Outdoor water-use efficiency is growing in importance as increasing demand for fresh water strains limited resources in many locales and where outdoor use represents a significant percentage of a water provider’s total water demand. Obtaining landscape water-use efficiency over the long term requires proper planning (design) for such landscape elements as:

- functionality
- grading, runoff, soil preparation, and mulches
- plant selection
- irrigation systems
- maintenance

Studies have shown that water-conserving landscapes, known as xeriscapes, can save significant water (50 percent or more) and reduce maintenance costs (up to 30 percent) by following appropriate planning principles, including the following:

- designing for functionality
- preparing soil properly
- selecting plants suited for the climate of the region
- using lawn appropriately
- designing irrigation-systems for efficiency
- using mulches
- employing appropriate maintenance practices

Landscape standards or guidelines incorporating these principles can be approached from three perspectives:

- water budget
- checklist
- a combination of the two

and can be adopted by either planning agencies or water providers.

A water budget establishes limits on allowable consumption in a given landscape area. This approach is best suited for adoption by water providers that can encourage water efficiency through pricing mechanisms. It offers the advantage of design flexibility, but requires financial incentives (surcharges for exceeding established budget) to be effective. Thus, a water provider needs to be prepared to take the necessary steps for program implementation, which involves securing the appropriate resources to monitor use (dedicated metering), determining water budgets, and adopting appropriate pricing structures and billing programs.

To establish a water budget for a given site, it is necessary to know the irrigated area and the region’s annual evapotranspiration (ET) rate. ET is the measure of water depletion from the soil due to evaporation and transpiration through plant
The ET rate is determined by such parameters as solar radiation, temperature, wind, humidity, and plant and soil types. While ET varies continuously, annual ET data have been developed by plant type and by region. A plant’s supplemental water requirement (annual water budget) is based upon effective precipitation and its ET rate, called net ET. Thus, a water budget can be established for a given area once the plant types and ET rates are known. Since most landscapes have a variety of plant materials, the ET rate for a cool season grass is typically used for reference. ET reference material is cited in the back of this section. A typical landscape water budget for a new landscape allows 80 percent of reference ET per square foot of landscaped area. An exception might be allowed for a large turf site in full sun by allowing 100 percent of reference ET per square foot of landscaped area.

A checklist approach prescribes design criteria. This approach can be adopted by both a planning agency and a water provider and typically involves plan review, site inspection, follow-up monitoring, and enforcement for non-compliance. In this case, a planning agency might provide the plan review and site inspection, and the water provider might provide the monitoring and enforcement. A combination approach involves using a checklist to help meet water-budget objectives.

The checklist following provides an example of what information might be requested of an applicant for water service in order to apply criteria for meeting landscape water-efficiency goals.
### Checklist of Landscape Water-Efficiency Measures

#### Functionality

Address how landscape is going to be used:
- Play, sports field (Is artificial turf appropriate?)
- Park
- Median strip

#### Soil Preparation

- Conduct soil analysis; amend soil with organic material to a depth of at least six inches to provide plant nutrients, if appropriate

#### Runoff

- Minimize runoff through use of pervious material, swales, terracing, rain gardens, and berms, as appropriate

#### Plant Selection and Groupings

- Use plants appropriate to the climate of the region
- Group plants into hydrozones (irrigated areas based on plant water requirements)
- Use water-efficient varieties of turf
- Prohibit use of invasive species

#### Irrigation

- If reclaimed water is available and appropriate for use, install approved hardware
- If not presently available or not yet appropriate for use, consider installing irrigation hardware adaptable to reclaimed water should circumstances change
- Install separate irrigation meters for properties with more than 5,000 square feet of total irrigated area
- Install irrigation equipment that meets the Irrigation Association design guidelines for maximum irrigation operational uniformity
- For all new nonresidential landscapes not required to have a separate water-service meter, install a private irrigation sub-meter and backflow prevention valve between the point of connection on the domestic water service and the first irrigation valve
- Design all irrigation systems to avoid runoff, over-spray, low-head drainage, and similar conditions where water flows off-site onto adjacent property, non-irrigated areas, walks, roadways, or structures
- Employ drip or low-volume irrigation equipment where it is determined that overhead spray irrigation would result in waste of water due to excessive runoff or overspray
- Follow proper hydrozoning principles when designing irrigation systems in order to water turf and bedded areas separately
- Install a pressure regulator if water-supply pressure exceeds 80 psi
- Match precipitation rates on sprinkler heads within a hydrozone
- Install anti-drain check valves as needed to minimize or prevent low head drainage
- Use Irrigation Association approved “smart controllers” (with dual- or multiple-programming capability to accommodate a five-day schedule, multiple start times, a percent switch, etc.) along with rain sensors, or use weather-based (ET) controllers
The table above provides some comparative estimated-cost information.

