



# Water Reuse: Using Reclaimed Water for Irrigation

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## What is water reuse?

**Water reuse** can be defined as the use of reclaimed water for a direct beneficial purpose. The use of reclaimed water for irrigation and other purposes has been employed as a water conservation practice in Florida, California, Texas, Arizona, and other states for many years.

## What is reclaimed water?

**Reclaimed water**, also known as **recycled water**, is water recovered from domestic, municipal, and industrial wastewater treatment plants that has been treated to standards that allow safe reuse. Properly reclaimed water is typically safe for most uses except human consumption.

**Wastewater** is not reclaimed water. Wastewater is untreated liquid industrial waste and/or domestic sewage from residential dwellings, commercial buildings, and industrial facilities. **Gray water**, or untreated wastewater from bathing or washing, is one form of wastewater. Wastewater may be land applied, but this is considered to be land treatment rather than water reuse.

## Why reuse water?

The demand for fresh water in Virginia is growing as the state's population increases. This demand can potentially exceed supply during times of even moderate drought. In recent years, the normal seasonal droughts that have occurred in Virginia have caused local and state government to enact water conservation ordinances. These ordinances limit the use of potable water (water suitable for human consump-

tion) for such purposes as car washing and landscape irrigation. The potential for developing new sources of potable water is limited. Conservation measures, such as irrigating with reclaimed water, are one way to help ensure existing water supplies are utilized as efficiently as possible.

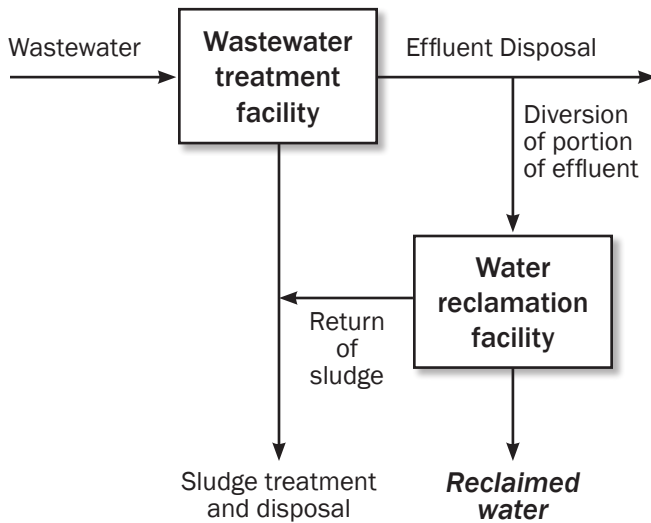
The environmental benefits of using reclaimed water include:

- Increased water quantity:
  - Decreased diversion of freshwater from wetlands and other ecosystems.
  - Reduced use of potable water by industrial, housing, and recreational development projects that use reclaimed water.
  - Reduction in the amount of groundwater withdrawal, which impacts base flow in many rivers and streams.
- Increased water quality:
  - Reduction in the amount of nutrients entering the Chesapeake Bay, its tributaries, and other water bodies.

## How is reclaimed water produced?

Reclaimed water typically comes from municipal wastewater treatment plants, although some industries (e.g., food processors) also generate water that may be suitable for nonpotable uses. (Figure 1).

**Figure 1. Water reclamation process at a wastewater treatment facility (adapted from EPA, 2012).**



During **primary treatment** at a wastewater treatment plant, inorganic and organic suspended solids are removed from plant influent by screening, and settling. The decanted effluent from the primary treatment process is then subjected to **secondary treatment**, which involves biological decomposition of organic material and settling to further separate water from solids. If a wastewater treatment plant is not equipped to perform advanced treatment, water is disinfected and discharged to natural water bodies following secondary treatment.

**Advanced or tertiary treatment** consists of further removal of suspended and dissolved solids, including nutrients, and disinfection. Advanced treatment can include:

- nutrient (nitrogen and/or phosphorus) removal by biological or chemical methods.
- removal of organics and metals by carbon adsorption or chemical precipitation.
- further removal of suspended and dissolved solids by filtration, coagulation, ion exchange, reverse osmosis, and other techniques.
- removal of organic chemicals by oxidation with hydrogen peroxide or ozone.

Water that has undergone advanced treatment is disinfected prior to being released or reused. Reclaimed water often requires greater treatment than effluent that is discharged to local streams or rivers because users will typically have more direct contact with undiluted reclaimed water than undiluted effluent.

