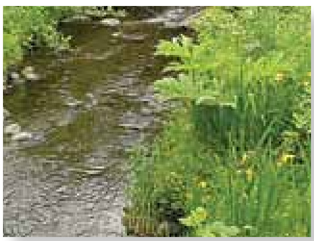
Surface-water quality monitoring on golf courses in the Pacific Northwest

Golf course management practices in the Pacific Northwest do not pose a hazard to water quality in golf course streams.



Environmental Institute for Golf

This research was funded in part by The Environmental Institute for Golf.

Eric Miltner, Ph.D.
Mike Hindahl, Ph.D.

Regulatory standards and public expectations increasingly demand protection of water quality from chemicals applied to golf courses. The regular use of pesticides and fertilizers on golf courses often leads to the assumption that these chemicals are transported into surface water and/or groundwater following application. This perception is often reinforced by information posted on the Internet, in public interest position publications (6) and in technical reports. For example, a recent United States Geological Survey technical report identified 27 pesticide active ingredients or pesticide degradation products in surface water samples collected from a watershed near Portland, Ore. (1). Of the 27 compounds, 16 were listed as being used on golf courses, implying that some of the detections may have resulted from golf course applications. However, eight of these 16 pesticides are not registered for use on Pacific Northwest golf courses, and two more are highly injurious to grasses grown in the Pacific Northwest.

To prevent negative impacts on water quality from fertilizer and/or pesticide applications, contemporary golf course management uses a combination of best management practices, integrated pest management strategies, improved chemical application methods and equipment, and the selection of products based on environmental fate. Basic research ranging from predictive modeling studies (4,7) to controlled small-scale studies (5) has evaluated nutrient and pesticide transport from golf course turfgrass into surface water and/or groundwater, yet little research has been performed at the field scale. Although monitoring fertilizer and pesticide impacts on water quality is often a condition of permits issued to golf courses,

The site for entry-point sampling **(left)** on Kelsey Creek at Glendale CC, Bellevue, Wash. One side of Kelsey Creek at Glendale CC is bordered entirely by golf holes. **(right)** The exit-point sampling area is shown here. Photos by E. Miltner

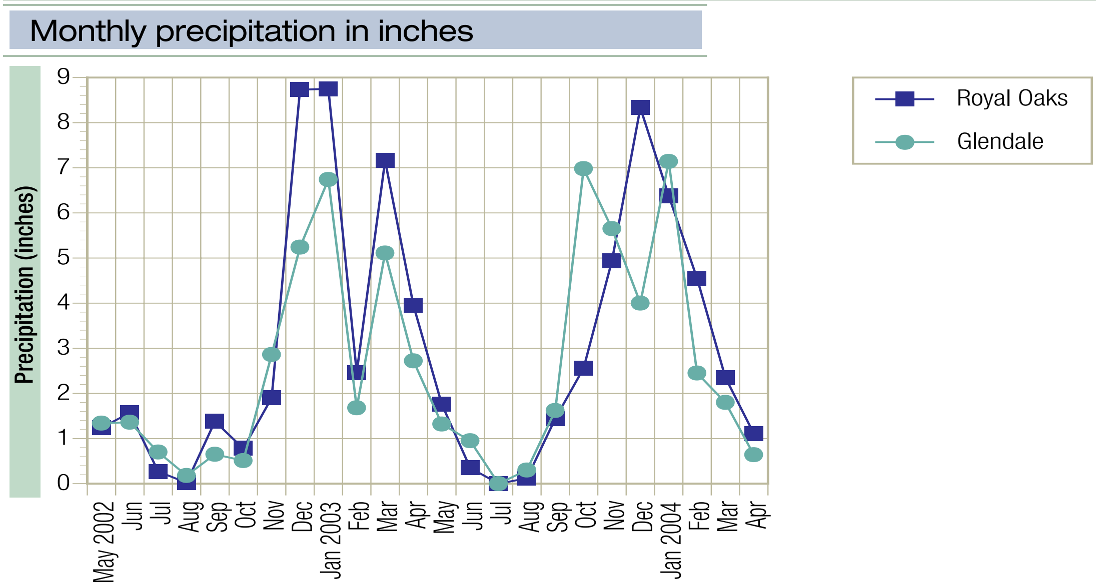


Figure 1. Monthly precipitation in inches for both research sites during the study period.

these field-scale data generally are not accessible to the scientific community (2).

