



# *Turfgrass and Environmental Research Online*

---

Using Science to Benefit Golf



For more than two decades, the USGA Turfgrass and Environmental Research Program has funded research to quantify fate and transport of nutrients and pesticides applied to turfgrass. Several studies involving a range of scales from small-plot research up to entire watersheds have yielded results important to minimize the extent to which applied pesticides and nutrients runoff into surface waters. This paper summarizes much of that USGA-funded research performed over the last decade.

**Volume 10, Number 21**  
November 1, 2011

## PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 400 projects at a cost of \$31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

### Editor

Jeff Nus, Ph.D.  
1032 Rogers Place  
Lawrence, KS 66049  
jnus@usga.org  
(785) 832-2300  
(785) 832-9265 (fax)

### Research Director

Michael P. Kenna, Ph.D.  
P.O. Box 2227  
Stillwater, OK 74076  
mkenna@usga.org  
(405) 743-3900  
(405) 743-3910 (fax)

## USGA Turfgrass and Environmental Research Committee

Steve Smyers, *Chairman*  
Gene McClure, *Co-chairman*  
Ron Dodson  
Kimberly Erusha, Ph.D.  
Michael Fidanza, Ph.D.  
Pete Grass, CGCS  
Ali Harivandi, Ph.D.  
Michael P. Kenna, Ph.D.  
Jeff Krans, Ph.D.  
James Moore  
Jeff Nus, Ph.D.  
Paul Rieke, Ph.D.  
James T. Snow  
Clark Throssell, Ph.D.  
Scott Warnke, Ph.D.  
Chris Williamson, Ph.D.

Permission to reproduce articles or material in the *USGA Turfgrass and Environmental Research Online* (ISSN 1541-0277) is granted to newspapers, periodicals, and educational institutions (unless specifically noted otherwise). Credit must be given to the author(s), the article title, and *USGA Turfgrass and Environmental Research Online* including issue and number. Copyright protection must be afforded. To reprint material in other media, written permission must be obtained from the USGA. In any case, neither articles nor other material may be copied or used for any advertising, promotion, or commercial purposes.

# Reviewing USGA-Funded Research: Nutrient Fate and Transport

Jeff Nus and Michael Kenna

## SUMMARY

For more than two decades, the USGA Turfgrass and Environmental Research Program has funded research to quantify fate and transport of nutrients and pesticides applied to turfgrass. Several studies involving a range of scales from small-plot research up to entire watersheds have yielded results important to minimize the extent to which applied pesticides and nutrients runoff into surface waters. This paper summarizes much of that USGA-funded research performed over the last decade. The following best management practices are a direct result of those studies.

- Schedule fertilizer applications to avoid rain storms.
- Do not apply fertilizer on dormant turf, or too early or late in the growing season.
- Phosphorous containing fertilizers should be applied in small amounts based on soil-test recommendations.
- Controlled-release products can reduce nitrogen leaching and runoff.
- Established turfgrass requires lower fertilization requirements.
- Use vegetative buffer strips around surface water.

Golf course superintendents know that consistent, quality playing conditions require inputs. Labor input for mowing and other maintenance tasks is number one, but there also are chemical inputs for nearly all golf courses. These include the use of fertilizers to maintain healthy turfgrass growth, and pesticides to protect turf from damage caused by weeds, diseases, and insects. It is important to ask, “What happens to nutrients after fertilizers are applied? To what extent can these nutrients be transported to ground water or surface waters, and what are the ecological effects? What can be done to minimize this risk?”

During the past decade, the USGA Turfgrass and Environment Research Program

JEFF NUS, Ph.D., Research Manager; USGA Green Section, Lawrence, KS; and MICHAEL KENNA, Ph.D., Research Director, USGA Green Section, Stillwater, OK.

continued to answer these questions. The focus of this effort was to determine adverse ecological effects (e.g., eutrophication) when nutrients are transported from the site of application. The two nutrients receiving attention in this regard are nitrogen (N) and phosphorus (P), and much has been learned about how to effectively limit the risk of these nutrients finding their way to surface and ground water.

## Nitrogen

Nitrogen-containing fertilizers are used to stimulate and maintain turf growth, although applied nitrogen can be lost via ammonification, leaching past the rootzone, runoff in surface water, and used by soil microorganisms. In gen-



Although the results of water quality monitoring studies suggest that instances of degradation of surface and ground water from nitrogen are minimal, data regarding phosphorus is much more alarming.



