the South Course needed updating for a modern golf game in which golf balls are driven far past the imaginings of Tom Bendelow or others of that era.

"The South Course was sound when it was built, but not now," Smyers says. "Changes that were made throughout the years caused elements that were integral to the design to be lost. So, we reread the land, moved the championship tees back to restore the historical landing areas, and adjusted and added bunkering to return the original shot values."

MacKenzie provided old aerial photos and design plans that Smyers and Andrews used to recreate the shapes and patterns of the South Course's classic bunker style. This was crucial to the process.

Of the club's original four golf courses, Bendelow designed Course 1 (now the South Course), Park designed Course 4 (now the North Course), and Bendelow and Watson tag-teamed on the design for Courses 2 and 3. But in 1945, Courses 2 and 3 were sold to developers, with the first and 18th holes from Course 2 becoming the eighth and ninth holes on Course 1. Since then, the North Course has become the favored son, while the South Course has been, largely, the members' course and hasn't received the care the North Course has, MacKenzie says.

"But the members absolutely love the South Course," he says.

The club's leadership agreed with Smyers that they would love the South Course even more if it played the way it was meant to be played and if its agronomic deficiencies were addressed.

One of the chief problems was that the third green sat in the flood plain of Butterfield Creek and any significant flooding put the front half of the green underwater. Smyers rerouted the hole that played from east to west. Now it plays northeast to southeast, and the new green complex is relocated on a wooded hillside. Crews from Wadsworth Golf Construction removed 1.5 acres of timber and cut a 10-foot wedge out of the hillside to build the green.

Meanwhile, the 13th fairway was rerouted, turning a straightaway hole into a slight dogleg. Smyers also designed a new creek that now wraps around a pond on the hole, which is now an irrigation source. This maneuver also pleased local environmental authorities. Runoff from U.S. 30 and neighborhoods south of the golf course was causing water-quality issues with the pond. But now the creek diverts that drainage

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water around the pond while creating a feature on the 13th hole.

"The green was left untouched, but the rest of the hole was completely rebuilt," MacKenzie says.

Crews also undertook a significant drainage project on the 17th hole, recontouring to help with the drainage issue.

MUCH-NEEDED IMPROVEMENTS

Throughout the South Course, bunkers, tees and greens have a new face. Yet there are some improvements MacKenzie cherishes that golfers won't even notice. Forty-nine bunkers – mostly greenside – were restored, repositioned or added to develop strategy, interact with the landscape and to highlight target areas. Tees were renovated and others added to lengthen the course by 700 yards to almost 7,200 while maintaining the 6,500-yard distance for member play. And greens that had shrunk significantly through the years were expanded an average of 1,450 square feet to their original size and shape.

The ground game is a critical part of play on the South Course and almost every green is open in the front so golfers can run the ball up onto the putting surfaces. MacKenzie points to regrassing the tees and fairways with a blend of Penneagle II and PennLinks II.

"This blend gives us a wide range of adaptation across the spectrum of the various microclimates on the course," he says. "The National Turfgrass Evaluation Program studies in Chicago showed they were good with wear and drought and heat tolerance and had good resistance to brown patch and dollar spot. If there's a reason to regrass, there are a lot of new cultivars that can help you."

The old irrigation – a single-row system with a mix of Toro, Rain Bird and Hunter heads with Rain Bird controllers – was replaced with Toro's newest, the Network VP, a satellite system with Site-Pro software.

The existing Flowtronex pump station, installed in 1999 and capable of pumping 3,600 gallons per minute, was retained. But everything else was replaced. MacKenzie is thrilled with the 1,200-head, triple-row system with two outside rows in the rough and perimeter watering around all the greens.

"The idea is to have single-head control, as opposed to two and three heads paired together before," MacKenzie says. "Now we have much tighter head-to-head coverage across the playing surface. I can dial in individual heads and manage water better in specific areas that are wetter or in shade, so the playing area is a lot more consistent."

The single-row system meant fairways were wet in the middle and dry on the outside. Now MacKenzie has the ability to run less water to the center row so he can make the middle of the fairway firmer.