The objective of this study was to evaluate the impacts of fertilizer and pesticide applications on surface-water quality on a field-scale level at two Pacific Northwest golf courses.

Experimental methods

We monitored concentrations of nitrate-nitrogen (NO_3-N), soluble orthophosphate and pesticides in streams on two Pacific Northwest golf courses from June 2002 through May 2004. No external treatments were imposed by the researchers; we simply monitored for potential water-quality impacts of management practices employed on the golf courses.

Study sites

The study was conducted at two private 18-hole golf courses located in urban/suburban settings in western Washington state. Turf management programs were consistent with those of other golf courses in the region and included documented integrated pest management programs. Both courses included fish-bearing streams that passed through the properties. Shallow subsurface drainage pipes were located throughout substantial areas of both golf courses, draining into the respective streams.

Site 1 was Royal Oaks Country Club in Vancouver, Wash. Built in 1945, the course had a predominantly gravelly loam soil type, and the topography was relatively flat with some mild slope and contouring. Three putting greens were rebuilt with sand-based root zones in the mid-1970s, with the remainder consisting of native soil that has been topdressed consistently with sand. Tees and fairways were all built from native soil. The golf course had approximately 65 acres (26.3 hectares) of maintained turfgrass, with annual bluegrass (*Poa annua* L.) on putting greens and a combination of *Poa annua* and perennial ryegrass (*Lolium perenne* L.) for all remaining turfgrass areas. Burnt Bridge Creek is bordered by golf holes for approximately 80% of its length through the golf course.

Site 2 was Glendale Country Club in Bellevue, Wash., built in 1959. The predominant soil type was gravelly sandy loam with minor portions of sandy loam. Much of the golf course lies on 6%-15% slopes, with Kelsey Creek passing through the course at the bottom of the slope. The creek is bordered entirely by golf holes on one side. The other bank is bordered by residential homes for approximately half its length, and by the golf course for the remainder. Tees and greens were originally constructed with the sandy loam soil from the site. Seven of the greens were rebuilt between 1988 and 2000 with sand-based root zones. Tees on 10 holes were also rebuilt during the same period. All greens have been consistently topdressed with sand. A sand topdressing program on fairways started in 1990, and a sand profile approximately 8 inches (20.3 centimeters) deep had accumulated by 2002.

Precipitation and irrigation

The Pacific Northwest has cool, wet winters

Nitrogen and phosphorus applications

Location	Year	Nutrient	Total applied (pounds)	% applied Oct - Mar
Site 1, Royal Oaks CC	1	nitrogen	5,640	34
		P2O5	2,929	5
	2	nitrogen	6,774	47
		P2O5	1,529	31
Site 2, Glendale CC	1	nitrogen	5,243	11
		P2O5	1,256	25
	2	nitrogen	10,582	35
		P2O5	1,844	24

Table 1. Total amounts of fertilizer nitrogen and phosphorus (as P2O5) applied to two golf courses during each year of the study, and percentage of total amount applied during the predominantly rainy season.

and warm summers. Monthly precipitation for each site throughout the study period is shown in Figure 1. Weather data, fertilizer and pesticide application records and water-quality data were organized by year (year 1, May 2002-April 2003; year 2, May 2003-April 2004) to allow comparisons of yearly management conditions. For Royal Oaks CC, total annual precipitation was 38.2 inches (97 centimeters) in year 1 and 33.9 inches (86.1 centimeters) in year 2 (long-term average precipitation is 39.5 inches [100.3 centimeters]); 78% (year 1) and 86% (year 2) of this precipitation fell in the six-month period from October through March. For site 2, annual precipitation was 29.1 inches in year 1 and 32.9 inches in year 2 (long-term average is 39.5 inches [100.3 centimeters]). October through March produced 76% and 85% of the total amount in each year. Because runoff (including shallow subsurface flow) is largely precipitation-driven, this wet winter period is important to note. During spring and summer, controlled irrigation should limit the conditions conducive to runoff.

