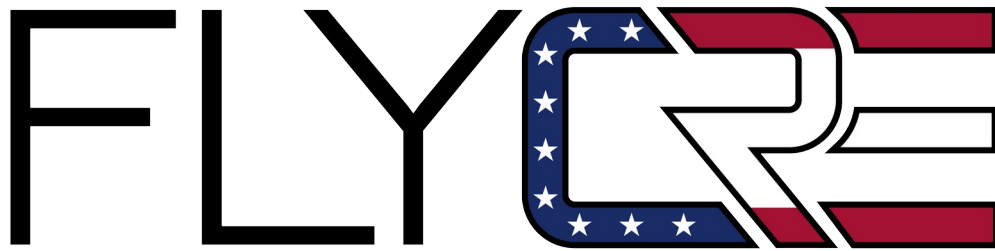


Every Hole on Record: Aerial Documentation for Golf Courses



A DIVISION OF BURGE CORPORATION

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Executive Summary

Golf has already done a lot with less water. A national survey by the Golf Course Superintendents Association of America found that U.S. golf courses used 31 percent less water in 2024 than in 2005 [1]. In the Southwest, applied water fell 16.9 percent between 2020 and 2024 alone [1]. The survey says about two-thirds of the national reduction since 2005 was likely the result of operating facilities applying water more efficiently, and lists wetting agents, hand watering, and drier turf conditions among the most common water management practices [1].

California is not easing off. In California, state law lists golf courses as an example of a recreational use area, where turf counts as functional under the nonfunctional turf rules that begin applying to public agency properties in 2027, to commercial, industrial, and institutional properties in 2028, and to homeowners association common areas in 2029 [2][3]. Starting in 2027, urban water suppliers must meet annual water use objectives that include landscape budgets [4]. In late 2022, the USGA reported that many California courses were being required to cut water use by 35 percent of their assigned budgets [5].

Water agencies, members, boards, and neighbors all ask a course the same things: how much turf do you irrigate, where, and how has that changed? Aerial documentation gives a course a dated, consistent map of every hole, captured on a schedule, so the course can answer those questions from its own record.

This paper covers the water picture for golf, the rules shaping it in California, what published research says about aerial sensors on golf turf, how an aerial record is captured, and where its limits are. It closes with a recordkeeping checklist for courses.

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1. Introduction

A golf course is a closely watched landscape. Members see it every round, neighbors see it from their backyards, and water agencies see it on the meter. Superintendents manage it at a level of detail few other landscapes get, yet many courses have no consistent record of the whole property from one season to the next.

1.1 Who This Paper Is For

- **Golf course superintendents** responsible for turf, irrigation, and water budgets.
- **Owners, general managers, and management companies** responsible for capital planning and costs.
- **Member clubs and boards** approving budgets and renovation projects.
- **Municipal courses and park agencies** reporting to councils and residents.

1.2 Scope of This Paper

This paper is about documentation. It does not tell anyone how to irrigate, fertilize, mow, or renovate a course, and it does not explain how to comply with any rule. Those decisions belong to superintendents, agronomists, irrigation professionals, golf course architects, and the agencies that set water rules.

2. The Water Picture for Golf

2.1 What the National Data Shows

The GCSAA's Golf Course Environmental Profile is a recurring national survey of golf course practices. Its most recent water report, published in HortTechnology in September 2025 and announced by GCSAA in December 2025, drew on responses from nearly 1,700 facilities and found [1]:

- **Less water:** U.S. golf courses applied a projected 1.63 million acre-feet of water in 2024, 31 percent less than in 2005 and 3.2 percent less than in 2020.
- **Water sources:** wells supplied 32 percent of irrigation water, lakes and ponds 27 percent, and recycled water 19 percent.
- **Regional change:** the Southwest reported the largest reduction from 2020 to 2024, at 16.9 percent.
- **Practices:** since 2020, facilities increased their use of hand-held moisture sensors, irrigation scheduling adjustments, the frequency of irrigation audits, and evapotranspiration data from onsite weather stations.

