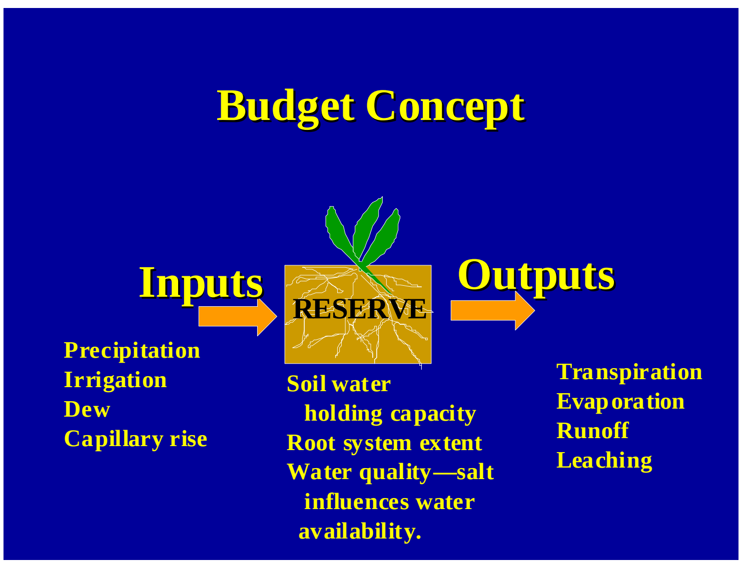
Template with Guidelines

This template is a step-wise document to develop a BMPs-based water-use efficiency/conservation plan on golf course sites

BMPs and

Water-Use Efficiency/Conservation Plan

For Golf Courses: Template and Guidelines



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What Is A Water Management Plan?

A Water Management Plan reviews current water management practices and identifies opportunities for improvement in water-use efficiency/conservation for the whole club facility – course, general grounds, clubhouse, maintenance facility, etc. Development of a comprehensive Water Management Plan entails:

Part 1. Setting a Goal, Planning Process, and Water Conservation Approach
Part 2. Site Assessment/Information Collection for Informed Decision-Making.
Part 3. BMPs Strategies for Water-Use Efficiency and Conservation – Current and Future.
Part 4. Implementation and Review

Purpose and Use of This Document.

The <u>primary use</u> of this document is to provide a detailed “template” for a golf course superintendent and club officials to **develop a site-specific BMPs (best management practices) plan for water-use efficiency /conservation for their golf course facility.** It is essential that all golf course officials and members be involved in BMPs plan development and implementation in order to demonstrate a club policy of environmental stewardship. This template has been developed to allow a very comprehensive BMPs plan to be developed; however, some clubs may not need such a comprehensive approach and in these situations appropriate sections can be used. While beyond the scope of this document, turfgrass managers and club officials are encouraged to understand and foster a State/Water District BMPs water plan (Carrow et al., 2008a), since site-specific BMPs best function within an overall BMP-based regulatory water plan.

The <u>secondary use</u> of this of this document is to serve a detailed "template" for individuals and state golf course associations to use in working with their state DNR/EPA agencies to foster the BMPs approach to enhanced water-use efficiency/conservation within the turfgrass industry. Within a state, the template document can be revised to better suit their conditions since the attached template was developed for all climates and situations. This document is also posted on the www.georgiaturf.com site and is used in the Golf Course Superintendents Association of America workshop entitled “Developing BMPs for Water-Use Efficiency/Conservation on Golf Courses”. This template document is purposely designed as an educational tool from two aspects; a) to provide a template that outlines the information necessary to develop a comprehensive water management plan using the BMPs approach, and b) to include educational information that can be incorporated in a BMPs document primarily to educate water authorities, the general public, and non-golf industry individuals as to the science, depth, breadth, and costs associated with implementing such a site-specific plan.

This document is copyrighted, but permission for use can be obtained from Dr. Robert N. Carrow (rcarrow@uga.edu) for use on a golf course. Also, the authors provide a CD of the template in Microsoft Word format to use as a working template for attendees of the seminar associated with this template or individual requests will be considered. If used as a template we

request that the document be referenced as: Carrow, R.N., R.R. Duncan, and C. Waltz. 2009. Best Management Practices (BMPs) Water-Use Efficiency/Conservation Plan For Golf Courses. University of Georgia, Crop and Soil Science Dept., 1109 Experiment Street, Griffin Campus, Griffin, GA. 30223-1797
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"Ode, On the General Subject of Water"

by Kenneth Boulding; Feather River Anthology

Water is far from a simple commodity,
Water's a sociological oddity,
Water's a pasture for science to forage in,
Water's a mark of our dubious origin,
Water's a link with a distant futurity,
Water's a symbol of ritual purity.

Water is politics, Water's religion,
Water is just about anyone's pigeon.
Water is frightening, water's endearing,
Water's a lot more than mere engineering.
Water is tragical, water is comical,
Water is far from Pure Economical,
So studies of water, though free from aridity
Are apt to produce a good deal of turbidity.

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PART 1. Setting the Goal, Planning Process, and Water Conservation Approach

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1.2. Water-Use Efficiency/Conservation Goal Statement.

1.3. Planning Process Statement

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Note on Use of This Document !!! *This is a template document that allows the user to go step-by-step through the document and fill in the information, especially if the CD Word format is used. There is included considerable information on philosophy (why) and background that can be omitted in a golf course BMPs plan; or, included in order to explain to those that read it the depth, breadth, and holistic approach used in developing you BMP plan.For example, in this section and some of the other sections, the information suggested for inclusion in the club BMPs plan may seem to not very important or necessary at the club level. However, it is critical for a club to: a) understand the long term importance of water availability on the economic viability of the club; and b) to understand that when governmental or regulatory individuals read their BMPs plan, the plan must be viewed as an educational tool – thus, goal statements, processes for setting goals (is it casual or real), and the environmental plan to deal with water-use efficiency/conservation (is it a sound environmental plan or not) are all of great interest to these audiences. Or, in short, remember who the audiences may be that are viewing such a document in the future and develop it accordingly.*

1.1. Golf Course

Name of Club/Course…………………………………………………………………….

Address……………………………………………………………………………………

Club Ownership Details……………………………………………………………….

Who Is Responsible For Managing the Land and Associated Water Resources?...............

Contact Information…………………………………………………………………..

1.2. Setting a Water-Use Efficiency/Conservation Goal Statement

The **goal statement** can be simple and concise. An example is: "The purpose of developing a BMPs water-use efficiency/conservation plan is to foster efficient use of water and to conserve water. Water-use efficiency supports the policy of this club to manage natural resources in a sustainable manner".

Comments: In this document, the phrases **"water-use efficiency/conservation" or "water-use efficiency"** are used rather than the term **"water conservation"**. The reason is that a club may already be utilizing many different strategies to efficiently use water compared to another club that is not efficiently using water resources. It is not uncommon for regulatory agencies to set a "water conservation" goal of a certain percent reduction of water use---for example, 20 % reduction. A club already efficiently using water, and thereby conserving water, may find it difficult to further reduce water use by 20 % without adverse turf quality/economic impact, while the second course can achieve the goal without adverse impacts and may still not be very efficient in water-use. The goal of any regulatory policy should be efficient water-use on the specific site rather than a one-for-all "water conservation" goal.

1.3. Planning Process Statement

In this section, a **statement of the overall planning process** is presented. This can be in table or text format or both. Table 1 (Appendix) outlines a proposed planning process and the components to consider in a golf course BMPs plan for water conservation. The purpose for listing this information is to clarify the process for the managers/members of the golf course facility, especially when a comprehensive plan is necessary; and to indicate to the water regulatory agencies the scope and comprehensive nature of the process. In some cases where considerable site information must be obtained over 1-2 years, it is beneficial to have a planning process that is understood by all. In many other cases, the planning process may be less detailed or formal

1.4. State the "Environmental Management Plan" Used for Achieving Water-Use Efficiency and the Justification.

Stating "the environmental management plan" used to foster greater water-use efficiency/conservation for the golf club is important because it has significant implications for the club and regulatory agencies. In fact, the method should not just be stated but a justification for using this approach should be included as a proactive educational message. An example statement of the environmental management plan or approach is: "The approach used by this golf course to enhance greater water-use efficiency and conserve water resources is the holistic, science-based "Best Management Practices" (BMPs) plan" (see the Comments section that follows for additional explanation).

A justification statement requires that golf club officials clearly understand the alternatives and implications of adopting a BMPs approach when developing a water-use efficiency/conservation plan for their unique golf club. The “Comments” section elaborates on these topics and a club may wish to include part of this information in their plan document as educational information for the club (current and future members and officials), water regulatory agency personnel, and groups/individuals who question the club’s water policies. A brief justification could be included in the section where the approach/method is stated—but a more expanded justification section could be added to the appendix.

Comments: When an environmental problem or issue is present on a site, there must be an environmental management plan to deal with the problem. It is very useful for clubs and golf course superintendents to understand: a) what is the “best” environmental management plan for a single environmental issue – answer is **Best Management Practices (BMPs)** plan; and b) what is the “best” environmental management plan for multiple environmental problems on a site – answer is **Environmental Management Systems (EMS)** plan. As a beginning, it is suggested that readers click the link on the Carrow et al.(2008b) article in the reference section for an overview of these approaches.

If the BMPs plan is the “best”, then there must be other plans that are not as good, what are they?? All plans to deal with a single environmental issue, such as water-use efficiency/conservation, can be grouped into one of four “environmental management approaches” namely:

1. Indifference/inaction (this one is no longer acceptable);
2. Rigid regulations; The initial political response to a water quantity/conservation crisis is often one of **rigid regulations (also called command and control**) where bans are suggested --- such as ban the square footage planted to turfgrasses, ban all water use on turfgrass/landscapes, or ban particular species. The inherent characteristics on rigid regulations are the opposite of the characteristics embodied in the BMPs approach--- discussed below.
3. “Plans limited in scope” or too narrow – this include “Xeriscape” plans or any plan that does not include all possible water-use efficiency/conservation strategies. For example, some may concentrate on the grass used, others on the irrigation system, or others on limiting irrigated area: but any one of these is just a part of the picture – what is need is all possible options which is the basis of the……
4. Holistic, science-based BMPs approach (Carrow and Duncan, 2008**)**. The BMPs approach does allow for more rigid regulations to be incorporated during a local water crisis; but in a science-based manner using known triggers for each level of restrictions ---- such as level of a local water reservoir. Normally, there are several levels of water bans that come into enforcement as a water crisis grows; and all water users are affected, not just golf courses or other specific businesses.

The author’s of this document strongly encourage the turfgrass industry and individual golf clubs adopt, implement, and promote the BMPs model for water conservation. **Why?? –**because it is the “Gold Standard Environmental Management Plan” that has been tested and improved as an approach or plan for dealing with various water quality issues for 30 years. The BMPs approach has up to now been very successful for water quality concerns, but increasingly in the past 5 years has been expanded to cover other environmental issues. **The first Federal initiative stating the term "best management practices" came from the 1977 amendment to the**

Clean Water Act that established BMPs as soil conservation practices to protect water quality (Rawson, 1995). The BMPs approach is widely understood to be a holistic means to address concerns over pesticides, nutrients, and sediments as related to water quality protection. The BMPs concept/terminology is now used in ordinances, regulations, and management manuals to deal with a wide variety of water quality issues such as: pesticide use and fate, nutrient use and fate, sediment control from wind and water erosion, and wetlands protection (GreenCo et al. 2004). As noted, in recent years the BMPs terminology and concept has been expanded as the best approach to addressing any individual environmental issue, including water quantity and conservation (Carrow and Duncan, 2008; Carrow et al., 2008b; IAA, 2005; CUWCC, 2005; GreenCo et al. 2004). Some states have overall BMP documents that encompass many of the environmental issues on golf courses or green industry locations, such as the Florida BMPs for golf (Florida DEP, 2007) and the green industries (Florida DEP, 2008), each which includes limited section on water conservation. The Florida DEP documents are somewhat similar to Environmenatal Management Systems (EMS) plans since they include a number of environmental issues combined together for a site with each environmental problem having a BMPs plan to address as noted by Carrow and Fletcher (2007a; 2007b) and Carrow, Waltz, and Fletcher (2008b). Golf club officials are encouraged to read these articles to obtain a stronge foundational understanding of BMPs and EMS concepts. In this template, the emphasis is on site-specific BMPs.