For more detailed information about the internal operations of wastewater treatment facilities, see <https://www.wef.org/globalassets/assets-wef/3---resources/for-the-public/public-information/following-the-flow-book-an-inside-look-at-wastewater-treatment.pdf>.

## Options for water reuse

Although the primary focus of this publication is on the use of reclaimed water for agricultural, municipal, and residential irrigation, reclaimed water can be used for many other purposes. Non-irrigation uses for reclaimed water include:

- Urban reuse:
  - Ornamental landscape water features and golf course water features such as ponds and fountains
  - Fire protection
  - Dust control and concrete mixing on construction sites
  - Vehicle and window washing
  - Toilet flushing in public, commercial, and industrial buildings
- Industrial reuse:
  - Cooling water
  - Boiler make-up water
  - Industrial process water
- Intentional indirect potable reuse.

*Intentional indirect potable reuse (IPR)* means the discharge of reclaimed water to a surface water body used as a raw water supply for a water treatment plant to intentionally augment the water supply. Such IPR may also occur unintentionally in rivers where water treatment plants withdraw raw water for potable water production. An example of intentional IPR in Virginia is the Upper Occoquan Service Authority's production and discharge of highly treated reclaimed water to the Occoquan Reservoir to intentionally supplement the raw water supply and improve water quality in the reservoir (<https://www.uosa.org/>)

*Direct potable reuse (DPR)* refers to the use of reclaimed water for drinking directly after treatment. Although DPR is prohibited in Virginia, it has been implemented to a limited degree in the United States and abroad.

# Water reuse regulations

## Introduction

The turfgrass and ornamental horticulture industries have grown as Virginia becomes more urbanized. The acreage devoted to high-value specialty crops that benefit from irrigation, such as fruits and vegetables, is also increasing. As demand for potable water increases, maintaining turf, landscape plants, and crops will require the utilization of previously under-utilized water sources, including reclaimed water.

The regulation of reclaimed water production and use encourages both the supply of and the demand for reclaimed water. The benefits to suppliers of reclaimed water include greater public awareness and demand for reclaimed water and clear guidelines for reclaimed water production. Benefits to end users include increased public acceptance of the use of reclaimed water and a subsequent decrease in the demand for fresh water.

## U.S. EPA guidelines

There are no federal regulations governing reclaimed water use, but the U.S. EPA (2012) has established guidelines to encourage states to develop their own regulations. The primary purpose of federal guidelines and state regulations is to protect human health and water quality. To reduce disease risks to humans, reclaimed water must be disinfected to meet standards at which the concentrations of pathogens will be reduced to levels protective of public health and/or human contact with reclaimed water must be limited.

The U.S. EPA (2012) recommends that water intended for reuse should:

- Be treated to achieve biochemical oxygen demand and total suspended solids levels of <30 mg/L, during secondary or tertiary treatment.
- Receive additional disinfection by means such as chlorination or other chemical disinfectants, UV radiation, ozonation, and membrane processing.

Biochemical oxygen demand (BOD) is an indicator of the presence of reactive organic matter in water. Total suspended solids (TSS) or turbidity (measured in nephelometric turbidity units, or NTUs) are measures of the amount of organic and inorganic particulate matter in water, which can greatly influence

the effectiveness and dosage of disinfection options. Some other parameters often measured as indicators of disinfection efficiency include:

- Fecal coliforms, *E. coli* or *enterococci*: The presence of these bacteria in water typically indicates the presence of pathogenic organisms associated with fecal contamination.
- Residual chlorine: The concentration of this disinfection chemical after a standard contact time measures effectiveness by inference.

The recommended values for each of these indicators depend on the intended use of the reclaimed water (Table 1).

## Pathogens and Microconstituents

Monitoring for specific pathogens and microconstituents may become a part of the standard testing protocol as the use of reclaimed water for indirect potable reuse applications increases. Pathogens of particular concern include enteric viruses and the protozoan parasites *Giardia* and *Cryptosporidium*, whose monitoring is required by the state of Florida for water reuse projects.

Microconstituents include organic chemicals, such as pharmaceutically active substances, personal care products, endocrine disrupting compounds, and previously unregulated inorganic elements whose toxicity may be re-assessed or newly evaluated. Fish, amphibians, and birds have been found to develop reproductive system abnormalities upon direct or indirect exposure to a variety of endocrine disrupting compounds. Such microconstituents may have the potential to cause reproduction system abnormalities and immune system malfunctioning in other wildlife and humans at higher concentrations. The impacts of the extremely low concentrations of these compounds found in wastewater effluent or reclaimed water are unknown. To date, there is no evidence that microconstituents cause human health effects at environmentally relevant concentrations.

