W 871

BASICS OF IRRIGATION AND INTRODUCTION TO SYSTEMS AND MANAGEMENT IN THE RESIDENTIAL LANDSCAPE

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PLANT WATER NEEDS

The central purpose of an irrigation system is to provide adequate water for plant needs, so the discussion on irrigation basics should begin with plants. All plants have different watering needs, depending on species, season and the environment. Homeowners and gardeners also need to consider whether the goal is to ensure survival of landscape and garden plants or whether the goal is optimum growth and performance. For instance, a general statement would be that plants need 0.7 to 1.0 inches of water per week, but this is a figure that applies to loamy soils with good water-holding capacity. Sandy soils often need more. In hot weather, these needs may increase to around 1.5 to 2.0 inches per week.

To supplement general watering estimates, it is important that gardeners know the signs signalling that a plant needs water. Stored soil moisture can provide some of the water needed for plants during hot weather, but most plants need to be watered during extended dry periods. Gardeners generally do not want to water every day because frequent watering encourages shallow root growth. So, it is best to add larger amounts of water less frequently (as long as water is infiltrating and not running off the site). Sandy soils require more frequent watering than loamy or clay soils that retain water longer.

General signs a plant needs water:

- Leaf color is darker and may have a bluish cast.
- Plant wilts, droops or has no upright stature.
- Leaves or stems get black spots.
- Stems appear dried out or woody on new growth.
- Plants experience little or no growth.
- Soil is dry more than 4 to 6 inches below the surface.

GUIDELINES FOR DIFFERENT PLANT MATERIALS

Some rules of thumb were mentioned above for watering requirements, but the following list contains more information on watering specific types of landscape plants. However, we always recognize that plant needs can be highly variable based on environmental conditions, species and plant establishment.

- **Annuals and vegetables:** Water when the top 4 to 6 inches are no longer moist; seedlings and transplants may need to be watered when the top 1 to 3 inches of soil starts to dry out as they are establishing new roots. Check soil often to ensure it stays moist. The depth of a shovel in soil can provide a simple way to observe soil moisture within rooting areas. Be aware of rainfall and consider using general estimates, such as watering three days after light rain events and up to seven days after heavy rainfall events. Use a natural or organic mulch to maintain more consistent moisture levels (Figure 1).
- **Perennials:** Many native and adapted species that are established (two to three years) may not require regular watering under relatively normal conditions. Newly planted perennials should be watered deeply to encourage deep rooting while establishing. Even established and well-adapted plants likely will need supplemental irrigation under stressful and moderate to long-term low rainfall periods.
- **Trees and shrubs:** Established trees and shrubs should not need to be watered unless conditions are extremely dry. Trees absorb water best when it soaks to a depth of up to 12 inches. During warm weather a tree needs 10 gallons of water per inch of tree diameter every one to two weeks. Using mulch instead of grass under a tree can reduce the competition for water. It is important to be aware that established trees and shrubs often need little irrigation under relatively normal rainfall. However, newly planted material should be watered frequently because container media can dry out more quickly than the surrounding soil. So, moisture should be managed carefully until the plant has root established in the soil. Other UT Extension publications contain more details on planting and managing trees and shrubs.
- **Grass:** Grass generally needs about 1 inch of water per week. Water if footprints show after someone has walked on the turf. However, across the state of Tennessee, there is a wide range of warm- and cool-season turfgrass species, and management can differ considerably based on rooting depth of the turfgrass species, soil conditions and establishment.

FIGURE 1. *Vegetable gardens require steady moisture. Many times during a Tennessee growing season, supplemental water will be needed to obtain optimum production. (Image source: Natalie Bumgarner)*

CALCULATING WATER NEEDS AND WATERING TIME

To further illustrate watering needs during hotter periods, let's take an example of a 1,000-square-foot garden (a space of 20 feet by 50 feet) on a hot summer day in July in Tennessee. This garden may use more than 150 gallons of water per day, with the majority of days during July and August around 125 gallons. Although some rainfall usually will occur during these months, there will often be periods of several days to a few weeks when it will be necessary to supply the total daily water needs from other sources. To convert these water needs into hand-watering time, let's use a garden hose (watering wands can be a great way to improve evenness of application when watering with a hose) as an example, that typically flows at a rate of 2 to 3 gallons per minute. Determining the rate of water application can be done simply by timing how fast a 5-gallon bucket is filled. To provide weekly water needs for this garden, it would require roughly one and a half hours of watering every two to three days; see calculations in the adjacent sidebar.

HOW LONG WOULD A GARDENER NEED TO WATER THEIR 1,000-SQUARE-FOOT GARDEN WITH A HOSE IN JULY AND AUGUST?

0.2 inches water per day = 0.0167 ft (0.2 / 12 in)

7.5 = conversion factor ft^3 to gallons

1,000 ft^2 * 0.0167 * 7.5 = 125 gallons per day

125 * 7 = 875 gal per week

Water hose with spray wand – 3 gallons per minute

875 gal / 3 gal/min = 292 minutes

Approximately five hours/week, but the garden might be best watered in two or three applications to prevent losses from runoff.

DROUGHT CONDITION GUIDELINES

Regions across Tennessee repeatedly have experienced drought conditions over the last decade. A drought can simply be defined as an extended period of time when a region experiences below average moisture conditions. During these periods, certain gardening practices (described below) are particularly important to conserving soil water.

- Weeds use water just like desirable plants do. Controlling weeds through the season when they are small will help reduce total water use.
- Mulches help reduce water loss from the soil surface by evaporation. This is especially true if the plants are small or widely spaced. The reduced water loss improves uptake of nutrients and may help control some problems that are related to a variable water supply, such as blossom-end rot in tomatoes. Organic mulches improve infiltration, and black plastic mulches greatly reduce infiltration but reduce evaporation. Mulches also help in weed control.
- Compacted soil layers restrict plant root growth. This reduces the total soil volume from which plants absorb water. Soil compaction is most often caused by traffic or tillage on wet soil. If the soil becomes compacted, tilling to break up the compacted zones will allow more extensive rooting and a reduction in drought stress. Keep in mind that tilling increases soil moisture losses, so it should not be done during drought conditions.

