Managing Use of Alternative Water for Irrigation

This is part of a two-course series on use of wastewater for irrigation. The course will focus on using municipal reclaimed water and greywater in landscape and industrial applications. These are:

Landscape Wastewater Irrigation I: Permitting of Alternative Water for Irrigation (8 hours)
Landscape Wastewater Irrigation II: Managing Use of Alternative Water for Irrigation (8 hours)

Wastewater Irrigation I Agenda

I. Introduction and Overview of Wastewater Reuse in Texas
II. Overview of Rules/Regulations
III. Permit Application Requirements
IV. Regulations on Use of Wastewater for Irrigation
V. Water Balance Calculations

Wastewater Irrigation I (Review)

Water Balance Calculations
- Evapotranspiration
- Effective rainfall
- Leaching requirement
- Water / irrigation requirement
- Conversion from “inches” to “gallons”

Wastewater Irrigation II Agenda

Consumptive Use Estimates
On-site storage of water
Special irrigation system design and management requirements
- Landscape Irrigation
- Agricultural Irrigation
Managing Water Quality
- Filtration & Chemigation
- Salinity Management
- Nutrient Loading
Irrigation Management
Wastewater Irrigation I
(Review)

30TAC Chapter 210 – Reclaimed Water and Graywater
30TAC Chapter 285 – On-Site Sewage Facilities (OSSF – “septic tank systems and other sewage on-site systems)
  • 285 (h) Disposal of Graywater
30TAC Chapter 344 – Landscape Irrigation

Reclaimed Water – Use in Irrigation

Providers are required to provide reclaimed water to users “on-demand” which eliminates the need for on-site storage or the application of water when it is not needed.

The user of reclaimed water must reasonably control application rates onto irrigation areas in order to ensure:
• the efficient use of reclaimed water and
• avoid excessive application of reclaimed water that results in surface runoff or excessive percolation below the root zone.

Providers and users must determine and document typical irrigation demands for the proposed use based on type of vegetation and land area to be irrigated (i.e., a water balance set of calculations)

The provider must conduct periodic audits of reclaimed water use. Water use records are required and submitted to the TCEQ periodically.

Reclaimed Water – Use in Irrigation

Provider and Users designing or operating an irrigation system using reclaimed water must ensure that reclaimed water overflow, crop stress, and undesirable soil contamination by salt does not occur.

Irrigation application rates and times must be developed so as to minimize “wet grass” conditions in unrestricted landscaped areas during the periods the area could be in use.

Spray irrigation systems must be designed to prevent water from reaching any privately-owned premises outside the designated irrigation area or public drinking fountains.

There shall be no application of effluent when the ground is water saturated or frozen.

Consumptive Use Estimates
Section 2: On-Site Storage of Reclaimed Water

Storage Considerations

May be a significant part of the design
Has a substantial impact on capital cost
Impacts operation and maintenance expenses
  - Especially if water is degraded due to storage and requires re-treatment before use (algae growth)
  - Design capacity must be sized for peak use and to prevent discharge

Typical Water Sources versus Treated Wastewater

Traditional water resources are used as both sources and storage facilities
- Groundwater
- Lakes
- Rivers

Treated wastewater is continuously generated. What cannot be used must be stored or disposed of in some manner.

Limited to No Storage in Dry Climates
Storage Needed in Wetter Climates

Average Monthly ET and Rainfall
College Station, Texas

Seasonal Irrigation Requirements
Potential evapotranspiration
Plant types
Average rainfall
Effective rainfall
Irrigation system efficiency
Leaching requirement

Volume of Water Required to Meet Irrigation Needs
Change “depth” to “volume”
Need total irrigated area (square feet)
Common English volumetric units:
• Gallons
• Cubic feet
• Acre-feet
• Acre-inch

Volume Conversion Factors
\[
\text{Gallons} = \text{Inches} \times \text{Acres} \times 43,560 \times 0.6234
\]
\[
\text{Gallons} = \text{Inches} \times \text{Square feet} \times 0.6234
\]
\[
\text{Cubic feet} = \frac{\text{Gallons}}{7.48}
\]
\[
\text{Acre-feet} = \frac{\text{Gallons}}{325,851}
\]
1000 Gallons = (Inches x Acres x 43,560 x 0.6234) / 1000

Acre-feet = (Gallons ÷ 325,851)

Storage Facilities

- Holding ponds
  - Golf courses
  - Large commercial properties

- Above-ground containers
  - Non-irrigation uses (dust suppression for road construction or gas/oil well locations)

Storage Pond Consideration

Typically have an aesthetic value

Need to maintain an “acceptable” water level – minimize too much drawdown

May be supplemented by rainfall runoff or other source (well)

Must be designed to prevent unauthorized discharge or deep percolation

Must be maintained to prevent excessive algae bloom
Storage Pond Capacity

Based upon depth, width, length and side slope

Generally over-designed to prevent excessive drawdown due to pumping

Water level maintained to prevent overflow from normal rainfall events

Storage from Runoff

Natural Resource Conservation Service (NRCS)

National Engineering Handbook-Hydrology Chapters


Engineering Spreadsheets


Drawdown from Storage Ponds

Irrigation requirement + surface evaporation

Depends upon the size of the pond

Dictates how often the pond must be refilled to maintain an acceptable level

Determining Drawdown from Irrigation

Scenario:

- In April, a 3-acre commercial property irrigates 2.5 inches during the week from a lined, rectangular-shaped storage pond.
- The storage pond is 100 feet wide by 300 feet long.
- Assuming no rainfall, how far will the water level fall each week due to irrigation?
Weekly irrigation = 2.5 in/12 x 3 acres x 43,560 sqft/acre
Weekly irrigation = 27,225 cu ft
Drawdown = 27,225 cu ft / 30,000 sqft = 0.91 feet (10.9 inches)

+ surface evaporation from storage pond

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**Surface Evaporation**

Texas Water Development Board maintains record of monthly and annual Gross Lake Evaporation Rates for Texas
- Database contains monthly, yearly and historical average from 1940-2014

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TWDB: Historic Evaporation for Texas Quadrangles. 1954 - 2007
### Lake Evaporation (inches)

#### Average Monthly Lake Evaporation (inches)

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#### Annual Evaporation Statistics

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### Weekly Irrigation Drawdown

- **100 feet**
- **300 feet**

Surface Area = 30,000 sqft

- Weekly irrigation drawdown = **10.9 inches**
- Storage pond evaporation drawdown = **1.22 inches**

Total drawdown = **12.12 inches (~ 1 foot)**

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### Pumping Water From Storage
Pumps

Irrigation Systems require pressure to operate correctly
Gravity alone from on-site storage may not produce the minimum pressure to operate the irrigation system

Centrifugal Pump, often referred to as "booster pumps" are the most common means to add pressure to the irrigation system

Centrifugal Pumps

Cross-section of a centrifugal pump

Centrifugal pump setting components
Centrifugal Pumps

Centrifugal Pumps
- Pull water (suck) not push
- Often used for pumping surface water
- Such as from ponds, rivers or storage tanks
- Requires careful design consideration when sizing
  - Need to know the pumps pulling capacity and pushing referred to as "Head Requirement"
- Often are used to boost pressure in irrigation systems
- Flexible to Power Units
  - Electric Motors, Diesel Engines, Tractor PTO

Typical mounting positions for horizon centrifugal pumps:
- (a): located above the water surface;
- (b): located below the water surface, the pump does not require priming prior to start.

Selecting Pumps Example
Use the Pump Curve to select a pump to produce 55 PSI and 12 GPM
Section 3: Special Irrigation Design and Management Requirements in Landscape Irrigation

Emission Devices
- Spray Heads
- Rotary Heads
  - Single Stream
  - Multi Stream
- Impacts
- Bubblers
- Drip

Spray Heads
Spray Heads

Conventional preset spray patterns
- such as 45, 90, 180, 270, 360 degrees
Most manufacturers have adjustable arc nozzles
Have a high precipitation rate
Work best in smaller areas and areas with tight, curving edges
Highly susceptible to misting under high pressure

Rotary Heads

Can rotate from 1 to 360 Degrees
Have a lower precipitation rate than sprays
Easily adjusted for different flows by changing nozzles
Good for irrigating larger areas
- Golf courses, sports fields & parks

Rotors – Single Stream

Rotors – Multi Stream
Impacts
Sprinkler which rotates using a weighted or spring loaded arm which is propelled by the water stream and hits the sprinkler body, causing movement.
- Usually arc pattern is 40-360 degrees
- Covers large areas
  - 20 – 150 feet
- Precipitation rate varies considerably
  - 0.1 – 1.5 inches per hour

Impacts – Common Heads

Bubblers
Water emission device that tends to bubble water directly to the ground or that throw water a short distance.
Drip Products – Drip Tubing with Embedded Emitters
Durable thick-wall tubing
Typically has pressure-compensating embedded emitters
Use in beds and turf applications

