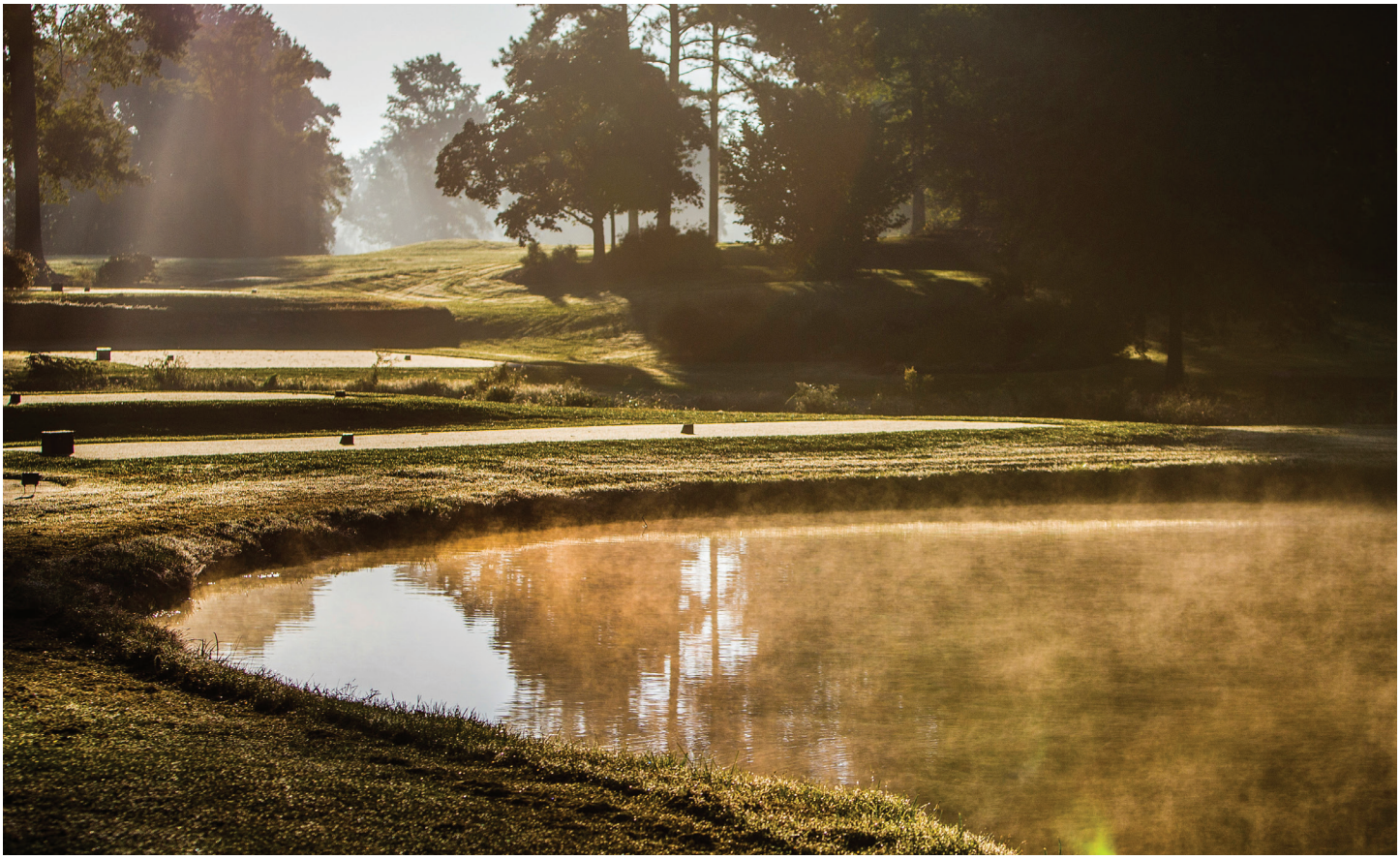
WATER SOURCING AND STORAGE STEWARDSHIP

Surface Water Optimization



Water features are common on golf courses in many environments. While they can have functional, strategic and environmental benefits, they can also be a source of water loss. Optimizing their design and maintaining them carefully will limit unnecessary water use.

SNAPSHOT

This strategy addresses limiting the loss of water from surface water features on golf courses. It is a medium-impact, high-cost strategy applicable for many golf courses.

Expected cost	> $50K per acre
Ease of implementation	Large capital project
Potential water savings for affected area	Up to 50% with water-loss management. Up to 100% if surface water is replaced by non-irrigated landscape.
Highest potential impact areas	Nationwide, especially in arid regions with high annual evaporation

OVERVIEW

Water features offer many benefits to golf courses and their surrounding communities. They provide irrigation water storage, habitat for aquatic plants and wildlife, and stormwater management that can mitigate damage during rain events. Golf course water features can also filter runoff before it continues downstream. USGA-funded research has shown that water can be cleaner when exiting a golf course than when it entered (Kohler et al., 2004). Water features also contribute to the strategy of the golf course and overall aesthetics of the property.

However, water features come with their own unique set of management challenges, and they can create issues for courses looking to conserve water. Evaporation, leakage, debris and sediment accumulation, and lack of maintenance can diminish the benefits of golf course water features and lead to significant water losses or a reduced supply of irrigation water. The presence of constructed golf course water features in areas prone to drought can also create a misperception that golf courses are using water for decoration while communities are trying to conserve.

Two comprehensive surveys recently conducted by the Golf Course Superintendents Association of America (GCSAA) report that surface water features cover an estimated 141,746 acres on U.S. golf courses compared to 1,044,924 acres of irrigated turfgrass. Reducing or eliminating unnecessary constructed surface water features can help golf courses conserve water by reducing the amount of water used to fill water features and by reducing evaporative losses. However, it is important to note that the evaporative loss from water areas is similar to the losses from turf areas, so what replaces the water feature is an important consideration. Replacing a pond with turf that needs to be irrigated may not save much water. Another benefit to having only essential surface water features is that they are costly and sometimes difficult to manage. For example, leaks can lead to wasted water and various playability issues, and can be very expensive to fix.

The good news is that with a measured approach that includes careful analysis, planning and execution, surface water optimization can be achieved. It may involve eliminating, consolidating or redesigning and rebuilding existing water features. It could also mean using better management strategies. When trying to optimize the constructed surface water features on a golf course, it is important to understand the potential trade-offs in water storage, stormwater management capacity and course strategy that may come with altering water features to save water. The goal should be to quantify how much water is being used for surface water features, especially constructed surface water features, and to reduce that amount where possible so that it can be redirected elsewhere or not used at all.

SCENARIOS FOR USE

The optimization of surface water on golf courses applies primarily to constructed bodies of water such as ponds, lakes and creeks. The term “surface water” is defined as the footprint or measured surface area when the feature is full of water. To get the total for a golf course, you simply measure the edges of all bodies of water and express the total in square footage or acreage. Total surface area of water features is important because this represents the quantity exposed to the atmosphere and subject to evaporative loss. Surface water loss due to leaks also must be considered, and there are strategies to help golf facilities locate and mitigate leaks.

Where Is the Strategy Typically Used?