UNDERSTANDING IRRIGATION SYSTEMS BASICS

IRRIGATION BASICS

During drier periods, which could be 10-12 days without a soaking rain, most plants need to be watered. The goal of watering plants or irrigating (used in its broadest definition) is not to water the plants, but to replenish the water in the soil that can be accessed by plants. In other words, the purpose of irrigating is to supply water for the land, which supplies water to plants. Two common gardening mistakes are overwatering or adding too little water too late. If water is ponding on the surface and the soil is waterlogged for several hours after watering, too much is being added. By observing soils and plants, gardeners will soon develop a good feel for irrigating.

There are many types of irrigation systems available for residential lawns, landscapes and gardens (Figures 4, 5, 6, 8, 9, 11). Table 1 provides an overview of irrigation systems. They include sprinklers that distribute water more than 50 feet as well as drippers, which provide water to a small circular area of soil. For the majority of homeowners, a domestic water supply can limit the design flow rate of an irrigation system. Municipal residential utilities often have a ¾-inch meter with a typical flow rate maximum of 10 gallons per minute (gpm). Residential wells often have a rate of flow between 5 and 20 gpm. Water supplies must provide needed flow in addition to having enough pressure to overcome losses due to friction and differences in elevation. For example, a sprinkler that sprays more than 25 feet often requires 35 pounds per square inch (psi) of pressure. To overcome losses in the system, 45 psi is often needed at the faucet.

MEASURING FLOW AND PRESSURE

A gauge and valve can be used to determine flow rate and pressure (Figure 2). You will need a pressure gauge that can read between zero psi and 100 psi. If the plan requires connecting an irrigation system to the main line going to a house, a professional may need to complete the job. However, useful information can still be gained by making these measurements. Readings taken generally will be lower than those taken from the city main line. For a small-acreage system, these readings are sufficient.

First, you need a valve to restrict the flow downstream of the pressure gauge. A PVC ball valve is easy to use, and all of the fittings can be purchased from a hardware store. A 3/4-inch pipe to garden hose adapter likely will be needed. Pressure and flow rate are related, but pressure versus flow rate is different for every system.

The pressure gauge should be connected to the manual valve on a hose bib or a hydrant that is fully open near the point of connection for the proposed irrigation system. After the hose bib or hydrant is fully open, the ball valve should be opened one position at a time. Pressure and flow are measured by:

1) Determining how long it takes to fill a 5-gallon bucket and then dividing that number by the 5-gallon volume. Keep in mind that there are 60 seconds in a minute. For instance, if it takes 30 seconds (0.5 minute) to fill up the 5-gallon bucket, the flow rate would be 10 gallons per minute; or

2) Determining how many times the flow meter needle turns in one minute and calculating gpm.

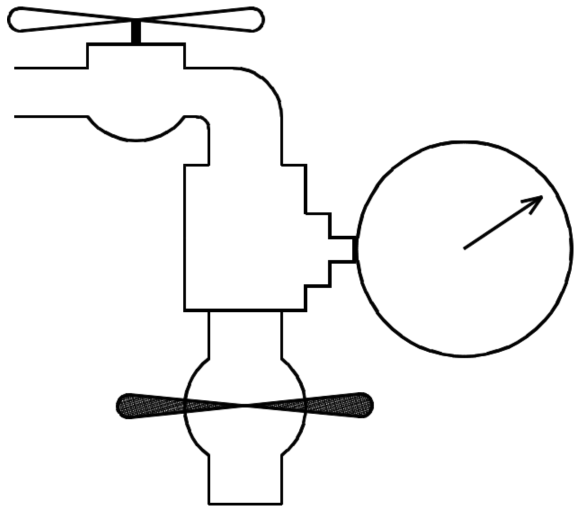

FIGURE 2. *Measuring flow rate and pressure by connecting a pressure gauge to a bib or hydrant. (Image source: Brian Leib)*

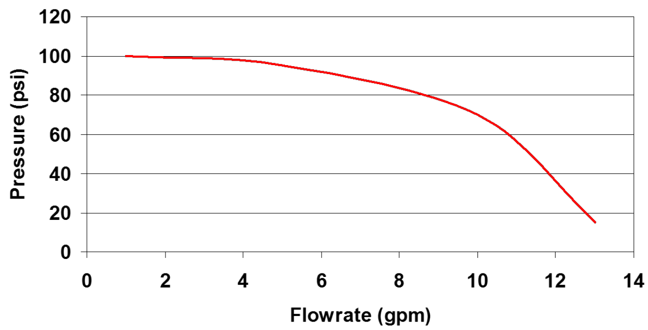

FIGURE 3. *Pressure and flow rate are related (pressure versus flow rate is different for every system). (Image source: Brian Leib)*

As flow increases, pressure should drop (Figure 3). Keep in mind that the pressure versus flow rate relationship is different for every irrigation system. Therefore, it is important to ensure that a design flow rate maintains enough pressure to operate the desired irrigation equipment. This may require some research and potential alteration. The utility can provide potential pressure and flow at a location, and a pressure reducer can often be adjusted to provide more or less pressure as required for irrigation. On a well system, there can be a pressure gauge on the pressure tank that can be used for rating pressure and flow as a bucket is filled. The pressure switch that controls when the well pump is turned on and off in conjunction with the pressure tank can be adjusted to better accommodate an irrigation system, but adjusting the pressure switch will not create more flow and pressure if the well pump size is limiting output.