Drip Tubing Under Turf
Follow manufacture’s guides for recommendations on product spacing and emitter flow rates

Texas Commission on Environmental Quality
LANDSCAPE IRRIGATION DESIGN RULES

TCEQ Definition: Design
The act of determining the various elements of a landscape irrigation system that will include, but not limited to, elements such as:
- Collecting site specific information
- Defining the scope of the project
- Defining plant watering needs
- Selecting and layout out emission devices
- Locating system components
- Conducing hydraulics calculations
- Identifying any local regulatory requirements
- Scheduling irrigation work at a site
Minimum Design and Installation Requirements

Defined by TCEQ Chapter 344.62

- No irrigation design or installation shall require the use of any component, including the water meter, in a way which exceeds the manufacturers published performance limitations for the component
- Be familiar with manufacturers product literature

Spacing

- Must not exceed manufacturers published radius or spacing of a device
- No above ground spray devices in areas less than 48 inches
  - Many ordinances exceed this
- Some areas may be exempt if the runoff drains into a landscaped area

Square Layout

Triangular Layout
Square Vs Triangular Spacing

Square Layouts
- Best for defined geometric spaces such as square or rectangular shaped fields or landscapes

Triangular Layouts
- Often work better in areas that are irregular in shape and where overthrow is not an issue
- Most adaptable to curved or circular areas

Minimum Design and Installation Requirements

Water Pressure
- Must operate at the minimum and not above the maximum based on the nozzle and spacing used

Piping
- Designed not to exceed 5 ft/s for PVC pipe

48 Inch Rule, 5ft Rule

Example: the landscape between roads and sidewalks

Determining Pressure

Pressure Gauges (either Static or Dynamic)
How is pressure created?

Weight of the Water (Gravity)
Mechanical Means (Pump)

Relationship between PSI & Feet of Head

1 PSI = 2.31 Feet of Head
1 Foot of Head = 0.433 PSI
Minimum Design and Installation Requirements

Irrigation Zones
- Irrigation system shall have separate zones based on:
  - Plant Material Type
  - Microclimate Factors
  - Topographic Features
  - Soil Conditions
  - Hydrological requirements
- Often referred to as “hydrozones”

Pressure Regulators

Some systems require pressure regulators to achieve manufacturers recommended pressure requirement
Some devices have pressure regulators built in

How many zones?
Zoning

Poor designs will often have multiple zones located within a station
- Example
  - Irrigating shrubs, flowers and turf on the same zone
- Often results in something being over or under watered

Zoning

Characteristics of a poorly zoned landscape:
- Impractical turf areas
- Impractical shrub or tree plantings

Zoning

Often established plants (non-turf) can be zoned into one of 3 categories
- Frequent Watering
  - Annual Flowers
- Occasional Watering
  - Perennial Flowers, groundcovers, tender woody shrubs and vines
  - Natural Rainfall
  - Tough woody shrubs and vines, shade trees

Minimum Design and Installation Requirements

Matched Precipitation Rate
- Zones must be designed so all devices in the zone irrigate at the same precipitation rate
Minimum Design and Installation Requirements

Overspray
- Cannot spray over surfaces made of:
  - Concrete
  - Asphalt
  - Brick
  - Wood
  - Stone set in mortar
  - Or any other impermeable material (walls, fences, sidewalks, streets, etc.)

Special Design Considerations for Alternative Water Sources

Design of Irrigation Systems

Hydraulics (pipe sizing) for treated wastewater is no different than with typical water sources
- Based upon flow rate, pressure and friction loss

Special design requirements for:
- Pipe material (color)
- Backflow prevention devices
- Valves
- Filters and screens
- Application devices

Design of Irrigation Systems

Special design requirements for:
- Pipe separation from potable lines
- Pipe separation from sewer lines
- Covers and caps for valve boxes, meter boxes and application devices
- Restricted access to system components
- Public awareness and safety
Management of Irrigation Systems

Special emphasis on:
- Preventing runoff into State waters (streams, rivers, lakes, etc.)
- Avoiding irrigation during wet or saturated conditions
- Managing irrigation applications to prevent soil contamination buildup
- Preventing foliar damage to landscape plants

Major Irrigation Issues Regarding Reclaimed Water

- Survey of 487 golf course superintendents
- 150 respondents, 40 currently use reclaimed water
- Purpose was to obtain a better perspective of issues associated with reclaimed water use for landscape irrigation

Major Irrigation Issues Regarding Reclaimed Water

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<td>2</td>
<td>2</td>
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Source: (Dixon, 2008)

Regulations

The Office of Water at the Texas Commission on Environmental Quality permits and governs the use of reclaimed water in Texas
Regulatory Requirements

Chapter 210 – Use of Reclaimed Water
- Pipe:
  - Buried pipe installed after February 12, 1997 must be:
    - Manufactured in purple
    - Painted purple
    - Taped with purple metallic tape
    - Bagged in purple
  - Exposed pipe should be stenciled in white with the words “NON-POTABLE WATER”
  - All exposed and buried reclaimed water pipes at a wastewater treatment facility is exempt from the color coding requirements
  - Color coding also applies to graywater

Piping

Purple Piping
Pipe Sleeves

Regulatory Requirements

Chapter 210 – Use of Reclaimed Water
- Pipe separation:
  - Must be separated from potable water piping by a horizontal distance of 9 feet (exemptions exist)
  - Must be separated from sewer lines by a horizontal distance of 3 feet with the reclaimed water line at the level or above the sewer line
  - Where a reclaimed water line crosses a sewer line, the reclaimed water line must be at least 2 feet above the sewer line

Hose bibs:
- All hose bibs and faucets must be painted purple
- Must be designed so that they prevent connection to a standard water hose
- Must be located:
  - Below ground
  - In vaults
  - Locked
  - Labeled as non-potable
- Exception: Above-ground non-lockable service boxes are allowed if they can only be operated with special tools
Regulatory Requirements

Chapter 344 – Landscape Irrigation
Reclaimed Water
- Definition: Domestic or Municipal water which has been treated to a quality suitable for beneficial use, such as landscape irrigation.

Non-Potable Water
- Definition: Water that is not suitable for human consumption. Includes irrigation systems, lakes, ponds, streams, gray water, water vapor condensate, reclaimed water and harvested rainwater

Valves

Constructed with materials that withstand high chlorine and other harsh chemicals - chemical resistant components
- Diaphragms reinforced to protect against corrosion
- Stainless steel, self-flushing filter screens
- Purple handles for easy identification
- Lockable valve boxes to prevent unauthorized operation

Application Devices

Purple ID caps and covers for conventional rotors and spray heads
- Check valves reduces low-head drainage
- Low angle nozzles minimizes spray drift
- Filters prevent clogged nozzles

Backflow Prevention Devices

The domestic potable water line must be connected using an air gap or a reduced pressure principle backflow prevention device
- Backflow prevention on the reclaimed water line must follow water purveyor regulations
- Check with local water utility for rules on cross connection of water to other wastewater sources, if allowed

30TAC Chapter 344.65 – Reclaimed Water
Public Safety and Awareness

The irrigation system may not spray water across property lines.
An minimum 8”x8” sign must be displayed in English and Spanish in the area being irrigated and stored. It must read:

“RECLAIMED WATER – DO NOT DRINK” and
“AQUA DE RECUPERACION – NO BEBER”

3OTAC Chapter 344.65 – Reclaimed Water

Public Safety and Awareness

There can be no contact with edible crops, unless the crop is pasteurized before consumption.
Application rates and times must be managed so as to minimize “wet” grass conditions in unrestricted landscaped areas.
Irrigation spray must not reach public drinking fountains.

Environmental Protection

Must ensure that reclaimed water overflow, crop stress, and undesirable soil contamination by salt does not occur.
The irrigated property must be maintained with vegetative cover at all times when reclaimed water is used.
Reclaimed water must not cause a nuisance, degrade groundwater quality, or be discharged into State waters.
Special Management Needs

Periodic soil and water tests to track levels of salinity and other constituents
Leaching to remove salt accumulation
Plant evaluation for foliar toxicity
Advanced irrigation scheduling methods and tools
Documentation of irrigation use, water quality and soil quality
System audits, filter cleaning and routine maintenance

Special Considerations

Corrosion

Definition:
The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties

Piping

Poly Liners for metal pipes with corrosive water
- Ex. Valley Irrigation - PolySpan
Top 10 List! Landscape Irrigation Problems

**#10 Over-Reliance on Drip Irrigation**

Drip Irrigation receives a lot of publicity for its “efficiency” and water conservation potential. However, many drip irrigation systems are:

- Poorly Designed
- Improperly Installed
- Poorly Maintained
- Excessive runtimes
#9 Irrigating Hardscapes
Misaligned Sprinkler
- Adjust Pattern or Rotation
Poor Design
- Not following spacing rules??

