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Response to Invitation to Submit Proposals - Spray Sprinkler Bodies

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Spray Sprinkler Bodies

Codes and Standards Enhancement (CASE) Initiative
For PY 2017: Title 20 Standards Development

Response to Invitation to Submit Proposals
Irrigation Spray Sprinkler Bodies
Docket #17-AAER-08

September 18, 2017

Prepared for:

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1. Purpose

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update California's Appliance Efficiency Regulations (Title 20) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and SoCalGas® – sponsored this effort (herein referred to as the Statewide CASE Team). The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve the energy and water efficiency of various products sold in California. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for potential appliance standards. This CASE Report covers a standards proposal for landscape irrigation spray sprinkler bodies.

2. Executive Summary

California Assembly Bill (AB) 1928 (AB 1928, 2016) updated prior legislation and requires that the California Energy Commission establish performance standards and labeling requirements for landscape irrigation emission devices and other landscape irrigation products by January 1, 2019. Spray sprinkler bodies are one major category of landscape irrigation emission device commonly used to irrigate residential and nonresidential landscape turf areas as well as other plant types.

Standards are especially important because landscape irrigation uses over one trillion gallons of water per year, which is approximately half of total urban water usage in California (PPIC 2016). In addition, the extraction and conveyance, treatment, and distribution of landscape irrigation water requires about two terawatt hours of embedded electricity per year.

This CASE Report proposes that the Energy Commission adopt Title 20 standards for landscape irrigation spray sprinkler bodies with pop-up stems (often called pop-ups) and shrub sprinkler adapters. The proposed standards would require that all covered products contain integral pressure regulation and meet minimum burst pressure requirements. The proposed standards would also require integral check valves to avoid drainage from low elevation sprinklers when irrigation systems are not in operation, except for shrub adapters. Impact sprinklers, gear-drive rotating sprinklers and valve-in-head sprinklers would not be covered.

The proposed standards are highly cost-effective and would provide consumers with a rapid payback. However, despite the short payback period for more efficient products, establishing Title 20 standards is critical to overcome a number of barriers including historical stocking choices, lack of standards, lack of consumer education, and split incentives between landscape installers and property owners or tenants.

The Statewide CASE Team estimates that the proposed standards will result in the following benefits:

- Over 80 billion gallons of water and about 290 gigawatt hours (GWh) of annual embedded energy savings once stock turns over and the standards are fully phased in (2028).
- Net present value of $440 million for first year shipments (2019) and $5.6 billion cumulative net present value for shipments through stock turnover (2028).
- Over 100,000 tons per year of avoided greenhouse gases (GHG) emissions once stock turns over and the standards are fully phased in (2028) and additional environmental benefits.

3. Product/Technology Description

Irrigation emission devices are used to dispense irrigation water to a landscape at specific rates, patterns, and distances. Various types of emission devices are currently available on the market, and different types are used for different landscape applications. Manufacturers classify landscape irrigation emission devices into five main categories: spray sprinklers (or sprays), rotor sprinklers (or rotors), bubblers, drip irrigation emitters, and microspray. This document focuses on specific types of spray sprinkler bodies, but information on the other related product categories can be found in Appendix E: Related Product Categories.

3.1 Spray Sprinklers

According to the ANSI ASABE/ICC 802-2014 standard, sprinklers are defined as landscape irrigation emission devices that convert irrigation water pressure to high-velocity water discharge at a minimum of 0.5 gallons per minute (gpm) (sprinklers intended for use exclusively within agricultural irrigation devices, hose-end watering products and valve-in-head devices are outside the scope of ANSI ASABE/ICC 802-2014 and of this proposed Title 20 Standard; and this proposed Title 20 Standard would also exclude impact-drive sprinklers).

A landscape irrigation spray sprinkler (also called spray head) consists of a sprinkler body, which contains all the internal parts essential to the function of the sprinkler, as well as a nozzle. The nozzle determines the radius (e.g., 8 foot, 10 foot) and pattern (e.g., full circle, half circle, quarter circle, rectangular strip) in which the water is sprayed. Nozzles are often marketed and sold separately from spray sprinkler bodies, and they are typically interchangeable between various spray sprinkler bodies. Nozzles can also be replaced without changing the spray sprinkler body. Spray sprinklers that are used with traditional nozzles (i.e., nozzles that do not rotate, but spray water in a fixed pattern) are common and typically used for relatively small landscape areas. Typically, the recommended operating pressure for these devices is 30 pounds per square inch (psi) with a water throw range of about 4 to 20 feet (Rain Bird 2001a).

Spray sprinkler bodies can also be used with newer rotating pattern spray nozzles (also known as multi-stream/multi-trajectory, rotator, or rotary nozzles), which fit onto traditional spray sprinkler bodies, but spray streams of water in a rotating pattern using the rotational energy provided by the flow of water through the device.[1] These rotary nozzles generally have a higher throw radius than fixed-pattern nozzles. Therefore, spray sprinkler bodies used in this application have a higher recommended operating pressure of 40 to 45 psi. (See Appendix E: Related Product Categories for a description of rotors, a different sprinkler product where rotational energy is commonly provided by gears in the body and long throw rates are typical; impact drive sprinklers; and valve-in-head sprinklers. These products are not included in the proposed standard.)

The most common type of landscape irrigation spray sprinklers are pop-up spray sprinklers, which pop up from the ground only when they are in use. Pop-up spray sprinklers are available in heights from 2 to 12 inches. Four- and six-inch units are common. Two- and three-inch heights are available, but not common.[2] Typically, pop-up spray bodies consist of the following components:

---

[1] The Statewide CASE Team uses the term spray sprinkler to include sprinkler bodies that accept this type of nozzle as well as nozzles with a fixed pattern. This usage is common in the industry and consistent with the draft WaterSense program (2016b). The Statewide CASE Team notes that this approach is somewhat different than ANSI ASABE/ICC 802-2014, which contain different sprinkler sub-categories for fixed and rotating nozzle; however the relevant ANSI ASABE/ICC 802-2014 testing methods for pressure regulation and burst pressure are the same for both sub-categories.

2 Two- and three-inch units may lack sufficient space for installation of integral pressure regulation. Four-inch units can substitute for these shorter units.

- Riser – extends a predetermined height aboveground for watering due to water pressure and retracts back into the spray body when watering is completed.
- Spring – retracts the riser when watering is complete.
- Wiper seal – seals the gap between the riser and the spray body to prevent leakage and keep debris out of the spray body.
- Body – outer housing in which the above components are contained.
- Cap – screws on to hold internal components inside sprinkler body. Can often be removed to allow access to interior sprinkler body components.

Some spray sprinkler bodies with pop-up stems include additional components to achieve water savings. These include:

- Pressure regulation – reduces the water pressure inside the sprinkler body to an optimal specified value, usually 30, 40, or 45 psi. Uniform flow rate is maintained at different inlet water pressures via the use of a pressure regulator integrated into the stem of the sprinkler body. Typically, these devices feature a spring-operated flow tube centered within the sprinkler stem that can move up and down between seats on either end of the flow tube. The movement of the tube relative to the inlet seat regulates how much water can flow through the stem, thus regulating water pressure at the outlet to the nozzle. The level of outlet pressure regulation is determined by the strength of the spring.[3] This feature is especially useful in landscapes where the water supply pressure exceeds the recommended sprinkler operating pressure, which is common and discussed later in Section 6.4.1.
- Check valve – eliminates drainage in irrigation systems when not in operation; otherwise, water will tend to drain from supply lines at low elevation points. Check valves can be integral to the sprinkler body or installed on-site as an add-on.
- Missing nozzle flow reduction feature – reduces or stops water flow from the sprinkler when a nozzle or riser is missing or damaged.

Without pressure regulation, the flow rate and radius of water emitted by the nozzle will typically increase as the inlet water supply pressure to the spray sprinkler increases. A small number of manufacturers market certain nozzles or nozzle screens with claims that they provide pressure compensation. A pressure compensator can reduce outlet pressure to some degree, but unlike a pressure regulator, it cannot maintain a specific outlet pressure across multiple inlet pressures.[4] Additionally, some nozzles allow for the radius of the water throw to be adjusted by turning a radius adjustment screw at the top of the nozzle. Reducing the radius in this manner will reduce the flow, which may help a knowledgeable user adjust run times based on the volume of water applied. However, this feature is unlikely to help an unskilled homeowner or yard maintenance worker, and it likely will not correct for misting and overspray when water supply inlet pressure exceeds a nozzle manufacturer's recommendations. Thus, relying on a nozzle radius adjustment screw is not preferable to integral spray sprinkler body pressure regulation.

[3] For more information, see: http://www.senninger.com/how-does-a-pressure-regulator-work/

[4] For example, regarding the 1800 PCS nozzle pressure compensating screen, Rain Bird (2017) states that: "With a pressure compensator, outlet pressure will be reduced, but will fluctuate as the inlet pressure changes. A pressure compensator cannot maintain outlet pressure at a constant rate. A pressure regulator establishes and maintains a constant outlet pressure of 30 psi (2.1 bar) as long as the inlet pressure at the spray head is greater than 30 psi (2.1 bar)."

3.1.1 Shrub Sprinklers

Shrub sprinklers are a subset of sprinklers that are permanently mounted aboveground. Shrub sprinklers are created by attaching spray sprinkler nozzles directly to a riser pipe with the use of a shrub adapter, a device designed to allow the use of spray sprinkler nozzles with a riser or pipe rather than a spray sprinkler body. Shrub sprinklers are much less common than spray sprinkler heads, because they protrude from the ground, and therefore are only suitable for areas without foot traffic to avoid equipment damage and potential tripping hazards. Most irrigation professionals recommend using shrub sprinklers only in applications where there are no other options.[5]

Typically, shrub adapters are simple devices that fit fixed or rotating spray nozzles to one-half-inch fixed threaded risers (not risers on spray sprinkler bodies). Shrub adapters with integral pressure regulation are available and provide irrigation water at a constant pressure (typically 30 psi) for a range of inlet supply pressures. Figure 1 shows examples of non-pressure-regulating and pressure-regulating shrub adapters.

Toro 570S Shrub Adapter
(for male threaded spray nozzles)

Orbit Shrub Adapter
(for female threaded spray nozzles)

Rain Bird PA-8S-PRS Pressure Regulated Shrub Adapter (30 PSI)

Hunter PROS-00-PRS40 Pressure Regulated Shrub Adapter (40 PSI)

Figure 1: Non-pressure-regulating and pressure-regulating shrub adapters[6]

[5] "For liability reasons, most irrigation professionals no longer use shrub sprinklers, except in very limited situations where nothing else will work." Irrigation Tutorials (n.d.) http://www.irrigationtutorials.com/faq/spraybackground.htm

[6] Image Sources:
Top left: The Toro Company - https://cdn2.toro.com/en/-/media/Toro-Media-Sharepoint-Libraries/_Images/ProductCatalog594X694/53299spk_53299_s_1188,-d-,jpg.ashx.
Top right: The Home Depot - http://www.homedepot.com/catalog/productImages/1000/07/070ba564-8b21-470d-a3b1-2778f46fb5e6_1000.jpg.
Bottom left: Rain Bird Corporation - http://store.rainbird.com/media/catalog/product/cache/1/image/9df78eab33525d08d6e5fb8d27136e95/p/a/pa-8s-prs.jpg.
Bottom right: Hunter Industries - https://www.hunterindustries.com/sites/default/files/styles/height_225/public/prs40_00-00.png?itok=68Oc8Qug

4. Standards Proposal Overview

The Statewide CASE Team proposes that the Energy Commission adopt Title 20 water efficiency standards for covered landscape irrigation spray sprinkler bodies as summarized below.

Table 1: Summary of Proposal

Topic	Description
Description of Standards Proposal	The Statewide CASE Team proposes to require that all covered landscape irrigation spray sprinkler bodies contain integral pressure regulation, meet minimum burst pressure requirements, and contain integral check valves (except that shrub adapters would not be required to contain check valves). The Statewide CASE Team also proposes associated testing and implementation requirements based on existing test methods and protocols with some minor adjustments.
Technical Feasibility	The standards can be met using existing products available from multiple manufacturers.
Water and Embedded Energy Savings	The Statewide CASE Team estimates that the proposed standards will save over 8.4 billion gallons of water and 30 GWh/yr of embedded electricity in the first year of implementation (2019) and 80 billion gallons of water and 290 GWh of embedded electricity annually once stock turns over and the standards are fully phased in (2028).
Environmental Impacts and Benefits	Additional benefits include over 100,000 tons of annual avoided greenhouse gas emissions after stock turnover and reduced contaminant runoff to surface waters.
Economic Analysis	The Statewide CASE Team estimates that the standards are very cost-effective, with lifecycle benefits of $440 million for products sold in the first year of standards implementation (2019) and $5.6 billion cumulatively by the time stock turns over (2028). The standards will have minimal impact on the industry and small businesses while providing major financial benefits to consumers and to the state economy overall.
Consumer Acceptance	Consumers will notice little difference other than improved performance and cost savings.
Other Regulatory Considerations	This proposal is responsive to a mandate from the California legislature to adopt Title 20 Standards for landscape irrigation products, and is consistent with related climate policy goals. The proposal for pressure regulation is generally consistent with the draft United States (U.S.) Environmental Protection Agency (EPA) WaterSense proposal. The CASE Team intends to evaluate the final WaterSense specification and supporting statement once available to determine whether any adjustments to this proposal are appropriate.

5. Proposed Standards and Recommendations

5.1 Proposal Description

The Statewide CASE Team proposes that the Energy Commission adopt Title 20 water efficiency standards for landscape irrigation spray sprinkler bodies. The proposal would apply to landscape irrigation emission devices with pop-up stems, with exemptions for specific products: hose-end watering products, gear-drive sprinklers, impact sprinklers and valve-in-head sprinklers. It would also apply to shrub adapters since cost-effective pressure regulated products are available as noted later. The scope is consistent with the draft 2016 WaterSense Specification.[7]

The proposal would require testing to demonstrate that:

1. Average flow rate across all tested pressures: The percent difference between the initial calibration flow rate at the manufacturer recommended inlet pressure and the flow rate at each tested pressure level, averaged across all pressure levels and all samples of a given model shall not exceed +/- 10.0 percent.
2. Maximum flow rate: The percent difference between the initial calibration flow rate at the manufacturer recommended inlet pressure and the highest flow rate recorded for each sample, averaged across all samples of a given model, shall not exceed +/- 15 percent.

The U.S. Environmental Protection Agency (EPA) has also released information based on testing that shows that pressure regulation technology can meet this proposed benchmark (Dukes 2017). This proposed standard would also apply to shrub sprinkler adapters.

The Statewide CASE Team proposes this benchmark so that covered landscape irrigation spray sprinkler bodies will produce the correct flow rate to the nozzle, even if the inlet supply pressure to the spray sprinkler body is greater than the spray sprinkler body operating pressure rating. Because pressure regulation is the technology used to control flow, a flow rate control-based metric will also eliminate excessive pressure to the nozzle. Over-pressurized nozzles cause excessive water application rates, increased wind drift, increased evaporation, overspray, and potentially also reduced uniformity of irrigate rates within a landscape.

The proposed standards would also require that manufacturers include check valves to prevent leakage during periods of non-operation. Leakage can occur from sprinklers installed at low elevation spots within a landscape irrigation system. Check valves would be required to hold at least seven feet (3.0 psi) of head (i.e., water column pressure), the performance standard in ANSI ASABE/ICC 802-2014 "Landscape Irrigation Sprinkler and Emitter Standard" section 302.7. The check valve requirement could be implemented at the same time as the requirement for pressure regulation, or phased in later since most savings will occur due to pressure regulation. The check valve requirement would not apply to shrub sprinkler adapters due to limited product availability, and because shrub sprinkler adapters are mounted above ground level and thus less susceptible to drainage during periods of non-operation.

In addition, the proposed standards would require compliance with the burst pressure performance requirements in ANSI ASABE/ICC 802-2014 section 302.6, which states that sprinklers shall withstand a hydrostatic test pressure of 1.5 times the maximum published operating pressure, but not less than 150 psi, when tested in accordance with ANSI ASABE/ICC 802-2014 section 303.5.1. Compliance with this ANSI

[7] While WaterSense does not explicitly exclude impact drive sprinklers, the Statewide CASE Team believes that they would be excluded in a practical sense due to the lack of products with pressure regulation.

standard is also required by the statewide Model Water Efficient Landscape Ordinance (MWELO) developed by the Department of Water Resources (DWR) for products subject to the MWELO. See Section 6.10.4 below for more information regarding the MWELO.

5.2 Proposal History

California and the federal government have not established any direct regulations for landscape irrigation spray sprinkler bodies. California Assembly Bill (AB) 1928 (AB 1928, 2016) updated prior legislation and requires that the Energy Commission establish performance standards and labeling requirements for emission devices, which include sprinklers (see ANSI ASABE/ICC 802-2014 section 202), and other landscape irrigation products by January 1, 2019. The legislation also requires that the Energy Commission consider the Irrigation Association (IA) Smart Water Application Technology (SWAT) program testing protocols, which are reflected in much of the Statewide CASE Team's proposed test methods either directly or through methods patterned on the SWAT protocols.

The proposed Title 20 Standards will complement and fill gaps in the existing California MWELO (California Title 23, Division 2, Chapter 2.7) (DWR 2015).[8] The MWELO requires that irrigation emission devices comply with ANSI ASABE/ICC 802-2014 burst pressure requirements. The MWELO section 492.7(a)(1) also requires pressure regulation but does not contain any performance standard and is not specific about where in the landscape irrigation system pressure regulation would occur. It also contains a general requirement to prevent low head drainage without a performance requirements or specific information about how to prevent low head drainage (such as by installing check valves).

Title 20 Standards for landscape irrigation spray sprinkler bodies would have a much broader reach than the MWELO because the MWELO primarily pertains to newly constructed landscapes and rehabilitated landscapes with a specified minimum size. Replacement units, which represent most product sales in California, would remain unregulated in the absence of a Title 20 standard.[9] In addition, homeowners and contractors are typically not required to obtain a permit when installing landscapes (e.g., backyards) after a new home is sold, and smaller landscapes will fall below the applicability threshold. The proposed Title 20 Standards will fill several important gaps.

5.3 Proposed Changes to the Title 20 Code Language

The proposed changes to the Title 20 Standards are provided below. Changes to the 2017 standards are marked with underlining (new language) and ~~strikethroughs~~ (deletions). The parentheses ( ) indicate that a relevant section number should be added based on where the CEC determines this content should be placed.

Section 1601. Scope.

…

( ) Landscape irrigation spray sprinkler bodies

…

Section 1602. Definitions.

8 Effective December 1, 2015. Regions that develop a joint local Water Efficient Landscape Ordinance (WELO) should have implemented their local WELO by February 1, 2016.

9 Most products are sold in the unregulated replacement market rather than installed in new landscapes, because product lifetimes are significantly less than the expected lifespan of a building (i.e., 30 years for a residential building).

…

( ) "Agriculture" means the production of crops, or the raising of fowl or animals.

( ) "Covered landscape irrigation spray sprinkler body" means a landscape irrigation spray sprinkler body that contains a pop-up stem or is a shrub sprinkler adapter. It does not include hose-end watering products, gear drive sprinklers, valve-in-head sprinklers or impact sprinklers.

( ) "Cracking pressure" means the pressure (feet of head or elevation) at which the check valve starts to leak.

( ) "Emission device" means an irrigation system component that is used to dispense irrigation water to the landscape at a specific rate.

( ) "Gear drive sprinkler" means a sprinkler containing gears as part of its rotational drive mechanism.

( ) "Hose-end watering product" means a temporarily positioned device that is used to dispense water to a landscape and is connected to a hose or pipe that is attached to a water supply system.

( ) "Impact drive sprinkler" means a sprinkler which rotates using a weighted or spring-loaded arm which is propelled by the water stream and hits the sprinkler body, causing movement.

( ) "Integral check valve" means a self-acting component integral to an emission device and designed to prevent water flow through an emission device up to a specified pressure when the emission device or group of sprinklers and emitters are not pressurized, usually expressed as 'feet of elevation' or 'feet of head.'

( ) "Landscape irrigation spray sprinkler body" means a sprinkler body that is not for use exclusively within agricultural irrigation systems.

( ) "Pop-up stem" means a sprinkler component that elevates one or more nozzles a distance above grade when subjected to water pressure and retracts when water pressure is reduced.

( ) "Set pressure" means the inlet pressure (feet of head or elevation) that causes the sprinkler to completely pop up.

( ) "Sprinkler" means an emission device consisting of a sprinkler body with one or more orifices to convert irrigation water pressure to high velocity water discharge through the air, discharging a minimum of 0.5 gallon per minute (1.9 liters per minute) at the largest area of coverage available for the nozzle series when operated at 30 psi (206.8 kPa) or more with a full-circle pattern.

( ) "Sprinkler body" means the exterior case or shell of a sprinkler incorporating a means of connection to the piping system, designed to convey water to a nozzle or orifice.

( ) "Shrub sprinkler adapter" means a sprinkler body that connects spray sprinkler nozzles to a riser or pipe and does not contain a pop-up stem.

( ) "Valve" means a device used to control the flow of water within an irrigation system.

( ) "Valve-in-head sprinkler" means a sprinkler with an integral control valve intended to be operated from a remote location.

Section 1604. Test Methods for Specific Appliances.

…

( )

1) Covered landscape irrigation spray sprinkler bodies shall be tested in accordance with ANSI ASABE/ICC 802-2014 section 303.5.2 for pressure regulation with the following modifications:

   a. Five samples shall be selected at random from three different lots of 25 with different date codes, resulting in a total of 15 samples to be tested.

   b. All units shall be conditioned by running water through the sprinklers, including an appropriate nozzle and screen. Prior to testing, units shall be conditioned at two different operating pressures (10 psi and 20 psi) above the manufacturer stated regulation pressure for two minutes for each pressure setting.

   c. In addition to the 1.5 gpm flow rate specified in ANSI ASABE/ICC 802-2014, each spray sprinkler body shall be tested with a test nozzle that has a measured flow rate of 0.75 +/- 0.1 gallons per minute (gpm) at the manufacturer rated pressure.

   d. Each test inlet pressure shall be maintained for a minimum of three minutes with inlet and outlet pressure and flow rate data logged at 30-second intervals.

   e. An inlet pressure of zero (0) psi shall be achieved for at least one minute between each non-zero test pressure. The time at which 0 psi is first obtained and the inlet pressure is increased above 0 shall be recorded in the test report.

   f. Outlet flow rate shall be recorded for each test pressure. Where flow metering devices are used, the flow shall be conditioned in accordance with manufacturer instructions and shall be installed in accordance with ASME PTC 19.5.

   g. A test report shall be prepared containing the information listed in the IA Smart Water Application Technology Pressure Regulating Spray Head Sprinklers Equipment Functionality Test Version 3.0, Table A-1 and A-2, as well as additional columns to record flow rate at each test point.

   h. A summary report shall be prepared. The report shall also be provided upon request. The report shall contain the information listed in the IA SWAT Pressure Regulating Spray Head Sprinklers Test, Appendix 6 "Example Summary Report." The report will list all features included in the model tested including check valves and missing nozzle water reduction features, if included. The report shall be repeated for both pressure (psi) and flow (gpm).

   i. [placeholder for flow control device pending final WaterSense test method]

   j. [placeholder: measurement accuracy and calibration]

2) Covered landscape irrigation spray sprinkler bodies shall be tested in accordance with the IA Smart Water Application Technology Pressure Regulating Spray Head Sprinklers Equipment Functionality Test Version 3.0 section 6.4.3 Stability Test. Any pressure taps utilized shall

comply with ASME PTC 19.2. Flow metering shall be conditioned in accordance with manufacturer instructions and shall be installed in accordance with ASME PTC 19.5.

a. [placeholder: measurement accuracy]

3) Covered landscape irrigation spray sprinkler bodies shall be tested in accordance with ANSI ASABE/ICC 802-2014 section 303.5.5 burst pressure requirements.

4) Covered landscape irrigation spray sprinkler bodies except shrub adaptors shall be tested in accordance with the SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol with the following revisions: the endurance test under section 5.4 shall be performed with 1,000 instead of 2,500 cycles; and Annex D and Annex E are not required. Cracking pressures under Annex A shall be determined based on the highest pressure at which no drainage occurs. In addition, compliance with the section 5.3.2 specification that check valves shall have a cracking pressure within +/- 10.0 percent of the manufacturer specified value is optional (compliance with the testing procedure and the performance standard in section CCR section 1605.3 is mandatory).

Section 1605.3. State Standards for Non-Federally-Regulated Appliances.

…

( ) Landscape Irrigation Spray Sprinkler Bodies and Shrub Adapters.

1) Covered landscape irrigation spray sprinkler bodies must meet the requirements specified below. Pressure regulation:

   a. Maximum flow rate—The percent difference between the initial calibration flow rate and the maximum flow rate at any inlet pressure, as measured by the test method described in Section 1604.( ) 1 for each sample, shall be within +/- 15.0 percent based on the maximum of each sample averaged across all samples.

   b. Average flow rate—The percent difference between the initial calibration flow rate and the average flow rate of all pressure levels, averaged across all samples, shall be within +/- 10.0 percent.

2) Covered landscape irrigation spray sprinkler bodies shall comply with ANSI ASABE/ICC 802-2014 section 303.3.2.2 burst pressure requirements as determined by the test method described in Section 1604.( ) 3.

3) Covered landscape irrigation spray sprinkler bodies except shrub adapters shall contain integral check valves with a cracking pressure of at least seven feet of water column (3.0 psi) as measured by the test method described in Section 1604.( ) 4 .

Section 1606

…

	Appliance	Required Information	Permissible Answers
( )	Covered Landscape Irrigation	Height (inches)	
		Features in model as tested	Integral pressure regulation,

	Spray Sprinkler Bodies		check valve, missing nozzle water reduction
		Rated minimum inlet pressure (psi)	
		Rated maximum inlet pressure (psi)	
		Rated outlet pressure (psi)	
		The percent difference between the initial calibration flow rate at the manufacturer recommended inlet pressure and the flow rate at each tested pressure level as measured by the test method in Section 1604 ( )(1), averaged across all pressure levels and all tested samples (percent).	
		The percent difference between the initial calibration flow rate at the manufacturer recommended inlet pressure and the highest flow rate recorded for each sample, as measured by the test method in Section 1604 ( )(1), averaged across all samples (percent).	
		The percent difference between the initial calibration pressure at the manufacturer recommended inlet pressure and the pressure at each tested pressure level as measured by the test method in Section 1604 ( )(1), averaged across all pressure levels and all tested samples (percent)	
		The percent difference between the initial calibration pressure at the manufacturer recommended inlet pressure and the highest pressure recorded for each sample, as measured by the test method in Section 1604 ( )(1), averaged across all samples (percent)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test mean of deviations at each test point (psi)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test standard deviation (psi)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test coefficient of variation (psi)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test mean of deviations (gpm)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test standard deviation (gpm)	
		SWAT Pressure Regulating Spray Head Sprinklers Test Equipment Functionality Test Version 3.0, Stability Test coefficient of variability (gpm)	

		Permanent distortion or leakage exceeding 10 ml/min during burst pressure test.	Yes, no
	Covered Landscape Irrigation Spray Sprinkler Bodies except shrub adapters	Check Valve "up" cracking pressure at 0 degrees (psi)	
		Check Valve "down" cracking pressure at 0 degrees (psi)	
		Set pressure at 0 degrees (psi)	
		Check Valve "up" cracking pressure at 15 degrees (psi)	
		Check Valve "up" cracking pressure at 30 degrees (psi)	
		Check Valve "up" cracking pressure at 45 degrees (psi)	
		SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol Version 2.3 "up" cracking pressure at 45 degrees after completing the "endurance" test (psi)	
		SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol Version 2.3 "down" cracking pressure at 45 degrees after completing the "endurance" test (psi)	
		SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol Annex B weeping at bleed hole at any time during test	Yes, No

Section 1607

…

d) …. ( ) Covered landscape irrigation sprinkler bodies manufactured on or after December 1, 2018 must be marked on the body to indicate the presence of integral pressure regulation meeting the requirements of section 1605.3 and an integral check valve meeting the requirements of section 1605.3 except that shrub adapters are exempt from the check valve labelling requirement.

5.3.1 Proposed Definitions

The Statewide CASE Team proposes to adopt the following definitions from ANSI ASABE/ICC 802-2014:

- Emission device;
- Hose-end watering product;
- Integral check valve;
- Pop-up stem;
- Sprinkler;
- Sprinkler body;
- Valve; and
- Valve-in-head sprinkler.

The Statewide CASE Team proposes to adopt the following definitions from the IA SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol Version 2.3 (June 2014): "cracking pressure" and "set pressure."

The Statewide CASE Team proposes to create a definition for "landscape irrigation sprinkler" based on the applicability section of ANSI ASABE/ICC 802-2014 (section 103), which excludes products for use exclusively within agricultural irrigation systems from the scope of the landscape irrigation standard. The Statewide CASE Team proposes to define "agriculture" based on language contained in Health and Safety Codes section 39011.5(a).[10]

The CASE Team proposes a new definition of "covered landscape irrigation spray sprinkler body" to define the scope of products subject to the proposed standard. The definition would include products with pop-up stems. Hose-end watering products, gear-drive sprinklers, valve-in-head sprinklers, and impact drive sprinklers are explicitly excluded from the proposed definition. Shrub adapters would be included.

The Statewide CASE Team proposes to adopt the following definitions from the IA glossary: Gear-drive sprinkler, impact drive sprinkler.[11]

5.3.2 Current and Proposed Test Procedure

This section summarizes ANSI ASABE/ICC 802-2014, the IA SWAT protocol, and the draft 2016 WaterSense test methods as related to potential spray sprinkler body standards.

5.3.2.1 Pressure Regulation

<u>Current Test Methods</u>

ANSI ASABE/ICC 802-2014 section 303.5 contains a test procedure for spray sprinkler body pressure regulation. The procedure requires the following:

- Spray sprinkler body outlet pressure is tested as inlet pressure is increased in increments of five psi up to 20 psi above the manufacturer-stated regulation pressure, and is then tested in 10 psi increments to the manufacturer stated maximum operating pressure.
- Descending pressure changes are tested starting at the highest value and then decreasing through the same increments as the first part of the test.
- The test is conducted with a 1.5 gpm nozzle.
- A minimum of five spray bodies must be selected from a batch of 25 units.
- The water supply temperature is limited to 78 °F (22.5 °C).
- Test duration must be a minimum of three minutes.
- The method does not require a reset to zero psi between test points.
- The method does not contain a specific method to control flow.

