“Reclaimed Water Use for Irrigation on Texas Golf Courses”

Directed Research Paper
Texas State University-San Marcos
Department of Geography

Daniel J. Ray

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Dr. Richard A. Earl
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CONTENTS

List of Tables

List of Figures

List of Maps

Introduction

Water is a valuable resource which becomes more precious as demand for fresh water increases. With increasing urban populations and diminishing sources of fresh, potable water, management practices must adapt to the new pressures on water resources. Texas is at a unique time in our water management practices. We have the ability to be proactive in our water management strategies to better conserve and protect our water resources before demand outpaces availability. Wastewater reclamation and reuse is a strategy used to mitigate the impacts of increased demand on fresh water resources. Potable water must meet high quality standards, while other uses of water can be conducted at lower qualities. Irrigation of turfgrasses on golf courses with treated wastewater effluent can reduce the demand on municipal water resources serving the need of water conservation, but this has "both advantages and disadvantages related to regulatory, agronomic, economic, and operational issues" (Huck, Carrow, and Duncan 2000, 15). Through this research those regulatory, agronomic, economic, and operational issues will be discussed and analyzed in the context of Texas golf courses.

Objective

The purpose of this research is to analyze the inherent benefits and potential problems associated with wastewater reused to irrigate golf courses. A recycled water use survey was prepared and sent to United States Golf Association (USGA) member courses in Texas to evaluate the spatial distribution of golf courses utilizing reclaimed water in Texas. This research will also analyze the regulatory and management issues and considerations identified by Texas golf course superintendents for beneficial use of reclaimed water.

Rationale/Justification

Golf courses generate substantial economic activity as sources of outdoor recreation for personal use for people of all ages. While providing social benefits golf courses generate substantial demand on water supplies due to the amount of irrigated land necessary for adequate playing conditions. Water resources in Texas are a fragile resource due to increasing population and periodic droughts. This situation has encouraged many golf course superintendents to seek alternative sources of irrigation water, such as reclaimed water. Although most previous research has focused on problematic areas such as Tucson, Arizona (Hayes, Mancino and Pepper 1990) or Florida (Cisar et al. 2006), the need for alternative sources of non-potable water are not exclusive to these regions. In Texas the major sources of potable water are reservoirs, rivers and underground aquifers (Thomas et al. 2006). The TWDB anticipates that the current estimated total water demand of 17 million acre-feet per year will increase to about 20 million acre-feet per year by 2050 (Krishna 2006). With growing populations creating increased demand on drinking water sources and restrictions being applied, many courses are turning to effluent wastewater for irrigation (TWDB 2001).

Definitions

Reclaimed water, as defined in the Texas Administrative Code, is “domestic or municipal wastewater which has been treated to a quality suitable for beneficial use” (TAC §210.31). *Beneficial use* is an economic use of wastewater in accordance with the purposes, applicable requirements, and quality criteria of chapter 30 of the Texas Administrative Code, and which takes the place of potable and/or raw water that could otherwise be needed from another source (30TAC 210.3). *Municipal wastewater* is wastewater that is “discharged into a publicly or a privately owned sewerage treatment works primarily consisting of domestic waste

(30TAC 210.3). *Type I* reclaimed water is water that is likely to come into contact with humans. *Type II* reclaimed water is unlikely to come into contact with humans. Reclaimed water may also be called recycled water, reused water, or effluent water (30TAC 210.3). Asano (2001) describes *wastewater reclamation* as the "treatment or processing of wastewater to make it reusable and that *water reuse* is the actual "use of treated wastewater for beneficial purposes."

Literature Review

The use of reclaimed municipal wastewater for irrigation on golf courses is not a new management practice. In many states such as California, Arizona, Florida, and Texas, treated effluent has been used for several decades on golf courses, and as of 1998 there were over 200 courses in the U.S. reportedly using reclaimed water (USGA 1994; Graves and Cornish 1998; Feigan, Ravina, and Shalhevet 1991). Golf courses are major users of municipal water with typical irrigation rates on 18-hole courses between 250,000 and 1 million gallons per day (Huck, Carrow, and Duncan 2000). Besides its obvious conservation benefits, reclaimed water users also experience other benefits associated with its use. The Texas Water Development Board (TWDB) notes that not only is reclaimed water a drought proof water source, it also increases in volume as the population increases, and sources of treated effluent are usually located near the intended use (TWDB, 2001).

Many course superintendents have reservations switching to reclaimed wastewater, having their "sweet dreams of fast greens and flawless fairways quickly turn into nightmares of deteriorating turfgrass quality" (Huck, Carrow, and Duncan 2000, 15). Managing golfers' expectations for near perfect turf conditions adds extra pressure for course superintendents when using recycled wastewater. Irrigating with effluent water comes with benefits but it also presents "unique challenges for a course superintendent" (Harivandi 2004a). Every course is not the same so special considerations on a site by site basis must be made to ensure "minimal negative impact of recycled water irrigation on the playability and agronomic health of a golf course" (Harivandi 2004a).

Important risks and considerations associated with the use of effluent water on golf courses include; soil degradation, storage capabilities, public perception, costs, and environmental impacts off site. Most previous research has primarily focused on soil and water properties. Risks to soil include "degradation of aggregate stability, a decrease in the soil hydraulic conductivity, surface sealing, runoff and soil erosion problems, soil compaction and a decrease in soil aeration" (Levy et al. 1999). Hayes, Mancino and Peppers' (1990) study of effluent water application to turfgrass found higher sodium, nitrogen, phosphorous, and potassium in soils irrigated with effluent water than in soils irrigated with potable water. While many constituents in reclaimed water have a detrimental effect on turfgrass growth, some nutrients can have positive effects on soils and turfgrasses. As King, Balogh, and Harmel (2000) point out, higher volumes of nitrogen allow for the reduction of nitrogen applied from fertilizer.