#8 Broken/Leaking Sprinkler Heads
Sprinklers may be operating when no one can see them
Broken heads loose 5-10 gallons per minute minimum!

#7 Runoff
Often Result of Too Long of Runtimes
- No Cycle Soak
- Rest time not long enough
- Precipitation Rate greater than Infiltration Rate

#6 Mixing Irrigation Zones
Mixed plant type
- Shrubs and Grass mixed
- Shrubs and Flowers mixed
Mixed sprinkler type
- Sprays and Rotors
- Sprays and Drip
Different plants have different Water Requirements!
State Regulations since 2009
#5 Missing, Misplaced or Broken Rain Sensor

No rain shut-off device:
- Irrigating when raining or following rainfall

Device not installed in proper location or maintained
- Controller is in sensor bypass mode
- Damaged sensor or sensor wires
- Sensor required on all new systems installed after 2009

#4 Lack of Pressure Regulation

Too Much Pressure
- Misting: 30-50% lost to wind and evaporation
- Can increase water use by as much as 20%

Low pressure limits coverage and decreases uniformity

#3 Lack of Regular Inspection and Maintenance

Sunken Heads
Cracked/Broken Heads/ Nozzles
Holes cut/chewed in drip hose
Solenoid valves not working properly

#3 Lack of Regular Inspection and Maintenance (cont.)

Backup battery dead-reverts to default program
- Wrong Day or Time of Day Irrigation?
Sprinkler heads or nozzles misaligned
Clogged Nozzles
#2 Improper Controller Programming

Not knowing how to program
No Seasonal changes
Same runtime for all zones?
  - No accounting for microclimates, precipitation rates, soil types, slope, plant water needs

#1 Poor Irrigation System Design

No Head to Head Coverage
Combining different microclimates into one zone
Improper sprinkler head installation techniques

Homeowners: not knowing the difference between start times and programs
  - Why is start time off??
  - Why are there 5 start times?
#1 Poor Irrigation System Design

Irrigation Top 10 Problems
1. Poor Irrigation System Design
2. Improper Irrigation Controller Programming
3. Lack of Regular Inspection & Maintenance
4. Lack of Pressure Regulation
5. Missing, Misplaced, Broken Rain Sensor
6. Mixed Irrigation Zones
7. Runoff
8. Broken/Leaking Sprinkler Heads
9. Irrigating Hardscapes
10. Over-Reliance on Drip Irrigation

Considerations for Large Turf Areas
Large Turf Landscape Areas

Large Turf areas are often ideal landscapes to use Reclaimed and alternative water supplies
- Golf Course
- Sports Complexes
  - Football, Soccer, Baseball, etc.

Irrigation Design and Management can vary for large turf landscape areas
- Use of Larger Sprinklers such as Impacts to cover more area
- Sprinkler layout
- Controller Operation – managing flow and pressure

Considerations for Large Turf Areas

Irrigation Blocks vs Valve in Head Management
- Irrigation Blocks – 1 Valve controls multiple sprinkler heads
  - Designed for a target flow and pressure
- Valve in Head – Each Sprinkler head has its own control valve.
  - More wiring, managing available flow and pressure

Runoff
- Large Turf areas like golf courses often have a mix of sloped to flat areas
- Sports Fields and Golf Course often use larger sprinklers

Sprinkler layouts – Square vs Triangular Design

Irrigation of the Critical/Target Areas
Other Irrigation Options

IRRIGATION TECHNOLOGIES

Other Irrigation System Options

Most likely to be used in Industrial wastewater reuse and for use in agriculture
- Center Pivots/Linear Move Systems

Less Frequently Used
- Solid set
- Surface Irrigation
  - Basin
  - Furrow
  - Drip

Center Pivot Terminology – water application systems

On top of mainline (least efficient)
- MESA
- LESA
- LEPA (most efficient)

On top of main line
MESA (medium elevation spray application system)

LEPA (low energy precision applicators)

MESA

LEPA with alternate row furrow dikes
Terminology – water application systems

- On top of mainline
- MESA
- LESA
- LEPA
- Above-canopy
- In-canopy
- Close drop spacing (with either LESA or LEPA)
Pivot Design Key Points

1. Actual lowest and highest elevations in field with relation to the pivot point were used in the computer design printout.

2. Actual measured flow rate and pressure available from pump or water source was used in the computer design printout.

3. Friction loss in pivot mainline is no greater than 10 psi for quarter-mile long systems.

4. Mainline outlets are spaced a maximum of 60 to 80 inches apart or, alternately, no farther apart than two times the crop row spacing.

Accessories

Propeller flow meter or other type of flow measurement device having accuracy to ± 3 percent.

- Reads flow rate (i.e., gpm) and total gallons
- The flow meter should be installed in a long straight section of pipeline at least 10 pipe diameters upstream and 5 pipe diameters downstream from any changes in pipeline.

System includes two pressure gauges, one on the mainline near the pivot point and one in the last drop,

Pivot Design

5. For non-leveled fields, less than 20 percent pressure variation in system-design operating pressure is maintained when pivot is positioned at highest and lowest points in the field (computer design printout provided for each case).

6. Pressure regulators were evaluated for fields with more than 5 feet of elevation change from pad to the highest or the lowest points in the field.

7. Tower wheels and motor sizes were selected based on soil type and slope following manufacturers’ recommendations.

8. Dealer has provided a copy of pivot design printout.
Surface Irrigation

"Flood Irrigation"

Field Layout
- Land Leveling
- Furrow Length

Irrigation Management
- Cut-Back irrigation
- Tailwater management
Furrow Irrigation

- NRCS (Natural Resources Conservation Service), an agency of the USDA, has developed the design guidelines for furrow irrigation
- Check with your regional NRCS office or with the NRCS state headquarters in Temple, Texas
  https://www.nrcs.usda.gov/wps/portal/nrcs/site/tx/home/

Basin Irrigation Systems

Good resource:
http://www.fao.org/3/S8684E/s8684e03.htm
Sprinkler Packages
Solid Set

Merry Christmas Tree Farm – a choose and cut operation. Occasional irrigation, no pipes or sprinklers in field when public comes.

Big gun

Big gun – travelers (reel-move)
Big Gun Performance Guide

Drip Irrigation

Managing Water Quality

Filtration
Chemigation
Salinity Management
Soil Sampling & Nutrient Loading
Irrigation Filtration

Water quality is the determining factor in choosing the proper filtration equipment
Is the water pumped under pressure directly from a supply line or is the water temporarily stored on site?
Common concerns for irrigation systems:
- Algae
- Suspended solids
- Pipe debris
- Sand

Screen Filters

Most common and least expensive
Used primarily to remove hard particulates from water, such as sand
Not effective at removing
- Algae
- Mold
- Slime
May be removed and cleaned by hand
Some models can be flushed by backwashing

Media Filters

Cleans water by forcing it through a container filled with a small, sharp-edged “media” (commonly sand)
Effective at removing organic material (algae, slime, etc.)
Common method for cleaning water at a high volume from rivers and ponds
Cleaned by backwashing
Must be properly sized to system flow rate

Disk Filters

Consist of a stack of round disks covered with various sizes of small bumps with sharp points
Particulates are filtered by the small openings
Organic matter is snagged by the sharp edges
Disks may be cleaned automatically or may be moved and cleaned by hand
Centrifugal Filters (sand separators)

Used primarily for removing particulates such as sand

“Dirty” water is pumped into the filter where centrifugal force causes sand to move to the outside edge of the filter. Sand then slides down the outside edge to a holding tank at the bottom

Commonly used to filter well-water

May require additional downstream filtration depending on the application

How much filtration do you need?

Depends upon:
- Type of irrigation system you have
  - Drip
  - Spray
- Emitter orifice size
- Allowable pressure loss through system
- Durability, construction, and quality of solenoid valves
  - Small sand grains are a common source of valve failure
  - Savings in valve repairs can pay for the extra cost of a filter in a short period of time

Approximate Filter Size Equivalents

<table>
<thead>
<tr>
<th>Micron</th>
<th>mm</th>
<th>Mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>0.8</td>
<td>20</td>
</tr>
<tr>
<td>500</td>
<td>0.5</td>
<td>30</td>
</tr>
<tr>
<td>300</td>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>250</td>
<td>0.25</td>
<td>60</td>
</tr>
<tr>
<td>200</td>
<td>0.2</td>
<td>75</td>
</tr>
<tr>
<td>180</td>
<td>0.18</td>
<td>80</td>
</tr>
<tr>
<td>150</td>
<td>0.15</td>
<td>100</td>
</tr>
</tbody>
</table>

“Mesh” is based upon the number of wires in 1 linear inch of the screen.

Drip product manufacturers will specify the level of filtration required.

