WaterSense® Draft Specification for Spray Sprinkler Nozzles Supporting Statement

I. Introduction

The U.S. Environmental Protection Agency's (EPA's) WaterSense program has developed a draft specification for spray sprinkler nozzles to promote and enhance the market for water-efficient irrigation products. The intent of the WaterSense specification is to help purchasers identify products that meet EPA's criteria for water efficiency and performance.

A spray sprinkler nozzle is a component of a spray sprinkler used for landscape irrigation. It is provided in combination with a spray sprinkler body to distribute water to the landscape. In 2014, the EPA released the *WaterSense Notice of Intent (NOI) to Develop a Draft Specification for Landscape Irrigation Sprinklers*, which considered specification development for both spray sprinkler bodies and nozzles. However, based on feedback received on the NOI indicating a lack of real-world water savings data and concerns about nozzle performance criteria, EPA only moved forward with specification development for spray sprinkler bodies at that time. The *WaterSense Specification for Spray Sprinkler Bodies* was released in September 2017.[1]

More recent water savings studies have indicated that several models of spray sprinkler nozzles can result in reduced water use, renewing EPA's interest in this product category as a candidate for the WaterSense label. Recent research has also identified notable program partner interest in a potential WaterSense label for spray sprinkler nozzles, particularly among water utilities. Many water utilities offer rebate programs for sprinkler nozzles and are interested in more easily identifying models that result in water savings. A WaterSense label will allow more consistency across rebate programs and confidence that models selected for rebates will result in water savings.

II. Current Status of Spray Sprinkler Nozzles

EPA estimates there are approximately 28.8 million in-ground irrigation systems installed in landscapes across the United States[2] and that at least 90 percent of those systems could be equipped with more efficient nozzles to reduce water use,[3] representing a large portion of the market available for transformation.

There are no current federal requirements that regulate water use or performance of spray sprinkler nozzles. However, there are several applicable industry standards that include test methods for spray sprinkler nozzles, including the American Society of Agricultural Biological Engineers (ASABE)/International Code Council (ICC) 802-2020 *Landscape Irrigation Sprinkler*

[1] EPA. 2017. *WaterSense Specification for Spray Sprinkler Bodies*, Version 1.0. www.epa.gov/sites/default/files/2017-09/documents/ws-products-spec-ssb.pdf.
[2] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Stratton, and Williams. 2017. Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products. Lawrence Berkley National Laboratory. Table A-4. Schein et al. describes the detailed technical approach to WaterSense's stock accounting practice for irrigation products using values available as of the publication date. As it is the EPA's practice to continuously update its work as data become available, the values referenced here are for the 2018 analysis, the most recent year available.
[3] Personal communication with Michael Dukes, P.E., Ph.D. University of Florida. 2021.

and Emitter Standard and ASAE S398.1 *Procedure for Sprinkler Testing and Performance Reporting*.[4]

ASABE/ICC 802 is the most widely accepted industry standard for this product category and serves as the basis of the *WaterSense Draft Specification for Spray Sprinkler Nozzles*, whereas ASAE S398.1 is referenced within ASABE/ICC 802.

As described in Section IV Potential Savings and Cost Effectiveness below, EPA has estimated that some models of spray sprinkler nozzles use approximately 10 percent less water than traditional spray sprinkler nozzles on the market. EPA has found many of these nozzles are marketed as “high-efficiency” by manufacturers. Some are multi-stream, multi-trajectory nozzles[5] that emit multiple streams of water at multiple trajectories, and some distribute water in a more traditional fan-shaped pattern.

