Version 1.0

CLIMATE ADAPTATION TOOL FOR WATER UTILITIES

Drinking Water

Visualize potential impacts | Estimate costs | Compare options

THE Water Research FOUNDATION®

Drinking Water Tool
User Guide & Methodology

Project: WRF 5222
Version: 1.0, January 2026
Prepared by: Corvias Infrastructure Solutions (CIS) and Radbridge Incorporated

Contents

Introduction

Climate change presents significant challenges to drinking water utilities, from reduced watershed runoff and shifting hydrologic cycles to more frequent and severe drought conditions. This Drinking Water Decision Support Tool, funded by the Water Research Foundation (WRF), translates climate-change projections into actionable planning scenarios. Specifically, it enables utilities to identify and quantify their future water-supply gaps and then close those gaps through a practical portfolio of climate adaptation solutions (CAS). The tool provides a simple, Excel-based decision-support framework that blends climate-informed planning with practical implementation constraints. This drinking water module complements the stormwater module by providing a parallel approach tailored specifically to drinking water utilities.

Tool Structure

The tool is organized into three primary modules:

1. **DW1_Inputs** – Define your utility's current supply conditions, assess future climate-driven risks, and quantify the resulting water supply gap under a selected drought scenario.
2. **DW2_CAS_Parameters** – Specify the feasibility and cost of potential adaptation strategies, including both demand-side and supply-side options.
3. **DW3_Results** – Review the recommended adaptation portfolio and explore key performance metrics such as cost, savings, and supply reliability.

Module 1: Inputs

This module establishes the geographic and hydrologic foundations of your drinking water supply analysis. You'll begin by identifying your service area, current water supply conditions, and the level of drought severity your system can reliably manage today. Using built-in climate datasets and your selected future scenarios, the tool then projects how climate-driven changes in watershed runoff might impact your system's future water reliability. These initial inputs directly inform subsequent modules, where you'll evaluate Climate Adaptation Solutions (CAS) to help close any identified future supply gaps.

Section 1: Location and Management Area

In this section, you'll specify the location and watershed that your analysis will focus on. This ensures that all subsequent projections are anchored to standardized climate data from the U.S. Geological Survey (USGS).

- **Location Name:** Enter a descriptive name for your project area (e.g., utility, community, or watershed). This is for internal reference and does not affect calculations.

- **HUC8 Watershed:** Identify the USGS-designated HUC8 watershed that best aligns with your supply area. HUC8s represent medium-sized drainage basins (~450,000 acres) and are used to link your area to built-in climate and runoff projections. If you're unsure of your watershed, a link to the USGS HUC viewer is provided.
- **Watershed ID and State:** These fields are auto filled based on the selected HUC8. No edits are required.

Section 2: Average Annual Inflow & "Tolerable Design Drought"

This section helps define your agency's current drought resilience threshold. You'll input the amount of water your system typically receives during "normal" years and during the worst multi-year drought it can manage using existing infrastructure and resources.

- **Average Annual Supply (Normal Years):** Input your average inflow or dependable yield under typical hydrologic conditions. This should reflect long-term historical averages and account for current infrastructure.
- **Tolerable Design Drought Supply:** Enter the lowest average annual inflow your system can reliably manage based on past droughts or conservative planning assumptions (e.g., 90% of baseline supply).
- **Deficit Calculations:** The tool auto-calculates the annual and 5-year cumulative shortfall between these two values. This defines your current drought planning threshold and will be used later to assess future risk.

These baseline supply values are used to convert adaptation strategy savings from percent (%) to annual volume (AF/year) in the portfolio analysis. See Methods, Section 2 (Baseline Water Volume and Supply Gap Target) for details.

Section 3: Average Annual Change in Inflow (%)

This table displays projected changes in average watershed runoff due to climate change across three climate scenarios (SSP245, SSP370, SSP585) and multiple planning periods. These projections serve as a guide to help you select a planning horizon and emissions scenario that best reflect your agency's priorities and risk tolerance.