Drainage is an issue MacKenzie believes never ends on any course. But now, at least, the South Course is a drier layout in many ways. Drainage on the old bunkers was hit or miss, and a third of the bunkers didn't drain properly. Now it's all new, just as it is on all other parts of the course that underwent construction or needed improvement.

Another important new element of the course is the practice range, which sits on the first and 18th holes of the original Course 3 and was languishing without turf, a vestige of the 2003 U.S. Open. Prior to the restoration, the range had been functioning as a parking lot and was in disrepair for the past five years. But Andrews spent an extraordinary amount of time shaping the target greens on the range, and MacKenzie opened the range with practice pads in early May.

ELEVATED STATURE

By building new tees and bunkers, changing the grass lines and expanding the putting surfaces, the golf course is dramatically different. So, which course is the better of the two? It's debatable.

"One reason the North Course got more attention is that it's a slightly better piece of ground, and the South Course can be wetter," MacKenzie says. "We corrected a lot of those problems. We'll go back next year and significantly upgrade some of the old drainage that needs to be replaced."

Some folks think the South Course will overtake the North Course, MacKenzie says.

"The North will always be a great test of golf and one of the top golf courses in the nation," he says. "We've elevated the South Course's stature without any question. But we we'd have to have something besides the club championship on it before we could say it has overtaken the North Course. The South Course is definitely dramatically improved. It's night and day from what it was." GCI

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BY DEYING LI, PH.D.

What lies beneath

TDR-tension infiltrometer tests root-zone materials, monitors green performance

The golf boom in the United States after World War II stimulated many practical changes in putting green construction. One of the adjustments is the increased use of sand as an amendment to the native push-up greens or using pure sand as root-zone material.

As a result of the research conducted in the 1950s, sand-based green specifications were generated by the USGA Green Section. These specifications have been revised several times since they were first published. The uniqueness of USGA greens is the inclusion of a gravel layer below the sand profile, which creates a hanging or perched water table. With an optimum size of sand particles, the root zone can provide sufficient air space and remain less vulnerable to compaction. The artificially created water table helps hold water, and the amount might be increased further by adding organic materials or inorganic soil amendments to the sand.

To meet USGA specifications, the material has to satisfy certain standards. Presently, USGA recommends total porosity be 35 to 55 percent, noncapillary porosity, 15 to 30 percent, and capillary porosity, 15 to 25 percent. The current USGA-recommended saturated water conductivity is at least 6 inches per hour.

It's important the material is tested before, during and after the construction of the putting greens for contracting, quality control and inspection purposes. Testing physical properties starts with particle size analysis, which dictates other properties. The confidence interval for particle size analysis is about 10 percent to around 35 percent. For water conductivity, it's about 20 percent using the USGA-specified procedures. The confidence interval is used to compare differences between loads as they're mixed, and for quality control purposes. For instance, if a standard drains at 10 inches per hour, then each subsequent load should drain between 8 and 12 inches per hour, based on the 20 percent confidence interval for saturated water conductivity (K_{sat}).

The inconsistency of those test results for root-zone materials within the labs has caused inconvenience in bidding and contracting processes during construction. At times, architects, contractors and superintendents didn't know how to use the results, so they applied much more stringent criteria than the K_{sat} tests were able to meet. Saturated water conductivity has been a magic phrase among golf course superintendents when they talk about greens. Saturated water flow occurs only for a short period during a rain or irrigation event. Conductivity is only a fraction of the water movement characterizing root-zone materials. More information is needed about the unsaturated flow of water to understand the root-zone materials better. A superintendent also might want to know how saturated water conductivity changes throughout time and how it's affected by cultural practices.

The primary objective of this study was to develop a methodology that allows easy measurement and monitoring of water conductivity of root zones without the need for destructive sampling. Some academic exercises also were involved to investigate factors that influence the accuracy and consistency of saturated water conductivity tests, such as the soil packing process, dissolved air in testing water, wetting direction and organic matter.

