SELECTING AND MAINTAINING TREES FOR URBAN DESERT LANDSCAPES

A Mojave Desert Water Conservation Perspective

Dale A. Devitt *and* Robert L. Morris

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PREFACE

Consider the life of trees.
Aside from the axe, what trees acquire from man is inconsiderable.
What a man may acquire from trees
is immeasurable.
From their mute forms
there flows a poise, in silence,
a lovely sound and motion in response to wind.
What peace comes to those
aware of the voice and bearing of trees!
Trees do not scream for attention.
A tree, a rock has not pretense,
only a real growth out of itself,
in close communion
with the universal spirit.
A tree retains a deep serenity.
It establishes in the earth not only its root system
but also those roots of its beauty
and its unknown consciousness.
Sometimes one may sense a glisten
of that consciousness,
and with such perspective,
feel that man is not necessarily
the highest form of life.

—Cedric Wright
(1899–1959)[1]

1 Permission to reprint given by the Cedric Wright estate in 2019.

Although trees may not scream out for attention, as Cedric Wright so elegantly writes in his poem, in their quiet presence and beauty, a well-placed tree in the landscape can make us pause, even for just a moment, to realize the uniqueness of life itself. Every landscape is different in size, purpose, orientation, slope, micro-environments, and soil. Trees that are appropriate for one site are not necessarily appropriate for another site. This book should interest water managers, irrigation designers, landscape architects, and even homeowners, where water conservation is a priority, where water availability is limited, and where landscapes need to be designed and maintained with plant water use in mind. This of course does not mean that a landscape anchored in water conservation can't be beautiful and make all who pass by pause to admire such beauty!

This book will guide those who live in the Desert Southwest and wish to know which trees to select and how best to irrigate them to achieve a healthy, beautiful landscape, more closely in tune with desert environments. Using trees that originate from arid and desert environments will save water when they are irrigated, when they need water. The need for water can be monitored by observing how they grow, following its seasonal water-use curve, or using sophisticated monitoring equipment. This book will guide community foresters and arborists in selecting the proper tree for a landscape and in how to make these judgment calls.

Trees should provide beauty and, when managed properly, use significantly less water than other plant alternatives. In arid and desert environments, the amount of irrigation water applied dictates the amount of water lost by a single blade of grass, every leaf on a shrub, and each tree planted. Water savings, by selecting the proper tree, varies from site to site. To meet the water needs of a landscape, one needs to be mindful of the environment, limit the number and sizes of plants, use desert-appropriate plants, and implement an irrigation strategy that minimizes plant stress but maintains high visual quality, all the while conserving water. That's a daunting task!

Conserving water starts on paper. A finished landscape design dictates the eventual total landscape water use when it's mature. This book guides architects, landscape architects, designers, contractors, and homeowners on how to conserve water during the landscape planning and designing stages. When landscapes are carefully designed and plants carefully selected and placed, water and energy costs will be minimized. For this to happen, one requires a thoughtful design that considers the complex interaction between a personal need for beauty, livability, and total landscape water use.

In this book, we will guide the homeowner and landscape contractor through an assessment of their existing landscape. We will spell out what needs to be known about the climate, soil, water, irrigation system, irrigation strategies, and landscape design that helps to select the ideal trees and maintenance plan suitable for a landscape.

We have taught and provided guidance to the professional desert landscape community through research, presentations, articles, and classes for decades. Our ninety years of combined experience is found in this book.

ACKNOWLEDGMENTS

We wish to thank the USDA and the Nevada Division of Forestry for funding this project. A special thanks to Ms. Nancy Villeda for the wonderful drawings and figures she created for the book. We also wish to thank Dr. Stan Smith and Dr. Lloyd Stark for peer reviewing the book.

I would like to thank my wife, Peggy Devitt (my best friend), for always inspiring me to be creative even if it meant spending many hours secluded in my office.—DAD

I would like to thank my wife, Gigi Morris, for her tolerance to my absences while this book was being written and for her endless support.—RLM

1 CHAPTER

Introduction

Native trees growing in arid regions are unique in that they can withstand water-limiting conditions and high summer temperatures and should be the focus for urban-landscape tree selection in desert regions. However, even these trees will be impacted by climate warming, especially in cities in the desert that are already showing elevated nighttime temperatures (urban heat island—Las Vegas, Nevada) as increased respiration rates (utilizing stored sugars to produce energy; increases with higher temperatures) will deplete total photosynthates (stored sugars) leading to irreparable damage at the cellular level (Turnbull et al. 2002; Zheng et al. 2002). Selection of trees that can tolerate higher temperatures will be key in addressing the warming of urban areas. Although water-conservation efforts in arid regions focus on landscape water use and reducing the size of landscapes, we must appreciate the impact of a well-placed tree in cooling buildings and other hardscape surfaces to lessen the urban heat-island effect.

Scientists believe trees first appeared on earth about three hundred million years ago. Since that time, trees have spread to every continent except Antarctica (modern day), adapting to a wide range of climates, soil, and topographic conditions. We find trees growing in the arid extremes of such locations as Death Valley but also in the extreme cold of high mountain elevations such as in Nepal. Current estimates place the number of tree species growing on earth at slightly over sixty thousand (Beech et al. 2017), with the largest number of species found in tropical regions that maintain year-round growing conditions. Although earth is mostly covered with water (71 percent), the amount of land available for tree growth is still significant enough that it is estimated that a staggering three trillion trees exist on the planet, which means about four hundred trees for every person (Crowther et al. 2015).

Did You Know?

About 1 percent of the water on earth is potable (drinkable).

Early man utilized trees for fuel, food, and protection from the elements. It is not surprising that these early inhabitants also developed a strong spiritual connection with trees as well. Egyptians spoke of the tree of life, as they believed the roots of trees connected to the netherworld, while the branches reached out high to the heavens. Once man moved from nomadic wanderer to residing in permanent dwellings, trees were planted for shade and beauty. The first of these formal plantings was documented in Mesopotamia, where King Nebuchadnezzar II planted trees and other plants around the royal grounds (known as one of the seven wonders of the world) to please his wife, who came from a region with more forested areas.

Did You Know?

The first certified botanical garden was established in the Vatican City in AD 1278 (Pope Nicholas III).

The Las Vegas Valley, Nevada, is part of the Mojave Desert that also reaches into California, Arizona, and Utah (photo 1). The southern region of Nevada was home to the Southern Paiutes long before the first trappers, led by Jedediah Smith, entered the valley in about 1827. The valley was known for its meadows (hence, its name), mesquite forests (or bosques), and shallow bodies of water (photo 2). It is doubtful that Smith could have imagined that, in less than two hundred years, more than two million people would call the valley home. Although early settlers would have planted native trees for shade, fruit trees would have been imported from greater distances. Today, however, the streets are lined with predominantly nonnative tree species, with many pine species being favored.

Photo 1. Mojave Desert near (top left) Las Vegas, Nevada; and (lower left) Baker, (top right) Barstow, and (lower right) Victorville, California (photos by D. Devitt). All sites are represented by a creosote-bursage plant community. It is difficult to imagine early settlers moving through this area in wagons!

Photo 2. Las Vegas Valley, early 1900s (photo provided by the Nevada State Museum). Early Spanish explorers recorded abundant flow from artesian springs and the presence of grassy meadows and a mesquite forest over four thousand acres in size.

In southern Nevada, it is estimated that about 60 percent of all the water used in the valley occurs in the residential sector, with about 70 percent of that water used outdoors to irrigate urban landscapes (Devitt et al. 2008). With over 40 percent of all the water supplied to valley users ending up in urban landscapes, it is not surprising that significant conservation efforts have been focused on outdoor water use.

Landscapes can be designed to be low in water use, but to save water, they must be managed properly, as any landscape can be overwatered. Saving water in the urban landscape requires knowledge and effort on the part of those who irrigate such landscapes. This book details how it is done.

Did You Know?

There are more water molecules in one cubic inch than there are visible stars in the universe, as observed with the Hubble telescope.

Devitt and Morris (2006, 182) stated, “Water conservation plans need to be based on an integrated planning process that considers the merits of all available options (landscape area, species, irrigation management, pricing) and encourages natural tradeoffs that lead to public acceptance and the net savings of water.” We need to encourage and support social change in the way we, as individuals, embrace water conservation. Clearly, we need to think differently than as Steinbeck wrote in *East of Eden*: "And it never failed that during the dry years the people forgot about the rich years and during the wet years they lost all memory of the dry years. It was always that way."

Each individual home is not the problem, but collectively, they are the problem with regard to attaining lower water use for any community, especially in fast-growing communities like Las Vegas and St. George, Utah. Questions that must be asked include:

- How much of an available landscape should be planted, and how should it be irrigated?
- How should the landscape be designed, such that specific zones can receive different amounts of water?
- What kind of irrigation system should be installed?
- What are the proper trees to select for a desert environment?
- How will one know if one is irrigating with the right amount of water? What signs should one look for that indicate that one's landscape is being over- or under-irrigated?
- What is the influence of local soils, water sources, and microenvironments on plant growth and water requirements?

These are not trivial questions, and answering them does require an appreciation for science. Although we now live in a time of great technological advancements, with information readily available at our fingertips, bringing relevant information together and interpreting that information still represents a major undertaking.

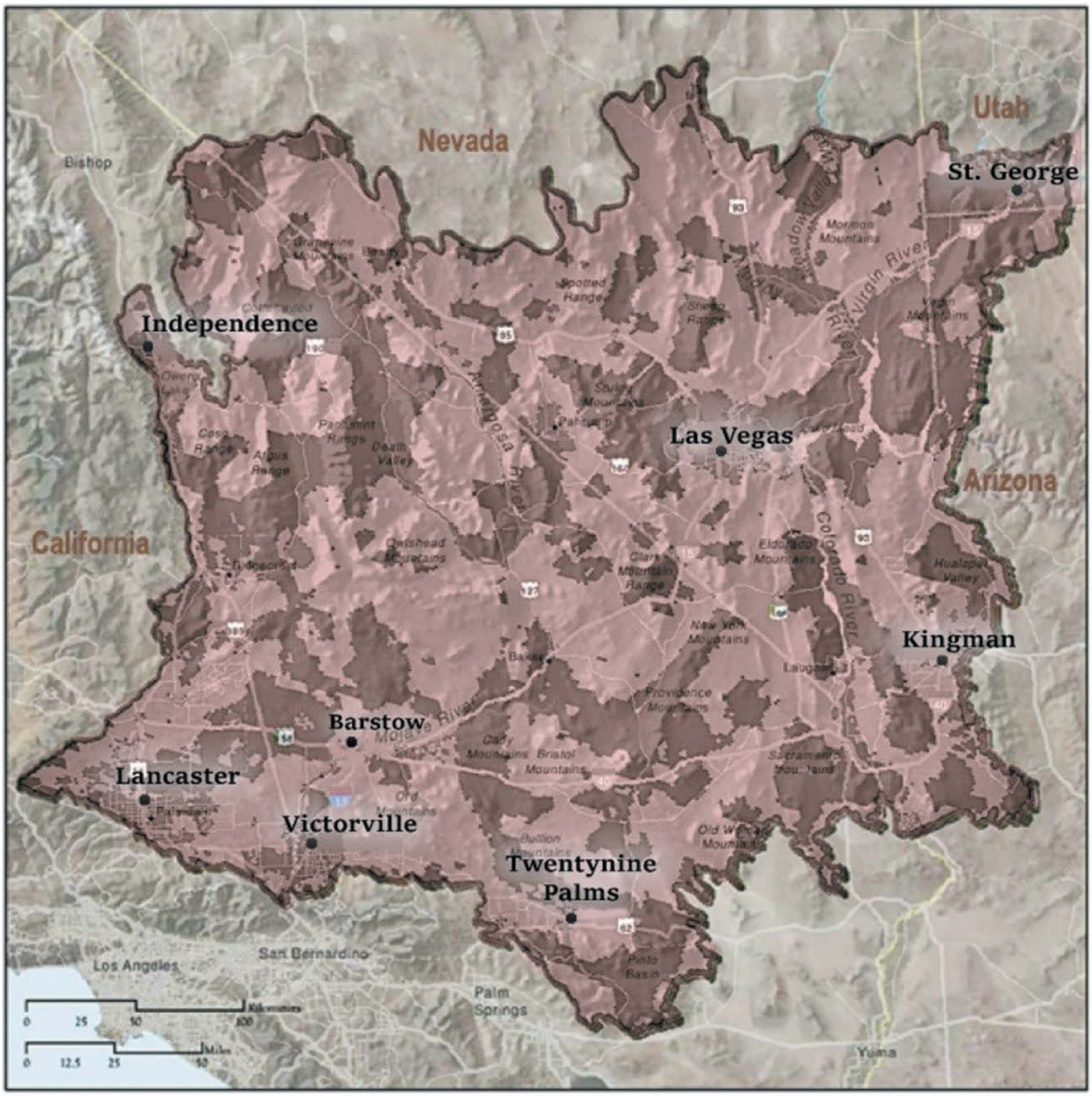
Mojave Desert

The Mojave Desert is the smallest of the four North American deserts (figure 1); the other deserts are the Sonoran, Chihuahuan, and the Great Basin. The Mojave Desert is dominated by mountain-valley topography and is classified as a "hot" desert and the driest of the four deserts. The Mojave Desert is also referred to as "high desert" because most elevations are over two thousand feet (table 1), which contrasts with the Sonoran Desert, which is referred to as "low desert." The Mojave Desert is approximately twenty-five thousand square miles in size, but its exact boundaries are not entirely agreed upon by all scientists. The majority of the Mojave Desert is in Southern California and southern Nevada, with the northeast boundary capturing St. George, Utah, and its eastern boundary capturing portions of western Arizona, including Kingman. The Mojave Desert is delineated from the other deserts of North America based on elevation, latitude and longitude, soils and geology, and indicator species. In the Mojave Desert, the iconic indicator species is the Joshua tree (*Yucca brevifolia*, photo 3), which is found only in this desert at higher elevations. It is typically found at the base of desert mountains, where runoff contributes additional water. It also has a cold-winter requirement for flowering and is pollinated only by one type of moth, the yucca moth (genus *Tegeticula*; note that there are different species of the moth that pollinate different species of yucca), that in turn only pollinate the Joshua tree—one of the best examples of a mutualistic symbiotic relationship found in the world). The Joshua tree is considered a vulnerable species to climate change, as significant warming is expected to impact its flowering and soil plant water balance.

> **Did You Know?**
>
> In 1900, more people lived in Kingman, Arizona; St. George, Utah; and even Victorville, California, than in Las Vegas, Nevada.

The Mojave Indian tribe (the desert was named for these original inhabitants) called this region home before being displaced to reservations by 1870. The Mojave Desert is now home to thirty cities and over two million inhabitants in the Las Vegas Valley alone.

Figure 1. Geographical area of the Mojave Desert, with major cities listed. This map was based on a map published by the Nature Conservancy. (Permission to use granted in 2019.)



City	Population	Elevation	Reference Evapotranspiration (annual total, in)
Barstow, California	23,498	2,175 ft	66.79”
Independence, California	669	3,936 ft	59.79”
Kingman, Arizona	28,549	3,333 ft	81.76”
Lancaster, California	160,107	2,355 ft	68.17”
Las Vegas, Nevada	632,916	2,000 ft	70.47”
St George, Utah	82,315	2,761 ft	55.85”
Twentynine Palms, California	25,902	2,001 ft	69.11”
Victorville, California	122,283	2,715 ft	67.46”

Table 1. Annual reference evapotranspiration estimates, along with elevation and population for eight cities located in the Mojave Desert

Photo 3. Joshua tree (*Yucca brevifolia*) growing in the Red Rock area of southern Nevada (photo by C. Philips). These trees are found only in the Mojave Desert. Although a member of the lily family, we call it a tree based on its height and trunk diameter. Native Americans used them to make bowls and also ate the fruit.

Did You Know?

Joshua trees can live more than five hundred years, with the oldest estimated age at about one thousand years.

Topography

Mountain-valley topography is typical of the Mojave Desert, but there are internal and external drainage basins within this region. Most of the Mojave Desert is probably external, but some areas are internal, such as the entire Death Valley region. *External* refers to the fact that water and eroded sediments can exit the valley, such as via the Las Vegas Wash in Clark County, Nevada. *Internal* refers to a closed basin, where no water or eroded sediments can exit. A good example is Lake Manley, in Death Valley, California, which evaporated thousands of years ago, leaving salts in place that formed what is now called the "Devil's Golf Course."

Erosion from surrounding mountains deposits sediments on valley floors. Heavier particles settle first, with smaller-size clay particles staying suspended in the runoff for longer periods and greater distances. This leads to higher clay-content soils at lower elevations in the valleys. In Las Vegas, coarser soils exist in the western portion of the valley (as in Summerlin), with higher clay deposits in the lower-elevation Henderson area (figure 2). Clay deposits, if extensive, can lead to shallow, perched bodies of groundwater. In the Las Vegas Valley this has led to over one hundred thousand acre-feet of water being perched in the upper forty feet of soil and sediment (water accumulated from the over-irrigation of urban landscapes). Unfortunately, these waters contain significant amounts of salts from the local soils. In figure 3, the depth to the shallow groundwater is noted, with the shallowest part of the system primarily in the southeast portion of the valley. Salts in the shallow groundwater can be brought back to the surface via capillary lift (driven by evaporation), salinizing the soil, and placing greater stress on landscape plants. In areas where the water table is within five to ten feet, great care should be taken in the selection of salt-tolerant tree species and in irrigation management to continuously push these salts downward. City planners need to ask themselves whether such areas should even be built on in the first place. Expansive clays and elevated salt levels will have a long-term negative effect on homes and landscapes in these areas.

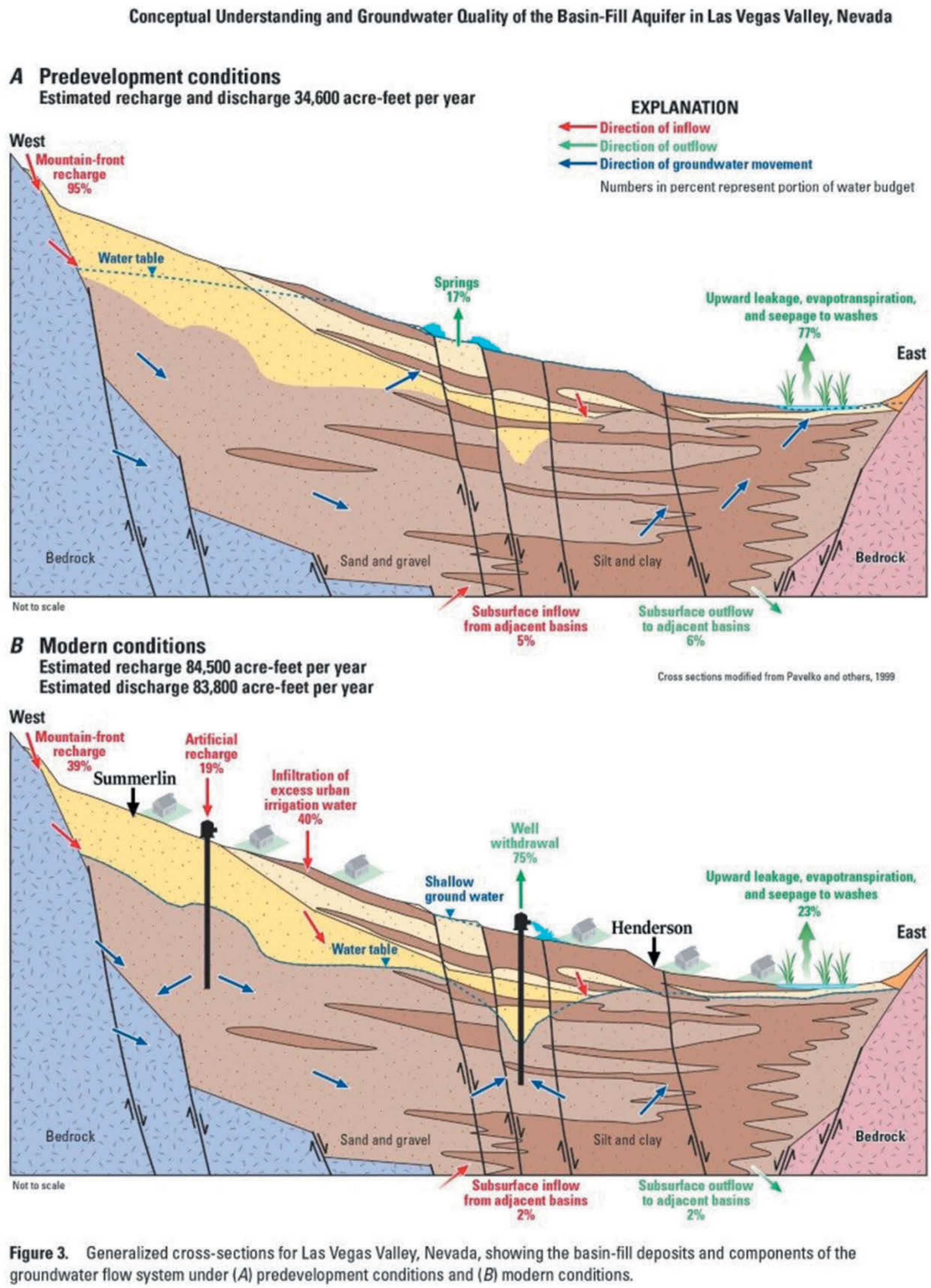


Figure 2. Generalized cross sections for Las Vegas Valley, showing the basin fill deposits and components of the groundwater flow system under (A) predevelopment conditions and (B) modern conditions (SNWA). Predevelopment conditions are shown in photo 2, in which artesian flow supported an extensive meadow and mesquite forest. Well withdrawals began, with the first well completed in 1907, and by 1911, seventy-five deep wells had been drilled, all flowing under artesian pressure. As the water level dropped, the meadows dried up. (Permission to use figure granted in 2019 by Jena Huntington with the USGS.)

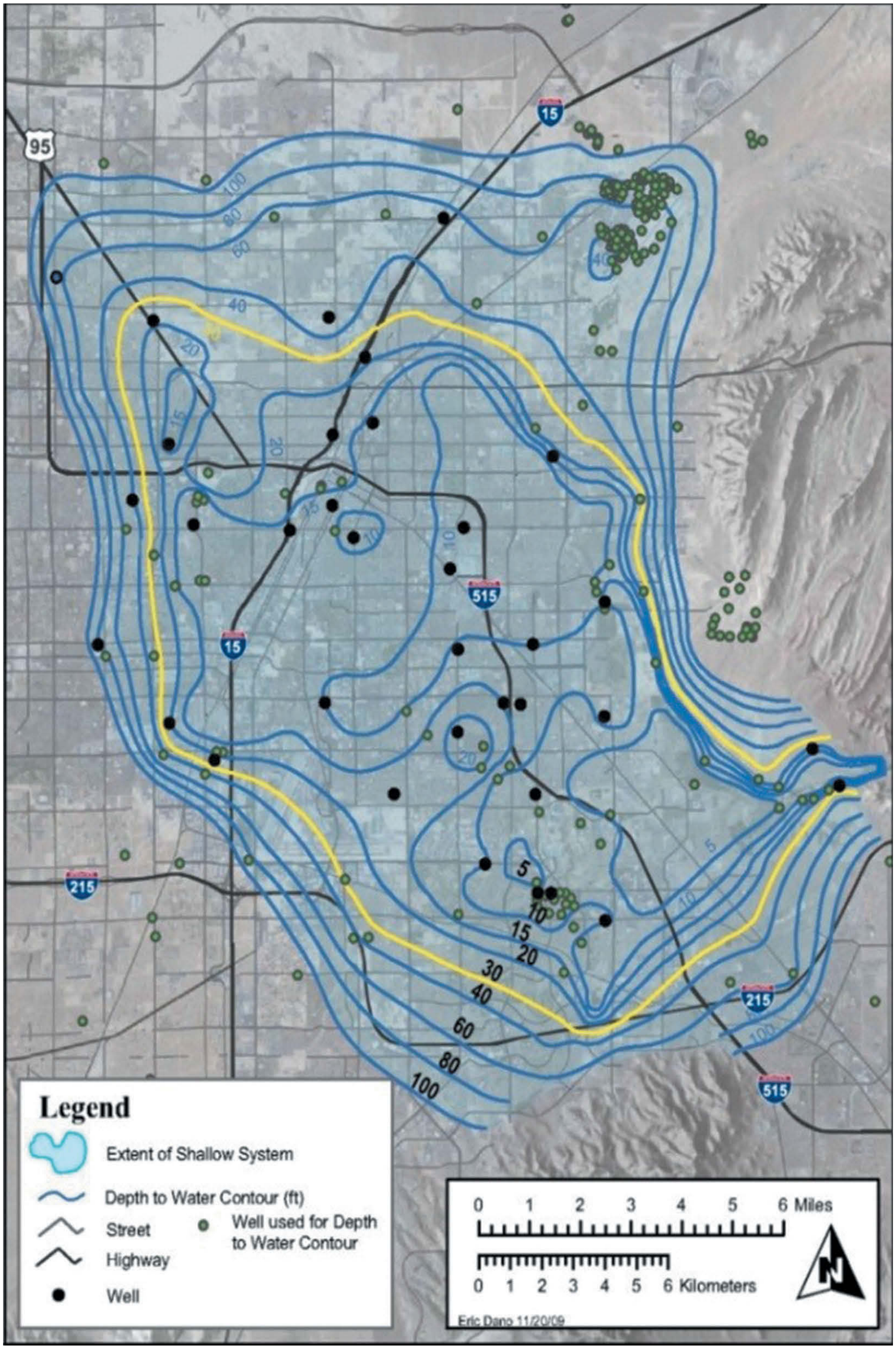


Figure 3. Extent of the shallow groundwater system in the Las Vegas Valley. Contour intervals reveal shallow groundwater as close as five feet to the surface in the southeastern section of the valley (SNWA). Water levels on campus at the University of Nevada, Las Vegas, have been around twelve feet, often requiring pumping to avoid damage to the swimming pool. Several casinos have wells they pump to lower water levels to reduce contact with basement structures. The famous Bellagio dancing waters uses shallow groundwater (considered nuisance water) that has been pumped and treated. Realize that most of this shallow groundwater is due to over-irrigation of urban landscapes. (Permission to use figure granted by SNWA in 2019.)

2 CHAPTER

Know Your Climate and Microclimates

The Mojave Desert is classified as *arid*, which means it receives less than ten inches of precipitation per year (figure 4). It is in a permanent state of aridity, and, therefore, it technically does not have droughts. As such, plants at the lower elevation must adapt to this dry environment if they are to survive. Some of these adaptations include:

- smaller leaves
- thick leaves
- light-colored leaves
- leaves covered with hairs
- leaves covered with (cuticular) wax
- recessed stomata (small opening on the leaves that regulates water loss and uptake of carbon dioxide)
- high root-to-shoot ratios
- summer dormancy

The plants typically planted in urban landscapes within the Mojave Desert, however, are not native and often have few of these adaptations; thus, they require quantities of water far in excess of what actual precipitation can provide.

Did You Know?

When water leaves the stomata of plants, it does so as vapor, meaning that there is a phase change from liquid to vapor. When this occurs, it absorbs about 540 calories per gram of water, meaning significant cooling is occurring. You can appreciate this when you walk from an asphalt parking lot onto the fairway of a golf course during summer.

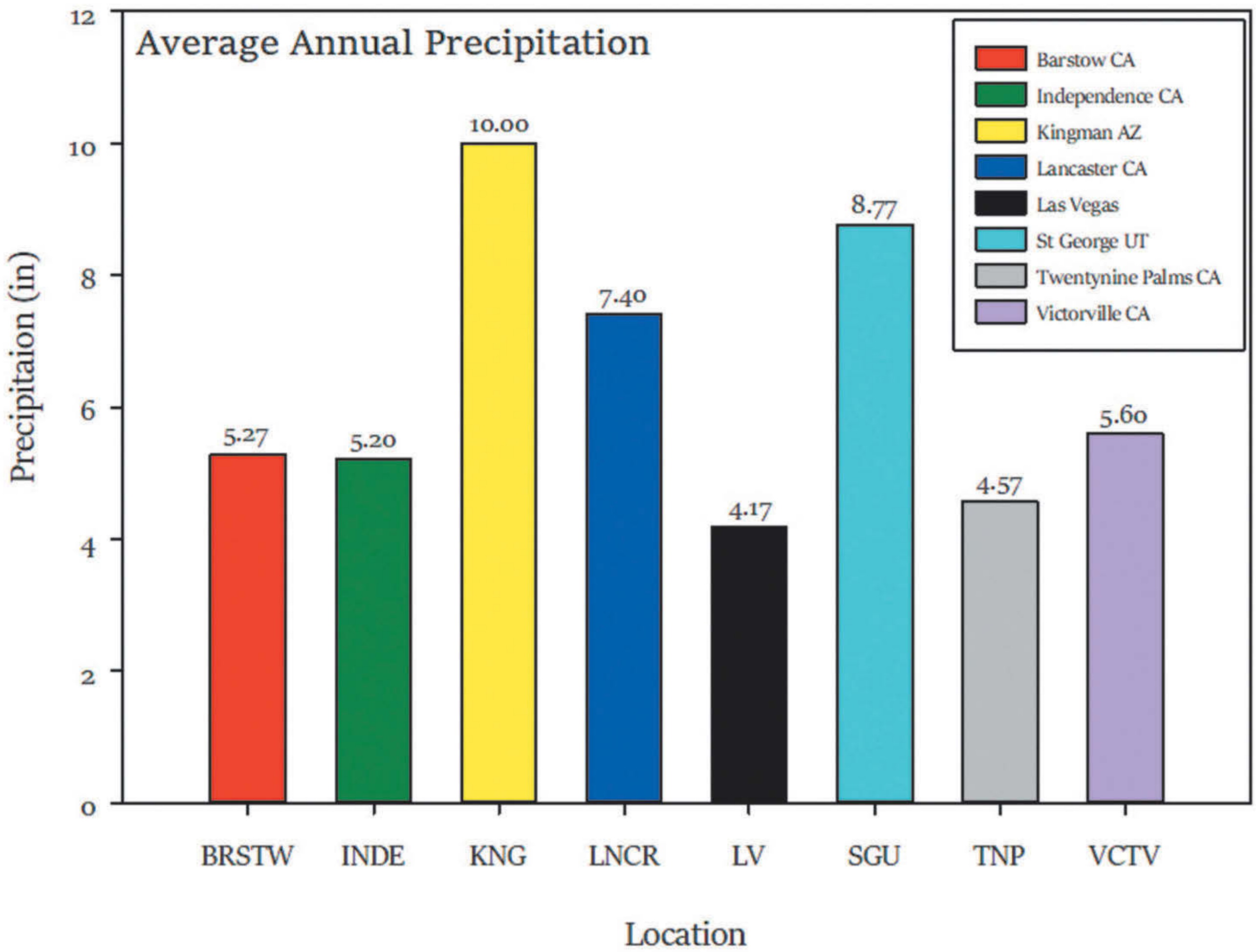


Figure 4. Average annual precipitation in inches for eight cities located in the Mojave Desert. Four to ten inches may be enough to support creosote and other desert-adapted plants, but it clearly is not enough to support lush urban landscapes dominated by cool-season turfgrass species (such as tall fescue) that are irrigated with little forethought.

Did You Know?

Although earth's atmosphere contains about forty trillion gallons of water, enough to cover the planet with one inch of water, rainfall is all about location. Las Vegas averages just over four inches per year, but Quibdo, Colombia, averages over 288 inches.

Within the Mojave Desert, most cities register over 280 sunshine days (except for St. George at 255 days) and over 280 frost-free days (except for Independence, St. George, and Victorville, all at fewer than 245 days). Average low and high temperatures reveal bell-shaped curves for all of the cities shown in figures 5 and 6, indicating a well-defined warm period in June, July, and August and well-defined cooler periods in November, December, January, and February, with transition months in spring (March, April, and May) and fall (September and October). As noted in figures 5 and 6, the Mojave Desert reveals a certain amount of variation in temperatures, with greater variation in low temperatures compared to high temperatures. Las Vegas maintains the highest low temperatures in most months, followed by Twenty-Nine Palms, with Victorville having the lowest average low temperatures. These higher low temperatures in Las Vegas are associated with an urban heat island effect (figure 7; greater heat retained overnight because of the higher percentage of area covered in asphalt, concrete, and buildings, which absorb and release/radiate heat back out at night and because of lower wind speeds). In fact, Las Vegas, in 2019, had the distinction of being the fastest-warming city in the United States (Toten, 2019). The difference in the average low temperatures in July between Las Vegas and Victorville is approximately 20˚F (warmer in Las Vegas), which is significant in terms of driving higher evaporative rates (not to mention the increased summertime peak-energy demand associated with air-conditioning).

Did You Know?

Although CO_2 is known to act as a greenhouse gas that warms the atmosphere, water vapor is the largest contributor to the warming of the planet (keeping earth at a comfortable average temperature of 59˚F). This water vapor is part of the natural global hydrologic cycle and does not change on a global basis, whereas a significant portion of the elevated CO_2 is associated with human activities.

Wind speeds do not reveal bell-shaped curves but do separate by location and do show higher values for March, April, and May (spring, figure 8). Wind occurs because of differences in air temperature driven by the uneven warming of our planet (greater radiation striking the earth at the equator, as compared to more northern and southern latitudes associated with the radiation striking at an angle—earth is a sphere; it is not flat!). The warmer air rises, and the cold air sinks and when you combine this with mountains and valleys you begin to establish wind patterns. In Nevada, most of the valleys are oriented in a north-south direction, leading to wind often moving north in the summer. It is important to consider the prevailing wind speed and direction when orienting the construction of a home and planting vegetation for effective wind barriers. Realize it is the continued movement of vapor off the leaves (lost from the stomata) that maintains higher transpiration rates. Twenty-Nine Palms and Independence, California, had the lowest average monthly wind speeds, with Kingman, Arizona, and Barstow, California, having the highest wind speeds.

Highest average monthly relative humidity always occurred in St. George, whereas Las Vegas and Kingman maintained the lowest relative humidity over most months (figure 9). It should be noted that all of these measurements are made at weather stations that reflect irrigated landscapes (agricultural crops, urban landscapes). The standardized approach is to place the weather station in an irrigated field, in which grass or alfalfa is grown under non-water-stressed conditions; as such, the relative humidity is much higher than if the weather station were placed in the open desert.

Environmental demand for water, which drives plant water use, is driven by solar radiation (high ↑), temperature (high ↑), relative humidity (low ↓) and wind speed (high ↑). These parameters are all incorporated into a water-use demand called *reference evapotranspiration*, which reflects the *potential* for water loss from soil and plant surfaces. Actual evapotranspiration occurs as evaporation from both plant surfaces and soil surfaces and transpiration from the stomata. (Some can also occur through leaf cuticles and the bark.)