- Higher SSP numbers and more distant future periods generally indicate larger decreases in inflow and higher uncertainty.
- These values are not editable but will inform your selections in the next section.

Runoff change values are derived from the CMIP6-LOCA2 MWBM watershed runoff dataset summarized at the HUC8 scale; see Methods, Section 1 (Developing Runoff Projections Data by HUC8 Watershed).

Section 4: Climate Scenario & Planning Period Selection

You'll now select a planning period and emissions scenario (Shared Socioeconomic Pathway, or SSP) that align with your utility's long-term planning goals.

- **Planning Period:** Choose from one of three available timeframes. Select the range that reflects your utility's planning horizon (e.g., 2050–2074).
- **Climate Scenario:** Select the emissions pathway you wish to use for analysis (SSP245 = moderate mitigation, SSP370 = intermediate, SSP585 = high emissions).
- Visual charts automatically update to show how runoff is projected to change across your selected time period and scenario, including both annual and monthly trends.

Section 5: Summary Statistics

This section calculates the projected future supply deficit (i.e., "supply gap") under your selected climate conditions. These auto-generated statistics compare your tolerable design drought to anticipated future deficits and identify the gap your adaptation strategy needs to address.

- **Future Drought Deficits:** Includes both annual average and cumulative 5-year deficits under climate change.
- **Climate-Driven Supply Gap:** Quantifies the additional shortfall (if any) beyond your tolerable design drought — this is the key metric that drives subsequent CAS evaluation.

The Climate-Driven Supply Gap is carried forward as the annual target that demand-side and supply-side strategies are scaled to address. See Methods, Section 2 (Overview of Tool Logic).

Section 6: Supplementary Statistics

This section provides additional planning insights that are not directly used in calculations but can help inform risk assessments and scenario planning.

- **Frequency and Timing of Future Droughts:** Shows how many future 5-year periods exceed your tolerable drought threshold, along with their projected timing.
- **Seasonal Shifts in Runoff:** Indicates how the midpoint of annual runoff may shift over time — a negative shift means runoff is occurring earlier in the year, which may affect seasonal reliability.

Module 2: Prioritize Climate Adaptation Solutions

This module helps you express your agency's relative interest in a wide range of climate adaptation strategies, based on your utility's goals, constraints, and planning context. By rating each option from 0 to 3, you define which solutions are likely to be part of your response portfolio — and how aggressively you might pursue them. These preferences guide how the tool allocates resources across supply- and demand-side actions in the optimization process.

Commitment ratings are translated into water savings and cost assumptions using built-in reference tables. Specifically:

- For demand-side actions, commitment levels map to low/medium/high savings assumptions.
- For supply-side actions, commitment levels determine how remaining gap volume is distributed across selected options.

See Methods, Section 2 (Demand-Side Water Savings Estimation; Supply-Side Gap Filling Method).

Module 3: Generate Portfolio of Climate Adaptation Solutions

This module builds your recommended CAS portfolio by estimating how much each strategy could help reduce demand (Step 1) and, if needed, fill any remaining supply gap through supply-side actions (Step 2). Based on your selected commitment levels and default performance/cost assumptions from the literature, the tool automatically calculates a mix of actions that can meet your drought-related shortfall. This helps you visualize potential systemwide impacts, estimate costs, and compare options based on their effectiveness and feasibility.

For a description of how the tool translates commitment levels into annual savings (AF/year) and cost-effectiveness ($/AF), see Methods, Section 2.

Methods

The remainder of this document describes the underlying calculation methods and reference assumptions used by the tool but is not necessarily required for operation of the tool.

Section 1. Developing Runoff Projections Data by HUC8 Watershed

To support drought-resilience planning for drinking water utilities, this tool includes watershed-scale projections of future runoff change, summarized at the HUC8 hydrologic unit level. These projections are used to estimate how climate change may affect long-term water availability and to help quantify future water-supply shortfalls under user-selected planning horizons and emissions scenarios.