ANSI ASABE/ICC 802-2014 also requires recording inlet and outlet pressure, though it does not require summarization of test results and does not contain a performance benchmark.

The SWAT Turf and Landscape Irrigation Equipment Pressure Regulating Spray Head Sprinklers Equipment Functionality Test Version 3.0 (IA 2012) contains a series of procedures related to landscape irrigation spray sprinkler body testing. For example, the "Continuous Test" requires testing of pressure regulation over a continuous range of increasing and then decreasing pressures, similar to ANSI ASABE/ICC 802-2014 section 303.5. Additionally, the SWAT protocol requires a "Low Flow" test with 12-foot-radius half-circle (12h) spray nozzles (e.g., this would result in a water application rate of 1.3 gpm

[10] The Statewide CASE Team notes that the Health and Safety Code Section 39011.5 definition addresses both the types of activities that constitute agriculture and other provisions related to air pollution regulation that are not related to this CASE Report.
[11] http://www.irrigation.org/IA/Resources/Tools-Calculators/Irrigation-Glossary/S-U/IA/Resources/S-U.aspx

for conventional Hunter 12h nozzles and 0.5 gpm for the Hunter MP Rotator nozzle set for 12h coverage), and a "High Flow" test with 15-foot-radius full-circle (15f) spray nozzles (e.g., this would result in a water application rate of 3.76 gpm for Hunter 15f nozzles).

The SWAT protocol also contains a "Step Test" for pressure regulation. The protocol requires depressurizing the testing apparatus before each test run. The operator then increases pressure and stabilizes at the appropriate inlet pressure. The operator records the inlet and outlet pressures and summary values and calculates mean, standard deviation, and coefficient of variation values. The test is conducted with 12h spray nozzles. The Step Test method may more closely represent real-world behavior for landscape irrigation systems than ANSI ASABE/ICC 802-2014 section 303.5 or the Continuous Test, assuming that spray sprinkler bodies are not subject to pressure swings.

The SWAT also includes a "Stability Test" to evaluate flow of spray heads at 20 psi above the manufacturer-advertised regulated pressure rating over a period of 30 minutes. The test is conducted with 12h nozzles.

The U.S. EPA WaterSense program has released a draft a test method (U.S. EPA 2016a) based on ANSI ASABE/ICC 802-2014 and the SWAT Step Test (U.S. EPA 2015) with specific modifications such as the use of a needle valve to control flow. WaterSense is expected to release a final test method soon.

Proposed Test Methods

The Statewide CASE Team proposes testing requirements that are similar to ANSI ASABE/ICC 802-2014, with several modifications to the pressure regulation test based on the SWAT Step Test:

- Five samples will be selected at random from three different lots (with different date codes) of 25, for a total of 15 samples to be tested. In addition, prior to testing, all units shall be conditioned by running water through the sprinklers, including an appropriate nozzle and screen, at two different operating pressures of 10 psi and 20 psi above rated regulation pressure for two minutes for each pressure setting. These revisions are based on recommendations from the IA in response to the WaterSense proposed test method (U.S. EPA 2017a).
- Testing would be required at two different flow rates consistent with the SWAT Step Test procedure: 1.5 gpm (in accordance with ANSI ASABE/ICC 802-2014) and 0.75 gpm, which may be more representative of some multistream, multitrajectory nozzles as well as traditional nozzles covering a relatively small irrigated area, such as a 10-foot-radius quarter circle or 8-foot-radius half circle. Note that stakeholders recommended that U.S. EPA include two flow rates when developing the WaterSense test method. U.S. EPA originally noted its intent to adopt this recommendation (U.S. EPA 2015), although it is now reconsidering whether to use one or two test flow rates (U.S. EPA 2016b).
- The test would include a requirement for the calculation of summary data regarding deviations in outlet pressure and flow from the flow rate and pressure at the calibration pressure representing the manufacturer's recommended inlet pressure.
- The test would retain the ANSI ASABE/ICC 802-2014 pressure levels at which testing must occur and add a required minimum time for operation at each inlet test pressure. Testing for U.S. EPA shows that product performance is nonlinear and the highest flow rate can occur at any point between the low end and the high end of the product operating range. U.S. EPA is currently considering the pressures at which testing will occur and the CASE Team will consider the final WaterSense test method and supporting statement once available.
- The test would require that the test facility reset the inlet test pressure to zero for at least two minutes between each test pressure. This step is not required by ANSI ASABE/ICC 802-2014.

However, U.S. EPA has found that omitting the "reset" step can distort the test results (U.S. EPA 2016b).

- The overall testing burden is expected to be low due to the limited number of spray sprinkler body products on the market and the short duration of the test procedures proposed by the Statewide CASE Team.
- The draft WaterSense test method would use a needle valve (with the spray sprinkler body in a horizontal position) to control flow rates through the spray sprinkler body instead of a nozzle as specified by IA SWAT. The Statewide CASE Team will review the final WaterSense test method and the WaterSense response to comments regarding the use of a needle valve once it is available. The CASE Team may provide an update to this report regarding the flow control method and other aspects of testing and reporting based on the final WaterSense test method, standard and supporting information.

The proposed test methods would require that pressure taps comply with ASME PTC 19.2 and that any required flow metering devices comply with ASME PTC 19.5. These methods are referenced in ANSI ASABE/ICC 802-2014 section 303.5.3, but not in the IA Pressure Regulating Spray Head Sprinkler Test.

The Statewide CASE Team also notes the importance of measurement accuracy, especially for flow rate, given that pressure-regulated products generally achieve flow rates within five percent to ten percent of nominal flow rate ratings (U.S. EPA 2016b). Flow appears to be inherently more difficult to measure with accuracy than pressure. However, the procedures used by the University of Florida in its testing to support the development of the draft WaterSense specification for spray sprinkler bodies are stricter than the measurement accuracy procedures proposed in the WaterSense test method. The University of Florida procedures are designed to achieve flow rate measurement within two percent of actual value and pressure measurement within one percent or better of the actual value at 30 psi and 1.5 gpm (Dukes 2017).[12] This level of measurement accuracy is highly desirable, especially for measuring relatively small differences in flow rate, and is described below:

> "A Campbell Scientific (Logan, UT) CR1000 datalogger was used to record measurements from the flowmeter and the pressure transducers. The flowmeter was a Seametrics (Kent, WA) PE202-075 low flow magmeter…with resolution of at least 0.01 gpm and accuracy of +/- 1% plus 0.005 gpm of reading across rated range. The pressure transducers were Campbell Scientific model CS451…with a resolution of 0.0035% full scale and accuracy of +/- 0.1% full scale range."

The Statewide CASE Team is also researching instrument calibration standards and intervals, e.g., relevant general laboratory certification.

The Statewide CASE Team also proposes that the standards require manufacturers to test and list data using the IA Stability Test and provide this information to the Energy Commission. The duration of the proposed Title 20 test method may be very short compared to longer run times in the field. A test and list requirement would enable the Energy Commission to determine whether future revisions to the regulatory compliance test method and/or standard are needed to accurately reflect performance in the field. The Statewide CASE Team does not believe that the test and list requirement would impose a significant burden on manufacturers.

12 Resolution of at least 0.01 gpm and accuracy of +/- 1% percent plus 0.005 gpm would lead to testing results within 2% percent of true flow rate value at 1.5 gpm (0.3% percent plus 1% percent plus 0.7%). percent). Pressure measurement with an accuracy of +/- 0.1% percent of full scale value and resolution of 0.0035% percent full scale would lead to test results within 0.6% percent of true pressure value at 30 psi.

5.3.2.2 Check Valves

Current Test Methods

The SWAT Pop-up Sprinkler Head Check Valves Equipment Functionality Test Protocol Version 2.3 (June 2014) contains several relevant test methods for check valves. Section 5.3.1 requires a test to verify that no visible weeping or formation of drops occurs over a one-hour period at 75 percent of a manufacturer declared cracking pressure (i.e., the point at which the check valve begins to allow the flow of water to the spray sprinkler nozzle). Section 5.3.2 requires testing to determine whether check valves have a cracking pressure within 10 percent of the manufacturer specified value (both "up" cracking pressure as water pressure is raised and "down" cracking pressure as water pressure is lowered). The protocol also tests for leakage with the spray sprinkler body oriented at 0, 15, 30, and 45 degrees from vertical. Section 5.3.3 requires long-term set tightness by testing over a 24-hour period. Section 5.4 specifies an endurance test of 2,500 cycles. The protocol requires that check valves undergo the endurance test, and then subsequent testing under sections 5.3.1, 5.3.2, and 5.3.3. The protocol also includes methods for determining pressure loss (section 5.2) and resistance to damage (section 5.1.1).

ANSI ASABE/ICC 802-2014 section 303.5.1 addresses check valve testing with a one-paragraph overview of testing for determining check valve cracking pressure and requires setting the pressure above the manufacturer's rating and observing the pressure at which no drainage occurs for a 60-minute period.

Proposed Test Methods

The Statewide CASE Team proposes a testing requirement similar to the IA SWAT protocol sections 5.3 and 5.4 for determining cracking pressures under several scenarios, except with 1,000 cycles instead of 2,500. A product operated three times per week for 40 weeks over nine years will cycle 1,080 times, so 1,000 cycles should provide a reasonable indication of the check valve durability over the product lifetime. Note that Annex A does not specify a minimum hold time before determining the pressure at which no drainage through the spray sprinkler body occurs. As such, the Statewide CASE Team proposes a mandatory 60-minute hold time based on ANSI ASABE/ICC 802-2014 section 303.5.1.

The Statewide CASE Team did not propose ANSI ASABE/ICC 802-2014 section 303.5.1 as a stand-alone test method because it appears to provide an overall description of the method rather than detailed implementation procedures.

5.3.2.3 Burst Pressure

ANSI ASABE/ICC 802-2014 section 305.5 contains a burst pressure test method for sprinkler bodies. Section 305.5.5 requires that each test sample shall withstand a hydrostatic pressure of 1.5 times the maximum published operating pressure, but not less than 150 psi for one minute without permanent distortion or leakage exceeding 10 milliliters per minute. The Statewide CASE Team proposes requiring testing in accordance with ANSI ASABE/ICC 802-2014 section 305.5 burst pressure requirements.

5.3.3 Proposed Standard Metrics and Benchmarks

The Statewide CASE Team proposes to use flow rate as a compliance metric to harmonize with the U.S. EPA WaterSense draft specification. This metric has the advantage of corresponding well with the objective of reducing water usage since flow is closely related to water savings, as described later. Pressure is an alternative metric which is easier to measure, though either metric can be measured with a high level of confidence with sufficiently rigorous procedures, as described earlier.

The Statewide CASE Team proposes to harmonize with the WaterSense draft performance standard levels for maximum (+/- 15 percent) and average (+/- 10 percent) flow rate deviations from the nominal flow rate (as measured at the regulation pressure stated by the manufacturer, typically 30 psi), averaged across all samples. In Figure 2 the U.S. EPA (U.S. EPA 2016b) shows that most products tested on behalf of the WaterSense program can achieve both standards. The Statewide CASE Team proposes to count the maximum flow rate at any pressure, and not just 70 psi as specified in the WaterSense draft proposal, because the maximum flow rate frequently occurs at pressures other than 70 psi, as shown by the University of Florida product testing data (see Appendix D: Data Tables). This revision is consistent with a comment from NRDC on the draft WaterSense specification (U.S. EPA 2017a), and we expect that WaterSense will provide a response to this comment when issuing a final specification.

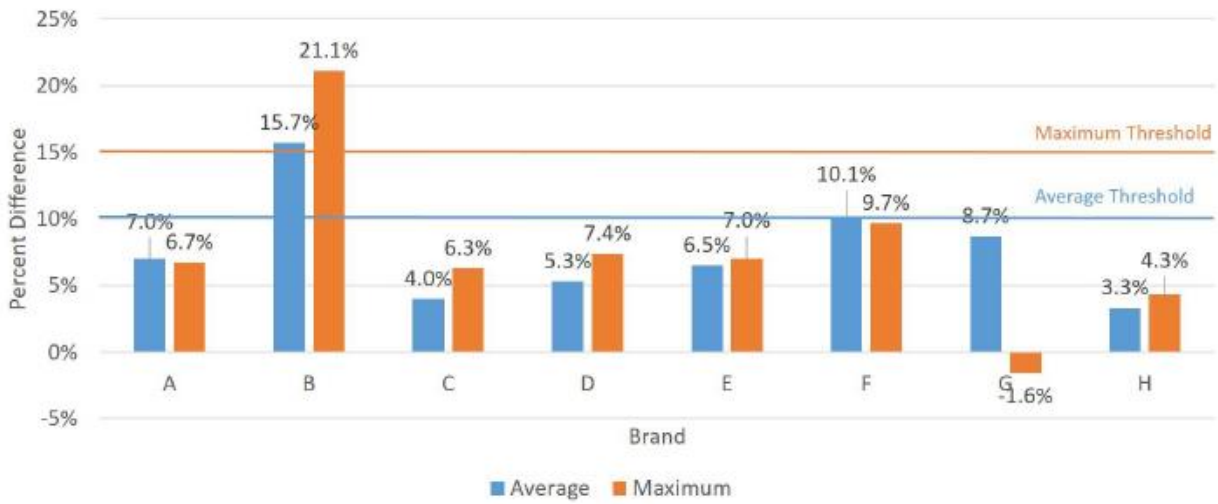

Figure 2: Percent difference between flow rate at tested pressure level(s) and flow rate at the nominal rated pressure (i.e., 30 psi)

Source: U.S. EPA 2016b.

5.3.4 Proposed Reporting Requirements

Manufacturers are not currently required to report any data to the Energy Commission. The Statewide CASE Team proposes requiring reporting of basic product information and test data. This test data will verify compliance with the proposed standards and will also provide information that could be used to consider future durability requirements for pressure regulation.

ANSI ASABE/ICC 802-2014 section 304.2 addresses basic product information and some more limited information regarding product performance (especially since it does not directly address the proposed Title 20 Standard test methods and performance benchmarks). It requires that the following information shall be made publicly available to the end user either in the product literature, on the product website, on the product packaging, or on the product itself:

- Manufacturer name;
- Presence of integral flow shut-off (missing nozzle) capability;
- Design pop-up height in inches and points of measurement used to establish the height;

- Flow rate at the minimum, recommended, and maximum operating pressure in units of gallons per minute. Where the flow rate varies depending on the nozzle or outlet selected, a range or table of flow rates shall be provided as an alternative;
- Pressure at which a check valve cracks (i.e., no longer holds back water) as determined in units of feet of water column;
- Regulation pressure.

5.3.5 Proposed Marking and Labeling Requirements

The Statewide CASE Team proposes a labeling requirement based in part on ANSI ASABE/ICC 802-2014 section 304. ANSI ASABE/ICC 802-2014 contains marking and labeling requirements for spray sprinklers, which are listed below:

The following features shall be marked on the device in a location visible after installation:

- Check valve feature for sprinklers that include an integral check valve (section 304.1.7);
- Pressure control or pressure compensation feature for sprinkler bodies and bubblers that include these features (section 304.1.8).

The Statewide CASE Team proposes the adoption of the marking and labeling requirements listed above. Qualifying products must include integral pressure regulation, and must also include integral check valves (except shrub adapters), and these features must be clearly marked on the device in a location visible after installation under ANSI ASABE/ICC 802-2014 (i.e., on the cap). Because the caps of compliant and non-compliant products are typically interchangeable, the same information should also be marked on the sprinkler body housing (these additional markings on the sprinkler body need not be visible after installation since products will be buried in the ground and the T20 compliance verification would typically occur before a product is installed).

Additionally, the Statewide CASE Team recommends that the Energy Commission consider a distinctive marking for units that comply with a Title 20 Standard, since units could be labeled as pressure regulating under ANSI ASABE/ICC 802-2014 without meeting the Title 20 Standard and/or labeled as containing a check valve without testing required under the proposed Title 20 Standard.

The Statewide CASE Team also notes the importance of marking the date of manufacture to facilitate compliance. Many manufacturers do so currently (to validate warranty claims), but some do not. All products within the scope of 20 CCR § section 1601 must comply with section 1607 including 1607(b) requirements:

> "Except as provided in Section 1607(c), the following information shall be permanently, legibly, and conspicuously displayed on an accessible place on each unit;
> (1) manufacturer's name or brand name or trademark (which shall be either the name, brand, or trademark of the listed manufacturer specified pursuant to Section 1606(a)(2)(A) or, if applicable, the designated manufacturer specified pursuant to Section 1606(f)(1)(F));
> (2) model number; and
> (3) date of manufacture, indicating (i) year and (ii) month or smaller (e.g. week) increment. If the date is in a code that is not readily understandable to the layperson, the manufacturer shall immediately, on request, provide the code to the Energy Commission."

6. Analysis of Proposal

6.1 Scope/Framework

This proposal includes landscape irrigation spray sprinkler bodies and shrub adapters, as defined in Section 5.3. Spray sprinkler bodies include pop-up spray sprinklers, gravity spray sprinklers (which are often made of brass), and flush spray sprinklers, which emit irrigation water flush to the ground. Gear-drive sprinklers, hose-end watering products, impact drive sprinklers, and valve-in-head sprinklers would be exempt as noted earlier and are note addressed in this section.

Spray sprinkler bodies with integral pressure regulation and/or check valves are readily available, and pressure-regulated shrub adapters are also available. Flush and gravity spray sprinklers are legacy products and not commonly used in newer landscapes.

This product category does not include nozzles. The Statewide CASE Team recognizes that some utilities offer rebates based on the expectation that certain nozzles contribute to water savings. Development of a generally accepted metric and test method for spray nozzle operational efficiency, as noted in Appendix E: Related Product Categories, will help inform any future consideration of standards for nozzles.

The Statewide CASE Team also notes that other landscape irrigation emission devices (e.g., bubblers, drip, micro-spray and/or rotor sprinklers) fall outside of the scope of this proposal because they are different product categories. However, these product categories could be considered as candidates for future standards.

6.2 Product Efficiency Opportunities

According to the MWELO, irrigation efficiency is defined as the amount of water beneficially used by plants divided by the amount of water that is applied (DWR 2015). Several landscape irrigation spray sprinkler body features that increase water efficiency are described in Section 3 above and summarized below:

- Pressure regulation, which reduces water pressure inside a spray sprinkler body to an optimal level;
- Check valves, which eliminate drainage at low elevation points in irrigation systems;
- Minimum burst pressure; and
- Missing nozzle flow reduction feature, which reduces or stops water flow from the sprinkler when a nozzle or riser is missing or damaged.

Good design, installation, operation, and maintenance practices can also provide additional water savings.

6.3 Technical Feasibility

The Statewide CASE Team found that many manufacturers offer landscapes irrigation spray sprinkler bodies with pressure regulation and check valves, as noted in Section 6.6. Manufacturers offering spray sprinkler bodies with internal pressure regulation, check valves, or both include the following: Hunter, Hydro-Rain, Irritrol, K-Rain, Orbit, Rain Bird, Signature, Toro, and Weathermatic. Testing performed for the U.S. EPA WaterSense program also demonstrates that numerous products with effective pressure regulation are available on the market, as described in Section 5.3.3.

While these qualifying products are a small share of the market today, as discussed later, the Statewide CASE Team interviews with several major manufacturers indicate that they could rapidly scale up

production to serve the California market if the Energy Commission were to adopt a Title 20 standard for this product

6.4 Per Unit and Statewide Water Savings Estimates

6.4.1 Per Unit Baseline Water Use

This section describes the Statewide CASE Team methodology for estimating baseline per unit water use. Annual water savings are based on average effective irrigation area per unit multiplied by irrigation rate. Both are described below followed by the results of the calculation for per unit baseline water use during operation (3,300 gallons per year). This section also summarizes the methodology used to determine baseline water use when not in operation (40 gallons per year).

6.4.1.1 Baseline Water Use during Operation

Effective Per Unit Irrigated Area

Equation 1 shows the calculation for sprinkler per unit irrigation area and Table 2 shows key assumptions and values. Because nozzles determine the coverage area and spray pattern for a landscape irrigation spray sprinkler body/nozzle combination in the field (see Section 3), the per unit sprinkler-irrigated area was determined based on estimates of spray sprinkler body nozzle weighted average arc type (e.g., full-circle, half-circle, quarter-circle) and radius. The layout of spray sprinkler bodies in a landscape will also affect the per unit water usage estimate since overlap will reduce the quantity of water supplied by each device.

The Statewide CASE Team assumed that each square foot of irrigated area would be covered by two sprinklers with head-to-head spacing (as is industry standard practice; Rain Bird 2001a). Thus, while a sprinkler would on average cover an area of 190 square feet as shown in Table 2, the average effective irrigated area per sprinkler would be 95 feet. The Energy Commission also assumed a similar effective irrigation area of 100 square feet per nozzle, i.e., 3,600 square feet divided by 36 sprinklers (Energy Commission 2017). The draft 2016 WaterSense supporting statement assumes a slightly higher value of 115 square feet on a national basis.[13]

Equation 1. Effective Per Unit Irrigated Area

Effective Per Unit Irrigated Area (sq. ft./unit)

= [radius (ft) squared] x [pi x arc (percent of full circle)] / [sprinkler overlap factor][14]

13 WaterSense estimates that a 2,913-square-foot area would be served by 25 sprinklers (U.S. EPA 2016b), or slightly greater than 115 square feet per unit.

14 The results of this equation are 11 feet squared x 3.14 x 0.5 / 2 = 95 feet squared.

Table 2: Key Assumptions and Results for Effective Irrigated Area

Data	Value	Reference(s)
Average spray sprinkler radius (ft.)	11	Statewide CASE Team assumption based on product research and industry interviews[15]
Average sprinkler arc (percent of full circle)	50% (i.e. 180 degrees)	Statewide CASE Team assumption based on product research and industry interviews[16]
Average coverage area per sprinkler (sq. ft.)	190	Statewide CASE Team calculation[17]
Sprinkler overlap factor	2	Statewide CASE Team assumption based on industry standard practice (head-to-head spacing)
Effective irrigation area per sprinkler	95	Statewide CASE Team calculation

Annual Irrigation Rate

Next, the Statewide CASE Team calculated the annual baseline irrigation water use rate based on the turf evapotranspiration requirement (i.e., ET, the amount of water a plant consumes) minus the water provided by available precipitation; and then adjusted for the efficiency at which the irrigation device provides water to the target landscape as shown in Equation 2. In general, water needs for plants can be calculated by multiplying the reference crop evapotranspiration rate (ET_O) by the crop coefficient (K_c) for the plant in question. In this case, the ET_O of 55.8 inches was multiplied by the coefficient of 0.7 for landscape turf to yield the turf ET requirement as shown in Table 3.

An additional adjustment was made to account for the potential that property owners would choose to use deficit irrigation. Studies have shown that acceptable turf appearance can be maintained at 75 percent of theoretical turf ET needs (ASIC 2014; GCSAA 2016). The Statewide CASE Team assumed that some property owners would choose to reduce irrigation to maintain an acceptable turf appearance though most would choose to irrigate based on the full turf ET needs and optimize appearance.[18] Thus, the Statewide CASE Team assumed an average water reduction of 10 percent due to deficit irrigation. The Statewide CASE Team may provide future updates to this estimate if additional consumer behavior data becomes available.

The average annual California rainfall of 0.028 inches/day and 10 inches per year (1981-2010 average) was calculated by weighting NCDC 2015 rainfall data by housing stock as shown in Table 4. The Statewide CASE Team also adjusted the weighted rainfall total to count only available annual precipitation, as described later. The resulting value is shown in Table 3.[19]

15 The most common radii are 10 and 12 feet, with both longer and shorter distances available, but less common based on interviews with representatives.

16 The most common arcs are half circle, quarter circle, and full circle by order of market share. Market share of quarter circle is assumed to be double full circle. Several industry representatives confirmed this value. Note that a full circle is 360 degrees and a half circle is 180 degrees.

17 Area of coverage is calculated based on pi times radius squared times percent of full circle.

18 This assumption was based on a personal communication with Brent Mecham of the Irrigation Association on August 23rd, 2017.

19 The Statewide CASE Team notes that an earlier Aquacraft (2011a) study estimated total irrigation rates for homes with and without automatic irrigation systems. The Aquacraft study reported average landscape irrigation rates of 93,900 gallons per year and average irrigated areas of 3,809 square feet for single-family homes. The Statewide CASE Team calculated an average irrigation rate of 3.3 feet of irrigation water per year across all types of irrigated areas and irrigation systems as follows, but did not find data that could be used to calculate irrigation rates specifically for turf: 93,900 gal/yr / 3,809 ft^2 x 1 / 7.48 ft^3/gal = 3.3 ft/yr

Equation 2. Baseline Irrigation Need

Irrigation need (inches/year)

= [Turf Plant Factor (0.7) x Average annual ET_O x Deficit irrigation adjustment] – [Average annual rainfall x (1 - discount factor for rainfall lost to runoff or deep percolation)]

Equation 3. Irrigation Application Rate

Irrigation Application rate (inches/year)

= [Irrigation need (inches/year)] / [irrigation efficiency]

Table 3: Key Assumptions and Results for Annual Irrigation Rate

Data	Value	Reference(s)
Annual ETo (inches)	55.8	CIMIS (2015) weighted by housing stock times 365 days/year
Turf – specific ETo adjustment	0.7	Average of cool season and warm season turf crop coefficient (Mecham and Vinchesi 2015, slide 9; UC Cooperative and DWR 2000, Table 1 - pg. 11)
California annual average precipitation rate (inches)	10.1	NCDC 2015
Precipitation unusable fraction	30%	Statewide CASE Team analysis of CIMIS data
Deficit irrigation adjustment factor	90%	Statewide CASE Team estimate; ASIC 2014; GCSAA.2016
Annual irrigation need (inches/year)	28.1	CASE Team calculations
Irrigation efficiency	50%	TAMU 2012
Unit conversion	7.48	Gallons/cubic ft.
Average California turf irrigation application rate (gallons/sq. ft.)	35	CASE Team calculations

Annual rainfall is discounted to account for losses due to runoff or deep percolation. The Statewide CASE Team estimates that for a given day with precipitation, the maximum amount of precipitation available to plants would equal the daily ET requirement (in inches) plus 0.36 inches, or the water-holding capacity of three inches of soil storage with average soil type (WDNR 2004) (see Equation 4). Three inches was selected as a reasonable approximation to account for the possibility that the root zone could extend beyond this level, as well as the possibility that the soil matrix may not be entirely available to plant roots. In addition, saturation or partial saturation could occur from prior irrigation events, thereby reducing the available holding capacity of the soil for additional water storage. The Statewide CASE Team notes that while this assumption may not be exact, it does not appear likely to significantly affect baseline irrigation needs.

The Statewide CASE Team analyzed 15 years of daily rainfall data from the California Irrigation Management Information System (CIMIS) for six California regions (see Table 4) to determine how much daily rainfall exceeds turf daily ET requirement (in inches) plus 0.36 inches. The Statewide CASE Team determined that the estimated aggregated runoff and/or deep percolation would, on a statewide basis, equal 30 percent of the total precipitation based on the regional results. The statewide results were the same when regional results were weighted by either population or housing.

Equation 4. Discount Rate for Rainfall Lost to Runoff or Percolation

Discount rate for rainfall lost to runoff or percolation =
= [sum for each day within analysis period of (daily rainfall > 0.36 inches + daily ET_O {in/day}) – average daily rainfall)], which is then divided by total average annual rainfall within the analysis period

Table 4: Summary of Precipitation and Irrigation Needs (2000 to 2015)

Region	CMIS Station Name	CMIS Station ID	2017 Regional Population	2017 Regional Housing Units	Annual Average Daily precipitation (in)	Annual Average Daily ETo (in)	Calculated Excess Precipitation
San Joaquin Valley	**Fresno State**	80	3,690,491	1,196,143	0.027	0.158	24%
Sacramento Valley	**Davis**	6	2,527,969	995,443	0.042	0.156	33%
Los Angeles Basin	**U.C. Riverside**	44	22,342,253	7,708,153	0.020	0.160	31%
Monterey Bay	**Castroville**	19	722,466	260,870	0.032	0.100	26%
North Coast Valley	**Petaluma East**	144	1,347,155	533,166	0.057	0.121	35%
San Francisco Bay	**Concord**	170	6,644,086	2,446,316	0.037	0.140	28%
Statewide weighted average by housing					0.028	0.153	30%
Statewide weighted average by population					0.027	0.153	30%

Source: CIMIS 2015; DOF 2017a and 2017b; Statewide CASE Team.

Wasted landscape irrigation water, about 50 percent of flow rate for spray sprinklers (TAMU 2012), may be lost to runoff to evaporation, deep percolation, or run-off to sewers or surface water. Thus, for every gallon of water necessary to meet plant needs, two gallons must be applied on average in the base case.

Calculation of Baseline Per Unit Annual Water Use

Finally, the Statewide CASE Team calculated the baseline device annual water use as shown in Equation 5. The results of this calculation are 3,300 gallons/year.[20]

Equation 5. Baseline Per Unit Annual Water Use

Annual Water Use Per Device (gallons/unit/year)

[20] See Equation 5. The calculation is 95 ft^2 x 28 in/yr x 1/12 ft/in x 7.48 gal/ft^3 x 1/0.5 efficiency.

= [Effective irrigation area per unit (square feet)] x [Plant irrigation need (feet/year)] x [7.48 (gallons/cubic feet) / irrigation efficiency]

6.4.1.2 Baseline Water Use from Drainage When Not in Operation

Some water will be lost through drainage when the landscape irrigation system is not in operation if the system is not equipped with check valves. The portion of the landscape irrigation supply pipeline that is higher in elevation than the lowest spray sprinkler will drain completely to the elevation of the lowest spray sprinkler when the irrigation system is not in operation in the absence of check valves, which prevent this drainage. The Statewide CASE Team modeled four example spray sprinkler and supply pipeline configurations combined with increasing slopes in one percent increments up to 12 percent. For each one percent slope increment, the total expected water loss from each of the four configurations was determined and then divided by the total number of spray sprinklers for all four scenarios. Please see Appendix C: Additional Details for Check Valve Water Savings for additional assumptions and calculations and diagrams of the four scenarios.

A breakdown of the amount of landscaped area across California by 1 percent slope increments was obtained using Geographic Information System (GIS) data. To do so, United States Geological Survey (USGS) California elevation data (2015) was overlaid with data from the National Land Cover Dataset (NGCE 2011). Please see Appendix C: Additional Details for Check Valve Water Savings for additional detail on the GIS slope analysis methodology.