With this draft specification, EPA is aiming to differentiate spray sprinkle nozzles that have demonstrated savings in the field and has identified attributes that can be used to identify these nozzles. Based on product literature published by manufacturers, as well as data generated by the University of Florida,[6] these attributes include:

- Distance of throw (i.e., radius)
- Application rate (also referred to as precipitation rate)
- Distribution uniformity

These attributes are already tested by manufacturers under ASABE/ICC 802 and to support product marketing materials. Of these three attributes, EPA has identified application rate as the primary, measurable mechanism leading to water savings in sprinkler nozzles. To understand the influence of application rate on water use by sprinkler nozzles, it is useful to compare the flow rate between WaterSense labeled showerheads and standard showerhead models. WaterSense labeled showerheads have a lower flow rate than standard models, but still provide adequate performance. Individuals tend to shower for approximately the same length of time regardless of the showerhead’s flow rate, meaning that a lower flow rate results in less water use. Similarly, even though some models of sprinkler nozzles provide a lower application rate to a landscape, homeowners are likely to maintain a similar irrigation schedule after retrofitting their sprinkler nozzles, leading to water savings. The lower application rate also allows water to percolate into the soil, limiting runoff that causes water waste.

Distribution uniformity (DU) is a measure of how evenly water is applied to a landscaped area. While EPA does not have evidence that DU is a primary driver of water efficiency, it is useful in ensuring nozzles provide adequate coverage and performance in the landscape.

EPA considered including droplet size as a performance criterion. As noted in Table 2 of the *WaterSense Notice of Intent to Develop a Draft Specification for Spray Sprinkler Nozzles*, traditional sprinkler nozzles produce fine droplets that can more easily be blown by the wind and diverted from their intended destination. However, some nozzle models on the market have a

[4] The American Society of Agricultural Engineers (ASAE) changed its name to the American Society of Agricultural and Biological Engineers in 2005, though many standards reference the original name, as does ASAE S398.1.
[5] Defined in ASABE/ICC 802 as “Nozzles designed to distribute discharge water in a number of individual streams, of varying trajectories, which rotate across the distribution area.”
[6] Dukes, Michael. 2023. Sprinkler Nozzle Testing Report. University of Florida. Institute of Food and Agricultural Sciences. Agricultural and Biological Engineering Department.

spray pattern that creates larger droplets and reduces misting. The spray pattern allows these models to distribute water more evenly across the landscape despite their lower flow rate. The larger droplet size may also prevent water from being applied to undesirable areas, such as hardscapes, potentially decreasing the total water applied for irrigation. While droplet size may result in water savings, EPA did not include it as a performance criterion at this time because there is a lack of published research measuring droplet size and data demonstrating a correlation between droplet size and water savings. If these data become available in the future, EPA may consider adding this criterion in a future version of the specification.

III. WaterSense Specification for Spray Sprinkler Nozzles

Scope

According to ASABE/ICC 802, a sprinkler is defined as "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 gallons per minute (gpm) at the largest area of coverage available for the nozzle series when operated at 30 pounds per square inch (psi) or more with a full-circle pattern." It consists of the combination of a sprinkler body and nozzle, as shown in Figure 1.

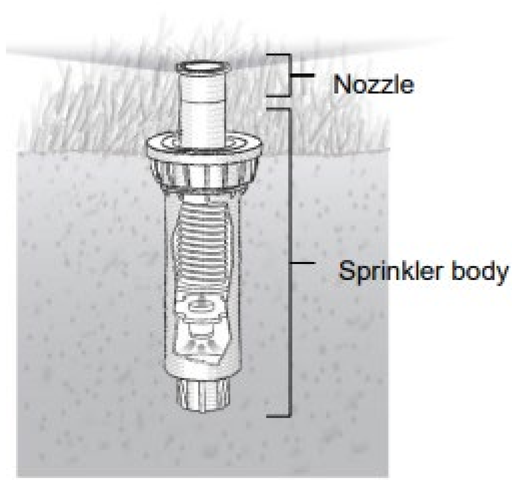

Figure 1. Diagram of a spray sprinkler consisting of a sprinkler body and a nozzle. Image courtesy of Irrigation Association, Smart Water Application Technologies

ASABE/ICC 802 defines the two components as follows:[7]

- **Sprinkler body:** 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.
- **Nozzle:** The discharge opening of a sprinkler used to control the volume of discharge, distribution pattern and droplet size.