Fertilizer and pesticide applications

Fertilizer and pesticide application records were maintained by the golf course staff and reported to us. Applications were reported by date, location (tees, greens, fairways, roughs, other), product, total amount used and total area treated. Table 1 shows the total amounts (in pounds) of fertilizer nitrogen and phosphorus (as P_2O_5) applied to each golf course during each year. Also shown is the percentage of each applied during the period of October through March, when conditions were most likely to promote runoff. The large increase in nitrogen applied at Glendale in year 2 was due to increased nitrogen rates on fairways.

A total of 810 pounds (367.4 kilograms) of pesticide active ingredients (a.i.) were applied during year 1 at Royal Oaks, and 563 pounds (255.4 kilograms) a.i. were applied during year 2. Fungicides made up 77% and 66% of the active ingredient applied during each year, respectively. The October through March period accounted for 84% of the applications in year 1 and 58% in year 2.

At Glendale, 607 pounds (275.3 kilograms) of active ingredients were applied in year 1 and 694 pounds (314.8 kilograms) in year 2. Fungicides accounted for 100% of active ingredients in year 1 and 93% in year 2. Applications from October through March constituted 63% in year 1 and 44% in year 2. Considering both golf courses, the most commonly used fungicides included azoxystobin, chlorothalonil, flutolanil, iprodione, mancozeb, PCNB and propiconazole. Herbicides, insecticides and plant growth regulators included 2,4-D, carbaryl, chlorpyrifos, clopyralid, dicamba, fenoxaprop-ethyl, MCPP and triclopyr.

Water sample collection and analysis

At each site, water samples were collected on the first Monday of each month for a period of two years. Samples were collected approximately 6 inches (15.2 centimeters) below the surface where the streams entered (entry point) and exited (exit point) the golf courses. Results of the analyses of the exit point and entry point samples were compared to assess the influence of golf course management practices on surface water quality. Following collection, samples were maintained at approximately 40 F (4 C) and transported immediately to testing laboratories.

For Royal Oaks, all water samples were analyzed for any pesticides that were applied to the golf course since the previous water samples were collected. This resulted in approximately one month transport time for pesticides to move into the stream. Because of the expense of pesticide analysis, tracking all of the applied pesticides for a longer period of time would have been cost-prohibitive.

To address longer transport times, a different analysis plan was used at Glendale. A group of 14 pesticides was selected before the study began. Selection was based on the likelihood of use on