Table 1. Particle analysis of the testing material

	Soil separate			Sand particle diameter					
	Sand	Silt	Clay	Gravel	Very coarse	Coarse	Medium	Fine	Very Fine
				2 mm	1 mm	0.5 mm	0.25 mm	0.15 mm	0.05 mm
	(%)			(% retained)					
Sand I	99.96	0.03	0.01	0.04	8.57	36.78	37.89	14.14	2.53
Sand II	99.28	0.57	0.15	0.28	3.78	21.79	40.19	21.01	12.23
Desired values		≤ 5%	3%	≤ 3% gravel		≤ 60%		≤ 20%	≤ 5%
				≤ 10% combined					

MEASURING METHODS

Two sand sources were included in the study (Table 1, at left). Sand I conformed to USGA specifications, and Sand II was higher in the fine fraction. The soil materials were packed into brass rings at a moisture condition of 8 percent.

A calcium sulfate-thymol solution was prepared following the procedure by Klute and Dirksen. Thymol was used to inhibit the growth of microorganisms in the solution. Before the solution was used, dissolved air was removed

A TDR-equipped tension infiltrometer can be used to monitor water conductivity *in situ* in the field and allows direct agronomic interpretation and comparison of laboratory test results.

with a vacuum boiling apparatus.

Before testing capillary porosity, water retention curve and water conductivity, the soil samples were saturated at normal atmospheric pressure or under a vacuumed condition with three test solutions: tap water, deionized water and a calcium sulfate-thymol solution. Because water conductivity increases exponentially with degree of saturation, a small variation at the saturating point can cause dramatic differences in saturated conductivity. The purpose of these procedures was to test if improvements made in the degree of saturation can help improve the consistency of saturated water conductivity measurements. Tap water can disperse soil aggregates and cause underestimation of water conductivity, so calcium sulfate was used to increase the concentration of testing water.

Using deionized water or a calcium sulfate-thymol solution didn't seem to improve the consistency in the measurement of water holding capacity and conductivity. One reason might be the low clay content and lack of soil structure in the testing materials. Saturating the soil material under reduced pressure generally provided higher estimation of water conductivity (Table 2, page 87) without much improvement in consistency. This led us to believe other random errors induced during the sample preparation and testing process might be underlying reasons for the poor repeatability. Because sand particle size distribution is fundamentally responsible for pore size distribution and water conductivity, it's important to have accurate estimation of the particle size analysis. This is especially true when organic materials are incorporated in the root zone because a thorough mixing is difficult to achieve.

Although there were large variations in saturated water conductivity, it might not be as problematic as commonly considered from an agronomic point of view. Saturated flow rarely happens under actual putting green conditions, and if it happens, it's in a different way than that of the laboratory test where saturation starts from the bottom of the sample.

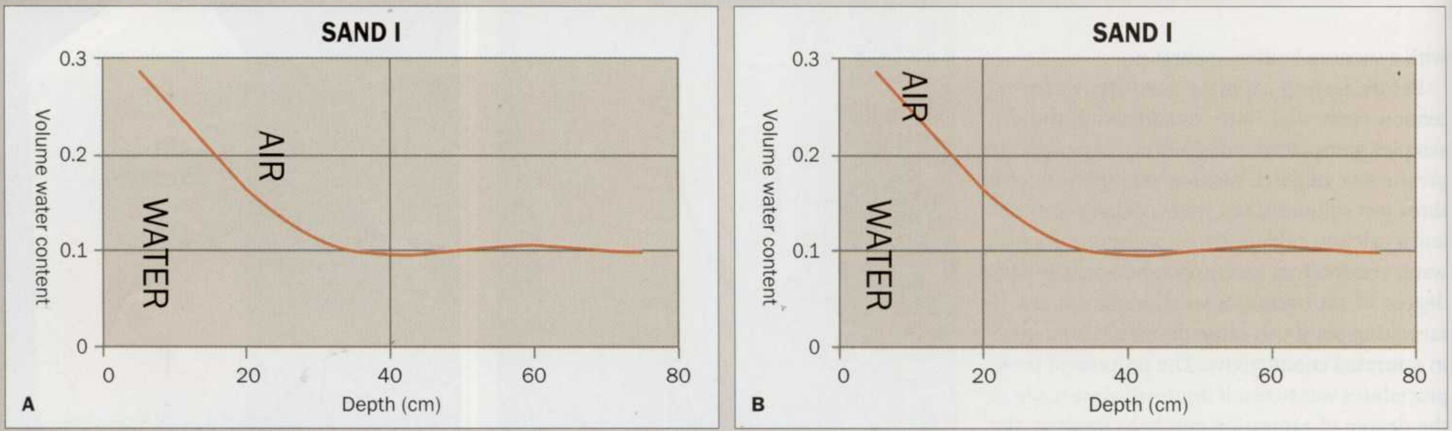
Furthermore, saturated water conductivity decreases quickly as the green ages because of fine particle migration, fine organic material accumulation and layering. Essentially, good drainage is maintained through diligent cultural practices, provided correct materials were used during construction and for topdressing.