Some possible options for the removal of microconstituents from wastewater are treatment with ozone, hydrogen peroxide, and UV light. These methods can destroy some microconstituents via advanced oxidation, but the endocrine disruption activity of the by-products created during oxidation may also be of concern.

No illnesses have been directly associated with the use of properly treated reclaimed water in the U.S.

**Table 1. Summary of U.S. EPA guidelines for water reuse for irrigation (Adapted from U.S. EPA, 2012).**

Reuse Type	Treatment	Water Quality	Setbacks	Monitoring
<b>-----Public contact-----</b>				
Irrigation for public areas: <ul style="list-style-type: none"> <li>• Parks</li> <li>• Cemeteries</li> <li>• Golf courses</li> <li>• Other landscape areas with public access</li> </ul> Agricultural irrigation for: <ul style="list-style-type: none"> <li>• Food crops that will not be commercially processed</li> <li>• Any crop eaten raw</li> </ul>	Secondary  Filtration and  Disinfection	<ul style="list-style-type: none"> <li>• pH 6-9</li> <li>• ≤ 10 mg/L BOD</li> <li>• ≤ 2 NTU</li> <li>• No detectable fecal coliforms/100 mL</li> <li>• At least 1 mg/L residual chlorine</li> </ul>	<ul style="list-style-type: none"> <li>• 50 feet to potable water wells</li> </ul>	<ul style="list-style-type: none"> <li>• Weekly: pH, BOD</li> <li>• Daily: Coliforms</li> <li>• Continuously: Turbidity, residual chlorine</li> </ul>
<b>-----Limited or no public contact-----</b>				
Irrigation of restricted access areas: <ul style="list-style-type: none"> <li>• Sod farms</li> <li>• Silviculture</li> <li>• Other areas with limited or no public access</li> </ul> Agricultural irrigation for: <ul style="list-style-type: none"> <li>• Food crops that will be commercially processed</li> <li>• Non-food crops and pastures</li> </ul>	Secondary  Disinfection	<ul style="list-style-type: none"> <li>• pH 6-9</li> <li>• ≤ 30 mg/L BOD</li> <li>• ≤ 30 mg/L TSS</li> <li>• ≤ 200 fecal coliforms/100 mL</li> <li>• At least 1 mg/L residual chlorine</li> </ul>	<ul style="list-style-type: none"> <li>• 300 feet to potable water wells</li> <li>• 100 ft. to areas accessible to public (if spray irrigation is used)</li> </ul>	<ul style="list-style-type: none"> <li>• Weekly: pH, BOD</li> <li>• Daily: Coliforms and TSS</li> <li>• Continuously: Residual chlorine</li> </ul>

(U.S. EPA, 20012). The U.S. EPA recommends, however, that ongoing research and additional monitoring for *Giardia*, *Cryptosporidium*, and microconstituents be conducted to understand changes in reclaimed water quality.

### Virginia Water Reuse Regulations

State regulations need not agree with U.S. EPA guidelines and are often more stringent. In Virginia, water reuse means the use of reclaimed water for a direct beneficial reuse, an indirect potable reuse, and indirect

nonpotable reuse, or a controlled use in accordance with the Water Reclamation and Reuse Regulation (9 VAC 25-740-10 et seq).

The Virginia Water Regulation and Reuse Regulation establishes legal requirements for the reclamation and treatment of water that is to be reused. These requirements are designed to protect both water quality and public health, while encouraging the use of reclaimed water. The Virginia Department of Environmental Quality, Water Permitting Division has oversight over the Virginia Water Reclamation and Reuse Regulation.

The primary determinants of how reclaimed water of varying quality can be used are based on treatment processes to which the water has been subjected and on quantitative chemical, physical, and biological standards. Most reclaimed water suitable for reuse in Virginia is categorized as either Level 1 or Level 2 (Table 2). The minimum standard requirements for specific uses of reclaimed water are summarized in Table 3.

## Water Reuse: Agronomic Concerns

### Reclaimed water quality considerations

Water quality must be considered when using reclaimed water for irrigation. The following properties are critical to plant and soil health and environmental quality.