There is no explicit definition for spray sprinkler nozzles within ASABE/ICC 802, so for the purpose of the draft specification, EPA developed the following definition, which is also

[7] ICC. 2020. ASABE/ICC 802-2020 *Landscape Irrigation Sprinkler and Emitter Standard*.

representative of the intended scope of this specification, based on related definitions included in the standard:

- **Spray sprinkler nozzle**: The discharge opening of a spray sprinkler used to control the volume of discharge, distribution pattern, and droplet size. A nozzle is attached to a spray sprinkler body that does not contain components to drive the rotation of the nozzle during operation and lacks an internal control valve.

This definition includes, but is not limited to, multi-stream, multi-trajectory (MSMT) nozzles, defined in ASABE/ICC 802 as "nozzles designed to distribute discharge water in a number of individual streams, of varying trajectories, which rotate across the distribution area."[8]

The scope includes both circular pattern nozzles and non-circular, asymmetrical, strip or other specialty patterns.

EPA intends to label a nozzle series, which it defines as "a group of nozzles, as indicated by the product manufacturer, with similar operating characteristics (e.g., distance of throw [or range of distances of throw, if adjustable], optimal pressure) but that may vary in spray pattern. For example, a nozzle series may include nozzles that have arcs of 90°, 180°, 270°, and 360° with a range radius of 8 feet."

This specification does not apply to the following products, based on the definitions in ASABE/ICC 802:

- Nozzles that attach to rotor sprinkler bodies or valve-in-head sprinklers;
- Nozzles that are used exclusively in agricultural irrigation systems; and
- Bubblers, hose-end watering products, and microirrigation emission devices (i.e., those that discharge water in the form of drops or continuous flow rates at less than 30 gallons of water per hour when operated at 30 psi).

Rotor sprinklers contain components within the body that drive the rotation of the nozzle or orifice during operation, whereas spray sprinklers do not have these components. Valve-in-head sprinklers have an integral control valve intended to be operated from a remote location. Because rotor and valve-in-head sprinklers are physically different products from spray sprinklers and the test methods and savings studies discussed in this supporting statement do not apply to them, these products are excluded from the scope.

EPA does not intend for this product category to include sprinkler nozzles that are used exclusively in agricultural irrigation systems, which are fundamentally different products with different testing requirements. EPA also intends to exclude other irrigation emission devices, such as bubblers, hose-end water products, and microirrigation emission devices (i.e., those that discharge water in the form of drops or continuous flow rates at less than 30 gallons of water per hour when operated at 30 psi) from the specification.[9] The exclusion of microirrigation devices effectively excludes drip emitters, drip line emitters, and point-source emitters, as well as micro sprays. These products have a different structure, purpose, and test methods compared to spray sprinkler nozzles. Even though EPA is aware of some asymmetrical pattern nozzles that operate at less than 30 gallons per hour at 30 psi, these products are considered in

[8] *Ibid.*
[9] *Ibid.*

scope of the specification because they are, in fact, spray sprinkler nozzles meant to connect to a spray sprinkler body.

As part of the feedback EPA received on the NOI, it was indicated that higher efficiency nozzles may not be appropriate for all applications, such as when reclaimed water is used. Reclaimed water may include higher levels of solids than potable water, increasing the likelihood of filter clogging, which could impact product performance. Limitations on where labeled products can and should be applied are not appropriate for the WaterSense specification. However, EPA intends to develop technical resources and marketing materials along with the publication of the final specification that will communicate proper irrigation system design and maintenance considerations that will benefit the operation of these nozzles in real-world applications.

General Requirements

In addition to meeting water efficiency and performance requirements included in the specification, the specification requires conformance with the following subsections of Section 302 of ASABE/ICC 802 Sprinkler and Bubbler Design Requirements, which addresses general design requirements for sprinklers:

- 302.1. Rated temperature
- 302.2. Inlet connections
- 302.3. Filters and strainers
- 302.4. Servicing
- 302.5. Adjustments

These requirements are important to ensure proper operability of sprinkler nozzles when installed in an irrigation system.

