1997, took a promotion at another course for two years, then returned as superintendent in 1999.

"I immediately started changing the sprinkler heads, but we were still having distribution issues," he recalls. "We played around with plugging nozzles to keep the turf from getting too wet near the sprinkler. But then we had to hand water to avoid brownouts."

Kachmarek almost resigned himself to the hand watering regimen. "After all, our irrigation season is only around 90 days," he says. But coupled with the poor uniformity, nozzles would clog on their own as the vintage 1953 mainlines sent rusty metal flakes through the system. "You could drive around in the morning and see where the nozzles were plugged by rust."

Voicing his frustration to his Underhill representative resulted in a dozen Profile nozzles provided as a sample. "I threw them out there and saw results right away," says Kachmarek. He immediately ordered 50 nozzles. Installation was easy; less than five minutes a head.

"The difference was night and day," he adds. "Night and day." He switched out 200 heads that year, 500 in 2012, and plans on completing the entire course with 500 next year.

"It'll probably run about $12,000 by the time we're done, but when you compare that to a $2-million system overhaul, it's worth it," Kachmarek says. "If you had to irrigate all year, it would pay for itself in water and electricity savings in a few years. And from an environmental aspect, it's cool to save water; it's cool to save electricity on pumping." GCI

Helen Stone is a West Coast-based freelance write and frequent GCI contributor.



Distribution uniformity is critical to flawless fairways and gorgeous greens at Tacoma Country and Golf Club, Lakewood, Wash.

NO SHORTCUTS

An irrigation audit reveals which areas of your course are covered... and which aren't. by Mike Vogt

THINKSTOCK

There remains no simple way or shortcut to arrive at a method to manage irrigation water, especially given the inherent inefficiencies of a water application with a circular pattern with designed overlaps along with single-head coverage.

However, the increase use of handheld moisture meters and in-ground moisture sensors have brought about many changes in water management and hand-water applications particularly on greens surfaces. The superintendent must quantify the use of the current irrigation system by adjustments individual heads on a constant basis, which remains our best practice today. Without the baseline numbers from an audit, it remains a guessing game on what areas of the course are receiving quality coverage. Out of all information attained from irrigation audits, the most important number to attain remains Distribution Uniformity (DU); that percentage is the broad report card of the irrigation systems ability to apply water evenly over a given area.

When a superintendent designs a schedule for water distribution, that schedule must be modified to accommodate changes in weather or evapotranspiration (ET) which can change the turfs need for water. An audit provides the tools necessary to meet these requirements.

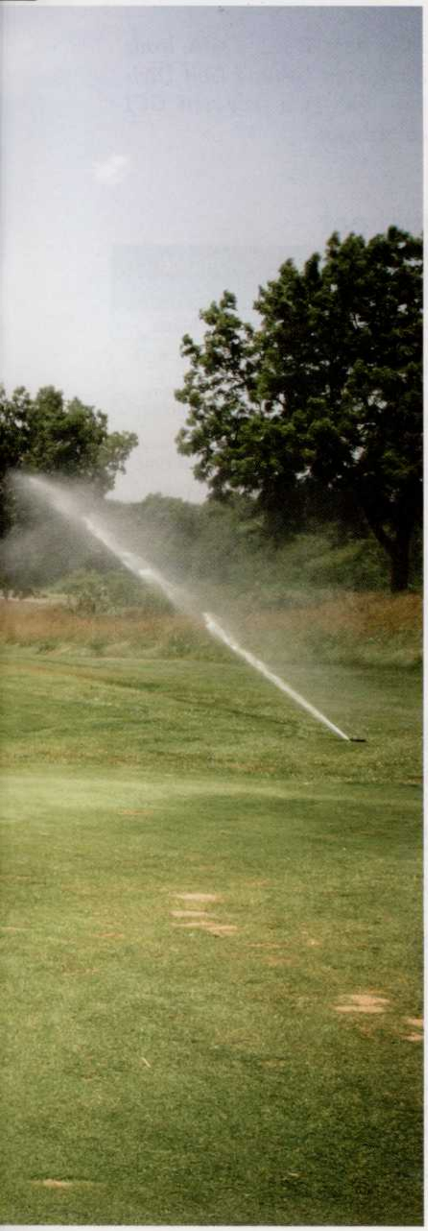
Our modern irrigation systems become less efficient with time and even the most advanced systems were never designed or intended to be a "set-it-and-forget-it" water distribution tool. The recommended schedule resulting from an audit is based on the field results; inspections, distribution uniformity, precipitation rate, soil intake amounts, turf water use, root zone depth and soil water holding capacity. Further adjustments to scheduling must be made to accommodate the limits of the control system used to operate the system.