The rigid regulation/command and control approach as the overall philosophy to deal with environmental issues is in direct conflict with the BMPs approach fostered by the US EPA and similar agencies for the critical issue of protecting water quality. A very common pattern for water conservation has been for rigid regulations/bans to be fostered for golf clubs and other turfgrass areas even when no water crisis is evident and in a manner that targets this industry more than other businesses or industries.

Currently, within the various state water regulatory agencies across the country there is not a consistent, well-defined approach to water conservation. This is in contrast to the issue of protecting water quality, which has a firm BMPs approach. The Georgia DNR has been the first state to adopt the BMP model specifically for golf course water conservation in 2004. Also, as the Georgia State Water Plan was formulated in 2008-2009, the BMPs model is being adopted for all water users in Georgia based on the Georgia Golf Course Superintendents Association adoption of this model as an industry – i.e., > 97% of GGCSA clubs have water conservation BMPs.

Unless the turfgrass industry has an approach or plan to successfully deal with society's water quantity concerns on a long-term basis, it can expect others to come up with a plan--- defining, adopting, and implementing the BMPs approach for water-use efficiency/conservation at the site-specific (club) level and fostering its adoption at the state regulatory level essentially establishes a plan or approach for all to use (Carrow et al., 2008a, 2008b) and Carrow and Duncan (2008).

The success and acceptance of the BMPs approach for prevention and remediation of water-use efficiency/conservation and other environmental problems by politicians, regulatory agencies, environmental groups, and the turfgrass industry is based on certain **inherent characteristics of**

<u>BMPs</u> and these same characteristics are inherent in BMPs for water quantity issues. These characteristics are:

- ***Science-based.*** The very definition of BMPs illustrates why this approach is effective: a) "best" implies that the best combination of strategies that can be adopted with current technology and resources are being practiced; b) "management" suggests that management decisions by trained managers can maximize the result, and c) "practices" imply that management practices do make a difference. Integrated Pest Management (IPM) and Sustainable Agriculture are two other federal programs that use the BMPs approach for protection of natural resources. Thus, whether called a BMP, IPM, or SA approach, all emphasize efficient use of resources using a science-based and flexible philosophy. These approaches can be documented and accountability can be easily monitored and are considered the **"gold standard"** for successfully dealing with environmental issues.

- ***Holistic in terms of options***. There is no “silver-bullet” or single factor to resolve specific environment issues including water conservation. Rather a combination of strategies is needed to achieve success. For example, effective water-use efficiency in the whole ecosystem includes consideration of soil, plant/landscape, atmosphere/climate, turf manager, irrigation system, irrigation water source, manager expertise, and any other aspect that may influence water-use.

- ***Holistic in terms of the considering effects of environmental measures on all stakeholders.*** Just as a ban on all pesticides, nutrients, and sediment sources was not considered as a reasonable for protection of water quality due to the negative impacts to society, water conservation practices (or other environmental issues) require consideration of impacts on all stakeholders. For example, water conservation programs should include consideration of the effects of measures on the economy, environment, jobs, and site use. The “customer” or user/manager/owner of a turf site is not the only “stakeholder” potentially affected by water conservation measures, but others include: the supply side [water authorities, suppliers]; demand side [turf site user, turf manager, turf industry, etc.]; and others affected by environmental and economic water conservation measures [society in general, local economy, health aspects, etc.].

- ***Site-specific adjustments.*** Environmental problems are complex and are not resolved by simplistic means. Just as no single factor could achieve protection of water quality, there is no single factor that will achieve maximum water conservation on a site. Each site is different and adjustments must, therefore, be site-specific.

- ***Values Education and Educated Site Managers.*** It is science-based, educated adjustments within the whole system that are the basis for the success of the BMPs approach. BMPs encourage professionalism and education of the turf manager, including continuing education.

- ***Fosters development and implementation of new technology and concepts.*** BMPs encourage on-going improvement in dealing with a specific environmental goal by incorporation and encouragement of new technologies and concepts.

- ***Develops a written BMPs plan for each site:*** Planning for water conservation must eventually develop into a written document with the various water conservation measures agreed upon by the owners, business managers, boards, and turf manager, while meeting all current regulations.

- ***Is an environmental management plan.*** This plan is to be a "living document" in the sense that: a) suggested water conservation practices should be incorporated into everyday and long-term management decisions at all levels within a facility; and b) revision is expected in response to on-going monitoring and to development of new water conservation concepts and technology.

- ***Is complimentary to future EMS plans***. Water-use efficiency/conservation BMPs can be easily combined with BMPs to deal with other environmental issues into Environmental Management Systems (EMS) documents for clubs. See Appendix B for additional information on the interrelations of BMPs and EMS (Carrow and Fletcher, 2007a, 2007b).

One additional comment on BMPs, which was briefly noted previously, is that site-specific BMPs work best when they are in the content of **"state-wide" or "water-district" water management plans or regulations that are based on BMPs for all water users**. The turfgrass industry is encouraged to work toward this goal with the first step being to actually apply BMPs to their site. The similarities and differences between site-specific and state or water district BMPs are presented by Carrow et al. (2008a) (see Appendix B).

PART 2. SITE ASSESSMENT/INFORMATION COLLECTION FOR INFORMED DECISION-MAKING.

Site Assessment is the first BMP strategy, while Part 3 details the remaining 10 BMP strategies. A BMPs plan for water conservation can be no better than the information that goes into the decision-making process; thus a BMP plan starts with site assessment. In many cases, development of a comprehensive BMPs water-use efficiency/conservation plan for a golf course is a process that is best done over a 1-2 year period, especially if alternative irrigation water sources or poor water quality sources are part of the plan. In other cases where the water supply is known as well as adequate in quantity and quality, some of the site assessment aspects presented in this section may be omitted. The overall planning process and various conservation strategies are outlined in Table 1 in Appendix A. In some cases, the "site assessment" or information gathering process requires contracting companies to do detailed water audits of the existing irrigation system, water source options along with water quality assessment, and other rather complex information gathering tasks. An initial plan can be made but may change over time as additional information is gained---for example, an anticipated irrigation water source may be deemed unacceptable due to quality or quantity constraints after a more detailed assessment is conducted. **Thus, an initial BMPs plan may be developed with a central component of the plan consisting of laying out how and when the full site assessment information may be obtained; and then it is integrated into a future plan**. That is the nature of BMPs --- not all the answers to questions need to be obtained before an initial plan is developed.

2.1. <u>Current/Past Water-Use Efficient/Conservation Practices</u>.

The first step in the planning process should be to <u>assess what has already been accomplished</u> by the course with respect to water-use efficiency conservation. This step is essential because:

- Aids in bringing together the whole management team at a club (superintendent, club officials, pro, etc) and club members to focus on the water conservation issue;
- Assists in establishing a common understanding of what is involved in development of a BMPs plan (i.e., scope, terminology, components involved as noted in Table 1, Appendix A).
- Clarifies for the club what water-use efficiency/conservation measures are already instituted---these become a benchmark for further improvements in management practices and infrastructure.
- Documents for regulatory agencies that the club is not starting at "ground zero" with respect to water conservation; and that considerable time, effort, and resources have been expended toward water conservation in the past.

Since a club's water conservation plan/document will likely be viewed by regulatory agencies, it is important to demonstrate what water-use efficiency/conservation practices have already been implemented—this information is **"educational"** in nature, or intended to **establish a benchmark** for future actions based on the past. Many times these past improvements are overlooked by regulatory agencies and even club officials---golf courses may improve water conservation programs by new measures, but that does not mean they are just starting in this endeavor or starting from "ground zero".

The water conservation strategies outlined in Table 1 (Appendix A) and within the Part 3 section of this document will assist in determining additional items that could be included in this part of the initial plan. When determining what conservation practices are already implemented, it is a good policy to estimate the costs of implementing these practices for the information/education of regulatory agencies and politicians. In Part 4, more will be discussed on establishing and presenting "costs and benefits" related to a comprehensive water-use efficiency/conservation plan. As examples of past BMPS, the following could be considered:

<u>Management, Personnel, and Education Aspects</u>

1. Scouting – costs
2. Hand watering – hours and costs
3. Night watering capability
4. Staffing in irrigation control and irrigation maintenance –Irrigation Assistant
5. Traffic controls and costs
6. Management for water conservation
    a. Height of cut
    b. Soil cultivation to promote root depth

c. Evapotranspiration utilization for irrigation scheduling
d. Selection and installation of drought resistant landscape plants
e. Natural vegetation areas
f. Fertilization practices to minimize water use.
g. Pest management – early morning or late evening applications to reduce water loss. Consideration of Integrated Pest Management protocols.
h. Wetting agent usage.

7. Record keeping and costs
8. Goal setting regarding water-use efficiency/conservation.
9. Education Efforts –Education taken by superintendent or any club official related to water conservation, list benefits of golf courses and turf areas; publish water conservation plans; engage stakeholders (members, patrons, neighbors, general public) with the benefits of water conservation.

Infrastructure Improvements

10. Grass selection and establishment– adapted species and cultivars or climatic/soil conditions. Use of drought resistant grasses, such as bermudagrasses.
11. Rain, leak, etc. loss controls and costs
12. Current irrigation controls and hard costs (parts, power)
13. Irrigation design and control improvements --- zoning of heads into similar water use areas; irrigation system design to take into account factors that influence water-use efficiency (slope, soil type, wind, etc);
14. Possible irrigation methods (plant-based, soil-based, budget approach, deficit, atmosphere-based). On-site weather station.
15. Use of alternative (non-potable) irrigation water sources --- reclaimed, water-harvesting from runoff, stormwater, saline sources, etc.
16. Metering – installation and ongoing calibration and replacement
17. Infrastructure improvements made due to using alternative irrigation water --- water treatment; soil treatments; extra cultivation, drainage, etc.
18. Note if and when any water audits were conducted.

2.2. Purposes and Scope of "Site Assessment/Information Collection".

Wise decision-making requires considerable site assessment and information collection in order to develop a successful water-use efficient/conservation plan. Thus, an early stage of development of a comprehensive BMPs water conservation plan is to obtain the appropriated information. **Since the information gathering phase may require 1-2 years, it may be necessary to submit or develop an initial overall BMP plan before all information is available in cases where there is a regulatory deadline.** In those situations, the BMPs plan would include what is planned in the future for site assessment and state that the overall BMPs plan would then be revised based on this information. The nature of BMPs is to revise and improve overtime --- therefore, a plan can be developed before all the information/answers are known.

In Section 2.2, the emphasis is on assessing the current status of a club and gathering information to make decisions on potential future changes that would improve water-use efficiency/conservation. In Part 3, the emphasis is on implementing the decisions, especially sections 3.6 (Use of Alternative Irrigation Water Sources), 3.4 (Irrigation System Design and Devices for Efficient Water Use), 3.5 (Irrigation Scheduling/Operation for Efficient Water-Use), and 3.2 (Landscape and Golf Course Design for Water Conservation).

2.2.1. **Basic Property and Landscape Information**. If a formal irrigation audit is performed (see next section), much of this information may come from the audit; otherwise, the information should be collected separately. Much of the information in this section can be presented in table format for each area type---greens, tees, fairways, roughs, other landscape areas. Denote the method of estimating area for each landscape type such as--- GPS, Topographical Survey, Aerial Photo/Survey, Field Tape Measurement, or Visual Estimation.

1. Type of course. 18-hole, general description
2. Greens. Grass type, square footage, cutting height, soil types and construction type (sand-based, perched water table, push-up but modified by topdressing over time for better water infiltration). Irrigation area.
3. Fairways. Grass type, square footage, cutting height, soil types. Irrigated area.
4. Tees. Grass type, square footage, cutting height, soil type. Construction aspects. Irrigated area.
5. Roughs. Grass type, square footage, cutting height, soil types. Irrigated area (note if roughs are infrequently irrigated)
6. Other landscape areas (clubhouse, entrance, etc.). Grass types, other plant types (denote any adapted plants, drought resistant plants), square footage, soil types, irrigated area and frequency of irrigation --- no irrigation, to prevent tree or shrub loss, by drip irrigation, frequently irrigated areas such as flowers.
7. Special technology or infrastructure aspects for each of the above areas that would relate to water-use efficiency/conservation. Examples;
    - contouring for stormwater harvesting and reuse,
    - sealed irrigation ponds,
    - soil modification to enhance water infiltration (sand-capping, amendments) --- i.e., improved rainfall and irrigation retention and use-efficiency. For greens, the high sand content favors rainfall retention.
8. Major infrastructures such as buildings, roads, parking areas with footage.
9. Water features --- included in the section on Irrigation and Water Audit.
10. Climate. Average annual and monthly rainfall, temperatures (low, average, maximum), humidity, and solar radiation).
11. Dormant turf and winter overseeding. Denote the weeks that particular areas are dormant and non-irrigated. Denote dormant acreage that is winter overseeded and irrigated.
12. Provision of any existing documents related to water aspects such as: irrigation, drainage, contouring plans, soil survey, maps, etc.

