Converting Reference Evapotranspiration into Turf Water Use

INTRODUCTION

Accurate estimates of turf water use are required to effectively manage a turf irrigation system. In Volume I of this series entitled "Basics of Evaporation and Evapotranspiration (ET)," we indicated that actual turf water use (ET_T) is rarely measured in the real world. Instead, we use meteorological data and mathematical models known as the Penman or Penman-Monteith Equation to estimate reference evapotranspiration (ET_o) — the ET from a tall, cool-season grass that is supplied with adequate water. In the lower elevations of Arizona the ET_o value would seem of limited value since we rarely grow turf that is equivalent to the reference surface. However, we get around this problem by adjusting the ET_o value to account for differences in turf type, turf quality and stage of development. This document describes the procedures used to adjust ET_o for use on managed turf surfaces in Arizona.

ESTIMATING TURF ET FROM ET_o

An adjustment is necessary to convert ET_o values to estimates of turf ET (ET_T; Fig. 1). The adjustment process is actually quite easy and consists of multiplying ET_o by an adjustment factor known as a crop coefficient (K_c):

$$ET_T = K_c \text{ x } ET_o$$

The procedure can be completed in seconds with a hand calculator provided you have access to an ET_o value and an appropriate K_c value for your turfgrass.

Reference ET values can be obtained from a private, on-site weather station or public weather networks such as the Arizona Meteorological Network (AZMET) which provides daily ET_o values for 23 southern Arizona locations via the Internet at http://ag.arizona.edu/azmet. Given that information on ET_o is readily available, the problem of estimating ET_T boils down to one of selecting an appropriate K_c value for your turf.

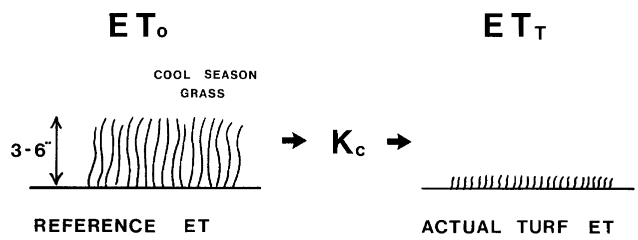

Figure 1. Reference Evapotranspiration (ET_o) must be adjusted with a crop coefficient (K_c) to estimate turf ET (ET_T).

CROP COEFFICIENTS (K_c)

A variety of factors impact the K_c value for turf. Among the most important are type of turf (cool vs. warm season grasses); turf quality; stage of turf development; and to a lesser degree, turf height. As a general rule, K_cs are higher for cool season grasses than for warm season grasses, and increase with turf quality and turf height. Stage of turf development refers mainly to time of the season. For example, water use of bermudagrass is lower (relative to ET_o) during the spring and fall transition seasons than during mid-season. Specific details on K_c selection are provided below.

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Crop Coefficients For Warm Season Grasses

The appropriate mid-season K_c for bermudagrass turf maintained at a mowing height of 5/8 – 1" (1.6–2.5 cm) rests somewhere in the range of 0.6–0.8 (Fig. 2). The low end of the range would be appropriate for areas where traffic is low, rapid regrowth is not required and fertilization levels are low. The upper end of the K_c range would be appropriate for areas of high quality turf where fertilization regimes are high and rapid regrowth is required (e.g. high profile sports turf). Research studies indicate the Kc range recommended in Fig. 2 should be applicable to other warm season grasses, including Zoysia and St. Augustine grass (Kneebone and Pepper, 1982).

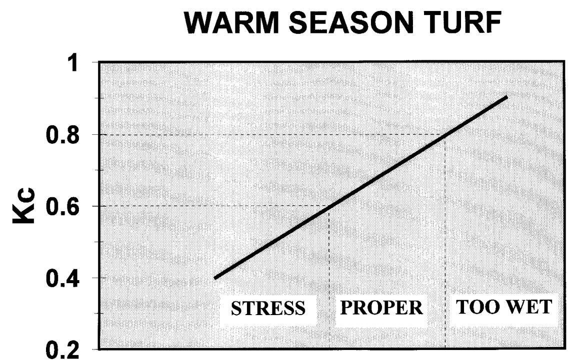

Figure 2. The appropriate K_c range for warm season grass is 0.6-0.8. Use of a K_c below 0.6 will likely produce water stress; use of K_cs above 0.8 will likely produce wet and/or muddy conditions.