An added benefit to an irrigation audit, or multiple audits, is to identify trends in irrigation system maintenance or other system needs. Typical irrigation maintenance activities that may be identified by an audit include:

- Adjusting and leveling sprinkler heads
- Adjusting arcs for proper pattern coverage
- Ensuring there is nozzle and sprinkler uniformity
- Clearing clogged nozzles;
- Replacing drive mechanisms or irregular rotating heads.

Also, an audit may alert superintendents to more significant problems, such as:

- Moving heads to more appropriate spacing
- Adjusting pressures at pumping source
- Adding pressure regulating devises
- Component upgrades – sprinklers, valves, pressure regulating valves, screens, filters).



Audit Worksheets

These worksheets use data accumulated from a proper and complete Irrigation Audit to quantify cost savings and operational efficiencies. *Editor's Note: These worksheets are based on information from Irrigation Association, Certified Golf Irrigation Auditor Manual, July, 2004.*

Power Savings Worksheet

#	Data Required	Value	Unit	Source
	Part 1: Calculate Irrigation Requirements			
1	Total Irrigated Area	110	Acres	Site Maps
2	Yearly Plant Water Requirements	32.20	Inches Per Year	ET0 3 Avg. K_c 3 Avg. K_{mc}
3	Yearly Irrigation Requirements	19.20	Inches per Year	#2 2 Effective Rain
4	Adjusted Yearly Irrigation Requirement (gross)	23.42	Inches per Year	#3 3 Run Time Multiplier
5	Total Gallons Recommended per Year	69,954,135	Gallons per Year	#4 3 27,154 3 Acreage
	Part 2: Calculate Power Cost			
6	Historic Yearly Power Cost	$8,379	$	Power Bills
7	Historic Gallons Pumped	76,973,885	Gallon per Year	Pump Station / Records
8	Historic Average Power Cost per Gallon	$.000109	$ per Gallon	#6 4#7
	Part 3: Estimate Power Savings			
9	Cost of Recommended Gallons	$7,625	$	#5 3 #8
10	Potential Yearly Power Savings	$754	$	#6 2 #9
11	Reduced Pump Maintenance Costs	$1,000	$	Estimate Impact of #5 on Frequency of Maintenance
12	Cost of Audit and/or Equipment Upgrades	$7,000	$	Calculate
13	Estimated Life of Pump Remaining	9	Years	Calculate
14	Return on Investment	$2.26	Ratio	#13 3 (#10 + #11) / #12

MONEY SAVINGS. A properly maintained and scheduled system will save money. An irrigation audit provides superintendents with the correct data to calculate accurate savings.

Once field data is gathered an illustration of saving can become clear and a return on investment can be communicated to club or course leaders.

WATER SAVINGS. Water will always have a cost, whether its cost is just pumping or you must actually purchase water. In the example above Distribution Uniformity (DQLQ) was collected for a golf course on the East Coast that purchased water by the unit (1,000 gallons) which costs $1.40. Simple math tells us that saving 10 percent in DQLQ will yield a savings of 4,236,024 gallons per year. The equation would look work out to be 4,236,024 divided by 1,000 to equal 4,236. Then multiply 4,236 by $1.40 to get a savings of $5,930.40.

POWER SAVINGS. Pump station pumps 1,000 gallons per minute, we save 4,236,024 gallons per year or 4,236 minutes of pumping time or 70.6 hours. If your course irrigation power bill was $21,000 per year based on 55,910,086 gallons at 60 percent DULQ that number would be 0.000376 (55,910,086 / $21,000 = 0.000376) per gallon in electricity or electricity savings of $1,592.00. In addition, saving 70.6 hours over the life of the pump system, that would equate to at least one free year added to the life of the pump station. Combined savings of $5,930.40 water plus $1,592.00 electricity would equal a total yearly savings of $7,522.40. **GCI**

Mike Vogt, CGCS, CGIA, leads McMahon Group's Golf Division and is a frequent GCI contributor.