Entry and exit point concentrations

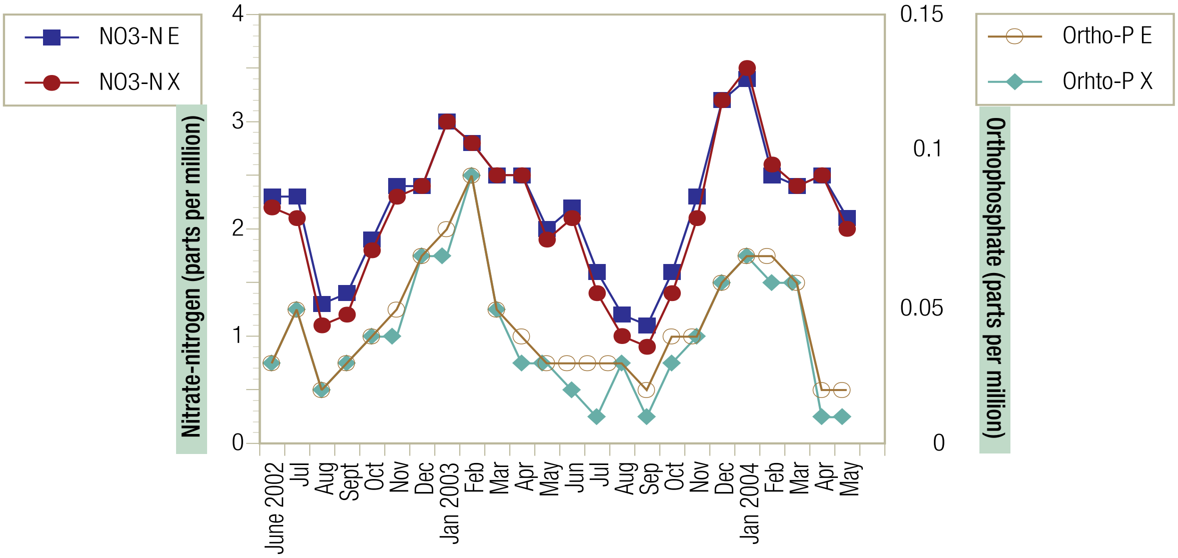


Figure 2. Entry (E) and Exit (X) point concentrations of nitrate-nitrogen (NO_3-N) and orthophosphate (ortho-P) in Burnt Bridge Creek, Royal Oaks CC, Vancouver, Wash., from June 2002 to May 2004.

the golf course and the cost of analysis. Most of the pesticides in the group could be analyzed using a single procedure. This saved cost, and allowed us to monitor this group of products over the long term. Analysis for each of these 14 pesticides was conducted every month. If a product on this list was applied only once (or even not at all), it would be monitored in every future sample collection, allowing us to track potential long-term transport to the stream. The 14 pesticides in the analysis package were 2,4-D, azoxystrobin, chlorothalonil, chlorpyrifos, dicamba, ethofumesate, fenarimol, iprodione, MCPP, metalaxyl, PCNB, propiconazole, triadimefon and triclopyr.

Commercial laboratories accredited by the State of Washington Department of Ecology analyzed samples for nitrate-nitrogen, orthophosphate and pesticides. The use of labs accredited by the Department of Ecology was important to ensure confidence in our data from external regulators. All analyses were performed using methods approved by the U.S. Environmental Protection Agency (EPA). The sole exception was for thiophanate-methyl, for which no EPA method existed at the time.

Paired samples with positive concentrations of nitrate-nitrogen and orthophosphate existed for every sample collection date at both sites. Nutrient data were statistically analyzed to detect significant differences between entry point and exit point samples at each golf course. Conversely, few pesticides were detected in the water samples, and therefore statistical analysis of the pesticide data was not possible.

Results

Nutrients

Nutrient concentrations in stream water at Royal Oaks (Figure 2) had a strong seasonal trend that followed the precipitation pattern (Figure 1). Note that dates in Figure 2 lag one month behind those in Figure 1 because sampling occurred early in the month (on the first Monday). The first monthly sample (June 2002) was therefore influenced mostly by weather conditions in the preceding May. Concentrations of nitrate-nitrogen were approximately three times higher in winter as compared to summer, and orthophosphate differed by a factor of about four (Figure 2).

For 15 of the monthly samples, nitrate-nitrogen concentration in exit point samples was lower than that in corresponding entry point samples by 0.1 to 0.2 parts per million (ppm). For seven events, the concentrations were the same, and for two events (December 2003 and January 2004) exit point nitrate-nitrogen was 0.1 ppm above that in matching entry point samples. Entry-point orthophosphate concentrations followed the same seasonal pattern, with concentrations highest during the winter months. Entry point orthophosphate ranged from 0.02 to 0.10 ppm. For all sampling events, exit point orthophosphate was equal to or lower than corresponding entry point samples. Statistical analysis of the data showed that

