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Surface water quality

Long-term monitoring determines the magnitude of nutrient loss in runoff related to development

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

Runoff occurs when the precipitation rate exceeds soil infiltration capacity. Runoff creates soil erosion, causing transport of pollutants (soil nutrients, suspended particles, pesticides) from one place to another. Soil erosion at two to 40,000 times the preconstruction erosion rate has been reported by Wolman et al. Soil erosion, and particulate and nutrient transport, can increase the concentration of nutrients in surface water, consequently harming wildlife habitats by inducing uncontrolled growth of algae, depletion of dissolved oxygen available in the water, fish kill and pipeline clogging.

While construction could affect the natural stream condition significantly, golf course operations require inputs of fertilizers that contain plant nutrients (nitrogen and phosphorus) and irrigation to maintain turf in acceptable conditions. The potential of surface water contamination through soil erosion and nutrient transport from golf courses has been a subject of environmental concern. Studies have reported water quality of native grassland, while others evaluated water quality affected by golf course operations.

This long-term monitoring study has been developed to assess the magnitude of the nutrient loss effect on the surrounding surface water during the different stages of 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 conducted to establish baseline water quality of native grasslands. Other researchers have conducted studies on golf courses to evaluate the impacts of golf course operations on surface water quality.

Table 1. Soil series for Little Kitten Creek watershed

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

LITTLE KITTEN CREEK WATERSHED

The Little Kitten Creek watershed is located in southwestern Riley County on the west side of Manhattan, Kan. (photo on page 42), covers 1,063 acres and has a typical Midwest topography with elevations ranging from 1,378 feet to 1,115 feet, decreasing from north to south. Land surface slope ranges from 0.04 to 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 two 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 is an intermittent stream. During a typical year, between five 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 below):

- 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're well 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, are usually deep and 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're moderately deep soils with a silty clay loam texture.
- The Dwight series soils consist of a thin surface layer and dense subsoil; they're composed of silty clay, and are moderately well drained and have low permeability.
- The Irwin series is derived mainly from weathered shale, is generally found on upland ridge tops and side slopes, and has low permeability.
- Reading soils consist of deep, nearly level and gently sloping soils on stream terraces and foot slopes in creek valleys. They're formed in alluvial sediments and are composed of silt loams and silty clay loams.
- The Tully series are sloping soils located on foot slopes and are formed in thick colluvial and

alluvial deposits. They're mainly comprised of silty clay loam with some silty clay. They're well drained, and the subsoil is slightly permeable.

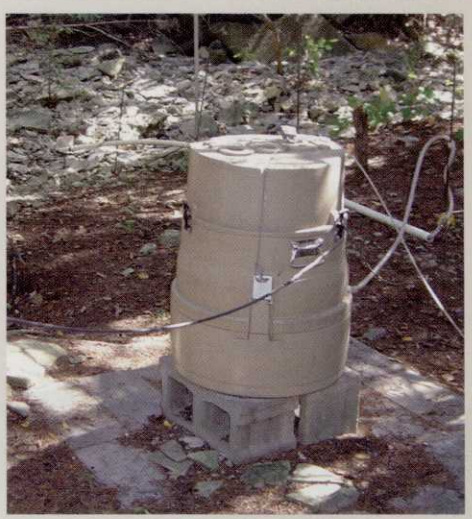
Benfield, Clime and Tully series soils are classified as hydrologic soil group C, which account for 68 percent of the watershed. Alluvial lands and Ivan soils are classified as B (11 percent), and Breaks and Dwight as D (21 percent). Because of their textures (erodibility factor K=0.37) and locations 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 percent grasslands, 11 percent woodlands and negligible residential lands. Construction of the golf course started in July 1998. By early 1999, alteration of land cover had attained its peak when about 20 percent of the total 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. Seasonal temperature and precipitation extremes are common. During the summer, temperatures can reach 100 F or higher. Winter months are characterized by influxes of cold, dry polar air with temperatures as low as -4 F. About 70 percent of the average annual precipitation of 34 inches falls during the warm growing season, April through September. Only 10 percent of the average annual precipitation falls as rain during the relatively dry months of December through February.

MATERIAL AND METHODS

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. 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 (top photo) and a sampling station.

ISCO 3700 portable samplers were set up at each of the three stations to collect water samples during runoff events (top photo above). Liquid detectors actuated the samplers at the beginning of a runoff event, and the samplers collected grab samples at a predetermined time interval of one or two hours (bottom photo above). Field sampling conditions didn't 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 lab in the department of agronomy at Kansas State University. Water samples were analyzed for total nitrogen, total phosphorus, NH4-N, NO3-N, ortho-P, total suspended solids and total dissolved solids. Field parameters measured at the time of sampling included specific conductivity, hydrogen-ion activity (pH), water temperature and dissolved oxygen concentration. Results discussed in the following section focus on total nitrogen and total phosphorus.

Background water quality monitoring (pasture cover stage) was conducted before the start of golf course construction in July 1998. Water quality at this period was used as a baseline to evaluate the impact of construction and early operation of Colbert Hills Golf Course. Water quality monitoring also was 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.

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. Background quality knowledge is 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, such as 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.

Watershed conditions changed during the three different stages of management the land experienced from 1998 to 2006. The area had pasture cover until 1998. There was a dramatic effect on the stability of the soil structure when the natural soil cover was removed. The high potential for runoff and contaminant transport to surface waters, upon the occurrence of rain events, is significantly higher under such conditions.

Once 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.