Table 1. Monthly crop coefficients (K_cs) appropriate for use with ET_o computed by public weather networks of Arizona (AZMET), California (CIMIS), Nevada (ET-Feedback) and New Mexico; and for weather stations/networks using the Penman Monteith Equation. The turf surface from November through May is 'Froghair' intermediate ryegrass. 'Tifway' bermudagrass serves as the summer turf surface. No K_cs are provided during the period of overseed establishment (October). Mean seasonal K_cs are provided in the rows labeled Winter and Summer. Turf was irrigated daily except on days with significant rainfall, and a maintenance regime was employed to maintain fairway quality turf. Reduce K_cs by 0.1 for thin turf stands and areas receiving less intense management.

Month	AZMET	California	New Mexico	Nevada	Penman-Monteith
Jan	0.68	0.86	0.49	0.62	0.78
Feb	0.70	0.82	0.55	0.66	0.79
Mar	0.73	0.83	0.61	0.73	0.86
Apr	0.77	0.86	0.66	0.75	0.89
May	0.76	0.83	0.65	0.72	0.85
Jun	0.72	0.81	0.62	0.64	0.78
Jul	0.78	0.89	0.66	0.69	0.78
Aug	0.83	0.92	0.70	0.74	0.82
Sep	0.77	0.87	0.64	0.72	0.83
Nov	0.76	0.95	0.54	0.67	0.83
Dec	0.70	0.90	0.48	0.62	0.80
Winter	0.73	0.86	0.57	0.68	0.83
Summer	0.78	0.87	0.65	0.70	0.80

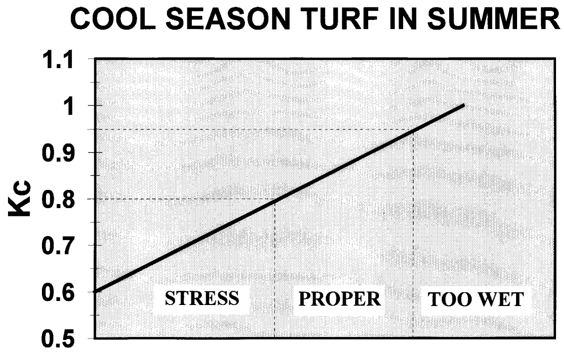

Figure 3. The K_c range for cool season grasses (e.g. fescue) during summer is 0.80-0.95. Use higher K_cs for high quality turf and turfs with less heat tolerance. Lower K_cs suffice for lower quality turf or for more heat tolerant varieties.

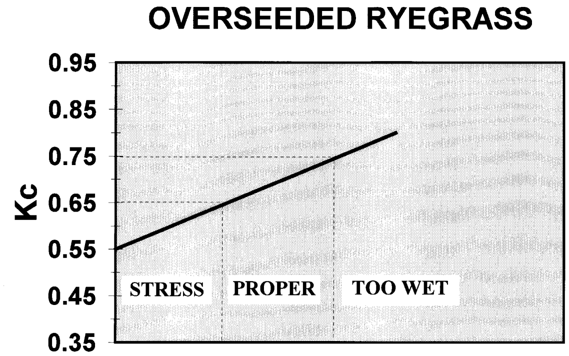

Figure 4. The K_c range for overseeded perennial rye is 0.65-0.75. Higher K_cs are required for high quality turf and warm weather. Lower K_cs suffice for cooler weather and lower quality turf.

Recent Arizona-based research (Brown et al., 1998; Brown et al., 2001) indicates the K_c of high quality bermudagrass varies with turf growth rate. As a result, peak K_c values develop during late summer when warm nights support rapid turf growth. Monthly adjustments in K_cs may therefore be appropriate for some high maintenance turf systems. Monthly as well as seasonal bermudagrass K_cs derived from this research are provided in Table 1.

Water use of warm season grasses decreases during the spring and fall transition seasons when growth slows due to suboptimal temperatures. Crop coefficients run about 0.1 lower for warm season grasses during these transition seasons. For example, if you use a K_c of 0.7 for mid-season turf, a K_c value of 0.6 should be adequate during transition periods.

Once warm season grasses attain full dormancy in winter, grass water use essentially declines to zero. Evapotranspiration from dormant surfaces is therefore comprised of soil evaporation. There is little quantitative research on the evaporation rates from dormant warm season turf surfaces; however, factors such as thatch density, surface soil texture and irrigation frequency will certainly impact the evaporation rate. Research completed by Kneebone and Pepper (1982) suggests K_cs for dormant warm season grasses run close to 0.5 when surface soil moisture remains relatively high (i.e. irrigated regularly). Lower K_cs approaching 0.2-0.3 should be applicable with lower soil moisture and / or less frequent irrigation.