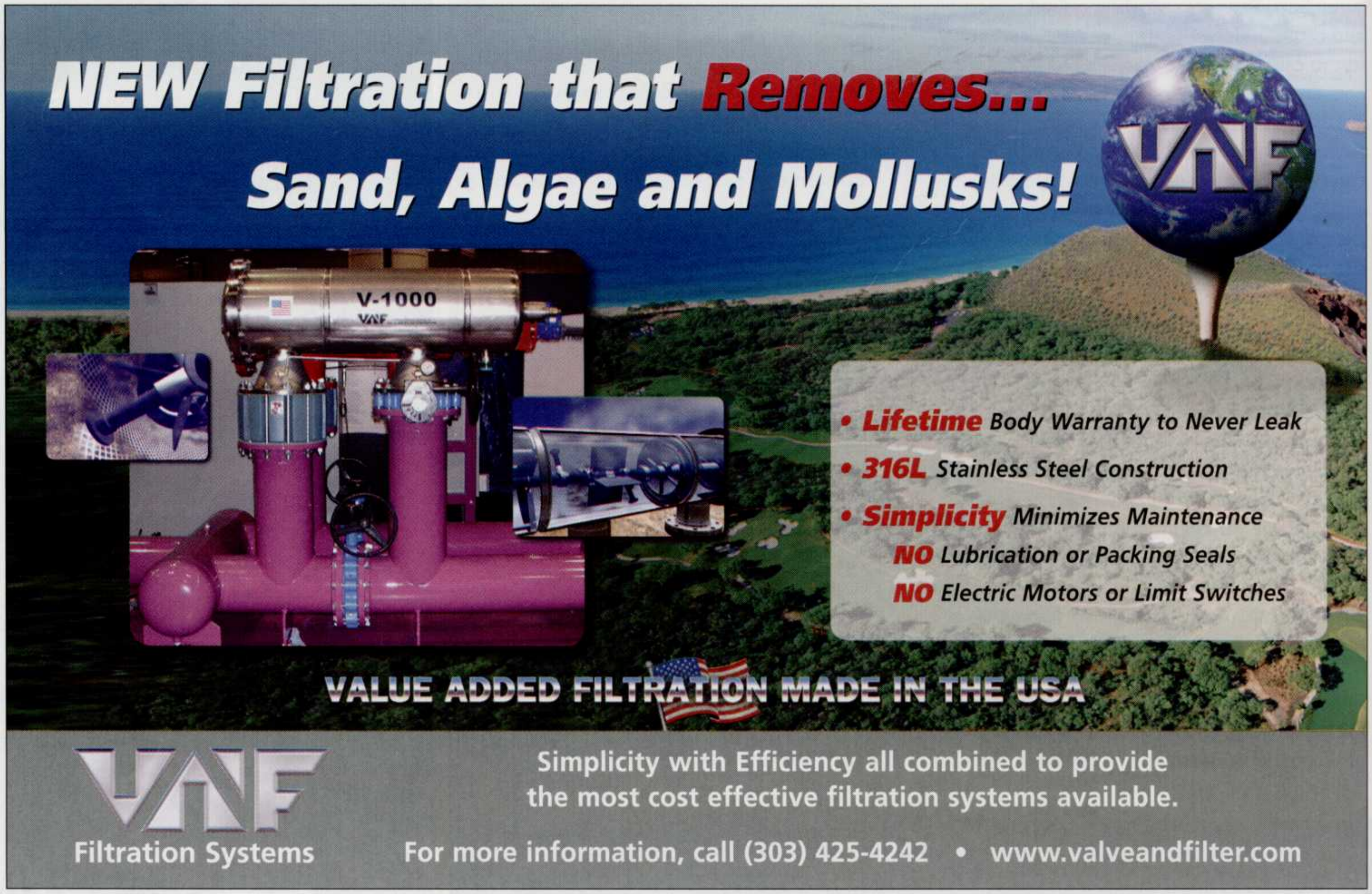
Including a water release curve in specified tests can be useful to bridge the gap between perception and reality. Water release curves provide more balanced information about hydraulic properties of the root-zone materials in addition to water holding capacity and saturated water conductivity. Instead of debating which pressure heads should be used to determine air porosity, water release curves allow the end user to interpret water holding capacity and air porosity based on the root-zone depth.

