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...Using Science to Benefit Golf

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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 450 projects at a cost of $29 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***.

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Long-term Monitoring of Nutrient Loss in Runoff from a Golf Course

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SUMMARY

Significant change in land use has occurred in the Little Kitten Creek watershed brought on by turning a native prairie into a championship golf course (Colbert Hills Golf Course, Manhattan, KS). An eight-year monitoring study was developed to assess the water quality changes in terms of total nitrogen and total phosphorus. The key observations and conclusions of the study were:

- The period having the worst water quality was during golf course construction.
- Sources of nutrients in stream during construction were soil erosion.
- During early operation, fertilizer was responsible for a spike of high nutrient concentrations in the stream.
- Nutrient concentrations in stream were greatly improved from construction period, however, still higher than the native prairie levels.
- Heavy storm events increased runoff, erosion, and nutrient transport at any stage.

Golf courses are often constructed close to natural streams or water bodies. Development of a new golf course represents a dramatic change in land use. The establishment of a new golf course requires the removal of the original natural soil cover, which represents a potential for contamination of nearby streams, lakes, and ponds through soil erosion and nutrient transport.

Occurrence of runoff is observed when precipitation rate exceeds soil infiltration capacity. Runoff creates soil erosion thus causing transport of pollutants (soil nutrients, suspended particles, pesticides) from one place to another. Erosion of soils at 2 to 40,000 times the pre-construction erosion rate has been reported by Wolman et al. (12). Soil erosion and particulate and nutrient transport can increase the concentration of nutrients in surface water and consequently harm wildlife habitats by inducing uncontrolled growth of algae, depletion of dissolved oxygen available in the water, fish kill, and pipeline clogging (6).

While construction could significantly affect the natural stream condition, operation of golf courses requires inputs of fertilizers that contain plant nutrients (e.g. nitrogen and phosphorus) and irrigation to maintain golf course turf in acceptable conditions. The potential of surface water contamination through soil erosion and nutrient transport from golf courses has been a subject of increasing environmental concern. Some studies have reported water quality of native grassland, while others have evaluated water quality impacted by the golf course operation management (1, 7, 9, 11).

An 8-year study of nutrient loss before/during/after construction of Colbert Hills Golf Course was performed by Kansas State University to assess the effect of human development on natural streams.

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Figure 1. Aerial photo of Colbert Hills Golf Course, Little Kitten Creek Watershed, and the surrounding area. The undeveloped surrounding area represents the Colbert Hills Golf Course area prior to construction.

This long-term monitoring study has been developed to assess the magnitude of the effect of nutrient loss on the surrounding surface water during the different stages of a golf course development. To the extent of our knowledge, this is the most extensive long-term study evaluating the nutrient concentration in surrounding natural surface water before, during, and after construction of a golf course.

Many research works have been done in an effort to establish baseline water quality of native grasslands (1, 7, 9, 11). Other researchers have also conducted studies on golf courses to evaluate the impacts of golf course operations on surface water quality (3, 4, 8).

Little Kitten Creek Watershed

The watershed is located in southwestern Riley County on the west side of Manhattan, Kansas (Figures 1 and 2). The watershed, covering 430 hectares (1,063 acres), has a typical midwest topography with elevations ranging from 420 to 340 meters (1,378 to 1,115 ft), decreasing from north to south. Land surface slope ranges from 0.04-0.14 (m/m) with an average channel gradient of 0.032 (m/m).

Originating from the northwest of the watershed, Little Kitten Creek flows about 3.2 kilometers (2 miles) from north to south before it leaves the studied watershed. It continues to run until it joins Wildcat Creek, a tributary of the Kansas River. Little Kitten Creek is an intermit-

Figure 2. Aerial photo of Little Kitten Creek Watershed and Colbert Hills Golf Course area after construction (terraserver.com)

Soil Type	Percentage
Alluvial Land	5.1
Benfield	43.5
Breaks	9.9
Clime	16.4
Dwight	7.8
Irwin	3.6
Ivan	1.9
Reading	3.6
Tully	8.2

Table 1. Soil series for Little Kitten Creek watershed

tent stream. During a typical year, approximately 5 to 10 runoff events occur resulting from intense, convective thunderstorms. The channels of the drainage network are dry for most of the remaining time.

Soils from nine different series were found in the watershed. Table 1 summarizes the type and percentage of each soil type. More detailed information about these nine soil series is provided in the Soil Survey of Riley County and part of Geary County, Kansas (5). Alluvial lands are located near channels and are frequently flooded. The soils of this series are silt loam, clay loam, silty clay loam, and silty clay. The Benfield series is the most common in the watershed. They are well

Figure 2. Watershed land management change over the 8-year term period: A) pasture coverage B) construction period, C) early operation of Colbert Hills Golf Course

drained with medium-to-rapid surface runoff and low permeability.