Crop Coefficients For Cool Season Grasses

Cool season (C-3) grasses typically use a higher fraction of ET_o than warm season grasses when both are grown under similar conditions. While cool season grasses are rarely grown in the low deserts during the summer months, there have been a few Arizona studies that have examined the water requirements of tall fescue grown during the summer. Appropriate K_cs for tall fescue maintained at 1.5" (4 cm) during the summer months range from 0.80-0.95 and support the general rule that cool season grasses use significantly more water than warm season grasses during the summer months (Fig. 3).

Cool season grasses (annual and perennial ryegrasses) are commonly overseeded into bermudagrass during the fall to maintain a green, winter turf surface. Appropriate K_cs for overseeded ryegrasses maintained at a height of 7/8–1.25" (1.7–3.0 cm) range from 0.65–0.75 (Fig. 4; Table 1). Lower Kcs are appropriate for less dense stands and during colder periods when frosts are common. Higher Kcs are appropriate for the warmer months and where high rates of fertilization generate dense, fast growing stands of turfgrass.

Adjusting K_cs for Turf Height

Turf height is another factor that can impact K_c value. Taller turfs use a little more water because they interact more effectively with the wind and absorb more solar radiation (a result of increased leaf surface). However, definitive research results showing the impact of turf height on water use are not available for Arizona. In lieu of such research reports, we recommend caution when adjusting K_cs for turf height and suggest increasing the K_c by 0.1 if the mowing height is doubled relative to the heights listed above. It is important to remember that ET_o is an estimate of the water use of a tall (3-6") cool season grass. The maximum K_c for most managed turf systems should therefore run below 1.0.

COMPUTING ET_T — SOME EXAMPLES

The computation of ET_T can be divided into three simple steps: 1) obtain a local ET_o value, 2) select an appropriate K_c value and 3) multiply the ET_o by the K_c to obtain ET_T. The following examples clarify this procedure.

Example 1. Determine daily ET_T for acceptable bermudagrass turf in Phoenix.

Step 1. Obtain the ET_o value from AZMET. From Fig. 5, the value is 0.3".

Step 2. Select a K_c value. An appropriate K_c would be 0.65 (Fig. 2).

Step 3. Multiply the ET_o value by K_c to obtain ET_T.

$$ET_T = K_c \times ET_o = 0.65 \times 0.3" = 0.195" \text{ or } \sim 0.2"$$

Example 2. Determine daily ET_T for high quality bermudagrass turf in Phoenix.

Step 1. Obtain the ET_o value from AZMET. Suppose ET_o is again equal to 0.3" (Fig. 5).

Step 2. Select a K_c value. An appropriate K_c value would be 0.80 (Fig. 2; Table 1).

Step 3. Multiply the ET_o value by K_c to obtain ET_T.

$$ET_T = K_c \times ET_o = 0.80 \times 0.3" = 0.24"$$

Example 3. Determine daily ET_T for acceptable quality overseeded ryegrass in Phoenix.

Step 1. Obtain the daily ET_o value from AZMET. From Fig. 6, the value is 0.13".

Step 2. Select a K_c value. An appropriate K_c would be 0.65 (Fig. 4).

Step 3. Multiply the ET_o value by K_c to obtain ET_T.

$$ET_T = Kc \times ET_o = 0.65 \times 0.13" = .084" \text{ or } \sim 0.08"$$

Example 4. Determine daily ET_T rate for high quality overseeded ryegrass in Phoenix.

Step 1. Obtain the ET_o total from AZMET. From Fig. 6, the value is 0.13".

Step 2. Select a K_c value. An appropriate K_c would be 0.70 (Fig. 4; Table 1).

Step 3. Multiply the ET_o value by K_c to obtain the daily ET_T

$$ET_T = K_c \times ET_o = 0.70 \times 0.13" = 0.091" \text{ or } \sim 0.09"$$

Turf ET was computed on a daily basis in the previous examples. It is important to note that ET_T can be computed for periods in excess of one day by simply summing the ET_o for the period in question, then multiplying the resulting sum by an appropriate K_c.