Following is a discussion of various landscape elements that may impact water-use efficiency, water quality (runoff), energy use, aesthetics, and a site’s microclimate. These issues should be considered in developing landscape standards.

### Landscape Design Based upon Functionality

#### Description of End Use

Appropriate landscape design enhances the attractiveness of a property and is friendly to the property users, while providing these additional benefits:

- reduces green-waste production
- provides shade
- improves air quality by capturing dust
- creates habitat for birds and wildlife
- avoids cost of energy to maintain landscapes and to produce water
- reduces seasonal water demand
- retains stormwater
- reduces maintenance costs

The following principles benefit the landscape-design process:

- shape the land so it captures and holds water from rainfall, irrigation, and runoff from impervious surfaces

<table>
<thead>
<tr>
<th>Estimated Cost Considerations</th>
<th>Water-Conserving Landscapes (10,000 sq. ft.)</th>
<th>Turf Landscapes (10,000 sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Costs per Square Foot of Installing Plant Materials (Except Grading)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant materials</td>
<td>$1.25 – 1.60/sq. ft.</td>
<td>$0.40/sq. ft.</td>
</tr>
<tr>
<td>Mulch and amendments</td>
<td>$0.10 – 0.20/sq. ft.</td>
<td>Not required</td>
</tr>
<tr>
<td>Irrigation system</td>
<td>$0.30-0.40/sq. ft.</td>
<td>$0.40/sq. ft.</td>
</tr>
<tr>
<td>Smart irrigation controller</td>
<td>$200-$6,000</td>
<td>$200-$6,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Maintenance Cost</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff from overhead irrigation system</td>
<td>Low-pressure systems greatly reduce runoff</td>
<td>Likely</td>
</tr>
<tr>
<td>Annual water cost based on annual net ET requirement of 39 inches and water cost of $2.50/Ccf</td>
<td>$240 (based on irrigating at 30% of ET)</td>
<td>$800 (based on irrigating at 100% of ET for cool-season grass)</td>
</tr>
<tr>
<td>Mowing</td>
<td>Not required</td>
<td>Required weekly</td>
</tr>
<tr>
<td>Irrigation repair</td>
<td>Reduced</td>
<td>Certain</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Considerably reduced</td>
<td>Likely</td>
</tr>
<tr>
<td>Weed control</td>
<td>Considerably reduced</td>
<td>Some</td>
</tr>
<tr>
<td>Mulch topping</td>
<td>Up to 20% replacement</td>
<td>Not required</td>
</tr>
</tbody>
</table>
• ensure that the landscape soil has enough holding capacity to retain received water (see the subsection “Grading, Runoff, Soil Preparation, and Mulches”).
• choose proper landscape plant material to fit climate and use (see subsection on “Plant Selection”).
• install efficient irrigation equipment (see subsection on “Irrigation Systems”).
• maximize use of on-site water sources, e.g., re-irrigate with runoff or use reclaimed process water; use other sources of reclaimed water where available (see subsection on “Irrigation Systems”).

Site designs need to conform to local stormwater management requirements, such as the following:
• maximize infiltration to promote movement of stormwater downward through soils to remove pollutants and restore surface and groundwater flows
• provide retention
• slow runoff
• minimize impervious land cover
• prohibit dumping of improper materials
• retain pollutants
• collect and convey stormwater or use for irrigation

Explanations of these objectives are provided in the “Grading, Runoff, Soil Preparation, and Mulches” subsection.

Good practices for water conservation are in many cases identical to good stormwater-management practices. One common goal is to shape the land and provide sufficient soil depth to slow runoff and retain the water that falls, in order to maximize infiltration into the soil. In most cases soil that retains water is the most cost-effective rainwater-harvesting technique.