DEVICE	LOCATION/USE	PLANT EXAMPLES	PRESSURE AND FLOW REQUIRED	EVAPORATION POTENTIAL AND CONSERVATION EFFICIENCY	COMMENTS
Hand watering/garden hose *(Figure 4)*	Individual plants or small areas	Container plants, newly established trees and shrubs	Varies. Can be done with a bucket, sprinkler cans or more efficiently with a hose and water breaker nozzle. Normal hose pressure from 35 psi to 50 psi is needed to overcome friction loss in a long length of hose and still have pressure to operate a spray wand. Elevated rain barrels will only have 1 to 2 psi, and flow can be slow out of long length of 5/8" hose, so there will not be enough pressure for a wand or breaker.	Low/Good *Excellent conservation potential*	*Simplest form of irrigation* *Labor Intensive*
Furrow *(Figure 5)*	Garden beds (evenly spaced, level is best)	Vegetable garden beds	Low/Low Can be done with a garden hose and could be used with rain barrel systems.	Low *Good (on short runs)*	*For short runs, furrows can be effective in a range of soils. Level beds are easier for furrow application evenness but are not a necessity.*
Rotating Sprinklers: constant discharge and do not automatically have matched precipitation rates for part circles *(Figures 6 and 7)*	Large, open areas (directional sprinklers can be added to address smaller or odd-shaped areas in the lawn)	Turfgrass	High/High 30-70 psi to deliver 0.5-20 gallons per minute, depending on the orifice size and pressure	Moderate/Variable *Conservation efficiency depends on design and use.* *Evaporation rate may be 10-15%, which can be higher than other types.* *Can be 75% efficient if well designed.*	*Good design is critical to efficiency and efficacy.* *Can throw water 20 to 60 feet.* *Elevation differences affect pressure, but this is uncommon on many small lots.*
Multi-stream Rotating Sprinklers: matched precipitation for part circles and radius of throw (typical pop-up sprinkler) *(Figure 9)*	Small-to-medium areas	Open turf areas, low, similar plant material in beds with similar water usage (8-30 ft radius)	Moderate/Moderate 30-50 psi, 0.2 to 4 gpm	Moderate/Good *Even delivery improves efficiency.*	*All models have almost the same precipitation or application rate (around 0.4 to 0.45 inches per hour).* *May be a good replacement for spray sprinklers (↑cost).* *Examples are the Nelson & Hunter MP Rotator.*
Spray Sprinklers *(Figure 8)*: automatically matched precipitation rate for part circles with sprinklers in the same series	Small areas	Open turf areas, low-growing shrub beds with similar plant material and water usage	Moderate/Variable 20-40 psi to deliver 0.25-4 gallons per minute, depending on the orifice size and pressure	Moderate/Variable *Depends on slope and soil infiltration*	*Throws water from 8 to 16 feet.* *High application rate has a potential for runoff losses on slopes or tight soils when run for long durations. May need to limit run time to 15 minutes.*

DEVICE	LOCATION/USE	PLANT EXAMPLES	PRESSURE AND FLOW REQUIRED	EVAPORATION POTENTIAL AND CONSERVATION EFFICIENCY	COMMENTS
Trickle/Drip (three types): **1) Drip tube with external emitters directed to specific plants and micro-lines can be used with each emitter.** **2) Drip tape with internal emitters at set distances *(Figures 10 and 11)*.** **3) Drip tube with internal emitters at set distances *(Figure 12)*.**	Direct to root zone of individual plants or in a wetted band around the drip tube or tape	Herbaceous and woody ornamental beds, vegetable gardens, fruit plantings	Low/Low 10-25 psi to deliver 0.5 to 2 gallons per hour per emitter or 0.22 gpm to 0.6 gpm per 100 ft of drip tape	Low/Good *Applies water at a slow rate for a long period of time.* *High water efficiency*	*Should purchase pressure compensating tubes and emitters for ease of use.* *Hoses and drip lines work best, and last longest, if used at appropriate pressures.* *Requires filtering if not well or city water.*
Bubblers	Small areas of plant beds, plants beneath taller, thicker vegetation	Individual trees, understory shrubs and herbaceous plants	Moderate/Variable 15-30 psi to deliver 8 gallons per hour to 2.5 gallons per minute	Moderate/Variable *Can reduce evaporation and improve water moving into root zone.* *High water efficiency if not overwatering.*	*Equipment can be expensive, complex to assemble, and require very clean water and/or extensive filtering.* *More maintenance involved than with sprinkler systems. Avoid bare soil due to runoff/erosion risks (mulches are an aid in reducing runoff/erosion).*

FIGURE 4. The simplest method of overhead watering may be a hose. It can allow for variation in plant size and water directed at roots to keep leaves dry. (Image source: Natalie Bumgarner)

FIGURE 5. Furrow irrigation is an option for garden beds. It is best for short runs and relatively level sites. (Image source: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org)

INSTALLATION PLANNING

CONSIDERING COSTS

Landscape irrigation can be quite expensive and has three primary areas of cost. First is the equipment and installation. Second is the cost of maintenance, including repairing/replacing emitters damaged by mowing, pipes that break as soil settles, and removing sediment from nozzles and controls. Third is the cost of operation. This cost includes modifications to the system as landscape and plant needs change, the amount of energy costs if pumps and other tools are needed, and water. Water is a significant and ongoing expense. One thing to consider is whether your water provider will allow you to avoid paying sewer costs on water used for irrigation. In some situations overall net costs for irrigation may be lessened due to reductions in paying someone to hand water.

SITE DRAWINGS

It can be helpful to make a drawing of the landscape to scale for planning and also to serve as a record of where irrigation equipment is installed. Distances don't have to be perfect, and the only things these scale drawings require are graph paper and accurate measuring of distances.