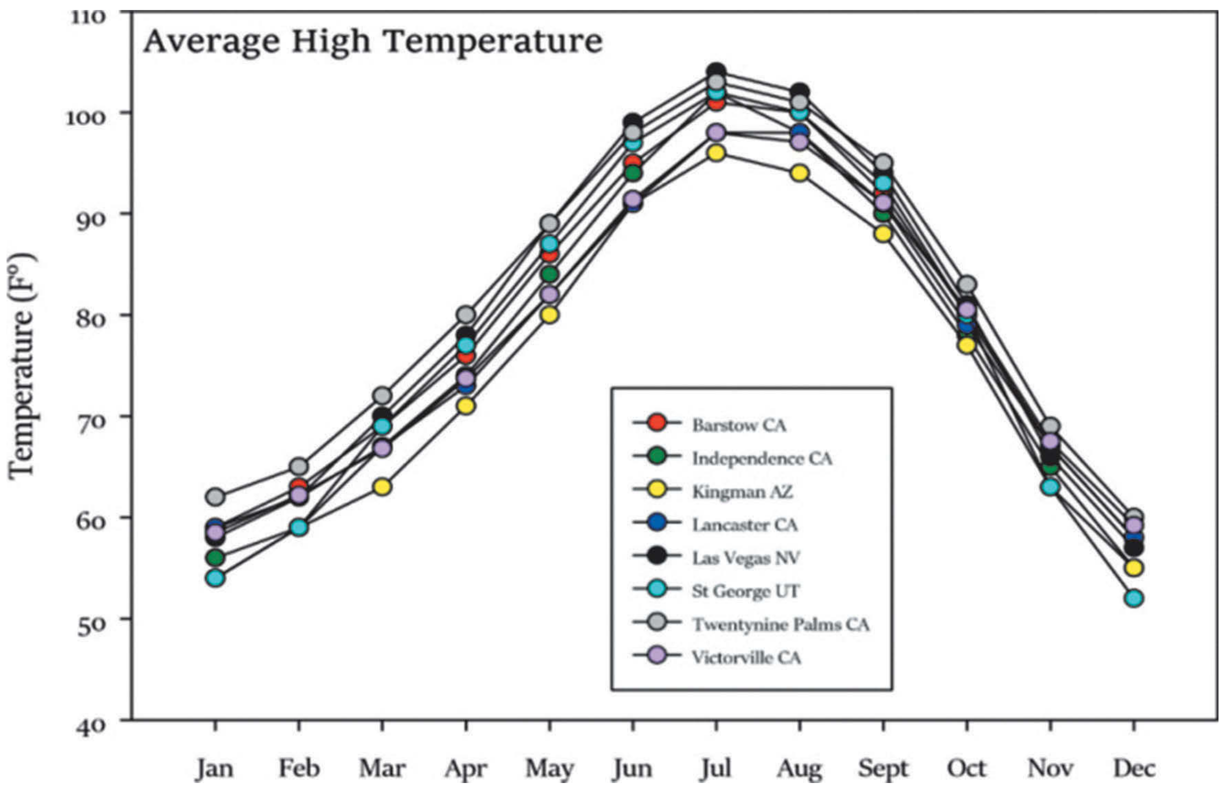


Figure 5. Average monthly high temperatures for cities located in the Mojave Desert

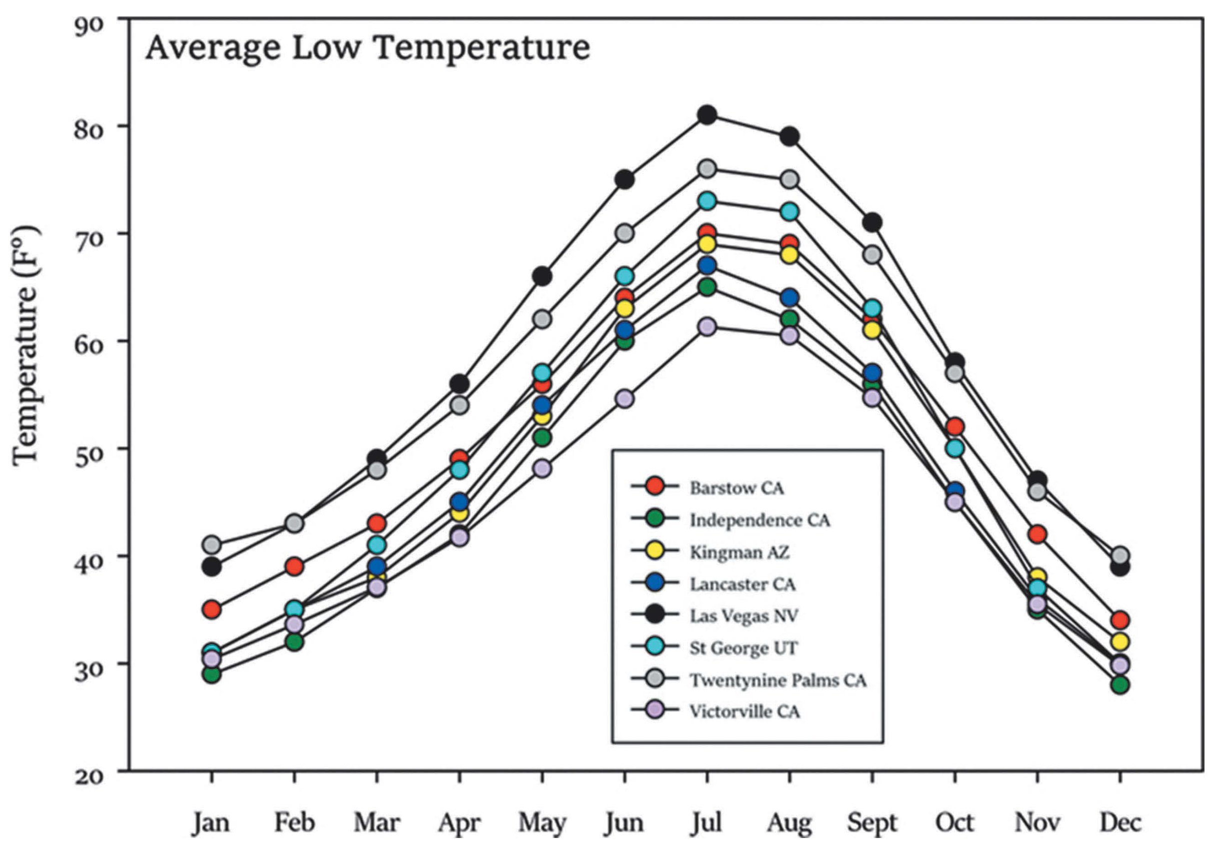


Figure 6. Average monthly low temperatures for cities located in the Mojave Desert. Note the big difference in nighttime low temperatures for Las Vegas vs. Victorville.

Did You Know?

For every molecule of carbon dioxide a plant takes up via its stomata, it loses four hundred molecules of water.

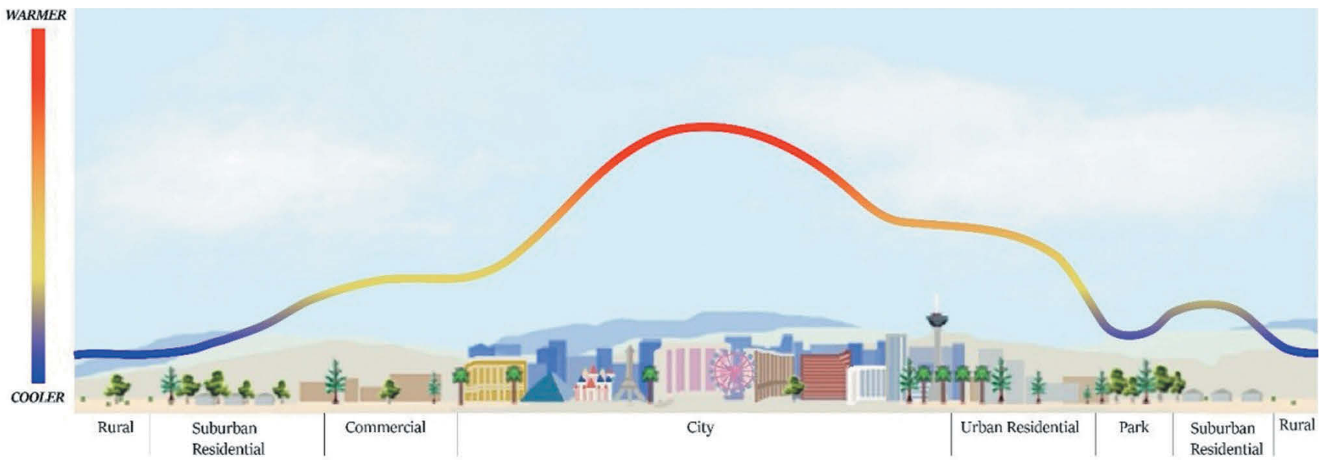


Figure 7. Urban heat island effect with a rise in temperature, compared to rural areas outside of the urban developed area, typically associated with larger metropolitan areas and often accentuated during the night. Asphalt, concrete, and buildings will store heat and release it once the sun goes down. (Drawing by Nancy Villeda.)

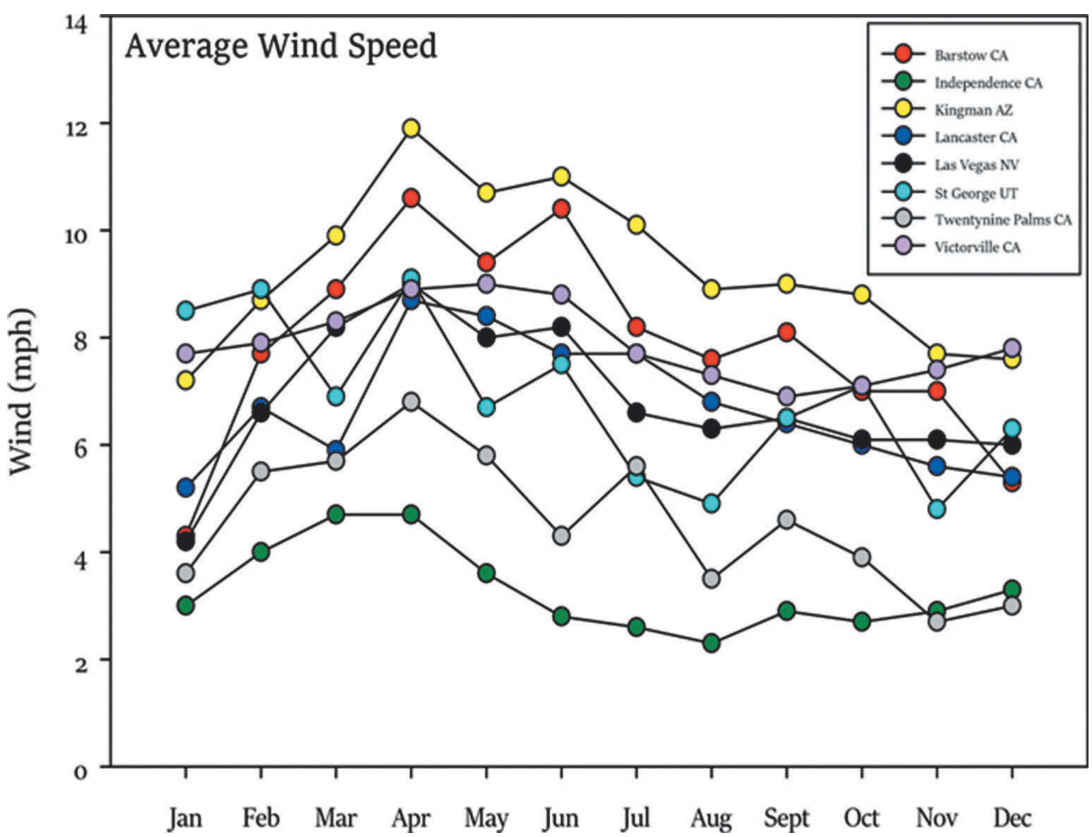


Figure 8. Average monthly wind speed for cities located in the Mojave Desert. Note the significantly higher monthly wind speeds for Kingman, Arizona. Higher wind speeds fuel higher water loss by plants, as it continually moves the vapor away from the leaf surfaces.

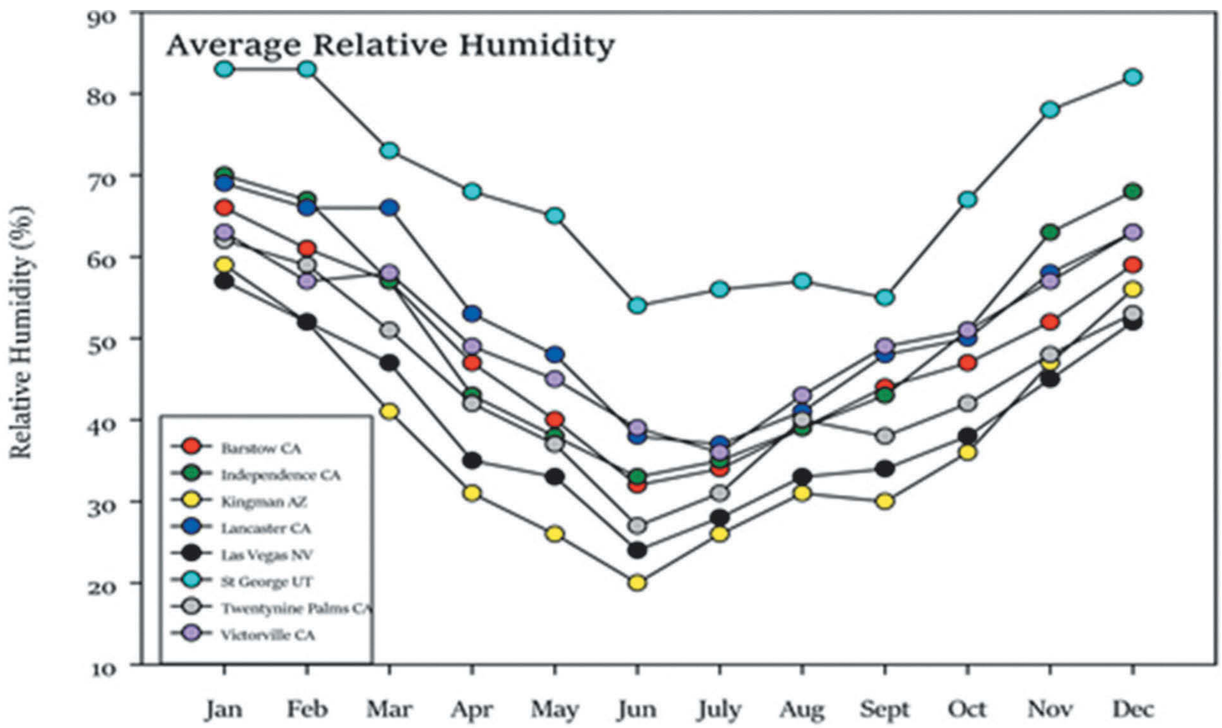


Figure 9. Average monthly relative humidity for cities located in the Mojave Desert. Note the lower relative humidity in Kingman and Las Vegas, which create a steeper vapor gradient from the leaf surface to the atmosphere, placing most plants under greater water stress conditions. If water is readily available (e.g., irrigation), lower relative humidity will typically be associated with higher plant water use.

Irrigations (quantity/time) should follow the shape of the reference evapotranspiration curve (figure 10), which has the strongest seasonal bell shape of all the meteorological parameters reported. Large water savings can be achieved by simply watering less when less water is needed—adjusting irrigations down during the winter period, stepping them up during the spring period, holding irrigations steady during the summer, and then stepping them back down during the fall months. As such, irrigation clocks should be reset a minimum of four times per year, and the amounts of applied irrigation water should reflect a bell-shaped curve that represents environmental demand for water. However, with sophisticated programmable clocks, adjusting irrigations on a weekly basis is easily achieved, as demonstrated by superintendents of golf courses throughout the Mojave Desert.

Did You Know?

Plants grown in coastal nurseries with a milder climate should be acclimated for at least two weeks before planting them in full desert sun.

It should be noted that the higher reference evapotranspiration values in spring at Kingman, Arizona, are driven by their significantly higher wind speeds and lower relative humidity (with the wind coming from the south, nine months out of the year). Also note that the most significant increase in reference evapotranspiration between sites occurs between April and August, which also correlates with the highest water-use period. As such, scheduling irrigations for landscapes in the Mojave Desert requires adjustments based on location. Such information is easily accessible in California via the University of

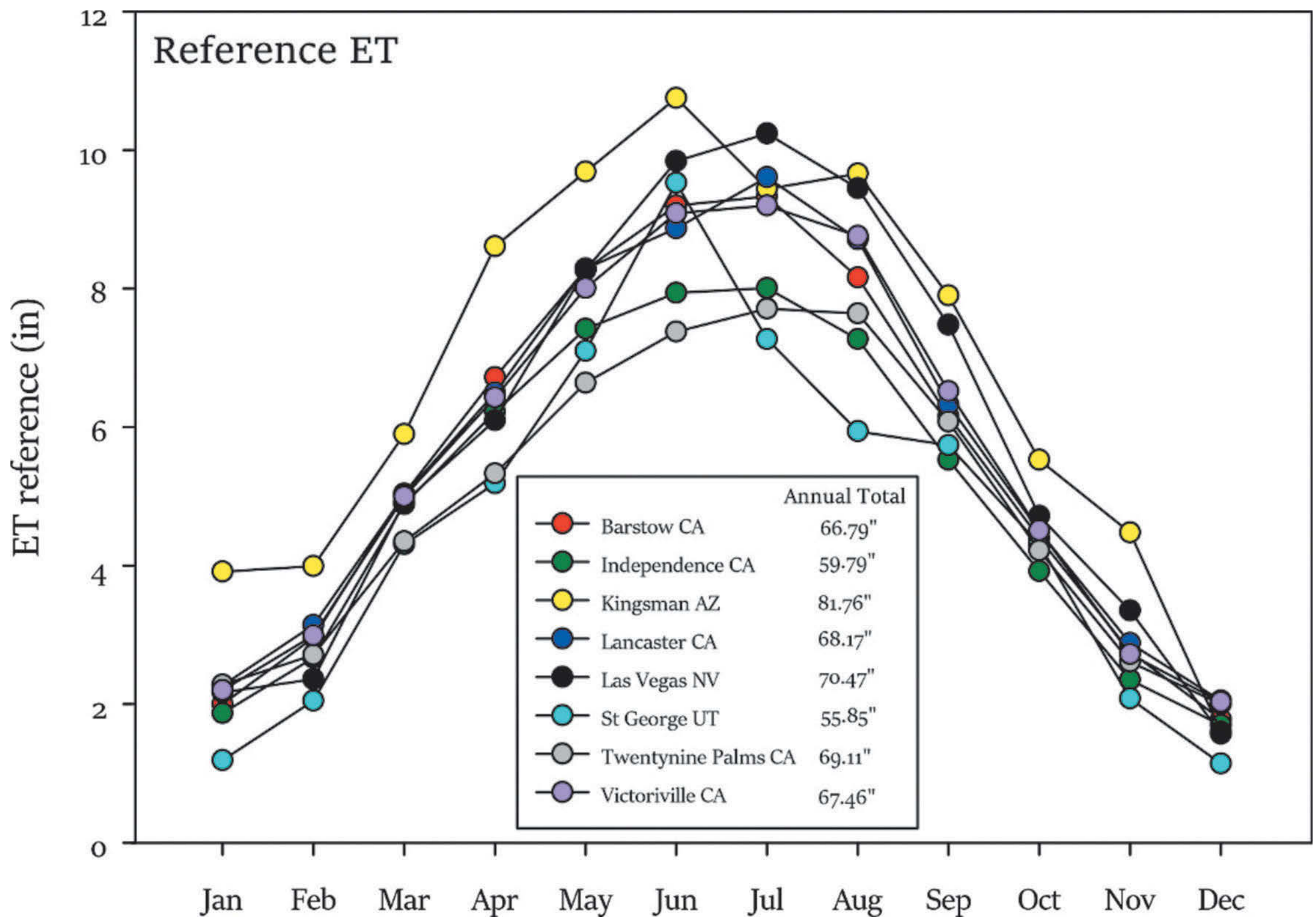


Figure 10. Average monthly reference evapotranspiration (ET) for cities located in the Mojave Desert. ET reference is calculated based on meteorological data, especially solar radiation, temperature, relative humidity, and wind speed. As environmental demand goes up, plant water use typically goes up.

California, Davis, network of meteorological stations, known as CIMIS (California Irrigation Management Information System, https://cimis.water.ca.gov) and in Arizona via the University of Arizona's network of stations, known as AZMET (Arizona Meteorological Network, https://ag.arizona.edu/AZMET). At these websites, one can access daily temperatures, relative humidity, wind speed, solar radiation, precipitation, and even estimates of reference evapotranspiration.

Because the Mojave Desert is so expansive, communities located in this desert are often strongly affected by large regional climatic systems that transfer dry air over irrigated landscapes, fueling higher water-use rates, much as one would observe at an oasis. These higher rates are more dramatic along urban desert edges of communities, where dry winds sweep in from the open desert. As one moves farther into an urban development, trees and buildings alter this climate, creating microclimates, where plants may be more sheltered and their water needs reduced (photo 3).

Did You Know?

Some cacti come from milder climates and need protection from afternoon sun when grown in Mojave Desert landscapes.

The urban heat island effect, however, can alter this relationship, especially with regard to temperature. Anything that slows wind (which constantly removes the water vapor, leaving the openings on the leaves) and/or alters the temperature of the plants (reducing the solar radiation from directly striking the plant) via buildings, walls, and even larger trees providing shade (photo 4), the demand for water subsequently goes down. Evapotranspiration has been reported to be 10 to 30 percent lower at a distance, within ten times the height of a barrier (Oke 2003). It is important to realize that valleys are not entirely flat but typically have significant changes in elevation, when moving from the foothills to the lowest point in a given valley. In the Las Vegas Valley, the elevation varies from about 1,400 feet at Lake Las Vegas to over 2,500 feet north of Tule Springs. As such, air temperatures can be more than 4°F cooler between the valley's lowest to highest points. Although this may not seem like much, it can be significant in terms of heat stress and plant water requirements in the middle of summer.

Photo 4. Buildings providing shade and reduced wind speeds, altering the microclimate for trees and other landscape vegetation. Trees, of course, also provide shade and reduce wind speeds, impacting vegetation in the surrounding area. (Photo by D. A. Devitt.)

The climate determines which plants can and cannot grow in an area. It is always good to do your homework before purchasing a tree to plant in a landscape. Trees are long-lived investments, so make sure you are satisfied with how well it can grow in a specific location. Many different types of trees can grow in an area if adequate water is available, but the extremes in temperature often lead to growth decline and even death.

Did You Know?

Some evergreen plants will drop their leaves if winter temperatures are low enough.

The Department of Agriculture classifies plant-hardiness zones for every region in the United States, typically based on average annual extreme minimum temperatures for an extended period (usually thirty years or more). The Mojave Desert is mostly classified as 8b (15–20˚F) or 9a (20–25˚F) (figure 11). This, of course, does not include regions at higher elevations, known as “sky islands,” which are radically different from lowland environments. An example is the Mount Charleston area in southern Nevada that has elevations up to 11,916 feet and is home to the long-lived Nevada state tree, the bristlecone pine (*Pinus longaeva*).

Although minimum temperatures below 15˚F are rare in the Las Vegas Valley, they can occur, which leads to significant dieback and even death to those trees that cannot tolerate such low temperatures. A homeowner may select a tree and have twenty or more years of good growth before an extreme minimum temperature occurs. This may result in possible removal of the tree or extensive pruning because of dieback and damage to the canopy architecture. On ten dates since 1931 (nine out of ten in January), the minimum temperature in Las Vegas dropped below 12°F (National Weather Service). In 1990, the temperature fell to 11°F during early spring, and extensive damage to African sumac and eucalyptus trees were observed. Interestingly, many of these trees are still readily available at most nurseries in Las Vegas. Readers should not hesitate to contact their local cooperative extension office to discuss the selection of a tree for their landscape before the actual purchase (ipm.ucanr.edu/GENERAL/ceofficefinder.html).

Figure 11. Plant-hardiness zone map for Nevada. Note the significant zone changes when comparing southern Nevada with central and northern Nevada. The Mojave Desert has a more uniform zone classification. (Permission to use map was granted by the Agricultural Research Service and Oregon State University, 2019.)

Did You Know?

There is a 10 percent chance that plants will freeze in the Las Vegas Valley after March 15.

3 CHAPTER

Know Your Soil

Soils suffer tremendously from spatial variability. By that, we mean that soil in your backyard, although it may look like soil in your friend's backyard a quarter of a mile away, is probably different. Soils form under the influence of time, parent material (rocks), topography (slopes), biotic factors (plants and animals), and climate (temperature and precipitation). When these forces vary on even a small scale, the outcome is a soil with different characteristics. Soil is what makes life possible on land for plants. It provides a porous structure for roots to anchor so plants can remain erect to intercept the sun's energy, which drives photosynthesis (the making of sugars). This porous matrix also holds water for absorption by the roots of plants and provides nutrient holding capacity as well.

Did You Know?

Some desert soils have a surface crust laden with living organisms (algae, fungi, bacteria, and mosses), called a cryptogamic crust, which reduces erosion by wind and rain and contributes nitrogen and carbon to the soil. They are very fragile, however, and can be easily destroyed by cattle, off-road vehicles, and even heavy foot traffic.

The particles that make up the solid components of soil are derived from physical and chemical weathering of parent material (rocks). These weathered particles are separated based on size, with sand being the larger-size particles, silt the intermediate, and clay the smallest. Although clay is small, it provides reactive sites that hold nutrients against leaching and contributes to higher water-holding capacity in soils. The combination of sand, silt, and clay varies from soil to soil. The composition percentage of each is used to classify soil texture. Knowing soil texture allows irrigators, landscapers, and horticulturalists to better manage a site, especially delivering irrigation water (frequency and run times when irrigating) and managing soil fertility (timing and application rates). Soil texture also gives a landscape manager greater insight on soil aeration. Damage to plants in desert urban landscapes are often associated with overwatering (as demonstrated by the shallow groundwater system in the Las Vegas Valley), which limits oxygen movement in the root zone.

Assess your soil's texture by using the jar test (figure 12). Dig a hole, and sample the soil below the organic layer (black color). Remove all rocks and roots, and let the soil air-dry. Put the dry soil in a mason jar, about half full. Add a teaspoon of powdered dishwashing detergent, and then fill the jar with water, to about an inch below the top. Shake the soil mixture for at least ten to fifteen minutes so that the soil is fully separated and the contents slide easily along the jar wall (in heavy-clay soils, this may take longer). Have a felt pen, ruler, and stopwatch ready to take measurements. Place the jar on a level surface. After one minute, make a mark on the jar, relative to the upper surface of the soil that has settled. After two hours make a second mark at the upper surface of the next layer, and then wait two days to make the final mark at the surface of the top layer. The lower layer represents the sand content, the middle layer represents the silt content, and the upper layer represents the clay content. Some layers may be quite small, depending on your soil type.

Did You Know?

One gram (not much) of montmorillonite clay has a surface area of over 3,000 square feet. This is because it has a large number of very small layers, each layer contributing to the overall surface area, much like a book with many pages. These layers are critical in providing exchange sites for holding ions, such as calcium, magnesium, and potassium.

Measure the distance from the bottom of the jar to your first mark, and divide it by the total distance from the bottom of the jar to the top of the soil in your jar. This bottom layer represents the percentage of sand in your soil sample. Similarly, measure the distance from your first measurement to the second measurement, and divide this by the total distance from the bottom of the jar to the top of the soil. This represents the percentage of silt. Finally, measure the distance from your second measurement to the top of the soil, and divide this by the distance from the bottom of the jar to the top of your soil. This represents the percentage of clay. Use the textural triangle (figure 13) to classify your soil texture. For example, if you determined your sample was 40 percent sand, 40 percent silt, and 20 percent clay, the soil texture would be classified as a loam. Convince yourself that when you follow the lines on each side of the triangle for sand, silt, and clay that the three lines intersect each other in the area labeled "loam." Compare your results from this jar test with information obtained from the Natural Resources Conservation Service (NRCS) website.

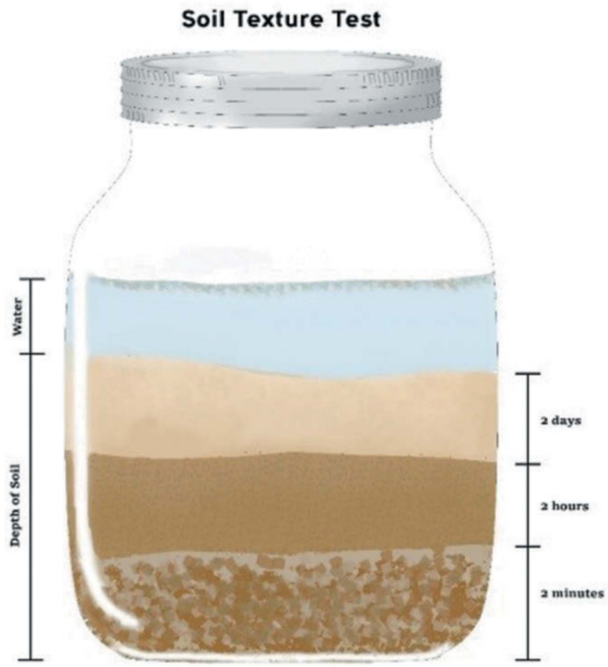


Figure 12. Assessing soil texture using the jar test. Soil particles settling within one minute reflect the sand component, two hours reflect the silt component, and two days reflect the clay component. (Drawing by N. Villeda.)

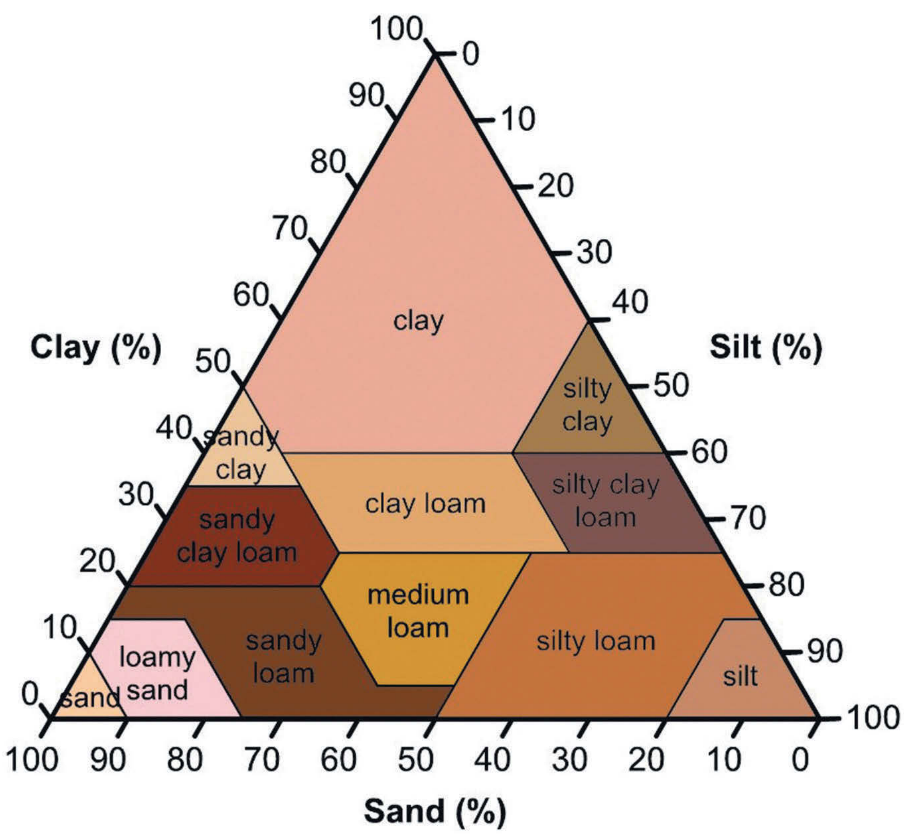


Figure 13. Textural triangle for classifying soil texture, based on the percentage of sand, silt, and clay. (Drawing by N. Villeda.)

The Natural Resources Conservation Service (NRCS) has mapped the soils of the Las Vegas Valley and significant parts of the Mojave Desert. In figure 14, a general soils map for the Las Vegas Valley is presented, which shows the variability in soils as influenced by erosional deposition scattered over the landscape from nearby mountains, along with existing soil development and activity from desert washes. Soil development occurs over time, as influenced by the soil-forming factors. Soils with similar characteristics, called a *soil series*, are often found close to the same locations or where similar soil formation forces are at work. A soil series is simply a classification unit that groups soils with similar characteristics together. Knowing these characteristics gives greater insight into management decisions that must be made, both for growing plants and constructing buildings.

The boundary between two soil series occurs on my (Devitt) property—a Cave gravelly fine sandy loam (0–4 percent slope, 3.5 centimeters of water storage capacity per 100 centimeters of soil depth) and a Goodsprings gravelly fine sandy loam (2–4 percent slope, 3.93 centimeters of water storage capacity). Whereas in the eastern part of the valley, a Glencarb silt loam occurs that has an average water storage capacity of 20 centimeters in the same depth of soil. The Glencarb soils holds over five times the amount of water as the soils reported on my property, demonstrating the water-holding capacity of a silt loam soil vs. one that's a fine sandy loam. Because of the lower water-holding capacity of my soil, I have amended the soil with composted organic matter and irrigate more frequently during the warm summer months.

Much information can be acquired from the NRCS website: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053587. The mapping units of the soil series are large, and so the soil at your location can vary somewhat from the soil series it represents. As an example, the McCarran soil series exists throughout a large part of the valley (approximately seventy-four thousand acres). On the NRCS website, it is classified as a very deep, well-drained soil that formed in gypsiferous- and calcareous-mixed alluvium on alluvial flats with 0–9 percent slopes. Information on soil series characteristics with depth is provided at the website. In the case of the McCarran series, pH values as high as 8.4 are reported in the surface soil, with clay content less than 18 percent, calcium carbonate high at 27 percent, and gypsum also high at 13 percent. Most plants perform better in slightly acidic soils (pH approximately 6.3–6.5), so mixing elemental sulfur in the soil might be recommended to help lower soil pH (follow directions on the bag). Highly calcareous soils (calcium carbonates) can be easily detected by applying a few drops of concentrated acid on a soil sample. (This test should be conducted by adults only. Pool acid works fine, but be careful; I suggest you wear rubber gloves and goggles). If it effervesces (bubbles), it means there is a significant amount of carbonates present. Highly calcareous soils can lead to micronutrient deficiencies. A classic example is iron deficiency found in crepe myrtle trees grown in the Las Vegas Valley. Calcium carbonate has low solubility in water so reducing these carbonates by leaching is extremely difficult.

Did You Know?

The frequent red color in many desert soils and rocks is iron oxide, a form of iron not available to most plants.

If the gypsum content in a soil is high, take care to limit plants and irrigation close to foundations, or structural damage can occur. Gypsum crystals ($CaSO_4$) formed when annual precipitation was probably less than five inches each year. In comparison, a homeowner waters tall fescue lawns with seven feet or more of water over a period of a year! Gypsum is over 150 times more soluble than calcium carbonate, and when it dissolves with irrigation water, it leaves behind voids that collapse under the weight of structures. This is not a uniform process so foundations and fences often shift, leading to significant structural damage.

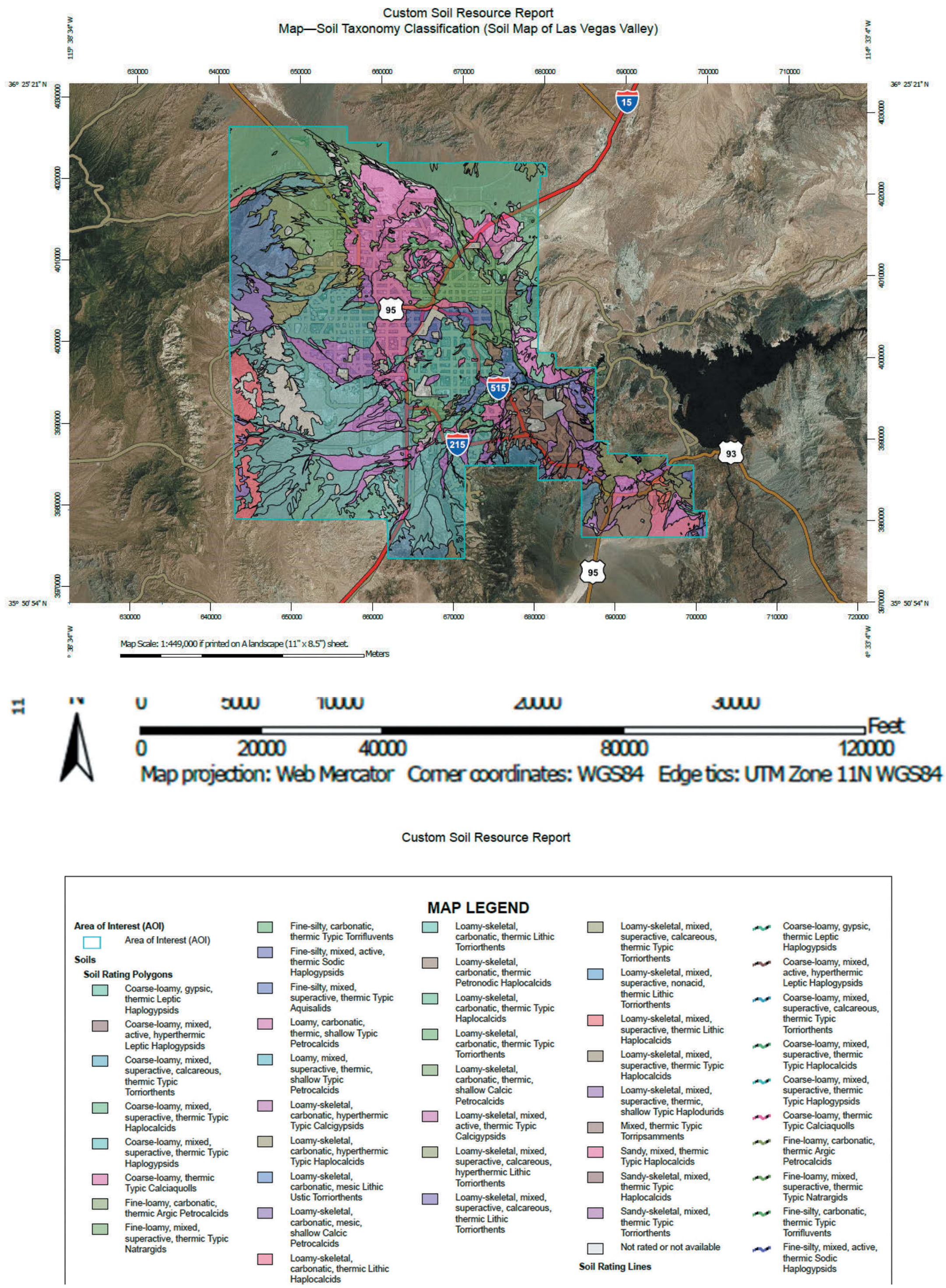


Figure 14. Soil map for the Las Vegas Valley. Note the large number of soil classifications, as influenced by erosional deposition, soil development, and wash activity (Soil Survey Staff, NRCS, USDA. Web Soil Survey, generated in 2019.)