The previous report in the series found that applied water fell 29 percent from 2005 to 2020, and that about one third of that decline was likely due to course closures, with the remaining two-thirds due to other factors, led by more efficient use of applied water [6]. The December 2025 release says about two-thirds of the reduction since 2005 was likely the result of operating facilities applying water more efficiently [1].

2.2 California's Nonfunctional Turf Rules

California's Water Code defines a recreational use area as an area designated by a property owner or a governmental agency to accommodate human foot traffic for recreation, and names golf courses among its examples. Turf in a recreational use area or community space is functional turf. Turf in street rights of way and parking lots, and turf permanently fenced off from recreation or assembly, is not [2].

Potable water may not be used to irrigate nonfunctional turf on properties owned by the Department of General Services, local governments, local and regional public agencies, and public water systems starting January 1, 2027 (later for local agency and water system properties in disadvantaged communities), on all other institutional properties and all commercial and industrial properties starting January 1, 2028, and on common areas of homeowners associations, common interest developments, and community service

organizations starting January 1, 2029; cemeteries are excluded [3]. Owners of commercial, industrial, or institutional property with more than 5,000 square feet of irrigated area must certify to the State Water Board starting June 30, 2030, and every three years through 2039; associations with more than 5,000 square feet of irrigated common area must certify starting June 30, 2031, and every three years through 2040 [3]. SB 1139 (Chapter 88, Statutes of 2026), effective January 1, 2027, amends the section to add the Monterey Peninsula Water Management District to the agencies that may enforce the prohibition and impose penalties for noncompliance [15]. How those rules apply to a particular course, and to turf around clubhouses, parking areas, and entries, depends on designation, use, and the course's water source (the prohibition applies to potable water), and is a question for the owner, its advisors, and its water supplier.

2.3 Supplier Water Use Objectives

The State Water Board's conservation regulation gives each urban retail water supplier an annual water use objective, with a budget component for commercial, industrial, and institutional landscapes on dedicated irrigation meters. For most of those landscapes the efficiency standard steps down in July 2028, July 2035, and July 2040, while special landscape areas and landscapes irrigated with recycled water keep a higher standard [4]. These are inputs to the supplier's objective, not budgets assigned to individual customers; how a supplier passes them on is up to the supplier. Suppliers must also identify commercial, industrial, and institutional landscapes of half an acre or more on mixed-use meters and bring them onto dedicated meters or in-lieu technologies over time [4]. Whether and how these provisions reach a given course depends on how it is metered and served, so courses should ask their supplier directly.

2.4 Drought Cutbacks

California courses have been through mandatory cutbacks before. In late 2022, the USGA reported that a third year of drought was requiring many California golf courses to cut water use by 35 percent of their assigned volumetric budget [5]. The same article quoted GCSAA's Southwest field staff saying water regulators across that region want less irrigated turf on golf courses, and noted that Arizona's groundwater management rules hold courses to about five acres of irrigated turf per hole and that the Southern Nevada Water Authority paid courses up to \$2 per square foot to remove turf at the time [5].

If another cutback comes, a course with its turf already mapped can spend its time on the cut itself, not on finding out what it has.

3. Why Records Matter for Courses

3.1 Irrigated Acreage

Water budgets, conversion projects, and conversations with water agencies all start with irrigated acreage. A dated map of every hole, the practice areas, and the surrounding landscape lets a course take approximate measurements of the areas it identifies as irrigated and see how they change over time.

3.2 Before and After Every Project

Turf reduction, bunker renovation, drainage work, and grassing changes all reshape a course. A record captured before the work shows where things started, and a record captured after shows the visible result. Together they give owners and members a dated record of the project, and they can accompany a submission to a rebate program or agency, which set their own inspection and documentation requirements.

3.3 Best Management Practices

GCSAA reported that by the end of 2020, every state had established golf course best management practices, with water management among the key areas [7]. Facility BMP manuals describe how a course manages water and the environment. A consistent visual record of the course supports those manuals with documentation of conditions over time.

