An eight-year study of nutrient loss before, during and after construction of Colbert Hills Golf Course in Kansas, US was performed to assess the effect of human development on natural streams

Long-term monitoring of nutrient loss in golf course runoff

Kansas State University researchers undertook an eight-year monitoring study to assess the water quality changes with the development of a new championship golf course. Here they present their key observations and conclusions.

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Golf courses are often constructed close to natural streams or water bodies and the development of a new course often represents a dramatic change in land used. The establishment of a new 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 nutrients transport.

Occurrence of runoff is observed when precipitation rate exceeds soil infiltration capacity. Runoff originates soil erosion thus,causing transport of pollutants (soil nutrients, suspended particles, pesticides) from one place to another. Erosion of soils at two to 40,000-times the pre-construction erosion rate has been reported by Wolman et al. (1967).

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 (Litke, 1996).

While construction could significantly affect the natural stream condition, operation of golf courses requires inputs of fertilisers that contain plant nutrients (e.g.: nitrogen and phosphorus) and irrigation to maintain turf in an acceptable condition.

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 some others have evaluated water quality impacted by golf course operation management (Dodds et al., 1996, Webb and Walling 1986, Olness et al., 1980, and Smith et al., 1992).

LITTLE KITTEN CREEK WATERSHED

This long-term monitoring study, undertaken by staff at Kansas State University, 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 effects of nutrient concentration in surrounding natural surface water before, during and after construction of a golf course.

The development in question was Colbert Hills Golf Course which was to be constructed on the Little Kitten Creek watershed located near Manhattan in the Midwest state of Kansas. The watershed, covering 430 hectares, has elevations ranging from 420-340 metres 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 kilometres 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 intermittent stream and during a typical year about 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. 'Alluvial land' series soils 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 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 account for 68 per cent of the watershed, Alluvial lands and Ivan soils (11 per cent) and Breaks and Dwight (21 per cent). Because of their textures 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 per cent grasslands, 11 per cent 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 88 hectares (20 per cent 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 can occur.

Winter months are characterised by influxes of cold, dry polar air with temperatures as low as -20°C. About 70 per cent of the average annual precipitation of 865mm (Emmert, 1998) falls during the warm growing season (April through September). Only 10 per cent of the average annual precipitation falls as rain during the relatively dry winter months (December through February).

DATA COLLECTION AND ANALYSIS

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.

Portable samplers were set up at each of the three stations to collect water samples during runoff events. 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.

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. So, 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 ▶

An aerial view of Colbert Hills which resides in the Little Kitten Creek watershed. The land the course was constructed on was originally 89 per cent pasture land and 11 per cent woodland

University. Water samples were analysed 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.

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 utilised 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-October 2006.

IMPACT OF THREE DISTINCT PHASES ON WATER QUALITY

Pasture Cover: The water quality of unpolluted water bodies is dependent on 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: 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 fertiliser could represent a source of increasing nutrient transport to surrounding streams. It was hypothesised that stabilisation 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.

RESULTS AND DISCUSSION

The discussion focuses on 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 utilising 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 1. On average 1.3mg/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 of importance 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 4.0mg/L total N was determined during the years of construction. The total N measured values exhibited a large interval of 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 2.4mg/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 reestablished).

During the first six years of the golf course operation, a reduction on the total N concentration was observed; however, the early operation total N concentration was about double the pasture cover total N value. Establishment of turfgrass required fertilisation 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 2. The total P in the inflow did not change significantly over the duration of this study. The average total P values for the pasture cover, construction and early operation stages were 0.49, 0.26 and 0.30mg/L.

During the pasture cover stage an average value of 0.45mg/L total P exited the watershed. Removal of soil vegetation cover increased the average value to 0.87mg/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 reestablished on the surface was the main cause of the reduction of total P

In order to monitor the environmental impacts before construction, during construction and during early operation of the golf course, three stream gauging stations were set up in the watershed

concentrations in the surface water. The recovery of the surface cover reduced erosion of soil particles and thus 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 could be returned back to its original conditions.

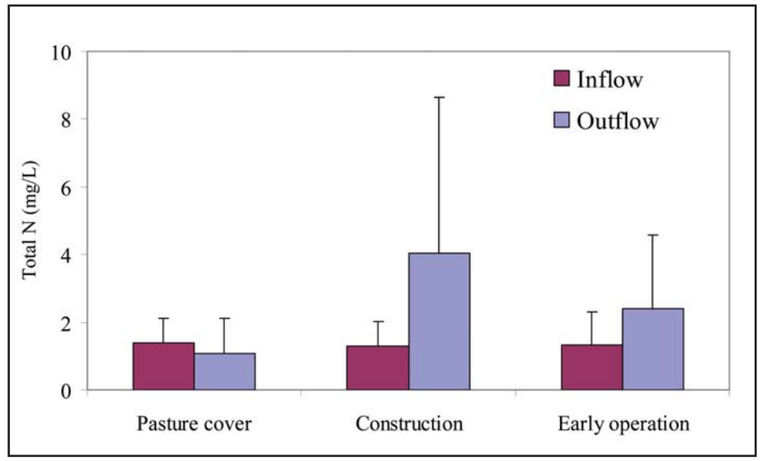
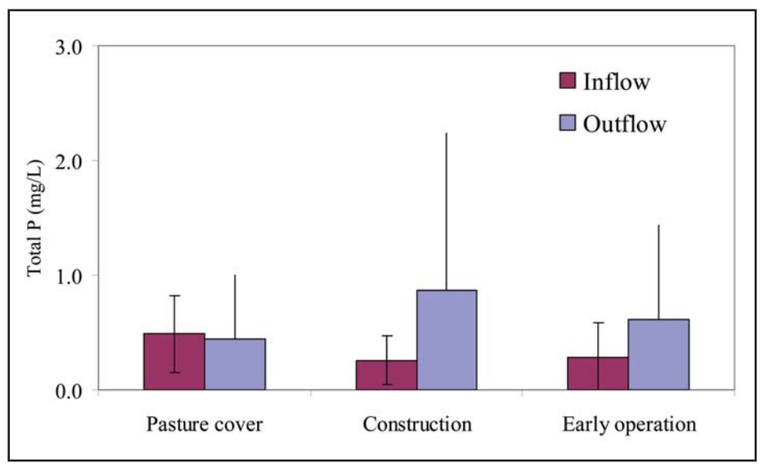


Figure 1: Total N measured in Little Kitten Creek entering and exiting Colbert Hills Golf Course during the three stages of land development

Figure 2: Total P measured in Little Kitten Creek entering and exiting Colbert Hills Golf Course during the three stages of land development



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