A typical scale equation is 1 inch on paper equals 20 feet in the landscape. Depending on the size of the lot, several sheets of graph paper may need to be taped together. Next, using a pencil with a good eraser, lay out the property, structure and hardscape boundaries. Identify the location of different plant material, beds and gardens. Additionally, identify water use zones (see below) in the landscape and consider plants with similar requirements. If making a scale drawing of a residential property seems daunting, consider printing an overhead image of the property using Google Earth, to be used as a template to assess needs and begin planning irrigation systems.

It is important to locate the point of connection where the irrigation system will hook into the existing supply. If the site is steep, noting the direction and estimated slope is important. Making note of underground utilities is helpful, but always call 811 and request the utility board to come out and mark the lines directly on the property before any installations are made.

COST FOR IRRIGATING ONE-HALF ACRE

- 1 inch of water applied to a half-acre landscape requires 13,500 gallons of water each application.
- 1 inch/12 = 0.0833 feet. Therefore, 0.0833 ft * 21,780 ft^2 (1/2 acre) = 1,814 ft^3
- 1814 ft^3 * 7.5 (conversion factor for ft^3 to gallons) = 13,500 gallons
- Example estimates are $0.40/100 gallons for water to a home and $0.60/100 gallons for sewage treatment.

  0.40/100 * 13,500 = $54.00

  0.60/100 * 13,500 = $81.00
- The combined cost for applying 13,500 gallons is $135.00.
- If 6 inches of water are required in a growing season, the yearly cost of irrigation is about $810.00 for half an acre.

DESIGNATE GENERAL WATER USE ZONES

When designing a home landscape, grouping plant material by water needs is very important to enable the irrigation to be optimally efficient and for plants to perform well. While these techniques may be common in larger commercial plantings, it is not often a high priority for homeowners in selecting plant material. So, if the goal is to install effective and efficient irrigation, then plant water needs should be considered.

High water use: Plantings that need regular watering and show water stress easily. Examples include entry to a home, containers and window boxes. These areas should have accessible water sources. A rain barrel (see UT Extension publication "W 300 Rainwater: Your Liquid Asset") could also be an excellent addition to manage high water use areas.

High-to-moderate water use: These moderate-to-high use plant types could include vegetable gardens and turf areas, and water needs will depend on homeowner and gardener preferences and the conditions of the growing season. To enable optimum garden yields and a high level of aesthetics in turf areas, many summer seasons require supplemental irrigation in these areas.

Moderate water use: Established plants that need watering when showing signs of water stress. Only half to 1 inch of rainfall per month is sufficient for most established woody ornamentals, assuming this water infiltrates the soil. Examples include drought-tolerant plants, native plants and plants in mulched beds.

Low water use: Plants that need water only in extreme drought situations, including naturalized or wooded areas with established plants.

GENERAL GUIDELINES FOR RESIDENTIAL IRRIGATION SYSTEMS

ASSESSMENT OF IRRIGATION NEEDS

A homeowner should understand the purpose of irrigating (and their own perspectives on the visual and yield attributes they desire); have a grasp of the concepts and technology of irrigation; and, most importantly, take responsibility for irrigation management. The following list can be used as a guide when setting up an irrigation system in your own residence or when assisting others through the Tennessee Extension Master Gardener program.

1. Assess the property and owner's need for irrigation.

2. Review several additional factors in irrigation:

- Ability to meet plant watering needs in relation to environmental conditions.
- Potential physical damage to plants and possible environmental impacts, including runoff, erosion and flooding.
- Affordability and maintenance requirements, including time and money.

FIGURE 6. *Rotating sprinkler head. (Image source: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org)*

- Irrigation system efficiency.
- Water supply issues: the irrigation system must not exceed water supply available in high-use periods and it must be sensitive to water use policies and conservation practices in the area.

3. Emphasize the importance of proper installation and maintenance.

4. Address best management practices and the importance of effective irrigation management. For example, irrigate when water is less likely to be lost as runoff or evaporation.

Effective irrigation management implies:

- Reasonable and attainable goals.
- Conscientious planning and design, including the consideration of long-term maintenance costs.
- Environmental sensitivity, including knowing local water supply ordinances.
- Using equipment suited to the task.
- Operations that are matched to needs.
- Responsible operation and maintenance.
- Careful monitoring and adjustment.

LOCATING AND USING SPRINKLERS, BUBBLERS AND DRIPPERS

The information below is intended to provide a basic overview of how to maintain a sprinkler system and how to address questions. It is not intended to provide all the information needed to install a residential irrigation system.

SPRINKLERS IN THE LANDSCAPE

In general, sprinklers are the least water efficient of irrigation practices outlined in Table 1. However, they are often the

FIGURE 7. *Rotating sprinklers are for large, open turf areas, such as this sports field. (Image source: Flickr: Beth Coll Anderson, bethcoll.com)*

only method that can be used in large, open areas and can be designed and operated in a manner that can provide around 75 percent efficiency (meaning water that doesn't evaporate or run off the soil). So, homeowners need to understand how to select irrigation systems for their needs and use them most efficiently. Suggestions for efficiency include:

- Run sprinklers in accordance with rainfall and plant needs and not based solely on timers.
- When possible, use sprinklers during the cooler times of day to lower the potential for evaporation losses.
- Make sure that sprinklers do not cover streets, sidewalks and other areas where all water applied runs off.
- If irrigating by overhead sprinklers, the water must be added slowly enough for the soil to absorb it. Use caution on clay soils or soils that crust, because sprinklers may exceed the infiltration rate and water may be lost as runoff. On bare clay soils, this may be a serious limitation, as infiltration rates may be as low as 1/10 inch per hour. Using mulch to protect the surface will increase infiltration, but on most soils, infiltration will not exceed ¾ to 1 inch of water per hour.