Optimization is especially important for surface water features that require active replenishment to be maintained at a desired level. Replenishment means that water is being drawn from another source, so mitigating that consumption is of value. The concern about how much water is required for surface water features is intensified when water is scarce and/or expensive and could be used elsewhere on the course or conserved entirely. The distinction between surface water features that must be continually filled to a desired level and ones that are naturally fed to maintain their level is an important one to make. In many instances, it is not always an obvious distinction.

Bodies of surface water on golf courses in arid climates are vulnerable to evaporation and their level will not be maintained by rainfall.

Reducing Surface Water Area Where Possible

Most golf courses will benefit from keeping surface water features to a minimum. Even when water is “free” and has no cost to the facility, there is a cost associated with many other aspects of water features and their required maintenance. Certainly, every golfer has encountered a few unkempt water features in their travels. The cost to remedy issues like siltation and aquatic weed growth is directly proportional to the surface area of the water feature – a simple premise that supports reducing surface water features wherever possible.

There are limited exceptions to this, including where surface water storage is mandatory. For example, treated effluent water must be stored in ponds or lakes on some golf courses where there isn't another discharge option. Storage capacity for flood control would be another example. Still, exception is the key word here.

All decisions to reduce the number or area of constructed water features must strike a balance that preserves golf strategy, aesthetics, functional drainage, stormwater management, and making sure that ample water is stored for irrigation needs. Less can be more, provided that we do not compromise the core design hallmarks of a golf course, nor diminish the challenge and appeal to golfers. Whatever is done needs to be handled by a golf course architect in concert with the management team at the facility to balance the many considerations involved.

Evaporation Management Strategies

The best way to reduce evaporation from a surface water feature is reduction or elimination. If water surface area reduction is desired, a solution may be to deepen the reservoir to maintain volume and reduce evaporation. When these strategies aren't possible, physical barriers also can potentially reduce evaporation. Tree shade, windbreaks and pond flotation devices – such as the plastic spheres often seen in industrial ponds – can reduce evaporation. Plastic covers or even floating solar panels have been used to reduce evaporation from surface water in various settings. Obviously, these measures come with an aesthetic impact that may not pass muster. Further, some barriers may reduce dissolved oxygen in water, which can reduce water quality and can be problematic for aquatic plants and animals.

Golf courses should not take for granted that the sources they rely on to sustain surface water features will always be available.

Opportunities To Expand Use

Courses located in the Sun Belt – i.e., states in the South and West from Florida and Georgia through the Gulf states into California – can benefit greatly from this strategy because their water features experience greater losses from evaporation. Even in areas where water resources are not in short supply, continually recharging some bodies of water to keep them aesthetically pleasing can amount to significant unnecessary water use.

An important consideration is the type of water being used to refill water features. Potable water is in short supply in many regions, so conservation is critical. Fresh water from rivers, lakes and underground sources is also of great conservation importance. Even reclaimed and brackish water are becoming more important for potable supply with new technologies and initiatives like direct potable reuse (DPR) in arid regions. Golf courses should not take for granted that the sources they rely on to sustain surface water features will always be available.

SOURCES OF WATER LOSS AND POTENTIAL WATER SAVINGS

Any surface water feature maintained in any region will be subject to evaporative losses. This accounts for most of the water lost from surface water features and is, of course, higher in warm and dry climates like the Desert

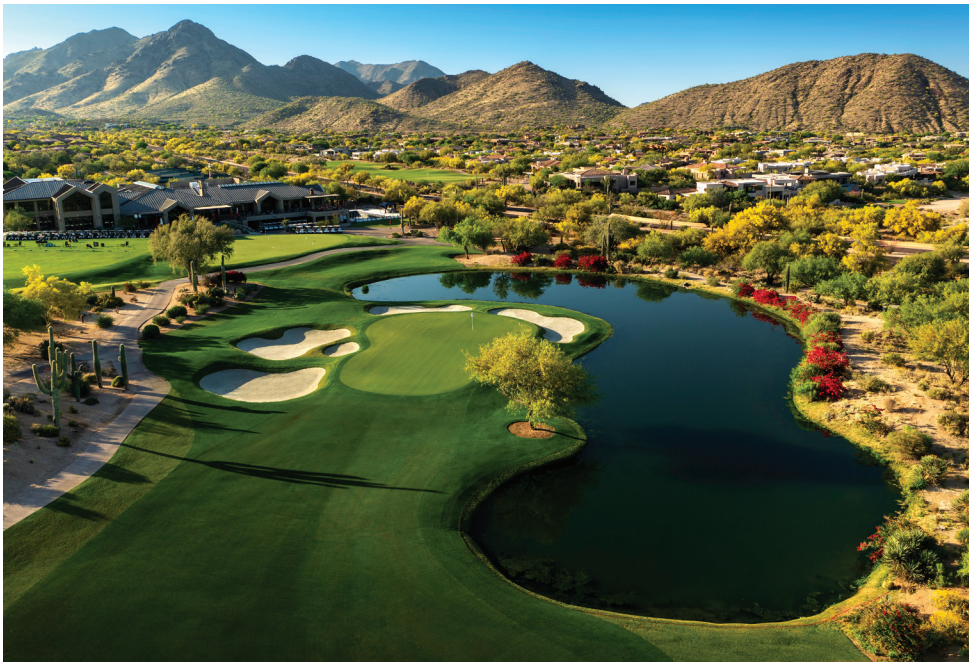
Southwest. The other main way surface water features lose water is through leaks in the materials designed to retain water within the footprint of the feature. We cover these and a few other sources of water loss in the sections below.

Evaporation

Evaporation rates depend on region, climate and even microclimatic factors like the amount of shade and air movement that impact a body of water. In the continental U.S., water loss from evaporation varies from less than 20 inches in regions such as the coastal Pacific Northwest to more than 80 inches in parts of the Southwest. Across most of the U.S., evaporation rates are in the range of 40 to 60 inches per year. The higher end of this range includes most of the warmer climates in the U.S., extending from California across the South to Florida. Especially in these regions, it is typical to find golf courses where annual evaporation greatly exceeds the amount of natural rainfall. In these situations, the amount of evaporative water loss from surface water features can be dramatic, and that amount increases when the surface area of ponds and lakes is larger than necessary.

As an example, a 1-acre lake in Southern California can be expected to experience a net loss of roughly 5 feet of water every year through evaporation – accounting for the influence of temperature, humidity, rainfall, drought dispersion, solar radiation and wind. The annual net evaporative loss, not including potential leaks, is 5 feet multiplied by the total surface area of open water. So, the 1-acre golf course lake in our example can be expected to lose about 5 acre-feet of water per year. For perspective, 5 acre-feet of water is equivalent to 1.6 million gallons, or roughly the amount of water required to fill two and a half Olympic-size swimming pools.

According to the land-use survey from the GCSAA referenced earlier, the median 18-hole U.S. golf course had 5.7 acres of surface water in 2021, representing 4% of total facility acreage. In the southwestern U.S., the median 18-hole golf course had 4.1 acres of surface water, and total projected surface water acreage on golf courses in the Southwest was 8,064 acres. Based on the example above, this means that potentially 40,320 acre-feet of water, or 13.1 billion gallons, are evaporated from golf course surface water features annually in the Southwest. By comparison, the water-use survey conducted by the GCSAA indicates that projected water use for golf courses in the southwestern U.S. was 487,332 acre feet in 2020, meaning potential surface water evaporation represents 8.3% of projected water use for golf course in that region.