Chemigation

General term that includes:
- Fertigation
- Insectigation
- Fungigation
- Nematigation
Advantages of Chemigation

Uniformity of application
Precise application
Economics
Timeliness
Reduced soil compaction and plant damage
Operator safety

Disadvantages of Chemigation

High management
Additional equipment
Must calculate injection rates and volumes

Chemigation and Regulations

General Classes
- Controlled Substances
- Pesticides and Herbicides
- Fertilizers and Nutrients
- Drip Maintenance/Clogging Control Chemicals
  - Chlorine and Acids

Chemigation Injectors and Pumps

The most common types:
Mechanical
- Piston (positive displacement) pumps
- Diaphragm pumps
- Venturi meters
Piston/Positive Displacement Pumps

Uses a “piston” to inject chemical into the irrigation water

Rate is determined by the
  - length of the stroke
  - number of strokes per minutes

Chemicals come into contact with piston, so materials should be matched

Piston/Positive Displacement Pumps

Injection rate remains constant and does not change if the irrigation pipeline pressure varies

Injection rates cannot be adjusted while operating
Commonly used to inject fertilizer (large rate injection)

Diaphragm Pumps

a membrane separates chemical from the drive mechanism (piston)

Easy to adjust flow rate while operating
Commonly used for low-rate injection (pesticides, etc.) or continuous injections (chlorine or acid to lower pH)

Easy to calibrate and maintain
Diaphragm Pump

Venturi Meters

Simple device with no moving parts

The meter used a reduced diameter throat tube (or a tube with a needle valve or orifice plate)

Velocity changes in tube create vacuum to pull chemical into stream

Venturi Meters

• Most low-end venturi injectors are not adjustable and have a constant proportion injection rate such as 1:50
  (one gallon injected for every 50 gallons flowing through meter)
Chlorine

Injected to control biological clogging of lines and emitters
Household bleach is often used in small systems (5.25% chlorine)
Higher concentrations (up to 100 ppm) if iron bacteria and/or organic matter are problems

Chlorine

Chlorine concentration at the end of the drip line should be:
- 1 to 2 ppm for occasional treatment
- 0.5 to 1 ppm for continuous treatment
Begin with a low concentration (5 ppm to 10 ppm) for one hour

Acid Injection

Acid is injected to control mineral clogging of emitters
Water with a high pH (>7.5) or "moderate" to "hard water" (>60 ppm Ca) more likely to cause problems

Acid Injection

98% sulfuric acid is commonly used in drip irrigation
Citric acid or vinegar can be used in organic farming
Titration can be used to determine concentration of acid need
(adding acid to a sample of the water to see how much is required to lower pH)
Acid Injection

Experimentation is used in absence of titration
Acid is injected until pH is lowered to 6.5
(measured at end of drip line)
Higher concentrations are added if needed, lowering pH to as low as ~4
Acid is corrosive – inject downstream of filter if made of metal

Calculations Injection Rates

Calculate injection rate based on concentration (ppm) of solution to be injected

\[ IR = (0.006 \times F \times C) + P \]

**IR** = injection rate (gal/hr)
**F** = flow rate of irrigation system (gal/hr)
**C** = concentration of chemical wanted (ppm)
**P** = Percentage of chemical in solution

Chemigation Calculations - Example 1

I want to inject chlorine at a concentration of 5 ppm for one hour.
My irrigation system has a flow rate of 100 gpm, and I’m using household bleach (5.25% chlorine)

\[ IR = (0.006 \times 100 \times 5) = 0.571 \text{ gal/hr of bleach} \]

**IR** = injection rate (gal/hr)
**F** = flow rate of irrigation system (gpm)
**C** = concentration of chemical wanted (ppm)
**P** = Percentage of chemical in solution

Chemigation Calculations - Example 2

Determining amount of solution for fixed ratio injectors

For example 2, my venturi injector has a 100:1 ratio
(injecting chlorine at a concentration of 5 ppm for one hour, a flow rate of 100 gpm, and using household bleach)

\[ IR = 0.571 \text{ gal/hr of bleach} \]

Step 1: Calculate total flow of irrigation system in one hour
100 gpm x 60 min/hr = 6000 gallons per hour

Step 2: Calculate total gallons of solution to be injected
(divide Step 1 by ratio)
6000 gph x 100 = 60 gallons of solution

Step 3: Mix the 0.571 gallons of bleach with 60 gallons of water in the injection tank
Managing Saline and Sodic Soils

Why is salinity important?
Most common problem associated with irrigating with treated wastewater
Can be toxic to some “salt-sensitive” plants
Can cause surface sealing of soils, decrease infiltration and increase runoff
Can accumulate in the soil, reduce plant productivity, and make plants more prone to disease
Can damage and corrode equipment

Inorganic Salts
Anions (- charge)
- Carbohydrates
- Chlorides
- Sulfates
- Nitrates
- Phosphates
Cations (+ charge)
- Potassium
- Magnesium
- Calcium
- Sodium

Dissolved Salts in Irrigation Waters

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride</td>
<td>NaCl</td>
</tr>
<tr>
<td>Sodium sulfate</td>
<td>Na₂SO₄</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>Calcium sulfate (gypsum)</td>
<td>CaSO₄</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>MgCl₂</td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>MgSO₄</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>KCl</td>
</tr>
<tr>
<td>Potassium sulfate</td>
<td>K₂SO₄</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>NaHCO₃</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td>Na₂CO₃</td>
</tr>
<tr>
<td>Borates</td>
<td>BO⁻³</td>
</tr>
<tr>
<td>Nitrates</td>
<td>NO⁻³</td>
</tr>
</tbody>
</table>

Adapted from Table 1 (Fipps, 2003)
Salinity (continued)

Water salinity is usually measured by:
- EC (electric conductivity) or
- TDS (total dissolved solids)

High salt concentrations:
- Can be toxic to plants as they absorb through leaf tissue
- Sensitivity levels differ significantly among plants
- Can accumulate in surface soils
  - Surface sealing
  - Reduced infiltration and drainage
  - Reduce water uptake in plants by lowering the osmotic potential of the soil

(Saengpuntiphat, 2009)

Salinity Sources

Non-point sources
- Underlying geologic formations
  - Ancient marine sediments
- Erosion and weathering of sedimentary rocks
- Groundwater intrusion
- Arid and semi-arid regions (high evaporation)
- Precipitation (trace amounts)
- Agricultural and urban water runoff and sediment displacement

Salinity Sources

Point sources
- Residential
  - Water softeners
- Detergents and cleaners
- Commercial
  - Car-wash bays (detergents)
- Industrial
  - Food processing (cleaning agents and preservatives)
- Water and wastewater treatment processes

(Saengpuntiphat, 2009)

Salinity

Salts in treated wastewater originate from:
- Elemental ions naturally found in water
- Ions retained in dissolved form after separation of solids during the treatment process
- Salts added during the treatment process

Water salinity is usually measured by:
- EC (electric conductivity) or
- TDS (total dissolved solids)
Electrical Conductivity (EC)

EC is a measure of the flow of electrical current in water. The more ions (salts), the higher the EC. Measured in units of:
- deci-Siemens per meter (dS/m), or
- milli-mhos per centimeter (mmhos/cm)

1 dS/m = 1 mmhos/cm

(Fipps, 2003)

Total Dissolved Solids (TDS)

Measured by allowing a sample of water to evaporate and then weighing the remaining solids (salts). TDS is usually reported in:
- milligrams of solids per liter of water (mg/L), or
- parts per million (ppm)

1 mg/L = 1 ppm

(Fipps, 2003)

Equivalency of EC and TDS

EC can be used to approximate TDS using the following equation:

TDS (mg/L or ppm) = EC (mmhos/cm or dS/cm) x 640

(Fipps, 2003)

Effects on Plants

Plants vary in their “sensitivity” and “tolerance” to salinity. Short-term effects:
- Leaf tip and marginal leaf burn
- Bleaching (discoloration)
- Defoliation

Long-term effects:
- Decreased osmotic pressure – water flows out of the plant to achieve equilibrium
Foliar Salt Damage

Increases with higher salinity concentrations in irrigation water

Plants more susceptible to damage if irrigation is:
- Applied during high ET hours
- Applied overhead (foliar spray)
- Applied frequently in light amounts

(Miyamoto, 2002)

Relative Tolerances of Common Turfgrass Species to Soil Salinity

<table>
<thead>
<tr>
<th>Sensitive (&lt;3 dS/m)</th>
<th>Moderately Sensitive (3 to 6 dS/m)</th>
<th>Moderately tolerant (6 to 10 dS/m)</th>
<th>Tolerant (&gt;10 dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual bluegrass</td>
<td>Annual ryegrass</td>
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<td>Bermudagrasses</td>
</tr>
<tr>
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<td>Fine-leaf fescues</td>
<td>Zoysiagrasses</td>
<td>Seashore paspalum</td>
</tr>
<tr>
<td>Rough bluegrass</td>
<td>Buffalograss</td>
<td></td>
<td>St. Augustinegrass</td>
</tr>
</tbody>
</table>

Adapted from Table 2 (Harivandi, 1999)

Effects on Soils

Surface sealing
- Phenomenon occurs when salts “precipitate” on the surface of the soil as water evaporates, leaving the surface in an impermeable, crust-like state
- Drastically reduces infiltration rate
- As water ponds, then evaporates, salt accumulation continues
- Common in arid southwestern U.S.