Entry and exit point concentrations

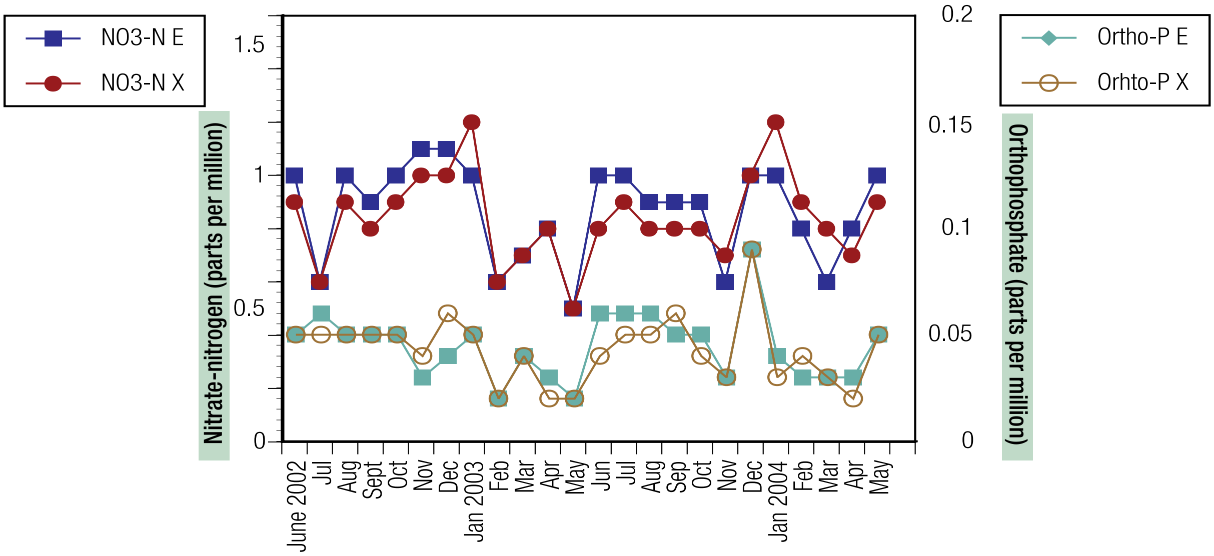


Figure 3. Entry (E) and Exit (X) point concentrations of nitrate-nitrogen (NO_3-N) and orthophosphate (ortho-P) in Kelsey Creek, Glendale CC, Bellevue, Wash., from June 2002 to May 2004.

average exit point concentrations for both nitrate-nitrogen and orthophosphate were significantly lower than the entry point concentrations.

At Glendale, nutrient concentrations did not follow the same seasonal trends as at Royal Oaks. The months of February through April generally had the lowest nutrient concentrations (Figure 3). Concentrations of nitrate-nitrogen at Glendale were generally lower than those at Royal Oaks, but orthophosphate concentrations were similar. For 15 sampling events at Glendale, exit point nitrate-nitrogen concentrations were lower than the entry point concentrations, and for six events they were equivalent. On five occasions exit samples were higher than entry samples. Differences were 0.1 to 0.2 ppm. For orthophosphate, exit-point concentrations were less than or equal to the entry point on 20 occasions. On four dates, the exit point concentration was higher. Differences were 0.01 to 0.02 ppm. Statistical analysis showed no significant difference between entry and exit point nutrient concentrations at Glendale.

Pesticides

Royal Oaks CC. During the study period, 104 active ingredient-specific analyses were performed for samples collected from Royal Oaks (53 in year 1, and 51 in year 2). No fungicides or insecticides were detected in any entry point or exit point samples. The herbicide triclopyr was detected on one occasion (July 2002) at a concentration of 0.1 part per billion (ppb) in the exit point sample (limit of detection of method = 0.08 ppb). No triclopyr was detected in the entry-point sample. An application of triclopyr to sections of the rough had occurred six days before sample collection, with 0.02 inch (0.5 millimeter) of precipitation falling between application and sample collection.

Glendale CC. Six of the 14 pesticides included in the analysis package for Glendale were applied during the time of the study (azoxystrobin, chlorothalonil, iprodione, PCNB, propiconazole and triadimefon). Eight of the pesticides were not applied (2,4-D, chorpyrifos, dicamba, ethofumesate, fenarimol, MCPP, metalaxyl and triclopyr). A total of 336 pesticide analyses were conducted on samples collected at Glendale (14 pesticides × 24 sampling events), which included 144 analyses for pesticides used on the golf course. On seven sampling dates, pesticides were detected in paired entry point and exit point samples. None of these pesticides had been applied to the course, and concentrations did not increase in exit point samples. The presence of these pesticides was not related to golf course management practices.

One occurrence of a pesticide in the stream was attributed to golf course application. In January 2003, chlorothalonil was present in the exit point sample (0.09 ppb, limit of detection of method = 0.06 ppb) but not in the entry sample. Chlorothalonil was applied to putting greens in August 2002, five months before the detection. This fungicide has low solubility in water (0.9 ppm) and a K_{oc} of 5,000, indicating a strong tendency to bind to soil organic matter. It is classified as a low-mobility pesticide. Based on these prop-

The entry-point sampling area for Burnt Bridge Creek **(left)** at Royal Oaks CC, Vancouver, Wash. Triclopyr at 0.1 ppb was detected in an exit-point sample at Royal Oaks CC **(right)** six days after application to the rough. This was the only detection of a pesticide in the water sampling that could be linked to golf course management at the course, and it was far below the concentration considered toxic to the most susceptible aquatic life in the stream.