Salinity

The most common water quality concern associated with effluent water irrigation is the salt content of the water (Feigin, Ravina, and Shalhevet, 1991). Total salts is reported as electrical conductivity of water (EC) or total dissolved salts (TDS), and "inhibits turfgrass water uptake" (Duncan, Carrow, and Huck 2000), potentially resulting in "physiological drought conditions (Fipps 2003). Soluble salts are present in all recycled waters and are acceptable up to 800 ppm (parts per million), with injury to turfgrass occurring at levels exceeding 2000 ppm, but adequate permeability and drainage allows for proper leaching of excessive salt from the rootzone (Harivandi 2004b). Excess salt is also detrimental to ornamental plants. Plant roots are less sensitive to salt than leaves; therefore drip irrigation is recommended on ornamentals rather than spray sprinkler heads. This keeps salt off leaves and reduces salt burn (Wu, Guo, and Harivandi 2001).

Sodium/SAR

Sodium also significantly impacts soil structure, specifically the permeability of the soil. Hayes, Mancino and Pepper (1990) found that irrigation with effluent water produced significantly higher sodium levels than use of potable water. The higher sodium properties found in reclaimed water "severely reduce both soil aeration and water infiltration and percolation" (Harivandi 1994, 114). The sodium absorption ratio (SAR) is used to assess sodium induced water permeability problems (Huck, Carrow, and Duncan 2000; Harivandi 1994; Harivandi 2004b). According to Harivandi (2004b), most plants will tolerate up to 70 ppm sodium. Symptoms of decreased permeability of soils due to excessive sodium include "waterlogging, slow water infiltration, crusting and/or compaction, poor aeration, weed invasion, and disease infestation" (Harivandi 1994, 115). In response to the hazards presented by sodium in effluent water, proper monitoring should be included in management practices.

Nutrients

Reclaimed water also includes beneficial nutrients such as nitrogen, phosphorous, and potassium. These nutrients are quite beneficial in turfgrass management programs, and since they are applied regularly, the nutrients can be "efficiently used by the turfgrass" (Harivandi 1994, 121). The "economic value of nutrients can be substantial" (Harivandi 2004b) since recycled water often contains enough nutrients to significantly reduce the amount of fertilizer needed, but Huck, Carrow, and Duncan (2000) warn that on greens, excess nitrogen can "produce more growth than desired." King, Balogh, and Harmel (2000) suggest establishing a "nutrient budget for sources of phosphorous and nitrogen for each zone of the course." Since nutrients such as these are contained in fertilizers, a nutrient budget is a good management practice in order to monitor levels of these nutrients.

Boron

Boron is an essential element for plant growth, but only in small quantities. If it occurs in amounts significantly greater than needed it becomes toxic (Ayers and Westcott 1985). Although there has not been much discussion of the presence of boron in reclaimed water, it is an element worth monitoring in irrigation waters because too much boron in the water can cause accumulation in the soil, resulting in drying and chlorosis in leaf tips (Huck, Carrow, Duncan 2000).

Chloride

According to Ayers and Westcott (1985), chloride is the most common toxicity in irrigation water. High levels of chloride "inhibits water uptake as a salt and, thereby, nutrient uptake" (Huck, Carrow, Duncan 2000). When excess chloride is present, sensitive plants exhibit leaf burn, or "necrosis" (Harivandi 2004b).

Carbonate and Bicarbonate

High levels of bicarbonate in irrigation waters can raise soil pH to "undesirable levels," and possibly affect soil permeability (Harivandi 2004b). Carbonate and bicarbonate in irrigation waters react with calcium and magnesium in the soil to cause increases in sodium, which allow for structural breakdown of the soil, meaning that the soil becomes sealed reducing water percolation (Duncan, Carrow, and Huck 2000).

pH

The pH of water is a measure of hydrogen ion activity in water, which "warns that the water needs evaluation for other constituents" (Harivandi 1994, 120). The USGA equates monitoring pH as being analogous to human body temperature as being a sign of illness. Desirable soil pH levels range from 5.5 to 7.0, while the desirable level for irrigation water is 6.5 to 8.4 (Harivandi 2004b; Harivandi 1994).

Storage and Algae Growth

The first choice for reclaimed water storage is an enclosed tank. Enclosed tanks or underground tanks allow for on-site storage while eliminating exposure to sunlight which reduces algae growth that is common in open ponds (Gill and Rainville 1994). The second choice and the most employed method of storage are open ponds and lakes. Algae growth in open storage tanks and reservoir ponds can be detrimental when using reclaimed water (Cisar et al. 2006; Terrey 1994; Huck, Carrow, and Duncan 2000). Although only cited as problematic by 13% of respondents in the Florida survey (Cisar et al. 2006), excessive algae growth can cause problems, particularly in small ornamental ponds and grass areas. This presents new management considerations and requires more frequent maintenance than fresh water reservoirs (Lazarova and Bahri 2005). Deeper lakes and ponds with less surface water are more desirable in controlling for algae blooms (Gill and Rainville 1994). Appropriate aeration and circulation may be necessary to improve odor and algae problems. Installing fountains, air injection, waterfalls and blending reclaimed water with fresh water can all improve algae and odor issues (Terrey 1994).

Costs and Availability

Costs and availability are major considerations when deciding to use reclaimed water, and may be the determining factor on the feasibility of reclaimed water use. As Gross (2004) points out, “the main impediment seems to be the expense and disruption caused by the installation of large delivery pipes.” Construction costs such as these, as well as maintenance, are considered indirect costs (Gill and Rainville 1994). Gill and Rainville identify retrofitting of irrigation systems and maintenance work to be the majority of costs incurred when using treated effluent.

Many places have adopted a philosophy that reclaimed water should be priced at 80% of potable water prices (Rodie 1994; Graves and Cornish 1998). Cisar’s survey of Florida courses returned a range in price of $500 - $816,000 annually, although 52% of respondents do not pay for reclaimed water (Cisar et al. 2006).