Effects on Soils

Root zone accumulation
- High salinity concentrations around plant roots can dehydrate plants by reversing osmotic conditions
- Water will flow out of the plant in an attempt to achieve equilibrium
- Can disrupt normal nutrient uptake of the plant
Effects on Plants

The rate of salt accumulation in the soil depends upon:
- Concentration in the irrigation water
- The amount of water applied
- Precipitation patterns
- Evaporation rates
- Soil condition (texture/structure/compaction)
- Chemical characteristics

Effects on Receiving Waters

Runoff containing high salt concentrations can create saline layers in receiving waters (lakes, ponds, etc.)

Saltwater has a higher density than freshwater, thus sinks to form a dense layer at the bottom – "hypolimnion"

The saline layer does not mix with the remainder of the lake, decreasing the dissolved oxygen levels in the hypolimnion

Permissible Limits for Irrigation Water

<table>
<thead>
<tr>
<th>Classes of Water</th>
<th>Concentration, total dissolved solids</th>
<th>Gravimetric (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>250 - 750</td>
<td>175 - 525</td>
</tr>
<tr>
<td>Good</td>
<td>250 - 2,000</td>
<td>175 - 1,400</td>
</tr>
<tr>
<td>Permissible¹</td>
<td>2,000 - 3,000</td>
<td>525 - 2,100</td>
</tr>
<tr>
<td>Doubtful²</td>
<td>3,000</td>
<td>1,400 - 2,100</td>
</tr>
<tr>
<td>Unsuitable²</td>
<td>3,000</td>
<td>2,100</td>
</tr>
</tbody>
</table>

¹Leaching needed.
²Good drainage needed and sensitive plants will have difficulty

Adapted from Table 4 (Fipps, 2003)

Sodium Effects on Plants

Most plants take up sodium through their roots where it accumulates in the leaves

Some plants absorb sodium through leaf surfaces

Sodium accumulation is some plants results in marginal scorching and defoliation

Because turfgrasses are mowed frequently (removing leaf tissue) sodium accumulation is usually not a problem
Sodium Accumulation in Soils

Excess sodium can lead to a breakdown of clay particles in the soil (deflocculation)
- Clogs the soil’s pore spaces
- Reduces air movement
- Reduces percolation rates

Generally a problem in clay and loam soils
A black crust on the soil surface is one sign of a sodic soil

Sodium Adsorption Ratio (SAR)

Used to determine the likelihood that sodium present in irrigation water will affect soil permeability
Dependent upon the water’s:
- Sodium concentration (Na)
- Ca concentration (Ca)
- Magnesium concentration (Mg)

Ca and Mg tend to counter the effects of Na

Example: SAR

\[
SAR = \sqrt{\frac{Na^+}{Ca^{++} + Mg^{++}}} \]

\(Na^+ = 13 \text{ meq}\)
\(Ca^{++} = 150 \text{ meq}\)
\(Mg^{++} = 83 \text{ meq}\)

\[
SAR = \sqrt{\frac{13}{150 + 83}}\]
\[
SAR = 1.2
\]
### Sodium Hazard of Water

<table>
<thead>
<tr>
<th>SAR Values</th>
<th>Sodium Hazard of Water</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 10</td>
<td>Low</td>
<td>Use caution on sensitive plants</td>
</tr>
<tr>
<td>10 – 18</td>
<td>Medium</td>
<td>Amendment/leaching needed</td>
</tr>
<tr>
<td>18 – 26</td>
<td>High</td>
<td>Generally unsuitable for continuous use</td>
</tr>
<tr>
<td>&gt;26</td>
<td>Very high</td>
<td>Generally unsuitable for use</td>
</tr>
</tbody>
</table>

Adapted from Table 5 (Fipps, 2003)

### Interaction of Salts and Sodium

Salts and sodium do not act independently in soil.

The negative effects of soil particle dispersion (permeability) are counteracted by high soluble salt concentration.

Access water’s sodium hazard in conjunction with salinity levels.

### Interpreting Na Effect on Soil Infiltration

<table>
<thead>
<tr>
<th>Soil Infiltration</th>
<th>Degree of restriction on use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>If SAR = 0 to 3 &amp; ECw =</td>
<td>&gt; 0.7</td>
</tr>
<tr>
<td>If SAR = 3 to 6 &amp; ECw =</td>
<td>&gt; 1.2</td>
</tr>
<tr>
<td>If SAR = 6 to 12 &amp; ECw =</td>
<td>&gt; 1.9</td>
</tr>
<tr>
<td>If SAR = 12 to 20 &amp; ECw =</td>
<td>&gt; 2.9</td>
</tr>
<tr>
<td>If SAR = 20 to 40 &amp; ECw =</td>
<td>&gt; 5.0</td>
</tr>
</tbody>
</table>

SAR = Sodium absorption ratio  
ECw = Electrical conductivity (dS/m)

Adapted from Table 3 (Harivandi, 1999)

### Management Strategies

- Leaching
- Deep-tine aeration
- Gypsum applications
- Salt-tolerance plants
- Acid-based water treatment
- Irrigation design
- Irrigation scheduling
- Water and soil quality monitoring
Leaching
Additional water applied in excess of plant water needs for the purpose of flushing soluble salts beyond the plant’s root zone
Basic management tool for controlling salinity
Leaching amounts and intervals depend upon the severity of the salinity problem and salt tolerance of the plant
In some regions, normal rainfall provides adequate leaching

Leaching Fraction
Leaching fraction is an addition amount of irrigation needed to flush salts beyond the root zone

\[ L = \frac{C_e}{C_l - C_e} \]

- \( C_e \) = Electrical conductivity of the irrigation water (or effluent) (mmhos/cm or dS/m)
- \( C_l \) = Maximum allowable conductivity of soil solution (mmhos/cm or dS/m)

Relative Tolerances of Turfgrass Species to Soil Salinity (C)

<table>
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<tr>
<th>Sensitive (&lt;3 dS/m)</th>
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<td></td>
</tr>
</tbody>
</table>

Adapted from Harivandi, 2009.

Calculating Leaching Fraction
Given:
- Electrical conductivity of irrigation water (effluent) = 2.0 dS/m
- Annual ryegrass (maximum allowable conductivity of soil solution) = 6 dS/m

Find:
- Leaching fraction
Calculating Leaching Fraction (continued)

\[
L = \frac{C_e}{C_i - C_e}
\]

L = Leaching requirement (inches)

\[
C_e = 2.0 \text{ dS/m}
\]

\[
C_i = 6 \text{ dS/m}
\]

Calculating Leaching Fraction

\[
L = \frac{C_e}{C_i - C_e}
\]

\[
L = \frac{2.0}{6 - 2.0}
\]

\[
L = 0.5
\]

Leaching fraction = 0.5 (50%)

Leaching Requirement

\[
L = \frac{C_e}{C_i - C_e} \times ET
\]

ET = plant evapotranspiration (inches)

Leaching Requirement

Weekly ET = 1 inch

Leaching fraction = 0.5

\[
L = \frac{C_e}{C_i - C_e} \times ET
\]

\[
L = 0.5 \times 1
\]

Leaching requirement = 0.5 inches
Bringing it together ...

**Irrigation requirement** = (Plant ET + Leaching)

Weekly ET = 1 inch
Weekly leaching = 0.5 inch
Irrigation requirement = 1.5 inches

---

Aeration

Physical process of creating holes in the soil to allow better infiltration and air movement through the soil surface layer

Aeration Methods:
- Hollow tines – remove cores
- Open spoons
- Spikes
- Deep-tines – (coring, spiking, drilling)
- Water injection systems
- Soil shattering units

---

Gypsum Applications

Calcium Sulfate - CaSO₄
Ca replaces Na on clay soil particles improving structure, infiltration and air movement

Improvement in soil condition may take several years

---

Irrigation Design

Pressure regulation – to prevent excessive misting and wind drift losses
Proper sprinkler spacing – to prevent uneven distribution uniformity
Maximize use of available flow rate – to enable irrigation with limited watering windows
Irrigation Management

SMART irrigation control technology
  - ET-based
  - Soil moisture sensor-based
Water budgeting and water use tracking

Section 4: Irrigation Management and Efficiency

Water and Soil Quality Monitoring

Irrigation quality testing plan
Soil quality testing plan
Recordkeeping
Leaching protocol

Irrigation Management Concerns

Preventing runoff into State waters (streams, rivers, lakes, etc.)
Avoiding irrigation during wet or saturated conditions
Managing irrigation applications to prevent soil contamination buildup
Preventing foliar damage to landscape plants
Important Concepts

Precipitation rate (application rate)
Distribution uniformity
Soil infiltration rate
Soil water holding capacity
Leaching requirement

Precipitation Rate

Defines how fast a station applies water in inches per hour
Varies from station to station on an irrigation system
Even varies within a station
Can be measured or calculated

Why is precipitation rate important?

