How much is a year's worth of water?

Estimating annual water usage on the golf course may not only placate the water police — it could also save money.

Jack Fry, Ph.D.

As water becomes a more costly resource, golf course superintendents find that they must furnish estimates of annual usage to those who provide the water. These estimates are used to develop a water budget specific to a particular golf course. Although this request comes most often when golf courses are in the planning stage or under construction, existing golf courses also may be required to provide estimated annual water requirements to water companies.

Measuring irrigation

Turfgrass irrigation requirements depend on water losses through evapotranspiration (ET) and gains from usable precipitation. Evapotranspiration is the sum of water lost by evaporation from the soil surface and by transpiration through small pores (*stomata*) on leaves. Although water is typically measured in units of volume, such as fluid ounces, pints or gallons, water requirements for large areas of agricultural land, including turf areas, are more easily expressed in units of measure, such as inches or feet. For example, if ET is reported as 1 inch, the amount of water lost is equivalent to water covering the entire surface of the turf area at a depth of 1 inch.

To take this a step further, engineers have determined the volume of water required to cover an acre of ground with 1 foot of water: 325,851.43 gallons or 1 acre-foot of water. Applying 1 foot of water to 3 acres would require 977,554.29 gallons of water (325,851.43 gallons × 3 acres). One acre-inch of water equals 27,154.29 gallons (325,851.43/12). Golf course irrigation requirements are commonly expressed in terms of acre-feet, primarily because this terminology is easier than using "hundreds of thousands" or "tens of millions" of gallons.

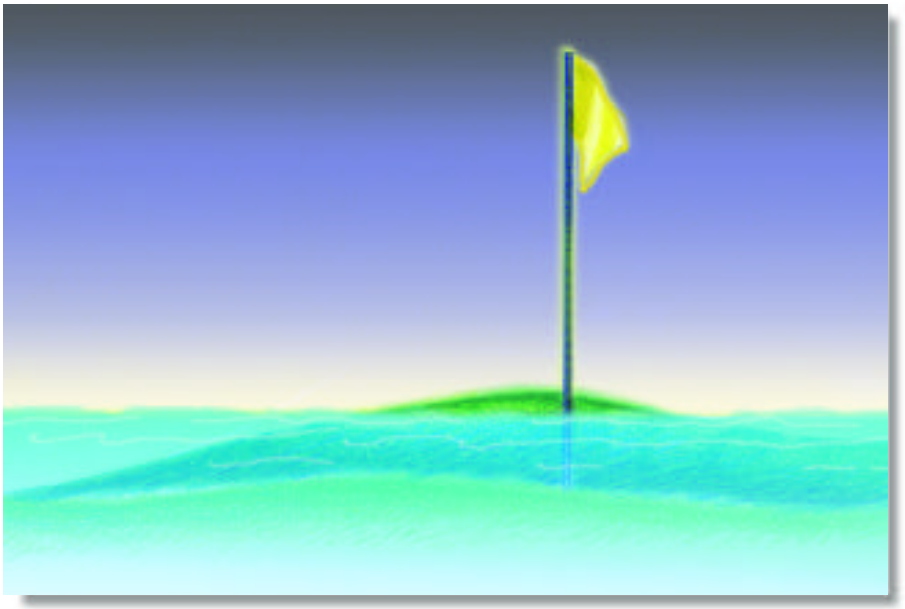


Illustration by Kelly Neis

Irrigation is commonly measured in acre-feet.One acre-foot,the amount of water needed to cover an acre of ground with 1 foot of water, is 325,851.43 gallons.

KEY points

More Info: www.gcsaa.org

- **Water is becoming an increasingly expensive commodity** for golf courses.
- **Municipalities and water companies** often want to know the estimated water use of a golf course before granting construction permits or in times of drought or water restrictions.
- **To determine estimated water use,** it is necessary to know the acreage of irrigated areas and an estimate of average turfgrass ET rates.
- **Once the basic information has been gathered,** simple mathematical formulas can be used to estimate annual water use.

