DRAFT Outdoor Irrigation M&V Protocol V.04

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KL McMordie Stoughton

SA Loper

JR Figueroa

Prepared by Pacific Northwest National Laboratory and Western Resource Advocates as model guidelines for the State Performance Contracting Programs of Colorado, Nevada, and New Mexico.

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Outdoor Irrigation Measurement and Verification Technical Advisory Group

Brent Q. Mecham	Industry Development Director, Irrigation Association
Ben Slick	Senior Vice President of Business Development, HydroPoint
Cable Jones	Project Developer, Water Management, Inc.
Niffy Ovuworie	M&V Program Manager for the Rocky Mountain Region, McKinstry
Megan Ferguson	Energy Engineer, Siemens Industry, Inc.
Patrick Watson	Conservation Services Administrator, Southern Nevada Water Authority
Paul Basset	Senior Vice-President and Chief Technology Officer, Water Savers, llc
Richard Chapman	President, Smart Use, llc
Philip Neff	Engineering Manager, Honeywell Energy Services Group of North America
Scott Winter	Lead Water Conservation Specialist, Colorado Springs Utilities
William Travers	Sr. Project Developer, NORESCO

Technical Lead

Kate McMordie Stoughton	Water Efficiency Engineer, Pacific Northwest National Laboratory

Project Co-Leads

Jorge Figueroa	Senior Water Policy Analyst, Western Resource Advocates
Taylor Lewis	Program Engineer, Colorado Energy Office

Senior Advisors

Chuck Kurnik	Engineer and Project Manager, National Renewable Energy Laboratory
Linda Smith	President, 9Kft Strategies in Energy
Amelia Nuding	Senior Water Resources Analyst, Western Resource Advocates

Steering Committee Members
Water, Measurement and Verification (M&V) Guidelines, and State Performance Contracts Project

Donald Gilligan	President, National Association of Energy Service Companies
Mary Ann Dickinson	President and CEO, Alliance for Water Efficiency
John Canfield	President, Trident Energy Services
Chris Halpin	President, Celtic Energy
Patrick Watson	Conservation Services Administrator, Southern Nevada Water Authority
Carlos Bustos	Water Conservation Program Manager, Albuquerque Bernalillo County Water Utility Authority
Frank Kinder	Senior Conservation Specialist, Colorado Springs Utilities
Paul Matuska	Manager, Water Accounting and Verification Group, US Bureau of Reclamation
William D. Taylor	Private Sector Co-Chair, Energy Services Coalition-Nevada Chapter
Oscar Rangel	Private Sector Co-Chair, Energy Services Coalition-Colorado Chapter
Scott Griffith	Private Sector Co-Chair, Energy Services Coalition-New Mexico Chapter
Harold Trujillo	Chief, New Mexico Energy Technology and Engineering Bureau, New Mexico EPC Program
Kelly Thomas	Energy Program Manager, Nevada Governor's Office of Energy, Nevada EPC Program
Taylor Lewis	Program Engineer, Colorado Energy Office, Colorado EPC Program

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Contents

Tables

Figures

1.0 Acronyms, Abbreviations, and Definitions

ASBE	American Society of Agricultural and Biological Engineers
Climate normal	Average weather conditions for a given location that is over the latest three-decade time period.
CAWQuer	Climate Atlas Web Query (online tool and database)
CoAgMet	Colorado Agricultural Meteorological Network
Commissioning	The process whereby the measure improvements made to the equipment and/or the control system have been verified to comply with the approved plan, and visually inspected and evaluated for proper operation.
ESCO	Energy Service Company (performance contractor)
Evapotranspiration (ET)	The combination of loss of water due to evaporation from soil and plant surfaces and the amount of water transpired by the plant over a given timeframe.
Hydrozone	A distinct area of the landscape that receives irrigation from the same system.
Irrigation efficiency	The percentage of irrigation water that is actually stored in the soil and available for use by the landscape (as compared to the total amount of water provided to the landscape).
IPMVP	International Performance Measurement and Verification Protocol
IWMI	International Water Management Institute
Measurement boundary	The specific landscape areas that are impacted by the WCM and monitored for water savings.
Measurement frequency	The number of measurements that will be collected over the measurement period to determine water use savings.
Measurement period	The timeframe water use is monitored, defined by the irrigation season.
M&V	measurement and verification
NOAA	National Oceanic and Atmospheric Administration
Study period	The total timeframe that water use will be monitored per the contractual arrangement for the baseline and post-installation periods.
WCM	water conservation measure

2.0 Introduction

This measurement and verification (M&V) protocol provides procedures for energy service companies (ESCOs) to determine water savings as a result of water conservation measures (WCMs) in energy performance contracts associated with outdoor irrigation efficiency projects. The water savings are determined by comparing the baseline water use to the water use after the WCM has been implemented. This protocol outlines the basic structure of the M&V plan, and details the procedures to use to determine water savings. **It is vital that the customer reviews the M&V plan thoroughly and agrees to the procedures used by the ESCO to collect data and measure water savings.**

The procedures presented in this protocol are performance based. ESCOs are required to measure the amount of water savings directly and do not have to prove the effectiveness of the measure itself. This protocol does not cover other cost streams such as operation and maintenance or energy costs.

3.0 Measure Description

This protocol specifies M&V requirements for WCMs associated with improving the efficiency of irrigation systems. Irrigation systems include all components that deliver and control the application of supplemental water in landscapes. System components include piping infrastructure, valves, sprinkler heads, and irrigation controls. WCMs that are covered by this M&V protocol include, but are not limited to, the following:

Irrigation System Efficiency Improvements

The objective of this measure is to increase irrigation system efficiency by improving the uniform distribution of water to meet the landscape irrigation requirements and minimize waste and losses from the system.[1] This WCM category may include measures such as reconfiguring the irrigation system, repairing system components, repairing system leaks, and replacing irrigation systems with more efficient technology such as drip irrigation and sub-surface irrigation.