3.4 Telling the Story

Golf's water use draws a lot of attention. The National Golf Course Owners Association has said owners, operators, superintendents, and PGA Professionals should be able to answer basic questions such as where their irrigation water comes from, how much is reclaimed or non-potable, how consumption has changed, and whether irrigated acreage has been reduced [8]. A dated record of turf reductions, conversions, and conditions gives a course something concrete to show members, neighbors, and officials.

4. What the Research Says About Aerial Sensors on Golf Turf

Researchers have flown sensors over turf and crops for years. Some results are strong, and the authors say plainly where they fall short.

- **Golf course irrigation zones:** a 2025 study at a golf course in Utah used multispectral and thermal imagery from drones to estimate turfgrass quality and actual evapotranspiration. The turf quality model correlated with evapotranspiration on fairways, roughs, and tees (R-squared values of 0.74, 0.75, and 0.66 on July 20, 2022), but much less on greens (0.25) and the driving range (0.36). The authors mapped the resulting zones against the course's sprinkler heads and concluded the approach can guide how much and where to irrigate in semi-arid settings [9].
- **Turf nitrogen status:** a 2016 study found drone-based NDVI strongly correlated with a handheld ground sensor on several warm season turfgrasses, with correlation coefficients from 0.83 to 0.97, and suggested drones suit large areas such as golf courses [10].
- **Timing matters:** a 2017 orchard study found that NDVI from the same drone differed significantly between flights on the same day, and the authors said further calibration for the effects of solar motion is needed [11].
- **What NDVI measures:** the U.S. Geological Survey describes NDVI as a way to quantify vegetation greenness, useful for understanding vegetation density and changes in plant health [12].

Here is what we take from these studies. Aerial data can map turf conditions across a whole course in a way that is hard to match on foot. Results vary by area of the course, and readings vary with timing. And turning any of it into an irrigation or agronomic decision is the superintendent's job. A consistent record gives the superintendent something solid to start from.

5. Aerial Documentation for Golf Courses

5.1 What Is Captured

Every FlyCRE flight captures four data layers, delivered in this order:

- **Orthomosaic:** a single overhead map of the course built from many overlapping images, showing greens, tees, fairways, roughs, bunkers, native areas, and cart paths in one view.
- **Thermal:** a record of surface temperature differences at the time of capture.
- **Asset Visibility:** close views of features such as pump stations, lakes, drainage, bridges, and cart path edges.
- **Multispectral:** spectral bands that can be used to calculate vegetation indexes such as NDVI [12].

Each layer records how the course looked at one time under one set of conditions. The studies above found that results differed by area of the course and that readings shifted between flights on the same day [9][11].

5.2 Timing

The most useful schedule follows the course's calendar: peak summer demand, seasonal transitions such as overseeding and dormancy, before and after aeration or renovation, and at regular intervals in between. Capturing at a consistent time of day helps keep thermal and multispectral records more comparable, though readings can still vary with conditions [11].

5.3 Consistency

Saved flight plans let us fly the course the same way each cycle. Every image carries a GPS position and capture time, and every capture is stored so it can be compared with earlier and later flights.

5.4 Measurements

Orthomosaic maps allow approximate measurements, such as the turf area of a hole that the course identifies as irrigated, a fairway, or a converted native area. They are for tracking and reference. They are not survey grade, are not certified by a licensed land surveyor, and should not be used to set property lines or legal boundaries. Water

suppliers and rebate programs use their own measurement methods, and those methods govern their decisions.

5.5 Data Ownership and Privacy

Many courses are lined with homes. Flight plans are built around the course property we are hired to document, and we do not target private residences or property outside that scope. Image overlap and turns can extend past the property line, so neighboring homes and yards can appear at the edges of a capture. All data from every flight is loaded into our encrypted platform and released only to the client who ordered it and to anyone the client authorizes, unless we are legally required to produce it. We do not publish client data or use it as a sample.