Soils around homes in subdivisions are sometimes modified by builders who import soil from off-site locations. Homeowners need to be aware that soil characteristics can be significantly different from what is reported on the NRCS website. Developers often refer to this soil as "topsoil," which can vary widely, based on supplier. Bringing in a second soil with a very different texture and placing it over an existing soil creates a textural discontinuity (contrasting soil layers), which alters water movement through the soil—rarely a good thing (photo 5). Trees, of course, are deep-rooted and can grow their roots deeper into a soil profile, complicating the interpretation of observed responses. In such cases, one needs to know the depth of the two soils and their different characteristics to interpret the plant response.

Photo 5. New residential site in Las Vegas, where almost three feet of soil taken from a distant location was used to create a new elevation for both the yard and foundation.

A perfect time to observe your soil is when digging a hole to plant a tree. Look to see if a darker organic layer is associated with the surface (O horizon in figure 15). Newer landscapes soils typically have little organic matter in the soil and require additions of composted organic material for many plants. Also, look for changes in the soil with depth (horizontal layers, called *horizons*). Do you observe rocky layers? Compacted layers? A gray soil color that might suggest waterlogging? The presence of caliche (cemented calcium carbonates)? Caliche can be in extensive layers that restrict rooting of plants and prevents water and air movement, or they may be in small clusters, often referred to as *popcorn caliche*. The presence of tiny gypsum crystals in the soil (such as in the Henderson area) indicates a need to prevent planting and irrigating close to foundations and fences.

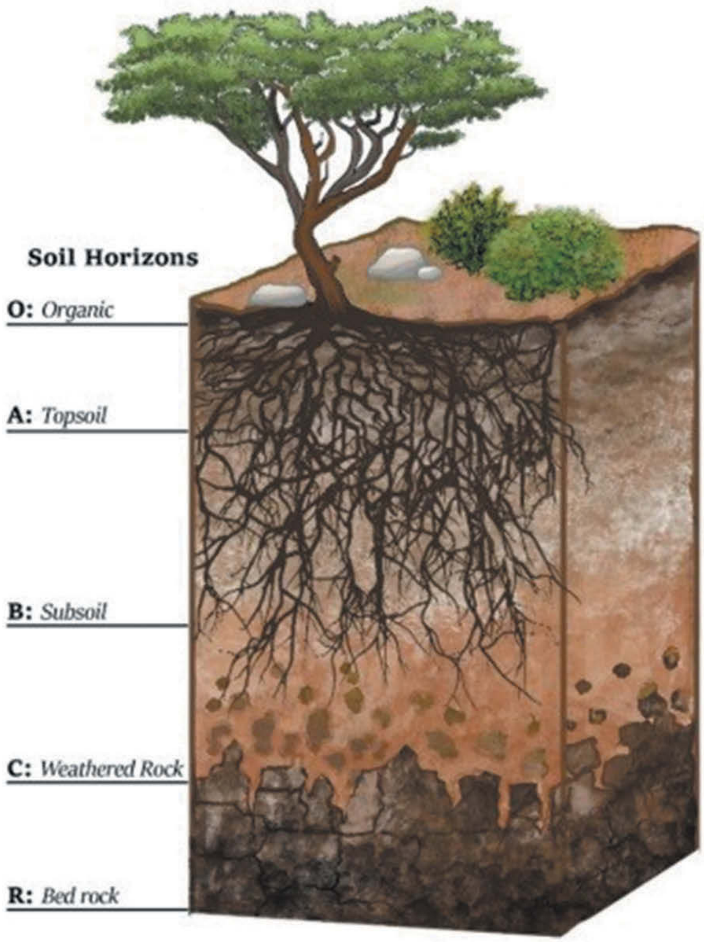


Figure 15. Soil horizons (distinct layers below the soil surface in response to climate and other soil forming processes). “O” horizon denotes an organic horizon; “A” horizon denotes topsoil; “B” horizon denotes a zone of accumulation, often higher in clay content, referred to as subsoil; “C” horizon denotes unconsolidated weathered rock; and “R” denotes the bedrock. (Drawing by N. Villeda.)

Before planting a tree is an ideal time to assess how readily water moves in your soil. If it moves too quickly, adding organic matter enhances the landscape soil’s water-holding capacity. However, if it moves slowly, great care is needed to make sure landscape tree roots get proper aeration (oxygen) in the soil. In higher clay-content soils, planting holes will act much like a bathtub and hold excess water so that tree roots suffocate. This condition can be highly damaging to a tree. Either the offending layer is eliminated by excavation; perforations are made through this clay layer; trees are planted in well-drained soils on mounds wide and deep enough to accommodate the tree; drain tiles are installed; or a professional arborist, horticulturist, or engineer is consulted for the proper remedy.

Conducting a percolation test is recommended (figure 16). Dig a hole (post-hole diggers work great) to a depth of twelve inches (deeper, if you are planting a large-specimen tree). Clean the hole so that it’s well-defined. Slowly fill the hole with water to within three inches of the surface. Let the water drain, and refill it several times to make sure the soil is saturated before going further. Refill the hole with water one more time, and measure its depth with a measuring stick. Monitor the rate at which the water drops on an hourly basis. If the hole drains at a rate of less than one inch per hour, a water-drainage and soil-aeration problem may exist, and alternative planting methods should be considered.

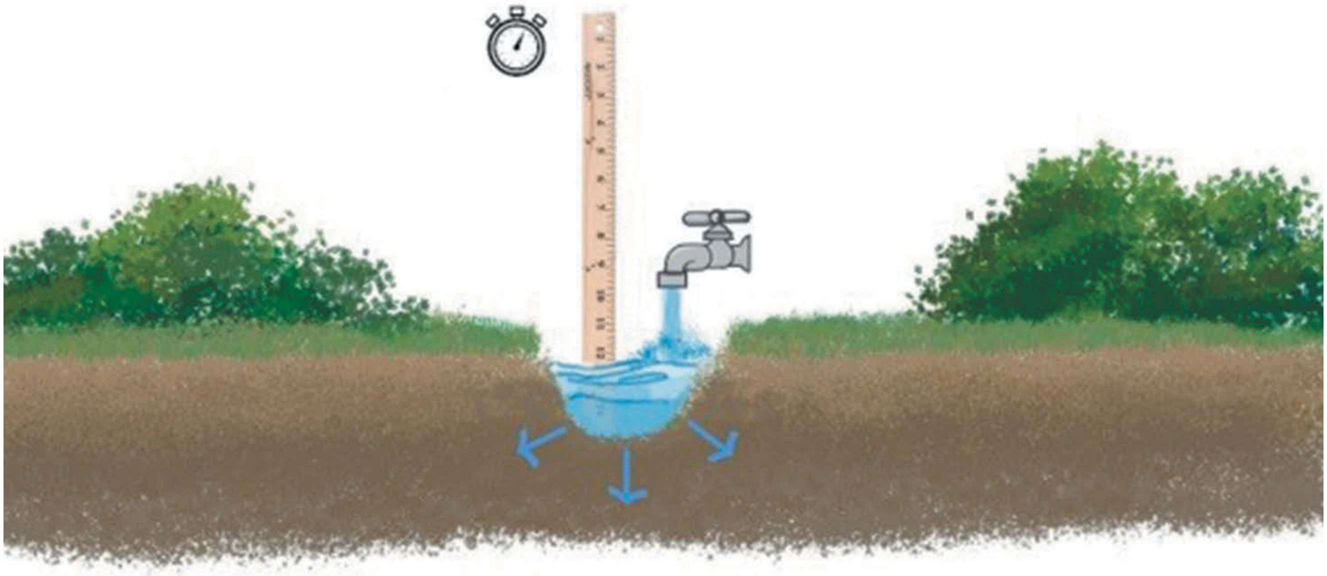


Figure 16. Percolation test to assess the rate at which water will move into a soil (drawing by N. Villeda)

It is often recommended that landscapers, horticulturists, and homeowners periodically perform a chemical soil test by sending a sample to an analytical laboratory. This soil test should include an assessment of soluble salts, pH, nitrogen, phosphorous, potassium, calcium carbonates, sodium, chlorides, and boron (figure 17). If you have concerns about certain areas in your landscape, send in samples of these areas separately. Typically, these laboratories prefer a soil sample equal to about two cups of soil. Sampling to a depth of the active root zone in several locations and mixing these subsamples together is recommended. Remove any organics from the soil surface before sampling. After the sample is taken, remove all rocks and roots from the sample, and place it into a clean plastic bag. Seal it and label the bag, indicating the site location, depth, and date. There are many private labs in the United States that can analyze soil samples, but it is best to send soil samples to labs that have experience with desert soils. A general soil analysis should cost less than fifty dollars. Some agricultural universities have soil laboratories that conduct these tests at a minimum cost for their residents. It is best to pay a little extra to get a print-out explaining the results. When in doubt, contact your local cooperative extension office to ask for assistance.

Several things worth noting when looking at your soil analysis:

A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

REPORT NUMBER: 00-336-047

CLIENT NO: 9999-D

SEND TO: A & L WESTERN AGRICULTURAL LABS
1311 WOODLAND AVE.
MODESTO, CA 95351-

SUBMITTED BY:

GROWER: EXAMPLE REPORT

DATE OF REPORT: 04/30/04

SOIL ANALYSIS REPORT

PAGE 1

SAMPLE ID	LAB NUMBER	Organic Matter * % Rating	Organic Matter ** ENR lbs/A	Phosphorus P1 (Weak Bray) **** * ppm	Phosphorus $NaHCO_3$-P (OlsenMethod) **** * ppm	Potassium K ***** * ppm	Magnesium Mg *** * ppm	Calcium Ca *** * ppm	Sodium Na *** * ppm	pH Soil pH	pH Buffer Index	Hydrogen H meq/100g	Cation Exchange Capacity C.E.C. meq/100g	PERCENT CATION SATURATION (COMPUTED) K %	Mg %	Ca %	H %	Na %
130-1	55931	4.0H	110	23M	14**	110L	460M	992VL	104L	4.7	6.2	9.7	19.1	1.5	19.8	25.9	50.5	2.4
130-2	55932	1.5L	60	27H	6**	41VL	569M	1154VL	185M	4.6	5.9	13.3	24.7	0.4	19.0	23.3	54.0	3.3
12-1	55933	3.5M	100	12L	11**	64L	471VH	841VL	87L	5.2	6.5	4.5	13.1	1.2	29.5	31.9	34.5	2.9
12-2	55934	2.8M	86	8VL	9**	29L	553VH	665VL	89M	5.3	6.6	3.7	12.1	0.6	37.7	27.5	31.0	3.2

** NaHCO3-P unreliable at this soil pH

SAMPLE NUMBER	Nitrogen NO_3-N ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Excess Lime Rating	Soluble Salts mmhos/cm	Chloride Cl ppm		PARTICLE SIZE ANALYSIS SAND %	SILT %	CLAY %	SOIL TEXTURE
130-1	5L	5L	0.3VL	3M	53VH	0.2VL	0.1VL	L	0.3L						
130-2	3VL	41VH	0.1VL	1VL	14M	0.2VL	0.1VL	L	0.6L						
12-1	2VL	5L	0.1VL	2L	50VH	0.1VL	0.3VL	L	0.2VL						
12-2	2VL	4L	0.1VL	1VL	53VH	0.1VL	0.2VL	L	0.1VL						

* CODE TO RATING: VERY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), AND VERY HIGH (VH).
** ENR - ESTIMATED NITROGEN RELEASE
*** MULTIPLY THE RESULTS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM
**** MULTIPLY THE RESULTS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P_2O_5
***** MULTIPLY THE RESULTS IN ppm BY 2.4 TO CONVERT TO LBS. PER ACRE K_2O
MOST SOILS WEIGH TWO (2) MILLION POUNDS (DRY WEIGHT) FOR AN ACRE OF SOIL 6-2/3 INCHES DEEP

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

Mike Buttress, CPAg
A & L WESTERN LABORATORIES, INC.

Figure 17. Soil analysis report showing results for various soil parameters, along with ratings to assist the user. (Note that this is not an endorsement of A&L Laboratories. Permission to reproduce granted by A&L Laboratories.)

- Salinity. If the soil electrical conductivity is greater than 4.0 dSm^{-1}, it is classified as a saline soil and can damage sensitive plants. Care should be taken to select salt-tolerant trees (table 2), and closer attention is needed to apply enough water to reduce the soil salt level. If you observe salts (typically, white residue on the soil surface—photo 6), address this issue before planting. However, if the salt residue is accumulating on the ridge of an irrigation basin and is over six feet from the trunk of the tree, it suggests that salts are being pushed downward and outward. Removing the layer of soil containing these salt residues is recommended if it is within six feet of the trunk. Next, make sure the tree has a functioning bubbler or drip system and wets the soil surrounding the tree, out to its drip line. If the salt accumulation is close to the tree, increase the number of emitters surrounding the tree, and increase the irrigation amount to flush these salts below and out of the root zone. Soil sampling six to twelve months later is a good idea to assess whether the salts are indeed being pushed deeper in the soil. If not, increase the number of emitters and amount of irrigation water.
- pH. If the soil pH is greater than 8.0, many micronutrients will have only limited availability to plants. Although most plants perform better in soils with pH values that are slightly acidic, desert soils typically will be greater than 7.3. If you are not growing acid-loving plants, pH in the 7.3 to 8.0 range is acceptable, but the acceptability varies with the tree species. This soil pH is typically not a problem for most xeric trees. However, do not be surprised that some mesic trees will show micronutrient deficiencies in this pH range. Apply micronutrients in a chelated form, if available.

Chelation helps increase micronutrient availability over a wider pH range. However, if your tree is small, an easier solution may be to apply a micronutrient spray to the leaves until the solution begins dripping from the leaves. (If the leaves have a heavy waxy covering, foliar absorption may be limited.) Follow the label directions when applying these products. Most fertilizers are salts, and applying at too high of a concentration or too close to the plant can damage it within a very short time. For trees that have a micronutrient deficiency, most should respond positively to a foliar spray within three days and some may require repeat sprays a few days apart. Look for leaves that are yellow to become a darker green and striations to disappear when corrected.

Did You Know?

Iron deficiency and nitrogen deficiency look similar at the leaf level. However, iron is very immobile in the plant and shows greater yellowing in younger leaves. Nitrogen, on the other hand, is mobile in the plant and shows yellowing in the older leaves, while the newer leaves are darker green.

- Nitrogen (N), phosphorous (P), and potassium (K) are considered macronutrients and are required by plants in large amounts to be healthy and productive. N, P, K are typically the major nutrients found in most fertilizers. The three numbers found on a bag of fertilizer represent the N, P, and K as a percentage of the weight of the fertilizer. A fertilizer analysis of 15-15-15 in a fifty-pound bag of fertilizer contains 7.5 pounds of nitrogen, 7.5 pounds of phosphorous (as P_2O_5), and 7.5 pounds of potassium (as K_2O). Follow recommendations on the bag and feedback from the soil analysis to apply the correct amount of fertilizer. Again, realize that most fertilizers are available to the plant as a salt, and applying a large amount of any salt can damage a plant. (Just because some fertilizer is good for the plant does not mean that more is better!)

Fertilizers are given to most temperate trees in the spring to supplement plant nutrients already in the soil and before trees grow most rapidly. The plant nutrient most often in short supply for tree growth is nitrogen. Fertilizers with a high nitrogen percentage are given to young trees to encourage rapid growth and establishment. As trees mature, fertilizers with smaller percentages of nitrogen, as compared to phosphorus and potassium, are typically provided. Encouragement of tree growth is a double-edged sword: tree maturity is desired because it encourages flowering in flowering trees and more shade in shade trees, but an increase in plant growth is always accompanied by an increase in tree water use. As trees get larger, their water use increases. It is important to minimize the number of large trees in a landscape. If there is concern for water conservation, large trees should be xeric or desert-adapted and in scale with the size of the home and landscape. When replacing turfgrass and mesic plants with xeric or desert-adapted plants, irrigation management has to change significantly, or no water savings will be realized.

Did You Know?

Using fertilizers that are high in phosphorous at planting time enables plants to better establish their roots in landscape soils.

- Organic matter. Desert soils generally are extremely low in organic matter, typically just a few tenths of 1 percent, whereas soils in Iowa may have organic matter in the 3–5 percent range. Soil organic matter in hot desert climates is broken down quickly. Adding additional organic matter on a yearly basis is always a good practice, as it increases the water-holding capacity, holds nutrients from being leached away, and provides energy for a healthy soil microbial community. One difference between establishing xeric trees (originating from extremely dry habitats) and mesic trees (originating from a moist habitat) is soil preparation at the time of planting. Xeric trees require less organic matter in the soil when planting, as compared to mesic trees. Under some soil situations, xeric trees may require little or no additional amount of organic matter during planting (based on background organic matter in the soil). Excessive additions are never warranted and will create future tree problems. Soil color can be used as an indicator of a soil's organic-matter content. The presence of organic matter darkens soil color. Soils that are tan or very light brown typically contain little organic matter. These soil colors indicate that additions of organic matter will most likely improve tree growth and performance. Soils light brown to medium brown in color often contain enough organic matter such that no additional amounts are necessary when planting either xeric or mesic trees.

Did You Know?

In a handful of soil, there are more living organisms (bacteria, fungi, worms, and more) than there are people living on earth (approximately 7.5 billion people).

- Boron. Boron is a micronutrient that has the narrowest range of all plant nutrients between deficiency and toxicity. Although boron is an essential element, too much (which is not much!) can be toxic to most plants (salt cedar and asparagus being exceptions). Boron can be leached from the soil, but it typically requires three times the amount of water, as compared to more soluble salts, such as sodium chloride (NaCl, table salt). Boron can also be locked up temporarily with organic matter, so that's another good reason to add organic matter to desert soils.

Table 2. Salt-tolerant landscape trees (Miyamoto et al. 2004, Bureau of Reclamation)

Moderately tolerant (6–8 dS m^{-1})
pomegranate (*Punica granatum*)
Texas pistache (*Pistacia texana)*
Chinese pistache (*Pistacia chinensis)*
Chinese elm (*Ulmus parvifolia)*
Tolerant (8–10 dS m^{-1})
honey mesquite (*Prosopis glandulosa*), Chilean mesquite (*Prosopis chilensis*)
black locust (*Robinia pseudoacacia*), honey locust (*Gleditsia triacanthos inermis*)
Highly Tolerant (>10 dS m^{-1})
screwbean mesquite (*Prosopis pubescens*)

Photo 6. Pine tree with a salt ring on the soil surface. Saline shallow groundwater is at a depth of approximately twelve feet on the UNLV campus. (Photo by D. Devitt.)

4
CHAPTER
Know Your Water

Water resources in the Mojave Desert are limited. This, of course, is with the exception of the Colorado River, which originates in the Rocky Mountains. The Colorado River flows over fourteen hundred miles, including through the eastern portion of the Mojave Desert, carrying over fifteen million acre-feet of water before eventually draining into the Sea of Cortez. However, because of heavy diversions in the United States and northern Mexico, this rarely occurs. Las Vegas depends heavily on the Colorado River. Without it, Las Vegas would be reliant solely on groundwater from mountain recharge. Safe, sustainable groundwater withdrawal rates for the Las Vegas Valley are around fifty-seven thousand acre-feet per year. This amount would support a population of about 250,000, not the more than two million residents that currently reside in the valley. This is all because of Hoover Dam and the large pumps (one million gallons per minute!) and piping system that successfully diverts this water to the Las Vegas Valley.

Did You Know?

Over ten million years ago, the Colorado River flowed west, emptying into what is modern-day Monterey Bay, California.

Four other rivers exist in the Mojave Desert: (1) The Amargosa River originates near Beatty, Nevada. Its flow is mostly below ground, with the exception of about seventeen miles of surface flow. After flowing through the Amargosa Valley, it terminates in Death Valley. (2) The Mojave River, originating in the San Bernardino Mountains, only has ephemeral flow. The river flows eastward, recharging the Mojave River Basin and allowing cities such as Victorville and Barstow, California, to access a reliable source of groundwater. (3) The Virgin River originates in the mountains just north of Zion National Park, flowing for about two hundred miles before emptying into Lake Mead. The cities of St. George, Utah, and Mesquite, Nevada, rely on this source of water to help balance their daily needs. (4) The Muddy River (previously known as the Moapa River—*moapa* meaning "muddy water" in Paiute), is located about sixty miles north of Las Vegas. The river originates from thermal springs in the upper Moapa Valley, where it then travels for about thirty-two miles before draining into Lake Mead. Water is diverted mostly for agriculture in the Moapa Valley.

Did You Know?

The Mojave Indians called the Colorado River *Aha Kwahwat*, and the early Spanish explorers called it the Rio Colorado. Its name was finally changed, by an act of Congress, to the Colorado River in 1921.

Not all water has the same quality. When assessing water for the irrigation of trees and landscapes, it is important to assess its salinity, pH, amount of boron, sodium-adsorption ratio, and the residual chlorine levels to deem its level of quality. Table 3 indicates the quality of water from four sources where it's available in the Las Vegas Valley. These sources include (1) the Colorado River, (2) groundwater, (3) shallow groundwater, and (4) treated sewage effluent. Water with an electrical conductivity between 0.75 and 1.50 dSm^{-1} will impact the growth and productivity of salt-sensitive plants, placing some limitations on its use. Colorado River water has an electrical conductivity around 1.05 dSm^{-1} (note that salinity measured in a soil and that measured in water are not directly comparable and are classified on a different scale). As such, the Colorado River supplies approximately one ton of salt for every 326,000 gallons of water (one acre-foot of water). This means that if you placed a foot of water from the Colorado River on an area the size of a football field (approximately one acre) and allowed the water to evaporate, it would leave behind about one ton of salt. Hybrid Bermuda grass grown on Las Vegas Valley golf courses needs about six acre-feet of water per year. This means six tons of salt per acre per year would enter the soil during irrigations every year. After ten years, sixty tons of salt would be applied to each acre.

Did You Know?

Water is considered the universal solvent because it dissolves more substances than any other liquid. Salts are very damaging to plants but fortunately are very soluble in water. Irrigations can be applied that leach these salts out of the root zone of plants.

Treated sewage effluent water has even a higher salinity, as much as 2.0 dSm^{-1} (higher salinity in the case of St. George, Utah). This means approximately two tons of salt is contained in one acre-foot of treated sewage effluent water. If hybrid Bermuda grass on a golf course is irrigated with treated effluent water, its soil will receive twelve tons of salt each year. You can do the math—after ten years, 120 tons of salt would enter each acre of irrigated hybrid Bermuda grass. Trees planted in parks and golf courses irrigated with treated sewage effluent (reuse water) are literally caught in the cross fire. Many plants will tolerate higher levels of salt if the salt does not come into direct contact with the foliage. We have observed spray-irrigated demarcation lines of salt damage to the canopies of trees that are sprinkler-irrigated with treated sewage effluent. In table 4, tree species are listed that have higher tolerance to treated sewage effluent being sprayed directly on the canopy (low damage to Aleppo, Mondell, and stone pines; high damage to Chinese pistache [photo 7] and Modesto ash).

Did You Know?

Water is the only substance known in which the solid form is less dense than the liquid form. As such, ice floats. If ice had higher density, it would sink, causing the bottom of lakes and oceans to stay frozen, locking up nutrients and altering life as we know it.

Table 3. Water quality of different sources of water available to communities located in the Mojave Desert.

Location	pH	Residual Chlorine mg/l	Electrical Conductivity dS/m
Groundwater			
North Las Vegas	7.09	1.12	0.40
Las Vegas (Summerlin)	7.35	0.90	1.23
Las Vegas (Southwest)	7.03	—	1.76
Henderson	8.20	0.80	1.10
Municipal Water*			
Colorado River	7.70	0.90	1.05
Reuse Water	7.80	4.92	1.87
Shallow groundwater	7.04	—	7.65
City Comparisons			
Municipal Water			
Barstow, CA	7.70	1.39	1.10
Victorville, CA	7.56	0.74	0.41
St. George, UT	7.60	0.2–1.27	1.23
Kingman, AZ	7.20	0.08	0.62
Reuse Water			
Victorville, CA	7.00	—	0.57
St. George, UT	7.70	1.7–2.4	2.95

* Approximately 90 percent of municipal water used in the Las Vegas Valley comes from Lake Mead, with the remaining 10 percent from groundwater.

Did You Know?

Bonds between water molecules break about once every trillionth of a second, allowing water to have great fluidity.

Species	Rating	Recommendation
Olive	0.26	R
Mesquite	0.26	R
Aleppo Pine	0.28	R
African Sumac	0.78	Recommend
Mondell Pine	0.87	R
Stone Pine	1.04	R
Raywood Ash	1.76	R
Idaho Locust	2.42	Q
Chaste Tree	2.87	Questionable
Heritage Oak	2.87	Q
Mimosa	2.88	Q
Navajo Willow	3.60	NR
Flowering Plum	3.82	NR
Japanese Privet	4.00	NR
Chitalpa	4.87	Not Recommended
Drake Elm	6.71	NR
Desert Willow	6.76	NR
Chinese Pistache	6.76	NR
Modesto Ash	7.04	NR

Table 4. Visual ratings for ornamental trees spray-irrigated with reuse water. The higher the rating number, the greater the visual damage (Jordan et al. 2001). Recommendations are separated into three categories.

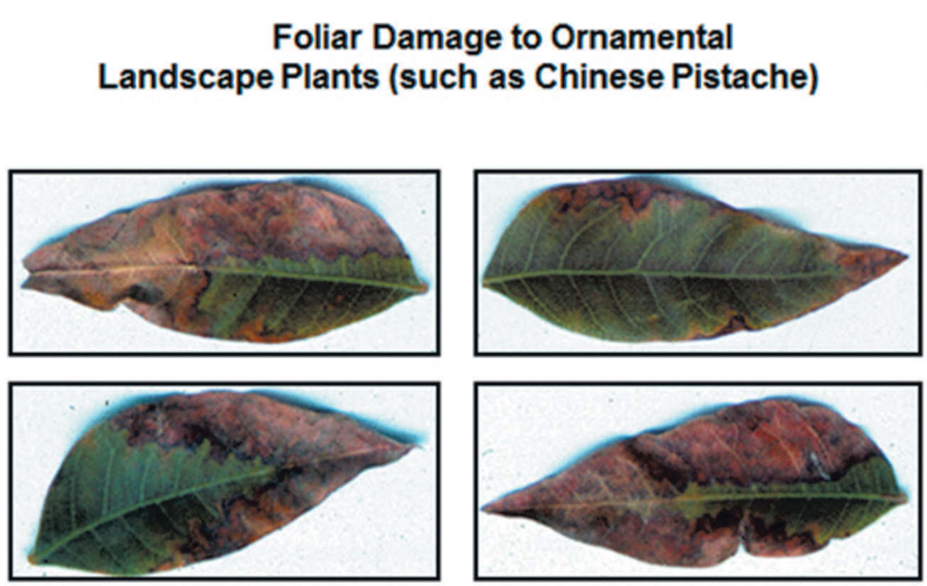


Photo 7. Foliar damage (marginal and tip necrosis) to the leaves of Chinese pistache sprinkler-irrigated with reuse water (treated sewage effluent) (photos by D. A. Devitt)

Most of the cities in the Mojave Desert, such as Barstow and Victorville, California, discharge the majority of their treated sewage effluent into percolation ponds, where it eventually recharges the local groundwater systems or is evaporated. A few cities in the Mojave Desert provide treated sewage effluent for the irrigation of parks and golf courses (Las Vegas, Victorville, St. George). In Las Vegas, about thirty-five of the fifty-three golf courses utilize treated sewage effluent (reuse water). More cities would probably directly utilize their treated sewage effluent for irrigation, but it requires a separate distribution system, representing a significant infrastructure cost to the community. In the case of Las Vegas, a separate distribution system was built that cost over $100 million. Smaller treatment plants were built in the northwest part of the Las Vegas Valley to intercept, treat, and discharge water into this distribution system. Zones of conservation were identified, and golf courses within these zones were "encouraged" to transition to reuse water. This decision to develop an active reuse program was driven, to a large extent, by the higher energy costs to move the wastewater greater distances to the main treatment plant, located on the Las Vegas Wash, and to pump municipal water (upgradient) greater distances from Lake Mead.

Did You Know?

Nevada earns return flow credits when it pumps Colorado River water from Lake Mead for use and then treats and returns the remaining water to the river system. This significantly increases the amount of water that southern Nevada can remove from the Colorado River on a yearly basis.

Salinity

The Las Vegas Valley has a well-defined shallow groundwater system, with salinity levels in some areas in excess of 7,500 parts per million (near 10 dSm^{-1}) (figure 18), with soil solution above this shallow groundwater approaching salt levels found in seawater (35,000 parts per million, or around 50 dSm^{-1}). The "Dancing Waters" at the Bellagio Hotel on the Las Vegas Strip is shallow groundwater that has been pumped up and forced, through reverse osmosis, to reduce the salt level before it is used. On the UNLV campus, this water is within twelve feet of the surface and has an electrical conductivity of approximately 3.3 dSm^{-1}. The state engineer classifies this water as "nuisance water," and, as such, it can be used by land owners whose property is above this shallow system. While on the more eastern edge of the valley, at Clark County Dog Fanciers Park, the shallow groundwater is within eight feet of the surface, with an electrical conductivity of approximately 7.3 dSm^{-1}. These waters are too high in salt to be considered as a sole source of irrigation water, but they could be blended or applied in an alternate cyclic fashion with Colorado River water. Although this water could be used to irrigate salt-tolerant turfgrass, such as Bermuda grass, few tree species would be able to tolerate it. Thus, it is critical that salts from this shallow system not be allowed to reach into the root zone of trees. In areas close to the Clark County Wetlands Park, in the southeast part of the valley, significant amounts of salt can be found on the soil surface (as white residue). New housing developments in this area reveal the same problem: salt accumulation on the soil surface and a negative impact on the growth and health of trees (as well as damage to concrete and block walls). Because the shallow groundwater is within four to eight feet of the surface in this area, irrigation water must continually be applied to keep these salts from moving upward via the process of soil evaporation (capillary lift).

In arid regions, salinity is a constant threat to plants. If the water used for irrigation contains appreciable salt levels, irrigation management and plant selection are all that stand between an acceptable landscape and one that will continue to suffer and fail over time. We conclude this section on salinity with a quote from W. A. Hall (1973 acting director of the Department of the Interior, Water Resources Institute) that is poetic and still relevant over forty-five years later:

> Salt problems are particularly insidious. They do not come charging at you with trumpets blowing and battle flags flying, a sight to set stirring the hearts of activists in any century. Rather, they slip in almost unnoticed. Time is of no concern, for they are supremely confident of their ultimate victory. History is on their side, as are the laws of physics, chemistry and biology. They have quietly destroyed, without fuss or fanfare, more civilizations than all the mighty armies of the world.

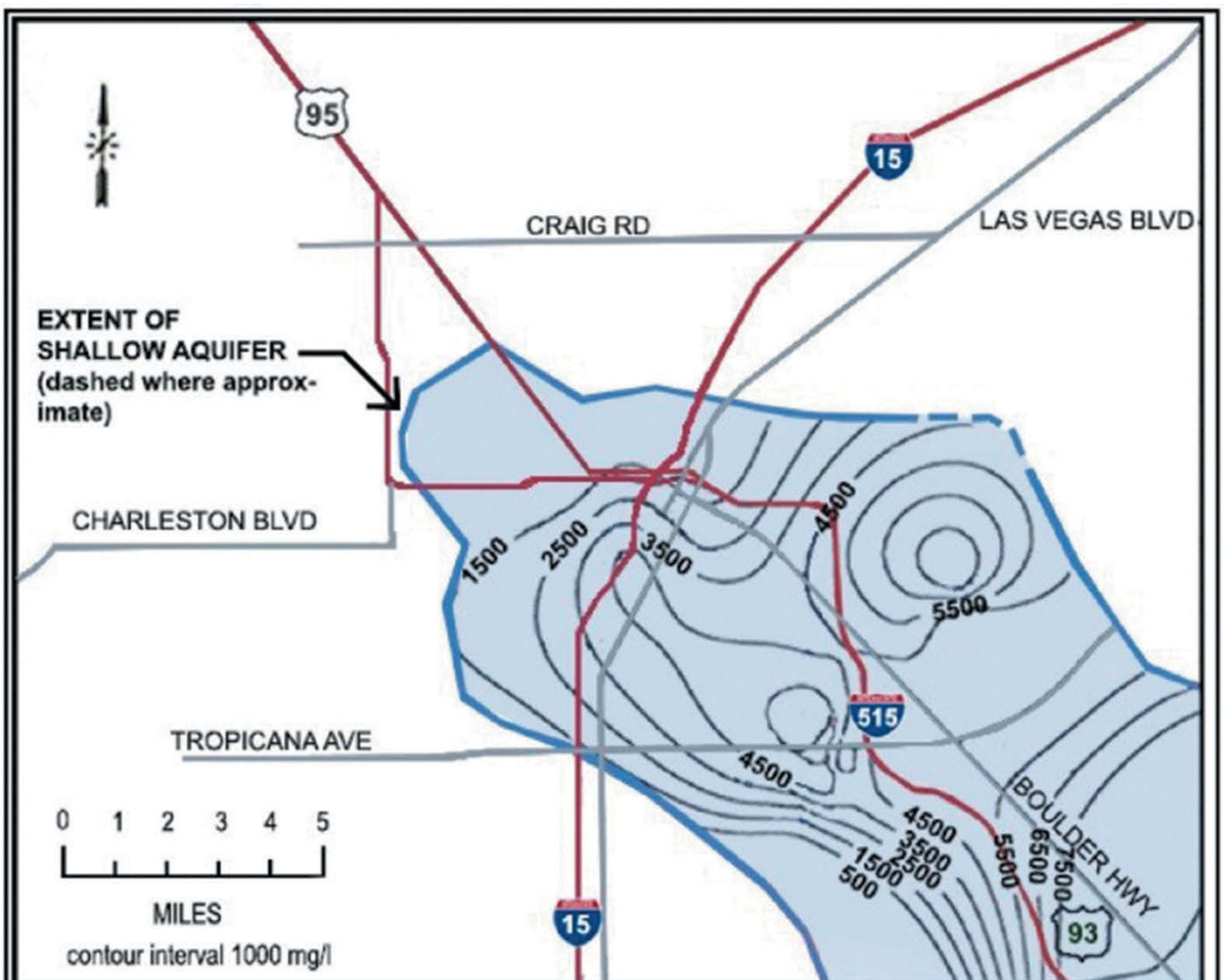


Figure 7.2 – Total dissolved solids contour map of the shallow aquifer.

Figure 18. Total dissolved solids contour map of the shallow aquifer in the Las Vegas Valley (permission to use granted by SNWA in 2019).

pH

Although pH can have a significant impact on the nutrient availability to plants and is typically high in desert soils, most water sources have pH values in the mid-7 range, which does not typically require any adjustment. However, because treated sewage effluent has elevated nitrate levels, algae growing in irrigation ponds can rapidly take these ions up, which contribute to pH drift (plants discharging hydroxyl ions). The pH of golf course irrigation ponds filled with treated sewage effluent in the Las Vegas Valley have been documented to drift to over 9.0, leading to fish kills. This requires superintendents to acidify the water to bring the pH back into the mid-7 range.