_Water-Savings Potential Based upon Functionality of Design_

The following practices help maximize water savings:
• Shape the land so it captures and holds water it receives from irrigation, rainfall, and runoff from impervious surfaces. Irrigation water should be retained in the soil. Stormwater can be retained in the soil and impoundments.
• Hydrozones comprise distinct groups of plants designed to have the same watering requirements. Use separate stations to irrigate plants that have been grouped together according to their high, medium, or low water needs. When high- and low-water-use plants are mixed in a hydrozone — an area watered by the same irrigation valve or station — it is impossible to apply the correct amount of water.
• Design water features, e.g., fountains, to recirculate water or use recycled wastewater treated to human-contact standards. See “Pools, Spas, and Fountains.”
• Vegetative strips in parking areas and highway medians and between sidewalks and pavement should be mulched, planted with water-thrifty shrubs, and irrigated with low-pressure systems. Avoid using turf on strips less than eight-feet wide or on slopes greater than 10 percent.
• Adjacent to pavement and other hardscapes, use a mulched border at least two-feet wide comprising shrubs, groundcover, or other landscape treatment that is not spray irrigated. This minimizes runoff from errant sprays of overhead sprinklers.
Trees, Groundcover, and Mulch Enhance a Parking Area and Traffic Island
(Photo source: C. Pike)

<table>
<thead>
<tr>
<th>Process or Equipment Alternatives</th>
<th>Water-Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulched borders adjacent to hardscapes and separating turf areas from hardscapes</td>
<td>Medium</td>
</tr>
<tr>
<td>Water features using recirculated or reclaimed water</td>
<td>High</td>
</tr>
<tr>
<td>Plant materials grouped in hydrozones</td>
<td>High</td>
</tr>
<tr>
<td>Narrow strips planted with water-thrifty shrubs and groundcover and irrigated with low-pressure systems</td>
<td>High</td>
</tr>
</tbody>
</table>

Grading, Runoff, Soil Preparation, and Mulches

Grading

The California Master Gardener Handbook advises: “Sometimes the soil to be landscaped has been amended or modified to construct building foundations or roadways, or to create new physical environments such as hills or lakes. Usually these alterations are performed to engineering standards, not horticultural standards. The discrepancy in the two standards often presents considerable problems in establishing and maintaining woody plant materials. Original grading specifications should be reviewed and considered when subsurface changes could cause soil-structure problems, such as extremes in soil texture, soil pH, pesticides, or phytotoxins.”

Steep slopes (greater than 10 percent) are difficult to irrigate properly and frequently promote irrigation runoff. On the other hand, properly graded swales and berms can assist in retaining water on-site and reducing runoff.
Runoff

Some counties and municipalities may require Stormwater Control Plans and may, therefore, include such language as: “Every application for a development project … or building permit that is subject to the development runoff requirements in the … NPDES permit shall be accompanied by a Stormwater Control Plan that meets the criteria cited in the … County Clean Water Program Stormwater Guidebook.”

Stormwater control plans are submitted with applications for planning and zoning review. The Stormwater Control Plan is to be coordinated and integrated with the site plan, drainage plan, and landscaping.

Stormwater runoff is a concern when landforms are covered with impervious materials. Without the ability to soak into soils and be slowed by vegetation, stormwater collects in large volumes that flow downhill at accelerating speeds over impervious surfaces. This means higher storm-peak flows, potentially contributing to downstream flooding and greater erosion rates.

The objectives of stormwater control plans are to minimize potential runoff pollution and runoff flows for the life of the project. The targeted pollutants include those deposited in airborne dust, liquids and dust from automobiles, cleaning solutions (e.g., from food service), litter, and trash.

Relationship between Impervious Cover and Surface Runoff (FISRWG 1998)

The objectives of stormwater control plans are to minimize potential runoff pollution and runoff flows for the life of the project. The targeted pollutants include those deposited in airborne dust, liquids and dust from automobiles, cleaning solutions (e.g., from food service), litter, and trash.
Post-construction stormwater-control measures can be divided into four categories:
  - site design
  - source controls
  - stormwater treatment
  - hydro-modification management

Each category may include landscape measures, depending upon site conditions and design.

Depending upon local conditions, factors such as high clay content, soil susceptibility to liquefaction, soil contamination from prior activities, or seismic activity may require stormwater-control measures to be focused on flow filtration and temporary retention rather than deep percolation.

Description of End Use
Stormwater-control measures that affect landscapes include:
  - minimizing land disturbance and preserving high-quality open space
  - minimizing impervious surfaces by using narrow streets, driveways, and sidewalks
  - using pervious surfaces
  - clustering structures and paved surfaces together
  - using landscaping as a drainage feature
  - building bioretention areas
  - extending detention basins
  - building infiltration trenches
  - using media filters
  - employing vegetated buffer strips
  - using vegetated swales
  - building retention ponds and vaults
  - using tree-well filters
  - employing flow-through planter boxes

**Stormwater Water-Savings Potential**

A Mediterranean climate may make stormwater an impractical supply without supplementary irrigation during the dry months. Due to concerns about disease, such as West Nile Virus, some agencies may specify a maximum number of days for standing water, based upon the incubation period of local mosquito species.

