# Excess Phosphorus from Golf Courses Can Taint Surface Water

By Kevin W. King and James C. Balogh

Environmentally sound management of golf course turf provides both public and private facilities with environmental, cultural and economic benefits. According to the National Golf Foundation (2003), there are approximately 16,000 golf courses operating in the United States. Public demand is increasing for golf course managers to maintain high-quality turf on golf courses but also to protect water and soil resources in the vicinity of these facilities (Balogh et al. 1992; Beard and Greene, 1994).

The perception (Kohler et al. 2004; Shuman, 2002; Peacock et al. 1996; Smith and Bridges, 1996; and Pratt, 1985) and potential (Balogh and Walker, 1992) for nutrients and pesticides to be transported in surface water is well documented. Management of existing golf courses and construction of new facilities is often a lightning rod of environmental and water quality concern (Balogh et al., 1992).

Whether or not that concern is warranted is often debated because of limited information on water quality exiting golf courses. High-quality watershed scale data are needed to adequately address this issue.

Previous studies (Easton and Petrovic, 2005; Gaudreau et al. 2002; Cole et al. 1997; Linde and Watschke, 1997; and Morton et al. 1998) have addressed runoff volume and nutrient loss from turf. However, these studies focused on small areas from plots up to individual greens or fairways (Cohen et al., 1999; Kenna, 1995). The data collected from plot studies is also limited with regard to the temporal domain.

Studies on small scales are valuable, but they may not represent the diversity and connectivity associated with a complete turf system. Cohen et al. (1999) emphasizes the need for field-scale water quality studies on golf courses. The objective of this research effort was to quantify nutrient transport in surface water runoff from golf courses.

## Experimental sites

Two golf courses with differing characteristics (Table 1) were selected for this research effort:

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**FIGURE 1**

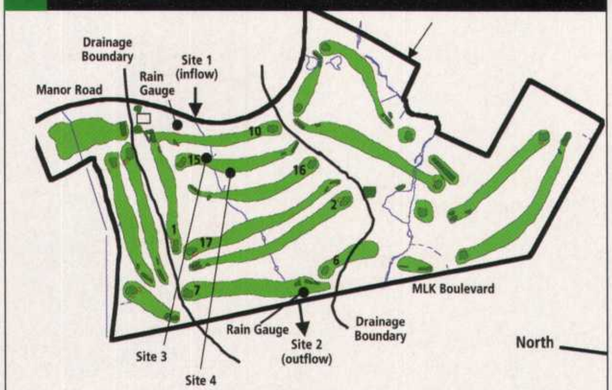
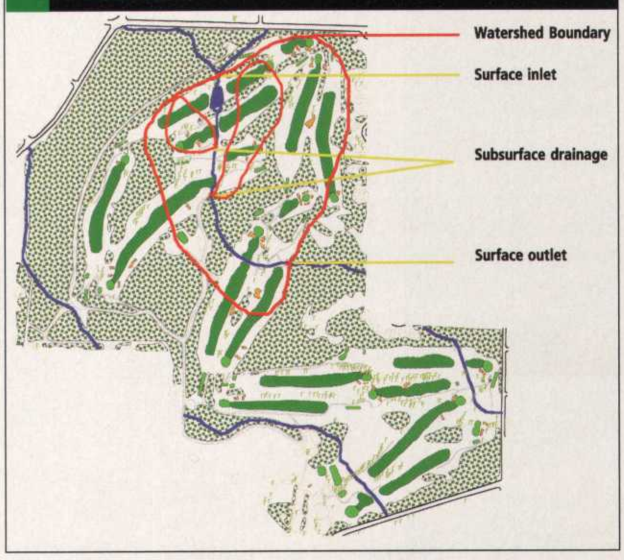



**FIGURE 2**




*Above: Layout of Morris Williams Municipal Golf Course and study area.*

*Right: Layout of Northland Country Club Golf Course and study area.*

## TABLE 1

### Site characteristics from two golf course watersheds:

| | Morris Williams Municipal | Northland Country Club |
|---|---|---|
| GRASS | tifdwarf bermudagrass (Cynodon dactylon L. Pers.) | creeping bentgrass (Agrostis palustris Huds. A. stolonifera L.) |
| CLIMATE | | |
| temperature | avg. min (4 °C); avg. max (35 °C) | avg. min (-9 °C); avg. max (25 °C) |
| precipitation | 810 mm | 1000 mm |
| growing season | 273 days | 220 days |
| MANAGEMENT | moderate | moderate to intense |
| SOILS | gravelly, silt clay to clay | clay |
| AREA | 29.0 hectares | 21.8 hectares |
| greens | 0.7 ha (10 greens) | 0.3 ha (8 greens) |
| tees | 0.3 ha (7 tees) | 0.5 ha (8 tees) |
| fairways | 8.2 ha (7 fairways) | 4.0 ha (8.5 fairways) |
| SLOPES | 4-8% | 3-25% |
| elevation change | 19 m | 37 m |