Primary Data Source: CMIP6-LOCA2 MWBM Runoff by Watershed

Runoff projections are derived from the CMIP6-LOCA2 MWBM watershed dataset,[i] provided as a NetCDF file: CMIP6-LOCA2_MWBsM_1950-2100_WBDHU8_monthly.nc

This dataset provides monthly runoff estimates (mm/month) for 2,193 HUC8 watersheds across the contiguous United States from 1950–2100, under multiple CMIP6 emissions scenarios (SSPs). The dataset includes multiple climate-model realizations per scenario, enabling robust multi-model summary statistics.

Because this tool is intended as a national screening framework, runoff projections are presented at the HUC8 watershed scale, which aligns well with drinking-water source regions while allowing consistent comparisons across utilities.

Annual Runoff Projections and Percent Change

Overview of Processing Approach

The tool's main workflow relies on annual runoff projections derived from the CMIP6-LOCA2 MWBM dataset and summarized by scenario and planning period. Behind the scenes, monthly runoff values were aggregated to annual totals and converted into percent change relative to a historical baseline, then embedded into the Excel tool as reference data.

Annual Aggregation and Scenario Averaging

For each watershed and emissions scenario (typically SSP245, SSP370, SSP585), monthly runoff values were summed to produce annual runoff totals (mm/year) for each year from 1950–2099. Where multiple model realizations were available within a scenario, an unweighted multi-model mean was calculated, treating each ensemble member equally to produce a transparent screening-level estimate.

Baseline Period and Change Calculations

To quantify climate-driven change, a historical baseline of 1981–2010 was used. For each watershed and scenario, a baseline mean annual runoff value was computed and then used to calculate:

- Absolute change (mm/year) from baseline, and
- Percent change (%) from baseline for each year in the time series.

These annual percent changes are summarized in the tool to populate the Average Annual Change in Inflow (%) table by planning horizon and scenario, forming the basis for later drought deficit and supply-gap calculations.

Tool Integration

Processed runoff outputs were exported to tabular format and incorporated directly into the tool's internal reference data. As a result, users interact with scenario-based runoff change results entirely within Excel, without needing to access the underlying runoff dataset or processing scripts.

Monthly Runoff Climatology and "Timing Changes"

In addition to annual runoff changes, the drinking water tool includes a supplementary indicator of seasonal runoff timing shifts, intended to help utilities interpret potential impacts to seasonal storage and operational reliability (e.g., runoff occurring earlier in the year).

These supplemental results were generated by calculating average monthly runoff climatologies (Jan–Dec) for each watershed under:

- a historical baseline climatology (1950–2010)
- three future windows: 2025–2049, 2050–2074, and 2075–2099

For each future window and scenario, monthly runoff was averaged across both time and ensemble members to produce a multi-model mean monthly runoff profile.

Midpoint of Runoff and Seasonal Timing Shift Indicator

The monthly climatology results support a simple "timing change" metric shown in the tool's Supplementary Statistics section, including:

- Date of midpoint of runoff (historical)
- Date of midpoint of runoff (future period / scenario)
- Change in midpoint (days)

This midpoint represents the day-of-year when 50% of total annual runoff (based on average monthly distribution) has occurred. A negative change indicates runoff is occurring earlier in the year, which may affect seasonal reliability in snowmelt- or spring-dominant watersheds. This timing feature is provided for context and is not part of the tool's core supply-gap calculations.

Section 2. Methods for Estimating Water Savings and Unit Cost ($/AF)

This appendix describes the analytical methods used in the Drinking Water Decision Support Tool to estimate (1) water savings associated with demand-side climate adaptation solutions (CAS) and (2) unit costs and cost-effectiveness metrics used to compare solutions and assemble a recommended portfolio. These methods translate user-selected commitment levels and literature-based assumptions into consistent, annualized water volumes (acre-feet per year) and costs ($/year and $/acre-foot).

Overview of the Tool Logic

The tool evaluates a climate-driven water supply gap and identifies a portfolio of climate adaptation solutions that can close that gap through two sequential steps:

1. **Step 1 – Demand-side savings:** The tool estimates water savings from conservation and efficiency measures (e.g., plumbing retrofits, leak reduction, metering, education) and allocates these savings toward closing the projected annual supply gap.
2. **Step 2 – Supply-side augmentation (if needed):** If demand-side measures do not fully close the gap, the tool assigns the remaining gap to supply-side options (e.g., reuse, storage, watershed management), based on user priorities and feasibility settings.

