In Volume 11.4 (July-August 2009) Australian Turfgrass Management published the first of a series of excerpts from the recent literature review undertaken by Dr. Ross Higginson and Peter McMaugh relating to golf courses and the environment. Having looked at the role golf courses play in carbon sequestration, in this instalment of AGCSATech Update the authors discuss sediment, nutrient and pesticide movement associated with golf courses.

Sediment, nutrient and pesticide **movement** on golf courses

Golf courses are frequently identified by many people as users of fertilisers and pesticides and therefore, by inference, present a high potential for off-site pollution. As part of their literature review (HAL Project No. TU07034 – Environmental and Health Benefits of Golf Courses - A Literature Review) Dr. Ross Higginson and Peter McMaugh explored research data which generally suggests that through industry best practice the pollution potential associated with golf courses is very low. The following is taken from their study.

"A dense, vigorous sward of turf (often as a monoculture) is the key goal of turfgrass systems used in sport. To achieve this is a challenging task for turf managers, requiring the use of pesticides, fertilisers and water to provide aesthetic, safe and performance-acceptable venues.

To provide modern playing conditions, certain management practices such as mowing have been intensified to achieve the desired condition. For example, modern golf course greens are mowed at a height of 2-3mm and are designed to receive 50 per cent of the play even though the total green area makes up less than 3 per cent of the total playing area of a golf course. Even under intensive management, the goal of turf management is becoming more sustainable as scientists and managers have identified systems that are more efficient and require fewer inputs (Cisar, J.L., 2004).

Although there can be potential environmental risks associated with turfgrass management, the overall benefits of turfgrass should not be underestimated. Healthy turfgrass provides considerable benefit to land surfaces in urban environments by providing resistance to insect and weed infestation. Its dense root system also enables an efficient use of applied nutrients and water, which in turn limits the need for unnecessary irrigation, fertiliser and pesticide applications (Beard, J.B., 1989b). Furthermore, it has a major influence in minimising diffuse pollution by sediments, pesticides and nutrients in surface waters (Petrovic & Easton, 2005).

Research on various land use types compared with turfgrass indicates that sediment and nutrient losses from urban and turfgrass systems is considerably less than losses from agricultural and forest systems (Table 1). The same can be said for golf courses. Golf courses provide a large area of green space within a community that can be shown to have many environmental benefits.

An Australian study looked at irrigation and fertiliser regimes on nitrogen (N) leaching from couchgrass sod (*Cynodon dactylon*) in sandy soils of Western Australia (Barton, Wan and Colmer, 2006a and 2006b). This University of Western Australia study concluded that N leaching from couchgrass production on sandy soils will be low if irrigation regimes supply sufficient water for turfgrass growth without causing excess water to move beyond the rooting zone.

Under well-managed irrigation regimes (i.e.: 70 per cent replacement of pan evaporation), they expect N leaching to be low for all fertiliser types as long as N is applied at a rate and frequency that matches turfgrass requirements. The risk of N leaching is greatest during the establishment of turfgrass, especially if this coincides with high rainfall. Higher irrigation rates (i.e.: 140 per cent replacement of pan evaporation) can be detrimental by enabling N leaching, and by decreasing root growth of the couchgrass sod by up to 30 per cent.

TABLE 1: ESTIMATED ANNUAL CONTRIBUTIONS TO SURFACE WATERS FROM SELECTED NON-POINT OR DIFFUSE SOURCES (ADAPTED FROM KOEHLER ET AL., 1982) – AVERAGE LOAD IN MILLION TONS PER YEAR.

Source	Sediment	Nitrogen (N)	Phosphorus (P)
Cropland	1870	4.3	1.56
Pasture and rangeland	1220	2.5	1.08
Forest	256	0.4	0.09
Urban, including turfgrass	20	0.2	0.02

Run off and nutrient loss research from turf has generally been conducted in small scale field studies and, to a lesser extent, in watershed studies. The general conclusions of the small scale studies indicate that with well maintained turf, the amount of run off is small and concentrations of nutrients are often below levels of major concern

Although there is an obvious direct relevance of this research to the Western Australian turfgrass industry, the study has considerable relevance to a large part of the Australian turf industry because of the importance of couchgrass within the Australian context.

This is particularly so within urban areas, such as sports fields, bowling greens and golf greens where a similar sand-based growth medium to that of the standard USGA green (see Snyder & Cisar, 1997) is utilised. These sand-based growth media would be expected to perform similarly to Western Australia's natural sandy soils.

Cisar (2004) also reports on techniques being used within the USA to reduce nutrient leaching from sand-based soils. For modern sports play, turfgrass is often grown on coarse-textured soils such as sands that require routine application of nutrients from fertilisers, particularly nitrogen and phosphorus.