Water Efficiency and Performance Criteria

Based on field studies (summarized in Appendix B: Summary of Water Savings Studies Reviewed by EPA) and the University of Florida data,[10] EPA selected water efficiency and performance criteria for distance of throw, application rate (i.e., precipitation rates), distribution uniformity, and matched precipitation. Application rate and distribution uniformity appear to be different for models tested in the field and in a laboratory setting when compared to other models on the market. Most significantly, models reported in field studies and included in data generated by the University of Florida have lower application rates, suggesting that less water is applied in the field. While EPA has a goal of promoting nozzles that can result in water savings, EPA is also setting a performance criterion to ensure that irrigation system functionality is not impacted. Distribution uniformity can impact the amount of water applied across the landscape. By including a minimum performance criterion to ensure the distribution uniformity is not too low, sprinkler nozzles functioning in the field should be able to perform adequately.

The subsections below further explain the water efficiency and performance requirements outlined in the specification. Generally, nozzles shall be tested in accordance with Section 303.1 of ASABE/ICC 802, Sprinkler and Bubbler Performance Requirements and Test Methods,

[10]Dukes, Michael. 2023. Sprinkler Nozzle Testing Report. University of Florida. Institute of Food and Agricultural Sciences. Agricultural and Biological Engineering Department.

General. Specifically, Section 303.1.1 requires testing of five samples of each product ensuring that the requirements address potential product variability.

EPA intends to test nozzles that are representative of a nozzle series, as indicated by the product manufacturer. The following selection of nozzle models and combinations of distance of throw (i.e., radius) and arc or pattern shall be selected for testing to represent a nozzle series:

- For a circular pattern nozzle series rated for a specific fixed distance of throw (i.e., radius) at the recommended operating pressure, the following nozzle models/nozzle settings shall be tested:
    - Minimum arc
    - Maximum arc

- For a circular pattern nozzle series with an adjustable distance of throw (i.e., radius) at the recommended operating pressure, the following nozzle models/nozzle settings shall be tested:
    - Minimum arc and minimum distance of throw
    - Minimum arc and maximum distance of throw
    - Maximum arc and minimum distance of throw
    - Maximum arc and maximum distance of throw

- For an asymmetrical or irregular spray pattern (e.g., strip) nozzle series rated for a specific fixed distance of throw at the recommended operating pressure, the following nozzles/nozzle settings shall be tested:
    - Minimum wetted area
    - Maximum wetted area

- For an asymmetrical or irregular pattern (e.g., strip) nozzle series with an adjustable distance of throw at the recommended operating pressure, the following nozzle models/nozzle settings shall be tested:
    - Minimum wetted area and minimum distance of throw
    - Minimum wetted area and maximum distance of throw
    - Maximum wetted area and minimum distance of throw
    - Maximum wetted area and maximum distance of throw

EPA developed examples of these nozzle model radius and arc/wetted area combinations for a variety of different nozzle series in Appendix B of the draft specification. This is intended to help stakeholders understand how representative models from certain nozzles series will be tested and the number of tests required.

EPA intends to require the testing of nozzle series using representative models in order to reduce the testing burden for products that are designed and intended to function the same, aside from their spray pattern. By selecting the above combinations of distance of throw and arc/wetted area to represent the nozzle series, EPA intends to evaluate performance at the outer bounds of the nozzle series' intended operating conditions, such that there is confidence that performance is assured across the range of operating conditions. EPA considered requiring the suite of tests for each nozzle model in a series at each distance of throw and arc/wetted area combination, but determined the number of resulting tests (e.g., over 100 tests for many existing nozzle series) would be too burdensome for manufacturers and not necessary to determine the performance of a nozzle series. Also, data from the University of Florida study suggest that flow rate and calculated application rates did not vary significantly between radius and arc variations within a nozzle series. EPA also considered selecting one representative model in a series and requiring tests at one radius and arc combination, but did not think that would be fully representative of a potentially wide range of throw distances (e.g., 8 to 15 feet) and arcs (e.g., 45° to 360°) found within many series. The minimum and maximum range of distance of throw and arc/wetted area allow for a reduced number of tests, while demonstrating nozzle series performance at the high and low end of these characteristics.

