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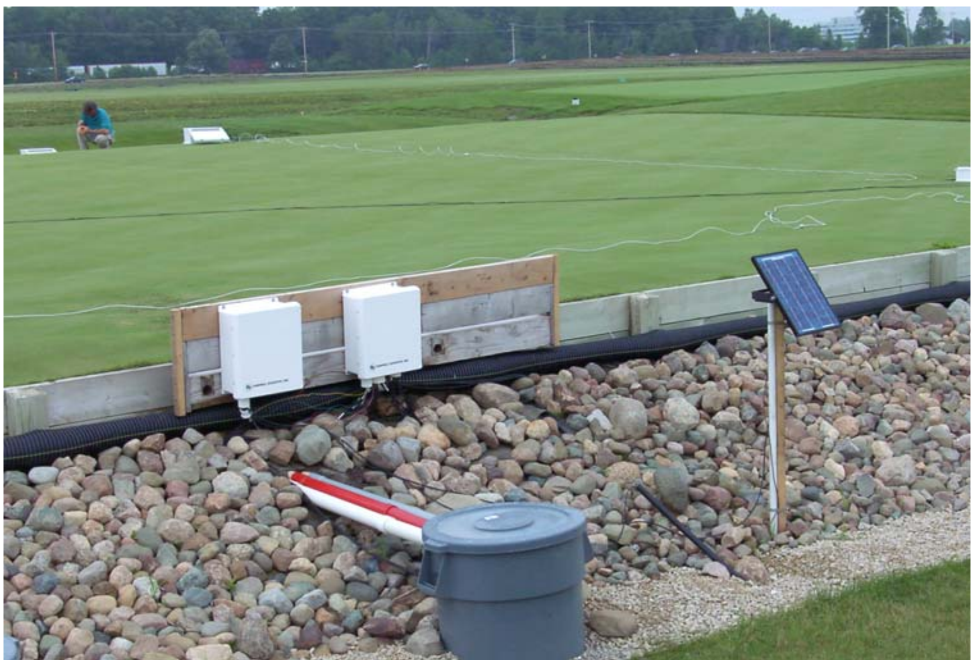

Researchers at Michigan State University investigated the hypothesis that reducing rootzone depth in higher-elevation areas and increasing depth of the rootzone in lower-elevation areas of contoured putting greens may result in more even moisture distribution across the entire putting green. Their findings support this hypothesis and may help reduce moisture-related management challenges that inflict putting greens with significant slope.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Effect of Rootzone Material and Depth on Moisture Retention in Undulating USGA Putting Greens

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SUMMARY

Research was undertaken at Michigan State University to determine if altering the rootzone depth of a USGA green, decreasing it in high areas and increasing it in low areas, increases soil moisture uniformity across the slope of an undulating green. The research found:

- Modifying the depth of the sand rootzone mix greens improved soil moisture uniformity across the slope of an undulating green.
- When soil or peat was added to the sand rootzone mix, extremes in soil moisture content between the high and low elevations of the green were reduced regardless of construction type (modified or standard USGA).
- This research emphasizes the importance of closely monitoring construction activities to ensure that, at a minimum, the rootzone is a uniform 12-inch depth from low to high areas.

The United States Golf Association (USGA) introduced guidelines for constructing putting greens over thirty years ago and since then the USGA green has become the standard for golf course putting greens. The concept behind the USGA recommendations for putting green construction is to build a green that provides a measure of resistance to compaction in the rootzone and drains quickly to an optimum soil moisture level (5). Specifications for a USGA putting green require that the sandy rootzone mixture be placed at a uniform depth of 12 inches, plus or minus one inch, across the entire surface of the green. If greens lacked slopes there is little doubt that most, if not all, USGA greens would perform well. However, with the slopes present on putting greens today, USGA greens do not always perform ideally.