Residual Chlorine

Treated sewage effluent typically has chlorine added to it prior to distribution to reduce bacteria levels in the water. If this residual chlorine level is higher than 5 parts per million in the water, and this water is used to sprinkle-irrigate trees, it can cause significant damage, in the form of yellowing and defoliation. However, if the water is kept in an irrigation pond for a period of twelve to twenty-four hours before using, the chlorine level declines rapidly, as it is lost to the atmosphere. Circulating and aerifying the water enhances this loss.

Boron

Boron concentrations in any irrigation water should not exceed 0.75 parts per million. Levels of 1.0 ppm boron and higher in irrigation water is toxic to trees, such as citrus. If the concentrations are above these levels, boron-tolerant trees (Italian cypress, raywood ash, silver dollar gum, and Arizona ash; Nevada Cooperative Extension, special publication, 12/04) should be planted, or the irrigation water should be blended with water lower in boron levels to bring down its concentration. It should be noted that boron tolerance and salt tolerance are different. Some trees, such as magnolia and honey locust, are rated as moderate to tolerant to salinity, but both are sensitive to boron.

Sodium Adsorption Ratio

A sodium adsorption ratio (SAR) below ten in irrigation water is recommended. The SAR reflects potential problems that may occur with high levels of sodium, if calcium and magnesium levels are low. Irrigating with high SAR waters can lead to deflocculating (separating) of some clay soils and plugging soil pores—especially if salt levels are low—which leads to impaired internal drainage. SAR values in irrigation waters available in the Mojave Desert are all safely below the threshold value of ten and have acceptable levels of electrolytes (salts) to keep clays in a flocculated state.

5
CHAPTER

Desert Landscape Design: Xeriscape, Mini-Oasis, and Hydrozones

The appropriate use of plants can beautify a landscape and make it more comfortable as an outdoor living space. Transpiration of water (vapor) cools leaves in a fashion similar to how perspiration cools our bodies. Trees provide beauty and shade, when it's needed, but they also cool homes and outdoor living spaces, making a landscape more usable and reducing energy costs (McPherson and Haip 1989). But plants also use water; the larger in size and number, the more water is needed to irrigate them appropriately. Key to creating an effective landscape in the desert is to establish a landscape that creates an effective balance between landscape water use, aesthetics, and usability.

Did You Know?

Lawn temperatures on a sunny summer day in the desert can be as much as seventy degrees Fahrenheit cooler than concrete or asphalt temperatures.

When landscapes are carefully designed and plants carefully selected and placed, water and energy costs will be contained (McPherson and Haip 1989). To do so requires a thoughtful landscape design that considers the complex interaction between a personal need for beauty and livability and trees' need for water.

Photo 8. Shading the walls of a residence with small water-conserving trees can save as much as 25 percent of an energy bill, without using significant amounts of water (not the case in this residence!). (photo by R.L. Morris)

The trade-off between conserving water and conserving energy in landscapes has been a topic of discussion among engineers and landscape architects for decades (Meerow and Black 2003). The relationship between these two resources is even more closely tied in desert landscapes. For instance, lawns that generate temperatures that are cool to the touch during summer months, due to transpiration, but use substantial amounts of water might be replaced with rock mulch that generates temperatures above 160°F on a hot summer day. If the landscape design is done ineffectively, any savings through water conservation might be offset by the energy required for cooling (McPherson and Haip 1989).

Did You Know?

Improperly designed desert landscapes can increase home cooling costs by 20–30 percent.

Functional landscape designs for the desert that reduce the need for energy and water incorporate both energy- and water-conservation principles. To achieve this, Xeriscape principles are applied through an appropriate landscape design (e.g., mini-oasis), together with water-conservation practices (e.g., hydrozoning).

What Is Xeriscape?

The creation of Xeriscape by Denver Water in 1981 was aimed at reducing landscape water use. The term was trademarked a few years later and turned over to the National Xeriscape Council in 1986. Xeriscape evolved into seven broad landscape practices, now interpreted regionally by Xeriscape councils located in twenty-seven states (Denver Water 2019). The seven principles of Xeriscape are as follows: (1) appropriate landscape planning and design, (2) soil improvement, (3) efficient irrigation, (4) use of mulch,

(5) use of low-water-use plants, (6) practical turf areas, and (7) appropriate maintenance (Denver Water 2019). Currently, there are no Xeriscape councils in the state of Nevada, but the term is used frequently for marketing, and the public is generally aware of the precepts. The following are the seven Xeriscape principles as they might apply to water efficient Mojave Desert landscapes:

> **Did You Know?**
>
> Water has the highest ability to store heat of any substance, except ammonia, meaning that it can absorb a lot of heat without its temperature rising. This is why living by a large body of water, such as an ocean, is advantageous, as it has a moderating effect on temperature.

1. *Appropriate landscape planning and design*. Xeriscape does not prescribe a certain method or way of designing a landscape. It prescribes that landscapes should be planned and thought out before they are installed. One example of a desert-landscape design concept developed at the School of Landscape Architecture at the University of Arizona is the mini-oasis landscape design concept (Duffield and Jones 1981). It divides the landscape into three water-use areas: high, medium, and low water use. Because these areas differ in how people use them and, thus, the plant materials in them, irrigation is separated into *hydrozones* for each area. It also encourages the planting of appropriately sized deciduous trees, in scale with the home, to shade the south and west walls and windows to reduce energy costs.

> **Did You Know?**
>
> Mojave Desert soils can contain as little as one-tenth of 1 percent organic matter in the soil.

2. *Soil improvement*. Xeriscape encourages soil improvement, when needed, at the time of planting. Most of this improvement is through the addition of organic amendments, such as compost, because desert soils are typically low in organics. Soils might be improved to achieve better drainage by deep tilling to break up compaction, sulfur added to lower soil pH, or soils deeply leached to move salts out of the root zone.

3. *Efficient irrigation.* Efficient irrigations occur when water is applied where and when plants need it. Water is applied to the area under a tree's canopy and at intervals dictated by irrigation-management techniques, such as management allowable depletion (MAD). Water waste occurs when it is delivered to plants where they don't need it, at a time when it's not needed, and in an inefficient manner. Broken pipes, leaky sprinklers, plugged drip emitters, and damaged walls of irrigation basins should be fixed when first observed (Photo 9). Drip-irrigation systems should be flushed and cleaned regularly.

Photo 9. Water wasted as it escapes a small basin that needs repair (photo by R. L. Morris)

4. *Use of mulch*. Xeriscape principles also include using a surface mulch to conserve water, control weeds, and insulate the soil. Mulch is anything applied to the surface of the soil that provides these benefits to a landscape. Mulch used in landscapes is either organic or inorganic in nature.

Photo 10. A newly planted tree in which the basin is covered with rock mulch to reduce evaporative losses and reduce weed growth. Note the drip emitters are placed above the root ball of the tree when first planted to ensure that water moves through the soil around the roots and into the surrounding soil. The original emitters are then moved to about twelve inches from the tree trunk. As the tree increases in size, more or different emitters are added to increase the area irrigated under the canopy and account for its increased water use. (Photo by R. L. Morris.)

Photo 11. Fruit tree (mesic) growth in native Mojave Desert soil, amended with compost, one year after planting. Wood-chip mulch was applied to half the fruit trees immediately after planting. Note the size difference in trees receiving wood-chip mulch vs. those that did not receive mulch. (Photo by R. L. Morris.)

Organic mulch, such as wood chips, decompose when kept moist, adding organic content to the soil, while bark mulch decomposes very slowly, adding only small amounts of organic content to the soil. Wood chips should be used to cover the soil surrounding non-desert or mesic plants, such as fruit trees, roses, and some landscape ornamentals (Chalker-Scott 2007; Photo 11). Inorganic mulch, such as crushed rock, is suitable for xeric plants. Some types of crushed rock also need to be refreshed regularly (photo 10). Landscape fabrics applied to the surface of the soil under wood chips or rock, if used, should be durable and allow air and water to reach the soil surface and plant roots.

5. *Low-Water-Use Plants.* Xeriscape recommendations include the use of native plants (or plants that originate from desert climates, a.k.a. xeric) in Mojave Desert landscapes. These plants have the potential for using smaller amounts of water (watered less frequently) than plants originating from non-desert climates (mesic) (photo 12), and most require less maintenance. Most people think the terms *drought-tolerant* and *low water use* are the same. They are not. Drought-tolerant means only that the plant will recover after too little water is available and says nothing about its water use. Low water use means the plant can use less water, compared to plants of the same size, usually with less visual damage. Drought-tolerant plants may or may not be low in water use. Many trees and large shrubs from desert regions are water "opportunists"; they grow or flower when water is present. Little growth or flowering occurs when water is not available. Roots of many xeric plants are frequently shallow and grow wider than mesic plants to take quick advantage of available water in the soil after infrequent rains.

Did You Know?

All cacti are succulents, but not all succulents are cacti.

6. *Limited turfgrass areas.* A lawn, because of its greenery, can give new residents from wet climates a "sense of place," reminding them of home. Lawns are acceptable in a Xeriscape landscape if they are utilitarian and serve a purpose other than as a green groundcover. But lawns require regular maintenance (mowing, watering, fertilizing) that native or desert groundcovers don't, and lawns require a significant amount of water! However, lawns that are functional (for recreation; cooler surface for pets or humans) may be warranted at times and can be easily replaced, if no longer wanted. If you want to have a lawn in desert climates, it should be large enough to serve your personal or

family needs, but the irrigation system should be designed and installed with the highest uniformity possible and with water applied in parallel with environmental demand.

Lawns are established in the high-water-use area of a mini-oasis landscape design but may use as much as sixty-five inches of water each year in the Las Vegas Valley (Devitt et al 1992). When establishing a lawn area, it should be in full sun, with its borders as straight as possible to facilitate overhead irrigation. The warm-season grasses (e.g., hybrid Bermuda grass or Paspalum) can use 40 percent less water than a cool-season grass, like tall fescue (Devitt et al. 1992). A mixture of landscape trees and shrubs with a lawn (mixed landscape, Photo 12) makes water conservation more difficult to achieve. Instead, lawns and trees should be grown separately.

Photo 12. Landscapes that are a mixture of lawn grasses, trees, and shrubs use more water because of interference to the overhead irrigation. Overhead sprinklers can cause visual and mechanical damage to plants. (Photo by R. L. Morris.)

7. *Appropriate maintenance*. Maintenance time on properties has shifted away from labor-intensive lawns to other types of work, such as irrigation maintenance, tree and shrub pruning, and landscape cleanup (photo 13). Unfortunately, this type of maintenance has generally fallen into the hands of tradesmen who are unfamiliar with proper irrigation practices and tree and shrub pruning and who do not understand the principles of water conservation, proper pruning practices, and plant health. Improper pruning practices, such as hedge-shearing plants into a "gumdrop" shape, pruning at the wrong time of year (which reduces or eliminates flowering), and failure to sanitize pruning equipment between properties has led to the early replacement of ornamental plants, a reduction in landscape aesthetics, and the spread of plant diseases in the community,

Photo 13. Correct pruning allows desert plants like these young Texas Rangers to flower profusely. The Texas Ranger on the left was pruned correctly, while the one on the right was pruned with hedge shears and at the wrong time of year. These types of improper pruning practices lead to early plant replacement, a reduction in landscape aesthetics, and the spread of plant disease. (Photo by R. L. Morris.)

Did You Know?

Conserve energy by planting trees in scale with the home to shade the south and west exterior walls.

Mini-Oasis Landscape Design Concept

About the same time that Xeriscape principles were introduced by Denver Water (Denver Water 2019), the mini-oasis concept of landscape design was introduced in the book, *Plants for Dry Climates* (Duffield and Jones 1981). The mini-oasis landscape design concept, combined with the creation of hydrozones for water conservation, increases landscape aesthetics while reducing the amount of landscape water required. Proper placement of deciduous landscape plants reduces the cost of energy needed for cooling and heating the home, as well as creating outdoor living spaces. Deciduous plants allow for summer cooling by providing shade and, in the winter, warmth, after they drop their leaves. Evergreen plants are effective visual barriers and living fences that create privacy, block unpleasant views, and keep unwanted light from entering the landscape, but landscape plants are not effective at blocking most noise.

The mini-oasis landscape design concept divides the landscape into three water-use zones: high, intermediate, and low, reflecting different levels of outside human activity, as well as plant water use. The frequency of human activity determines the choice, numbers, and placement of landscape plants, (i.e., the landscape design). Ultimately, the finished landscape design has a large potential impact on the amount of exterior water used. In turn, these three zones receive varying amounts of irrigation water and at different times because of the type of plants selected, mature size, and their numbers.

These landscape zones can vary in size, depending on the amount of human activity. The important thing to remember is to water plants with different irrigation requirements, separately from each other, and to create different hydrozones.

Did You Know?

When creating a dry riverbed in the landscape, it will look more natural if there is a mixture of rocks of many different sizes.

High-Water-Use Zone

The high-water-use zone is where most outdoor physical activity occurs So it requires the highest plant densities, and it's where mesic trees are located. A lawn, vegetable garden, fruit trees, roses, flower beds, and other frequently irrigated plants are located here. Shade and flowering trees are planted here to provide for human activities. The high-water-use zone, compared to the other two zones, requires the highest amount of irrigation water to support the highest plant densities, and it's where water is applied more frequently. If mesic landscape trees are used like Chinese pistache, rayburn ash, ornamental pear, or flowering plum, they have their own hydrozones. They are irrigated as mesic trees, creating shade, a sense of enclosure, living walls, screens, and barriers for directing foot traffic

High-water-use zones are typically located near the house and living areas close to the house. For families who spend little time outside, this zone might be very small. For others, who spend more time outside, the zone might be quite large and decorative. Because many plants used in this zone may be mesic and not xeric, wood chips and other types of organic mulch will benefit them.

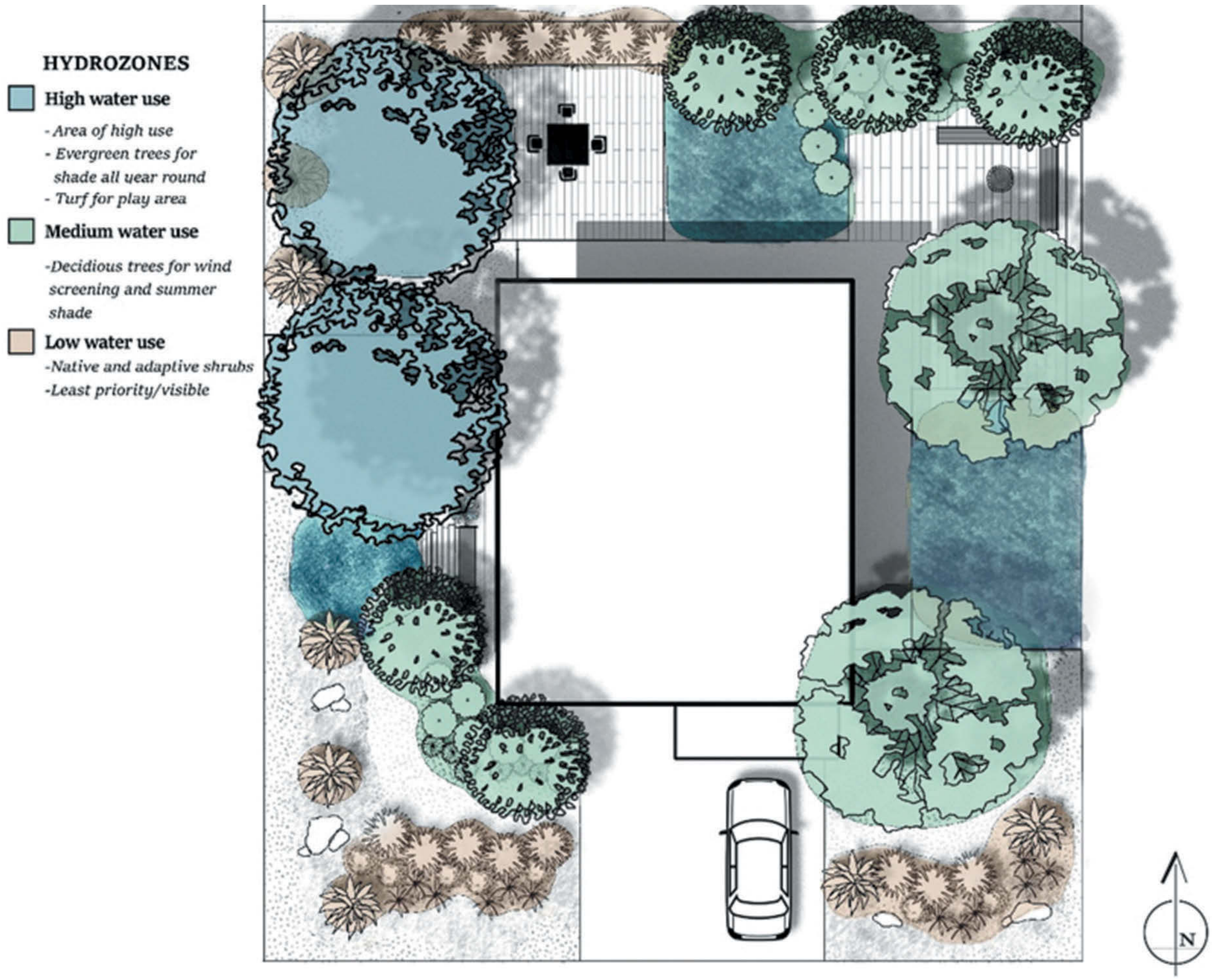


Figure 19. Bird's-eye view of a mini-oasis landscape design, showing the high-water-use zones (blue), intermediate-water-use zones (green), and low-water-use zones (brown). (Drawing by N. Villeda.)

The high-water-use area typically decorates the front and rear entries of the house. High-water-use zones may be subdivided into exterior "rooms," where people gather and spend time outdoors, such as recreation areas, eating areas, or places for conversing, playing cards, etc. All these activities might require protection from intense sunlight, wind, or inclement weather. Plants chosen for this zone provide cooler temperatures in the summer and allow for warmer temperatures in the winter (deciduous vs. evergreen trees). Evergreen trees are typically used as visual screens to create privacy.

Plant densities, design elements (pavers, artwork, ponds fountains, etc.), and the complexity of the irrigation system make high-water-use areas the most expensive zone to install and maintain. Irrigation of the high-water-use zone is typically more frequent than other zones. Because plants are growing close together, drip tubing with built-in emitters is commonly installed in the high-water-use area. Overhead sprinklers might be used for irrigating lawns.

Did You Know?

Xeric trees provide visual cues, such as leaf drop, that they need water applied.

Intermediate-Water-Use Zone

The intermediate-water-use zone provides a "transition" between the high-water-use area and the low-water-use area, both visually and in the amount and frequency of water applied. Plants in this zone are xeric, smaller in size, and are planted further apart. Sometimes a "hard transition" is designed, and walls or fences are used to separate zones. Other times, the transition is "soft," with a blend of mesic, xeric, and perhaps cacti, but xeric plants receive water less often and have their own hydrozone. Human activities are less frequent in this zone, so the total number of plants and amount of water needed is less. Because of this, the intermediate-water-use zone appears drier and less inviting than the high-water-use zone. Rock mulch is commonly used in this zone because most plants are xeric. Because plants or plant groupings are farther apart, drip emitters are commonly used.

Some people prefer to use xeric trees to shade the south and west walls of their home. In cases like this, the hydrozone used for irrigating xeric trees may include these trees as well. Plants used in this zone are xeric, from desert climates, and might include Joshua tree, Texas mountain laurel, little-leaf cordia, and others that are smaller in size and fewer in number. Because there are fewer plants, and the irrigation system is less complex, it is intermediate in cost to establish and maintain.

Did You Know?

Because cacti can store water, a sign that they need to be irrigated is the shriveling of the "skin," or outer surface of the plant.

Low-Water-Use Zone

This is the landscape zone where few, if any, trees are planted. Instead, small xeric plants are watered infrequently. You will find cacti, agave, yucca, ocotillo, and cholla planted in the low-water-use zone. If xeric trees are used, they are small and watered infrequently. This area can be quite spectacular and provide focal points for the landscape. In fact, this zone may be watered by hand only, when needed, or watered occasionally by the irrigation controller. The low-water-use zone may occupy nearly the entire front yard or the area close to the street and may be used to capture rainwater or irrigation runoff before it enters the street.

Creating Hydrozones

The term *hydrozone* is well established in the landscape and irrigation fields and an accepted tenet of landscape water conservation. The term hydrozone was originally coined by two landscape architects (Thayer and Richman 1984). Even though they were landscape architects, the purpose of hydrozoning was not to dictate landscape design but to improve landscape irrigation efficiency. The purpose of hydrozoning is to group together plants with similar water requirements so they receive water only when needed.

Xeric plants are watered separately from mesic plants, using separate irrigation valves/stations. Three basic pieces of information are needed by the irrigation controller, which tells the valves to open or close: time of day to open or close, how often to open or close, and how many minutes to keep the valve open before it closes. Different microclimates in the landscape might also be irrigated separately, if their need for water is substantially different from each other, such as the southern and western exposures vs. the northern and eastern exposures. The hydrozone concept allocates water to plants, based upon their need for water. Desert trees are irrigated along with other desert plants, while mesic plants are irrigated with other mesic plants. The watering depth and the area where water is applied is adjusted to plant size by increasing the number of drip emitters and the amount of area they irrigate as the tree increases in size.

The creation of hydrozones gives the irrigation manager more control over plant growth of desert (xeric) plants. Plants are watered when they need water, rather than providing water on a specific schedule, regardless of whether water is needed. It is common sense that the more plants used in a landscape, The more water is required. But applying water when it's needed improves irrigation efficiency and improves the aesthetics of the landscape, all while conserving water.

Managing Tree Growth and Water Use

The total amount of water used by a landscape can be managed by selecting xeric plants of a smaller size and planting fewer of them. But climatic factors also impact tree water use, such as sunlight intensity, air temperature, wind speed, and relative humidity. Many times, these factors are out of our control. This section is about the impact of management decisions on water use. Any landscape management decision that encourages tree growth has the potential for increasing tree water use. The question remains, "Is the type and amount of growth contributing in some way to my quality of life?"

Pruning and Its Effect on Water Use

Pruning always reduces the size and density of landscape trees (photo 14). Reducing tree size reduces plant water use. But thinning the canopy of a large tree is a double-edged sword; it reduces the chance of tree blow-over, but it also increases wind movement (turbulence) through the canopy that sweeps water vapor from the leaf surface. Thinning the canopy may actually fuel higher water use. Most pruning practices reduce plant water use immediately after it's done. However, pruning is considered an invigorating management practice. In other words, pruning stimulates plant growth, so the decrease in plant water use is frequently short-lived. It might be more accurate to say that pruning a tree *alters* plant water use but not significantly enough to warrant a change in irrigation practices, unless there are dramatic changes in tree size.

Did You Know?

When pruning trees or shrubs, make sure the canopy occupies two-thirds to three-quarters of its total height.

Photo 14. Pruning high in the canopy of a pine tree in southern Nevada (photo by R. L. Morris)

Fertilizers and Their Effect on Water Use

Fertilizers, together with the soil microbiome and the decomposition of organic matter, supply the nutrients that plants need for growth and health. Fertilizer applications are typically done once a year in the early spring. If the soil is healthy, adding more fertilizer, particularly nitrogen (first number on the fertilizer bag), stimulates tree growth. When trees are small, growth is desirable, and so fertilizers with higher nitrogen are recommended. As trees get larger, they require more water so growth is less desirable. As trees get older and reach a desirable size, less nitrogen may be needed. The amount to apply is listed on the label and represents the maximum amount to apply, but actual tree growth and health will dictate if the amount applied should be decreased or not. Xeric tree growth is heavily influenced by water applications and may be less influenced by fertilizer applications. When the tree is young, water and fertilize it more to increase growth. As the tree reaches a desired size, decrease the amount of fertilizer, particularly nitrogen, and the frequency of applied water.

Microclimate and Its Effect on Water Use

Landscape microclimates are smaller parts of a community-wide landscape microclimate that differs from the overall climate. Landscape microclimates may be very small in size. Sometimes these microclimates may be warmer than the overall climate (southern and western exposures), and sometimes they may be colder (northern and eastern exposures). Some parts of the Las Vegas Valley always get freezing temperatures in the winter, and other parts don't. Think about winds channeling through the streets in winter, reflected light from windows, radiant heat from stucco walls, wind channeling between buildings, runoff from roofs and driveways, landscape depressions, or having a pool or lawn. All of these contribute to a different landscape microclimate. Incorporating these microclimates into your irrigation plan and tree selection should be considered.

Did You Know?

Protect the trunk and limbs of young trees and shrubs from sunburn by pruning lightly or not at all until plant parts are older.

Microclimates can occur because of natural landscape conditions, or they can be created through careful landscape designs. Seasonal observation of the landscape area gives clues about how to use existing microclimates or how to create new ones. Examples that impact a residential microclimate include changing the landscape topography to accumulate water, establishing semipermeable barriers to reduce wind, installing heat-absorbent surfaces to improve the survivability of winter-tender plants, and using light-colored surfaces to reflect light and increase plant growth. Many of these landscape design enhancements don't require additional plants and thus require no new assessment of landscape water use, unless the change in microenvironment significantly enhances plant growth.

6 CHAPTER

Desert Trees for Mojave Desert Communities

Using xeric or desert-adapted trees that originate in Nevada, the Desert Southwest or desert regions of the world can provide unique opportunities to conserve water in home landscapes. Many of these xeric trees grow and perform well in desert soils and require less-frequent irrigations, compared to mesic trees (non-desert-adapted trees), which struggle to grow well with the same amount of water. Nevada and Southwestern native trees require less-frequent irrigations, but there is a difference in irrigation needs, even among these trees. With a little bit of care at planting and judicious applications of water as they grow, xeric trees can substitute for most mainstream mesic trees available to homeowners—and conserve water at the same time.

Landscape and Irrigation Design

Trees mentioned in this section can be found in both the xeric (desert) and mesic (non-desert) categories. Xeric trees should be irrigated separately (hydrozoned) from mesic trees when conserving water and controlling tree growth. This is because mesic trees need to be irrigated more frequently than xeric trees, and they grow best in parts of the landscape where soil improvement and higher water applications are practiced. Mesic trees recommended here come from dry but not necessarily desert climates. Examples include vitex, which originates from a Mediterranean climate (dry summers but wet winters); Chinese pistache, from dry interior climates; and subtropical palms, which have adapted to arid or desert climates but grow best near bodies of water.

Planting

Planting should be done during spring or fall months, avoiding the extreme hot or cold temperatures of summer or winter. Palms are most successful when planted in the spring or early summer, avoiding the fall and winter months.

The width of the planting hole, not necessarily its depth, is extremely important for successful future growth and health of the tree, unless there is a drainage problem. The width of the planting hole should be a *minimum* of three times the width of its original container. Trees with a large mature size should have a planting hole dug five times the width of its original container.

Trees should be planted at the same depth as they were growing in their nursery containers. Planting holes should be dug to a depth similar to its container height and no deeper, unless there are problems with drainage. Trees planted in deep holes may "sink" after planting, causing a disease on the lower trunk called *collar rot*. If the planting hole is deeper, then the soil at the bottom of the hole should be compacted before planting. This can be done with water. Trees should be staked to immobilize the lower trunk and roots but to allow the top of the tree to bend and move with the wind, without moving the roots. Stakes should be removed after one growing season.

> **Did You Know?**
>
> Root-bound plants establish their roots poorly in landscapes, regardless of how they are planted.

The amount of organic matter (e.g., compost) incorporated into the backfill depends on the original organic content of the soil. In some desert soils that previously had growing plants and where the organic-matter content is high, additions do not improve planting success or plant vigor. When organic matter of the landscape soil is very low (significantly less than 1 percent), such as in most unimproved Mojave Desert soils or imported landscape soils in subdivisions, a moderate addition of compost to the backfill (20 percent v/v) improves both mesic and xeric tree performance after planting.

Water should be added to the planting hole as amended soil is backfilled around the roots. Doing this settles the soil around the roots and removes pockets of trapped air. Construct an irrigation basin (doughnut) around the tree to hold water. Water trees twice with a hose the first day after planting; then weekly for a month after starting a normal irrigation schedule. A normal irrigation cycle should apply enough water to wet the soil so that small trees are watered at least eighteen inches deep, medium-size trees twenty-four inches deep, and large trees as much as thirty-six inches deep (figure 20). Once xeric trees are established, the frequency of irrigations can be used to encourage or discourage growth, thus becoming a growth-management tool for these trees. For this reason, hydrozone landscape plants.

Pruning

Pruning should be done after the tree finishes flowering, if flowers are conspicuous and part of its aesthetics. Trees without conspicuous flowers are primarily pruned during the winter. Many trees, like Arizona ash and bottle tree, are susceptible to sunburn if pruned heavily outside of the winter months. Some trees, again like Arizona ash, do not respond vigorously if pruning is extensive at any time during their lives. Many native trees can be shrub-like in their growth habits. It is important to establish these trees into a tree-like form early in their lives, but prune carefully to not expose the trunk and large limbs to direct intense sunlight.

Irrigation

After planting young trees in the spring or fall, construct an irrigation basin to hold water, and water with a hose weekly, for a month, along with the normal irrigation cycle. This practice aids in their establishment. Once new growth appears, supplemental water from the hose should not be needed. The area where water is applied should increase in size over the years, along with the size of the tree, as it gets older and its need for water increases. In other words, the amount of water applied in a single application increases as the tree gets larger, and this water is applied to a larger area under the tree.

Did You Know?

Plants lose more than 90 percent of the water they take up from the soil via transpiration.

Trees originating from the desert (xeric) are water opportunists; they begin growing rapidly a few days after the soil is wet. The growth of these trees can be controlled by controlling their irrigation frequency. This is generally not true of non-desert trees (mesic), which follow seasonal growth patterns; this is a primary reason why xeric and mesic trees are watered separately. As the size of a desert tree approaches its ideal size, watering frequency is reduced to slow its growth, but the amount of water per irrigation applied remains the same. During summer months, extra irrigations stimulate the growth of desert trees, when needed. Desert trees, along with four inches of surface mulch, may need irrigations as little as once or twice a month during the summer and after establishment. During the winter, irrigation may be needed only once during the entire winter! Watering may be more effective if irrigations are supplemented with a hose, rather than using the automated irrigation system. Many native desert trees can tolerate deficit irrigations for varying periods of time.

Nevada Native Trees

The following xeric trees are native to the Mojave Desert of southern Nevada:

Catclaw Senna (formerly Catclaw Acacia)
***Senegalia gregii* (formerly *Acacia gregii*)**

Catclaw, also called devil's claw, *Una de Gato*, and, formerly, catclaw acacia, received its name from the single, quarter-inch-long recurved spine, located at each of its nodes (Photo 15). It grows as a spiny, large-spreading shrub or occasionally a small tree, from three to twenty-three feet tall, with a broad crown. It has one- to three-inch-long hairy leaves and dense clusters of bright-yellow fragrant flowers from April to October, particularly after a rain. These flowers produce a flattened pod, one and a half to four inches long that remains attached during the winter (Little 1968; USDA USFS 2019). This is one of the few small desert trees (xeric) that can produce a canopy wider than its height (Little 1968).

Its gray bark is thin and fissured into narrow scales. Its wood is hard and dense. It often forms thickets along washes, slopes, and rocky canyons in the desert and desert grasslands, from close to sea level to five-thousand-foot elevations. It is widely distributed through southern and central Texas, to southwestern Utah, New Mexico, Arizona, northern Mexico, and southeastern California (Little 1968; USDA USFS 2019). A native of the desert region of southern Nevada, it grows in southern Lincoln, southern Nye, and Clark Counties, and southward (Billings 1954).

Photo 15. Catclaw senna growing as a small tree to twenty-three feet (left: Tule Springs, Nevada; right: an urban landscape. Photos by D. A. Devitt).

This seldom-used native shrub serves as a screen, physical barrier, or small multiple-trunk desert tree, if trained and irrigated (Martin 2019). Contact with catclaw should be avoided because of its sharp spines, which tear clothing and flesh; hence, it does make an excellent protective barrier. The dense wood is used for souvenirs, locally made tool handles, and fuel. Native Americans made flour from the seeds (Little 1968).

Irrigation: The water needs of catclaw senna grown as a tree are moderate, like western redbud. It can be used in the low- and intermediate-water-use areas of a mini-oasis landscape but should be hand-watered occasionally, if more size is needed. Watering infrequently and careful pruning results in a small shrub or protective barrier.

Desert Willow

Chilopsis linearis

Desert willow is used as a shrub or small tree, with a spreading crown that can grow up to twenty-five feet in the wild (photos 16 and 17) but under landscape conditions may reach thirty feet or more with additional irrigations. Desert willow has been given the name "California orchid tree" because of its showy flowers (Las Pilitas Nursery 2019). The tree is not a true willow but closely related to catalpa and exhibits the same type of showy, fragrant flower clusters most of the year. Desert willow produces four- to eight-inch-long pods that stay attached during the winter, which is objectionable to some people. The flowers from native stands are whitish, tinged with purple or pink, and bloom from April through August (Mountain States Nursery 2019). Trees with other flower colors are available from nurseries. Leaves are narrow, straight or curved, and three to six inches long (Little 1968).

Photo 16. Desert willow growing in a landscape in Las Vegas (photo by D. A. Devitt)

The bark is ridged, scaly, and dark brown. The wood is durable and used for fence posts (Little 1968).

In Nevada, it is native only in the warm desert regions of the south and found growing along washes and drainage areas in the desert and foothills at 1,500- to 5,000-foot elevations (Billings 1954). Desert willow is important for erosion control and is widely used for this purpose. Native plants are available through the State Forestry Nursery in Las Vegas (Nevada Division of Forestry 2019).

Outside of Nevada, it is found widely distributed in western Texas, the desert regions of New Mexico, the south-central and northwestern parts of Arizona, southwestern Utah, and Southern California to northern Mexico (Little 1968). Desert willow has gone through extensive breeding programs to produce trees with an assortment of different-colored flowers, from white to pink to dark purple (Martin 2019). The flowers of the tree attract hummingbirds, and the cultivar name often contains the flower color (Las Pilitas Nursery 2019; Monrovia Nursery 2019).

Photo 17. Desert willow growing in a wash in southern Nevada (photo by C. K. Kelly, www.naturalist.org/observations/41501)

Irrigation: Desert willow grows along washes. Not surprisingly, soil moisture is more important for establishment and growth, flowering, and canopy density than perhaps other desert trees. It is suitable for medium- and even high-water-use zones of the mini-oasis landscape. After establishment in the landscape, irrigate this tree along with western redbud, Gambel oak, velvet ash, and other desert trees that require more frequent irrigations. To slow growth and encourage flowering, water less often. However, watering less often might affect its landscape quality and growth. Adjust irrigation frequency and amounts to maintain its landscape aesthetics by wetting the soil twelve to eighteen inches deep.

Gambel Oak

Quercus gambelii

Sometimes called Utah white oak, Rocky Mountain white oak or southwestern scrub oak, Gambel oak is named after William Gambel (1821–1849), a physician who identified over one hundred new species of plants and animals while traversing the southwestern United States (photos 18 and 19). The bark of mature Gambel oak is rough, deeply furrowed, and scaly gray. Its wood is hard and dense, so it was primarily used for fence posts and fuel by ranchers and pioneers (Billings 1954).

Photo 18. Gambel oak, *Quercus gambelii*, grows to a height of twenty to seventy feet (2018 Toiyabe National Forest, Las Vegas. C. K. Kelly. https://www.inaturalist.org/photos/25804337).

Photo 19. Gambel oak growing at the Springs Preserve in Las Vegas (SNWA) (photo by D. A. Devitt)

Gambel oak grows at the same elevation as ponderosa pine in the mountains and plateaus of southern Nevada, from White Pine County to Clark County (Billings 1954). Outside of Nevada, its distribution ranges from southwestern Texas and northern Mexico, through New Mexico, Oklahoma, Colorado, and Arizona, and as far north as southwestern Wyoming, South Dakota, and Utah (Little 1968; USDA, USFS 2019).

This southwestern oak is variable in height, leaf size, and the size of its acorns. In its native habitat, it can range in height from twenty to seventy feet, and it possesses a strong, vertical central trunk. In landscapes, it is reported as growing from thirty to fifty feet in height. But it also may be found suckering in thickets and growing as low as only six feet in height. Its deciduous, two- to seven-inch-long leaves are characteristic of many oaks, with acorns, lobed leaves, soft hair on the leaf undersides, and turning a rich fall color. Its roundish acorns may range in size from three-eighths to three-quarters of an inch (Little 1968; USDA, USFS 2019). It should be planted in full sun and propagated by seed (USDA, USFS 2019).