A separate study was conducted to test the hypothesis of whether putting greens that vary in depth can provide water regime control. As

shown in Figure 1, when the water release curve is rotated 90 degrees, total air and water volumes, as indicated in the figures, are determined by root-zone depth – 0 being the bottom of the root zone. Contrary to the traditional air porosity report, which reflects only the average across the depth of soil core being used in the test, using the whole water release curve can provide information of air and water in the whole profile.

Figure 1. The charts below compare water and air capacity in root zones at a depth between 40 cm (A) and 20 cm (B) using the water-release curve generated from Sand I. Another way to look at these figures is to rotate them 90 degrees counter-clockwise and visualize the root-zone depth from the bottom. The total air and water capacity ratio changes as you change the root-zone depth.





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Water content and air capacity can be predicted from the water release curve using the van Genuchten equation. Graphically, the water capacity is the area to the right of the curve enclosed by the curve, axis, and soil depth line, while the air capacity is the area to the left of the curve enclosed by the curve, top line of water content and line of soil depth. In this case, the total water and air capacity is 20 percent and 10 percent, instead of 10 percent and 20 percent, respectively, for the 40-cm-deep root zone. The water content and air capacity would be 25 percent and 5 percent, instead of 17 percent and 13 percent, respectively, for the 20-cm-deep root zone.

MEASURING WATER INFILTRATION

A tension infiltrometer equipped with a differential transducer as described by Casey and Derby was used to measure water infiltration in the lab and in the field. The transducer calibration was conducted on a suction table from saturation to 350 mm, in 10-mm increments. A linear regression equation ($R^2=0.99$) was achieved between the voltage reading and the tension setting. Water tension at the bottom of the disk was monitored from the transducer by closing the water inlet briefly and then checked against the flow rate of water.

Soil samples also were packed in brass rings 10 cm in diameter and 10 cm tall to a bulk density of 1.55 g/cm^3. Water infiltration was tested on the repacked soil cores and in the field using a

Table 2

		K_{sat}			
	Testing solution	**Sand I**	**Sand II**	**Sand I: Peat (9:1)**	**Sand II: Peat (9:1)**
		cm/hr (SD)			
Wetting pressure					
Saturation at ATM	Tap water	51.3 (3.0)	38.2 (3.8)	40.4 (3.1)	26.8 (2.1)
	Deionized water	54.6 (4.6)	35.7 (5.2)	36.2 (2.8)	22.9 (5.0)
	$CaSO_4$	53.7 (3.0)	39.1 (4.0)	41.8 (3.3)	25.4 (4.2)
Saturation at vacuum	Tap water	54.6 (3.4)	46.2 (3.5)	52.0 (4.6)	35.2 (3.0)
	Deionized water	58.2 (5.1)	43.7 (4.1)	38.6 (4.4)	32.5 (3.4)
	$CaSO_4$	59.4 (2.9)	40.4 (3.7)	39.1 (3.8)	36.9 (3.2)

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time domain reflectometer (TDR)-tension infiltrometer. Materials were tested on 300, 250, 120, 60, 30, 20, 10, and 0 mm tension settings, 10 minutes for the first four settings and 5 minutes for the last four settings. The transducer was logged every second for the first 1 minute and every 2 seconds afterward. Water conductivity for 3-D infiltration in the field was calculated following a nonlinear regression method. Water conductivity of one-dimensional infiltration was calculated by the method described by Klute and Dirksen.

