GCSAA

Golf Course Environmental Profile

Phase III, Volume I
Water Use and Management Practices
on U.S. Golf Courses

GCSAA

WATER USE

Golf Course Superintendents Association of America

Golf Course Environmental Profile

Phase III, Volume I

2022 Water Use and Management Practices on U.S. Golf Courses

The third phase of the Golf Course Environmental Profile was conducted by the Golf Course Superintendents Association of America.

GCSAA

Contents

Study shows continued commitment to water protection

When the first phase of the Golf Course Environmental Profile (GCEP) was launched in 2005, the goal was to measure the golf industry's progress and demonstrate its commitment to environmental stewardship.

The results from phase three clearly show that golf course management professionals are dedicated to water conservation and water quality protection and employ practices that have yielded continuous improvement. And while water use varies depending on agronomic region, the amount of water used on golf courses in the U.S. has been reduced in the last 15 years.

As with the first two phases of the GCEP, the data from the most recent results give the industry the ability to communicate how our members are making a difference in the communities they serve through best management practices that protect and conserve one of the world's most vital resources.

The data for the landmark project would not be possible without the participation from the golf course superintendents who are on the front lines of the industry's water conservation efforts. On behalf of the GCSAA Board of Directors, I thank all of those who took the time to be a part of the study. The valuable information they provided gives the profession and the industry a stronger voice.

Kevin P. Breen, CGCS
2022 GCSAA President

Executive Summary

This report provides the most accurate representation of water management on U.S. golf courses. Data within this report reflect changes over time since the first report in 2005.

National Water Use

- U.S. golf facilities applied approximately 1.68 million acre-feet of water in 2020, a 29% reduction since 2005.
- Approximately two-thirds of this reduction was likely a result of operational golf facilities applying less water per acre in 2020 than in 2005.
- The remaining one-third of this reduction was a result of course closures.

Regional Water Use

- Less water was applied within each region in 2020 than in 2005.
- About one-half of applied water (58%) was applied in the Southeast and Southwest regions.
- Median applied water and applied water per acre was greatest in regions with high average temperature and low average rainfall (Southwest and Upper West/Mountain).

Water Sources

- The most common sources of water were wells (32%) and lakes and ponds (23%).
- Less water was applied in 2020 from each water source than in 2005 except from recycled water, which accounted for 21% of projected water applied in 2020.

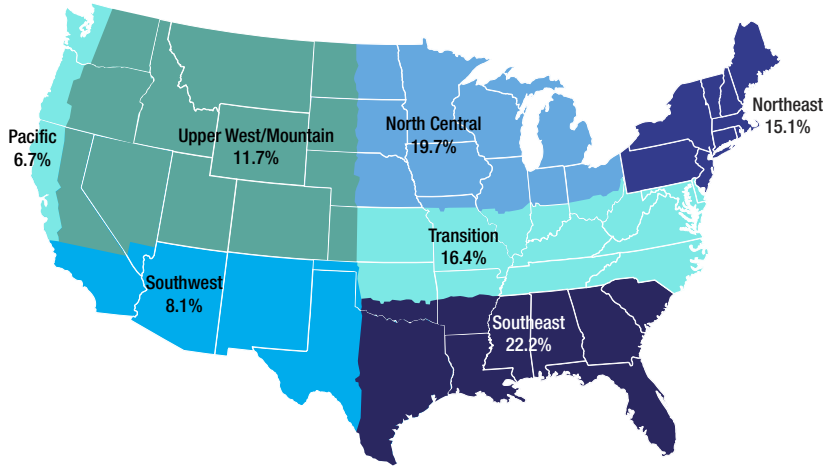


Figure 1. Agronomic regions and proportion of surveys received in 2021.

Irrigated Acres

- Projected irrigated acres of U.S. golf facilities declined by 11.5% since 2005 to 1.04 million acres in 2020. This was likely a result of course closures.
- The median irrigated acres on U.S. golf facilities increased by 10% since 2005 to 60.9 acres. This increase was primarily a result of increased irrigated rough acres.

Facility Influence

- The number of U.S. golf facilities declined to 14,145, which was 11.9% reduction since 2005 (Table 9).
- Operational golf facilities reduced irrigated acres by 11,423 acres and applied water by 29,294 acre-feet in 2020 (Table 12).
- The reduction of applied water resulting from facility closures since 2005 was 234,269 acre-feet, which accounted for approximately 1/3 of the applied water reductions since 2005 (Table 1 and Table 9).

Management Practices

- Use of most best management practices has increased since 2005.
- Keeping turf drier, pruning tree roots, changing to a more drought-tolerant turfgrass, mulching landscape beds, and increasing no-mow acres were significantly associated with reductions in applied water.

Applied Water Units – What do they mean?

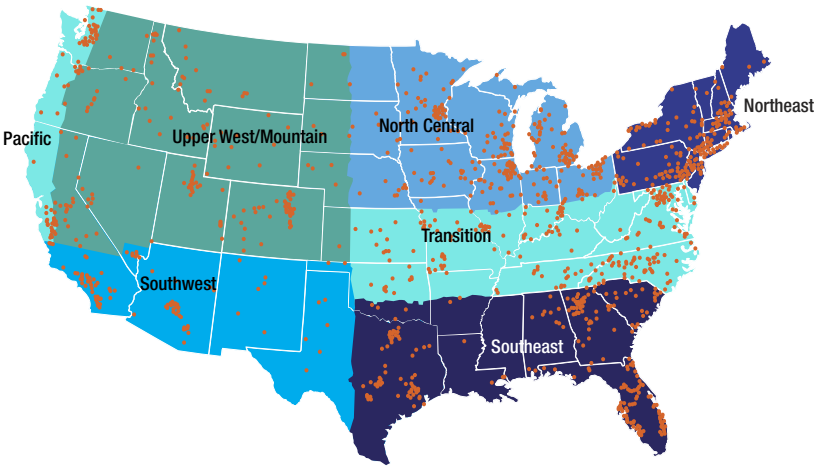
Applied water is reported in three units – projected applied water in acre-feet, median applied water in acre-feet, and median applied water in acre-feet per acre.

An acre-foot of water is one foot of water applied to one acre and is equal to 325,851 gallons.

Projected applied water (national and regional) is the sum product of the average amount of water applied to a 9-, 18-, or 27+-hole facility using the known number of 9-, 18-, or 27+-hole facilities within each region. It is an estimate of the total volume of applied water.

Median applied water is the median water applied to a golf facility regardless of the facility's irrigated acres. It is the amount of water where half of golf facilities apply more, and half apply less.

Median applied water per acre is the median water applied to a golf facility divided by the facility's irrigated acres. It is an estimate of the efficient use of water and allows for a commensurable comparison of applied water across facilities, regions, etc.



Distribution of 2021 survey responses and the seven agronomic regions.

Mean vs. Median

Mean = sum of all values divided by the number of values.
Median = midpoint of a frequency distribution.

The mean is more influenced by extremely high or low outliers than the median and is regularly used in agricultural sciences where these high or low outliers are rare. The median is less influenced by extremely high or low outliers and is regularly used in survey sciences where these high and low outliers are common. Therefore, the use of the median in this survey provides a greater probability of reporting the true value than using the mean.

Water cost data is no longer available in this series. However, GCSAA refers members to the maintenance budget surveys and reports available on GCSAA's website.

Significant Differences

Throughout this report, some tables and graphs contain letters such as a, b, or c next to numeric values. These letters indicate whether the values being compared are different. Values followed by a common letter are not different at the 90% confidence level. This means that when we state that two values are different, we are 90% confident that the true values differ.

Introduction

"'Benchmark' – a point of reference from which measurements may be made." The Golf Course Superintendents Association of America's (GCSAA's) Golf Course Environmental Profile (GCEP) Survey Series, now in its third iteration, serves as the golf course management industry's benchmark by providing comprehensive data on the management practices, property features, and environmental stewardship of U.S. golf courses.

The GCEP survey series was first launched in 2005 to establish baseline data on issues ranging from land use to regulations and practices governing water use, nutrients, and pest control. A subsequent set of surveys were conducted starting in 2014 and provided scientifically valid measurements of industry change as it related to the five survey topics (Energy Use and Environmental Practices on U.S. Golf Courses, Land Use Characteristics and Environmental Stewardship Programs on U.S. Golf Courses, Pest Management Practices on U.S. Golf Courses, Nutrient Use and Management on U.S. Golf Courses, and Water Use and Conservation Practices on U.S. Golf Courses).

Results from these surveys are published in *Golf Course Management* and in online documents (https://www.gcsaa.org/Environment/golf-course-environmental-profile) and they are frequently used by the GCSAA and other golf-centric organizations to communicate to the public the golf industry's commitment to environmental stewardship and to promote the efforts golf course superintendents are making on their golf courses. Similarly, the GCEP survey data are used to assist in determining the future direction of GCSAA environmental efforts, to identify key issues for potential research projects, to respond to governmental and public inquiries, and to provide a solid basis for comments on proposed regulatory issues affecting the golf industry.

The GCEP survey results are also published in the peer-reviewed scientific journal *Crop, Forage and Turfgrass Management* (previously *Applied Turfgrass Science*) benefiting scientists who routinely use the survey data to guide their research direction and regulators who must make evidence-based decisions.

The objective of the Water Use and

Management Practices Survey was to document water usage on U.S. golf courses in 2020 and to identify potential factors influencing its use and conservation. Data from this survey strengthens the industry benchmarking process.

Methodology

The GCEP third phase/series survey questions mirrored those in the prior two GCEP surveys to maintain survey continuity. Slight changes were made to the questions only to provide clarity where needed.

Dr. Travis Shaddox, Bluegrass Art and Science, LLC, and Dr. J. Bryan Unruh, University of Florida, focused on the scientific aspects of the project including data analysis and interpretation, and writing the peer-reviewed scientific journal article and the GCSAA publications. The National Golf Foundation (NGF) provided oversight of the survey instrument programming, recruited and administered the survey, collated the data, and computed the projected water use data. GCSAA staff worked closely with the scientists and NGF to bring the project to completion.

Survey Distribution and Response – The link to the online survey was distributed by e-mail through the mailing lists of the NGF and the GCSAA, which sent the survey link to 14,145 golf facilities (a facility was defined as a business location where golf can be played on one or more golf courses). Each phase of the GCEP surveys target the same population, however, the respondents from 2006, 2014, and 2021 are not identical. For ease of comparison and to maintain consistency between surveys, respondents were classified using the same agronomic regions (Figure 1), facility type (i.e., daily fee, municipal, or private), number of holes (i.e., 9, 18, or 27+), and green fees (i.e., < $40, $40 - $70, > $70/round).

The survey, promoted on social media platforms and by GCSAA staff, was available for completion for seven consecutive weeks beginning on October 12, 2021. Three email reminders were sent to encourage survey participation and/or completion by those who had started but not finished. Respondent names were omitted from the data file and each respondent received a unique identify-

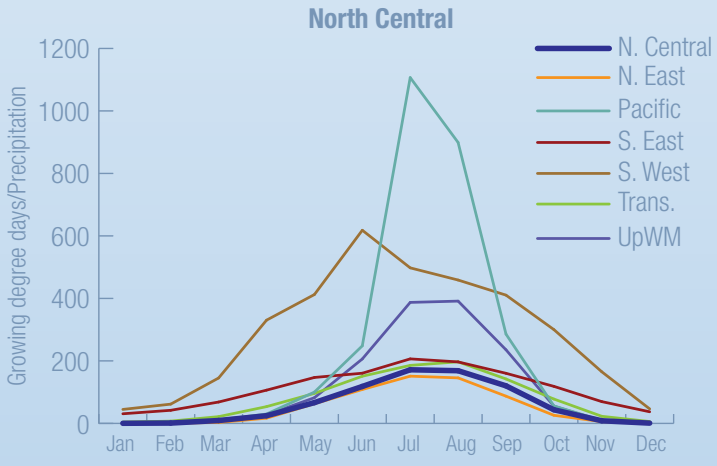
Growing Degree Days

Water, light, temperature, and nutrition are four major drivers of turfgrass growth and development. Of these, temperature is the one that exerts a major influence over most biological processes. Growing Degree Day (GDD) models are often used to quantify temperature accumulation and many golf course superintendents use GDDs to schedule pesticide applications for weed and insect control as well as timing the application of plant growth regulators.

In its simplest form, a degree day is a measure of heat above a threshold for one day. Growing Degree Day accumulation is the total of GDDs over time. Because the amount of heat varies from one day to another, GDD accumulation provides a more accurate method for tracking the development of biological organisms (turfgrass, pests, etc.) compared to the number of calendar days since their growth and development is more a function of temperature than time. To calculate GDDs, the daily high and low air temperatures are averaged, and the base temperature (minimum temperature at which growth initiates) is subtracted from this average. These GDDs are then added to the running total resulting in accumulated GDDs.

The usefulness of GDD models can be applied to agronomic practices other than pesticide applications. In this report, the 30-year average accumulated GDDs is divided by the 30-year average precipitation received to graphically illustrate the months of the year when temperature-driven growth may exceed rainfall amounts for the seven agronomic regions. Three regions – Pacific, Southwest, and Upper West/Mountain – reveal a greater magnitude of water need as evidenced by the taller curves on the graph. The taller curves suggest that temperature-driven growth is increasing at a greater rate than precipitation. The resultant effect is a greater need for supplemental irrigation. Conversely, the North Central, Northeast, Southeast, and Transition regions have relatively flat curves suggesting that the increased temperature during summer months is more closely accompanied by precipitation which, in turn, results in less supplemental irrigation required to sustain acceptable turfgrass.

All modeling tools, including GDDs, have limitations and do not always account for other factors that influence plant growth and development. For example, the Southeast region usually receives adequate precipitation throughout the year, yet drought-stricken turf may be observed. In some cases, the limiting factor is not precipitation or high heat; it may be sandy soils with low water-holding capacity. The resultant effect is a greater need for supplemental irrigation.



ing number, which provided anonymity within the data file and only one response was allowed per golf course.

Survey responses were received from 1,575 facilities representing 11.1% of the U.S. total (Table 33). By comparison, the response rates for the 2014 and 2006 survey were 12.7% and 15.2% respectively.

Data Analysis – Survey data were downloaded from the survey software and aligned with data from previous water use survey data from GCEP Phase 1 and 2 surveys. Prior years' data were analyzed with data from the 2021 survey allowing for statistical comparisons between years.

Data were weighted to provide a valid representation of U.S. golf courses and were analyzed using appropriate statistical procedures. Projected water use and irrigated acres were determined by calculating the sum product of the regional water use means with the respective number of golf facilities in each region. As a result, statistical separation of projected water use and irrigated acres was not conducted.

Statistical procedures evolve and change over time. Consequently, water use and acreage data from the current and prior two surveys were analyzed using methodology that resulted in minor numeric deviations from previously reported results.

In the current and prior surveys, respondents were asked if they reported water use by using a water meter, estimation, or both. As with the prior surveys, responses based solely on estimated water use were omitted from water use analysis along with variables that included water use, such as water use per acre.

To provide a relative context of water use, meteorological data were collected from an online database (National Oceanic and Atmospheric Administration, 2022) and grouped into agronomic regions using the latitude and longitude of each collection station. Degree days were determined using a base temperature of 50 °F and calculated using a parametric method (Thom, 1966) described by Arguez et al. (2012).

To determine if the percent of respondents engaged in management practices changed over time, years were paired, and differences between all pairwise comparisons were determined.

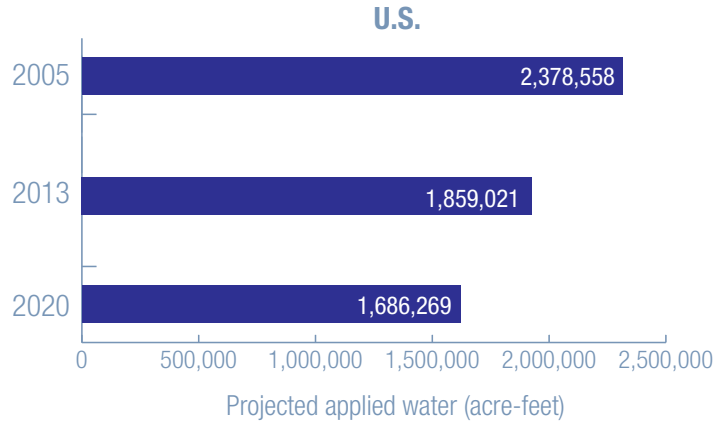


Figure 2. Projected water applied on U.S. golf facilities in 2005, 2013, and 2020. Ref: Table 1

	2005	2013	2020	Δ 2005-2020	Δ 2013-2020
	acre-feet			%	
U.S.	2,378,558	1,859,021	1,686,269	-29.1	-9.3
North Central	266,575	198,041	183,867	-31.0	-7.2
Northeast	116,930	94,194	95,843	-18.0	1.8
Pacific	107,811	107,185	72,498	-32.8	-32.4
Southeast	904,234	548,524	491,689	-45.6	-10.4
Southwest	531,189	532,149	487,332	-8.3	-8.4
Transition	243,034	181,379	158,913	-34.6	-12.4
Upper West/Mountain	208,785	197,548	196,126	-6.1	-0.7

Table 1. Projected water applied to U.S. golf facilities in 2005, 2013, and 2020.

Results
National Summary

Water Use

- A projected 1.68 million acre-feet of water was applied to U.S. golf facilities in 2020. This represents a 9.3% reduction of applied water since 2013 and a 29.1% reduction since 2005 (Figure 2 and Table 1).
- Median applied water per U.S. golf facility in 2020 was 66.3 acre-feet, which was 23.6% less than that reported in 2005 and equivalent to 2013 (Figure 3 and Table 2).
- Median acre-feet per acre of applied water per U.S. golf facility in 2020 was 1.01, which was 22.9% less than that reported in 2005. Similar to acre-feet, the acre-feet per acre was also similar to that reported in 2013 (Figure 4 and Table 2).
- Combined, the Southwest and Southeast regions accounted for 58% of the total applied water in the U.S. in 2020 (Figure 10), which was comparable to 2005 and 2013.

Water Sources

- Since 2005, a reduction in projected applied water was measured within each water source except recycled

water where the quantity of recycled water remained equivalent to that applied in 2005 (Table 5).

- Generally, the percentage of water applied from canal, river, municipal, or well sources remained unchanged since 2005. The percentage of water applied from lakes and ponds declined and the percentage of water applied from recycled water increased since 2005. The percentage of water applied from these sources has remained relatively unchanged since 2013 (Figure 5).
- Wells and lakes and ponds supplied 55% of the applied water in 2020, whereas wells and lakes and ponds supplied 63% of the applied water in 2005 (Figure 5).
- The percentage of golf facilities applying recycled water in 2020 (12.6%) was equivalent to those in 2005 and 2013 (Figure 6 and Table 3).
- The projected quantity of recycled water applied to U.S. golf facilities in 2020 was 351,364 acre-feet and was equivalent to the quantity applied in 2005. Approximately 25% less recycled water was applied in 2020 than in 2013 (Figure 7 and Table 3).
- The top reason why some U.S. golf facilities did not use recycled water was that there was no source of effluent water (51%), recycled water was unnecessary given that other water sources were available (31%), or there was no infrastructure to deliver the recycled water (14%) (Table 6).
- Water scarcity and cost were not major concerns nationally with 49% and 58% of respondents, respectively, stating they were not worried about either at this time (Table 7).

Irrigated Acres

- Projected irrigated acres of U.S. golf facilities in 2020 were 1.04 million, which was 11.6% less than that reported in 2005 (Figure 8 and Table 4).
- The median irrigated acres on U.S. golf facilities were 60.9 acres, which was 10.2% greater than that reported in 2005 but equivalent to 2013. The median irrigated acres of roughs, practice areas, greens, and tees increased since 2005, whereas irrigated acres of fairways declined by 8.5% and the

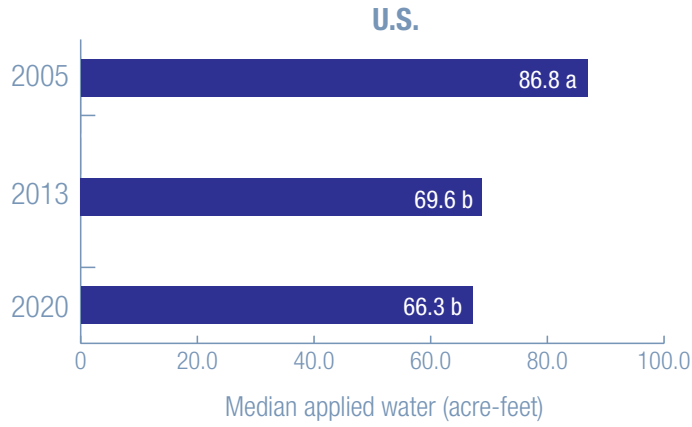


Figure 3. Median acre-feet of applied water on U.S. golf facilities in 2005, 2013, and 2020. Ref: Table 2

Year	U.S.	NC	NE	Pac.	SE	SW	Trans.	UWM
	acre-feet							
2005	86.8 a	52.0 a	32.7 a	114.8 a	194.8 a	372.4 a	60.3 a	178.1 a
2013	69.6 b	35.7 b	27.3 a	123.8 a	127.5 b	358.3 a	44.0 b	170.6 a
2020	66.3 b	40.5 b	29.0 a	68.4 b	111.1 b	375.7 a	38.5 b	163.2 a
	acre-feet/acre							
2005	1.31 a	0.94 a	0.74 a	1.66 a	2.00 a	3.43 b	0.96 a	2.10 a
2013	1.10 b	0.78 b	0.63 b	1.66 a	1.37 b	3.80 ab	0.70 b	2.02 a
2020	1.01 b	0.77 b	0.64 b	1.07 b	1.21 b	4.18 a	0.58 b	2.09 a

Note. NC=North Central, NE=Northeast, Pac.=Pacific, SE=Southeast, SW=Southwest, Trans.=Transition and UWM=Upper West/Mountain. Within columns, medians followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

Table 2. Median applied water and applied water per acre on U.S. golf facilities by agronomic regions in 2005, 2013, and 2020.

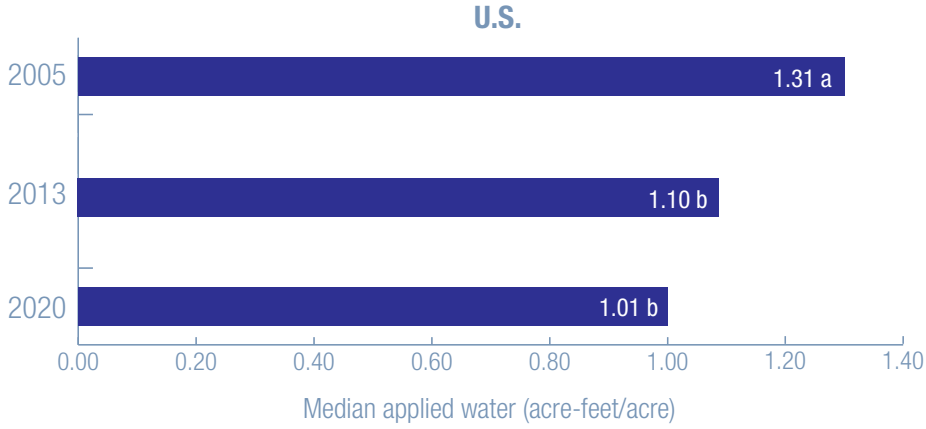


Figure 4. Median acre-feet/acre of applied water on U.S. golf facilities in 2005, 2013, and 2020. Ref: Table 2

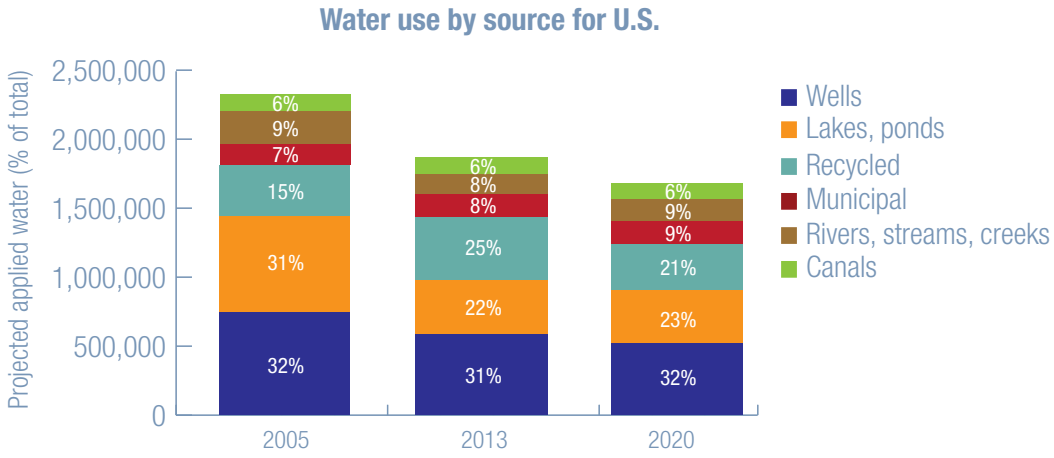


Figure 5. Projected water applied on U.S. golf facilities and percentage of water applied from wells; lakes, ponds; recycled; municipal; rivers, streams, creeks; and canals in 2005, 2013, and 2020. Ref: Table 5

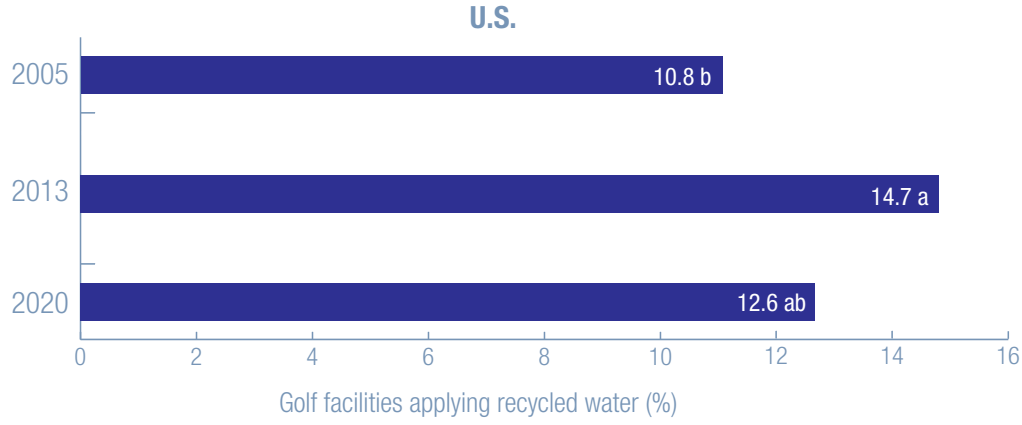


Figure 6. Percent of U.S. golf facilities applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

	Facilities Applying Recycled Water			Projected Recycled Water Applied				
	2005	2013	2020	2005	2013	2020	Δ 2005-2020	Δ 2013-2020
	%			acre-feet				
U.S.	10.8 b	14.7 a	12.6 ab	351,576	466,503	351,364	-212	-115,139
North Central	3.5 a	6.5 a	0.8 a	3,509	9,045	1,675	-1,834	-7,370
Northeast	3.5 a	1.5 b	2.6 ab	2,082	2,219	1,898	-184	-321
Pacific	12.5 a	21.5 a	16.5 a	10,253	24,975	7,858	-2,395	-17,117
Southeast	23.5 a	28.6 a	27.2 a	145,611	192,849	139,733	-5,878	-53,116
Southwest	33.5 b	44.3 a	39.9 ab	151,653	193,394	164,937	13,284	-28,457
Transition	5.3 a	6.4 a	8.6 a	12,682	18,856	15,330	2,648	-3,526
Upper West/Mountain	14.6 a	17.8 a	12.1 a	25,786	25,165	19,933	-5,853	-5,232

Note. Within a row, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.

Table 3. Frequency of U.S. golf facilities applying recycled water and projected recycled water applied in 2005, 2013, and 2020.

irrigated acres of landscape did not change (Figure 9 and Table 8).

Facility Influence

- The number of U.S. golf facilities declined to 14,145, which was an 11.9% reduction since 2005 (Table 9).
- The reduction of applied water resulting from facility closures since 2005 was 234,269 acre-feet, which accounted for approximately one-third of the applied water reductions since 2005 (Table 1 and Table 9).
- Both public and private facilities reported a reduction in applied water per acre since 2005 but applied equivalent water per acre since 2013 (Table 10).
- Operational golf facilities reduced irrigated acres by 11,423 acres and applied water by 29,294 acre-feet in 2020 (Table 12).

Management Practices

- The frequency of most water management practices has increased since 2005 (Table 11).
- Pruning tree roots and changing to drought-tolerant turfgrass has increased since 2005 and 2013 (Table 11).
- Management practices that were associated with reductions in applied water included keeping turf drier than in the past, pruning tree roots, changing to a more drought tolerant turfgrass, mulching landscape beds, and increasing no-mow acres (data not shown).
- The use of new hand-held sensors for irrigation system improvements and the use of fully automated irrigation systems have increased to 39% and 73%, respectively, since 2013, but the majority of irrigation system management practices have declined or remained unchanged since 2005 (Table 13).