Runoff studies at several universities have shown that nutrient runoff from applied fertilizers can be reduced by not applying fertilizers when soils are saturated.

eral, nitrogen runoff and leaching losses from turfgrass are minimal in studies including creeping bentgrass (8, 11, 15), Kentucky bluegrass (7), zoysiagrass (19), and bermudagrass (2, 3, 4, 16).

Research at Michigan State University on Kentucky bluegrass demonstrated that a ten-year old stand required less nitrogen to maintain turf (7). If annual rates of 5 lbs N per 1,000 ft<sup>2</sup> are continued for mature Kentucky bluegrass turf, then leachate will contain unacceptable amounts of nitrate-nitrogen (See Table 1). However, it is important to note that less than 1% of ground water samples collected for 20 years from 44 golf courses exceeded nitrate-nitrogen maximum contaminant levels, as set by the U.S. Environmental Protection Agency (1).

On newly constructed sand-based putting greens, research at Auburn University showed that nitrate leaching was greater in the first four

months after construction, but decreased substantially as the green matured and nitrogen fertilization was reduced to maintenance levels (8). During the first year after construction, nitrogen is sequestered in the surface organic layer of greens. Subsequently, an equilibrium is established between sequestering nitrogen and mineralization of nitrogen by microbes (16). Although research by Washington State University demonstrates that nitrogen leaching increases 7 to 21 days following fertilizer application on mature, sand-based greens, the amount of nitrogen leached poses little potential for ground water contamination when healthy turfgrass is maintained (11).

Nitrogen runoff from fairways is a greater threat to water quality than drain outlets from greens and tees because of the increased acreage, greater slopes, and higher application rates for fairways (16). The USGA supported water quali-

| Year | Low N Rate      | High N Rate |
|------|-----------------|-------------|
|      | ----- ppm ----- |             |
| 1998 | 2.6             | 5.0         |
| 1999 | 2.0             | 8.5         |
| 2000 | 2.1             | 14.7        |
| 2001 | 3.7             | 18.9        |
| 2002 | 4.8             | 25.3        |

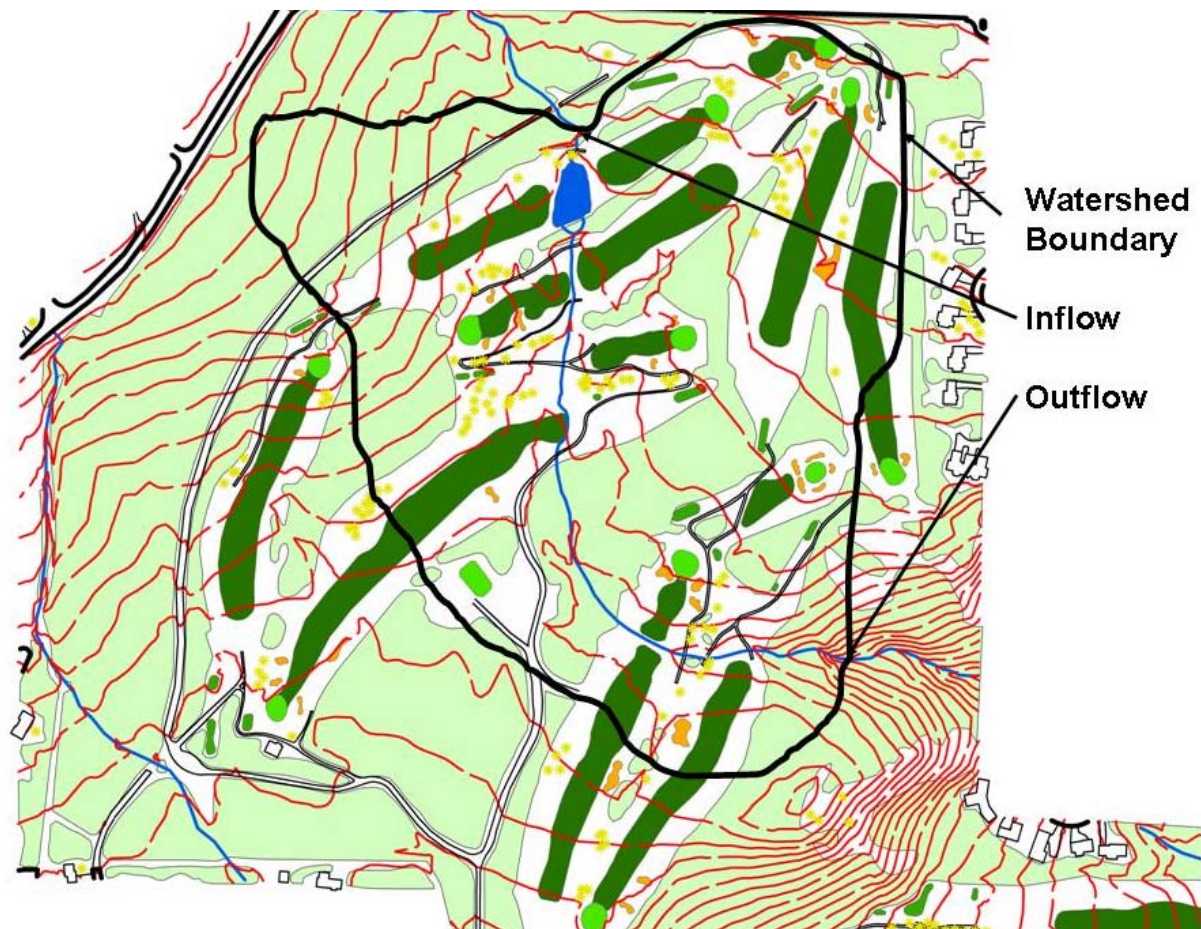
**Table 1.** Mean concentration (ppm) of nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ) in weighted flow during 1998 through 2002 for both low (2 lb. N/1000 ft<sup>2</sup> split over two applications) and high (5 lb. N per 1000 ft<sup>2</sup> split over 5 applications) nitrogen fertilization rates (7).