Did You Know?

Most oak trees do not produce acorns until they reach an age of fifty years.

Gambel oak, because of its suckering, is best used in mass plantings. It is not considered a good choice for a single-specimen tree or a street tree because of the suckering (unless controlled). It can be used to screen parking lots and undesirable views. Due to its small size, Gambel oak fits well on residential lots. Because Gambel oak is xeric, it requires infrequent but deep irrigations and is adaptable to harsh growing conditions. It is slow-growing but will increase in its growth rate with moderate irrigations and applications of fertilizer. Gambel oak is a tough, durable plant with few serious pest problems. Probably the most serious problems are galls produced on leaves and stems (Olsen and Amundsen 2011).

Irrigation: This tree grows best with moderate amounts of water and covering an area suitable for its size. It should be planted in intermediate-water-use areas of mini-oasis landscapes. Frequent irrigations, applications of fertilizers, and appropriate pruning will cause more rapid growth and a taller tree. Like the other trees mentioned here, apply fertilizers in a single application in the spring of each year. Irrigate similarly to western redbud, desert willow, velvet ash, and other desert trees requiring moderate irrigations.

Did You Know?

Nonnative black oak may have as many as 375,000 stomata per square inch on the lower leaf surface and no stomata on the upper leaf surface.

Joshua Tree

Yucca brevifolia

The Joshua tree is referred to as an arborescent yucca and is unlike any other tree growing in Nevada (photo 20 and photo 21). The Joshua tree's visual counterpart in the Sonoran Desert of Arizona and Mexico is the saguaro. This tree attains heights of twenty-five to thirty feet with a trunk, one to three feet in diameter, that is straight and unbranched, commonly, for four to twelve feet above the ground. Above this, branches may spread widely or sometimes droop at intervals of two to three feet (Little 1968).

Photo 20. Joshua trees growing in the Red Rock recreation area of southern Nevada (photo by Cindy Philips)

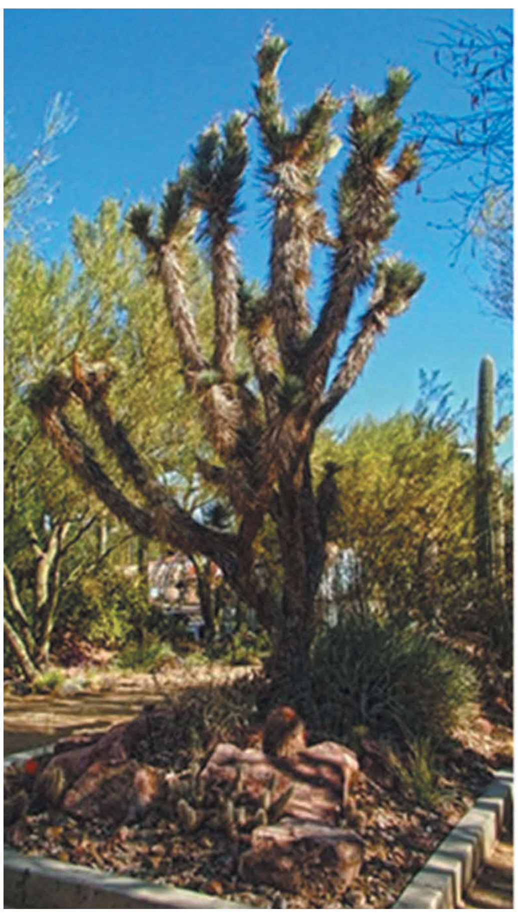


Photo 21. Joshua tree growing at the Springs Preserve in southern Nevada (photo on left by D. A. Devitt) and growing near the St. George, Utah, area (photo by Fred Landau)

The stiff, pointed leaves vary in length from four to ten inches and grow in green rosettes at the ends of branches. The length of these green tufts varies with rainfall and irrigation. Branches and small trunks are covered with stiff, dead brown leaves that press inward on the trunk or stem. The tips of branches bear large, greenish, lily-like white flowers, with an unpleasant odor when they open in March and April. These flowers are followed by a three-sided capsule from one and a half to four inches long that bear the seeds (Little 1968).

The Joshua tree ranges in the eastern Mojave Desert from southeastern California, across southern Nevada and northwestern Arizona, to southwestern Utah (Little 1968; Data Basin 2019; Southwest Ecology 2018). In Nevada, it is common in the southern desert region, where it forms extensive groves (such as the Hidden Forest in the Sheep Range), with a shrub understory on gravelly flat plains and lower mountain slopes. It grows as far north as Lincoln County in the east and eastern Esmeralda County to the west, where it can be found as high as 6,900 feet but more commonly at elevations of 2,000 to 3,500 feet (Billings 1954).

The paucity of seed production, slow growth rate, and short-lived seed viability (Southwest Ecology 2018), combined with a lack of popularity, may explain why it is frequently not found in landscape nurseries or even native plant nurseries (Las Pilitas Nursery 2019).

Irrigation: After the first year, this tree should be irrigated as a low-water-use plant (planted in the low-water-use areas of mini-oasis landscapes). The most common issue in establishing Joshua trees is watering too often and having poor drainage after irrigations. Selection of small plants and judicious applications of water commonly lead to better success in its establishment. It is best watered by hand, as needed, until it is established.

Joshua trees maintain a length of green rosettes at the ends of branches, the length of which is directly related to the frequency of irrigations. If long green growth is desired, irrigate in the medium-water-use area of a mini-oasis landscape. Applying water frequently can result in long, green, bending rosettes; poor establishment; and even death. When short rosettes are desired, irrigate (infrequently) in low-water-use areas of a mini-oasis landscape. In my (Morris's) opinion, these trees look most natural when irrigated less often and by using a small amount of compost in the backfill mix when planted.

Mesquite

Prosopis glandulosa, P. glandulosa* var. torreyana, *P. velutina,* and *P. pubescens

Varieties of similar mesquite reported growing in Nevada include honey mesquite (*P. glandulosa*), western honey mesquite (*P. glandulosa* var. torreyana), velvet mesquite (*P. velutina*), and screwbean mesquite (*P. pubescens*) (Billings 1954; USDA 2019). We will discuss the first three varieties as *Prosopis glandulosa* (mesquite) because they are similar, from a landscape perspective.

Mesquite is a spiny shrub or tree, reaching twenty to thirty feet tall but can reach fifty feet tall in some irrigated landscapes (Photo 22). It can have a trunk one to four feet in diameter, covered with thick, reddish-brown bark. The branches are crooked and straggling, with yellowish spines, a quarter-inch to one inch long, in pairs, and producing a wide, round crown. The small but conspicuously fragrant flowers are born on dense spikes, from one and a half to three and a half inches long from the axils of leaves and are important in honey production (Little 1968; USDA NRCS 2019). They are evergreen when water is available but drop their leaves in extreme drought and after freezing temperatures.

The roots of mesquite grow extremely deep, reportedly over one hundred feet in native stands and in alluvial soils of the deserts. Deep roots enable the tree to withstand extreme drought (USDA NRCS

2019). The wood is heavy, hard, and decay-resistant; thus, it makes excellent fence posts. Mesquite wood provides one of the best fuels found in the desert, and it imparts a popular aroma and flavor to food when used for cooking. The sweet pods are used to feed livestock and were prepared into meal and cakes by southwestern Native Americans (Little 1968; Jepson Herbarium 2019). The California mistletoe is found as a frequent plant parasite, growing along the branches of these trees, producing a "witch's broom" effect.

Desert mesquite varieties can be found growing abundantly on sandy plains, sandhills, along stream valleys and washes, in short grass, in the desert and desert grasslands, and sometimes in the oak woodland zones, from near sea level to elevations of 5,500 feet (Little 1968). In some dry grasslands, mesquite has been reported as invasive and is considered a weed (USDA USFS 2019). Its northwestern distribution ends in the desert region of southern Nevada, occurring mainly in parts of Clark, southern Nye, and extreme southern Lincoln Counties (Billings 1954).

Photo 22. Irrigated mesquite growing in North Las Vegas (top photo) and in an urban landscape in southern Nevada (bottom photo, photos by D.A. Devitt)

Outside of Nevada, there is a slightly different range, with *P. velutina* restricted to four southwestern states, plus northern Mexico, while *P. glandulosa* is found in nine southwestern states and northern Mexico (Jepson Herbarium 2019; USDA NRCS 2019). Differences in their range may be because of differences in cold tolerance (Jepson Herbarium 2019). Outside the southwest, these trees are found as introductions in Africa, the West Indies, Central America, Venezuela, and Colombia (Little 1968).

Irrigation: Mesquite responds to irrigation by increasing leaf density and canopy growth. When water is not available, leaves drop from the canopy, signaling the need for an irrigation. Native stands of mesquite are considered indicator trees of soil moisture, as they are deeply rooted phreatophytes. This trait is common to many desert or desert-adapted trees that grow predominately in washes or arroyos. Excessive growth of these trees in landscapes is a signal that it is irrigated too often. Irrigate similarly to western redbud, Gambel oak, desert willow, netleaf hackberry, and other desert trees that require irrigation to look their best. It performs best when watered along with other trees that are planted in the intermediate-water-use zone.

Screwbean Mesquite

Prosopis pubescens

This tree is also called Fremont screwbean or *tornillo* ("screw," in Spanish). It differs from the western honey mesquite (*Prosopis glandulosa* var. torreyana) in its smaller, mature size; smaller, one- to three-inch-long leaves; and tightly coiled, one- to one-and-a-half-inch-long spiraled seed pods. It flowers from May to August (Little 1968). In Nevada, the screwbean mesquite (Photo 23) is found in the desert region of southern Nye County and eastward (Billings 1954).

In the wild, it grows as a shrub or small tree to twenty feet, with a one-foot trunk diameter, with light-brown or reddish bark that separates into long strips. It can be found growing along streams in valleys and in desert areas, from near sea level to 5,500-foot elevations. It can be found from west Texas and northern Mexico through southwestern New Mexico and the southern and western parts of Arizona, into southwestern Utah, southeastern California, and southern Nevada (Little 1968; USDA USFS 2019). The dense, very hard wood was used for fuel and fence posts (Little 1968). The sweet pods were made into meal and cakes by Native Americans and the sweet-tasting pods chewed and eaten (Little1968).

If this plant is to resemble a single or multitrunked tree, then pruning will be required. Use it as an accent or specimen tree in the landscape and plant in the intermediate-water-use areas for shade near courtyards or patios (Arid Zone Trees 2019).

Irrigation: Like many mesquite trees, its size, appearance, and leaf density can be controlled with irrigation. Its roots favor deep irrigations, like western redbud, netleaf hackberry, velvet ash, and other desert trees that grow best in moist soils.

Photo 23. Screwbean mesquite, growing at the Springs Preserve in southern Nevada (top photo) and near a wash in southern Nevada (bottom photo, photos by D.A. Devitt)

Netleaf Hackberry

***Celtis laevigata* var. reticulata**

Sometimes this deciduous tree is called *palo blanco* or western hackberry. It grows in the wild as a large shrub or small tree to thirty feet (photo 24), one foot or more in trunk diameter, and with a spreading crown (Little 1968). With irrigation, it can grow much larger. Leaves are one and a half to two inches long, strongly veined, with a sandpaper-like rough upper-leaf surface. Flowers produced in March and April are small, inconspicuous, and greenish. Fruit produced by the flowers is small, orange-red, dry, and sweet (Little 1968).

Gray bark becomes rough and fissured as it gets older, with large, corky warts along the surface. It is widely distributed from 2,500- to 6,000-foot elevations along streams, canyons, washes, and oak woodland zones in moist soil (Little 1968).

This tree grows in Nevada only in Lincoln and Clark Counties and is the only native member of the elm family found in Nevada (Billings 1954). In the Southwest, it can be found growing in southern and central Texas, Oklahoma, west to Colorado, and to the mountains of New Mexico and Arizona, northern Mexico, and California. The wood was used for fuel and fence posts, and the sweet fruits eaten by wildlife. Many leaves have rounded, swollen galls caused by insects, while the branches often have a "witch's broom" appearance (Little 1968).


Photo 24. Netleaf hackberry growing in the Mount Potosi area (photo on left, Stan Sheb 2008) and growing at the Springs Preserve in southern Nevada (photo on right, D. A. Devitt)

Irrigation: Netleaf hackberry is irrigated similarly to western redbud, Gambel oak, desert willow, mesquites, and other xeric trees that require perennially moist soils. Place it in intermediate-water-use areas of mini-oasis landscapes. This tree can get large when irrigated like a mesic tree.

Did You Know?

An average tree can contain enough wood to produce over 150,000 pencils while a single giant Sequoia tree can contain enough wood to build 35 homes.

Pinyon Pine

Pinus monophylla

As the species name (*monophylla*) suggests, this tree is sometimes called "single-leaf pinyon pine." It may also be referred to as Colorado pinyon pine or nut pine and can be found growing in Lincoln and east Clark Counties, Nevada (photo 25). Uncharacteristically, Nevada has a two-needled form of this tree as well. It can be found throughout the state, except in the extreme northwestern region, northwest of Reno (Billings 1954). It is one of two Nevada state trees, the other being bristlecone pine.

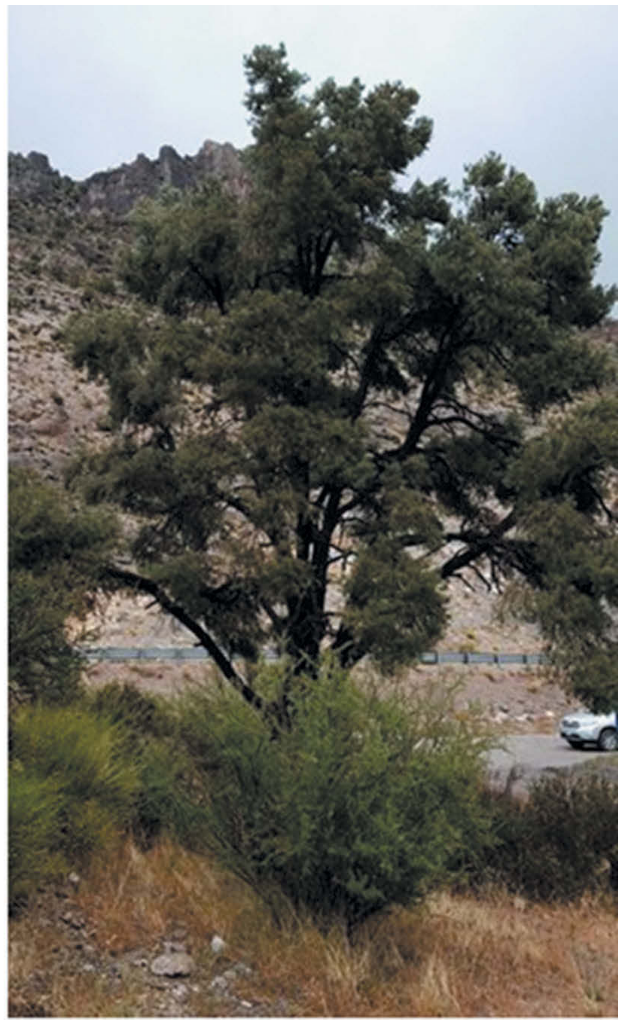



Photo 25. Pinyon pine, growing in the Mount Potosi area of southern Nevada.
Grows to a height of forty feet. (Photos by Cindy Philips.)

It grows on plateaus and mesas and is associated with canyon walls, slopes, and foothills in arid, shallow, rocky soil, from 2,700 to 7,800 feet, in close association with Utah juniper. Although relatively small compared to many native pines, it can grow to a height of forty-five feet and twenty feet wide, with a trunk one foot in diameter or more (Little 1968; USDA USFS 2019), if irrigated and fertilized.

The tree is bushy in shape when older and pyramidal when young. It has three-quarter- to half-inch-long stiff, twisted, dark-green needles that can grow singly or in pairs (Little 1968; Cole et al. 2009). It has orange-brown, oblong cones that are a half inch to two inches in length that produce two large, edible seeds about three-quarters of an inch long (Little 1968; USDA USFS 2019). Nuts are collected by Native Americans in the region. Nuts are produced only after fifteen to eighteen years of age, and it may produce nuts in alternate years when growing in native stands. The bark of young trees is smooth and gray but later turns rough, scaly, and brown in color.

Pinyon pine can withstand extreme cold, heat, and low humidity (Cole 2009). For this reason, it makes an excellent smaller pine tree for xeric landscapes, when irrigation is controlled. Because it is evergreen, it makes an excellent year-round visual screen. Unfortunately, it was marketed for southwestern desert landscapes in the past but never became as popular as the mesic larger pine trees currently used in landscaping. This plant is available from native plant nurseries (Las Pilitas Nursery 2019).

Irrigation: Like Utah juniper, this tree is truly low in water use but should be irrigated deeply when watered. Irrigate in moderate- to low-water-use areas of a mini-oasis landscape, similar to Joshua tree, yellow palo verde, Utah juniper, and other desert trees that require less-frequent irrigations. If planted in high-water-use areas, this tree can grow over forty feet tall and twenty feet wide.

Utah Juniper

Juniperus osteosperma

This evergreen, upright tree, sometimes called simply “common juniper,” grows ten to thirty feet tall and ten to thirty feet wide in the wild (Photo 26). It can be found growing alongside pinyon pine on dry plains, plateaus, hills, and mountains at altitudes of 2,500 to 9,000 feet; sometimes, it grows alone (Little 1968; USDA USFS 2019). It is the most widespread of all Nevada conifers and occurs in all seventeen Nevada counties. It is found throughout Nevada, particularly in the Great Basin, but not in the northwest corner of the state (Billings 1954).

Photo 26. Utah juniper growing at the Springs Preserve in Las Vegas (photo on left, D. A. Devitt) and in the Mount Potosi area (photo on right, Cindy Philips)

It is long-lived and is thought to survive 350 years or more. It can grow to forty feet or more in irrigated landscapes. Giving it more water will cause it to grow taller. Outside of Nevada, it is found growing from Montana, southern Idaho, and Wyoming to southern Arizona, and from Colorado, west to the Sierra foothills of Nevada and California (Little 1968; USDA USFS 2019).

Pyramidal to rounded in shape when young, this single-trunked tree may become multitrunked and spreading when older, with branches nearly to the ground. As with all junipers, leaves are scale-like. This tree produces a three-eighths-inch diameter fruit that is a reddish-brown berry. The bark is brown to gray and is fibrous as it matures. The wood is light but extremely durable because it is decay-resistant (Little 1968). Because it is evergreen and not tall, it could make an excellent low-water-use screen or windbreak in landscapes (Utah State University Forestry Extension 2019).

Irrigation: This tree is extremely resistant to drought and cold. Sometimes the foliage becomes bronze-colored late in winter, due to low temperatures. Irrigate in the low-water-use areas of mini-oasis landscapes along with pinyon pine, yellow palo verde, Joshua tree, and other desert trees that require less water. Planting in high-water-use areas promotes growth but may encourage root diseases associated with continuously moist soil.

Velvet Ash

Fraxinus velutina

This tree may also be called desert ash, smooth ash, or Arizona ash. This small- to medium-sized tree grows from twenty to forty feet with a similar spread and one foot or more in trunk diameter (photo 27). The tree has a rounded crown and spreading branches but demonstrates a lot of variability in its leaflets and twigs. Some botanists distinguish two or three different varieties of this tree because of this variability (Little 1968; USDA 2019). With moderate amounts of water, it is planted as a shade tree in southern Nevada (Billings 1954) and gives reliable fall color (Martin 2019).

Male and female trees are separate (dioecious), with winged seeds produced in dense clusters from flowers in female trees during April or May. The male form has inconspicuous flowers that produce only pollen. The bark is deeply furrowed as it matures and gray in color (Little 1968).

In the wild, this tree grows along streambanks, perennial washes, and moist mountain canyons, but it also can be found in the desert and in desert grasslands, oak woodlands, and alongside ponderosa pine, up to the 7,000-foot elevation. This tree is native to southwestern Texas; New Mexico mountains, south to the border; through southern and central Arizona; and is spreading up to the northwestern parts of Nevada. It is found growing in southern Nevada to southwestern Utah and westward to Southern California and northern Mexico (Little 1968; USDA NRCS 2019).

Photo 27. Arizona ash growing in the Mount Potosi area in southern Nevada (photo by Fred Landau)

Arizona ash and its hybrid relatives (Modesto ash, Fan-Tex ash, bonita ash, Rio Grande ash, and raywood ash) are used as "backbones" in many urban landscapes for deciduous shade, as well as aesthetics.

Note: This tree and its hybrid relatives are subject to a dieback disease found in many ash trees, called *ash decline* in Arizona (Martin 2019) and *ash dieback* in California (UCIPM 2019). So far, shamel ash (*F.*

uhdei) shows resistance to this disease but may have difficulty surviving the freezing temperatures of the Mojave Desert in some areas. Planting of Arizona ash and its relatives (any ash trees with Arizona ash genetics) in landscapes may be discouraged in the future. In some places in the Desert Southwest, their removal is encouraged when found infected (Morris 2019).

Irrigation: Ash trees can be found in canyons and along streambanks, as they grow best in protected areas that receive additional water and good drainage. The preferred locations for planting this native tree are the intermediate-water-use areas of mini-oasis landscapes. Its water needs are like desert willow, Gambel oak, and western redbud. Hybrids of Arizona ash are mostly mesic and can be planted in the high- or moderate-water-use areas of mini-oasis landscapes.

Western Redbud

Cercis occidentalis

Sometimes called California redbud, Arizona redbud, or Judas tree because of its purplish-pink flowers in March and April, this shrubby, deciduous tree is native to southern Nevada and can be found in the Spring Mountains in valleys and along streams, from 4,000 to 6,000 feet (Billings 1954; Kartez 2015) (photo 28). The University of Nevada Cooperative Extension (2019) also includes Nevada in the tree's native distribution range. Outside of Nevada, it can be found in mountainous parts of Arizona in Pima, Pinal, and Mohave Counties and in New Mexico (Little 1968; Kartez 2019b). It can also be found in southern Utah and parts of California (Little 1968).

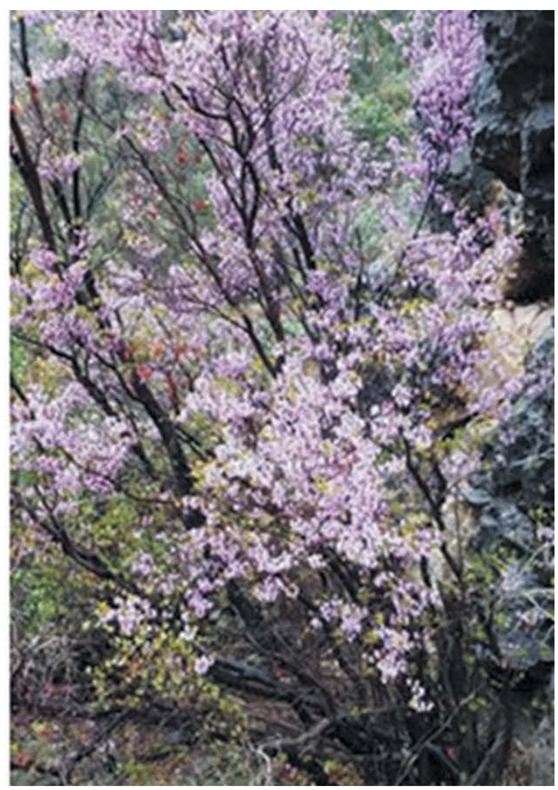


Photo 28. Western redbud grows to a height of fifteen feet, with showy flowers appearing before spring growth. (Photo on left by M. L. Robinson; photo on right by Cindy Philips—Mount Potosi, Nevada.)

Roundish in shape, the tree, in its natural surroundings, is reported to reach a maximum height of fifteen feet with a similar canopy spread. One specimen tree was found in Santa Rosa, California, with a height of forty-five feet, a trunk circumference of seventy-one inches, and spread of thirty-eight feet (Little 1968). This tree performs best when planted in locations away from intense sunlight and near sources of water, in settings like desert valleys near streams. As with velvet ash, avoid planting in extremely hot locations in the landscape.

Western redbud should be grown as a multitrunked tree and for its spring flowering accent of colors and beautiful fall color, but it could be maintained as a single-trunked specimen. New woody growth is reddish-brown but older branches and trunks are smooth-to-fissured and dark gray. It blooms in spring, with clusters of pea-shaped flowers appearing before spring growth. Flowers develop into two- to three-inch-long brown or purplish flat pods by summer. These pods drop to the ground and cause a small amount of litter each year beneath the tree. Roundish leaves measure two to four inches across and emerge light green in the spring and become darker as they mature.

Western redbud is used in planters, medium-sized parking lots, lawns, as a specimen tree, in sidewalk cutouts, and as a street tree. It performs best when grown in filtered light. Currently, it is not planted in the eastern United States, and it is available only from a few small nurseries (Gilman and Watson 1993). Propagation is by seed in a complicated process, which is probably one reason why more are not available in nurseries.

Irrigation: Growth is best with regular but deep irrigations and a light application of fertilizer in the spring. This tree performs best with moderate applications of water, such as the intermediate-water-use areas in a mini-oasis landscape. Irrigate along with Gambel oak, desert willow, velvet ash, netleaf hackberry, mesquite, blue palo verde, and trees with similar water requirements.

Southwestern Desert Trees Not Native to Nevada

The following xeric trees are found growing in the deserts of the southwestern United States but not in the Mojave Desert. They can be grown, however, in urban landscapes in the Mojave Desert, if provided with proper care.

Blue Palo Verde (*Parkinsonia florida*, formerly *Cercidium florida*)
Yellow Palo Verde *(Parkinsonia microphylla*, formerly *Cercidium microphylla)*

The Spanish common name, *palo verde*, means green tree, green pole, or green stick, and it refers to the smooth green branches and twigs that manufacture food in the absence of leaves (photo 29 and photo 30). The common name, yellow palo verde (*Parkinsonia microphylla*), refers to the color of the leafless branches, twigs, and foliage (USDA 2019). The common names for *P. microphylla* include foothills palo verde, yellow palo verde, little-leaf palo verde, or horsebean (Martin 2019). Both trees may be leafless during the summer months due to a lack of water or low-temperature damage to the leaves but are covered in yellow flowers in the spring (Little 1968).

Photo 29. Palo verde growing in an urban landscape in Las Vegas (photo by D. A. Devitt)

Palo verde are native to the Colorado River desert region, only a short distance south of the Nevada state line (Billings 1954). Yellow palo verde (*P. microphylla*) blossoms later than blue palo verde and has smaller, paler, yellow flowers. Yellow palo verde is more common, growing more slowly among saguaro and in drier locations in the Sonoran Deserts. *P. florida*, or blue palo verde, is less common and occurs chiefly along desert drainages, which signals a need for a greater amount of water than *P. microphylla*. Seeds of palo verde were ground and used as food by Native Americans. These trees and their hybrids are now common ornamentals (Little 1968).

P. florida, or blue palo verde, is a spiny, small tree that grows to thirty feet in height and one and a half feet in trunk diameter, with a wide, spreading, very open crown and smooth, bluish-green bark. Bright yellow flowers cover the tree in late March or April (sometimes August to October, if summer rain occurs) and are one to two inches long and about three-quarters of an inch across. Pods produced from the flowers are three to four inches long. Its bark is smooth, thin, and blue-green when young, but it eventually becomes scaly and brown as it gets older. Its wood is soft (Little 1968).

Photo 30. Palo verde growing at the Springs Preserve in Las Vegas (photo by D. A. Devitt)

P. microphylla is a spiny, small tree growing to twenty-five feet and one foot in trunk diameter, with a widely spreading, open crown. Its bark and branches in native stands are smooth, yellow-green, and leafless for most of the year. The trunk becomes rough and gray as it matures (Little 1968). Its light-yellow flowers in April and May produce pods that are two to three inches long. It is more abundant than *P. florida* in the wild and is found on the plains and in foothills and mountains, from near sea level to 4,000-foot elevations throughout Arizona, southeastern California, and northwestern Mexico (photo 31). Its wood is denser than the wood of *P. florida* (Little 1968).

Both *Parkinsonia* make excellent shade trees for urban landscapes but are considered "messy" after flowering. Some pruning will be required to raise the canopy only high enough for traffic. This is to protect the trunk from sunburn—for that reason, they are less desirable as a street or parking lot tree. All *Parkinsonia* hybridize with each other, which has allowed for the release of some outstanding landscape selections (Martin 2019). Palo verde may be deciduous during some cold winters in Nevada. The palo verde root borer (*Derobrachus geminatus*) has been an occasional problem with these trees in urban landscapes.

Irrigation: *Parkinsonia* performs well in the moderate-water-use areas of a mini-oasis type landscape. Blue palo verde is accustomed to more frequent and deeper irrigations than yellow palo verde, so it is more tolerant of high-water-use areas, provided the soil has good drainage. Of the two, *P. microphylla* requires less water but is not as spectacular when flowering and is a slightly smaller tree than *P. florida*, although it gives a similar floral display in the spring (Little 1968). However, *P. microphylla* is more likely to drop its leaves when water is limited (Martin 2019).

Photo 31. Palo verde growing in the Sonoran Desert (photo by M. L. Robinson)

Sweet Acacia

Vachellia farnesiana **(**formerly ***Acacia farnesiana*****)**

Also called *huisache*, this spiny shrub or small tree grows to twenty feet, with a one-foot trunk diameter in the wild or multiple trunks, with a widely spreading crown (photo 32). In irrigated locations, it may grow to thirty feet or more, with a similar spread (Martin 2019). Flowers, from April to November, are golden-yellow balls, three-eighths of an inch in diameter, and very fragrant. Some people have an allergic reaction to the flowers (Martin 2019). It produces a brown pod two to two and a half inches long and a quarter to three-eighths of an inch in diameter; it is considered messy in some landscapes. Bark is thin, ridged, and scaly and is reddish-brown. Its wood is hard and dense (Little 1968).

This tree grows in the widest range of all acacias and can be found in tropical and semitropical climates throughout the world (Bell et al 2017). As a native, this tree is found from 3,500 to 5,000 feet in elevation from southern Texas to northern Mexico, through Arizona, and as far west as San Diego County, California (Little 1968). It is widely planted as a landscape tree, from Florida through Texas and California, because of its spreading crown, production of shade, and fragrant flowers. It can also be found planted in Mexico, Central America, the Caribbean, and South America. In southern Europe, it is extensively grown for its flowers, known as cassie flowers, from which perfume is made (Little 1968).

Use as a multitrunk accent tree in small spaces in desert landscapes for its flower color and aroma. It should not be used as a street tree or in any location where pruning exposes the trunk to sun-scald injury. In warm winters, it may remain evergreen but is deciduous in cold climates (Martin 2019).

Photo 32. Sweet acacia growing in the Springs Preserve in southern Nevada
(photo on left by D. A. Devitt; photo on the right by R. L. Morris)

Irrigation: Water this tree deeply and infrequently, using water to control the amount of growth and canopy density. Providing irrigation causes it to grow larger. Irrigation needs are similar to catclaw senna, yellow palo verde, and screwbean mesquite and can be placed in the intermediate-water-use areas of a mini-oasis landscape.

Texas Mountain Laurel

Dermatophyllum secundiflorum (formerly ***Sophora secundiflora***)

Also called mescalbean, coralbean, goat-bean, and *frijolito,* this xeric evergreen shrub or patio tree (photo 33) can reach heights of fifteen feet and four inches in trunk diameter (Little 1968) but has been reported to grow to fifty feet in native stands (Gilman and Watson 2006). It is reported as an evergreen, but in cold winters, it could be deciduous. It has become very popular in desert landscapes in recent years. Flowers produced in April are in dense, drooping clusters, two to three inches long, large and showy, purple, and fragrant. Pods produced by the flowers are one to four inches in length. Seeds are red and poisonous, as are its leaves. Its wood is hard and very dense (Little 1968).

Its native distribution is in canyons and the limestone cliffs of foothills and mountains from 4,500 to 6,500 feet in elevation. It can be found in Texas, northeastern Mexico, and New Mexico in native stands (Little 1968; USDA USFS 2019). The leaves of this tree may be damaged by the larvae of the genista broom moth during the spring months (Drees and Bogran 2019).

Use as an accent plant, informal hedge, or patio tree for its very fragrant flowers, which occur in mid- to late spring. Because the tree grows slowly, recovery from severe pruning is slow (Martin 2019; Gilman and Watson 2006). It has been suggested for use in parking areas and as a median tree in Florida (Gilman and Watson 2006).

Irrigation: With irrigation, this tree can reach thirty feet tall or more (Martin 2019). Use in the moderate-water-use area of a mini-oasis landscape. Irrigate as with western redbud, Gambel oak, desert willow, netleaf hackberry, and other desert trees with moderate water needs.

Photo 33. Texas mountain laurel growing in a park in southern Nevada. Grows to a height of twenty feet or more and produces large, showy purple flowers in mid- to late spring. (Photos by R. L. Morris.)

International Desert-Adapted Trees

Trees mentioned here are not xeric trees but frequently are used in desert landscapes. They should be considered mesic in their water needs and planted in the intermediate- to high-water-use areas of the landscape. Their irrigation needs are like other mesic trees planted in the landscape, and they should be watered accordingly.

Chinese Pistache
Pistacia chinensis

Chinese pistache is a deciduous, ornamental pistachio, originating from the rocky soils or hills and mountains of western China and central Asia, from about 500 to 9,000 feet in elevation (photo 34). It tolerates the heat, poor soils, and low humidity of desert landscapes, as well as lawns. This ornamental pistachio is selected primarily for fall color but has other ornamental traits.

Chinese pistache grows to heights of thirty-five to forty feet, with a similar canopy spread, and it produces dense shade, if watered regularly. Leaves are dark green, about ten inches long, with ten to twelve pairs of leaflets comprising each leaf which gives the tree a moderately coarse visual texture. The leaves turn anywhere from yellow to orange to bright red in the fall (Martin 2019).

It is planted in home landscapes for its shade, endurance to desert climates, tolerance to a wide variety of soils, and ornamental fall color. It is also planted as a street tree because of its shape and height and its tolerance to adverse conditions (Martin 2019). Trees are dioecious, so a male and a female tree are needed for seed (a.k.a. nut) production. Trees are wind-pollinated, just like date palms, but the nuts produced by these trees are inferior to commercial varieties of pistachio. Several new hybrids and selections provide a wider choice in height and fall color (Martin 2019). Lawn survival under its canopy may be a problem in later years, due to its heavy shading.

Irrigation: Chinese pistache is a mesic tree and should be watered similarly to other mesic trees and planted in the intermediate- to high-water-use areas of a mini-oasis landscape. This tree has been successfully planted in lawns with good drainage but can suffer from phytophthora root rot if soil drainage is a problem (Martin 2019).

Photo 34. Chinese pistache can grow to forty feet in height and provide dense shade. (Photo by D. A. Devitt.)

Date Palm *(Phoenix dactylifera)*
Canary Island Date Palm (*Phoenix canariensis*)
Mexican Blue Palm (*Brahea armata*)

Palm trees are included because they provide *verticality*, or an upward form, for a landscape design. This element is an important feature in landscapes but hard to find in desert-adaptable trees.

The palms chosen are large trees, which should be a consideration when selecting them for residential landscapes. Because of their size and height, they should be selected for large landscapes with buildings in scale to their size.

Three palm trees were chosen from several that will grow in southern Nevada: date palm, Canary Island date palm, and Mexican blue palm. These trees are moderate to high in their water use on a canopy-area basis. They might be considered oasis trees but are tolerant of a desert climate.

Irrigation: Palms are considered mesic in water use but tolerant of desert conditions, provided water is available. They should be placed in the high-water-use areas of mini-oasis landscapes. Soils must have good drainage for their best performance and high visual quality. A backfill soil mix high in sand is often selected for better establishment. Avoid planting in low-water-use areas.

Date palm (photo 35): An important feature to consider with the date palm is the production of edible fruit. Date trees typically grow to seventy-five feet in height or more and may be grown singly or in “clumps,” with several suckers or new stems growing from their bases. Date fruit ranges in color from bright red to brown to yellow, depending on the variety. The fruit is very sweet and can contain as much is 75 percent sugar when dried. The fruits are enjoyed by many different animals (birds in particular), including humans. Trees will tolerate temperatures as low as 10–15°F before they are damaged.

Photo 35. Date palms growing in a parking lot in southern Nevada. Date palms grow to seventy-five feet in height and produce sweet, edible fruit. (Photo by D. A. Devitt.)