Advanced Controls

Irrigation controllers manage the application of water on a landscape. This measure includes installing advanced controllers that use real-time data to irrigate landscape based on local conditions, which can reduce overall watering times, thereby decreasing water use. Advanced controllers include weather-based systems that use weather data to calculate evapotranspiration (ET) to determine the landscape's current irrigation requirements. Another type of advanced controller is the soil-moisture-based controller, which uses real-time soil moisture data and adjusts the irrigation schedule to meet the specific water needs.

Real-Time Sensors

Real-time sensors monitor live conditions of the landscape, and can temporarily suspend irrigation when irrigation is not optimal. Examples include rain, wind, and freeze sensors. These sensors are typically tied into an automated control system to optimize the irrigation schedule, thereby reducing the overall amount of irrigation applied to the landscape.

[1] Irrigation efficiency is defined as the percentage of irrigation water that is actually stored in the soil and available for use by the landscape as compared to the total amount of water provided to the landscape.

A flow sensor is another type of real-time sensor. Flow sensors monitor water flowing in the irrigation distribution pipes, and can detect abnormal flow conditions that may indicate a system problem. The flow sensor can interface with an irrigation controller to suspend irrigation under abnormal conditions.

4.0 Measurement and Verification Plan Elements

The ESCO is required to develop a plan that specifies how the M&V will be performed. This section provides the basic structure of the M&V plan.

4.1 M&V Method

The International Performance Measurement and Verification Protocol (IPMVP) has four options (A, B, C, and D) that can be used to verify the savings of measures.

For outdoor irrigation efficiency measures, the recommended IPMVP option to verify water savings is Option B, "Retrofit Isolation."

The objective of Option B is to verify performance by measuring the system usage, which increases the accuracy of the verified savings. The retrofit isolation method uses real-time field measurements of the irrigation system to verify the savings, whereby short-term or continuous measurements are taken throughout the study period. The flow of each irrigation hydrozone is the key parameter that is required to be measured using Option B.

IPMVP's Option A, "Partially Measured Retrofit Isolation", allows some stipulated savings, and is a less desirable method because it does not accurately measure the full impact of the measure. Option C ("Whole Building") and Option D ("Calibrated Simulation") are not appropriate M&V methods for outdoor irrigation efficiency projects because they assess usage at the building level rather than the system level.

This section provides information on the main elements of data collection that should be included in the M&V plan when using the IPMVP's Option B M&V method.

4.2 Measure Description and Measurement Boundary

The M&V plan should describe the specific WCMs and the intended results. In addition, the plan should clearly define the measurement boundary. The measurement boundary defines the specific landscaped areas that will be impacted by the WCM and monitored for water savings.

4.3 Baseline and Post-Installation Condition

The M&V plan should provide a detailed description of the baseline and post-installation conditions that includes information related to the irrigation audit, irrigation schedule, and the general condition of the landscape.

4.3.1 Baseline Condition

The plan should include information relevant to the baseline conditions that is collected during the irrigation audit that describes the state of the existing irrigation system components such as, but not limited to, component leaks, nozzle type, and head spacing.

The plan should also detail the irrigation schedule, including the type of controller and specific changes made to the irrigation schedule during the baseline year that impact the baseline water use.

The description of the baseline condition may also cover the general characteristics of the landscape, which could include, among other things: the landscape slope, soil type, significant drainage issues, and current planting type and condition (from aesthetic or visual quality to general plant health). The customer may require that the baseline landscape condition be maintained in the post-installation period. If this is the case, the ESCO should estimate the savings potential based on the required level of irrigation to maintain the landscape to the desired level.

4.3.2 Post-Installation Condition

Similarly, the M&V plan should specify the condition of the irrigation systems and landscapes that will be achieved through the study period per the commissioning plan (see section 6.0). This should include information on the irrigation system components and schedules. If the customer requires maintaining the general baseline appearance of the landscape during the study period, the required appearance of the landscape should also be included.

4.4 Water Use Calculations

The M&V plan should include the procedures used to determine the baseline water use and post-installation water use, which are used to calculate the water savings and to properly normalize the data if required. Section 5.0 of this protocol provides detailed procedures on the calculation methods.
The procedures used to determine baseline and post installation water use should be described in detail and reviewed and approved by the customer.

4.5 Data Categories

The M&V plan should specify the distinct categories of data that will be gathered and the methods used to gather the data. It is important for the customer to review and approve the type of data that will be used to determine water use savings. The following describes the type of data that may be collected.

- *Continuous measurement using a dedicated meter*
    - Volume of water logged by the metering system over the measurement period. Specify the interval at which the volumetric water use will be logged. If multiple meters are in place that measure water use in the measurement boundary, make sure that all meters are included. Data should be gathered monthly, which is required in the normalization process (see Section 5.3).
- *Flow rate determination*
    - Hydrozone flow rate logged by a dedicated or temporary metering system over distinct time periods, typically measured in gallons per minute. The plan should include the procedure to isolate the flow rate of the specific hydrozones within the measurement boundary (see Section 4.8 for additional information on flow rate determination).
- *Irrigation audit to determine the irrigation precipitation rate (baseline water use only; see Section 5.1 for additional information)*
    - Hydrozone precipitation rate, which is the amount of water distributed to a specific area, typically measured in inches per hour.