LOCATING AND USING SPRINKLERS

Proper location of sprinklers is key to providing even distribution of irrigation water that is not wasteful. If the distance is too wide, irrigation will be insufficient. If it is too close, then more water (and money) than is needed will be used and runoff could increase. If they are placed too far apart, some areas will be too dry. There are a variety of sprinklers on the market. Some general suggestions for avoiding overwatering when using sprinklers include:

- Use a rain gauge to check how much water has fallen, check soil moisture and look for signs of drought stress.
- Decrease the amount of water by the amount it has rained.
- Use average daily temperatures to help predict the rate of evapotranspiration.
- Wait until 4 to 6 inches of soil is dry before watering.
- Do not water when it is raining.

The following discussion will be focused on the three types of sprinklers presented in Table 1.

Rotating Sprinklers

These sprinklers have a constant discharge and are best used for large open areas. Turfgrass is commonly irrigated with these devices (Figures 6 and 7). They require the highest pressure and deliver the highest flow rate of the three types of sprinklers. Directional sprinklers can be added for corners and odd-shaped areas, but sprinklers do not automatically match precipitation for partial circles. So, determining the precipitation rate and proper spacing is critical for these sprinklers.

Sprinklers operating correctly actually apply more water close to the sprinkler. For this reason, proper placement of sprinklers provides an overlap in their patterns to enable even watering. A sprinkler is placed at the edge of the wetted area of the previous sprinkler so that it will throw water back across the previous sprinkler's pattern. One simple way to remember this is to place sprinklers with coverage that is head to head, meaning that the area wet by each sprinkler should extend to the next sprinkler. If there is little wind in the area and rainfall is frequent, this standard can be relaxed somewhat.

These guidelines apply only to sprinklers operating with the specified pressure. Pressure over the recommendation can result in small droplets that are moved by wind. Conversely, lower-than-suggested pressure can result in large water drops that don't travel as far as intended, leading to dry areas between sprinklers. Odd-shaped areas make sprinkler location even more challenging, so these tips can help.

FIGURE 8. *Example of spray sprinkler in small lawn area. (Image source: Flickr: Fabrice Florin)*

FIGURE 9. *Multi-stream sprinkler. (Image source: energy.gov)*

RULES FOR SPACING SPRINKLERS

1. Select a sprinkler that covers the area but doesn't throw water beyond the narrowest areas. You can break the area into sections and select two or three sprinklers with different sized wetting areas.
2. Part-circle sprinklers will need to be placed at all corners.
3. Place part-circle sprinklers evenly along the edges between corners using appropriate head-to-head spacing.
4. Then, add sprinklers with full circles to the middle areas with a similar spacing as used on the edges.
5. Spacing between sprinklers will not always be exact, so allow for a margin of 10 percent.
6. Go back and adjust if needed to even out the coverage and prevent any gapping between wetted areas.
7. Sprinkler layout is an art as much as a science, so adjust over time as needed.

Spray Sprinklers

Spray sprinklers do not rotate and spray out of all sides of the sprinkler at one time, thus reducing their radius of throw (8 to 16 feet compared to 20 to 60 for rotating) and fitting better into small areas (Figure 8). This smaller delivery area makes them well suited for smaller lawn areas or landscape beds where the plant material is similar in height and in water needs. These sprinklers deliver 0.25 up to 4 gallons per minute, and the higher rates over smaller areas have the capacity to increase runoff and erosion if water is delivered faster than it can infiltrate. Mulches can be an asset in these situations. Because of these variations in flow, site and use, the efficiency and conservation potential of spray sprinklers varies in the home landscape.

Multi-Stream Rotating Sprinklers

The above discussion focused on traditional rotating and spray sprinklers. A more recently developed sprinkler design that can be an asset in residential irrigation applications is fixed application rate pressure compensating rotating sprinklers (such as MP and ECO brand rotators). These sprinklers are designed to deliver similar precipitation whether being used for a small or large radius area or in part or full circles (Figure 9). Most models have a similar application rate of around 0.4 to 0.5 inch per hour. These sprinklers can help homeowners avoid many of the challenges of covering odd-shaped spaces and avoiding dry spots and other inefficiencies in sprinkler irrigation. Because the design and layout is simpler with these sprinklers, homeowners are more likely to be able to design and install efficient home irrigation systems.

These stream-rotating sprinklers operate at a lower pressure than rotating sprinklers and deliver less flow than spray sprinklers. They are ideally suited to replace spray sprinklers, producing a much lower application rate, and at the same time can be used in many medium-sized areas that were tradition-

FIGURE 10. *Drop tape installed under plastic mulch in crop field. (Image source: Natalie Bumgarner)*

FIGURE 11. *Close-up view of drip tape showing internal emitter embedded in the plastic. This tape had emitters at 12-inch spacing. (Image source: Natalie Bumgarner)*

ally covered by rotating sprinklers. One drawback is a slightly higher initial cost. If you have trouble with runoff and erosion of an existing spray sprinkler area, MP rotators can be retrofitted into many types of spray sprinklers by replacing the internal parts. These sprinklers are well suited for open turf areas (albeit covering a smaller area than rotating sprinklers) as well as low-growing plant material in landscape beds that require similar amounts of water.

BUBBLER AND DRIP EMITTER CONSIDERATIONS

Bubbler and drip layouts vary from sprinkler arrangements. The goal with bubblers is to flood the entire bed or at least make sure that the roots of all plants can reach an area wetted by a bubbler. With both bubblers and drip systems, the leaves of plants are able to remain dry, which is an important disease management technique for a range of herbaceous and woody plants in the landscape.

There are three main types of driplines. The first type includes a solid tube that can be run through the bed, and then individual small lines with emitters can be installed on a per-plant basis. If all the plants are the same size and type and get the same amount of sunlight, their water needs should allow them to have the same number of emitters (often one per plant). Plants that have a dripline twice as large are often given two emitters unless they are more tolerant of dry conditions. An asset of this type of irrigation system is that emitters can be added, moved or removed (and the hole plugged) to provide flexibility as landscapes grow and change.