The Breaks series is located in small V-shaped drainage ways. Soils of this series are found on steep slopes and are usually deep. They are mostly silt loam or silty clay loam with some silty clay in the subsurface. The Clime series comprises calcareous soils located on uplands. They are moderately deep soils with a silty clay loam texture. The Dwight series soils consist of a thin surface layer and dense subsoil. They are composed of silty clay. These soils are moderately well drained and have very low permeability. The Irwin series is derived mainly from weathered shale. It is generally found on upland ridge tops and side slopes. Its permeability is very low.

Reading soils consist of deep, nearly level and gently sloping soils on stream terraces and foot slopes in creek valleys. They are formed in alluvial sediments and are composed of silt loams and silty clay loams. Tully series are sloping soils located on foot slopes. These soils are formed in thick colluvial and alluvial deposits. They are mainly comprised of silty clay loam with some silty clay. They are well drained and the subsoil is slightly permeable. Benfield, Clime, and Tully series soils are classified as hydrologic soil group C which account for 68% of the watershed, while Alluvial lands and Ivan soils are classified as B (11%), and Breaks and Dwight as D (21%). Because of their textures (erodibility factor K=0.37) and locations in the watershed, Alluvial lands, Benfield, and Tully are the most erosion-prone soils in the watershed.

As part of the Flint Hills rangeland in northeastern Kansas, the Little Kitten Creek watershed had a pasture cover land use before construction of the typical mixture of tall grasses and woods with around 89% grasslands, 11% woodlands, and negligible residential lands (Figure 1). Construction of the golf course started in July 1998. By early 1999, alteration of land cover had attained its peak when about 88 hectares (20% of the total) of native cover was removed. By April 2000, the course was completed and disturbed lands were covered with grasses.

Climates in northeast Kansas are controlled by the movement of frontal air masses over the open inland plains topography, and seasonal temperature and precipitation extremes are common. During the summer, temperatures near or above 38° C (100° F) can occur. Winter months are characterized by influxes of cold, dry polar air with temperatures as low as -20° C (-4° F). About 70 percent of the average annual precipitation of 865 mm (34 in) falls during the warm growing season, April through September (2). Only 10 percent of the average annual precipitation falls as rain during the relatively dry winter months of December through February.

Material and Methods

<u>Data collection and analysis</u>

In order to monitor the environmental impacts before construction (pasture cover), during construction, and during early operation of the golf course, three stream gauging stations were set up in the watershed. Two stations, N16 (north of hole 16) and N14 (north of hole 14), were located on the north side of the area to monitor the quality of water entering the golf course property. SLK (South Little Kitten) was located at the south boundary of the golf course to monitor the quality of water leaving the golf course property.

ISCO 3700 portable samplers were set up at each of the three stations to collect water samples during runoff events (Figure 3A). Liquid detectors actuated the samplers at the beginning of a runoff event and the samplers collected grab samples at a pre-determined time interval of one or two hours (Figure 3B). Field sampling conditions did not allow inclusion of sample replicates as part of the study. Collecting runoff samples from almost all storms would produce higher constitute concentrations than a sampling method that collected samples every three months, for example. Thus, these sampling methods would capture the periods with the highest concentrations.

Raw samples were stored in a freezer for future laboratory tests. Laboratory analyses were conducted at the Soil Testing Laboratory, Department of Agronomy at Kansas State University. Water samples were analyzed for total nitrogen (N), total phosphorus (P), NH_4-N, NO_3-N, ortho-P, total suspended solids (TSS), and total dissolved solids (TDS). Field parameters measured at the time of sampling included specific conductivity, hydrogen-ion activity (pH), water temperature, and dissolved oxygen concentration (DO). Results discussed in the following section focus on total nitrogen and total phosphorus.