Putting greens constructed to USGA specifications function very well on a level surface (4); however, when the green has undulating areas, moisture extremes in the rootzone can lead to turfgrass decline (3). Two conditions associated with moisture extremes in the rootzone are localized dry spot (LDS) and black layer. Both impair turfgrass growth and can be problematic on undulating USGA putting greens.

Moisture extreme problems on USGA putting greens could be attributed to the uniform depth of the rootzone layer. In theory, on a level surface, there is minimal lateral flow of water within the rootzone and the putting green drains at a uniform rate. However, Nektarios et al. (2) have shown that drainage in the rootzone is not always uniform. In an unstaturated putting green root-

The research objective at Michigan State was to determine if modifying the rootzone depth increases soil moisture uniformity across the slope of an undulating USGA putting green.

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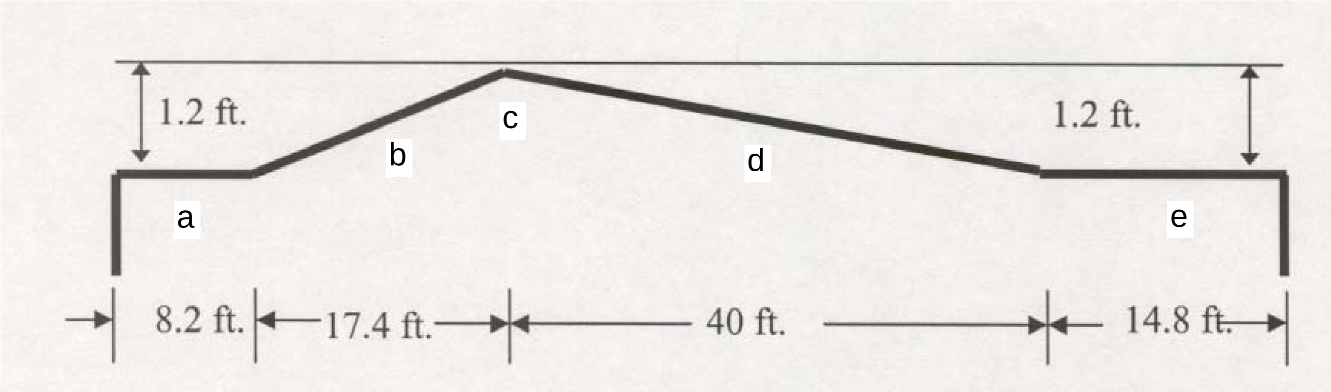

Figure 1. Cross sectional view, and dimensions of putting surface: (a) north toe slope, (b) 7% north slope, (c) summit, (d) 3% south slope, and (e) south toe slope.

zone, water does not drain from the rootzone into the gravel layer, thereby allowing water to move laterally along the rootzone/gravel layer interface to lower elevations in the green. The resultant problems associated with this down-slope water movement are particularly evident at the higher elevations of the green where hand syringing is often necessary to prevent turf loss.

Research was initiated to investigate if altering the rootzone depth, decreasing it in high areas and increasing it in low areas, will increase the water content near the soil surface in high areas and decrease the water content near the soil surface in low areas. Our research objective was to determine if modifying the rootzone depth increases soil moisture uniformity across the slope of an undulating USGA putting green.

Materials and Methods

A sloped USGA putting green was constructed at the Hancock Turfgrass Research Center on the campus of Michigan State University in 1998. The putting green was designed for monitoring the down-slope movement of water in the rootzone. Time domain reflectometry (TDR) instrumentation was installed in the green to monitor soil volumetric water content (VWC).

The putting green was constructed with a summit 1.2 ft. in height, with two downhill slopes of different magnitude (Figure 1). The peak of the summit was constructed 26 ft. from the northern edge of the green, and 55 ft. from the southern edge. North of the summit, the putting green has a seven percent slope (north slope) to the level north toe slope. South of the summit, the putting green has a gradual three percent slope (south slope) to the level south toe slope. These slope gradients were chosen to represent average and extreme slopes that occur on modern USGA recommendation putting greens.

