Appendix C: Guidelines for Using Recycled Wastewater for Golf Course Irrigation in the Northeast

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INTRODUCTION

The availability of fresh water for irrigation in many parts of the United States is becoming critically limited. This is especially true for irrigation of non-food and fiber productions sites including parks, commercial and residential lawns, athletic fields, golf courses, cemeteries, sod farms and other landscape plantings. This is true even for the northeastern US where many people perceive an abundance of fresh water. In order to meet demand, major metropolitan water suppliers in the northeastern US are required to double the supply capacity of their systems for the three summer months that are dominated by landscape irrigation demands.

As urban and suburban sprawl continues, the demand for freshwater resources also increases. Water conservation and/or the use of alternative water sources, such as waste water for landscape irrigation can help address the growing demand for fresh water. Most large-scale waste water irrigation comes from sewage treatment plant effluent. The southwestern US has successfully used treated sewage effluent and gray water for irrigation for many years.

The benefits of using waste water as an irrigation source include: conservation of freshwater that would be used for irrigation, supply of small amount of nutrients to enhance plant growth every time the site is watered, and a reduction of pollutant (phosphorus and nitrogen) discharge in to surface water.

The potential hazards from waste water irrigation involve salt injury to plants, long term effects on soil health (reducing in drainage and increase in runoff/erosion), other soluble compounds in the water and human pathogens in the waste water. Proper water treatment has all but eliminated the human pathogen issue. Long-term use of waste water irrigation of turfgrass sites in the desert southwest, a low rainfall area, has shown to increase salts levels in the soil which could harm plant growth and impede drainage by destroying the structure of soils with clay. However, in areas with 30 to 60 inches of rainfall per year, will waste water irrigation harm plant growth and soil health?

In the Northeast, waste water use for irrigation has been very limited. For example,, in New York State only two golf course complexes out of 850 golf courses use waste water for irrigation. One golf course (45 holes) in Lake Placid, NY, gets all its irrigation water from the Village of Lake Placid and the Village of Lake Placid has reduced its phosphorus loading into Lake Champlain by 25 percent. At the Turning Stone Casino Resort, four of the five courses use recycled waste water, which is generated by on-site use, exclusively for irrigation. To date, neither the Lake Placid golf courses nor the Turning Stone Casino golf courses have reported any observable turf damage from the use of recycled waste water.

Water as an Essential Resource

Potable water reserves comprise only 2-5% of the total global water supply. Ground water makes up only 1.7% of that total. Ground water supplies only 30% of the water resources used for human and industrial purposes, the remaining 70% comes from surface water sources.

The demand for fresh water for human consumption and uses continues to increase. Interest in conserving fresh water and finding alternative water sources to be used for agriculture and landscape management has become important societal concerns/issues.

What is Waste Water?

Waste water is water that has been reclaimed from municipal waste water or sewage treatment plants. Waste water is also referred to as recycled water, reclaimed water, effluent water and gray water. Recycled water can beneficially be used for agricultural or landscape purposes and for recharging ground water supplies.

Before being recycled or discharged into streams or lakes, the waste water goes through a primary, secondary or tertiary treatment process. The primary treatment process removes the sediments and is not recommended for use. The secondary treatment uses a process of biological oxidation and disinfection. The resulting effluent can be used to irrigate non-food crops, and possibly for industrial cooling processes, wetland and wildlife habitat, stream augmentation and ground water recharge of aquifers not supplying potable water. Tertiary treatment involves chemical coagulation, filtration and disinfection. This water can be used for golf course and landscape irrigation, food crop irrigation and other uses.

Using recycled waste water for golf course irrigation can decrease the diversion of freshwater from sensitive ecosystems, decrease the discharge of waste water to sensitive water bodies, may be used to enhance wetlands and riparian habitats and prevent or reduce pollution.

Why golf courses?

Golf courses serve important environmental, recreational and economical roles in our communities as sites for recreation, wildlife sanctuaries and comprise land that can help to filter recycled water.

The typical Northeast 18-hole golf course uses between 15-30 million gallons of water per year. The Northeast is currently fortunate to have access to water to meet this demand under most non-drought conditions. Other parts of the country with low rainfall have had to switch to alternative water sources for irrigation so enough freshwater would be available for human consumption.

Use of Recycled Waste Water for Golf Course Irrigation

Golf course managers in the Northeast are largely unfamiliar about using recycled waste water for irrigation. Many questions have slowed the adoption of this practice including:

1. Will the waste water be harmful to the turf?
2. Will I have a consistent water supply when I need it for irrigation?
3. Would extra equipment or retrofitting the current irrigation system be necessary?
4. How would the public or clients react to the use of this water on the golf course?
5. Is it necessary and easy to get approval to use waste water for irrigation?
6. How must management be changed when using waste water?
7. What are the costs or savings associated with using waste water?

Potential benefits of irrigating with waste water include the opportunity to conserve a precious natural resource, to provide a site that would serve as a biofilter (thus reducing the amount of effluent water reaching streams and lakes), to use a water source that contains some nutrients (which would reduce the need for some additional fertilization) and to find a less expensive water source than potable water.