This information can also be used to determine how many gallons of water have been lost through ET. For example, if 0.25 inch of ET occurred in one day from 40 acres of fairways, the total gallons of water lost can be calculated as follows:

Gallons lost through ET in 1 acre
= ET rate (inches per day) × 27,154.29 gallons
= 0.25 inch × 27,154.29
= 6,788.57 gallons ET per acre

Gallons of ET lost over the entire area
= number of acres of turf × gallons ET per acre
= 40 acres × 6,788.57 gallons ET per acre
= 271,542.8 gallons ET across 40 acres

Case Study: Colbert Hills Golf Course

Given background information on calculating water usage, it is possible to determine annual water requirements for a golf course.

The golf course used in the examples presented here is Colbert Hills Golf Course, an 18-hole championship course located in Manhattan, Kan., the home of Kansas State University (KSU).

Irrigated acreage at the course is 5 acres of L-93 creeping bentgrass (*Agrostis stolonifera*) greens mowed at 0.130 inch; 45 acres of Meyer zoysiagrass (*Zoysia japonica*) fairways and tees mowed at 0.5 inch; and 100 acres of turf-type tall fescue (*Festuca arundinacea*) mowed at 2.5 inches. Turf ET values for June to September were based on turfgrass research data conducted at KSU since 1993. Weather-based estimates were used to determine values for March-May and October-November.

1. Measure the acreage of irrigated areas on the golf course.

The acreage of irrigated areas on the golf course may already be on file at the course. If not, the superintendent or a member of the staff should be prepared to spend a few days with a measuring wheel to determine areas for greens, tees, fairways and rough. It is important to determine areas separately, because ET of turf on putting greens is different from ET of fairways, and fairway turf ET may be different from ET in roughs. For more information on determining area, see "The Mathematics of Turfgrass Maintenance" (1).

2. Get an estimate of average turfgrass ET rates.

Turfgrass ET rates can be obtained from numerous sources, including historical weather data, mathematical-based models that employ weather data, evaporation pan data and university turfgrass researchers. Researchers at land-grant universities in several states have measured ET rates of turfgrasses during the growing season.

Turfgrass ET values are almost always reported as water loss under conditions in which soil water was not limiting for plant growth. This is important, because ET declines as soil dries. Evapotranspiration data obtained from weather-based estimates may have to be adjusted for the specific golf course conditions, because some mathematical models provide data appropriate for stands of cool-season grass maintained at a 3- to 6-inch height, considerably higher than turf on most golf courses. Therefore, although the illustration in this article provides a reasonable estimate of annual turfgrass water requirements, many interacting factors may increase or decrease the total amount of water required.

In some cases, interacting factors can be accounted for by using a multiplier, or crop coefficient, to adjust an ET estimate. For example, a crop coefficient may be used to adjust ET for effects of mowing height, irrigation frequency, nitrogen fertility level or soil type. In such a case, university Extension personnel may be able to provide more accurate numbers. (A list of Web sites that provide ET calculators is shown below.)

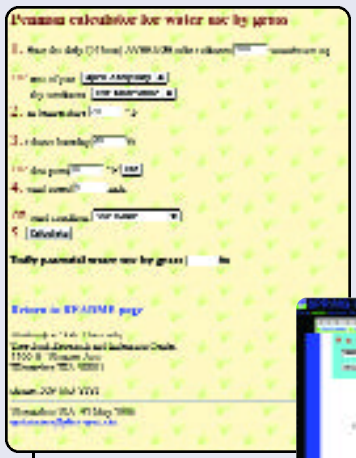
Typical average ET rates during active growth, and under well-watered conditions, range from 0.1 to 0.3 inch per day for cool-season grasses and 0.05 to 0.2 inch per day for warm-season grasses. However, ET can be quite variable, and values can be higher or lower than the ranges provided because many environmental and cultural factors influence ET. (See the table, "Environmental and cultural factors vs. ET.")