2.2.2. **Surface Water Inventory**.

For each pond or lake, the following inventory information should be included: Surface area and storage capacity; lined or sealed; source (potable, reclaimed, groundwater, stormwater collection, etc.); indicated all uses for each pond/lake (irrigation, wildlife habitat, golf hazard, aesthetics, flood control and water reuse, recreation, reclaimed water retention).

2.2.3. **Irrigation System Inventory**

Sprinkler Heads, Configuration, and Zoning. A summary of irrigation sprinkler heads can be included with information for each head type. The local irrigation distributor can supply this information. Basic information is:

- Quantity
- Flow (gpm)
- Radius (ft.)
- Arc (deg.)

Provide a brief description of head spacing, configuration, and zoning --- this may be in irrigation system maps. Relative to zoning of irrigation heads, the following information is useful.

- Head configuration – triangular; square; single, double row, other design such as around greens or along roughs.
- Head spacing (feet, percent radius)
- Number of zones.
- Number of zones that can be irrigated to bring the soil to field capacity per 12 hour period based on maximum system operation.

Control System and Components. Relative to irrigation system control, indicate with a yes or no whether the following features are part of the central control system (if a central control system is not present, describe the golf course control system)

- Automatic Daily ET Adjustment
- On-Site Weather Station. Also indicate the presence of any sensors that are part of the station -- temperature, rainfall, wind speed, wind direction, solar radiation, relative humidity.
- Real-time Weather Monitoring and Automatic Reaction (rain shut-off devices)
- Visual Monitoring of Irrigation Status Throughout the Course
- Real-time Flow Monitoring and Automatic Reaction
- Automatic Flow Management
- Reporting Capabilities.
- Soil Moisture Monitoring by Soil Depth on Selected Indicator Areas and Integration into the Control System
- Soil Salinity Monitoring by Soil Depth on Selected Indicator Areas to Monitoring Efficiency of Salinity Leaching and Integration into the Control System.

Irrigation Scheduling Methods. Describe a brief description of your irrigation scheduling methods. These may include the following: periodic adjustment of crop or landscape coefficients, daily ET (evapotranspiration) monitoring, weather reports, turf appearance (such as on key indicator areas), soil moisture probes or sensors, rules of thumb based on past experience, other. Note any current constraints on efficient irrigation scheduling – system water supply capacity, soil infiltration rates, number of zones, etc.

Irrigation Pump System. Key information relative to the irrigation pump system and components include:

- Maximum rated flow (gpm) of the irrigation pump station.
- Variable rate system (yes/no)
- Flow meter and type
- Is flow meter calibrated? How often?
- Is the flow meter data available in real-time at the irrigation central controller?
- How does the total daily flow estimated by the central controller compare with the total daily flow of the pump station flow meter?

2.2.4. Irrigation System Audit (Water Audit).

When site assessment is discussed, most individuals think of an **"irrigation audit"**. The term **"water audit"** is used in the same context or meaning as an irrigation audit. As noted in the previous section on "Basic Property and Landscape Information", a water audit can provide considerable information (or update information) related to the sections 2.2.1, 2.2.2, and 2.2.3. As part of a comprehensive BMPs for water-use efficiency/conservation plan, an irrigation and water audit is important. However, a more comprehensive site assessment that includes a water audit, but goes beyond it in scope, may be necessary and should be determined in the initial planning phase. Report in the BMPs document a summary of all water audit activities, costs, and changes made (and how they related to improved water management).

A. Traditional Catch-Can Based Water Audit. There are training courses for individuals who do irrigation audits, such as by The Irrigation Association (2003a, 2003b) and Irrigation Association of Australia (2003). Vickers (2001) and Connellan (2002) present basic steps to turf and landscape water auditing. Consistent terminology will help prevent misunderstandings as to the scope of a site assessment. In their excellent book used for training of certified golf irrigation auditors, The Irrigation Association (2003b) **defined an irrigation audit as:** "Information about each area's technical characteristics and controller capabilities should be obtained. An irrigation audit involves collecting data, such as site maps, irrigation plans and water use records. Tuning of the irrigation system is accomplished during the inspection….Field test are then conducted to determine the system's uniformity and to calculate various zone precipitation rates." When conducting an irrigation audit or water audit:

- Very detailed information is determined on the irrigation system design and performance. The main focus is on the irrigation system.
- Water source availability and needs are determined.

- Some soil information is determined as related to irrigation system design, zoning, and water application.
- Grass type and location are often noted.
- Climatic conditions may be available from a local or on-site weather station to assist in scheduling irrigation.

The first phase of a traditional catch-can or New wateraudit is the same and starts with inspection of the site plans and system tune-up. Professional irrigation auditor can be contracted to obtain the necessary information. In this initial phase, the main components are:

- Obtain any available site plans/maps of the irrigation system layout and location of specific components: heads, lines, valves, water lines, wiring, controllers, pumps, backflow prevention devices, water meters, water connections, shut off valves, drain valves, etc.). It is not unusual that plans may need to be updated and system features accurately located and mapped.

- Inspect the system and the system operation. Water information at this stage may include: pressure tests, sources, and flow data. The auditor would also document the current programming schedule and main/satellite controller features or capabilities such as: number of programs, ability to repeat cycles, number of zones per controller, syringe cycle ability, interfacing with any sensors to affect scheduling, During inspection of the irrigation system components, The Irrigation Association (2003b) would recommend evaluating for:

    1. Valve performance
    2. Sprinklers that are tilted, sunken, broken, missing, clogged, misaligned, or with spray deflected by objects.
    3. Rotation speed.
    4. Plugged nozzles.
    5. Drainage from low sprinkler locations.
    6. Leaks detection and repair.
    7. Areas with slow water drainage or ponding, dry areas, compaction/thatch/runoff.

NOTE: The above components of a traditional water audit can be done by current golf course maintenance staff such as an Irrigation Assistant and do not have to be contracted unless this is desired to obtain an outside documentation of system status. In fact, these components are a part of good system maintenance.

The second phase focuses on documenting system performance by the catch-can method. Initially, select appropriate zones that will be representative of the whole course. There may be a combination of zones selected that represent different soil/climatic site conditions; locations such as fairways, tees, greens, and roughs; problem sites where there is a history of irrigation problems related to system inadequacies; and zones that are considered the best on a course. If data from these selected zones demonstrate that water uniformity is acceptable or can be improved (new nozzles, head replacement, addition of some heads, etc.) using the existing system, then a full audit of all zones can be performed --- this would be the most robust audit but does require considerable time and effort in contrast to selected, representative zones.

Sometimes the initial sites selected for catch-can evaluation as well as other information from the water audit reveals major problems with the irrigation system and may indicate investigation of major renovations or replacement. In this instance, there is no need to further assess current equipment performance, but to plan for a system with the performance needed to achieve the water conservation goals desired. Typical examples, of such major problems are:

1. Improper design such as sprinkler spacing or zoning or scheduling capability.
2. Inadequate piping, pressure, or flow rate for system operation.
3. Outdated equipment or worn out equipment.

During the test periods for the catch-can method, it is critical that system pressure and wind conditions be suitable and recorded. However, the test should also represent conditions similar to normal irrigation conditions. Typical information obtained from each test zone is:

1. System pressure
2. Wind speed and direction.
3. Sprinkler rotation speed.
4. Type of sprinklers and nozzles---are nozzles worn or not matched for precipitation rate.
5. Head spacing between heads and between rows of test areas must be determined in order to calculate precipitation rate of each zone; and to determine proper design.
6. Catch can data to determine water application rate and uniformity over the zone---if more than one zone covers a test area, then both zones must be operated. Note the location and spacing of the catch can grid.
7. Controller information such as type, run time or multiple run times.
8. Determine additional site conditions such as: soil type, grass type, rooting depth, any microclimate influences.

After test data are gathered, the results are used to calculate several factors important for efficient irrigation operation. These are (Irrigation Association, 2005):

- **Distribution uniformity (DU**) a measure of how uniformly water is applied over an area, where a DU of 100 is 100% uniformity. Normally, the DU is based on the average of all samples and the average of the lowest 25% of readings; and in this case would be termed $DU_{LQ.}$ An irrigation system with $DU_{LQ} > 80$ is good. The DU can be used to determine **irrigation water requirement** for a zone, where irrigation water requirement = plant water requirement / DU.

- **Run time modifier (RTM),** which is used to adjust timing in an irrigation zone to allow adequate water over the whole site – i.e., not dry spots.

- **Gross Precipitation Rate (PR_{gross})** is based on flow from the sprinkler and sprinkler spacing to obtain an average sprinkler precipitation rate over the area in inches/hour. It does not take into account any water loss that occurs between the sprinkler nozzle and the turfgrass.

- **Net Precipitation Rate (PR_{net})** is a measure of the amount of water that actually reaches the turfgrass at a particular location. This is determined from the catch can data.

- **Scheduling Coefficient (SC)** measures uniformity in an area by comparing the lowest precipitation rate in a defined area to average precipitation rate over the entire test area. The lowest precipitation rate may be based on the driest 1, 2, 5, or 10% of the defined area. The SC indicates the quantity of additional water that must be applied to adequately irrigate the driest area that was defined.

- **Coefficient of Uniformity (CU)** is another measure of irrigation uniformity based on comparing average catch can precipitation to the average deviation from the catchment's mean. While used in agriculture, it is less useful in turfgrass situations.

- When the irrigation water requirement is determined by using the DU, the run times in minutes for the controller can be used to establish an irrigation schedule.

- A very important additional piece of information that can be generated from the irrigation audit data on a zone is a **densogram** that visually shows the wettest and driest areas within the area. This is very valuable for making corrective measures such as changing nozzles to obtain greater uniformity. The Center for Irrigation Technology (2003) has a software program, SPACE Pro™ that creates the densograms.

B. <u>New WaterAudit Approach Based on Spatial Mapping With Mobile Units.</u> Currently an alternative to the traditional catch-can method for assessing system application performance is being developed by The Toro Company and research scientists at the University of Georgia (Krum et al., 2008; Carrow et al., 2009a; 2009b). The concept **(Precision Turfgrass Management, PTM)** is based on principles of Precision Agriculture where site-specific management depends on obtaining robust site information using mobile devices to obtain key soil and plant information. The new protocol would use rapid, detailed field mapping of soil moisture, grass stress, soil compaction, slope, salinity parameters, and possibly other site characteristics on all areas --- greens, fairways, tees, roughs, grounds--- with GPS/GIS maps. After corrective measures of areas identified as problem sites, the same protocols can be used to assess the degree of correction and for further fine-tuning of irrigation design and scheduling for superior irrigation application efficiency--- as well as provide additional information for site-specific management efficiency. These procedures could be conducted under a wider set of environmental conditions relative to the catch-can method.

The spatial mapping approach using mobile sensor platforms allows the following field applications (Krum et al., 2008**):**

1. Use of the initial mapping information to <u>identify relatively easy-to-do alterations in irrigation design and/or scheduling for uniformity of water application;</u>

2. Defining site-specific management units (SSMU) on saline and non-saline sites – SSMUs are areas of similar soil texture/organic matter content, grass, and management requirements – for example, they would be sub-areas on a fairway. SSMU information can assist irrigation scheduling, aid in evaluating the efficiency of the irrigation system, where to place sensors, and other information such as site-specific fertilization, liming, or gypsum needs. Volumetric water content of the soil at field capacity can be presented in DU format.
3. For current irrigation systems, evaluation of system design for degree of uniformity of soil moisture uniformity to determine if the system is efficient or does it need replacement – i.e. the core of a **New WaterAudit Approach**.
4. Determination of the best location for placement of in-situ sensor arrays within SSMU areas;
5. For salt-affected sites, the use of these technologies for monitoring salinity spatial and temporal changes for salt management – where to leach, how much water to apply, is leaching effective. This is a **New SaltAudit Approach**.