NEW YORK GOLF COURSE EXPERIENCES WITH RECYCLED WASTE WATER FOR IRRIGATION

We are using the experiences of three New York golf courses to provide insight on using waste water for irrigation: Lake Placid Resort Golf Course, Turning Stone Casino and Resort, and Indian Island Golf Course.

Lake Placid Resort Golf Course

The Lake Placid Resort Golf Course is a rather large operation with 45 holes of resort golf turf. For the last 7 years, 12 - 20 million gallons of recycled waste water have supplied all their irrigation needs. The Lake Placid Resort Golf Course had the opportunity to be part of a New York State Energy Research Development grant associated with the Lake Champlain Basin program with the objective of helping to reduce the amount of phosphorus reaching the lake. The grant funded the testing of the river water and ground water as well as some startup costs at the treatment plant and the golf course.

The close supply of recycled water, within a mile of the golf course, aided a quick start up. The water was tested weekly and a close working relationship with treatment plant manager was established. Joe De Forest, assistant golf course superintendent, stated that access to this waste water allowed the golf course to irrigate the fairways which previously were not irrigated. He found that the turf was healthier and better able to handle periods of stress. The regular fertilizer program could be reduced slightly and there was a dramatic increase in the turf quality which led to increased revenue from more play.

With the ability to irrigate areas not previously irrigated, such as the fairways and by keeping the turf growing during the summer period, there was a slight increase in disease, insect and weed pressure and expense to manage these changes. More labor was needed to handle the extra mowing and pest management which was an expected outcome when increasing the amount of irrigated land.

When irrigating with waste water, Deforest suggests:

1) Developing a good relationship with the treatment plant personnel so they can keep you informed of plant operations that might affect your water supply.

2) Having the water tested on a routine basis, monthly as a minimum and weekly if the water has a high salt content.

3) Keeping or developing an alternate water supply in case there is an interruption of water supply from the treatment plant.

The overall environmental impact to the community included a 25% reduction of phosphorus loading into the Lake Champlain Basin from the Village of Lake Placid Sewage Treatment Plant. On average the golf course used 20 million gallons of waste water per year and served as a bio-filter thus reducing the amount of waste water directly discharged into the Chubb River.

Turning Stone Casino and Resort

Turning Stone Casino and Resort had the unique opportunity to build their golf courses knowing that waste water would be the main source for irrigation. This is a very large complex with three 18-hole and two 9-hole golf courses. Four of the five courses use waste water exclusively for irrigation. The golf course managers anticipated certain benefits of using waste water including the ability to conserve a natural resource by using recycled waste water, have a constant reliable supply of water that contained some needed nutrients and have a relatively inexpensive source of water. However the managers had some concerns which focused on water quality issues for growing turf including: 1) the pH of the waste water, 2) whether there would be a slight odor, any pathogens or trace organics, and 3) the heavy metal and salinity content.

The Oneida County Waste Water Treatment Facility is a two stage aerobic processes in which the water passes through a series of filters and screens, then a chlorine contact, next through a tertiary filter, chlorinated and finally discharged. Water is tested four times a day for non-turf related water quality parameters before it leaves the plant.

Turning Stone has two of their 18-hole courses and one 9-hole par three course certified in the Audubon International Sanctuary Program. This certification program requires water quality analysis be made twice a year for total phosphorus, pH, total calcium carbonate (CaC03), total metals, total kjeldhal nitrogen as nitrogen, chloride, nitrate nitrogen, sulfate, alkalinity as CaC03 and total dissolved salts. The results indicated the water was suitable for irrigation with minor modification.

Daily 1.1 million gallons of waste water is pumped to the golf course regardless of demand and held in a holding pond. The unused water or extra water moves through an overflow system which drains into a stream that has many opportunities for the water to be filtered before it exits the golf course and finally reaches Oneida Lake.

The golf course director, Andy Knappenburger and the course manager Frank Albino have been quite pleased with the quality of the turf and playability. They advise regular water testing so informed management decisions can be made throughout the growing season.

Indian Island Golf Course on Riverhead, Long Island

In this situation, the Waste Water Treatment Plant in Riverhead discussed with the Suffolk County Parks Committee the possibility of using effluent water from the plant to irrigate the golf course which was right next to the plant. The goal was to conserve their fresh water supply and hopefully reduce the effluent discharged into the Peconic Estuary. The golf course agreed to consider using the waste water for irritation if the Health Department verified a lack of public safety concerns and if trial applications demonstrated the recycled water was suitable for growing turf.

The golf course built a practice green, tee and fairway as a test model to see how the use of this recycled water would affect the turf. They replicated the grasses and management regime used elsewhere on the golf course and began testing the soil and water. The results from the demonstration site showed no impact from using recycled waste water.

However, in order to meet the daily quality and quantity requirement of 350,000 gallons of high quality water for the golf course, the existing water treatment system at the plant would need to be upgraded. The original cost of the system upgrade was estimated in 2004 to be almost two million dollars. Current estimates now come close to three million dollars so the project is on hold until supplemental funding is procured to launch this project.