ty monitoring studies of fairway turfgrass, as well as watershed studies with several golf course holes to provide a larger-scale perspective of potential nutrient loss (4, 12, 13, 19, 20).

At Oklahoma State University, normal rainfall caused 0.5% of the nitrogen applied to runoff a bermudagrass golf course fairway with a 5% slope (Figure 1). During a season of near record rainfall, this same fairway lost 1.3% of the nitrogen applied as fertilizer (3, 4). Nitrate-nitrogen concentration in runoff from a northern Minnesota golf course site during storm flow events was 3.3% of the applied nitrogen (12). Researchers noted, however, that nitrate-nitrogen concentrations and load transported through the subsurface drainage water were approximately one-tenth the concentration and load typically reported for tile drainage from row-crop agriculture (12).



Research at the University of Maryland indicated that greater phosphorus runoff from large-size plots was attributed to mass transport of triple superphosphate granules in large streams of runoff that developed within the these plots during a rainstorm event (5).



More recent studies that are have utilized much larger plots or entire watersheds to characterize nutrient losses from golf courses.

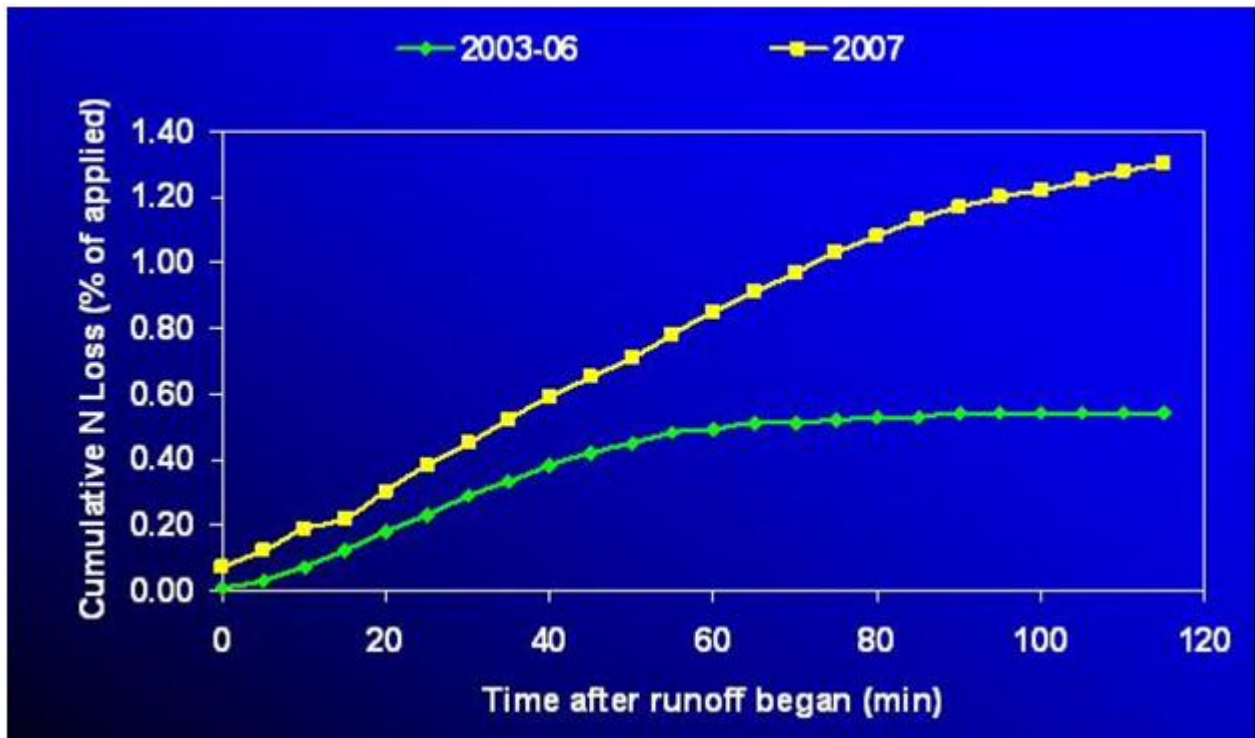
## Phosphorus

The results of water quality monitoring studies indicate minimal degradation of surface and ground water from nitrogen; however, data regarding phosphorus is more alarming. Phosphorus concentrations exceeded acceptable levels in 86% of ground and surface water samples collected from 44 golf course water quality monitoring studies spanning 20 years (1). Part of the reason for the large percentage of water samples exceeding the criteria for phosphorous is the very low concentrations of total phosphorous allowed by the U.S. Environmental Protection Service.

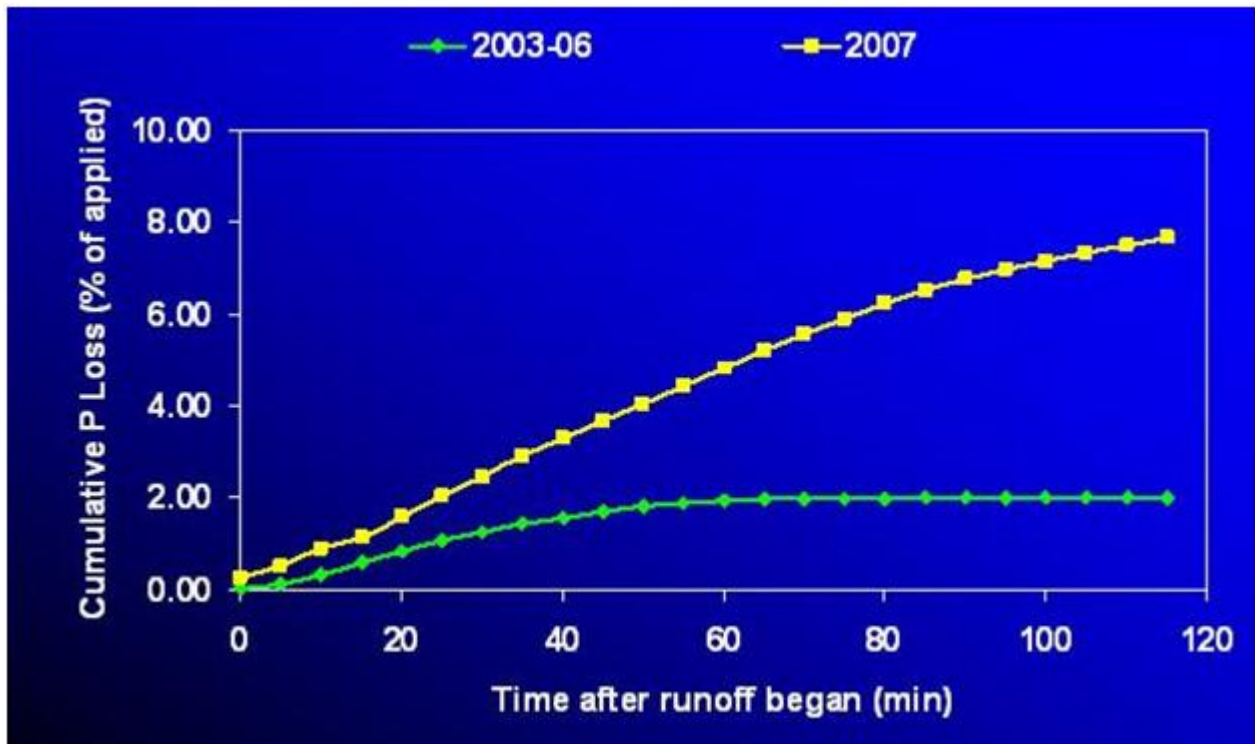
Research at the University of Minnesota (15) indicated that phosphorus concentrations in runoff from fertilized turfgrass remained above levels associated with increased algal growth and eutrophication of lakes. Research at the University of Maryland indicated that greater