Combining systematic protocols for applications 1, 2, 3 and 4 can provide a more precise and robust water auditing (New WaterAudit) approach that could replace the current water auditing procedures that depend on catch-can data (Irrigation Association, 2005). To date, there has not been a procedure to assess soil moisture status (spatially and temporally) across the whole landscape for a more vigorous water audit compared to the use of localized catch-can information that only assesses the irrigation system uniformity under ideal conditions. The traditional catch-can approach has some real hindrances to being effective, namely: it is time-consuming; can only be conducted on non-windy days; assesses only irrigation sprinkler distribution and not other sources of site variability; can only be conducted on limited areas and not a whole golf course, for example; it only deals with site variability related to the irrigation system design and not soil or climatic conditions; and it does not assist in defining where to scientifically place soil moisture sensors for usefulness.

Also, to date, there has not evolved a systematic means (equipment hardware, software, protocols) to spatially and temporally map soil salinity as well as identify specific sites for in-place salinity sensors. A **salinity auditing approach (New SaltAudit)** is under development as part of the PTM program that would allow more accurate leaching of salts on a site-specific basis and define where to place salinity sensors in the landscape (Carrow et al. 2009a; 2009b).

2.3. Additional Comprehensive Site Assessment Information.

In this document, we use the term **"site assessment"** for water conservation planning to denote a more detailed or robust evaluation of a site than a traditional irrigation audit. As previously noted, not all sites will require such an in-depth site assessment, but some will. Such a site assessment would include an irrigation audit, but would include a number of other factors depending on the golf course need. We anticipate that site assessment requirements will be an evolving area in the near future with **more stringent assessment becoming routine** due to a combination of factors related to water conservation strategies, such as: sensor technology improvements; altering turf management practices; concept changes in irrigation system design and scheduling equipment; making golf course design changes for water conservation purposes; and the increasing use of poor water quality on turf sites. Thus, it is will be important for golf course officials to know what information will be supplied in a contracted audit, including the detail of the audit. A comprehensive site assessment may require more than one contracting firm to accomplish all aspects. As the need for more detailed site assessments increases, sensor technology will likely be adapted to provide more in-depth information in a rapid and concise manner (Lahoch et al. 2002; Carrow et al., 2009b). We envision a "site assessment" that will provide the best information to maximize water conservation options to include:

- **Alternative irrigation water sources**. Determination of alternative irrigation water sources beyond those that a club may already be utilizing will be a part of the overall BMP program for water conservation for many clubs ---i.e. one of the first strategies to reduce potable water use is to switching to non-potable sources. Thus, water quantity/conservation plans often result in water quality issues. In some situations, specialists may be necessary such as to determine water available from an aquifer or potential for development of a water treatment facility to provide water. Planned use of some alternative irrigation water sources such as reclaimed water or stormwater reuse, may entail earthwork and construction. In the case of stormwater that may come from hard surface sites or other areas that allow pollution loading (sediment, oils, pesticides, nutrients, salts, etc.), earthwork and construction may involve a combination of flood control, treatment trains (sequence of features to reduce pollutants), and final storage for reuse in irrigation of the landscape. See Section 3.6 "Use of Alternative (Non-Potable) Irrigation Water Sources" for a more detailed discussion of information that is required to make wise decisions on management and infrastructure changes to achieve improved water-use efficiency/conservation.

- **Irrigation Water Quality Tests.** When a potential source of irrigation water is of poor quality, especially with high total soluble salts and/or sodium, decisions well be required concerning:
    1. Water treatment,
    2. Soil amendment treatment,
    3. Subsurface drainage to remove leached salts,
    4. Assessment of the hydrological conditions on a site to insure that leached salts do not contaminate existing ground water,
    5. Identification of potential lake management issues related to water quality.

- **Golf Course Design Modifications.** If a course is considering design modifications for the purpose of reducing highly irrigated, close mowed turfgrass area, design plans should be developed by a golf course architect before considering irrigation system design changes. Also, course design changes will greatly alter the irrigation system and require a detailed ***Irrigation Alteration Design Plan*.** See section 3.2 Landscape and Golf Course Design/Site Preparation for Water Conservation.

- **Soil Conditions.** More detailed assessment of soil conditions to allow enhanced or more precise irrigation design, zoning, and scheduling, as well as potential placement of soil sensors to aid in irrigation scheduling. Topographic information, especially slope and aspect, may need to be determined in a more systematic manner as well as various soil physical and chemical conditions that could influence water relationships. One type of soil condition on salt-affected sites will be soil salt variability over the landscape and within the soil profile. When salts are to be a continuing problem, intensive site assessments of soil, water, drainage, and salt sources are required. Carrow and Duncan (1998) provide an in-depth discussion of this aspect. Salinity mapping for the purposes of more efficient salt leaching is likely to come in the near future.

- **Aboveground Climatic Conditions.** In order for weather station ETo or reference crop ET (an older concept was ETp or potential ET), to be adjusted for more site-specific conditions, characterization of microclimate areas are necessary. One use of more specific soil and atmospheric site assessment, as noted, is to develop a better irrigation design and operation. But, another use would be to determine soil moisture sensor placement and any additional atmospheric sensor placement. For example, it is not inconceivable that mini-weather stations be on selected microclimate sites to improve ETo adjustments to obtain actual turf ET (actual crop ET, or ETc).

With more intensive site assessment as an important component of developing water conservation plans, golf courses should consider obtaining site-specific data in GPS (Global Positioning System) formats where site features or characteristics can be clearly identified as to location. Then the data can be presented in GIS (Geographic Information Systems) maps that can be overlaid. Such maps are very useful for investigating relationships within a site area.

2.4. Current Water-Use Profiles.

A **comprehensive water-use profile** will consist of several types of information, namely:

- Determination of total current water use is of first importance, including seasonal use and water-use during drought stress periods. This information becomes the primary benchmark for future changes from water conservation measures.
- Water use by type of turfgrass area, such as fairways, tees, roughs, greens, and any other site facility is also very necessary, since water conservation measures may vary with each type of area.

Irrigation Water Supply Inventory and Use. When multiple irrigation sources are used, it is important to determine how much of the total water comes from each source throughout the year as well as the reliability or stability of each water source over a season. Water use data is often determined from digital flow meters, analog turbine/turbo meters, theoretical flow from central irrigation controller, or other methods. Records of irrigation system operating time per area coupled with application rates can be used to estimate water use for greens, tees, and other areas. The same means that irrigation system designers use to estimate water system needs (average precipitation per month, typical turfgrass water needs, accounting for the maximum water use during dry periods, etc.) can also provide an interesting comparison of projected water needs (i.e., initial projections when the irrigation system was designed or modified) relative to actual water use.

For each irrigation water source, indicate for a particular year or average/range over several years, the following information--- along with the method of obtaining the data (digital flow meters, analog turbine/turbo meters, theoretical flow from central irrigation controller, other):

- Potable water used for irrigation (acre-ft.); cost.
- Reclaimed water used for irrigation (acre-ft.); cost
- Groundwater used for irrigation (acre-ft.); cost
- Irrigation lakes/ponds recharged by stormwater collection and reused for irrigation (acre-ft.); cost
- Irrigation lakes/ponds fed by streams or springs or high water table used for irrigation (acre-ft.); cost
- Total irrigation water used (acre-ft.), cost
- Total amount of domestic water (non-irrigation uses, clubhouse, pool, maintenance facility, etc.) used (acre-ft); cost
- Total irrigation + domestic water use (acre-ft.); cost

If not available, an irrigation water quality test should be conducted of each water source and if time allows determine seasonal changes in water quality by obtaining water quality data over time.

2.5. Anticipated Future Water Needs.

In previous section as part of the information gathering process, current water-use is established as well as water use by specific golf course areas---fairways, tees, greens, roughs, general grounds, maintenance facility, and clubhouse. The next step is to **determine future water needs**. Future water needs should be broken down by water sources and site use as in the current water-use profiles on section 2.4. Estimated cost of each source and the total may be included based on a cost per volume used.

How goals are established and how a club may approach establishing a water-use efficiency conservation program depends very much on specific conditions. Course additions (holes added) will obviously increase water needs. If an alternative irrigation water source is planned that contains sufficient salts that would require periodic leaching, then the quantity of water required for the leaching fraction should be included to avoid deterioration of soil resources and plants. Reduced acreage of irrigated area would alter irrigation needs. The future water needs should be determined after inclusion of anticipated BMPs to enhance water-use efficiency/conservation that are discussed in Part 3 of this document. Major water related infrastructure additions for future water needs should be noted. These include: main pipelines; drainage; water storage; pumping; water treatment facilities, etc.

2.6. Water Licenses, Permits, and Regulations.

List any water licenses or permits along with the title, date, and issuing agency for any of the water sources used. Provide any details that would influence future water availability or restrictions. For example, if stormwater is collected as part of the stormwater management plan, are there restrictions on the use of the water for irrigation.

PART 3. BEST MANAGEMENT PRACTICES FOR WATER CONSERVATION: CURRENT AND FUTURE.

Ten Core BMPs.

3.1. Turfgrass and Landscape Plant Selection.

3.2. Landscape and Golf Course Design for Water Conservation.

- **3.2.1. Minimizing Close-Cut, Highly Maintained Turf Area.**
- **3.2.2. Landscape Design to Improve Water Conservation and Management.**

3.3. Altering Management Practices to Enhance Water-Use Efficiency.

3.4. Irrigation System Design and Devices for Efficient Water Use.

- **3.4.1. Assure Overall Quality Of The Irrigation System.**
- **3.4.2. Design of the Irrigation System for Uniformity and Efficient Operation.**
- **3.4.3. Maintenance of the Irrigation System for Optimum Performance.**
- **3.4.4. Subsurface Irrigation and Surface Drip Systems.**

3.5. Irrigation Scheduling/Operation for Efficient Water-Use.

- **3.5.1. Irrigation Tools or Methods.**
- **3.5.2. Irrigation Budget Approach For Efficient Irrigation.**

3.6. Use of Alternative (Non-potable) Irrigation Water Sources.

3.7. Education.

3.8. Development of Written Water Conservation and Contingency Plans.

3.9. Indoor and Other Landscape Water Conservation Practices.

- **3.9.1. Indoor Water Conservation Measures.**

3.9.2. Other Landscape Areas.

3.10. Monitoring, Reviewing, and Modifying Conservation Strategies

In Part 3, site-assessment information gathered in Part 2 is used to develop BMPs that are combined together into an overall BMPs plan. BMPs can be categorized into **ten BMPs strategies** combined with the site assessment information of Part 2; therefore, we will present the components of an overall BMPs plan as the combination of these ten strategies. **The BMPs reported under each strategy can be formatted to include:** a) current practices – these are already reported in section 2.1. "Current Water-Use Efficiency/ Conservation Practices", b) new practices that have been initiated during the site assessment phase, and c) future anticipated practices that can be incorporated when appropriated infrastructure structure changes have been made. Additionally, estimated improvements in water-use efficiency/conservation can be included in a report. However, care should be taken to point out that not all strategies result in a net decrease in water usage --- especially when using more saline irrigation water sources. Two key science resources related to turfgrass water conservation have been recently published and provide additional details on many of the individual BMP strategies noted in this section (Beard and Kenna, 2008; Leinauer and Cockerham, 2010) (see below).

Key Resource: J. B. Beard and M. Kenna (Eds.). 2008. *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes.* CAST Special Publ. 27. Council for Agricultural and Science and Technology, Ames, IA. CAST is a council of scientists in all areas of agriculture and it develops position publications related to agriculture. CAST publications are widely respected as balanced and fair; and as a result are primary resource publications for regulatory agencies and congressional staff use. This book is the most comprehensive science-based publication on turfgrass and landscape water quality and quantity issues; and it uses the BMPs model in the development of the book, as noted in Chapter 16. Several chapters are directly related to water-use efficiency and conservation.