Substantial amounts of water can be lost to evaporation from golf course water features in hot and dry climates.

Estimates of annual precipitation and evaporation can give a partial picture of net evaporative potential for a given location. However, monthly estimates will be more informative and will highlight the time of year when replenishing certain surface water features may be most needed – i.e., when evaporation exceeds precipitation, especially for consecutive months. For example, even in a rainy climate like Seattle, evaporation often exceeds precipitation in summer months, resulting in the lowering of surface water levels. Of course, the reverse also can be true and sometimes water must be released from lakes and ponds to prevent overtopping.

Ideally, the total area of constructed surface water features on a golf course should be the minimum required to adequately store water for irrigation, provide necessary retention of stormwater, and provide interest to the golf experience. It also is important to remember that where storage is needed, reducing surface area can be offset by making water features deeper to achieve the same volume of water with less evaporation.

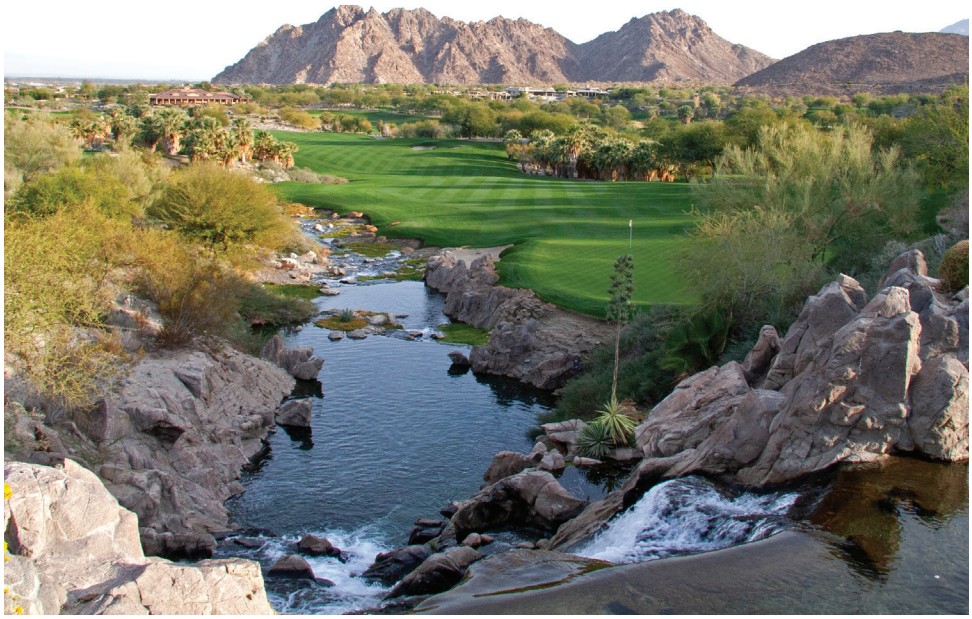
Leaks

The most-difficult water loss to measure from surface water features is leakage. Whether water features are lined or unlined, they may have significant leaks. Even small, seemingly insignificant leaks can amount to considerable water loss over time. Leaks are also typically escalating in nature and small leaks become larger over time as water moves through and expands voids. Many superintendents continue to replenish ponds and lakes, not really knowing for certain whether they are losing water from evaporation or because of leakage.

Other Loss Factors

Breaches: This situation is where a pond or lake water overtops and "leaks" behind an artificial liner. Technically, this is not a leak but a correctable condition that will require resetting the water level or raising portions of the lined shoreline. Unlike underwater leaks, such breaches are much easier to pinpoint as it is simply a matter of raising the level of the pond until it is evident that water is overtopping in a particular area.

Waterfalls, rapids and aeration: Water that gets mixed with air, such as waterfalls, rapids in streams, and fountains, can experience increased water loss. Evaporation is accelerated when water is churned with air by such features. A balance should be struck where water quality can be improved by aeration and movement to prevent stagnation, yet evaporation is minimized. Water loss from waterfalls and fountains may be difficult to measure, but a rule of thumb is that as much as



Waterfalls, fountains and rapids in streams can increase evaporative loss because the water is mixed with air.

one percent of each gallon pumped or moved for such features can be lost above and beyond typical evaporation. This is commonly referred to as "splash loss."

Vegetation: Finally, surface water can be lost when shorelines are heavily planted or allowed to overgrow with waterborne plants. Cattails, for example, consume water at a significant rate. Other plants that live around or in water can have high water-use rates depending on species, plant size and plant density. While some plants, such as floating lily pads, cover the water surface and can reduce evaporation, they also consume water, and their net water conservation potential can be difficult to discern. Some tree varieties can be invasive to a water feature with aggressive roots that may eventually damage liners and should be avoided. Trees also consume water.

Maintenance Inputs

If surface water features are to look and perform as intended, they will require constant maintenance. Repairing liners, removing trees, aquatic weed control, replacing bulkheads and retaining walls, maintaining aeration devices like fountains or bubblers, and repairing breaches are just some of the tasks golf course superintendents need to perform regularly to ensure proper function. If surface water features are part of stormwater management infrastructure, even more attention needs to be paid to maintaining proper function to minimize the risk of property damage. This can include costly dredging, removing sediment and debris deposits in waterways and repairing pipes. Additional maintenance costs that can be reduced by decreasing the area of surface water features include:

- Managing shoreline erosion and controlling plant growth.
- Mowing turfgrass edges along surface water bodies, which is often hazardous.
- Cost of eventually relining ponds or lakes.
- Electricity and labor costs to pump or transfer water between surface water bodies.
- Capital costs to replace, repair and maintain water infrastructure such as wells and pipes.
- Costs associated with water quality management.
- Insurance premiums associated with open bodies of water, generally based on the number of water features and the likelihood of them being an attractive nuisance.

Finding out whether a water feature is leaking is a tricky task. It can be even more difficult to figure out where it is leaking from.

CONSIDERATIONS

Determining Whether an Existing Water Feature Is Leaking

Finding out whether a water feature is leaking is a tricky task. It can be even more difficult to figure out where it is leaking from. Rarely is there one spot that is leaking. Most of the time, because artificial liners wear out and are subject to the same conditions, leaks will be widespread. A plastic liner that is intended to last for 25 years typically begins to wear out and leak in multiple locations simultaneously. The same holds true for other liner types.

Unfortunately, leaks are not isolated to the actual pond, lake or creek itself. The pipes and conveyances that deliver water to such features, as well as the pipes that extend from water bodies for irrigation intake or transfers between ponds, can be prone to leaks. Leaks are elusive and can be among the most maddening water-loss issues to locate and resolve.