Regulations and Standards

Reclaimed water use in Texas is governed by the Texas Commission on Environmental Quality (TCEQ) Chapter 210 (Use of Reclaimed Water). Chapter 210 addresses the quality criteria, design, and operational requirements for the beneficial uses of reclaimed water. These guidelines are authorized under the Texas Water Code (TWC). Section 5.102 of TWC provides the TCEQ with the general powers to carry out duties under TWC. Section 5.103 allows the TCEQ the authority to adopt any rules necessary to administer the powers and duties under the provisions of TWC and other laws of Texas. TWC 26.011 gives the TCEQ the power to establish water quality levels to be maintained and to control the quality of water in the state (TWC).

Sites using reclaimed water in Texas are required to post signs alerting people to the on-site use of reclaimed water. These signs must be in Spanish and English. All plumbing pipes and fixtures used in the transport and delivery of reclaimed water must be painted purple. Purple is the industry standard color to represent reclaimed water. Cross connection and backflow prevention measures must be constructed to prevent contamination of potable sources where dual distribution systems are in place. Nine feet horizontal distance is recommended, but not required, between reclaimed water lines and potable water lines.

Methodology

A survey questionnaire was drafted to identify challenges and benefits to Texas golf courses in their use of reclaimed water, and the spatial distribution of golf courses using reclaimed water. The survey contained thirty-three questions pertaining to physical attributes and water use details of the individual course. The survey was formatted in a fashion to adhere to a previous survey on this topic conducted among Florida golf courses (Cisar et al. 2006). Funding for this research has been awarded via grant from the United States Environmental Protection Agency (USEPA). Additionally, this study has been endorsed by Mr. Bud White, USGA Green Section Director for the Midcontinent Region. Surveys were mailed to course superintendents of the 487 USGA member clubs in Texas. Included with the surveys were self-addressed stamped envelopes to encourage and facilitate the response process. Of the 487 surveys mailed, 150 were returned providing a 31% response rate. Returned surveys were entered into a Microsoft Excel spreadsheet for statistical analysis. The collection period lasted approximately four months to allow adequate response time. Descriptive statistics are used to determine commonality of benefits and issues.

United States Postal Service 5 digit zip codes were used to determine latitude and longitude for mapping purposes of all 487 USGA member clubs. Responses indicating reclaimed water use were extracted from these to create an additional map for analysis of spatial distributions and geographic patterns. ArcMap Version 9.2 was used to map the coordinate locations on a Texas county map.

Limitations

The use of a survey is limited by the fact that not all golf courses in Texas will be accounted for and although our response rate of 31% is acceptable; this only captures 31% of the USGA member courses in Texas. The research also relies on respondents to answer truthfully, since the survey was not conducted on site. The regional study area can also be a limitation to the study.

Results

Surveys were mailed to 487 USGA member courses (Map 1) and 150 were returned (Maps 2,3) providing a respectable 31% response rate. Of those 150, 40 courses (27%) indicated reclaimed water use, and another 40 not currently using reclaimed water expressed interest in using reclaimed water in the future (Table 1). Many clubs (35) not actively using recycled water stated that a reclaimed water source is not available to them. Eighteen more cited costs as a deterrent to retrofitting their course, another 15 found their current water source to be sufficient, and two did not respond to the question. The rest of this section deals solely with the 40 courses practicing reclaimed water use. Total numbers of responses are not uniform for all survey questions due to non-response of some questions. This is reflected here in the text as well as in the tables presented in the back.

The majority of courses participating in recycled water use are private facilities (21) (Table 2), with all courses averaging 142 acres being irrigated with recycled water (Table 3). The average number of rounds of golf played at courses using recycled water is 34,760 (Table 4). Eleven superintendents reported treated effluent comprising 100% of their irrigation water while treated effluent makes up over 90% of the irrigation water used at eight more courses (Table 5). Many courses have been using recycled water for a number of years. Six courses indicated recycled water use for over twenty-five years, while another twelve have used recycled water for over fifteen years (Table 6). The highest monthly mean use of recycled water is 14,331,586 gallons and the lowest monthly mean use is 1,148,669 gallons (Table 7). Areas most commonly irrigated with recycled water are the greens, fairways, primary roughs and tees, each being irrigated by at least 95% of the respondents (Figure 1). Thirty-seven percent of the courses receive their water under significant pressure (Table 8), and the majority (83%) utilized open ponds or lakes to store the reclaimed water (Table 9). One surprising statistic that is beneficial to the acceptance of reclaimed water use is that almost half of the respondents (48%) reported no charges or fees for receiving recycled water (Table 10). For those golf courses paying for their treated waste water, the mean annual price is approximately $50,000, with costs ranging from $1000 to $200,000 annually (Table 11).

The major concern when receiving reclaimed water is its chemical properties (Figure 2). Only five courses are provided a detailed chemical analysis of the water from their provider, but 26 reported that an analysis is available upon request and 32 superintendents indicated performing their own chemical analysis (Table 12). Salinity, sodium/SAR and pH were the most commonly monitored water quality parameters, but boron, chlorine, chloride, bicarbonates, carbonates, nitrogen, phosphorous, potassium, and suspended solids are all monitored by a significant proportion of the superintendents (Figure 2). As expected from review of the relevant literature, salinity was identified as the most important problem associated with irrigation using recycled water, followed by algae growth, clogged irrigation heads and equipment rust. Another important statistic is that complaints from golfers and neighbors were commonly cited as the least important problem associated with recycled water use (Table 13).

Course superintendents reported regulatory inspections and employee training to be the most important regulatory issues impacting their use of reclaimed water (Table 14). Management issues certainly differ when compared to use of potable water for irrigation. This is reflected in the survey responses. The need to periodically leach soils was at the top of the management issues most important to superintendents (53%), while water and fertilizer savings and equipment deterioration were also considered important by a significant number of superintendents (15 and 10 responses respectively) (Table 15). Fourteen superintendents noted that they are limited in time in which they can irrigate (Table 16), mostly at night while no golfers are present. The employment of low water use grasses and plants is another management practice adopted on thirty-one of the courses (Table 17).