Regulations

- Water use reporting has increased from 48% to 58%, recurring annual allocations has increased from 21.7% to 26.2%, and additional mandatory water restrictions have declined from 15.8% to 7.7% since 2005 (Table 14).
- Written drought, water, stormwater,

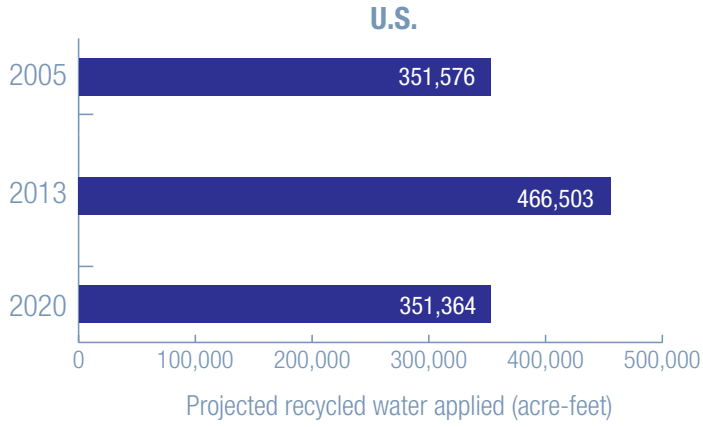


Figure 7. Projected recycled water applied to U.S. golf facilities in 2005, 2013, and 2020. Ref: Table 3

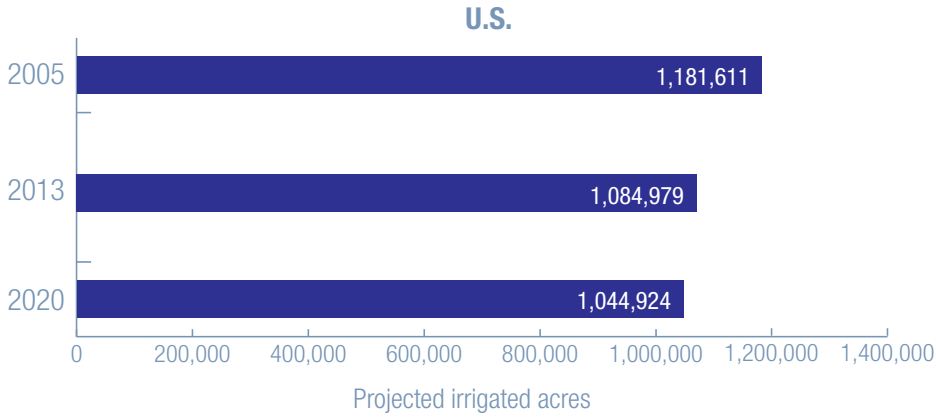


Figure 8. Projected irrigated acres of U.S. golf facilities in 2005, 2013, and 2020. Ref: Table 4

	2005	2013	2020
	acres		
U.S.	1,181,611	1,084,979	1,044,924
North Central	242,483	210,340	213,282
Northeast	136,252	131,570	139,952
Pacific	52,249	48,083	44,529
Southeast	319,600	286,439	271,760
Southwest	136,321	125,462	107,006
Transition	203,124	193,217	177,266
Upper West/Mountain	91,582	89,868	91,130
Golf Holes			
9	122,667	116,443	106,395
18	810,667	766,343	739,458
27+	248,278	202,193	199,071

Table 4. Projected irrigated acres of U.S. golf facilities in 2005, 2013, and 2020.

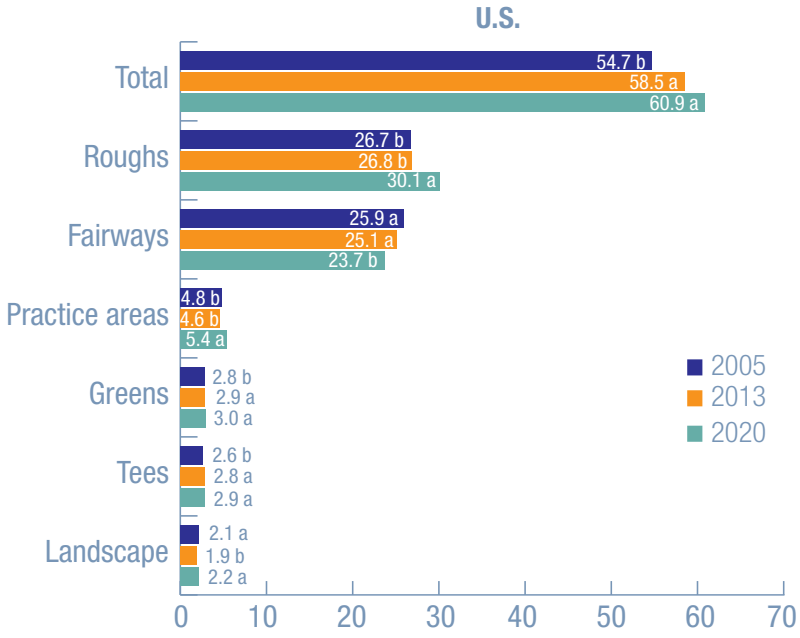


Figure 9. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

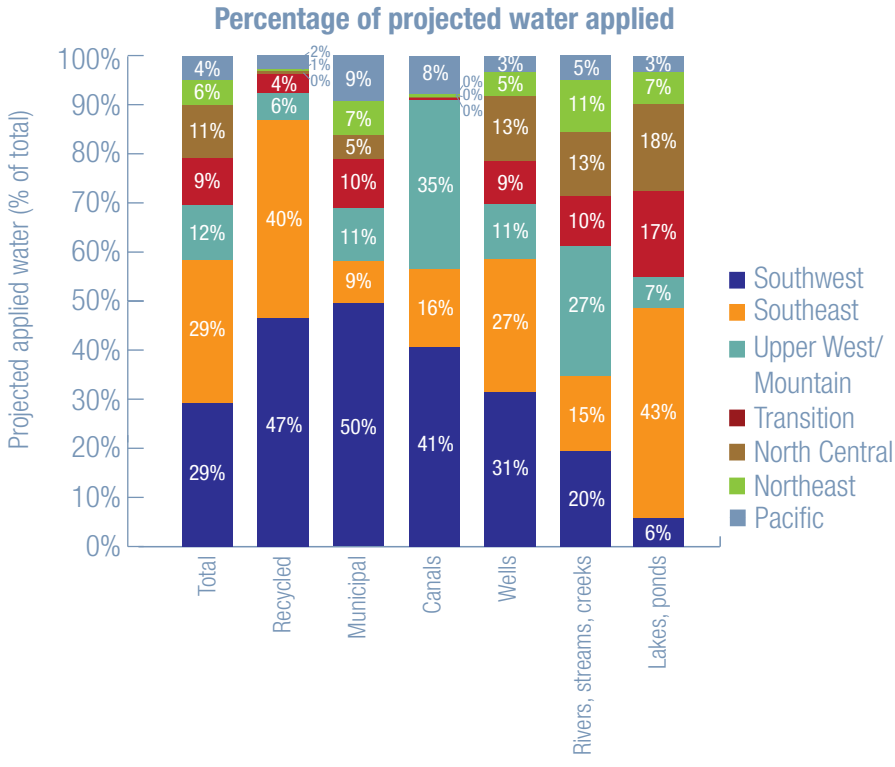


Figure 10. Percentage of projected water applied as total and from recycled; municipal; canals; wells; rivers, streams, creeks; lakes, ponds in 2020 by agronomic region. Ref: Table 5

and preventative irrigation management plans were uncommon in 2020 (Table 15). However, the majority of facilities that report having a written plan (except for stormwater) do so without being required.

Miscellaneous

- 92% of facilities reported soil moisture sensors had a positive impact on operations (Table 16).
- 61% of facilities that reduced irrigated acres indicated that the decision was based on water conservation (Table 17).
- 86% of facilities that reported a water-use reduction also reported that golfers were receptive (respondents answered 3, 4, or 5) to any perceived changes in course appearance (Table 18).
- Wetting agents (34%) and nutrients (12%) were the most common treatments used for irrigation injection (Table 20).
- The COVID-19 pandemic resulted in little to no influence on applied water for most facilities in 2020 (Figure 95).

Water Testing

- 92% of facilities had surface water and 35% of those facilities tested their surface water in 2020, which was equivalent to 2008 (Table 21).
- 60% of facilities that tested surface water tested their water at least once per year (Table 22).
- Of the facilities that tested surface water, 84% had at least one dedicated monitoring site (Table 23).
- Nutrient testing was the most common test conducted (77%) by facilities that tested surface water (Table 24).
- 58% of facilities had ground water wells and 40% of those facilities tested their ground water in 2020. The frequency of ground water testing declined since 2008 (Table 25).
- Of the facilities that tested ground water, 99% had at least one dedicated monitoring site (Table 26), and 83% had protected ground water wells (Table 27).
- 42% of facilities that tested ground water tested their water once per year, whereas the remaining facilities tested their ground water more frequently (Table 28).

- Nutrient testing was the most common test conducted (65%) by facilities that tested ground water (Table 29).
- 62% of facilities that tested ground water did not have a dedicated ground water monitoring site (Table 30).

Budget Influence

- Golf facilities within each budget range reported a reduction in applied water and applied water per acre since 2005 except for facilities with a budget range of $750,000 to $999,999 (Table 31).
- Intuitively, nine-hole facilities irrigated the fewest acres, applied the least amount of water, and applied the least amount of water per acre compared to 18-hole and 27+-hole facilities in 2005, 2013, and 2020 (Table 32).

Results
Regional Summary

Water Use

- Each region reported reductions in projected applied water since 2005 (Table 1).
- The greatest percentage and magnitude decrease in projected applied water since 2005 occurred in the Southeast (Table 1).
- Since 2013, projected applied water in the Northeast and Upper West/Mountain regions has remained relatively unchanged (Table 1).
- Median applied water and applied water per acre was greatest in the Southwest, Upper West/Mountain, and Southeast regions (Table 2), which were regions generally associated with low rainfall and/or high temperatures.

Water Sources

- The prevalence of facilities using recycled water within each region in 2020 was equivalent to 2005 (Table 3).
- The volume of recycled water applied in 2020 was less than that applied in 2005 in each region except in the Southwest and Transition where applied recycled water increased by 8% and 21%, respectively (Table 3).
- The Southwest and Southeast regions accounted for 87% of applied recycled water and 58% of the well water applied in 2020 (Figure 10).
- The primary reasons why some U.S. golf facilities did not use recycled water in 2020 were consistent across regions. The most common reason was a lack of available recycled water, followed by recycled water not being necessary, and finally some facilities do not have the necessary infrastructure to deliver the recycled water (Table 6).
- Water scarcity was not a concern for most respondents in each region except the Southwest and Upper West/Mountain regions where less than 20% of respondents stated there was nothing to be concerned with but more than 23% stated water scarcity was a major issue (Table 7). Water cost was also not a concern for most respondents in each region except the Pacific, Southwest, and Upper West/Mountain regions.
- 50% of the municipal water applied in 2020 was applied in the Southwest region (Figure 10).

Irrigated Acres

- Projected irrigated acres declined between 2020 and 2005 within each region except the Northeast, which was approximately equal to 2005 (Table 4).
- Projected irrigated acres declined between 2020 and 2005 at 9-hole, 18-hole, and 27+-hole facilities (Table 4).
- The Southwest and Southeast reported the greatest median irrigated acres of 91.4 and 87.5, which were 50% and 44% greater than the national median (Table 8).
- Irrigated rough acres increased in the Northeast, decreased in the Southwest, and remained unchanged in other regions since 2005 (Table 8).
- Irrigated fairway acres declined in the Southeast, Transition, and Upper West/Mountain regions and remained unchanged in other regions since 2005 (Table 8).
- Irrigated practice acres increased in the North Central, Southeast, and Upper West/Mountain, decreased in the Southwest, and remained unchanged in the remaining regions since 2005 (Table 8).
- Irrigated green acres increased in the North Central, Northeast, and Pacific and remained unchanged in the remaining regions since 2005 (Table 8).
- Irrigated tee acres increased in the North Central and Pacific and remained unchanged in other regions since 2005 (Table 8).
- Irrigated landscape acres increased in the North Central, Northeast, and Pacific, decreased in the Southwest, and remained unchanged in other regions since 2005 (Table 8).

Course Closures

- Course closures between 2005-2020 were greatest in the North Central (535) followed by the Southeast (484) and the Transition (433) (Table 9). The greatest water reduction resulting from course closure was reported in the Southeast (87,217 acre-feet).

Management Practices

- The most common water management practices in each region were the use of wetting agents, hand-watering, and keeping turf drier than in the past (Table 11). Increasing no-mow acres was associated with a reduction in applied water, but no region reported an increase in no-mow acres since 2013.

Regulations

- Water use reporting increased in the

North Central, Northeast, and Transition, but remained unchanged in other regions since 2005 (Table 14).
- While 23% of the U.S. facilities have drought plans, 40% do in the Southwest and 29% in the Southeast. Other regions are 20% or less.
- Nearly 14% of the U.S. facilities have water management plans, while 21% of facilities in the Upper West / Mountain have them. Other regions are lower.
- Approximately 16% of U.S. facilities have stormwater plan, while 31% of the facilities in the Southwest have them. Other regions are lower.
- Also, 15% of U.S. facilities have preventive irrigation maintenance plans while, 25% the Southwest region facilities have them. Other regions are lower. (The majority of facilities in each region do not typically have written drought, water, stormwater, or preventative irrigation management plans (Table 15).
- Facilities within each region consistently reported a positive impact resulting from the use of soil moisture sensors (Table 16).
- Among facilities that reduced irrigated acres, water conservation was the most common reported reason. The percentage ranged from 80% in the Upper West/Mountain to 52% in the North Central region (Table 17).

Miscellaneous

- Facilities within each region reported that golfers were consistently receptive to any perceived changes in course appearance resulting from a reduction in applied water (Table 18). Receptiveness ranged from 75% to 91% in the Upper West/Mountain and Transition regions, respectively.
- Wetting agents were the most common irrigation injection treatment within each region. Nutrients were the second most common injection treatment in the Pacific, Southeast, Southwest, Transition, and Upper West/Mountain, whereas acid injection was the second most common in the North Central and Northeast regions (Table 20).

Water Testing

- The prevalence of facilities that had surface water declined since 2008 in the Transition region but remained the same in each remaining region (Table 21). The prevalence of facilities that had surface water and tested their surface water declined since 2008 in the Pacific and Upper West/Mountain regions. Otherwise, the prevalence did not change since 2008.
- In 2020, surface water testing was most common in the Southwest (51%) and least common in the North Central (26%) (Table 21).
- 48% or more of golf facilities that tested their surface water did so at least once per year with 45% of facilities in the Southwest testing their surface water monthly (Table 22).
- Of the golf facilities that had surface water and tested their surface water, the most frequent number of surface water monitoring sites was one (Table 23).
- In general, the most common variable tested in surface water within each region was nutrients followed by oxygen and bacteria (Table 24).
- The prevalence of ground water wells did not change since 2008 except for a decline in the North Central region (Table 25). The prevalence of facilities that had ground water wells and tested their ground water declined since 2008 within each region except for the Southwest and the Upper West/Mountain regions, which did not change since 2008. Facilities that tested ground water ranged from 24% in the Pacific to 51% in the Southwest.
- Of the golf facilities that had ground water wells and tested their ground water, the most frequent number of ground water monitoring sites (Table 26) and protected ground water wells was one (Table 27).
- Between 36% and 54% of facilities that test ground water tested their ground water at least once per year (Table 28).
- Generally, the most common variable tested in ground water within each region was nutrients followed by bacteria (Table 29).
- The majority of facilities that tested ground water in 2020 did not have dedicated ground water monitoring sites (Table 30).

Irrigation Audits and Efficiency (Table 19)

Irrigation distribution uniformity is a common efficiency irrigation test related to the distribution and/or pattern of water on a golf course feature. This is not a test where 100% is realistic but helps with water management in light of constant improvement. For all courses that conducted irrigation audits across the region's values range:

- Overall - U.S. average was 80% ranging from 93% in the Southwest to 63% in the Pacific regions.
- Fairways - U.S. average was 54% ranging from 80% in the North Central to 19% in the Transition regions.
- Tees - U.S. average was 45.4% ranging from 88% in the North Central to 28% in the Transition regions.
- Greens - U.S. average was 61% ranging from 91% in the North Central to 47% in the Pacific regions.

North Central Region

Water Use

- Projected applied water was 31% less in 2020 than in 2005, resulting in a water savings of 82,708 acre-feet (Figure 11).
- Median applied water per facility declined from 52.0 acre-feet in 2005 to 40.5 acre-feet in 2020, a 22% reduction (Figure 12).
- Median applied water per acre declined from 0.94 in 2005 to 0.77 in 2020, an 18% reduction (Figure 13).

Water Sources

- In 2020, 40% of projected applied water was sourced from lakes and ponds and 42% was sourced from wells (Figure 14).
- In 2020, 1% of projected applied water was sourced from recycled water (Figure 14).
- The percentage of facilities using recycled water reduced from 3.5% in 2005 to 0.8% in 2020 (Figure 15).
- Projected recycled water applied reduced from 3,509 acre-feet in 2005 to 1,675 acre-feet in 2020, a 52% reduction (Figure 16).

Irrigated Acres

- Projected irrigated acres declined by 12% from 242,483 acres in 2005 to 213,282 acres in 2020 (Figure 17).
- Irrigated acres at 9-, 18-, and 27+-hole facilities declined by 34%, 6%, and 14%, respectively (Figure 17).
- Median irrigated acres increased from 41.4 in 2005 to 47.1 in 2020 (Figure 18 and Table 8).
- Median irrigated acres of roughs and fairways did not change since 2005, but the median irrigated acres of practice areas, greens, tees, and landscape all increased since 2005 (Figure 18 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 13% to 3,592 (Table 9).

Management Practices

- The frequency of most management practices has increased since 2005, notably: using wetting agents, keep-

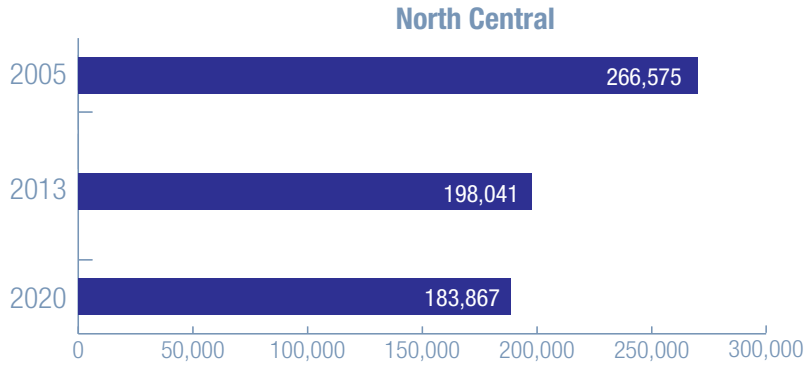


Figure 11. Projected water applied to U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Ref: Table 1

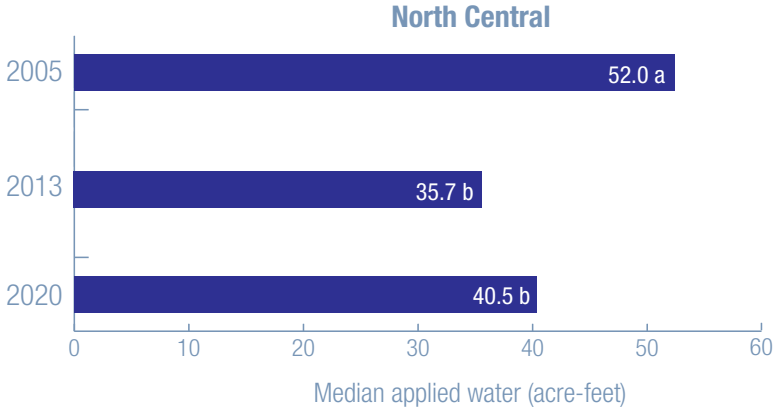


Figure 12. Median acre-feet of applied water on U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

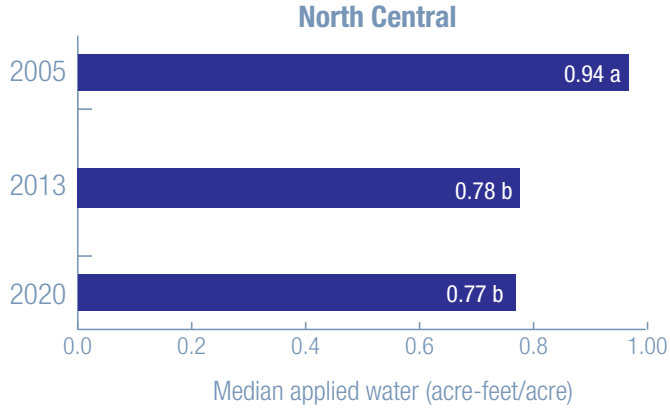


Figure 13. Median acre-feet per acre of applied water on U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

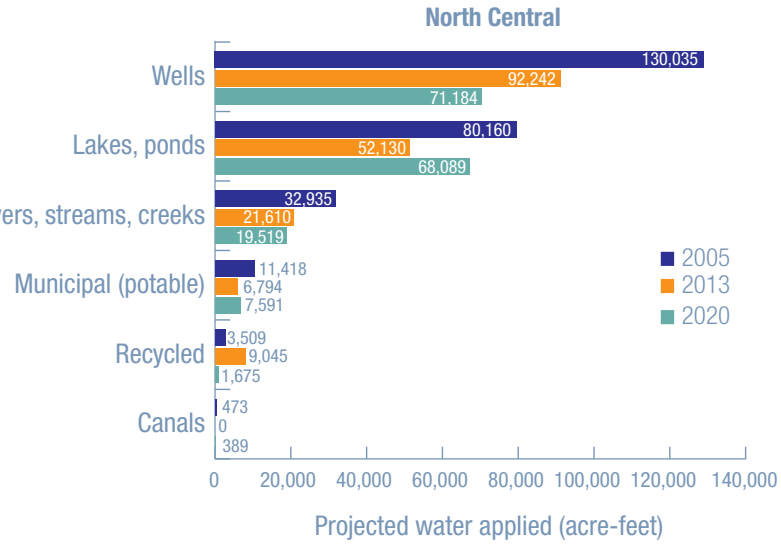


Figure 14. Projected water applied at U.S. golf facilities in the North Central region by water source in 2005, 2013, and 2020. Ref: Table 5

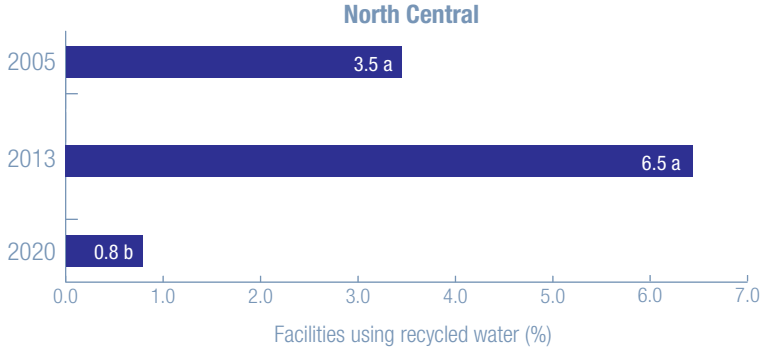


Figure 15. Percent of U.S. golf facilities in the North Central region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

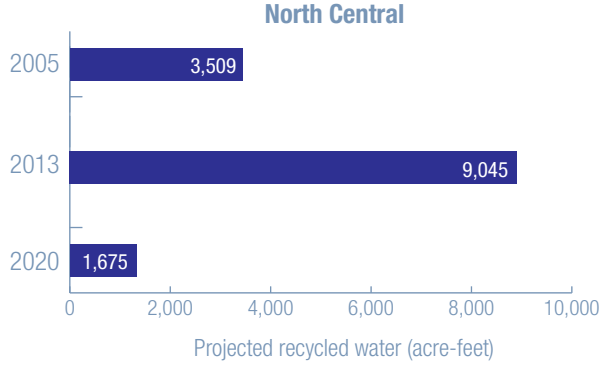


Figure 16. Projected recycled water applied to U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Ref: Table 3

ing turf drier, reducing irrigated acres, pruning tree roots, using rain shut off switches, and changing to drought-tolerant turfgrass (Table 11).

Regulations

- Required water use reporting increased to 68%, recurring annual allocations increased to 21%, and additional mandatory water restrictions was 3% and was equivalent to 2005 (Table 14).
- The prevalence of facilities that have a written drought, water management, stormwater, or preventative irrigation maintenance plan was 19%, 7%, 11%, and 10%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 88% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 86% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 35% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water and that tested their surface water were 93% and 26%, respectively, and has not changed since 2005 (Table 21).
- Among facilities that tested surface water, 83% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 79% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 75% tested for nutrients, which was the most common variable tested (Table 24).
- The prevalence of facilities that had ground water wells and that tested their ground water both declined since 2005 to 66% and 37%, respectively (Table 25).
- Among facilities that tested ground water, 100% had 1 or more ground

water monitoring sites (Table 26).

- Among facilities that tested ground water, 84% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 43% tested once per year with the remaining facilities testing more frequently, and 45% testing every 3 months (Table 28).
- Among facilities that tested ground water, 75% tested for bacteria, whereas 54% tested for nutrients, which were the most common and second most common variables tested (Table 29).
- Among facilities that tested ground water, 35% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation reached a low of one inch in the winter months of December, January, and February and peaked at 4 inches in June (Figure 19).
- The lowest average monthly temperature was 19° F in December and January and reached a peak of 70° F in July (Figure 20).
- Growing degree days were zero starting in December and remained until March. A maximum growing degree days of 680 occurred in July (Figure 21).
- The greatest gap between growing degree days and precipitation occurred in July when 171 degree days was accompanied by 1 inch of rainfall (Figure 22 and Table 34). This ratio was similar to the Northeast, Southeast, and Transition regions and indicates that turfgrass growing in the North Central region may experience minor heat and moisture related stress and may not require as much supplemental irrigation as turfgrass growing in the Pacific, Southwest, or Upper West/Mountain regions.

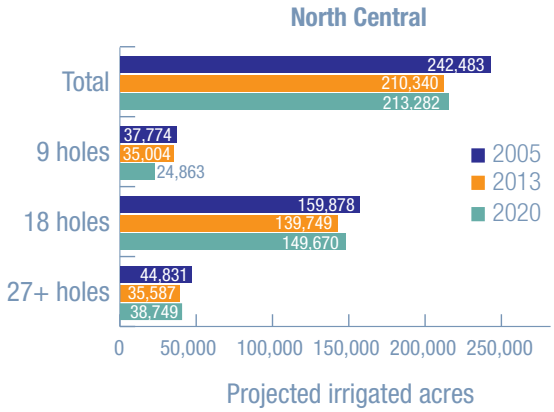


Figure 17. Projected irrigated acres of U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Ref: Table 4

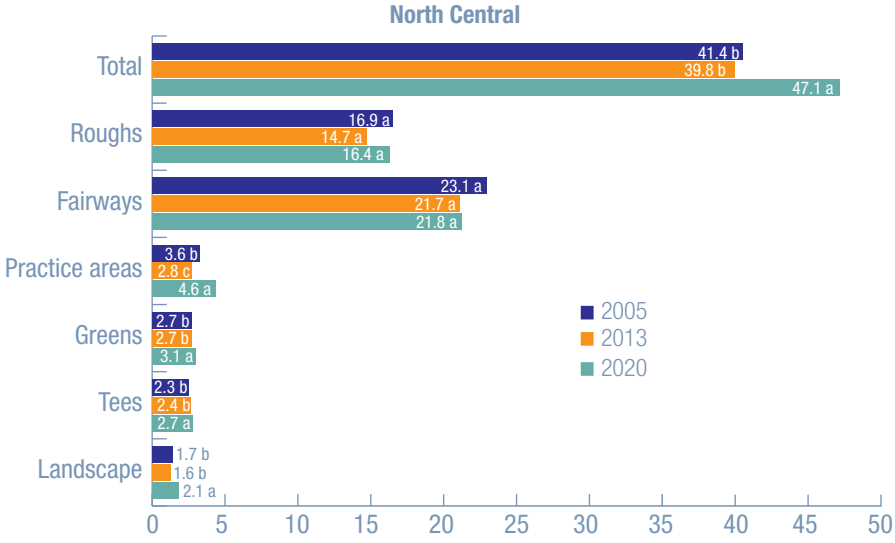


Figure 18. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the North Central region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

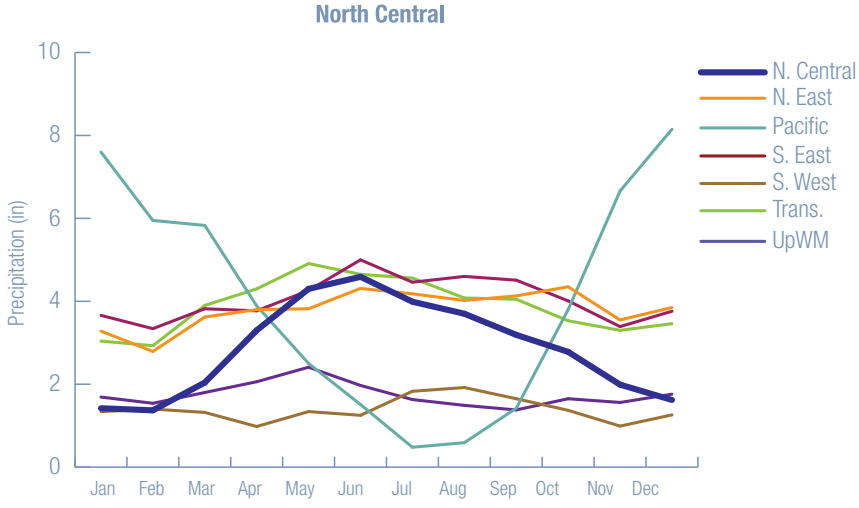


Figure 19. 30-yr monthly average precipitation in the North Central region.

