RESULTS OF THE INITIAL WATER QUALITY MONITORING PLAN FOR AN AUDUBON INTERNATIONAL SIGNATURE COURSE

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Abstract. Cateechee Golf Club (Hartwell, GA) is an Audubon International Signature Course. To establish and maintain this distinction, a golf course must adhere to Audubon Society requirements for environmentally-friendly course management and check the efficacy of that management through an extensive, on-going water-quality monitoring program. The golf course serves as a land-application area to provide final treatment for the effluent from the Hartwell municipal wastewater treatment facility (MWTF). At Cateechee Golf Club, Cedar Creek and two other tributaries enter the property and converge into one stream before flowing off-site. To date, Cateechee Golf Club has been able to maintain high quality water in all streams and ponds. Water quality in Cedar Creek has improved dramatically since land application of wastewater effluent began and it is no longer discharged into the stream. In an effort to anticipate potential problems, the Agricultural and Environmental Services Laboratories (AESL) is closely monitoring high sodium and salinity in the effluent for potential impacts to turf production and soil hydrologic properties.

INTRODUCTION

The Cateechee Golf Club is an 18-hole championship length golf course constructed to model sound environmental practices. Located in the rolling hills of the Piedmont Plateau of Georgia, the 460 acre site was designed by nationally-known golf course architect Mike Young to blend into the natural surroundings of a predominantly mixed hardwood forest. Care was taken to enhance the small wetland areas and other wildlife habitats within the course. The course uses effluent water from the Hartwell municipal wastewater treatment facility (MWTF) for irrigating the greens and fairways. Thus, the community receives the economic and aesthetic benefits of a championship course and uses wastewater in an environmentally sound manner.

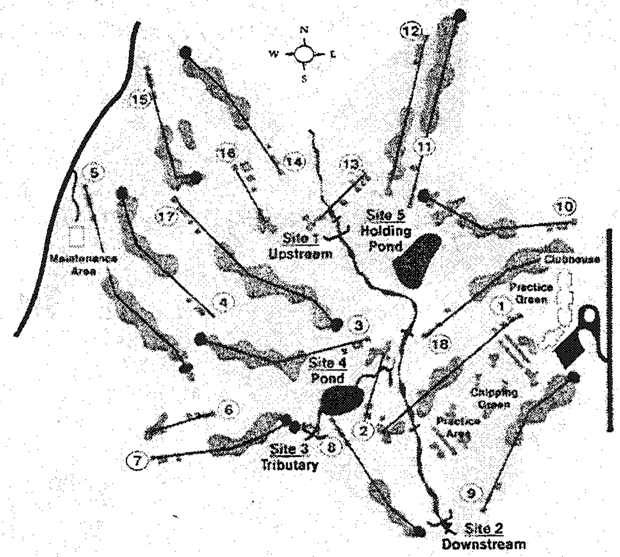

Figure 1: Schematic layout of Cateechee Golf Course. The Wastewater treatment facility is approximately 0.5 miles north (upstream) of the course. A tributary originating below an inactive landfill enters the course from the west, passes through a small pond (designated Pond 4) and enters Cedar Creek. (Map not to scale.)

The objectives of this study were to: 1) design a monitoring plan that would document potential changes in water quality of Cedar Creek entering and leaving the golf course, 2) determine the impact of wastewater application on water quality leaving the golf course, and 3) ensure that integrated pest management is functioning properly and not degrading downstream water quality.

MATERIALS AND METHODS

The Cateechee Golf Club is located in the rolling terrain of the upper Georgia Piedmont Plateau south of Hartwell, GA. Figure 1 presents a map of the course.

The Hartwell MWTF is located north of the site. Prior to August 13, 1999 effluent from this facility discharged into Cedar Creek, which flows from the northwest to the southeast across the course. A major tributary originating near an inactive landfill to the south southwest of the property joins Cedar Creek on the golf course. Numerous ephemeral streams originate on the course property. Wastewater is stored in a holding pond located in the center of the course before being used for irrigation.