The second type of drip tubing has internal emitters on set distances. This tube can be placed at or below the surface to provide consistent water flow along the length of the line. No punching or installing of emitters and micro lines are needed. These systems are simpler to install but cannot be adjusted as well to accommodate plants of different sizes together in the same beds. However, the tube can be snaked through beds to accommodate different plant arrangements. It can be bent slightly but will kink if bent at too great an angle. A range of emitter distances are available (Figure 12).

The third type of dripline is often called drip tape, and it is usually installed with one line for every plant row (Figures 10 and 11), but sometimes a single dripline can be installed between two close rows of small plants. It has internal emitters at predetermined spacing, but the line is thin and can kink easily. Thus, generally it is installed in a straight line to enable water flow. Drip tape is most common in gardens for individual rows of vegetable plants. Also because it is thin, it must be operated below 15 to 20 psi to avoid bursting. A pressure regulator will prevent bursting and control pressure and flow in drip tape. The thicker walls in driplines and emitters prevent bursting below 60 psi, and pressure-compensating emitters will avoid flow variation caused by pressure differences in these drip products.

FIGURE 12. *Drip tube with internal emitters. This small tubing is called microirrigation and works well for containers or raised beds where precision is needed. (Image source: Natalie Bumgarner)*

DETERMINING IRRIGATION ZONES

THE NEED FOR IRRIGATION ZONES

Dividing the irrigated area into zones is usually needed to provide uniform water distribution. Zones are quite simply bubblers, drippers or sprinklers that are controlled by a common valve.

Most water sources do not have enough pressure to run the entire irrigation system properly at the same time. For example, if a system has 12 gpm at 45 psi but is connected to eight sprinklers that require 3 gpm each, it will not be able to meet the demand. The result will be dropping pressure, low flow and poor sprinkler operation, causing areas with wet and dry spots. Irrigation zones ensure that the demand doesn't exceed the supply.

Even if the water supply can provide irrigation for the entire landscape at one time, zones still may be needed if different irrigation products or sprinkler spacings are used. Different products such as sprinklers, sprayers, bubblers and driplines usually have very different application rates. If they are operated for the same length of time, they will apply different amounts of water. If different sprinkler spacings are used, the discharge rate may be the same, but the sprinklers with tighter spacing will have a higher application rate than sprinklers located farther apart. This means it is important to have different zones so overwatering or poor watering does not occur.

ZONING CONSIDERATIONS FOR DIFFERENT EQUIPMENT

Zoning also is useful in managing different landscape materials. Some plants need more water than others, so these areas could be zoned separately to apply the desired amount of water. Zoning decisions can also improve irrigation uniformity on steep slopes by creating zones that follow contours instead of traversing up and down a slope. Finally, zones should consist of sprinklers or drippers that are near each other, because long pipe runs in a zone can cause high friction loss (see pipe sizing section below) that interferes with the uniform operation of irrigation equipment.

Sprinkler specifics: Full- and part-circle sprinklers and rotating sprinklers are needed in most landscapes. When purchased, they have a single nozzle that produces the same flow rate (constant discharge). Full- and half-circle rotating sprinklers can be placed in the same zone if the half-circle is re-nozzled to produce half the flow to create matched precipitation. The same is true for half- and quarter-circle sprinklers in the same zone, but this practice is not recommended for full- and quarter-circle sprinklers re-nozzled to one-fourth the flow rate because the radius of throw is significantly reduced, preventing proper overlap of sprinklers. If necessary, leave the corner sprinklers at half the flow of the full-circle sprinklers. In contrast, spray sprinklers and stream rotators of the same model already produce matched precipitation when located at the same spacing, and full circles can be mixed with part circles in a zone without modifying the nozzles. A new generation of stream rotators named MP rotators or R-VAN maintains matched precipitation with different models, operating pressures and radius adjustments, making them much easier to place in a landscape (head to head) and maintain good uniformity with a known application rate (i.e., precipitation rate).

Drip irrigation can be treated differently with respect to application rate, because emitters can be located on a plant canopy basis instead of a land area basis. For instance, one emitter could be placed to supply water to every 9 square feet of canopy such that bigger plants would have more emitters than smaller plants, and all sizes of plant material can be widely scattered within a bed.

To summarize, zones should only contain irrigation equipment that has similar application rates, either on a land area basis for sprinklers or on a plant canopy basis for drip.

PIPE SIZING

Pressure is lost in an irrigation system due to the friction of water moving along the pipe walls and passing through each piece of irrigation equipment. Friction losses require that the pipe size corresponds to the flow rate in each segment of pipe. Pipe that is too small will create excessive pressure drop and water will not be applied uniformly, or some equipment may fail to operate at extremely low pressures. On the other hand, pipe that is too large will unnecessarily add to the cost of the irrigation system. The higher the velocity of water, the higher the friction loss and pressure drop in a pipeline. For example, if 20 gpm is carried by a 1.5-inch PVC pipe, the velocity is 2.65 feet per second and the pressure drop will be 0.71 psi per 100 feet of pipe, while the same 20 gpm flow in a 1-inch pipe would cause the velocity to be 5.71 feet per second and the pressure drop to be 4.59 psi per 100 feet of pipe.

To keep pressure loss due to friction at acceptable levels, a simple three-step method has been devised.

1. Route the mainline pipe from the water source to the zones and route pipe to sprinklers within the zone (consider how a trencher will operate and the efficient use of pipe).