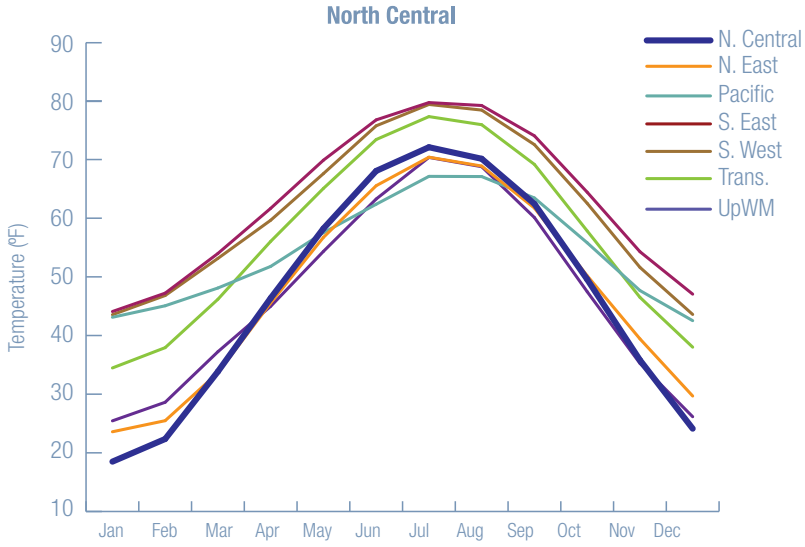


Figure 20. 30-yr monthly average temperature in the North Central region.

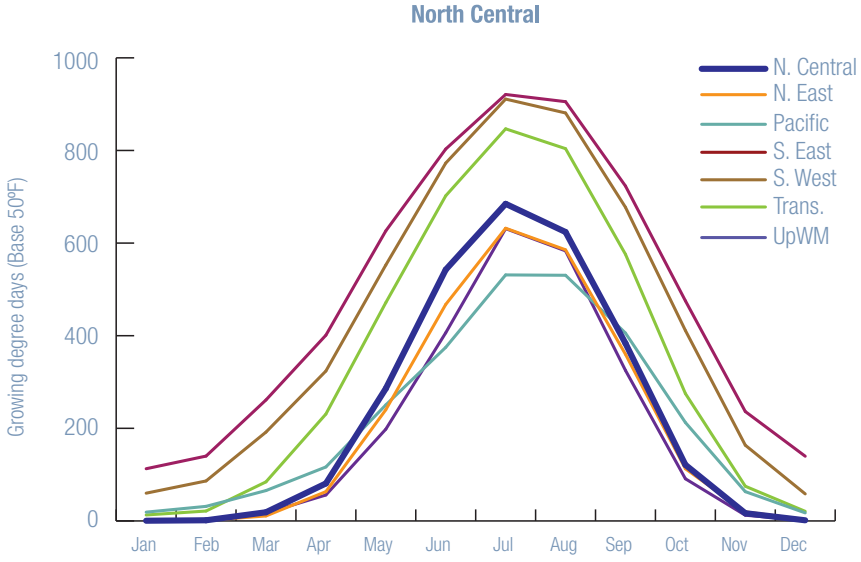


Figure 21. 30-yr monthly average growing degree days in the North Central region. (Growing degree days are calculated by subtracting the base temperature from the average daily temperature.).

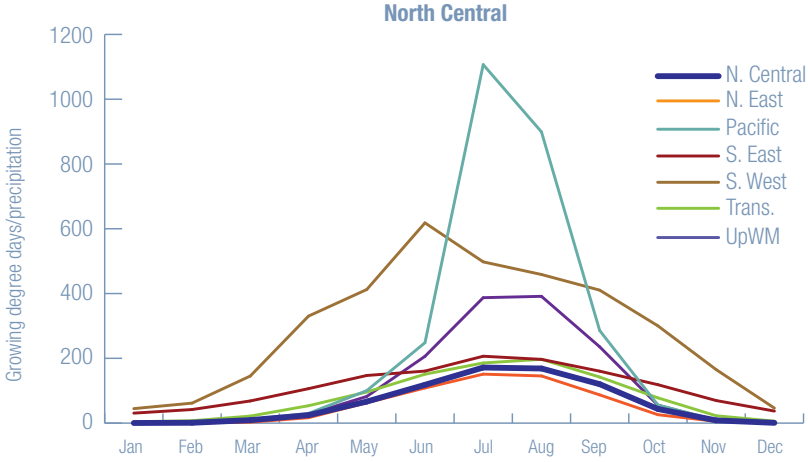


Figure 22. 30-yr monthly average growing degree days/precipitation in the North Central region.

Northeast Region

Water Use

- Projected applied water was 18% less in 2020 than in 2005, resulting in a water savings of 21,087 acre-feet (Figure 23).
- Median applied water per facility was 29.0 acre-feet in 2020 and was equivalent to 2005 (Figure 24).
- Median applied water per acre declined from 0.74 in 2005 to 0.64 in 2020, a 14% reduction (Figure 25).

Water Sources

- In 2020, 32% of projected applied water was sourced from lakes and ponds and 32% was sourced from wells (Figure 26).
- In 2020, 2% of projected applied water was sourced from recycled water (Figure 26).
- The percentage of facilities using recycled water was 2.6% in 2020, which was equivalent to 2005 (Figure 27).
- Projected recycled water applied reduced from 2,082 acre-feet in 2005 to 1,898 acre-feet in 2020, a 9% reduction (Figure 28).

Irrigated Acres

- Projected irrigated acres increased by 3% from 136,252 acres in 2005 to 139,952 acres in 2020 (Figure 29).
- Irrigated acres at 9-hole facilities decreased by 31%, whereas irrigated acres at 18-, and 27+-hole facilities increased by 10% and 3%, respectively (Figure 29).
- Median irrigated acres were 37.6 in 2020 and were equivalent to 2005 (Figure 30 and Table 8).
- Median irrigated acres of roughs, greens, and landscape increased since 2005, but the median irrigated acres of fairways, practice areas, and tees did not change since 2005 (Figure 30 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 10% to 2,482 (Table 9).

Management Practices

- The frequency of some management

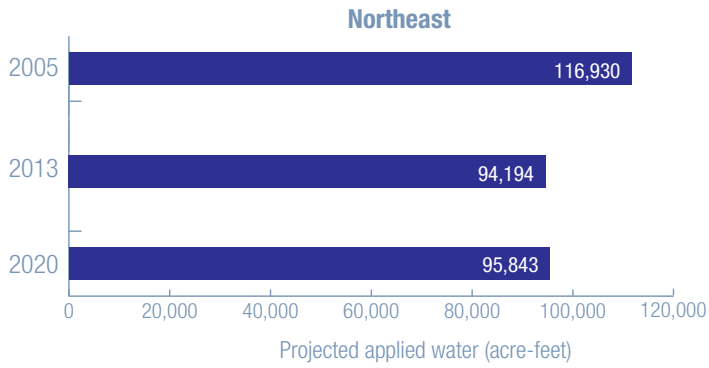


Figure 23. Projected water applied to U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Ref: Table 1

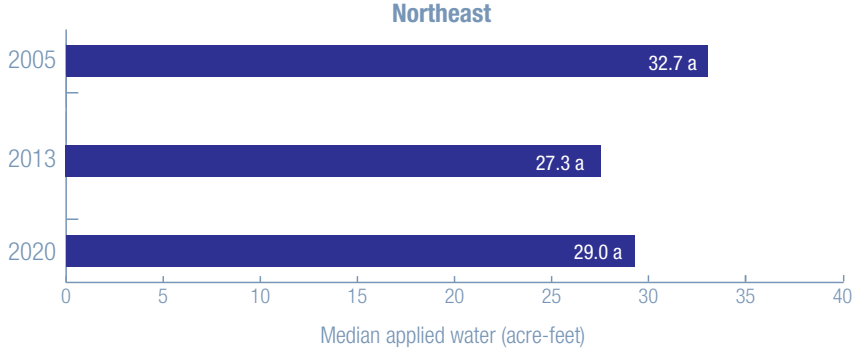


Figure 24. Median acre-feet of applied water on U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

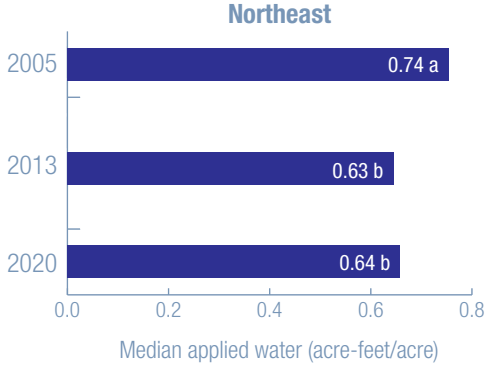


Figure 25. Median acre-feet per acre of applied water on U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

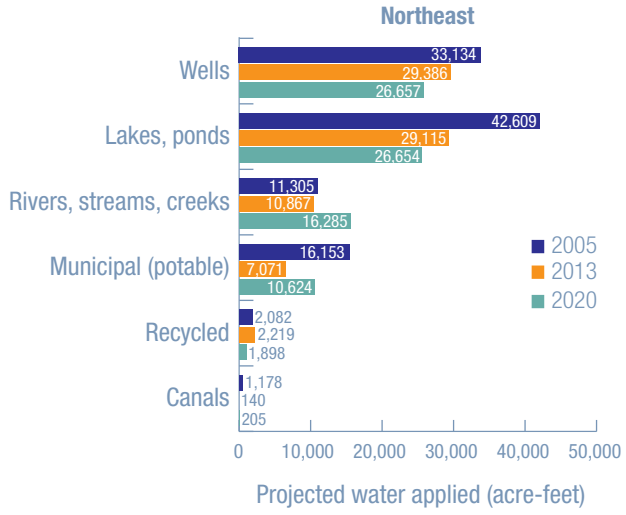


Figure 26. Projected water applied at U.S. golf facilities in the Northeast region by water source in 2005, 2013, and 2020. Ref: Table 5

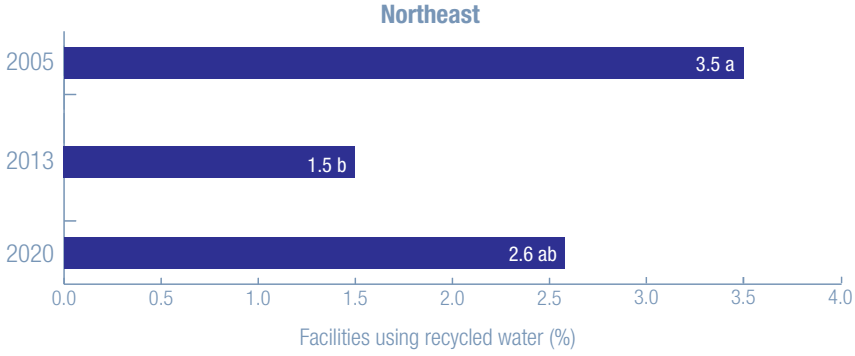


Figure 27. Percent of U.S. golf facilities in the Northeast region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

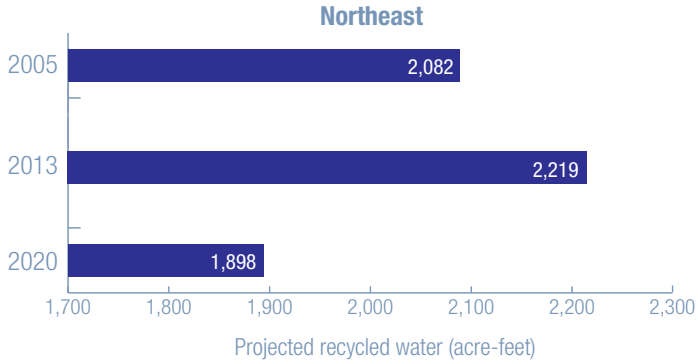


Figure 28. Projected recycled water applied to U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Ref: Table 3

practices has increased but many remained unchanged since 2005. Some notable increases included hand-watering, use of soil amendments, reducing irrigated acres, pruning tree roots, using rain shut-off switches, and changing to drought-tolerant turfgrass (Table 11).

Regulations

- Required water use reporting increased to 64%, recurring annual allocations increased to 32%, and additional mandatory water restrictions decreased from 29% to 6% since 2005 (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 20%, 19%, 12%, and 17%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 97% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 85% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 33% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water and that tested their surface water were 95% and 28%, respectively, and has not changed since 2005 (Table 21).
- Among facilities that tested surface water, 66% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 88% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 82% tested for nutrients, which was the most common tested variable (Table 24).

- The prevalence of facilities that had ground water wells was 67% and did not change since 2005, but those that tested their ground water declined to 48% (Table 25).
- Among facilities that tested ground water, 100% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 83% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 44% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 72% tested for nutrients, which was the most common tested variable (Table 29).
- Among facilities that tested ground water, 44% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation remained relatively constant throughout the year ranging from 2.8 to 4.3 inches per month and was similar to the Southeast and Transition regions (Figure 31).
- Average monthly temperature was similar to the Upper West/Mountain and North Central regions ranging from 23° F in January to 70° F in July (Figure 32).
- Growing degree days were zero starting in December and remained until March. A maximum growing degree days of 630 occurred in July (Figure 33).
- The greatest gap between growing degree days and precipitation occurred in July when 151 degree days was accompanied by 1 inch of rainfall (Figure 34 and Table 34). This ratio was similar to the North Central, Southeast, and Transition regions and indicates that turfgrass growing in the Northeast region may experience minor heat and moisture related stress and may not require as much supplemental irrigation as turfgrass growing in the Pacific, Southwest, or Upper West/Mountain regions.

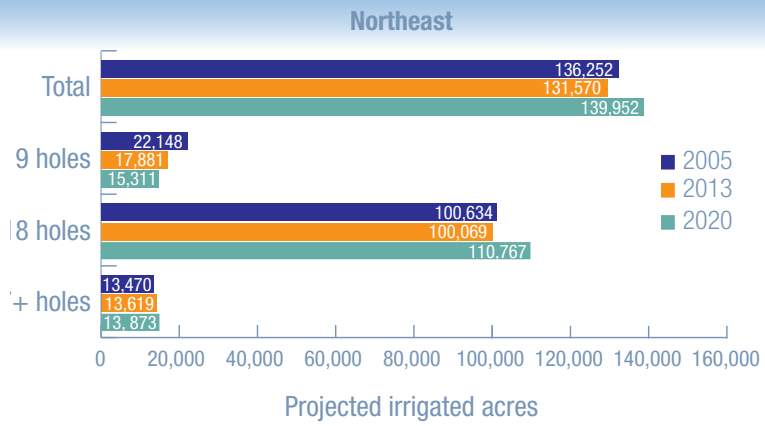


Figure 29. Projected irrigated acres of U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Ref: Table 4

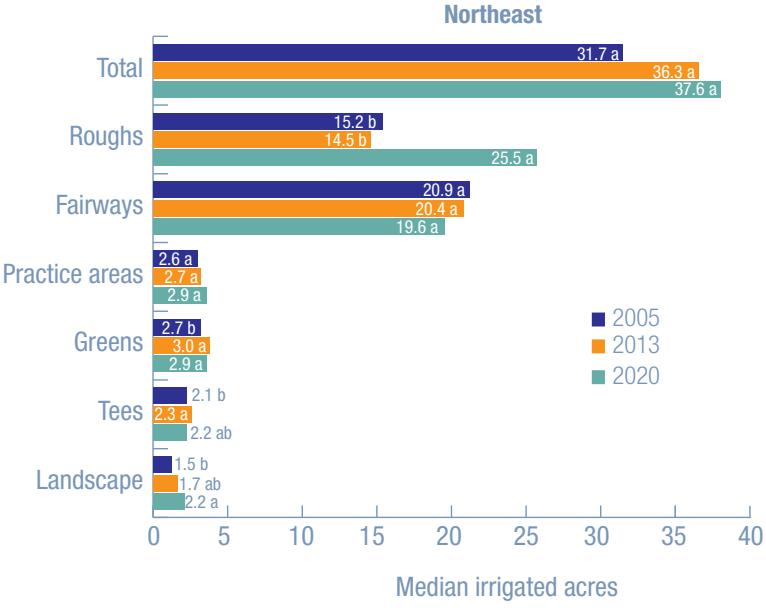


Figure 30. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Northeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

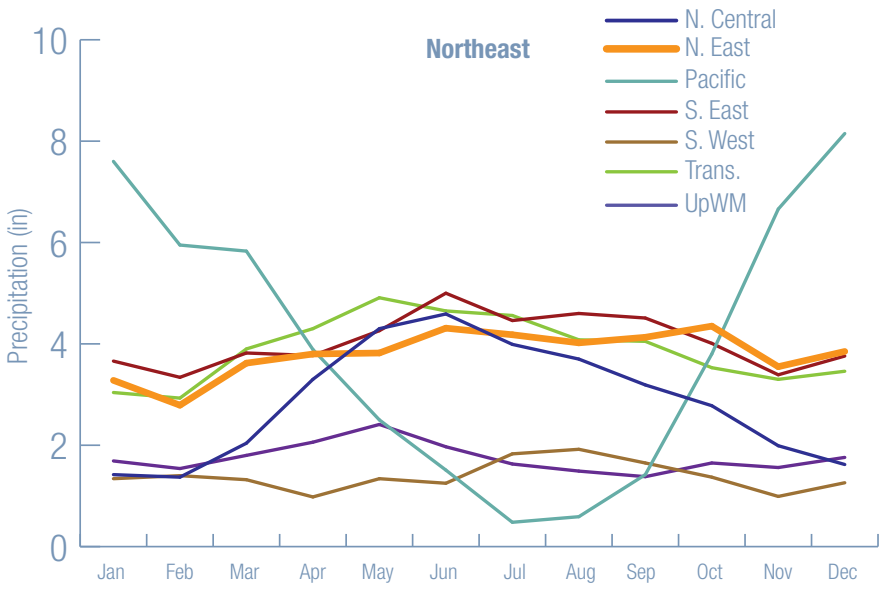


Figure 31. 30-yr monthly average precipitation in the Northeast region.

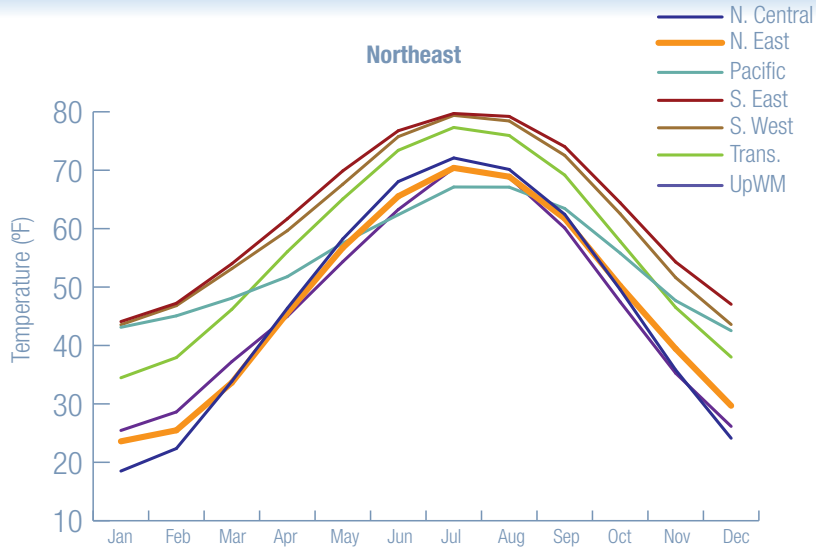


Figure 32. 30-yr monthly average temperature in the Northeast region.

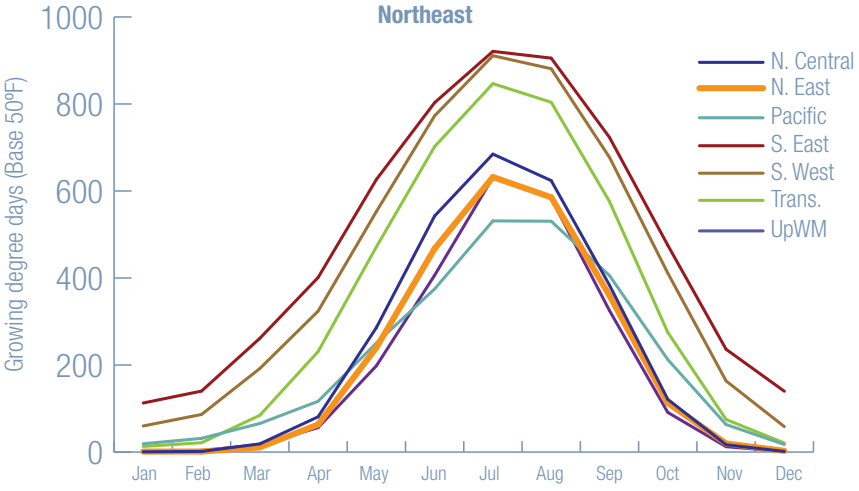


Figure 33. 30-yr monthly average growing degree days in the Northeast region.

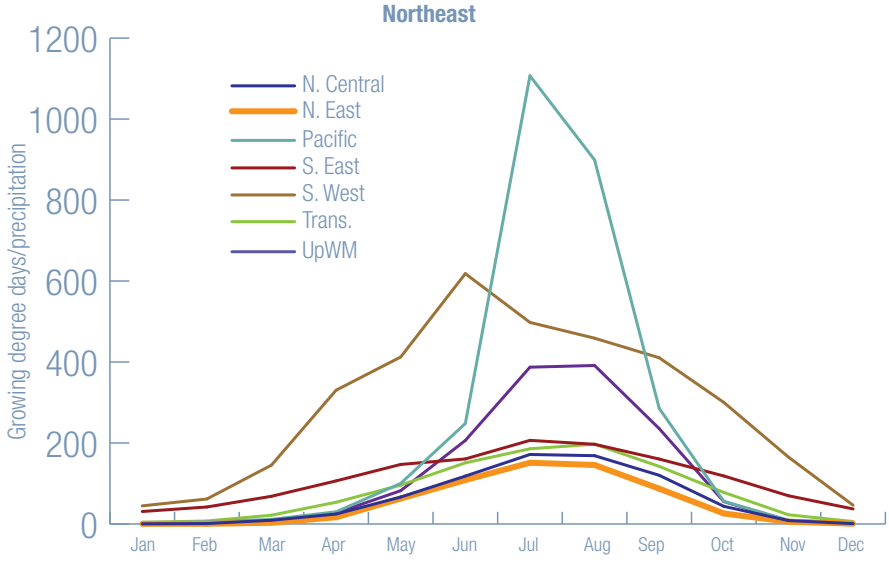


Figure 34. 30-yr monthly average growing degree days/precipitation in the Northeast region.

Pacific Region

Water Use

- Projected applied water was 33% less in 2020 than in 2005, resulting in a water savings of 35,313 acre-feet (Figure 35).
- Median applied water per facility declined from 114.8 acre-feet in 2005 to 68.4 acre-feet in 2020, a 40% reduction (Figure 36).
- Median applied water per acre declined from 1.66 in 2005 to 1.07 in 2020, a 36% reduction (Figure 37).

Water Sources

- In 2020, 26% of projected applied water was sourced from wells and 22% was sourced from municipal water (Figure 38).
- In 2020, 13% of projected applied water was sourced from recycled water (Figure 38).
- The percentage of facilities using recycled water was 16.5% in 2020, which was equivalent to 2005 (Figure 39).
- Projected recycled water applied decreased from 10,253 acre-feet in 2005 to 7,858 acre-feet in 2020, a 23% reduction (Figure 40).

Irrigated Acres

- Projected irrigated acres decreased by 15% from 52,249 acres in 2005 to 44,529 acres in 2020 (Figure 41).
- Irrigated acres at 27+-hole facilities slightly increased (0.7%) from 2005 to 2020, whereas irrigated acres at 9-, and 18-hole facilities declined by 36% and 11%, respectively (Figure 41).
- Median irrigated acres were 62.2 in 2020 and were equivalent to 2005 (Figure 42 and Table 8).
- Median irrigated acres of roughs, fairways, and practice areas did not change since 2005, but the median irrigated acres of greens, tees, and landscape all increased since 2005 (Figure 42 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 13% to 571 (Table 9).

Management Practices

- The frequency of some management practices has increased but many

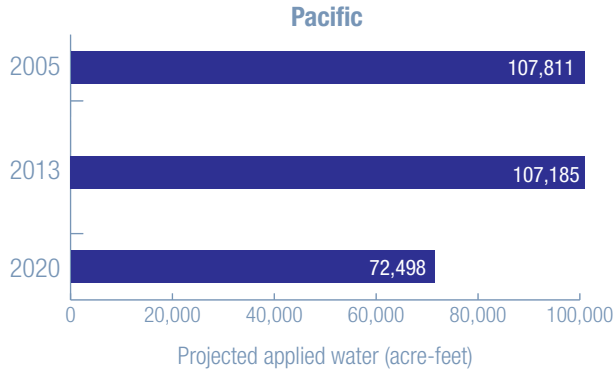


Figure 35. Projected water applied to U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Ref: Table 1

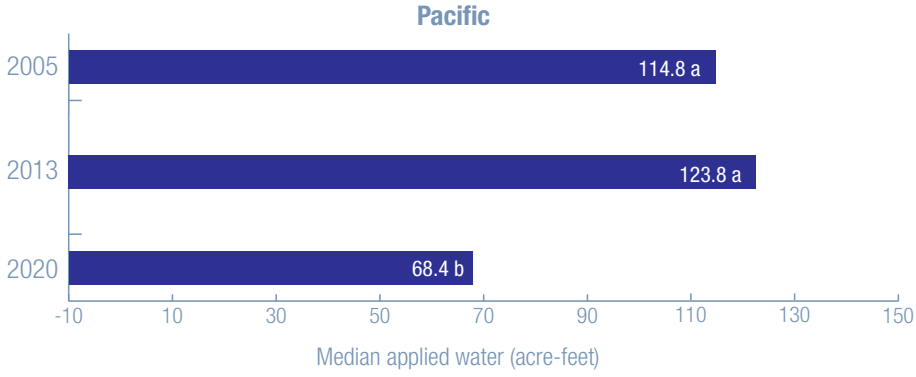


Figure 36. Median acre-feet of applied water on U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

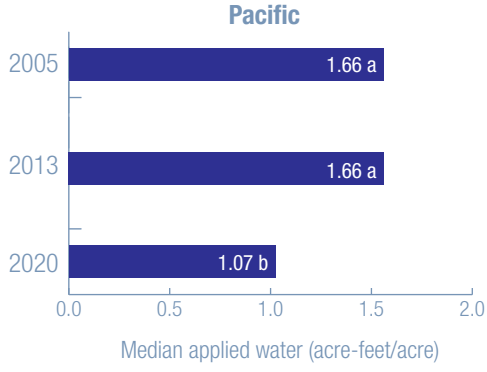


Figure 37. Median acre-feet per acre of applied water on U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

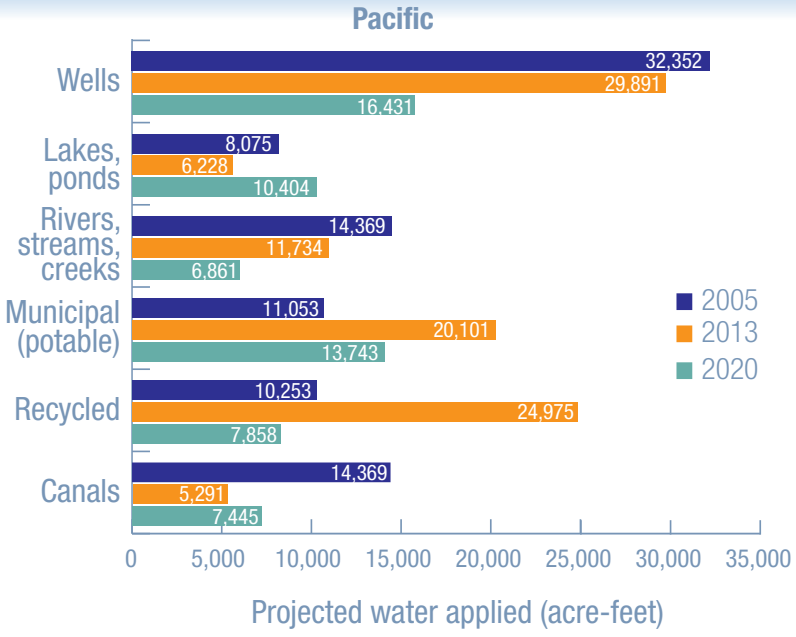


Figure 38. Projected water applied at U.S. golf facilities in the Pacific region by water source in 2005, 2013, and 2020. Ref: Table 5

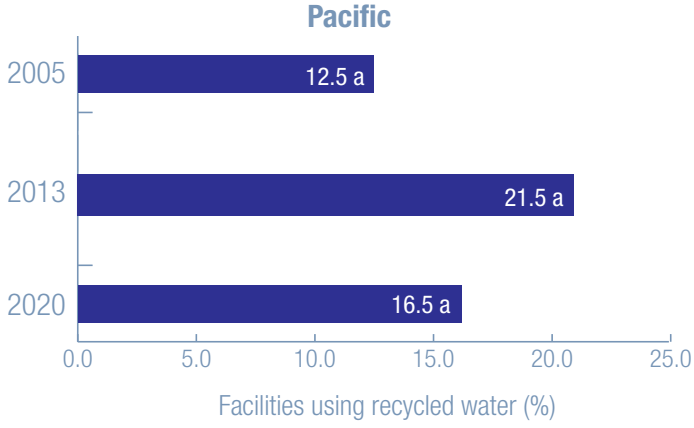


Figure 39. Percent of U.S. golf facilities in the Pacific region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

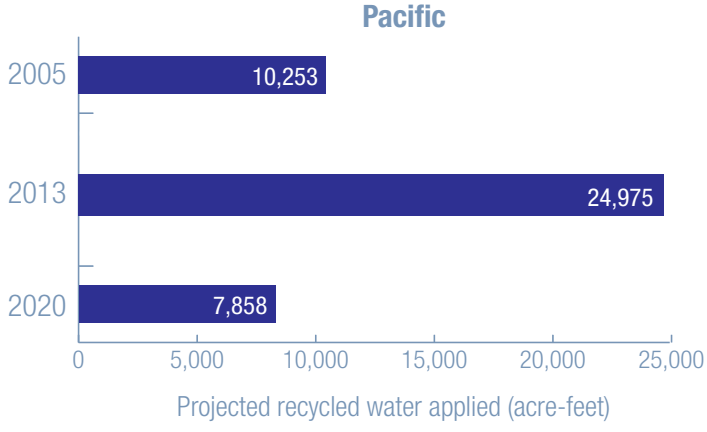


Figure 40. Projected recycled water applied to U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Ref: Table 3

remained unchanged since 2005. Some notable increases included using wetting agents, hand-watering, adjusting fertilizer practices, and reducing irrigated acres (Table 11).