The course was designed so that where fairways cross streams, a 25-ft wide strip of unmanaged land acts as a buffer zone around all surface water sources to mediate runoff water contaminants and create wildlife habitat. On holes that slope dramatically toward water, pesticide and fertilizer applications are reduced to no more than 50% of recommended rate. A 100-ft zone which is not irrigated was established around all streams and ponds. Catch basin release points designed to hold fairway runoff are at least 100 ft from water sources and where water from these basins can filter through unmanaged vegetation before entering ponds and streams. Water draining from the wash pad used to maintain pesticide and fertilizer application equipment is filtered through more than 100 ft of unmanaged vegetation and disposed of on an unused part of the property. Water used to rinse the application equipment is recycled.

During course design and construction, it was anticipated that land application of treated wastewater to the golf course would be permitted and allow the city to comply with NPDES regulations. Since there are at least two off-site sources of nutrients and industrial chemicals, base line nutrient and industrial chemical concentrations were established prior to full-season turf management to document prior conditions.

The monitoring plan by the Agricultural and Environmental Services Laboratories (AESL) was initiated when golf course turf was established and pesticides and fertilizers first applied. Beginning in March 1998, surface water was sampled at three stream and two pond locations designated as follows (Figure 1):

- Site 1: Upstream location where Cedar Creek enters the Cateechee Golf Club property,
- Site 2: Downstream location where Cedar Creek leaves the Cateechee property,
- Site 3: Culvert where landfill tributary enters the Cateechee property,
- Site 4: Spillway of small lake (Pond 4) in southwestern tributary, and
- Site 5: Holding pond for effluent wastewater.

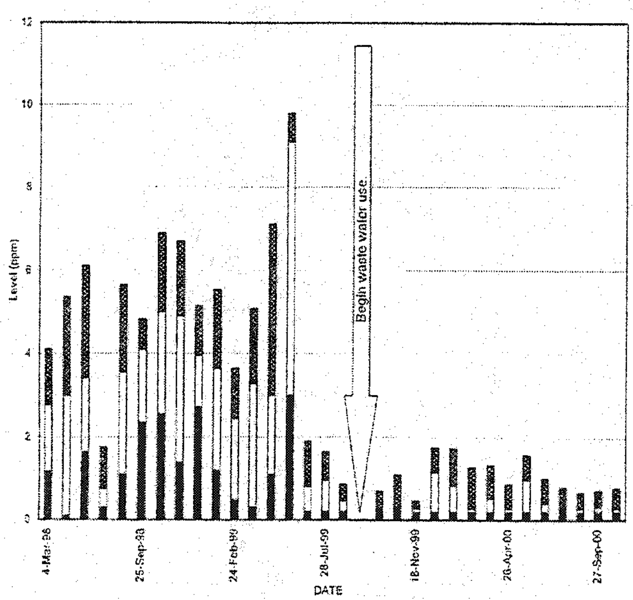

Figure 2. Nitrogen levels in Cedar Creek as it enters the course. ░ = nitrate, □ = organic nitrogen, ■ = ammonium

Table 1. Analytical Parameters

Variable	Analytical Method	Sampling Frequency		
		Stream	Holding Pond	Pond 4
Ammonia	Standard Method 4500-NH_4	Monthly	Quarterly*	Quarterly
Nitrate-Nitrite Nitrogen	AOAC 892.01	Monthly	Quarterly*	Quarterly
pH	EPA 150.1	Monthly	Quarterly*	Quarterly
Specific Conductance	EPA 120.1	Monthly	Quarterly*	Quarterly
TKN	AOAC 955.04	Monthly	Quarterly*	Quarterly
Total P	EPA Method 200.1; ICP	Monthly	Quarterly*	Quarterly
Chlorinated Acidid Pesticides	EPA 515.1	Quarterly**		
Chlorinated and Organophosphate Pesticides	EPA 508	Quarterly**		
Fungicides	EPA 507	Quarterly**		
Herbicides	EPA 507	Quarterly**		
BOD	Standard Method 5210B	Monthly	Quarterly*	Quarterly
Fecal Coliform	Standard Method 9222B	Monthly	Quarterly*	Quarterly
Minerals	ICP EPA Method 200.7	Monthly	Quarterly*	Quarterly
TKN	AOAC Method 955.04	Monthly	Quarterly*	Quarterly
Total Coliform	Standard Method 9222B	Monthly	Quarterly*	Quarterly
COD	Standard Method 5220D	Quarterly	Quarterly*	Quarterly
Orthophosphates	Standard Method 4500-P (E)	Quarterly	Quarterly*	Quarterly
Suspended Solids	Standard Method 2540D	Quarterly	Quarterly*	Quarterly