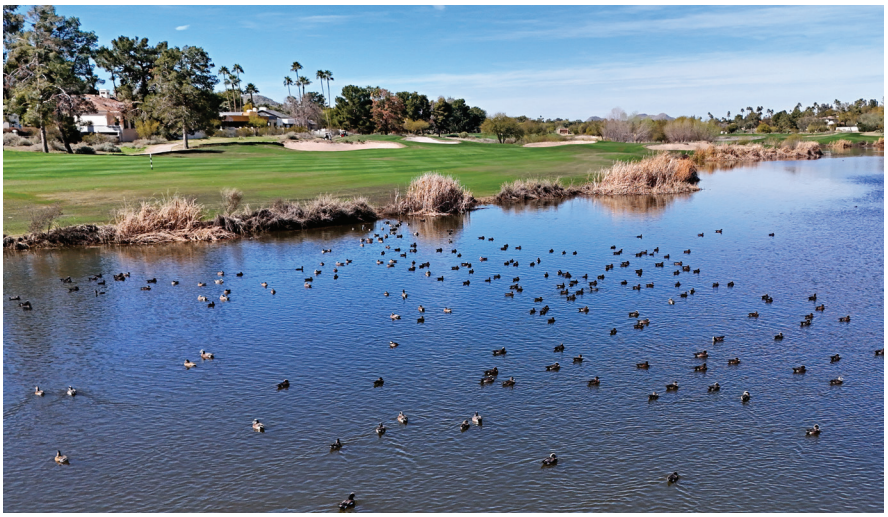
Resources for golf facilities to help determine if and where leaks are occurring include working with a golf irrigation consultant, lake management contractor or golf course builder. These professionals will often have the skills to assist superintendents in locating leaks. Specialized inspection procedures may involve using dyes to trace water flow toward leaks, underwater and pipeline cameras, and qualified scuba divers trained to inspect lake liners and the many pipe and intake penetrations through those liners.

Surface water features should not be arbitrarily eliminated or made smaller without careful consideration and planning.

Preserving the Integrity of the Golf Course Design

Water features can be of great value to the overall golf experience. They can bring charm, intrigue, tranquility and drama to a golf hole or series of golf holes. In his book "Routing the Golf Course," Dr. Ed Sadalla, a noted professor of environmental psychology, wrote: "Water is a dominant visual landscape resource and almost always increases scenic value." Dr. Sadalla went on to point out that many of the greatest golf holes in the world derive their greatness from water. Further, three-time Masters champion and multiple-time winner on the PGA Tour Jimmy Demaret noted "If you moved Pebble Beach 50 miles inland, no one would have heard of it" (Richardson, 2002). According to Dr. Sadalla, the impact of water on golf course architecture has been shown to depend on factors like land-to-water contrast, shoreline complexity, size of the water body and internal contrast, such as vegetative elements within or around a water feature.

Surface water features should not be arbitrarily eliminated or made smaller without careful consideration and planning. The best advice will come from a qualified golf course architect and irrigation consultant who can study the value of a pond, lake or stream while considering the strategic, aesthetic and experiential value the water brings to the golf course.



Golf course water features can provide valuable habitat and other environmental benefits. These must be carefully considered before making alterations.

Environmental Benefits

Whether a golf course water feature is constructed or not, they often provide various environmental benefits including wildlife habitat and stormwater filtration.

These benefits must be carefully understood before alterations are made to golf course water features and, in many cases, regulations may prohibit changes because of the existing or potential environmental benefits or harm. If some environmental benefits are affected by alterations to a surface water body, there may be ways to preserve or even enhance them in the replacement landscape treatment or elsewhere on the course while also achieving the goal of reducing unnecessary water use. Finding the best possible solution among these tradeoffs requires thorough planning and careful consideration.

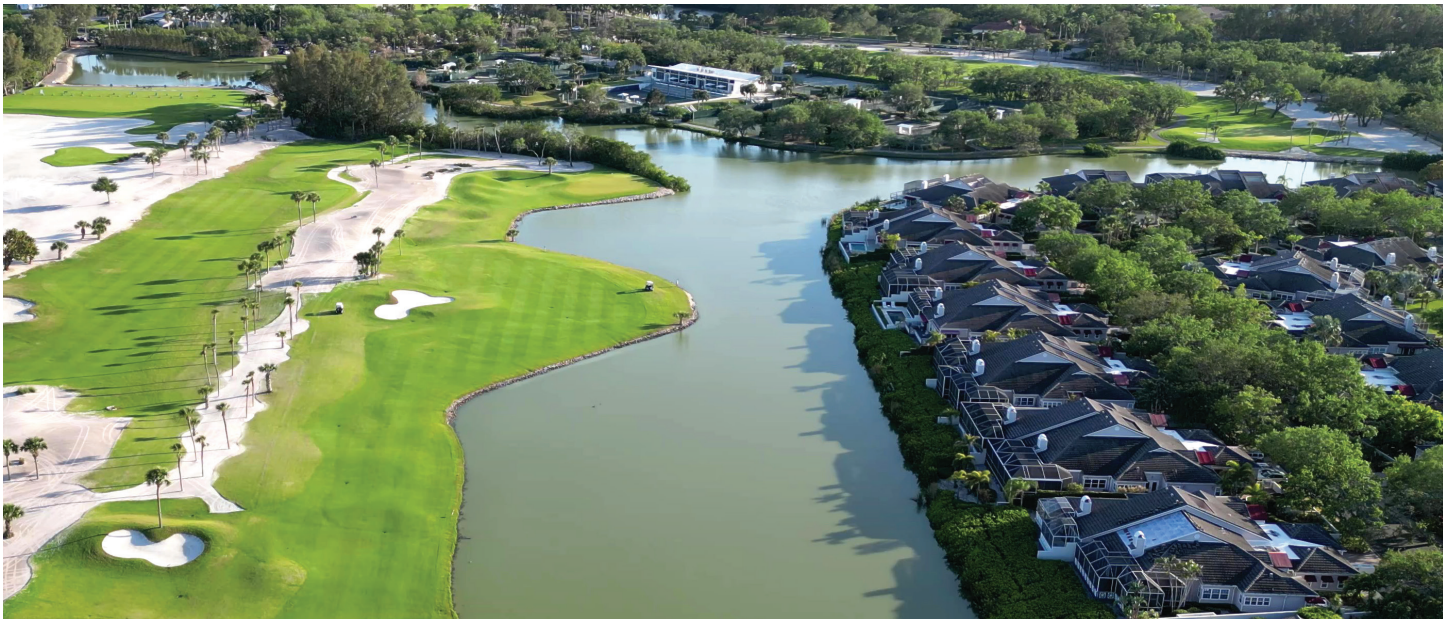
Impact on Quality of Life

Removing water features can have an emotional effect on people. Humans are naturally drawn to water because of its role in our survival. Early civilizations settled near water because it was an important resource to thrive. Our evolutionary bond with water is why we derive pleasure from its presence. It has been shown to promote feelings of safety, tranquility and positivity (Wilson, 1984).

Studies on the psychological effects of water have been persistent throughout the history of environmental psychology. Human benefits from the presence of water include its restorative properties, recovery from mental fatigue and social benefits when water features become the focal point for community connection or gathering (Kaplan, 1995; Strang, 2004; Maas et al., 2009; Gascon et al., 2017).

Impact on Property Value

Golf courses are often built as an amenity of a larger residential development, and water views or waterfront property significantly increase property values. Reducing the size of water features or removing them altogether can elicit a negative response from homeowners who live adjacent to golf course ponds or lakes and benefit from increased property values.



Making changes to golf course water features may have a real or perceived impact on adjacent property values. Addressing potential concerns requires active community engagement.