These steps are designed to support a screening-level evaluation for planning, not detailed engineering design. The tool outputs include annual water savings (AF/year), annualized costs ($/year), and cost per unit ($/AF).

Baseline Water Volume and Supply Gap Target

Baseline annual supply

All savings estimates are converted to annual volumes using the user-provided baseline annual supply in **acre-feet per year**. This value represents average annual inflow or dependable yield under "normal" conditions, inclusive of current infrastructure and operations.

- **Where it is entered:** *DW1_Inputs* ("Average Annual Supply During Normal Years")
- **Used as:** Tool-wide baseline for converting percent savings into AF/year (named range: Baseline_AF)

Annual supply gap under climate stress

The tool estimates future drought shortfall using the selected climate scenario and planning period (as described in the runoff methods section). The output of this process is a climate-driven supply gap expressed as an annual deficit that must be addressed by the portfolio.

- **Where it is calculated:** *DW1_Inputs* ("Climate-Driven Supply Gap")
- **Where it is used in portfolio building:** *DW3_Results* as the annual "gap target" for closure

In the Results module, the annual supply gap is treated as the planning target that the CAS portfolio must offset through demand-side savings and/or supply-side augmentation.

Demand-Side Water Savings Estimation

Demand-side measures reduce the volume of water required to meet demand, thereby reducing the amount of supply needed during drought conditions. The tool estimates demand-side savings using a structured approach based on user commitment levels and literature-based savings ranges.

Commitment-based savings selection

For each demand-side CAS, users provide a **Level of Commitment** (typically 0–3) indicating whether the utility is unlikely to pursue the action (0) or is willing to pursue it at increasing intensity (1–3).

The tool translates commitment level into a savings assumption using literature-based **low/medium/high** savings ranges:

- Commitment **1 → Low savings assumption**
- Commitment **2 → Medium savings assumption**
- Commitment **3 → High savings assumption**
- Commitment **0 → No savings applied**

The savings assumptions are pre-populated in a reference table and represent screening-level estimates consistent with the planning intent of the tool.

Where defined: *DW_REF_Costs+Savings* (demand-side savings ranges table)

Portfolio-level cap on total demand-side savings

To prevent unrealistically high aggregate savings, the tool applies a conservative portfolio-level cap on demand-side savings. If the sum of demand-side savings assumptions exceeds a preset maximum, the tool scales savings down proportionally so total demand-side savings do not exceed the cap.

Conceptually:

- If combined demand-side savings ≤ cap → savings are retained as selected
- If combined demand-side savings > cap → each action's savings share is reduced proportionally until the cap is met

This approach preserves the relative contribution of each selected demand-side action while enforcing an upper bound on total savings.

Where applied: *DW3_Results* (Step 1 demand-side calculations)

Conversion of percent savings to annual volume (AF/year)

After savings percentages are selected (and capped if needed), the tool converts savings into water volumes:

$$\text{Savings (AF/year)} = \text{Savings Fraction} \times \text{Baseline Annual Supply (AF/year)}$$

This provides an annualized volume of potential demand reduction for each demand-side CAS.

Baseline source: Baseline_AF from *DW1_Inputs*

Allocation of savings toward the annual gap target

The tool does not automatically assume that the full theoretical savings potential of each action is realized. Instead, it allocates the annual supply gap target across demand-side actions **in proportion to their potential savings**.

Conceptually:

- Actions with higher potential savings are assigned a larger share of the gap closure target.
- The sum of allocated demand-side savings is limited to the total gap target (or the capped demand-side total, whichever is smaller).

This allocation method is intended to represent a practical "portfolio deployment" framing, where selected actions are scaled to meet a specific planning objective rather than assuming all available savings are fully achieved.