- Chapter 1. Urban turfgrasses in times of a water crisis: benefits and concerns. Douglas H. Fender.
- Chapter 2. Integrated multiple factor considerations in low-precipitation landscape approaches. J. B. Beard.
- Chapter 5. Turfgrass and the environment. Michael P. Kenna.
- Chapter 6. Soil water in managed turfgrass landscapes. Ed McCoy.
- Chapter 10. Urban landscape water conservation and the species effect. Dale A. Devitt and Robert L. Morris.
- Chapter 11. Turfgrass water requirements and factors affecting water usage. Bingru Huang.
- Chapter 12. Turfgrass cultural practices for water conservation. Robert C. Shearman.
- Chapter 13. Achieving high efficiency in water applications via overhead sprinkler irrigation. Michael T. Huck and David F. Zoldoske.
- Chapter 14. Recycled, gray, and saline water irrigation for turfgrasses. M. Ali Harivandi, Kenneth B. Marcum, andYaling Qian.

- Chapter 15. San Antonio water conservation program addresses lawngrass/landscapes. Calvin Finch.
- Chapter 16. Best management practices for turfgrass water resources: Holistic-systems approach. Robert N. Carrow and Ronny R. Duncan.

Key Resource. Leinauer, B. and S. Cockerham (Eds.) 2010. *The Science of Turfgrass Water Conservation.* University of California Press, Los Angles, CA. 12 chapters.

3.1. Turfgrass and Landscape Plant Selection.

Key Resources: J. B. Beard and M. Kenna (Eds.). 2008. *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes.* CAST Special Publ. 27. Council for Agricultural and Science and Technology, Ames, IA.

- Chapter 5. Turfgrass and the environment. Michael P. Kenna.
- Chapter 10. Urban Landscape Water Conservation and the Species Effect. Dale A. Devitt and Robert L. Morris.
- Chapter 11. Turfgrass water requirements and factors affecting water usage. Bingru Huang

As part of the initial site assessment and description of the course, the grasses and landscape plants used on different areas were reported in terms of location and acreage (Section 2.2.1. "Basic Property Information) and under section 2.1. "Current Water Conservation Practices". In section 3.1, it would be appropriate to:

1. Summarize current drought resistance/lower water-use turfgrass and landscape species/cultivars that are being used. Also, note which are adapted to the region's climatic and pest stresses, and soil conditions. Non-adapted plants require more water for survival and growth; and require greater pesticide use (a concern for protection of water quality--- i.e. water conservation is not the only water issue that must be considered in plant selection).

2. Report any planned incorporation of more drought resistant/low water-use grasses and landscape plants in the future along with an estimated time frame.

3. Overseeded grasses. Inclusion of overseeded grasses is often necessary during the winter months in southern regions due to heavy use of the sites and to compete for market share. The influence winter over-seeding on water use should be noted, including: restriction of over-seeded area; omitting over-seeding to conserve water; choice of grasses, especially if salinity is an issue.

A general ranking to different turfgrass species for drought resistance is noted in Table 2 (Appendix C). The drought resistance rankings in Table 2 are based on certain conditions: a) rankings are based on the most widely used cultivars within the species. Thus, some cultivars may perform better and some worse, b) rankings are based on performance in the region of adaptation for the species, c) rankings are based on field dry-down trials where low water use would be a component of overall drought resistance, and d) rankings reflect performance under conditions where root limiting stresses are not present or are minor. This latter aspect is important since drought performance can be greatly affected if the cultivar is susceptible to any root limiting conditions on a site. Management for good root development is important to maximize drought resistance. Within a species there can be considerable differences in drought resistance of individual cultivars due to genetic-based differences in various drought avoidance and tolerance mechanisms as well as tolerances to root limiting factors. Results from local turfgrass studies at land-grant universities and research institutes can often provide information on the best species and cultivars within a species to use for the particular location.

In addition to assessing and developing drought resistant cultivars among the "traditional" species, non-traditional species bred for superior drought resistance and/or other stress resistance traits will become more common (Duncan and Carrow 2001; Loch, D. S., E. Barrett-Lennard, and P. Truong. 2003; Brede 2000). Aldous and Chivers (2002) provide information on the use on several species that are currently not of wide use as turfgrasses but have promise for development. Also, Brede (2000) has considerable information on a number of less common grasses that may be useful for certain golf course situations including grasses that can be grown with less than 450 mm annual precipitation: Arizona fescue, big bluegrass, blue grama, Boer lovegrass, bottlebrush squirreltail, buffelgrass, bulbous bluegrass, Canby bluegrass, crested wheatgrass, curly mesquite, desert saltgrass, galleta, giant bermudagrass, green sprangletop, Idaho fescue, Indian ricegrass, Lehmann lovegrass, natalgrass, Nuttal alkaligrass, prairie junegrass, prairie sandreed, purple three awn, red grama, sand dropseed, Sandberg bluegrass, Siberian Wheatgrass, sideoats grama, spike muhly, standard crested wheatgrass, streambank wheatgrass, timothy, Western wheatgrass, Wilman lovegrass.

The combination of high drought resistance and low water use are not the only characteristics required for many golf courses. If plants are not adapted to these stresses, more water is often applied just for plant survival during stress periods. The grasses and landscape plants selected must possess:

- Tolerance to the climatic extremes for the location, especially high and low temperatures.
- Tolerance to common pest stresses.
- Tolerance to soil physical and chemical stresses that may limit rooting.
- Ability to withstand the mowing height required for the particular use (for grasses).
- Suitable turfgrass or landscape quality and performance for the use.
- Salinity tolerance with respect to any saline irrigation water to be used---see section 3.6.

3.2. Landscape and Golf Course Design For Water Conservation.

On larger, more complex sites, such as golf courses, during construction or renovation planning stages many decisions can be made that will either foster water conservation or greatly limit it. Items listed and discussed in this section include any current or future practices that: a) minimizing close-cut, highly maintained turf areas, or b) landscape design to improved water management.

3.2.1. Minimizing Close-Cut, Highly Maintained Turf Area.

All areas on a golf course do not need to be maintained as a closely mowed, highly irrigated turfgrass. Some current golf courses under severe water limitations may consider design alterations to reduce the area of closely-mowed and highly maintained turfgrass. Changing design must be carefully done in a manner that does not interfere with the game of golf/playability. When design changes are made, the irrigation system must also be substantially modified to eliminate irrigation on many sites, but maintain good zoning and uniformity of application on the turf areas. Using alternative landscape features on selected areas that do not hinder the game of golf can result in substantial water savings. Numerous design "looks" can be achieved with combinations of design features such as:

- Use of various mulch materials as a ground cover. Pine mulch is often used in the Southeast and helps in retaining water while protecting the soil.
- Using alternative, drought-resistant grasses that are left un-mowed in non-landing areas;
- Higher mowing heights can often be used on parts of the fairway or adjacent roughs that may receive little or limited irrigation. Golfers seem to accept brown or drought affected turf when it is mowed higher than on the primary landing areas or left un-mowed, but may not accept as much discoloration or lower plant density on the closely mowed high-use areas. Since golf courses must compete for local, and in some locations, national and international customers, the visual aspects on the close-mowed playing area influences marketing and the associated tourist industry. Also, courses with high play will require sufficient irrigation to maintain a good turf under the continuous traffic stresses. Thus, the primary landing areas on fairways, along with tees and greens normally require adequate irrigation for play, visual impact, and recovery from traffic.
- In other instances with less demand or play or competition for customers, dormant, semi-dormant, or lower quality turf may be very acceptable on large expanses of many golf courses, including primary landing areas on fairways. However, greens and tees would require adequate irrigation to maintain a good cover and recover from wear stress.
- Incorporation of adapted, drought resistant low growing ground covers, shrubs, and trees that require minimal irrigation and possess unique looks in areas where they will not interfere with routine play.
- Features such as rock, sand bunkers, and non-irrigated mounds can be used in some locations.
- Extra wide expanses of closely mowed, highly maintained fairways should be avoided or alternative materials used in the out-of-play areas to reduce irrigated area.
- Contouring to avoid excessive slopes, mounds, and berms within any areas that would require highly maintained turf. These features are difficult to irrigate even with an excellent irrigation system. However, if browning or even dormant turf on these features are acceptable [i.e.—no irrigation is then needed], then they can be used. In some cases where a berm or mound is necessary and desirable to irrigate, low volume spray heads may be installed on a separate zone to allow slow, pulsed irrigation to achieve water infiltration.

Golf course owners and managers should be aggressive in quantifying costs involved with any landscape changes for the purposes of water conservation. Water agency officials, politicians, environmental advocacy groups, and the general public should be informed of costs to your business for implementation of specific water conservation strategies. When water conservation measures are promoted for implementation by the homeowner that will cost money, assistance is often provided by means of water rebates, special funds to help make changes, or tax incentives. However, many of the audiences noted do not understand the cost to golf courses—that often have to implement more strategies and some, such as using a poor quality alternative water source or reducing irrigated area, that carry very high costs with the change. For example, altering the irrigated area also alters the irrigation system design and zoning, which must them be changed.

3.2.2. Landscape Design To Improve Water Conservation and Management.

Landscape design can markedly influence the potential for water harvesting and prevention of undesirable runoff. Examples include:

- Careful contouring and surface drainage to capture stormwater in on-site storage lakes – i.e, water harvesting, discussed below.
- Use of sub-surface drains to capture storm water and move it to storage lakes.
- Avoiding steep slopes that foster runoff on sites where it is desirable to allow water infiltration into the soil for plant use.
- When soils are very high in clay content and have very low water infiltration rates, sand-capping with a 4 to 8 inch layer of sand above the heavy soil can greatly improve water infiltration and capture from irrigation and rainfall. Sometimes the sand-cap is added later by vigorous sand topdressing and cultivation over several years.
- Extra excavated or bermed ponds can be included in the design to maximize water harvesting and storage capacity, especially in semi-arid or humid climates with periodic storm events.
- Sometimes water is moved onto a golf course or within a golf course to a storage pond or lake through canals, ditches, or pipelines. Water losses in these conveyance features should be minimized. Canals or ditches may be lined to eliminate leaching losses. Excess vegetation such as large trees that withdraw water fro ditches may be controlled. Pipeline should be checked for leaks.
- During flood flows in streams or rivers, high flow diversion of water into storage ponds may be feasible. Also, high volume pumps may be used to fill storage ponds during high flow periods. Dry ponds or detention basins can be constructed to allow filling with water when high flow events occur.
- Lining of excavated ponds with impervious materials such as clays or synthetic liners can greatly reduce leakage losses, especially on soils with high percolation rates.
- Construct storage ponds deep to minimize surface area for evaporation losses.
- Install staff gages to measure the water level and check periodically for leakage and monitor lake levels.
- On sites where the irrigation water contains high soluble salts and/or sodium, storage lakes and ponds may be lined to prevent seepage of salts into the water. Sites with existing saline or sodic soils can have the same problems.

- When near coastal areas, during prolonged dry periods salt-water intrusion sometimes occurs either into irrigation wells or sometimes directly into lakes and ponds. Water sources should be periodically tested on sites susceptible to this problem. Once the water source is salt-laden, it often requires dilution to achieve useable water.

Water harvesting is especially important for golf courses (Duncan et al., 2009). Water harvesting in larger landscapes is usually thought of as treating or modifying watersheds to enhance and/or direct runoff that is collected in a lake or wetland for future use (FAO, 1994; Thomas et al., 1997; Todd and Vittori, 1997). The environmentally friendly term "water harvesting" is not often used in relation to golf courses, yet it is a common practice and golf courses are one of the most prevalent users of this concept – but not widely acknowledged for this practice that is becoming increasingly popular for other sites. Many golf course irrigation lakes also serve as landscaping features and catch excess runoff, preventing the loss of substantial amounts of water from the site and retaining sediment that would otherwise be carried into streams or rivers. Catchment features are often part of an overall community stormwater control program mandated by governmental policies to control flooding. A recent survey of Georgia golf courses indicated that as much as 67 percent of irrigation water came from such non-potable, surface sources (Florkowski and Landry, 2002). In the case of golf courses, the landscape is purposely contoured to collect the excess runoff from rainfall, while allowing good infiltration of water into the soil under normal conditions.

3.3. Altering Management Practices To Enhance Water-Use Efficiency.

Key Resource: J. B. Beard and M. Kenna (Eds.). 2008. *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes.* CAST Special Publ. 27. Council for Agricultural and Science and Technology, Ames, IA.

- Chapter 11. Turfgrass water requirements and factors affecting water usage. Bingru Huang.
- Chapter 12. Turfgrass cultural practices for water conservation. Robert C. Shearman.