Sample Audit

Plant Water Requirements	Uniformity DU_{LQ}	Irrigation Water Requirement	Gallons per Acre Inch	Irrigated Acres	Total Gallons per Year
15.6 Inches per Year	60%	20.59 Inches per Year	27,154	100 Acres	55,910,086
15.6 Inches per Year	70%	19.03 Inches per Year	27,154	100 Acres	51,674,062
				Difference	4,236,024

Pump Operation Savings Worksheet

#	Data Required	Value	Unit	Source
	Part 1: Calculate Irrigation Requirements			
1	Total Irrigated Area	110	Acres	Site Maps
2	Yearly Plant Water Requirements	32.20	Inches Per Year	ET_0 3 Avg. K_c 3 Avg. K_{mc}
3	Yearly Irrigation Requirements	19.20	Inches per Year	#2 2 Effective Rain
4	Adjusted Yearly Irrigation Requirement (gross)	23.42	Inches per Year	#3 3 Run Time Multiplier
5	Total Gallons Recommended per Year	69,954,135	Gallons per Year	#4 3 27,154 3 Acreage
	Part 2: Calculate Pump Operation Hours			
6	Recommended Hours of Pump Station Operation	1214	Hours Per Year	#5 4Avg. Pump GPM / 60 Minutes
7	Historic Hours of Pump Operation	1,336	Hours Per Year	Yearly Gallons Used4Avg. Pump GPM / 60 Minutes
8	Potential Operational Reduction	122	Hours Per Year	#7 2#6
	Part 3: Estimate Pump Operational Savings			
9	Potential Operational Savings	$765	$ per Year	#8 3 (Yearly Power Cost 4#7)
10	Potential Yearly Power Savings	$754	$	#6 2 #9
11	Reduced Pump Maintenance Costs	$1,000	$ per Year	Estimate Impact of #8 on Frequency of Maintenance
12	Cost of Audit and/or Equipment Upgrades	$7,000	$	Calculate
13	Estimated Life of Pump Remaining	9	Years	Calculate
14	Return on Investment	$2.27	Ratio	#12 3 (#9 + #10) / #11

Water Cost Savings Worksheet

#	Data Required	Value	Unit	Source
	Part 1: Calculate Irrigation Requirements			
1	Total Irrigated Area	110	Acres	Site Maps
2	Yearly Plant Water Requirements	32.20	Inches Per Year	ET_0 3 Avg. K_c 3 Avg. K_{mc} [1]
3	Yearly Irrigation Requirements	19.20	Inches per Year	#2 2 Effective Rain
4	Adjusted Yearly Irrigation Requirement (gross)	23.42	Inches per Year	#3 3 Run Time Multiplier
5	Total Gallons Recommended per Year	69,954,135	Gallons per Year	#4 3 27,154 3 Acreage
	Part 2: Calculate Water Cost			
6	Cost per Billing Unit	$1.40	$ per Unit	Water Bills
7	Convert Recommended gallons to Billing Units	93,522 ccf[2]	Units per Year	$5 4748 (for ccf units) -OR- #5 41,000 (for 1,000 gallon units)
	Part 3: Estimate Water Savings			
8	Historic Yearly Water Cost	$135,485	$ per Year	Water Bills
9	Cost of Recommended Gallons	$130,931	$ per Year	#6 3#7
10	Potential Yearly Water Cost Savings	$4,554	$ per Year	#8 2 #9
11	Cost of Audit and/or Equipment Upgrades	$7,000	$	Calculate
12	Estimated Life of Pump Remaining	9	Years	Calculate
13	Return on Investment	$5.86	Ratio	(#103#13)4#12

(Footnotes) 1. ETO refers to Evapotranspiration, specifically in turf; Kc refers to Crop Coefficient - type of turf and height of cut. Kmc refers to Microclimate factor for different exposures, such as south facing slopes, shade, high wind areas. 2. ccf refers to 100 cubic feet

BY CHAD PENN, GREG BELL, JASON WARREN, AND JOSH MCGRATH

Phosphorus Remediation

Improving water quality with phosphorus removal structures.