    - Landscape area that defines the irrigation coverage of the hydrozone, typically measured in square feet. The plan should specify how the irrigation area is measured (e.g., aerial map, direct measurement).
- *Irrigation system's runtime logged over the measurement period*
    - The amount of time that the irrigation system operates over the same time frame as the flow rate, measured in minutes (e.g., irrigation control system, manual logs). The runtime should be collected from the irrigation controller or operator logs. The total runtime should be the sum of the total daily runtime over the measurement period for each hydrozone.
- *Weather data*
    - ET and precipitation data used to normalize water use. The plan should include the data source and the location of the weather data relative to the site location (See Appendix A for local ET and precipitation data sources and methods.)

4.6 Study Period

The study period covers the total timeframe that water use will be monitored per the contractual arrangement for the baseline and post-installation periods. The study period should follow the established M&V requirements of the State Performance Contracting Program.[2]

The plan should define the baseline period. The baseline study period should be a minimum of one full irrigation season, but preferably is an average of multiple irrigation seasons. Using an average of multiple years for the baseline study period is preferable because it helps to dampen anomalies in water use caused by operation changes such as scheduling issues or system maintenance problems.

Preferable: *baseline study period is an average of multiple irrigation seasons*

Acceptable: *baseline study period is minimum of one full irrigation season*

The plan should also define the study period for the post-installation water use measurement. For example, in the state of Colorado ESCOs are required by statute to provide a written cost savings guarantee for the first 3 years of the contract period. [3] At the agency's discretion, the savings guarantee can be extended beyond the legislatively required time period. At the end of each performance year, the ESCO is required to submit an annual M&V report to demonstrate that the savings have occurred.

4.7 Measurement Period

The M&V plan should specify the measurement period, which defines the irrigation season. For Colorado, the typical irrigation season runs from mid-April through October.

[2] See, for example, the State of Colorado's M&V Guidelines for Energy Savings Performance Contracts. Nexant. 2008. *Measurement and Verification (M&V) Guidelines for Energy Saving Performance Contracts in State of Colorado Facilities*. Boulder, CO. June.

[3] Colorado Energy Performance Contracting Office. *Colorado Statutes Regarding Energy Performance Contracts for State Government*. Title 24 Government – State: Principal Departments: Article 30 Department of Personnel – State Administrative Support Services, Part 20 Utility Cost-Savings Measures.

4.8 Measurement Frequency

The measurement frequency is the number of measurements that will be collected over the measurement period to determine water use savings. To properly normalize the data, water use should be collected monthly.

- *Water use with a dedicated meter*
  - Water use data should be collected from the dedicated meter at least monthly and capture the full measurement period.

- *Flow rate determination*
  - Flow rate for each hydrozone in the measurement boundary should be measured at the beginning, mid-point, and end of the measurement period to determine an average flow rate. This will ensure that an accurate flow rate is determined. Flow rates may vary due to system issues such as line leaks or broken heads. Therefore it is important that system leaks are detected and corrected prior to flow rate measurement for post-installation water use determination. In addition, it is recommended that flow rate data is collected from a dedicated meter rather than from a controller because a meter records flow rate directly.

- Irrigation runtime
  - Runtime for each hydrozone should be collected over distinct time periods from the irrigation controller or operator logs (e.g., monthly, daily.)

- *Precipitation rate*
  - Precipitation rate for each hydrozone in the measurement boundary should be measured at least once during the baseline measurement period if an irrigation audit is being used to determine baseline water use. (See Section 5.1.1 for additional information.)

4.9 Metering Equipment

The M&V plan should specify the metering equipment that will be used to measure water use, which should be dedicated meters that monitor only the irrigated landscape within the measurement boundary. An existing dedicated meter can be used to determine the baseline water use, which may be customer-owned or provided by the water utility.

It is important that the meters used to determine the water use are calibrated. Uncalibrated meters can under-record or over-record water use and therefore can underestimate or overestimate the water use. The ESCO should provide the method used to calibrate the meters and provide a calibration certificate to their customer, which should follow the established M&V requirements of the State Performance Contracting Program. If there are potential metering inaccuracies, the ESCO should follow any established dispute resolution steps identified in the State Performance Contracting Program relevant to this issue.

For post-installation water use measurement, the M&V plan should provide detailed information on the metering equipment, including the manufacturer, model number, and quantity being installed as part of the measure. The M&V plan should also provide the metering equipment's installation procedure that includes the length of straight pipe required. The following meter information should be provided in the M&V plan:

- Volumetric resolution (e.g., within 0.1 gallons)
- Accuracy range at specified ranges of flow rates
- Flow range
- Durability of construction to protect against high pressure and corrosion (e.g., plastic versus brass)
- Water quality requirements (e.g., filtered versus unfiltered water)
- Line size
- Minimum and maximum operating pressure
- Calibration method and frequency to ensure that the post-installation water use is accurately determined

The M&V plan should also provide the type of data management system that will log water use. The following data management options should also be considered when selecting an appropriate metering system:

- Data logging capability that allows for collection of volumetric water use over distinct interval periods (such as 15-minute or 1-hour intervals)
- Web-enabled interface with secure data storage options
- Automated software updates that patch programming issues
- Capability to interface with other building automation systems
- Customizable data forms and trending options that allow for short- and long-term graphing of data to evaluate operational issues

5.0 Water Savings Calculations

This section of the document provides the procedures that are used to calculate water savings. The general water savings equation is:

Water Use Savings = (Baseline Water Use – Post Installation Water Use) ± Adjustments

Where:

Baseline Water Use = Irrigation water use of the existing system prior to WCM implementation
Post Installation Water Use = Irrigation water use after implementation of WCM
Adjustments = Factor applied to normalize water use when appropriate

5.1 Baseline Water Use

This section of the document describes methods to determine the baseline water use and the required normalization of the baseline.