When considering recycled water for irrigation, plan ahead and use the following steps:

- Determine what town, county and state permits and approvals are necessary when considering using recycled waste water for irrigation.

- The ideal situation would be to have the recycled water source fairly close to the golf course. If this is not possible the costs to set up a deliver system can be extremely costly.

- Visit the water treatment plant, learn about their water treatment process, ask for an analysis of the water and begin to develop a relationship with the plant manager.
- Your course may need some additional equipment to be able to utilize the new water source efficiently. A booster pump and electricity may be needed for the additional pump capacity.
- Where will the extra recycled water be stored? Are there lakes or ponds on the golf course that could serve as holding areas? These ponds may have an odor problem.
- Be prepared to devote more time to management. More time will be necessary to monitor soil nutrient levels and water quality. With the increase in acreage irrigated there will be more mowing and possibly more pest pressure to deal with. Depending on water quality more time will be necessary to monitor drainage.
- If weeds and algae build up in the irrigation pond a herbicide treatment may be necessary to reduce aquatic weed growth. Be sure the herbicide treatment will not harm golf course grasses or have any restrictions for use as an irrigation source.
- Be sure your membership is aware that recycled water is being used.
- Take steps to be sure the irrigation water does not reach adjacent properties or potable water sources by runoff off or overspray into wetlands or water courses.
- Make sure it will not be used for drinking.

EVALUATING RECYCLED WASTE WATER FOR GROWING TURF

Begin with a water sample

Be sure to use a certified water testing laboratory. Each water testing laboratory has specific guidelines for sampling water and submitting samples for testing so be sure to follow their instructions. Generally, the water should be sampled from the irrigation head after it has run for a few minutes so that stagnant water can be flushed from the line. Do not sample directly from the pond or well. Laboratories usually require about 12-16 oz for a sample. If the laboratory does not supply a sampling bottle, place the sample in a clean plastic bottle after it has been rinsed with the same water to be tested. Avoid using bottles containing carbonated beverages, sports drinks or food. Be sure to label the sample and keep notes regarding the location of where the sample was taken. See appendix for a list of a few labs that test waste water for irrigation.

Which parameters should you test?

When assessing irrigation water quality the following components should be evaluated: the salt content, which is expressed as electric conductivity (ECw) or total dissolved salts (TDS), the sodium (Na) hazard expressed as the sodium adsorption ratio (SARw), the levels of carbonate, bicarbonate, residual sodium carbonate (RSC), calcium, magnesium, boron, chlorine, and pH. Table A lists the common units used to report water test results.

Table A. Water Components and Units

Quality Factor	Preferred Units
Water – degree of acidity/alkalinity	pH
Total Salinity – impact on plant growth from higher total salts	
Electrical conductivity (EC)	dS/m, mmhos/cm
Total dissolved salts (TDS)	mg L^{-1}
Carbonates and Bicarbonates	mg L^{-1}, ppm, meq L^{-1}
Sodium Permeability Hazard – impact on soil structure	
Sodium adsorption ratio (SAR)	meq L^{-1}
Adjusted SAR (adj SAR)	meq L^{-1}
Residual sodium carbonate (RSC)	meq L^{-1}
Ion Toxicity – impact on root and foliar contact	
Na – sodium	meq L^{-1}, mg L^{-1}
Cl – chloride	mg/L
B – boron	mg/L
Nutrients	mg L^{-1}, meq L^{-1}

Note: 1 milligram per liter (mg L^{-1}) equals 1 part per million (ppm). Another unit is miliequivalent per liter (meq L^{-1}).

Additional water quality factors impacting irrigation water include the presence of solid particles which can be organic (organic matter) or inorganic in nature (sand, silt, clay). These particles can clog irrigation heads and nozzles, cause wear and tear on equipment and plug soil pores causing a reduction in drainage. A filtering system should be added to the golf course irrigation system to prevent this. Weed seeds, algae and chemical materials can also be found in recycled water.

Water testing labs may use different units when reporting results. Table B provides conversion factors to convert mg L^{-1} to meq L^{-1}. For a more comprehensive listing of conversion factors, see Table K at the end of this document.

Table B. Conversion Factors

Component	To convert mg L^{-1} to meq L^{-1}, multiply by	To convert meq L^{-1} to mg L^{-1}, multiply by
Sodium (Na^{+})	0.043	23
Calcium (Ca^{++})	0.050	20
Magnesium (Mg^{++})	0.083	12
Bicarbonate (HCO_3^{-})	0.016	61
Carbonate (CO_3^{--})	0.033	30
Chloride (Cl^{-})	0.029	35

For example, if your water test report states the calcium level was 1.6 meq L^{-1} and you wanted to know the level in mg L^{-1}, take 1.6 x 20 = 32 mg $L^{-1}$of calcium.