Superintendents were asked to rank the potential benefits of using recycled water based on their experience using a Likert scale (with 1 ranking most important and 3 least important). Guaranteed water supply received the best ranking followed by conservation of fresh water and finally costs benefits (Table 18). Respondents displayed an overall satisfaction with using recycled water. Again employing a Likert scale rating system (one indicating high satisfaction and five indicating high dissatisfaction), twenty-seven respondents were either satisfied or highly satisfied with their reclaimed water experience, while only two responses indicated dissatisfaction or high dissatisfaction (Table 19) and eighty-three percent of the golf course superintendents claimed they would continue to use the treated effluent if the choice was theirs alone (Table 20).

Discussion

Wastewater reuse on golf courses in Texas has two distinct regions of widespread use; the San Antonio to Georgetown corridor along Interstate 35 in the Edwards Aquifer region, and the Houston area (Map 2). The abundance of reclaimed water use in the Edwards Aquifer region is attributed to the need for alternative water sources in the face of exploding populations in the last several decades and the legislative push to reduce demands on groundwater. The combination of increasing population, periodic droughts, and the overall need to mitigate demands on potable water sources has lead to a progressive and aggressive approach to conserving water resources in this region. San Antonio Water Systems (SAWS) is exemplary in their aggressive approach towards implementing reuse projects to curb demand on the Edwards Aquifer. The current reclaimed water infrastructure in San Antonio is designed to provide 35,000 AF/year of recycled water to commercial and industrial businesses, 20% of their annual demand on the Edwards Aquifer (SAWS 2007).

Although more conservative in its approach, Austin has been providing reclaimed water for irrigation since the 1970's and codified their intent on reducing potable water demand in 1990 with the city's Water Reclamation Initiative. Austin now conserves 900 million gallons of water per year (2762 AF/Year) (Austin 2007).

Houston's high use of reclaimed water is possibly a result of subsidence problems due to excessive groundwater pumping of the Gulf Coast Aquifer (Seifert and Drabek 2006). This problem has resulted in stricter regulations from subsidence districts in the area (TWDB 2005).

The need for alternative sources of water in this region has probably helped incentivize the use of treated wastewater for irrigation of golf courses.

Possibly the most interesting spatial pattern found is the lack of courses reporting reclaimed water use in the Dallas-Fort Worth region (Map 3). This highlights the future issues regarding water resources in the DFW area. Several cities in the DFW region rank among the highest in the state regarding water use. The 2007 state water plan identifies three of the top five most water consumptive cities in Texas as being in the DFW region. The rankings are on a per capita water use scale and include Richardson, Dallas, and Plano (TWDB 2005).

Another area lacking representation in reclaimed water use is the panhandle and west Texas. The panhandle region and west Texas are areas a person would expect to find more widespread use of reclaimed water on golf courses due to the lack of precipitation. But this spatial pattern is not found in the results of the survey. This is partially a result of unreturned surveys, but might also possibly highlight the common problem of not being in close proximity to a wastewater plant. A common response in returned surveys was the non-availability of reclaimed water.

The first consideration in retrofitting a course to reclaimed water use is costs and availability. According to the results of the survey, the biggest impediment to reclaimed water use appears to be proximity to a treatment plant. Thirty-five superintendents reported that the reason they do not use recycled water is that it’s not available, and another eighteen cited costs as prohibitive in reclaimed water use. Availability and costs are inherently connected since more costs are incurred as the distance that the water must be delivered increases. While initial costs may be prohibitive to some course superintendents, it is encouraging to see that almost half of the course superintendents do not pay for the water once they start receiving it, much like the courses in the Florida survey. This should be a positive indication for the future of reclaimed water use as more treatment facilities are built and restrictions are placed on potable water uses.

As indicated in the review of previous literature, salinity proved to be the highest ranking problem for course superintendents in Texas, followed by algae growth and clogged irrigation heads. To understand if these problems were consistent among old and new reclaimed water users, I classified respondents' surveys into two groups; one group consisted of courses that have used reclaimed water for over fifteen years and another for courses that have been using reclaimed water for less than fifteen years. The order of importance of problems remained constant among both groups, and most ranking scores were similar, although clogged irrigation heads received a higher mean importance rank (3 to 2.28) for courses in the second group as did equipment rust (4 to 3.35). The difference in perceived importance of these issues may be related to management practices and that older courses may have adapted to manage these issues over time.

A similar approach was taken to determine if there is a difference in problem identification between courses that exclusively use reclaimed water for irrigation compared to courses that use a mix of treated effluent and fresh water. Surveys were divided into two groups; the first consisting of courses that indicated reclaimed water use constituting over ninety-five percent of irrigation water and those using a mix consisting of less than ninety-five percent reclaimed water. The importance rank once again remained the same and means were quite consistent, except for clogged irrigation heads and equipment rust. Clogged irrigation heads had a higher importance mean for courses using less than 95% recycled water (2.88 compared to 2.33), and equipment rust had a higher mean score for courses using over 95% recycled water (3.84 compared to 3.56).

Consistent with the Cisar et al. (2006) survey, 83% of superintendents would continue to use reclaimed water if the choice was theirs alone. The guarantee of a reliable source of water was the most commonly cited benefit to using reclaimed water, and surprisingly conservation of fresh water ranked above costs even though half of the responding superintendents do not pay for their water. Another commonly cited benefit was the reduction of fertilizer needed, and one superintendent even replied that more people come to his course during droughts because the course still has green fairways. Additionally 40% of superintendents have systems in place to educate golfers about the use of recycled water (Table 21) and 38% have systems in place to manage golfers' expectations of aesthetics of the course versus the playability of the course (Table 22).