Each test listed below shall be conducted at the recommended operating pressure. This is a modification to ASABE/ICC 802, which requires nozzle testing at the minimum, recommended, and maximum operating pressures. EPA is specifying testing only at recommended operating pressure to reduce the number of tests and to represent how these products should operate in the field. While high pressure occurs in irrigation systems, EPA is recommending the installation of labeled nozzles in combination with WaterSense labeled spray sprinkler bodies, which have been certified to include integral pressure regulation, decreasing the likelihood of the nozzle receiving water at a high pressure and flow rate.

Distance of Throw

EPA is including criteria for distance of throw to ensure manufacturer reported data are accurate, allowing for a greater likelihood of head-to-head coverage when sprinklers are installed in a landscape. This verification is supported by comments received by EPA on the NOI encouraging EPA to include distance of throw as a performance criterion, comparing measured values to manufacturer published literature.

Nozzles shall be tested in accordance with ASABE/ICC 802 Section 303.5.4 (Distance of throw test method), with the modification that nozzles shall only be tested at their recommended operation pressure. An average distance of throw across the five samples for each nozzle/nozzle setting required for a nozzle series (as discussed above) shall be calculated. The difference between the manufacturer's rated distance of throw (or distance of throw range, as applicable) and the tested average distance of throw for each nozzle model shall not exceed the maximum allowable difference shown in Table 1.

Table 1. Maximum Allowable Difference Between Tested and Rated Distance of Throw

Rated Distance of Throw (i.e., Radius)	Maximum Allowable Difference
>1.0 foot and ≤10.0 feet	1.0 foot
>10.0 feet and ≤20.0 feet	2.0 feet
>20.0 feet and ≤39.0 feet	2.5 feet
>39.0 feet	5.0 feet

This maximum allowable difference is based on maximum collector spacing, as specified in Table 2 of ASAE S398.1, which is the existing test method for determining distance of throw for sprinklers. Because spacing ranges from 1.0 to 5.0 feet, the maximum detectable difference cannot be less without modifications to the test method.

Application Rate

EPA is including application rate criteria because a review of field studies and University of Florida data suggest that models that demonstrated water savings had a lower application rate when compared to others on the market.

A nozzle's application rate shall be calculated in accordance with ASABE/ICC 802 Section 303.6.1 (Application rate calculation method) at the recommended operating pressure, using the average flow rate determined according to ASABE/ICC 802 Section 303.5.3 (Flow rate test method (at the recommended operating pressure only)). The application rate shall be calculated for each nozzle model/nozzle setting required for a nozzle series (as discussed above). The average application rate across the five samples shall be calculated and shall be 1.2 inches per hour (in/hr) or less.

As demonstrated in the University of Florida study, there is a clear grouping of nozzle models that have lower application rates when compared to other models on the market (Figure 14 in Dukes, 2023[11]). Each of the nozzles characterized as "high-efficiency" in the University of Florida study demonstrates a calculated application rate of 1.0 in/hr. EPA conducted a subsequent review of product literature related to the nozzle series that were tested and is establishing a threshold of 1.2 in/hr to accommodate potential variance within the nozzle series compared to the specific spray patterns tested in the University of Florida study. Because these nozzle series demonstrated water savings in multiple field studies (see Appendix B), EPA is establishing this threshold to determine more efficient products.

Distribution Uniformity

EPA is including a criterion for distribution uniformity of the lowest quarter (DU_{LQ}) as this measure contributes to the uniformity of water applied in a landscape. EPA acknowledges that DU in the field is impacted by a variety of factors, including design, installation, and maintenance, so is therefore setting a minimum performance level based on laboratory measurements and computer modeling, as opposed to a high performance level that may not be reflected in the field.

DU_{LQ} shall be calculated in accordance with ASABE/ICC 802 Section 303.6.2 (Uniformity modeling method) at the recommended operating pressure and with rectangular or square spacing for each nozzle model/nozzle setting required for a nozzle series (as discussed above). An average DU_{LQ} shall be calculated for each nozzle, and shall be greater than or equal to 0.65 (or 65 percent).