![Turf Block and Paver Mat](Alameda CCWP, 2006)
However, by providing proper shaping of the land and proper soil depth and composition, rainfall will be retained in the soil, minimizing stormwater runoff and keeping the soil moist for later plant use, without aggravating potential mosquito problems. This is also the most cost-effective method for harvesting intermittent rainfall in Mediterranean climates.

Green roofs offer a somewhat controversial opportunity to apply landscape features while retaining precipitation (rain and fog) and saving energy used to cool buildings. The City of Chicago extols their success with green roofs, and Leadership in Energy and Environmental Design (LEED) points may be gained from green roofs. Other authorities point out that vegetation on a roof still needs irrigation during dry periods, so at a minimum, green roofs should be considered a part of the landscape when determining irrigation requirements. At this time, the guidebook withholds any recommendations for green roofs.

Soils are mixtures of mineral particles, living and dead organic materials, and pore spaces containing water and air. Soils are formed from weathered rock and organic materials as modified by the actions of climate, living organisms, and positions on the landscape over a period of time. Soil texture affects watering and fertilizing schedules and may determine the kinds of plants that grow.
Soil texture characterizes the size of the mineral particles. Sand particles are large enough to be easily seen by the eye, are irregularly shaped, have lots of pore space, and consequently drain well. Clay soils are flattened, platelike, microscopic particles that pack together closely and can hold the greatest volume of water, although drainage is slow. Silt particles are somewhat larger than clay. Loams are mixtures of all three soil-particle sizes.

Description of End Use
Soil acts as a reservoir that holds air and water for plants. The amount of water available to plants is the difference between the amount of water the soil can hold (field capacity) and the point at which plants can no longer draw water from the soil (wilting point). As shown below, sandy soils hold less water at field capacity than clay soils. However, due to their high surface area to volume ratio, water adheres more tightly to clay soils. Therefore, loam soils have the most available water per foot of soil depth.

![Water Available to Plants as a Function of Soil Depth and Texture](image)

The deeper the soil profile the greater the amount of water available to plants, to the depth that plant roots extend. New landscapes should have at least six inches of soil for good plant growth and effective irrigation. Adding organic matter can improve the water-holding capacity. Compost can improve soil porosity and water infiltration rates, especially in fine-textured or compacted soils. To avoid horizontal water movement at boundaries of soil layers, mix the soil types together at the boundaries, using techniques such as scarification of the underlying layers, before new topsoil is applied. Water will then move downward providing a deeper soil-moisture reservoir for plants. These and other means of adding soil moisture capacity are effective at capturing rainfall (rainwater harvesting) and in irrigation applications (Lower Colorado River Authority, 2007).

Watering to the plant-root depth creates a healthier, more efficient garden. The mix of sand, clay, and silt dramatically affects irrigation schedules. Water drains through porous sandy soils easily, so small amounts of water need to be applied frequently. Clay soils and slopes require small amounts of water to be applied intermittently, otherwise the water runs off the surface. Adding too much fertilizer may negatively affect irrigation efficiency. Fertilizer adds nutrients soils may lack to promote plant growth (primarily nitrogen, phosphorus, and potassium). The faster a plant grows the more water it will require.

Soil amendments influence plant growth by improving the soil’s physical characteristics: the ability to provide nutrients, water, and air to plant roots. Sunset’s Western Garden Book advises: be generous
when adding organic amendments. When preparing a new planting bed, spread a three- to four-inch layer of amendment over the soil. Some authorities suggest tilling the amendments into the top four to nine inches; others authorities take a more natural approach without tilling. Around established plantings, add organic material by spreading it over the soil surface as mulch. Earthworms, microorganisms, and water will help mix it into the top layer of soil.