Soluble Salts

Salts found in the soil originate from mineral weathering to form soil, from fertilizers or irrigation water. All irrigation water will contain some soluble salts and traces of other materials. Soluble salts include sodium chloride, calcium chloride or magnesium sulfate and at high concentrations can inhibit growth. Insoluble salts, which do not inhibit growth but can clog soil pores, include limestone, calcium carbonate and gypsum (magnesium sulfate). Some salts are nutrients and are beneficial to turf but many can be toxic at high concentrations. Salt is the most common problem with recycled water.

Caution must be used if the waste water being used to establish turf or renovate turf is high in soluble salts and if rainfall is limited. Young plants are more sensitive to salt injury than well established mature plants.

High levels of salt in the soil inhibit water uptake by the roots causing reduced growth, discoloration, wilting, leaf curling and eventually desiccation or leaf firing. High salt levels in the soil influence water infiltration into and percolation through the soil resulting in poor drainage.

The salt content of the waste water will depend on the water source. High levels of salt can accumulate if the irrigation water is high in salts, if there is limited rainfall and if capillary rise of water brings salts to the soil surface due to evapotranspiration. Soils with high levels of salt are called saline soils.

The salinity of the water is reported in several ways, as electric conductivity (ECw) and stated as milimhos per centimeter (mmhos cm^{-1}), micromhos per centimeter (umhos cm^{-1}), decisiemens per meter (dSm^{-1}) or siemens per meter (Sm^{-1}) or as total dissolved salts (TDS) in units of milligrams per liter (mg L^{-1}) or parts per million (ppm). Most sewage effluent contains 200-3000 mg L^{-1} TDS or 0.30 – 4.7 dSm^{-1}. (Feigin et al.1991). Table C lists the total salinity hazard based on electric conductivity (ECw) and total dissolved salts (TDS).

Table C. Total Salinity Hazard Classification Guidelines for Variable Quality Irrigation Water based on Electric Conductivity (ECw) and Total Dissolved Salts (TDS) (Adapted from Carrow and Duncan, 1998)

Salinity Hazard Class	ECw (dSm^{-1})	TDS (mg L^{-1})	Management Requirements
Low	<0.75	<500	no detrimental effects expected
Medium	0.75 – 1.50	500 - 1,000	moderate leaching* to prevent salt accumulation
High	1.5 – 3.00	1,000 – 2,000	turf species/cultivar selection, good irrigation, leaching*, drainage

Very High	>3.00	>2,000	most salt-tolerant cultivars, excellent drainage, frequent leaching*, intensive management

** It has not been determined that leaching is required in higher rainfall areas like the Northeastern US.*

Turfgrasses tolerance to salt

Turfgrasses differ in the tolerance to salt (see Table D). Cultivars within a species can also vary in their salt tolerance. Acceptable levels for turf irrigation water ranges from 200-800 mg L^{-1}. Soluble salt levels greater than 2000 mg L^{-1} may injure turf.

Table D. Turfgrasses Tolerance to Total Salinity (Adapted from Harivandi and Beard, 1998)

Sensitive	Moderately Tolerant	Tolerant	Very Tolerant
0-3 dSm^{-1}	**3.1-6 dSm^{-1}**	**6.1-10 dSm^{-1}**	**>10 dSm^{-1}**
Annual bluegrass Colonial bentgrass Kentucky bluegrass Rough bluegrass Most zoysia spp.	Annual ryegrass Creeping bentgrass Fine-leaf fescues	Perennial ryegrass Tall fescue	Bermudagrass Seashore Paspalum

In the Northeast, the annual rainfall ranges between 30" and 60". We do not expect the accumulation of high levels of salt with this amount of rainfall. However, under serious periods of drought and when the irrigation water has high soluble salts, management strategies may be employed to reduce the salt concentration.

In situations where the salt concentration is medium (500-1000 mg L^{-1}), leaching with fresh water may be necessary to prevent salt accumulation. The volume of water applied should be increased by 12.5% for each 640 mg L^{-1} rise in TDS in the irrigation water. Additional management strategies must be used when trying to manage sites with very high concentrations of salt, >2000 mg L^{-1}. Along with frequent leaching with good quality water, salt tolerant species should be used, and a routine aeration program should be established, comprised of frequent shallow core aeration and deep tine cultivation (8-12" once or twice a year) to help maintain excellent drainage (Duncan, Carrow and Huck 2000). Leaching could lead to ground water quality problems, so do it as little as possible!

Sodium Permeability Hazard

The sodium (Na) concentration and the quantity of other salts in the irrigation water can affect soil permeability, which is the ability of water to infiltrate into the soil and move through the profile. When irrigation water has sodium levels > 200 mg L^{-1} sodium (Na) may build up over time and will affect permeability. Calcium which is important to soil structure stability is displaced by sodium which causes the soil structure to break down resulting in reduced water and oxygen infiltration and percolation. This problem can become a more serious problem on fine-texture clayey soils, than sand-based systems. (See Table E).

To assess the potential of the problem you need to know the following:

1) **sodium adsorption ratio** (SARw) which incorporates the influence of sodium, calcium and magnesium concentrations. SAR values >6 meq L^{-1} contain sodium (Na) high enough to cause structural deterioration of some soils.