5.1.1 Baseline Water Use Determination

The following options can be used to estimate baseline water use, listed in order of accuracy:

> ***Preferable:*** *Continuous measurement using dedicated meters*
>
> ***Acceptable:*** *Flow rate determination*
> *Irrigation audit to determine system precipitation rate*

1. **Continuous measurement using a dedicated meter/s**. If the existing irrigation system has a flow meter that monitors water use for the measurement boundary, metered data should be collected to determine the baseline water use (see Section 4.5).

   This is the preferable method because it most accurately measures water over the measurement period. If metered data is not available for the baseline, then the other options listed below can be used to supplement missing time periods.

2. **Flow rate determination**. If a dedicated meter is not installed on the existing system or does not record volumetric data, flow rates for each hydrozone, logged by a dedicated or temporary metering system within the measurement boundary, can be determined using a temporary meter or other procedure that is agreed upon in the M&V plan. The flow rate for each hydrozone is multiplied by the hydrozone's runtime to determine the volume of water used for each hydrozone. The total baseline irrigation water use is the sum of each hydrozone's water use, represented by:

$$\sum_{Z=1}^{n}(FR_Z \times RT_Z)$$

   Where:

   FR_Z = The hydrozone's flow rate, measured in gallons per minute
   RT_Z = The runtime of the hydrozone irrigation system during the baseline, measured in minutes
   n = The total number of hydrozones

   When calculating the water consumption using the flow rate method, it is important to document the following items in the M&V plan:

   - Designate the measurement frequency for hydrozone flow rate (see Section 4.8)
   - Describe how the average hydrozone flow rate was determined
   - Describe how the irrigation runtime was collected over the baseline

3. **Irrigation audit to determine system precipitation rate**. If metering the baseline water use or using flow rates to calculate the baseline is not an option, the third most accurate approach is to perform an irrigation audit. An irrigation audit measures the precipitation rate of each irrigation hydrozone by capturing and measuring the amount of water distributed by the irrigation system, typically measured in inches per hour. The irrigation audit should follow the protocol set in the Irrigation Association's *Recommended Audit Guidelines*[4] or American Society of Agricultural and Biological

[4] Irrigation Association. *Recommended Audit Guidelines*. September 2009. Available at: https://www.irrigation.org/uploadedFiles/Certification/CLIA-CGIA_AuditGuidelines.pdf

Engineers (ASBE) Standard S626 *Landscape Irrigation System Uniformity and Application Rate Testing*[5]. The precipitation rate for each hydrozone is applied to the hydrozone's run-time and landscape area that the hydrozone covers. The total baseline irrigation water use is the sum of the hydrozone's water use, represented by:

$$\sum_{Z=1}^{n}(PR_Z \times A_Z \times RT_Z \times 0.0104)$$

Where:

PR_Z = The hydrozone's precipitation rate, measured in inches per hour

A_Z = The hydrozone's irrigation area, measured in square feet

RT_Z = The runtime of the irrigation system during the baseline, measured in minutes

0.0104 = A conversion factor that converts precipitation rate and hydrozone square footage to gallons

n = The total number of hydrozones

Irrigation demand using a calibrated model can provide additional information on the baseline water use, when using the three prescribed methods above. An irrigation demand method uses ET and precipitation data to calculate the amount of water needed to maintain a healthy landscape for a given location, based on the amount of water transpired and evaporated from the plants and the precipitation received at that location. Determining the irrigation demand of specific landscapes can provide critical information on the overall performance of the current irrigation system by comparing the actual water use to the water requirements of the landscape. This information can provide insight on the water savings potential. However, the irrigation demand method should not be used solely to estimate the baseline because it does not accurately reflect actual water use.

ASBE Standard S623, *Determining Landscape Water Demands*[6] is the preferred method to determining the irrigation demand. The M&V plan should clearly state all of the assumptions that are used in this method.

5.1.2 Baseline Normalization

If the existing irrigation is scheduled with a conventional system that irrigates based on a set "clock schedule" where adjustments are not made, then the baseline water use should not be normalized. However, **the baseline water use should be normalized (see Section 5.3 for the normalizing procedure) under the following circumstances**:

- The existing irrigation controller is a weather-based and/or soil-moisture-based controller that uses live data to adjust the irrigation schedule based on actual conditions.
- There are existing weather sensors such as rain or wind gauges that use live data to adjust the irrigation schedule based on actual conditions.

[5] American Society of Agricultural and Biological Engineers Standard S626. *Landscape Irrigation System Uniformity and Application Rate Testing.* October 2016.

[6] American Society of Agricultural and Biological Engineers Standard S623. *Determining Landscape Water Demands.* January 2017.

- The irrigation schedule is routinely monitored and adjusted by grounds maintenance staff. The system has a flow meter that shows water use fluctuations throughout the irrigation season that reflect these adjustments.

5.2 Post-Installation Water Use Determination

The IPMVP Option B M&V method requires a meter to measure the post-installation water use over the measurement period. The two methods for determining the post-installation water use are described below, listed in order of accuracy.