2. Total the flow in gpm for each pipe section based on the expected flow rate per sprinkler.

3. Choose the smallest pipe that will keep the flow velocity below 5 ft/sec in each section. Manufacturers provide pipe charts that show the friction loss and water velocity for different pipe types, pipe sizes and flow rates. Using the manufacturer's literature and the 5 ft/sec rule, a simplified pipe chart showing the pipe size that correlates with a flow range can be created. Remember that different pipes have different hydraulic characteristics. Make a chart for each pipe type because the material roughness and the inside diameters differ. Using the simplified pipe chart, assign a pipe size to each pipe section based on flow. Many homeowners will discover that their water supply is often limited to less than 15 gpm, so they can simply use a 1-inch PVC pipe for their entire system.

CONTROLLING IRRIGATION ZONES

AN INTRODUCTION TO VALVES AND AUTOMATION

Valves controlling irrigation can be manual (usually ball or gate) or electric solenoid valves that will be needed for an automatic system. In a manifold, the main water supply is connected to all valves, and the valves control the flow to the individual zones or laterals in a zone. Valves can be placed subsurface to protect from freezing and lawn equipment that can be accessed through a valve box.

Automation is accomplished by means of electronic solenoid valves and a controller (timer). Solenoid valves are placed at the head of every zone (Figure 13). Each valve requires a common wire and power (actuation) wire that connect to a central controller. Most solenoid valves have a manual override that allows operation of the zone when power is not available (solenoid valves are normally closed when the electricity is off).

FIGURE 13. *Irrigation box showing an automatic controller and one irrigation zone. Additional zones could be added if required. (Image source: Natalie Bumgarner)*

Any electrical system used around the home should be installed and maintained using sound electrical practices. Once the valves and the controller are properly wired, the controller program can be set up. The controller program has three main settings: the length of time to operate each valve, the start time to initiate the valve sequence, and the days that the valve sequence will operate. Controllers come in all makes and models but fall into three basic categories: electromechanical, solid-state electronic and hybrids.

Electromechanical controllers were the first type of controllers with settings made on rotating dials with trip pins. Later, solid-state controllers were introduced with all settings entered on a keypad within a program loop. Presently, hybrid controllers are the most popular, because a limited number of dials helps the user enter the settings without having to enter a long programming loop. Even with automation, a manual valve should be installed at the beginning of the irrigation system so that all components can be maintained with the water turned off.

A normal timer program is set for the days of the week to water (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday) and the starting time to initiate the valve sequence with a valve run timer for each zone. The optional features available to manage water are rain delays, rain gauge shutdown and soil sensor shutdown. If you don't use one of these features to help you manage irrigation, remember to turn off your controller when it is raining.

OTHER EQUIPMENT

Choosing manual or automatic operation of the irrigation system depends on personal preference. However, with either system, backflow prevention is required. Backflow prevention is necessary on many landscape irrigation systems to keep stagnant or contaminated water out of the water supply. It is especially important for protecting drinking water but can also be important in other situations. Backflow can occur when a pump is turned off (intentionally or by loss of power), when there is major pipe break, or when there is a large demand for water for another use, such as a fire truck pumping from a municipal water system. Backflow occurs when pipes are full and when there is an upstream pressure drop causing water in the pipe to change direction. When this happens, the vacuum in the pipes can pull soil, debris or other materials into the water stream. So, backflow prevention is needed if you use utility water to prevent the water or other contaminants from flowing into the water supply line if pressure is lost in the system. Homeowners with wells should consider backflow prevention to protect their own water supply.

There are many backflow prevention devices. They range from a simple check valve, like a foot valve used in pumping from a pond or stream, to a Reduced Pressure Backflow Device (RPBD). A RPBD provides the most protection, has the highest cost, causes the greatest loss in pressure, and is required for hook up to domestic water by many municipalities. The RPBD can be used in most situations, but it cannot be located where it will be submerged.

A pump is required if the intended water supply is a stream, a pond, a well or a domestic supply that does not provide enough pressure to operate the irrigation system (booster pump). The pump type (centrifugal, vertical turbine or submersible: electrical or engine driven) can be chosen based on the location and type of water supply, the flow that it will deliver, and the height of the pump above the water supply. Pump flow can be determined from the zone with the highest flow. The required pressure or head is a summation of pipe friction to the most distant location, friction loss through all equipment (valves, backflow prevention device, etc.), elevation gain from the water source to the highest water emission point, and the pressure needed to operate the highest pressure sprinkler, sprayer, bubbler or dripper in the system. It is advisable to seek the aid of an irrigation professional in making the calculations needed to size a pump. Even if using a pressurized source, such as municipal drinking water, it is important to subtract the friction losses and the elevation gain from the existing pressure to ensure there is enough pressure to operate the sprinklers, bubblers, and/or drippers.

Excess pressure can also damage an irrigation system. A pressure-reducing valve will maintain pressure at an acceptable level, and a pressure relief valve will release water when a high-pressure threshold is reached. A pressure reducer is usually required to control high pressure in the utility main line before it is released into your home. A pressure reducer can be adjusted to meet the needs of a home irrigation system in most situations. If water is pumped, a system can be designed to operate at acceptable pressures. Class 160 or schedule 40 PVC pipe is rated to operate at pressures up to 160 psi and is commonly used in landscape irrigation. Normal operating pressures will be exceeded temporarily when flow starts and stops in a pipeline, resulting in pressure spikes known as water hammer. These pressure surges can be excessive and break pipe when the flow velocity exceeds 5 feet per second and air is not purged from the pipeline.

Airflow in a pipeline needs to be controlled in addition to water. Air release/vacuum relief valves allow air to evacuate when filling the pipe and also allow air to enter the line when the pipe is drained. A continuous-acting air relief valve allows air to be purged from high points in the pipeline once the system is under pressure. In many instances, sprinklers allow for proper air management; the devices described above often are not needed for small landscape systems.

In addition to the valves, some equipment is related to specific irrigation products. For sprinklers, a swing joint is a flexible connection between a sprinkler and the lateral pipe that allows easy adjustment of the sprinkler height, protecting the sprinkler head from mower damage. This flexible connector also protects the lateral pipe when vehicles run over the sprinkler heads, allows the sprinkler to be moved deeper if the soil settles, and facilitates removal/replacement when a sprinkler is damaged.