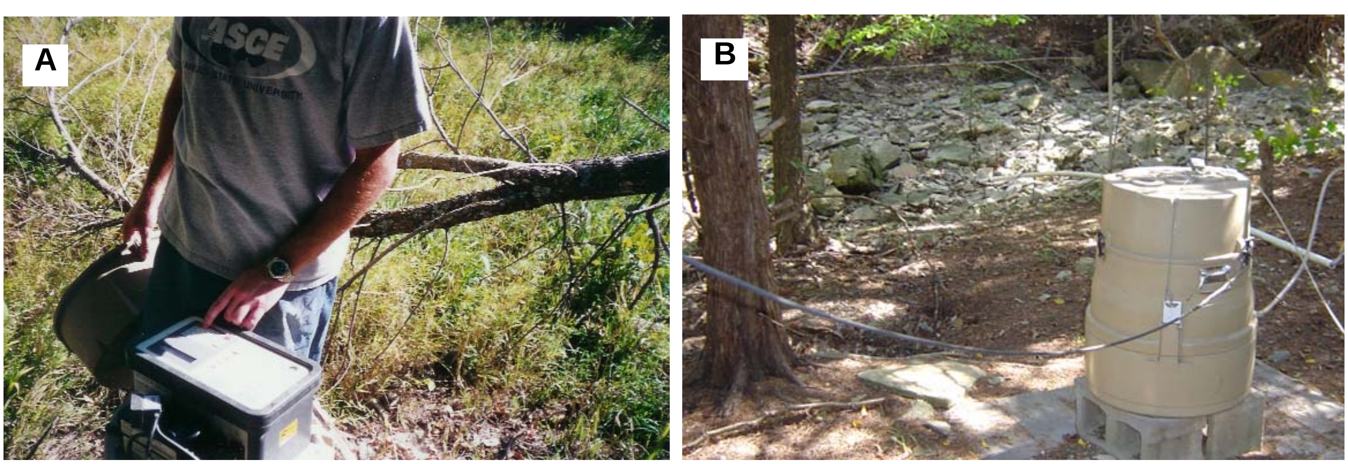

Figure 3. A) ISCO 3700 portable samplers and B) sampling station

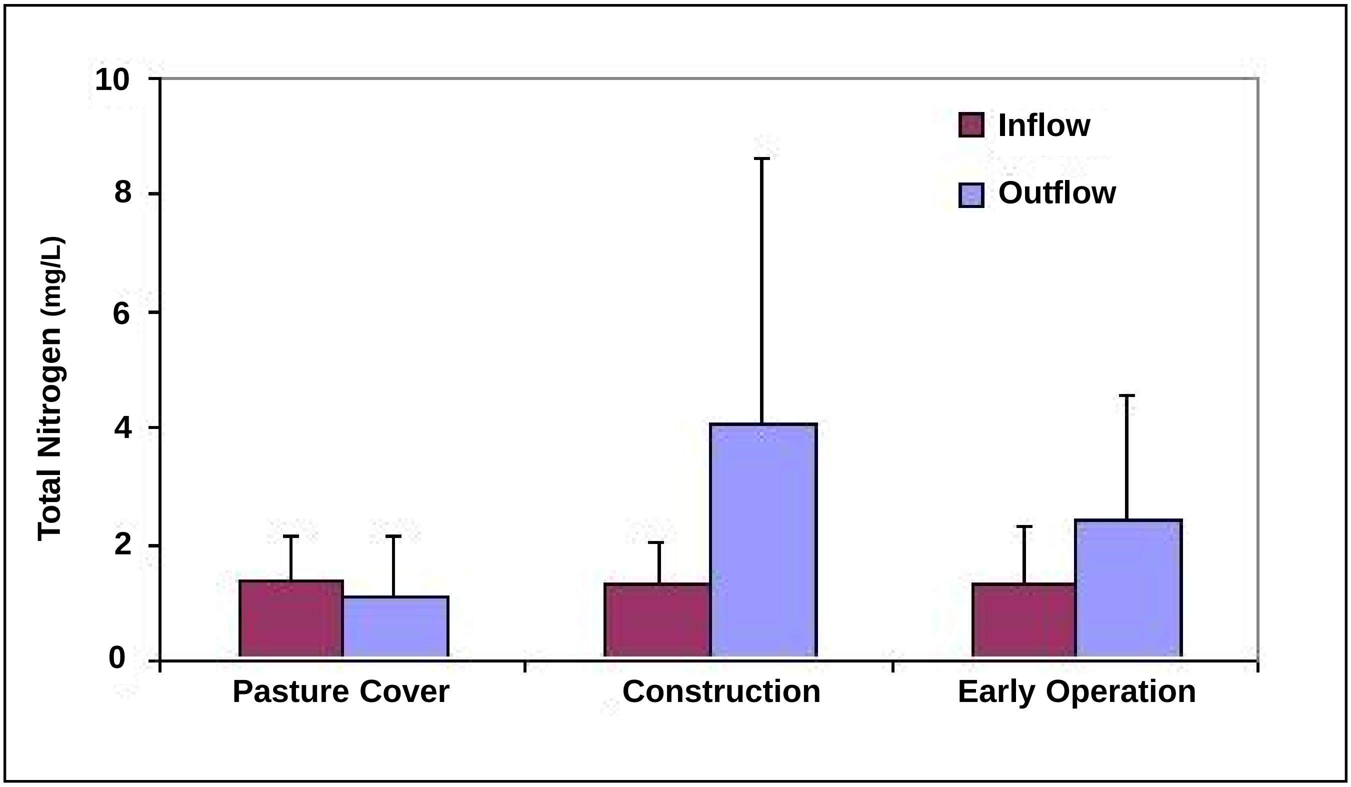

Figure 4. Total N (mg/L) measured in Little Kitten Creek entering and exiting Colbert Hills Golf Course during three stages of land development

Background water quality monitoring (pasture cover stage) was conducted prior to the start of golf course construction in July 1998. Water quality at this period was utilized as a baseline to evaluate the impact of construction and early operation of Colbert Hills Golf Course. Water quality monitoring was also conducted during the construction period, from August 1998 (when construction work officially started) to April 2000 (when the golf course officially opened for play). Monitoring of water quality during early operation of the golf course was conducted from May 2000 through October 2006.

Impact of Three Distinct Phases on Water Quality Pasture Cover

The water quality of unpolluted water bodies is dependent on the local geological, biological, and climatological conditions. These conditions control the mineral quality, ion balances, and biological cycles of the water body. To preserve the quality of the aquatic environment, the natural balances should be maintained. Knowledge of the background quality is therefore necessary to assess human impacts.

Construction

The loss of land's natural coverage promotes rapid and significant erosion of soil surface, thus enhancing the loss of nutrients in runoff during and after rainfall events. Change in land use can highly increase the concentration of nutrients, like nitrogen and phosphorus, in the natural streams.

Early Operation

It was hypothesized that stabilization of the nutrient concentration in natural streams would be a slow process. Thus, monitoring of the early operation period was important to determine how long it would take the watershed streams to recover back to native stage-like conditions.