Factors to consider when choosing a soil amendment:
- how long the amendment will last in the soil
- soil texture
- soil salinity and plant sensitivity to salts
- salt content and pH of the amendment
- the impact on beneficial soil microorganisms and fauna

### Mulches

Mulches are opaque organic or inert materials applied in layers on top of bare soil and around trees and shrubs. The purpose of mulches is to reduce water evaporation, prevent weeds by stopping photosynthesis, buffer soil temperatures, protect irrigation systems from harmful solar rays, and give the garden a finished look. Mulch should be porous to air and water. The coarser the material, the thicker the mulch layer needs to be. Organic mulch, such as shredded cedar bark or compost, will also amend the soil as it decomposes. To prevent crown rot and other problems, avoid applying mulch up against the main stem or trunk of a plant. Mulch is reported to reduce watering demand by 40 to 70 percent.

Alternative irrigation techniques should be used with plants surrounded by mulch. Apply water with bubblers, soaker hoses, or drip lines beneath the mulch to the plant-root areas. Sprinklers are inefficient methods of applying water to mulched areas, since mulch materials restrict water flow and absorb large amounts of water before it is able to reach the soil.

### Water-Savings Potential

Example: a 10,000 square foot area planted in shrubs and trees with a four-inch layer of mulch. Mulch substantially reduces labor for weeding, but may need as much as 20 percent replacement each year, as it deteriorates into beneficial organic material for the soil.

- Material Capital Costs: Approximately 100 cu. yd. @ $10/cu. yd. = $1,000 (prices actually range from $0 to $40/cu. yd.). Add installation labor @ 1 hour/cu. yd. @ $10/hour = $1,000. Total cost of installed mulch = $2,000.
- Estimated Material Life: Five years.
- Water and Energy Savings: Assume: 50 percent water savings due to mulch, traditional shrubs, and ground cover (Ks=0.8). Dry season (May through October) ETo of 39 inches; plant species using water at a rate of 80 percent of ETo.

<table>
<thead>
<tr>
<th>Water Savings Using Mulch</th>
<th>With Mulch</th>
<th>Without Mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry season water use in AF</td>
<td>0.371</td>
<td>0.742</td>
</tr>
<tr>
<td>Value of irrigation water</td>
<td>$381</td>
<td>$763</td>
</tr>
</tbody>
</table>

Maintenance without mulch requires periodic weed-spraying and weed-removal. The mulch requires as much as 20 percent replacement annually, as the organic material deteriorates into soil amendments. The mulch provides an annual benefit of approximately $75.
Landscape Element | Water-Savings Potential
---|---
Apply mulches to non-turf areas | High
Use soil amendments for good plant health and to minimize watering needs | Medium

*Plant Selection*

Effective use of plants can soften, mitigate, screen, and enhance a property. Turf is appropriate for sports, recreation, walking, sitting, and picnicking. Trees screen and shade; shrubs and groundcovers screen and provide color. They all help to control erosion. Good design will provide these benefits, consume low amounts of water, and avoid difficult maintenance, as well (Ash 1998).

Select plants that are in keeping with the site’s “sense of place.” Each location is part of a larger region with its own soils, topography, weather patterns, and microclimates.

Choose native or very-well-adapted plants that will thrive on less water in summer. Various plants are adapted to summer fog, cool evenings, or sunny baking-hot days. Many plants are available to create a colorful, interesting, and lush garden, well-suited to the climates and soils found in each region of the country.

When selecting plant species, consider their size at maturity. Avoid the temptation to install shrubs and trees too close together. This may initially fill the space, but will eventually result in crowding, with the avoidable expense of removing shrubs or trees as well as disposing of the solid waste.
Some communities and properties require that tree shade be provided from islands in parking lots. Select varieties that do not drop annoying litter during pollination or shed limbs during summer heat.

**Description of End Use**
For specific-use landscapes, such as parking lot islands, streetscapes, medians, or buffers, non-turf landscapes are recommended for their ability to thrive on drip or subsurface irrigation. For athletic fields, golf courses, parks, and large recreational areas, unshaded turf is typically required. Where turf is desired, artificial turf should be considered. This can also be used for mixed landscapes.

**Water-Savings Potential**
Perennials and shrubs require less frequent watering than lawns. For areas where natural turf is desired, select grass species that use less water.