The research says

→ Monthly stream sampling was conducted at two Pacific Northwest golf courses for two years.

→ Concentrations of nitrate-nitrogen and orthophosphate were marginally but statistically lower in exit point samples than in entry samples at Royal Oaks CC, and there were no differences between entry and exit point samples for Glendale CC.

→ At each golf course, there was one instance in which a pesticide was detected in the exit point sample. In one case, the concentration of the pesticide was 1,000,000 times lower than the LC_{50} for the most sensitive species, and in the other case, the concentration was more than 1,000 times lower.

→ These results show that management practices typical of many Pacific Northwest golf courses pose little risk to water quality in golf course streams.

erties, a five-month lag between application and detection is not surprising. No additional pesticides were detected in the stream after January 2003.

Conclusions

Two years of monthly stream sampling at two Pacific Northwest golf courses indicated that golf course management practices resulted in no significant negative impacts on water quality. Concentrations of nitrate-nitrogen and orthophosphate were marginally but statistically lower in exit point samples than in entry samples at Royal Oaks, and there were no differences between entry and exit point samples for Glendale.

The detection of triclopyr (0.1 ppb) at Royal Oaks and of chlorothalonil (0.09 ppb) at Glendale were compared to toxicity data (3) for a variety of aquatic species. The level of triclopyr detected was over six orders of magnitude (1,000,000 times) lower than the LC_{50} for the most sensitive species listed (rainbow trout = 117 ppm). The concentration of chlorothalonil was more than three orders of magnitude (1,000 times) lower than the LC_{50} for rainbow trout (0.25 ppm). Even though the vast majority of the precipitation fell from October through March and the majority of the pesticides were applied during this same period, there was no indication of significant precipitation-driven runoff. This study demonstrated that management practices typical of many Pacific Northwest golf courses pose little risk to water quality in golf course streams.

Funding

This project was funded by The Environmental Institute for Golf and the Northwest Turfgrass Association.

Acknowledgments

The authors are indebted to Alan Nielsen, CGCS, Royal Oaks CC, and Steve Kealy, CGCS, Glendale CC, for their cooperation during this project. We also thank Barry Bergman, Clackamas Community College, for assistance with statistical analysis.

Special acknowledgment

Mike Hindahl, Ph.D., was the owner of Links Analytical in Estacada, Ore. He was a driving force behind many advances in turfgrass environmental stewardship in the Pacific Northwest. He passed away suddenly in 2005 and is greatly missed by many.

Literature cited

1. Carpenter, K. 2004. Pesticides in the lower Clackamas River basin, Oregon, 2000–2001. United States Geological Survey. Water-resources report 03-4145.
2. Chen, S., A. Sverjcek, T. Durborow and N.L. Barnes. 1999. Water quality impacts by golf courses. *Journal of Environmental Quality* 28:798-809.
3. Extoxnet (Extension Toxicology Network). http://extoxnet.orst.edu (verified April 22, 2009).
4. Haith, D.A., and F.S. Rossi. 2003. Risk assessment of pesticide runoff from turf. *Journal of Environmental Quality* 32:447-455.
5. Kenna, M.P. 1995. What happens to pesticides applied to golf courses? *USGA Green Section Record* 33:1-9.
6. Primi, P., M.H. Surgan, D.I. Volberg and J.A. Sevinsky. 1991. Toxic fairways: risking groundwater contamination from pesticides on Long Island golf courses. Environmental Protection Bureau, Office of New York State Attorney General Eliot Spitzer.
7. Raturi, S., M.J. Carroll and R.L. Hill. 2003. Turfgrass thatch effects on pesticide leaching. *Journal of Environmental Quality* 32:215-223.

GCM

Eric Miltner (miltner@wsu.edu) is an associate professor at Washington State University Puyallup Research and Extension Center in Puyallup.