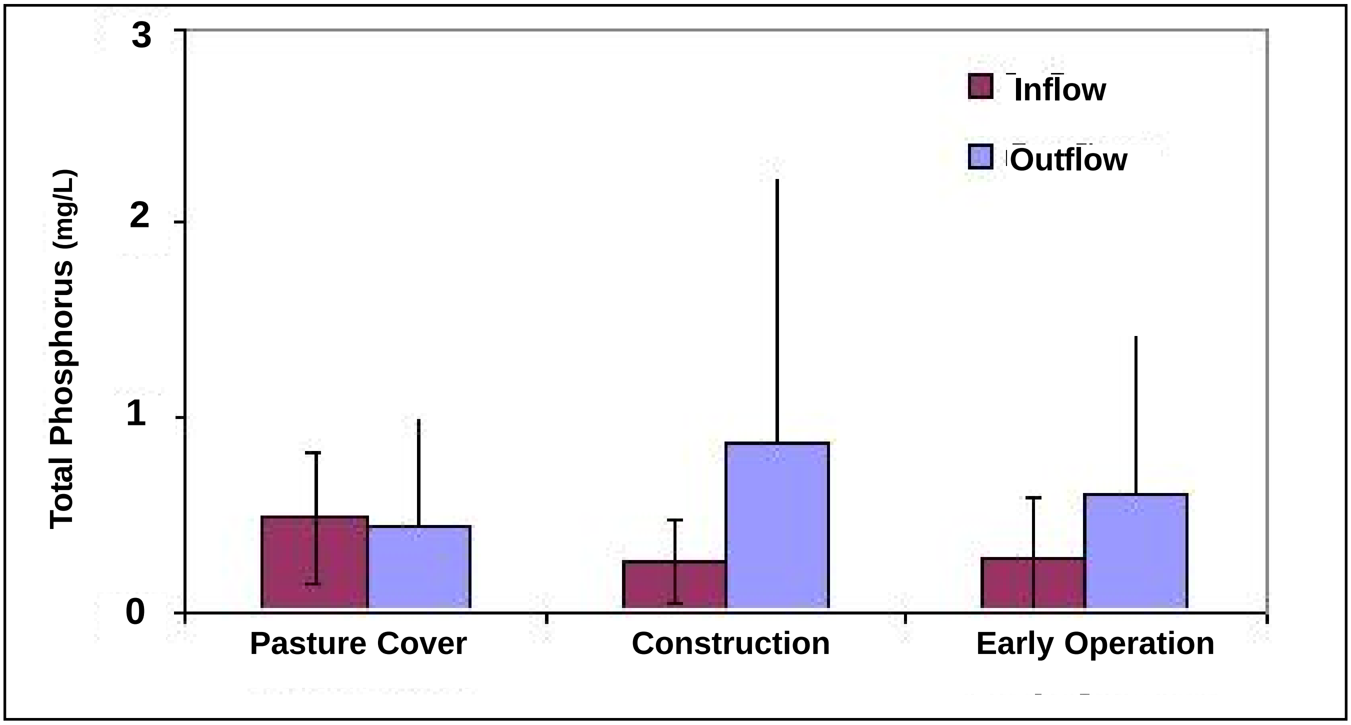

Figure 5. Total P (mg/L) measured in Little Kitten Creek entering and exiting Colbert Hills Golf Course during three stages of land development

Figure 2 illustrates the watershed conditions during the three different stages of management that the land experienced from 1998 to 2006. Figure 2A shows the pasture cover that the area had until 1998; Figure 2B illustrates the dramatic effect on the stability of the soil structure upon removal of the natural soil cover. The high potential for runoff and contaminant transport to surface waters, upon the occurrence of rain events, is significantly higher under such conditions.

Once the golf course turf has been established, the potential of surface water contamination through soil erosion and runoff decreases significantly. However, the application of fertilizer could represent a source of increasing nutrient transport to surrounding streams (Figure 2C).

Results and Discussion

The discussion focuses water quality changes in Little Kitten watershed, as affected by total N and total P. Mean values and standard deviations were used to describe the trend of total N and total P changes through the three different studied stages. Weather conditions (dry years vs. wet seasons) increased the variability of the data collected. However, the mean values were obtained utilizing all collected data points for the correspondent watershed stage. Standard deviations represent the variability of the data.

Total Nitrogen

Total N concentration during pasture cover, construction, and early operation stages is illustrated in Figure 4. On average 1.3 mg/L of total N was in Little Kitten Creek as it entered the golf course property during the eight years of study, the averaged value did not vary significantly during 1998 to 2006 early operation period. During the pasture cover stage, the total N concentration in the surface water entering and exiting the watershed was similar and not statistically different. This information is important to demonstrate that beyond the boundaries of Little Kitten Creek watershed there was no significant change in soil management that affected the incoming total nitrogen. However, the outflow data showed a different response than the total N concentration in the inflow.

Once the construction stage started, the measured total N concentration increased significantly in the surface water due to runoff, especially when heavy rainfall events occurred. An average of 4.0 mg/L total N was determined during the years of construction. The total N measured values exhibited significant variation. Importance of this result is that the concentration of total N in the stream during construction is sensitive to both soil management and weather condition.