<table>
<thead>
<tr>
<th>Water-Thrifty Turf Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warm-Season Grasses</strong></td>
</tr>
<tr>
<td><em>Ks = 60% of ETo</em></td>
</tr>
<tr>
<td>Bermudagrass</td>
</tr>
<tr>
<td>Kikuyugrass</td>
</tr>
<tr>
<td>Seashore paspalum</td>
</tr>
<tr>
<td>St. Augustine</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Cool-Season Grasses</strong></td>
</tr>
<tr>
<td><em>Ks = 80% of ETo</em></td>
</tr>
<tr>
<td>Annual bluegrass</td>
</tr>
<tr>
<td>Annual ryegrass</td>
</tr>
<tr>
<td>Colonial bentgrass</td>
</tr>
<tr>
<td>Hard fescue</td>
</tr>
<tr>
<td>Highland bentgrass</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process or Equipment Alternatives</th>
<th>Water-Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use water-thrifty shrubs, trees, and ground cover instead of turf</td>
<td>High</td>
</tr>
<tr>
<td>Use water-thrifty shrubs, trees, and ground cover instead of high water-use shrubs, trees, and ground cover</td>
<td>High</td>
</tr>
<tr>
<td>Use warm-season instead of cool-season grasses for turf</td>
<td>Medium</td>
</tr>
</tbody>
</table>

**Cost-Effectiveness Analysis**
- **Plant-Material Capital Costs**: Installed turf cost (excluding soil preparation and grading) is estimated at $0.40 per square foot or $4,000 for a 10,000-square-foot landscape (2007 costs, which can vary from region to region). Non-water-thrifty shrubs and ground covers may cost approximately 15 percent less than the $1.60 per square foot for water-thrifty species, primarily due to their availability from nurseries.
- **Estimated Plant-Material Life**: Ten years.
- **Water and Energy Savings**: See table below.

The following table compares water use for water-thrifty plants with that of water-thirsty plants at 80 percent of ETo and 100 percent ETo; 80 percent ETo is recommended as an upper limit by the CUWCC Landscape Irrigation Taskforce. The calculation uses irrigation efficiencies of 80 percent (a desirable goal) and 65 percent (a more typical performance).
### Average Irrigation Season (May – October)
#### Water Use and Water Costs
10,000 square foot area

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Budget 80% ET</th>
<th>Budget 100% ET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigation System Efficiency</td>
<td>Gallons/AF</td>
</tr>
<tr>
<td>Low-water-using plants</td>
<td>80</td>
<td>72,500 0.223</td>
</tr>
<tr>
<td>Low-water-using plants</td>
<td>65</td>
<td>89,280 0.274</td>
</tr>
<tr>
<td>Low-water-using plants with mulch</td>
<td>80</td>
<td>36,270 0.111</td>
</tr>
<tr>
<td>Low-water-using plants with mulch</td>
<td>65</td>
<td>44,640 0.137</td>
</tr>
<tr>
<td>Warm-season grasses</td>
<td>80</td>
<td>145,000 0.445</td>
</tr>
<tr>
<td>Warm-season grasses</td>
<td>65</td>
<td>178,560 0.548</td>
</tr>
<tr>
<td>Turf with cool-season grasses</td>
<td>80</td>
<td>193,400 0.594</td>
</tr>
<tr>
<td>Turf with cool-season grasses</td>
<td>65</td>
<td>238,080 0.731</td>
</tr>
</tbody>
</table>

*Irrigated landscapes that are metered independently from interior uses are spared fees for wastewater services. This table assumes a May to October ET<sub>o</sub> of 39 inches.

Because turf is mowed frequently, may require more fertilizer than shrubs, and needs other maintenance procedures, the annual maintenance cost of turf is approximately 25 to 30 percent higher than that for permanent shrubs and ground cover.

### Incremental Cost per AF of Water-Efficient Plant Materials*

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Present Value Benefit of Water Savings</th>
<th>Benefit /AF over Plant Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-water-using shrubs vs. thirsty shrubs</td>
<td>$2,945</td>
<td>$794</td>
</tr>
<tr>
<td>Warm-season grasses vs. thirsty grasses</td>
<td>$1,178</td>
<td>$794</td>
</tr>
<tr>
<td>Low-water-using shrubs vs. thirsty grasses</td>
<td>$4,124</td>
<td>$794</td>
</tr>
</tbody>
</table>

*For simplicity, maintenance costs, such as weeding and mowing, are excluded.*
Irrigation Systems

Irrigation systems replace water in the soil that is used by shrubs, trees, and grass, where natural moisture is inadequate for the intended landscape. Without regard to the type of landscape, the primary guideline for landscape irrigation design is to avoid over-watering by applying:

- the right amount of water
- to the right place
- at the right time

The proper design of an irrigation system takes into account:

- types of plants and their spatial distribution
- slope, soils, and soil amendments
- climate factors, such as wind and ET rates
- zero runoff goal from the area to be irrigated
- adjacent structures, features, and hardscapes

Description of End Use
To replace the soil moisture, an irrigation system receives water from a source and distributes it to plants when desired.