ET estimates for each area of the golf course are best broken out by month or by groups of months. In the case study below for a golf course in Manhattan, average ET estimates are provided for March-May, June-September and October-November. Months or groups of months may be divided differently depending on geographic location. For example, superintendents in the southern United States may have significant ET values every month of the year.

3. Determine annual ET rates for the golf course, and then convert to acre-feet.

An example of determining annual ET rates is illustrated by using the average ET loss from 5 acres of creeping bentgrass turf (0.2

HELPdesk | Web sites for ET calculators



http://www.tfrec.wsu.edu/Orchard/pET/pETCalc.html

http://www.springirrigation.com/management/penman_calculator_for_water_use_.htm

http://aggieturf.tamu.edu/tools.html

http://weather.nmsu.edu/nmcrops/grasses/index.htm

inch per day) over the 122-day period from June through September:

Step 1.

Total ET for the time period in inches
= average daily ET in inches
× number of days in the period
= 0.2 inch × 122 days
= 24.4 inches ET

Step 2.

Total ET for the time period in feet
= inches ÷ 12 (12 inches = 1 foot)
= 24.4 inches ÷ 12
= 2.03 feet ET

Step 3.

Acre-feet of ET over the time period
= feet of ET × number of acres of turf
= 2.03 feet ET × 5 acres
= 10.15 acre-feet ET

The total acre-feet of water required for each time period can then be added together to determine the total water requirement for the creeping bentgrass putting greens. (See the table, "Estimating irrigation at Colbert Hills.")

ENVIRONMENTAL AND CULTURAL FACTORS VS. ET

Environmental factor	Influence on ET
Air and soil temperature	Increases with temperature
Sunshine	Increases with intensity and day length
Wind speed	Increases with wind speed
Relative humidity	Decreases with increasing humidity
Cultural factor	
Mowing height	Increases with mowing height
Nitrogen	Increases with nitrogen

4. Subtract usable precipitation to determine net acre-feet of water required.

Not all precipitation that falls is used by the plant. Usable rainfall varies depending on many factors, including precipitation rate, soil type, soil water content and turfgrass rooting characteristics. An accurate measure of precipitation at several locations across the

ESTIMATING IRRIGATION AT COLBERT HILLS

Months	(1) Average daily ET (inches)	(2) No. days	(3) Total ET (inches) (col. 1 × col.2)	(4) Acre-feet/acre (col.3 ÷ 12)	(5) Acres	(6) Total acre-feet (col. 4 × col.5)	(7) Usable precip. (acre-feet over the area given)	(8) Net acre-feet (col.6 – col.7)
CREEPING BENTGRASS GREENS								
March-May	0.10	92	9.2	0.77	5	3.85	2.06	1.79
June-Sept.	0.20	122	24.4	2.03	5	10.15	3.39	6.76
Oct.-Nov.	0.10	61	6.1	0.51	5	2.55	1.01	1.54
Total								10.09
ZOYSIAGRASS FAIRWAYS AND TEES								
March-May	0.08	92	7.36	0.61	45	27	18.5	8.5
June-Sept.	0.17	122	20.74	1.73	45	77.78	30.5	47.28
Oct.-Nov.	0.08	61	4.88	0.41	45	18.45	9.09	9.36
Total								65.14
TALL FESCUE ROUGHS								
March-May	0.12	92	11.04	0.92	100	92	41.13	50.87
June-Sept.	0.27	122	32.94	2.75	100	275	67.8	207.2
Oct.-Nov.	0.12	61	7.32	0.61	100	61	20.2	40.8
Total								298.87

Estimates of acre-feet requirements at Colbert Hills Golf Course in Manhattan,Kan.

course will better document irrigation needs. Less than 0.10 inch of rainfall generally does not provide irrigation usable to the turf. When precipitation is heavy, amounts greater than 1.5 inch are likely to run off. Some water will also move beyond the root zone.