The tensions at the bottom of the infiltration disk were close to the set tensions except minor differences for Sand I. The discrepancy was attributed to the high flow rate at near saturation. The problem can be corrected through increasing the diameter of the connecting tube from the water reservoir to the infiltration disk and reducing friction loss of the pressure head from the valves and fittings.

With inclusion of water measuring probes, such as TDR, the water content can be measured during the same process of measuring water conductivity. The whole process can be automated to measure and estimate the major soil hydraulic properties at the same time with the same set up, reducing human error and operation time.

Tensiometers were built with the same principle as described by Ankeny, et al. Two dimensions of the infiltration disk were manufactured, 10 cm and 20 cm in diameter. The three-rod probes are 86 cm long, 0.25 cm in diameter and spaced 1.5 cm apart. The performance of TDR probe was evaluated with a TDR-100 with water and air, respectively. The wave form provided enough resolution for precise measurement of water depth, which was calculated from L minus x, where L is the TDR rod length, and x is the distance of water surface to the top of the water supplying tower.

Sand materials were prepared in a PVC tube 10 cm in diameter and 7.8 cm in length with a double layer of cheese cloth attached at the bottom with a rubber band. At the side of the PVC tube, three access holes were drilled to insert a three-rod TDR probe 5 cm long. Both TDR probes in the soil and the TDR probe in the infiltrometer were multiplexed via a SDMX50 multiplexer to a data logger.

The performance of TDR automated water level measurement was compared with differential pressure transducer automated and visual observation. Water level measurement automated with TDR is as good as, or better than, differential pressure transducer automated measurements.

Table 3

Material	K_{sat}		Air porosity	
	Measured	Estimated	Measured	Estimated
	--------cm/hr (SD)------		------% (SD)-------------	
Sand I	51.3 (3.0)	47.2 (2.6)	8.5 (0.08)	8.2 (0.10)
Sand II	38.2 (3.8)	35.4 (2.2)	12.7 (0.11)	11.4 (0.09)
Sand I : Peat (9:1)	40.4 (3.1)	37.8 (2.6)	15.1 (0.16)	13.8 (0.14)
Sand II : Peat (9:1)	26.8 (2.1)	24.1 (1.3)	18.2 (0.20)	16.9 (0.18)

Measured (traditional ASTM specified methods) and estimated (TDR-infiltrometer) saturated water conductivity and air porosity (n=10).

Water content and infiltration were measured at 10-cm water tension. Soil sorptivity for the laboratory materials was estimated using the differentiated linearization method developed by Vandervaere et al. Saturated water conductivities were calculated according to this method as well. Water release curve could be established from the tension and water content in the soil cores. Alternatively, air porosity was derived from the water content and bulk density measurement at the 30-cm tension set on the infiltrometer. Saturated water conductivity and air porosity data are shown in Table 3.

WATER RETENTION AND CONDUCTIVITY

Using the tension infiltrometer equipped with TDR for water-level monitoring, we were able to monitor water level without the need for calibration for each measurement, which is required for transducers. Water content in the sample immediately below the infiltrometer also was measured with a TDR probe at the same time infiltration was measured. Thus, the soil water retention and water conductivity can be measured simultaneously, whereas in the traditional procedures, water retention and water conductivity are measured in two separate steps.