The putting green was divided into 12 plots, 8 ft. wide and 80 ft. long. Six test plots were built to standard USGA specifications consisting of a uniform depth rootzone (12 inches). The remaining six test plots were built with variable depth rootzone: 8 in. at the summit and gradually increasing in depth to 16 in. at the toe slopes (Figure 2). Three rootzone mixes were used in the construction of the test plots: four plots of each construction method (standard or modified USGA) were built with a sand rootzone, four plots were built with an 85:15 sand/peat (reed-sedge) rootzone, and four plots were constructed with an 85:15 sand/soil rootzone. A polyvinyl chloride liner was placed between adjacent plots to prevent the lateral movement of water between plots.

Prior to construction, rootzone materials were tested for particle size distribution, organic content, and soil physical properties following USGA guidelines (1). The sand/peat rootzone mix conformed to USGA specifications, but the sand/soil and sand rootzone mixes did not conform (Table 1). The sand/soil rootzone did not

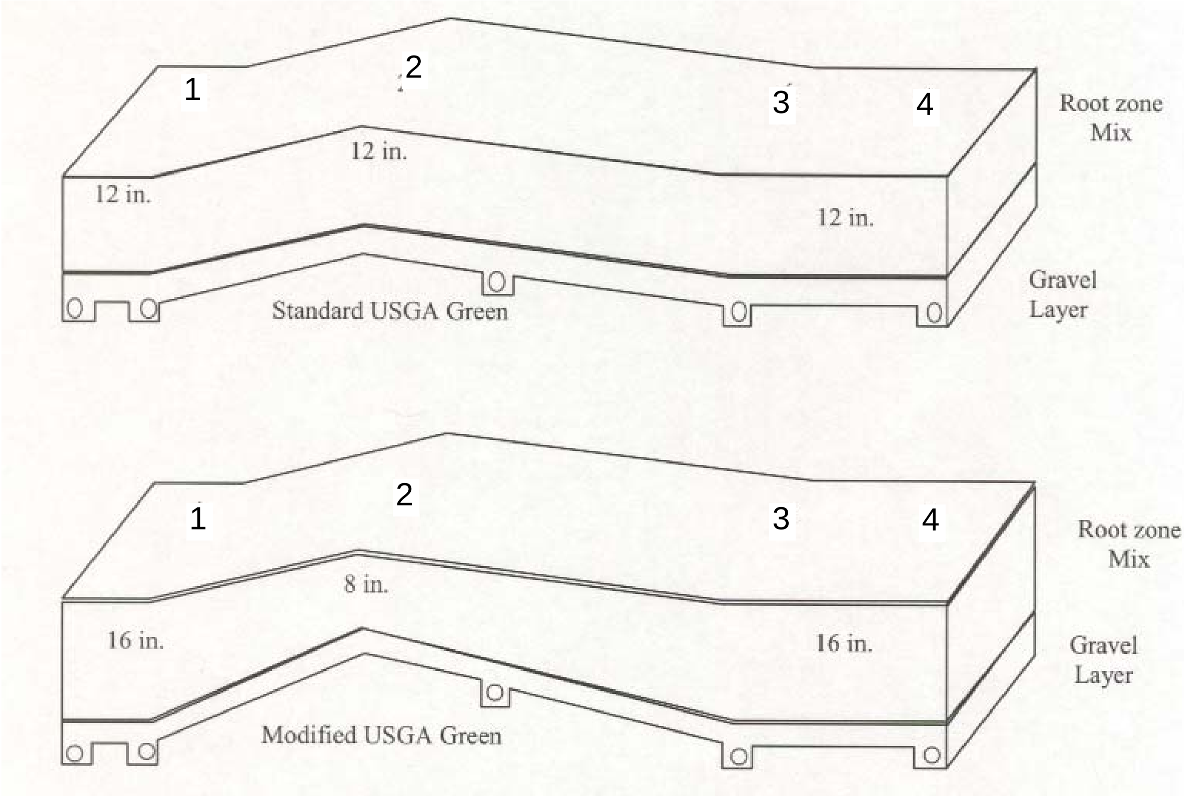

Figure 2. Cross sectional three-dimensional view of standard and modified construction types with TDR probe locations: (1) Location 1, (2) Location 2, (3) Location 3, and (4) Location 4.

conform to specifications because of particle size distribution. The sand rootzone mix did not conform to the USGA specifications for hydraulic conductivity and percent capillarity.

