Part 1 of 2

See January's TurfGrass Trends for results in Part 2.

Computer Simulation Tracks Water Flow in Greens

By Ed McCoy and Kevin McCoy

Putting green soil profiles are frequently classified into three general categories: USGA (United States Golf Association), California and push-up greens. The USGA and California profiles are purposely constructed with each documented by written guidelines (USGA Green Section Staff, 1993; Davis et al., 1990). Push-up green soil profiles, on the other hand, have evolved from decades of sand topdressing applied to native soil. Whereas each has a sandy surface layer, or root zone, the thickness of this layer and the type of material underlying the sandy root zone varies for each particular category.

Measurement of water flow is often accomplished by frequent monitoring soil water content using probes that are placed in the soil profile. These studies document how layered soils increase water retention within a sandy root zone by the formation of perched water, the propensity of this water to migrate down slope creating lateral non-uniform water contents, and how organic and soil amendments to the root zone appear to modulate this response.

But experimental studies of water flow in greens have limitations due to the high cost of construction, maintenance, instrumentation and monitoring. Consequently, these studies have employed less than full-size greens with relatively few sensors that capture data over widely spaced time intervals and/or for a limited duration.

Computer simulation of water flow in soil can remove many of these experimental limitations. A simulation can be built to represent a full-size putting green and capture flow events throughout the soil profile. Also, a simulation allows us to challenge the system under climactic scenarios that rarely occur in a specific location.

Because simulations do not generate random errors, they need not be replicated. Yet the quality of a simulation output is solely reliant on the quality of the parameters used to describe the system, so much care must be taken in specifying these parameter values.

We chose the software package HYDRUS-2D (Simunek et al., 1999), which has been employed for a variety of applications including irrigation and drainage design, study of irrigated land salinization, transport of pesticides and toxic trace elements and analyses of riparian systems. We sought to construct simulations for mature, full-size greens having natural surface contours, built according to published guidelines, and supporting a closely mown turfgrass stand. Rainfall and evapotranspiration scenarios were selected to challenge the hydrologic response of these three putting greens.

Simulations were designed to describe water flow through a two-dimensional slice through the center of a typical putting green. To accomplish this, we enlisted the help of Jason Straka, a senior design associate with Hurdzan/Fry Design, who provided putting green surface elevation data along a 100-foot transect. The respective soil profiles corresponding to a USGA green, a California green and a push-up green were subsequently created below this surface. In each case, the putting surface consists of a 10-foot false front at 5-percent slope; a 30-foot lower landing area at 1.5 percent slope; a 6-foot terrace face at 15 percent slope; a 41-foot upper landing area at

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TABLE 1

Total porosity, air-filled porosity, capillary porosity and saturated-hydraulic conductivity values of the organic enriched and lower root zone layers of the simulated putting greens.

Green Style	Layer	Total Porosity (%)	Air-Filled † Porosity (%)	Capillary † Porosity (%)	Ksat (in h-1)
USGA	Organic Enriched ‡	46	20	26	6
	Lower Root Zone	40	24	16	20
California	Organic Enriched	45	22	23	12
	Lower Root Zone	39	27	11	40
Push-up	Organic Enriched	46	12	34	4
	Lower Root Zone	42	14	28	8

† Air-filled and capillary porosities are defined at 30 centimeter tension. ‡ The organic enriched layer is the surface 2 inches of the soil profile.

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1.5 percent slope and a 13-foot section falling away off the back of the green at 1 percent slope. Smooth curve transitions also occurred between each of these surfaces and the total elevation change across the green was 2.5 feet.

The USGA green soil profile consisted of a 12-inch thick root zone overlying a 4-inch-thick gravel layer placed upon an 8-inch-thick clay-loam subgrade soil. Gravel-filled drainage trenches (6-inches wide by 8-inches deep) were placed in the subgrade and spaced at 15 feet apart. To represent the influence of turf rooting and organic matter accumulation within the surface layer of the root zone (Carrow, 2003), this 12-inch layer was further subdivided into two surfaces, a 2-inch-thick organic enriched layer and a 10-inch-thick lower root zone layer.

The California green soil profile consisted of a 12-inch-thick root zone overlying an 8-inch-thick clay-loam subgrade soil. Gravel-filled drainage trenches (6-inches wide by 8-inches deep) were placed in the subgrade and spaced at 15 feet apart. Although maximum drain spacing is not specified for a California green, we chose this drainage system configuration to be consistent with the USGA green scenario. Also, consistent with the USGA green, the 12-inch root zone was subdivided into a surface with 2-inch-thick organic enriched layer and a 10-inch-thick lower root zone layer.