RESULTS

Water quality changes in Little Kitten watershed are affected by total nitrogen and total phosphorus. Mean values and standard deviations were used to describe the trend of total nitrogen and total phosphorus changes through the three different studied stages. Weather conditions (dry years versus wet seasons) increased the variability of the data collected. However, the mean values were obtained using all collected data points for the correspondent watershed stage. Standard deviations represent the variability of the data.

TOTAL NITROGEN

On average, 1.3 mg/L of total nitrogen was in Little Kitten Creek as it entered the golf course property during the eight years of study. The averaged value didn't vary significantly during the 1998 to 2006 early operation period. During the pasture cover stage, the total nitrogen concentration in the surface water entering and exiting the watershed was similar and not different statistically. 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 nitrogen concentration in the inflow.

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

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

TOTAL PHOSPHORUS

The total phosphorus in the inflow didn't change significantly throughout this study. The inflow average total phosphorus 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 phosphorus exited the watershed. Removal of soil vegetation cover increased the average value to 0.87 mg/L total phosphorus. Increase of total phosphorus concentration in surface water was because of erosion and runoff enhanced rain events, and lack of surface vegetation during the construction period.

An aerial photo of Little Kitten Creek watershed and Colbert Hills Golf Course area after construction.

Similar to what was observed for total nitrogen, the concentration of total phosphorus in the water decreased during the early stage operation. Vegetation reestablished on the surface was the main cause of the reduction of total phosphorus 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 nitrogen and total phosphorus 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 total-nitrogen-to-total-phosphorus ratios of the averages, at the three studied stages, were always lower than 8, which indicated limiting nitrogen availability in the streams.

The study of nitrogen and phosphorus in surface water is extremely important because 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. **GCI**

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IMPACT ON THE BUSINESS

Manage your image with proactive research

By Dean Baker, CGCS, and Buckley Brockmann, assistant superintendent, Kinston Country Club

Kinston (N.C.) Country Club is an 18-hole, traditional-style golf course – established in 1924 – that has undergone expansion, renovation and layout changes throughout the years. In 1999, the 130-acre course became a Certified Audubon Cooperative Sanctuary.

While the club was seeking certification, there was a focus in the news and state legislature about pollutants in the nearby Neuse River. The club's staff was concerned about a possible negative image as a pollution source because the club is in the Neuse River basin and uses fertilizers.

Audubon certification was a step in the right direction for the club's image as an environmental steward, but certification didn't provide documentation that would support the course's maintenance practices that protect and ensure water quality. That was about to change.

In 1998, the golf course maintenance staff implemented a proactive water monitoring practice to monitor surface water surrounding the course. Along two edges of the golf course, city storm drain water and surface water combine and flow through a drainage ditch almost 10 feet wide and 8 feet deep. On an average day, there's about a foot of water in the ditch. During a heavy rain, water may rise to 6 feet. Ultimately, this water drains into a creek that drains into the Neuse River.

The maintenance staff collected water samples at two sites – a point where the water enters the course at the start of the drainage ditch and a point where the water exits the course before entering the creek. All samples were sent to North Carolina State University for analysis. Early test results showed the water leaving the course seemed to contain lower concentrations of nitrogen compared to the water entering the course. Therefore, the disciplined and methodical collection of the water samples appeared to be worthwhile; however, the water monitoring program didn't provide long-term data to prove the golf course was filtering water in the ditch.

Fortunately, the crop science department at N.C. State also was concerned about water quality and, specifically, the effects of nitrate leaching – the movement of nitrates through the soil. Many forms of nitrogen are present on a golf course, and depending on the circumstances, some may be considered a water pollutant. A form of nitrogen that receives the primary attention for environmental impacts is nitrate. High levels of nitrate may have environmental impacts such as promoting algae growth. Research had been done about the effects of nitrate leaching in soils that included cool-season turfgrasses, but little research had been done in an environment that supported mostly warm-season varieties of turfgrass.

N.C. State scientists intended to conduct research on nitrate leaching in soils associated with warm-season turfgrass. They wanted an active, real-world environment in which to conduct research. One of two golf courses they chose was Kinston Country Club because of the water quality monitoring already started by the club's staff.

First, N.C. State researchers installed devices called lysimeters around the course to measure the soil's nutrient levels near grass root zones. They also drilled shallow wells to measure levels in the groundwater. Additionally, the research team and Kinston's staff continued to sample the surface water surrounding the course. The idea was that the water moving through and under the golf course's grounds would be contributing to the water in the ditch and Neuse River.

N.C. State scientists found the water leaving the golf course contained lower nitrate levels than the water entering the course. The reduction of nitrate levels was partly because of the groundwater seeping into the ditch from the golf course and diluting the surface water in the ditch. Also, vegetation left to grow taller, thicker and in a more natural state along the edges of the ditch served as a riparian buffer strip and helped to filter runoff from rain and irrigation.

These natural areas and buffer strips created during the Audubon certification process helped the environment by creating a habitat and removing pollutants before they reached the groundwater and surface water. Having the findings of a well-recognized and highly respected university show the course wasn't hurting the environment was invaluable.

Ultimately, the proactive approach Kinston staff took helped change local public opinion of the golf course. A little extra work brought N.C. State to the club and added some legitimacy to the club's claim that it wasn't polluting, but actually helping to improve water quality.

On top of that, some important research took place, and Kinston staff established a great working relationship with N.C. State. It feels good to know that our efforts helped change the perception of our profession and contributed to meaningful research. GCI