Must consider precipitation rate in irrigation scheduling to prevent ponding and runoff
Determines how long a station must be operated in order to apply a specific depth of water
May exceed soil infiltration rate, requiring multiple start times or cycles

Typical Infiltration vs. Precipitation Rates
How is precipitation rate measured?

**Area/flow (design) method** – “estimated” based upon rated nozzle flow rate and coverage area

**Meter method** – measures “gross” amount of water applied over an area

**Catch can method** – measures “average” amount of water applied by a station

---

**Basic Precipitation Rate Equation**

\[ PR = \frac{GPM \times 96.25}{A} \]

- **PR** – precipitation rate (inches per hour)
- **GPM** – flow rate (gallons per minute)
- 96.25 - Constant, coverts gallons and square feet to inches and minutes to hours
- **A** – coverage area (square feet)

---

**Area/Flow (design) Method**

Used to establish a “design” precipitation rate

Based upon pressure, nozzle size and coverage area

Manufacturer’s nozzle performance charts give PR for square and triangular spacing

---

**Manufacturers Nozzle Performance Charts**

Spray radius and flow vary with pressure

Precipitation rate assumes head to head coverage

Performance data taken in zero wind conditions

---
Example: Area/Flow Method

<table>
<thead>
<tr>
<th>Method</th>
<th>Area (A):</th>
<th>Flow (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter-circle</td>
<td>Length x Width = 75 ft x 15 ft, or 1,125 sq ft</td>
<td>0.5 GPM x 4 heads = 2 GPM</td>
</tr>
<tr>
<td>Half-circle</td>
<td></td>
<td>1 GPM x 8 heads = 8 GPM</td>
</tr>
<tr>
<td>Full-circle</td>
<td></td>
<td>2 GPM x 5 heads = 10 GPM</td>
</tr>
</tbody>
</table>

Total GPM = 20 GPM

Example: PR Calculation

\[ PR = \frac{GPM \times 96.25}{A} \]

Total Area (A):
- For a rectangular area, \( A = \text{length} \times \text{width} \)
- Length = 75 feet
- Width = 15 feet
\( A = 75 \times 15, \text{ or } 1,125 \text{ square feet} \)

\[ PR = \frac{20 \times 96.25}{1,125} \]

\[ PR = 1.71 \text{ inches per hour} \]
Precipitation Rate using the Meter Method
Utilizes water meter readings and coverage area
Measures “gross” precipitation rate
Does not account for water loss due to leaks, wind drift, and evaporation

Calculating Precipitation Rate

\[
PR = \frac{GPM \times 96.25}{A}
\]

GPM is measured at flow meter
Area (A) is measured by using area equations for basic shapes (circle, square, rectangle)

Guidelines for Measuring Flow Rate
Understand the units of measure (gallons, 1000 gallons, cubic feet, 100 cubic feet, etc.)
Before test, make sure meter is not measuring flow
During test, make sure there are no other downstream users
Perform a test run to ensure proper interpretation of flow

Options for Testing Flow Rate
Track volume of water discharged over a specific time
- Turn on station
- After flow has stabilized, mark “Time 1”, record meter reading
- Wait one minute, mark “Time 2”, record meter reading
- Repeat if necessary
- Calculate gallons per minute

<table>
<thead>
<tr>
<th>Flow Rate Test</th>
<th>Zone (Station) #:</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading at &quot;TIME 1&quot; 0 minutes</td>
<td>346000</td>
<td></td>
</tr>
<tr>
<td>Reading at &quot;TIME 2&quot; 1 minute</td>
<td>346040</td>
<td></td>
</tr>
<tr>
<td>Flow Rate (40 gallons = 1 minute)</td>
<td>40 GPM</td>
<td></td>
</tr>
</tbody>
</table>
Options for Testing Flow Rate

Track time needed to discharge a certain volume of water
- Turn on system, let flow stabilize
- Start stopwatch when meter dial is on known volume (e.g. "0")
- Let system run until dial has completed a known volume (e.g. one full rotation)
- Stop stopwatch and record time
- Calculate flow rate

<table>
<thead>
<tr>
<th>Flow Rate Test</th>
<th>Zone (Station) #: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial reading (gallons):</td>
<td>346000</td>
</tr>
<tr>
<td>Final reading (gallons):</td>
<td>346010 (1 full rotation)</td>
</tr>
<tr>
<td>Time expired:</td>
<td>30 seconds, 0.5 minutes</td>
</tr>
<tr>
<td>Flow Rate (10 gallons * 0.5 minutes)</td>
<td>20 GPM</td>
</tr>
</tbody>
</table>

Guidelines for Measuring Area

Sketch the landscape
Note the position of sprinkler heads and delineate individual stations
Use a tape measure or measuring wheel to measure dimensions
Approximate coverage areas into basic geometric shapes

Area Equations for Basic Shapes

Circle

\[ \text{Area} = \pi \times R^2 \]

\[ \text{Area} = \frac{\pi \times D^2}{4} \]
Area Equations for Basic Shapes

**Square**

Area = \( L \times L \)

\[ \text{Area} = L^2 \]

**Rectangle**

Area = \( L \times W \)

North Residence Driveway

Drip 1 drip drip 4 drip

North Residence Driveway

Drip 1 drip drip 4 drip
**Meter Method Review**

\[ PR = \frac{GPM \times 96.25}{A} \]

GPM from water meter readings (method of recording flow may vary)
Area \((A)\) from station dimensions using common geometric shapes

**Catch Can Method**

Most accurate method of determining station precipitation rate
Indicates how well water is distributed throughout coverage area
Requires multiple catch devices (cans)
Measurements can be either a depth (inches) or a volume (milliliters)
Catch Can

Catch Can Layout
Minimum recommendation for catch can layout is at a head and halfway between the heads
- At a head does not mean directly next to it, usually 10% of the throw away from the head
Try to maintain a “grid-like” pattern
With all the catch cans about equally spaced

Catch Device Placement – Stand-Alone

Catch Can Placement
Basic PR Equations

Readings in Milliliters  
Readings in Inches

\[ PR = \frac{\sum V \times 3.6612}{n \times a_t \times t_R} \]

\[ PR = \frac{\sum D \times 60}{n \times t_R} \]

Efficiency

Application efficiency – accounts for wind drift and evaporation losses

Distribution efficiency (uniformity) – how uniformly water is applied over a landscape

Overall system efficiency – factors include conveyance losses, application efficiency and distribution efficiency

Water management efficiency – applying the right amount of water, when you need it

Distribution Uniformity (DU) (%)

Ratio: dry vs. wet areas

Based on irrigation system hardware

Easy to measure using catch devices

Limiting factor when producing good schedules

Uniformity

Water Depths in Soil After Application

Uniform  
Non-Uniform
What factors determine DU?
Spray distribution profile of individual nozzles
Wind distortion at the time of operation
Spacing patterns and distance between sprinklers
Operating pressure
Speed of rotation
Hardware problems (i.e., clogged nozzles, head misalignment, and sprinkler head rotation problems)

Why is distribution uniformity important?
Systems with poor DU:
- must be operated longer to ensure “dry” areas get enough water (this may lead to ponding and runoff in some areas)
- lead to plant stress from over- and under-watering
- wastes water (must overwater some areas to ensure all areas get enough water)
Poor DU can lead to isolated areas of salt accumulation

What can be done to minimize DU problems?
Ensure matched precipitation rate nozzles within individual stations.
Use proper sprinkler spacing and operating pressure according to manufacturers’ product recommendations
Utilize and maintain proper nozzle filtration
Periodic inspection of system performance

Soil Infiltration Rate
The rate at which water enters the soil surface
Influenced by:
- Antecedent moisture conditions (drier soils tend to accept water more rapidly than wet soils, with exceptions)
- Soil type/texture/structure
- Vegetative surface conditions
- Surface salinity concentration (sealing effect)
Typical Infiltration vs. Precipitation Rates

Infiltration Rates
- Sandy
- Loamy
- Clay

Precipitation Rate
- Start
- 8 minutes
- 10 minutes
- 18 minutes
- 20 minutes

Infiltration rates may change considerably over time with compaction and salt accumulation without leaching.