The USGA continues to examine and support innovative ways to reduce the environmental impact of golf courses. Previous research indicated that phosphorous can be found in runoff and tile drainage water leaving golf course properties. The transport of phosphorus (P) from soils to surface waters is a major cause of eutrophication (enriched with dissolved nutrients and lacking oxygen). Eutrophication results in algal blooms, excessive aquatic plant growth, low dissolved oxygen levels, and potential fish kills. Phosphorus is more important than nitrogen in this regard because P is the most limiting nutrient for aquatic life.

The uncompleted phosphorus removal structure shown during construction.

There are two main forms of P, particulate P and dissolved P, which are transported to surface waters via surface runoff and subsurface flow. Particulate P is sorbed onto soil particles and it is not 100% available after it reaches a water body. Controlling erosion eliminates articulate P transport. Dissolved P is 100% bio-available upon reaching a water body, and erosion control does little for reducing its movement. Controlling dissolved P losses from suburban and urban landscapes is especially challenging when soil P accumulates due to several years of P fertilization beyond plant needs. Even after cessation of P fertilization and implementation of traditional best management practices, dissolved P will continue to leak out of high-P soils for many years.

One potential solution to this problem is through the use of various industrial byproducts that are rich in P-sorbing minerals. These materials (phosphorus sorbing materials, or PSMs) are able to react with dissolved P and remove it from solution, preventing transport (Penn et al., 2011). Some examples of PSMs include acid mine drainage residuals from the coal mining industry, drinking water residuals from municipalities, and steel slag from steel production. Specifically, P can be directly removed from runoff and drainage waters through the use of a P removal structure containing a PSM (Penn et al., 2010). These structures can be strategically placed in "hot spots" or drainage ditches where runoff with elevated concentrations of issolved P is likely. The P removal structure intercepts runoff or subsurface drainage and channels it through contained PSMs. After the PSMs become saturated with P, they can be replaced with new PSMs, thereby effectively removing P from the watershed.

An ideal PSM should be locally available, inexpensive (or free), able to sorb P quickly,

This article first appeared in the Green Section Record Vol. 50 (10) May 11, 2012. It is reprinted with permission.

have high hydraulic conductivity, and be safe in regards to potential pollutants such as sodium, trace metals, and various organic compounds. Generally, materials that are rich in calcium (Ca), aluminum (Al), and iron (Fe) are potential PSMs. For a Ca-rich PSM to be effective, it needs to be well buffered to a pH above 6 and the Ca must be soluble in water. These conditions are necessary to precipitate Ca phosphates effectively and quickly. PSMs containing Al and Fe minerals must not be coated, and the pH must not be excessively high (>8.5) for them to effectively sorb P by a process known as "ligand exchange."

After studying many PSMs and conducting laboratory and pilot scale experiments, we constructed a P removal structure on the property of Oklahoma (Superintendent, Jared Wooten). The P removal structure was placed at the outlet of a 150-acre suburban watershed, which consisted of approximately 35%, 50%, and 15% residential, undeveloped area, and golf course, respectively. Two irrigated golf greens were located within 300 to 400 feet from the structure. The greens were regularly irrigated as necessary, and this irrigation sometimes produced runoff that reached the structure.

The structure was located in a drainage ditch immediately on the downstream side of a drainage culvert where all water exited the watershed via a concrete, trapezoidal bar ditch maintained by the City of Stillwater. The bar ditch drained directly into Stillwater Creek. Some runoff entered the structure by flowing along the side of the culvert into the structure inlet. Runoff entered the structure through several 2-inch-diameter pipes connected to buried perforated pipe for evenly distributing the water throughout the PSMs. The water could then infiltrate through the bed of PSMs and drain out through the 4-inch-diameter outlet.

The PSM selected for this 8 foot x 10 foot structure was electric arc furnace steel slag that was sieved to ¼ inch in size in order to ensure a high hydraulic conductivity, thereby treating as much water as possible. Although the finer size fraction of the slag is more effective at absorbing dissolved P, a pilot scale study showed that the non-sieved slag was prone to clogging. However, after observing the system for several months, it is probable that we could have used a smaller size fraction than ¼ inch for improved P sorption without greatly compromising hydraulic conductivity. Three tons of slag was placed in the structure to a depth of 8 to 9 inches.