The Statewide CASE Team weighted the modeled per unit water loss in each 1 percent slope increment bin by the prevalence of each slope bin in California to estimate total statewide average per unit baseline water loss, as shown in Table 5. This analysis resulted in an average estimated annual drainage loss of 40 gallons per spray sprinkler body per year in the absence of a check valve.

Table 5: Results of Baseline Water Loss Evaluation

Slope	Annual per Unit Baseline Water Loss (gallons)	Share of Developed Lands with < 50% Hardscape in this Slope Bin
0%	0	17.5%
1%	0	15.5%
2%	23	9.5%
3%	41	6.3%
4%	52	4.9%
5%	58	3.9%
6%	62	3.3%
7%	65	2.9%
8%	68	2.6%
9%	69	2.3%
10%	71	2.1%
11%	72	1.9%
12%	73	1.8%

> 12%[21]	74	25.7%
Statewide	**40**	**100%**

Source: Statewide CASE Team.

6.4.2 Per Unit Water Savings Methodology during Operation

This section describes the water savings calculation methodology. The Statewide CASE Team calculated the impacts of the proposed code change on spray sprinkler body water use during operation by comparing non-qualifying products under several use cases with qualifying products. The Statewide CASE Team separately calculated the water savings due to check valves during non-operation.

6.4.2.1 Spray Sprinkler Body Inlet Pressure

This section describes the estimate of inlet water pressure (the water savings estimates described later use pressure as an input) based on the U.S. EPA national estimate of 60 psi at the spray sprinkler body inlet and California-specific data. The Statewide CASE Team calculated typical California water supply pressure at the point of irrigation system connection based on a weighted average of responses to a survey of California Landscape Contractors Association (CLCA) members in 2016 by CLCA and PG&E as shown in Table 6. (See Appendix F: CLCA-PG&E Survey Summary Memo for the survey summary memo).

Table 6: Average Static Water Supply Pressure at the Point of Irrigation System Connection

Irrigation System Connection pressure Bin	Irrigation System Mid-point value (psi)	Response Count
Less than 30 psi	25.5	0
31-40 psi	35.5	2
41-50 psi	45.5	6
51-60 psi	55.5	17
61-70 psi	65.5	15
71-80 psi	75.5	12
81-90 psi	85.5	4
91-100 psi	95.5	4
Over 100 psi	105.5	1
Weighted average	**65.7**	**61**

Source: Statewide CASE Team.

The Statewide CASE Team then estimated pressure at the spray sprinkler body inlet based from the CLCA-PG&E results using Equation 6 below. The Statewide CASE Team assumed that pressure loss within a landscape irrigation system due to friction and pressure loss at the valve can equal roughly 5 psi at the point farthest from the irrigation valve based on good design practices (Rain Bird 2011b). The Statewide CASE Team also assumed that the pressure loss at an average spray sprinkler body inlet should be half of that value. The inlet valve to an irrigation zone can lead to additional losses of, for instance, three to five psi that

21 Potential incremental losses for slopes above one percent were considered small and were not calculated. The greater than 12 percent slope category represents 13 percent slope.

affect all downstream irrigation units.[22] Thus, the U.S. EPA estimate of water pressure at the spray sprinkler body inlet will match or will be close to the CLCA-PG&E data after adjusting for pressure loss between the irrigation system connection and the spray sprinkler body (depending on the assumptions used for that adjustment). Table 7 shows that the U.S. EPA WaterSense estimate at the spray sprinkler body is well below estimates of curb pressure for California water systems (Lee 2017).[23]

Equation 6. Calculation of Spray Sprinkler Body Inlet Pressure

Spray sprinkler body average inlet pressure (psi)
= [average landscape irrigation system inlet pressure] - [average pressure loss through landscape irrigation system]

Table 7: Estimates of water supply pressure

Source	State(s)	Measurement Point	Estimate (psi)
CLCA-PG&E Survey; Statewide CASE Team	California	Irrigation System Connection	65.7
WaterSense (U.S. EPA 2016b)	Multiple	Spray sprinkler Body	60
American Water Works Association (AWWA 2016)	Multiple	Curb	76
NRDC (Lee 2017)	California	Curb	77.5

Source: Statewide CASE Team.

6.4.2.2 Sources of Excess Water Usage

Spray sprinkler body integral pressure regulation can avoid wasting water in several ways as shown in Figure 3. This section describes these mechanisms and the calculation of water savings.

[22] For instance, one example product from RainBird would have losses of 3-5 psi at 10 gpm depending on whether a vacuum breaker is included and other product details. http://www.rainbird.com/landscape/products/valves/ASVFseries.htm

23 The inlet pressure at the irrigation system valve may be slightly lower than the AWWA and NRDC estimates at the curb due to minor losses in the water meter and possibly piping between the curb and the irrigation system valve.

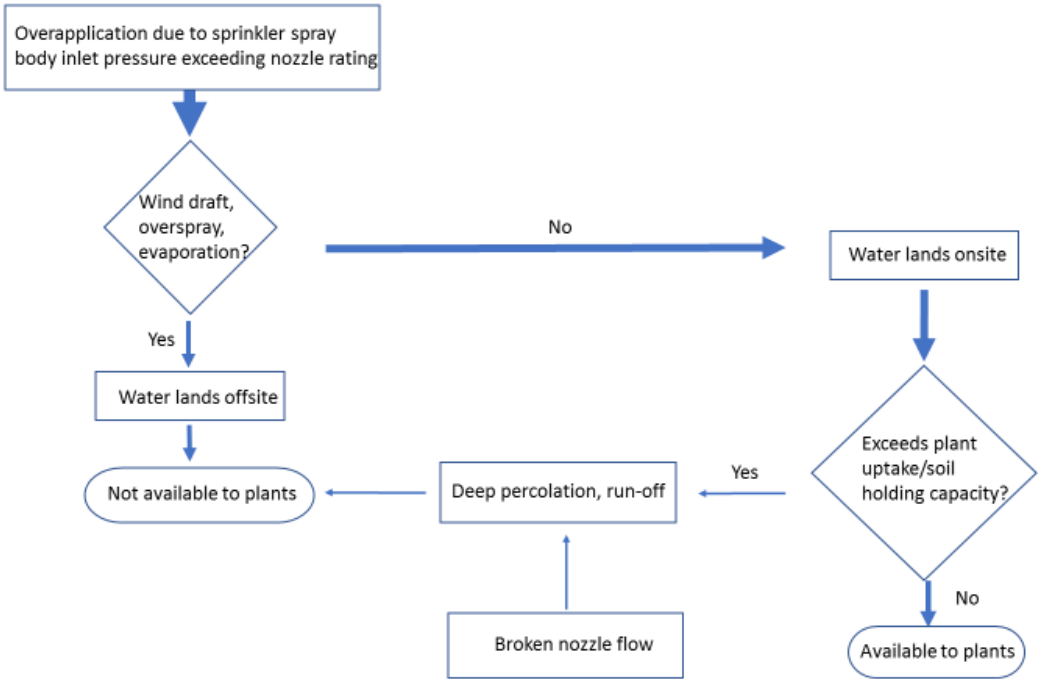

Figure 3: Results of overpressure at spray sprinkler body inlet

Source: Statewide CASE Team.

6.4.2.3 Flow Rates

Non-pressure-regulating spray sprinkler bodies have significantly higher flow rates as inlet pressures increase above manufacturer recommendations. The theoretical relationship between flow rate and pressure for an unobstructed and frictionless pipe and orifice can be described by a simplified version of Bernoulli equation shown in Equation 7 and Equation 8 below. For example, a change in pressure from 60 psi to 30 psi would reduce flow rate by 28 percent under these theoretical conditions based on Equation 8.

Equation 7: Simplified Bernoulli Equation

$$\frac{\text{Flow}_{\text{PR}}}{\text{Flow}_{\text{NR}}} = \sqrt{\frac{\text{Pressure}_{\text{PR}}}{\text{Pressure}_{\text{NR}}}}$$

Pressure = sprinkler pressure at the nozzle
NR = no pressure regulation; PR = with pressure regulation

Assumptions: no change in elevation, no obstacles and frictionless flow

Source: Statewide CASE Team.

Equation 8: Theoretical Change in Flow Rate Based on Bernoulli Equation

$$\text{Flow Rate Reduction} = \frac{\text{Flow}_{\text{NR}} - \text{Flow}_{\text{PR}}}{\text{Flow}_{\text{NR}}} = 1 - \sqrt{\frac{\text{Pressure}_{\text{PR}}}{\text{Pressure}_{\text{NR}}}}$$

Pressure = sprinkler pressure at the nozzle
NR = no pressure regulation; PR = with pressure regulation

Assumptions: no change in elevation, no obstacles and frictionless flow

Source: Statewide CASE Team.

The Statewide CASE Team also evaluated the changes in flow rates for spray sprinkler bodies with and without pressure regulation based on University of Florida testing data provided by the U.S. EPA WaterSense program. The University of Florida collected 160 datasets of sprinkler body inlet flow and inlet and outlet pressure at 1.5 gallons per minute. The University of Florida set a needle valve to allow 1.5 gallons per minute at 30 psi, the recommended inlet pressure for most fixed nozzles and increased pressure from 30 to 40, 60, and 70 psi followed by decreases to 60 and 40 psi (Dukes 2017).[24] Four products were tested with and without pressure regulation to 30 psi at the nozzle inlet, along with one additional product tested only with pressure regulation. The Statewide CASE Team aggregated all test points as shown in Table 8 and estimated a 30 percent reduction in flow rate due to pressure regulation at 60 psi inlet pressure. The original data points are shown in Appendix D: Data Tables.

Table 8: Summary of U.S. EPA Test Data at 1.5 Gallons per Minute Nominal Flow

	Pressure Regulated		Not Pressure Regulated		Difference (non-pressure regulated vs pressure regulated)	
Spray Sprinkler Body Inlet Pressure (psi)	Ratio of Measured vs. Nominal Pressure (psi)	Ratio of Measured vs. Nominal Flow Rate (gpm)	Ratio of Measured vs. Nominal Pressure (psi)	Ratio of Measured vs. Nominal Flow Rate (gpm)	Pressure	Flow Rate
30	85%	100%	100%	100%	15%	0%
40	96%	104%	133%	114%	38%	11%
60	98%	105%	200%	135%	102%	30%
70	103%	111%	233%	145%	130%	34%

Source: Statewide CASE Team.

24 U.S. EPA also provided testing data at 3.5 gpm. The 1.5 gpm flow rate was considered more representative of products in the California market than 3.5 gpm, as explained in Section 5.3.2.1.

Equation 9: Flow Rate Reduction

$$\text{Flow Rate Reduction} = \frac{\text{Flow}_{\text{NR}} - \text{Flow}_{\text{PR}}}{\text{Flow}_{\text{NR}}}$$

NR = no pressure regulation; PR = with pressure regulation

6.4.2.4 Wind Drift, Evaporation, and Overspray

Overpressure at the nozzle inlet results in smaller droplet sizes (misting) and increases susceptibility to wind drift and evaporation as shown below in Figure 4 (CUWCC 2014). The amount of wind drift and evaporation also depends on climatic conditions, time of day, and length of irrigation run-time (Zazueta 2011). In addition, overpressure results in overspray. The Statewide CASE Team estimates that spray sprinkler bodies operating at 60 psi cause five to ten percent overspray based on example product data from Toro (Toro 2016).[25]

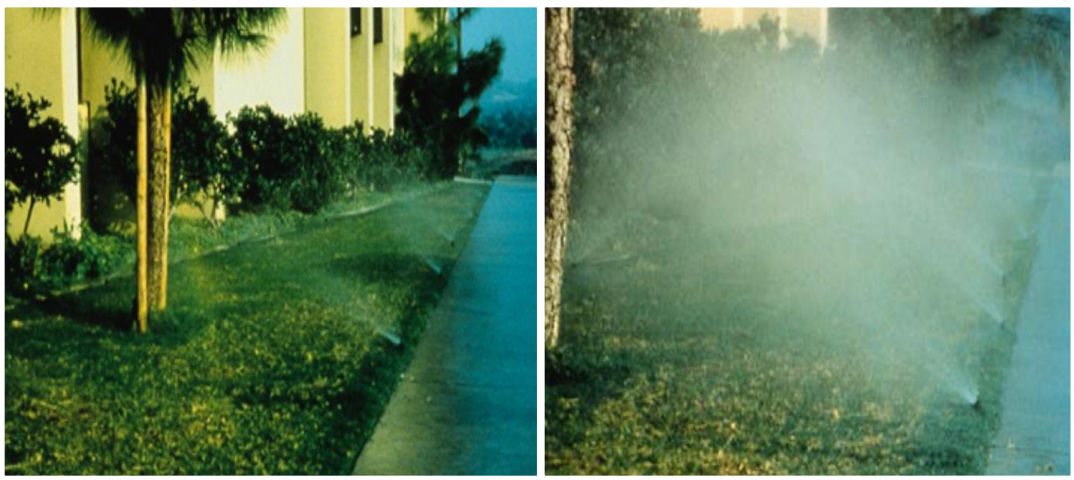

Figure 4: Effect of pressure regulation on misting

Source: Qualified Water-Efficient Landscaper Class Eleven (QWEL 2012).

The Statewide CASE Team estimated total water losses due to wind drift, evaporation, and overspray based on testing of landscape irrigation spray sprinkler bodies with and without pressure regulation conducted by the University of Arizona with funding from a grant that the Metropolitan Water District of Southern California issued to Rain Bird (Brown and Gilbert 2015). The University of Arizona used 32 catch cans to determine the fraction of irrigation water reaching a target landscape at different wind speeds for both pressure-regulated and non-pressure-regulated spray sprinklers. See example results from this research in Figure 5 showing that the fraction of water reaching the landscape is higher with pressure regulation (shown as "+pr") compared to without pressure-regulation (shown as "-pr") with an inlet supply pressure of 70 psi at the sprinkler inlet.

25 For instance, a nozzle intended to operate at 30 psi with a 10-foot radius and full-circle arc would provide 314- square-foot coverage (radius squared times 3.14). (pi)). The same nozzle would operate with a 10.4-foot radius and 339- square-foot coverage at 50 psi, or about 8 percent additional area (Toro 2012).

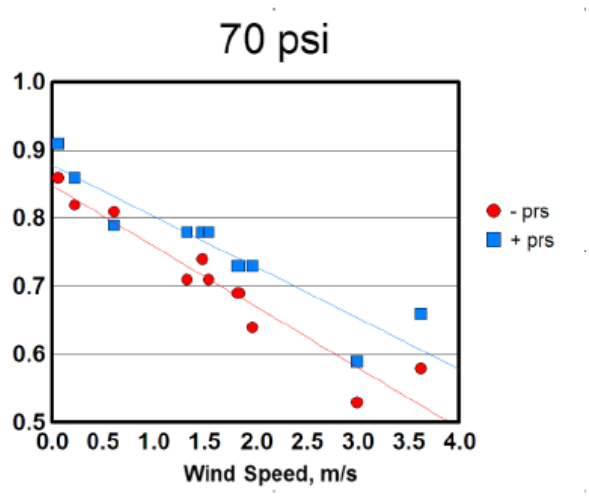

Figure 5: Effect of pressure regulation on fraction of irrigation water reaching landscaped area

Source: Brown and Gilbert 2015.
Note: "-prs" is without pressure regulation; "+prs" is with pressure regulation; inlet pressure at the sprinkler is 70 psi. Vertical axis does not have units.

The University of Arizona results show that pressure regulation at a sprinkler with a 70 psi pressure and a typical California wind speed of 3.2 m/s (WRCC 2006) would result in a 14 percent reduction in irrigation needs because less water would be lost off-target, as shown in Equation 10 (e.g., for each gallon of water applied, 0.64 gallons would reach the target with pressure regulation and 0.56 gallons would reach the landscape without pressure regulation).

Equation 10: Change in Water Reaching Irrigated Area

$$\text{Change in Water Reaching Irrigated Area} = \frac{\text{Percent}_{\text{NR}} - \text{Percent}_{\text{PR}}}{\text{Percent}_{\text{NR}}}$$

$\text{Percent}_{\text{NR}}$ = Percent of water reaching landscape with no pressure regulation
$\text{Percent}_{\text{PR}}$ = Percent of water reaching landscape with pressure regulation

The Statewide CASE Team then adjusted the calculated savings to 10.4 percent to match the expected 60 psi inlet supply pressure for a spray sprinkler body in California (based on the ratio of California overpressure, 30 psi, versus 40 psi over-pressure in the study conducted by the University of Arizona). It is noted that the Alliance for Water Efficiency estimates that as much as 15 percent of water is lost to overspray alone when nozzles are operated above their design pressure (AWE 2010).

6.4.2.5 Distribution within a Landscape

Distribution of water within a landscape also affects water usage since a user will typically increase irrigation rates if any brown spots occur. Overpressure can interfere with the ability of a nozzle to distribute water within a landscape, but the Statewide CASE Team did not find sufficient information to quantify this effect. Development of well-established irrigation distribution metric may allow quantification of the expected improved distribution from pressure regulation.

6.4.2.6 Missing Nozzle

A missing nozzle can occur when the tops of spray sprinklers are accidentally damaged (e.g., mowed off) and pressure regulation would reduce the "geyser" due to the missing nozzle by reducing the inlet pressure (AWE 2010; U.S. EPA 2016b). (A specialized missing nozzle flow reduction feature will likely reduce these losses even further.) The Statewide CASE Team did not calculate the potential savings due to a lack of readily available data on the prevalence of missing nozzles and expected water savings, though the CLCA-PG&E survey (see Appendix F: CLCA-PG&E Survey Summary Memo) did indicate that missing nozzles occur periodically.

6.4.2.7 Burst Pressure

The Statewide CASE Team did not calculate the savings from the proposed burst pressure requirements (based on ANSI ASABE/ICC 802-2014) due to a lack of readily available information on potential savings and testing as well as uncertainty over the level of market adoption that would occur in the base case due to the ANSI ASABE/ICC 802-2014 standard.

6.4.3 Use Cases

The Statewide CASE Team prepared three use cases as summarized in Table 9 and estimated the percent unit water savings from pressure-regulated spray sprinkler bodies in each. Per unit savings and statewide savings estimates are based on these use cases as explained below.

Table 9: Summary of Use Cases without Pressure Regulation at the Spray Sprinkler Body

<table>
<tr><th rowspan="2"></th><th colspan="3">Use Cases Without Qualifying Products in the Base Case</th><th rowspan="2">Qualifying Products</th></tr>
<tr><th>One</th><th>Two</th><th>Three</th></tr>
<tr><th>Description</th><th>No run time true-up[26] or pressure regulation</th><th>Run time true-up at installation; no pressure regulation</th><th>Pressure regulation at irrigation system valve</th><th>Pressure regulation at spray sprinkler body inlet</th></tr>
<tr><td>Overapplication</td><td rowspan="6">no mitigation</td><td>partial mitigation</td><td rowspan="5">assume mitigation similar to pressure-regulated spray sprinkler bodies to be conservative</td><td rowspan="6">mitigated</td></tr>
<tr><td>Misting/evaporation</td><td rowspan="5">no mitigation</td></tr>
<tr><td>Overspray (off-target area)</td></tr>
<tr><td>Deep percolation/run-off</td></tr>
<tr><td>Decreased application uniformity</td></tr>
<tr><td>Missing nozzle flow</td><td>no mitigation</td></tr>
<tr><td>Average pressure at nozzle inlet (psi)</td><td>60</td><td>60</td><td>34</td><td>30</td></tr>
</table>

Source: Statewide CASE Team.

[26] See discussion or true-ups in the description of Case Two.

6.4.3.1 Case One

The Statewide CASE Team considered three potential use cases when calculating expected water savings from pressure-regulated spray sprinkler bodies as summarized in Table 9. Case One represents an irrigation system without any pressure regulation. This use case assumes that the irrigation system run time is set based on manufacturer-reported nozzle flow rates at the recommended inlet pressure of 30 psi for fixed nozzles.[27] In this scenario, all reductions in flow rate due to pressure regulation will result in an equal reduction in water usage. Wind drift, evaporation, and overspray are assumed to be components of excess flow rate and no additional savings are assumed from avoiding these effects. Additional overapplication may be lost to deep percolation beyond the root zone and runoff as noted earlier.

6.4.3.2 Case Two

Case Two represents a system without pressure regulation but with run times determined during initial system installation using catch cans to determine the amount of water reaching the irrigated area.[28] The system operator could potentially "true-up" theoretical run times to account for higher application rates without pressure regulation if the additional water reaches the landscape area and is available to the root zone.

However, the system operator cannot recover the estimated ten percent of irrigation that never lands on the irrigated areas in the base case (e.g. no pressure regulation) due to wind drift, evaporation, and overspray.

In addition, an installer would likely set a sufficiently long run time to ensure adequate irrigation at all times and for all areas within the landscape. The irrigation rate would likely be determined midday when inlet supply pressure is potentially 15 psi lower than the pressure at nighttime or early morning, as shown in Figure 6. The Statewide CASE Team conservatively assumed that the difference between the pressure during testing and during operation, typically at nighttime or early morning, is half of this value, or 7.5 psi.

In addition, the Statewide CASE Team assumed that run times would be set to ensure adequate irrigation at the point where the lowest pressure and flow rate occurs in a landscape. The CASE Team estimated that pressure within an irrigation zone can vary by up to five psi due to friction in the supply piping and up to two psi due to a variation in elevation of five feet across the landscape.[29] Thus, the average pressure within the zone may be three-four psi greater than the minimum pressure within the zone.

The Statewide CASE Team estimates that due to these factors, pressure at the spray sprinkler body inlet would on average exceed the pressure used to set irrigation run times by ten psi. This level of overpressure would lead to an average overapplication rate of eleven percent, as noted in Table 8. This value may be conservative if seasonal variations in municipal water supply pressure lead to additional variability between the minimum and typical inlet water supply pressure, thus leading to greater average operating pressures at the spray sprinkler body to compensate.

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27 A contractor or homeowner may not actually perform this calculation for every installation and may instead rely on a recommendation from a knowledgeable retailer or their own experience.

[28] See "How to Perform a Catch Can Irrigation Audit on a Home Lawn Sprinkler System" for more information at http://aces.nmsu.edu/pubs/_h/H510.pdf.

29 This value seems reasonable to account for difference in flow rate, pipe friction, and elevation across a given landscape. The Statewide CASE Team assumed an average landscaped area of 5,826 square feet (U.S. EPA 2016b) in a square configuration, i.e., 76 feet on each side and a diagonal of 108 feet ($a^2 + b^2 = c^2$) with a typical California slope of 4.6 percent (see Appendix F: CLCA-PG&E Survey Summary Memo), resulting in a variation of 5 feet in elevation (equal to 2 psi) between the furthest corners for instance.

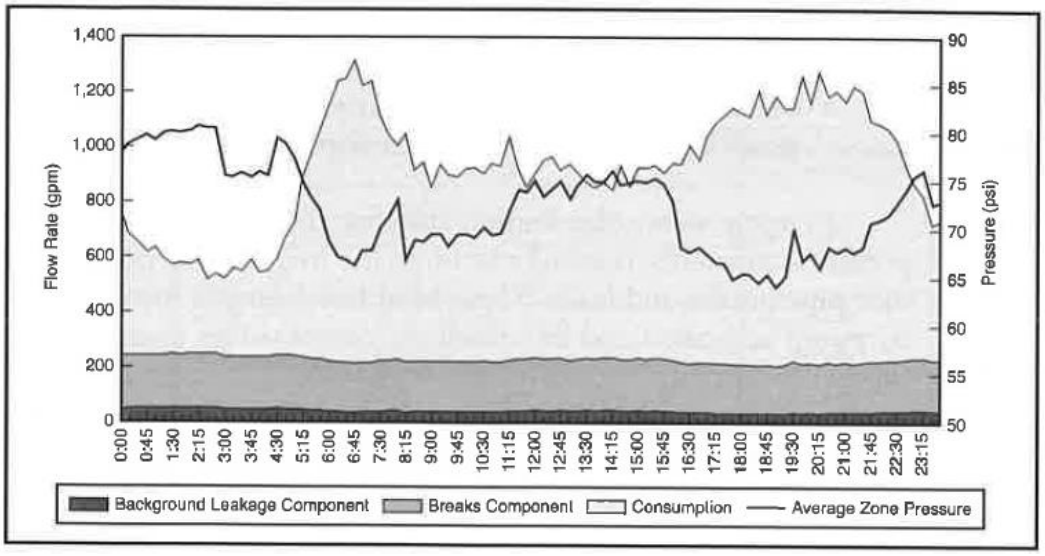

Figure 6: Pressure and flow variations in municipal water supplies without specific pressure management controls

Source: AWWA 2016.

Thus, the average California irrigation system inlet water pressure (60 psi) would lead to 21 percent water loss in Case Two. The value is slightly lower than U.S. EPA estimated water savings of 22 percent (2016b), which assumed (unlike Case Two) that water savings are equal to the change in flow rate.

6.4.3.3 Case Three

Case Three represents an irrigation system designed and installed by an expert with pressure regulation at the valve or at the spray sprinkler body.[30] Pressure regulation at the valve is typically set at 40–45 psi to ensure adequate pressure throughout the system. The WaterSense Draft Specification Supporting Statement (U.S. EPA 2016b) indicates that regulating pressure from 40 psi down to 30 psi could result in a 5 percent reduction in flow rate, so qualifying products will likely still achieve some savings during operation in Case Three, though much less than in the other use cases.

6.4.3.4 Rotating nozzles

The Statewide CASE Team notes that spray sprinklers with rotating nozzles may have different savings levels than sprinklers with fixed nozzles. One study for one product showed four percent lower savings for rotating nozzles compared to fixed nozzles.[31] Thus, savings for spray sprinkler bodies with rotating nozzles may be slightly less than for products than with fixed nozzles.

30 Flow restriction devices are a potential variation in Use Case Three. Nozzles typically contain an adjustment screw that can restrict flow through the device. However, the Statewide CASE Team did not find any evidence that they can consistently regulate pressure to meet the recommended spray sprinkler body inlet pressure when inlet pressure varies. Thus, they would not have the ability to adapt to changes in water supply pressure due to seasonal or hourly variations and would presumably need to be set to ensure acceptable irrigation rates when water supply pressure is at a valley, resulting in over-irrigation at other times. Thus, an expert installer seeking to maximize efficiency would presumably select pressure regulation instead.

31 The results were 10 percent at 60 psi compared to 14 percent at 60 psi for fixed nozzles (Brown and Gilbert n.d.).

6.4.4 Baseline Water Use and Water Savings from Avoided Drainage When Not in Operation

The Statewide CASE Team assumed that check valves would prevent drainage through spray sprinkler bodies when landscape irrigation systems are not in operation. These products are generally rated to hold 10 feet of water column pressure, with a minimum of seven feet required by the proposed standard, and they should generally prevent any drainage during non-operation. For instance, a 60-foot irrigation supply line installed at a 10 percent grade will generate six feet of water column pressure head, and a 45-foot irrigation supply line installed at a 15 percent grade will generate just under seven feet of pressure head.

While in theory some landscape water supply piping systems could generate higher non-operational pressures, the Statewide CASE Team assumed that these situations are unusual and will not affect the accuracy of the water savings estimates. [32] While installing irrigated turf on steep slopes is possible and could lead to high pressures in irrigation supply lines, it is unlikely due to greatly increased runoff and potential for erosion. New installation of turf on steep slopes is barred by MWELO.

6.4.5 Summary of Per Unit Water Use Impacts

Annual per unit water impacts are presented in Table 10 below. Savings are reduced slightly due to account for potentially lower savings for the share of products fitted with rotating nozzles as noted earlier.[33] As previously described, non-qualifying products are products that do not meet the proposed standard and qualifying products are products that meet the proposed standards. These results are based on calculations in the baseline water use estimates and water savings estimated earlier in this section.

Table 10: Annual per Unit Water Use and Potential Savings from Qualifying Products

	Use Case	Total Baseline Water Use (gallons)	Potential Water Savings - Qualifying Products	
			Percent	Gallons
During Product Operation	One	3,340[34]	29%	960
	Two		20%	660
	Three		0-5%	0-200
Additional Savings During Product Non-operation (i.e., drainage)	All		1%	40

Source: Statewide CASE Team.
Note: totals may not match exactly due to rounding.

32 In cases where supply lines generate greater pressure heads at the lower spray sprinkler than the check valve rating, the spray sprinkler body would drain only until the pressure head is reduced to the rated capacity of the check valves.

33 The Statewide CASE Team reduced expected savings by five percent (i.e. Case Two savings dropped from 21% to 20%), and may revise this adjustment if additional data becomes available in the future.
The Statewide CASE Team estimates that 35–40 percent of all sprinkler bodies installed by experts are combined with rotating nozzles, based on the CLCA-PG&E survey in the Appendix. The Statewide CASE Team assigned a specific value to each bin in the survey (i.e., the 91–100 percent bin was counted as 95.5 percent) and weighted each bin by the number of respondents who that selected that bin. The Statewide CASE Team estimated that the market share for sprinklers is 19 percent rotors, 29 percent spray sprinkler bodies with rotating nozzles, and 47 percent spray sprinkler bodies with fixed nozzles. The Statewide CASE Team then divided the share of spray sprinkler bodies with rotating nozzles by the total share of all spray bodies to get the share of spray sprinkler bodies installed by experts that are fitted with rotating nozzles. Do-it-yourself installers and unlicensed contractors are probably less likely to use this product due to lack of education about this product.

34 This valve is based on combined water use during operation and non-operation as shown in Table 2.

Water savings estimates reported by manufacturers or found in the literature for spray sprinkler bodies range from 17 to 50 percent (Austin 2009; Rain Bird 2015c Smith 2009), indicating that the Statewide CASE Team estimates are reasonable.

6.4.6 Per Unit Embedded Energy

Energy is required for water supply (e.g., pumping), conveyance, treatment and distribution of potable water. The Statewide CASE Team assumes that every million gallons of water used for an outdoor application in California results in 3,565 kWh of electricity use. This value was derived from a California Public Utilities Commission (CPUC) cost-effectiveness analysis of water and energy prepared by Navigant Consulting, Inc. (CPUC 2015). See Appendix B: Embedded Electricity Usage Methodology for further discussion on the methodology used to develop the embedded energy factor. While some landscapes are irrigated using recycled water or on-site collection of rainwater or shower & laundry drains, etc., this fraction is considered small and thus excluded from the methodology described in the Appendix.

6.4.7 Future Market Adoption of Qualifying Products

For this report, the Statewide CASE Team assumed that the current market share of qualifying products that would meet the proposed standards is about 10 percent of the total landscape irrigation spray sprinkler body market in California.[35] This assumption is consistent with industry estimates from manufacturers interviewed by the Statewide CASE Team. Without Title 20 Standards, the market adoption of spray sprinkler bodies with integral pressure regulation might increase somewhat due to the MWELO, as described earlier.

