton bloom management strategy. Identify mechanism to minimize phytoplankton blooms. Adaptive monitoring. Implementation of reservoir TMDL. Reduction strategies for both total phosphorus and total nitrogen. Sediment modeling. Evaluate use of forebays. Shoreline protection. Change to outlet structure. Sealing bottom. Bear Creek Park Infrastructure modifications.	$450,000.00-$65,000,000.00
Decision Models That Incorporate Uncertainty	Adapt water quality and environmental decision-making frameworks for investments at your utility and watershed to incorporate uncertainty. This uncertainty can be handled in quantitative or qualitative fashion, depending on the amount of information known regarding uncertainty. Elements of decision-making framework that may be uncertain include budgets, climate change, supply-demand, and land use.	$50,000.00-$300,000.00
Expanded Water Quality Monitoring	Add additional monitoring of water quality trends in the region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions and stricter standards. Add water quality stations in Bear Creek Watershed. Increase monitoring parameters.	$50,000.00-$350,000.00

Improvement of Bioretention Facilities and Green Infrastructure Projects	Promote green infrastructure in the community or at facilities. Promote Urban Drainage practices and programs. Develop green infrastructure projects and demonstration. Green infrastructure is a sustainable approach to wet weather management. Green Infrastructure approaches maintain or restore natural hydrology by improving stormwater infiltration or capturing water for re-use. Bioretention can include infiltration basins, rain gardens, infiltration trenches and bioswales. Promote rain gardens.	$100,000.00-$3,000,000.00
Improvement of Climate Modeling/ Training For Personnel, Decision Makers & Watershed Members	Expand and run climate models. Improve data inputs. Out reach climate data results. Conduct climate-related training (for example, tabletop exercises, knowledge building) for utility personnel and emergency response community. Draw from resources provided by associations and government agencies to provide information regarding the potential impacts of climate change and effectiveness of response actions.	$25,000.00-$100,000.00
Improvement of Coldwater and Warmwater Management	Develop or alter policies and procedures for cold water management. Adding structure and depth to the stream for species or ecosystem protection. Current practices for balancing ecological and water supply priorities may be challenged more often and plans should address this issue	$500,000.00-$5,000,000.00
Improvement of Fire Management	Develop, practice, and regularly update management plans to reduce fire risk. Controlled burns, thinning, and weed and invasive plant control help to reduce the frequency and severity of wildfires in fire-prone areas. Pre-permitting and Installation of additional sedimentation catch basins will be required. This is primarily other stakeholders with water quality support from Association.	$100,000.00-$6,000,000.00
Improvement of Public Communication (Plans)	Raise public awareness of what Bear Creek Watershed Association is planning and the potential for changes in levels of service during events. These notifications should balance information on hazards with details of prepared response strategies, including opportunities for the public to assist in preparing and responding to water shortages, contamination, or other events related to climate change. Use other social media methods to reach broader audience and stakeholders. Develop fund raising programs and establish funding support mechanisms. Jefferson County, Morrison, Districts, Lakewood, others	$25,000.00-$75,000.00
Improvement of Temperature Monitoring	Add additional monitoring of water and air temperature trends in the region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions and stricter standards. Add air temperature stations at areas within middle Bear Creek Watershed. Additional water temperature probes into tributaries. Develop mitigation strategies. Model temperature trends. Evaluate site-specific temperature standards. Develop or identify practices to mitigate stream temperature rises.	$10,000.00-$275,000.00
Recreation Users	Evaluate recreational users' impact to water quality. Changes to recreational uses with changes to reservoir expansion. Trails and erosion control. Establish an erosion pin monitoring network for trails and shoreline. Increased beach use.	$25,000.00-$150,000.00
Regulatory Flexibility Water Quality Standard Updates	Using collected watershed data (spatial and temporal), identify opportunities to develop and get WQCC approval of site-specific standards. A decision process is needed to identify when standards could or should be adjusted. This process must address antidegradation. Standard changes must be protective of uses. These standards can include nutrients, temperatures, dissolve oxygen and metals. UAA's	$25,000.00-$150,000.00
Storm-related Excessive Erosion Mitigation Bear Creek	Add engineered control structures to restore and maintain stream bank integrity from excessive storm runoff. Improved storm sewer sizing and implementation of best management practices, including Low Impact Development or green infrastructure	$250,000.00-$2,500,000.00