Flow rate measurements and samples were collected during runoff events using ISCO automatic samplers at the structure inlet and outlet. Using both P concentration and flow rate data, we were able to calculate the mass of P (P load) entering the structure and the P load removed by the structure. It is important to evaluate P losses as loads rather than concentrations only. After delivery to a water body, the dissolved P concentration in the body will be a function of the total P load in the water/sediments and the volume of water in the body. This concentration can vary annually and with season. Consider that a large volume of runoff water with a low P concentration can potentially deliver a greater P load than a small volume of runoff water with a high P concentration. For this reason, comparing P concentrations can be misleading. Regulating agencies are more interested in P loads, for example, total maximum daily loads (TMDLs).

During the first five months of operation, there were 54 total runoff events, the majority of which were irrigation induced. Dissolved P concentrations in irrigation runoff originating from nearby putting greens were typically between 0.3 and 0.5 mg L-1, while rainfall-induced runoff events were normally 0.5 to 1.3 mg L-1. Most of the rainfall-induced runoff was produced from the residential areas outside of the golf course. Rainfallinduced runoff events also delivered the majority of dissolved P loads to the structure, compared to golf course irrigation events (90% of total P load delivered to structure).

After five months, the P removal structure captured 25% of the total P load enter-

Top: The 150-acre mixed residential and undeveloped watershed in Stillwater, Okla. Right: The completed phosphorus removal structure filled with steel slag.

Close-up of steel slag.

ing the structure. As expected, the removal efficiency of the structure was highest at the beginning (near 100%), then decreased with further P inputs. Phosphorus removal efficiency was greater for the low-flow irrigation-induced runoff events compared to rainfall-induced events. The lower flow rate of the irrigation events resulted in a greater retention time, i.e., the time of contact between runoff water and PSMs, compared to rainfall events. Retention time is calculated as the total pore space divided by flow rate. In fact, we found a significant relationship between retention time and P removal efficiency. The P removal efficiency of steel slag increased with increasing retention time. However, this is not true for all materials; some PSMs sorb P so quickly that they do not respond to changes in retention time (Stoner et al., 2012).

We conducted numerous laboratory flow-through P sorption experiments on 14 different PSMs and developed a user-friendly model to aid in designing P removal structures. The result is a "universal model" that can predict P removal and longevity of any PSM as a function of inflow P concentrations, flow volumes, retention time, and characteristics of the PSM. The model was successful at predicting the performance (P load removal and longevity) of the Stillwater structure. In addition, this model can be used to determine how much of a particular PSM is necessary for removing a targeted P load at a particular site.

It is important to keep in mind that the Stillwater structure was a prototype. Using the previously mentioned model, if the goal was to remove 60% of the P load instead of 25%, then the structure could have simply been built to a larger size to accommodate 17 tons of sieved steel slag. On the other hand, based on laboratory experiments with non-sieved slag, only 500 lbs. of material would be necessary to remove 60% of the dissolved P load. However, the non-sieved slag is likely to exhibit poor hydraulic conductivity. Future research is required to determine the steel slag size fraction that achieves the ideal balance between maximum P sorption and hydraulic conductivity.

Phosphorus removal structures should be designed to be free-draining, especially if Fe-rich PSMs are utilized; stagnant water may induce Fe reduction and potential release of previously absorbed P. Also, P removal structures should only be constructed in areas with high dissolved P concentrations only. The reason for this is because many PSMs are less effective when P concentrations in runoff are less than 0.2 mg L-1. Ultimately, structures can have a variety of designs. They do not have to resemble the "box" structure displayed on page 75.

The keys to successfully constructing a P removal structure are use of a suitable amount of effective PSM, water flow through the PSM, and containment of the PSM. Once the PSM is no longer able to remove P, it can be removed from the structure and replaced with fresh material. The "spent" PSM may be suitable as a P fertilizer applied elsewhere, depending on the PSM utilized, or it may simply make a good soil amendment. For the ¼-inch sized slag used in our structure, we intend to test the ability of the material to serve as landscape mulch.

The golfing public needs to be aware that there are a few environmental consequences when providing quality playing surfaces for the game. Through USGA-supported research, scientists have identified potential problems where the management of golf courses can be improved to reduce the environmental impact and still provide an excellent golfing experience. We need to support the efforts of golf course superintendents who identify an environmental problem and then, based on reliable information, provide a management solution such as phosphorous removal structures. **GCI**

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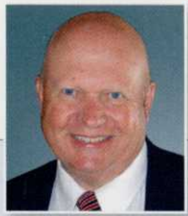


Dennis Lyon, CGCS, is a GCSAA past president. He spent more than 35 years as the golf division manager in Aurora, Colo., and is the 2011 recipient of the USGA Green Section Award. Dennis can be reached at dlyon@gie.net.