EPA selected a DU_{LQ} threshold of 0.65 to ensure a minimum level of performance for sprinkler nozzles. This criterion aligns with California's Model Water Efficient Landscape Ordinance,[12] which was developed be the California Department of Water Resources in collaboration with local agencies, water suppliers, landscape industry groups, and other interested parties to increase water efficiency in landscapes and improve environmental conditions in the built environment. Aligning with this criterion will ensure nozzles that earn the WaterSense label can

[11] Dukes, Michael. 2023. Sprinkler Nozzle Testing Report. University of Florida. Institute of Food and Agricultural Sciences. Agricultural and Biological Engineering Department.
[12] California Department of Water Resources. Model Water Efficient Landscape Ordinance. https://water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance.

be selected and used to demonstrate compliance throughout California, which represents a large portion of the market for irrigation systems.

While EPA is including a minimum performance requirement of 0.65 in the draft specification, EPA will continue to evaluate DU data related to water savings. If future studies demonstrate that a higher level of DU is correlated to additional water savings, EPA may consider future revisions to the specification to increase this threshold, shifting the criterion from a minimum performance criterion to a higher bar.

Matched Precipitation

EPA is including a matched precipitation requirement to further promote uniform application of irrigation water in landscapes. Sprinkler nozzles can be designed to apply water at the same application rate for all spray patterns and distances of throw, meaning that the application rate will be equivalent across the irrigated area. This feature is known as “matched precipitation.” In uniform landscapes such as turfgrass, matched precipitation nozzles help ensure that all areas of the landscape receive approximately the same amount of water during an irrigation event.

To ensure matched precipitation, EPA is requiring that the application rate for each tested nozzle/nozzle setting shall be at least 90 percent of the highest application rate at the recommended operating pressure for the series. For example, if the highest application rate for the tested nozzles/nozzle settings within a series is 1.0 in/hr, the other tested nozzles/nozzle settings must have an application rate of at least 0.9 in/hr.

This threshold ensures that nozzles installed in the field apply a similar amount of water as other nozzles in that series, contributing to a higher likelihood of uniform water application in the landscape.

Product Marking Requirements

The specification requires conformance with all applicable requirements within Sections 304.1 and 304.2 of ASABE/ICC 802, which describe the general product marking requirements for sprinklers. Specifically, each nozzle in a certified nozzle series shall meet subsections:

- 304.1.1. Units
- 304.1.2. Location
- 304.1.3. Manufacturer name
- 304.1.4. Connectors
- 304.1.5. Nozzle series marking
- 304.1.6. Instructions
- 304.2. Marking of sprays and rotors requirements 2, 3, 4, 5, and 7.

These requirements aim to ensure that purchasers and end users are aware of product features that are essential for product selection and proper design and maintenance of an irrigation system.

EPA is not requiring the publication of DU_{LQ} in product literature nor on the product, because laboratory and computer modeled DU_{LQ} does not translate to the same value in the field, and other factors, such as design, installation, and weather conditions impact field DU_{LQ}. Publishing

DU_{LQ} could result in purchasers or installers expecting the reported level of DU_{LQ} to translate to their field application, resulting in a false sense of uniformity and an inaccurate schedule.

Additionally, nozzles shall not be packaged, marked, nor provided with instructions directing the user to an operational setting that would override the nozzle's intended operating characteristics, as established by this specification, and verified through testing. Any instruction related to the maintenance of the nozzle shall direct the user on how to maintain the nozzle's intended operating characteristics.

Finally, EPA is requiring that product packaging of WaterSense labeled spray sprinkler nozzles recommend that the nozzle be installed on a WaterSense labeled spray sprinkler body with integral pressure regulation. This will help inform purchasers of related products (i.e., sprinkler spray bodies) that should be used to ensure sprinkler nozzles are operated at or close to their recommended operating pressure.

IV. Potential Savings and Cost Effectiveness

Appendix A provides the assumptions and calculations used to derive the following estimates.

Potential Water Savings

EPA estimates that more efficient spray sprinkler nozzles use approximately 10 percent less water than standard spray sprinkler nozzles. This is a conservative weighted average based on data from the savings studies included in Appendix B. Assuming 10 percent savings, the average household with an in-ground irrigation system could save more than 2,400 gallons of water annually by replacing standard spray nozzles with WaterSense labeled spray sprinkler nozzles in the future. On a national scale, WaterSense estimates that nearly 26 million irrigation systems could be retrofitted with spray sprinkler nozzles,[13] which corresponds to an estimated 90 percent of irrigation systems.[14] If every automatic landscape irrigation system in the United States installed WaterSense labeled spray sprinkler nozzles, we could save nearly 63 billion gallons of water across the country.