Infiltration Rate Concerns
- Sandy soils (high infiltration rates)
  - Must be careful not to apply too much water that can percolate below the root zone
- Clay soils (low infiltration rates)
  - Must manage irrigation cycles to prevent ponding and surface runoff

Soil Water Holding Capacity
- Defines the amount of water that is available in the soil (inches water per foot of soil)
- Clays have high SWHC, sands have low SWHC
- Helps determine irrigation frequency

Double-Ring Infiltrometer
Typical Water Holding Capacity
(inches of water per foot of soil)

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>At Field Capacity</th>
<th>At Permanent Wilting Point</th>
<th>Soil Water Holding Capacity</th>
<th>Plant Available Water (@ MAD = 50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1.0-1.4</td>
<td>0.2-0.4</td>
<td>0.8-1.0</td>
<td>0.45</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>1.9-2.3</td>
<td>0.6-0.8</td>
<td>1.3-1.5</td>
<td>0.70</td>
</tr>
<tr>
<td>Loam</td>
<td>2.5-2.9</td>
<td>0.9-1.1</td>
<td>1.6-1.8</td>
<td>0.85</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>2.7-3.1</td>
<td>1.0-1.2</td>
<td>1.7-1.9</td>
<td>0.90</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>3.0-3.4</td>
<td>1.1-1.3</td>
<td>1.9-2.1</td>
<td>1.00</td>
</tr>
<tr>
<td>Clay</td>
<td>3.5-3.9</td>
<td>1.5-1.7</td>
<td>2.0-2.2</td>
<td>1.05</td>
</tr>
</tbody>
</table>
Effective Root Zone

The depth containing about 80% of the total root mass

Excludes “tap” and “feeder” roots

Easily measured with a soil probe

Managed Allowable Depletion (MAD)

Percentage of water within the effective root depth allowed to deplete between irrigation events

Influences irrigation frequency

50% MAD is typically used for irrigation scheduling purposes

Plant Available Water for Three Root Zone Depths at 50% MAD

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>2&quot; root zone</th>
<th>4&quot; root zone</th>
<th>6&quot; root zone</th>
<th>Total Plant Available Water (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.90</td>
<td>0.45</td>
<td>0.038</td>
<td>0.08</td>
</tr>
<tr>
<td>Loam</td>
<td>1.70</td>
<td>0.85</td>
<td>0.071</td>
<td>0.14</td>
</tr>
<tr>
<td>Clay</td>
<td>2.10</td>
<td>1.05</td>
<td>0.088</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Factors that Influence Soil-Water Holding Capacities

- Soil type/texture
- Soil structure
- Effective root zone depth
- Excessive sodium concentration (deflocculates clay soil particles)

Irrigation Scheduling Factors

- Plant water requirements
  - Seasonal evapotranspiration rates
  - Microclimate adjustments
- Soil and root zone limitations
  - Soil water holding capacity
  - Infiltration rate
- Sprinkler system performance
  - Precipitation rate
- Leaching requirements
  - May be regular or periodic depending on rainfall patterns

Evapotranspiration (ET)

- Refers to the total amount of water used by plants
- Includes water evaporated from the soil and plant surface AND water transpired by the plant
- Different plants have different ET rates
- Most plants can withstand a ET deficit (or allowable stress) from its maximum use and still maintain acceptable quality

Reference Evapotranspiration (ET₀)

- Refers to the amount of water used by a cool-season grass, growing 4 inches tall under well-watered conditions
- Used as a “reference” to which the ET for all other plant types is related.
- For example, the ET for common bermudagrass is approximately 60% of that for the cool-season reference grass
  - i.e. ET = 0.60 x ET₀ for this example
Reference Evapotranspiration (ET₀)

Varies with location and weather conditions:
- Wind speed
- Relative humidity
- Temperature
- Solar Radiation

Should not be confused with Lake Evaporation data

TexasET Network

Contains:
- Current weather and ET data
- Irrigation scheduling tools

Historic ET₀ Records

<table>
<thead>
<tr>
<th>City</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abilene</td>
<td>2.08</td>
<td>2.57</td>
<td>4.14</td>
<td>5.48</td>
<td>6.47</td>
<td>7.65</td>
<td>8.36</td>
<td>7.46</td>
<td>5.48</td>
<td>4.21</td>
<td>2.67</td>
<td>2.08</td>
<td>58.65</td>
</tr>
<tr>
<td>Amarillo</td>
<td>1.84</td>
<td>2.27</td>
<td>3.73</td>
<td>5.06</td>
<td>5.89</td>
<td>7.51</td>
<td>8.08</td>
<td>7.29</td>
<td>5.61</td>
<td>4.65</td>
<td>2.4</td>
<td>1.78</td>
<td>55.51</td>
</tr>
<tr>
<td>Austin</td>
<td>2.27</td>
<td>2.72</td>
<td>4.34</td>
<td>5.27</td>
<td>6.39</td>
<td>7.15</td>
<td>7.22</td>
<td>7.23</td>
<td>5.57</td>
<td>4.38</td>
<td>2.74</td>
<td>2.21</td>
<td>57.51</td>
</tr>
<tr>
<td>Brownsville</td>
<td>2.65</td>
<td>3.02</td>
<td>4.48</td>
<td>5.17</td>
<td>6.03</td>
<td>6.32</td>
<td>6.86</td>
<td>6.65</td>
<td>5.21</td>
<td>4.34</td>
<td>3.01</td>
<td>2.59</td>
<td>56.16</td>
</tr>
<tr>
<td>College Station</td>
<td>2.2</td>
<td>2.77</td>
<td>4.22</td>
<td>5.2</td>
<td>6.25</td>
<td>5.89</td>
<td>7.1</td>
<td>6.85</td>
<td>5.6</td>
<td>4.3</td>
<td>2.8</td>
<td>2.2</td>
<td>56.32</td>
</tr>
</tbody>
</table>

Source: Texas ET Network
http://texaset.tamu.edu
How to Estimate Plant ET from ET₀

Crop coefficients (also referred to as “plant or turf coefficients” is some cases)
Abbreviated as Kc, Tc, etc.
 Represents the percentage of ET₀ a specific plant type will use for maximum growth
Crop coefficients may be reduced to an acceptable level of stress (quality factor)

Common Turf Classifications

<table>
<thead>
<tr>
<th>Warm season turfgrasses</th>
<th>Cool season turfgrasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermudagrass</td>
<td>Fescue</td>
</tr>
<tr>
<td>St. Augustinegrass</td>
<td>Kentucky bluegrass</td>
</tr>
<tr>
<td>Centipede grass</td>
<td>Bentgrass</td>
</tr>
<tr>
<td>Zoysia grass</td>
<td>Ryegrass</td>
</tr>
<tr>
<td>Buffalograss</td>
<td></td>
</tr>
<tr>
<td>Carpetgrass</td>
<td></td>
</tr>
<tr>
<td>Paspalum</td>
<td></td>
</tr>
</tbody>
</table>

Common Plant Classifications

<table>
<thead>
<tr>
<th>Once the plants are established (may take one or two growing seasons), the plants will thrive on...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural rainfall – When normal rainfall does not occur, irrigation may be required</td>
</tr>
<tr>
<td>Occasional watering – In the absence of rainfall, irrigation is required every two to four weeks</td>
</tr>
<tr>
<td>Regular watering – Once-a-week or more irrigations are necessary</td>
</tr>
</tbody>
</table>

Typical Crop Coefficients for Turfgrasses

Source: Texas ET Network
http://texaset.tamu.edu
ASABE Standard Landscape Coefficients

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Recommended Plant Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turf, cool season</td>
<td>0.8</td>
</tr>
<tr>
<td>Turf, warm season</td>
<td>0.8</td>
</tr>
<tr>
<td>Annual forage</td>
<td>0.8</td>
</tr>
<tr>
<td>Woody plants and herbaceous perennials, wet (^*)</td>
<td>0.7</td>
</tr>
<tr>
<td>Woody plants and herbaceous perennials, dry</td>
<td>0.5</td>
</tr>
<tr>
<td>Desert plants</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Tropical plants: for tropical plants with precipitation the majority of months, a plant factor of 0.7 applies. Where monsoonal climates are present, 0.7 applies for the wet season, and 0.5 during the dry season.