However, the Statewide CASE Team expects that the installation of products without these features will continue to dominate the market without a Title 20 standard to overcome market barriers. Market barriers, such as historical stocking decisions, lack of customer information regarding expected savings, and the lack of performance standard(s) for pressure-regulated spray sprinkler bodies limit the natural market adoption of qualifying products absent a Title 20 standard. Another potential barrier is split incentives. Property owners are generally responsible for paying water bills but may not be educated about potential water savings, while installers may be under pressure to install the system with the lowest initial cost creating a split incentive. In other cases, tenants may be responsible for paying water bills without the ability to influence the installation of water efficiency products.

6.4.8 Statewide Savings

The statewide savings estimates were calculated by determining the statewide per unit water savings and multiplying this value by the statewide shipment estimates and stock forecast shown in Table 16. The standards case savings are based on converting the market to qualifying products without changing the distribution of product types, such as shifting from overhead spray to drip or other product types.[36] The up-front incremental cost of the standard is not likely to shift consumers away from this product, because the cost is modest and would be rapidly paid back.

The Statewide CASE Team made the following assumptions to simplify the analysis and, where feasible, provide conservative estimates in cases of uncertainty:

- The Statewide CASE Team assumed that Case Three, with pressure regulation installed and maintained at the landscape irrigation system inlet valve, is equal to the collective market share of

[35] Pressure regulation estimate based on interviews with the Center for Irrigation Technology at Fresno State University and industry stakeholder interviews. Check valve estimate based on stakeholder interviews.

36 Any such shifts would likely increase the water and associated energy savings since drip is considered significantly more water-efficient than overhead spray.

systems installed at commercial, industrial, government, and institutional properties. The Statewide CASE Team also assumed that residential properties generally do not have pressure regulation in the base case. The Statewide CASE Team recognizes that some commercial landscapes will have pressure regulation at this valve, whereas on the other hand, some residential landscapes will have pressure regulation.

- The Statewide CASE Team conservatively assumed zero savings in Case Three, due to lack of robust test data to quantify the amount of water savings when the water supply input to a spray sprinkler body is 1-9 psi above the manufacturer recommended range.
- The Statewide CASE Team did not find data to qualify the prevalence of Case One versus Case Two for residential landscapes. The Statewide CASE Team assumed the lower savings estimate for Case Two for all residential landscapes to be conservative when calculating benefits.

Table 11: Inputs for Calculation of Statewide Baseline Water Use and Savings

Baseline Water Use		
Stock (units)	170 million	Statewide CASE Team analysis
Shipments (annual units)	18.6 million	Statewide CASE Team analysis
Statewide Water Saving Inputs		
Commercial, government, institutional, and industrial share of landscape areas	27%	Landscape and Lawn, 2014
Qualifying product existing market share	10%	Statewide CASE Team estimate based on industry expert interviews[37]
Per Unit Water Savings from Pressure Regulation		
Water savings, Case One	29%	Statewide CASE Team analysis of U.S. EPA data
Water savings, Case Two	20%	Statewide CASE Team analysis
Water savings, Case Three	0%	Statewide CASE Team assumption
Prevalence of Case One	0%	Statewide CASE Team assumption
Prevalence of Case Two	73%	Assumption, Statewide CASE Team
Prevalence of Case Three	27%	Assumption, Statewide CASE Team
Average savings, qualified products vs. non-qualified products	15%	Statewide CASE Team calculation

The Statewide CASE Team determined statewide water savings for pressure regulation based on the following calculations:

Equation 11

Baseline water use (first year)

[37] U.S. EPA estimates that less than 10% percent of products constrain pressure regulation, confirming that these products currently have a low market share (U.S. EPA 2016b). The Statewide CASE Team believes that a 10% percent estimate for California is reasonable given the potential for greater uptake in California and to be conservative when calculating savings.

= [Product shipments (annual)] x [baseline water use (per unit)]

Equation 12

Baseline water use (stock turnover)
= [Product stock] x [baseline water use (per unit)]

Equation 13

Average savings from pressure regulation, qualifying products vs. non-qualifying products
= [baseline water use] x [(Use Case One prevalence x water savings, Case 1) + (Use Case Two prevalence x water savings, Case 2) + (Use Case Three prevalence x water savings, Case 3)]

Equation 14

Statewide water savings from pressure regulation (first year)
= [Product shipments (annual)] x [baseline water use (per unit)] x [1 – market share of qualifying products] x [water savings (pressure regulation)]

Equation 15

Statewide water savings from pressure regulation (stock turn-over)
= [Product stock] x [baseline water use (per unit)] x [1 – market share of qualifying products] x [water savings (pressure regulation)]

Equation 16

Statewide water savings from check valve (first year)
= [Product shipments (annual)] x [baseline water use (per unit)] x [1 – market share of qualifying products] x [water savings (check valves)]

Equation 17

Statewide water savings from check valve (stock turn-over)
= [Product stock x baseline water use (per unit)] x [1 – market share of qualifying products] x [water savings (check valves)]

Table 12: California Statewide Water and Energy Use With and Without Standards

Year	Case	Annual Sales		Stock	
		Water Use (million gal/yr)	Embedded Electricity Use (GWh/yr)	Water Use (million gal/yr)[38]	Embedded Electricity Use (GWh/yr)
2019[a]	No standards	62,000	220	551,000	1,960
	Pressure regulation	53,600	191	543,000	1,936
	Pressure regulation and check valves	53,100	189	542,500	1,933
2028[b]	No standards	63,800	228	567,000	2,021
	Pressure regulation	55,200	197	490,000	1,749
	Pressure regulation and check valves	54,700	195	486,000	1,732

Source: Statewide CASE Team
Notes: Totals may not match exactly due to rounding
a. First-year standards are in effect.
b. Year stock turns over after standards take effect, assuming 9-year product life.

The Statewide CASE Team then determined statewide savings based on the difference in water use and embedded energy with and without standards.

Table 13: California Statewide Water and Energy Savings - Standards Case After Effective Date

	Year	Annual Sales		Stock	
		Water (million gal/yr)	Embedded Electricity (GWh/yr)	Water (million gal/yr)	Embedded Electricity (GWh/yr)
Pressure Regulation Only	2019[a]	8,400	29	8,400	30
	2028[b]	8,700	31	77,300	274
Check Valves Only	2019[a]	500	2	500	1
	2028[b]	500	2	3,900	15
Qualifying Products (PR and CV)[c]	2019[a]	8,900	31	8,900	31
	2028[b]	9,100	32	81,200	289

Source: Statewide CASE Team.
Notes: Totals may not match exactly due to rounding.
a. 2019 is the first year that standards are in effect.
b. Year stock turns over after standards take effect in 2028, assuming 9-year product life.
c. PR is pressure regulation; CV is check valve

[38] This value is based on the per non-qualifying unit baseline water unit times stock, with a small adjustment to reflect that some existing units are qualifying products with lower water use.

6.4.9 Stock

The Statewide CASE Team estimates that a stock of approximately 170 million spray bodies are currently in use in California. This includes shrub adapters, which represent a very small portion of the sprinkler market as described in Section 3.1.1 and regulate pressure using mechanisms similar to units with pop-up stems. As shown in Equation 18, this estimate is based in part on estimated per unit water use outlined in Section 6.4, as well as estimated total urban irrigation water use of 1.1 trillion gallons per year, excluding water use for large landscapes such as golf courses and parks (DWR 2013).

Equation 18

Total stock = [Total statewide irrigation via spray sprinkler bodies (gallons/year)] / [water use per unit (gallons/unit)]

The Statewide CASE Team also assumed that approximately 50 percent of landscape irrigation water is emitted via spray sprinklers, based on industry interviews, a U.S. EPA national estimate (2016b) and several California baseline water use studies. For instance, one statewide study estimates that approximately 72 percent of residential homes are irrigated through automatic irrigation and 28 percent are irrigated manually (Aquacraft 2011a). In addition, the Santa Clara County Residential Water Use Baseline Survey (2004) found (see Table 14) that most landscape irrigation occurs through spray sprinklers (based on irrigation type by irrigation zone).

Table 14: Santa Clara County Distribution of Irrigation Equipment

	Single Family Homes	Multifamily Homes
Spray Sprinklers	66%	80%
Rotor/Impact Sprinklers	8%	8%
Drip/Microspray Irrigation	19%	6%
Hose Watering	7%	5%
Bubbler	1%	1%

Source: Santa Clara Valley Water District 2004.

Furthermore, the 2013 Residential and Commercial Baseline Water Use Study conducted by the City of Santa Cruz found the following equipment breakdown for sites with irrigation, listed in Table 15 below. For each sector, spray sprinklers account for more than 50 percent of irrigation equipment used, and similar to the Santa Clara study, multifamily homes have a larger percentage of irrigation with spray sprinklers than single-family homes.

Table 15: City of Santa Cruz Distribution of Irrigation Equipment

	Single Family Homes	Multifamily Homes	Commercial
Spray Sprinklers	52%	67%	51%
Rotor Sprinklers	3%	8%	4%
Drip Irrigation	44%	22%	25%
Hose-End Watering	<1%	-	13%
Not Available	-	3%	6%

Source: City of Santa Cruz Water Department 2013.

Although the prevalence of spray sprinklers in the literature ranges from 50 to 80 percent depending on building type and location, the Statewide CASE Team assumed the lower-end value for the analysis presented in this report to be conservative when calculating estimated savings from the proposed standard.

6.4.10 Current and Future Shipments

The Statewide CASE Team prepared an estimate of current and future shipments based on feedback from numerous industry experts since publicly available sales data is not available and is unlikely to become available in the near future. The Statewide CASE Team estimates annual California sales of approximately 18.6 million spray bodies for the residential and commercial markets combined. This figure is based on the stock estimate described earlier as well as the expected product lifespan of nine years from the PG&E-CLCA survey, as detailed in Section 6.6.3.

Table 16 presents the estimated spray sprinkler body sales and stock in years 2017 through 2027. Please note that these values are intended to represent long-term sales trends, and may fluctuate from year to year. The Statewide CASE Team does not expect that the actual level of historical sales will have a significant effect on the analysis in the CASE Report, since the analysis is based on future sales. This sales estimate is lower than the assumption of 21 million units sold per year proposed by the Energy Commission in the July 20, 2017, workshop on the "Results of the Invitation to Participate: Spray Sprinkler Bodies." Some variation is reasonable given the lack of published data, and the Statewide CASE Team estimate leads to similar statewide baseline water use results to the Energy Commission estimates because the Energy Commission assumed lower throughput per unit.

Table 16: California Sales and Stock - Landscape Irrigation Spray Bodies

Year	Annual Shipments	Stock
2017	18,600,000	169,500,000
2018	18,600,000	171,100,000
2019	18,700,000	172,600,000
2020	18,800,000	174,200,000
2021	18,800,000	175,700,000
2022	18,900,000	177,300,000
2023	18,900,000	178,900,000
2024	19,000,000	180,500,000
2025	19,100,000	182,100,000
2026	19,100,000	183,800,000
2027	19,200,000	185,400,000
2028	19,300,000	187,100,000

Source: Statewide CASE Team.
Note: Estimates are based on California irrigation water use, housing growth[39], and per unit water use.

[39] An average household growth rate (0.9%) is used to estimate increase in landscape irrigation controller stock over time, which also influences annual shipments. The CEC Demand Analysis office provided the projected annual residential dwelling starts for the single family, multi-family, and mobile sectors. CEC provided three projections: low, mid and high estimates with each case broken out by Forecast Climate Zones. The Statewide CASE Team used the mid scenario of forecasted residential new construction for statewide savings estimates. The estimates are for dwellings that are not apartments.

6.5 Environmental Impacts/Benefits

6.5.1 Greenhouse Gases

Table 17 presents the annual and stock greenhouse gas (GHG) savings for the first year the standard takes effect (2019), and the year of full stock turnover (2028). The estimated annual statewide GHG savings is 11,000 MTCO2e the first year the standard is in effect, and about 100,000 MTCO2e after full stock turnover in 2028.

The Statewide CASE Team calculated the avoided GHG emissions from the adoption of the standard assuming a 2020 emissions factors of 353 metric tons of carbon dioxide equivalent ($MTCO_2e$) per GWh of electricity savings (CARB 2010). The California Air Resources Board (CARB) prepared an analysis of increasing California Renewables Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020 with different future electricity demand scenarios.[40] The emissions factor used in this report is intended to provide a benchmark of emissions reductions attributable to energy-efficiency measures that would help achieve the low load scenario. The emissions factor is calculated by dividing the difference between California emissions in the high and low generation forecasts by the difference between total electricity generated in those two scenarios. While emission rates will likely continue to drop over time due to increasing Renewables Portfolio Standard requirements, 2020 carbon intensity values will provide a representative value for this measure.

Table 17: Estimated California Statewide Greenhouse Gas Savings for Standards Case

Year	Annual GHG Savings ($MTCO_2e$/yr)	Stock GHG Savings ($MTCO_2e$/yr)
2019	11,200	11,200
2020	11,200	22,400
2021	11,200	33,600
2022	11,300	44,900
2023	11,300	56,200
2024	11,300	67,500
2025	11,400	78,900
2026	11,400	90,300
2027	11,500	101,800
2028	11,500	102,100

Source: Statewide CASE Team.

6.5.2 Water Resources

Water is essential to supporting and sustaining the environmental, economic, and public health needs of the state. The continuing risk of severe future droughts, shifts in regional climate patterns, and California's population growth are leading to concerns about the sustainability of ever-growing demands on a limited

(Data is sourced from the California Department of Finance and California Construction Industry Research Board (CIRB) building permits. The Department of Finance uses census years as independent data and interpolates the intermediate years using CIRB permits.)

40 CARB calculated GHG emissions for two scenarios: (1) a high load scenario in which load continues at the same rate and (2) a low load rate that assumes the state will successfully implement energy-efficiency strategies outlined in the AB 32 (Global Warming Solutions Act) Scoping Plan, which would reduce overall electricity load in the state (CARB 2010). The Statewide CASE Team calculated the emissions factors of the incremental electricity savings between the low- and high-load scenarios.

(and shrinking) water supply. Since water security is critically important to the state, improving water efficiency is a well-established statewide policy goal. For instance, legislation enacted in 2009 (SB X7-7, 2009) established the goal of achieving a 20 percent reduction in urban per capita water use in California by 2020.

Establishing more stringent water-efficiency standards is a cost-effective intervention for reducing California water demand. It may be the most cost-effective intervention when compared to solutions that aim to increase and maintain reliable water supplies. For instance, projects such as ocean water desalination, dams, or new water conveyance cost billions of dollars.[41] The water-efficiency standards presented in this document, on the other hand, will reduce Californians' expenditures on water bills at a much lower cost.

In addition, qualifying products will reduce runoff as well as releases of pesticides, fertilizers, and sediment into streams, rivers, lakes, and oceans, either directly through flows into surface waters or as residuals from treated wastewater treatment plants.

6.5.3 Indoor or Outdoor Air Quality

This measure will have no direct effect on air quality. The measure will reduce embedded energy and thus indirectly reduce air pollution.

6.5.4 Hazardous Materials

The Statewide CASE Team did not identify any impacts on hazardous materials from this measure.

6.6 Impact on California's Economy

6.6.1 Impacts to Businesses and Disadvantaged Communities

The Statewide CASE Team does not believe that proposed standards would negatively affect California businesses, including small businesses, for several reasons.

First, the Statewide CASE Team is not aware of any comments made during the adoption of California legislation requiring these standards (see Section 6.9) that Title 20 Standards would adversely affect California businesses, including small businesses. Second, total U.S. revenues for landscaping services are estimated at $83 billion, including a variety of installation and maintenance services.[42] Irrigation consists of a relatively small share of overall revenue and even less for the smallest businesses (see Table 18 below), so any costs that they cannot recover should be a small share of total revenue. Third, the Statewide CASE Team does not anticipate any significant reduction in consumer spending for this market, even if costs are passed onto consumers, due to the relatively low cost of compliance compared to the overall cost of installing a landscape. The lifecycle cost will also decrease significantly.

41 Though it can produce a reliable source of water, desalination is a very expensive and energy-intensive technology. It also has an impact on the local aquatic environment, as well as electric consumers and ratepayers, since energy is a major expense (Pacific Institute 2013). Further, upgrading infrastructure for water conveyance and storage can cost tens of billions of dollars.

42 See https://www.ibisworld.com/industry-trends/market-research-reports/administration-business-support-waste-management-services/administrative/landscaping-services.html.

Table 18: Revenue by Market Segment and Company Size

	Sales Under $200k	Sales of $200k or More
Lawn mowing/ maintenance	59%	34%
Design/build	13%	27%
Lawn care	10%	17%
Tree and ornamental	7%	5%
Irrigation	3%	8%
Other	9%	9%

Source: Lawn and Landscape 2014.
Note: The Statewide CASE Team calculated market segments without the ice and snow removal category that was included in the national survey.

The Statewide CASE Team does not anticipate any negative impacts on disadvantaged communities. These communities will likely benefit from these products in the same way that other consumers will benefit.

6.6.2 Incremental Cost

Adjusting for sprinkler size, the primary driver in the price of a spray sprinkler is the number of features the device offers. Price is also affected by the perceived quality of the device, as estimated by the warranty. Thus, the average price of spray sprinklers on the market without pressure regulation or check valves is lower than that of qualifying products.

Table 19 below provides an example of the range of retail prices for irrigation emission devices that are currently on the market. Based on retail price data, the Statewide CASE Team estimated that the cost of a basic pressure-regulated pop-up spray head is consistent with the U.S. EPA estimate that basic products cost on average $1.84 and pressure regulation adds $3.35 to the price (U.S. EPA 2016b). The Statewide CASE Team used the U.S. EPA value in the cost-effectiveness evaluation.

U.S. EPA did not estimate the cost of check valves. The Statewide CASE Team estimates that the additional cost of adding an integral check valve capable of holding back a seven-foot column of water is about $0.80. This estimate was derived from the cost of add-on check valves rated at 10 feet. Many of the spray sprinkler bodies offering integral pressure regulation and check valves have check valves rated at 14 feet with a higher incremental cost. If integral check valves become a requirement, costs are likely to drop as production scales up, and manufacturers will potentially also offer more qualifying products with a check valve capacity of seven to ten feet.

U.S. EPA did not estimate prices for pressure-regulated shrub adapters, which the Statewide CASE Team estimates cost about $2.25 more than non-pressure-regulated shrub adapters. Since shrub sprinklers represent a small portion of the spray sprinkler market, the cost-effectiveness analysis for the pressure regulation standard relies on the incremental cost of pressure regulation in spray sprinkler bodies alone, for simplicity. Given the very high benefit/cost ratio calculated for spray sprinkler bodies with pressure regulation, pressure regulation for shrub adaptors will also be highly cost-effective.

Table 19: Example Retail Prices of 4-inch Pop-up Spray Sprinklers with Pressure Regulation

Manufacturer	Model*	Retail Price	Warranty (Years)
4" Basic Pop-Up Spray Body (No Nozzle)			
Toro	570Z-4P	$1.42	5
Rain Bird	1804	$1.97	5
Rain Bird	US400	$1.62	3
Hunter	PROS-04	$1.58	5
K-Rain	Pro-S 78004	$1.43	5
Signature	63XA-04	$2.78	5
Weathermatic	LX4	$1.62	5
Typical Range		**$1.58-$1.97**	**4.3**
4" Pop-Up Spray Body with 30 PSI Pressure Regulation (PR)			
Toro	570Z-4P PR	$5.10	5
Rain Bird	1804-PRS	$5.90	5
Hunter	PRS-04-PRS30	$4.24	5
K-Rain	Pro-S 78004-PR	$4.43	5
Orbit	Eco-Spray	$3.19	1
Irritrol	I-PRO400-PR	$4.17	5
Typical Range		**$4.17-$5.10**	**4.3**

Source: Statewide CASE Team

Table 20: Example Prices of 4-inch Pop-up Spray Sprinklers with Additional Features

Manufacturer	Model*	Retail Price	Warranty (Years)
4" Pop-Up Spray Body with Integrated Check Valve (CV)			
Toro	570Z-4P COM (10')	$3.85	5
Rain Bird	1804 SAM (14')	$3.87	5
Hunter	PROS-04-CV (14')	$3.17	5
K-Rain	Pro-S 78004-CV (10')	$3.09	5
Signature	63XB-04 (10')	$4.72	5
Orbit	54583	$4.20	1
Weathermatic	LX4 CV (9.5')	$3.98	5
Irritrol	I-PRO400-CV (14')	$2.92	5
Average		**$3.72**	**4.5**
4" Pop-Up Spray Body with Integrated CV and PR			
Toro	570Z-4P PR COM (10')	$6.81	5
Rain Bird	1804 SAM PRS (14')	$6.59	5
Rain Bird	RD-04-S-P30 (14')	$6.59	5
Hunter	PRS-04-PRS30-CV (14')	$5.54	5

Manufacturer	Model*	Retail Price	Warranty (Years)
Irritrol	I-Pro400-PR-CV (14')	$5.69	5
Hydro-Rain	HRS 200 PC	$4.31	3
Average		**$5.92**	**4.7**
Add-On Check Valve Only			
K Rain	P53428 (10')	$0.75	5
Hunter	437400 (10')	$1.05	5
Signature	6319 (10')	$1.45	5
Toro	570CV (10')	$0.19	5
Irritrol	I-Pro CV (10')	$0.73	5
Average		**$0.83**	**5**
Shrub Adapter			
Toro	570S	$0.96	
Landscape Products	Shrub Adapter (Female Thread)	$0.56	
Landscape Products	Shrub Adapter (Male Thread)	$0.52	
Rain Bird	PA-8S	$0.94	
Hunter	PROS-00	$0.67	
Average		**$0.73**	
Shrub Adapter with Integrated PR			
Hunter	PROS-00-PRS30	$2.85	
Rain Bird	PA-8S-PRS	$3.10	
Toro	570Z PRX Shrub Adapter 102-0006	$4.24	
Average		**$3.40**	

*Check valve rating in parentheses if available.
Source: Statewide CASE Team

Because pressure-regulated spray sprinklers can be installed in irrigation systems without any additional effort on the part of the installer, the Statewide CASE Team assumed that there are no additional installation or maintenance costs associated with qualifying equipment. Since the MWELO already requires manufacturer compliance with the equipment quality features in ANSI ASABE/ICC 802-2014, the Statewide CASE Team does not anticipate any additional incremental cost to comply with these requirements.

6.6.3 Design Life

The Statewide CASE Team calculated an average product lifespan of nine years in Table 21 based on survey responses from the California Landscape Contractors Association (See Appendix F: CLCA-PG&E Survey Summary Memo).

Table 21: Calculation of product life

Answer Bins	Percent of Responses	Bin Mean (years)
Less than 1 year	0%	0.5
1–2 years	5%	1.5
3–5 years	23%	4
6–10 years	49%	8
11–20 years	18%	15.5
More than 20 years	5%	25
Weighted average	**100%**	**9 years**

Source: Statewide CASE Team.

6.6.4 Lifecycle Costs/Benefit Ratio and Net Present Value (PV)

The benefit/cost ratio, as shown below in Table 22 is very favorable to consumers. The Statewide CASE Team predicts that lifecycle benefits for first-year sales will equal or exceed $450 million and that cumulative lifecycle savings will reach $5.6 billion once stock completely turns over in 2028. These estimates are based on water bill savings and on consumer costs, assuming that all product costs are passed on to consumers.

Table 22: Costs and Benefits for Qualifying Products (2017 $)

Product Class	Product Features	Lifecycle Benefit/ Cost Ratio[b]	Lifecycle Incremental Costs per Unit (2017 PV $)	Lifecycle Benefits per Unit (2017 PV $)[a]
2019	Pressure regulation without check valves	8.6	$3.38	$29
	Pressure regulation with check valves	7.2	$4.21	$30

Source: Statewide CASE Team.

Notes: Totals may not match exactly due to rounding
a. The analysis does not include cost savings associated with embedded energy savings.
b. Total present value (PV) benefits divided by total present value costs. PV indicates a reduced total cost of ownership over the life of the appliance.

The water rates for future savings are escalated based on the "Water CPI" and discounted by three percent per year as noted in Appendix A: Potable Water and Wastewater Rates. Water and wastewater rates have been increasing faster than inflation and are expected to continue escalating, contributing to expected future avoided water costs.

Table 23: Statewide Total Lifecycle Costs and Benefits for Standards Case (2017 $)

	Measure Lifecycle Cost for First-Year Sales[a]	Measure Lifecycle Benefit for First-Year Sales	NPV for First-Year Sales	NPV for Cumulative Sales Through Stock Turnover[b]
Pressure Regulation	$57,000,000	$490,000,000	$430,000,000	$5,400,000,000
Pressure Regulation with Check Valves	$71,000,000	$520,000,000	$450,000,000	$5,600,000,000

Source: Statewide CASE Team

Notes: Totals may not match exactly due to rounding

a. The analysis does not include cost savings associated with embedded energy savings.

b. Stock turnover net present value (NPV) is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year (i.e., the NPV of "turning over" the whole stock of less-efficient products that were in use at the effective date to more efficient products, plus any additional non-replacement units due to market growth, if applicable). For example, for a standard effective on January 1, 2019, applied to a product with a nine-year design life, the stock turnover NPV includes the NPV of products purchased from January 1, 2019, through December 31 2027.

6.7 Consumer Utility/Acceptance

Qualifying products are a convenient solution for contractors and/or homeowners. They are installed the same way as non-qualifying products (typically threaded to supply piping) and do not require any special training or tools. Consumers will presumably be happy that qualifying products reduce misting, runoff, and overspray, resulting in water savings and fewer puddles on walkways. In addition, the burst pressure requirement would improve product quality.

The Statewide CASE Team recognizes that some variation in flow between landscape irrigation spray sprinkler bodies within a landscape could occur if a user replaced a single damaged unit. This could lead to brown spots if run times are not increased. However, most of the higher original excess flow would not have been available for beneficial irrigation, as noted earlier. In addition, due to head-to-head spacing, most areas are covered by more than one spray sprinkler body; this further minimizes the possibility for variation in irrigation rates within a landscape if a single non-pressure-regulated spray sprinkler body is replaced with a pressure-regulated spray sprinkler body.

The up-front incremental cost of the standard is not likely to shift consumers away from this product because the cost is modest and would be rapidly paid back.[43]

The Statewide CASE Team notes that some legacy, existing spray sprinklers, including plastic or brass flush or gravity pop-up sprinklers, typically with no more than one inch of clearance above the ground surface, may not be available if standards are adopted. If an entire unit of this type failed and an appropriate replacement were no longer sold, a modern replacement would be needed. This replacement could require cutting a short section of the water supply line (usually PVC) to accommodate a modern spray sprinkler body with a slightly longer length. The Statewide CASE Team is continuing to evaluate options for replacement of these legacy units when they fail.

43 Any such shifts would likely increase the water and associated energy savings since drip is considered significantly more water efficient than overhead spray.

6.8 Market Structure and Supply Chain Timelines

6.8.1 Market Structure

The three largest manufacturers of landscape irrigation equipment in the California market are Rain Bird, Hunter, and Toro. All three companies offer a variety of residential and commercial landscape irrigation emission device equipment, including spray sprinkler bodies that are potentially qualifying products. (For information on additional landscape irrigation emission devices, please see Appendix E: Related Product Categories.

Several other manufacturers also produce landscape irrigation emission devices that are sold in California. For spray sprinklers, these manufacturers include Orbit, Hydro-Rain, K-Rain, Irritrol, Weathermatic, and Signature. The market focus of these manufacturers ranges from professional-level products (e.g., Irritrol and Signature) to do-it-yourself residential products sold in retail stores (e.g., Orbit). Most low-volume manufacturers also supply potentially qualifying products as shown below.

The landscaping industry contains many small businesses as shown in Table 24; the average company employs 15 people year-round, has $1 million in revenues, and has a net profit of 10 percent according to the National Association of Landscape Professionals.[44] There are 11,466 active licensed C-27 landscape contractors (Silva, 2017)[45]. Though contractors play a significant role within this market structure, landscape irrigation emission devices are distributed through several outlets.

Table 24: Percent of Firms by Revenue

Gross sales (2014)	Percent
Less than $200k	45
$200k–$400k	18
$400k–$750 k	7
$750k–$1 million	6
$1 million–$7 million	19
More than $7 million	5

Source: Lawn and Landscape 2014.

Landscape professionals often obtain products through direct sales from manufacturers to homebuilders or other large-volume purchasers and sales from large irrigation product distributors, such as Ewing Irrigation and SiteOne Landscape Supply (formerly John Deere Landscapes). Retail sales (e.g., Home Depot, Lowe's, or online retailers) are common suppliers for do-it-yourself repairs and remodels.

Because many irrigation contractors use irrigation product distributors, distributors have a significant influence on which products reach the mainstream market. Brand, price, performance, added features, and ease of use and installation play a role in which products distributors choose to stock. Some manufacturers have localized distribution channels that use wholesale distributors to deliver a tailored distribution strategy

44 See https://www.landscapeprofessionals.org/nalp/media/landscape-industry-statistics.aspx.

[45] The California Department of Consumer Affairs Contractors State License Board states that "A landscape contractor constructs, maintains, repairs, installs, or subcontracts the development of landscape systems and facilities for public and private gardens and other areas which are designed to aesthetically, architecturally, horticulturally, or functionally improve the grounds within or surrounding a structure or a tract or plot of land. In connection therewith, a landscape contractor prepares and grades plots and areas of land for the installation of any architectural, horticultural and decorative treatment or arrangement." http://www.cslb.ca.gov/About_Us/Library/Licensing_Classifications/C-27_-_Landscaping.aspx

for different regions. Wholesale distributors may work with builders, contractors, water utilities, and retail stores. Sales representatives for the wholesaler can educate customers about features such as water-saving options. Wholesalers also tend to target markets with high sales or markets that have an appetite for the specialty products they carry.

6.9 Stakeholder Positions

The Statewide CASE Team is not aware of significant opposition to standards. For instance, the Senate Rules Committee found that no person or organization opposed the AB 1928 (2016) requirement to adopt mandatory standards for spray sprinkler bodies and other landscape irrigation products (Senate Rules Committee 2016).

The Independent Technical Panel (ITP) also supports standards. The ITP "Report to the Legislature on Landscape Water Use Efficiency" (2016) recommends the adoption of California appliance energy-efficiency standards for landscape irrigation spray sprinkler bodies requiring pressure regulation and check valves (ITP 2016a). (The proposal does not include specific code language.) The membership of the ITP is shown below in Table 25.