IMPLEMENTATION

Step 1: Analyze Existing Features to Identify Goals and Opportunities

Establish goals

Every project should begin with a clear understanding of goals. In this case, the goal is smarter use of surface water as a functional, aesthetic and strategic component of the golfing experience. Engage a golf course architect to determine how changes to water features will affect the overall strategy and experience. Engage other experts to help determine the potential water savings of various approaches to modifying those water features. A comprehensive inventory and analysis of water features, drainage patterns and water requirements are critical for identifying alternatives to the current arrangement of surface water on a golf course.

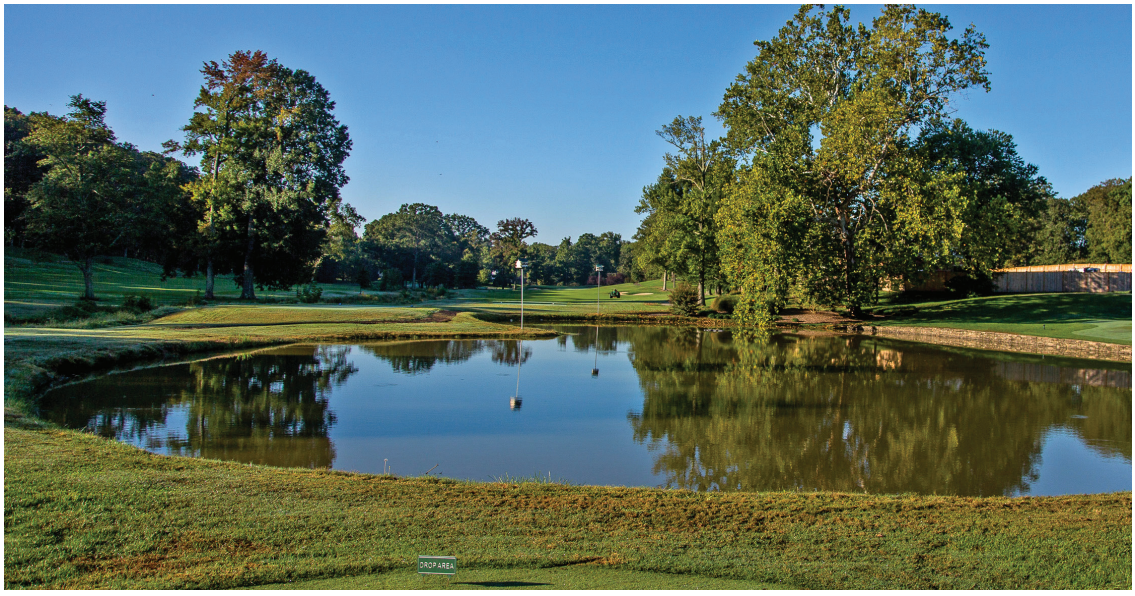
Optimizing the amount of surface water on a golf course can vary from simple adjustments to more complex, integrative efforts. As noted earlier, modifying existing water features needs careful consideration due to the potential regulatory, environmental, social and economic implications. Altering or removing a water body can impact the golf course's functionality, appearance and compliance with regulations.

Assemble your team

Decisions regarding water features impact not only the golf course but also its surroundings. Assemble a multidisciplinary team that may include a golf course architect, engineers, environmental consultants, landscape architects and irrigation specialists. You may even want to include community leaders if the golf course handles stormwater from residential areas or has homes adjacent to water features. This diverse expertise and perspective ensures that all social, environmental and economic aspects are considered.

Surface water analysis

Evaluate whether the current size and/or location of water features aligns with their purpose and with the golf course's current water use goals. Assess each water feature to determine if alteration or removal is desirable and feasible.



If water conservation is an important goal at a golf course, every water feature should be evaluated for functional purpose, strategic impact, environmental value and the potential water savings from shrinking or removing it.

Rank the importance of surface water features

Consider the importance of each water body at the facility. Listed below are categories of surface water features, organized by their relative importance. This classification can be helpful in identifying which water features may be feasible to eliminate or reduce in surface area.

Essential surface water feature: Any body of water that helps protect people or property through stormwater management, or is used to store treated effluent that cannot otherwise be distributed, normally cannot be changed and therefore options are very limited.

Essential habitat: Protected water areas cannot be altered without mitigation and approval. Whenever a water feature is or has become important habitat, any change to the size may result in environmental harm. Therefore, this category of open water needs careful assessment and will typically not be available for significant change. However, if artificially refilled, many surface water bodies may not be considered protected. This determination varies by jurisdiction and many variables apply.

Essential storage: Primary irrigation reservoirs like storage lakes and ponds must be sized to hold an appropriate volume to efficiently irrigate the facility. The key term here is "essential," and it is important to know that volume and how it works with drawdown – i.e., the lowering of the water level when pumping and irrigation use is at its peak – and refilling back to the desired level. Essential storage is therefore a question to be studied early on.

A golf course may also choose to reduce total irrigated area, which would save water on its own and reduce the amount of water that needs to be stored for irrigation. It is surprising how many golf courses have taken the step to reduce irrigated turfgrass acreage, yet do not reduce the size of their irrigation storage ponds to fit their new water storage requirements. More drastic approaches are to replace all or part of the irrigation reservoir with storage tanks, either below or above ground. This can be costly because required volumes will typically take multiple tanks or extremely large tanks.

Nonessential, but strategically important: If the water feature is important to golf strategy, then it must be given the utmost consideration, even if it does not serve a critical storage or retention function. While water may be the preferred challenge, if water conservation is an overriding factor the feature can be converted into terrain that is landscaped and aesthetically pleasing yet functions as an obstacle in the same way it would if filled with water. The Rules of Golf accommodate such conversions by allowing courses to identify "penalty areas" regardless of whether they are filled with water or not. In many cases, taking an old pond or lake and creating a new feature without water can be a great way to both save water and create interest. Fields of native grasses and ground covers, waste areas, wildflowers, desert landscaping and passive wetlands all require far less water to manage than a surface water feature yet can be an exciting addition to a golf course.

Nonessential: These are the easy, low-hanging fruit when it comes to eliminating surface water. If water conservation is a primary goal and a constructed pond, lake or stream does not add necessary storage or golf strategy, nor is it of real value in terms of aesthetics, then it should be removed. Especially if there is a regular refilling requirement or if its upkeep is expensive. Golfers, homeowners or others may claim that a nonessential surface water feature should not be removed for any number of reasons, but usually there is an alternative that meets their needs and the water conservation goals of the facility.

Identify opportunities and constraints

After conducting an inventory of water features and understanding their purpose and importance, explore what modifications are feasible. The fact that a feature is manufactured doesn't automatically permit alterations or removal. Many artificial water features built decades ago have since gained regulatory protection as wetlands, Waters of the United States, or areas of interest to authorities. These features were often created with specific functional purposes such as irrigation, stormwater management, recreation, water treatment or habitat creation. The challenge is to determine whether these features present constraints or opportunities. Some may be subject to regulatory restrictions, while others may have outlived their original purpose and offer potential for site improvement. Consulting an environmental engineer or consultant is crucial to understanding the possibilities and guiding a golf course through potential changes.

Public outreach

Engaging the community, golfers, homeowners and other stakeholders early in the process can help avoid conflicts and build support for proposed changes to the golf course's surface water features. Public input can provide valuable insights, and hearing concerns fosters goodwill and ensures alignment with community values.