After the construction of the putting green was completed, 108 TDR probes (locally manufactured by B.R. Leinauer) were buried in the soil to measure volumetric soil moisture at four locations within each test plot: probe location 1 at the base of the north slope, probe location 2 at the summit, probe location 3 at the base of the south slope, and probe location 4 in the middle of the south toe slope (Figure 2). The TDR probes were positioned in the soil at a 45-degree angle to measure VWC at depths of 4-8, 8-12, and 12-16 in. A hand-held TDR was used to record VWC at the four locations of the surface (0-4 in.).

After installation of the TDR probes in the summer of 1998, the putting green was seeded with creeping bentgrass (*Agrostis stolonifera* sp. *palustris* ‘L-93’). To evaluate soil moisture relationships, the putting green was subjected to "dry-down" cycles, four cycles in each year from 2000 through 2002. Dry-down cycles were scheduled during dry periods without rainfall, and no irrigation was applied to the putting green. During each cycle, VWC was monitored daily with the TDR probes at the four locations in each plot. VWC was recorded at each location at depths of 0-4 in. and 4-8 in. At the locations where depths were present, VWC was recorded at 8-12 and 12-16 in. depths.

Each dry down cycle began with uniform, healthy turf across the entire putting surface. To establish near field capacity soil moisture content, irrigation (1 inch) was applied the night before each cycle, and the morning of "day 0" (0.5 inch). After the morning irrigation, TDR readings were taken at the four locations on each individual plot. The TDR readings were taken at 24-hour intervals for the length of the cycle. Each dry down cycle was ended after either 3 or 4 days at which time there were visible signs of severe turfgrass moisture stress on the sand rootzone plots at the peak

	USGA Recommendation*	Rootzone Mix: Sand	Sand/Peat	Sand/Soil
Physical Properties				
Organic Matter (%)	1-5	1.2	3.2	2.0
Hydraulic Conductivity (cm hr^{-1})	Minimum 15	86.2	27.9	15.7
Bulk Density (g cm^{-3})	N/A	1.75	1.57	1.74
Particle Density (g cm^{-3})	N/A	2.64	2.35	2.66
Porosity:				
Total (%)	35-55	35.2	42.8	36.0
Capillary at 40 cm tension (%)	15-25	8.9	16.7	15.8
Air-filled at 40 cm tension (%)	15-30	27.3	26.1	20.2
Particle Size (mm)		----------------%------------------		
2.0 - 3.4†	Maximum 10	0.1	0.1	0.8
1.0 - 2.0		7.6	7.3	12.0
0.5 - 1.0	Minimum 60	26.0	25.4	24.6
0.25 - 0.50		45.4	46.6	36.8
0.15 - 0.25	Maximum 20	19.1	18.3	16.6
0.05 - 0.15‡	Maximum 5	0.6	1.1	1.3
0.002 - 0.05‡	Maximum 5	1.2	1.2	7.9
< 0.002‡	Maximum 3			

*The USGA Green Section Staff, 2004

† Maximum of 3%, preferably none.

‡ Maximum of 10% total between the three categories.

Table 1. Rootzone mix physical properties and particle size distribution.

of the summit.

Statistical analysis was conducted independently for each day and for the measurement depths 0-4 and 4-8 in., as these were the only depths present at each location within each test plot. Coefficient of variation (CV) was calculated for VWC data in each plot and analyzed for treatment differences. The CV is a relative measure of variation in the data. CVs were used to assess the variability of VWC across the slope of the putting green.