Preferable: *Continuous measurement using dedicated meter/s*

Acceptable: *Flow rate determination*

1. **Continuous measurement using dedicated meters.** In-line meters should be connected to a centralized control system or a data logger to continuously record water use data over the study period within the measurement boundary. This is the preferable method because it most accurately measures water over the measurement period.
2. **Flow rate determination.** If the dedicated meter cannot accurately determine the water use of the measurement boundary, flow rates of the hydrozones within the measurement boundary can be used to estimate water use. (See Section 4.8 for additional information.) The flow rate for each hydrozone is multiplied by the hydrozone runtime to determine the volume of water used for each hydrozone. The total post-installation irrigation water use is the sum of hydrozone's water use, represented by:

$$\sum_{Z=1}^{n} (FR_Z \times RT_Z)$$

Where:

FR_Z = The hydrozone's flow rate, measured in gallons per minute

RT_Z = The runtime of the hydrozone irrigation system over the study period, measured in minutes

n = The total number of hydrozones

When calculating the water consumption using the spot measurement method, it is important to document the following items in the M&V plan:

- Designate measurement frequency for hydrozone flow rate (see Section 4.8)
- Describe how the average hydrozone flow rate was determined
- Describe how the irrigation runtime was collected over the measurement period

5.2.1 Post-Installation Normalization

Post-installation water use will be normalized only if the WCMs includes a weather-based control system or weather-sensing technology that adjusts the irrigation schedule for weather changes. See Section 5.3 for detailed normalization procedures.

5.3 Data Normalization

This section provides the procedures that should be used to normalize irrigation water use.

As described in Sections 5.1.2 and 5.2.1, irrigation water use should be normalized if the irrigation schedule is altered for weather changes. For example, if a drought occurs during the measurement period, the landscape will need more water to survive because of reduced rainfall. Conversely, weather can be abnormally wet, where more precipitation is received than normal, thus decreasing irrigation demand. In these cases, the water use should be normalized to be commensurate with water used during a typical irrigation season.

The normalization method accounts for variations in the weather and adjusts water use to historical average weather patterns, also referred to as "climate normal". **Climate normal weather data represents the average weather conditions for a given location. This M&V protocol adopts the National Oceanic and Atmospheric Administration (NOAA's) Climate Data Center definition of climate normal as "the latest three-decade averages of climatological variables".[7]**

The historical average (climate normal) ET and precipitation data can provide an estimate of the typical irrigation requirements of a landscape and can thereby be used to normalize water use. ET is the combination of loss of water due to evaporation from soil and plant surfaces and the amount of water transpired by the plant and is typically measured in inches over a given timeframe (e.g., inches per week).[8] Reference ET (ET_o) is the amount of water that is needed to keep a reference plant (e.g., alfalfa) healthy. The amount of precipitation received over the timeframe is subtracted from ET_o requirements to determine the "net ET_o."

The method for determining water demand is described in the ASBE Standard S623, *Determining Landscape Water Demands.*[6] This standard was used to develop the normalization methods used below.

Follow these steps to normalize the post-installation water use over the measurement period water use. These same procedures can be used to normalize baseline water use if required (see Section 5.1.1).

1. Determine the average monthly ET_o and precipitation for the location over the current measurement period (See Appendix A for average ET_o and precipitation data sources and calculation methods.)

2. Determine the current monthly ET_o and precipitation for the location over the current measurement period (See Appendix A for approaches to determining current year ET_o and precipitation.)

3. Calculate the historical average (climate normal) monthly net ET_o by subtracting local monthly historical average precipitation (climate normal) from average ET_o to determine the monthly net ET, represented in this formula:

$$Monthly\ Average\ Net\ ETo\ (inches) = (Average\ ETo - Average\ Precpitation)$$

[7] NOAA's National Climate Data Center. Satellite and Information Service. "NOAA's 1981-2010 Climate Normals" website, accessed at: https://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

[8] American Society of Agricultural and Biological Engineers Standard S623. *Determining Landscape Water Demands* January 2017.

4. Calculate the current measurement period monthly net ET_o by subtracting local monthly current precipitation from ET_o during the measurement period to determine the monthly net ET, represented in:

$$Monthly\ Measurement\ Period\ Net\ ETo\ (inches) = (Measurement\ Period\ ETo - Measurement\ Period\ Precpitation)$$

5. Determine the monthly ratio of average net ET_o to the current study period net ET_o, represented by:

$$Monthly\ Net\ ETo\ Ratio = (Monthly\ Average\ Net\ ETo \div Monthly\ Measurement\ Period\ Net\ ETo)$$

6. Gather the post-installation water use for each month from metered data collected during the study period.

7. Normalize each month's water use by multiplying the monthly post-installation water use by monthly net ET_o ratio. Then sum all of the monthly values to determine the total post-installation water use, represented in:

$$\sum_{n=1}^{n}(Monthly\ Post\text{-}Installation\ Water\ Use \times Monthly\ Net\ ETo\ Ratio)$$

Table 1 below provides an example of this normalization method. This example depicts an irrigated landscape in Aurora, Colorado. The post-installation water use was 488,422 gallons measured by the metering system. Abnormally hot and dry conditions were experienced during the irrigation season, whereby the total net ET over the measurement period was 44.2 inches, compared to the historical average of 34.5 inches, giving a net ET ratio of 78%. Applying this value, the normalized post-installation water use is 381,219 gallons.

Table 1. Sample Normalization of Post-Installation Water Use in Aurora, Colorado.