Where applied: *DW3_Results* (Step 1 allocation logic)

Supply-Side Gap Filling Method (if needed)

If demand-side measures do not close the full annual gap target, the tool assigns the remaining gap to supply-side options.

Remaining gap calculation

The tool computes remaining gap as:

Remaining Gap (AF/year) = Annual Gap Target – Demand-Side Savings Allocated

Where shown: *DW3_Results* ("Remaining Gap after Demand-Side Savings")

Allocation across supply-side actions

Supply-side allocation is based on the user's Level of Commitment for each supply-side CAS. The tool distributes the remaining gap proportionally to the commitment "weights" across all supply-side actions with non-zero commitment.

Conceptually:

- If only one supply-side action is selected → it receives 100% of the remaining gap
- If multiple are selected → each receives a share proportional to its commitment level

This produces an annual supply augmentation requirement (AF/year) for each supply-side CAS.

Where applied: *DW3_Results* (Step 2 supply-side allocation logic)

Cost Estimation and Unit Cost ($/AF)

The tool estimates annual costs for each CAS using literature-based **unit cost** assumptions expressed as dollars per acre-foot. For a screening-level tool, this approach provides consistent cross-option comparisons without requiring a full capital planning model.

Unit cost reference tables

Unit cost assumptions are stored in the tool's internal reference tabs and represent typical planning-level costs across the U.S. context. These values are differentiated by CAS type and are intended to reflect ranges reported in the literature and agency planning documents.

- Demand-side unit costs: *DW_REF_Costs+Savings*
- **Supply-side unit costs:** *DW_REF_Costs+Savings* and supporting tables in *DW_REF_Costs1* / *DW_REF_Costs2*

For transparency, the tool includes references (authors/organizations and year) associated with each cost and savings assumption.

Annual cost computation

For both demand-side and supply-side actions, the tool calculates annual cost using a unit cost multiplied by the allocated annual water volume:

$$\text{Annual Cost (\$/year)} = \text{Allocated Volume (AF/year)} \times \text{Unit Cost (\$/AF)}$$

This produces an annualized planning cost for each action, which can be summed across the portfolio.

Portfolio-level cost-effectiveness metric

The tool's core cost-effectiveness indicator is:

$$\text{Cost per Unit} = \frac{\text{Annual Cost}}{\text{Annual Water Savings or Supply Added}}$$

Depending on the CAS type:

- **Demand-side:** "unit" represents water saved (AF/year)
- **Supply-side:** "unit" represents water supplied/augmented (AF/year)

This enables direct comparison of measures across different strategy types within a consistent unit framework.

References Supporting Savings and Cost Assumptions

The tool compiles screening-level assumptions from planning and peer-reviewed sources, including (but not limited to):

- Cooley et al. (2016). *The Cost of Alternative Water Supply and Efficiency Options in California.*
- EPA (2016). *Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative Water Supply.*
- EPA (2017). *Cases in Water Conservation*: *How Efficiency Programs Help Water Utilities Save Water and Avoid Costs.*
- WRF. *Residential End Uses of Water, Version 2 (Executive Report).*
- Perrone & Rohde (2016). (Unit costs for supply-side options; DOI referenced in tool.)
- SFPUC (2020). Retail Water Conservation Plan.
- Additional supporting sources embedded in tool reference tabs (*DW_REF_Costs+Savings*, *DW_REF_Costs1*, *DW_REF_Costs2*), including case studies and program cost examples.

Because regional costs vary widely, the default values are intended to support prioritization and sensitivity testing rather than definitive budgeting.

---

[i] Alder, J. R. (2025). *CMIP6-LOCA2 spatial summaries of HU8 and HU10 watershed boundaries from 1950–2100 for the Contiguous United States* [Data set]. U.S. Geological Survey. https://doi.org/10.5066/P1QAUBWU

For questions, contact

Rowan Schmidt, Radbridge: rowan@radbridge.com

Sri Vedachalam, CIS: sri@cisolutions.com

Harry Zhang, The Water Research Foundation: hzhang@waterrf.org

THE Water Research FOUNDATION®