Cost-Effectiveness

WaterSense estimates that the average household with an in-ground irrigation system could save approximately $32 annually per landscape by replacing standard spray nozzles with more efficient sprinkler nozzles. The payback period is 3 years and 5 months, which is comparable to the average product warranty period for MSMT sprinkler nozzles.[15] However, homeowners likely leave their spray sprinkler nozzles installed for much longer—typically until there is a problem—rather than replacing them every 3 to 4 years. As a result, sprinkler nozzles may prove to be more cost-effective in reality.

[13] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Stratton, and Williams, 2017. Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products. Lawrence Berkeley National Laboratory. Schein et al. describes the detailed technical approach to WaterSense's stock accounting practice for irrigation products using values available as of the publication date. As it is EPA's practice to continuously update its work as data become available, the values referenced here are for the 2018 analysis, the most recent year available.
[14] Personal communication with Michael Dukes, P.E., Ph.D. University of Florida. 2021.
[15] EPA's market research found that the most common efficient sprinkler nozzles on the market offer warranties between 2 and 5 years.

V. Certification and Labeling

WaterSense has established an independent, third-party product certification process, described in the *WaterSense Product Certification System*. Under this process, products are certified to conform to applicable WaterSense specifications by accredited licensed certifying bodies. Manufacturers are authorized by licensed certifying bodies to use the WaterSense label in conjunction with labeled products.

Following testing and verification that the representative models of a nozzle series meet the criteria of the specification, all nozzle models within a nozzle series can be certified. Upon certification, packaging for individual nozzle models and online and printed product documentation shall include the WaterSense label. Marketing materials, brochures, point-of-purchase displays, web pages, and other materials associated with a certified nozzle series may also display the WaterSense label.

Appendix A: Calculations and Key Assumptions

Potential Water Savings Calculations

Assumptions:

- Water-efficient sprinkler nozzles have the potential to use approximately 9.6 percent less water than standard sprinkler nozzles.[16]
- Average outdoor water use per household is 50,500 gallons per year.[17]
- Fifty percent of outdoor water is used for spray irrigation.[18]
- There are an estimated 28,820,000 irrigation systems in the United States.[19]
- 90 percent of irrigation systems do not currently have a more efficient spray sprinkler nozzle system installed.[20]

Equation 1. Average Annual Irrigation Water Savings From Installing WaterSense Labeled Spray Sprinkler Nozzles

(50,500 gallons/year) x (50 percent spray irrigation use factor) x (9.6 percent savings) = 2,424 gallons/household/year

Equation 2. Candidates for Installation of Labeled Models

(28,820,000 irrigation systems) x (90 percent candidates for installation) = 25,938,000 irrigation systems

Equation 3. Annual National Water Savings From Installing WaterSense Labeled Spray Sprinkler Nozzles

(25,938,000 candidate irrigation systems) x (2,424 gallons/household/year) = 62.8 billion annual water savings (gallon)

Cost-Effectiveness Calculations

Assumptions:

- The average annual irrigation water savings from installing WaterSense labeled spray sprinkler nozzles is 2,424 gallons per household per year.
- The cost of water for irrigation is $13.11 per thousand gallons.[21]
- Assumes the lifetime of a spray sprinkler nozzle is 5 years.
- Average household landscape area is 5,826 square feet.[22]

[16] This estimate is a weighted average based on the number of landscapes in the savings studies in Appendix B.
[17] DeOreo, Mayer, Dziegielewski, and Kiefer, 2016. *Residential End Uses of Water*, Version 2. Published by the Water Research Foundation. Table 6.32, Page 154.
[18] Personal communication with Brent Mecham, Irrigation Association. October 18, 2016.
[19] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Stratton, and Williams, 2017. Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products. Lawrence Berkeley National Laboratory. Table A-4. Schein et al. describes the detailed technical approach to WaterSense's stock accounting practice for irrigation products using values available as of the publication date. As it is EPA's practice to continuously update its work as data become available, the values referenced here are for the 2018 analysis, the most recent year available.
[20] Personal communication with Dukes, Michael. 2021.
[21] Raftelis Financial Consulting, Inc. American Water Works Association. 2021 Water and Wastewater Rate Survey.
[22] Water Research Foundation. DeOreo, William B., Peter W. Mayer, B. Deziegielwski and J, Kiefer. Residential End Uses of Water, Version 2. 2016. Table 6.31, Page 151.