While most course superintendents are happy with their experience using reclaimed water, there were still a variety of problems indicated in the survey. Salinity problems (on turf and leaf burn), odor, and supply issues were cited most. The need to leach soils once every two to four weeks was also indicated by many of the respondents. Most of the courses are also required to irrigate at night, or when there are no golfers present. These issues highlight the increased management needed to properly maintain turf health and reduce issues in the future.

Two golf superintendents reported being unhappy with their reclaimed water. Both of these courses use reclaimed water exclusively for irrigation. One course did not elaborate on his dissatisfaction, although chloride was the only water quality parameter routinely monitored and the respondent also noted that they have not performed an irrigation audit. The other dissatisfied superintendent receives his recycled water from the city wastewater plant where the water is not screened before distribution. This has lead to a continuous problem of clogged intake screen baskets due to trash in the effluent. The maintenance required to keep the intake screens clean costs the superintendent an estimated $10,000 annually. Besides these two responses, reclaimed water appears to be making a positive impact on Texas golf courses.

Conclusion

As evidenced in the survey results, irrigating a golf course with recycled water commands more management, regulatory, and maintenance attention than irrigating with potable water. But, with proper implementation and management, recycled water is an effective conservation measure as well as cheap, continuous source of irrigation water. All new course development should consider the feasibility of recycled water use, as this would reduce retrofit costs at a later time. The success shown in this and the Florida survey depict a bright future for recycled water use, especially as technology and management practices improve.

The future though does hold uncertainties regarding recycled water use. Will prices for reclaimed water increase as it becomes more desirable? Another consideration is water rights. Is it possible that the water we reclaim has deleterious effects on downstream flows for other surface water users? These are some issues that can be discussed in future research on the topic, but at this time reclaimed water is serving as a beneficial use of wastewater in hopes of sustaining our potable water demand.

Table 1

Recycled Water Use Survey	
Surveys Sent	487
Surveys Returned	150
Response Rate	31%
Courses Using Reclaimed Water	40
Courses Not Using Reclaimed Water	110
Courses Considering Use in Future	40

Table 2

Type of Facility		
Private	21	53%
Municipal	7	18%
Daily Fee	8	20%
Military	2	5%
Resort	2	5%

Table 3

Number of Acres Irrigated with Recycled Water	
Highest	400
Lowest	10
Range	390
Mean	142

Table 4

Number of Rounds Played Per Year on Each Course	
Mean	34,760
Median	30,000
Highest	100,000*
Lowest	1200

*72 hole course

Table 5

Percentage of Total Irrigation Met by Recycled Water		
100%	11	28%
90-99	8	20%
80-89	3	8%
70-79	3	8%
60-69	2	5%
50-59	2	5%
<49	7	18%

Table 6

Number of Years of Recycled Water Use		
> 25	6	15%
20-24	6	15%
15-19	6	15%
10-14	3	8%
5-9	11	28%
<5	3	8%

Table 7

Mean Monthly Recycled Water Use	
Highest	14,331,586
Lowest	1,148,669
Range	13,182,917

Table 8

Is Recycled Water Received Under Significant Pressure For Immediate Use?		
Yes	15	38%
No	22	55%

Table 9

Recycled Water Storage		
No Storage	3	8%
Tanks	1	3%
Open Ponds/Lakes	33	83%

Table 10

Charges and Fees		
No Charge	19	48%
Flat Fee	7	18%
Pumping Expense Only	3	8%
Monthly Usage Fee	10	25%
Staggered By Usage	3	

Table 11

Annual Costs for Recycled Water		
No Charge	19	48%
Highest		$200,000
Lowest		$1,000
Mean		$49,916
Median		$30,750

Table 12

Chemical Analysis		
Provided By Supplier		
Yes	5	13%
No	26	65%
Available By Request	9	23%
Performed at Owners Expense	32	80%

Table 13

Potential Problems of Using Recycled Water (Rank)	Number of responses for rank score (1=most important; 5=least important)					
	1	**2**	**3**	**4**	**5**	**Total**
1. Salinity	30	4	3	0	0	47
2. Algae Growth	5	16	6	3	0	67
3. Clogged Irrigation Heads	7	8	10	3	4	85
4. Equipment Rust	2	1	8	15	5	113
5. Complaints from Golfers/Neighbors	1	2	2	7	19	134

Table 14

Regulatory Issues Impacting Use of Recycled Water	Respones	
Regulatory Inspection	8	35%
Employee Training	3	33%
Public Notification of Use	13	28%
Positive Cross-Conection Prevention	11	20%
Plan Submission to Regulatory Body	14	13%
Line Separation Distances	5	8%

Table 15

Management Issues Impacting Use of Recycled Water	Responses	
Need to Periodically Leach Soils	21	53%
Water/Fertilizer Savings	14	35%
Equipment Deterioration	9	23%
Over-Seeding Issues	8	20%
Restricted Use of Plant Species Due to Salt Tolerance Issues	6	15%
Retrofit Cost Recovery	1	3%

Table 16

Limited in Time When You Can Irrigate Using Recycled Water?		
Yes	14	35%
No	25	63%

Table 17

Attempt to Incorporate Low Water Use Grasses and Plants		
Yes	31	78%
No	8	20%

Table 18

Rank of Potential Benefits of Using Recycled Water Based on Experience (1=most important; 3=least important)		
	Sum	Mean Score
Guaranteed Water Supply	58	1.76
Conservation of Fresh Water	71	1.87
Cost	78	2.17

Table 19

Overall Satisfaction Level In Using Recycled Water		
Highly Satisfied	13	33%
Satisfied	14	35%
Neutral	10	25%
Dissatisfied	1	3%
Highly Dissatisfied	1	3%

Table 20

If Choice Was Mine I Would Continue Using Recycled Water		
Yes	33	83%
No	6	15%

Table 21

Systems in Place to Educate Golfers to the Use of Recycled Water		
Yes	16	40%
No	23	58%