*Sampling changed to monthly with initiation of wastewater application.
**Pesticide sampling was initially quarterly but changed to semi-annually for Year 2000.

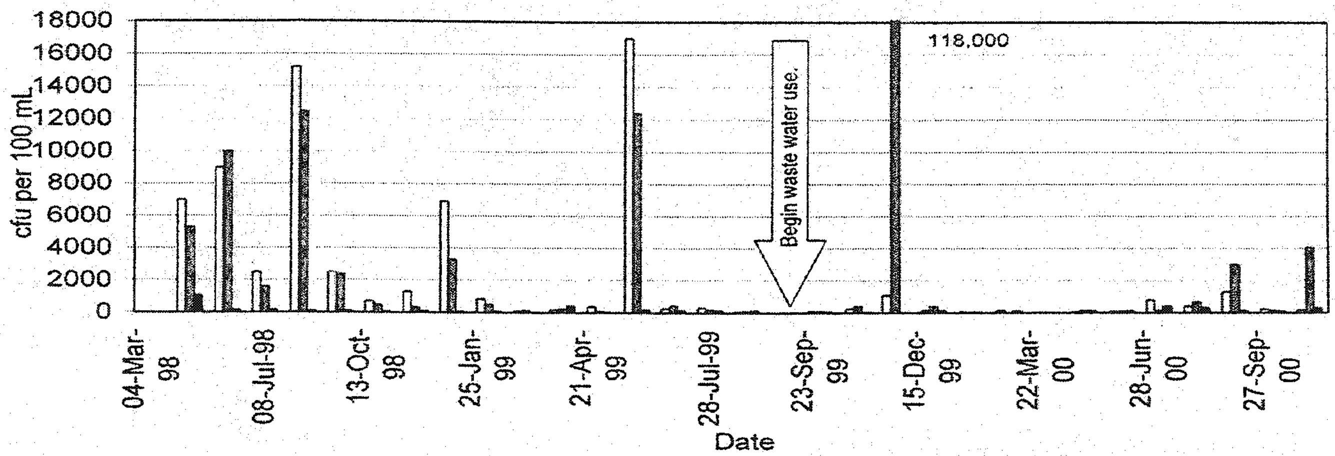

Figure 3. Fecal coliform levels in Cedar Creek as determined in monthly grab samples. □ = upstream, ░ = downstream, ■ = tributary.

Initially, Stream Sites 1, 2, and 3 were sampled monthly, while the small lake in the southwestern tributary (Pond 4) and holding pond were sampled quarterly. Following initiation of land application of wastewater in August 1999, the holding pond was sampled monthly for nutrient analysis. Re-evaluation of sampling schedule and intensity was made after one year and monitoring frequency adjusted accordingly. Water analytical parameters are presented in Table 1.

RESULTS AND DISCUSSION

Monitoring data in Figures 2 and 3, together with other parameters (data not presented) show that water entering the course prior to August 1999 carried heavy N and fecal coliform concentrations. The stream had a septic odor and fish kills were documented. After the initiation of wastewater application in August 1999, water quality of Cedar Creek significantly improved (Figures 2, 3 and 4). Total N levels decreased to <1 ppm, while P levels decreased to <0.2 ppm (Figure 5). Cedar Creek BOD levels decreased from 5-10 ppm to baseline (<5 ppm) levels (data not presented). Sodium adsorption ratio (SAR) also decreased (Figure 5).