- Half of the average landscaped area is spray irrigated.[23]
- Assumes four sprinklers are required for head-to-head coverage at square spacing.
- Assumes 50 percent of sprinklers are 12-foot radius, and 50 percent are 15-foot radius. The majority of the spray sprinklers installed are 12-foot and 15-foot quarter and half circle sprinklers.[24]
- An adjustment factor of 1.5 was used to account for overlap of sprinklers in a continuous pattern and to account for additional sprinklers required in real-world irregular shaped landscapes.
- More efficient sprinkler nozzles cost $4.32 per nozzle.[25]
- Standard sprinkler nozzles cost $0.79 per nozzle.[26]

Equation 4. Annual Water Cost Savings per Landscape From Installing WaterSense Labeled Spray Sprinkler Nozzles

(2,424 gallons/system/year) x ($13.11/1,000 gallons) = $31.78/system/year

Equation 5. Return on Marginal Cost Difference Between More Efficient and Standard Nozzles

[($4.32– $0.79) x 25 nozzles per average spray area)] / ($31.78/year) = 2.78 years

Equation 6. Payback Period for Average Cost of Landscape of More Efficient Nozzles

(($4.32/nozzle) x (25 nozzles per average spray area)) / ($31.78/year) = 3.40 years

[23] Personal communication with Brent Mecham, Irrigation Association. October 18, 2016.
[24] Personal communication with Michael Dukes, P.E., Ph.D. University of Florida. October 18, 2016.
[25] Based on review of Hunter, Toro, and Rain Bird models. Data provided by Michael Dukes in October 2021.
[26] *Ibid.*

Appendix B: Summary of Water Savings Studies Reviewed by EPA

<table>
<tr><th>Title</th><th>Year</th><th>Author (or who conducted the study)</th><th>Number of Landscapes Included in Study</th><th>Savings</th></tr>
<tr><td>High Efficiency Nozzle Evaluation, Measurement and Verification FINAL DRAFT</td><td>2015</td><td>A & N Technical Services, Inc.</td><td rowspan="2">2,175 single-family residences

171 high-use customers</td><td rowspan="2">Single-family residences: 7 percent

High-use customers: 38 percent</td></tr>
<tr><td>High Efficiency Nozzle Evaluation, Measurement and Verification</td><td>2016</td><td>Mark Graham</td></tr>
<tr><td>Evaluation of Potential Best Management Practices—Rotating Nozzles</td><td>2014</td><td>Melissa Baum-Haley</td><td rowspan="2">82 single-family residences

148 commercial customers</td><td rowspan="2">Single-family residences: 8 percent

Commercial customers: 11 percent</td></tr>
<tr><td>Measured Water Savings and Cost Effectiveness of Smart Timers and Rotating Nozzles</td><td>2012</td><td>Joseph Berg, Melissa Baum-Haley, and Thomas Chestnutt</td></tr>
<tr><td>Water Savings From Turf Removal and Irrigation Equipment Rebates</td><td>2019</td><td>Neeta Bijoor</td><td rowspan="2">40 single-family residences</td><td rowspan="2">20 percent</td></tr>
<tr><td>Saving Water With a Landscape Water Conservation Rebate Program</td><td>2021</td><td>Neeta Bijoor</td></tr>
<tr><td>Irrigation Conservation Program Evaluation in Orange County, Florida</td><td>2019</td><td>Bernardo Cardenas, Michael Dukes, and Nick Taylor</td><td>34 single-family residences</td><td>17 percent</td></tr>
</table>

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