2) **bicarbonate and carbonate levels.** The bicarbonate ion can combine with calcium and or magnesium and precipitate out as calcium carbonate and magnesium carbonate. This increases the Sodium Adsorption Ratio because it lowers the amount of dissolved calcium concentration. Also, high levels of bicarbonate in the water can raise the pH to undesirable level.

3) **type of clay in the soil**. Expanding clays like montmorillonite and illite are more susceptible to structural breakdown than other clays that do not crack when drying.

Table E. Sodium Permeability Hazard (Adapted from Harivandi and Beard, 1998: Carrow and Duncan, 1998)

Irrigation Water Components	Degree of Problem		
SARw or adj SARw (sodium adsorption ratio by clay type (mg L^{-1})	**Low**	**Moderate**	**High**
Clay type unknown	<10	10 – 18	>18
Clays that shrink and swell*	<6*-8**	6*-16**	>9*->16**
Clays do not crack on drying *** or swell on wetting	<16	16 – 24	>24
Sands with ECw >1.5 dSm^{-1}	<10	10 – 18	>18
Sands with ECw <1.5 dSm^{-1}	<6	6 -9	>9
RSC (residual sodium carbonate)	<1.25	1.25 – 2.50	>2.50

** Montmorillonite clays (2:1); ** Illite clays (2:1); *** Kaolinite (1:1). Other 1:1 types are Fe/Al oxides and allophones.*

Another fact to keep in mind is that sodium (Na) is absorbed by plant roots and transported to the leaves, where it can accumulate and can cause plant injury.

The Residual Sodium Carbonate (RSC) is also used to assess the sodium permeability hazard and includes the influence of bicarbonates and carbonates as compared to the calcium and magnesium concentration. To determine the residual sodium carbonate (RSC) the levels of bicarbonate and carbonate are added and the combined calcium and magnesium levels are subtracted and reported as meq L^{-1}. RSC = (CO3 + HCO3) – (Ca + Mg), in meq L^{-}. If the RSC is >1.25 meq L^{-1} and the SARw is >6 meq L^{-1}, water acidification may be necessary.

The total salt content of the water (ECw) and the sodium adsorption ratio (SARw) must be considered together when determining the sodium permeability hazard. The high soluble salt concentration inhibits or counteracts the dispersing influence sodium. The electric conductivity and the sodium adsorption ratio of the waste water can be used to assess the potential for irrigation problems (Table F).

Table F. Assessing Soil Permeability* and Potential Irrigation Problem using Electric Conductivity (ECw) and Sodium Adsorption Ratio (SAR) together (Adapted from Harivandi 1998)

	Degree of Restriction on Use		
Soil water infiltration	**None**	**Slight to Moderate**	**Severe**
if SARw = 0-3 & ECw=	>.7	0.7 – 0.2	<0.2
if SARw = 3–6 & ECw =	>1.2	1.2 – 0.3	<0.3
if SARw = 6-12 & ECw =	>1.9	1.9 – 0.5	<0.5
if SARw =12-20 & ECw =	>2.9	2.9 – 1.3	<1.3
if SARw =20-40 & ECw =	>5.0	5 – 2.9	<2.9

** Soil permeability is the ability of water to infiltrate into the soil and percolate/drain. Gas exchange is also reduced by low soil permeability.*

Ion Toxicities

Ions that can cause some toxicity problems include sodium (Na^+), chloride (Cl^-), boron (B^+), bicarbonate (HCO_3^-), and pH (H^+ or OH^-). (See Table G). Germinating seeds and young seedlings are especially sensitive to high levels of these ions. Use Table G to assess the risk factor in terms of toxicity to roots or leaves.

Table G. Specific Toxic Ion Reference Points (Adapted from Harivandi and Beard, 1998: Carrow and Duncan, 1998)

Specific Toxic Ions		Risk		
		Low	**Moderate**	**High**
Sodium Content				
toxicity to roots	SARw	<3	3 -9	>9
	mg L^{-1}	<70	70 – 210>210	
toxicity to leaves	meq L^{-1}	<3	>3	
	mg L^{-1}	<70	>70	
Chloride Content				
toxicity to roots	meq L^{-1}	<2	2 – 10	>10
	mg L^{-1}	<70	70 – 355>355	
toxicity to leaves	meq L^{-1}	<3	>3	
	mg L^{-1}	<100	>100	
Residual Chlorine (Cl_2)	mg L^{-1}	<1	1 – 5	>5
Boron				
toxicity on roots	mg L^{-1}	<0.7	0.7 – 3.0>3	
Bicarbonate	meq L^{-1}	<1.5	1.5 – 8.5 >8.5	
	mg L^{-1}	<90	90 – 500>500	

Nutrient Levels

Recycled water contains a number of different nutrients that can have an impact on the golf course fertility program and can have an environmental effect. Routine testing is necessary so in season adjustments can be made to reduce supplemental fertilization when sufficient nutrients are supplied by the recycled waste water. Table H offers some general guidelines for interpreting the nutrient content of the recycled waste water.