Irrigation-System Components

Typical components of irrigation systems include:

- water meter: measures the volume of water entering the system
- backflow prevention device: prevents potentially contaminated water from an irrigation system from flowing into a potable-water system
- pressure regulator: controls water pressure within set limits
- pressure reducer: reduces water pressure to desired range
- controller: regulates the irrigation cycles to activate the control valves at the times and days selected
- soil moisture sensor: installed at the root zone at strategic locations representing the irrigation zone; signals the controller if irrigation cycles may be omitted
- rain sensor: detects recent rainfall and signals the controller if irrigation cycles may be omitted
- valve: allows water flow when actuated by controller
- anti-drain check valve: prevents water loss from sprinklers or emitters at low spots in the irrigation system
- sprinkler head: emits streams of water through the air to plants
- filter: removes from water oversized particles that might clog emitters
- bubbler: head that emits flows short distances at 0.25-2 gpm
- drip emitter: low-pressure device that emits water drops at rates of 0.5 to 2 gph
- micro-spray: low-pressure device that sprays water a short distance at flows of 0.5 to 5 gph
- drip or soaker line: tubing that emits water along its length
- zone: a portion of the landscape with the same irrigation requirements
Block Diagram of an Irrigation System

Zone 1 — Overhead Sprinklers

Water source → Water meter → Backflow preventer → Filter → Pressure Regulator

Smart controller

Valve → Valve → Valve → Valve

Rain sensor

Soil moisture sensor

Valve → Valve → Valve

Fine-mesh

Pressure reducer

Zone 2 — low-pressure drip, bubblers, and micro-spray

Water flow → Control

Source: C. Pike
Alternative Irrigation Sources

On-site water may be used as an irrigation source if it is properly separated from potable supplies by backflow preventers or similar devices. Each alternative source requires storage vessels, plumbing, and sometimes filters and pumps to move stored water to the irrigation system. Some alternative sources are:

- air-conditioning condensate
- swimming-pool-filter backwash water
- cooling-tower blow-down water (if water quality will not harm plants and meets local code)
- fountain drain water
- rainwater and stormwater harvested from buildings and hardscapes
- treated gray water from interior and process uses

Irrigation Scheduling

Water needs to be delivered to plants when they need it. Plant water requirements, ET, reflect both evaporation from the soil and plant surfaces and transpiration through plant surfaces. ET varies from one site to another and changes constantly with the weather, especially sunshine, wind, and rainfall. The chart below displays typical 100 percent ET curves for any given year. Irrigation may partially or fully replace natural precipitation during all but the winter months in a typical year for most regions of the country. The timing and quantities of water deliveries are the important goals in proper irrigation scheduling.

![Typical Monthly ET in Inches](chart)

An important corollary to irrigation scheduling is applying only the amount of water the soil can absorb without runoff. The duration of irrigation depends upon the discharge capacity of the emitters, slope, vegetation density, soil type, and moisture depletion. Steeper slopes and clay soils require multiple short run times. For example, three five-minute applications with an hour between each will allow the soil to absorb more of the applied water than one fifteen-minute application.

Flat ground with sandy soils may allow longer irrigation applications. Whether the irrigation applications are short or long, the total water volume delivered to the root zones should be adequate to restore depleted soil moisture without wasteful runoff.

Water-Savings Potential

Metering and billing deliveries to irrigated systems separately from interior uses are incentives to improve irrigation efficiency.
Smart Controllers (also known as ET controllers, weather-based controllers, smart sprinkler-controllers, and water-smart irrigation-controllers) use weather conditions, current and historic ET, soil-moisture levels, and other factors to adapt water applications to meet the actual needs of plants. The Irrigation Association states that smart controllers may reduce water by 20 to 40 percent annually.

Generally, there are two types of smart controllers (CUWCC, 2006):

- controllers with the irrigation schedule pre-programmed for local conditions using historical weather data, which also permit adjustments in the irrigation schedule with real-time measurements of local factors using precipitation and temperature sensors
- signal-based controllers that receive daily weather data via radio, telephone, cable, cellular, Internet, or pager technology to establish irrigation schedules

Distribution uniformity (DU) measures how evenly water is applied to the landscape. For overhead sprays, the irrigation system should be designed for head-to-head coverage. Ideally, equal amounts of water are applied to each square foot of the zone being irrigated, resulting in a distribution uniformity of 100 percent. However, many factors may result in a lower distribution uniformity, such as improper sprinkler-head spacing, blocked or clogged sprinkler heads, mismatched sprinkler nozzles, or tilted sprinkler heads. DU is evaluated by collecting water in evenly spaced cups from a complete irrigation cycle per zone. The value is typically calculated by dividing the average of the lower quartile of samples by the average of all the samples. Proper system design and installation, as well as regular maintenance, are necessary to achieve high DU. DU is evaluated at least once annually on all well-maintained systems.