The push-up green soil profile consisted of a 4-inch-thick root zone overlying a 16-inch-thick clay-loam soil. For consistency with the other green designs, 6-inch-wide by 8-inch-deep gravel filled drainage trenches were spaced at 15 feet apart across the green with the upper surface of the drainage trench placed 10 inches below the surface of the green. As with the other scenarios, the 4-inch root zone was subdivided into a surface with 2-inch-thick organic enriched layer and a 2-inch-thick lower root zone layer.

In addition to soil layer thickness and orientation, the water flow simulation requires information on the water-retention curve and the saturated hydraulic conductivity.

Our aim was to generate hydraulic properties that corresponded to a root zone having sand particle sizes on the coarse side of the acceptable range. We did this for the lower root zone layer of the USGA and California greens by generating hydraulic properties of a construction root zone mix since the lower root zone layer of a mature green is expected to have hydraulic properties similar to the root zone mix of a newly built green. The organic-enriched layer for each green was intended to contain about 6 percent organic matter by weight. Thus, the construction root zone mix properties for each green were adjusted as to appropriately reflect this organic enrichment. Finally, in order to supply the most realistic information to the simulation, we generated candidate hydraulic properties from in-house data and then provided this information to Dr. Norm Hummel (Hummel & Co.) and Mr. James Thomas (Thomas Turf Services) for a critical review. Following their review, we adjusted the hydraulic properties of both the organic-enriched and lower root zone layers as appropriate.

Our approach to generating hydraulic properties of the push-up was more subjective because there are no published descriptions of the most prevalent root zone characteristics.

The hydraulic properties of the root zone layers for the USGA, California and push-up greens are given in Table 1 (p. 44). The USGA green root zone had hydraulic properties characteristic of minimally amended and fairly uniform medium-coarse sand. This is indicated by small total and capillary porosity values and large Ksat (saturated hydraulic conductivity, a measure of soil's capacity to transmit water, or permeability).

The California green root zone had hydraulic properties characteristic of unamended and uniform medium sand with greater Ksat and air-filled porosity values and smaller total and capillary porosity values than the USGA root zone. The push-up green root zone had hydraulic properties as would be expected from years of consistent and frequent topdressing using quality topdressing sand. In all cases, organic enrichment resulted in an increase in total and capillary porosity values and a reduction in air-filled porosity and Ksat values. Finally, the clay-loam subgrade had a Ksat value of 0.02 inches per hour and the gravel had a Ksat value of 4,700 inches per hour characteristic of these respective materials.

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The simulation scenario

The simulation runs for 168 hours, beginning at 12 a.m. and continuing for seven days. Initially (at hour zero), the soil profile is moist with equilibrium water contents corresponding to the presence of a water table 0.5 inches below the drainage trenches.

At hour one (1 a.m. of the first day) rainfall occurs across the USGA and California greens at a precipitation rate of 1.0 inch per hour and continuing for four hours (ending at 5 a.m.). This high intensity rainfall delivering 4 inches of rain was selected to challenge the infiltration and drainage capabilities of each green. Because the push-up green was incapable of infiltrating 4 inches of rain, the precipitation rate for this scenario was adjusted down to 0.25 inch per hour yielding a 1 inch total rainfall.

A diurnal evapotranspiration (ET) cycle was imposed on these greens and consisted of an atmospheric demand of 0.014 inch per hour between the hours of 8 a.m. and 8 p.m. with no water uptake during the intervening hours. This hourly ET rate over a 12-hour daylight period yielded a daily atmospheric demand (referred to as ETcrop) of 0.17 inches of water. Our choice of this value was based on the work of McCoy and McCoy (2005) wherein daily ETcrop values corresponding to putting green turf were generated for a 20-year period at each of six locations throughout the United States.

Examining the distribution of the April-September daily ETcrop values from this previous study indicated that our selected rate of 0.17 inch per day was about one standard deviation greater than the mean for Phoenix; two standard deviations greater than the mean for Boulder, Colo.; and three standard deviations greater than the mean for Columbus, Ohio. So our selected ETcrop value represents a moderately above-average drying event for Phoenix, and somewhat extreme drying event for Boulder and a severely extreme drying event for Columbus. This was consistent with our goal to challenge the water retention properties of the simulated greens.

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ACKNOWLEDGEMENTS
This research was supported by funds received from the USGA and the Ohio Turfgrass Foundation.

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