#### Salinity levels

Salinity, or salt concentration, is probably the most important consideration in determining whether water is suitable for reuse (U.S. EPA, 2012). Water salinity is the sum of all elemental ions (e.g., sodium, calcium, chloride, boron, sulfate, nitrate) and is usually measured by determining the electrical conductivity (EC, units = dS/m) or total dissolved solids (TDS, units = mg/L) concentration of the water. Water with a TDS concentration of 640 mg/L will typically have an EC of approximately 1 dS/m.

Salts in reclaimed water come from:

- elemental ions naturally found in water.
- ions retained in dissolved form after separation of solids during wastewater treatment.
- any salts added during the wastewater treatment process.

Most reclaimed water from urban areas is slightly saline ( $TDS \leq 1280$  mg/L or  $EC \leq 2$  dS/m). High salt concentrations reduce water uptake in plants by lowering the osmotic potential of the soil. For instance, residential use of water adds approx 200-400 mg/L dissolved salts (Lazarova *et al.*, 2004a). Plants differ in their sensitivity to salt levels so the salinity of the particular reclaimed water source should be measured so that appropriate crops and/or application rates can be selected. Most turfgrasses can tolerate water with 200-800 mg/L soluble salts, but salt levels above 2,000 mg/L may be toxic (Harivandi, 2004). For

further information on managing turfgrasses when irrigating with saline water, see Carrow and Duncan (1998).

Many other crop and landscape plants are more sensitive to high soluble-salt levels than turfgrasses, and should be managed accordingly. See Wu and Dodge (2005) for a list of landscape plants with their relative salt tolerance and Maas (1987) for information on salt-tolerant crops.

### Concentration of sodium, chloride, and boron

Specific dissolved ions may also affect irrigation water quality. For example, irrigation water with a high concentration of sodium (Na) ions may cause dispersion of soil aggregates and sealing of soil pores. This is a particular problem in golf course irrigation (Sheikh, 2004) since soil compaction is already a concern due to persistent foot and vehicular traffic. The Sodium Adsorption Ratio (SAR), is another means to evaluate the potential effect of sodium in irrigation water on soil structure. For more information on how to assess and interpret SAR levels, please see Harivandi (1999).

High levels of sodium can also be directly toxic to plants both through root uptake and by accumulation in plant leaves following sprinkler irrigation. The specific concentration of sodium that is considered to be toxic will vary with plant species and the type of irrigation system. Turfgrasses are generally more tolerant to sodium than most ornamental plant species.

Although boron (B) and chlorine (Cl) are necessary at low levels for plant growth, dissolved boron and chloride ions can cause toxicity problems at high concentrations. Specific toxic concentrations will vary depending on plant species and type of irrigation method used. Levels of boron as low as 1 to 2 mg/L in irrigation water can cause leaf burn on ornamental plants, but turfgrasses can often tolerate levels as high as 10 mg/L (Harivandi, 1999). Very salt-sensitive landscape plants such as crape myrtle (*Lagerstroemia* sp.), azalea (*Rhododendron* sp.), and Chinese privet (*Ligustrum sinense*) may be damaged by overhead irrigation with reclaimed water containing chloride levels over 100 mg/L, but most turfgrasses are relatively tolerant to chloride if they are mowed frequently (Harivandi, 1999; Crook, 2005).

**Table 2. Minimum standards for treatment of Level 1 and Level 2 reclaimed water. (Summarized from Virginia Water Reclamation and Reuse Regulations: 9 VAC 25-740-10 et seq.)**