6. Flight Operations

Every FlyCRE flight is flown by FAA certified remote pilots under 14 CFR Part 107, including its visual line of sight, altitude, and operations over people rules [13]. Because golfers and staff are on the course, flights are scheduled around play, maintenance crews, and events, typically early morning or on maintenance days, at a consistent time for each cycle. In controlled airspace, we obtain FAA authorization before takeoff, through LAANC where it is available [13][14].

7. What Aerial Documentation Does Not Do

FlyCRE documents sites from the air. Here is what we do not do:

- **No agronomic diagnosis:** we do not determine turf health, disease, pests, nutrient status, or water stress, or the cause of any pattern in the data.
- **No irrigation recommendations or audits:** irrigation scheduling, system audits, and water management decisions belong to the superintendent and irrigation professionals.
- **No turf classification:** we do not decide whether any area is functional or nonfunctional turf.
- **No compliance or rebate outcomes:** water suppliers, rebate programs, and the State Water Board make those decisions.
- **No surveying:** measurements are approximate and not survey grade.

Within those limits, we give the course, and anyone it chooses to share with, the same dated view of every hole.

8. Conclusion

Golf has cut its water use substantially, and the industry has the data to show it. What national data cannot show is any one course's own record: a dated, consistent picture of every hole, captured the same way each season, that shows where turf is and how its extent has changed.

That record does not grow grass or set a water budget. It gives superintendents, owners, and boards something solid to point to when water agencies, members, or neighbors start asking questions.

Documented Today, Defensible Tomorrow.

Appendix

A. Regulatory and Industry References

- **Water Code section 10608.12:** definitions of functional turf, recreational use area, and community space [2].
- **Water Code section 10608.14:** the nonfunctional turf ban, deadlines, and certification [3].
- **Making Conservation a California Way of Life (Title 23, California Code of Regulations):** urban water use objectives and landscape budgets [4].
- **GCSAA Golf Course Environmental Profile:** national survey of golf course water use and practices [1][6].
- **GCSAA best management practices:** state golf course BMP guidelines [7].
- **14 CFR Part 107:** operating rules for small unmanned aircraft [13].

B. Research Summaries

Meza et al., Crop Science, 2025 [9]

- **What they did:** used drone multispectral and thermal imagery at a Utah golf course to model turfgrass quality and actual evapotranspiration, then mapped management zones against the course's sprinkler heads.
- **What they found:** the turf quality model tracked evapotranspiration on fairways, roughs, and tees, but much less on greens and the driving range.
- **Why it matters:** aerial data can map conditions across a course, and results differ by area of play.

Caturegli et al., PLoS ONE, 2016 [10]

- **What they did:** compared drone-based NDVI with a handheld sensor on warm season turfgrasses under different nitrogen rates.
- **What they found:** strong correlation between the two, from 0.83 to 0.97.
- **Why it matters:** the authors suggested drone data can help manage large turf areas such as golf courses.

Zhao et al., Journal of Intelligent and Robotic Systems, 2017 [11]

- **What they did:** flew a multispectral drone weekly over an almond orchard and compared canopy NDVI with stem water potential measured on sample trees.
- **What they found:** NDVI differed significantly between flights on the same day, and the authors called for further calibration.
- **Why it matters:** records are easier to compare when flown at similar times under similar conditions.

C. Golf Course Recordkeeping Checklist

This checklist applies whether or not you use aerial documentation. It is a starting point, not legal or agronomic advice.

- Know your water sources, meters, and supplier for every part of the property.
- Map irrigated turf by hole, practice area, and surrounding landscape, and update it after every change.
- Ask your water supplier how its conservation rules and the nonfunctional turf rules apply to your property.
- Capture a dated record before and after every renovation, conversion, or turf reduction project.
- Keep irrigation audits, water bills, and meter data with your property records.
- Keep your facility BMP manual current and link it to your records of conditions.
- Store original files with capture dates and who captured them.
- Calendar any certification dates that apply to your property.

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