Table H. Nutrient Guidelines in Irrigation Water (mg L-1) (Adapted from Duncan, Carrow and Huck, 2000)

Nutrient	Low	Normal	High	Very High
		mg L^{-1}		
P	<0.01	0.1 – 0.4	0.4 – 0.8	>0.8
PO_4^-	<0.3	0.3 – 1.21	1.21 – 2.42	>2.42
P_2O_5	<0.23	0.23 – 0.92	0.92 – 1.83	>1.83
K	<5	5 – 20	20 – 30	>30
K_2O	<6	6 – 24	24 – 36	>36
Ca	<20	20 – 60	60 – 80	>80
Mg	<10	10 -25	25 -35	>35
N	<1.1	1.1 – 11.3	11.3 – 22.6	>22.6
NO_3^-	<5	5 – 50	50 – 100	>100
S	<10	10 – 30	30 – 60	>60
SO_4^-	<30	30 – 90	90 -180	>180

By calculating the ratios of specific nutrients you may be able to detect a possible nutrient deficiency. Concerns should be verified by a plant tissue analysis before making major fertilizer program changes.

Table I. Nutrient Ratios in Irrigation Water and Potential Deficiencies* (Adapted from Duncan, Carrow and Huck. 2000)

Ca: Mg	<3:1	Ca deficiency
	>8.1	Mg deficiency
Ca:K	<10.1	Ca deficiency
	>30:1	K deficiency
Mg:K	<2:1	Mg deficiency
	>10.1	K deficiency

** Irrigation water with nutrient concentrations outside these ranges can be used; the fertility program may be adjusted to avoid deficiencies*

EXAMPLE WASTE WATER REPORT

The reference tables provided can be used to assess the suitability of the waste water for turf irrigation. The following is a sample water test report.

CAYUGA LABORATORIES

Green Valley Golf Club
Pleasantville, NJ

File Number: 736548
Date Received:

Sample Location:
Sample Description:

pH	8.43
Hardness	304.36 mg L^{-1}
Hardness	17.80 grains/gal
Conductivity	1.61 dSm^{-1}
Sodium Adsorption Ratio	5.23
Adjusted SAR	9.62
pHc	7.56
Residual Sodium Carbonate	-2.10

		mg L^{-1}	meq/L	lbs/ac in
Calcium	(Ca)	57.95	2.89	13.14
Magnesium	(Mg)	38.66	3.18	8.77
Potassium	(K)	16.05	0.41	3.64
Sodium	Na)	209.66	9.12	47.55
Iron	(Fe)	< 0.30		
Total Alkalinity	$CaCO_3$)	198.36		44.99
Carbonate	(CO_3)	21.90	0.73	4.97
Bicarbonate	(HCO_3)	197.53	3.24	44.80
Hydroxide	(OH)	0.00		
Chloride	(Cl)	319.99	9.02	72.57
Sulfur as	(SO_4)	76.52	1.59	17.36
Salt Concentration	(TDS)	1033.60		234.42
Boron	(B)	0.18		0.04

Use the following steps to determine the suitability of the water represented in the above water sample report (Modified from Carrow).

1. Check **Electric Conductivity (ECw)** and **total dissolved salts (TDS)** for their impact on turfgrass.

   Check the values listed in the sample report for conductivity 1.61 mmhos/cm* and the TDS level of 1033.60 mg L^{-1} with Table C. Both values are considered high.

   *** 1 mmhos cm^{-1} = 1dSm^{-1}**

High total salinity values in conjunction with low sodium Na^{+} and bicarbonate HCO_3^- levels would indicate the potential to create a saline soil condition. Do not use this water if possible or other management practices may be needed such as aeration and leaching.

2. 2. Check sodium (Na) level.

   Use Table G to evaluate the sodium (Na) level which is 209.66 mg L^{-1}**. Although this is a moderate level, Na levels >200** mg L^{-1} **can build up over time.**

3. It may be worthwhile to note the Sodium Adsorption Ratio (SARw) at this time especially if the soils are more fine-textured. These soils are more susceptible to structure deterioration when the salt concentration is high.

   According to Table G. the SARw level of 5.23 meq L^{-1} is under the level of concern for plant roots.

4. The permeability hazard can be determined by evaluating the electric conductivity (ECw) in conjunction with the sodium adsorption ratio (SAR) levels. Knowledge of the clay type will be useful. These values will determine the level of aerification, amendments and leaching that may be needed.

   Use Table F to see that with ECw at 1.61 (mmhos/cm which = dSm^{-1}) and a SARw of 5.23 there would be no restriction in permeability with this water.

5. Now check for bicarbonates and carbonates in the water. If concentrations are greater than 120 mg L^{-1} and 15 mg L^{-1}, respectively, you will have to take an additional step.