GOLFER, GRASS GROWER OR PLAYING SURFACE PROVIDER?

I recall a few years ago having a conversation with a Men's Club president, who was very unhappy with course conditions. The rough was long, the fairways were wet and the greens were slow. However, the course looked great. The superintendent and assistant were not golfers. This golfer said to me, "the staff here is a bunch of grass growers when they should be playing-surface providers."

I've given serious thought to the question, should superintendents be golfers and play their own course? I've posed this to USGA committee members, superintendents, golfers, educators and consultants. Their answer was a resounding, "Yes."

There are exceptions. There may be a few superintendents who provide superior course conditions and never hold a club. There may be a few successful superintendents with physical handicaps who cannot play the game. I am convinced, experiencing our course as a golfer is essential to provide superior playing conditions.

I will go one step further. Since a multitude of surveys say course conditions are the primary reason golfers choose one course over another, I believer it is as important that the superintendent is a golfer as it is the golf pro is a golfer. Pros are expected to play, teach and be excellent golfers. Supers, on the other hand, do not need to be great or even good golfers. They do need to play the game to understand how course conditions impact affect their players.

When I talk to superintendents who don't play their course – or play it on a very limited basis – they often say they already work 50-plus hours per week and would rather be with their family than spend time playing golf. I have also heard them say they do not enjoy playing their course as they spend too much time thinking about work.

I agree, finding the time and inclination to play one's course can be difficult. However, in my opinion, looking at course conditions from a golfer's perspective is an important aspect of every superintendent's job.

If the superintendent can't find time often enough for an 18-hole round of golf, I may have the answer. Instead of playing an 18-hole round, my suggestion is the superintendent invest his time in a Super Golf Tour.

> If the superintendent can't find time often enough for an 18-hole round of golf, I may have the answer.

A Super Course Tour is not a new ide,a but I feel it is an under-utilized one. Most supers drive around their course looking at conditions, problem areas, etc. To conduct a Super Course Tour the superintendent takes his or her clubs and a cart and evaluates course conditions from a golfer's perspective. The goal is to complete the tour in 90 minutes or less.

For example, a tour can begin on the first tee. The super tees off on the first tee. He or she picks up the ball where it lands and drives to a greenside bunker and drops the ball into the bunker and hits it onto the green. The super then putts out. The superintendent can then move to the second fairway and drop the ball 150 yards from the putting surface and strike the ball. If the ball lands on the putting surface the super can play it or pick it up. If it lands in front of the putting surface the ball can be pitched onto the green. A similar process of playing various places on the course takes place on every hole with the purpose of quickly evaluating course conditions.

The superintendent can use the Super Golf Tour to determine – from the golfer's perspective – the condition of green, tees, fairways and rough; the speed of greens and quality of putting surface; evaluate the condition and quantity of sand in bunkers; and evaluate the growth of trees and shrubs to see if they negatively impact a golf hole.

By striking a ball from the fairway and letting it bounce onto the green, the super can determine if the area is firm enough to allow the ball to bounce properly without plugging. Conducting a Super Course Tour once or twice per week provides the superintendent with beneficial information on course conditions from a golfer's perspective, without investing too much valuable time.

The Super Golf Tour should be conducted differently each time it is held. All areas of the course should be evaluated over time with maintenance activities modified to provide superior playing surfaces throughout the course.

Agree with my assessment of the importance of a superintendent playing their course?

Ideally, a round of golf with a staff member, the golf pro, a club official or other key individual can be a valuable asset to the superintendent. However, if time is limited, why not spend some time using the Super Golf Tour as a tool to evaluate course conditions. Give it a try and let me know what you think? You can contact me at lyondennis48@aol.com. **GCI**

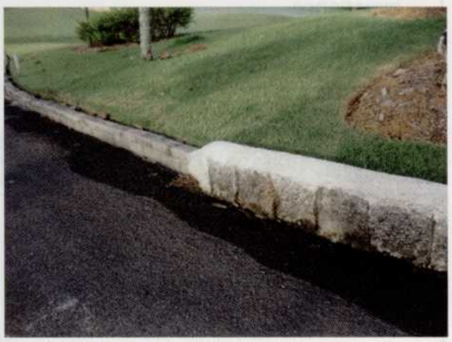
Terry Buchen, CGCS, MG, is president of Golf Agronomy International. He's a 41-year, life member of the GCSAA. He can be reached at 757-561-7777 or terrybuchen@earthlink.net.