Regulations

- Required water use reporting and recurring annual allocations remained unchanged since 2005, whereas additional mandatory water restrictions increased from 2 to 18% between 2005 and 2020 (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 18%, 15%, 17%, and 16%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 89% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 89% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 26% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water remained the same as 2005 at 86%, but those that tested their surface water decreased to 27% (Table 21).
- Among facilities that tested surface water, 70% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 91% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 75% tested for nutrients, which was the most common tested variable (Table 24).
- The prevalence of facilities that had ground water wells was 64% and did not change since 2005, but those that

tested their ground water declined to 24% (Table 25).

- Among facilities that tested ground water, 89% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 63% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 54% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 63% tested for nutrients, which was the most common tested variable (Table 29).
- Among facilities that tested ground water, 55% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation was inverse of most other regions and varied greatly throughout the year with a maximum precipitation of 8 inches occurring in December and January and the minimum of less than 0.5 inches occurring in July (Figure 43).
- Average monthly temperatures varied the least among regions with maximum and minimum monthly averages of 67° F and 42° F occurring in July and December, respectively (Figure 44).
- Growing degree days were the least among regions, were zero in January and December, and were maximized at 530 in July (Figure 45).
- The greatest gap between growing degree days and precipitation occurred in July when 1,106 degree days was accompanied by 1 inch of rainfall (Figure 46 and Table 34). This ratio was greater than all other regions and indicates that turfgrass growing in the Pacific region may experience significant heat and moisture related stress and may require greater supplemental irrigation than turfgrass growing in other regions.

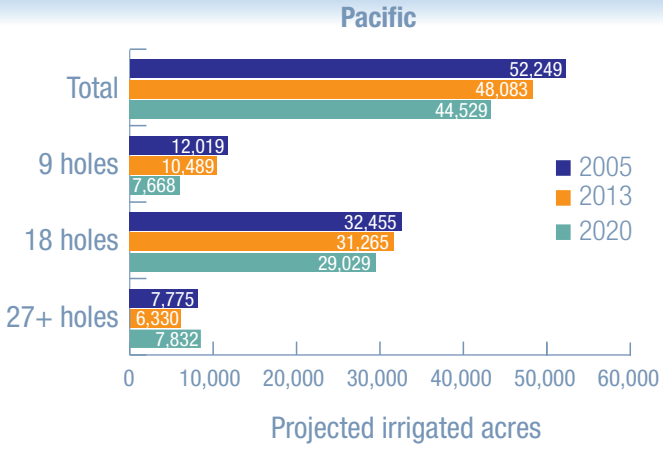


Figure 41. Projected irrigated acres of U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Ref: Table 4

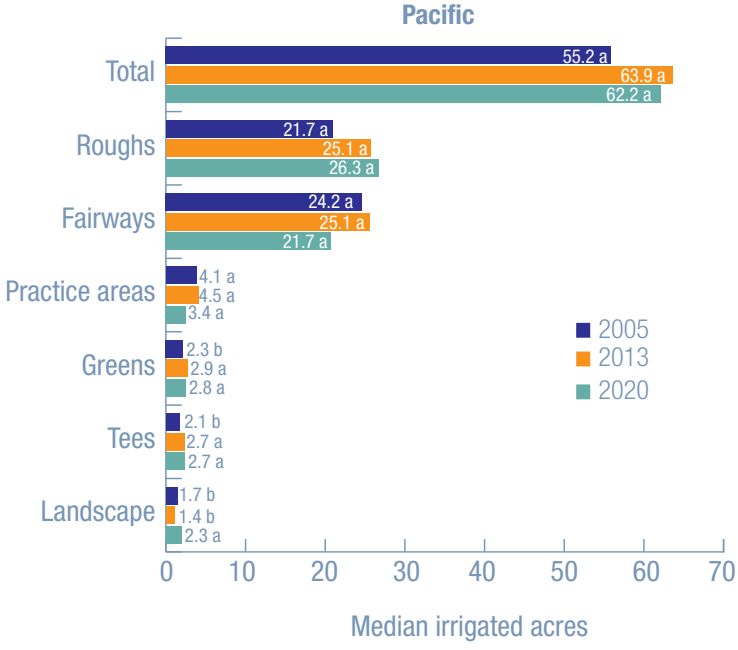


Figure 42. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Pacific region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

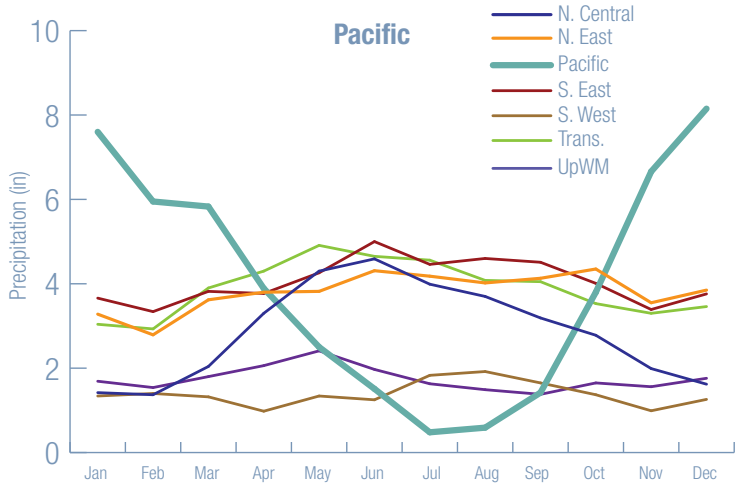


Figure 43. 30-yr monthly average precipitation in the Pacific region.

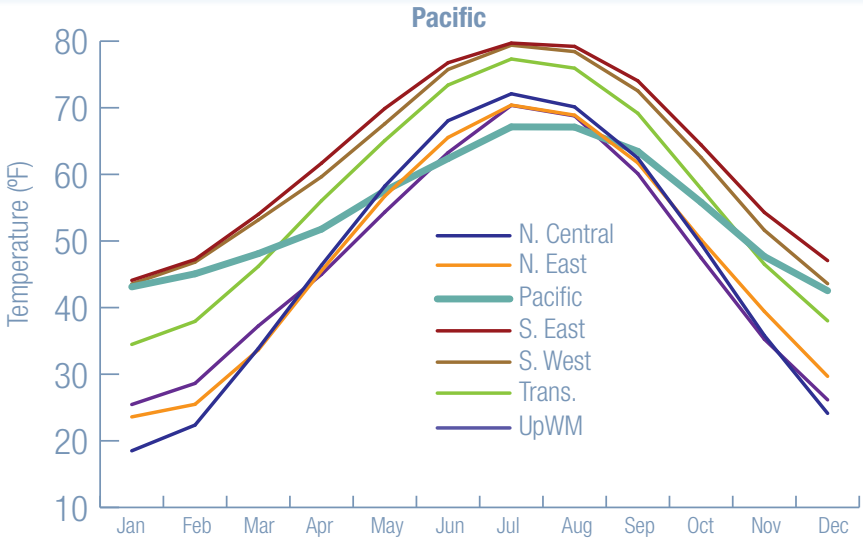


Figure 44. 30-yr monthly average temperature in the Pacific region.

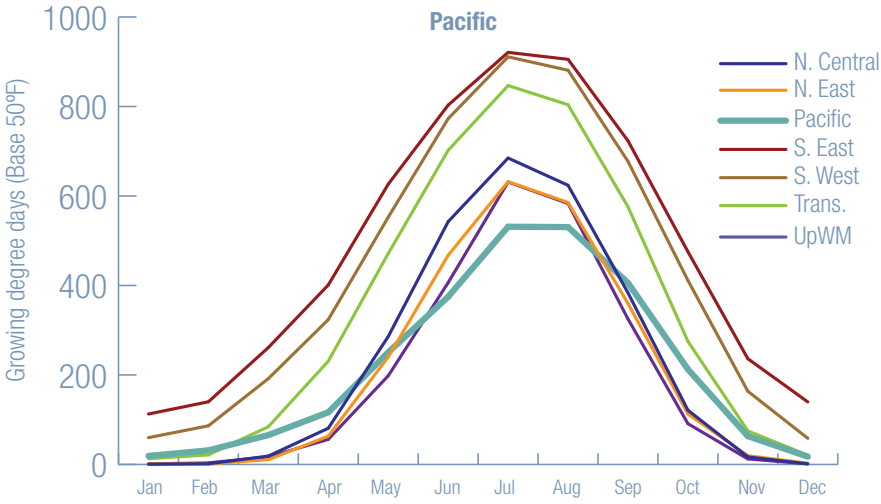


Figure 45. 30-yr monthly average growing degree days in the Pacific region.

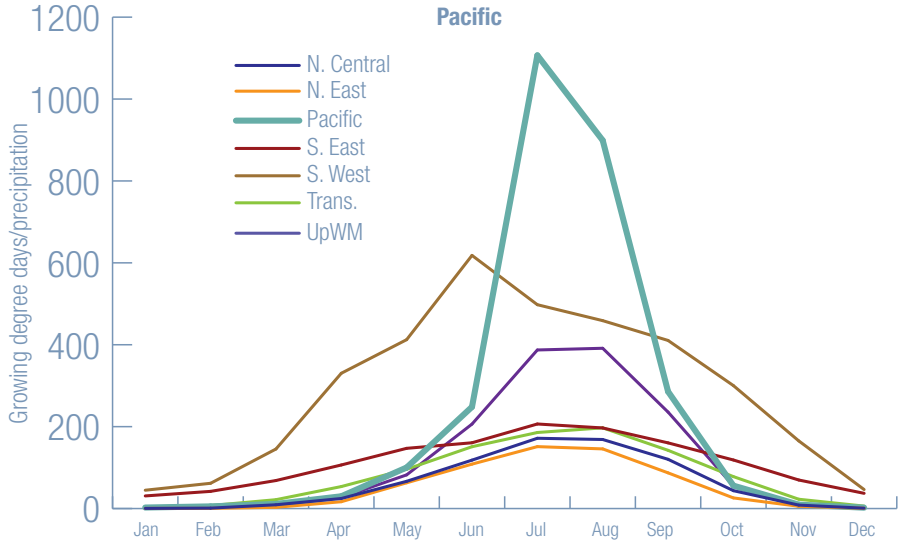


Figure 46. 30-yr monthly average growing degree days/precipitation in the Pacific region.

Southeast Region

Water Use

- Projected applied water was 46% less in 2020 than in 2005, resulting in a water savings of 412,545 acre-feet (Figure 47).
- Median applied water per facility declined from 194.8 acre-feet in 2005 to 111.1 acre-feet in 2020, a 43% reduction (Figure 48).
- Median applied water per acre declined from 2.00 in 2005 to 1.21 in 2020, a 40% reduction (Figure 49).

Water Sources

- In 2020, 34% of projected applied water was sourced from lakes and ponds and 30% was sourced from wells (Figure 50).
- In 2020, 28% of projected applied water was sourced from recycled water (Figure 50).
- The percentage of facilities using recycled water was 27.2% in 2020, which was equivalent to 2005 (Figure 51).
- Projected recycled water applied reduced from 145,611 acre-feet in 2005 to 139,733 acre-feet in 2020, a 4% reduction (Figure 52).

Irrigated Acres

- Projected irrigated acres decreased by 15% from 319,600 acres in 2005 to 271,760 acres in 2020 (Figure 53).
- Irrigated acres at 27+-hole facilities increased by 15% from 2005 to 2020, whereas irrigated acres at 9-, and 18-hole facilities declined by 22% and 15%, respectively (Figure 53).
- Median irrigated acres were 87.5 in 2020 and were equivalent to 2005 (Figure 54 and Table 8).
- Median irrigated acres of roughs, greens, tees, and landscape did not change since 2005, the median irrigated acres of fairways decreased by 12%, and the median irrigated acres of practice areas increased 13% since 2005 (Figure 54 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 15% to 2,766 (Table 9).

Management Practices

- The frequency of some manage-

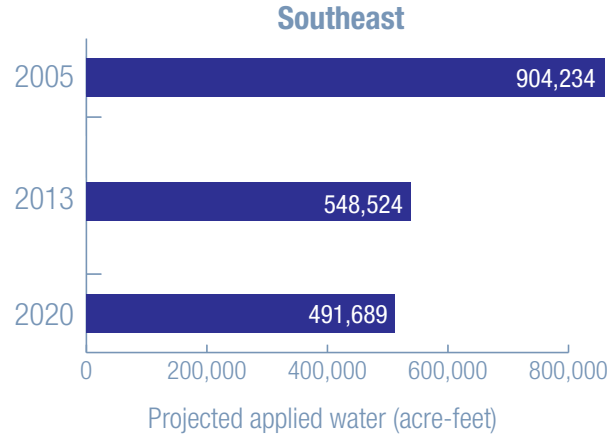


Figure 47. Projected water applied to U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Ref: Table 1

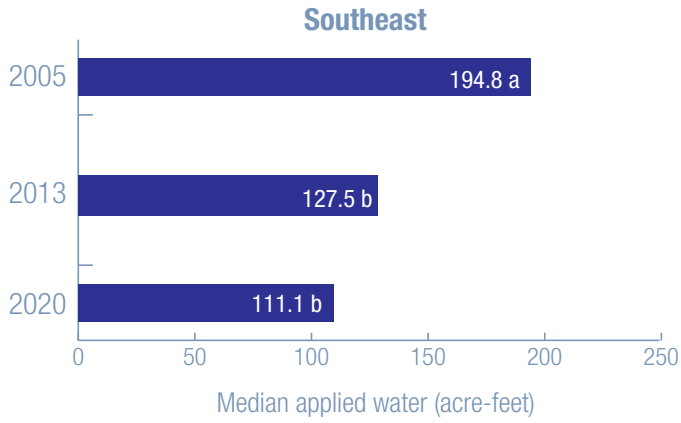


Figure 48. Median acre-feet of applied water on U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

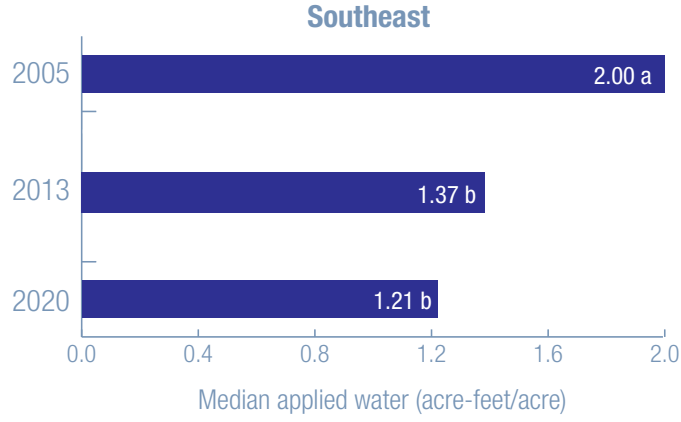


Figure 49. Median acre-feet per acre of applied water on U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

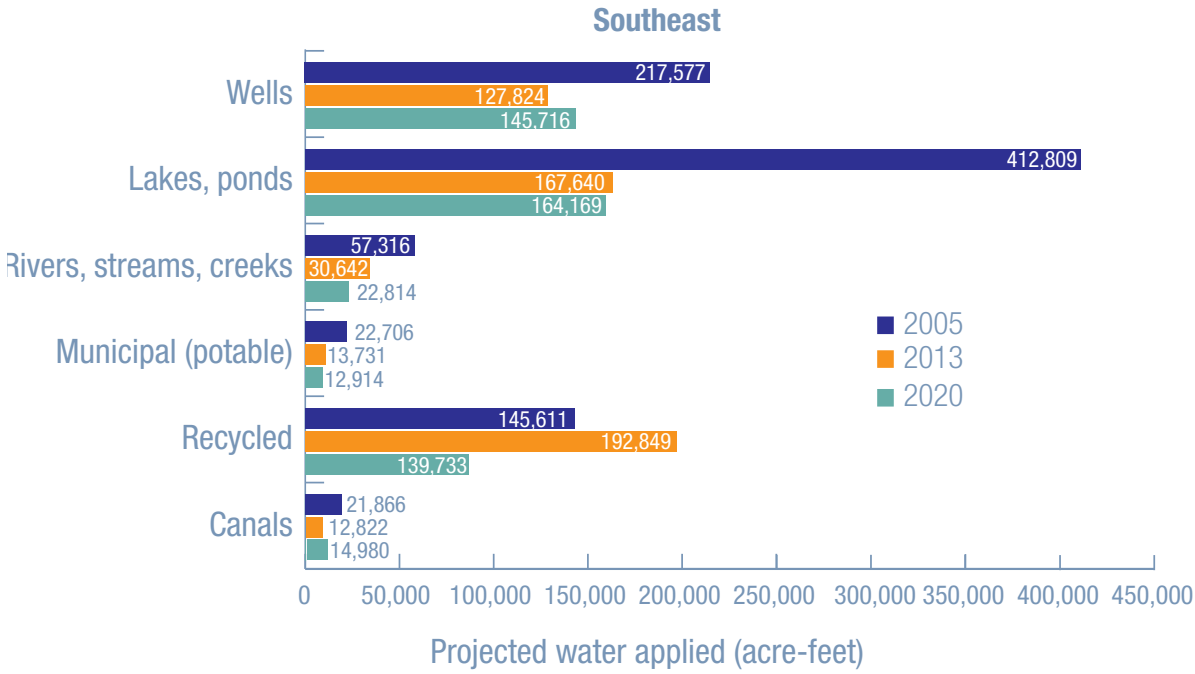


Figure 50. Projected water applied at U.S. golf facilities in the Southeast region by water source in 2005, 2013, and 2020. Ref: Table 5

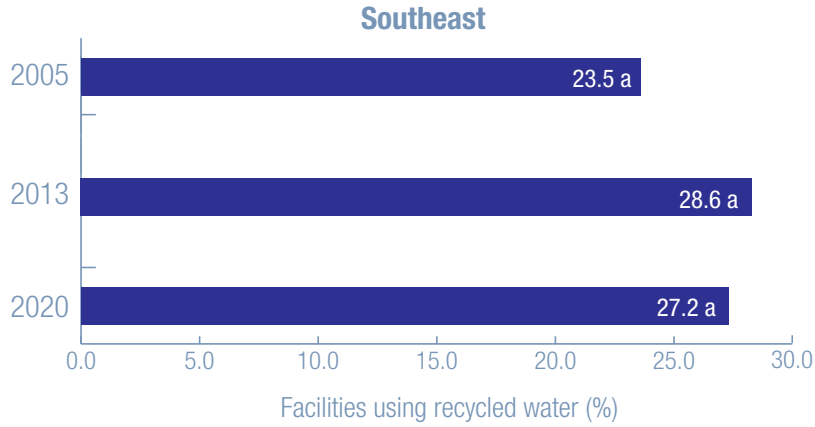


Figure 51. Percent of U.S. golf facilities in the Southeast region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

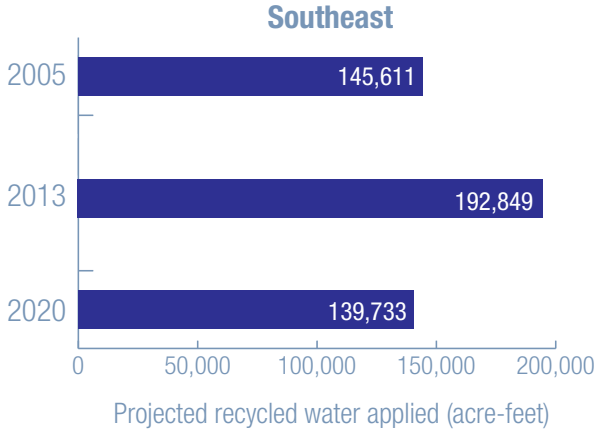


Figure 52. Projected recycled water applied to U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Ref: Table 3

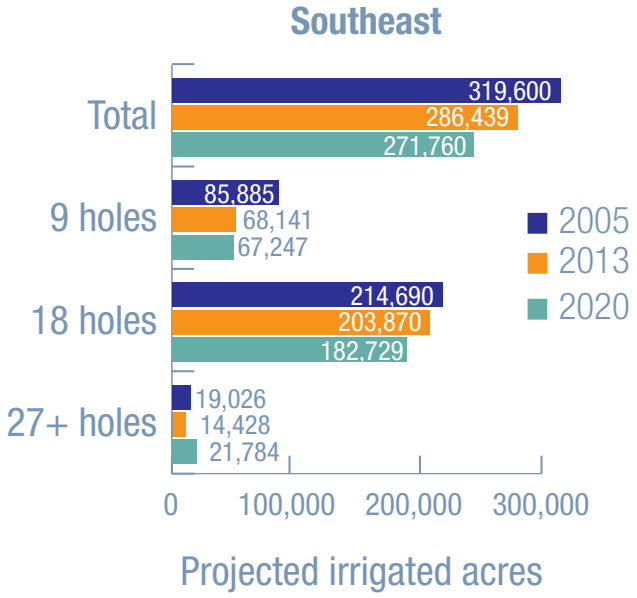


Figure 53. Projected irrigated acres of U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Ref: Table 4

ment practices has increased but most remained unchanged since 2005. Some notable increases included using wetting agents, soil amendments, pruning tree roots, and changing to drought-tolerant turfgrass (Table 11).

Regulations

- Required water use reporting and recurring annual allocations remained unchanged since 2005, whereas additional mandatory water restriction decreased to 10% (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 29%, 17%, 22%, and 22%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive

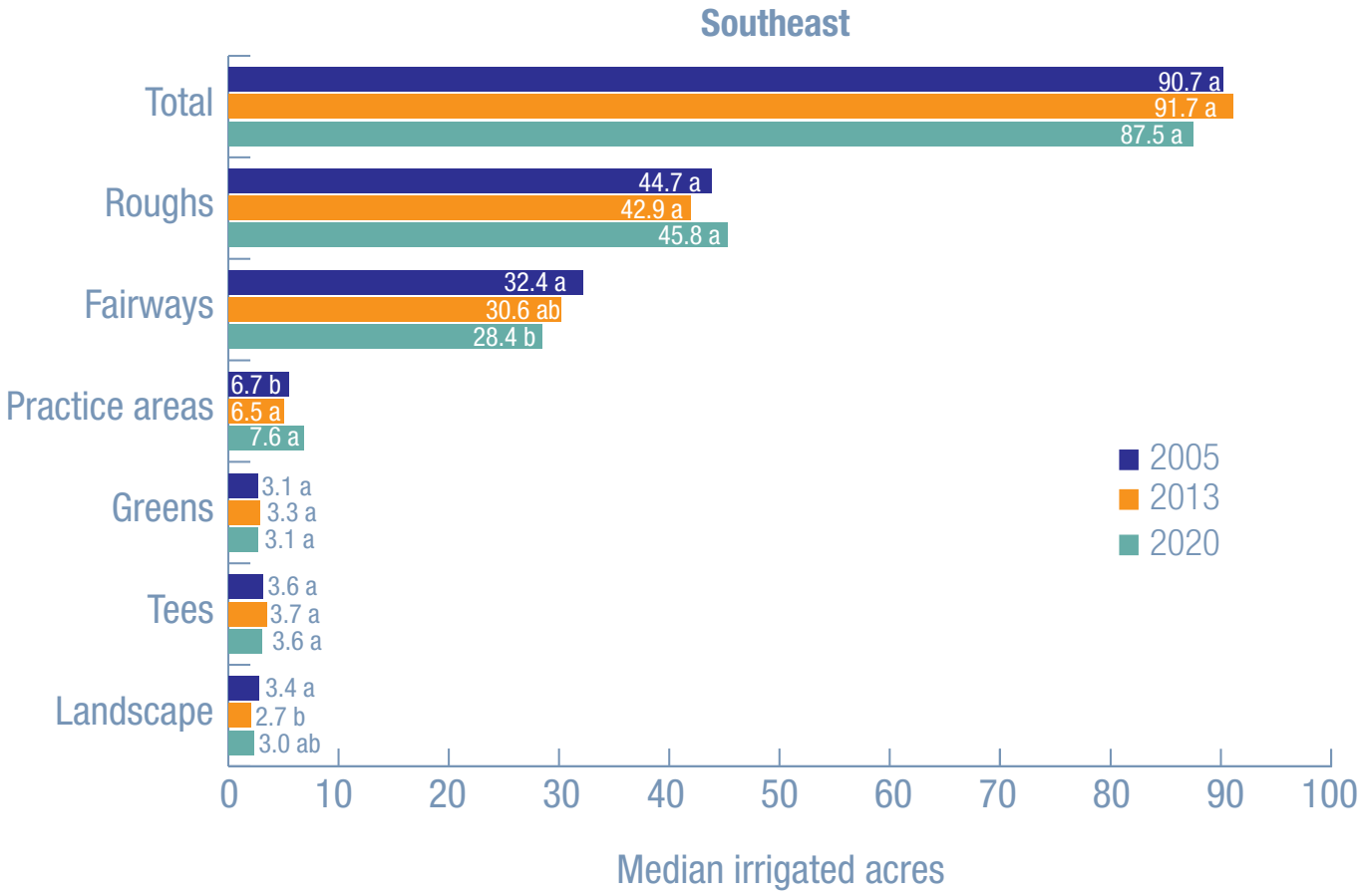


Figure 54. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Southeast region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

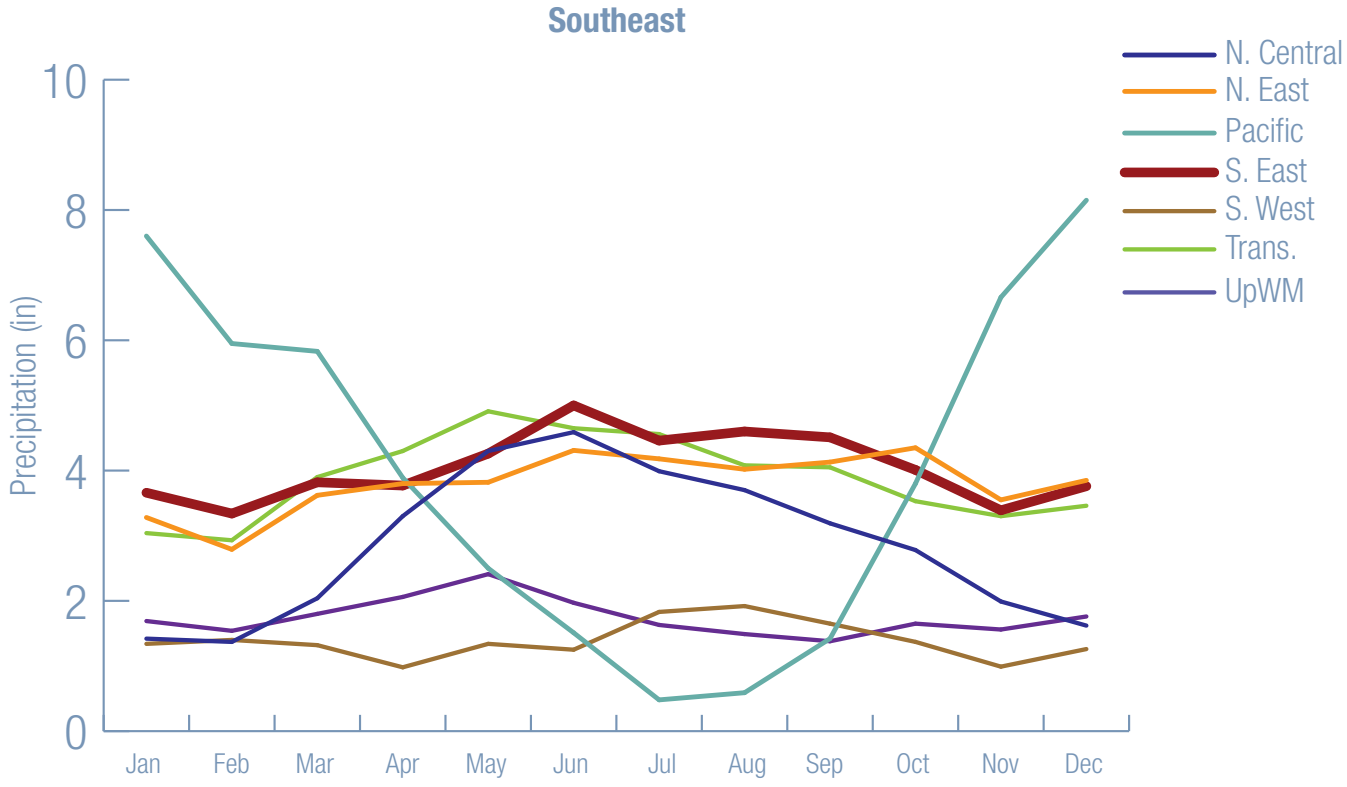


Figure 55. 30-yr monthly average precipitation in the Southeast region.

impact on 92% of facilities in 2020 (Table 16).

- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 90% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 38% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water and that tested their surface water were 98% and 51%, respectively, and has not changed since 2005 (Table 21).
- Among facilities that tested surface water, 49% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 92% had 1 or more surface water monitoring sites (Table 23).

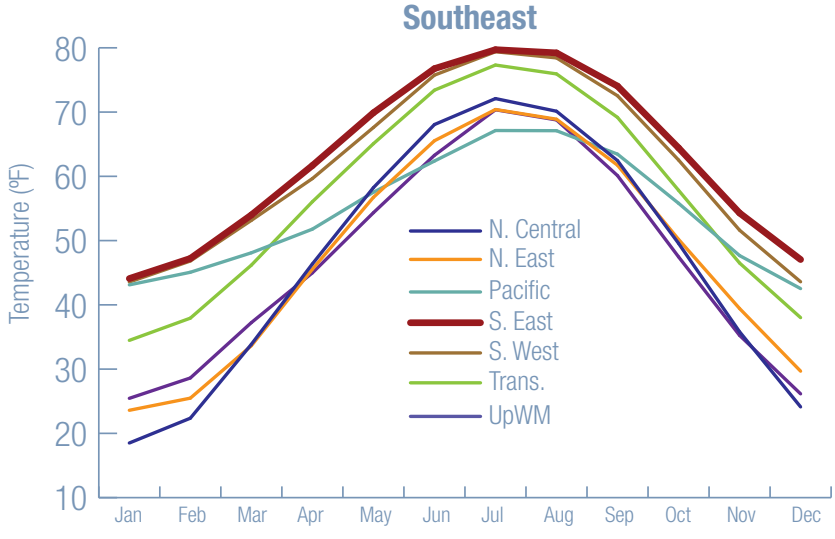


Figure 56. 30-yr monthly average temperature in the Southeast region.

- Among facilities that tested surface water, 79% tested for nutrients, which was the most common tested variable (Table 24).
- The prevalence of facilities that had ground water wells and that tested their ground water were 58% and 48%, respectively, and has not changed since 2005 (Table 25).
- Among facilities that tested ground water, 99% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 82% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 40% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 73% tested for nutrients, which was the most common tested variable (Table 29).
- Among facilities that tested ground water, 34% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation remained relatively constant throughout the year ranging from 3.3 to 4.5 inches per month and was similar to the Northeast and Transition regions (Figure 55).
- Average monthly temperatures were greater each month than in other regions and ranged from 44° F in January to 79° F in July (Figure 56).
- Growing degree days were greater each month than other regions ranging from 112 in January to 920 in July (Figure 57).
- The greatest gap between growing degree days and precipitation occurred in July when 206 degree days was accompanied by 1 inch of rainfall (Figure 58 and Table 34). This ratio was similar to the North Central, Northeast, and Transition regions and indicates that turfgrass growing in the Southeast region may experience heat and moisture related stress and may not require as much supplemental irrigation as turfgrass growing in the Pacific, Southwest, or Upper West/Mountain regions.

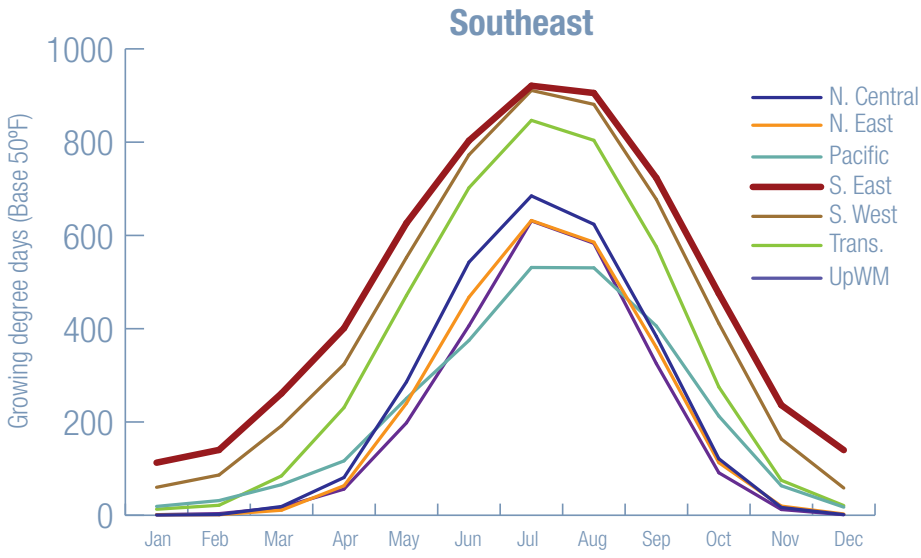


Figure 57. 30-yr monthly average growing degree days in the Southeast region.

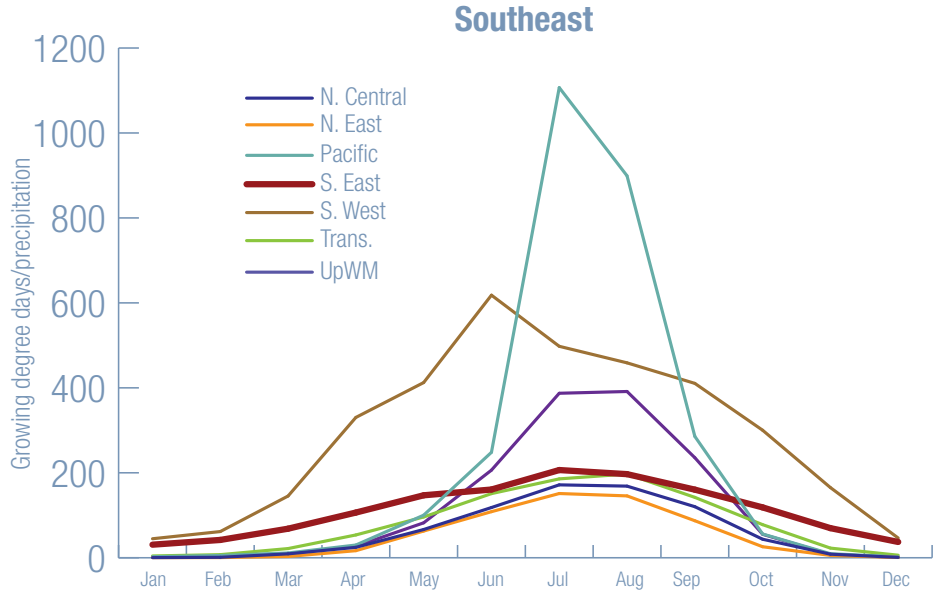


Figure 58. 30-yr monthly average growing degree days/precipitation in the Southeast region.

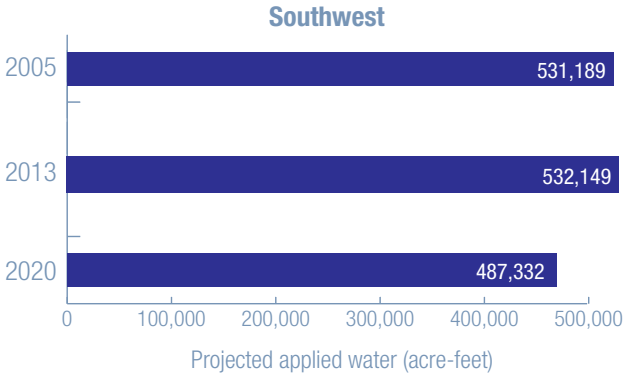


Figure 59. Projected water applied to U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Ref: Table 1

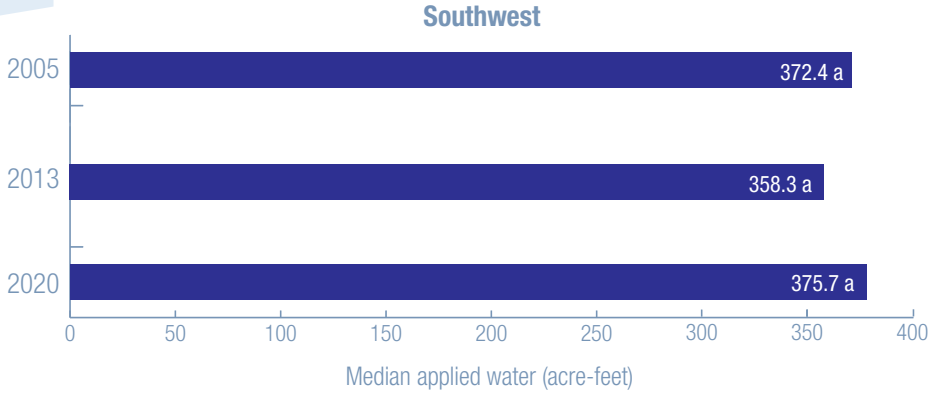


Figure 60. Median acre-feet of applied water on U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

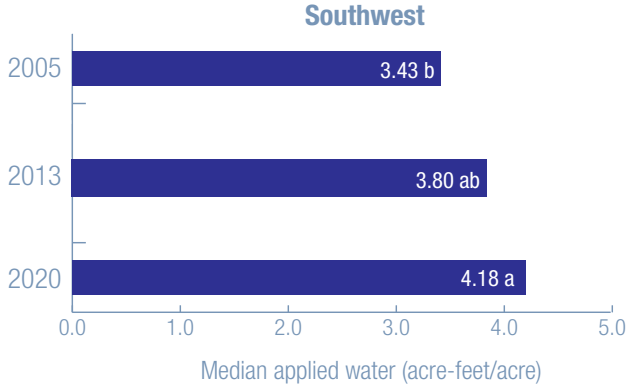


Figure 61. Median acre-feet per acre of applied water on U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

Southwest Region

Water Use

- Projected applied water was 8% less in 2020 than in 2005, resulting in a water savings of 43,857 acre-feet (Figure 59).
- Median applied water per facility was 357.7 acre-feet in 2020 and was equivalent to 2005 (Figure 60).
- Median applied water per acre increased from 3.43 in 2005 to 4.18 in 2020, a 22% increase (Figure 61).

Water Sources

- In 2020, 34% of projected applied water was sourced from wells and 15% was sourced from municipal water (Figure 62).
- In 2020, 33% of projected applied water was sourced from recycled water (Figure 62).
- The percentage of facilities using recycled water was 39.9% in 2020, which was equivalent to 2005 (Figure 63).
- Projected recycled water applied increased from 151,653 acre-feet in 2005 to 164,937 acre-feet in 2020, a 9% increase (Figure 64).

Irrigated Acres

- Projected irrigated acres declined by 22% from 136,321 acres in 2005 to 107,006 acres in 2020 (Figure 65).
- Irrigated acres at 9-, 18-, and 27+-hole facilities declined by 20%, 22%, and 17%, respectively (Figure 65).
- Median irrigated acres were 91.4 in 2020 and were equivalent to 2005 (Figure 66 and Table 8).
- Median irrigated acres of roughs, practice areas, and landscape decreased since 2005, whereas the median irrigated acres of fairways, greens, and tees did not change since 2005 (Figure 66 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 7% to 1,139 (Table 9).

Management Practices

- The frequency of most management practices increased since 2005. Some notable increases included using wet-

ting agents, hand-watering, adjusting fertilizer practices, using soil amendments, reducing irrigated acres, and changing to drought-tolerant turfgrass (Table 11).

Regulations

- Required water use reporting, recurring annual allocations, and additional mandatory water restriction remained unchanged since 2005 (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 40%, 18%, 31%, and 25%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 94% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 86% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 56% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water and that tested their surface water were 88% and 51%, respectively, and has not changed since 2005 (Table 21).
- Among facilities that tested surface water, 45% tested once per month with the remaining facilities testing less frequently (Table 22).
- Among facilities that tested surface water, 74% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 70% tested for nutrients, which was the most common tested variable (Table 24).
- The prevalence of facilities that had ground water wells and that tested their ground water were 43% and 51%, respectively, and has not changed since 2005 (Table 25).

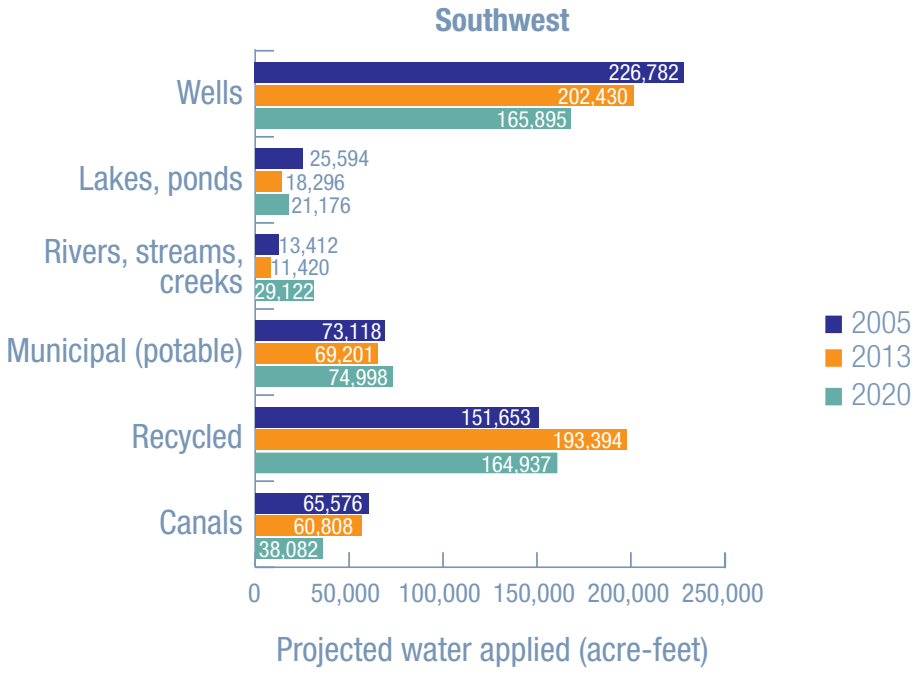


Figure 62. Projected water applied at U.S. golf facilities in the Southwest region by water source in 2005, 2013, and 2020. Ref: Table 5

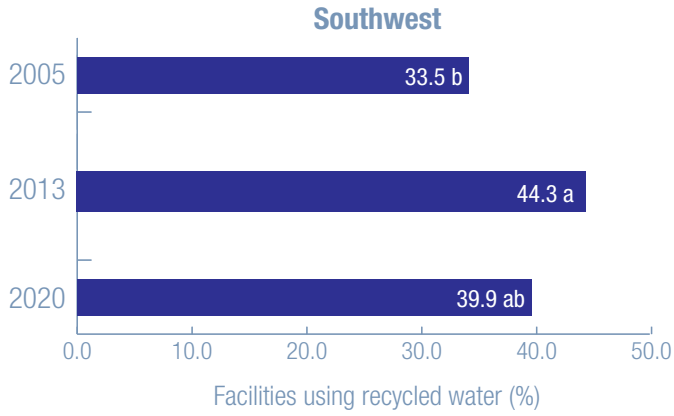


Figure 63. Percent of U.S. golf facilities in the Southwest region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

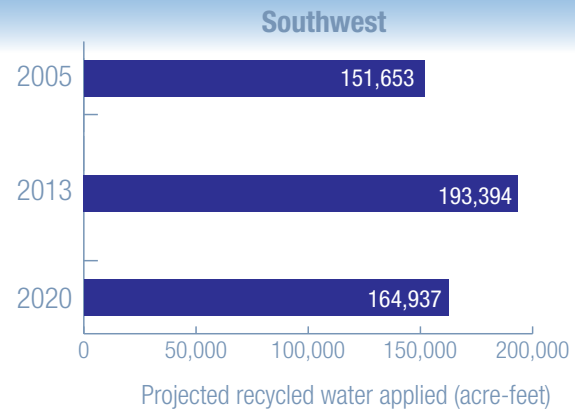


Figure 64. Projected recycled water applied to U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Ref: Table 3

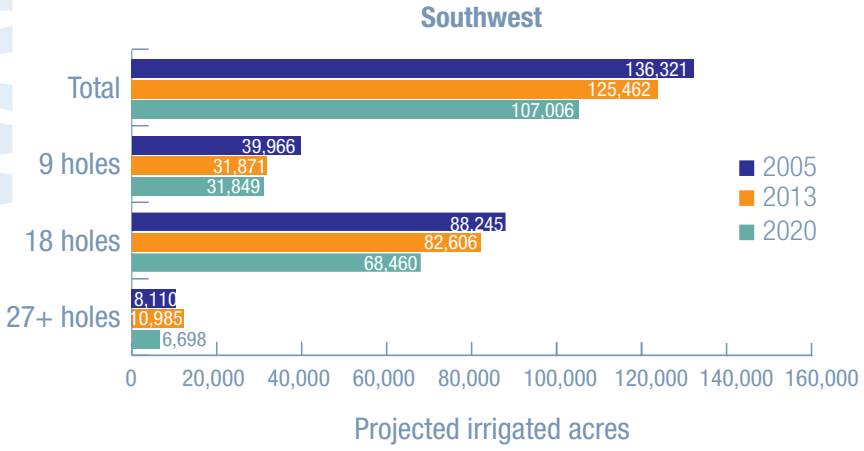


Figure 65. Projected irrigated acres of U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Ref: Table 4

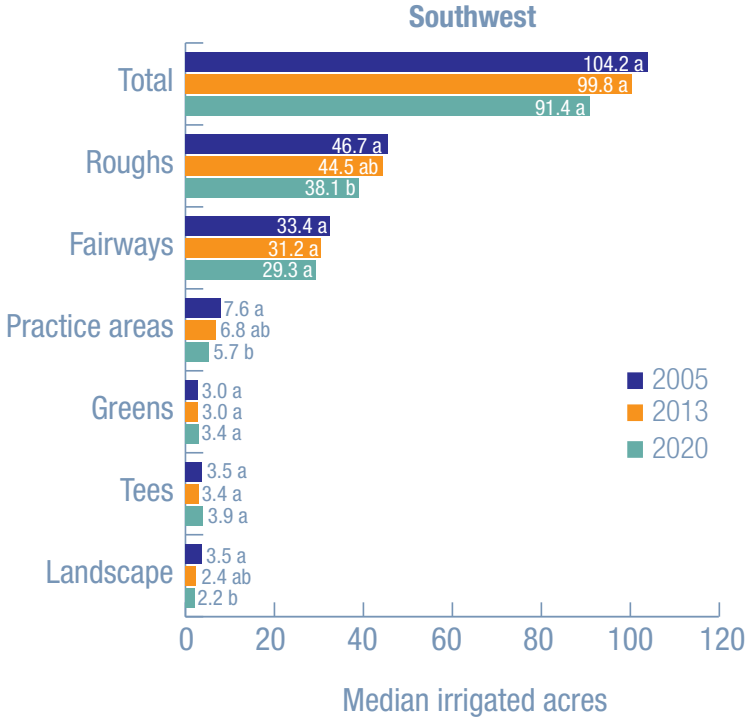


Figure 66. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Southwest region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

- Among facilities that tested ground water, 100% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 94% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 40% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 73% tested for nutrients, which was the most common tested variable (Table 29).
- Among facilities that tested ground water, 48% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation was relatively constant throughout the year ranging from 1.0 inch in November to 1.9 inches in August resulting in the least amount of annual precipitation of any region (16.6 inches) (Figure 67).
- Average monthly temperatures were nearly equal each month to that of the Southeast region with minimum and maximums of 44° F and 79° F occurring in January and July respectively (Figure 68).
- Growing degree days were second only to the Southeast each month ranging from 58 to 910 in January and July, respectively (Figure 69).
- The greatest gap between growing degree days and precipitation occurred in June when 618 degree days was accompanied by 1 inch of rainfall (Figure 70 and Table 34). This ratio was greater than all other regions except the Pacific region and indicates that turfgrass growing in the Southwest region may experience significant heat and moisture related stress and may require greater supplemental irrigation than turfgrass growing in the North Central, Northeast, Southeast, Transition, or Upper West/Mountain regions.

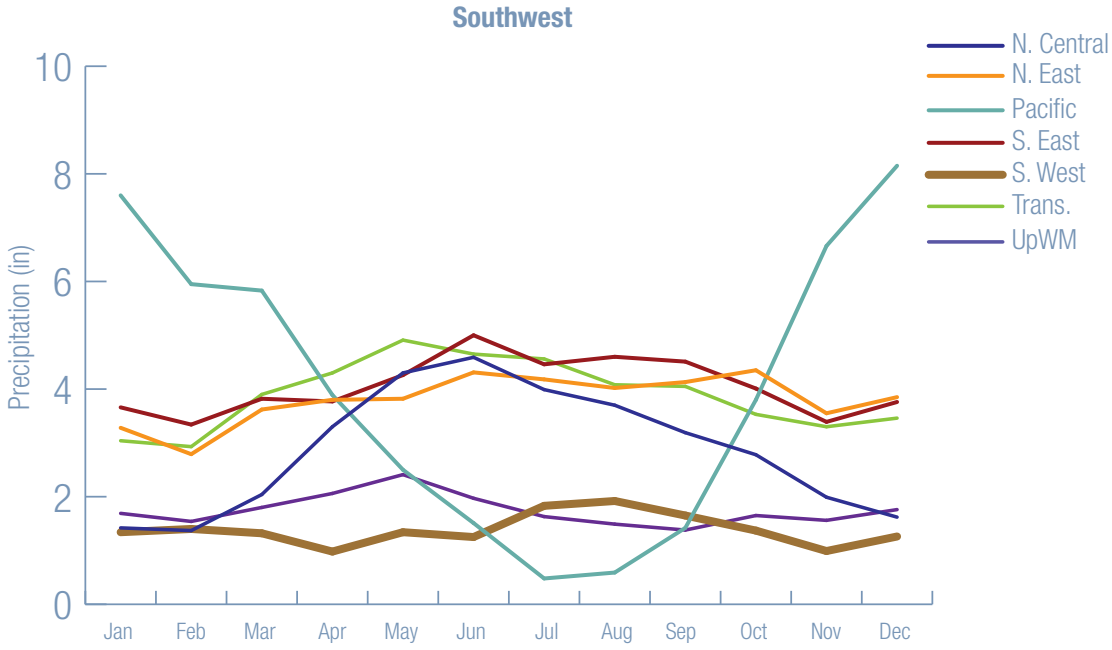


Figure 67. 30-yr monthly average precipitation in the Southwest region.

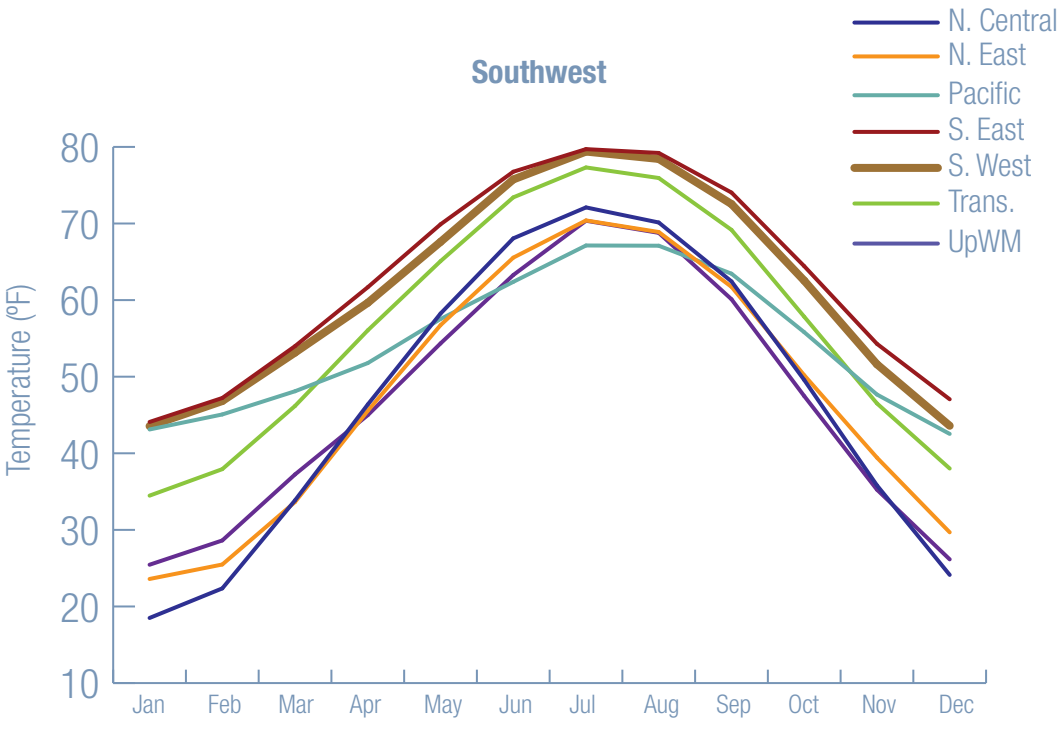


Figure 68. 30-yr monthly average temperature in the Southwest region.

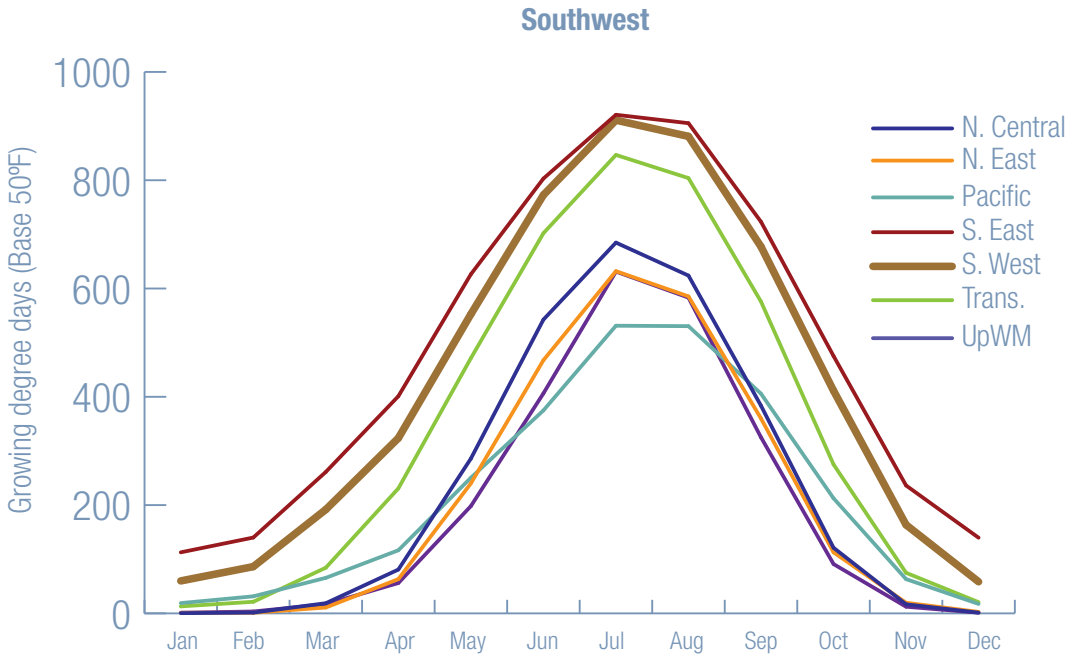


Figure 69. 30-yr monthly average growing degree days in the Southwest region.