Date palms are dioecious, meaning there are both male and female trees. In commercial date farms, there is a mixture of male and female trees planted together in a ratio of one to ten, so that female trees produce adequate amounts of fruit. Female trees produce edible fruit because of the pollen they receive from the male trees, which is dispersed by wind. Date palms freely hybridize among themselves, affecting the seed but not the fruit. Date palms of a known variety are propagated vegetatively by harvesting suckers of a specific age from the base of trees. Date palms grown from seed will produce plants of an unknown sex and fruit quality.

There are enough date palms planted in the Las Vegas Valley that fruit set in isolated female trees is usually successful. When female date palms are planted in remote areas, without male trees nearby, fruit production may be irregular or low in yield. Commercially, male and female trees are interplanted, or sometimes female trees are pollinated by hand. Because of their mature size, planting in small landscapes or around single-story homes is discouraged (Martin 2019).

Canary Island date palm is native to the Canary Islands and produces edible fruit from female trees. It is used in mixed and desert landscapes (photo 36). The tree is dioecious, meaning there are male and female trees, just as in the *P. dactylifera*. Even though the Canary Island palm is a relative of the date palm, the edible portion of the fruit is small, compared to its seed size. However, this tree can be used for producing a palm syrup from its sap (University of Arizona 2019).

Canary Island date palms can grow sixty feet in height, producing no suckers at its base. It is sometimes referred to as the pineapple palm because the bottom of the crown, also called the nut, appears to have a pineapple shape. Like the date palm, these slow-growing trees tolerate temperatures to as low as 15°F before they are damaged. Canary Island date palm is propagated from seed (University of Arizona 2019).

Canary Island date palm should be used only in very large urban spaces, such as parks, estates, and large commercial properties (Martin 2019).

Photo 36. Canary Island palms growing along the Las Vegas Strip; they grow to a height of sixty feet. (Photo by D. A. Devitt.)

Mexican blue palm, also called the blue hesper palm, blue fan palm, sweet brahea, or *palma blanca*, is the most common native palm found in Baja, California, Mexico (photo 37). It tolerates temperatures to 15°F and grows to a height of fifty feet, with a massive trunk. This robust tree grows at moderate rates when water is present and, like Canary Island date palm, occupies large urban spaces. It is widely planted as an ornamental; its fronds or leaves have a beautiful silver-blue color (University of Arizona 2019). The seed can be roasted and eaten, as the Cochpa people did who inhabited the Baja area (University of Arizona 2019).

Because of its color and uniqueness, it is used as an accent plant for large residential and commercial landscapes. It can be used in desert landscapes, where water and good drainage are available. It is best planted in high-water-use areas of a mini-oasis landscape. This is an oasis plant and not suitable for low-water-use areas of the landscape (Martin 2019).

Photo 37. Mexican blue palms growing along the Las Vegas Strip can grow to a height of fifty feet. (Photo by D. A. Devitt.)

Did You Know?

Although palms produce fruit, not all are edible; in the case of the sago palm, the fruit is actually poisonous to humans.

Vitex

Vitex agnus-castus

Also called chaste tree, lilac chaste tree, monk's pepper, and hemp tree, vitex is a deciduous, aromatic shrub or small tree, fifteen to twenty feet tall and just as wide (photo 38). It is native to the Mediterranean region and arid parts of western Asia. Frequently, it is multitrunked, with leaves that resemble marijuana, which is why sometimes it is nicknamed hemp tree (Texas A&M 2019). During early to mid-summer, it produces white, pink, or blue flowers at the ends of new growth, which can grow to a foot long with added irrigation and fertilizer. In the Southern states, it is sometimes used as a substitute for lilac and is named the lilac chaste tree. It can be found planted throughout the Southern states and as far north as Oregon and Pennsylvania (USDA NRCS 2019).

After flowering, the flower spikes produce peppercorn-sized black fruits, which is why it is sometimes called monk's pepper. The plant has a long medicinal history and is still marketed today for this purpose. It attracts bees, butterflies, and hummingbirds. Its leafless form in winter has been described as "stark" by some. Use as a large shrub; a small, multiple-trunked shade tree; or in mass plantings in larger landscapes. Selections can be found that have white flowers, blue flowers, pink flowers, larger leaves, and dense structure (Martin 2019).

Irrigation: Vitex is a Mediterranean plant, preferring wet winters and dry summers. Plant in moderate- to high-water-use areas of a mini-oasis landscape. Vitex can be planted in lawns, provided the soil has good drainage. Apply water with an irrigation frequency similar to other mesic plants.

Photo 38. Vitex grows fifteen to twenty feet in height and produces white, pink, or blue flowers. (Photo by D. A. Devitt.)

7 CHAPTER

Tree Health and Irrigation

Ornamental landscape trees under stress do not grow or perform as they should. Plant stress might not be apparent visually, but the tree may not be growing at its potential. Signs of extreme stress to trees can be easy to identify—branch or trunk dieback or death, leaf yellowing, or scorch (photo 39). The exact cause of the stress, however, may be difficult to pinpoint without some detective work. Plant stress is divided into two categories: stress from environmental factors (abiotic) and stress from living organisms (biotic).

Biotic stress includes damage created by insects, diseases, weeds, or humans or anything living. Abiotic factors include excessive hot or cold temperatures, intense sunlight, low or high humidity, too much shade or too much sun, excessive amounts of wind, and physical damage from the weight of snow. Canyon or streambank native trees might display stress if they are planted in intense, sunny locations with minimal access to water. Semitropical desert trees might demonstrate freezing damage (stress) because of low temperatures found in colder desert landscapes.

Native and desert-adapted trees are more resistant to most stresses found in the desert if their new landscape environment is closely matched with their native environment. It is always a good idea to match these two environments as closely as possible when selecting a tree.

This next section addresses some of the more common stressors arising from abiotic factors.

Photo 39. Pine needles may develop brownish tips as a result of stress. The stress might be caused by too much heat, lack of water, salts, etc. (Photo by R. L. Morris.)

Intense Sunlight

Intense sunlight can cause damage to tree trunks, limbs, and leaves of trees, either because the tree is not suited to its new landscape environment, or it has been mismanaged (photo 40). Changes in the color of the trunk or limbs in a direction facing the sun (and a lack of this discoloration on the opposite side) indicates sunburn due to intense sunlight. Intense sunburn can damage the vascular tissue and slow the delivery of water and photosynthates to the leaves; it can contribute to leaf scorch, particularly on hot days when the demand for water is high. Frequently damage to the trunk or limbs by intense sunlight is followed by physical damage created by wood-boring insects. South-facing, west-facing, and upper sides of limbs of trees with thin bark (e.g., ash, palo verde, bottle tree) are the most commonly damaged. Pruning trees so that lower limbs remain attached and shade the trunk helps to prevent sunburn damage to trees that have a thin bark when they are young. Planting a tree grown in a nursery from a mild climate into a landscape located in a harsh desert environment may lead to sunburn or leaf drop. A period of several weeks of protection, or planting during the cooler fall or spring months so that a tree can acclimate to its new environment, is a good idea in these cases. Planting trees and shrubs during late spring or the summer months is always a challenge in the desert, unless you are an experienced gardener.

Photo 40. Ash tree pruned so that its trunk was exposed to intense sunlight. The discolored side of the trunk is dead. Some trees have thin bark that can be sunburned if exposed to intense sunlight when they are young, recently planted, or planted in a hot location. This can lead to leaf scorch and damage from borers. (Photo by R. L. Morris.)

Drought

A sign of a lack of water, or drought, is a "burning" of leaf margins, called leaf scorch (photo 41). But leaf scorch happens for a variety of reasons including a lack of water, water applied too often (which can suffocate and kill tree roots), physical damage to the trunk, diseases, damage from lawnmowers or line trimmers, and excessive salt in the soil. Unhealthy trees are more susceptible to damage from drought than healthy trees.

Determine the possible reasons for leaf scorch and develop possible solutions to correct it. Lack of water? Poor drainage? Watering too often? Damage to the tree trunk? Salinity? If irrigation is a problem, then make sure irrigations are deep, are not frequent, and are applied to the area underneath the tree canopy. Improving irrigation will remedy a soil salt problem as well. Surface mulch is always a good idea, but when wet mulch lays against the trunk, collar rot can occur, a disease that contributes to leaf scorch. If the tree is small, push on it to see if the roots are firmly anchored in the soil. Plants grown too long in containers before planting can have large, circling roots that prevent the tree from becoming established. Watering too often or keeping the soil wet can lead to root rot, a disease that causes symptoms that look like drought. Root rot or circling roots can prevent the tree from becoming established in the soil or possibly can kill it, particularly during hot weather.

Inspect the trunk of the tree for mechanical damage from tools and equipment and possible damage from borers or disease. Look at the easiest solutions first, and, in a process of elimination, work toward the more difficult possibilities. Compare the problem your tree is having with the same type of tree growing under different circumstances. Is leaf scorch "normal" for this type of tree at this time of year growing under these conditions?

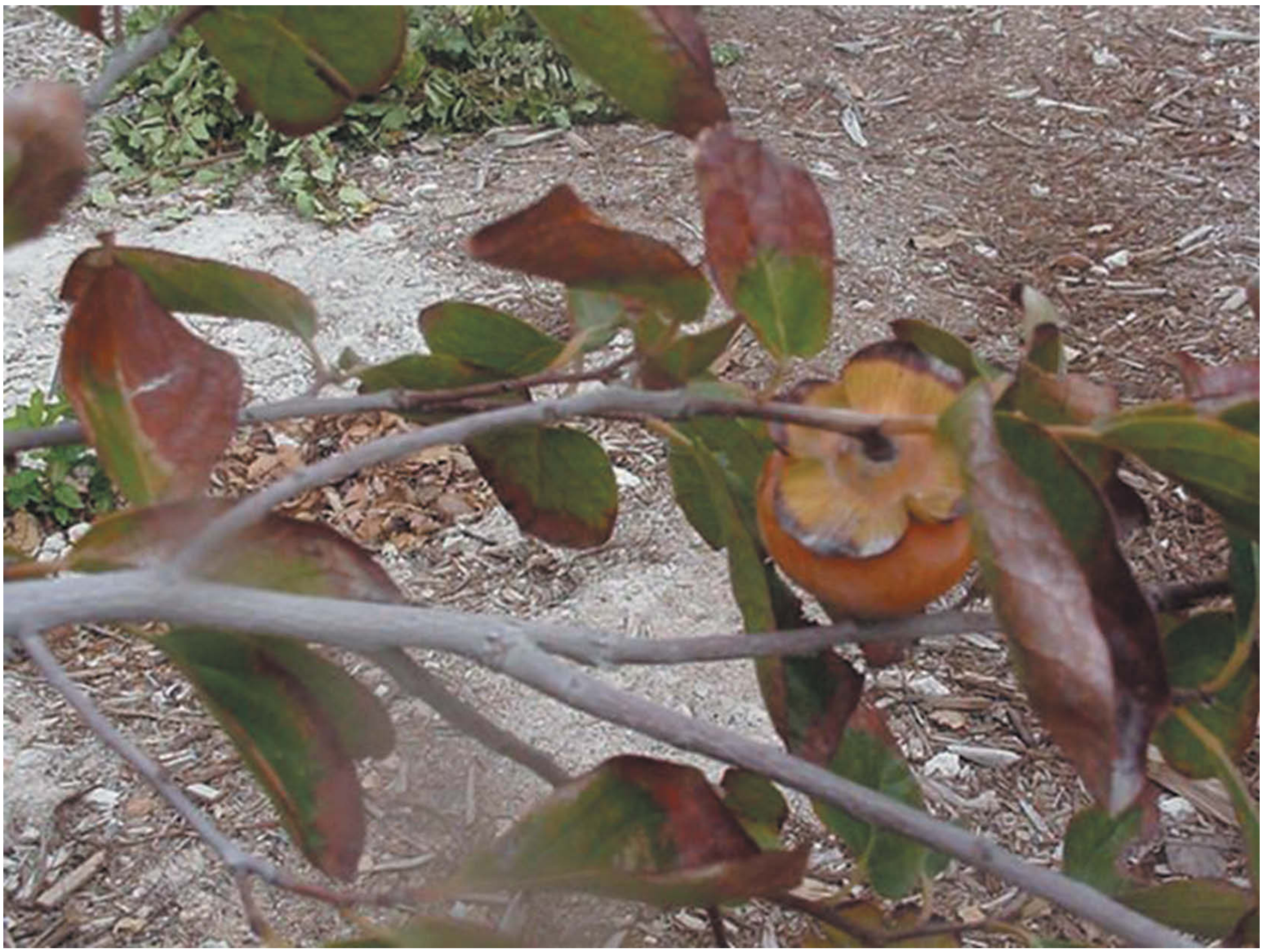


Photo 41. Leaf scorch and tip burn of leaves of persimmon. Browning on the edges and tips of leaves is a sign of drought. The causes of drought can be a lack of applied water, not watering often enough, interruption of water transported from the roots to the leaves by mechanical damage (borers, lawn mowers, line trimmers), or excessive salt in the soil. However, know the limitations of the plant in question. Persimmon is best grown in wetter and cooler climates; it struggles during the heat and low humidity of the desert summer. (Photo R. L. Morris.)

Cold Damage

Cold damage to native and desert-adapted trees can be more devastating than damage caused by high temperatures. Cold damage occurs either because of extreme low temperatures during midwinter or unusually low temperatures during unexpected times of the year (photo 42). For instance, low temperatures occurring in early spring or late fall are more likely to cause low-temperature damage than these same temperatures during midwinter, due to acclimation. Cold- or low-temperature damage is a combination of the lowest temperature, time of year it occurs, condition of the plant, and the duration of the cold temperatures.

Pay strict attention to the minimum temperature that plants can survive when selecting key plants for a landscape. The most important plants in a landscape should survive the lowest temperatures expected in that environment over the long term, not just two or three years. Minimum temperatures of 20°F for plants that play prominent roles in landscapes would be adequate for the Las Vegas Valley in most years. For instance, the damage created during the winter of 1989–90 was due to low temperatures of 11°F in February in parts of the Las Vegas Valley (personal communication, golf course superintendent at Painted Desert Golf Course). These minimum winter temperatures killed trees that had been established for twenty or thirty years. Winter temperatures were low enough that Bermuda grass (minimum temperature: 10–15° F) was killed in some locations on the golf course. The fronds of newly established date and fan palms were damaged at a local resort due to low winter temperatures. It helps to monitor the lowest temperatures experienced by landscapes, to protect sensitive plants if possible, and to recognize that differences exist between site-specific locations and broader locations, due to landscape microclimates (Duffield and Jones 1981).

Photo 42. Winter damage to the leaves of acacia. The tree was not damaged, but freezing temperatures caused it to drop all its leaves. (Photo R. L. Morris.)

Salt Damage

Damage to plants can occur because of excessive amounts of salts in the soil or irrigation water (photo 43). This can be due to the total amount of salt, the specific type of salt, or both. If the concentration of salts in the soil is excessive, and the plant is not salt-tolerant, its ability to take up water through the roots is limited, and this can contribute to water stress, particularly during times of high temperature and low humidity. Sometimes the type of salt present in the soil damages plants. Particularly damaging are salts containing sodium, chloride, and boron. Salt damage is often associated with the stunting of growth, scorching of leaves, and even plant death. The remedy for damaging levels of salts in soil is discussed in another section, but one should improve soil-water drainage and increase the amount of water applied so that these salts are leached from the soil. In some cases, this might require additions of soil amendments, like gypsum (calcium sulfate), to assist the displacement of sodium. However, if your soil is calcareous, there should be enough calcium to displace the sodium. When unacceptable levels of salt are in the irrigation water, salt-tolerant plants should be selected. Overhead applications of water should be avoided, and an irrigation strategy should be adopted that keeps soil salts to a minimum.

Photo 43. Salt damage to roses (photo R. L. Morris)

Snow Damage

Snow is a relatively rare occurrence in the Mojave Desert at lower elevations, but these light snowfalls can cause major limb breakage that ruins the shape and form of susceptible landscape trees (photo 44). In extreme cases, the damage is severe enough that the tree must be removed.

These light snowfall events are typically not damaging to needled evergreen trees such as pines, unless they've been subjected to poor pruning practices. Broadleaf evergreen trees, such as African sumac, and semievergreen pepper trees exhibit limb breakage due to their wide leaves, horizontal limb architecture, and soft wood, as compared to other, more-tolerant trees. The snow can be heavy enough to cause limb breakage to trees that begin their growth early in the spring or retain their leaves late into the fall and are not accustomed to snow.

This is true of California and Brazilian pepper trees; as such, they should not be selected if snow damage is a concern. Damaged trees, if they are to be kept, should be pruned by a qualified arborist or someone who has received advanced training in pruning ornamental trees. If damage is severe enough that the tree cannot recover its form in a few years, the tree should be removed. The African sumac in the photo below was removed because of its degree of damage.

Photo 44. Snow damage to African sumac, an evergreen mesic tree, in the Las Vegas Valley after a light snow event. Notice pine trees in the background are not damaged due to the light snow load. (Photo by R. L. Morris.)

Wind Damage

Wind damage to trees can include tree blow-over, limb breakage, leaf damage, fruit damage, or loss of fruit production (photo 45). Canopy thinning, combined with adequate irrigation, helps prevent tree blow-over and limb breakage. Blow-over can occur because of improper irrigation or poor pruning practices. One method of decreasing tree blow-over from wind is to thin out the tree canopy through proper pruning. Opening the canopy requires selective removal of limbs that allows for better airflow. Improper pruning can increase the chance of limb breakage or blow-over in future years. Deep but infrequent irrigations improve deep root development and tree anchorage in the soil. The important concept to remember is that larger trees require deeper irrigations. Applied water should penetrate the soil deeply, out to a distance of at least half the canopy diameter.

Photo 45. Water was applied too often to this young mesquite tree because of the frequent watering needed to meet the water requirements of shallow-rooted flowering plants and turfgrass. Shallow irrigations result in an abundance of roots growing close to the trunk and a lack of deep roots to provide anchorage to keep it erect during strong winds. (Photo by R. L. Morris.)

Irrigating Landscapes in the Desert

There are fewer plants per square mile in the Mojave Desert than in other deserts in the southwestern United States. The plants that grow in the Mojave Desert are different from those in other southwestern deserts, and these plants are substantially smaller (photo 46). These differences are primarily due to rainfall. There is a distinct connection between the amount of rainfall, plant size, and plant numbers; in other words, total biomass of a landscape. For this reason, when designing a home landscape, it is important to limit the total number of plants used, limit their size, and use plants that originate from deserts or are adapted to desert climates.

Irrigation can be done in a variety of ways, but application of water is essential. Mojave Desert native plants require less water and are easier to grow here, as they tolerate less-frequent watering and are more tolerant of extreme desert conditions. Key to the success of growing trees in the Mojave Desert is providing adequate amounts of water at times when they need it.

Photo 46. The Mojave Desert has fewer plants growing in it (plant density) than other deserts, and these plants are generally smaller than those growing in other deserts with greater rainfall. (Photo by R. L. Morris.)

Once the landscape design and the types, sizes, and numbers of plants have been decided, the next critical factor is deciding the irrigation method to use and how it's to be managed. Simply selecting an irrigation system because it is renowned for conserving water, such as drip irrigation, does not guarantee irrigation water will be applied efficiently and uniformly (photo 47). Designing and installing the irrigation system so it applies water uniformly, maintaining it to minimize unnecessary losses, and scheduling it at the right time is critical to conserving water.

Irrigation Design and Uniformity

Irrigation uniformity is the application of water evenly to irrigated areas of a landscape. Irrigations are useless to plants if water is applied where roots are not present, at times when they are not needed, or is applied so deeply that tree roots can't access it. A mature tree is watered uniformly when it receives enough water to wet the soil where all its roots are growing and at a time it is needed. Young trees are watered uniformly when they receive enough water to wet the soil where all their roots are growing, *and* it encourages new root growth in currently unexplored areas to accommodate a growing canopy.

Photo 47. For good irrigation uniformity, water from neighboring emitters should overlap. Emitters in this picture are probably too few and far apart to provide good water overlap. Applied water should wet the soil under the entire tree canopy to an appropriate depth, according to the size of the tree (fig. 20). (Photo by R. L. Morris.)

Water loss also occurs when irrigation systems are not maintained properly. How water is over-applied, how to gauge uniformity, and how to fix uniformity problems varies with each irrigation system. Suggestions on how this can be done are addressed in each method.

Methods of Irrigation

Three methods of irrigation are used to water landscape trees: some form of flooding, sprinklers (usually in a mixed landscape setting), and drip irrigation. *Flood irrigation* varies from flooding the entire landscape with water to bubbler-and-basin irrigation, with water delivered through irrigation bubblers to trees, either together with the lawn or separately. A second method of irrigation, *sprinkler irrigation*, delivers water to trees, primarily in mixed landscapes, through overhead, high-pressure sprinklers. The third method, *drip or trickle irrigation*, has the potential to deliver precise amounts of water to trees using low water pressure, if the system is designed and maintained properly. Drip irrigation shows the greatest promise in desert landscapes for conserving irrigation water.

Bubbler-and-Basin Irrigation

Probably the least common form of flood irrigation of trees for home yards is bubbler-and-basin irrigation. This type of landscape irrigation rapidly delivers water to a level basin, a doughnut or "moat," surrounding a tree (photo 48), shrub bed, or a group of plants with similar water requirements.

Photo 48. Basins for irrigation should be constructed on top of the root ball after planting the tree and later expanded in diameter to at least half the area under the tree canopy to encourage root growth and establishment. (Photo by R. L. Morris.)

For uniform wetting of a large basin, bubblers should be spaced no further than five feet apart, and the basin should be maintained level and flat. Irrigation bubblers deliver water in a range of one-half gallon to two gallons per minute. Bubblers can be adjusted to deliver less water but not more. Settle the soil around the roots of the tree with water from a hose in the basin after planting.

Did You Know?

Basins for bubbler-and-basin irrigation should be constructed on top of the root ball after planting the tree. Expand the basin in diameter later, as the tree grows in size, to at least half the area under the tree canopy.

Water is delivered to the basin more rapidly than it can infiltrate the soil, thus flooding the basin (photo 49). Basins are surrounded with a hill, or “berm,” large enough so it contains enough water to wet the roots beneath the basin. The inside of the basin should be approximately the same size as the tree’s canopy. Cover the inside of the basin with an appropriate surface mulch to reduce soil evaporation.

Photo 49. A high-pressure bubbler inside a constructed basin around the tree. The bubbler releases water rapidly, filling the basin. The bottom of the basin around the tree must be flat for an even distribution of water. Wood chips are applied to the soil surface as a mulch to conserve water by reducing soil evaporation. (Photo by R. L. Morris.)

When a tree growing within a basin is irrigated using bubblers, enough water should be applied to infiltrate the soil to a depth appropriate for the tree’s size (figure 20).

Water conservation is best served by delivering more water to individual basins (more bubblers), rather than increasing the minutes for an irrigation station. Increasing the irrigation time affects the amount of water delivered to *all* plants sharing the same irrigation station. Basins should be kept level and flat, and berms should be repaired when needed and reconstructed larger as the tree grows.

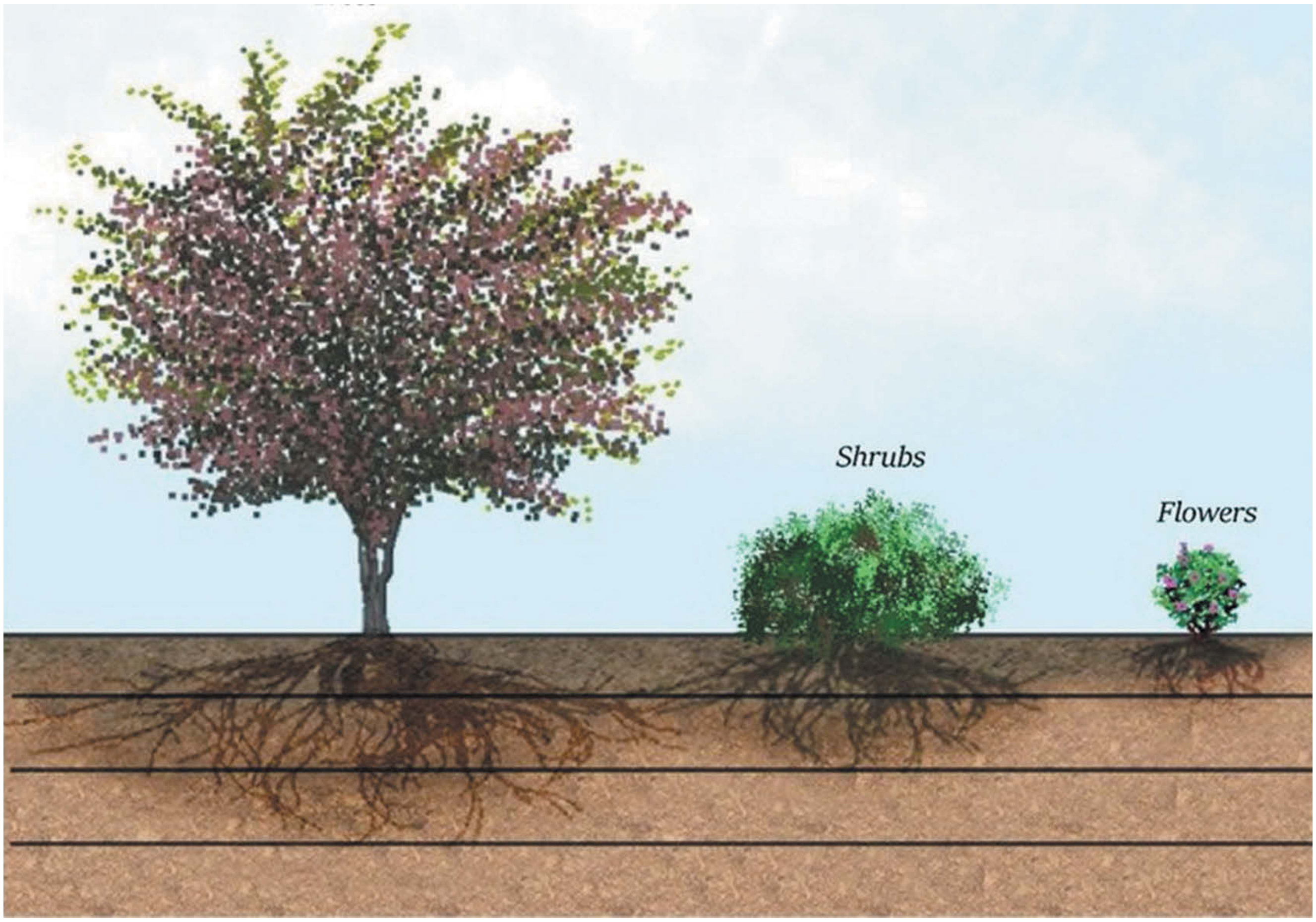


Figure 20. Root depth of plants varies with their sizes. Bigger plants are irrigated more deeply than smaller plants. (Drawing by N. Villeda.)

Mesic and xeric trees should not share the same irrigation zone but should be irrigated separately. This is done by creating hydrozones (discussed previously) during the irrigation design. As you may recall, hydrozones group plants with similar water needs together on the same valve or station. For instance, xeric trees are grouped with other xeric plants, and mesic trees with other mesic plants. Trees requiring water applied at different irrigation intervals (mesic vs. xeric vs. cacti and succulents) are best irrigated independently, using separate valves and stations.

Bubblers can be used to irrigate trees growing on slopes. The design of the bubbler-and-basin is the same as it is on level ground; the basins must be flat and level as water is applied quickly, filling the basin (figure 21).

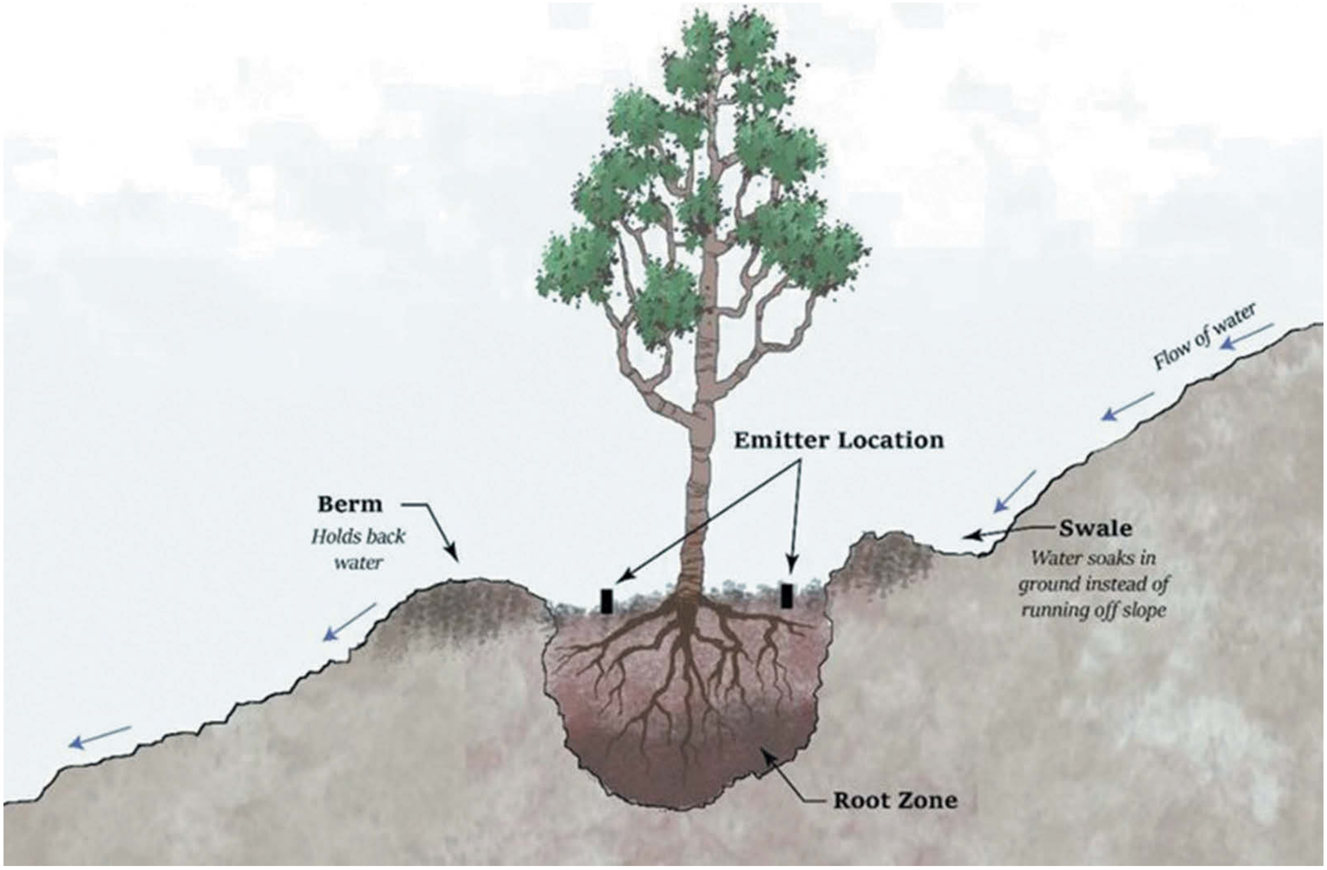


Figure 21. Bubbler-and-basin irrigation can be used on slopes, provided the basin is level and flat. (Drawing by N. Villeda.)

Sprinkler Irrigation of Mixed Landscapes

High-pressure, overhead sprinkler irrigation (sprinklers or sprinkler heads) is commonly used to water lawns, shrub beds, and flower beds. If sprinklers are designed, installed, and maintained correctly, they can uniformly apply water to a landscape area.

> **Did You Know?**
>
> The first automatic sprinkler system was patented by Philip W. Pratt of Abington, Massachusetts, in 1872.

Sprinklers, however, are sometimes used to irrigate mixed landscapes (photo 50). Mixed landscapes combine lawns with trees and shrubs and perhaps even flowers or vegetables, all irrigated by overhead sprinklers. Mixed landscapes are difficult to irrigate properly because of the differences in plant-root depths and plant water requirements. In mixed landscapes, root depth of plants may vary from six inches to twenty-four inches or more. Plants with the shallowest roots "force" the irrigation intervals to be shorter than needed by deep rooted plants such as trees and large shrubs.

Photo 50. Mixed landscapes are difficult to irrigate effectively by sprinklers alone because of the difference in root depth of the plants growing in it and interference by trees of the water delivered by sprinklers. (Photo by D.A. Devitt.)

Mixed landscapes are always irrigated in favor of shallow-rooted plants, such as lawns. This causes trees and shrubs to grow more slowly due to a lack of soil aeration and deep watering and the competition with the lawn for water air and fertilizer. Tree and shrub roots, which might normally be deep, instead would grow closer to the soil surface, competing for water air and fertilizer with turfgrass roots (photo 51). To help resolve this problem, additional deep irrigations should be provided seasonally to trees and large shrubs to encourage deeper rooting. Mixed landscapes alter the uniform distribution of sprinkler-applied water, as taller trees and shrubs intercept the water before it can land where it should. This nonuniform application of water means that some plants may receive too much water or not enough water. Under such conditions, homeowners typically choose to overirrigate to make sure the area that's not receiving enough water gets the amount it should—a situation that does not allow for maximum conservation of water.

Photo 51. Trees growing in mixed landscapes frequently have their roots growing at the same depth as the lawn. This is because of the shallow irrigations that lawns require and a lack of deep irrigations that favor tree root growth. (Photo by R. L. Morris.)

Interactions with Other Plants

All plants interact with each other. Each plant may interact with another plant in a positive, negative, or neutral manner, depending on the parameters. Neighboring plants might buffer each other from otherwise stressful situations, such as damaging winds and intense sunlight. However, plants may "steal" nutrients (fertilizer) and water from neighboring plants. Science has uncovered many different types of plant interactions and has created terms to describe them, such as allelopathy, commensalism, plant competition, nurse plants, push-and-pull plants, trap plants, and companion plants.

One of the biggest impacts that landscape plants have on each other is their direct competition for water. Water use of plants growing alone is much easier to isolate and quantify than characterizing the water use of a group of plants. The scientific community knows, for instance, that plants growing alone are subjected fully to environmental factors that increase plant water use. However, plants growing together with intertwining roots or canopies that alter light, wind, temperature, and humidity will have a different water use than the same plants growing alone. Because of this, total water use of plant groupings is not estimated by simply adding together the water use of individual plants. Because of plant interactions, quantifying collective plant water use of a landscape becomes difficult.

Drip Irrigation

Drip irrigation, sometimes called micro-irrigation or trickle irrigation, is a low-pressure irrigation system that delivers a precise amount of water, slowly and directly, to the soil surrounding plants. Because it relies on lower water pressure and filtered water to prevent plugging of drip emitters, drip-irrigation systems require a pressure regulator and a water filter, installed after the irrigation valve (figure 22). Regular flushing of the drip system and cleaning the filter are necessary maintenance practices that prolong drip irrigations high uniformity and contributions to water conservation. The length of time needed between these maintenance practices depends on the salt level, nutrient level, and turbidity of the irrigation water.

Did You Know?

Drip irrigation was first used to irrigate avocado orchards in the United States in 1969.

Drip irrigation has distinct advantages over other methods of irrigation: improved water conservation, excellent compatibility when irrigating desert landscapes, growth of fewer weeds, and operation that is not easily visible. Compared to high-pressure irrigation systems, such as bubbler-and-basin and sprinkler irrigation, drip irrigation delivers water more slowly to trees, which helps conserve greater amounts of water. Water delivery is measured in gallons or liters *per hour* (gph/Lph), rather than gallons *per minute* (gpm), which is common in high-pressure bubbler-and-basin and sprinkler systems. Remember that lower water-application rates translate into much longer operation times. If drip irrigation is designed, installed, and maintained properly, it has the potential for a high degree of uniformity and efficiency.

Drip irrigation's current limitations are associated with poor irrigation design prior to installation, improper expansion of an existing system, lack of maintenance in existing systems (regular flushing of irrigation lines and cleaning filters), and improper irrigation management. These problems are typically due to a lack of knowledge about drip-irrigation technology by landscape professionals. Much of this will probably not change without economic incentives.

Did You Know?

Drip emitters work best when used with plants that require different amounts of water.