phosphorus runoff from large-size plots was attributed to mass transport of triple superphosphate granules in large streams of runoff that developed within the these plots during a rain-storm event (5).

Oklahoma State University scientists estimated that under normal conditions, a bermudagrass golf course fairway on a 5% slope was likely to lose around 2.0% of the phosphorous applied as fertilizer (Figure 2). However, during a season of near record rainfall, this same fairway would lose around and 7.7% of the phosphorous applied as fertilizer (4). In addition, a U.S. Department of Agriculture (USDA) water quality monitoring study in Austin, Texas reported that dissolved reactive phosphorus (DRP) concentrations in the subsurface drainage water exiting a golf course were greater than concentrations measured in tile drains from agriculture (13). The reported concentrations could pose a potential threat of eutrophication to a surface water system.



**Figure 1.** The average amount of nitrogen (N) lost in natural rainfall from a bermudagrass fairway study site at Oklahoma State University in 2003 through 2006 (Green Line -♦-), and in the abnormally high rainfall of 2007 (Yellow Lines -■-). Runoff losses are measured as percentage of N applied. Normal rainfall caused 0.5% of the N applied to runoff a bermudagrass golf course fairway with a 5% slope. During a season of near record rainfall, this same fairway lost 1.3% of the N applied as fertilizer (3).



**Figure 2.** The average amount of phosphorous (P) lost in natural rainfall from a bermudagrass fairway study site at Oklahoma State University in 2003 through 2006 (Green Line -♦-), and in the abnormally high rainfall of 2007 (Yellow Lines -■-). Runoff losses are measured as percentage of P applied. Normal rainfall caused 2.0% of the P applied to runoff a bermudagrass golf course fairway with a 5% slope. During a season of near record rainfall, this same fairway lost 7.7% of the P applied as fertilizer (3).



The use of constructed wetlands to filter runoff from golf courses is another way to effectively limit the risk of nutrient contamination. In a constructed wetland on a golf course at Purdue University, the wetland efficiently removed an estimated 97% of N-NO<sub>3</sub>/NO<sub>2</sub> and 100% of N-NH<sub>3</sub>.

### Factors Affecting Nutrient Loss

The amount of nutrient loss is closely tied to the level of nutrients applied for both nitrogen and phosphorus. Sites receiving higher application rates of nitrogen and phosphorus lost more of these nutrients as runoff compared to sites receiving lower application rates (13). In addition, both nitrogen leaching and runoff follow a strong seasonal pattern where nitrate concentrations are highest during winter months when turf is dormant, precipitation is more plentiful, and microbial activity is reduced (7, 13). For this reason, fertilizers should not be applied to turf too early or late in the growing season.

Water quality monitoring conducted by Kansas State University before, during, and after construction of Colbert Hills Golf Course indicated that water quality was most adversely affected during the construction phase, although heavy storm events increased runoff, erosion, and nutrient transport at any stage (19, 20). During construction, nutrients found in streams and ponds were from soil erosion (19).

The amount of rainfall or irrigation plays a key role in determining nutrient runoff and leaching. In a study conducted by Oklahoma State University on bermudagrass fairway turf (4), a near-perfect relationship was established between the amount of natural rainfall runoff that occurred and the amount of nutrient lost. Research completed by the USDA in Texas indicated that the timing of nitrate-nitrogen and dissolved reactive phosphorus (DRP) through subsurface drainage from golf course turf is dependent on climatic factors (temperature and precipitation). Runoff volume was linearly related to soil moisture before a rainfall event (12). Therefore, fertilizer applications should be avoided when soils are near saturation and rain is in the forecast.