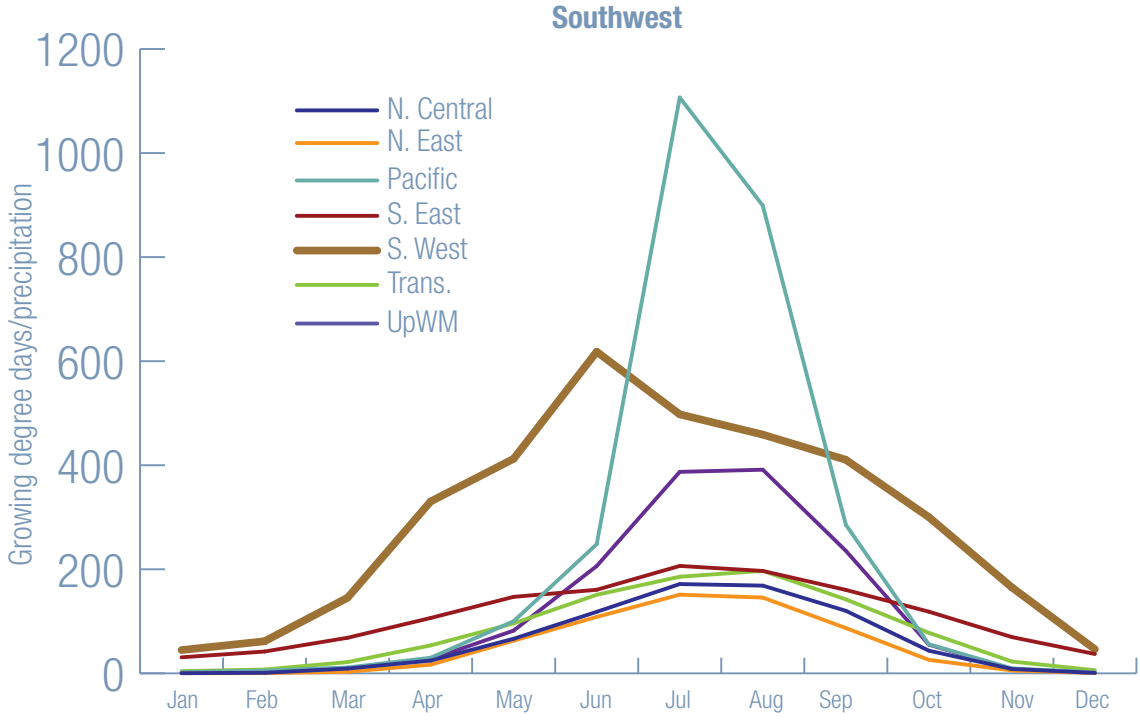


Figure 70. 30-yr monthly average growing degree days/precipitation in the Southwest region.

Transition Region

Water Use

- Projected applied water was 35% less in 2020 than in 2005, resulting in a water savings of 84,121 acre-feet (Figure 71).
- Median applied water per facility declined from 60.3 acre-feet in 2005 to 38.5 acre-feet in 2020, a 36% reduction (Figure 72).
- Median applied water per acre declined from 0.96 in 2005 to 0.58 in 2020, a 40% reduction (Figure 73).

Water Sources

- In 2020, 41% of projected applied water was sourced from lakes and ponds and 30% was sourced from wells (Figure 74).
- In 2020, 10% of projected applied water was sourced from recycled water (Figure 74).
- The percentage of facilities using recycled water was 8.6% in 2020, which was equivalent to 2005 (Figure 75).
- Projected recycled water applied increased from 12,682 acre-feet in 2005 to 15,330 acre-feet in 2020, a 21% increase (Figure 76).

Irrigated Acres

- Projected irrigated acres declined by 13% from 203,124 acres in 2005 to 177,266 acres in 2020 (Figure 77).
- Irrigated acres at 9-, 18-, and 27+-hole facilities declined by 22%, 11%, and 13%, respectively (Figure 77).
- Median irrigated acres were 58.5 in 2020 and were equivalent to 2005 (Figure 78 and Table 8).
- Median irrigated acres of roughs, practice areas, greens, tees, and landscape did not change since 2005, whereas the median irrigated acres of fairways decreased 8% since 2005 (Figure 78 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 15% to 2,528 (Table 9).

Management Practices

- The frequency of the most common management practices did not change since 2005. However, some notable

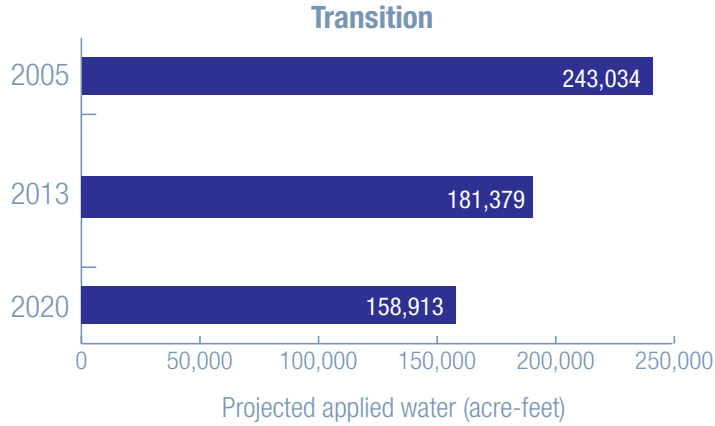


Figure 71. Projected water applied to U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Ref: Table 1

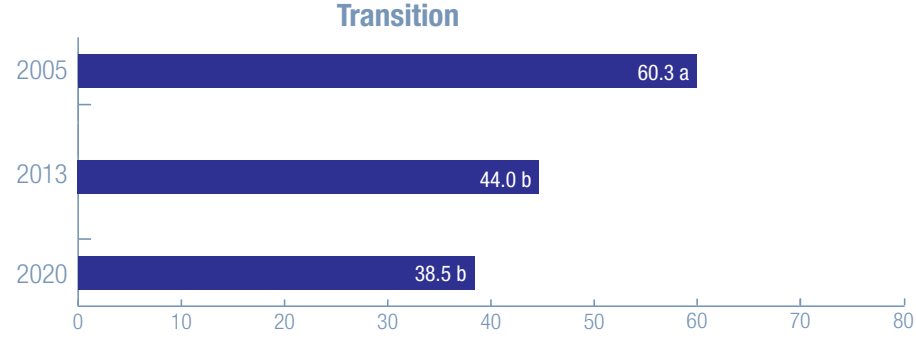


Figure 72. Median acre-feet of applied water on U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

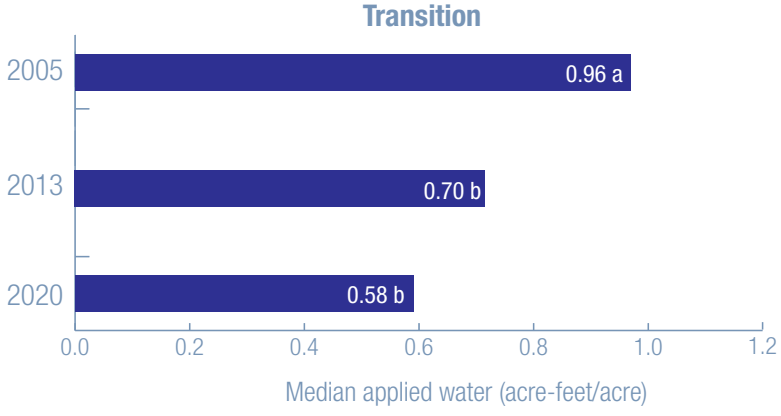


Figure 73. Median acre-feet per acre of applied water on U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

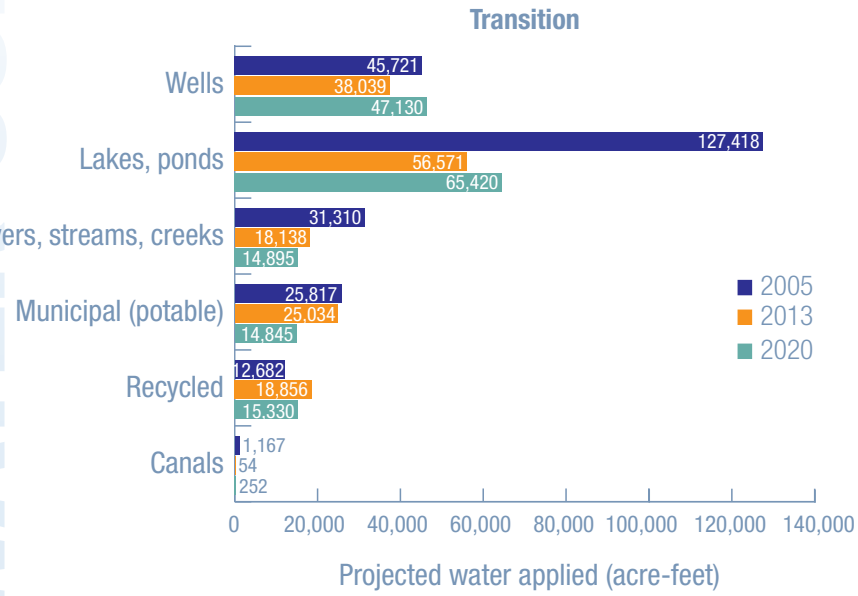


Figure 74. Projected water applied at U.S. golf facilities in the Transition region by water source in 2005, 2013, and 2020. Ref: Table 5

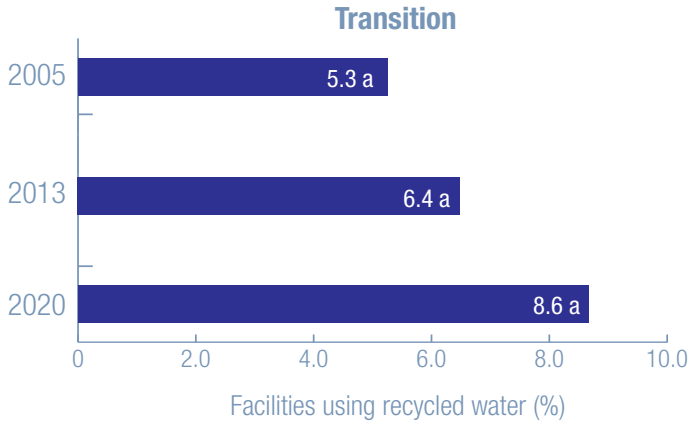


Figure 75. Percent of U.S. golf facilities in the Transition region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

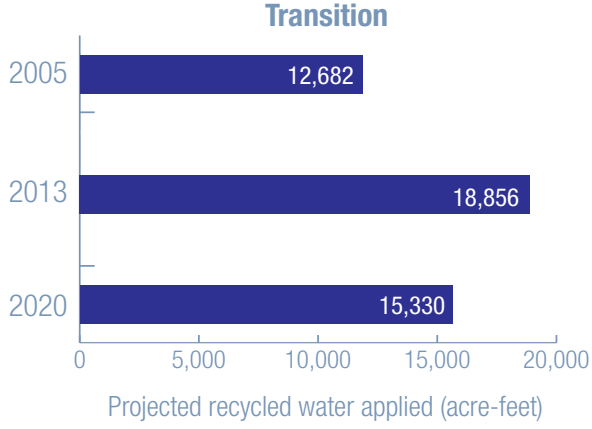


Figure 76. Projected recycled water applied to U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Ref: Table 3

increases included using soil amendments, pruning tree roots, using rain shut off switches, and changing to drought-tolerant turfgrass (Table 11).

Regulations

- Required water use reporting increased to 59%, recurring annual allocations were unchanged, and additional mandatory water restrictions decreased to 1% since 2005 (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 21%, 7%, 13%, and 10%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 88% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 91% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 22% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water declined since 2005 to 89%, but those that tested their surface water did not change at 34% (Table 21).
- Among facilities that tested surface water, 67% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 76% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 73% tested for nutrients, which was the most common tested variable (Table 24).
- The prevalence of facilities that had ground water wells was 45% and did not change since 2005, but those that tested their ground water declined to 30% (Table 25).

- Among facilities that tested ground water, 100% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 87% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 49% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 67% tested for nutrients, which was the most common tested variable (Table 29).
- Among facilities that tested ground water, 30% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation was relatively constant throughout the year ranging from 3.0 inches in February to 4.9 inches in May and was similar to the precipitation patterns in the Southeast and Northeast regions (Figure 79).
- Average monthly temperatures varied from 34° F in January to 77° F in July (Figure 80).
- Growing degree days were as low as 12 in January and as high as 846 in July and were the third greatest annually among regions (Figure 81).
- The greatest gap between growing degree days and precipitation occurred in August when 197 degree days was accompanied by 1 inch of rainfall (Figure 82 and Table 34). This ratio was similar to the North Central, Northeast, and Southeast regions and indicates that turfgrass growing in the Transition region may experience minor heat and moisture related stress and may not require as much supplemental irrigation as turfgrass growing in the Pacific, Southwest, or Upper West/Mountain regions.

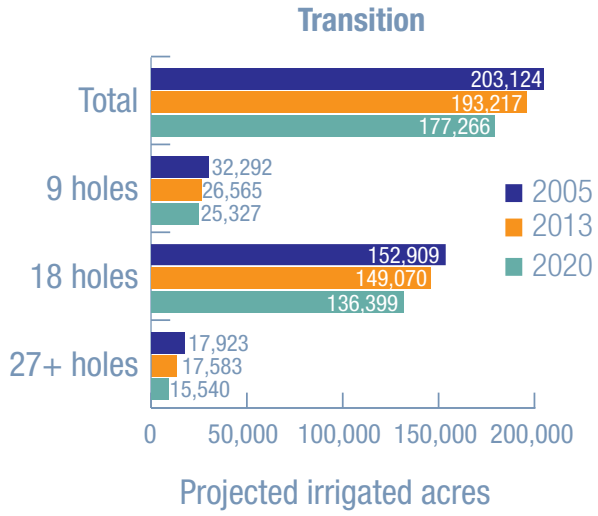


Figure 77. Projected irrigated acres of U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Ref: Table 4

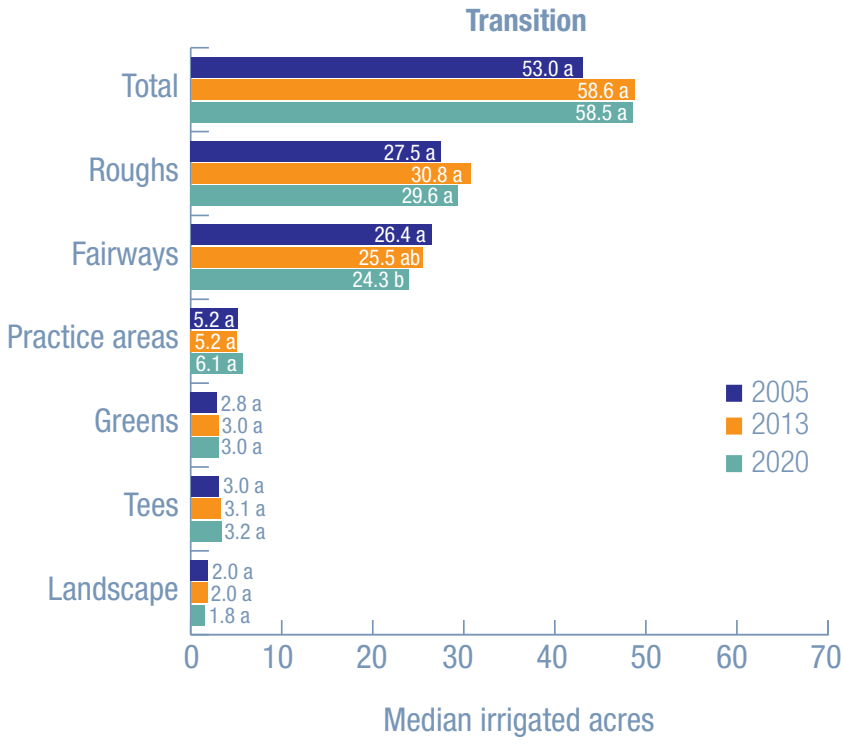


Figure 78. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Transition region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

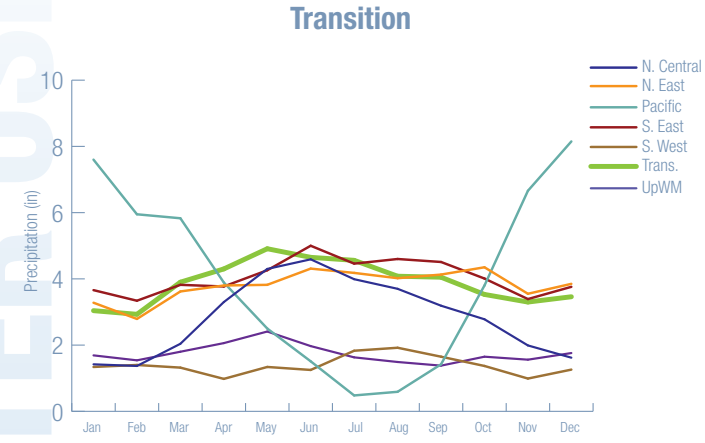


Figure 79. 30-yr monthly average precipitation in the Transition region.

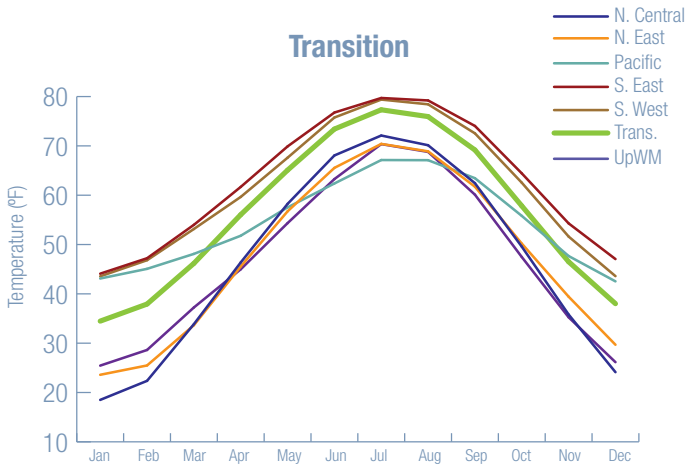


Figure 80. 30-yr monthly average temperature in the Transition region.

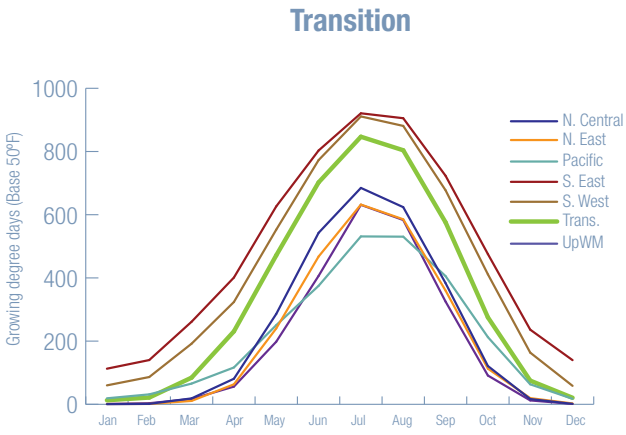


Figure 81. 30-yr monthly average growing degree days in the Transition region.

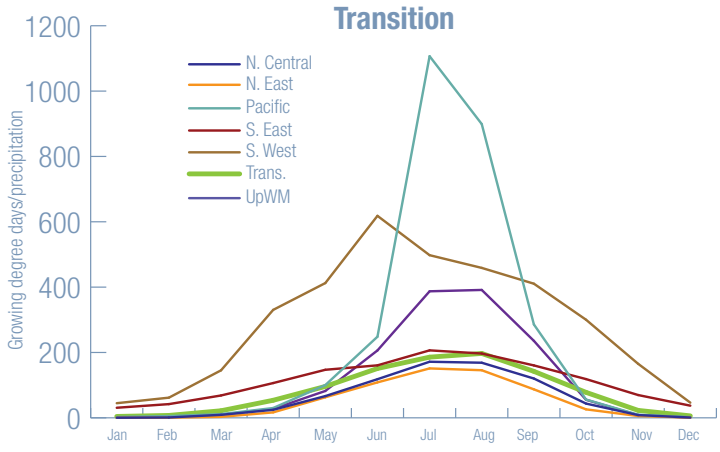


Figure 82. 30-yr monthly average growing degree days/precipitation in the Transition region.

Upper West/Mountain Region

Water Use

- Projected applied water was 6% less in 2020 than in 2005, resulting in a water savings of 12,659 acre-feet (Figure 83).
- Median applied water per facility was 163.2 acre-feet in 2020 and was equivalent to 2005 (Figure 84).
- Median applied water per acre was 2.09 acre-feet in 2020 and was equivalent to 2005 (Figure 85).

Water Sources

- In 2020, 30% of projected applied water was sourced from wells and 21% was sourced from rivers/streams (Figure 86).
- In 2020, 10% of projected applied water was sourced from recycled water (Figure 86).
- The percentage of facilities using recycled water was 12.1% in 2020, which was equivalent to 2005 (Figure 87).
- Projected recycled water applied decreased from 25,786 acre-feet in 2005 to 19,933 acre-feet in 2020, a 23% decrease (Figure 88).

Irrigated Acres

- Projected irrigated acres in 2020 was 91,130 and was approximately equivalent to 2005 (Figure 89).
- Irrigated acres at 9-hole facilities increased by 16%, at 18-hole facilities was unchanged, and at 27+-hole facilities declined by 15% since 2005 (Figure 89).
- Median irrigated acres were 75.8 in 2020 and were equivalent to 2005 (Figure 90 and Table 8).
- Median irrigated acres of roughs, greens, tees, and landscape did not change since 2005, whereas the median irrigated acres of fairways decreased, and the median irrigated acres of practice areas increased since 2005 (Figure 90 and Table 8).

Facility Influence

- Operational golf facilities declined since 2005 by 2% to 1,067 (Table 9).

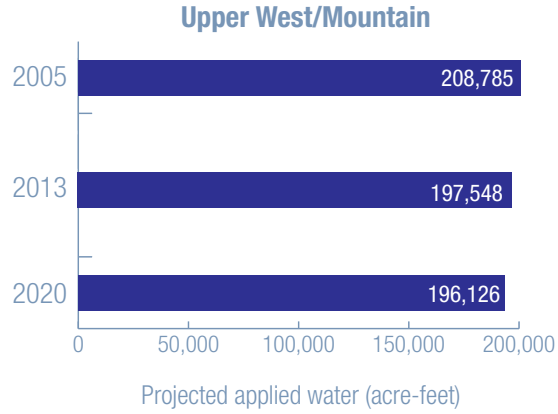


Figure 83. Projected water applied to U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Ref: Table 1

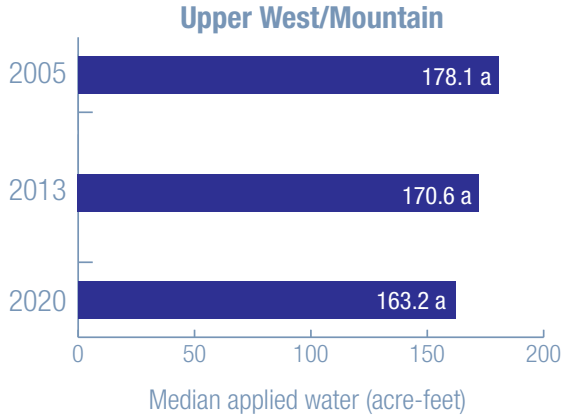


Figure 84. Median acre-feet of applied water on U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

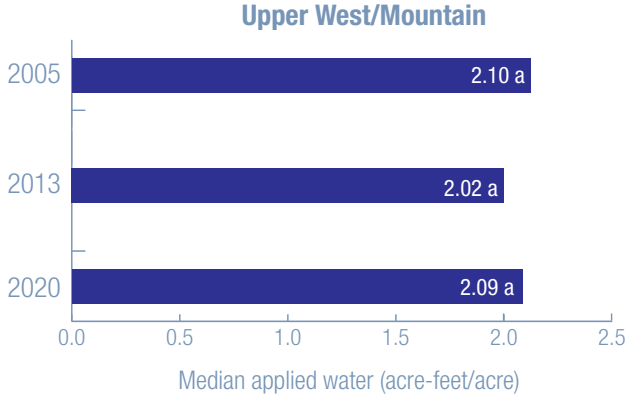


Figure 85. Median acre-feet per acre of applied water on U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 2

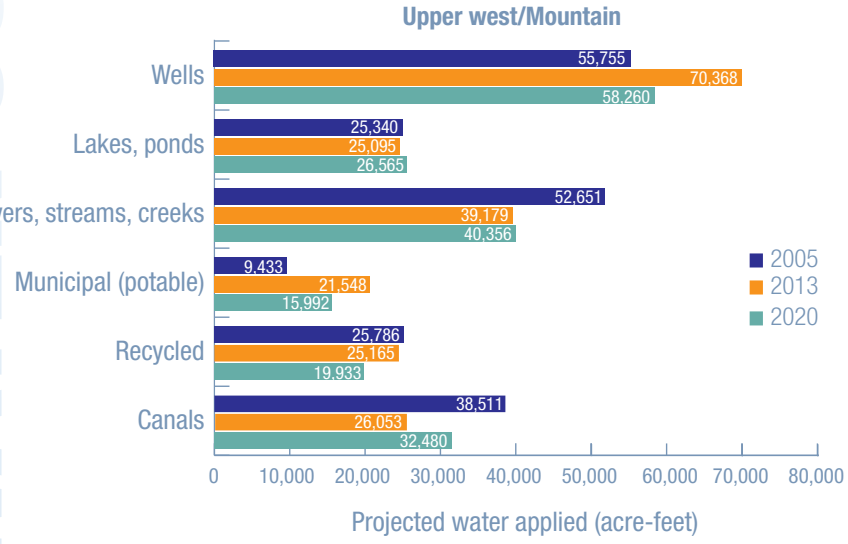


Figure 86. Projected water applied at U.S. golf facilities in the Upper West/Mountain region by water source in 2005, 2013, and 2020. Ref: Table 5

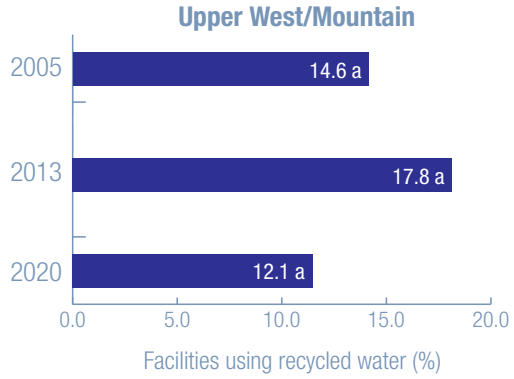


Figure 87. Percent of U.S. golf facilities in the Upper West/Mountain region applying recycled water in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the chi-square test at the 10% significance level. Ref: Table 3

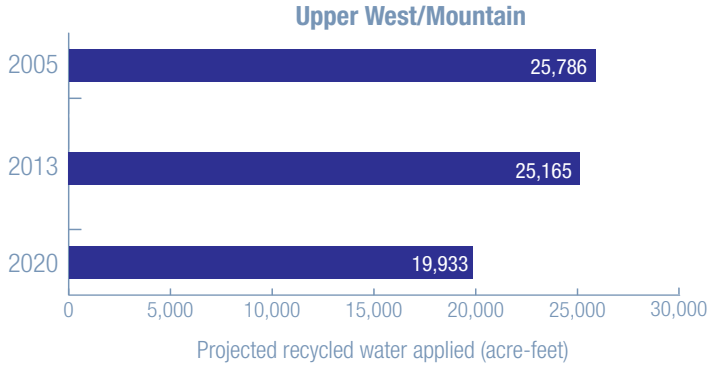


Figure 88. Projected recycled water applied to U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Ref: Table 3

Management Practices

- The frequency of the most management practices did not change since 2005. However, some notable increases included using wetting agents, keeping turf drier, reducing irrigated acres, and using rain shut off switches (Table 11).

Regulations

- Required water use reporting and recurring annual allocations were unchanged, and additional mandatory water restrictions decreased to 15% since 2005 (Table 14).
- The prevalence of facilities that had a written drought, water management, stormwater, or preventative irrigation maintenance plan was 24%, 21%, 13%, and 16%, respectively (Table 15).

Miscellaneous

- The use of soil moisture sensors had a somewhat positive or very positive impact on 95% of facilities in 2020 (Table 16).
- Water conservation was the most common factor motivating the decision to reduce irrigated acres (Table 17).
- 75% of golfers were receptive to any perceived change in course appearance resulting from a reduction of applied water (Table 18).
- The most common irrigation injection treatment was wetting agents used at 40% of facilities (Table 20).