Strategies used to reduce N and P leaching include regulations that limit the amounts of N and P applied, management systems that minimise off-site losses and the use of slow or controlled release fertilisers. Other techniques used include applying lower rates of fertiliser frequently through the irrigation system (fertigation) and/or adjusting irrigation rates to replace only the amount of water used in evapotranspiration (ET) (Cisar, J.L., 2004).

Surface run off is important in transporting both dissolved chemicals and suspended sediment from turfgrass systems to surface waters. Although the volume of surface run off and sediment loss from turfgrass systems is relatively low compared to other management systems (see Table 2), the volume of run off from bare soil on turfgrass construction sites is considerably higher (19.2 vs <1 tonnes/ha per year of sediment) (Daniel T.C. et al., 1979).

These results clearly demonstrate the effectiveness of turfgrass in minimising sediment movement from catchments to adjacent waterways. As nitrogen, phosphorus and pesticides are transported primarily in association with eroded sediment (see Higginson & McMaugh, 2007), turfgrass is also highly effective in minimising their movement.

A study in the USA looked at nutrient and pesticide losses from a small hillside seeded to turfgrass (Easton, Z.M. et al., 2005). The aim was to examine the relationship between run off, hill slope hydraulics and turfgrass growth. The research was conducted on a 6 to 8 per cent hill slope on a sandy loam soil seeded to 80 per cent Kentucky bluegrass and 20 per cent perennial ryegrass. The results indicate that it is imperative to assess site suitability prior to applying nutrients and pesticides given that certain areas simply pose a higher risk to ground and surface water contamination.

In this study, upper slope areas produced less run off, and subsequently lower mass losses of nutrients and pesticides, when compared with lower slope areas which generally produced greater run off, and as a result greater mass losses of applied compounds. This was due to the compounding effects of lower soil infiltration and hydraulic conductivity on the lower slopes due to a finer textured soil, and higher average soil moisture content. The higher overall water content at the bottom of the slope, due to run off from the upper slope areas, decreased infiltration rates and therefore increased run off and leachate levels.

TABLE 2: AVERAGE ANNUAL SEDIMENT LOSSES FROM SELECTED SOILS AND SLOPES UNDER DIFFERENT MANAGEMENT CONDITIONS (ADAPTED FROM GROSS, C.M. ET AL., 1990) – ANNUAL SEDIMENT LOSS IN TONS PER ACRE.

Soil Texture/% Slope	Fallow	Cropping	Rotation	Turfgrass
Loam/4	41.6	19.7	2.7	0.3
Silt Loam/8	112.8	85.5	11.4	0.3
Silt Loam/16	151.9	84.1	25.3	<0.1
Fine Sandy Loam/8	20.3	28.1	5.5	<0.1
Sandy Clay Loam/10	64.7	25.8	10.8	<0.1

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The overall pesticide losses in this study were low with no compound having more than 0.5 per cent of the applied amount lost in run off. Nitrate and ammonium concentrations in the run off were also low but at levels that could possibly pose a threat to aquatic organisms in some circumstances. Phosphate levels in run off were lower than contaminant levels set by the EPA.

The above study clearly demonstrates that it is best to avoid nutrient and pesticide applications in areas close to water bodies, and/or at the bottom of slopes having a long expanse of upslope area to contribute to the overall run off volume.

In 1990, the United States Golf Association (USGA, 1994) began funding an environmental research programme to quantify and document the impact of turfgrass management on the environment. The major objective was to understand and quantify the degradation and fate of turfgrass pesticides and fertilisers so as to be able to accurately predict or simulate their environmental impacts.

Research programmes were established at 12 universities within the USA and the results of this massive undertaking were published (Clark & Kenna (Eds.), 2000) by the American Chemical Society in 2000.

This extensive publication is a key reference for readers interested in the degradation and environmental fate of turfgrass chemicals and in the development of alternative pest control strategies using biological and biotechnical approaches.

Results from the study (USGA, 1994) reported that for fertilisers there is a very strong trend between the rate of nitrogen application and leaching losses of nitrogen as nitrate. The relationship between soil type and subsurface loss of nitrogen agrees closely with previous research conducted on both turf and agricultural systems.

Regardless of the turf cover used, run off concentrations of applied nitrogen did not appear to be different for different species of turfgrass. Results reported are consistent with those of other researchers, namely that run off decreases with an increasing amount of soil vegetative cover.

Turfgrass, due to its dense surface vegetative cover, not only attenuates surface losses of water but reduces the potential for surface and subsurface losses of nitrogen as well because of its dense surface layer and its underlying dense thatch layer.