The examples above clearly show the process of computing ET_T is simple. Selection of an appropriate K_c value represents the major challenge when computing estimates of ET_T, and turf managers will need to experiment a little to determine the proper Kc for their turf. For managers new to the concept of ET-based irrigation management we recommend starting with a K_c value 0.70 for both warm and cool season grasses. Adjust the K_c upward or downward based on turf performance. More experienced managers may wish to fine tune their irrigation management by adjusting K_cs on a seasonal or monthly basis. Consult Table 1 for recommended monthly and seasonal K_cs for high maintenance turf in Arizona. Reduce the K_cs in Table 1 by approximately 0.1 for thin turf stands and areas receiving less intense management regimes (e.g. lower fertilizer rates).

PRECAUTIONS WHEN USING NON-AZMET WEATHER STATIONS

Several companies now sell weather stations and software that provide turf managers with ET_o values. While we encourage use of private weather stations, individuals that use these stations should understand that the K_cs presented above may need some adjustment when used with non-AZMET stations. Crop coefficients should be developed for (or matched to) a specific Penman or Penman-Monteith Equation since each version of the equation produces a slightly different ET_o value. The K_cs presented in this document were developed for use with ET_o as computed by AZMET. AZMET recently completed a three-year study that developed turf K_cs for the ET_o procedures used by public entities supplying ET_o in the states surrounding Arizona (Brown et al., 1998). These crop coefficients are presented by month in Table 1.

Turf managers with access to ET_o computed by Rainbird, Toro, Motorola or other systems will likely need to adjust the K_c values presented here. We have found older Rainbird Maxi-5® weather stations generate ET_o

values that run approximately 10% higher than AZMET values when compared under identical weather conditions. Thus, K_c values presented here should be reduced by 10% when used with ET_o obtained from Rainbird Maxi-5 weather stations. For example, a K_c of 0.7 for AZMET should be lowered to about 0.63 if used with ET_o from a Rainbird Maxi-5 station. Newer, Rainbird Nimbus® weather stations use the Penman Monteith Equation to estimate ETo. Crop coefficients appropriate for use with the Penman Monteith Equation are presented in Table 1. Adjustment factors for ET_o values computed by weather stations from other companies are not available at this time.

REFERENCES

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Brown, P.W., T. Thompson, D.M. Kopec, M.H. Young, P. Wierenga and B. Whitlark. 1998. Turf irrigation with municipal effluent: nitrogen fate, turf crop coefficients and water requirements. Final Project Report. United States Golf Assn. 26p.

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AZMET DAILY WEATHER SUMMARY: PHOENIX-GREENWAY
AUG 13, 1998

	MAX.	MIN.	MEAN	TOTAL	UNITS
TEMPERATURE	104.3	81.4	91.4		DegF
RELATIVE HUMIDITY	68.7	17.4	39.8		%
VAPOR PRESS. DEF.			3.2		KPas
SOLAR RADIATION				648.4	Langleys
PRECIPITATION				0.00	Inches
SOIL TEMP. 2 IN	99.1	79.7	87.2		DegF
SOIL TEMP. 4 IN	94.8	81.0	86.7		DegF
WIND SPEED	24.0		3.3		MPH
WIND VECTOR MAG.			0.5		MPH
WIND VECTOR DIR.			313		Degrees
REF. EVAPOTRANSPIRATION (ETo)				0.30	Inches

Figure 5. AZMET daily weather summary for Phoenix on 13 Aug. 1998 showing ETo equal to 0.30".

AZMET DAILY WEATHER SUMMARY: PHOENIX-GREENWAY
FEB 27, 1998

	MAX.	MIN.	MEAN	TOTAL	UNITS
TEMPERATURE	60.0	38.6	49.4		DegF
RELATIVE HUMIDITY	100.0	29.6	69.3		%
VAPOR PRESS. DEF.			0.4		KPas
SOLAR RADIATION				477.1	Langleys
PRECIPITATION				0.00	Inches
SOIL TEMP. 2 IN	69.8	40.7	51.2		DegF
SOIL TEMP. 4 IN	62.1	44.4	51.9		DegF
WIND SPEED	16.6		3.5		MPH
WIND VECTOR MAG.			2.3		MPH
WIND VECTOR DIR.			256		Degrees
REF. EVAPOTRANSPIRATION(ETo)				0.13	Inches

Figure 6. AZMET daily weather summary for Phoenix on 27 Feb. 1998 showing ETo equal to 0.13".