Step 2: Planning and Design

Once the team identifies goals, existing conditions and opportunities for reducing surface water area, it is time to develop design options. With input from other consultants, the golf course architect should formulate alternatives to open water that meet functional needs and follow sound golf course design principles. Ensure that planning adheres to regulatory requirements and considers the long-term impacts on golf strategy, aesthetics and environmental sustainability. The consulting team must account for the course's topography, soil and climate while respecting the course's design and hopefully enhancing playability and pace of play with any changes. Replacing water hazards with alternative features can enhance a course's strategic intent and character. Some other design considerations are discussed below.

Pace of play

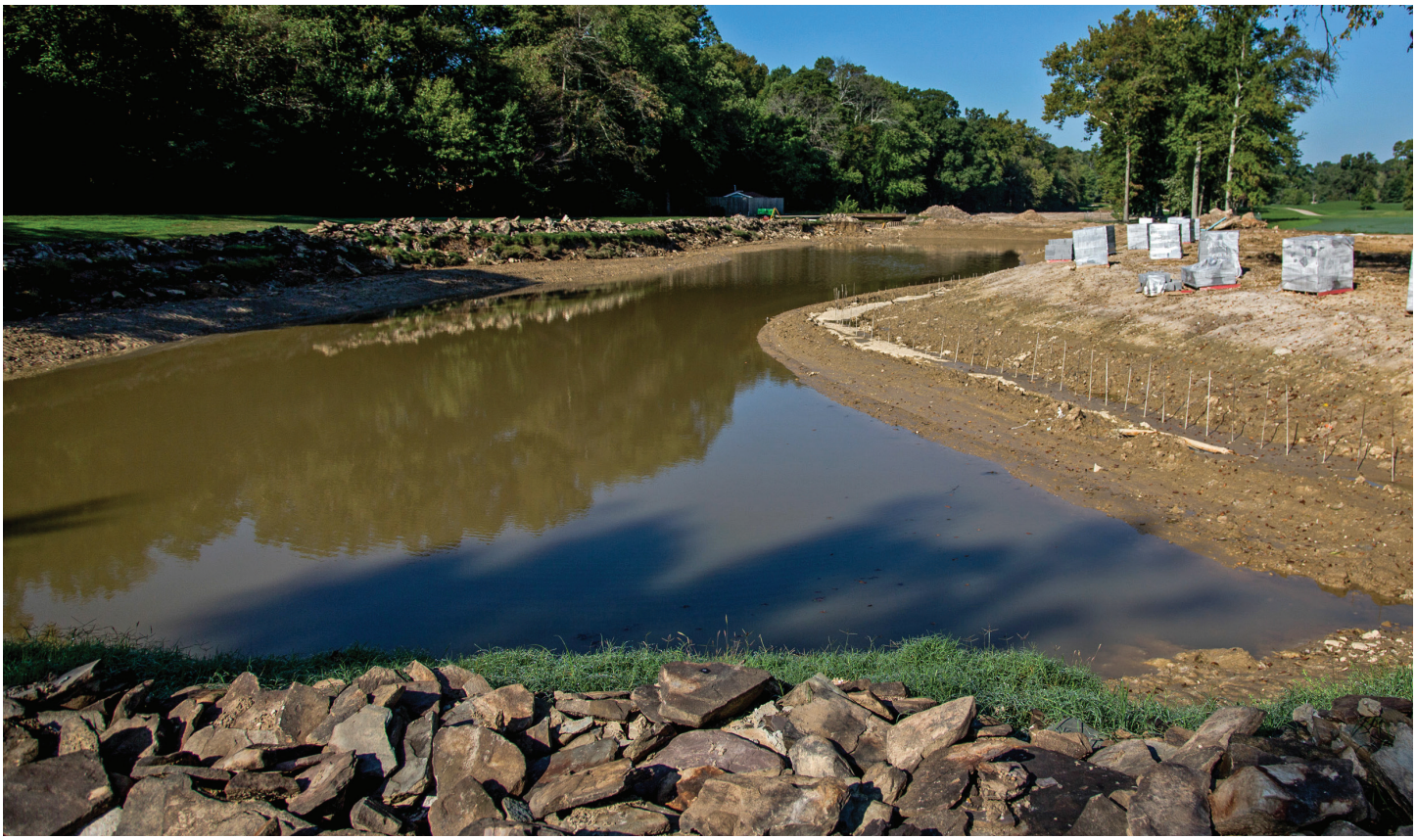
Water features can contribute to slow play depending on their size and location. When an area of surface water is altered or replaced, pace of play should be considered and a golf course architect should be engaged to offer advice.

Water rights

Water rights are complex and must always be considered when making modifications to water features. Whether local in nature, such as a homeowners' association maintaining agreements to preserve a particular lake or pond, or more complicated surface or groundwater rights for impounding water on a golf course, the legal implications of water rights are not to be taken lightly. A water rights attorney familiar with the specific jurisdiction of the golf course property should be consulted.

Dredging and silt removal

Often, the deficiencies of ponds and lakes used for irrigation storage are due to long-term silt and organic matter accumulation that makes the water shallower. This reduced storage can also exacerbate drawdown and cause shoreline erosion from an inconsistent water level. Rebuilding a lake with less surface area is a good opportunity to explore dredging to make the water deeper. This will optimize storage capacity within a smaller footprint.



Water features can be made deeper to maintain or increase their capacity even while their surface area is decreased.

Wildlife

Changing or eliminating golf course water features can potentially have impacts on plants and animals that benefit from the water feature or depend on it for survival. A qualified biologist who understands the nuances of golf facilities is the best resource to evaluate and help mitigate any impacts of this nature.

Rating and slope

Removing or altering a water feature can affect the difficulty of the course and the Course Rating and Slope Rating. A golf course architect will be able to help the course balance strategic and challenge considerations with water conservation goals to find the best possible outcomes.

Step 3: Executing the Plan

The execution phase of a surface water optimization project is critical to achieving the desired outcomes. This phase involves more than just implementation, it requires careful attention to details, developing ongoing water management strategies, and maintaining continued communication to achieve long-term goals.

Regulations and permits

Before proceeding with any modifications, golf course managers must review local regulations and permitting requirements related to water bodies. The following factors must be considered:

Environmental regulations: Laws aim to protect ecosystems and wildlife habitats, many of which depend on water bodies like ponds, lakes and wetlands. These areas may be protected or designated as critical habitats, which could restrict any modifications. Golf course managers need to comply with these regulations to ensure sustainability and avoid legal consequences.

Zoning regulations: Zoning laws dictate how land can be used. Water bodies may be subject to specific zoning rules, such as restrictions on their expansion or mandatory buffer zones. Understanding these regulations ensures that any modifications are compliant with local zoning requirements.

Water usage regulations: In areas facing water scarcity, water consumption on golf courses is often closely regulated. Modifying or removing water bodies might be part of a water conservation strategy, but it's essential to comply with usage limits and explore sustainable management practices.

Impact on surrounding areas: Modifying water features can affect local hydrology, drainage and water availability for nearby properties or ecosystems. Careful consideration must be given to the broader environmental impact and balancing your operational needs with community and ecological concerns.

Construction

During construction, the focus is on executing the planned water optimization strategies. The effort can involve significant earthwork, reshaping existing features, or installing new drainage systems. In addition, new irrigation components may be installed to better manage water flow and distribution across the course.