Phosphate concentrations in leachate never exceeded the irrigation water content of 1-2.5mg/L. This is not surprising given the high affinity of phosphate for soil particle surfaces, which effectively decreases leaching potential (USGA, 1994). Loss of phosphate in both agricultural and turfgrass systems usually occurs through sediment loss and transport during construction or turf establishment (Higginson & McMaugh, 2007; USGA, 2001).

Periodic nutrient applications are an integral and essential part of establishing and maintaining high-quality turf on golf courses. However, these applications increase the potential for nutrients to be transported off-site in surface run off or through subsurface drainage features.

Run off and nutrient loss research from turf has generally been conducted in small scale field studies and, to a lesser extent, in watershed studies. The general conclusions of the small scale studies indicate that with well maintained turf, the amount of run off is small, and the concentrations of nutrients in the surface run off are often below levels of major concern. However, while studies on a small scale are valuable, they may not represent the diversity and connectivity associated with a watershed-scale study (King K.W. & J.C. Balogh, 2006).

A US study (Miltner, E., 2007) conducted in Washington State measured nitrate – N and soluble P in soil solution at 36 sites strategically located around a golf course. The results indicate that even in fertilised fairways, soil solution concentrations of N and P were usually below water quality thresholds.

Grasses proved to be extremely efficient in scavenging nutrients from the soil due to their dense, fibrous root systems. As soil solution moved down-slope through the monitored areas, concentrations remained low. In the few cases where nutrient concentrations increased in buffers and wet cells, there was no evidence that these higher concentration waters continued to move down-slope or percolated deeper into the soil profile.

This indicates that as the soil solution moved through these areas, where the rate of flow was lower due to gentler slopes, nutrients were likely to be removed from the water through uptake by plants or soil micro-organisms, or immobilised by other soil processes (such as absorption onto clay or other particles). Nutrient concentrations in native wetlands and lakes on the course were not impacted by fertiliser practices.

When the potential movement of water and dissolved nutrients from a golf course to surrounding areas is a concern, grass buffers, bio-swales, wet cells and constructed wetlands can be useful tools in maintaining water quality. Increasing the residence time of the soil solution on the golf course is critical and can allow the grass root system, as well as other soil organisms, to effectively filter nutrients from the water before it leaves the golf course site (Miltner E., 2007).

A more recent study (Starrett, S., et al., 2009) investigated nutrient loading via surface water run-off from a new golf course in Kansas, USA, and compared this to the site's previous native prairie condition. The purpose of the study was to investigate the new golf course's impact on surface water quality during construction and during golf course operations.

The study began in 1998 and monitoring continued for nine years afterwards. Data analysis showed that the golf course construction phase had the greatest impacts on surface water quality, with average concentrations of 3.94mg/L, 0.93mg/L and 2.955mg/L for total N, total P and sediment (TSS) respectively. This compared with 1.18mg/L, 0.39mg/L and 477mg/L for the pre-construction period.

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During operation of the golf course, sediment concentration was lowered significantly to an average of 550mg/L, slightly higher than that of the native prairie condition. The average concentrations of total N and total P were 2.02mg/L and 0.49mg/L respectively, much lower than those during the construction phase, but still 70 per cent and 25 per cent higher than those in the native prairie condition.

Sources of nutrients in streams under native prairie condition and during construction are thought to be from the input of rainfall and sediment eroded from fertile topsoils. During golf course operation, fertiliser application is considered to be another source of nutrients in streams in addition to those mentioned above.

Further analysis has shown that there are direct connections between fertiliser application and concentrations of total N and total P in streams. There are cases that clearly indicate that the amount and timing of the fertiliser application are to be blamed. For example, when a large amount of fertiliser is applied over a large area and a significant rainfall event occurs shortly after the application (Starrett, S., et al., 2009).

Another major study (Snyder, G.H. and Cisar, G.L. 1997) looked at the mobility and persistence of turfgrass pesticides applied to a USGA-type green. Because water percolation can be much more appreciable in a coarse-textured man-made rooting media, leaching of pesticides from a USGA green is an obvious area for investigation.

In the above study, two commonly used herbicides were investigated, namely Dicamba and 2,4-D. The results indicate that although only 10 per cent as much Dicamba as 2,4-D was applied, nearly 65 per cent as much Dicamba was recovered in the percolate water over a two-month period following application. Clearly, Dicamba was much more mobile than 2,4-D in the USGA green.

Nevertheless, the average concentration of both herbicides in the percolate was well below maximum contaminant levels set by USA authorities (2.6 and 1.2 micrograms per litre compared to 70 micrograms per litre). Clearly, herbicide leaching from turfgrass grown on an ideal drainage media (such as that of a standard USGA green) indicates that herbicide leaching under normal turfgrass circumstances is not likely to be a major environmental problem."