The averaged concentration of total N in the outflow during the early operation stage (May 2000-October 2006) was observed to be smaller than that observed during the construction stage. An average concentration of 2.4 mg/L total N was determined. The standard deviation indicated that the magnitude of variation of the total N concentrations in the surface water decreased upon change of soil management, i.e., once soil vegetation cover was re-established. During the first six years of the golf course operation, a reduction of the total N concentration was observed. However, the early operation total N concentration was about double of the pasture cover total N value. Establishment of turfgrass required fertilization which was a potential source of total N in the watershed.

Total Phosphorus

The results for total P in the watershed inflow and outflow during eight years of study are illustrated in Figure 5. The total P in the inflow did not change significantly over the duration of this study. The inflow average total P values for the pasture cover, construction, and early operation stages were 0.49, 0.26, and 0.30 mg/L, respectively. During the pasture cover stage, an average value of 0.45 mg/L total P exited the watershed. Removal of soil vegetation cover increased the average value to 0.87 mg/L total P. Increase of total P concentration in surface water was due to erosion and runoff enhanced rain events, and lack of surface vegetation during construction period.

Similarly to what was observed for total N, the concentration of total P in the water decreased during the early stage operation. Vegetation re-established on the surface was the main cause of the reduction of total P concentrations in the surface water. The recovery of the surface cover reduced erosion of soil particles and reduced transport of nutrients to surface water streams.

Concentrations of total N and total P were found significantly greater during golf course construction than during the pasture stage. The increase of eroded soils carried particle-bound nitrogen and phosphorus to the stream. Inflow and outflow TN:TP ratios of the averages, at the three studied stages, were always lower than 8, which indicated limiting N availability in the streams. Study of nitrogen and phosphorus in surface water is of extreme importance since excessive amounts of both nutrients in natural streams lead to eutrophication problems in lakes and water bodies. This study indicates that, if course management is operated adequately, the surface water quality in a golf course dominated watershed can be returned back to its original conditions.

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