In this section, any cultural practices that are practiced or alterations in management that are anticipated in the future that will enhance water conservation or water-use efficiency should be noted. Cultural or management practices can affect the turfgrass and soil system by several means:

- Alter the soil water balance by influencing runoff, evaporation, transpiration, soil water retention, and leaching.
- Alter plant water status by influencing succulence, osmotic adjustment, rooting, shoot characteristics that affect ET.
- Influence salt problems such as poor structure, high salinity, high sodium, or specific ion toxicities in situations where the water quality is poor.

Thus, cultural practices have a profound influence on turfgrass water relations. Cultural practices have the capability of improving conditions so the plant can be near its genetic capability in drought/salt resistant, or, conversely, improper cultural practices can negate the plant's inherent genetic potential. In addition to the key references above, several authors have reviewed turfgrass management practices and water use (Balogh and Watson 1992; Brede 2000; Carrow et al. 1994; Gibeault and Cockerham 1985; Kenna and Horst 1993; Kneebone et al. 1992; Beard and Kenna, 2008; Leinauer and Cockerham, 2010). Turfgrass cultural practices that influence turfgrass water relationships and relative importance in affecting water relations are noted below. When including specific practices in the BMPs document, it would be beneficial to briefly explain how the practice contributes to improved water-use efficiency or conservation.

Cultural Practice	**Relative Importance**[a]
	1=most, 4=least
Irrigation scheduling program	1
Soil cultivation---for water infiltration, rooting	1
Alleviation of salt-affected soils---correction of high salinity and specific ions toxic to roots (Na, Cl, B)	1
Alleviation of sodic soil conditions	1
Soil modification—for water infiltration, rooting	2
Selection of species	2
Selection of cultivar	2
Turfgrass site use and quality expectations	2
Mowing height—within the tolerance range for the grass	2
Nitrogen fertilization	2
Potassium fertilization	2
Liming acid soils—especially acid soil complex conditions.	2
Wetting agents	2
Mowing frequency	3
Mowing blade sharpness	3
Plant growth regulators	3
Soil insect control	3
Soil disease control	3
Phosphorus nutrition	4
Iron nutrition	4
Antitranspirants	4
Other pesticides with PGR activity	4

[a]Based on the experience of the authors as an average across most sites.

On a specific site, the relative importance of each of these practices may change due to local conditions, but the above is a good overall generalization; and list to consider in terms of possible practices on a site. Of particular importance are: a) irrigation scheduling – the focus of section 3.5; and b) cultivation practices. Since many golf courses have routine cultivation on various areas of the course, it is important to recognize how this positively influences water-use efficiency, such as:

- Cultivation creates temporary macropores (pores > 0.08 mm in diameter) that enhances infiltration of rain and irrigation into the soil surface. If deep cultivation is practiced, percolation (though the root zone) is also enhanced. By capturing a higher percent of rain and irrigation water, irrigation events can be omitted and result in considerable water conservation.

- Cultivation also enhances deep rooting which allows plants to use a greater quantity of soil moisture and, thereby, delay irrigation events and enhance the opportunity for rain to provide the water before irrigation is needed. Weicko et al. (1993) found that root growth in the lower profile (1 to 2 feet depth) was increased up to 41 % by deep drilling; 120 % better rooting by Aerway slicing; and 38 % by deep-hollow tine cultivation

In addition to cultural practices on the turfgrass and landscape plant site, strategies to reduce surface water evaporation or leaching losses from surface water features should be considered. Examples, include:

- Lining or sealing of ponds.
- Minimizing ornamental water features.
- Converting ornamental water features to grasses hollows.
- Using below surface aerators instead of fountain aerators.
- Use of anti-evaporants.

3.4. Irrigation System Design and Devices for Efficient Water Use.

Key Resources.

- J. B. Beard and M. Kenna (Eds.). 2008. *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes.* CAST Special Publ. 27. Council for Agricultural and Science and Technology, Ames, IA. Chapter 13. Achieving high efficiency in water applications via overhead sprinkler irrigation. Michael T. Huck and David F. Zoldoske.
- R. R. Duncan, R. N. Carrow, and M. Huck. 2009. *Turfgrass and Landscape Irrigation Water Quality*. CRC Press, Boca Raton, FL. Chapter 10. Irrigation system design for poor-quality water.

On irrigated turf sites, the irrigation system design and operation (scheduling) will have a major influence on water conservation, especially when used in conjunction with the other water conservation strategies (Beard and Kenna, 2008; Duncan et al., 2009). The Irrigation Association is a primary organization in agriculture, horticulture, and turfgrass areas in fostering water conservation through proper irrigation (Irr. Assoc. 2009). In their extensive *"Turf and Landscape Irrigation Best Management Practices"* document, they note that maximum water conservation on irrigated sites requires five BMPs related directly to the irrigation system (Irr. Assoc. 2005a) (this document is available as printable on-line or by order and is highly recommended). The five irrigation BMPs are:

1. Assure overall quality of the irrigation system.
2. **Design** the irrigation system for the efficient and uniform distribution of water.
3. Install the irrigation system to meet the design criteria.

4. Maintain the irrigation system for optimum performance.
5. **Irrigation scheduling**---managing the irrigation system to respond to the changing requirements for water in the landscape.(see section 3.4 Irrigation Scheduling/Operation for Efficient Water-Use).

3.4.1. Assure Overall Quality Of The Irrigation System.

Whether a new system or renovation of an existing irrigation system, it will become increasingly important for all golf courses owners and boards to be proactive in obtaining the best designed system for uniform water application, excellence in zoning, and a flexible control system. Quality irrigation systems cost more money than inferior systems, but a good system can also save on water costs. A new or renovated irrigation system will be with the course for a long time; and the future will bring increasing pressure for water conservation practices. Golf course superintendents should be proactive in promoting excellence in design aspects to the owners or board; as well as strongly influencing the selection of the most knowledgeable and skilled irrigation designers, contractors, and consultants.

Assurance of overall quality aspects that can be reported in this section include:

1. Making this a goal of the owners or board.
2. Providing sufficient funds to achieve the goal of design and installation.
3. Insisting of excellence in system design, installation, maintenance, and operation.
4. Provision of the funds for trained personnel to maintain the system and operate it effectively.

3.4.2. Design Of The Irrigation System For Uniformity and Efficient Operation.

Uniformity of water application is of prime importance, but quality design also requires effective zoning and flexibility in water applications (good controllers and sufficient water to allow good irrigation) to insure that adequate quantity of water can be applied at a rate that allows infiltration into the soil and with sufficient water to meet needs in a timely fashion. All three of these design criteria are necessary to achieve efficient water application---applying water in a manner that maximizes infiltration into the soil. General approaches or options for achieving these criteria in the initial system design or in modification of an existing system are covered in considerable detail in publications such as: IA (2005a; 2005b); Irrigation Association bookstore contains several publication related to irrigation design on golf courses (IA 2009). Also, the Center for Irrigation Technology (2009) offers services and information relative to maximizing irrigation uniformity.

Specific aspects that are important to consider in design for efficient and uniform distribution of water are noted below and may be discussed or reported in the BMPs document. Much of this information would arise out of the Water Audit in Part 2, but any modification or improvements should be noted. Also, if the existing irrigation design exhibited good attributes for uniform and efficient water application, these should be noted.

A. Sprinklers, Design, Zoning.

- Careful evaluation of design criteria for selection of proper heads, nozzle sizes, rotation speed, head spacing, pipe size, and pressure. Errors in these aspects can adversely affect all uniformity of water application on all zones. Wind speed and direction are critical factor influencing head spacing.
- Choosing sprinkler heads that do not exceed the infiltration rate of the soil. On sites where runoff does occur, nozzle adjustment may be necessary and the use of pulse irrigation.
- Matched nozzles to insure the same water application rate within a zone including when part and full circle sprinklers are within the same zone.
- Low or adjustable trajectory nozzles can reduce the influence of wind.
- Pressure control to assure proper sprinkler operation with minimal misting.
- Adjustable arc heads for more site-specific targeting of water.
- Low volume heads for sloped areas; sites with low water infiltration; and where wind drift is a problem.
- If a flexible control system, ample quantity of water, and good pressure, low volume heads can reduce evaporation losses and wind drift, while allowing water to infiltrate into the soil.
- Use part circle sprinklers on edge areas to reduce water application on out-of play areas.
- Careful zoning into hydrozones (site-specific management units, SSMUs; Carrow et al., 2009a; b; Krum et al., 2010) that are areas with similar soil water holding-capacity (i.e, soil texture, organic matter content); plants, and environmental for similar ET requirements. The primary factors generally considered are: presence of different types of plants (trees, shrubs, turf, mixed plants); slope; sun exposure; solar radiation (sun versus shade). Soil type and soil variation---organic matter content, and subsoil variation are also important. For site-specific irrigation that is necessary for water-use efficiency and for salt leaching of salt-affected sites; irrigation zones should be: a) 1 to 2 heads per zone; and b) all heads of a zone within a SSMU.
- Zoning sprinklers on mounds to control irrigation times and using appropriate low volume sprinklers, including low volume spray heads for smaller mound areas.
- Use of high efficiency nozzles for better uniformity of coverage.
- Dual lines and sprinklers for greens versus surrounds.
- Triangle spacing is more efficient than single row or square spacing of sprinklers.
- Use more sprinklers to achieve better coverage uniformity and allow closer spacing.
- In areas with strong prevailing winds at certain times of the year, consider an extra row of sprinklers located on the windward side zoned to be used during windy periods.
- Backflow devices and any necessary hardware required for a particular water source—such as effluent water with dual lines and safety measures to protect potable water.
- Variable frequency drive pumping system to apply water at the quantity required in an energy efficient manner.
- Future: a) sprinklers with greater flexibility in water delivery; b) heads that have two-way communication to controllers for changing sprinkler performance and to assure correct operation; and c) wireless heads; and d) increasingly components of the irrigation system must be designed to allow for multiple means of electronic interfacing and a higher level

of interfacing, especially with water saving devices used as aids for irrigation scheduling. These features could change zoning and irrigation concepts.

B. Water Saving Devices.

- Appropriately placed water meters with electronic flow rate coupled with the controller to monitor water use and detect leaks.
- Automatic rain shut-off devices.
- Soil moisture sensors feedback to shut-off a zone or to prevent irrigation until needed.
- Check valves to prevent drainage from heads in low areas.
- Isolation valves to allow sections of the system to be isolated when major leakage or break events occur.
- Pressure regulating devices to control high pressure misting.
- Climate sensors that prevent irrigation under freezing or high wind conditions.
- Environmental sensors, especially weather stations, to measure reference ETo based on solar radiation, wind, humidity, and temperature for scheduling purposes.
- Soil sensors with multiple depths to measure ET based on soil water depletion; monitor potential for capillary rise of moisture: determine depth of the root system; determine the quantity of water to apply and when.
- Future will include: a) greater use of advanced control systems to regulate irrigation through soil moisture, climatic, and soil salinity sensors to provide real-time data to the control program and make automatic daily adjustments in irrigation; b) use of salinity sensors along with soil moisture sensors to control salt leaching with the least quantity of water; and c) coupling various sensors with the control system using 2-way communication in order to adjust irrigation and to alter sensor criteria.

C. Control System.

- Automatic central control systems should allow great diversity in programming including multiple start times; multiple independent programs; capability of short run times; pulse or cyclic irrigation scheduling; syringe and pre-wet cycles; interfacing with potable hand-held controllers; interfacing with sensors; program ability to use weather data or soil data to schedule irrigation. Controllers vary in their capabilities where some are fixed irrigation intervals with fixed run times that can only be changed manually. Other controllers have fixed run times the user can rapidly change run times by a percent adjustment. The next level is a controller that has user-programmed irrigation intervals but can be automatically adjusted by historic or current ET data. The most automatic are controllers that automatically adjust the interval and run times within set limits.
- Future: Advanced control systems that can be highly automated using 2-way communication and sensors to integrate real-time data will become the “norm” in many cases.

3.4.3. Maintenance Of The Irrigation System For Optimum Performance.

Even the best-designed system must be maintained on a routine basis. On courses with highly automated irrigation systems with integrated real-time sensor inputs, it will be important to assign personal that have the responsibility to routinely maintain a system and periodically conduct irrigation audits on parts to the system. The most common reasons for system malfunction are discussed below. If the existing system does not exhibit these problems, this can be stated; if improvements are needed, then the nature and plan to make these improvements can be noted.