Table 25: Independent Technical Panel Members

Name	Representation	Organization
Peter Estournes	Business	Gardenworks, Inc., Santa Rosa
Penny Falcon, P.E.	Retailer	Los Angeles Department of Water and Power
David W. Fujino, Ph.D.	Academia	UC Davis, CA Center for Urban Horticulture
William Granger	Retail Water Provider	City of Sacramento
Lisa Maddaus, P.E.	At large	Maddaus Water Management
Edward R. Osann	Environmental	Natural Resources Defense Council
Jeff Stephenson	Wholesaler	San Diego County Water Authority

Furthermore, the Statewide CASE Team reviewed many of the public comments on the ITP report and found numerous comments that support adoption of Title 20 Standards and none that oppose adopting standards. Several examples are listed below:

- The Municipal Water District of Orange County (MWDOC) found that the absence of pressure regulation in irrigation systems is widespread, contributing to a significant amount of water being wasted. MWDOC also found that low-head drainage is common, especially in hilly areas, which results in wasted water and excess time to recharge an empty irrigation system. MWDOC stated that the proposed recommendation will result in solutions to prevent low-head drainage and water loss due to excess pressure, and that the savings will accrue in both new systems and existing systems (MWDOC 2016).
- The California Landscape Contractors Association (CLCA), a nonprofit trade association of approximately 2,000 licensed landscape contractors, supported the recommendation and suggested an implementation deadline of January 1, 2018 (CLCA 2016). (The implementation deadline recommendation may no longer be current due to the passage of time since this comment was made.)
- The IA supported the recommendations. The IA represents 1,500 members in the irrigation industry and includes large irrigation equipment manufacturers (e.g., Hunter, Orbit, Toro, and

Rain Bird), several smaller manufacturers, distributors, retailers, and a variety of other companies and organizations. The IA was involved in the development of ANSI ASABE/ICC 802-2014 and encouraged referencing that standard in the development of a Title 20 Standard (IA 2016).

- The Association of Professional Landscape Designers (APLD), which primarily represents residential landscape designers, but also includes contractors and landscape architects who provide design services for commercial, industrial, and institutional landscapes, supported the recommendations (APLD 2016).
- The Contra Costa Water District (CCWD) recommended addressing low-quality sprinkler heads sold in big box stores (CCWD 2016). The proposed Title 20 standard would address this comment at least in part by setting a burst pressure standard.

The Statewide CASE Team also received valuable feedback through informal outreach to numerous stakeholders.

- The Statewide CASE Team coordinated extensively with the IA. The IA has developed numerous test protocols as discussed earlier and the Statewide CASE Team made extensive use of IA testing protocols.
- Members of the CLCA provided valuable information that the Statewide CASE Team used in the development of this report.
- The Statewide CASE Team interviewed six major manufacturers, and one distributor, to gain an understanding of the market, product performance and availability, and technical feasibility of potential standards (this outreach focused on pressure regulation). The Statewide CASE Team notes that several manufacturers stressed the importance of a well-designed, installed, maintained, and operated landscape irrigation system, and recognizes the importance of these factors in addition to more water-efficient products.
- The Statewide CASE Team also interviewed other stakeholders, including staff at the Center for Irrigation Technology at the University of Fresno, NRDC, and the U.S. EPA WaterSense program.

The Statewide CASE Team reviewed one comment to the Energy Commission (Norum 2017) recommending the development of a new metric to evaluate nozzle performance. The comment noted that the distribution uniformity metric sometimes used to evaluate nozzle performance has significant drawbacks. The comment also recommended pursuing this effort to the exclusion of standards on pressure regulation without providing specific information to explain why pressure regulation standards should not be adopted. The Statewide CASE Team agrees with the benefits of an effective metric for nozzle performance, but does not see a conflict between this goal and issuing standards for pressure regulation of spray sprinkler bodies.

6.10 Other Regulatory Considerations

6.10.1 Federal Regulatory Background

The Statewide CASE Team did not identify any federal laws or mandatory standards for this product. The Energy Commission can consider harmonizing Title 20 test procedures and/or standards with the voluntary U.S. EPA WaterSense program once the WaterSense program is finalized, but is not required to do so.

6.10.2 California Regulatory Background

California AB 1928 (2016) updates prior legislation and requires the Energy Commission to establish performance standards and labeling requirements for spray sprinkler bodies and other landscape irrigation

products by January 1, 2019.[46] The legislation also requires that the Energy Commission consider the IA SWAT Program testing protocols. This proposal draws heavily on the testing protocols that were issued by the IA or developed with extensive IA involvement.

This effort is also consistent with prior California legislation and policy. For instance, legislation enacted in 2009 (SB X7-7, 2009) established a goal of achieving a 20 percent reduction in urban per capita water use in California by 2020. In addition, the California Climate Change Scoping Plan (Volume I p. C-132) calls for the Energy Commission and other state agencies to adopt standards including Appliance Efficiency Standards and Landscape Water Standards to avoid greenhouse gas emissions (CARB 2008). The Statewide CASE Team also notes that climate change is likely to increase the frequency and severity of California drought cycles. Thus, water efficiency standards are a vital step toward adaptation in response to climate change.

Furthermore, the California Public Utilities Commission (CPUC) has directed the IOUs to pursue water efficiency activities, such as rebate programs and codes and standards advocacy, as part of their energy management portfolios to reduce the amount of embedded energy use associated with water use. A significant amount of energy is used to fulfill California water supply needs. For instance, the Energy Commission California Energy Consumption Database reports about 90,000 GWh of residential electricity use in 2015.[47] Outdoor irrigation alone accounted for about 2,000 GWh of embedded energy.

6.10.3 Utility and Other Incentive Programs

Many water utilities and municipalities provide rebates to residential and commercial customers for water-efficient irrigation emission devices. In California, examples include internal pressure regulation for landscape irrigation spray sprinkler bodies, drip irrigation conversion, high-efficiency rotating spray nozzles, and spray sprinklers with integrated check valves. Rain Bird, a major manufacturer of irrigation equipment, compiled a list of rebate programs in over 80 jurisdictions for pressure regulation or check valves, many of which are offered through the California Water Service (Rain Bird 2015a, 2015b, California Water Service 2017). Programs are often designed to replace older existing units since these units are not subject to water efficiency regulations. Once enacted, these incentive programs can complement the Title 20 Standards required by AB 1928, by encouraging early replacement of inefficient products with qualifying products.

6.10.4 Model Codes and Voluntary Standards

Many government and non-government entities have made substantial progress establishing model, building codes and voluntary standards that address water efficiency. Many of these existing codes and standards have been developed through rigorous public vetting processes with participation by key industry stakeholders. Table 26 below shows a variety of model codes and standards related to landscape irrigation emission devices. Please note that test methods developed by the IA and the related draft WaterSense test method are discussed earlier in this document.

Table 26: Model Codes and Standards for Landscape Irrigation Spray Sprinklers

Model Code or Standard	Requirements
American National Standards Institute (ANSI) American	Addresses sprinkler (spray and rotor), bubbler, point- and line-source drip emitter, and microspray landscape irrigation emission devices. Contains approximately 30 product specific test methods either directly or by reference

46 The legislation includes emission devices.
47 The databased is available at this link: http://www.ecdms.energy.ca.gov/

Model Code or Standard	Requirements
Society of Agricultural and Biological Engineers (ASABE)/International Code Council (ICC) 802-2014 Landscape Irrigation Sprinkler and Emitter Standard (2014)	to other standards. Contains approximately 10 mandatory product specific performance requirements. <u>Sprinkler and Bubbler Requirements</u> Section 302.6 requires that devices withstand pressure up to 150 percent of the maximum published operating pressure. Section 302.7 requires that devices with check valves prevent flow for elevation changes up to seven feet (3.0 psi). Section 302.8 requires integral pressure regulation for spray bodies, but does not contain a performance requirement. Section 303 contains test methods for check valve function, pressure regulation, flow rate, distance of throw, burst pressure, uniformity, and missing nozzle flow reduction.
International Association of Plumbing and Mechanical Officials (IAPMO) Green Plumbing & Mechanical Code Supplement (2012) (note that IAPMO intends to release a revised standard November 2017)	Section 413.10 Sprinkler Head Installations. All installed sprinkler heads shall be low precipitation rate sprinkler heads. Section 413.10.1 Sprinkler Heads in Common Irrigation Zones. Sprinkler head installed in irrigation zones served by a common valve shall be limited to applying water to plants with similar irrigation needs, and shall have matched precipitation rates (identical inches of water application per hour as rated or tested, plus or minus five percent). Section 413.10.2 Sprinkler Head Pressure Regulation. Sprinkler heads shall utilize pressure regulating devices (as part of irrigation system or integral to the sprinkler head) to maintain manufacturer recommended operation pressure for each sprinkler and nozzle type. Section 413.10.3 Pop-up Type Sprinkler Heads. Where pop-up type sprinkler heads are installed, the sprinkler heads shall rise to a height of not less than 4 inches (102 mm) above the soil level when emitting water. Section 413.11 Irrigation Zone Performance Criteria. Irrigation zones shall be designed and installed to ensure the average precipitation rate of the sprinkler heads over the irrigated area does not exceed 1.0 inch per hour as verified through either of the following methods: (a) manufacturer documentation that the precipitation rate for the installed sprinkler head does not exceed 1.0 inches per hour where the sprinkler heads are installed no closer than the specified radius and where the water pressure of the irrigation system is no greater than the manufacturer recommendations. (b) catch can testing in accordance with the requirements of the Authority Having Jurisdiction and where emitted water volume is measured with a minimum of 6 catchment containers at random places within the irrigation zone for a minimum of 15 minutes to determine the average precipitation rate, expressed as inches per hour.
International Green Construction Code (IgCC) (2012)	Section 404.1.2.6 Sprinklers shall: Section 404.1.2.6.1. Have nozzles with matched precipitation rates. Section 404.1.2.6.5. If of the pop-up configuration, pop-up to a height of not less than four inches (101 mm). Section 404.1.2.6.6. Only be installed in zones composed exclusively of sprinklers and shall be designed to achieve a lower quarter distribution uniformity of no less than 0.65.

Model Code or Standard	Requirements
California Model Water Efficient Landscape Ordinance (July 9, 2015)	The MWELO contains numerous requirements. Below are several examples related to spray sprinkler bodies: Section 491 Definitions: "check valve" or "anti-drain valve" means a valve located under a sprinkler head, or other location in the irrigation system, to hold water in the system to prevent drainage from sprinkler heads when the sprinkler is off. Section 492.7(a)(1)(C): If the water pressure is below or exceeds the recommended pressure of the specified irrigation devices, the installation of a pressure regulating device is required to ensure that the dynamic pressure at each emission device is within the manufacturer recommended pressure range for optimal performance. Section 492.7(a)(1)(S): Check valves or anti-drain valves are required on all sprinkler heads where low point drainage could occur. Appendix D – Prescriptive Compliance Option Section b.5.C - Pressure regulators shall be installed on the irrigation system to ensure the dynamic pressure of the system is within the manufacturer recommended pressure range. Section b.5.E - All irrigation emission devices must meet the requirements set in the ANSI standard, ASABE/ICC 802-2014 "Landscape Irrigation Sprinkler and Emitter Standard."
WaterSense Draft Spray Sprinkler Body Specification Version 1.0 (November 17, 2016)	WaterSense proposed a draft voluntary standard and test method for pressure regulated spray sprinkler bodies in late 2016. The standard would require that products regulate pressure to keep flow within specific limits. The test method would require testing each product at four inlet pressures to determine pressure to the nozzle and flow rate from the nozzle.

6.10.5 Compliance

6.10.5.1 Implementation deadline

The Statewide CASE Team recommends that the Energy Commission set a compliance date of 12 months. Twelve months should be adequate to complete manufacturing scale-up and labeling of qualifying products. Some manufacturers informed the Statewide CASE Team that they are equipped to quickly scale up existing production lines for pressure-regulated products, while in other cases a change to the configuration of manufacturing lines would be required to scale up production. The Statewide CASE Team is not aware of any need to consider a compliance date longer than 12 months. Compliance testing should not impact manufacturers' ability to meet the compliance deadline set by the Energy Commission.[48] The burst pressure

48 The Statewide CASE Team estimates that pressure regulation product testing can be conducted relatively quickly and would not delay a manufacturer's ability to comply, and that test procedures should take less than one day per product after equipment set-up. In addition, there are a limited number of models on the market since each spray body model can be used with a wide range of nozzles from the spray body manufacturer and typically from other manufacturers as well.

requirement would not impose any new significant burden on manufacturers since they must already meet this requirement by December 1, 2015, under the MWELO.[49]

The Energy Commission should also consider requiring consistent marking of products with the date of manufacture. The Statewide CASE Team understands that some manufacturers mark individual units with the manufacturing date to validate warranty claims, while others do not. Marking the box in which multiple units are packaged appears to be a common industry practice, and may be helpful in some cases, but not sufficient when products are sold individually.[50]

The Energy Commission could consider a staggered phase-in to require pressure regulation in 12 months and check valves later if any difficulties for implementing check valves at the same time as pressure regulation are identified. Pressure regulation will capture the largest share of benefits, though check valves will also achieve large additional savings.

6.10.5.2 Compliance Process

The Statewide CASE Team expects that compliance can be verified for products sold through California retail channels by examining retail stock and checking online sales offerings against qualifying products in the Energy Commission Modernized Appliance Efficiency Database System, similar to procedures for other retail products. These compliance efforts should be sufficient to address most smaller, do-it-yourself new installations or replacement of broken units, as well as smaller contractors who use retail sales channels.

Certain sales may be less publicly visible, for example, sales from wholesale distributors to large contractors. Therefore, the Statewide CASE Team recommends several approaches to address this sales channel. The first is outreach and education to distributers and contractors, potentially in collaboration with organizations such as the IA and CLCA. Another is the verification of products offered for sale through distributor websites and/or other sources.

The Statewide CASE Team also notes that online retail sales may cross state lines and recommends additional outreach to online retailers.

In addition, the Statewide CASE Team recommends that DWR issue guidance on using local MWELO compliance audits to verify that qualifying products are installed in the field. The proposed Title 20 standard requires labeling qualifying products, and furthermore the MWELO requires labeling for the presence of pressure regulation and check valve features on irrigation devices in an area visible after installation because the MWELO requires that landscape irrigation spray sprinklers meet ANSI ASABE/ICC 802-2014 including section 304.1. Thus, MWELO auditors should be able to verify at least the presence or absence of integral pressure regulation and check valves, and ideally would also verify whether compliant products are installed. While the MWELO will not apply to some smaller installations, the Statewide CASE Team assumes that most contractor installations in California will be subject to the MWELO.

The Statewide CASE Team also encourages building code officials to consider harmonizing landscape irrigation requirements in CALGreen (Title 24, Part 11) with Title 20 Standards. Educating local building officials can also help facilitate detection of installation of noncompliant products in the field.

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49 In theory, a manufacturer could offer a product for sale only for the replacement market to avoid compliance with the MWELO, but in practice the Statewide CASE Team is not aware of any technical differentiation or market differentiation between replacement units and units for new landscaped areas.

50 While the box may be dated based on date of packaging instead of date the unit is manufactured, this difference should be small since manufacturers have an incentive to package and ship promptly to avoid carrying excess inventory.

7. Conclusion

Landscape irrigation is the single largest use of potable water in the residential sector and accounts for approximately half of total urban water usage in California (PPIC 2016). Across all sectors, residential and commercial landscape irrigation uses over one trillion gallons of water per year. The extraction, conveyance, treatment, and distribution of landscape irrigation water requires about two terawatt hours of embedded electricity per year. The recent California drought emergency further highlights the ongoing importance of more efficient landscape irrigation.

The proposed standards would achieve dramatic water, energy, GHG, and cost savings for California consumers and businesses. Establishing Title 20 Standards is critical to achieving these benefits and overcoming market barriers, such as historical stocking choices, lack of standards, lack of consumer education, and split incentives between landscape installers and property owners or tenants. The Statewide CASE Team found broad stakeholder support and did not identify economic or technical feasibility barriers to implementing landscape irrigation spray sprinkler body standards.

The Statewide CASE Team estimates that the proposed standards will result in the following benefits:

- Over 80 billion gallons of water and about 290 GWh of annual embedded energy savings once stock turns over and the standards are fully phased in (2028).
- Net present value of $440 million for first year shipments (2019) and $5.6 billion cumulative net present value for shipments through stock turnover (2028).
- Over 100,000 tons per year of avoided GHG emissions once stock turns over and the standards are fully phased in (2028) and additional environmental benefits.

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Appendix A: Potable Water and Wastewater Rates

The 2017 potable water rates used in the analysis are based on residential water rate data from a Black & Veatch study that includes the eight largest cities in California (Black & Veatch 2016).[51] This data was weighted by the number of single-family homes in each city based on data from the California Department of Finance. About 30 percent of Californians live in one of the eight cities, and the Statewide CASE Team assumed that rates for these cities are representative of rates throughout the state. The Statewide CASE Team assumes that a typical customer with irrigation uses 11,000 gallons per month as a baseline (Aquacraft 2011b) and the 7,500–15,000 gallons per month rate tier would apply to water saved by this measure. The estimate only considers the variable portion of the residential potable water bill and does not include fixed charges that occur regardless of the amount of water consumption. See Table 27 for the estimated water costs to consumers in each city and the number of single family houses in each city in 2016 dollars. Costs in 2016 were escalated to 2017 rates using Black & Veatch annual increases.

To determine the statewide average wastewater rates, the Statewide CASE Team calculated average volumetric residential wastewater rates of $3.63 per 1000 gallons based on the data for the four California cities that were listed with volumetric (volume-related) wastewater (Black & Veatch 2016). Thirty percent of California residents pay a volumetric wastewater rate, which is typically linked to the potable water meter (Chesnutt 2011). The CASE Team multiplied the average wastewater rate in cities with volumetric rates (assuming the same baseline water usage noted above) by 0.30 to resulting in an average state-wide volumetric wastewater cost of $1.46 for 2017.[52]

Future potable water and wastewater rates were projected based on the Black & Veatch reported annual increases (5.8% annual increase for water and 5.9% for wastewater) and then discounted to 2017 dollars using a three percent annual discount rate (U.S. Department of Labor 2012). See the rates by year in Table 28.

Table 27: Residential Water and Wastewater Costs

	Fresno	Long Beach	Los Angeles	Oakland	Sacramento	San Diego	San Francisco	San Jose
Number of single family detached homes	105,031	74,394	557,495	73,991	113,494	237,084	65,783	175,614
Incremental Res Water Cost ($/1000gal)	$1.81	$4.84	$7.48	$6.92	$0.00	$9.01	$11.76	$2.24
Incremental Res Wastewater Cost ($/1000gal)	$0.00	$0.53	$5.05	$0.00	$0.53	$5.08	$14.80	$0.00

[51] The eight largest cities in California are Fresno, Long Beach, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, and San Jose.

[52] Wasted irrigation water, about 50 percent of flow rate for spray sprinkler bodies (AWE 2016), may be lost to runoff to sanitary sewers, storm sewers, surface water, or deep percolation. The Statewide CASE Team has not quantified the cost avoided from reduced runoff to sanitary sewers and stormwater collection systems or surface waters because the Energy Commission determines cost-effectiveness from a consumer cost perspective.

Table 28: Statewide Average Residential Potable Water and Wastewater Rates 2017-2030 (in $2017)[53]

Year	Res Water ($/1000 gal)	Res Wastewater ($/1000 gal)	Total Water ($/1000 gal)
2017	$6.08	$1.46	$7.54
2018	$6.25	$1.50	$7.75
2019	$6.43	$1.59	$8.02
2020	$6.61	$1.62	$8.23
2021	$6.79	$1.65	$8.45
2022	$6.98	$1.69	$8.67
2023	$7.18	$1.72	$8.90
2024	$7.38	$1.75	$9.13
2025	$7.59	$1.79	$9.37
2026	$7.80	$1.82	$9.62
2027	$8.02	$1.85	$9.87
2028	$8.24	$1.89	$10.13
2029	$8.47	$1.92	$10.39
2030	$8.71	$1.95	$10.66

Note: Totals may not match exactly due to rounding.

Appendix B: Embedded Electricity Usage Methodology

The Statewide CASE Team assumed the following embedded electricity in water values: 4,848 kWh/million gallons of water (MG) for indoor water use and 3,565 kWh/MG for outdoor water use. Embedded electricity use for indoor water use includes electricity used for water extraction, conveyance, treatment to potable quality, water distribution, wastewater collection, and wastewater treatment. Embedded electricity for outdoor water use includes all energy uses upstream of the customer; it does not include wastewater collection or wastewater treatment. The embedded electricity values do not include on-site energy uses for water, such as on-site pumping. On-site energy impacts are accounted for in the energy savings estimates presented in this report.

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011 (CPUC 2013). The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by CPUC on embedded energy in water throughout California (CPUC 2015a, 2015b). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. Since accurate estimates of the embedded natural gas in water were not available at the time of writing, this CASE Report does not include estimates of embedded natural gas savings associated with water reductions.

The CPUC embedded electricity values used in the CASE Report are shown in Table 29. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU supplied and non-IOU supplied). The CPUC calculated the energy intensity of marginal supply, but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 29: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh per acre foot (AF))

Table 16. Total (IOU + Non-IOU) Energy Intensity (KWh/AF)

Region	Extraction, Conveyance, and Treatment	Distribution	Wastewater Collection + Treatment	Outdoor (Upstream of Customer)	Indoor (All Components)
NC	235	163	418	398	816
SF	375	318	418	693	1,111
CC	513	163	418	677	1,095
SC	1,774	163	418	1,937	2,355
SR	238	18	418	255	674
SJ	279	18	418	297	715
TL	381	18	418	399	817
NL	285	18	418	303	721
SL	837	163	418	1,000	1,418
CR	278	18	418	296	714

Hydrologic Region Abbreviations:
NC = North Coast, SF = San Francisco Bay, CC = Central Coast, SC = South Coast, SR = Sacramento River, SJ = San Joaquin River, TL = Tulare Lake, NL = North Lahontan, SL = South Lahontan, CR = Colorado River
Source: Navigant team analysis

Source: CPUC 2015b.

The Statewide CASE Team used CPUC outdoor embedded electricity estimates by hydrologic region and population data from the U.S. Census Bureau (separated by hydrologic region) to calculate the statewide population-weighted average outdoor embedded electricity values that were used in the CASE Report (see Table 30). The energy intensity values presented in Table 29 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE Report. There are 3.07 acre feet per million gallons.

Table 30: Statewide Population-weighted Average Embedded Electricity in Water

Hydrologic Region	Outdoor Water Use[1] (kWh/ million gallon)	Percent of California Population[2]
North Coast	1,221	2.1%
San Francisco	2,127	18.2%
Central Coast	2,078	3.8%
South Coast	5,944	44.8%
Sacramento River	783	8.1%
San Joaquin River	911	4.7%
Tulare Lake	1,224	6.3%
North Lahontan	930	0.1%
South Lahontan	3,069	5.5%
Colorado River	908	6.5%
Statewide Population-weighted Average	**3,565**	

Sources: [1] CPUC 2015b; [2] U.S. Census Bureau 2014 and California Department of Conservation 2007

Appendix C: Additional Details for Check Valve Water Savings

This Appendix describes in additional detail several main components of the check valve water savings methodology described in Section 6.4. The first section of this appendix describes how the observed frequency of slopes in developed land was determined. The second section describes example irrigation system layouts used in this analysis. The third describes how the water savings for each of the example piping layout scenarios was calculated on a total and per unit basis for slope increments between one and 12 percent. A weighted average per unit savings estimate was then calculated based on a statewide distribution of slopes.

GIS Characterization of California Landscaped Area Slope

The Statewide CASE Team used GIS elevation and land cover datasets for California to determine the frequency of the various slope percentages across developed land in California with less than 50 percent hardscape. Hyphae Design Labs led this GIS analysis based on the following steps:

1. GIS datasets for California elevation (USGS 2015) and land cover (NGCE 2011) were downloaded. Both datasets are composed of cells 30 meters by 30 meters (one arc-second) for the whole state with a relative vertical accuracy of 1.64 meters for the elevation data, which accounts for random errors (USGS 2007).
2. The land cover dataset classifies land into developed land subcategories and undeveloped land subcategories, as well as others. Subtypes of developed land in both databases are differentiated based on percentage of impervious surfaces: open space (less than 20 percent) consisting of single-family housing, parks, etc.; low (20 to 49 percent) consisting primarily of single-family homes; medium (50 to 79 percent); and high (80 to 100 percent).
3. The elevation and land cover datasets were loaded into GIS and matched to each other using geographic coordinates.
4. The GIS Raster Mosaic Tool was used to merge the two datasets and allow correlation of land type and elevation for each cell. This tool takes a dataset of 30 by 30 meter cells and merges it into a single "mosaic."
5. A slope analysis of the merged datasets was prepared. GIS calculates the slope for each cell based on the maximum elevation difference between each cell and its neighboring cells. Analysis cells are defined as 30 by 30 meters.
6. Slope statistics were aggregated for each type of developed land into a series of 1 percent bins ranging from 0.50 percent to 12.50 percent, with two additional bins for less than .50 percent and greater than 12.50 percent. For instance, values between 0.50 percent and 1.50 percent slope are aggregated into the one percent slope bin. The data is summarized and presented for the median of each bin.
7. The results of the slope analysis were exported for each subcategory of developed land to determine the percentage of each developed land area subtype that falls into each slope bin. Results for open space and low-intensity developed land were selected as most representative of irrigated landscapes, as these categories contain between zero and 50 percent hardscape. These two categories combined cover 66 percent of the state's developed land area.

8. The elevation across a limited set of 30 by 30 meter cells in Lake Merritt, Oakland, was compared to review the comparative accuracy of the GIS data for a series of contiguous cells as compared to the 1.64-meter relative accuracy statewide. The GIS analysis returned the same elevation for each of these contiguous cells, indicating that the accuracy of the relative elevation of contiguous cells should be high.

As an example, an area of San Francisco was selected (see Figure 7) with GIS elevation data shown for that selected area (see Figure 8). The elevation data resulted in the outputs in Figure 9.

Figure 7: Sample San Francisco analysis area

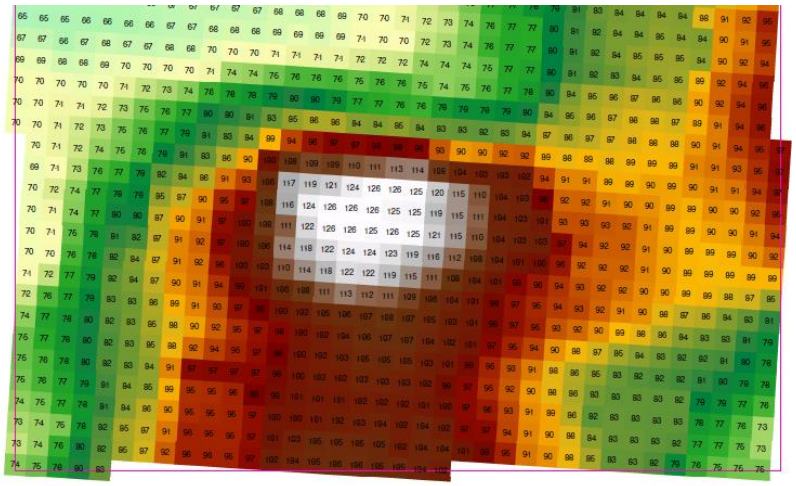


Figure 8: GIS elevation data for selected San Francisco area (meters above sea level, partial results)

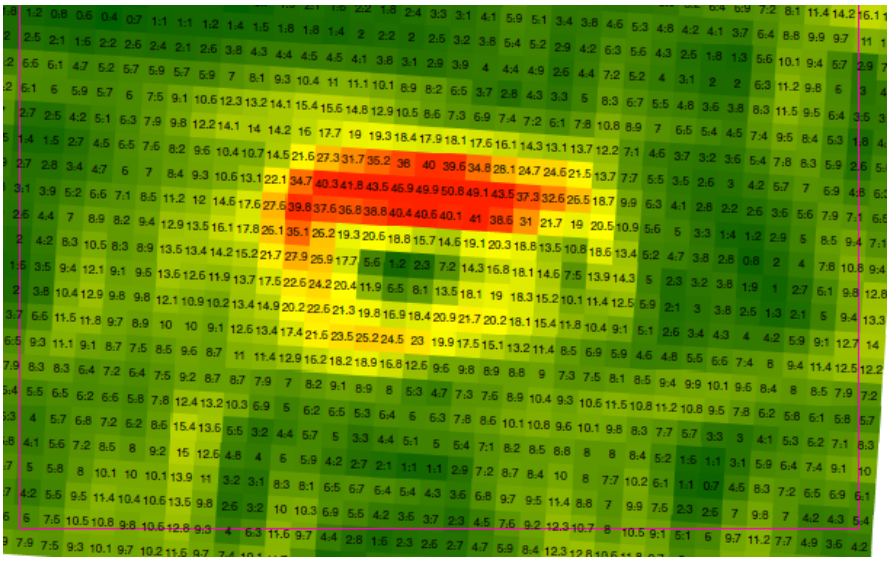


Figure 9: GIS slope analysis output for selected San Francisco area (percentage, partial results)

To review the comparative accuracy of the GIS data, Hyphae also completed a slope analysis of a limited set of 30 by 30 meter cells in Lake Merritt in Oakland, California, where no changes in elevation were expected. The following images in Figure 10 present the results.