The following points highlight the differences between the TDR-equipped infiltrometer approach and the traditional approach specified in the ASTM methods:

- The TDR-infiltrometer method uses core soil samples 10 cm in diameter – twice as big as in traditional methods. The TDR-infiltrometer method has less error introduced by marginal flow effects.
- Because water retention and water conductivity are measured simultaneously, compaction of soil samples after water retention measurements and before water conductivity measurement as in the traditional procedures is avoided, which greatly reduces variations associated with compacting.
- Measurements of the TDR-infiltrometer method are conducted in the unsaturated range of soil samples, which reduces the inconsistency of saturation that contributes to major vatiation in the water conductivity measurement.
- Wetting direction in the TDR-infiltrometer method is the same for laboratory and field samples. It also can be used to monitor water conductivity *in situ* in the field and allows direct agronomic interpretation and comparison of laboratory test results.
- Devices used in traditional methods usually are fabricated by individual laboratories, while the TDR-infiltrometer method uses a more accurate, specially manufactured instrument. The initial cost can be quickly offset by savings in labor and time.

Confidence intervals of the water holding and water conductivity test results can be reduced among and within laboratories. Soil hydraulic properties from the laboratory test can be compared with the field performance because of the consistent methodology. The TDR-infiltrometer method also can be used to collect soil water movement information to be used for subsurface irrigation control and estimation of chemical movement within soil profiles. **GCI**

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Cited literature can be found with this article online at www.golfcourseindustry.com.

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TOURNAMENT INSIDER

TURF TIPS AT THE TPC

Q While preparing for the PGA Tour's Tournament Players Championship, golf course superintendent Fred Klauk used an interesting method to light the way for his staff early in the morning so they could see where they were mowing. What lighting devices were used?

A Other host superintendents have used Department of Transportation lighting units. However, these units are heavy, noisy, fuel-powered and not moved easily, and often result in complaints from neighbors. Additionally, the light is so bright it's incredibly difficult to look into. Klauk's solution was inflatable lighting units made by Prism Lighting Services in Jacksonville, Fla. The benefits are:

- One person can raise the metal halide light as high as 15 feet in a few seconds without using a metal structure.
- The brightness is equivalent to 1,000 watts.
- A series of fans inflate and support the structures, projecting a low level light and making the system quiet.
- The structure is enlarged vertically and can be used in a narrow space.
- Support ropes and sand bags provide anchorage, which allow the device to be operated in wind gusts as fast as 25 mph.
- The system can be powered by an autonomous generator or irrigation system electronics.
- The weight and dimension make it possible for one person to operate and transport the unit with a small utility vehicle and trailer.
- The light projected is easy on the equipment operator's eyes, especially in early morning darkness.

Q The practice teeing ground during the Tournament Players Championship is huge – 550 feet by 175 feet. Yet, incoming golf course superintendent Tom Vlach installed an artificial practice surface from end to end. With a teeing ground so large, why is there a need for an artificial surface?

A At The Players Club, every detail is attended to so the competitors can concentrate on their craft completely. A perfect and spacious natural surface is essential for their practice routine. A flawless practice surface is vital for the competitors' daily routine during the Championship.

Vlach placed a strip of artificial turf within the boundaries of the regular practice teeing ground to provide a maintained, easy-to-use surface for resort guests. The material, from Turf Evolutions of Georgia, is a great alternative for play leading up to and after the event. The turf is relatively easy to install, which the company does.

> For upright growth to occur, the thickness of the mower bedknives during pretournament weeks becomes vital.

From Vlach's perspective, it's a low-maintenance material that requires no topdressing or additional servicing other than blowing off organic debris that accumulates on the surface. It's easy on the physical components of long practice sessions. For example, it's soft under foot, making it relaxing to stand for a long period of time and hit balls. It's also less stressful on the players' muscles and reduces the impact to the joints of those who practice their flaws for an extended period of time.

Members and guests say the surface has a good playing feel, similar to real grass. Vlach can let members and guests practice on the artificial turf when the existing teeing ground is too wet or dormant during the off season. The only drawback is the inability to use a longer tee.

Q With The Players Championship now held in May, were there any maintenance adjustments Klauk and his staff needed to make in their agronomic or mechanical programs to prepare the new ultradwarf playing surfaces?

A With the new Mini Verdi putting surfaces, preparations and attention to mowing details within the equipment facility increased, says Mark Sanford, equipment manager of the Tournament Players Club.