Irrigation Month	Average ET_o (inches)	Average Precipitation (inches)	Average Net ET_o (inches)	Current Measurement Period ET_o (inches)	Current Measurement Period Precipitation (inches)	Current Measurement Period Net ET_o (inches)	Monthly Net ET_o Ratio	Post-Installation Water Use (gallons)	Normalized Post-Installation Water Use (gallons)
Apr	4.86	1.44	3.42	5.84	1.33	4.51	0.76	29,997	22,761
May	6.08	2.40	3.69	7.30	2.21	5.09	0.72	63,501	45,942
Jun	7.76	1.37	6.39	9.31	1.26	8.05	0.79	100,369	79,670
Jul	8.45	1.88	6.57	10.14	1.73	8.41	0.78	104,859	81,909
Aug	7.52	1.36	6.16	9.03	1.25	7.78	0.79	96,934	76,821
Sep	5.73	0.88	4.85	6.88	0.81	6.07	0.80	75,628	60,450
Oct	4.05	0.65	3.40	4.86	0.60	4.26	0.80	17,133	13,666
Total	44.46	9.98	34.48	53.36	9.19	44.17	0.78	488,422	**381,219**

5.4 Other Considerations

The M&V plan should state any potential issues that may significantly impact water use. If there are issues that significantly impact water use, the baseline water use may need to be adjusted to account for the increased water use. The ESCO should follow the established dispute resolution steps identified in the State Performance Contracting Program, which should be reviewed and agreed upon between the ESCO and the customer. Such issues may include, among other things:

- Changes to irrigation control settings, such as local grounds maintenance crews overriding pre-programmed controllers.
- Changes in landscape area or planting type at any time during the study period, which may change the irrigation requirements.
- Undetected leaks that are not repaired quickly.
- Grounds maintenance issues such as disease of landscape that require extra watering not anticipated in the savings estimate.
- Drought management and other types of watering restrictions imposed by the water utility, or local or state government entities that may reduce water use and change the appearance of the landscape.
- Deficit watering during the baseline period, which is a reduction in water use compared to the required water needs of the landscape—this may reduce the overall potential water savings of the WCM.

The annual M&V report should provide a detailed description of any significant issue that was experienced, the subsequent impact on water use, and adjustments made to the baseline estimate as a result of the issues.

6.0 Commissioning Protocol

Commissioning is an important step to ensure the WCM will achieve the guaranteed savings. Commissioning is the process whereby the WCM improvements made to irrigation equipment and/or control system have been verified to comply with the approved plan and visually inspected and evaluated for proper operation. In addition, commissioning verifies that the correct irrigation schedule has been implemented for current landscape needs, and that the manager of the irrigation system has been trained to properly operate it.

Commissioning ensures system components are functioning optimally per the measure's design and checks system performance and operational issues such as misaligned heads or leaks. A commissioning plan should be established that outlines the specific steps that will be performed. The commissioning plan should follow the Irrigation Association's *Irrigation System Inspection and Commissioning Guidelines,* found in the *Landscape Irrigation Best Management Practices*.[9] Critical components of the commissioning plan include:

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[9] Irrigation Association and American Society of Irrigation Consultants. *Landscape Irrigation Best Management Practices*. March 2014. Falls Church, VA. https://www.irrigation.org/uploadedFiles/Standards/BMPDesign-Install-Manage.3-18-14(2).pdf

- **Qualified inspector**. A commissioning agent should have the training and competencies to perform the required steps. Examples of qualifications may include the Irrigation Association certifications such as Certified Landscape Irrigation Auditor, Certified Landscape Manager, and Certified Irrigation Designer[10]; and the Qualified Water Efficient Landscaper Program[11].

- **Equipment**. The plan should detail the type of equipment necessary to perform the commissioning steps.

- **Inspection frequency**. The plan should provide the timeframe of the commissioning inspection, which should be done during and after construction. It may be necessary to recommission the system within the study period to ensure the system is operating optimally.

- **Training**. The plan should also include the training that is required to operate the new equipment including training personnel on controller programming.

- **Inspections and tests**. The plan should specify the types of inspections and tests that will be performed to gauge the performance of the system, which may include, but are not limited to:

    - *Controller irrigation schedule.* Ensure the controller has been properly programmed to meet the specific requirements of the landscape, which should include among other things, accounting for plant types, landscape slope, and exposure.

    - *Irrigation audit.* Perform an irrigation audit to check the performance of the irrigation system to determine:
        - Precipitation rate
        - Distribution uniformity
        - Sensor performance

    - *System tests.* Conduct tests to ensure that the system meets the specifications of the design, including:
        - Flow rate tests
        - Pressure tests for both high and low pressure
        - Leak tests
        - Valve operation
        - Verification that equipment matches design plans
        - Proper head spacing
        - Backflow prevention

    - *Landscape condition assessment*. Conduct an evaluation that determines the general condition of the landscape, including:
        - Plant health
        - Plant appearance and visual quality
          (See Sections 4.3.1 and 4.3.2)

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[10] Irrigation Association Certification Program: http://www.irrigation.org/Certification/

[11] Qualified Water Efficient Landscaper Program: http://www.qwel.net/

- **Minimum performance requirements**. The commissioning plan should specify the minimum requirements of the inspection and tests to meet the expected performance of system.

After the commissioning has been performed, the contractor should provide a report that outlines the findings. **It is recommended that the customer (or consultants) witness commissioning activities, review the commissioning report, provide comments to the ESCO, and have comments resolved to the customer's satisfaction prior to approving the WCM.** The report should include the results of all tests performed, state if the system is functioning per the design, and list necessary corrections.

Appendix A – Local Weather Data Sources and Evapotranspiration Calculation Methods

Precipitation and reference evapotranspiration (ET_o) data is needed to normalize water use to a typical year, as described in Section 5.3. Precipitation data is relatively easy to locate but ET data can be more difficult to access. ET is the combination of water loss due to evaporation from soil and plant surfaces and the amount of water transpired by the plant, which is typically a calculated value.

Preferable: *Penman-Monteith equation using climate normal weather data*

Acceptable: *Hargreaves equation with climate normal weather data or weather data obtained in IWMI CAWQuer database*

The preferable method for determining ET_o is the Penman-Monteith equation using climate normal weather data because it is the most accurate process. Alternate acceptable methods for determining ET_o are the Hargreaves equation with climate normal weather data or weather data obtained in the International Water Management Institute (IWMI) database, as described below.