Results

Differences in Rootzone Type

VWC for rootzone type, when averaged across the two construction types, was significantly different throughout the dry down cycles in 2000 and 2002. For the 0-4 in. depth, for the majority of sampling days there were no differences in VWC among the sand/soil and sand/peat rootzones (Table 2). The sand rootzone consis-

0-4 in. depth	Sand	Sand/Soil	Sand/Peat
	--------------------------------	%	-------------------------------
Aug. 23, 2000	15 B†	25 A	27 A
Aug. 24, 2000	14 C	21 B	24 A
Aug. 25, 2000	13 C	18 B	23 A
Aug. 26, 2000	12 C	18 B	23 A
July 23, 2002	18 C	25 A	27 A
July 24, 2002	17 B	23 A	27 A
July 25, 2002	14 B	20 A	21 A
July 26, 2002	12 B	18 A	21 A
Sept. 28, 2002	20 B	27 A	29 A
Sept. 29, 2002	16 B	22 A	25 A
Sept. 30, 2002	18 B	24 A	25 A
Oct. 1, 2002	13 C	21 B	24 A
4-8 in. depth			
July 10, 2002	17 B	20 A	22 A
July 11, 2002	15 B	19 A	20 A
July 12, 2002	14 B	18 A	20 A
Sept. 28, 2002	18‡	20	31
Sept. 29, 2002	15 B	19 AB	22 A
Sept. 30, 2002	16	19	21
Oct. 1, 2002	15 B	17 AB	21 A

† Means in a row followed by the same letter are not significantly different according to t-test (p=0.05).
‡ Data not followed by letters are not significantly different.

Table 2. Mean percent volumetric water content for different rootzone types.

tently had the lowest VWC. For the 4-8 inch depth, the results were similar. There were no differences among VWC for the sand/soil and sand/peat rootzones, and the sand rootzone had the lowest VWC. The results indicate that regardless of construction type, the water holding capacity of the rootzone mixes containing soil or peat is higher than the sand rootzone. Sand rootzones with peat or soil added should reduce the extremes in VWC that are often encountered in 100% sand rootzones.

Among the standard USGA greens, the sand rootzone had the highest CV, indicating that the sand rootzone green had the greatest variation in VWC across the slope of the green (Table 3). Generally, for the USGA greens, there were either no differences in CV among the sand/soil and sand/peat rootzones, or the sand/peat rootzone had the lowest CV. For the modified USGA greens, there were either no differences in CV among the rootzones or the sand rootzone had the highest CV.

	Const. Type	Sand	Sand/Soil	Sand/Peat
		---------------Coefficient of Variation---------------		
2000				
Aug. 23: Day 0	Standard	31	12	9
	Modified	12	11	9
Aug. 24: Day 1	Standard	44 A†a‡	15 Ba	20 Ba
	Modified	20 Ab	18 Aa	16 Aa
Aug. 25: Day 2	Standard	38	16	13
	Modified	29	16	25
Aug. 26: Day 3	Standard	43 Aa	19 Ba	16 Ba
	Modified	11 Ab	17 Aa	15 Aa
2002				
July 23: Day 0	Standard	24 Aa	24 Aa	8 Ba
	Modified	14 Aa	10 Ab	14 Aa
July 24: Day 1	Standard	30	21	10
	Modified	10	12	12
July 25: Day 2	Standard	45 Aa	35 Ba	15 Ca
	Modified	32 Ab	19 Bb	19 Ba
July 26: Day 3	Standard	42 Aa	32 Ba	22 Ca
	Modified	22 Ab	13 Bb	16 ABa

† Means in a row followed by the same upper case letter are not significantly different according to t-test (p=0.10).
‡ Means in a column, for each date, followed by the same lower case letter are not significantly different according to t-test (p=0.10).
Data not followed by letters are not significantly different.

Table 3. Coefficients of variation (CV) for volumetric water content for construction and rootzone type, 0-4 inch rootzone depth.