Water Testing

- The prevalence of facilities that had surface water remained the same as 2005 at 89%, but those that tested their surface water decreased to 30% (Table 21).
- Among facilities that tested surface water, 58% tested once per year with the remaining facilities testing more frequently (Table 22).
- Among facilities that tested surface water, 82% had 1 or more surface water monitoring sites (Table 23).
- Among facilities that tested surface water, 89% tested for nutrients, which was the most common tested variable (Table 24).
- The prevalence of facilities that had ground water wells and that

tested their ground water were 56% and 38%, respectively, and has not changed since 2005 (Table 25).

- Among facilities that tested ground water, 100% had 1 or more ground water monitoring sites (Table 26).
- Among facilities that tested ground water, 86% had 1 or more protected ground water wells (Table 27).
- Among facilities that tested ground water, 36% tested once per year with the remaining facilities testing more frequently (Table 28).
- Among facilities that tested ground water, 60% tested for bacteria, whereas 52% tested for nutrients, which were the most common and second most common variables tested (Table 29).
- Among facilities that tested ground water, 40% had 1 or more dedicated ground water monitoring sites in 2020 (Table 30).

Meteorological

- Average monthly precipitation was second least only to the Southwest and ranged from 1.5 inches in August to 2.4 inches in May (Figure 91).
- Average monthly temperatures varied from 25° F in January to 70° F in July (Figure 92).
- Growing degree days were as low as 1 in January and as high as 631 in July and were lowest annually among regions (Figure 93).
- The greatest gap between growing degree days and precipitation occurred in August when 391 degree days was accompanied by 1 inch of rainfall (Figure 94 and Table 34). This ratio was greater than all other regions except the Pacific and Southwest regions and indicates that turfgrass growing in the Upper West/Mountain region may experience significant heat and moisture related stress and may require greater supplemental irrigation than turfgrass growing in the North Central, Northeast, Southeast, Transition regions.

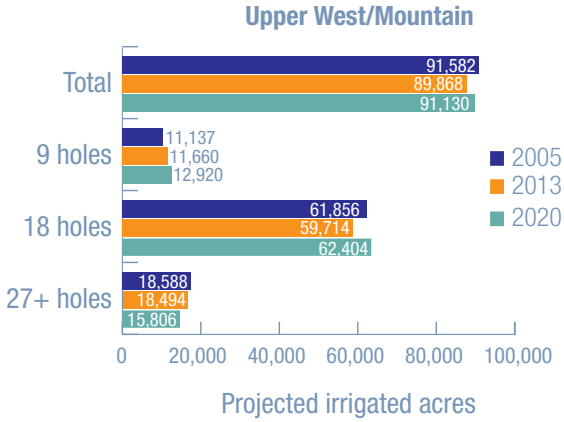


Figure 89. Projected irrigated acres of U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Table 4

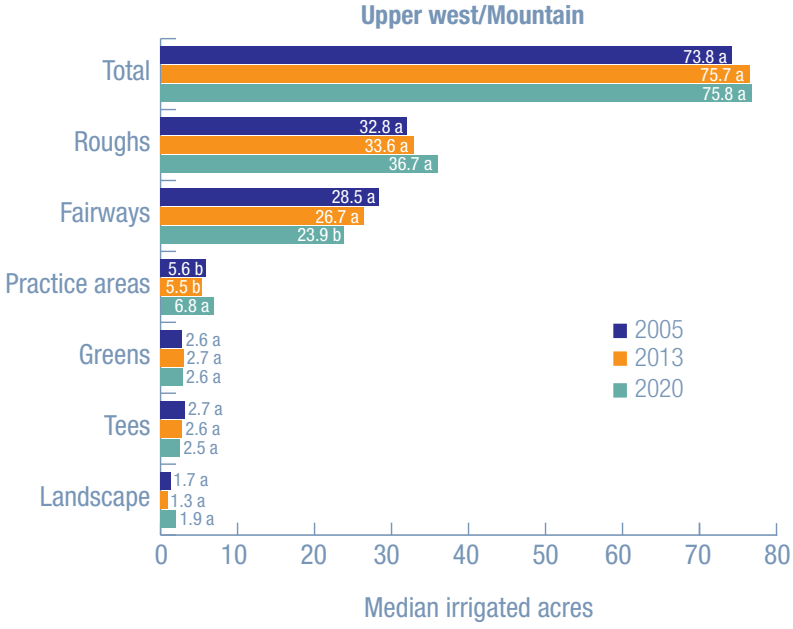


Figure 90. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape, and total of U.S. golf facilities in the Upper West/Mountain region in 2005, 2013, and 2020. Bars with a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level. Ref: Table 8

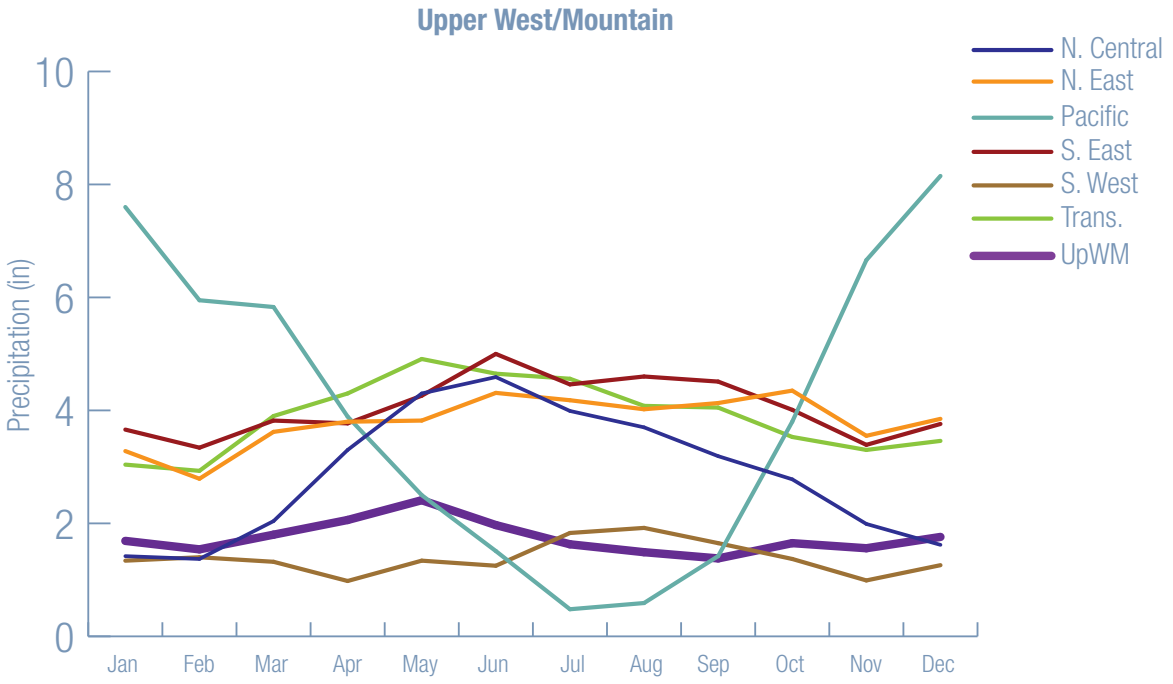


Figure 91. 30-yr monthly average precipitation in the Upper West/Mountain region.

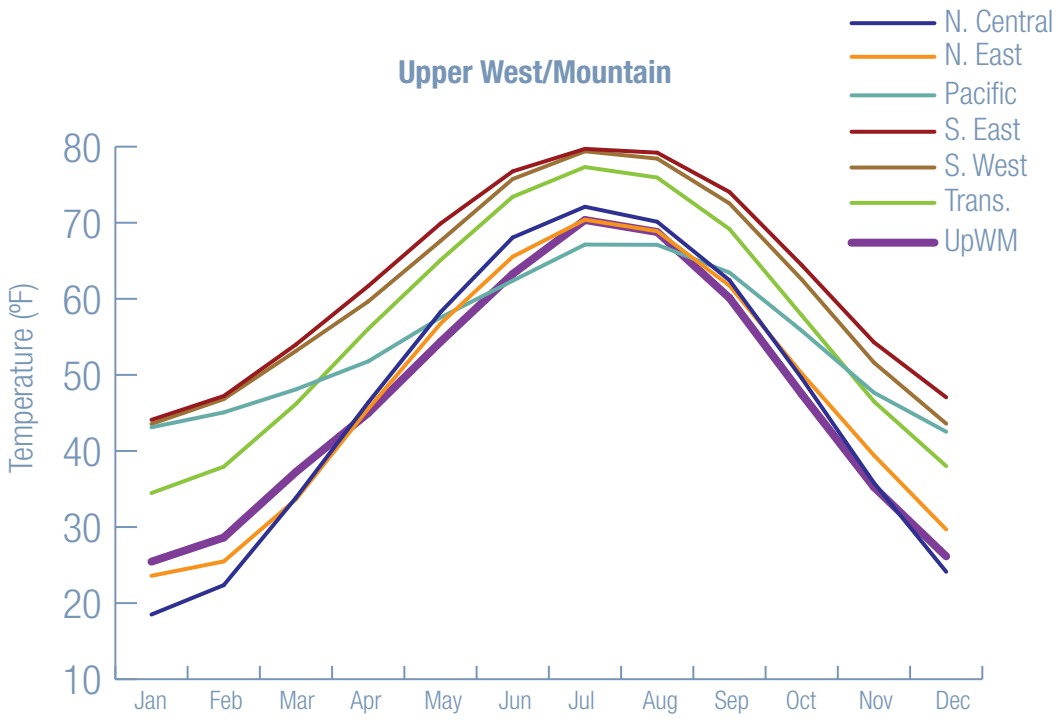


Figure 92. 30-yr monthly average temperature in the Upper West/Mountain region.

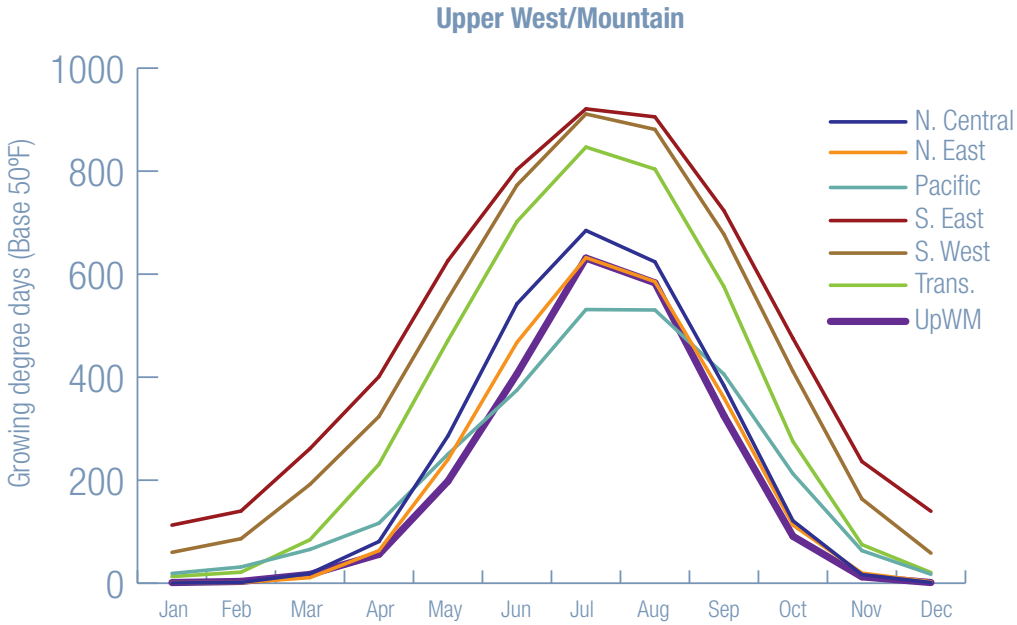


Figure 93. 30-yr monthly average growing degree days in the Upper West/Mountain region.

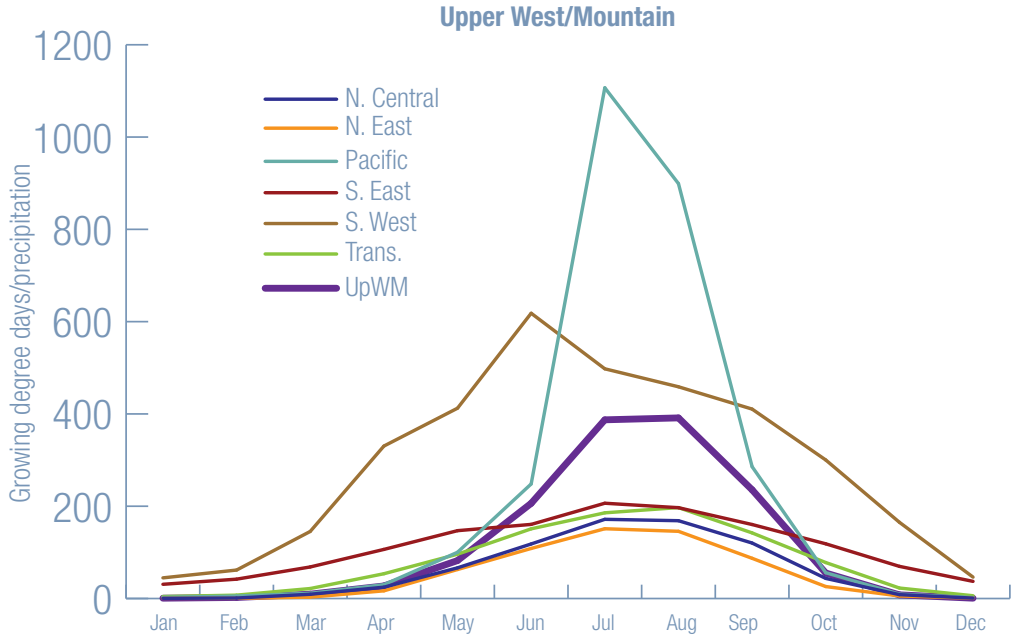


Figure 94. 30-yr monthly average growing degree days/precipitation in the Upper West/Mountain region.

Conclusions and Recommendations

Water applied to U.S. golf courses has declined by 29% since 2005 to 1.68 million acre-feet per year. Of that amount, approximately 1/3 was likely due to course closures with the remaining 2/3 due to other factors. A major contributing factor was likely the more efficient use of applied water, a postulation supported by the 30% reduction nationally in water applied per acre.

Recycled Water. 87% of recycled water on U.S. golf facilities was applied in the Southeast and Southwest. Recycled water can be challenging to acquire due to the unique infrastructure requirements that are normally beyond the control of the golf facility. However, where recycled water exists, golf facilities are encouraged to reach out to their local municipalities to determine if recycled water can be conveyed into their facilities.

Irrigated Acres. The median irrigated acres of U.S. facilities increased since 2005. However, fairways and landscapes continued to decline. The primary area contributing to the national increase was roughs, which increased by 3.4 acres. If expansion of roughs is desired, educating players of the playability of non-irrigated roughs may allow for this expansion without increasing irrigated acres.

Management Practices. Of the management practices documented, keeping turf drier, pruning tree roots, changing to a more drought-tolerant turfgrass, mulching landscape beds, and increasing no-mow acres were significantly associated with reductions in applied water. Thus, facilities that include these management practices in their program may realize a water savings. Golf facilities should maintain their Best Management Practices manual and strive for continuous improvements with water management. Water management plans are an important aspect of BMPs as well as water quality testing. Visit www.gcsaa.org for more information.

Educational Planning. Strategic educational efforts may be most effective if the following recommendations are implemented. First, the percentage of total water applied to U.S. facilities allocated by regions shows that 58% is applied within the Southeast and Southwest, whereas the remaining 42% is split between the remaining five regions. Thus, the total applied water shown in Figure 10 may be used as an indicator where to allocate educational efforts to have the greatest impact on national water use. Second, 18-hole facilities account for 70% of irrigated acres and applied water with 9- and 27+-hole facilities accounting for approximately 10% and 20%, respectively. Therefore, educational resources may be most efficient if allocated accordingly. And lastly, median irrigated acres have increased since 2005 including areas of the course that may be managed to acceptable levels without being irrigated, such as roughs. Promoting case-studies of courses that have successfully maintained or even increased non-irrigated acres without impacting the golfer's perception of the course may play a key role in other facilities adopting this approach.

Appendix

	Lakes/Ponds			Canals			Rivers, streams, creeks		
	2005	2013	2020	2005	2013	2020	2005	2013	2020
Region	acre-feet								
North Central	80,160	52,130	68,089	473	—[a]	389	32,935	21,610	19,519
Northeast	42,609	29,115	26,654	1,178	140	205	11,305	10,867	16,285
Pacific	8,075	6,228	10,404	14,583	5,291	7,445	14,369	11,734	6,861
Southeast	412,809	167,640	164,169	21,866	12,822	14,980	57,316	30,642	22,814
Southwest	25,594	18,296	21,176	65,576	60,808	38,082	13,412	11,420	29,122
Transition	127,418	56,571	65,420	1,167	54	252	31,310	18,138	14,895
Upper West/Mountain	25,340	25,095	26,565	38,511	26,053	32,480	51,651	39,179	40,356
U.S.	722,007	409,766	382,476	143,355	115,020	93,834	212,298	159,674	148,496
	Wells			**Recycled**			**Municipal**		
	2005	2013	2020	2005	2013	2020	2005	2013	2020
	acre-feet								
North Central	130,035	92,242	71,184	3,509	9,045	1,675	11,418	6,794	7,591
Northeast	33,134	29,386	26,657	2,082	2,219	1,898	16,153	7,071	10,624
Pacific	32,352	29,891	16,431	10,253	24,975	7,858	11,053	20,101	13,743
Southeast	217,577	127,824	145,716	145,611	192,849	139,733	22,706	13,731	12,914
Southwest	226,782	202,430	165,895	151,653	193,394	164,937	73,118	69,201	74,998
Transition	45,721	38,039	47,130	12,682	18,856	15,330	25,817	25,034	14,845
Upper West/Mountain	55,755	70,368	58,260	25,786	25,165	19,933	9,433	21,548	15,992
U.S.	741,357	580,204	531,274	351,576	466,503	351,364	169,698	155,667	150,707

[a]Insufficient data to compute a value

Table 5. Projected water applied nationally and within each agronomic region from lakes/ponds; canals; rivers, streams, creeks; wells; recycled; and municipal sources in 2005, 2013, and 2020.

	No Source	No Infrastructure	Cost	Poor Quality	Unnecessary	Other
	%					
U.S.	50.8	13.9	1.4	0.9	30.8	2.2
North Central	53.9	7.6	1.5	0.4	36.0	0.5
Northeast	57.9	13.7	0.5	0.2	26.6	1.0
Pacific	41.1	8.2	0.7	0.0	36.4	13.6
Southeast	48.5	12.6	5.0	4.7	27.0	2.2
Southwest	42.2	21.5	0.0	0.8	31.8	3.6
Transition	51.3	10.8	0.0	0.0	37.1	0.8
Upper West/Mountain	46.0	34.0	1.1	0.4	17.0	1.6

Table 6. Factors influencing the lack of effluent water use at U.S. golf facilities that did not use effluent water in 2020.

	Water Scarcity					Water Cost				
	1	2	3	4	5	1	2	3	4	5
	%									
U.S.	48.9	17.4	17.4	8.7	7.5	58.2	14.1	15.3	7.1	5.3
North Central	64.4	18.7	12.1	3.5	1.4	67.8	16.7	10.8	3.9	0.8
Northeast	53.0	20.1	17.9	3.8	5.2	67.6	14.9	9.3	6.0	2.2
Pacific	50.7	6.1	21.5	6.0	15.8	37.7	7.2	40.2	7.0	7.9
Southeast	51.0	18.8	16.4	11.5	2.3	62.1	13.1	14.5	7.1	3.2
Southwest	17.4	16.2	26.3	17.4	22.7	20.9	7.7	22.7	24.0	24.6
Transition	55.7	21.3	19.0	3.4	0.6	69.4	12.5	12.1	4.2	1.9
Upper West/ Mountain	18.9	12.0	18.2	25.0	26.0	40.1	19.7	16.9	9.6	13.6

Note. Respondents rated threat on a 1-5 scale, where 1 = Nothing we really need to worry about at this time, and 5 = It is a major issue for our course.

Table 7. Threat of water scarcity or increasing water costs on U.S. golf facilities in 2020.

Year	U.S.	NC	NE	Pac.	SE	SW	Trans.	UWM
	acres							
	Total							
2005	54.7 b	41.4 b	31.7 a	55.2 a	90.7 a	104.2 a	53.0 a	73.8 a
2013	58.5 a	39.8 b	36.3 a	63.9 a	91.7 a	99.8 a	58.6 a	75.7 a
2020	60.9 a	47.1 a	37.6 a	62.2 a	87.5 a	91.4 a	58.5 a	75.8 a
	Roughs							
2005	26.7 b	16.9 a	15.2 b	21.7 a	44.7 a	46.7 a	27.5 a	32.8 a
2013	26.8 b	14.7 a	14.5 b	25.1 a	42.9 a	44.5 ab	30.8 a	33.6 a
2020	30.1 a	16.4 a	25.5 a	26.3 a	45.8 a	38.1 b	29.6 a	36.7 a
	Fairways							
2005	25.9 a	23.1 a	20.9 a	24.2 a	32.4 a	33.4 a	26.4 a	28.5 a
2013	25.1 a	21.7 a	20.4 a	25.1 a	30.6 ab	31.2 a	25.5 ab	26.7 a
2020	23.7 b	21.8 a	19.6 a	21.7 a	28.4 b	29.3 a	24.3 b	23.9 b
	Practice Area							
2005	4.8 b	3.6 b	2.6 a	4.1 a	6.7 b	7.6 a	5.2 a	5.6 b
2013	4.6 b	2.8 c	2.7 a	4.5 a	6.5 b	6.8 ab	5.2 a	5.5 b
2020	5.4 a	4.6 a	2.9 a	3.4 a	7.6 a	5.7 b	6.1 a	6.8 a
	Greens							
2005	2.8 b	2.7 b	2.7 b	2.3 b	3.1 a	3.0 a	2.8 a	2.6 a
2013	2.9 a	2.7 b	3.0 a	2.9 a	3.3 a	3.0 a	3.0 a	2.7 a
2020	3.0 a	3.1 a	2.9 a	2.8 a	3.1 a	3.4 a	3.0 a	2.6 a
	Tees							
2005	2.6 b	2.3 b	2.1 b	2.1 b	3.6 a	3.5 a	3.0 a	2.7 a
2013	2.8 a	2.4 b	2.3 a	2.7 a	3.7 a	3.4 a	3.1 a	2.6 a
2020	2.9 a	2.7 a	2.2 ab	2.7 a	3.6 a	3.9 a	3.2 a	2.5 a
	Landscape							
2005	2.1 a	1.7 b	1.5 b	1.7 b	3.4 a	3.5 a	2.0 a	1.7 a
2013	1.9 b	1.6 b	1.7 ab	1.4 b	2.7 b	2.4 ab	2.0 a	1.3 a
2020	2.2 a	2.1 a	2.2 a	2.3 a	3.0 ab	2.2 b	1.8 a	1.9 a

Note. NC=North Central, NE=Northeast, Pac.=Pacific, SE=Southeast, SW=Southwest, Trans.=Transition, and UWM=Upper West/Mountain. Within columns, medians followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

Table 8. Median irrigated acres of roughs, fairways, practice areas, greens, tees, landscape and total of U.S. golf facilities in 2005, 2013, and 2020.

Region	2005	2013	2020	Δ2005-2020	Area	Applied Water	Δ2005-2020	
	U.S. golf facilities				acres	acre-feet	acres	acre-feet
North Central	4,127	3,925	3,592	-535	62.8	47.9	-33,616	-25,611
Northeast	2,746	2,677	2,482	-264	51.9	33.1	-13,711	-8,734
Pacific	655	638	571	-84	70.4	112.2	-5,914	-9,421
Southeast	3,250	3,046	2,766	-484	102.2	180.2	-49,488	-87,217
Southwest	1,224	1,201	1,139	-85	105.0	482.4	-8,921	-41,003
Transition	2,961	2,795	2,528	-433	73.6	59.7	-31,860	-25,869
Upper West/Mountain	1,089	1,104	1,067	-22	86.6	186.8	-1,904	-4,110
U.S.	16,052	15,386	14,145	-1,907	76.6	122.8	-146,113	-234,269

Table 9. U.S. golf facilities, acres and applied water as influenced by change in golf facilities from 2005 to 2020. The change in acres and acre-feet from 2005 to 2020 was determined by multiplying the change in facility number by the mean acres or acre-feet, respectively.

	Golf course size			Golf course type	
	9 holes	18 holes	27+ holes	Public	Private
	acre-feet/acre				
2005	1.09 a	1.37 a	1.47 a	1.32 a	1.28 a
2013	0.83 b	1.15 b	1.40 a	1.11 b	1.08 b
2020	0.73 b	1.07 b	1.23 a	1.02 b	1.00 b

Note. Within columns, medians followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level

Table 10. Acre-feet of water applied per acre on 9-hole, 18-hole, 27+-hole, public and private golf facilities in 2005, 2013, and 2020.

Management Practice	U.S.			NC			NE			Pac.			SE			SW			Trans.			UWM		
	2005	2013	2020	2005	2013	2020	2005	2013	2020	2005	2013	2020	2005	2013	2020	2005	2013	2020	2005	2013	2020	2005	2013	2020
	%																							
Wetting agents	88 b	94 a	96 a	90 b	96 a	97 a	84 a	87 a	92 a	86 b	94 b	99 a	91 b	95 b	99 a	76 b	91 a	92 a	91 a	94 a	95 a	90 b	98 a	97 a
Hand-watering	72 b	77 a	78 a	65 a	71 a	63 a	70 b	74 ab	83 a	79 b	86 ab	92 a	69 a	74 a	72 a	72 b	79 b	87 a	85 a	86 a	85 a	74 a	81 a	85 a
Keep turf drier than in past	62 c	73 a	68 b	61 b	70 a	70 a	62 b	76 a	72 ab	57 b	79 a	65 ab	63 b	76 a	61 b	59 b	74 a	61 ab	64 a	70 a	68 a	63 b	78 a	78 a
Hand-held moisture sensors	—[#]	33 b	49 a	—	26 b	41 a	—	41 a	52 a	—	23 b	44 a	—	38 b	51 a	—	29 b	54 a	—	43 a	53 a	—	29 b	53 a
Adjust fertilizer practices	41 b	52 a	47 a	40 b	49 a	44 ab	37 b	51 a	39 b	45 b	47 b	67 a	47 a	53 a	45 a	47 b	59 a	61 a	38 b	51 a	46 ab	43 a	51 a	51 a
Irrigation scheduling	42 b	49 a	45 a	33 b	47 a	37 b	41 a	49 a	41 a	45 a	51 a	38 a	49 a	51 a	46 a	58 a	57 a	59 a	39 a	43 a	44 a	51 a	58 a	60 a
Soil amendments	29 b	40 a	42 a	22 b	34 a	32 a	35 b	48 a	52 a	25 a	33 a	31 a	34 b	44 a	50 a	33 b	37 ab	47 a	27 b	43 a	39 a	34 a	39 a	44 a
Increase no-mow acres	—	46 a	41 b	—	48 a	50 a	—	51 a	54 a	—	52 a	45 a	—	38 a	25 b	—	28 a	27 a	—	56 a	42 b	—	42 a	39 a
Mulch landscape beds	43 b	48 a	39 b	38 b	47 a	41 ab	42 b	50 a	37 b	36 b	50 a	36 ab	59 a	64 a	47 b	27 a	34 a	28 a	48 a	49 a	39 a	40 a	37 a	35 a
New irrigation nozzles	—	39 a	31 b	—	34 a	30 a	—	41 a	29 b	—	47 a	38 a	—	31 a	28 a	—	44 a	37 a	—	45 a	23 b	—	45 a	48 a
Reduced irrigated acres	18 c	35 a	30 b	13 b	25 a	27 a	15 b	27 a	36 a	18 b	49 a	36 a	22 b	37 a	26 b	25 b	42 a	51 a	18 b	42 a	19 b	24 b	36 a	34 a
Prune tree roots	17 c	25 b	30 a	18 b	22 b	31 a	23 b	30 a	32 a	17 a	19 a	17 a	16 c	25 b	38 a	12 b	20 a	17 ab	17 b	29 a	36 a	14 a	20 a	20 a
New irrigation software	—	31 a	28 a	—	28 a	29 a	—	25 a	27 a	—	34 a	36 a	—	36 a	26 b	—	33 a	33 a	—	31 a	27 a	—	39 a	28 b
Convert irrigation heads to part-circle	—	32 a	26 b	—	28 a	23 a	—	29 a	21 a	—	48 a	43 a	—	35 a	25 b	—	35 a	32 a	—	34 a	20 b	—	33 a	32 a
New irrigation central controller	—	30 a	26 b	—	28 a	25 a	—	24 a	24 a	—	33 a	23 a	—	37 a	24 b	—	32 b	48 a	—	29 a	23 a	—	34 a	23 b
Use rain shut-off switch	16 b	23 a	25 a	13 c	20 b	29 a	11 b	19 a	19 a	11 a	15 a	12 a	32 b	39 a	34 ab	15 a	21 a	20 a	14 b	24 a	20 a	12 b	18 b	27 a
Change to drought-tolerant turfgrass	12 c	18 b	22 a	7 b	11 a	12 a	19 b	28 a	36 a	8 b	15 a	15 ab	9 b	14 a	18 a	8 c	22 a	13 b	18 b	28 a	35 a	13 ab	9 b	20 a
Plant low-water landscape species	14 b	23 a	20 a	6 b	15 a	13 a	11 b	17 a	16 ab	17 a	26 a	24 a	23 b	35 a	26 b	21 b	38 a	33 a	12 b	24 a	19 a	17 a	21 a	24 a
Drip irrigation for landscape plants	13 b	16 a	15 ab	4 a	6 a	5 a	6 a	7 a	9 a	18 a	27 a	21 a	15 a	18 a	16 a	38 a	47 a	40 a	9 a	9 a	10 a	32 a	30 a	28 a
Full irrigation system upgrade	20 b	14 a	12 a	20 a	10 b	12 b	22 a	15 b	13 b	17 a	18 a	9 b	23 a	18 a	12 b	18 a	24 a	15 a	16 a	11 ab	10 b	20 a	17 a	10 b
Irrigation audit	5 b	8 a	7 a	4 a	3 a	3 a	4 a	3 a	5 a	7 a	7 a	8 a	9 b	13 a	13 a	12 b	22 a	9 b	2 b	7 a	5 a	6 b	11 a	12 a
In-ground moisture sensors	1 b	7 a	6 a	1 b	4 a	5 a	1 b	8 a	9 a	1 b	7 a	4 a	2 b	5 a	4 ab	1 b	6 a	8 a	1 b	7 a	6 a	<1 c	12 a	6 b
Course designed for water harvesting	7 a	6 ab	5 b	6 a	7 a	3 b	7 a	8 a	8 a	4 a	4 a	6 a	11 a	9 ab	5 b	4 a	2 a	3 a	10 a	8 a	6 a	3 a	2 a	3 a

Note. NC=North Central, NE=Northeast, Pac.=Pacific, SE=Southeast, SW=Southwest, Trans.=Transition, and UWM=Upper West/Mountain.
Within a row and region, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.
[#]Question not asked in 2005.