A.1 Evapotranspiration Calculation Methods

Two common methods to calculate ET_o are the Penman-Monteith and the Hargreaves equations. The Penman-Monteith equation uses daily mean temperature, wind speed, relative humidity, and solar radiation to determine ET_o. The Hargreaves equation is a simplified method to estimate ET_o that only requires solar radiation and minimum and maximum temperatures over a distinct timeframe (e.g., daily, weekly, or monthly).

For the purposes of normalizing water use, ET_o can be determined using either method. Generally, the Penman-Monteith method is considered more accurate because it uses multiple metrological factors to calculate to the total water losses from the reference plant.[12] However, the simplified Hargreaves method can be used to approximate ET_o and is appropriate to use when there is limited metrological data.[13]

If ET_o is calculated using either of these the equations, the methods described in the following reference documents should be used, in order of preferred method:

1. **Penman-Monteith equation:** Chapter 4 "Determination of ET_o" in the *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements*, produced by the Food and Agricultural Organization for the United Nations, accessed at: http://www.fao.org/docrep/X0490E/X0490E00.htm

[12] Allen RG. et al. *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements*. Food and Agricultural Organization for the United Nations. Rome, Italy. 1998. Accessed at: http://www.fao.org/docrep/X0490E/X0490E00.htm

[13] Hargreaves GH and Allen RG. *History and Evaluation of Hargreaves Evapotranspiration Equation*. Journal of Irrigation and Drainage Engineering. January 2003. Accessed at: http://onlinecalc.sdsu.edu/onlinehargreaves.pdf

2. **Hargreaves equation**: Equation 8 listed in the *History and Evaluation of Hargreaves Evapotranspiration Equation* published in the Journal of Irrigation and Drainage Engineering in January 2003, accessed at: http://onlinecalc.sdsu.edu/onlinehargreaves.pdf

A.1.1 Climate Normal Data

To determine the climate normal net ET_o, climate normal data for ET_o and precipitation needs to be collected monthly over the measurement period. Climate normal data is considered average weather conditions over the latest three-decade time period. This data is accessible at the National Oceanic and Atmospheric Administration (NOAA's) *1981-2010 Climate Normals* landing page: https://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

A.2 International Water Management Institute Data

The IWMI database provides an alternate means for gathering average ET_o instead of using the above calculation methods. The IWMI Climate Atlas Web Query (CAWQuer) is a web-based tool that allows users to access historical climate summary data for specified locations, assembled from weather stations world-wide and averaged from 1961 to 1990. The dataset includes average ET_o and precipitation. Even though this time period is not officially considered "climate normal" because it does not span the latest three-decade timeframe, this dataset is a reasonable approximation of average climate data and is allowed to be used in the normalization process described in Section 5.3.

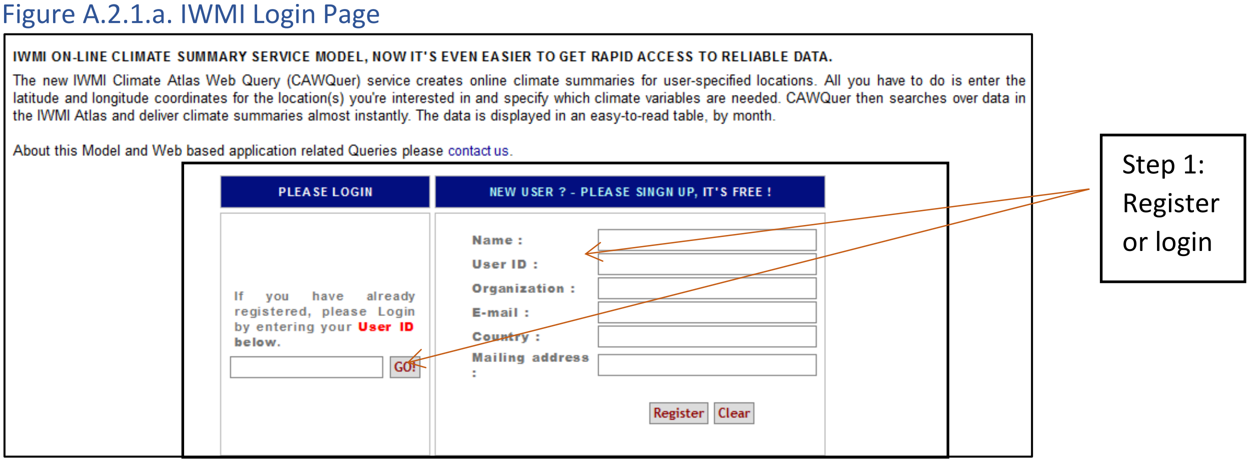
The following sections of this appendix provides a step-by-step process for gathering data from the IWMI web-based tool.

A.2.1 IWMI Web-Based Tool Inputs

Below is the step-by-step process for inputting information into the IWMI web-based tool:

1. Go to http://wcatlas.iwmi.org/Default.asp.
2. Register if a new user, or login if you are an existing user (see
3. Figure A.2.1.a. IWMI Login Page