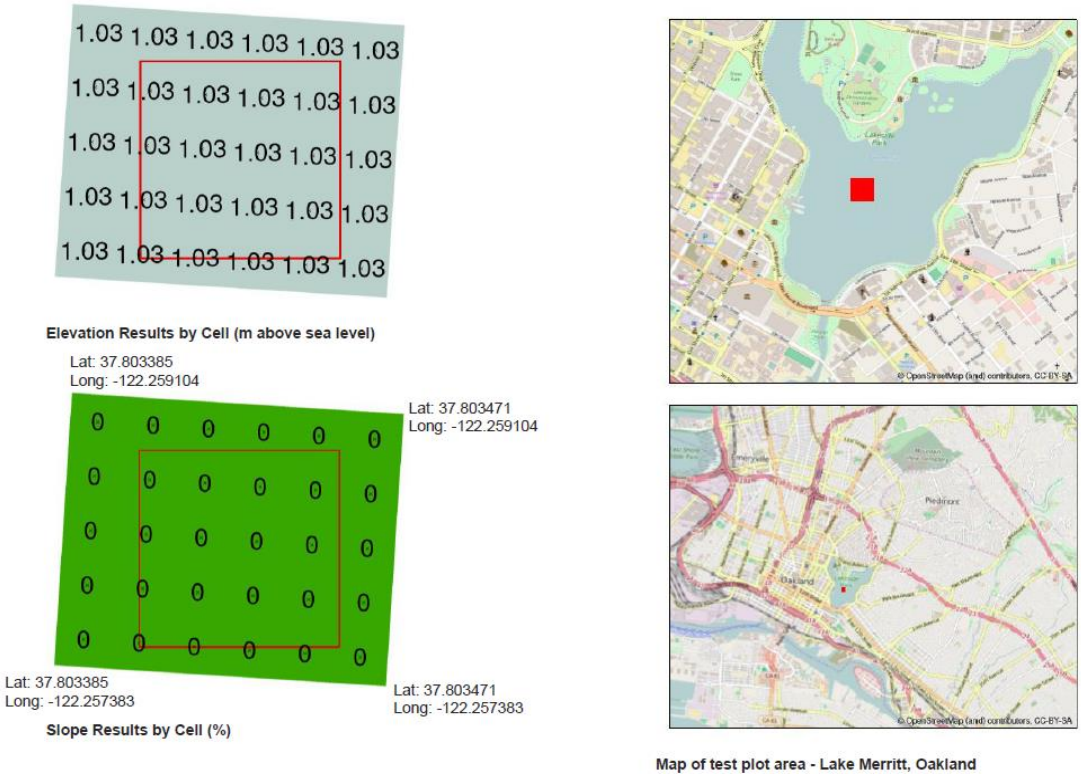


Figure 10: Slope analysis of Lake Merritt section, Oakland, CA

Example Irrigation System Layouts

The sample irrigation piping layouts shown below were used to model the volume of water remaining in the irrigation system piping just as irrigation ends and drainage potentially occurs; and also to estimate the number of spray sprinklers as shown below in Figure 11. These example layouts are based on dimensions provided by MWD (Metropolitan Water District 2006). The solid blue lines in each scenario represent the irrigation piping and the circles represent fixed-pattern spray nozzles. The nozzles used in this layout are assumed to have a 15-foot radius (see below for information regarding this assumption), and the nozzle pattern is indicated as follows: "Q" for quarter-circle nozzle, "H" for half-circle nozzle, and "F" for full-circle nozzle. In this case of nozzles with a shorter radius, there will be less linear feet of pipe per spray sprinkler body; the reverse is also true for units with a longer radius.

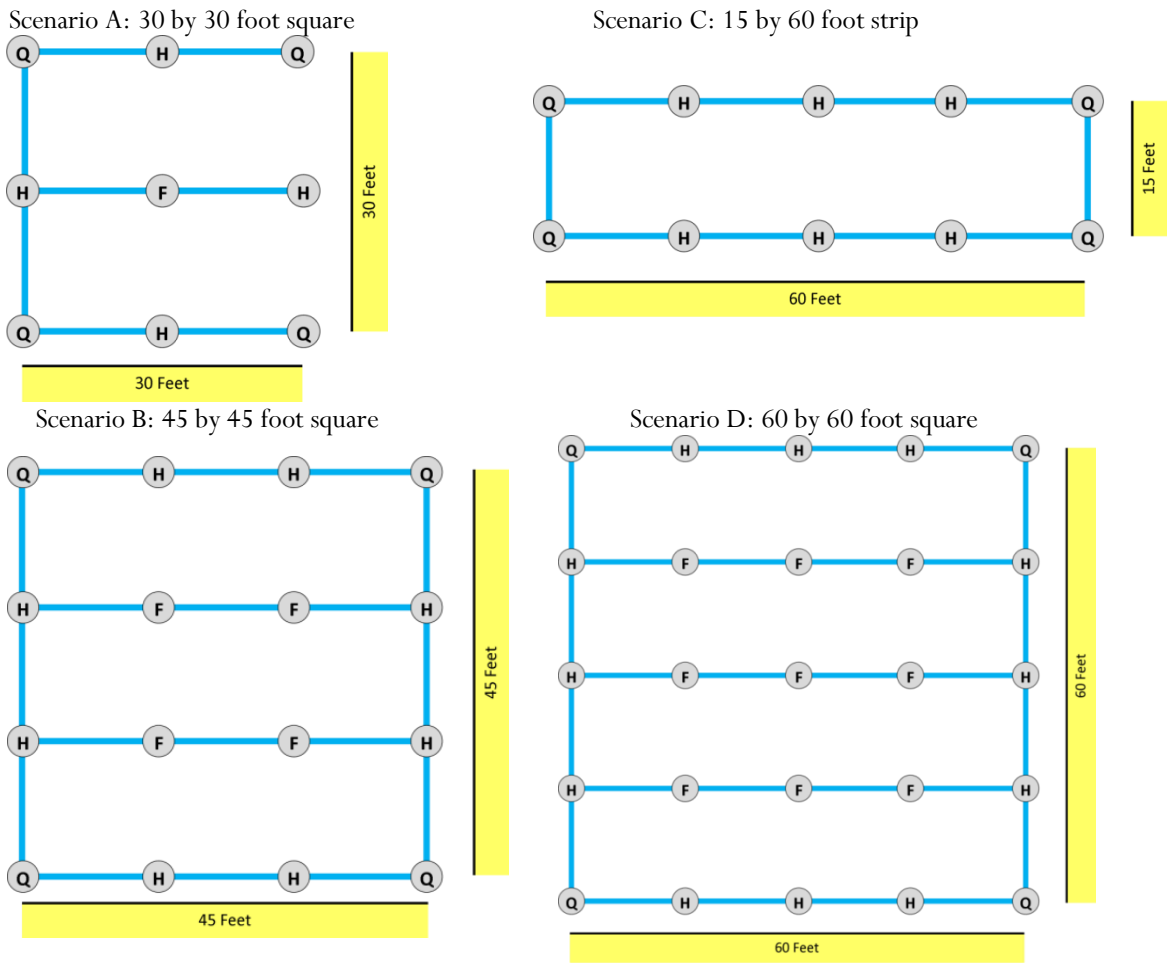


Figure 11: Sprinkler layout and supply piping diagrams

Check Valve Water Savings Calculations

As noted in the main report, the Statewide CASE Team modeled the quantity of water that would drain out of the landscape irrigation system supply pipe in the absence of check valves when the landscape irrigation system is not in operation.

The volume of drainage is based on the total volume of entrained water in the system supply pipe times the percent of pipe above the elevation of the lowest spray sprinkler (when retracted). The total volume of entrained water in the pipeline is based on the cross-sectional area of the supply pipe times the total length of pipe (Equation C.1). The percent of supply pipe above the lowest spray sprinkler head is determined based on the length of pipe, the slope, and the depth of pipe below grade (Equation C.2). For instance, 50 percent of a pipe buried 9 inches below grade with a maximum rise of 18 inches would exceed the lowest sprinkler height and drain between periods of operation.

Equation C.1

$$\text{Volume of entrained water} = \left(\frac{\text{pipe diameter}}{2}\right)^2 * 3.14 * \text{ total pipe length}$$

Equation C.2

$$\text{Percent of pipe exceeding lowest sprinkler height} = \left(\frac{(\text{maximum pipe rise} - \text{pipe depth})}{\text{pipe depth}}\right)$$

The assumptions used for the check valve water savings calculation are listed in Table 31 below. For instance, the Statewide CASE Team estimates that the typical depth of the supply pipeline would be nine inches below ground for protection from damage, to allow sufficient depth to accommodate the height of spray sprinkler bodies, and for convenience when installing connectors from supply pipe to the spray sprinkler bodies. This depth is also the mid-point of the typical values specified by Rain Bird (2016).

Table 31: Assumptions for Baseline Water Use

Metric	Value	Units	Source
Pipe diameter	1	inch	Typical industry practice
Pipe depth	9	inches	Rain Bird 2016
Watering schedule	4	cycles per week	Assume 2 days per week, 2 cycle & soaks per day
	32	weeks per year	Rain Bird 2010; Hunter 2016
Head spacing	15	feet	Approximation based on 85 percent/15 percent market share of fixed and rotating nozzles as shown in Eqn. D-3

The number of spray sprinkler bodies for each scenario is based on an assumed 15-foot average head spacing (see Equation C.3 below). This spacing is based on an assumed market share of 85 percent fixed nozzles (11-foot radius) and 15 percent rotating nozzles (30-foot radius) based on informal industry input.

Equation C.3

$$\text{Average head spacing} = \sqrt{85\% * 11^2 + 15\% * 30^2}$$

For example, a 45-foot pipe with a five percent slope would have two-thirds of its length above the lowest sprinkler head, as shown in Figure 12 showing a side view of a pipe and sprinkler head configuration for piping layout in Scenario B. The total entrained water is 11 gallons (total pipe length is 270 feet) and the total water leakage during non-operation is 7.4 gallons per cycle in this example. The Statewide CASE Team assumed that changes in supply pipe elevation due to slope occur only along the longest dimension of

the supply piping system. Since additional elevation changes can also occur across the other dimension, the resulting estimates of pipe rise may be conservative.

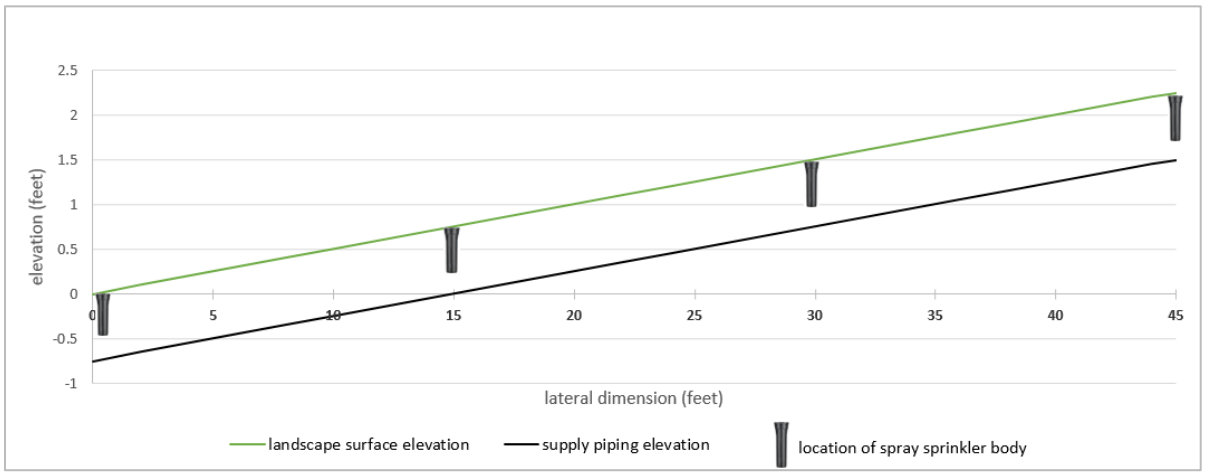


Figure 12: Illustration of supply pipe elevation versus lateral pipe run

Note: Water supply piping above 0 feet of elevation will drain in the absence of a check valve when the sprinkler system is not in operation.

After determining the quantity of water lost per cycle, the Statewide CASE Team determined the total annual quantity based on the estimated number of annual watering cycles using the assumptions in Table 31. The Statewide CASE Team then determined the per unit baseline annual water lost based on the total lost for Scenarios A-D, and divided by the total number of spray sprinkler bodies for Scenarios A-D.

The per unit results for each slope bin, along with a total weighted average, are shown in Table 32 below and Table 5 in the main report. These results do not account for potential increased water savings in slopes greater than 12 percent, nor the potential decreased water savings in situations where severe slopes could exceed the holding capacity of a check valve.

Table 32: Results of Baseline Water Loss Evaluation Due to Slope

Slope	Annual per Unit Baseline Water Loss (gallons)	Share of Developed Lands with < 50% Hardscape in this Slope Bin
0%	0	17.5%
1%	0	15.5%
2%	23	9.5%
3%	41	6.3%
4%	52	4.9%
5%	58	3.9%
6%	62	3.3%
7%	65	2.9%
8%	68	2.6%
9%	69	2.3%
10%	71	2.1%
11%	72	1.9%
12%	73	1.8%
> 12%[54]	74	25.7%
Statewide	**40**	**100%**

54 Potential incremental losses for slopes above 12 percent were considered small and were not calculated. The greater than 12 percent slope category represents 13 percent slope.

Appendix D: Data Tables

This Appendix contains additional data to support analysis in the main report. This Appendix contains data on windspeed; evapotranspiration; WaterSense testing data; and regional population and housing data.

Table 33: California Irrigation Management Information System Wind Speed Weather Data (meters/second)

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
ALTURAS AIRPORT ASOS	1998-2006	4.9	5.5	6.4	7.2	7	6.7	6	5.3	4.4	4.1	4.4	4.9	**5.5**
ARCATA AIRPORT ASOS	1996-2006	6.9	7.4	7.4	7.2	7	7.2	6.3	5.6	5.3	5.1	6	7.1	**6.5**
AUBURN AIRPORT AWOS	2002-2006	4.3	5.2	6.1	5.9	5.6	5.4	5.8	5.2	5.1	4.3	4.1	5.5	**5.2**
AVALON-CATALINA AP ASOS	2000-2006	7.9	8.8	8.8	9.2	6.8	5.7	5.4	5.5	6.4	6.7	7.5	8	**7.2**
BAKERSFIELD AP ASOS	1996-2006	4.6	5.6	6	7.1	7.3	7.7	7.2	6.8	6.3	5.2	4.5	4.8	**6.1**
BEALE AFB	1996-2006	6.8	8	7.4	8.3	7.6	7.9	7.2	6.8	6.7	6.7	6.6	7.7	**7.3**
BISHOP AIRPORT ASOS	1996-2006	6.8	8.2	9.6	10.4	9.2	8.8	8.1	8.3	8.1	8	7.1	7.1	**8.3**
BLUE CANYON ASOS	1996-2006	5.8	5.9	5.9	5.9	5.2	4.8	4.4	4.4	5.1	5.3	5.4	6.9	**5.4**
BLYTHE AIRPORT ASOS	1996-2006	6.6	7.2	7.8	9.3	8.9	9.4	9.6	8.7	7.5	6.8	6.1	6.7	**7.9**
BURBANK AIRPORT ASOS	1996-2006	4.8	5.8	5.7	6.7	6.4	6.3	6.8	6.1	5.5	4.8	4.2	4.8	**5.6**
CAMARILLO AIRPORT ASOS	1996-2006	6.3	7.4	6.4	6.7	5.8	5.6	5.1	4.9	4.8	5.4	6	7.5	**6**
CAMP PENDLETON MCAS AP	1996-2006	3.2	3.9	4.1	4.8	4.8	4.8	4.8	4.5	4.1	3.7	3.1	3	**4.1**
CAMPO ASOS	1997-2006	8.5	9.1	8.4	8.7	8	7.9	7.4	7.2	7.5	8.1	8.1	9.5	**8.2**
CARLSBAD AIRPORT ASOS	1996-2006	4.3	5.4	5.3	5.8	5.6	5.5	4.9	4.8	4.4	4.3	4.1	4.3	**4.9**
CHINA LAKE-ARMITAGE FLD	1996-2006	6.4	7.4	9.1	11.1	10.1	10.2	8.9	8.8	7.9	7.2	6.4	6.2	**8.3**
CHINO AIRPORT ASOS	1996-2006	4.5	5.2	5.7	6.5	7.2	7.2	6.9	6.5	5.6	5	4.5	4.8	**5.8**
CONCORD-BUCHANON FIELD	1996-2006	5.6	6.2	7.6	9.1	9.9	11.4	11.1	10	8.1	6.7	5.4	5.7	**8.1**
CRESCENT CITY AP ASOS	1996-2006	10	10	9.8	9.4	8.5	8.7	7	6.5	7.2	7.5	8.6	9.9	**8.6**
DAGGETT-BARSTOW AP ASOS	1996-2006	8.5	9.5	11.5	14.3	14.8	14.6	12.1	11.2	10.5	9.7	8.7	7.9	**11.1**
EDWARDS AFB	1996-2006	8.7	10.1	11.1	13.1	13.7	13.8	12	10.8	9.6	9.2	8.3	8.2	**10.8**
EL CENTRO NAF	1996-2006	5.7	6.7	8.2	10.7	8.7	8.9	7.5	6.7	7.1	6.9	5.4	5.4	**7.3**
FAIRFIELD-TRAVIS AFB	1996-2006	8	9.5	11	12.9	14.9	16.9	17.7	16.2	14.3	11.7	8.4	8.9	**12.7**
FRESNO AIRPORT ASOS	1996-2006	4.3	5.1	5.8	7.4	8.8	9.1	7.9	7.2	6.1	4.6	3.9	4.1	**6.1**
FULLERTON AIRPORT ASOS	1996-2006	3.3	4.3	4.4	5.1	4.8	4.9	4.4	4	3.8	3.3	3.1	3.2	**4**
HANFORD AIRPORT ASOS	1998-2006	3.4	4.2	5.2	6.5	7.9	7.8	6.5	6.3	5.2	4	3.2	3.4	**5.3**

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
HAWTHORNE AIRPORT ASOS	1998-2006	3.3	4.7	5.4	6.4	6.1	6.2	6.1	5.7	5.2	4.2	3.2	3	**4.9**
HAYWARD AIRPORT ASOS	1996-2006	5.5	6.8	7.7	9	9.2	9.4	8.6	8.2	7.1	6	5.5	5.9	**7.4**
IMPERIAL AIRPORT ASOS	1996-2006	5.8	7	8.4	10.5	9.3	9.4	8.3	7.6	7	6.6	5.8	5.5	**7.5**
IMPERIAL BEACH NAS	1996-2006	6.6	8.2	8	9.3	8.6	8.9	9	8.5	8.2	7.2	6.5	7	**8**
LANCASTER-WJ FOX FLD	1996-2006	8.2	9.8	11.8	14	15.3	15.5	13.1	11.4	10.1	9.3	8.5	8.1	**11.2**
LEMOORE NAS	1996-2006	5.6	6.9	8.2	10	10.6	9.8	8.1	7.9	7.5	6.8	6	5.9	**7.8**
LIVERMORE AIRPORT ASOS	1998-2006	4.9	5.5	6	7.3	8.3	9.3	9.1	8.4	6.8	5.6	4.7	5.2	**6.8**
LOMPOC AIRPORT AWOS	1996-2006	5.7	6.9	7.2	7.6	8.6	8.5	7.7	7.1	6.1	6	6.1	6	**7**
LONG BEACH AIRPORT ASOS	1996-2006	3.9	5.1	5.3	6.2	5.9	6	6	5.8	5.3	4.5	3.8	3.8	**5.1**
LOS ANGELES INTL AP	1996-2006	6.9	8.3	8.2	9.3	8.4	8.4	8.3	7.9	7.7	7	6.5	6.6	**7.8**
LOS ANGELES-DOWNTOWN	1999-2006	1	1.3	1.7	2.1	1.8	1.6	1.4	1.3	1	0.8	0.8	0.8	**1.2**
MADERA AIRPORT ASOS	1998-2006	5.2	5.9	6.2	7.4	8.4	8.6	7.5	7.1	6	5.2	4.7	5.3	**6.4**
MARYSVILLE-YUBA CTY AP	1996-2006	6.8	8	8.1	8.6	8.3	8.6	7.9	7.3	6.9	6.7	6.3	7.6	**7.6**
MERCED AIRPORT ASOS	1998-2006	4.7	5.5	5.9	7	8.1	8.4	7.7	7.1	5.9	5	4.4	5.1	**6.2**
MIRAMAR MCAS	1996-2006	6	6.6	6	6.5	5.7	5.7	5.3	5.4	5.5	5.6	5.7	6.1	**5.8**
MODESTO AIRPORT ASOS	1996-2006	5	6.2	7	7.8	8.9	9.4	8.6	8.1	6.9	6	5	5.6	**7**
MONTAGUE-SISKIYOU CY AP	1996-2006	5.3	6.6	7.2	6.9	7.1	7.7	6.4	6.2	5.4	5	5	5.4	**6.1**
MONTEREY AIRPORT ASOS	1996-2006	5.2	6.1	6.5	7.2	7.3	7.6	6.7	6.3	5.3	5.1	5.1	5.6	**6.2**
MOUNT SHASTA ASOS	1996-2006	2.3	3	3.7	3.8	3.4	3.7	1.8	1.5	2.3	2.5	2.3	2.9	**2.7**
MOUNTAIN VIEW-MOFFETT	1996-2006	4.2	5.6	6	6.8	7.5	8	7.7	7.1	5.8	4.8	4.2	4.8	**6**
NAPA AIRPORT ASOS	1997-2006	7.2	6.9	7.4	8.9	9.3	10.4	10.2	9.5	7.7	6.4	5.8	7.1	**8.1**
NEEDLES AIRPORT ASOS	2001-2006	8	8	8.2	9.4	9	9.3	8.5	8	8.2	7.5	7.8	7.6	**8.3**
NORTH ISLAND NAS	1996-2006	5.5	6.9	7	7.9	7.1	7.5	7.1	7	6.9	6	5.3	5.3	**6.6**
OAKLAND INTL AP ASOS	1996-2006	6.8	8.3	9	10.4	10.4	10.4	10.2	9.6	8.5	7.5	7	7.6	**8.8**
OCEANSIDE AIRPORT ASOS	1999-2006	3.9	4.4	4.4	4.7	4.8	4.8	4.5	4.2	4	3.6	3.5	3.5	**4.2**
ONTARIO INTL AP ASOS	1996-2006	5.2	5.7	6.3	6.9	7.2	7.3	7	6.5	5.8	5.6	5.2	5.7	**6.2**
OROVILLE AIRPORT ASOS	1998-2006	5.9	7	7.2	7.7	7.1	7	6.4	5.9	5.6	5.5	5.5	6.6	**6.4**
OXNARD AIRPORT ASOS	1996-2006	7.1	8.2	7.7	8.3	7	7.1	7.2	6.9	6.6	6.4	6.8	7.7	**7.2**
PALM SPRINGS AP ASOS	1996-2006	5.7	5.9	7.3	9	9.6	9.2	8.2	7.5	7.5	6.8	6	5.7	**7.3**

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
PALMDALE AIRPORT ASOS	1996-2006	8.1	9.2	10.4	12.5	12.6	12.8	11.5	10.3	9.3	8.9	7.9	8.1	**10.1**
PALO ALTO AIRPORT	1996-2006	7	8.9	9.8	10.3	11.2	11.6	11.4	10.7	9.3	8.2	7	6.8	**9.4**
PASO ROBLES AP ASOS	1996-2006	5	5.9	6.3	7.7	9.1	9.9	8.6	7.9	6.5	5.5	4.7	5	**6.8**
POINT MUGU NAS	1996-2006	7.3	8.5	7.8	8.3	7.4	7.2	6.8	6.6	6.2	6.6	6.9	8.4	**7.3**
POINT PIEDRAS BLANCAS	1996-2005	9.2	10.2	10.8	12.9	14.1	13	11.2	11.4	10	9.6	8.7	9.2	**10.9**
PORTERVILLE AP AWOS	1996-2006	3.7	4.3	4.5	5.2	5.7	6	5.9	5.6	5.1	4.3	3.7	3.7	**4.8**
RAMONA AIRPORT ASOS	1998-2006	4.5	5.3	5	5.2	5	5.2	5.2	4.9	4.6	4.6	4.4	4.6	**4.9**
RED BLUFF AIRPORT ASOS	1996-2006	7.4	8.9	8.7	8.9	8.5	8.8	7.2	7	7.5	7.7	7.5	8.7	**8**
REDDING AIRPORT ASOS	1996-2006	5.2	6.8	6.4	6.9	6.6	6.9	5.7	5.4	5.7	5.7	4.9	6.2	**6**
RIVERSIDE AIRPORT ASOS	1998-2006	5	5.2	4.9	5.1	5.6	5.8	5.5	5.1	4.4	4.1	4.3	5.4	**5**
RIVERSIDE-MARCH AFB	1996-2006	5.2	5.9	5.4	6	6.2	6.2	6.2	6	5.5	5.3	5	5.6	**5.7**
SACRAMENTO EXEC AP ASOS	1996-2006	5.5	6.4	6.8	7.6	7.5	8.2	7.8	7.2	6.3	5.8	5	6	**6.6**
SACRAMENTO INTL AP ASOS	1996-2006	6.9	8	7.9	8.7	8.6	9.4	9	8.4	7.6	7.3	6.4	7.7	**8**
SACRAMENTO-MATHER AP	2000-2006	4.8	5.8	6.5	6.8	6.7	7.2	6.9	6	5.7	5.2	4.6	6.2	**6**
SACRAMENTO-MCCLELLAN AF	1992-2000	7.7	8.1	7.5	8	7.9	8.7	8.8	8.5	7.4	6.8	6.3	7.9	**7.8**
SALINAS AIRPORT ASOS	1996-2006	7.3	8.1	7.7	8.4	9.2	9.8	9.1	8.4	7.5	6.9	6.9	7.8	**8.1**
SAN CARLOS AIRPORT	1996-2006	8.2	9.5	10.6	11.5	12.1	12.7	11.8	11.3	10.3	9.4	8.5	8.6	**10.5**
SAN DIEGO-BROWN FIELD	1996-2006	5.6	6.7	6	6.4	5.9	5.6	5.3	5	5	5.1	5.5	6	**5.7**
SAN DIEGO-GILLESPIE FLD	1996-2006	3.8	5.4	6.1	7.4	7.1	7	6.9	6.8	6.4	5.5	4.1	3.7	**5.9**
SAN DIEGO-LINDBERGH FLD	1996-2006	4.8	6.1	6.6	7.4	7	7.2	6.9	6.8	6.5	5.6	4.8	4.5	**6.1**
SAN DIEGO-MONTGOMERY AP	1996-2006	4.6	5.6	5.9	6.7	6.3	6.5	6	6	5.9	5.2	4.6	4.5	**5.6**
SAN FRANCISCO INTL AP	1996-2006	6.7	8.2	10.2	12.1	13.6	14.1	12.9	12.3	10.6	9	7.2	7.2	**10.3**
SAN JOSE INTL AP ASOS	1996-2006	5.4	6.6	7	8	8.2	8.4	7.7	7.4	6.5	5.8	5.3	6	**6.8**
SAN JOSE-REID HILLVIEW	1996-2006	5.3	7.2	8.1	9.3	9.7	9.8	8.8	8.5	7.5	6.5	5.5	5.9	**7.7**
SAN LUIS OBISPO AP ASOS	1996-2006	5.4	6.5	7.4	8.2	9.3	8.5	7.6	7.7	7.1	6.5	5.8	5.3	**7.1**
SAN NICOLAS ISLAND NAS	1996-2006	11.1	13.1	13	14.8	13.2	12.5	11.6	12	11.9	10.8	11.8	11.8	**12.3**
SANDBURG ASOS	1996-2006	14.3	15.4	14.6	14.7	15.5	14.5	12.1	11.9	12.1	13.1	14.1	15.5	**14**
SANTA ANA AIRPORT ASOS	1996-2006	4.3	5.2	5.7	6.4	6.7	7	6.7	6.3	5.6	4.9	4.4	4.4	**5.6**
SANTA BARBARA AP ASOS	1996-2006	4.2	5.7	5.8	6.6	6	6	5.9	5.5	5.2	4.5	4.1	4.1	**5.3**

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
SANTA MARIA AP ASOS	1996-2006	5.7	6.7	7.2	7.8	8.3	7.7	6.5	6.1	5.6	5.7	5.8	5.8	**6.5**
SANTA MONICA AP ASOS	1996-2006	5.1	6.1	6.2	7	6.7	6.8	6.5	6.2	5.7	5.1	5	5.3	**6**
SANTA ROSA AIRPORT ASOS	1996-2006	3.5	4.8	5.4	5.8	6	6.3	5.8	5.3	4.7	4.2	3.6	4.1	**4.9**
SOUTH LAKE TAHOE AP ASOS	1996-2006	5.5	5.7	6.7	7.5	6.9	6.6	5.9	5.8	5.6	5.4	6	6.1	**6.1**
STOCKTON AIRPORT ASOS	1996-2006	6.2	7.3	7.4	8.8	9.6	10	8.7	8.3	7.4	6.4	5.7	7	**7.7**
THERMAL AIRPORT ASOS	1996-2006	5.1	5.7	7.6	9.2	9.3	9	7.4	6.6	6.8	6.2	5.2	4.9	**6.8**
TORRANCE AIRPORT	1996-2006	5.6	7.2	7.9	8.7	8.7	9.4	9.5	9.2	8.5	7.1	6	5.7	**7.8**
TRUCKEE AIRPORT AWOS	1996-2006	3.5	4	4.8	5.5	5.5	5	4.8	4.6	4.2	3.7	4	3.8	**4.4**
TWENTYNINE PALMS EAF	1996-2006	7	7.8	8.5	10.4	9.5	9.7	8.3	7.8	6.9	6.7	6.6	6.9	**8**
UKIAH AIRPORT ASOS	1996-2006	2.6	3.5	4.1	4.6	4.9	5.5	4.5	4	3.2	2.7	2.5	2.9	**3.7**
VACAVILLE AIRPORT ASOS	1998-2006	4.4	5.5	6.3	7.1	7	7.5	7.3	6.7	5.9	5.5	4.4	4.9	**6**
VAN NUYS AIRPORT ASOS	1996-2006	5.9	6.3	5.5	6	5.7	5.7	5.6	5	4.6	4.5	5.1	6.5	**5.5**
VISALIA AIRPORT AWOS	1996-2006	3.3	4	4.3	5.1	5.9	5.9	4.9	4.4	3.8	3.2	3	3.1	**4.2**
WATSONVILLE AP ASOS	1998-2006	3.2	3.8	3.7	5.1	5.1	5.2	4.9	4.6	4.1	3.6	3.1	3.4	**4.1**
Average Windspeed		**5.7**	**6.7**	**7.1**	**8.1**	**8.1**	**8.2**	**7.6**	**7.1**	**6.6**	**6.0**	**5.6**	**6.0**	**6.9**
ETo by month		1.5	2.1	3.5	4.9	6.2	7.0	7.5	6.8	5.2	3.6	2.1	1.4	**4.3**
Annual windspeed weighted by ETo														**7.6**

Source: CIMIS 1999, 2015 (raw data), CASE Team (calculations).