For drip irrigation, filtration is needed to keep the emitters from plugging. Municipal and well water are often clean enough to use without filtration, but a screen filter is still recommended to protect the emitters from debris caused by pipe breaks and the sand that is sometimes carried in well water. A disc filter is a better choice if surface water is used on a small drip area. If an extensive area is drip irrigated with surface water, a sand filter is a better choice than a disc filter. Filters for drip irrigation will be in the 120- to 160-mesh range; the manufacturer's literature for the actual requirement should be checked. When sprinkler and drip are used in the same landscape, small pressure regulators will help reduce the pressure for use in the drip-irrigated zones.

RECOMMENDATIONS FOR DRIP PRODUCT USAGE

- Water must be cleaned with 120-200 mesh filters, depending on the drip product.
- Screen filters should be used for well and utility water.
- Disc filters should be used for surface water irrigating a small area.
- Sand media filters are best suited for surface water and large drip projects.
- Water pressure must be within the appropriate range.
- Pressure regulators should be used to protect the drippers and ensure operation at a designated flow.
- Pressure compensating emitters should be used when operating under a greater range of pressures.

FIGURING APPLICATION RATE

Ar = application rate in inches per hour

Q = flow or discharge in gallons per minute

A = area into which flow is applied in feet^2

Conversion factor = 96.3

Example: A full-circle sprinkler discharges 2.4 gpm and the sprinkler spacing is 30 by 30 feet.

Ar = (96.3 x 2.4) / (30 x 30)

= 0.25 inches per hour

DETERMINING IRRIGATION TIMING IN THE LANDSCAPE

Once an irrigation system that uniformly applies water within each zone is designed and installed, it is important to know how to operate the system so the landscape always looks its best and neither water nor money is wasted by overirrigating.

The first step in determining how long to operate each zone is to calculate the rate water is applied to each zone. An application rate is calculated by dividing the flow into the area irrigated (gpm/square feet) and multiplying by the conversion factor, 96.3, to determine the inches of water applied in one hour. For sprinklers, this can be done by dividing the flow rate of a single sprinkler by the area of the individual sprinkler spacing or by dividing the flow of the entire zone by the total area of the zone.

For drip irrigation, the flow for one emitter can be divided by the plant canopy area (remember to divide gallons per hour by 60 to obtain gallons per minute). For drip tape, the flow per 100 feet is divided by the area between drip lines (100 feet multiplied by the line spacing). Some may prefer to place rain gauges or vertical-sided baking pans in a zone, run the zone for an hour (two hours may work better), and measure the depth of water caught in inches to determine the inches applied in an hour. However, this method will not work very well for bubblers and drip.

Once the application rate for each zone has been obtained, the operation time is calculated by dividing the irrigation amount by the application rate. For instance, during peak water-use periods, apply 0.5 inches of water two times per week if there is no rainfall. If a zone's application rate is 1.0 inch per hour, the zone would need to be operated for 30 minutes (0.5 inch / 1.0 in/hr = 0.5 hours). Once the peak operation times for each zone have been calculated, program the valves on the controller to operate for the desired time (often referred to as valve run time). Next, program the days of the week the zones or valves will operate and the start time that initiates the sequential operation of all valves on a program.

Often there is no need to operate your zones for the full length of time. Peak water use generally occurs in June, July and August when solar radiation and temperatures are high. Even during potential peak water-use times, plants may not use water at a peak rate when the weather conditions are cool, cloudy and humid with little or no wind. Also, during the spring and fall, landscapes will not use as much water. Therefore, operation time should be reduced by shortening the valve run times or by skipping days when the program is scheduled to operate.

As mentioned earlier, in addition to periods of lower water use, rainfall can meet the landscape water requirements. The controller should be turned off during periods when rainfall exceeds water-use rates. Some controllers have a rain delay feature that allows the controller to be turned off for a specified time period before resuming normal operation. For instance, after a 1-inch rainfall, a rain delay may be set so that normal operation of the controller will be suspended for seven days. Some controllers are equipped with rain gauges (most controllers can be retrofitted) that automatically suspend controller operation for different lengths of time depending on the rainfall amount. Finally, some controllers are equipped with soil moisture sensors (most controllers can be retrofitted) that will not allow the controller to operate until the soil dries to specified soil moisture. This type of control will respond both to rainfall and a change in the landscape water-use rate.

Although automation and sensors can help manage water more efficiently, it always pays to observe what is happening in the landscape. A zone on an exposed, south-facing slope will dry out faster than a shaded area on a north slope, causing a need to increase the valve run time on the former while decreasing the time on the latter. Runoff may be observed on sloping ground or on heavy, more clayed soil. To prevent this loss of water leading to dry soil conditions, shorten the run time and operate more often. Sandy soils show signs of stress sooner than silt or clay soil. Since sands hold less water, irrigate more often than once or twice per week and reduce the run time accordingly, because long irrigations on sandy soils are liable to percolate water through the root zone where the plant cannot access the water.

HOW DEEP SHOULD YOU WATER?

Determining how deep to water depends on several factors: soil texture, soil structure, plant type, age and size, and watering practices. A mature plant needs a certain amount of water to survive, whereas young plants need water to continue to grow and develop. Compacted or shallow soils inhibit deep rooting, and plants may not be able to be watered deeply. Consider the following when watering:

- Leafy vegetables and annual bedding plants: 6 inches to 1 foot (15 to 30 cm).
- Small shrubs, cool-season turfgrass, corn and tomatoes: 1 to 2 feet (30 to 60 cm).
- Large shrubs, trees, warm-season turfgrass: 1.5 to 5 feet (45 to 150 cm).

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