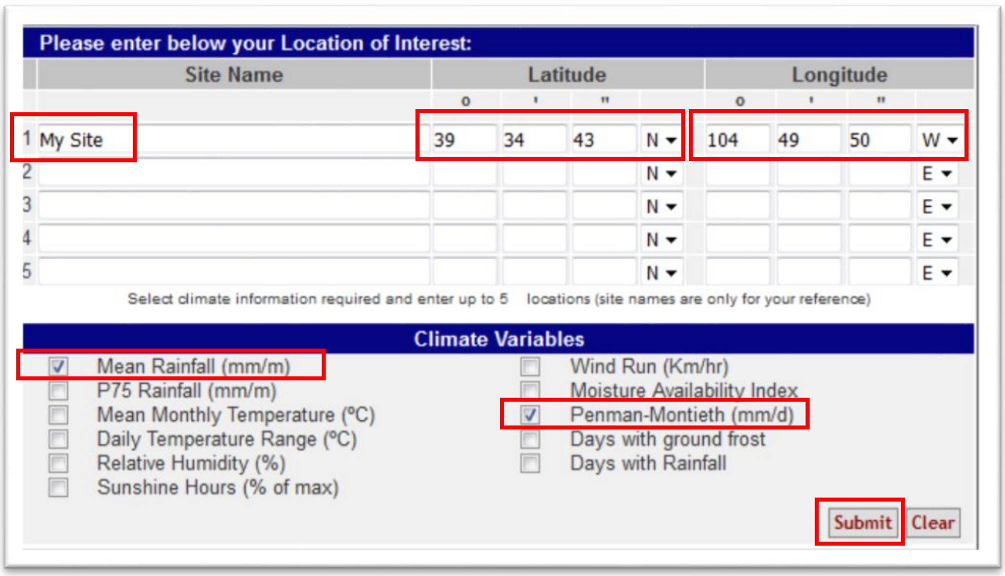
Figure A.2.1.a. IWMI Login Page



4. Enter site name(s). See Figure A.2 for an example of IWMI data entry for user-specified location information and climate variables available for download.

5. Enter site's latitude in degrees, minutes, seconds and whether north or south (see Section A.2.3 below for instructions on how to get site location latitude.)
6. Enter site's longitude in degrees, minutes, seconds, and whether east or west (see Section A.2.3 for instructions on how to get site location longitude).
7. Climate variables that need to be checked are P50 (mm/m) and Penman ET_o (mm/d) for normalization.
8. Click the **Submit** button.

Figure A.2.1.b. IWMI User-Specified Location and Climate Variables.



A.2.2 IWMI Web-Based Tool Ouputs

Figure A.2.2. Example of IWMI Climate Variable Outputs Needed for Normalization.

	P50 (Mm/month)	Penman ETo (mm/day)
Jan	9.35	1.51
Feb	13.99	1.94
Mar	28.61	2.64
Apr	35.05	3.95
May	55.87	4.98
Jun	39.10	6.31
Jul	57.20	6.71
Aug	50.35	5.89
Sep	23.95	4.63
Oct	17.30	3.34
Nov	16.73	1.94
Dec	11.33	1.46

The following covers the IWMI web-based tool outputs needed for normalization as discussed in Section 5.3:

Figure A.2.2 provides an example of the climate variable outputs of the IWMI web-based tool.

a. P50 is the 30-year historical amount of rainfall in millimeters for the month.

b. Penman ET_o is the 30-year historical reference evapotranspiration in millimeters per day.

A.2.3 Latitude and Longitude

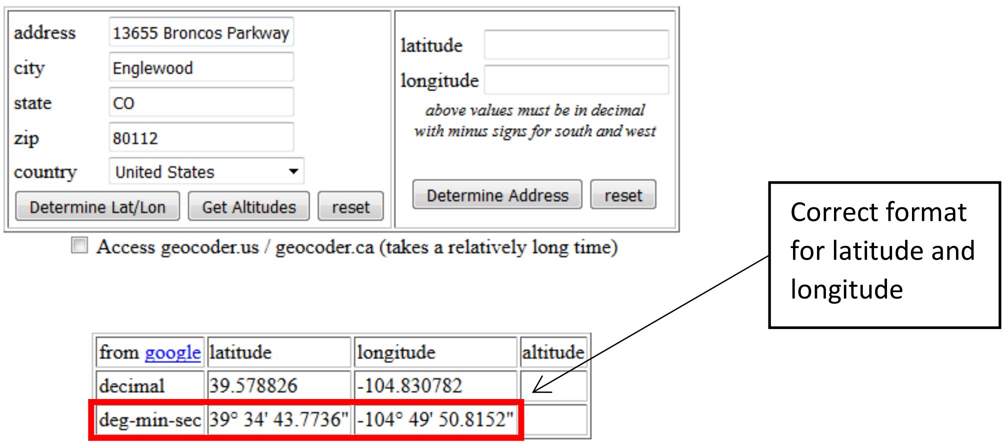
Below is a step-by-step process for obtaining latitude and longitude for a user-specified location, which is needed for the IWMI web-based tool covered in Section A.2.1.

1. Any online latitude/longitude converter can be used (e.g., http://stevemorse.org/jcal/latlon.php).

2. Latitude and longitude format needs to be in degrees, minutes, seconds. Also, note north, south, west, or east.
   a. Colorado: Latitude = North; Longitude = West

3. See Figure A.2.3 below for an example of an online latitude/longitude converter with the input and resulting output.

Figure A.2.3. Example of an Online Latitude and Longitude Converter for a User-Specified Address.



A.3 Current Weather Data Sources

As part of the normalization process, ET_o data for the current study period must be identified. One possible data source is the Colorado Agricultural Meteorological Network's CoAgMet Crop ET_o home page:

http://ccc.atmos.colostate.edu/cgi-bin/extended_etr_form.pl

This website provides monthly ET_o data for multiple weather stations across Colorado. Other possible data sources are below:

- Northern Water - http://www.northernwater.org/WaterConservation/WeatherandETInfo.aspx
- Denver Water – provides a daily weather report including 24-hour total ET (inches) and historical monthly weather data for 2016 and 2017 http://www.denverwater.org/Conservation/WeatherReporting/WeatherData/

For current precipitation data, a reliable source of data can be found at NOAA's National Centers for Environmental Information, accessed at: https://www.ncdc.noaa.gov/cdo-web/