As Cedar Creek passes through the course, water quality parameters usually decrease (downstream levels ≤ upstream parameters), indicating no input from course management. Exceptions are nitrate-N levels during turf establishment (Figure 4) and one fecal coliform observation, November 1999. Some nitrate-N originating on the course during turf establishment may have entered the stream before leaving the course. As turf establishment progressed, nitrate-N levels leaving the course decreased to levels below entry levels. The one incident of high downstream fecal coliform probably resulted from a non-point source. The MWTF was no longer discharging into the stream and the upstream sampling point contained low level fecal coliform.

Initiation of wastewater transfer to the holding pond and utilization for irrigation resulted in increased

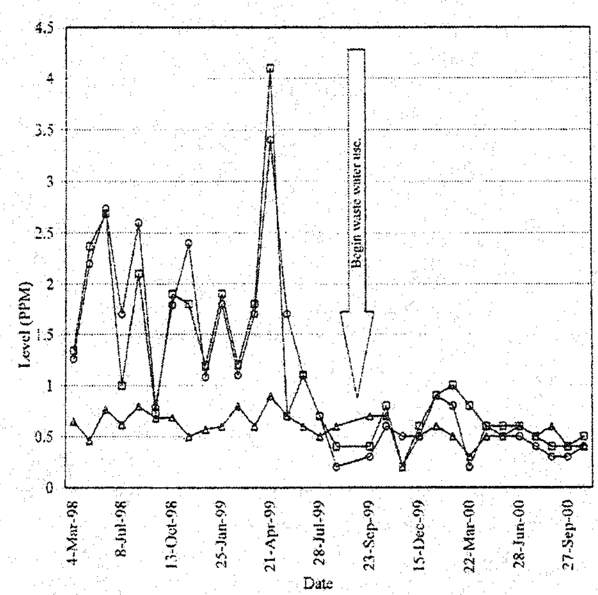

Figure 4. Upstream/downstream/tributary nitrate-N levels with time. • = downstream, ■ = upstream, ▾ = tributary stream.

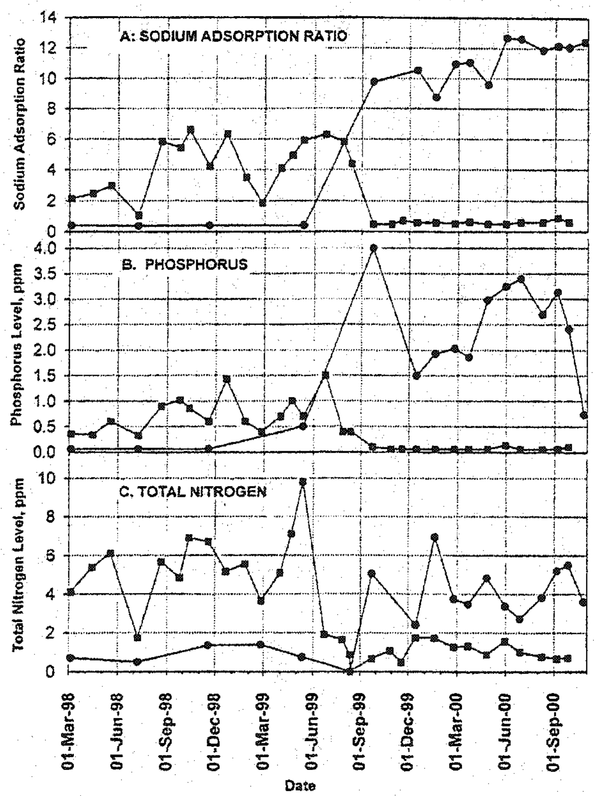

Figure 5. Comparison of stream and holding pond TKN, P and SAR levels as a function of time. •= holding pond, ■ = upstream.

nutrient levels in the pond (Figure 5). The N and P levels in the holding pond increased (>3 ppm N and 2-3 ppm P) and were sufficient to support a substantial number of algal blooms during summer of 2000. Currently odors and aesthetic appearance of the holding pond are manageable but require close attention to avoid problems.