Table 11. Frequency of management practices used at U.S. golf facilities in 2005, 2013, and 2020.

	2005		2013		2020	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
Survey respondents (%)	24	8	14	21	10	14
Mean irrigated area of survey respondents (acres)	13	12	10	11	11	13
Mean irrigation volume of survey respondents (acre-feet)	21	32	13	23	15	25
National Projection						
Golf facilities	3,858	1,317	2,098	3,176	1,436	2,006
Irrigated area (acres)	51,548	15,790	20,828	35,250	15,395	26,818
Applied water (acre-feet)	81,018	42,693	27,703	72,245	20,953	50,247
Net irrigated area (Δ acres)	35,758		-14,421		-11,423	
Net applied water (Δ acre-feet)	38,324		-44,542		-29,294	

Table 12. Change in irrigated acres at operational golf facilities and the resulting impact on projected water use in 2005, 2013, and 2020.

	2005	2013	2020
Irrigation system improvements		%	
New sprinkler heads	64 a	66 a	60 b
New nozzles	51 a	49 ab	47 b
New hand-held sensors	—[#]	30 b	39 a
New software to control irrigation	34 a	37 a	34 a
Added sprinkler heads	48 a	36 b	30 c
Removed sprinkler heads	25 b	30 a	27 ab
New master controller	25 a	24 a	24 a
New pump	30 a	29 a	24 b
New field controller	31 a	25 b	19 c
Pump station	19 a	14 b	19 a
New lateral lines	17 a	9 b	6 c
New main lines	12 a	5 b	6 b
New in-ground sensors	—	6 a	4 b
Irrigation system automation			
Fully automated	64 b	70 a	73 a
Semi-automated	31 a	28 ab	25 b
Manual system	21 a	16 b	15 b
Irrigation scheduling methods			
Observe turf	96 a	94 b	88 c
Short-term weather forecasts	52 c	56 b	61 a
Observe soil moisture	80 a	63 b	54 c
Hand-held soil moisture sensors	—	29 b	39 a
Evapotranspiration from on-site weather station	14 b	18 a	17 a
Evapotranspiration from weather service	15 a	13 a	14 a
Long-term weather records	6 b	5 b	9 a
In-ground soil moisture sensors	3 a	4 b	3 b
Drone	—	—	1
Mounted Sensor	—	—	<1

Note. Within a row, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.
[#]Question not asked in that year.

Table 13. Irrigation system improvements, system type and scheduling methods used at U.S. golf facilities in 2005, 2013, and 2020.

	required water use reporting			recurring annual allocations			additional mandatory water restrictions		
	2005	2013	2020	2005	2013	2020	2005	2013	2020
	%								
U.S.	48.4 b	55.0 a	58.0 a	21.7 c	30.3 a	26.2 b	15.8 a	10.7 b	7.7 c
North Central	57.7 b	62.3 ab	67.6 a	11.5 b	23.5 a	20.5 a	4.4 a	2.1 a	2.7 a
Northeast	50.6 b	63.8 a	64.1 a	24.7 b	33.3 a	31.6 ab	28.8 a	4.6 b	5.5 b
Pacific	28.9 a	25.0 a	28.1 a	13.7 a	15.0 a	19.3 a	2.0 b	13.9 a	17.8 a
Southeast	57.2 b	65.0 a	62.9 ab	34.8 b	42.6 a	36.1 ab	21.4 a	26.4 a	10.3 b
Southwest	50.8 a	53.3 a	50.6 a	36.4 a	40.8 a	39.1 a	11.8 a	18.6 a	14.0 a
Transition	36.5 c	48.4 b	59.0 a	10.4 b	23.4 a	13.8 b	14.5 a	4.2 b	1.0 c
Upper West/Mountain	35.3 a	36.0 a	46.0 a	36.1 a	34.7 a	30.0 a	31.3 a	19.1 b	15.3 b

Note. Within a row, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.

Table 14. Frequency of water use restrictions at U.S. golf facilities in 2005, 2013, and 2020.

Region	Drought		Water management		Stormwater		Preventive irrigation maintenance	
	w/plan	required	w/plan	required	w/plan	required	w/plan	required
	%							
U.S.	23.3	14.0	13.7	41.6	15.5	56.5	15.4	34.6
North Central	18.6	1.1	7.2	16.2	10.7	46.4	9.9	7.4
Northeast	20.1	21.2	19.1	80.3	11.7	44.8	17.1	54.1
Pacific	18.2	11.4	15.3	19.0	16.9	68.3	15.8	19.8
Southeast	29.4	25.4	16.8	43.8	21.8	51.6	21.7	44.0
Southwest	39.6	13.8	18.0	24.3	30.9	66.5	25.2	51.9
Transition	21.4	4.2	6.7	41.9	13.2	66.6	9.8	20.7
Upper West/Mountain	23.6	17.0	20.7	26.8	13.4	59.3	16.2	27.2

Table 15. Frequency of U.S. golf facilities that have a written drought, water management, stormwater or preventive irrigation maintenance plan in 2020. For those respondents with written plans, the "required" columns indicate the frequency with which those plans were required by state or local authorities.

	No	Somewhat	Very Positive
	%		
U.S.	8.1	45.2	46.6
North Central	12.1	49.1	38.8
Northeast	2.6	37.3	60.0
Pacific	10.9	46.6	42.6
Southeast	7.8	49.1	43.1
Southwest	6.5	61.0	32.6
Transition	11.6	32.9	55.5
Upper West/Mountain	4.5	52.2	43.4

Table 16. Frequency of U.S. golf facilities indicating whether the use of moisture sensors had a positive impact on operations in 2020.

	Water Cost	Regulations	Water Conservation	Water Availability	Drought	Environmental Stewardship
	%					
U.S.	20.7	5.6	61.3	19.8	22.4	10.9
North Central	21.7	0.6	51.9	15.8	8.9	16.0
Northeast	13.8	2.7	59.6	12.8	13.6	5.6
Pacific	34.2	7.7	66.3	21.4	42.4	17.8
Southeast	20.7	14.0	57.7	23.8	24.2	17.0
Southwest	35.4	15.7	58.7	15.0	36.7	4.0
Transition	20.3	1.0	61.1	7.6	11.4	10.1
Upper West/Mountain	9.3	1.8	80.4	42.8	37.1	6.0

Table 17. Factors motivating the decision to reduce irrigated acres at U.S. golf facilities in 2020.

	1	2	3	4	5
	%				
U.S.	4.1	9.6	27.5	25.2	33.7
North Central	2.8	10.9	27.4	24.5	34.5
Northeast	4.7	10.4	28.8	15.8	40.3
Pacific	4.9	6.0	34.1	29.2	25.7
Southeast	2.6	7.5	29.0	26.7	34.3
Southwest	9.1	4.5	30.3	29.2	26.8
Transition	2.4	6.7	21.8	32.9	36.2
Upper West/Mountain	7.0	17.9	26.4	20.3	28.4

Note. Respondents rated golfer receptiveness on a 1-5 scale, where 1 = not receptive at all, and 5 = very receptive.

Table 18. Golfer receptiveness resulting from reduced water use and any perceived change in course appearance and playability among U.S. golf facilities that reported a reduction in water use in 2020.

	Fairways	Tees	Greens	Overall
	%			
U.S.	53.5	45.4	60.9	79.8
North Central	80.1	88.2	90.5	78.1
Northeast	55.6	32.9	54.4	88.2
Pacific	48.6	41.4	46.7	62.8
Southeast	59.9	49.4	49.5	84.1
Southwest	45.6	39.8	49.6	92.7
Transition	18.9	27.6	60.7	72.4
Upper West/Mountain	58.5	52.3	61.7	69.0

Table 19. Irrigation distribution uniformity on fairways, tees, greens and overall on U.S. golf facilities that conducted an irrigation audit in 2020.

	Wetting Agent	Acid	Fertigation	BioControl	Sulfur	Gypsum
	%					
US	34.1	7.2	12.1	3.6	0.7	0.7
North Central	34.5	5.2	1.3	0.3	0.2	0.0
Northeast	33.1	8.4	8.3	4.4	0.0	0.0
Pacific	25.8	3.9	6.0	1.4	1.0	2.8
Southeast	38.1	10.0	25.4	3.2	0.3	0.2
Southwest	55.9	19.9	36.5	4.4	4.2	1.9
Transition	21.9	2.4	5.6	0.4	0.7	0.0
Upper Mountain/West	39.7	7.4	15.6	14.5	1.2	2.6

Table 20. Frequency of water treatment used with irrigational systems at U.S. golf facilities in 2020.

	Had Surface Water			Had Surface Water and Tested		
	2008	2015	2020	2008	2015	2020
	%					
U.S.	93.5 a	93.8 a	92.0 a	39.1 a	37.9 a	34.7 a
North Central	94.6 a	95.0 a	92.8 a	27.2 a	24.4 a	26.2 a
Northeast	92.9 a	89.7 a	94.5 a	34.9 a	37.3 a	27.9 a
Pacific	85.3 a	84.8 a	86.1 a	49.3 a	26.8 b	27.3 b
Southeast	96.6 a	97.2 a	97.7 a	49.0 a	51.1 a	50.6 a
Southwest	85.4 b	95.7 a	87.8 b	65.9 a	56.3 a	51.2 a
Transition	95.4 a	94.6 ab	88.6 b	34.8 a	37.9 a	34.0 a
Upper West/Mountain	91.0 a	91.2 a	89.2 a	43.6 a	35.8 ab	29.8 b

Note. Within a row, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.

Table 21. Frequency of U.S. golf facilities that had surface water and tested their surface water in 2008, 2015, and 2020.

	Monthly	Every 3 months	Every 6 months	Annually
	%			
U.S.	10.4	11.9	17.8	59.9
North Central	2.2	2.2	12.8	82.8
Northeast	6.0	10.0	17.8	66.1
Pacific	11.1	12.2	7.0	69.6
Southeast	10.6	21.7	19.0	48.7
Southwest	44.5	9.3	18.7	27.5
Transition	4.2	8.5	19.9	67.4
Upper West/Mountain	7.0	10.4	24.5	58.1

Table 22. Surface water testing frequency of U.S. golf facilities that tested surface water in 2020.

	Monitoring Sites						
	0	1	2	3	4	5	>5
	%						
U.S.	16.0	36.1	18.3	13.3	4.3	2.6	9.5
North Central	21.3	36.0	15.8	13.9	8.8	2.2	1.9
Northeast	11.6	39.0	17.7	18.4	5.6	4.7	3.1
Pacific	8.7	35.5	24.4	22.3	7.1	0.0	2.0
Southeast	8.5	31.8	18.6	16.8	2.7	3.5	18.2
Southwest	26.1	41.7	13.7	4.0	2.7	2.8	9.0
Transition	24.1	42.0	18.6	5.2	4.2	0.8	5.1
Upper West/Mountain	17.7	30.2	22.2	11.5	0.0	2.5	15.9

Table 23. Number of surface water monitoring sites at U.S. golf facilities that tested surface water in 2020.

	Nutrients	Oxygen	Bacteria	Chemicals/ Fuels	Pesticides	Water Level	Biosolids	Temperature	Turbidity	Macroinvertebrates	Stream Flow
	%										
U.S.	77.5	29.5	26.7	21.5	19.5	19.5	18.1	15.8	13.3	4.6	3.0
North Central	75.0	24.8	17.9	21.4	35.6	11.3	19.1	23.2	5.3	2.1	3.6
Northeast	81.6	41.7	38.0	24.9	23.1	9.3	20.6	17.3	17.9	3.5	3.5
Pacific	75.1	21.0	21.5	39.3	30.4	17.0	9.8	17.3	14.5	8.7	2.4
Southeast	79.0	27.7	23.2	17.3	15.0	22.7	20.9	10.8	16.0	7.9	1.5
Southwest	69.8	29.4	39.2	27.0	6.2	32.4	10.8	30.2	6.0	2.8	1.4
Transition	72.8	32.0	29.3	17.7	15.5	19.2	16.9	9.5	13.4	2.7	2.7
Upper West/ Mountain	88.6	27.9	24.5	20.7	14.0	26.2	18.3	12.5	19.5	3.7	7.8

Table 24. Frequency of U.S. golf facilities that tested surface water and tested for the listed variable in 2020.

	Had Ground Water Wells			Had Ground Water Wells and Tested Ground Water		
	2008	2015	2020	2008	2015	2020
	%					
U.S.	61.4 a	59.5 a	58.1 a	57.3 a	58.8 a	39.6 b
North Central	75.1 a	70.8 ab	66.4 b	50.8 a	49.9 ab	37.0 b
Northeast	66.7 a	73.9 a	66.7 a	71.0 a	59.7 ab	47.5 b
Pacific	57.9 ab	42.8 b	64.2 a	67.4 a	60.5 a	23.9 b
Southeast	59.4 a	57.1 a	58.3 a	57.2 ab	65.0 a	48.4 b
Southwest	45.8 a	54.2 a	42.6 a	66.5 a	69.3 a	50.6 a
Transition	50.2 a	39.3 a	44.7 a	51.0 b	69.2 a	29.9 c
Upper West/Mountain	52.4 a	58.2 a	56.0 a	49.8 a	49.2 a	37.8 a

Note. Within a row, values followed by a common letter are not significantly different according to the chi-square test at the 10% significance level.

Table 25. Frequency of U.S. golf facilities that had ground water wells in 2008, 2015, and 2020.

	Monitoring Sites						
	0	1	2	3	4	5	>5
	%						
U.S.	1.2	38.9	27.5	17.0	6.5	4.1	4.7
North Central	0.0	33.1	32.2	16.1	12.0	4.0	2.6
Northeast	0.0	26.9	32.9	20.9	4.5	9.2	5.6
Pacific	11.6	57.5	16.4	8.2	1.5	3.2	1.7
Southeast	1.1	47.9	26.1	12.9	5.3	1.8	4.9
Southwest	0.0	43.4	26.8	11.5	5.1	4.7	8.5
Transition	0.0	31.1	24.9	28.3	5.8	3.4	6.6
Upper West/Mountain	0.0	48.7	23.2	15.1	5.0	1.7	6.4

Table 26. Number of ground water monitoring sites at U.S. golf facilities that tested ground water in 2020.

	Protected Ground Water Wells						
	0	1	2	3	4	5	>5
	%						
U.S.	17.5	32.6	23.6	14.7	4.7	3.5	3.4
North Central	16.4	30.1	28.2	12.3	7.8	2.6	2.6
Northeast	17.4	22.4	28.0	17.7	2.1	9.4	3.0
Pacific	37.5	35.7	15.7	6.1	0.9	2.5	1.7
Southeast	18.0	35.8	25.0	11.5	4.8	1.6	3.3
Southwest	5.6	46.2	21.0	11.5	3.9	3.2	8.5
Transition	13.3	24.3	21.4	27.7	4.7	3.4	5.2
Upper West/Mountain	14.2	50.1	14.1	13.4	5.0	0.5	2.7

Table 27. Number of protected ground water wells at U.S. golf facilities that tested ground water in 2020.

	Monthly	Every 3 months	Every 6 months	Annually
	%			
U.S.	16.2	31.0	10.4	42.4
North Central	6.3	44.5	6.6	42.6
Northeast	18.4	23.6	14.4	43.6
Pacific	19.3	27.0	0.0	53.7
Southeast	24.7	22.0	13.8	39.5
Southwest	14.9	21.6	24.0	39.5
Transition	6.1	39.2	5.7	49.1
Upper West/Mountain	24.2	34.6	4.9	36.2

Table 28. Ground water testing frequency of U.S. golf facilities that tested ground water in 2020.

	Nutrients	Bacteria	Pesticides	Biosolids	Chemicals/ Fuels	Depth to Water	Oxygen	Turbidity	Temperature
	%								
U.S.	64.7	53.2	31.1	26.9	22.6	20.6	14.4	10.0	7.5
North Central	54.3	74.7	30.3	23.7	17.3	17.5	11.9	2.5	4.2
Northeast	71.6	63.6	46.9	32.4	42.3	21.6	16.8	10.1	12.9
Pacific	63.0	35.9	21.4	10.0	21.5	48.3	3.6	15.8	0.0
Southeast	72.8	27.3	9.5	26.1	14.1	12.0	16.7	15.8	7.7
Southwest	72.6	28.6	25.7	28.8	23.1	43.0	23.6	16.4	11.8
Transition	66.5	56.6	53.3	50.9	18.5	10.7	13.2	7.5	8.8
Upper West/Mountain	51.8	59.8	34.6	9.2	18.0	26.4	11.5	9.5	3.3

Table 29. Frequency of U.S. golf facilities that tested ground water and tested for the listed variable in 2020.

	Monitoring Sites						
	0	1	2	3	4	5	>5
	%						
U.S.	61.6	17.8	6.3	3.9	5.5	1.8	3.1
North Central	65.3	12.8	6.5	3.2	10.5	1.7	0.0
Northeast	55.8	17.8	5.5	7.2	3.4	4.4	5.9
Pacific	44.8	35.6	4.3	15.3	0.0	0.0	0.0
Southeast	66.0	14.1	3.3	1.4	8.4	1.9	4.8
Southwest	52.4	23.0	11.9	6.3	2.9	0.0	3.5
Transition	69.7	18.5	10.1	0.0	0.0	0.0	1.6
Upper West/Mountain	60.0	24.7	8.4	1.8	1.8	0.0	3.3

Table 30. Number of dedicated ground water monitoring sites at U.S. golf facilities that tested ground water in 2020.

Operational Budget	Acres			AF			AF per Acre		
	2005	2013	2020	2005	2013	2020	2005	2013	2020
< $250,000	31.9 a	30.5 a	29.0 a	30.0 a	25.2 ab	20.8 b	0.99 a	0.91 ab	0.75 b
250,000 to 499,999	62.0 a	60.4 a	56.3 a	70.9 a	55.7 b	46.2 b	1.19 a	0.94 b	0.89 b
500,000 to 749,999	81.3 a	80.1 a	78.3 a	105.4 a	82.4 b	75.4 b	1.34 a	1.06 b	1.01 b
750,000 to 999,999	95.6 a	94.6 a	95.4 a	127.2 a	116.4 a	101.4 a	1.39 a	1.23 a	1.11 a
1,000,000 to 1,249,999	106.4 a	100.9 a	104.6 a	177.0 a	148.9 ab	122.6 b	1.66 a	1.49 ab	1.17 b
1,250,000 to 1,499,999	104.7 a	109.4 a	102.1 a	194.4 a	142.2 ab	111.1 b	1.84 a	1.31 ab	1.12 b
>1,500,000	154.2 a	125.0 b	123.3 b	377.2 a	252.0 b	220.9 b	2.47 a	1.98 ab	1.75 b

Note. Within rows, medians followed by a common letter are not significantly different according to the Tukey-Kramer test at the 10% significance level.

Table 31. Median acres, acre-feet, and acre-feet/acre of U.S. golf facilities in 2020 by budget.

Year	Facility Type		
	9-hole	18-hole	27+-hole
	acres		
2005	23.9 Aa	75.9 Ba	142.6 Ca
2013	24.4 Aa	72.6 Bb	136.8 Ca
2020	25.5 Aa	75.0 Bab	138.7 Ca
	acre-feet		
2005	29.1 Aa	105.5 Ba	211.5 Ca
2013	21.4 Ab	84.0 Bb	193.2 Ca
2020	18.7 Ab	79.1 Bb	174.4 Ca
	acre-feet/acre		
2005	1.09 Ba	1.37 Aa	1.47 Aa
2013	0.83 Bb	1.15 Ab	1.40 Aa
2020	0.73 Bb	1.07 Ab	1.23 Aa

Note. Within columns and rows, medians followed by a lower-case or upper-case common letter, respectively, are not significantly different according to the Tukey-Kramer test at the 10% significance level.

Table 32. Median irrigated acres, acre-feet, and acre-feet per acre at 9-, 18-, and 27+-hole facilities in the U.S. in 2005, 2013, and 2020.

	U.S. Golf Facilities		Surveys Received	
	Total	Proportion of Facilities (%)	Total	Proportion of Surveys Received (%)
U.S.	14,145	100.0	1,575	100.0
Region				
North Central	3,592	25.4	310	19.7
Northeast	2,482	17.5	238	15.1
Pacific	571	4.0	106	6.7
Southeast	2,766	19.6	350	22.2
Southwest	1,139	8.1	127	8.1
Transition	2,528	17.9	259	16.4
Upper West/Mountain	1,067	7.5	185	11.7
Type				
Daily Fee	7,930	56.1	542	34.4
Municipal	2,545	18.0	304	19.3
Private	3,670	25.9	729	46.3
Holes				
9	3,708	26.2	95	6.0
18	9,117	64.5	1,211	76.9
27+	1,320	9.3	269	17.1

Table 33. Total U.S. golf facilities and surveys received partitioned by region, type, and holes in 2020.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Precipitation (in.)											
North Central	1.42	1.37	2.04	3.30	4.30	4.59	3.99	3.70	3.19	2.78	1.99	1.62
Northeast	3.28	2.79	3.62	3.80	3.82	4.31	4.18	4.02	4.13	4.35	3.55	3.85
Pacific	7.60	5.95	5.83	3.89	2.50	1.51	0.48	0.59	1.42	3.80	6.66	8.15
Southeast	3.66	3.34	3.82	3.77	4.26	5.00	4.46	4.60	4.51	4.01	3.39	3.76
Southwest	1.34	1.40	1.32	0.98	1.34	1.25	1.83	1.92	1.65	1.37	0.99	1.26
Transition	3.04	2.93	3.90	4.30	4.91	4.65	4.56	4.08	4.05	3.53	3.30	3.46
Upper West/Mountain	1.69	1.54	1.80	2.06	2.41	1.97	1.63	1.49	1.38	1.65	1.56	1.76
	Temperature (°F)											
North Central	18.50	22.36	33.86	46.37	58.24	68.06	72.10	70.13	62.44	49.57	35.81	24.12
Northeast	23.59	25.48	33.64	45.55	56.73	65.54	70.40	68.89	61.73	50.19	39.43	29.68
Pacific	43.11	45.07	48.10	51.78	57.53	62.38	67.13	67.10	63.45	55.81	47.67	42.53
Southeast	44.09	47.22	53.99	61.68	69.89	76.76	79.71	79.21	74.04	64.43	54.29	47.05
Southwest	43.55	46.82	53.15	59.65	67.60	75.75	79.39	78.43	72.54	62.54	51.62	43.59
Transition	34.47	37.93	46.18	56.05	65.08	73.41	77.32	75.94	69.17	57.83	46.51	38.01
Upper West/Mountain	25.45	28.62	37.24	44.98	54.34	63.27	70.36	68.78	60.11	47.47	35.25	26.15
	Growing Degree Days											
North Central	0.47	1.44	18.77	80.92	285.91	542.57	684.76	623.88	383.54	121.19	16.72	1.40
Northeast	1.08	1.16	10.80	63.26	240.12	467.54	632.04	585.48	359.91	112.78	19.61	2.72
Pacific	18.99	31.48	65.60	116.54	250.53	374.82	531.26	530.47	405.70	212.58	63.26	17.42
Southeast	112.73	140.05	261.26	401.08	626.34	803.06	920.89	905.33	723.23	475.39	236.23	139.73
Southwest	59.94	86.34	191.83	323.73	552.63	772.73	910.93	880.97	677.31	411.30	163.53	58.40
Transition	12.91	21.40	84.38	230.81	471.38	702.12	846.72	803.90	575.83	275.10	74.94	20.72
Upper West/Mountain	1.24	3.47	16.99	56.03	198.13	406.29	631.20	583.17	325.10	91.09	12.33	1.26
	Growing Degree Days /Precipitation											
North Central	0.33	1.05	9.20	24.52	66.49	118.21	171.62	168.62	120.23	43.59	8.40	0.86
Northeast	0.33	0.42	2.98	16.65	62.86	108.48	151.21	145.64	87.15	25.93	5.52	0.71
Pacific	2.50	5.29	11.25	29.96	100.21	248.23	1106.79	899.10	285.70	55.94	9.50	2.14
Southeast	30.80	41.93	68.39	106.39	147.03	160.61	206.48	196.81	160.36	118.55	69.68	37.16
Southwest	44.73	61.67	145.33	330.34	412.41	618.18	497.78	458.84	410.49	300.22	165.18	46.35
Transition	4.25	7.30	21.64	53.68	96.00	150.99	185.68	197.03	142.18	77.93	22.71	5.99
Upper West/Mountain	0.73	2.25	9.44	27.20	82.21	206.24	387.24	391.39	235.58	55.21	7.90	0.72

Table 34. 30-year monthly average precipitation, temperature, growing degree days, and growing degree days/precipitation for the seven U.S. agronomic regions.

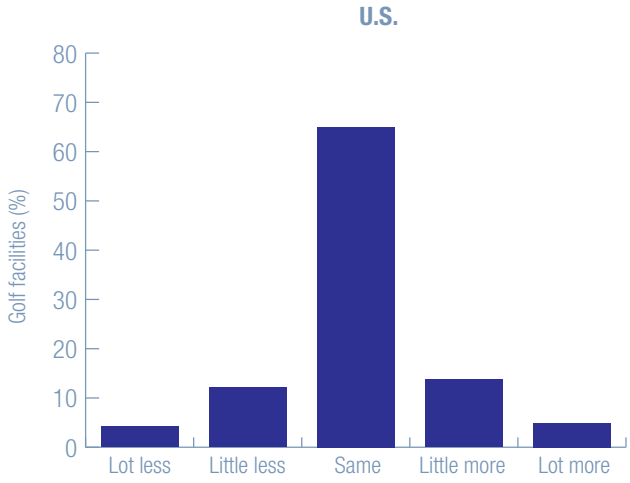


Figure 95. Influence of the COVID-19 pandemic on whether U.S. golf facilities used more or less water in 2020.

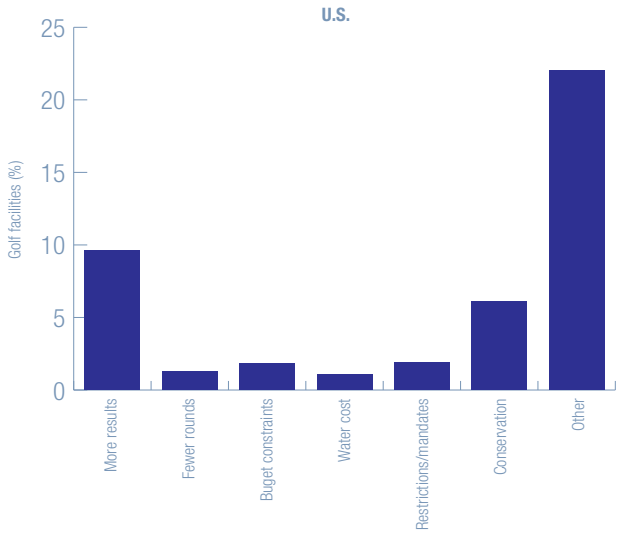


Figure 96. Factors contributing to changes in water use on U.S. golf facilities resulting from the COVID-19 pandemic in 2020.

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