Differences in Construction Type

Comparisons between the two construction types reveal that the standard USGA sand greens had a higher CV than the modified USGA sand greens on almost all dates (Table 3). For the sand/soil greens, there were no differences between the construction types in 2000, but in 2002, the modified USGA greens had a lower CV on 3 of 4 dates. The sand/peat rootzones did not have a different CV regardless of construction type. The CV data supports our hypothesis that

Day 0	Location 1	2	3	4
USGA Sand	21	15	21	20
USGA Sand/Peat	30	26	28	27
USGA Sand/Soil	29	23	27	25
Modified Sand	16	17	18	17
Modified Sand/Peat	26	28	24	24
Modified Sand/Soil	24	26	22	22
Day 3				
USGA Sand	17	7	18	18
USGA Sand/Peat	27	20	26	25
USGA Sand/Soil	27	16	24	21
Modified Sand	11	11	12	11
Modified Sand/Peat	21	22	18	19
Modified Sand/Soil	18	19	16	15

Table 4. Mean percent volumetric water content for the 0-4 inch depth, 2000-2002.

by altering the rootzone depth, the variability in VWC across the slope of the green, especially for the sand rootzone greens, can be greatly reduced.

Mean VWC: Construction Type and Soil Type

Mean VWCs for all dry-downs and years are presented in Table 4 and explains the differences in CV for construction and soil types. The consistency of VWC data for the modified USGA greens for all rootzone mixes is clear. On day zero, the greatest difference in VWC among sampling locations for all rootzone mixes within the modified USGA greens was 4%. On day three, the greatest difference among sampling locations was still 4%.

Differences in VWC among locations remained consistent as the green dried down. In contrast, for the USGA greens, the greatest difference in VWC among locations on day zero was 6% and for day three was 11%. The differences between the standard and modified USGA construction types on day zero was small (2%), but by day 3 was large (7%). This data further supports our conclusions that for the modified USGA greens the VWC was more uniform across the slope of the green.

Also, the difference in VWC among the sampling locations explains the high CV of the standard USGA greens. For the standard USGA sand greens on day 3, the range in VWC was a low of 7% at location 2 (summit of slope) and a high of 18% at location 3 and 4 (base of south slope and south toe slope) (Figure 3). In contrast for the modified USGA sand greens, there was only a 1% difference in VWC among the locations.

Conclusions

The USGA specifications for putting green construction, first published in 1960, were designed to improve the quality of putting greens. Although the USGA has published several revi-