Using irrigation water high in sodium can cause problems associated with the soil's clay and organic matter. The soil's cation-exchange-capacity (CEC) can become saturated with sodium, leading to changes in soil properties which can lead to lower water infiltration rates, less soil aeration, poor root penetration, and loss of soil productivity. The degree to which these properties can affect production is a function of many variables. Usually these problems become worse as clay content and CEC increase. However, many other factors interact and can ameliorate or exacerbate these problems. Sodium hazard from irrigation water is measured using SAR. If sodium is high and calcium and magnesium low, CEC may become saturated with sodium and soil acquire undesirable properties. Before wastewater utilization began at Cateechee, irrigation water SAR was below levels considered hazardous (Figure 5). When wastewater was diverted to the holding pond, SAR increased to levels from about 10 to 25, while average electrical conductivity was 950 Mhos/cm. At these levels, sodium hazard ranges from medium to very high. Sodium and salinity in the irrigation water should be managed, especially during heat and drought. During times of low rainfall and high evaporation/transpiration, salinity of the wastewater may become very high. Bermuda grass is considered salt tolerant but Bentgrass greens may receive salinity damage. Soluble calcium salts should be used to leach sodium only when there is enough CEC to affect the soil's nutritional quality and should be used sparingly when salinity is high.

CONCLUSIONS

Before wastewater was applied, stream water quality was documented. After the wastewater application was initiated, the monitoring program established at Cateechee Golf Course documented the following results:

1) Water quality in Cedar Creek improved and it improves as the stream crosses the golf course.
2) Course pesticide usage does not result in downstream residues. No pesticide residues (insecticide, herbicide, or fungicide) were detected

Table 2. Analytical Detection Limits of Pesticides Monitored (ppb)

2,4-D	5.2	methyl parathion	0.1
2,4-DB	3.9	metolachlor	3.0
2,4,5-T	0.1	metribuzin	1.5
alachlor	2.0	mirex	0.07
aldrin	0.01	molinate	1.0
atrazine	0.5	myclobutanil	1.0
benefin	1.9	napropamide	1.0
bromacil	1.0	oxadiazon	1.0
butylate	1.0	oxyfluorfen	5.0
chlordane	0.2	parathion	0.1
chlorothalonil	1.0	PCB 1242	0.6
chlorpyrifos	0.5	PCB 1254	0.6
cycloate	1.6	PCB 1260	0.6
DDD	0.04	pebulate	2.0
DDE	0.02	penaconazole	1.0
DDT	0.09	pendimethalin	1.9
dicamba	0.8	picloram	1.0
dieldrin	0.02	profluralin	2.0
endrin	0.03	propachlor	1.5
EPTC	2.0	propazine	0.5
etaconazole	1.0	propiconizole	1.0
ethion	0.1	silvex	0.5
flusilazole	1.0	simazine	0.7
heptachlor	0.01	terbacil	1.0
heptachlor epoxide	0.01	toxaphene	1.2
hexazinone	1.0	triadimefon	1.0
imazalil	1.0	triadimenol	1.0
isoprapalin	5.0	triclopyr	1.0
lindane	0.01	tridemorph	1.0
malathion	1.4	trifluralin	1.8
methoxychlor	0.3	vernolate	1.0

at upstream or downstream sampling station during the entire monitoring period. (See methods for pesticides included and analytical detection limits [Table 2]).

3) After turf establishment course fertilization practices are not resulting in increased N or P discharges from the course; wastewater utilization on the course has resulted in decreased nutrient levels entering and leaving the course via Cedar Creek.
4) Wastewater nutrients are being incorporated into the total nutrient management plan to maximize productivity without over-application of nutrients resulting in degradation of water quality.

The result of land application of wastewater is Hartwell MWTF is closer to compliance with surface water standards and the course has a source of irrigation water and nutrients. Using wastewater requires increased water and nutrient management, management of algal blooms, and monitoring salinity and SAR. Wastewater is generated daily and must be applied frequently, depending upon storage capacity. In winter and rainy periods it may need to be applied to off-course sites.

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