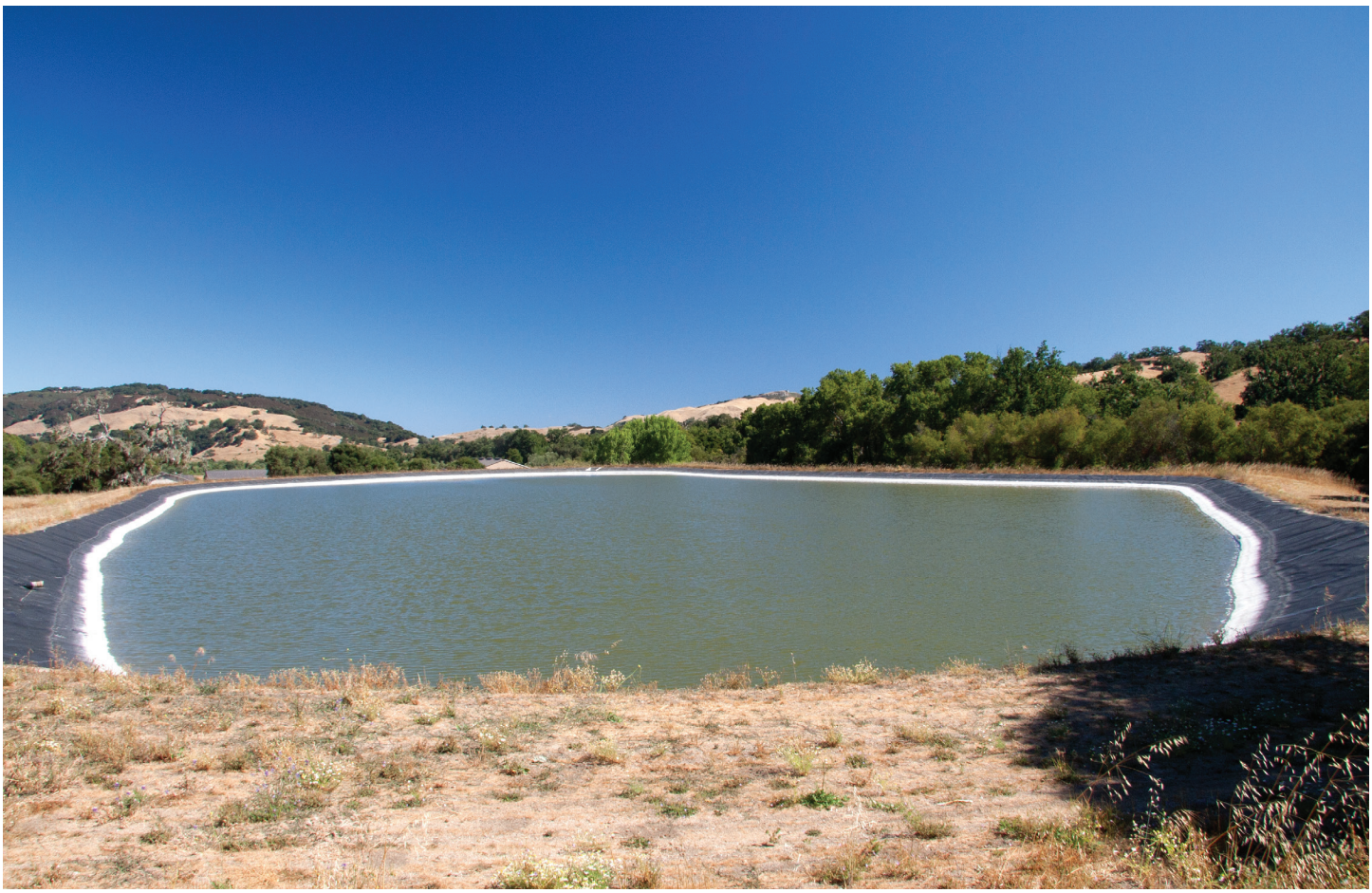
Liner options

Knowing how your surface water features are currently lined – or not lined – is an important first step. Once the functionality of the existing liners is understood, plans for modifications can be made. There are several common approaches to lining water features and there may be specific requirements in your area. If the goal in this project is water conservation, you want to select a liner that is unlikely to leak.

Relying on clay soil or a high water table: Unlined lakes and ponds may rely on clay soils, or in some cases may be situated over a high water table where there is an equilibrium of pressure that keeps the water body full without

leakage losses. Other water features may have been lined with a layer of clay soil, which is a common practice in construction of water features where clay soils are available. The clay layer, when properly specified and applied, is intended to form an impermeable barrier that does not allow water to move beyond it. This approach is not always precise, which often is discovered too late. The result is that water eventually breaches the clay layer.

Plastic liners: Today, the most reliable liner materials include high-density polyethylene (HDPE) and other sheet plastics that are seamed together and separate water from the underlying soil. These liners are often plated with soil to conceal the liner and prevent it from floating to the surface. While plastic liners are highly effective, they can still have issues. These barriers can be damaged, incorrectly installed, or may not be set to a consistent surface level, in which case the water can overtop it and leak behind portions of the liner. Settling, soil shifting and shoreline erosion also can cause overtopping. Repairing leaks in HDPE and sheet plastics is problematic. When such liners fail due to age or widespread damage, replacement is the typical remedy and costs are often significant



Most liners for golf course ponds today are made from plastic. While these liners are highly effective, they do require monitoring for damage, leaks or overtopping.

Soil additives: Soil additives such as bentonite (a swelling clay) or liquid polymers can be blended with native or imported soils to form a sealing layer. An advantage to this approach is that additive liners can be reapplied should the layer need repair.

Concrete: Concrete is rarely used to line water features today due to the porous nature of most concrete mixes. Nonetheless, there remain many concrete-lined ponds throughout the world.

Long-Term Maintenance and Monitoring

Once construction is complete, ongoing maintenance and monitoring of surface water features is essential to ensure their continued functionality. Monitoring efforts should include measuring water levels and tracking refilling requirements to provide data that can inform future adjustments.

If the project includes removing a water feature altogether, it will be essential to monitor the success of the replacement landscape treatment. For example, if we fill in a lake or pond, it will be essential to ensure the health and stability of the growing medium for turfgrass, vegetation or other ground cover materials. It is also essential to ensure that the area previously designed to hold water will no longer hold water and that the area performs as designed.

Education and Communication

The success of surface water optimization projects hinges on engaging with those who interact with the golf course. Education and communication are not just tools but the keys to unlocking this engagement. Golf course staff need to be educated about the benefits of changes to surface water features. Players can be informed about how they impact water conservation, helping to foster a culture of environmental stewardship. Engaging nearby communities can further extend the positive environmental impacts, particularly when water management practices also contribute to reducing flooding risks or improving local water quality. Effective communication ensures all stakeholders understand the importance of these initiatives and their role in protecting water resources.

TIPS FOR SUCCESS

Conduct a water feature audit.

If you are looking to save water at your course, don't overlook the opportunities presented by surface water features. Conduct a comprehensive evaluation of all water features on the course. Understanding the current state of ponds, lakes and other water bodies will help identify areas with excessive evaporation or leaks. Use tools like geographic information systems (GIS) or drones to map the surface areas and pinpoint high-evaporation zones. Assess whether you can meet the functional, aesthetic and strategic needs of the golf course with fewer or smaller man-made water features.