- Poorly adjusted sprinkler heads.
- Broken heads or sprinklers that are not rotating properly.
- Sprinklers that are not properly aligned, but are crooked or out of plumb. Use of 3-elbowed swing joints help maintain alignment.
- Sunken heads.
- Heads where grass leaves or thatch interferes with operation.
- Clogged nozzles.
- Worn nozzles.
- Mismatched nozzles or heads within a zone for uniform precipitation rate.
- Mismatched nozzles or heads for the soil infiltration rate.
- Spray deflection by plants or other features.
- Malfunctioning valves.
- Water saving devices not functioning, such as rain switches or soil moisture sensors.
- Improper irrigation scheduling problems---run time per cycle or number of cycles are not adequate to apply sufficient irrigation; over-application of water due to incorrect scheduling; schedules that are not adjusted for weather or for specific zones.

All of the above aspects are part of a Water Audit (whether a traditional Water Audit or the New WaterAudit approach using spatial soil moisture measurements at field capacity) as noted in section 2.2.4. Irrigation System Audit (Water Audit). Both these Water Audit approaches start with making sure the irrigation system is functioning to maximum capability and that the programmed schedules are appropriate. For turfgrass sites without an experienced turfgrass manager, inspection by a Certified Water Auditor is a primary means of evaluating the system. However, <u>for golf courses this should be normal operating procedures</u>. This should be pointed out in your BMPs water management plan that this component of a water audit is done on an on-going basis. Regulatory individuals and politicians often look favorably on a site conducting a water audit – but, they do not usually recognize that there is a normal internal water audit for the above aspects. When highlighting this in a BMP plan, note the individual and their training – e.g. Irrigation Assistant, 4-year BS in Turfgrass Science, list any further training courses that are irrigation related.

3.4.4. <u>Subsurface Irrigation and Surface Drip Systems.</u>

Above ground sprinklers distribute water through the air and leave the surface moist. These conditions can result in high evaporative losses of water and wind distortion of water application. Subsurface application of water to the plant rootzone would reduce these problems. Subsurface irrigation can be achieved by several means (Krans and Johnson 1974; Daniel 1990; Leinauer 1998; Zoldoske et al. 1995; Suarez-Rey et al. 2000; Weeks and Maurer 2003).

1. Using a fluctuating or adjustable water table, such as the PAT and Cellsystems (Leinauer, 1998). This approach has been successfully used on golf course greens and athletic fields. Good turf performance and water savings can be achieved. With changes in grade, construction becomes more complicated but can be accomplished. If the irrigation water contains even modest levels of salts, salt accumulation can occur at the surface as salts are carried with water during capillary rise as the surface dries from ET.

2. Using a stationary water table. This approach is not used in turfgrass since grasses have seasonal root growth patterns, which influences the appropriate depth for the water table.

3. Use of buried water emitters (SDI, surface drip irrigation) has also been used (Zoldoske et al. 1999; Suraez-Rey et al. 2000; Weeks and Maurer, 2003). The article by Suarez-Rey (2000) discusses pros and cons of this approach as well presenting an overview of past research. Some of the problems to consider are: emitter clogging; uneven water distribution due to clogging or improper design; difficulty in performing cultivation operations; and potential for surface salt accumulation.

Both the SDI and fluctuating water table systems will likely increase in use in arid regions, especially on greens or tees. If water quality is such that salt accumulation may occur, a surface water application system may be needed to periodically leach salts. Surface drip systems are very useful for site-specific irrigation on golf courses for trees, shrubs, and flower beds. With proper design and maintenance, these systems can effectively irrigate mixed plant types and single plants.

3.5. Irrigation Scheduling/Operation For Efficient Water-Use.

3.5.1. Irrigation Tools or Methods.

Four key principles that will be increasingly important in the near future (Carrow et al., 2009a; 2009b; Krum et al. 2010).

1. ***Site-specific irrigation*** = applying water where it is needed; when it is required; and at the quantity necessary to replenish ET losses.
2. ***Site-specific information*** **is required for site-specific irrigation.**
3. ***Site-specific information can obtained by detailed spatial mapping of a site*****: a) at field capacity** for irrigation scheduling applications, or at **b) after a normal irrigation during a dry period** when the intention is to evaluate the irrigation system (New WaterAudit Approach, see section 2.2.4. Irrigation System Audit (Water Audit).
4. ***Site-mapping to be of most value must involve both:***
   - ***Key soil properties*** that influence water use/retention ---- volumetric water content (represents soil texture and organic matter content), penetrometer resistance (soil structure), and slope;
   - ***Measure of plant performance*** **–** i.e. NDVI (normalized difference vegetative index) by spectral reflectance.

Tools or methods to improve irrigation scheduling should be addressed within this section, including current tools/methods as well as expected future improvements that are anticipated. Irrigation scheduling options include:

1. Experience of the turf manager.
2. Climate-based approaches, such as the use of weather stations, evaporation pans, or evaporometers that estimate climate ET or evaporation.
3. Soil-based methods using soil sensors.
4. Plant-based methods. The most common plant-based approach is to use indicator areas that drought stress can be first noticed. Other approaches are the use of infrared thermometers or multispectral data, but these are less developed.
5. Combinations of these approaches.

In terms of sensor technology to monitor soil, plant, or climatic conditions/characteristics, these may be a combination of:

- Hand-held devices for spot measurements.
- In-place sensors such as soil moisture or salinity sensors that may be placed in key indicator areas to provide real-time data by soil depth.
- Mobile monitoring using GPS/GIS technology to better define spatial variability of selected soil or climatic characteristics and/or plant responses to these characteristics.

Comments: It will be important for golf courses planning new systems or renovation of an existing system to consider changes that will occur in the near future. Irrigation scheduling of the future must involve information from within an irrigation zone to provide more site-specific guidance using an integrated irrigation system with controllers and sensors linked (Buss 1996; Neylan 1997; Sudduth et al., 1999; Carrow et al. 2009a; 2009b). While many in the turf industry may be skeptical of adopting or developing new technologies and concepts that are necessary for site-specific irrigation, the demand for water conservation measures will (and is) bringing these changes. As stated previously, site-specific or precision irrigation cannot be done without precise data on the microclimate level; nor without precision in water application. One scenario that is becoming increasingly common, especially in arid regions, is for a golf course to be limited to a set quantity of water that is well below current use for many facilities. In such a situation, the facility must view all options to achieve the water limit; and ideas that seemed impractical before may suddenly become very attractive.

Highly automated controllers that can automatically adjust irrigation using daily climatic and soil sensor data will become more prevalent as the necessity for water conservation increases. In the future, the authors believe that the most highly automated irrigation scheduling systems on golf courses will have the following components:

On-site weather station will provide real-time data on the reference crop ETo. Soil sensors will be used in selected microclimate sites to monitor soil water loss, which is actual turf water use. These indicator areas will be selected by more rigorous site assessment procedures targeted to identifying common microclimate types and classification of similar microclimates together; then a representative microclimate site for a particular class can become the indicator for all other similar microclimates. The soil sensor data can provide: a) real-time actual ETc, which then can be used to provide a real-time K_L to adjust the ETo value for an estimated ETc for the other sites, b) information on soil water status by depth, c) the quantity of water to replace ET losses, d) estimate of rooting depth, and e) whether any capillary water movement into the root zone is occurring. Golf course fairways, for example, may be classed into several microclimate types, with each type having a representative microclimate site with soil sensors to obtain the data for that particular microclimate type. The calculated K_L factor could be automatically inputted into the controller to estimate when to irrigate and how much water to add to replace ET losses. Soil moisture status by depth could be viewed by the turf manager to determine adjustments, while also providing another estimate of how much water to apply to replenish the root zone.

<u>Key questions for soil sensors</u>: a) where should they be placed?; b) what areas do they represent?; and c) what are the minimum number required? Current research is underway that is starting to answer these questions by using spatial mapping of soil volumetric content when the site is at field capacity (Carrow et al., 2009a; 2009b; Krum et al. 2010). The basic requirement is to identify site-specific management units (SSMUs) which are areas that have similar soil texture and organic matter content. Once SSMUs are identified on each fairway, as well, as how many SSMU types (i.e, how many different types of SSMUs) and their location across a course. The process is being tested on selected courses to take the information to the point of being incorporated into irrigation scheduling programs.

3.5.2. <u>Irrigation Budget Approach For Efficient Irrigation</u>.

In the BMPs plan for a golf course, it would be beneficial to state what the "irrigation approach" is for routine irrigation. Regardless of the irrigation scheduling technology used, an easily understood irrigation approach is "**<u>the Budget Approach</u>"** as a good means to foster water conservation on a whole-systems basis (Figure 1). The Budget Approach is a useful way to visualize turf water management, similar to a bank checking account. Certain additions (**inputs**) of moisture are made and there are losses (**outputs**) of moisture from the plant environment. At any point in time, the plant has available to it a certain **reserve** of available water in the soil within the plant's root zone. **The objectives of a wise turfgrass manager are to maximize inputs, minimize outputs, and maintain a large reserve**. Within this section of the BMP plan, the approach for irrigation can be stated and briefly described. The Budget Approach can also be a means to categorize BMPs for water conservation, but listing specific practices that enhance inputs, minimize outputs, and foster an extensive root system to capture rainfall more efficiently. The key components of the budget approach to irrigation scheduling are. .

<u>Inputs</u>.

Inputs of moisture are **precipitation, overhead irrigation, dew, and capillary rise of moisture** from below the root system. Precipitation and overhead irrigation are the major inputs. Normally, capillary movement to turfgrass roots from below the root zone is minor except where a water table is within 2 to 4 feet of the roots. While the turf manager cannot control natural precipitation, irrigation can normally be controlled with respect to when to apply water and the quantity.

<u>Outputs</u>.

Outputs or losses include runoff, leaching beyond the root zone, evaporation, and transpiration. Reducing undesirable losses or outputs will retain more water for future use.

Runoff can be a problem on sloped sites and can be increased by fine-textured soils, thatched turf, compacted soils, and applying water faster than the soil can receive it—these issues will be discussed in a later section of **infiltration**. Water loss by runoff is especially a problem on sites with heavy soils and sloped areas. Soil moisture cannot be replenished if the water is lost by runoff onto another site. Runoff causes not only a dry site but also an excessively moist site. Reducing runoff requires correcting the above situations through cultivation, thatch control, or proper irrigation application rates.

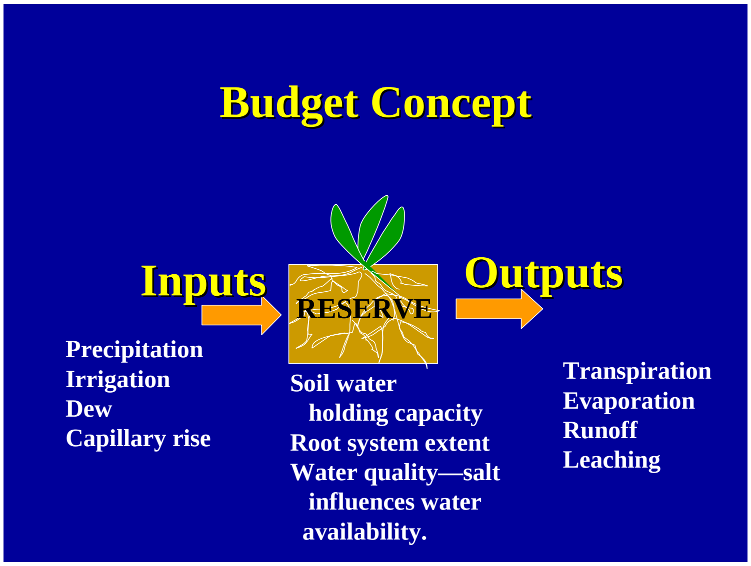

Figure 1. Components of the Budget Concept of turfgrass water management.

Leaching or water movement beyond the root system is often an unrecognized water loss. Irrigators whose watering is based on the driest site often over-irrigate other areas. Irrigating slightly beyond the existing root is acceptable because it provides a moist zone for further root extension. To reduce leaching losses, the irrigator must know the depth of rooting and depth of moisture penetration after applying a specific quantity of water. Well-designed irrigation systems that apply water uniformly reduce leaching losses. Also, proper zoning of irrigation heads is important. Heads in similar areas should be zoned together. Poor zoning, with heads on slopes and low spots zoned together, results in poor uniformity of water application.