		<b>Level 1: Secondary treatment with filtration and higher-level disinfection</b>	<b>Level 2: Secondary treatment with standard disinfection</b>
<b>Bacterial Standards: (one of these three standards must be met)</b>	<b>Fecal coliforms<sup>a</sup></b>	Monthly geometric mean <sup>b</sup> ≤ 14/100 mL CAT <sup>c</sup> > 49/100 mL	Monthly geometric mean <sup>b</sup> ≤ 200/100mL CAT > 800/100 mL
	<b><i>E. coli</i><sup>a</sup></b>	Monthly geometric mean <sup>b</sup> ≤ 11/100 mL CAT > 35/100 mL	Monthly geometric mean <sup>b</sup> ≤ 126/100mL CAT > 235/100 mL
	<b><i>Enterococci</i><sup>a</sup></b>	Monthly geometric mean <sup>b</sup> ≤ 11/100 mL CAT > 24/100 mL	Monthly geometric mean <sup>b</sup> ≤ 35/100mL CAT > 104/100 mL
<b>Total Residual Chlorine (TRC)<sup>d</sup></b>		CAT < 1 mg/L after a minimum contact time of 30 minutes at average flow, or 20 minutes at peak flow	CAT < 1 mg/L after a minimum contact time of 30 minutes at average flow, or 20 minutes at peak flow
<b>pH</b>		6.0-9.0	6.0-9.0
<b>5-day BOD (BOD<sub>5</sub>)<sup>e</sup></b>		Monthly average ≤ 10 mg/L	Monthly average ≤ 30 mg/L Maximum weekly average = 45 mg/L
<b>5-day Carbonaceous BOD (CBOD<sub>5</sub>)<sup>f</sup></b>		Monthly average ≤ 8 mg/L	Monthly average ≤ 25 mg/L Maximum weekly average = 40 mg/L
<b>Turbidity</b>		Daily 24-hour average ≤ 2 NTU CAT > 5 NTU	N/A
<b>TSS</b>		N/A	Monthly average ≤ 30 mg/L Maximum weekly average = 45 mg/L

<sup>a</sup> After disinfection.

<sup>b</sup> Monthly Geometric mean = The *n*th root of the product of all the members of the data set measured within a monthly monitoring period, where *n* is the number of members.

<sup>c</sup> CAT (Corrective Action Threshold) = A bacterial, turbidity or total residual chlorine standard for reclaimed water at which measures shall be implemented to correct operational problems of the reclamation system within a specified period, or divert flow from the reclamation treatment process in accordance with this regulation.

<sup>d</sup> Applies only if chlorine is used for disinfection.

<sup>e</sup> Five-day BOD (BOD<sub>5</sub>) = A BOD test that measures the amount of oxygen consumed by biochemical oxidation of organic compounds in water in a five-day period.

<sup>f</sup> Five-day Carbonaceous BOD (CBOD<sub>5</sub>) = A five-day BOD test with an inhibitor added to prevent the oxidation of nitrogen compounds such as ammonia. Note that this standard applies only if CBOD<sub>5</sub> is used in lieu of BOD<sub>5</sub>.

**Table 3. Minimum treatment requirements for irrigation and landscape-related reuse of reclaimed water in Virginia. (Summarized from Virginia Water Reclamation and Reuse Regulations: 9 VAC 25-740-10 et seq.)**

Irrigation Reuse Type	Minimum Standard Requirements
<ul style="list-style-type: none"> <li>• Food crops that are not commercially processed; any food that will be eaten raw<sup>a</sup></li> <li>• Container plant sales outlet</li> <li>• Landscape irrigation, including:               <ul style="list-style-type: none"> <li>– Golf courses</li> <li>– Parks</li> <li>– Athletic fields</li> <li>– School yards</li> <li>– Cemeteries</li> <li>– Impoundments with potential public access or contact</li> </ul> </li> </ul>	Level 1
<ul style="list-style-type: none"> <li>• Food crops that are commercially processed</li> <li>• Nonfood crops and turfgrass</li> <li>• Pasture for foraging livestock</li> <li>• Ornamental nursery (non-container)</li> <li>• Sod farms</li> <li>• Silviculture</li> <li>• Landscape impoundments with no potential for public access or contact</li> </ul>	Level 2

<sup>a</sup> Irrigation of food crops not commercially processed and/or consumed raw is limited so that there is no direct or indirect contact between the reclaimed water and edible portions of the crop (with the exception of root crops.)

## Nutrient levels

Reclaimed water typically contains more nitrogen (N) and phosphorus (P) than drinking water. The amounts of N and P provided by the reclaimed water can be calculated as the product of the estimated irrigation volume and the N and P concentration in the water. To prevent N and P leaching into groundwater, the Virginia Water Reclamation and Reuse Regulation requires that a nutrient management plan be written for bulk use of reclaimed water not treated to achieve biological nutrient removal (BNR), which the regulation defines as treatment that achieves an annual average of 8.0 mg/L total N and 1.0 mg/L total P. Water that has been subjected to BNR treatment processes contains such low concentrations of N and P that the

reclaimed water can be applied at rates sufficient to supply a crop’s water needs without risk of surface or ground water contamination.