Table 22

Systems in Place to Manage Golfers Expectations of the "Aesthetics" versus the "Playability" of the Course		
Yes	15	38%
No	23	58%

Figure 1

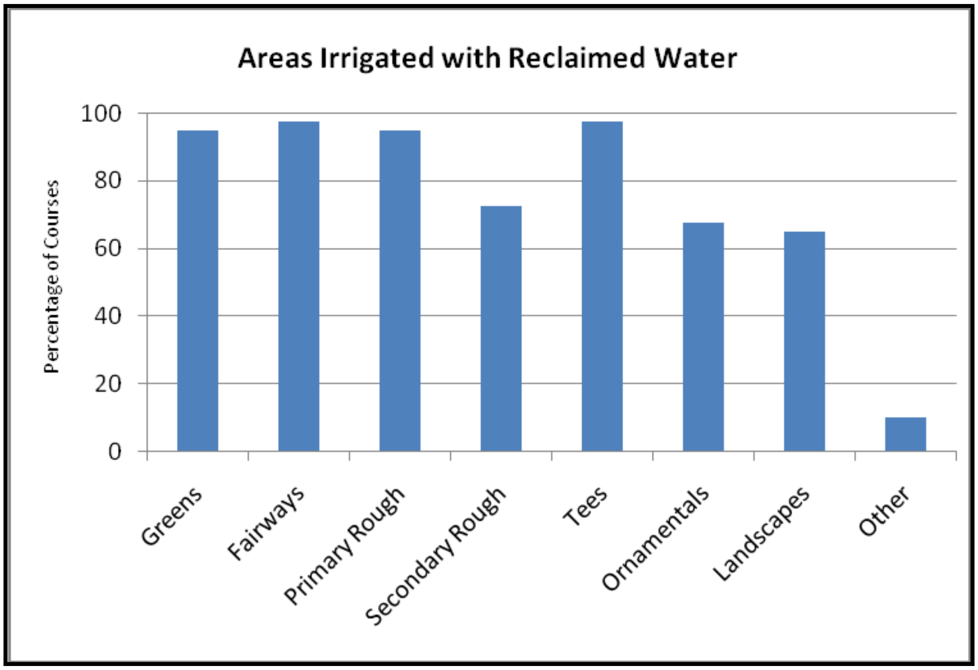
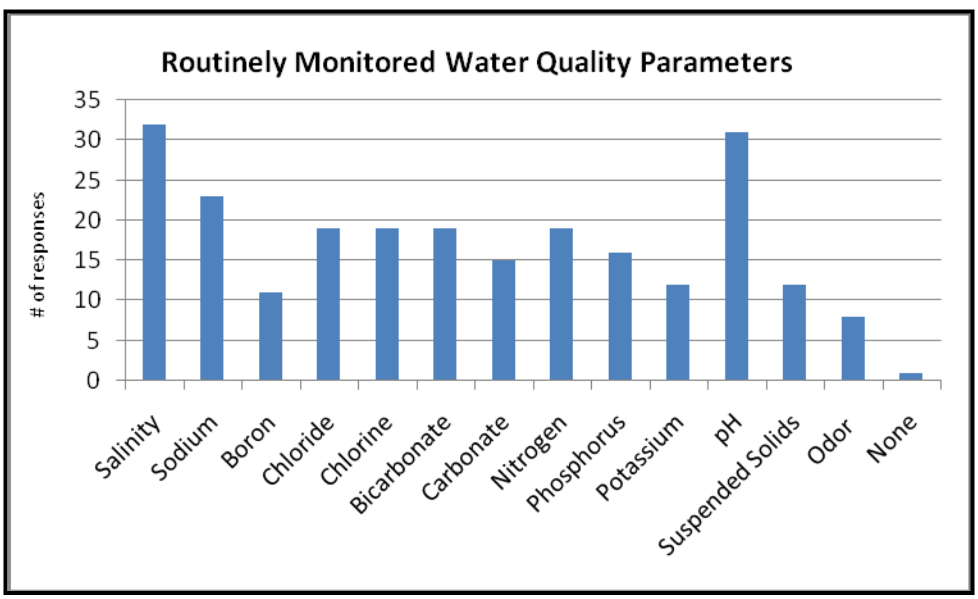
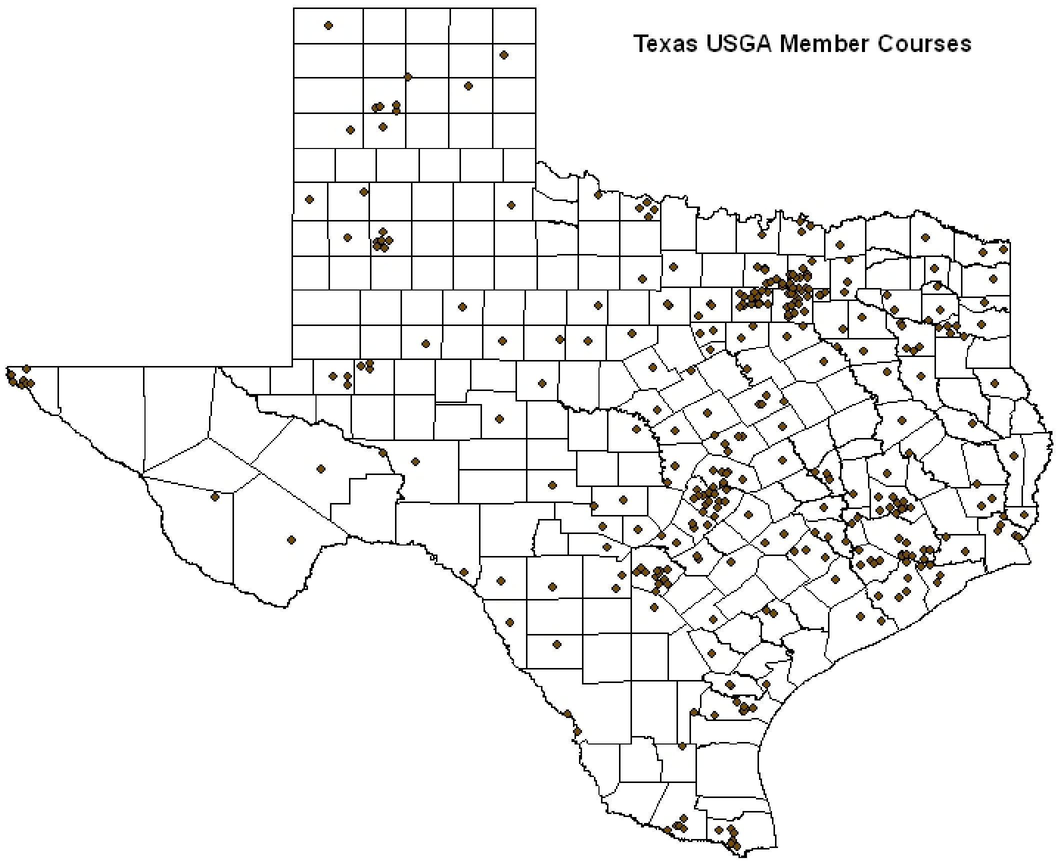