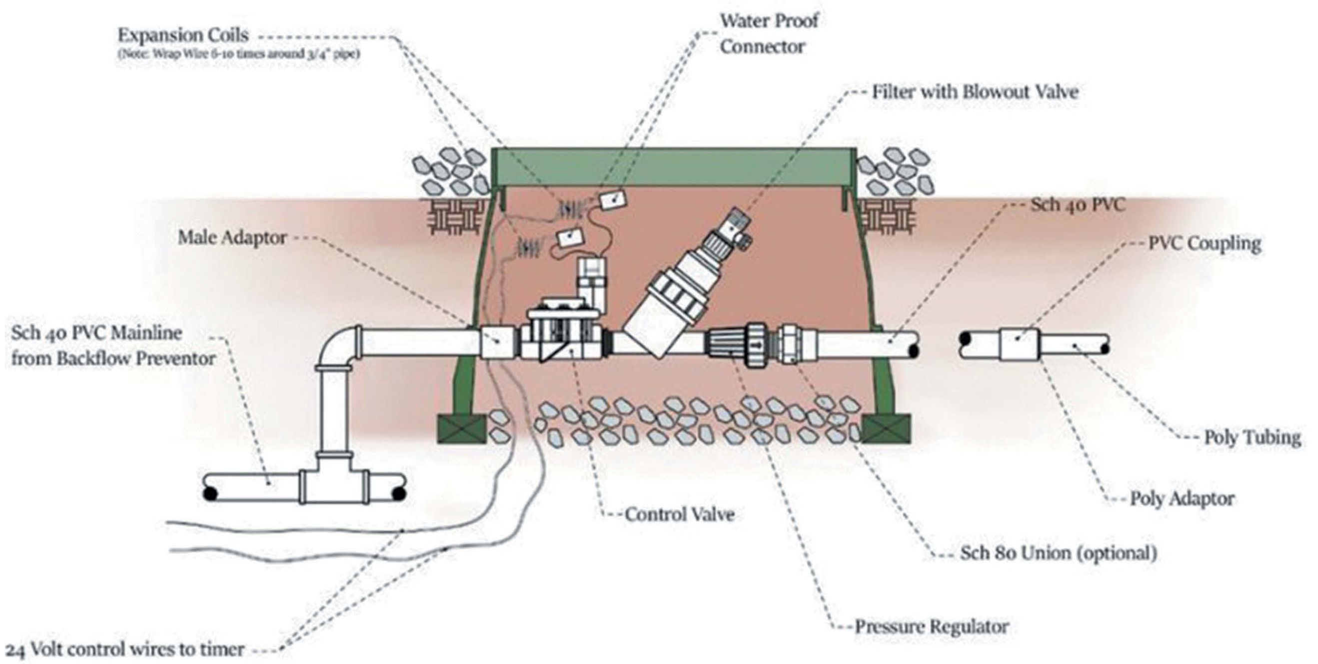


Figure 22. Typical drip-irrigation installation, with the water flow from left to right and installation of the filter and the pressure regulator to the control valves (Permission to use drawing given by the AMWUA in 2019.)

Drip-irrigation applications. Two types of drip-irrigation products are typically used in landscapes: polyethylene (PE) tubing, with drip emitters embedded into its walls (photo 52) and solid PE tubing (blank tubing) for installing drip emitters of various types and at various distances along its length (photo 53). Various types of fittings are available to configure drip tubing and blank tubing in different arrays. Drip tubing and drip emitters operate at a set water pressure, so the pressure regulator must match the pressure required by the drip tubing and emitters designed for the array. The degree of filtration used must match the size of the emitter openings to prevent plugging.

Photo 52. Drip tubing showing the opening of an embedded drip emitter for the release of a precise amount of water in Lph or gph (photo by R. L. Morris)

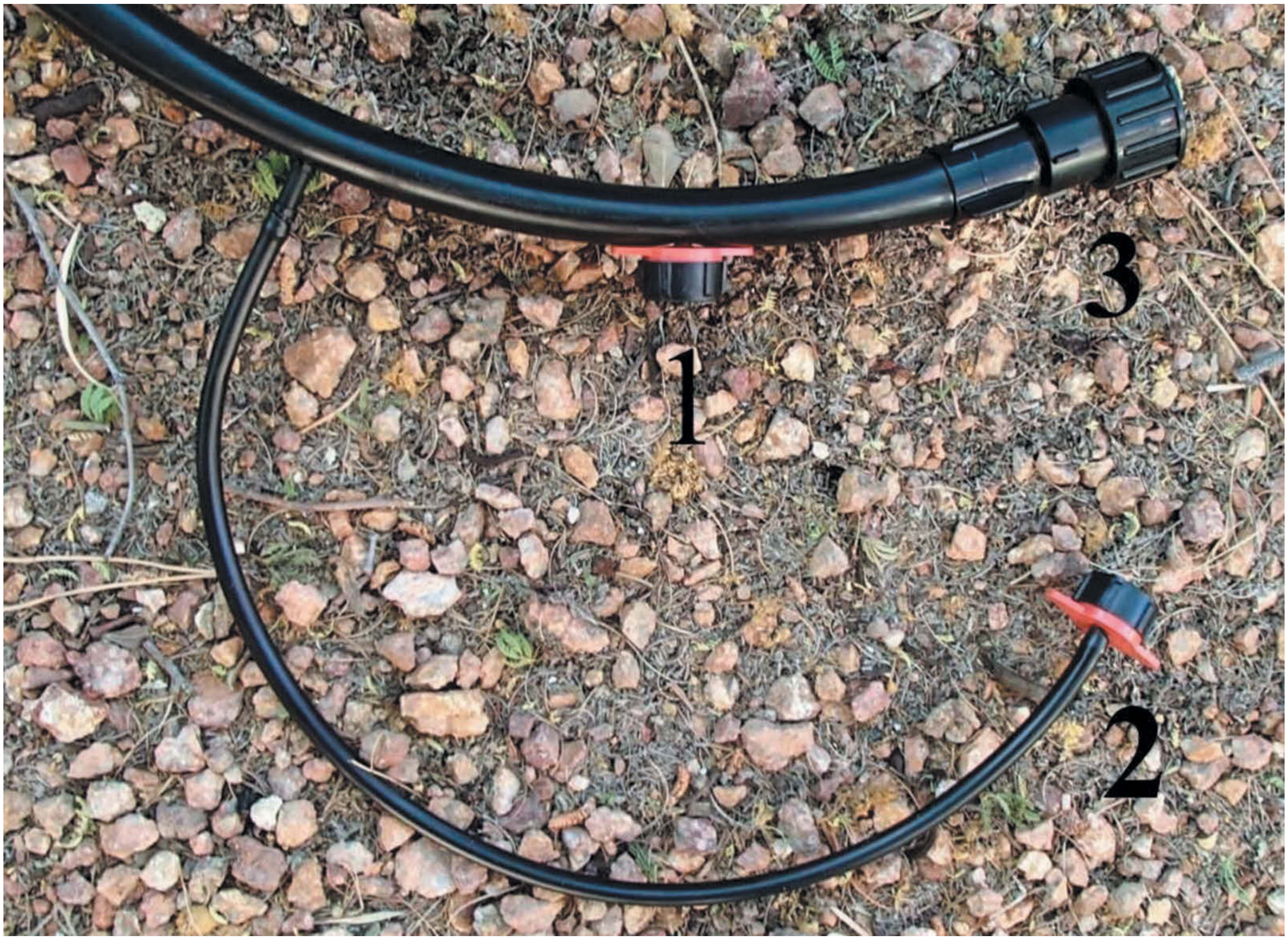


Photo 53. Single emitters can be connected to blank tubing, either directly (1) or by attaching them to one-quarter-inch distribution tubing (2). An end cap can be removed to flush the blank tubing to prevent plugging (3). (Photo by R. L. Morris.)

Drip tubing. Drip tubing has identical emitters embedded into its walls along its length at uniform spacings (photo 54). These emitters typically deliver 0.5 or 1.0 gph at a recommended water pressure. Drip tubing is primarily used in large irrigated areas with high plant densities, where a precise delivery of water is required to a uniform depth. It can accurately irrigate a grouping of plants that have the same rooting depth and that require a similar watering schedule. Examples include a line of trees or large shrubs used for a border planting or a hedge.

Did You Know?

Drip tubing works best with plants that require similar amounts of water and that grow together.

Photo 54. Drip tubing showing wetted soil, with embedded emitters spaced twelve inches apart, with each emitter delivering 0.9 gallons of water per hour (photo by R. L. Morris)

Drip tubing can also be used to irrigate trees by coiling it under the canopy and spacing the coils appropriate distances apart, depending on soil texture. The number and size of emitters under the tree canopy is tallied to determine the total water-application rate. The irrigation run time is long enough to wet the soil to the appropriate rooting depth of the tree (figure 20). Both ends of the coil can be connected to the source of water in a continuous loop, to eliminate flushing it separately from the system. The irrigated area can be expanded as the tree gets larger by adding new coils of tubing.

Drip emitters and blank tubing. Single drip emitters can be inserted directly into blank tubing or can be connected to it by using quarter-inch supply tubing. Single emitters are available that release from 0.25 to 5.0 gph irrigation water. There are adjustable drip emitters (variable-rate emitters) that can be opened to deliver much more water than this, but using them decreases application precision and may diminish water-conservation efforts. The principal advantages of using a variety of single drip emitters is spacing the emitters at uneven distances apart, while releasing water at various rates (gph), combined with a precise rate of delivery.

Using individual drip emitters irrigates a variety of plants, spaced unevenly apart, that require different amounts of water. They are suitable for irrigating small trees but are needed in large numbers when watering large mature trees. Enough emitters should be used to irrigate most of the area under the canopy of a tree to its entire rooting depth, using a predetermined run time. Emitter spacing depends on the soil texture but is usually about eighteen inches apart. Trees with a canopy area greater than twenty feet in diameter are better suited for other methods of irrigation, such as bubbler-and-basin or coiled drip tubing.

Irrigation Scheduling

Three questions must be answered when applying irrigations: What time of day should irrigation begin? How many minutes are needed for each station (run time)? Which days should they deliver water (frequency)? It is best if the irrigation run time for each station is decided when the drip irrigation system is designed.

Time of day. It is good to start irrigating in the early-morning hours and finish by sunrise. Sprinkler irrigations should finish before wind speeds typically increase at sunrise. Tree roots should have access to moist soil prior to the heat of the day. However, this may require turning the system on periodically to check for leaks and plugging.

> **Did You Know?**
>
> At night, the surface of the earth rapidly cools to a temperature below that of the air above, causing what is known as a *temperature inversion*, reducing the amount of mixing between different layers of the atmosphere, but once the sun comes up, air mixing and wind gusts increase. Sprinkler irrigations need to be applied when wind speeds are low or the distribution pattern will become distorted.

Run time. The number of minutes on the irrigation clock is seldom changed, once it's firmly established. The number of minutes (run time) needed is determined by how quickly and deeply water infiltrates the soil after an irrigation application (figure 20). Irrigation run times are frequently easier to establish when designing the irrigation system, rather than after it's installed. A good place to start is one hour for drip irrigation and fifteen minutes for sprinklers and bubblers. Use a three-foot metal rod, such as a length of rebar, to help judge the depth of an irrigation. The metal rod pushes easily into wet soil but becomes difficult to push into deeper, dry soil.

Plants growing in sandy soils require shorter irrigation run times, but water is applied more frequently. Sandy soils fill with water more quickly and drain more quickly than clay soils (table 5). Less water is available to tree roots in sandy soils than in clay soils because of the significant difference in water-holding capacity. As mentioned earlier, adding organic matter to the soil will increase the water-holding capacity of the soil.

Table 5. How deeply one inch of water drains in different soils

Type of Soil	*Percent Sand*	*Percent Silt*	*Percent Clay*	*Soil Depth (Inches)*
Sand	100–85	15–0	10–0	21
Sandy loam	80–45	50–15	20–0	10
Silt loam	28–0	80–50	27–0	7
Clay loam	45–20	43–15	40–27	6

Irrigation frequency. Changing the irrigation frequency (days of the week) seasonally is the primary scheduling method used to conserve water. Irrigation frequencies vary with the type of soil, type of tree (mesic vs. xeric), and time of year. For mesic trees, water is applied when 50 percent of the water in the soil has been depleted (50 percent MAD, or management allowable depletion). For some xeric trees, irrigations can be scheduled when nearly 70 percent of the soil moisture is gone (70 percent MAD). However, care is needed in monitoring the physiological status of the trees when pushing the MAD to values to greater than 50 percent (as such, we do not recommend such high depletions on trees). Cacti can be watered even less frequently (lower MAD) than xeric trees.

Creating irrigation hydrozones conserves water by grouping together the plants with similar irrigation needs together and watering them at the same time; in other words, providing a method for addressing differences in MAD between hydrozones. Hydrozones also may be created to address differences in landscape microclimates surrounding the home.

Maintenance of Irrigation Systems

Each form of irrigation requires its own type of maintenance. Obviously, leak repair of pipes and plugging should be done any time it's observed.

Did You Know?

The primary reason for drip-irrigation failure is not cleaning the filters and flushing the lines regularly.

All three forms of irrigation rely on screened or filtered water to minimize plugging of the emitters. Sprinklers and bubblers will have an obvious decline in water delivery or uniformity if plugging occurs. Preinstalled screens can be found separately in sprinklers and bubblers. Drip-irrigation filters should be cleaned on a set frequency, as plugging is not easily seen. In addition to cleaning the filters, drip-irrigation systems should be flushed on a regular basis, and emitters should be visually inspected for an even flow of water on a regular basis. Always clean the filters and flush the system immediately after an installation. Start a weekly maintenance program at first; if little maintenance is required, decrease to monthly monitoring and adjust as needed. In arid environments such as the Mojave Desert, high evaporation rates and irrigating with poor-quality water can lead to salt buildup in the emitters, which, if not cleaned on a regular basis, can reduce flow significantly (photo 55).

Photo 55. Salt buildup on drip emitters. Salts might be removed by flushing the irrigation lines or cleaning or replacing the emitters. (Photo by R. L. Morris.)

8 CHAPTER

When Should I Irrigate My Trees?

The question of when to irrigate trees is especially important if landscape trees are totally isolated from irrigated turfgrass areas. However, if established trees are in a sprinkler-irrigated turfgrass area, irrigating the turfgrass areas may provide most of the water that the trees need. Frequent irrigation of the lawn, however, often causes tree roots to grow shallower and compete with the grass. Established trees growing in mixed landscapes are part of the turfgrass water balance, and the amount required to irrigate the turfgrass area must be increased for this shared resource. As these trees get larger, their water requirements increase, and they compete for available soil moisture with the turfgrass.

At my (Devitt's) old house, I had a forty-foot Mondell pine that would out-compete the tall fescue turfgrass for water. Visual stress (footprints when stepped on and leaf roll) would signal that more irrigation water was needed by the turfgrass. In my case, it increased the mixed-landscape irrigation by five minutes per irrigation event, as compared to the same grass in my backyard with no Mondell pine. When this tree blew over in a windstorm, the shallow root system tore up turfgrass in my front yard and my neighbor's front yard. A tree growing close to a turfgrass area can have extensive roots that reach into the turfgrass area and even some distance away, including your neighbor's yard! Tree-root lengths of deciduous trees (excluding most conifers and palm trees) can be about thirty-eight times their trunk diameter when water is available and perhaps greater than this as they get older (Day et al. 2010). Contrary to popular belief, tree roots are not evenly distributed in the soil around the tree (Day et al. 2010).

Did You Know?

Farmers sometimes irrigate at night during freezing weather to release energy (associated with hydrogen bonds) when water changes from liquid to ice.

If xeric trees are deciduous and drop their leaves, irrigation frequencies can be reduced to perhaps once or twice per month during the deciduous period, from about late November to early February, provided the soil holds enough water. Even less frequently than this might be okay if the soil moisture is monitored and found adequate. The winter period is a good time to leach soil salts (if present) through an over-application of water (increase the frequency reported in table 6), without contributing to a lot of tree or weed growth. If trees are evergreen, irrigations must be more frequent during winter months.

To help readers understand irrigation from a practical standpoint, in table 6, we report the irrigation practices used to maintain ten typical landscape tree species (a combination of xeric and mesic, twenty years in age), growing at a research site in the Las Vegas Valley. Trees were irrigated with basin-and-bubbler but could have easily been converted to drip irrigation by using the same volume of water and applying it over the same area with the same frequency. As the trees became larger, the basin size increased to accommodate the increased amounts of applied water.

Table 6. Average irrigation estimates for fifteen- to twenty-five-foot-tall landscape trees growing at a research site in the Mojave Desert

(Twenty-year-old trees were a mixture of xeric and mesic, irrigated at the same time; numbers generated based on ten-foot diameter basins delivering fifty gallons per irrigation. Numbers for frequency have been rounded off.)

Month	**Total gallons**	**Depth in inches per month and irrigation frequency (irrigation events per month)**	
		(fifty gallons per irrigation—1 in. depth)	(one hundred gallons per irrigation—2 in. depth)
January	100	1 (2.0)	2 (1.0)
February	100	1 (2.0)	2 (1.0)
March	150	1 (3.0)	2 (1.5)
April	200	1 (4.0)	2 (2.0)
May	250	1 (5.0)	2 (2.5)
June	300	1 (6.0)	2 (3.0)
July	400	1 (8.0)	2 (4.0)
August	400	1 (8.0)	2 (4.0)
September	400	1 (8.0)	2 (4.0)
October	250	1 (5.0)	2 (2.5)
November	200	1 (4.0)	2 (2.0)
December	150	1 (3.0)	2 (1.5)

* Note that these values may need to be increased if your trees grow in more open landscapes. If soil sampling revealed that the salinity should be decreased, increase the amount of applied water by 15–20 percent so that enough water is applied to move salts out of the soil profile. The authors smoothed the water-use numbers to establish an irrigation starting point. These estimates were generated from data used to irrigate twenty-year-old, fifteen- to twenty-five-feet-tall trees that were irrigated on a weekly basis to replace water lost via evapotranspiration during the previous week (Wynne et al. 2019).

In this book, we make the case for selecting desert-adapted xeric trees over mesic trees. We also make the case for embracing hydrozoning where xeric species are located in areas controlled by different valves than areas planted to mesic species. Why, then, does table 6 show only a single irrigation volume for each month, with no separation between xeric and mesic species? The research that supported the values in table 6 came from the Wynne study (2019), in which ten different tree species were grown in a high-density planting (such as what one might find in an orchard setting or even an open forest setting). Under high planting density, trees frequently reveal similar water use on a per-tree basis. Separation in water use often occurs only when tree species are grown in more open landscapes. Variation occurred between the tree species in the Wynne study (2019), but only the smallest trees (crepe myrtle, black locust, Modesto ash) had significantly different water use from the larger trees, with the smaller trees using less overall water but actually higher amounts of evapotranspiration on a canopy basal area (area of the base of the canopy). We believe this occurred because the smaller canopies allowed for greater air movement (turbulence) within the higher-planting-density area to drive higher transpiration rates. The values in table 6 are meant as a starting point to get all trees on a bell-shaped water-use curve. We believe that using sensor feedback and imposing allowable soil-moisture depletions over time will begin to shift the irrigation requirements of xeric species down and shift mesic species up.

Seasonal irrigations should track a bell-shape environmental-demand curve, shown in figure 8. Adjustments to irrigations are expected, based on site conditions and if the trees are not performing in an acceptable manner. Realize increasing the irrigation volumes may require building higher berms for bubbler-and-basin irrigation, leveling them, and/or expanding the size of the basin to accommodate an increased volume of water. Make sure that you always irrigate the entire root zone (figure 20) and that the water is applied to an area close to the size of the tree's canopy.

If not applying enough water (either by not applying water often enough or not watering deeply enough), you may observe leaf wilt and scorch on the outermost leaves in the canopy, particularly those facing the south and west sides and toward the top of the tree. Some trees, such as oak, demonstrate leaf drop if they do not receive adequate amounts of water, thereby reducing the demand for water by the tree. Irrigating trees less frequently but in larger volumes can push the water deeper into the soil and may encourage deeper rooting with time and create a larger reservoir of soil moisture for the tree to access as the surface soil begins to dry. It is worth noting that this is particularly true of pines (Hasselquist et al. 2010).

One must be careful, however, not to irrigate trees too frequently, as this can be very damaging, especially in heavier soils that drain poorly. Watering frequently encourages shallow root growth. Watering too frequently often occurs in urban landscapes, where homeowners do not adjust their irrigation controller seasonally and follow the bell-shaped seasonal water needs of trees. I (Devitt) visited a home in Las Vegas where the owners complained of how poorly their trees looked. Upon examining the yard, I pushed on the trees and caused movement of the trunk where it entered the soil. The soils were extremely wet, and several of the trees showed extensive marginal and tip damage to the leaves—most likely due to poor soil aeration and a lack of root development, associated with excessive amounts of irrigation water. Seasonal adjustment of irrigations and closer attention to soil-moisture levels when irrigating solved this problem.

Did You Know?

Golfers are not allowed on golf courses when frost is present because water crystals on (and, in some cases, in) the leaves of grass rupture and damage cell walls if the grass is walked on. This damage leaves behind visible footprints!

Although few homeowners take a scientific approach to irrigating, golf course superintendents do, as the cost of irrigation in many desert regions is second only to personnel expenses. Most superintendents working with high irrigation costs utilize weather-based reference evapotranspiration data (environmental demand), incorporate adjustments (known as crop coefficients for turfgrass), and even add a leaching fraction adjustment to the irrigation volume, if salts are present. These adjustments help compensate for irrigation and salt-load uniformities that are far less than perfect. Sprinkler-irrigated areas need to be designed and maintained to improve the uniformity of applied water so that most areas receive the same amount of water. This means maintaining a high but cost-effective irrigation uniformity. It is important that uniformity be addressed continuously during the lifetime of the irrigation system. This is especially critical when irrigating with poor-quality water because salts are distributed with the applied irrigation water. Poorly designed and maintained irrigation systems lead to under-irrigated areas, where salts accumulate because of a lack of leaching, all because of poor uniformity. Refer to cooperative extension fact sheets for methods of measuring sprinkler uniformity for home lawns (Donaldson 2013).

A leaching fraction is simply the percent of the irrigation water that must drain from the root zone of plants to remove salts; essentially, watering plants beyond their ET (evapotranspiration). Most soil salts are highly soluble and can be removed from the soil profile by leaching them downward with drainage water. A leaching fraction of 15 percent is recommended in southern Nevada (Devitt 1989) because of the level of salts present in Colorado River water. This means the amount of irrigation water needed (ET) must be increased by 15 percent to remove excessive salts in the root zone. Adding a leaching fraction adjustment to the irrigation amount not only pushes salts below plant roots but also dilutes the potentially damaging salts in the soil water. Leaching salts from the soil profile improves the growing conditions for landscape plants. Clearly, a leaching fraction means *more* water must be applied to remove these salts, not less. Conserving water sometimes becomes a delicate balance between using the least amount of water and achieving acceptable growing conditions for landscape plants (especially if salts are present).

Estimating How Much Water to Apply

Unfortunately, there are few, if any, tables that list the water requirements of landscape trees, especially in arid environments. Instead, most published data on the water use of trees categorize the trees as low, medium, or high water-users (Costello et al. 2000; Kjelgren et al. 2016). These estimates often do not consider the tree size or the fact that many trees are opportunistic in their water use and use more water, if available.

Here's what is known:

1. Larger trees use more water than smaller trees of the same species (Devitt et al. 1995).
2. Trees growing in open areas (with significant distance between other trees and structures) have higher water requirements than trees growing in more densely planted areas and/or protected by structurers (Bernatzky 1978; Oke 1987).
3. Water requirements of trees are highest during the summer period, with their overall water use following a bell-shaped curve, similar to reference evapotranspiration (environmental demand). This assumes that the trees are not being deficit-irrigated, as some xeric trees under deficit irrigation may not track reference evapotranspiration as closely. The approach put forward in this book is not to deficit-irrigate trees, as it may affect landscape aesthetics (Devitt et al. 1994). This

is particularly true for hot, arid environments, in which the irrigation water contains significant levels of soluble salts, such as with Colorado River water (and reuse water), as tree damage can happen quickly. Deficit irrigating under such conditions will only exacerbate the situation, leading to increased stress, dieback, and even plant death (Devitt et al. 1995). Although you can deficit-irrigate for short periods, long-term deficit irrigation should not be considered an acceptable water-conservation option under the conditions described here.

4. Higher light intensities, higher temperatures, lower relative humidity, and higher wind speeds increase plants' water use (Bernatzky 1978; Allen et al. 2005).
5. Applying higher irrigation volumes above a tree's actual needs can lead to greater water use. Doing this can cause some so-called low-water-use trees to shift into higher water-use categories (Sun et al. 2012), which often fuels increased growth. In an earlier study by Devitt et al. (1994), water-use rates were significantly higher in both mesquite and oak, when higher amounts of water were applied; however, a more subtle change was observed in desert willow, which showed leaf yellowing and leaf drop under wetter conditions. Such results led Devitt et al. (1994) to conclude that plant selection alone will not be enough to achieve maximum water savings; water management must play a critical role in developing low-water-use landscapes.

ET values are reported for ten tree species (both xeric and mesic) grown in the Las Vegas Valley in figure 23 (photo 56, Wynne 2019). Many of the trees had similar water use on a yearly basis, averaging around 2,100–3,100 gallons per year. These trees were different from each other in size (height, trunk diameter, basal canopy area) but not age. When their individual water use was adjusted for size, crepe myrtle (mesic) required the same amount of water as tall fescue turfgrass. (This does not mean it was watered with the same frequency!) This information impacts the potential landscape trade-off between plants (replacing turfgrass with crepe myrtle, for instance), based on how much water is used per unit area. We believe that the values reported in figure 23 represent a safe, sustainable level of irrigation for these tree species, based on a high-density landscape. Considering tree sizes used in the Wynne study (2019), these ET values represent a good starting point for irrigating these tree species, when they are established and grown in the Mojave Desert. However, when using this information, remember there are differences in environmental demand between different geographic locations in the Mojave Desert (figure 8). If your trees are growing in a more open landscape and are larger than the trees reported in table 6, increase the irrigation volumes reported in table 6 by as much as 20 percent (for example, peak irrigation volumes in July are reported as 400 gallons in table 6; a 20 percent bump would move this to 480 gallons and would change the frequency to about nine or ten times per month. Lower frequencies could occur if the basins were enlarged or a greater depth of water was applied, such as two inches of water at each application, which would reduce the twice-weekly applications in summer to once weekly (table 6)—this would be our recommendation.

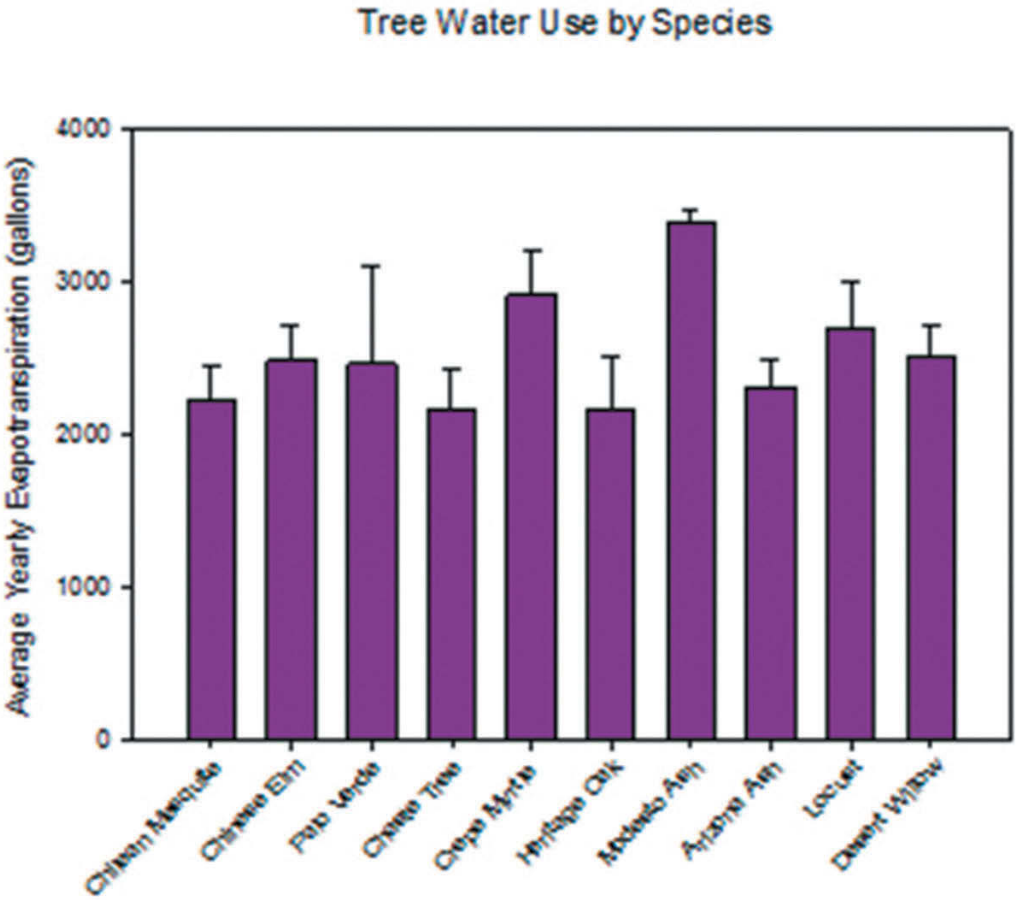


Figure 23. Annual water use (evapotranspiration) of ten ornamental tree species grown in North Las Vegas, Nevada (Wynne 2019)

Photo 56. Crepe myrtle tree (left) growing in the experimental plot (right) in North Las Vegas, Nevada, to assess weekly evapotranspiration rates (photos by D. A. Devitt)

In figure 24, Wynne (2019) showed the water use of black locust (*Robinia pseudoacacia*) on a monthly basis, along with monthly reference evapotranspiration. Maximum water use on a monthly basis was around four hundred gallons during September of the second year. The seasonal shift in environmental demand is reflected in the monthly water use of the tree. In most of the trees studied, there was a two-month offset in ET, with higher ET during August and September, not in the higher-demand months of June and July, as the ET curve might predict. We (Wynne and Devitt 2020) believe this was a physiological adjustment on the part of the trees, perhaps more tightly regulating the small openings on the leaves (stomata) during the highest-temperature period, which occurred during June and July. Although it is always best to irrigate following the reference ET curve, irrigators should make necessary adjustments up or down to avoid possibly stressing the trees. As such, we did not adjust down the July values to be equal to the June values.

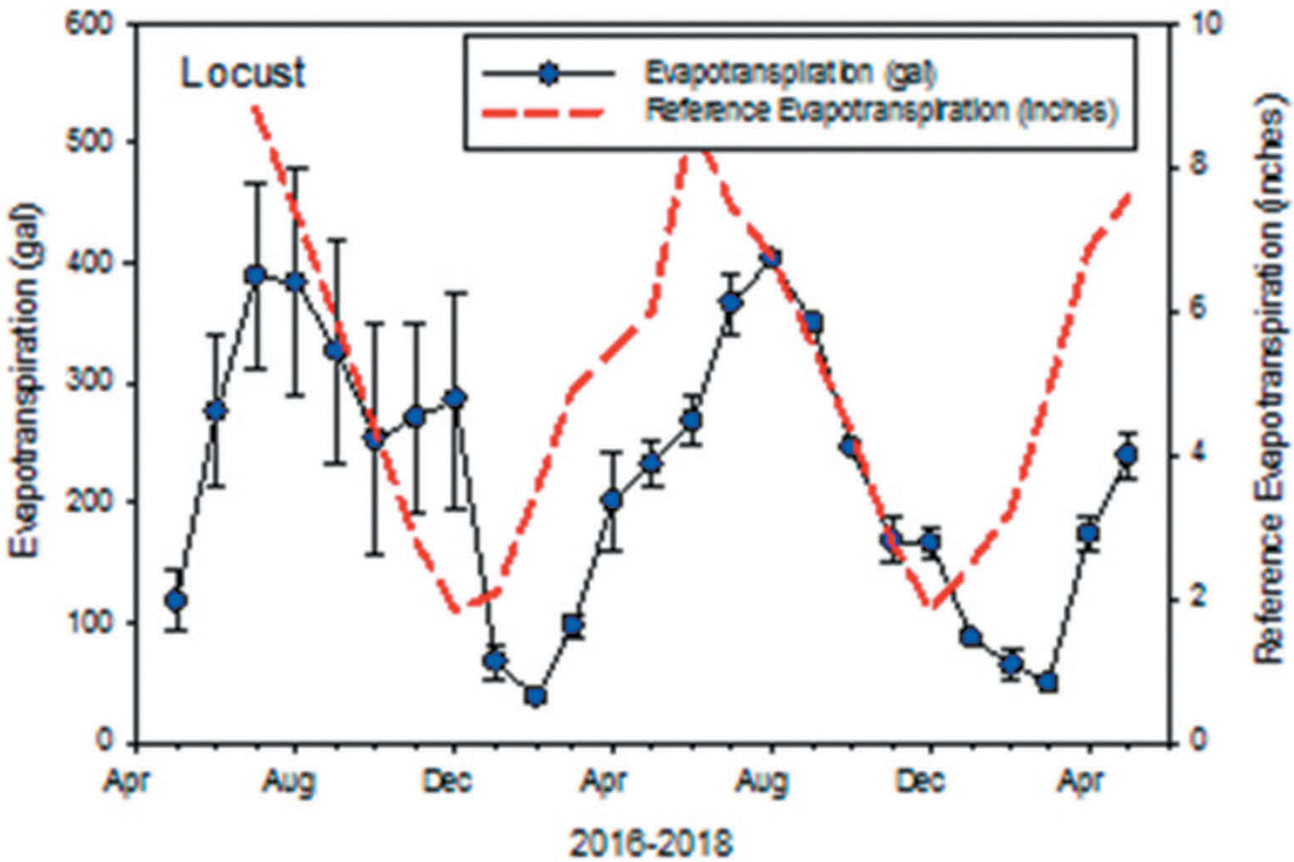


Figure 24. Monthly evapotranspiration estimates for locust trees growing in North Las Vegas, Nevada, along with reference evapotranspiration estimates (environmental demand) (Wynne 2019)

Did You Know?

Some plants can move water in the xylem (water-conducting tissue) as fast as thirty inches per minute. The xylem is dead at maturity, functioning as a hollow conduit for the transfer of water.

If the landscape is open, and the trees can freely access water from turfgrass areas, your trees' ET rates may be significantly higher than reported here. The trees in our study were isolated from turfgrass and were fifteen to twenty-five feet in height, which is typical for many landscape trees in Las Vegas. Disregarding the increase of plant size over time can result in significant irrigation errors. Because many types of trees are grown in a mixed landscape, their need for water will change as they grow larger. Since water may be available to them from multiple sources, it may be difficult to apply the exact amounts trees need, and the amounts needed may vary from the amounts reported in table 6. We are not suggesting that table 6 reports the definitive ET estimate for urban landscape trees, but it does provide a reasonable starting point.

A second approach is to estimate the landscape water use needed by examining your total landscape area and the total amount of water applied as irrigation. The average home in the Las Vegas Valley now uses about 222 gallons per day, which totals 81,030 gallons per year (SNWA 2019). The Southern Nevada Water Authority states that 70 percent of this value represents outdoor water use (56,721 gallons), with the majority used for irrigating landscapes. Outdoor water use in Tucson (a similar climate to Las Vegas) has been estimated to be 30 percent of total residential water use, a decrease of 50 percent over the past three decades, due to water-conservation efforts (City of Tucson 2019).

If we assume your home is average in its interior water use and has an average-sized landscape, relative to the home, then calculate 70 percent of the water used each month (find it on your monthly water bill; realize the 70 percent is based on a yearly average so some overestimation would occur during winter months), and plot the amounts used for each month as outdoor water use. Since most of this water is used for landscaping, monthly outdoor water use should have a bell-shaped curve, with highest water use in summer months, lower values during transition months in spring and fall, and the lowest amounts during winter (again, some error may occur in estimating the winter months using a constant value of 70 percent). If this is not the case, adjust your landscape irrigations to follow a bell-shaped ET curve. (Hint: outdoor summer use is about four times winter use.)

To estimate your annual landscape water use per square foot, you will use information found in your water bill. To do this, first calculate the total irrigated landscape area in square feet (length times width will give your area in square feet). Divide your annual outside water use (70 percent of water use reported in your bill) by the square feet of your irrigated landscape area (not counting the area of a pool or patio, for instance). This results in gallons of water you applied each year per square foot of irrigated landscape. As an example, if an average home had 2,000 square feet of irrigated landscape, that would mean 28.36 gallons (56,721 gallons [see above] per 2,000 square feet) were applied annually, per square foot of landscape. This value would be equal to 3.79 feet of water applied over the entire 2,000 square feet of landscaping (28.36 gallons square feet times 0.1337 conversion factor from gallons to feet).