## TABLE 2

### Statistical analysis† of nutrient concentrations (milligrams L-1) in storm flow and baseflow at Morris Williams Municipal Golf Course:

| | Storm Flow Concentrations (mg L-1) (n = 1049 for inflow and n = 1063 for outflow) | | | | | |
|---|---|---|---|---|---|---|
| | NO3+NO2-N | | NH4-N | | DRP | |
| | Site 1 | Site 2 | Site 1 | Site 2 | Site 1 | Site 2 |
| Mean | 0.30 | 0.44 | 0.10 | 0.09 | 0.12 | 0.15 |
| Median | 0.23 a | 0.35 b | 0.05 a | 0.04 b | 0.10 a | 0.13 b |
| Maximum | 2.25 | 3.52 | 4.04 | 3.23 | 0.90 | 0.99 |

| | Baseflow Concentrations (mg L-1) (n = 239) | | | | | |
|---|---|---|---|---|---|---|
| | NO3+NO2-N | | NH4-N | | DRP | |
| | Site 1 | Site 2 | Site 1 | Site 2 | Site 1 | Site 2 |
| Mean | 0.30 | 0.79 | 0.10 | 0.03 | 0.11 | 0.10 |
| Median | 0.27 a | 0.73 b | 0.08 a | 0.02 b | 0.10 a | 0.10 a |
| Maximum | 1.84 | 2.35 | 0.69 | 0.17 | 0.37 | 0.27 |

† — Medians were evaluated with the Mann-Whitney non-parametric test. Medians for each constituent followed by the same letter are not significantly different ($p<0.05$).

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Morris Williams Municipal Golf Course (MWMGC) in Austin, Texas, and Northland Country Club (NCC) in Duluth, Minn.

A sub-area of each course was instrumented with ISCO 6700-automated collection systems. Discharge and nutrient concentrations were recorded for five years (1998-2003) on MWMGC and 2.5 years (2002-2004) at NCC.

The study area (Figure 1) on MWMGC is characterized by a series of grassed waterways, culverts and casual water detention areas that cross the center of the course. The topography is such that the contributing area (29 hectares [ha]) contains 10 greens (0.73 ha), seven fairways (8.23 ha) and seven tees (0.30 ha). The managed areas (greens, fairways and tees) represent 32 percent of the total area. The contributing area also contains approximately 6.5 ha of reduced-managed rough, with the remainder comprised of unmanaged trees and shrubs.

NCC has several sub-watersheds or drainage areas with unnamed streams draining into Lake Superior. The study area is located along a stream on the northeastern part of the golf course (Figure 2). This area forms a discrete drainage area composed of six complete holes, three partial holes and unmanaged areas of mixed northern hardwoods and bedrock outcroppings.

The 21.8 ha drainage area is comprised of eight greens (0.3 ha), 8.5 fairways (4.0 ha), eight tees (0.5 ha) and 17 ha of unmanaged trees and grass. The managed turf area accounts for 21.7 percent of the measured drainage area. The drainage stream enters a natural pond located at the top of the small watershed. This stream then bisects the proposed study area.

## Nutrient concentrations and loadings

Nutrient concentrations were measured at various magnitudes from each course (Tables 2 and 3).

Median concentrations of NO3-N were below 1 milligram (mg) per liter and the maximum recorded concentration was well below the EPA drinking water standard of 10 mg per liter. Median outflow concentrations of NO3-N were significantly greater than the inflow concentrations at MWMGC.

No statistical differences in median NO3-N concentrations were measured at NCC. Similarly, dissolved reactive phosphorus (DRP) concentrations were significantly greater in the outflow compared to the inflow at both courses. The measured phosphorus concentrations were consistent with concentrations shown to cause eutrophic conditions in lakes, ponds and streams.

Nutrient loadings (the mass of nutrient transported in surface flow) from MWMGC and NCC were calculated from the concentration data and the measured runoff from each course. The loadings from these two golf courses are generally greater than similar loadings reported for native prairies and forested catchments but less than loadings reported for agriculture, the exception being phosphorus. Despite the relative immobility of phosphorus in soil (Walker and Branham 1992), the results of this study suggest that these courses may have the potential for small but

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**TABLE 3**

**Statistical analysis† of nutrient concentrations (milligrams L-1) in surface flow at Northland Country Club in Duluth, Minn.**

| | Surface flow concentration (mg L-1) (n = 325 for inflow and n = 508 for outflow) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NO3+NO2-N | | NH4 | | DRP | | TN | | TP | |
| | Inflow | Outflow | Inflow | Outflow | Inflow | Outflow | Inflow | Outflow | Inflow | Outflow |
| Mean | 0.38 | 0.37 | 0.21 | 0.17 | 0.05 | 0.09 | 0.71 | 1.00 | 0.08 | 0.10 |
| Median | 0.25 a | 0.26 a | 0.02 a | 0.03 a | 0.01 a | 0.04 b | 0.62 a | 1.01 b | 0.09 a | 0.10 b |
| Maximum | 2.65 | 3.16 | 6.30 | 6.39 | 2.42 | 2.59 | 2.97 | 3.93 | 0.23 | 0.55 |

† — Medians were evaluated with the Mann-Whitney non-parametric test. Medians for each constituent followed by the same letter are not significantly different ($p<0.05$).

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significant contributions of phosphorus to surface water. Both courses have a long history of phosphorus applications. Once the soils become saturated with precipitated phosphorus, any additional phosphorus is more readily available for loss in surface runoff.

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