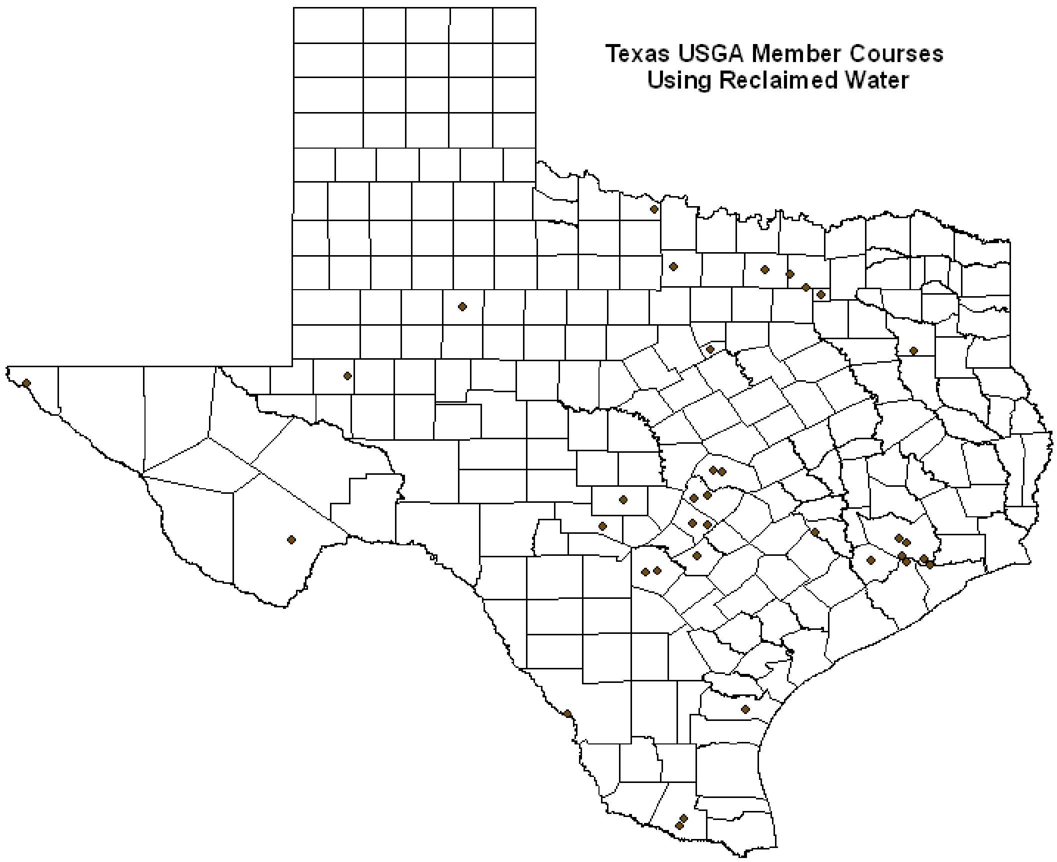
Figure 2



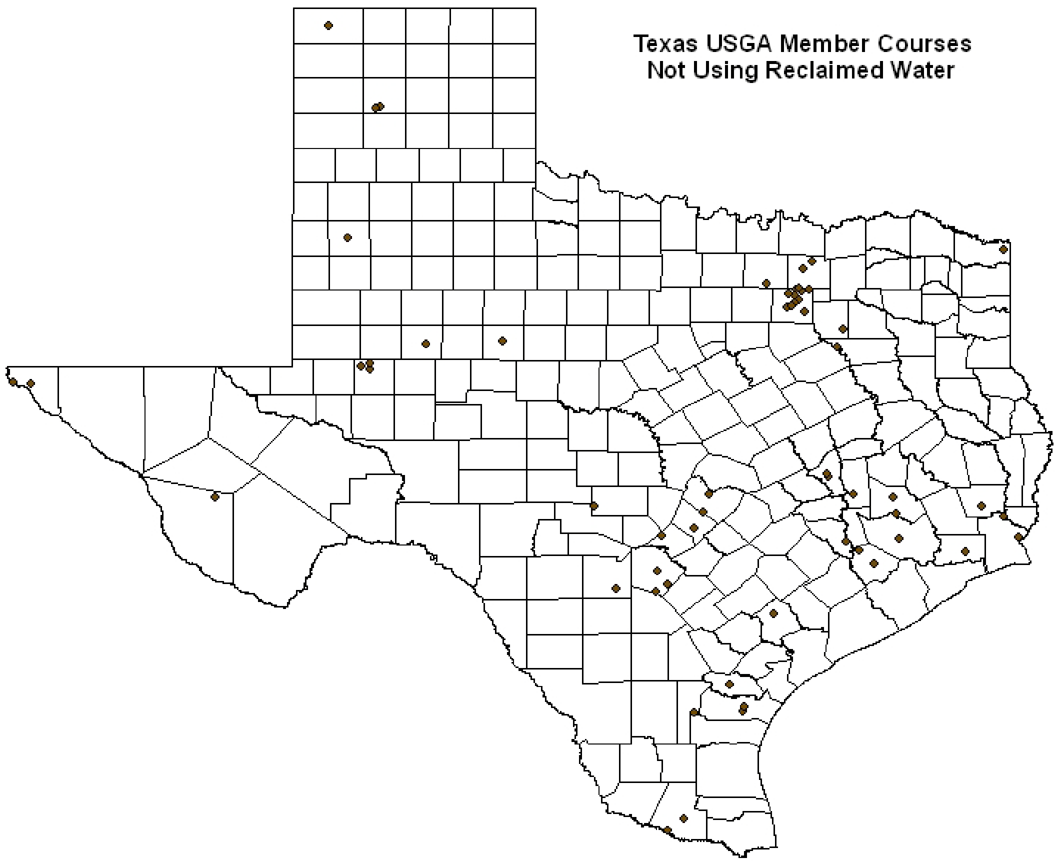
Map 1



Map 2



Map 3



Recycled Water Use Survey

The purpose of this survey is to determine the extent of recycled water use on Texas golf courses. Your participation in this voluntary survey is appreciated. If you have any questions on the survey please contact Dr. Rich Dixon of the Texas State University Geography Department at 512-245-7436 or rd11@txstate.edu

1. Facility name: ____

2. Type of facility:

   Private _____ Municipal _____ Daily Fee _____ Military _____ Resort _____

   Number of holes? ______________

3. Do you presently use recycled water at your facility? Yes____ No___
   (if yes please skip to question 6)

4. If no, are you considering its use in the future? Yes____ No_____

5. If no, what is the most important reason for your answer? ___________________

   (Please return survey. Thank you for your participation)

6. What is your primary source of recycled water? __________________________

7. How many acres do you irrigate with recycled water? ______________________

8. Which areas do you irrigate with recycled water (check all that apply)?

   Greens _____ Fairways _____ Primary rough _____ Secondary rough _____

   Tees _____ Ornamentals _____ Landscapes _____ Other (list) _________

9. How many years have you been using recycled water at this facility? ___________

10. What is your average recycled water usage for the highest and lowest usage months of the year?

   Highest ___________________ Lowest ___________________

11. What other sources of irrigation water do you use?

   Lakes or springs _______ Wells ________ Other (list) _____________

12. What percentage of your total irrigation water is met by recycled water? ___________

13. Is your recycled water received under sufficient pressure for immediate use?

Yes ________ No _________

14. How is your recycled water stored on your facility?

No storage ________ Tanks ______ Open ponds or lakes ________

Other (specify) ______________________________________

15. How does your provider charge you for supplying recycled water?

No charge _____ Flat fee _____ Pumping expense only ________

Monthly usage fee__________ Is this fee staggered by usage? ___________

Other (describe) _________________

16. What is your annual cost for recycled water? ________________________

17. Does your recycled water supplier provide you with a detailed chemical analysis?

Yes ________ Available by request ________ No __________

18. Do you perform (or have performed at your expense) a detailed chemical analysis of the recycled water?

Yes ________ No ___________

19. Which of the following do you routinely monitor in your recycled water.

Salinity _____ Sodium/Sodium Adsorption Ratio ______ Boron ______

Chloride _____ Chlorine ______ Bicarbonate _________ Carbonate ______