   The report states the bicarbonate and carbonate levels at 197.53 + 21.90 = 219.43 mg L^{-1} **Both levels are higher than the cautionary levels.**

6. Check the Adjusted Sodium Adsorption Ration (adj SAR) and the Residual Sodium Content (RSC) to verify the degree of impact that these ions will have on Ca and Mg activity. A SARw level >6 meq L^{-1} and a RSC level >1.25 mg L-1 may indicate that acid treatment plus lime or gypsum applications are needed.

   The SARw level of 5.23 meq L^{-1} and the RSC level of -2.10 are under the level for concern as shown in Table D.

7. Use Table H to check sulfur (S) and or sulfate (SO^4) levels in the water. If S >60 mg L^{-1} or SO4 > 180 mg L^{-1}, you may need to use lime as an amendment. The high sulfates (sulfur) in the water will combine with lime to form gypsum. Removing the excess sulfur and sulfates will help minimize anaerobic problems and black layer formation when regular aeration and leaching are used in management protocols.

Sulfur reported as sulfate is 76.52 mg L^{-1}**. Table H indicates this level is in the normal range and below the level of concern which is 180** mg L^{-1}**.**

8. Check actual Chloride (Cl) and Boron (B) levels for their specific ion toxicity potential. These ions normally will affect susceptible turf cultivars but continued accumulation can eventually influence even tolerant species. Plants tolerant to high total salinity also are generally tolerant to high levels of these specific ions.

   The value for Cl it is 319.99 mg L^{-1} and for B it is 0.18 mg L^{-1}. Both levels are considered moderate according to Table G.

9. Check levels of actual nutrients and make appropriate adjustments in your fertility program to account for nutrient additions or any induced deficiencies. Check the report levels for the following nutrients and compare with Table H. Calcium at 57.95 ppm is in the normal range, magnesium at 38.66 ppm is considered very high and potassium 16.05 ppm is in the normal range.

10. Calculate Ca:Mg, Ca:K and Mg:K ratios and adjust the fertility program accordingly.

    The ratio of Ca: Mg is 1.5:1, for Ca:K it is 3.5:1 and for Mg:K 2.4:1. According to Table I, these ratios indicate there could be calcium and magnesium deficiencies. At this point, you could look for symptoms of calcium and magnesium deficiencies and have a tissue test done to confirm this possibility.

In summary, this water poses some concerns if used because of its high electric conductivity, moderate sodium level and high bicarbonates and possible calcium and magnesium deficiencies.

HOW MUCH NUTRIENTS ARE SUPPLIED BY WASTE WATER IRRIGATION?

Another useful management step is to determine the amount of nutrients supplied with the irrigation water so that the total amount of supplemental fertilization can be reduced accordingly. Table J lists the amount of nutrients supplied per inch of irrigation water per 1000 sq. ft.

Table J. Nutrients Supplied by Waste Water Irrigation per 1000 sq ft per Inch of Irrigation at a concentration of 1 mg L-1

Nutrient or Element	**Concentration** mg L^{-1}	**Lb of nutrients/ 1000 sq ft/ Inch of irrigation**
N	1	.005
NO_3^-	1	.001

P	1	.012
PO_4^-	1	.004
P_2O_5	1	.005
K	1	.006
K_2O	1	.005
Ca^{++}	1	.005
Mg^{++}	1	.005
S	1	.005
SO_4^{-2}	1	.002

The below sample water test results will be used to demonstrate how to calculate the nutrients provided given the analysis of this particular irrigation water.

Sample

Waste Water Results from Sun Mountain Golf Course

Parameter		
Ammonium	NH_4	12.07 mg L^{-1}
Nitrate Nitrogen	NO_3	3.17 mg L^{-1}
Phosphorus	P	.32 mg L^{-1}
Potassium	K	8.62 mg L^{-1}
Calcium	Ca	85.69 mg L^{-1}
Magnesium	Mg	15.17 mg L^{-1}
Sulfur	S	.33 mg L^{-1}
Sodium*	Na	21.36 mg L^{-1}
Chloride*	Cl	230.85 mg/kg
Electric Conductivity *	EC	.82 dS/m

During the 2005 growing season, Sun Mountain Golf Course irrigated with 20" of the above waste water. The manager wanted to determine if an adjustment in their fertilizer program would be necessary after applying 20" of this particular water.

To calculate the amount of nutrients supplied by waste water irrigation follow the steps below.

1. **Add the ammonium (**NH_4**) and nitrate nitrogen (**NO_3**) amount to come up with total nitrogen.**

   12.07 + 3.17 = 15.24 mg L^{-1} total nitrogen.
   From Table J note that each mg L^{-1} of nitrogen contributes .005 lb of nutrients with each inch of irrigation. Multiply 15.24 by .005 which = .077 mg L^{-1} of nitrogen per inch of water. Multiply this by 20 (the amount of total irrigation) to come up with **1.5 lb of nitrogen** which was supplied per 1000 sq ft last year with the waste water irrigation.

2. **Phosphorus (P) fertilizer recommendations are reported in the oxide form P_2O_5.**
   To calculate the P_2O_5 when you have the P value multiply the P value by 2.29.