The first rain event after a fertilizer application will produce the greatest phosphorous or nitrogen transport by runoff water. “Watering-in” will reduce transport as should applying fertilizer when significant rainfall is not expected for several days (16).



## Measuring Runoff

Earlier nutrient runoff investigations utilized small plots, and it is important to know whether such small-plot results can be used to estimate nutrient loss on a watershed scale. Researchers at the University of Maryland demonstrated that plot size had no effect on total N losses found in runoff water (5). Several studies have utilized much larger plots or entire watersheds to characterize nutrient losses from golf courses (3, 4, 12, 13, 15, 19, 20). Using this approach, nitrogen and phosphorus loadings from an Austin, Texas golf course were generally greater than or similar to losses from native prairies and forests, but less than loadings reported for agriculture (12). Large-plot research at Oklahoma State University revealed that approximately 2.5% of the N applied was lost in irrigation runoff (3).

Concerns were raised by scientists about the effect of nutrient runoff losses into surrounding streams on aquatic macroinvertebrate (insect) populations. Research at the University of

Maryland was conducted to test whether such population shifts were occurring downstream from golf course watersheds. Monthly sampling did not reveal increases in downstream nutrient concentrations and researchers concluded that golf course fertilizer applications did not appear to contribute to long-term stream nutrient enrichment or impact stream-macroinvertebrate communities (17).

## Remediation/Mitigation

Although a review of golf course water quality monitoring studies indicated that widespread or repeated water quality impacts by golf courses did not occur at the sites studied, concerns were raised about phosphorus (1). It is important to determine what measures will reduce the risk of phosphorus runoff, as well as the less frequent nitrate-nitrogen runoff and leaching losses from golf course sites.

Scheduling applications around rain storm events that favor near-term runoff is one of the most powerful management tools superintendents



Current research includes investigations involving end-of-tile filters to remove both nutrients and pesticides before drainage water is released to surrounding streams and drainage ditches.

have at their disposal to minimize nutrient transport to surface waters (5). Research indicates that the use of controlled-release fertilizers can reduce nitrogen leaching, but do not appreciably retard phosphorus leaching (16). Because leaching of phosphorus may occur in sand-based putting greens, P-containing fertilizers should only be applied in small amounts based on soil-test recommendations (9, 10).

The use of vegetative buffer strips is an effective method to limit nutrient runoff into surface waters (2, 6, 18). Researchers at the University of Wisconsin demonstrated that fine fescue buffer strips provided runoff and leachate results similar to prairie plantings (18). Research at Oklahoma State University demonstrated that a multiple cutting height buffers reduced P loss by 11% in natural rainfall runoff and by 14 % in irrigation runoff compared with the single cutting height buffers. Nitrogen loss also was reduced by 17% in natural rainfall runoff and by 18% in irrigation runoff using multiple cutting height buffers compared with the single cutting height buffers (2).

Constructed wetlands can filter runoff from golf courses and effectively limit the risk of nutrient contamination. On a golf course at Purdue University, a constructed wetland efficiently removed 97% of nitrate nitrogen and 100% of ammonia nitrogen (14). The research demonstrated that the golf course wetlands could be used to filter golf course tile drains, as well as runoff from adjacent residential and business property (14).

Current research efforts include cultivation techniques to reduce runoff from turfgrass sites and the use of end-of-tile filters to remove nutrients from sub-surface drainage water. As results from these studies are attained, turf managers will have additional tools to limit the amount of nutrients transported to surface and ground water from managed golf course turf.

## Acknowledgements

The authors wish to thank the many scientists for their dedicated work to complete USGA-funded studies, members of USGA's Turfgrass and Environmental Research Committees for selecting appropriate research projects, and to the USGA Executive Committees during the past several years that provided funding necessary to gain an understanding of nutrient fate and transport of turfgrass systems.