Nitrogen _____ Phosphorus ______ Potassium ________

pH _____ Suspended solids ________ Odor _________ None_________

20. Please rank the following potential benefits of using recycled water based on your experience. Rank the most important benefit to you as 1.

Guaranteed water supply _____ Cost ____ Conservation of fresh water _______

21. Please list any other benefits you experience in using recycled water.

22. Please rank the following potential problems of using recycled water based on your experience. Rank the most important problem as 1.

Salinity _____ Algae growth _____ Clogged irrigation heads _____

Excessive equipment rust _____ Complaints from golfers/neighbors ______

23. Please list any other problems you experience in using recycled water.

24. Which of the following regulatory issues impact your use of recycled water.

Positive cross-connection prevention ______ Line separation distances ________

Employee training ________ Public notification of use ____________

Regulatory inspection ________ Plan submission to regulatory body __________

Other (specify) ____

25. Which of the following management issues impact your use of recycled water.

Equipment deterioration _______ Retrofit cost recovery _________

Water/fertilizer savings ________ Over-seeding issues ________

Need to periodically leach soils _______ How often? ________

Restricted use of plant species due to salt tolerance issues _____________

Other costs or savings (specify) ____

26. Overall what is your satisfaction level in using recycled water. _____________
(1=highly satisfied, 2=satisfied, 3=neutral, 4=dissatisfied, 5=highly dissatisfied)

27. Are you limited in the time when you can irrigate using recycled water?

No ____ Yes _____ Please explain _________________________________

28. If the choice was mine alone to make I would continue to use recycled water.

Yes ___________ No _______________

29. How often do you perform an irrigation audit? ______________

30. Do you attempt to incorporate low water use grasses and plants where appropriate?

Yes _____________ No ____________

31. Do you have systems in place to educate golfers as to the use of recycled water?

Yes _____________ No _____________

32. Do you have systems in place to manage golfers expectations of the "aesthetics" of the course versus the "playability" of the course?

Yes _____________ No _____________

33. Approximately how many rounds per year are played on your course? ____________

Thank you for your participation in this survey. If you would like to be kept appraised of this research, please provide contact information below.

Name: ____

Course: ____

E-mail: ____

Please return this survey in the enclosed envelope to:

Dr. Rich Dixon
Department of Geography
Texas State University
San Marcos, TX 78666
rd11@txstate.edu
512-245-7436

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