Minimize surface area and maintain water volume.

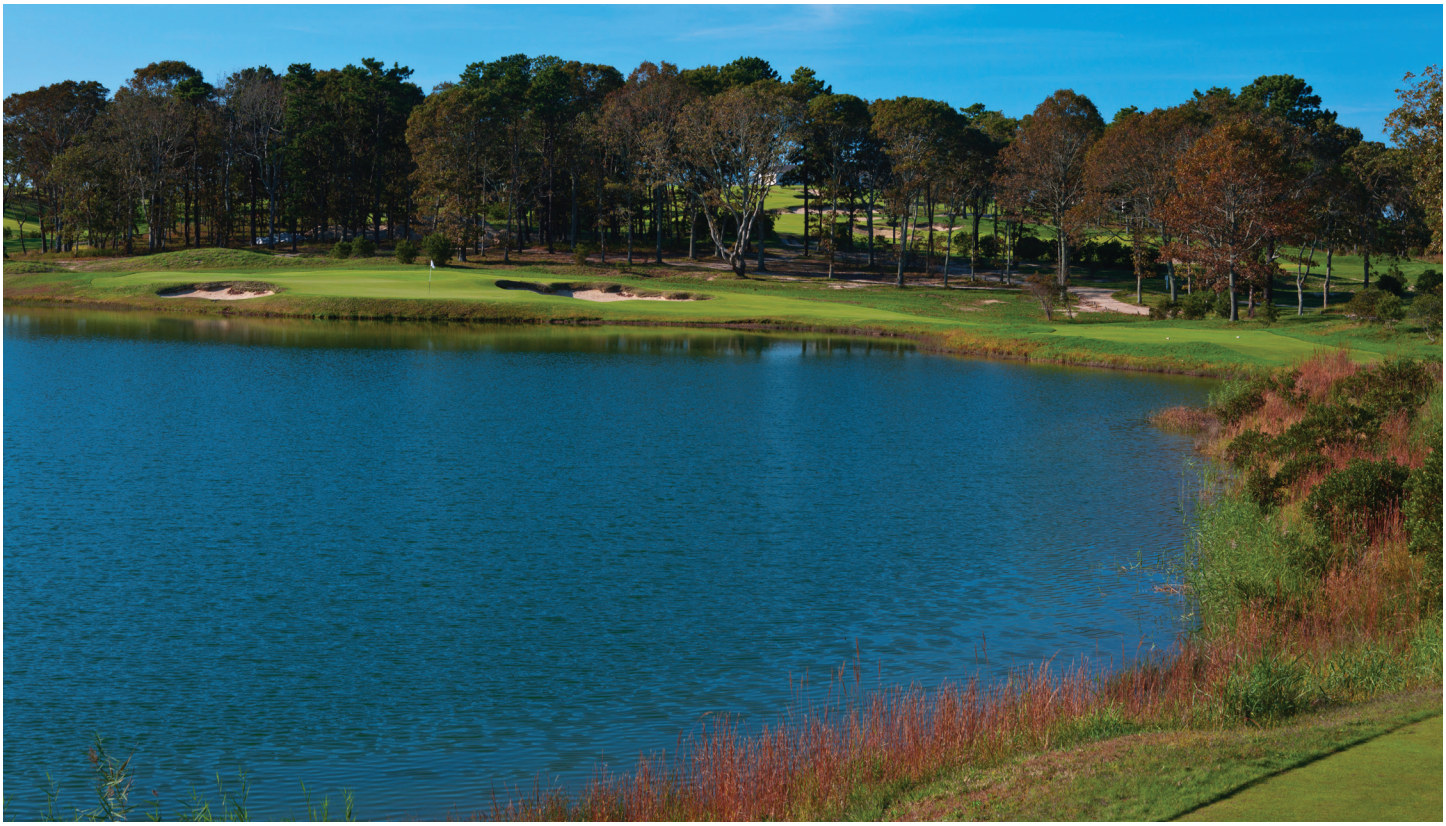
One of the best ways to reduce water loss from evaporation is by minimizing the surface area of water features. Larger surface areas contribute to more evaporation, which increases water usage. By deepening ponds or lakes, you can maintain the same water volume with a smaller footprint, which cuts down on evaporation and helps conserve water.

Classify water features by importance.

Not all water features serve the same purpose. Prioritize water features based on their importance for irrigation, stormwater management or habitat. Essential features should be preserved, while nonessential or purely decorative ponds can be made smaller or eliminated.

Utilize native vegetation for shoreline protection.

Planting native vegetation along water feature shorelines can help control erosion, reduce evaporation, and lower water usage. These plants require less irrigation and maintenance than turfgrass, making them ideal for conserving water while adding value to the landscape and filtering any runoff entering the water features.



Surrounding golf course water features with native vegetation can limit erosion and filter runoff from the golf course before it enters the water body. Native buffers also provide habitat for plants and wildlife.

Monitor evaporation and leakages.

Install evaporation pans and use water-level loggers to track water loss over time. Utilize dye testing or hire professional services to identify hidden leaks in liners, pipes or drainage systems.

Assemble a multidisciplinary team for major projects.

Water optimization projects require expertise in many areas, from golf course architecture to environmental compliance. Engaging a multidisciplinary team early in the planning process ensures that all social, environmental and strategic aspects of the project are considered.

Address regulatory compliance early.

Modifying or removing water features often requires navigating environmental laws and permits. Engage local regulatory bodies early to ensure that all modifications comply with zoning laws, water rights and environmental protections. By understanding the regulatory landscape beforehand, golf courses can avoid delays and legal complications.

Engage stakeholders in decision-making.

Golf course water features often have sentimental or aesthetic value to players and surrounding communities. Engage golfers, homeowners and environmental groups early in the planning process. Open communication and outreach efforts will help gather feedback, build support and minimize resistance to changes that optimize water use.

Plan for long-term maintenance and monitoring.

Long-term success in water conservation relies on consistent maintenance and monitoring of irrigation systems and water bodies. Develop a maintenance schedule to check for leaks, manage silt accumulation and monitor water levels regularly. Proper staff training ensures that the course can maintain water efficiency over time while keeping operational costs down.

REFERENCES

Gascon, M., Zijlema, W., Vert, C., White, M.P., & Nieuwenhuijsen, M.J. (2017). Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. *International Journal of Hygiene and Environmental Health*, 220(8), 1207-1221.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology,* 15(3), 169-182.

Kohler, E.A., Poole, V.L., Reicher, Z.J., & Turco, R.F. (2004). Nutrient, metal, and pesticide removal during storm and nonstorm events by a constructed wetland on an urban golf course. *Ecological Engineering,* 23(4-5), 285-298.

Maas, J., Van Dillen, S.M., Verheij, R.A., & Groenewegen, P.P. (2009). Social contacts as a possible mechanism behind the relation between green space and health. *Health & Place,* 15(2), 586-595.

Richardson, F.L. (2002). Routing the golf course: The art & science that forms the golf journey. John Wiley & Sons.

Strang, V. (2020). *The meaning of water.* Routledge.

Wilson, E.O. (2017). Biophilia and the conservation ethic. In *Evolutionary perspectives on environmental problems* (pp. 250-258). Routledge.