Matched precipitation rates of sprinklers — the water volume applied per unit time, for example, gallons per minute — help achieve uniform distribution.

Water budgets compare the amount of water needed by the landscape to the amount of water actually applied. The CUWCC Landscape Irrigation Task Force recommends a site water budget that does not exceed 80 percent of ETo. Water bills should report the customer’s water budget and highlight excessive water use to call attention to the need for irrigation-system evaluation.

A site water budget is the sum of the water budgets for each of the zones served by the irrigation system. The budget calculation is:

$$0.8 \times (ET \times K_s \times K_m \times K_d \times Area) / \text{(Irrigation Efficiency)}$$

Where:

- ET is measured in inches of water per day, week, month, or year. The amount of irrigation water equals ET minus the effective rainfall.
- Crop or plant coefficient (Ks) is the relative ET for specific plant species. [Many plants do not have specific plant coefficients calculated for them, but are grouped together by horticulturists. A good resource for coefficients for plants other than turfgrass is WUCOLS, produced by the University of California Cooperative Extension (2000).]
- Area is the surface area of the irrigated landscape in square feet.
- Irrigation Efficiency (IE) is the percentage of applied irrigation water actually retained in the root zone. Irrigation efficiency decreases when water is lost due to runoff, when wind evaporates the water as it sprays from emitters, and when water sinks below the root zone due to deep percolation. Sprinkler efficiency may be as high as 70 percent. Drip irrigation systems
are rated at 85 to 90 percent efficiency. Irrigation efficiencies of 80 percent are usually considered good.

- Km is the microclimate factor, comparing local conditions to a standard ET reference site.
- Kd is canopy density, the percent of ground covered by foliage.

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Cost-Effectiveness Analysis

- Equipment Capital Costs: Cost of a low-pressure system is approximately 2/3 that of a high-pressure sprinkler system with the same controller. Costs vary depending upon the types of plants selected and the irrigation systems installed. A low-pressure drip system with water-thrifty plants may cost only 70 percent of a turf and sprinkler system (Santa Monica). Elsewhere water-efficient plants and sprinkler systems may cost $1.60 per square foot versus $0.80 per square foot for turf (Ash).
- Estimated Equipment Life: Ten years.
- Water and Energy Savings: A low-pressure system can be 15 percent more efficient in delivering the right amount of water to the right place at the right time. The annual water-cost saving of a low-pressure system, compared with a sprinkler system, is $135, given plants of the same Ks factor. Drip systems can be 90 percent efficient versus 75 percent efficiency for overhead sprinklers. For a 10,000-square-foot site, the same plant materials, and water costing $2.50 per Ccf, the low-pressure system saves $135 per year in water costs (0.65 AF for drip versus 0.79 AF for sprinklers).
- Incremental Cost per AF of Efficient Equipment: Lifetime water savings (equals annual water savings × life of systems) due just to the irrigation equipment is approximately 1.3 AF. Since the low-pressure system is less expensive than the sprinkler system, the payback for the less-expensive system is immediate. The annual operating and repair costs (water + maintenance — fertilizing, mowing, mulch replacement, irrigation parts repair/replacement, etc.) of the low-pressure system are less than for the sprinkler system by approximately $240, resulting in per AF benefit of $2,400 for the low-pressure system versus the sprinkler system.

References

_Water-Efficient Landscape Guidelines_
Bennett, R., and Hazinski, H. 1993. _Water-Efficient Landscape Guidelines_. AWWA.


Other References


City of Santa Monica. August 2006. Garden/Garden: A Comparison of Native and Traditional Gardens in Santa Monica.

City of Santa Monica. March 2006. Guide to Successful Drip Irrigation for Landscape Professionals.


Lower Colorado River Authority. 2007. LCRA Soil Depth and Soil Amendment Specifications—Background.


San Francisco Bay Regional Water Quality Control Board. Stormwater Program. www.waterboards.ca.gov/sanfranciscobay/programs.html#stormwater.