Table 34: Evapotranspiration by Climate Zone (inches)

Climate Zone	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.4	2.48	3.3	4.03	4.5	4.65	4.03	3.3	2.48	1.2	0.62	**32.9**
2	1.24	1.68	3.1	3.9	4.65	5.1	4.96	4.65	3.9	2.79	1.8	1.24	**39.0**
3	1.86	2.24	3.72	4.8	5.27	5.7	5.58	5.27	4.2	3.41	2.4	1.86	**46.3**
4	1.86	2.24	3.41	4.5	5.27	5.7	5.89	5.58	4.5	3.41	2.4	1.86	**46.6**
5	0.93	1.68	2.79	4.2	5.58	6.3	6.51	5.89	4.5	3.1	1.5	0.93	**43.9**
6	1.86	2.24	3.41	4.8	5.58	6.3	6.51	6.2	4.8	3.72	2.4	1.86	**49.7**
7	0.62	1.4	2.48	3.9	5.27	6.3	7.44	6.51	4.8	2.79	1.2	0.62	**43.3**
8	1.24	1.68	3.41	4.8	6.2	6.9	7.44	6.51	5.1	3.41	1.8	0.93	**49.4**
9	2.17	2.8	4.03	5.1	5.89	6.6	7.44	6.82	5.7	4.03	2.7	1.86	**55.1**
10	0.93	1.69	3.1	4.5	5.89	7.2	8.08	7.13	5.1	3.1	1.5	0.93	**49.2**
11	1.55	2.24	3.1	4.5	5.89	7.2	8.06	7.44	5.7	3.72	2.1	1.55	**53.1**
12	1.24	1.96	3.41	5.1	6.82	7.8	8.06	7.13	5.4	3.72	1.8	0.93	**53.4**

13	1.24	1.86	3.1	4.8	6.51	7.8	8.99	7.75	5.7	3.72	1.8	0.93	**54.2**
14	1.55	2.24	3.72	5.1	6.82	7.8	8.68	7.75	5.7	4.03	2.1	1.55	**57.0**
15	1.24	2.24	4.03	5.7	7.44	8.1	8.68	7.75	5.7	4.03	2.1	1.24	**58.3**
16	1.55	2.52	4.03	5.7	7.75	8.7	9.3	8.37	6.3	4.34	2.4	1.55	**62.5**
17	1.86	2.8	4.65	6	8.06	9	9.92	8.68	6.6	4.34	2.7	1.86	**66.5**
18	2.48	3.36	5.27	6.9	8.68	9.6	9.61	8.68	6.8	4.96	3	2.17	**71.5**
Average	**1.5**	**2.1**	**3.5**	**4.9**	**6.2**	**7.0**	**7.5**	**6.8**	**5.2**	**3.6**	**2.1**	**1.4**	**51.8**

Source: CIMIS 1999.

Table 35: U.S. EPA Flow Rate Data: Non-pressure regulated (gallons per minute)

	Manufacturer A			Manufacturer B			Manufacturer C		
Inlet Pressure (psi)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
30	1.51	1.49	1.53	1.51	1.47	1.52	1.52	1.47	1.54
40	1.66	1.60	1.77	1.76	1.93	1.85	1.63	1.75	1.78
60	1.97	1.87	2.07	2.00	2.24	2.16	1.98	2.05	2.17
70	2.10	1.97	2.16	2.15	2.27	2.29	2.26	2.13	2.26
60	1.99	1.88	1.97	1.65	2.20	2.16	1.95	2.00	2.10
40	1.68	1.58	1.72	1.40	1.89	1.86	1.64	1.71	1.71

Table 36: U.S. EPA Flow Rate Data: Pressure regulated (gallons per minute)

	Manufacturer A			Manufacturer B			Manufacturer C			Manufacturer A		
Inlet Pressure (psi)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1a	Sample 1b	Sample 1c
30	1.52	1.53	1.49	1.48	1.51	1.48	1.54	1.50	1.50	1.52	1.48	1.52
40	1.65	1.67	1.61	1.64	1.60	1.76	1.58	1.56	1.61	1.65	1.51	1.52
60	1.65	1.60	1.57	1.68	1.62	1.81	1.68	1.45	1.45	1.65	1.51	1.58
70	1.66	1.59	1.61	1.80	1.68	1.93	1.69	1.50	1.63	1.66	1.57	1.53
60	1.57	1.60	1.60	1.38	1.55	1.64	1.56	1.46	1.54	1.57	1.54	1.54
40	1.51	1.56	1.55	1.28	1.28	1.76	1.49	1.47	1.53	1.51	1.56	1.51

Table 37: U.S. EPA Pressure Data: Non-pressure regulated (psi)

	Manufacturer A			Manufacturer B			Manufacturer C		
Inlet Pressure (psi)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
30	30.14	30.23	29.88	30.06	30.28	30.22	30.03	30.27	30.22
40	39.96	40.04	40.30	39.59	40.28	40.18	40.18	40.04	40.06
60	59.92	59.92	59.90	59.76	60.28	59.72	60.16	59.75	59.96
70	70.04	70.39	69.73	69.94	70.17	69.99	69.90	69.86	69.60
60	60.24	59.86	60.12	59.84	59.97	59.83	59.57	60.01	59.94
40	39.93	40.02	40.10	39.97	39.90	39.79	40.12	39.68	40.11

Table 38: U.S. EPA Pressure Data: Pressure regulated (psi)

	Manufacturer A			Manufacturer B			Manufacturer C			Manufacturer A		
Inlet Pressure (psi)	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1a	Sample 1b	Sample 1c
30	26.43	26.93	27.17	23.89	25.63	19.90	28.97	29.05	27.77	26.43	27.35	27.53
40	32.38	35.75	30.74	30.35	28.95	26.03	32.87	35.36	34.95	32.38	29.20	29.26
60	32.99	33.47	30.63	32.02	29.90	27.78	34.94	31.67	30.00	32.99	30.60	31.57
70	32.95	31.96	30.45	32.02	30.94	28.17	33.93	33.30	32.36	32.95	30.97	30.79
60	29.70	31.00	30.07	22.66	26.32	23.32	30.90	32.18	32.57	29.70	30.64	30.61
40	27.83	29.21	28.37	22.25	19.33	26.86	28.69	31.35	31.46	27.83	29.65	29.28

Table 39: Regional Weighting Factors for ETo and Precipitation

Region	Code	Population	Housing Units
San Joaquin Valley	SJV	3,690,491	1,196,143
Sacramento Valley	Sac	2,527,969	995,443
Los Angeles Basin	LA	22,342,253	7,708,153
Monterey Bay	MB	722,466	260,870
North Coast Valley	NCV	1,347,155	533,166
San Francisco Bay	SFB	6,644,086	2,446,316
Other	Other	1,314,278	480,161
None (under 100,000)	none	934,915	450,622
Total all		**39,523,613**	**14,070,874**

Source: Statewide CASE Team, DOF 2017a and 2017b.

Table 40: County-Level Population and Housing

County	Population (DOF E-1)	Housing Stock (DOF E-5)	Region Code
Alameda	1,645,359	596,936	SFB
Alpine	1,151	1,780	none
Amador	38,382	18,189	none
Butte	226,404	98,871	SAC
Calaveras	45,168	27,908	none
Colusa	22,043	8,112	none
Contra Costa	1,139,513	412,196	SFB
Del Norte	27,124	11,306	none
El Dorado	185,062	90,353	SAC
Fresno	995,975	329,736	SJV
Glenn	28,731	11,130	none
Humboldt	136,953	62,672	Other
Imperial	188,334	57,401	LA
Inyo	18,619	9,515	none
Kern	895,112	296,596	SJV
Kings	149,537	45,408	SJV
Lake	64,945	34,473	none
Lassen	30,918	12,748	none
Los Angeles	10,241,278	3,527,312	LA
Madera	156,492	50,125	SJV
Marin	263,604	111,999	NCV
Mariposa	18,148	10,492	none
Mendocino	89,134	40,894	none
Merced	274,665	85,168	SJV
Modoc	9,580	5,262	none

County	Population (DOF E-1)	Housing Stock (DOF E-5)	Region Code
Mono	13,713	14,048	none
Monterey	442,365	139,821	MB
Napa	142,408	55,559	NCV
Nevada	98,828	53,557	none
Orange	3,194,024	1,083,563	LA
Placer	382,837	162,489	SAC
Plumas	19,819	15,814	none
Riverside	2,384,783	834,652	LA
Sacramento	1,514,770	567,281	SAC
San Benito	56,854	18,510	none
San Bernardino	2,160,256	715,634	LA
San Diego	3,316,192	1,201,517	LA
San Francisco	874,228	392,619	SFB
San Joaquin	746,868	241,021	SJV
San Luis Obispo	280,101	121,049	MB
San Mateo	770,203	277,189	SFB
Santa Barbara	450,663	157,578	Other
Santa Clara	1,938,180	661,875	SFB
Santa Cruz	276,603	105,501	SFB
Shasta	178,605	78,537	Other
Sierra	3,207	2,344	none
Siskiyou	44,688	24,088	none
Solano	436,023	157,555	NCV
Sonoma	505,120	208,053	NCV
Stanislaus	548,057	181,374	Other
Sutter	96,956	34,339	none
Tehama	63,995	27,536	none
Trinity	13,628	8,795	none
Tulare	471,842	148,089	SJV
Tuolumne	54,707	31,477	none
Ventura	857,386	288,074	LA
Yolo	218,896	76,449	SAC
Yuba	74,577	28,305	none

Source: DOF 2017a and 2017b; Statewide CASE Team.

Appendix E: Related Product Categories

Rotor Sprinklers

Rotors apply water to a landscape by means of one or more rotating streams. In rotor sprinklers, the rotor body itself or the internal parts of the rotor body may rotate, unlike the fixed bodies of spray heads.

Impact Rotors

Impact rotors were the first type of rotor technology developed. Impact sprinklers typically contain a "weighted, spring-loaded swim arm attached to the nozzle assembly, which is deflected sideways upon entering the stream of water exiting the nozzle. The swing arm recoils and returns, creating an impact with the nozzle assembly, which causes the sprinkler to rotate." (Barrett, 2003). These products sometimes contain an irrigation valve in their head in order to allow staggered operation across a golf course, park, or other large turf area. Due to the imprecise motion of impact rotors, their loud noise, and the possibility of dirt lodging into the large, open cavity of the rotor casing during irrigation, impact rotors have diminished in popularity in comparison to newer, gear-driven rotors.

Gear-Drive Rotors

In gear-driven rotors, water that moves through the sprinkler turns a set of gears which rotates the nozzle, thus rotating the water stream across the landscape. Gear-driven rotors are smaller and have a lower profile than impact rotors. They are also quieter and require less maintenance. Figure 13 below shows an impact rotor compared to a gear-driven rotor.

Figure 13: Impact rotor (left) vs gear-driven rotor (right)[55]

Like sprays, gear-driven rotors are commonly offered in the pop-up variety. Although cheaper gear-drive rotors are sold with one preinstalled nozzle, many rotors are also offered with interchangeable nozzles that determine the radius and flow rate of the rotor water throw. Compared to sprays, gear-driven rotors

55 Source (left): http://store.Rain Bird.com/media/catalog/product/cache/1/image/9df78eab33525d08d6e5fb8d27136e95/a/g/ag5maxipaw_actioncloseup_2.jpg
Source (right): https://www.orbitonline.com/site_files/feed/products/600/55069_action2_600.jpg

typically operate at a higher recommended pressure of 30 to 100 psi (depending on the model). They are also most often used in larger landscapes due to the larger radius of water throw (15 to 100+ feet). The water throw radius of many rotors can be adjusted by turning a radius reduction screw, and many models offer arc adjustment from 20 to 360 degrees. Gear-driven rotors tend to have fewer available features than sprays, but check valves are available for gear-driven rotors. A couple manufacturers also offer a pressure-regulating rotor body, but this feature is not widely available. In the future, the Energy Commission could evaluate potential standards for this product, especially if the number of products with pressure regulation increases. In the meanwhile, several water suppliers offer rebates for the installation of rotors based on expected water savings.

Valve-in-Head Sprinklers

ANSI ASABE/ICC 802-2014 defines valve-in-head sprinklers as those that contain an integral control valve intended to be operated from a remote location. They are typically impact or gear-drive rotor sprinklers, as described above. Valve-in-head sprinklers are designed to be used in applications where precise control over each sprinkler head is necessary, most commonly in golf courses or other large turf field applications. Due to their high cost (for example, each sprinkler head can cost $100 or more) and complex control requirements, these sprinklers are not typically used in low-cost applications such as residential or smaller commercial landscapes.

Nozzles and Distribution Uniformity

Spray sprinklers utilize nozzles to determine the pattern and radius of the sprinkler water throw. Nozzles are available in a variety of throw patterns, including arcs ranging from 90 to 360 degrees, squares, and strip shapes. Some nozzles allow for the radius of the water throw to be adjusted by turning a radius adjustment screw at the top of the nozzle, allowing for even greater flexibility. Nozzles are often interchangeable to allow for greater flexibility in landscape applications. Nozzles from one manufacturer can also be matched with spray bodies from another manufacturer if they have consistent threads (i.e., depending on whether the spray bodies and the nozzle have compatible threads).

Rotary (or rotator) nozzles are also becoming increasingly available. Rotary nozzles fit onto spray sprinkler bodies; rather than spraying water in a fixed spray pattern, rotary nozzles spray water more slowly and more uniformly in multiple higher-outlet pressure-rotating streams. Rotary nozzles generally have a higher throw radius than traditional sprays, and they also have a higher recommended operating pressure of 40 to 45 psi, as compared to the 30 psi recommended operating pressure for traditional spray nozzles. To reduce potential runoff, rotary nozzles feature a lower precipitation rate than traditional spray nozzles; also, thicker water streams from rotary nozzles allow for greater wind resistance than traditional sprays. Figure 14 below shows the spray pattern of a tradition spray nozzle compared to that of a rotary nozzle.

Figure 14: Traditional spray nozzle (left) vs rotary nozzle (right)[56]

The Statewide CASE Team recognizes the potential benefit of a nozzle standard, but this document does not contain a recommendation for a nozzle standard due to the current lack of a generally accepted metric and test method for spray nozzle operational efficiency.

Distribution uniformity (DU) is currently referenced in standards, such as ANSI ASABE/ICC 802-2014. DU is measured with catch cans that collect spray water and is used in design calculations to ensure that sufficient water is applied so that all areas of a landscape receive sufficient irrigation. Low DU is sometimes used as a proxy for wasted water due to runoff and deep percolation from high water-application spots that exceed plant needs. However, research has found varying results in terms of actual water savings from improved DU, which may be due in part to the ability of soil to redistribute water based on site-specific conditions (CUWCC 2014). In addition, DU does not address overspray, evaporation, or drift. Recent research has also shown that interference between different sprinklers may occur, which is not captured by DU testing of individual nozzles (Zoldoske and Mecham 2015). Thus, some of the key mechanisms for water loss of sprinkler systems are not covered currently by any current test method identified by the Statewide Codes and Standards Team.

U.S. EPA originally intended to establish a WaterSense program for nozzles based on DU. However, U.S. EPA subsequently found that DU lab measurements may not correlate with DU in the field, and it received comments that DU may not be an effective metric for determining water savings. "Based on the lack of field studies demonstrating savings and the public comments received discouraging WaterSense from basing savings on theoretical calculations based on DU, EPA has decided to put specification development for high-efficiency nozzles on hold. WaterSense continues to collect data and would be interested in collaborating with the industry on field studies or other research that would assess tangible savings, develop consensus around a new performance measure, or demonstrate DU as a viable performance measure for high-efficiency nozzles" (U.S. EPA 2015).

Thus, development of a metric and test method for nozzle operational efficiency is an additional future study opportunity for a potential Title 20 Standard. Ideally, a landscape operational efficiency metric for nozzles would address uniformity of water distribution as well as drift, evaporation, overspray, and potential interference between sprinklers. Ideally, a future standard would test equipment under controlled

56 Source (left): https://ak6.picdn.net/shutterstock/videos/3793262/thumb/1.jpg.
Source (right): http://www.waterirrigation.co.uk/media/catalog/category/12_1.png.

air velocity conditions to test for drift. The Statewide CASE Team also notes that system design would likely affect the level of water savings achieved in the field from an improved nozzle.

Quantifying the ability of soil to redistribute water laterally, as noted above, is another area for potential further study. For instance, sandy soils have less capacity to hold and laterally redistribute water from high water-application areas to low water-application areas than soils with more clay content. This factor will influence the potential benefit of improved application uniformity.

Bubblers

Bubblers are irrigation emission devices used to apply irrigation water directly to the plant root zone. They flood the soil, discharging greater than 6.3 gallons per hour as defined under ANSI ASABE/ICC 802-2014. They are typically installed in landscapes designed for specialty applications, such as irrigating trees, flower beds, vegetables, and shrubs. Stand-alone bubblers are generally screwed directly onto a half-inch riser pipe, but bubbler nozzles are also available, which are threaded to fit onto spray head bodies. The watering distance for bubblers is much smaller than that of spray or rotors (only up to approximately three feet). Pressure-compensating bubblers that modulate water output for a range of input pressures are available, but pressure regulation for bubblers can also be achieved by matching a bubbler nozzle with a pressure-regulating spray body. Figure 15 below shows two different types of bubblers: 1) flood or umbrella bubblers which flood a small area, and 2) stream bubblers in which water is shot out away from the bubbler body.

Figure 15: Flood or umbrella bubbler (left) and stream bubbler (right)[57]

Drip Irrigation

Drip emitters are a type of micro-irrigation device intended to discharge a small uniform flow rate of less than or equal to 6.3 gallons per hour when operated at 30 psi (ANSI ASABE/ICC 802-2014). Drip irrigation systems are generally designed to operate in a pressure range of 10 to 30 psi (NMSU 2011), as opposed to spray and rotor sprinkler systems, which operate at or above this level. (For landscapes with water supply pressures above 30 psi, a pressure regulator should be installed on the drip irrigation system valve to avoid damage to system components.)

57 Source (left): http://irrigationrepair.com/images/diyimages/flood_bubbler.jpg.
Source (right): https://s-media-cache-ak0.pinimg.com/736x/d8/9c/5f/d89c5fc04c803ea6ecf54fdc574bfa05.jpg.

Compared to sprinklers, properly designed and maintained drip irrigation systems can save water by reducing evaporation, runoff, and deep drainage since the irrigation water is slowly applied more closely to the plant root system. However, drip irrigation systems may also require more careful maintenance than sprinkler systems.

Drip emitters include line-source emitters and point-source emitters. Due to the variety of types of drip irrigation, it can be used for most types of plant applications. Drip irrigation may also be desirable in situations where waterborne diseases are a concern, such as in edible crop production, since it keeps irrigation water near the root zone of the plant and does not spray irrigation water into the air or onto plant leaves, fruits, or vegetables, like sprays or rotors would.

Line-source Drip Emitters

Drip irrigation systems are typically built using flexible polyethylene tubing. Unlike sprays or rotors, which may have trouble watering landscape plots with irregular shapes or dimensions, the flexibility of drip tubing allows for installation in a variety of geometries. In line-source drip emitter tubing, drip emitters are placed in the tubing walls at spaced intervals. Line-source drip emitters are typically used in applications where plants are evenly spaced, such as gardens or orchards. For residential and commercial applications, typical in-line emitter spacing intervals are 12, 18, and 24 inches, and typical water emission flow rates range from 0.5 to one gallon per hour. Line-source drip emitters include rigid drip line tubing, as well as thin and flexible drip tape, which is less durable and often replaced after a couple growing seasons (often used for agricultural applications).

Pressure-compensating drip line emitters are also available, which aim to provide a uniform water flow rate across a range of inlet pressures. Even without pressure-compensating emitters, most drip systems will have some degree of pressure reduction since the long pipe length and small pipe diameter of drip tubing will naturally reduce water pressure. Figure 16 below shows a drip line emitter, drip tape line-source drip emitter, and point-source drip emitter.

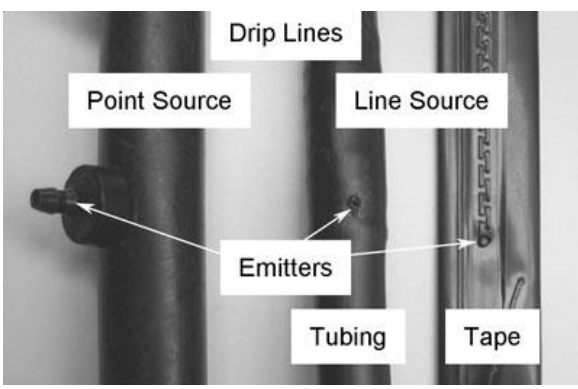


Figure 16: Types of drip emitters[58]

Point-source Drip Emitters

Point-source drip emitters emit water at a single point and are often used to irrigate irregularly spaced plants such as trees and bushes where drip line might be insufficient. Typical water emission flow rates range from 0.5 to 4 gallons per hour. Point-source emitters can be punched directly into polyethylene

58 Source: http://aces.nmsu.edu/pubs/research/agmech_eng/rr-773/welcome.html

tubing with attached barbs or they can be threaded onto tubing. Types of point-source drip emitters are shown in Figure 17 below.

As with drip line emitters, pressure-compensating point-source emitters that maintain a constant flow output for a range of inlet pressures are also available. Pressure compensation is useful for ensuring that irrigation water is applied evenly. However, it is not recommended for flat landscapes with very low water pressure, such as landscapes that use low-pressure gravity-fed irrigation from on-site water barrels.

Point-Source Emitter Type	Example Product
Turbulent flow path emitters, which route water through a complex water path to reduce flow rate and minimize clogging.	Netafim BD
Take apart or flag emitters, which have an open flow path. Although they are more likely to clog than turbulent flow emitters, they are a low-cost option which works well at very low pressures.	Toro E-2
Diaphragm emitters, which contain a flexible diaphragm which helps to adjust for varying water pressures.	DIG PC Drip Emitter

Figure 17: Types of point-source emitters

Opportunities for potential Drip Emitter standards

While this document does not contain recommended standards for drip (line and point) emitters, they could be considered for a future Title 20 standard based on ANSI ASABE/ICC 802-2014 or other standards. For instance, ANSI ASABE/ICC 802-2014 requires that product flow rates, as a function of inlet pressure, fall within +/- 7 percent of manufacturer published values. The standard also contains a requirement for devices with pressure regulation. Similar types of requirements could also be studied for other microspray devices.

Microspray

Another type of irrigation emission device that is gaining popularity is the microspray. A blend between traditional spray sprinklers and drip irrigation, these devices are designed to operate at lower pressure and emit irrigation water near a plant root zone. Microsprays are typically marketed for agricultural uses and not commonly used for landscape irrigation. If agriculturally focused microspray incentives or standards are applied to this product, then the residential landscape market would likely also see impacts.

Landscape Irrigation Audits

The Statewide CASE Team also received feedback during the development of this document regarding the importance of proper landscape irrigation system design and post-installation audits to verify proper design and installation. The Statewide CASE Team recognizes the importance of verifying proper irrigation system design and installation to complement equipment standards. Several organizations provide training that includes this topic and U.S. EPA WaterSense includes a list of certified professionals on its website (2017b). The Statewide CASE Team also notes that the draft ITP report recommends several opportunities to strengthen the MWELO irrigation audit requirements for new landscapes. In addition, local jurisdictions have authority to adopt the ITP recommendations and/or other regulations under their authority to achieve equal or greater water savings than the MWELO.

Appendix F: CLCA-PG&E Survey Summary Memo

MEMORANDUM

Date: October 7, 2016

To: Mary Anderson, PG&E

From: Jenny Fraser, Evergreen Economics

Re: PG&E CLCA Irrigation Survey Results

This memo presents the findings from an online survey of California landscape irrigation contractors regarding trends in business practices and irrigation systems. The first section of this memo provides an overview of the objectives and methods of the study, section two presents detailed survey results, section three summarizes the findings, and section four contains the survey instrument used to collect responses.

1 Study Overview

Evergreen Economics conducted this study on behalf of PG&E and the California Landscape Contractors Association (CLCA) to collect information on current irrigation practices and identify opportunities for efficiency improvements in irrigation equipment.

Questions for the online survey were developed in coordination with PG&E and CLCA staff and were designed to gather data on the type of irrigation services provided, the service area and sectors served by contractors, and characteristics of irrigation equipment and systems that the contractors work on. Evergreen Economics implemented the online survey and provided a survey link to CLCA, which they emailed to CLCA members to collect responses. Respondents were offered a $25 gift card as a thank you for taking the time to complete the survey.

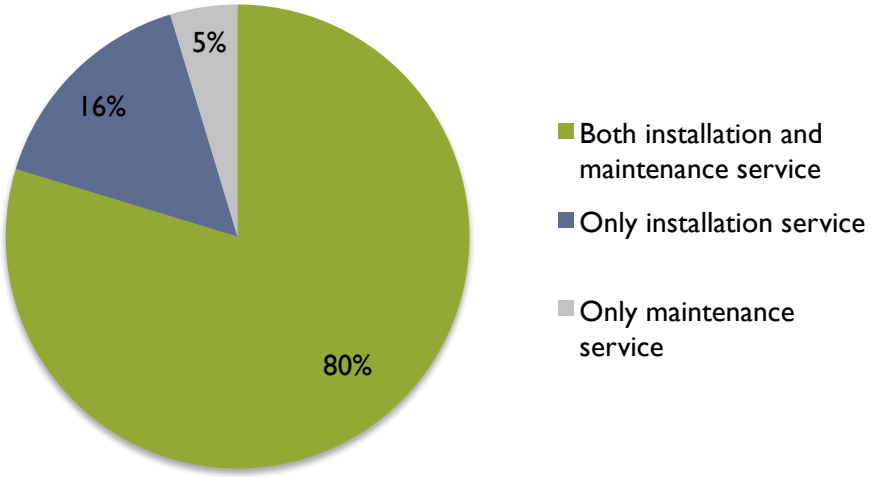
The online survey was available for a little over four weeks, from June 23, 2016 through July 24, 2016. CLCA sent emails on July 7 and July 13 to over 600 members to request their participation in the survey. Ultimately, 64 contractors completed the survey. Three of those contractors did not complete the whole survey, so questions that appear at the end of the survey have a total of 61 responses.

Detailed results of the online survey are presented in the next section.

2 Survey Results

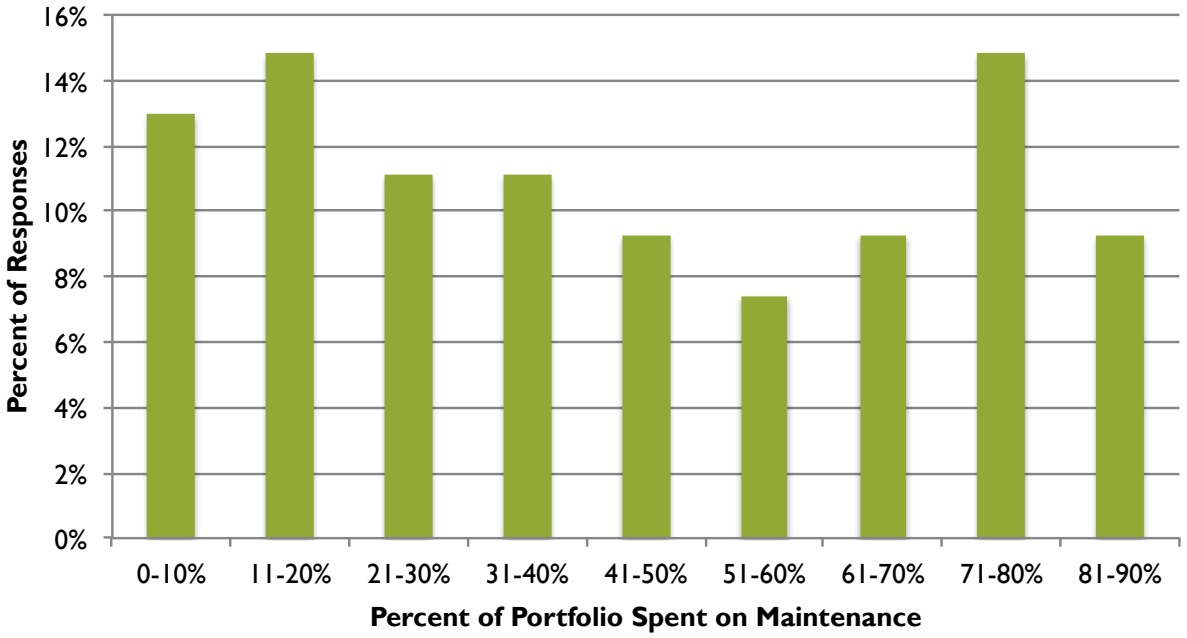
We began by asking respondents whether their business provides installation and/or maintenance services for irrigation equipment. Figure F-1 shows that of the 64 respondents, 80 percent stated they provide installation and maintenance service, 16 percent provide only installation service, and five percent provide only maintenance service.

Figure F- 1: Type of Irrigation Services Provided



We then asked respondents what percent of their annual business portfolio is spent on maintenance of irrigation equipment. Figure F-2 shows that there was a fairly even distribution of responses across the 54 contractors that provide maintenance services. The two most frequent responses, each making up 15 percent of the total responses, were that contractors spend between 11 and 20 percent or between 71 and 80 percent of their annual business portfolio on maintenance. Another 13 percent stated that less than ten percent of their portfolio is maintenance.

Figure F- 2: Percent of Business Portfolio Spent on Maintenance



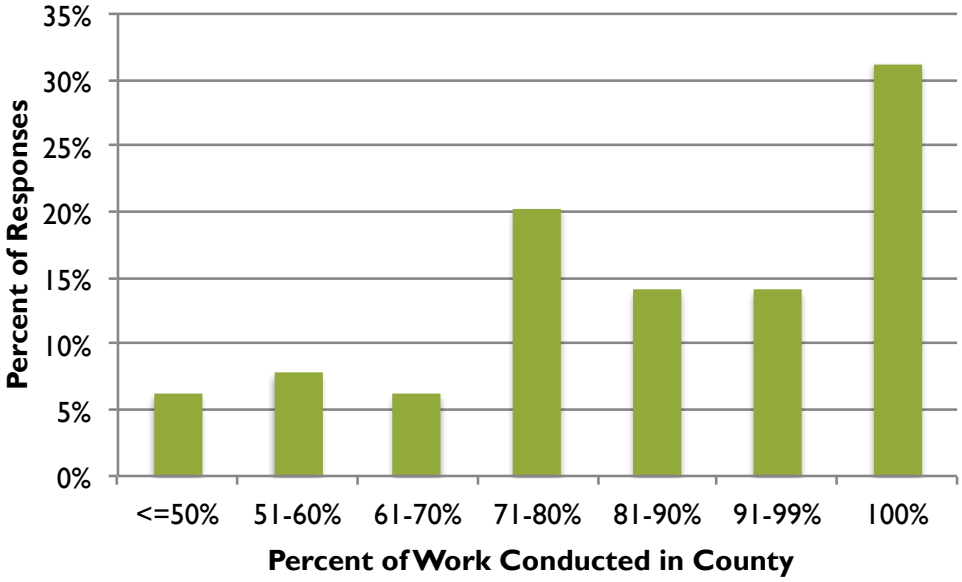
We also asked respondents in which county they conduct the majority of their work. Of the 64 respondents, 17 percent stated they conducted the majority of their work in San Diego County, 13 percent conducted most of their work in Contra Costa County, and eight percent in Orange County. This geographic distribution is generally consistent with the areas where CLCA reports that they have the majority of their members (in no particular order): North Coast, Bay Area, Los Angeles, San Diego, and Sacramento. Table F-1 shows that there are a number of other counties where respondents stated they conduct the majority of their work.