Did You Know?

Evaporation from an open body of water (such as a pool) is typically considered to be about 20 percent higher than reference evapotranspiration, whereas water loss from many plants can be significantly below reference ET (low-fertility Bermuda grass, 40 percent below reference ET).

Suggested Categories of Landscapes, Based on Annual Water Use per Square Foot

- Low water use: below two feet of water per square foot of landscaped area (below 15 gal./sq. ft.)
- Medium water use: 2–4 feet of water per square foot of landscaped area (below 30 gal./sq. ft.)
- High water use: 4–6 feet of water per square foot of landscaped area (below 45 gal./sq. ft.)

If your landscape falls into the high-water-use category, begin water conservation efforts by first fixing any areas where water waste is occurring and making sure irrigation adjustments follow a bell-shaped seasonal ET curve. Second, audit your landscape water use so you are confident that your trees are not receiving too much water. Third, remove unnecessary plants, and eliminate the irrigation that was applied to those plants. Fourth and finally, decrease the amount of water applied, either by run time or irrigation frequency or both, by about 10 percent on all stations. After a week, observe the plant response to this decrease in applied water, and increase the amount of water delivered—to each plant individually—for those that are showing signs of stress. Continue to decrease the amount of water delivered by each station. Make these irrigation changes until your landscape water use moves into a lower-water-use category or at least to a lower level within a given water-use category. Some fine-tuning will be required, as the greatest savings will occur during the summer months, but this is also when the trees are under greatest potential stress.

At some point you may not be pleased with the aesthetics of the total landscape or of a particular tree when moving into a lower-water-use category. Sometimes, difficult and costly choices must be made. These choices may include reducing the irrigated landscape area, reducing or eliminating an unused lawn (especially cool-season turfgrass, such as tall fescue), reducing the size of or eliminating large trees, or reducing the total number of trees and plants in the landscape or replacing them with more appropriate selections. Capture any potential water savings by redesigning the irrigation system and adjusting the irrigation volumes, in accordance with the reduced landscape size and reduced water needs. If the landscape was not designed with hydrozones in mind, it is highly recommended the landscape irrigation be redesigned such that mesic vs. xeric plants are watered separately. Hydrozones provide more flexibility in deciding where best reductions in irrigation should take place. The first step would be to make sure that the individual hydrozones are managed separately to achieve maximum water savings.

Using Sensors (Tensiometers, Soil-Moisture Sensors): The Scientific Way to Schedule Irrigations

If you track the environmental demand and use the information in table 6, you will schedule irrigations as soil moisture is depleted. However, table 6 is meant as a starting point, based on the site location, tree species, the size of the tree, planting density, location of the tree, soil type, and form of irrigation (drip, sprinkler, or bubblers). As such, the amount needed may vary from the amounts presented in table 6.

One way to see if the values in table 6 are adequate (and if differences exist between mesic and xeric species) is to track the soil moisture with a device called a *tensiometer* and observe how landscape trees respond. A tensiometer is a device filled with water that helps an irrigator decide if the irrigation frequency and the amount of water applied is correct (photo 57). Tensiometers detect how dry the soil is, as they measure soil suction. As the soil dries, it places a suction on water inside the tensiometer, via the white porous ceramic tip buried in the soil (photo 57). As the water is pulled slowly out of the tensiometer through the ceramic tip, the suction created is recorded by a vacuum gauge attached to the tensiometer. It is critical to follow the information provided by the manufacturer in maintaining the sensors to get accurate readings.

Photo 57. A tensiometer is an instrument filled with water that is placed in direct contact with the moisture in the soil via a ceramic tip. Soil moisture is indirectly assessed as a vacuum (negative pressure) created on the tensiometer's internal water, which is recorded with a gauge. It is used for assessing when to schedule irrigations. (Photo by R. L. Morris.)

Take measurements from the vacuum gauge on a regular basis, especially after irrigations, when the tensiometer reading is at its lowest value, but also as the soil dries down (high values equal greater suction because the soil is dry; low values arise because the soil is wet). The dial on the vacuum gauge can read values between 0 and 100 centibars but it's only operational up to about 80 centibars. You will need to monitor the water level in the tensiometer and recharge with water, as described in the manual.

Most plants visually reveal stress in the 30–70 centibar range, depending on species and soil type. To avoid stress to plants, most plants are typically watered in the 20–30 centibar range. When using tensiometers to schedule irrigations for trees, it is best to install two tensiometers—one at a one-foot depth and the other at the tree's maximum rooting depth (figure 25). Placing these two tensiometers midway between the trunk and the canopy edge is recommended. If you are applying water via drip or bubbler, it is best to place the tensiometers in an area that is uniformly wet after each irrigation.

When using two tensiometers, schedule irrigations off both sensors. Realize that the shallower zone will dry more quickly (give higher readings), but you do want to see water extracted from the deeper zone as well, so do not ignore the deeper values. As long as the maximum allowable depletion does not exceed 50 percent, it is okay to allow the soil to go through drying cycles, particularly during the cooler months. You may find that if you irrigate and incorporate a 15 percent leaching fraction (presence of salts), the soil remains too wet, and the trees show stress; if so, lower the leaching fraction to 10 percent and attempt to shift the higher leaching to the winter months. Always use the visual response of the tree as the true barometer of proper irrigations and soil-moisture content.

Table 7 reports the influence of soil texture on available water-holding capacity. This shows that loam and clay soils hold significantly more water than sandy soils. This means that trees growing in loam and clay soils are watered less often than those growing in sandy soils, but they are given more water during an irrigation. When they receive water, irrigations should apply enough water to wet the entire rooting depth of the tree. For irrigation purposes, small trees (up to twenty feet) are watered to a depth of eighteen inches, medium-sized trees (twenty to forty feet) to twenty-four inches, and large trees (above forty feet) to thirty-six inches. As an example, a large tree has the majority of its root system in the upper three feet of soil, so it is critical that this zone is not depleted by more than 50 percent of its available water. Note that we take a value of 50 percent but the actual allowable depletion will vary by species and is probably in the 40–70 percent range. To calculate how much water to apply, multiply the water-holding capacity of your soil (table 8) by the rooting depth in feet, and multiply this number by 0.5 to allow for the acceptable soil water depletion of 50 percent.

Table 7. Available water-holding capacity of soils, based on soil texture (Storlie 1995)

Soil Texture	**Available Water-Holding Capacity (Inches of Water per Foot of Soil)**
Sand	0.25–1.00
Loamy sand	0.75–1.50
Sandy loam	1.25–1.75
Loam and silt loam	2.00–2.75
Clay loam	1.75–2.50
Clay	1.50–2.25

Example: You have a sandy-loam soil with a 1.5 inch per foot of soil water-holding capacity (table 7). A large tree is irrigated to a depth of three feet. Calculate the amount of water to apply as follows: (1.5 inches of water per foot of soil) x (3-foot rooting depth of the tree) x (0.50 allowable depletion) = 2.25 inches of irrigation.

Table 8 helps guide when to schedule an irrigation and if the amount, based on table 6, is adequate.

Table 8. Threshold tensiometer readings for scheduling irrigations to prevent greater than 50 percent depletion of available soil water (Storlie 1995). Note that values above 80 cb are typically problematic.

Soil Moisture and Irrigation Status	**Soil Texture**	**Soil Tension (cb)**
Soil at field capacity	Sand, loamy sand	5–10
No irrigation required	Sandy loam, loam, silt loam	10–20
	Clay loam, clay	20–40
50 percent of available water depleted—irrigation	Sand, loamy sand	20–40
required	Sandy loam, loam, silt loam	40–60
	Clay loam, clay	50–100

Figure 25. Placement of two tensiometers in a tree basin to help schedule irrigation events. One tensiometer is shallow (12 inch), and the other tensiometer is placed at a depth to represent the tree's maximum rooting depth, according to its mature height (e.g., 18 inch, 24 inch, or 36 inch). (Drawing by Nancy Villeda.)

Record the tensiometer values after an irrigation and relate these values to table 8. Are these values associated with an available water-holding capacity of the soil, with greater than 50 percent depletion? Do they exceed the tension values reported in table 8? If the answer is yes, then make an adjustment to the amount of water applied, based on table 6. (Is the response different between xeric and mesic species?) Continue to track the tensiometer values and any adjustments you make, and determine if further adjustments should be made, especially during the hot summer months. Having two tensiometers at two different depths allows you to assess if the water has moved deep enough to wet all the roots and which depths are more active, in terms of soil-water extraction by roots. Realize the depth of water penetration depends on soil texture but also on the irrigation rates—higher rates on sandy soils push the wetting front deeper (figure 26).

Readings from the two tensiometers can also be used to calculate the hydraulic gradient. This tells you which direction water already in the soil is moving (you cannot assess this with one tensiometer). Water moves in the soil from where it is wetter to where it is drier. If you are trying to move salts downward, keep a positive gradient (more negative with depth) from the shallow tensiometer to the deeper tensiometer. To calculate the hydraulic gradient, take the reading at the one-foot depth (these are negative numbers because we are measuring suction, not pressure), and subtract the reading from the deeper tensiometer. Then divide this difference by the distance between the two tensiometers in centimeters (e.g., approximately -31 cm [12 inch] and -91 cm [36 inch] for a large tree—negative numbers for depth because we are setting the surface at zero). If the hydraulic gradient is a negative number, water movement is upward; if it is positive, water movement is downward. If you are dealing with salinity, it is critical to know that your irrigation management is, in fact, achieving downward leaching of salts. Note that no adjustments to the tensiometer values were made, based on different water column heights in the 31 and 91 cm tensiometers. Contact your cooperative extension office if you wish to refine the calculation.

Example: You read 70 centibars on the tensiometer gauge at the one-foot depth (31 cm) and 20 centibars on the tensiometer at a three-foot depth (91 cm). Which direction is water moving?

[-70 cb – (-20cb)] / (-31 cm-(-91 cm) = -50cb/60cm (-500 mb/60 mb) = -8.3. Water movement is upward

In this example, the tensiometer values indicate a significantly drier soil at the one-foot depth than at the three-foot depth. For this reason, the hydraulic gradient indicates that water movement is upward. A larger (more negative) hydraulic gradient indicates a stronger driving force for upward water movement, whereas a smaller negative number also indicates upward water movement but with a weaker driving force. Soils at the surface will dry out after an irrigation, leading to an upward gradient. The key is to track the tensiometer values over time, relative to values reported in table 8, and make necessary adjustments. If you are increasing irrigations to leach salts, it is okay if the gradient shifts upward after an irrigation as the soil dries. It is actually more effective, in terms of leaching, to allow the soil to wet up and then dry down, as water in both macro- and micro-pores in the soil will be better displaced. The key is to know the soil salinity level and the sensitivity to salts of the tree in question (soil sampling and analysis). If you know your soils have elevated levels of salinity (shallow saline groundwater, irrigating with reuse water), soil salinity sensors can be purchased and either read with a meter or downloaded directly to your computer, which will allow you to assess how effective the set irrigation is in leaching the salts from the root zone. Once the soil-salinity levels have been reduced, back off the higher-irrigation volumes, and return to the irrigation scheduling based on table 6. However, if the salinity level of the irrigation water used is elevated, such as the Colorado River and reuse water, continue to incorporate a 15 percent leaching fraction by adjusting the volumes in table 6 accordingly.

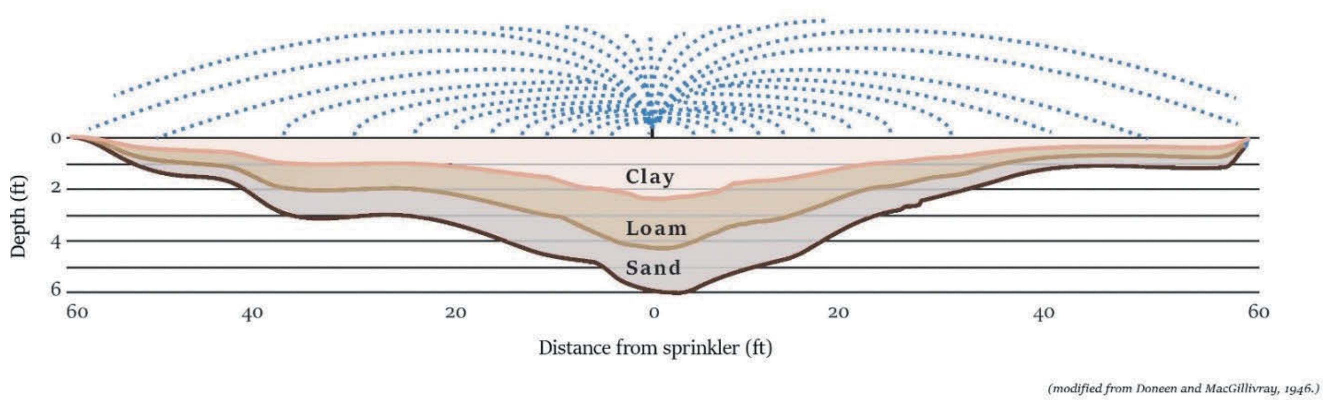


Figure 26. Depth of applied water in the soil by a single sprinkler, based on different soil textures with a single application rate. As the distance from the sprinkler increases, the application of water from a sprinkler decreases. Higher application rates of applied water lead to greater differences in penetration depth of soil moisture. A well-designed sprinkler system spaces sprinkler heads in a manner that achieves overlap to attain maximum uniformity. (Drawing by Nancy Villeda.)

A tensiometer can be purchased to function in an automated mode that signals the solenoid to open and close the irrigation valve. Although the shallow tensiometer is typically used to set the irrigation events, the deeper sensor is still extremely valuable in assessing recharge in the deeper part of the root zone. Other sensors also exist that assess the soil "matric potential"—how dry the soil is—and will not require continuously filling an internal water chamber for it to operate. There are also soil-moisture sensors that assess the soil water content. Many soil-moisture sensors available in the market operate on different principles, including one that emits a high-frequency electric pulse that moves outside of the sensor, into the soil, and slows down when it comes in contact with soil water, enabling the sensor to estimate soil-moisture content. These soil-moisture sensors are significantly smaller in size than tensiometers and can be read with a meter and automated to control the irrigation valve. In fact, many can be read with a smartphone. Finally, is one sensor actually enough, such that the soil-water content at one location is reflective of the entire area irrigated by a separate valve? The answer is probably no, unless the valve delivers water to a single tree, so always rely on the response of the tree when adjusting the irrigation run times reported in table 6.

To properly use the moisture sensors, you must establish the soil-moisture content (Θ) of your particular soil at two extremes: *field capacity* and *permanent wilting point*. Field capacity reflects the soil-moisture content in a soil profile following a heavy irrigation and after the soil has freely drained for a certain period. This period varies with each soil type, based on its texture. Sandy soils may drain in several hours, while a heavy clay soil might not stop draining for two weeks. Usually waiting one to two days after a heavy irrigation and determining that the soil-moisture content has stabilized is one way to establish its field capacity soil-moisture content (Θ). Although a tensiometer can be used to assess field capacity by assuming it occurs at one-third bar or at about one-third of the tensiometer range, it cannot be used to assess the *permanent wilting point*.

You must be able to establish the soil-moisture content (Θ) at its permanent wilting point. This varies, based on soil type and plant species, but is generally assumed to be at fifteen bars soil-water potential. Fifteen bars is way outside the upper limit of the tensiometer (0.8 bars), so instead, you will need to use a soil-moisture sensor. Stop irrigation and monitor the soil-moisture content (Θ) until the leaves on plants begin to show the first signs of wilting. Establish this soil-moisture content (Θ) as the permanent wilting point. It is, however, a temporary wilting point. The difference between the soil-moisture content (Θ) at field capacity and the soil-moisture content (Θ) at permanent wilting point reflects the plant's available water.

Next, establish the soil-moisture (Θ) threshold (Cuenca 1989) that signals when irrigation is required.

Threshold Soil Moisture Content (Θ) = field Capacity (Θ) - MAD*(field capacity (Θ) - permanent wilting point (Θ))

The management allowed depletion (MAD) varies with plant species (mesic vs. xeric) but is often taken to be 50 percent for landscape trees. MAD values greater than 50 percent can be used for xeric plants, but close monitoring of the plant is required. MAD also varies by soil type and irrigation technique, with higher MAD values in sandy soils with sprinkler systems and lower MAD values in clay soils under drip irrigation. When the threshold soil-moisture content (Θ) is reached, a signal is sent to open the irrigation valve. Prior to this, one must decide on how long to keep the irrigation valve opened (gallons of water needed in minutes of run time). We recommend using the information in table 6.

Example: Estimate the threshold soil-moisture content for a hydrozone containing a tree. To do this, you will need to apply a large amount of water to the area where you placed soil-moisture sensors at different soil depths. Apply enough water to wet the soil past the deepest moisture sensor. Start recording the soil-moisture measurements from all soil-moisture sensors on the first day after the water application. Conduct this assessment during the winter, when evaporation and transpiration are low. Record the soil-moisture values daily. Look for soil moisture to stabilize after about two days in sandy soils; it takes longer in loam and clay soils because they hold water longer. Use this stable soil-moisture value as representing field capacity. During early summer, turn the irrigation off to the area where the soil-moisture sensors are located. Record the soil-moisture sensor values daily, and watch the plants in this area for their first signs of midday wilting. Make sure this soil-moisture value is recorded; use this soil-moisture value to represent the wilting point. In the Cuenca equation (1989) above, permanent wilting point is used, but this might lead to death or dieback in the tree, so we recommend replacing the permanent wilting point with a temporary wilting point (point where leaves wilt but quickly recover once water is provided). Realize the Cuenca (1989) equation assesses how much water is available in the soil profile, as the difference between field capacity and the permanent wilting point. The values are all soil volumetric water-content estimates, which tell us the percentage of the soil volume that contains water, reported as a percentage (%) or in decimal form. If the soil water content is 40 percent (or 0.40) at field capacity and the soil moisture content at the wilting point (temporary) is 4 percent (0.04), use the Cuenca equation (1989) to calculate the threshold soil-water content to signal when to irrigate. Let's select a MAD (maximum allowable depletion) value of 50 percent:

Threshold (Θ) water content to signal when to irrigate = field capacity – [MAD (field capacity – wilting point)] = 0.40 – [0.50(0.40 -0.04)] = 0.22.

This means when the soil-water content reaches a value of 0.22, plants in that area near the sensors should be irrigated. If your system is not automated, simply track the soil-moisture values over time, and when the soil-water content drops to the threshold value, schedule an irrigation, using the information from table 6. If, however, your sensor is synchronized with your clock, the soil-moisture sensor would signal the solenoid to open when the threshold value is reached. A program would need to be written that would incorporate the information from table 6 to automatically set the correct run times, based on time of year. Using this approach, you may find your trees need amounts of water greater or less than reported in table 6 and that greater distinction occurs between mesic and xeric species. Always let the physiological response of the tree guide your final decisions—the goal is not to save water at the expense of the tree!

Automation is great, but irrigators cannot take an out-of-sight/out-of-mind approach with these sensors. Realize that all sensors can fail, and some types are negatively impacted by the presence of elevated levels of salts (not tensiometers). Sensor values of soil-moisture content (Θ) should be compared periodically to the original field capacity (Θ) measurement after an irrigation event to assess any failures. These failures might signal the need for maintenance or replacement of the sensors. It should be noted that many sensors on the market today claim a life expectancy of twenty-five years. Seasonal oscillations in soil-water content will occur as the environmental demand increases, reflecting that the plants are more actively extracting water from the soil. This means the sensor that detects threshold values will signal the solenoid to open the irrigation valve more frequently. Having multiple sensors at different depths and for each hydrozone (xeric vs. mesic) is also suggested, especially for deeper-rooted trees (compared to shallow-rooted grass), but this will require integrating all these values into your soil-moisture threshold estimates.

Finally, irrigators should also consider installing a rain sensor to shut down the system during a rainfall event. These sensors can be set to turn off the clock, based on a preset amount of rain (triggered by the weight of water). Although rainfall is low in the Mojave Desert, individual rainfall events can exceed a half inch. It will take some time for rainwater to infiltrate the soil (especially heavier soils that are high in clay content) and move to the depth of the soil-moisture sensor for it to respond. If you install sensors to help schedule irrigations, rain sensors will allow you to take full advantage of the free water—you also don't want to give the wrong impression to your neighbors and the local water district that you are irrigating while it rains. However, some would suggest (including Morris) that rainfall in the desert is more of a nuisance to a good irrigation schedule, especially rainfall that occurs during the summer months that is not effective enough to meet the actual irrigation need for the day.

We believe everyone should embrace technology, especially with regard to water conservation, as significant savings can be achieved by using a scientific approach. This can be achieved by using the simpler user-friendly technology, such as tensiometers (reliably used in commercial orchards for decades) or more advanced soil-moisture sensors, with which the data can be accessed with a laptop, meter, or smartphone. It is also worth mentioning that very sophisticated irrigation controllers can be purchased that actually download weather data to the controller and can be programmed to fine-tune the information for every irrigation valve (such as soil type, sprinkler precipitation rates, slope, vegetation, etc.). One of these clocks is referred to as a satellite-based ET controller and was demonstrated by Devitt et al. (2008) to reduce the need for irrigation by an average of 20 percent for homes in Las Vegas. Such clocks, however, are expensive.

Did You Know?

About 70 percent of all fresh water is used to irrigate crops. With a growing world population, it is estimated that the world will need to produce 60 percent more food by 2050. It takes 127 gallons of water to produce one pound of corn but about 2,000 gallons to produce one pound of beef. Obviously, it would be a lot easier to meet the global water challenge if more people were vegetarians!

To properly irrigate trees in the Mojave Desert, it is important to know the climatic conditions at your site (weather-based environmental demand, table 1), the water-holding capacity of your soil (table 8), the quality of the irrigation water (table 3), the irrigation system (drip, bubbler, sprinkler), and, of course, the tree species and tree size (see section on tree selection). With this information, landscapers, horticulturists, water managers, golf course superintendents, and homeowners can apply basic scientific methodology to achieve lower water use of trees, as well as the entire landscape. Water conservation should not be based on achieving reduced water use by simply sacrificing the functionality and aesthetics of the trees and landscape. Conserving water is easier in newer housing developments that have embraced water conservation and have incorporated the concepts of xeriscape and hydrozoning. Although landscapes at older homes may not have been designed based on these concepts, the potential for water savings is even greater if the homeowner or land manager is open to embracing change. In the case of the Las Vegas Valley, the Southern Nevada Water Authority currently pays homeowners for each square foot of turfgrass removed, if the landscape is redesigned to demonstrate significant water conservation (a cash-for-grass program)—a great way to help offset the cost of retrofitting a landscape to save water but also to be aesthetically pleasing.

9 CHAPTER

Work toward Sustainable Desert Communities

Trees give beauty to landscapes by providing a wide range of sizes, shapes, color, and textures. Landscape architects often anchor the design of landscapes on the presence or inclusion of trees. In areas where water is not limiting, little thought typically goes into reducing the total biomass (vegetative cover) of a landscape simply to improve the conservation of water. In arid environments, however, where annual precipitation is typically less than ten inches per year, it must be recognized that all plants, trees, shrubs, and grasses consume water, and the amount varies, not only based on the species and time of year but—more important—simply on the amount of water provided. Because over 40 percent of the total water consumed in a city like Las Vegas is associated with outdoor water use, special attention must be placed on the conservation of water in irrigated urban landscapes. The design and maintenance goals of urban landscapes in arid regions must be based on enhancing the conservation of water.

Although many tree species possess characteristics that allow them to survive and grow in harsh arid environments, they often respond to higher levels of available water in an opportunistic fashion, leading to enhanced growth and greater loss of water through transpiration. If water is limiting in a region, irrigations need to support tree health but not support luxurious growth. To accomplish this, trees need to be irrigated to track the bell-shaped seasonal curve of environmental demand and adjust irrigations, based on the physiological response of the trees.

Achieving greater conservation of water in urban landscapes located in arid regions must be founded on providing homeowners, landscapers, and water managers with a reasonable path that easily can be followed and embraced. We believe this should be based on the following:

1. Emphasize native and desert tree species and limit the total biomass (vegetative cover) used in the landscape through appropriate landscape design.

2. Irrigate in parallel with environmental demand.
3. Initiate an irrigation strategy for trees, based on the baseline values provided in table 6, and adjust the amounts, based on the physiological response of the trees.
4. Consider the purchase and use of soil sensors (and their maintenance) to provide soil-water status feedback.
5. If landscape adjustments are made (reduced area, plant removal, reconfiguration of irrigation system), capture water savings by adjusting irrigations accordingly. Such adjustments must be done with plant responses closely monitored.
6. If irrigating with reuse water, more water, not less, must be used to maintain favorable salt balances in the soil. Realize that a leaching fraction must be incorporated into irrigations to maintain this salt balance. Application of reuse irrigation water to the foliage of trees should always be avoided.
7. If renovating a landscape or establishing a new landscape, irrigate plants using hydrozones.
8. Apply enough fertilizer to maintain tree health. Over-fertilizing, however, will lead to excessive growth and higher water consumption.
9. Drip irrigation can be an excellent option for applying water only where it's needed to conserve water, but it does require good maintenance practices. Contact your local cooperative extension office to learn more about this method.

Living in a desert environment requires everyone to be good stewards of their natural resources but especially water resources. The future is uncertain, with regard to how climate warming might alter flow in the Colorado River and what impact elevated temperatures might have on the water requirements of landscapes. The steps we take today, in terms of managing our water resources, will impact the quality of life for future generations. Reducing outdoor water usage is a key element, especially in light of continued population growth. We also must not forget that water conservation and energy conservation go hand and hand, as it takes a great deal of energy to move water from its source to all of the end-users. The larger societal question for cities like Las Vegas is, what population number is sustainable, in terms of water. Smart growth that is based on vertical growth, water pricing, water reuse, and smaller residential landscapes that are designed properly—with desert-adapted plants and are irrigated based on a scientific approach—will allow cities like Las Vegas to continue to grow. Getting residents to buy in on a water-sustainability plan will be based on educational programs to enlighten the residents, cost incentives, and the ability to achieve aesthetically pleasing low-water-use landscapes, with the knowledge that such steps will collectively reduce the water footprint of homes, neighborhoods, cities, and entire regions of our country.

GLOSSARY

actual evapotranspiration (ET_a): Quantified water loss of evaporation and transpiration from a soil plant system, typically assessed with water or energy balances.

arid: Land or climate having little or no rain and too dry for traditional agricultural production without supplemental irrigation.

AZMET (Arizona Meteorological Network): A network of weather stations developed in Arizona to help agricultural producers and growers efficiently manage water resources, thereby saving water, energy, and money.

blank tubing: Plastic pipe (usually made from polyethylene) ranging in size from one-eighth inch to over two inches in inside diameter, used in low-pressure irrigation systems, primarily for transporting water.

boron: Essential plant micronutrient found in soils that has the narrowest range in concentration between essentiality vs. toxicity to plants. Concentrations are especially high in regions with ancient marine deposits.

bubbler-and-basin irrigation: Modified method of flood irrigation that contains water above plant roots and thus provides additional time to infiltrate the soil surface.

calcium (calcareous): Essential plant macronutrient needed in large amounts by plants. When soils have high amounts of calcium, often as calcium carbonates, they are referred to as calcareous.

caliche: Calcium carbonate deposits in soils frequently cemented together in layers, sheets, or as “popcorn,” due to soil weathering.

capillary lift: Transport of soil water upward.

carbonates: A common anion (negative charged ion—a gain of two electrons) associated with many desert soils, most commonly as calcium carbonate.

centibar (cb): 1/100 of a bar. A measuring unit of a tensiometer that reflects how tightly water is held by the soil.

chlorine: Chemical element (atomic number 17), whereas chloride is an anion (negative charged ion—a gain of one electron). Chloride is an essential micronutrient of plants but can become toxic at higher concentrations.

CIMIS (California Irrigation Management Information System): A network of weather stations developed in California to help agricultural producers and growers efficiently manage water resources, thereby saving water, energy, and money.

crop coefficient: Ratio of actual evapotranspiration to reference evapotranspiration, used to adjust irrigations to meet plant water needs.

deficit irrigation: Water applied to plants below their actual requirements for water.

desert: Arid land with sparse vegetation and receiving less than 25 centimeters (10 inches) of sporadic rainfall annually.

desert-appropriate plants: Plants suited for desert environments that may originate from mesic or xeric environments.

desert landscape design: Method of designing and installing landscapes that includes the seven principles of Xeriscape but focuses on the use of desert plants, design, and irrigation strategies that apply low amounts of total water and reduce energy costs during summer months.

drip emitters: Orifices designed to deliver water at low rates of application and often at low pressure. They can be available individually or incorporated into the surface of drip tubing.

drip irrigation: A method of precision agriculture that delivers irrigation water to plants at low rates of application, high uniformity, and low pressure, when designed, installed, and maintained correctly.

drip tubing: Low-pressure plastic pipe (usually made from polyethylene), ranging in size from half inch to over one inch inside diameter, with embedded drip emitters spaced evenly along its surface at specified distances, typically eight inches to seventy-two inches apart.

drought-tolerant: Often confused with low water use; survival of some plants through periods of water scarcity, often with a dramatic drop in aesthetics.

effluent water: Wastewater (treated or untreated) that is discharged from a wastewater treatment plant or industrial plant into a body of water such as a river, lake, or ocean.

emitters: Holes or orifices designed to deliver water at specific rates through a wide range of water pressure.

environmental demand: The need for water by plants, dictated by environmental conditions such as solar intensity, amount of wind, air temperature, and humidity.

evapotranspiration (ET): Combined process of water loss to the atmosphere from soil and plant surfaces and transpiration from plants.

evapotranspiration, actual (ET_a): See actual evapotranspiration.

evapotranspiration, reference (ET_o): See reference evapotranspiration.

evaporation: The process of turning water from liquid to vapor. In the term *evapotranspiration* (ET), water lost from the surface of soils and living surfaces not accounted for by transpiration.

field capacity: The maximum amount of water a soil contains, after drainage has ceased, typically assessed over the rooting depth of the plants being grown.

flushing: Maintenance practice used for drip irrigation to clean blank tubing and drip tubing of water contaminants that could plug the drip emitters, including debris, mineral deposits, and microbiological growth.

gypsum (gypsiferous): Calcium sulfate, which is common in some desert soils. It dissolves more readily than carbonates, leading to possible soil subsidence.

hydraulic gradient: The transport of water through a porous substance (soil) due to a difference in tension or suction.

hydrozoning: An irrigation-scheduling strategy that focuses on watering plants together similarly if they are similar in size and similar in water needs.

iron deficiency: Reduced amounts of available iron in plants, which results in interveinal yellowing of new leaves and total yellowing in severe cases.

irrigation frequency: How often water is applied to plants.

irrigation scheduling: Water delivered to plants that includes both the watering frequency and the amount required.

landscape microclimate: The climate of a small area of the landscape, especially when this differs from the dominant climate of the surrounding landscape.

leaching fraction: The ratio or proportion of irrigation water that drains through the root zone of plants, relative to the amount applied; incorporated into irrigations to achieve proper leaching of salts from the rootzone.

macronutrients: Essential elements needed by plants in large amounts (such as nitrogen, phosphorous, and potassium).

management allowable depletion (MAD): The amount of water that can be "lost" from a soil before the next irrigation occurs. In most soils and with most plants, the amount lost should not total over 50 percent.

Mediterranean climate: Climate distinguished by warm, wet winters and calm, hot, dry summers and frequently occurring in coastal parts of California, Chile, South Africa, and southwestern Australia.

Mediterranean trees: Trees that evolved in a Mediterranean climate. Typically, these trees are not xeric.

mesic trees: Trees that evolved in a climate with a well-balanced supply of soil moisture.

microclimate: The climate of a very small or restricted area, especially when this differs from the climate of the surrounding area.

micronutrients: Essential elements needed in smaller amounts by plants (such as iron, zinc, copper, boron).

mini-oasis landscape design: Method of designing and installing desert landscapes that divides the area into three separate water-use zones—low (none or very little supplemental water), intermediate (moderate plant water use) and high water use. These three water-use zones correspond to outside areas of human activity.

mixed landscape: Residential landscape composed of a lawn with trees and shrubs growing in the lawn. Often all plants receive water through sprinkler irrigation.

mulch: Surface accumulations or applications that are mineral, organic or industrial which conserve water, reduce soil erosion, moderate surface temperature, and resist the invasion of foreign plants.

organic matter: Former biological life that has decayed or is in in the process of decaying or decomposing.

percolation test: A measurement of the speed at which water moves through a soil.

permanent wilting point: The amount of water remaining in the soil after plants no longer recover from drought when water is applied again.

pH: A logarithmic scale (0.0 to 14.0) used to specify a substance's acidity or alkalinity, with neutrality at 7.0. Technically, the negative logarithm of the hydrogen ion concentration of a liquid. A significant driving force behind the solubility and availability of plant nutrients in soils.

potential evapotranspiration (PET_o): The amount of water transpired in a given time by a short green crop completely shading the ground, of uniform height and with adequate water status in the soil profile. It is assessed with weather data, which is entered into an equation to assess environmental demand. It is not related to a specific crop.

reference evapotranspiration (ET_{ref}): The rate of evapotranspiration from a hypothetical reference crop with specific growth characteristics, with the reference crop typically being either alfalfa or tall fescue.

Often used interchangeably with *potential evapotranspiration* but preferred by irrigation engineers to generate transferable *crop coefficients*.

reference evapotranspiration curve: A plot of reference ET on a monthly basis, revealing seasonal changes in environmental demand.

return flow credits: When Nevada diverts Colorado River water and returns treated sewage effluent to Lake Mead it is allowed to take additional water equal to the volume (of Colorado River water) which was returned.

reuse water: Water treated at a suitable level for reuse. Treatment often includes primary, secondary, and tertiary treatment. Reuse water is also used for recharging groundwater. Treated sewage effluent must meet all state and federal standards for its specific reuse. A valuable water resource in arid areas, where it has been demonstrated safe for the irrigation of turfgrass and mixed landscapes but does require excellent irrigation-management practices due to its elevated salt content.

run time: Irrigation delivery measured in minutes or hours, rather than volume. The amount of water delivered divided by the run time equals rate of water delivery.

salinity: The concentration of a dissolved salt in a given volume of water. Salinity can be measured in a variety of ways, including a concentration (e.g., grams of salt per kilogram of water, parts per million—ppm or TDS) or approximated through electrical conductivity (e.g., mhos/cm or dS/m).

sodium: A natural-occurring cation (positive charged ion—loss of one electron) found in desert soils and saline water. It is not an essential element for land plants and often interferes with potassium uptake.

sodium adsorption ratio (SAR): An index related to water quality that assesses potential problems to both plants and soils when the amount of sodium is significantly higher than the combination of calcium and magnesium in the irrigation water.

soil structure: The arrangement and organization of the mineral and organic content of a soil, which directly impacts a soils porosity—the amount of open pore space in a soil that enables soil gasses to diffuse in and out, water to enter, and get distributed and affect the depth that roots will grow and proliferate.

soil texture: The relative percentages of sand, silt, and clay contained in soils.

soil textural triangle: Diagram developed by the USDA that helps determine the textural nomenclature for a soil, once the percentages of sand, silt, and clay are known.

soil-water content (ϴ): The amount of water found in soil, expressed as either gravimetric soil water—grams of water per gram of dry soil, or volumetric soil water—volume of water per volume of soil.

sprinkler irrigation: A method of irrigation, usually using high pressure, that applies irrigation water overhead through emitters, called "sprinklers."

temporary wilting point: The amount of water remaining in the soil when plants reveal first signs of midday wilt. The plant is able to completely recover after water is applied again.

tensiometer: A device placed in the soil to assess how wet or dry the soil is; used to schedule irrigations.

transpiration: Water released to the atmosphere (as vapor) from plants.

treated sewage effluent: Water moved through the various stages of treatment at a wastewater treatment plant; see *reuse water*.

uniformity: The distribution of water from several emitters or sprinklers over an irrigated area.

urban heat island: Term that reflects warmer temperatures in urban areas compared to rural areas, based on how constructed surfaces absorb and hold heat. Often more dramatic at night.

xeric trees: Trees that evolved growing in an environment containing little seasonal moisture. Xeric trees typically evolved in desert climates.

Xeriscape: Method of landscape design and installation that follows seven core principles: planning and design, soil improvement, practical turfgrass areas, efficient irrigation, use of mulch, use of lower-water-use (frequently native) plants, and appropriate maintenance.

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