   Take the P value of 0.32 multiple it by 2.29 to come up with 0.73 mg L^{-1} of P_2O_5. Then multiply this by .005 (the pounds of nutrients supplied with each inch of irrigation) which totals .004 mg L^{-1} and then multiply by 20 (the total inches of irrigation) to see that **0.07lb of P_2O_5** was supplied per 1000 sq ft last year with the waste water irrigation.

3. **Potassium (K) fertilizer is reported as K20 so you will have to make this calculation first.**
   To calculate the K_20 when you have the K value multiply K by 1.2.

   8.62 mg L^{-1} of potassium multiplied by 1.2 equals 10.3 mg L^{-1} of K_20. Multiply this by .005 (the pounds of nutrients supplied with each inch of irrigation) to get .05 mg L^{-1} then multiply this by 20 (the total inches of irrigation) to see that **1.0 lb of K_20** was supplied per 1000 sq ft last year with the waste water irrigation.

* Other reported parameters:
  According to Table G, the sodium level of 21.36 mg L^{-1} is very low and is not of concern, but the chloride level of 230.85 mg/kg is in the moderate risk category. Table C indicates salinity as reported as electric conductivity is in the medium range.

With 20" of irrigation water applied in 2005 the turf was receiving a total of 1.5 lb of nitrogen, 0.07 lb of P_2O_5 and 1.0 lb of K_20. The golf turf manager should take this nutrient contribution into consideration and adjust the fertilization program accordingly.

SUMMARY

This initial survey of the potential for using waste water to irrigate golf course shows great promise. Managers found that the benefits of using the recycled waste water out weighed the costs. Especially when the waste water source was close to the golf courses, waste water offered less expensive water for irrigation.

It was acknowledged that extra management would be necessary to monitor the water and soil nutrient content through routine testing so timely adjustments could be made throughout the growing season. Managers found that having access to waste water would increase the areas irrigated and offered more play. Extra mowing and pest management may be necessary.

The community would reap environmental benefits by having more water from the treatment plants diverted to the golf course where the soil would serve as a bio-filter and reduce the amount of phosphorus and nitrogen reaching streams and lakes.

These guidelines provide the necessary information on what testing should be done on waste water and how to interpret the results to use waste water safely.

Golf course managers and community members are encouraged to learn all they can about their local water sources. The references listed at the end of this publication contain in-depth information which should be thoroughly reviewed by all interested parties.

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Examples of Water Testing Labs that do complete waste water analysis:

Brookside Farms Laboratories, Inc., 308 South Main St., New Knoxville, OH 45871
419-753-2448. www.blinc.com

CLC Labs, 325 Venture Dr., Westerville, OH 43081. 614-888-1663

A & L Great Lakes Lab, Inc. , 3505 Conestoga Drive 209, Fort Wayne, IN 46808
260-483-4759. www.algreatlakes.com

MDS Harris -Agronomic Services, 624 Peach St., Lincoln, NE 68502
402-476-2811. http://ag.mdsharris.com

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Table K. Conversion factors

	To convert mg L^{-1} to meq/L, multiply by:	To convert meq/L to mg L^{-1}, multiply by
Sodium Na^{+}	0.043	23.0
Calcium Ca^{++}	0.050	20.0
Magnesium Mg^{++}	0.083	12.2
Chloride Cl	0.029	35.4
Potassium K^{+}	0.026	39.0
Sulfate SO_4^{--}	0.021	48.0
Carbonate HCO_3	0.016	61.0

Note: 1 mg L^{-1} = 1 ppm

For example, to convert 220 mg L^{-1} Na^{+} to meq L^{-1}: (220 mg L^{-1}) x (0.043) = 9.46 meq L^{-1} Na^{+}

	Convert ECw	Multiply by:
Electrical Conductivity of Water	mSm^{-1} to dSm^{-1}	0.01
	dSm^{-1} to mSm^{-1}	100
	mScm^{-1} to mSm^{-1}	100
	mSm^{-1} to ppm	6.4
	dSm^{-1} to ppm	640
	mScm^{-1} to ppm	640
	ppm to dSm^{-1}	0.0016

Other Conversion Factors:

1 mmhos cm^{-1} = 1 dSm^{-1} = 1,000 umhos cm^{-1} = 0.1 Sm^{-1}
1 umhos cm^{-1} =0.001 dSm^{-1} = 0.001 mmhos cm^{-1}
1 ppm = 1 mg L^{-1} (solution) = 1 mg kg^{-1} (soil)
1% concentration = 10,000 ppm
1 mmolc^{-1} = 1meq L^{-1}
1 ECw (dSm^{-1}) = 640 ppm (TDS = Total Dissolved Salts)
TDS (ppm) = ECw x 640; TDS (lb./ac.ft.) ≈ TDS (ppm x 2.72)
ppm = grains per gallon x 17.2
(grains/gallon is still used by domestic effluent water purveyors to report hardness)
Sum of cations and anions (meq L^{-1}) ≈ EC (dSm^{-1}) x 10