Travels With Terry

Globetrotting consulting agronomist Terry Buchen visits many golf courses annually with his digital camera in hand. He shares helpful ideas relating to maintenance equipment from the golf course superintendents he visits – as well as a few ideas of his own – with timely photos and captions that explore the changing world of golf course management.

WORLD'S GREATEST CART PATH CURBING

The Dorado Beach Resort & Club in Dorado, Puerto Rico, has replaced their 6-inch-high cart path curbing on the par-4 10th hole on the Sugar Cane Course with a state-of-the-art curb where it is now impossible for a golf cart to jump over the curbing and drive onto the turf. The new curbing is made out of local concrete cinder blocks that are 15.25 inches long and 7 inches thick that have a natural, rustic appearance. A hand-formed concrete rolled cap is placed on top of the cinder blocks giving a total height of 11 inches. Brad Boyd, director of agronomy, and Randall Small, Sugar Cane superintendent, had their staff install the new curbing from tee to green as a test to see how keeping the golf carts on the path on the entire hole affected play and comments from the members and the resort guests. The feedback has been very positive and Boyd is planning on installing additional tee to green cart paths on the 72-hole venue. The cost is about $3.50-$4 per lineal foot installed, 1,700 lineal foot total. The Dorado Beach East Course is hosting the Puerto Rico Classic on November 12th-18th during the inaugural 2012 PGA Tour Latinoamerica. **GCI**



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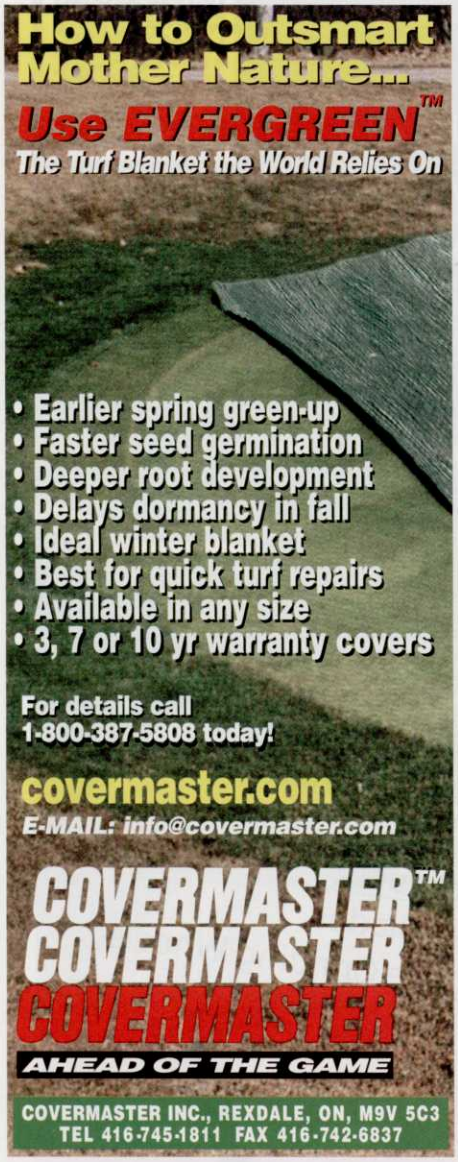

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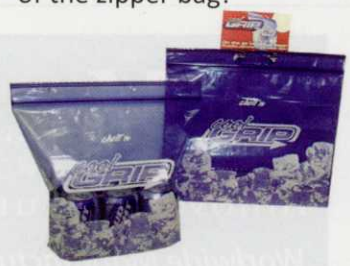

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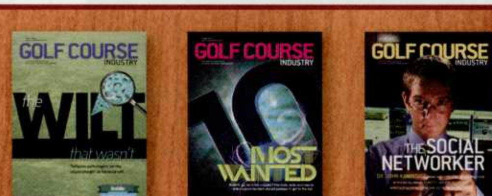

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