Sanford reviews the agronomic requirement for additional light sand topdressing in the months leading up to the tournament. For upright growth to occur, the thickness of the mower bedknives during pretournament weeks becomes vital. Thinner bedknives are used to reduce dragging, streaking and uneven cut lines. Entering the championship week, sand topdressing is eliminated and even thinner bedknives are used, especially when mowing below 0.1 inch.

Moisture content in the air and in the turf creates a fat and puffy leaf tissue. This swelling can alter the quality of cut daily, requiring Sanford to recheck the height of cut constantly.

Sanford ensures each putting surface is walked and checked before mowing to remove organic debris and sand. He also checks to make sure there are no coins, ball markers, long tees or items stuck in the putting surface that can damage the bedknife, reel and quality of cut.

To ensure the height of cut remains the same throughout the morning and afternoon, all transport vehicles and trailers remain on the smooth and even cart paths. Having the vehicles remain on a smooth surface eliminates the mowing unit from bouncing up and down on the trailer and upsetting the height of cut, prevents damage to the unit in any way and reduces gas from being spilled or overflowing from the tank. Sanford suggests using a dipstick when filling equipment with gas to measure tank depth to ensure the fuel level is set 1 inch below the tank cap level. This reduces spills onto the turf. **GCI**

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Travels With Terry

Globetrotting consulting agronomist Terry Buchen visits many golf courses annually with his digital camera in hand. He will share 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.

Ramp it up

A Salsco greens roller comes standard equipped with a transport trailer, which also can be used to transport walk-behind greensmowers. Scott Kroll, golf course superintendent, and Brian Gunning, assistant superintendent, at the Sunnybrook Golf Club in Plymouth Meeting, Pa., modified the transport trailer to haul walk-behind mowers.

The wire-mesh trailer floor and ramp were covered with 3/4-inch-thick, construction-grade plywood sheets held in place with four 5/8-inch-diameter carriage bolts, flat and lock washers, and nuts. On either side of the ramp, notches were cut into the plywood so the ramp could be closed completely and latched vertically.

Before the plywood floors were installed, the 1/4-inch-thick rubber strips, which provide additional traction for the greens roller when entering and exiting the trailer, were removed. Eighteen-inch-long-by-6-inch-wide 1/4-inch-thick rubber strips were installed to act as a bumper by softening the impact of the walk-behind mowers front rollers against the trailer safety railing. The rubber strips were screwed into railing supports with two 3/16-inch-diameter hex-head screws and 3/4-inch-diameter flat washers.

The 4-foot-by-8-foot sheets of plywood cost about $20 from Lowe's, the mounting hardware cost about $10, and the labor time took about an hour and a half.

Mix it up

What started out as a 1,600-gallon fertigation system tank was converted to a premix tank for chemicals and granular fertilizers. To customize the premixing operation, Eric D. Spurlock, Manakin Course superintendent, and John Haley, director of golf course operations at the Hermitage Country Club in Manakin-Sabot, Va., installed a separate stand-alone Banjo inductor manifold system with a 15-gallon storage tank.

Granular fertilizers, such as ammonium sulfate, are added through the 15-gallon inductor tank. Then, valves are opened and closed on the manifold, and the inductor acts as a toilet bowl that sucks the products through and breaks them down in the process, adding them into the 1,600-gallon storage tank. About 375 pounds of ammonium sulfate are mixed into about 600 gallons of water, which takes about 20 minutes. One control valve agitates the mixture, and another keeps the flow from being restricted into the large tank when it's in use. The agitator is used constantly as the sprayer applies chemicals or fertilizers to keep them in suspension.

The storage tank was on hand already. The 5-horsepower, 220-volt motor and 2-inch-diameter, centrifugal flooded-suction pump were slightly used. The hose, fittings and agitator assembly were purchased new and cost about $1,500. The inductor manifold system cost $375. The 15-gallon inductor tank, stand, wye strainer and fittings cost $250.

An electrical contractor hooked it all up in about two and half to three hours. **GCI**