## Literature Cited

1. Baris, R. D., S. Z. Cohen, N. L. Barnes, J. Lam, and Q. Ma. 2010. Qualitative analysis of over 20 years of golf course monitoring studies. *USGA Turfgrass and Environmental Research Online* 9(15):1-16. ([TGIF Record 167025](#))
2. Bell, G., and J. Moss. 2005. Managing golf course roughs to reduce runoff. *USGA Turfgrass and Environmental Research Online* 4(12):1-9. ([TGIF Record 105342](#))
3. Bell, G. E., and K. Koh. 2011. Nutrient and pesticide losses caused by simulated rainfall and sprinkler irrigation. *USGA Turfgrass and Environmental Research Online* 10(2):1-10. ([TGIF Record 174787](#))
4. Bell, G. E., and K. Koh. 2009. Natural rainfall runoff from a bermudagrass golf course fairway. *USGA Turfgrass and Environmental Research Online* 8(20):1-11. ([TGIF Record 156471](#))
5. Carroll, M. J., C. J. Hapeman, and F. J. Coale. 2007. Turfgrass runoff investigations: Does plot size matter? *USGA Turfgrass and Environmental Research Online* 6(24):1-7. ([TGIF Record 131198](#))
6. Clark, J. M. 2008. Optimizing vegetative filter strips treating runoff from turf. *USGA Turfgrass and Environmental Research Online* 7(19):1-8. ([TGIF Record 139488](#))

7. Frank, K. W., K. O'Reilly, J. Crum, and R. Calhoun. 2006. Nitrogen fate in a mature Kentucky bluegrass turf. *USGA Turfgrass and Environmental Research Online* 5(2):1-6. (TGIF Record 108947)
8. Guertal, E. A. 2008. Nitrate leaching in bentgrass putting greens. *USGA Turfgrass and Environmental Research Online* 7(6):1-6. (TGIF Record 134410)
9. Guertal, E. A. 2007. Phosphorus leaching from sand-based putting greens. *USGA Turfgrass and Environmental Research Online* 6(16):1-6. (TGIF Record 127551)
10. Guertal, E. A. 2006. Phosphorus movement and uptake in bermudagrass putting greens. *USGA Turfgrass and Environmental Research Online* 5(12):1-7. (TGIF Record 112010)
11. Johnston, W. J., and C. T. Golob. 2002. Nitrogen leaching through a sand-based golf green. *USGA Turfgrass and Environmental Research Online* 1(19):1-7. (TGIF Record 83193)
12. King, K. W., and J. C. Balogh. 2008. Hydrologic and water quality assessment from managed turf. *USGA Turfgrass and Environmental Research Online* 7(2):1-12. (TGIF Record 132901)
13. King, K. W., and J. C. Balogh. 2006. Surface and subsurface nutrient transport from a golf course watershed. *USGA Turfgrass and Environmental Research Online* 5(6):1-14. (TGIF Record 110193)
14. Reicher, Z. J., E. A. Kohler, V. L. Poole, and R. F. Turco. 2005. Constructed wetlands on golf courses help manage runoff from the course and surrounding areas. *USGA Turfgrass and Environmental Research Online* 4(2):1-14. (TGIF Record 100503)
15. Rice, P., and B. Horgan. 2010. Nutrient loss in runoff from turf: Effect on surface water quality. *USGA Turfgrass and Environmental Research Online* 9(1):1-10. (TGIF Record 159992)
16. Shuman, L. M. 2002. Nutrient leaching and runoff from golf courses. *USGA Turfgrass and Environmental Research Online* 1(17):1-9. (TGIF Record 83191)
17. Soli, A. M., and W. O. Lamp. 2004. Pesticide and fertilizer contamination of streams adjacent to golf courses and the response of the benthic macroinvertebrate community. *USGA Turfgrass and Environmental Research Online* 3(5):1-18. (TGIF Record 97529)
18. Stier, John C., and Wayne R. Kussow. 2006. Impact of prairie and turf buffer strips on golf course fairway runoff and leachate. *USGA Turfgrass and Environmental Research Online* 5(22):1-10. (TGIF Record 118245)
19. Starrett, S., Y. Su, T. Heier, J. Holste, and M. Paloma. 2008. Long-term monitoring of nutrient loss in runoff from a golf course. *USGA Turfgrass and Environmental Research Online* 7(18):1-9. (TGIF Record 139398)
20. Starrett, S., Y. Su, T. Heier, J. Klein, and J. Holste. 2006. Nutrient runoff from three phases of a golf course project. *USGA Turfgrass and Environmental Research Online* 5(8):1-8. (TGIF Record 110517)