Application rates of reclaimed water that has not been subjected to BNR treatment processes and does not achieve an annual average of 8.0 mg/L total N and 1.0 mg/L total P (non-BNR reclaimed water), may be limited by the nutrient content of that water. For example, in a drier year when additional water is needed to meet the water demands of the irrigated vegetation, it may not be possible to apply an additional volume of non-BNR reclaimed water once the crop nutrient demands have been met by the application of the same water.

In any case, application rates of reclaimed water

should not exceed (1) the infiltration rate of the soils at the irrigation site to avoid runoff and possible nonpoint source discharges to surface water, or (2) supplemental irrigation rates (see “Application Rates” below).

### **Other agronomic water quality concerns (Harivandi, 1999; Landschoot, 2007; Lazarova *et al.*, 2004a)**

- *High suspended solids (TSS) concentrations* may clog irrigation systems, and can fill pore spaces near the soil surface resulting in reduced drainage. Acceptable TSS levels will vary depending on the type of suspended solids and type of irrigation system. Generally, TSS levels less than 50-100 mg/L are safe for drip irrigation.
- *Free chlorine (Cl<sub>2</sub>)* is necessary for disinfection, but can damage plants at high concentrations (> 5 mg/L). Storage for a short time reduces the residual free chlorine concentration in water.
- *High or low pH* is an indicator of presence of phytotoxic ions, and pH should be approximately 6.5 to 7, if possible.
- *High bicarbonate (>120 mL) and carbonate (>15 mg/L) levels* can clog sprinklers and cause white lime deposits on plant leaves, and may increase soil pH and decrease permeability.
- *Heavy metals* can be a concern in wastewater that has high industrial input, but such metals (for example, cadmium, copper, molybdenum, nickel, and zinc) are typically strongly bound to the solid fraction, or biosolids portion, of the wastewater and rarely are found in high enough concentrations to pose a reclaimed water quality problem.

### **Application Rates**

The Virginia Water Reclamation and Reuse Regulations require that irrigation with reclaimed water shall be limited to supplemental irrigation. Supplemental irrigation is defined as that amount of water which, in combination with rainfall, meets but does not exceed the water demands of the irrigated vegetation to maximize production or optimize growth.

Irrigation rates for reclaimed water are site- and crop-specific, and will depend on the following factors (U.S. EPA, 2004; Lazarova *et al.*, 2004b).

1. First, *seasonal irrigation demands* must be determined. These can be predicted with:
  - an evapotranspiration estimate for the particular crop being grown
  - determination of the period of plant growth
  - average annual precipitation data
  - data for soil permeability and water holding capacityMethods for calculating such irrigation requirements can be found in the U.S. Department of Agriculture Part 623 National Engineering Handbook (Chapter 2 - Irrigation Water Requirements: <https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=39767.wba> and in Reed *et al.* (1995). These calculations are more complicated for landscape plantings than for agricultural crops or turf because landscape plantings consist of many different species with different requirements.
2. The *properties* of the specific reclaimed water to be used, as detailed in the section above, must be taken into account since these may limit the total amount of water that can be applied per season.
3. The *availability* of the reclaimed water should also be quantified, including:
  - the total amount available
  - the time of year when available
  - availability of water storage facilities for the non-growing season
  - delivery rate and type

## **Water Reuse Case Studies**

### **Landscape and residential case studies**

#### **State of Florida**

Water reuse is actively promoted by the Florida Department of Environmental Protection since Florida law requires that the use of potable water for irrigation be limited. In 2005, 462 Florida golf courses, covering over 56,000 acres of land, were irrigated with reclaimed water. Reclaimed water was also used to irrigate 201,465 residences, 572 parks, and 251 schools. St. Petersburg is home to one of the largest dual distribution systems in the world. (A dual distribution system is one where pipes carrying reclaimed water are separate from those carrying potable water.) In existence since the 1970s, this network provides reclaimed water to residences, golf courses, parks,



schools, and commercial areas for landscape irrigation, and to commercial and industrial customers for cooling and other applications.

For more information, see Crook (2005) and Florida Department of Environmental Protection (2006).

### **Cary, North Carolina**

The town of Cary is the first city in the state of North Carolina to institute a dual distribution system. The system has been in operation since 2001 and can provide up to 1 million gallons of reclaimed water daily for irrigating and cooling. The reclaimed water has undergone advanced treatment and meets North Carolina water quality rules. To date, there are over 400 residential and industrial users.