For this example, the bentgrass greens at Colbert Hills GC assume that 50 percent of precipitation is available for turfgrass use. This estimate is conservative because in some years turf in the Midwest may be able to use more than 75 percent of precipitation and irrigation. The greens at Colbert Hills can serve as an example of how usable precipitation is deducted from the total turf water requirements.

Step 1.

Usable precipitation for the period

= normal precipitation ÷ 2 (assuming 50 percent of precipitation is usable)

= 16.28 inches of precipitation ÷ 2

= 8.14 inches of usable precipitation

Step 2.

Total acre-inches of precipitation

= usable precipitation × number of acres

= 8.14 inches of usable precipitation × 5 acres

= 40.7 acre-inches of usable precipitation

Step 3.

Total acre-feet of usable precipitation

= acre-inches of usable precipitation ÷ 12

= 40.7 acre-inches of usable precipitation ÷ 12

= 3.39 acre-feet of usable precipitation

Following the steps outlined above, seasonal water requirements for greens, tees and fairways and rough have been determined for Colbert Hills. (See the table, "Total estimated irrigation for Colbert Hills.")

Based on this process, the annual irrigation requirement for Colbert Hills is 374.10 acre-feet, or 121,901,019 gallons. Of the total water applied, greens receive 2.7 percent, fairways 17.4 percent and rough 79.8 percent.

The Colbert Hills illustration demonstrates how reducing irrigation of the rough could result in significant water savings. This may be accomplished by zoning rough irrigation separately from fairways or using drought-resistant turfgrasses that require only minimal irrigation (e.g., buffalograss in Kansas).

Estimated vs. actual water use

In all likelihood, the water requirement calculated for Colbert Hills represents an amount that will be required during a dry year, such as 2002, but overestimates water requirements in a wet year. Nevertheless, it is better to err on the high side than to submit a request that will not allow for sufficient water. Actual water use may also be less because ET values assumed that turf was growing under well-watered conditions. As mentioned above, ET declines as the soil dries between irrigation or rain. Actual turf ET values will be lower than the calculated values depending on irrigation frequency and other factors. Usable rainfall also may be greater than 50 percent, further reducing the amount of water required.

Once an irrigation budget is determined, the superintendent should strive to stay within the targeted allotment. In fact, some water providers penalize golf courses that exceed the identified goal. For example, the city of Wichita, Kan., currently charges $518.10 per acre-foot of water for golf courses inside the city limits. However, once a course has exceeded its targeted limit, the cost increases to $785.30 per acre-foot.

Irrigation efficiency

The steps outlined above for determining annual irrigation requirements do not take into account the inefficiency of the irrigation system. Poor water distribution will increase the amount of water required to maintain turf quality (2). In the Colbert Hills example, if the system is assumed to be 80 percent efficient, the new water requirement would be 467.63 acre-feet, which is 20 percent higher than originally calculated (374.1 acre-feet ÷ 0.80 = 467.63 acre-feet). Once again, a higher, rather than lower, estimate of irrigation need may help to account for minor problems with distribution uniformity.

Keep in mind, however, that water providers have little empathy for superintendents managing water on courses with inefficient delivery systems. If such problems exist, efforts should be made to correct them, because the money saved on water will more than cover the cost of correcting irrigation system woes.

Acknowledgments

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TOTAL ESTIMATED IRRIGATION FOR COLBERT HILLS

Area	Acre-feet
L-93 creeping bentgrass greens	10.09
Meyer zoysiagrass fairways and tees	65.14
Turf-type tall fescue rough	298.87
Total	374.10

Literature cited

1. Christians,N.,and M.Agnew. 1997.The mathematics of turfgrass maintenance.Ann Arbor Press, Chelsea,Mich.
2. Kopec,D.1994.Adjusting irrigation systems for greater efficiency. *Golf Course Management* 62(8):74-82.

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