Table F-1: County in Which Majority of Work is Conducted

County	Response Count	Percent of Total
Alpine County	1	2%
Butte County	1	2%
Contra Costa County	8	13%
Fresno County	2	3%
Kern County	3	5%
Los Angeles County	1	2%
Marin County	2	3%
Napa County	1	2%
Orange County	5	8%
Placer County	4	6%
Riverside County	1	2%
Sacramento County	1	2%
San Diego County	11	17%
San Francisco County	2	3%
San Luis Obispo County	2	3%
San Mateo County	4	6%
Santa Barbara County	1	2%
Santa Clara County	3	5%
Santa Cruz County	2	3%
Shasta County	1	2%
Solano County	1	2%
Sonoma County	2	3%
Stanislaus County	1	2%
Ventura County	4	6%
Total	**64**	**100%**

Building on the respondent's answer to the previous question, we asked what percent of their work is conducted in the county where they reported that they conduct the majority of their work. Of the 64 respondents, 31 percent stated that 100 percent of their work is conducted in that county, 28 percent said anywhere between 81 and 99 percent, and 20 percent stated between 71 and 80 percent of their work came from the single county. Figure F-3 shows that the majority of landscape contractors are conducting over 70 percent of their work within a single county.

Figure F- 3: Percent of Work Conducted in One County



To find out where else contractors are providing irrigation services, we asked them what other counties they conduct work in. Contractors were allowed to provide multiple responses to this question. Of the 64 respondents, 28 percent stated they do not conduct work in any other county, 14 percent also conduct work in San Mateo County, and 13 percent also conduct work in Contra Costa County. Table F-2 lists all other counties where respondents reported that they provide irrigation services.

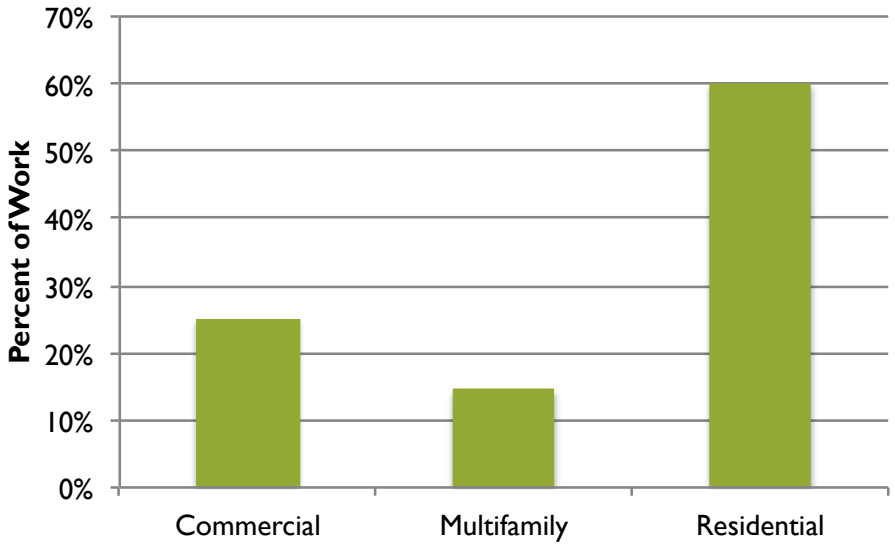
Table F-2: Other Counties in Which Work is Conducted

County	Response Count	Percent of Total
Amador County	1	2%
Butte County	1	2%
Calaveras County	2	3%
Colusa County	3	5%
Contra Costa County	8	13%
El Dorado County	2	3%
Fresno County	1	2%
Humboldt County	2	3%
Kern County	1	2%
Kings County	1	2%
Lake County	1	2%
Los Angeles County	7	11%

County	Response Count	Percent of Total
Madera County	1	2%
Marin County	5	8%
Mariposa County	2	3%
Mendocino County	5	8%
Merced County	2	3%
Monterey County	4	6%
Napa County	4	6%
Nevada County	3	5%
Orange County	4	6%
Placer County	4	6%
Riverside County	4	6%
Sacramento County	6	9%
San Benito County	1	2%
San Bernardino County	1	2%
San Diego County	2	3%
San Francisco County	4	6%
San Joaquin County	2	3%
San Luis Obispo County	1	2%
San Mateo County	9	14%
Santa Barbara County	4	6%
Santa Clara County	6	9%
Santa Cruz County	3	5%
Siskiyou County	1	2%
Solano County	4	6%
Sonoma County	4	6%
Sutter County	2	3%
Tehama County	1	2%
Trinity County	2	3%
Tulare County	1	2%
Tuolumne County	1	2%
Ventura County	3	5%
Yuba County	2	3%
I don't conduct work in any other counties	18	28%

We then asked respondents how much of their irrigation work is conducted in the commercial, multifamily, and residential sectors as a percentage of their yearly projects. Figure F-4 shows the average percent of work conducted in each of these sectors across all 64 respondents. On average, 60 percent of irrigation work is conducted in the residential sector, 25 percent in the commercial sector, and the remaining 15 percent in the multifamily sector.

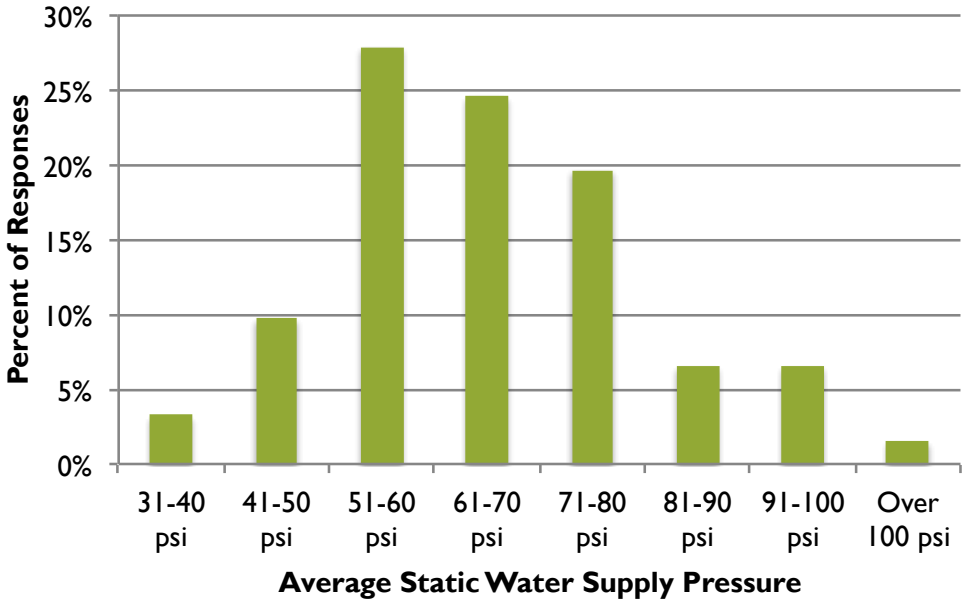
Figure F- 4: Percent of Irrigation Work by Sector



After asking the above questions regarding business practices, we shifted our focus to the irrigation equipment that contractors maintain and install. We first asked respondents what the average static water supply pressure is at the point of connection for the irrigation systems that they work on. Figure 5 below shows that the majority of respondents (72 percent) reported that the average static water supply pressure is between 51 and 80 psi.[59]

59 Only 61 out of 64 respondents answered this and the following questions, as 3 respondents did not complete the survey.

Figure F- 5: Average Static Water Supply Pressure



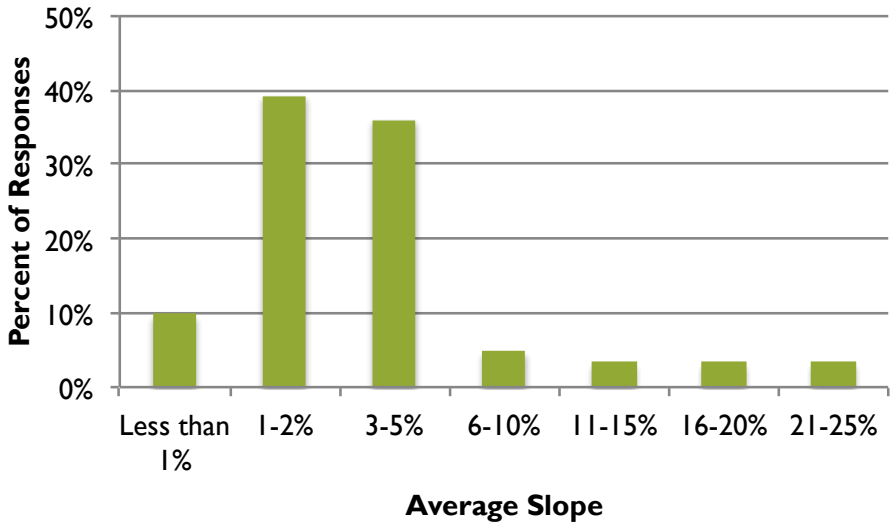
We then asked respondents how frequently they install pressure regulation at the valve or sprinkler for an overhead irrigation system. Table F-3 below shows that of the 61 respondents who answered this question, 43 percent stated that they sometimes install pressure regulation at the valve or sprinkler, 33 percent said they do most of the time, 15 percent said always, and 10 percent stated they never do.

Table F-3: Frequency of Installing Pressure Regulation at Valve or Sprinkler

Response	Response Count	Percent of Total
Never	6	10%
Sometimes	26	43%
Most of the time	20	33%
Always	9	15%
Total	**61**	**100%**

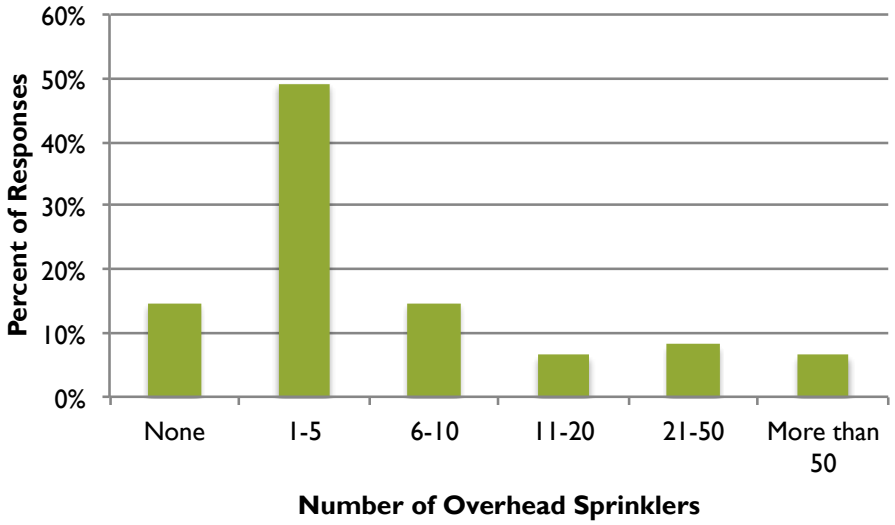
We also asked respondents what the average slope is (in percentage terms) of an irrigated area planted with turf on the majority of their projects. Of the 61 respondents, 40 percent stated that the average slope was between one and two percent, 36 percent said it was between three and five percent, and 10 percent state the average slope is less than one percent. Figure F-6 below shows that the majority of respondents reported an average slope between one and five percent for irrigated areas planted with turf.

Figure F- 6: Average Slope of Irrigated Area Planted with Turf



We asked respondents how many overhead sprinklers they encounter on a weekly basis that have missing or damaged nozzles that lead to significant leakage, run off, or "geysers". Of 61 respondents, 49 percent stated they encounter one to five per week, 15 percent said they encounter six to ten per week, and another 15 percent said they encounter none on a weekly basis.

Figure F- 7: Broken Overhead Sprinklers Encountered per Week



We explored which types of sprinklers are most commonly used by asking respondents what percentage of the sprinklers on their projects are sprinkler heads with spray nozzles, rotating nozzles, or rotors. Figure F-8, Figure F-9 and Figure F-10 show the distribution of responses for spray nozzles, rotating nozzles, or rotors, respectively. The

majority of respondents (52 percent) stated that anywhere from 31 to 60 percent of sprinklers are spray nozzles on their projects, making this the most frequently installed type of sprinkler. Sprinklers with rotating nozzles are less common, with the majority of respondents (62 percent) reporting that less than 30 percent of sprinklers on their projects have a rotating spray head. Finally, rotors were the least common type of sprinkler in use, with 66 percent of respondents reporting that rotors typically make up less than 20 percent of the sprinklers on their projects.

Figure F- 8: Sprinkler Heads with Spray Nozzles

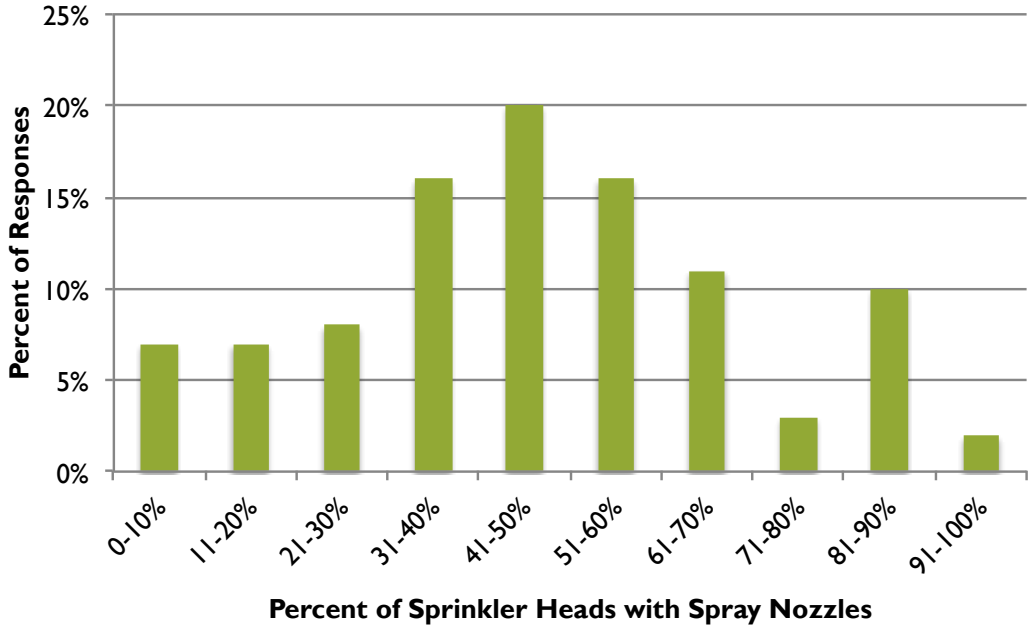


Figure F- 9: Sprinkler Heads with Rotating Nozzles

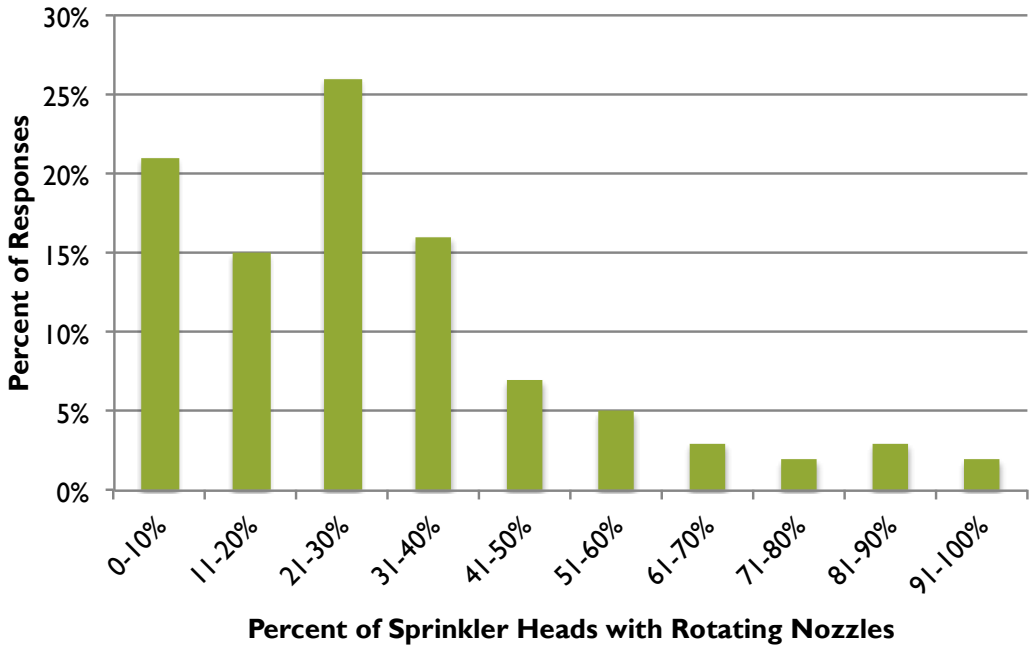
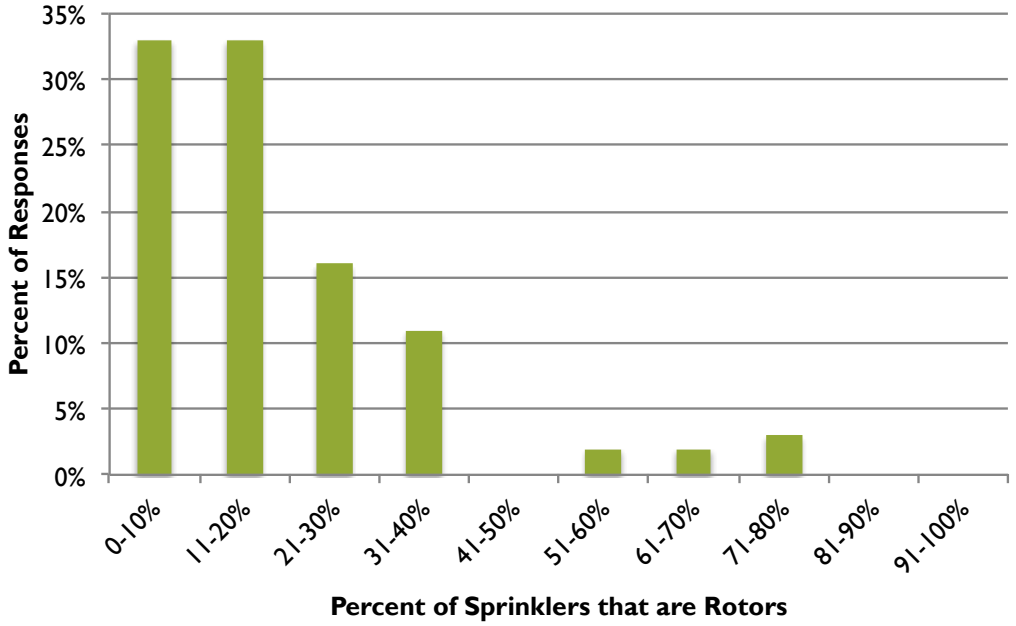


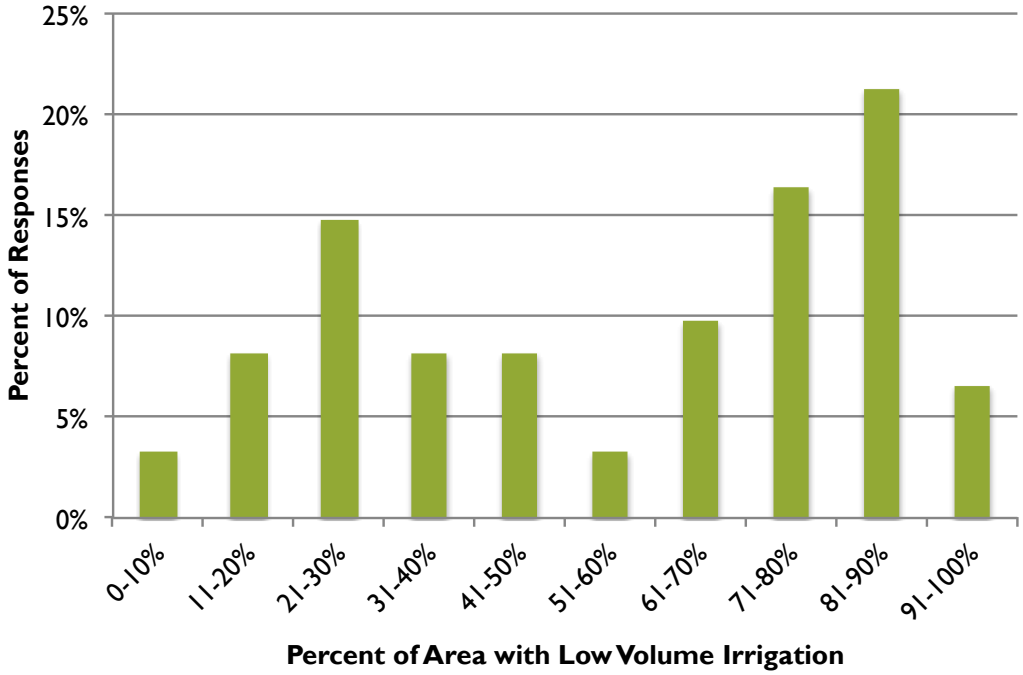
Figure F- 10: Rotor Sprinklers



In addition to sprinklers, we asked respondents what percentage of area is irrigated with drip or other low volume irrigation within their project portfolio. Figure F-11 shows that there are two peaks in the distribution of responses, one in the range of 21 to 30 percent and another between 71 and 90 percent of area irrigated with low volume irrigation. Of the 61 survey respondents, 21 percent stated 81 to 90 percent of area is

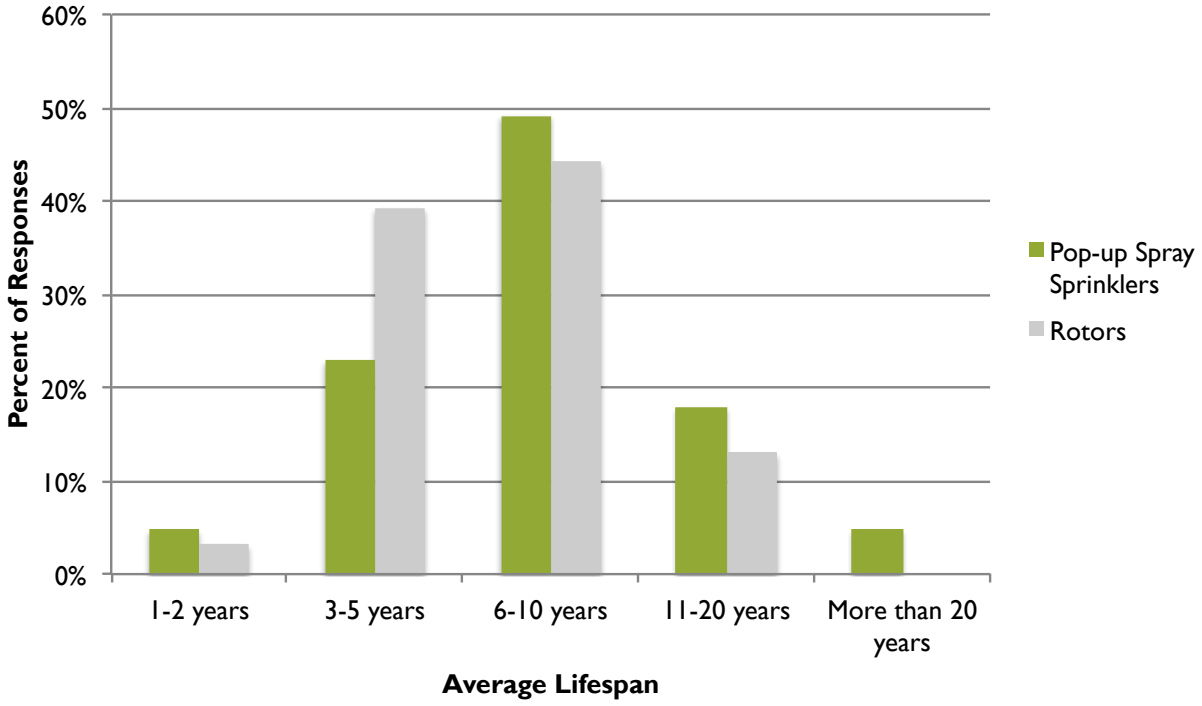
irrigated with drip or other low volume irrigation, 16 percent said it was between 71 and 80 percent, and 15 percent said between 21 to 30 percent.

Figure F- 11: Percent of Area Irrigated with Low Volume Irrigation



Finally, we asked respondents, based on their own experience, what is the average lifespan of pop-up spray sprinklers and rotors. Figure F-12 below shows that the most common response for both types of equipment was a lifespan of six to ten years. For pop-up spray sprinklers, 49 percent of respondents stated the average lifespan is between six and ten years, 23 percent said between three and five years, and 18 percent said between 11 and 20 years. For the lifespan of rotors, 44 percent of respondents stated the average is between six and ten years, 39 percent said between three and five years, and 13 percent said between 11 and 20 years.

Figure F- 12: Average Lifespan of Pop-up Spray Sprinklers and Rotors



3 Summary of Findings

Based on the detailed survey results presented above, the main findings of this study are as follows:

- The majority (80 percent) of irrigation contractors responding to our survey provide both installation and maintenance service for irrigation equipment. Another 16 percent provide only installation service and five percent provide only maintenance service.
- Respondents most frequently reported that they conduct the majority of their work in San Diego County (17 percent), Contra Costa County (13 percent), and Orange County (eight percent).
- Approximately 30 percent of respondents conduct irrigation work within a single county. Most contractors that conduct work in multiple counties still focus over 70 percent of their work within a single county.
- On average, contractors are conducting 60 percent of their work in the residential sector, 25 percent in the commercial sector, and 15 percent in the multifamily sector.
- Average static water supply pressure at the point of connection for irrigation systems was reported by the majority (72 percent) of respondents to be within the range of 51 to 80 psi.
- Over 75 percent of contractors reported that they install pressure regulation at the valve or sprinkler for overhead irrigation systems "sometimes" (43 percent) or "most of the time" (33 percent).
- For the majority of irrigation projects in these contractor's portfolios, 76 percent stated that the average slope of an irrigated area planted with turf is between one and five percent.
- Nearly half (49 percent) of respondents encounter between one and five broken overhead sprinklers in a typical week.
- Sprinkler heads with spray nozzles are the most common type of sprinklers present in irrigation projects according to survey respondents, followed by sprinkler heads with rotating nozzles, and rotors being the least common.
- Drip or other low volume irrigation is also frequently used, with 37 percent of respondents stating that 71 to 90 percent of the irrigated area in their project portfolios uses this type of irrigation.

- Equipment lifetime of pop-up spray sprinklers and rotors was most frequently reported to be within the range of six to ten years, based on the experience of survey respondents.

4 Survey Instrument

[ONLINE SURVEY INTRO PAGE]

Thank you for taking the time to complete this survey. Your feedback will help CLCA and PG&E better understand irrigation systems and the challenges in installing water efficient landscape irrigation equipment, which also result in associated energy savings.

Your responses will remain anonymous and will not be associated with your name or business.

If you complete this survey and provide your name and mailing address at the end, we will send you a $25 Visa gift card as a thank you for your help.

[FIRST PAGE OF SURVEY]

First, we have a couple of questions about the areas and sectors that you serve.

Q1. Do you provide both installation and maintenance service?

1. Yes
2. No, I provide only installation service
3. No, I provide only maintenance service

Q2. What percent of your yearly business portfolio is spent on maintenance (rather than installation)?

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Q3. In which county do you conduct the majority of your work?

1. List of CA counties [respondent may only select one answer]

Q4. What percent of your work is conducted in that one county?

1. [Text box for respondent to enter a percent]

Q5. In what other counties do you conduct work?

1. List of CA counties [respondent may select multiple answers]

Q6. Please indicate the amount of irrigation work you conduct in the following sectors as a percentage of your yearly projects (total should add to 100%):

1. Commercial ___[enter percent]___
2. Multifamily ___[enter percent]___

3. Residential ___[enter percent]___

   [Program will require that these sum to 100%]

[SECOND PAGE OF SURVEY]

Next we have a few questions about irrigation systems and equipment that you work on.

Q7. What is the average static water supply pressure at the point of connection for irrigation systems you work on? (Please provide your answer in psi.)

<30 31-40 41-50 51-60 61-70 71-80 81-90 91-100 >100

Q8. How commonly do you install pressure regulation at the valve or at the sprinkler for an overhead irrigation system?

Never sometimes most of the time always

Q9. What is the average slope (in percentage terms) of a landscape irrigated area planted with turf on the majority of your projects?

<1% 1-2% 3-5% 6-10% 11-15% 16-20% 21-25% >25%

Q10. How many overhead sprinklers do you encounter on a weekly basis that have missing or damaged nozzles leading to significant leakage, run off or "geysers"?

none 1-5 6-10 11-20 21-50 >50

Q11. What percent of the sprinklers on your projects that you see are:

A) sprinkler heads with spray nozzles?

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

B) sprinkler heads with rotating nozzles?

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

C) rotors?

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Q12. In thinking about your project portfolio, what percentage of area is irrigated with drip or other low volume -irrigation?

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Q13. In your experience, what is the average lifespan, in years, of a pop-up spray sprinkler (excluding nozzle replacements)?

<1 year 1-2 years 3-5 years 6-10 years 11-20 years >20 years

Q14. What is the average lifespan, in years, of a rotor?

<1 year 1-2 years 3-5 years 6-10 years 11-20 years >20 years

[THIRD AND FINAL PAGE OF SURVEY]

Thank you for participating in this survey!

Q15. Please enter your contact information below so that we can send you a $25 gift card (optional):

1. Name: [Text box for respondent to enter information]
2. Mailing address: [Text box for respondent to enter information]