For more information, see <http://www.townofcary.org/services-publications/water-sewer/water/reclaimed-water>.

### **Bayberry Hills Golf Course, Yarmouth, Massachusetts**

The Bayberry Hills Golf Course expansion is one of numerous water reuse projects in Massachusetts. It was initiated in 2001 as an addition to an existing golf course of seven holes irrigated with reclaimed water. These seven holes use approximately 18 million gallons of water per year, and water reuse was necessary since Yarmouth's water supply was already operating at capacity during summer months. The reused water undergoes secondary treatment followed by ozone treatment, filtration, and UV disinfection. There are provisions for water storage during the nongrowing season. The water reuse project has reduced the nitrogen needed for golf course fertilization.

For further information on irrigation of golf courses with reclaimed water, see the USGA website for Water Use on Golf Courses (<http://www.usga.org/course-care/digitalcollections/irrigation-management.html>) and United States Golf Association (1994).

## **Agricultural irrigation case studies**

### **Southeast Farm, Tallahassee, Florida**

The Southeast Farm in Tallahassee, Florida, has been irrigating with reclaimed water since 1966. The farm is a cooperative between the city of Tallahassee, which supplies water, and farmers who contract acre-

age. Until 1980, the farm was limited to 20 acres of land for hay production, but has expanded since then to 2,163 acres. The irrigation water receives secondary treatment. The crops grown are corn (*Zea mays* L. subsp. *Mays*), soybeans [*Glycine max* (L.) Merr], bermudagrass [*Cynodon dactylon* (L.) Pers], and rye (*Secale cereale* L.).

In recent years, however, elevated nitrate levels have been found in the waters of Wakulla Springs State Park south of Tallahassee, which is one of the largest and deepest freshwater springs in the world. This has apparently resulted in excessive growth of algae and exotic aquatic plant species, causing reduced clarity and changes in the spring's ecosystem. Dye studies have confirmed that at least a portion of the nitrate comes from the Southeast Farm's irrigated fields, although studies are on-going. As a result, in June 2006, the city of Tallahassee removed all cattle from Southeast Farm, eliminated regular use of nitrogen fertilizer on the farm, and implemented a comprehensive nutrient management plan for the farm.

### **Water Conserv II – City of Orlando and Orange County, Florida**

Water Conserv II has been in existence since 1986, and is the first project permitted by the Florida Department of Environmental Protection for crops for human consumption. Over 3,000 acres of citrus groves are irrigated with reclaimed water, in addition to nurseries, residential landscaping, a sand mine, and the Orange County National Golf Center. No problems have resulted from the irrigation. The reclaimed water provides adequate boron and phosphorus and maintains soil at correct pH for citrus growth. The adequate supply of water permits citrus growers to maintain optimum moisture levels for high yields and ample water for freeze protection, which requires more than eight times as much water as normal irrigation.

## **Acknowledgements**

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## Websites for More Information

### General information

<https://watereuse.org>: WateReuse Association. “The WateReuse Association is a non-profit organization whose mission is to advance the beneficial and efficient use of water resources through education, sound science, and technology using reclamation, recycling, reuse, and desalination for the benefit of our members, the public, and the environment.” Page contains links to water reuse projects (mostly in the western U.S.), and other useful links.

### Virginia water reuse

[http://missionh2ovirginia.com/wp-content/uploads/2013/12/Water-Reuse-White-Paper\\_6.2014.pdf](http://missionh2ovirginia.com/wp-content/uploads/2013/12/Water-Reuse-White-Paper_6.2014.pdf) Water reuse as a solution in the eastern Virginia groundwater management area. Description of water reclamation and reuse as a means of replacing or reducing groundwater withdrawals.

### East Coast water reuse

[www.floridadep.org/water/reuse/index.htm](http://www.floridadep.org/water/reuse/index.htm): Florida Department of Environmental Protection water re-use page. Links to many water reuse-related resources on site, including general education/information materials, and Florida-specific links on water reuse policy, regulations, and projects.

[https://epd.georgia.gov/sites/epd.georgia.gov/files/related\\_files/site\\_page/GAEPD\\_Guidelines\\_Water-Reclamation\\_Reuse\\_Y2012.pdf](https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/GAEPD_Guidelines_Water-Reclamation_Reuse_Y2012.pdf) Georgia Department of Natural Resources Environmental Protection Division’s “Guidelines for Water Reclamation and Urban Water Re-Use (2012).

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