For FAO Crop Coefficients:
- Forages/Pastures/Trees
- [http://www.fao.org/3/X0490E/x0490e0b.htm#crop%20coefficients](http://www.fao.org/3/X0490E/x0490e0b.htm#crop%20coefficients)

Other Plant Water Requirements:
- TWDB Bulletin 6019

Basic Plant Water Requirement Equation

\[
WR = ET_o \times K_c
\]

- \(WR\) = water requirements (inches/month, inches/week)
- \(ET_o\) = evapotranspiration rate (inches/month, inches/week)
- \(K_c\) = plant or crop coefficient (decimal)

Calculating Plant ET

Given:
- Bermudagrass turfgrass
- College Station
- July

Required:
- July ET

\[
ET = ET_o \times K_c
\]

\(ET_o\) = 7.1 inches (from table)
\(K_c\) = 0.6 (from table)

\[
ET = 7.1 \times 0.6
\]

\[
ET = 4.26 \text{ inches}
\]
### Determining Weekly Irrigation Need

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reference evapotranspiration (ETo)</td>
<td>6</td>
<td>Inches per month</td>
</tr>
<tr>
<td>2</td>
<td>Crop coefficient (Kc)</td>
<td>0.6</td>
<td>Decimal</td>
</tr>
<tr>
<td>3</td>
<td>Adjustment factor (Af)</td>
<td>0.8</td>
<td>Decimal</td>
</tr>
<tr>
<td>4</td>
<td>Monthly plant water requirement</td>
<td>2.88</td>
<td>Inches ($#1 \times #2 \times #3$)</td>
</tr>
<tr>
<td>5</td>
<td>Leaching requirement</td>
<td>0.58</td>
<td>Inches ($#4 \times 0.2 \times LF = 0.2$)</td>
</tr>
<tr>
<td>6</td>
<td>Total monthly irrigation need</td>
<td>3.46</td>
<td>Inches ($#5 + #6$)</td>
</tr>
<tr>
<td>7</td>
<td>Total weekly irrigation need</td>
<td>0.87</td>
<td>Inches ($#6 + 4$)</td>
</tr>
</tbody>
</table>

Leaching Fraction (LF) calculated separately based upon irrigation quality test results.

### Determining Irrigation Frequency

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Total weekly irrigation need</td>
<td>0.87</td>
<td>Inches ($#6 + 4$)</td>
</tr>
<tr>
<td>8</td>
<td>Effective root zone depth (D)</td>
<td>6</td>
<td>Inches</td>
</tr>
<tr>
<td>9</td>
<td>Soil water holding capacity (SWHC)</td>
<td>1.7</td>
<td>Inches H₂O/ft soil (loam)</td>
</tr>
<tr>
<td>10</td>
<td>Managed allowable depletion (MAD)</td>
<td>0.5</td>
<td>Decimal (MAD for turf = 50%)</td>
</tr>
<tr>
<td>11</td>
<td>Plant available water (PAW)</td>
<td>0.43</td>
<td>Inches ($#7/12 \times #8 \times #9$)</td>
</tr>
<tr>
<td>12</td>
<td>Irrigation frequency (I)</td>
<td>2</td>
<td>Whole number ($#7 \times #11$)</td>
</tr>
</tbody>
</table>

### Determining Station Run Time

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Total weekly irrigation need</td>
<td>0.87</td>
<td>Inches ($#6 + 4$)</td>
</tr>
<tr>
<td>12</td>
<td>Irrigation frequency (I)</td>
<td>2</td>
<td>Whole number ($#7 \times #11$)</td>
</tr>
<tr>
<td>13</td>
<td>Precipitation rate</td>
<td>1.5</td>
<td>Inches per hour</td>
</tr>
<tr>
<td>14</td>
<td>Station run time</td>
<td>17</td>
<td>Minutes per irrigation event ($#7 \times 60 \div (#12 \times #13)$)</td>
</tr>
</tbody>
</table>

### Section 5: Soil Sampling and Nutrient Loading
Value of Reclaimed Water

Reclaimed water commonly contains small amounts of elements beneficial for plant growth

- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Manganese
- Zinc
- Boron

Plant Nutrient Uptake

Depends upon:
- Concentration of nutrients in reclaimed water
- Amount of reclaimed water applied
- Residence time of reclaimed water in root zone
- Environmental factors

Turfgrasses are relatively efficient in extracting nutrients from reclaimed water

How often should you sample?

May be dictated by local permitting authority
At least twice per year for nutrients
- Beginning of growing season
- End of growing season
May need more frequent sampling if salinity is a major issue

Soil Sampling Supplies

Sampling containers
- Sample bags for this purpose are available from testing labs
- Plastic bags and other containers acceptable

Sampling tools
- Trowels
- Spades
- Augers
- Core samplers
Sampling Process
Take multiple samples from various locations throughout the landscape
- Small lawns and landscape (5 to 6 samples)
- Sports fields and large landscapes (8 to 10 samples)
- Golf courses (10 to 15 samples)
Combine all samples into 1 composite sample of at least 1 pint of soil

Sample Depth
Sample from a depth within the plant’s effective root zone
Depend upon normal root growth characteristics and soil type
Typical root depth for turfgrasses is 4 to 6 inches in good soil for most landscapes
Deep-rooted perennials may have deeper root depths

Storage and Submission of Samples
Samples should not be stored for a long period of time prior to shipping to the lab
- Levels of nitrate-nitrogen may change if samples are stored wet
Do not oven dry samples
Air drying samples in the shade on clean brown paper is recommended
If possible, submit soil sample in original sample container

Typical Analysis Options
Routine (pH, salinity, nitrites, primary nutrients) with basic N-P-K fertilizer recommendations
Micronutrients (Zn, Fe, Mn, Cu)
Boron
Detailed Salinity (EC, soluble salts, SAR)
Lime requirement to raise pH
Soil texture and organic matter content
Calculating Nutrient Contribution from Reclaimed Water

Step 1: Find specific nutrient concentration from water quality report (in mg/l or ppm)

Step 2: Multiply this number by 2.71 (converts mg/l to lbs/acre-feet)

Step 3: Divide step 2 number by 43.56 (converts lbs/acre-feet to lbs/1,000 ft²)

This is how much of the nutrient is applied for each foot of irrigation water. You must adjust for different irrigation depths.

Example: Calculating Nutrient Contribution from Reclaimed Water

Given:

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>30</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>10</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>20</td>
</tr>
</tbody>
</table>

Remember: 1 ppm = 1 mg/l

Find:

If 6 inches of water is applied over the summer, how many pounds of N, P and K per 1,000 square feet were applied?

Nitrogen (N)

Step 1:
- N concentration = 30 mg/l

Step 2:
- 30 mg/l * 2.71 = 81.3 lbs. N/acre-foot

Step 3:
- 81.3 lbs. N/acre-foot / 43.56 =

Application Rate of N = \( \frac{1.87 \text{ lbs. N}}{1,000 \text{ ft}^2} \) (for every 1 ft of water applied)

Nitrogen (N)

Adjust from 12 to 6 inches of water applied

Application Rate of N = \( \frac{1.87 \text{ lbs. N}}{1,000 \text{ ft}^2} \times \frac{6'}{12'} \) (for every 12" of water applied)

Application Rate of N = \( \frac{0.93 \text{ lbs. N}}{1,000 \text{ ft}^2} \) (for every 6" of water applied)
Phosphorus (N)

Step 1:
- $P$ concentration = 10 mg/l

Step 2:
- $10 \text{ mg/l} \times 2.71 = 27.1 \text{ lbs. P/acre-foot}$

Step 3:
- $27.1 \text{ lbs. P/acre-foot} \times 43.56 = 1,192 \text{ lbs. P/acre}$

Application Rate of $P = \frac{0.62 \text{ lbs. P}}{1,000 \text{ ft}^2}$ (for every 1 ft of water applied)

Potassium (K)

Step 1:
- $K$ concentration = 20 mg/l

Step 2:
- $20 \text{ mg/l} \times 2.71 = 54.2 \text{ lbs. K/acre-foot}$

Step 3:
- $54.2 \text{ lbs. K/acre-foot} \times 43.56 = 2,374 \text{ lbs. K/acre}$

Application Rate of $K = \frac{1.24 \text{ lbs. K}}{1,000 \text{ ft}^2}$ (for every 1 ft of water applied)

Phosphorus (N)

Adjust from 12 to 6 inches of water applied

Application Rate of $P = \frac{0.62 \text{ lbs. P}}{1,000 \text{ ft}^2} \times \frac{6''}{12''}$ (for every 12” of water applied)

Application Rate of $P = \frac{0.31 \text{ lbs. P}}{1,000 \text{ ft}^2}$ (for every 6” of water applied)

Potassium (K)

Adjust from 12 to 6 inches of water applied

Application Rate of $K = \frac{1.24 \text{ lbs. K}}{1,000 \text{ ft}^2} \times \frac{6''}{12''}$ (for every 12” of water applied)

Application Rate of $K = \frac{0.62 \text{ lbs. K}}{1,000 \text{ ft}^2}$ (for every 6” of water applied)
# Example Summary

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Measured Sample Concentration (ppm)</th>
<th>Amount Received for 6&quot; Water Application (lbs. per 1,000 ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>30</td>
<td>0.93</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>10</td>
<td>0.31</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>20</td>
<td>0.62</td>
</tr>
</tbody>
</table>