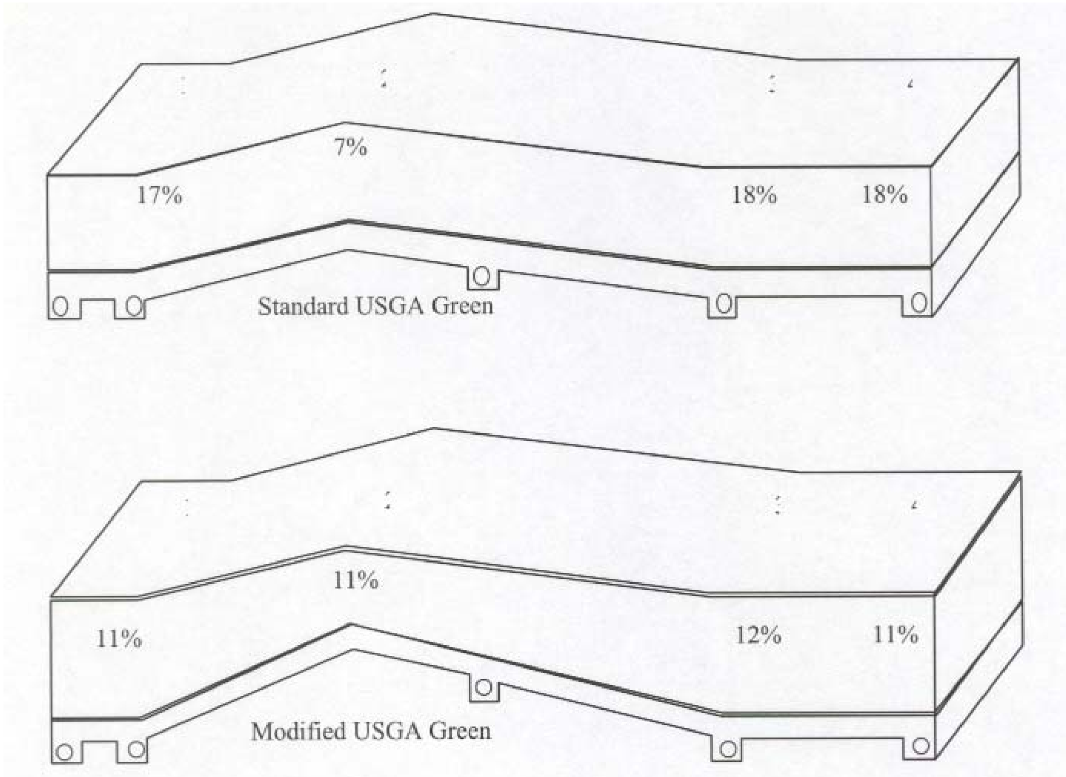

Figure 3. Mean percent volumetric water content for the 0 - 4 inch depth rootzone for the standard and modified USGA sand rootzone on day 3 of the dry downs, 2000 - 2002.

sions, most recently in 2004, the recommendation for a uniform 12-inch rootzone layer has remained unchanged. The layering of a sand-based rootzone mix over a gravel layer maintains optimum moisture across the putting green on a level-putting surface, however, in areas of undulation the uniform rootzone depth can result in moisture extremes at the different elevations.

Our research confirmed that the addition of peat and/or soil to the rootzone mix increased water holding capacity. Modifying the depth of the sand rootzone mix greens improved the uniformity of VWC across the surface of an undulating putting green. When soil or peat was added to the sand rootzone mix, extremes in soil moisture content between the high and low elevations of the green were reduced regardless of construction type. For greens constructed with a 100% sand rootzone, it would be beneficial to modify the depth of the rootzone to maintain uniform soil moisture content across the surface of the putting green. The uniformity of soil moisture content within the modified USGA greens was due to the variable-depth rootzone.

Even if greens are not constructed with a variable depth rootzone, this research reveals the importance of closely following rootzone depth specifications during construction. Special attention should be given to following rootzone depth specifications during construction and not making alterations based on aesthetics. In certain situations, rootzone material might be excavated from lower areas and moved to other regions of the green to increase elevation changes. The result is that the green would have a shallower rootzone depth in low areas and rootzone depths in excess of 12 inches in higher areas. This research emphasizes the importance of closely monitoring construction activities to ensure that, at a minimum, the rootzone is a uniform 12-inch depth from low to high areas.

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Literature Cited

1. Hummel, N.W. 1993. Laboratory methods for evaluation of putting green rootzone mixes. *USGA Green Section Record* 31(2):23-33. (TGIF Record 27303)

2. Nektarios, P.A., T.S. Steenhuis, A.M. Petrovic and J.-Y. Parlange. 1999. Fingered flow in laboratory golf putting greens. *J. of Turf. Mgt.* 3(1):53-67. (TGIF Record 64379)

3. Prettyman, G., and E. McCoy. 1999. Subsurface drainage of modern putting greens. *USGA Green Section Record* 37(4):12-15. (TGIF Record 82697)

4. Taylor, D. H., S. D. Nelson, and C. F. Williams. 1993. Sub-root layering effects on water retention in sports turf soil profiles. *Agron. J.* 85:626-630. (TGIF Record 27946)

5. U.S. Golf Association Green Section Staff. 2004. USGA Recommendations for a Method of Putting Green Construction. USGA World Wide Web Site. http://www.usga.org/turf/course_construction/green_articles/putting_green_guidelines.html. (TGIF Record 94463)