Evaporation is the vaporization of water from a surface. When moisture evaporates, it removes energy (heat) from the surface. Thus, evaporation helps cool the soil and plant if free water, such as dew, is on the leaf surface. Excessive evaporation is wasteful. Growers can control the quantity of water lost by evaporation. For example, immediately after irrigation, evaporation rates from the soil surface are high, but as the surface dries evaporation dramatically decreases. Thus, light frequent irrigation results in high evaporative losses contrasted to heavier, less frequent applications. Other ways to reduce evaporation are: maintain good infiltration rates to

get the moisture into the soil; maintain a dense turf to shade the soil surface; mow your turf as high feasible for your situation to insure further shading; avoid applying so much water that standing water occurs; and avoid afternoon irrigation.
Transpiration is the vaporization of water inside the plant leaf that diffuses the cuticle and through the open stomata., which are pores on the surface of leaves, where most transpiration occurs. During this process, heat is removed from the plant. In many situations more than 90 percent of the moisture taken in by a turfgrass plant is utilized for cooling purposes. Transpiration is a desirable use of water, especially in hot conditions. However, excessive transpiration can occur and thereby waste water. Over-watering turf promotes excessive transpiration.

<u>The Reserve.</u>

The reserve of plant-available moisture at any point in time depends primarily upon soil texture and the volume of soil occupied by the plant root system. Obviously, over a period of time, irrigation and precipitation are the sources of the reserve moisture. Soil texture and water-holding relations are detailed in the "water-holding capacity" section, but as a generalization sands do not retain as much plant-available moisture as do loam soils.

The turfgrass grower can markedly improve the moisture reserve by managing to promote development and maintenance of a good deep, extensive plant root system. This is especially important in humid and semi-arid regions where a deep root system aids in capturing rainfall and, thereby, delaying irrigation events. Turfgrass breeders in some locations have placed considerable emphasis on development of grasses that can tolerate the soil stresses that limit rooting and on grasses that can better maintain their roots during the hot, dry summer months. This approach has been developed and articulated by Duncan and Carrow (1999) and Carrow and Duncan (2003) where they identified key soil physical and chemical stress that directly limit rooting development and longevity as:

- high soil strength
- acid soil complex – combination of acid soil pH (pH < 4.8) that results in Al/Mn toxicity to roots; nutrient deficiencies (Ca, Mg, P), and usually high soil strength
- low soil oxygen – from water-logging; compaction; soils with limited macropores
- soil drought – different genotypes of a species can tolerate soil drying without root tissue loss better than others
- excessive Na – that causes root deterioration for as a Na toxicity to roots by displacing Ca in root cells
- high soil temperatures – in combination with high air temperature that result in excessive carbohydrate loss in summer months for cool-season grasses.

In arid climates with little rainfall to capture, deep rooting is less important (Brede, 2000). In these climates, the goal is to have sufficiently deep roots for a relatively deep and infrequent irrigation scheduling. However, since ET losses from the turfgrass root zone starts at the surface and progressively works downward, irrigation frequency and amount depends on: the degree of surface drying and consequences on turf quality, localized dry spots, too hard of surface (soil strength); and ability of the irrigation system to practically apply replacement ET losses back to the depth of water extraction. Maximum rooting may not be necessary, but reasonably deep rooting is of most importance and for these roots to maintain viability.

Thus, selecting adapted grasses with enhanced rooting capabilities suitable to either humid/semi-arid or an arid situation, as noted above, is an important way to "increase the water reserve". A turfgrass with a 12-inch root system will have twice the quantity of plant-available moisture as one with only a 6 inch root system. **Development and maintenance of a good root system will require:**

- Selection of grasses with high drought resistant and capable of rooting into any root limiting soil physical and chemical stresses, as well as root resistance to any biotic stresses such as root diseases, root insects, and nematode.
- Proper mowing height.
- Good irrigation practices to favor deep rooting.
- Liming when needed and good fertilization.
- Control of root-feeding insects.
- Cultivation when soils are hard or compacted

3.6. Use of Alternative Irrigation Water Sources.

Key Resources: Duncan, R. R., R. N. Carrow, and M. Huck. 2008. Turfgrass and Landscape Irrigation Water Quality: Assessment and Management. CRC Press, Boca Raton, FL. 461 pages

PART 1. UNDERSTANDING ASSESSMENT OF IRRIGATION WATER
Chapter 1. Overview of Irrigation Water Quality Concerns
Chapter 2. Constituents of Concern in Irrigation Water
Chapter 3. Understanding Irrigation Water Quality Tests
Chapter 4. Field and Laboratory Monitoring of Salinity

PART II. IRRIGATION WATER QUALITY SITUATIONS AND MANAGEMENT
Chapter 5. Ultra Pure/Low Electrolyte/Low Salinity Irrigation Water
Chapter 6. Irrigation with Saline Water Sources
Chapter 7. Seawater and Seawater-Blended Irrigation Water
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PART III. MANAGEMENT OPTIONS FOR SITE-SPECIFIC PROBLEMS
Chapter 10. Irrigation System Design for Poor-Quality Water
Chapter 11. Effective Leaching of Saline/Sodic Sites with Irrigation Water
Chapter 12. Water Treatment for Specific Problems
Chapter 13. Nutritional Considerations with Variable Water Quality
Chapter 14. Lake, Pond, and Stream Management

PART IV. ENVIRONMENTAL CONCERNS RELATED TO IRRIGATION WATER SOURCES ON THE WATERSHED/ LANDSCAPE LEVEL

Chapter 15. Integration of Irrigation Water Sources to Minimize Environmental Concerns: An Increasing Challenge to Turfgrass Performance Chapter 16. Case Studies: Water Data Analysis and Interpretation

Within this section, the following information should be included in the overall BMPs plan. This information would arise out of Part 1 and Part 2 of the planning process.

1. Current water-use profiles are reported earlier under Section 2.4 ---see this section for details.
2. As a result of the site assessment/information gathering phase, near-term or long-term changes in irrigation water sources should be reported and how they will impact overall water conservation aspects.

A feasibility study that analyzes water supply sources usually requires a qualified professional consultant to evaluate all potential sources with respect to supply adequacy, economic viability, engineering considerations, and environmental impacts. Various irrigation water quality sources may have different issues to consider and potential management costs or options; and these are discussed in detail by Duncan et al. (2008). Some general considerations that may apply to one or more of the sources are listed below; and much of this information may be reported in section of the BMPs document.

- Location of the source.
- Development needs, costs, and potential problems relative to a water supply,
- Design and installation costs for wells, ponds, well-field layout, pumping, distribution lines, and other facilities.
- Pond/lake location, construction, and inflow/outflow features.
- Pond/lake seepage control measures.
- On ponds or lakes where water withdrawal may exceed water recharge, especially in the summer, the influence of a drop in water level may have on fish, aquatic plants, and growth of undesirable plants along the exposed shore. When these water features are a part of a housing development, these issues are of concern to these individuals.
- Determination of water rights, competition for a source, permitting, regulatory negotiations,
- Regulatory issues related to maintenance of in-stream flow for aquatic organisms, habitat, dilution needs, or the needs of other users,
- Regulatory issues concerning permitting for use of the water source that is under consideration,
- Investigation of any incentive programs for the use of a particular water source,
- Determination of any regulations requiring use of effluent water,
- Determination of how effluent water will be transported and stored on a site.
- Watershed analyses may be necessary to estimate the potential runoff capture in order to design and locate storage ponds. These analyses should be conducted along with a site assessment for drainage features and any storm water runoff features required on a site.
- Sheet flow of water into ponds can be enhanced by use of uniform turf areas and grass waterways from fairways and rough and non-use areas.

- When considering surface water collection into ponds, appropriate buffer zones should be used to avoid water quality protection.
- Well yield and drawn-down determinations.
- Stream flow during dry periods versus irrigation demand,
- Reliability and water volume both in the long-term and over the seasons of a year for all water sources. Included should be the anticipated effects of any water use restrictions that may apply to a water source during drought periods.
- Investigate any pricing regulations or water price structures.
- Investigate any water rebates or other incentive plans for using water conservation practices or devices.
- Characterization of the underlying aquifer, which is the process of quantifying the physical and chemical features of an aquifer that may influence ground water or the potential for contaminant from an alternative irrigation water source. With more saline irrigation water that requires a leaching program, the potential for contamination of the existing aquifer must be determined. If this potential exists, very careful contouring and sub-surface drainage with an appropriate outlet is necessary (Huck et al. 2000; Carrow and Duncan 1998).
- A complete water quality test for any natural constituents in the water as well as any contaminants. Any permanent grasses must be able to tolerate the salt levels in the water; as well as any overseeding grasses.
- Potential to use an aquifer that is not used for potable purposes, but may be suitable for irrigation.
- Potential for interaction of water removal from a source on wetlands, streams, sink-hole problems, etc.
- Energy costs to move water. This should be for well pumps and for transfer pumping costs ---whether in pipelines or to pump from one pond to another.
- When more than one water source is used, consideration should be given the potential loss of one or more of the sources due to drought, increased costs of maintenance, regulatory, or other reasons; and to the ramifications of losing a source.
- Costs associated with treatment of water prior to irrigation use. In recycling of storm/drainage waters for irrigation, treatment may encompass a typical water treatment facility. For use of desalinized water, the RO or other treatment facility would be a significant cost. The most common water treatment is for irrigation water containing high sodium in conjunction with high bicarbonates that interfere with use of calcium amendments to prevent formation of a sodic soil (Carrow et al.1999).

3.7. Education.

It is important to stress that on golf courses, the golf course superintendent is an educated professional who has a continuing education plan. Educated turfgrass managers are an integral component of BMPs, just as education has been essential in fostering BMPs for water quality protection and in IPM. Documentation of prior formal education and continuing education that relates to enhancing management skills related to water conservation should be noted in this section. Additionally, the golf course superintendent is often involved as an educator for other audiences concerned with water conservation on golf courses, such as policy makers, water management authorities, turf management students, club officials and members, crew members, etc. Any activities as an educator should be noted.

Superintendents will be required to develop and implement comprehensive BMPs for water conservation and water quality; use sophisticated technology (which is evolving to assist in management decisions and to quantify results); and carry out management regimes that complement water conservation. Additionally, on many sites water quality issues will require considerable expertise to deal with salt and nutrient problems. These complex management issues demand an educated manager to maximize efficient use of water.

3.8. Development of Written Water Conservation and Contingency Plans.

A successful water-use efficient/conservation program – whether at a specific turf site or at the local, regional or national level – requires the development of a science-based, detailed water conservation plan that incorporates various strategies. A water conservation plan conserves water on a continuous basis. The overall focus of this document has been to provide information to assist golf course superintendents and course officials to develop “BMPs for Golf Course Water-Use Efficiency/Conservation” that would be specific to their conditions.

In addition to on-going water conservation plan, a golf course should consider developing a water contingency plan, where a contingency plan deals with water-conserving measures in time of severe shortages. Waltz et al. (2009) developed a water contingency plan/template for times of water restrictions during prolonged drought periods for the turfgrass industry. It can be used to define the types of components that would go into a contingency plan. One of the primary reasons that a state-wide or water district water plan should be based in BMPs principles and why the golf industry should work toward this at the state level is for times of water restrictions (Carrow et al., 2008a; Waltz et al. 2009).

At the golf course level, it is essential that club owners, members and officials assist in formulating these plans and understand their implications. Club policies must include water conservation. Everyone associated with golf clubs (owners, pros, members, managers, superintendents) should educate public officials, implement a proactive attitude of environmental stewardship, and become involved in the political process concerning water conservation. It is likely that in the future, clubs may have a position devoted to maintenance of water conservation practices, where the individual would conduct on-going water audits, maintain the irrigation system, and have other responsibilities related to a club water conservation plan.

The authors anticipate that the integration of the combination of environmental concerns such as use of poor water quality for irrigation, water conservation, and protection of waters, as well as other environmental concerns, will require an **Environmental Management Systems (EMS) approach** on many sites (USEPA, 2005). The USEPA (2005) defines an Environmental Management System (EMS) as "a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. An EMS is a continual cycle of planning, implementing, reviewing and improving the processes and actions that an organization undertakes to meet its business and environmental goals" (Carrow and Fletcher, 2007a; 2007b). EMSs are being strongly promoted by the USEPA. When EMS plans are formulated for the various environmental issues on a site, each individual environmental issue has a management plan – i.e, a BMPs plan. Thus, if a BMP for water conservation is developed, it becomes incorporated into the EMS.

3.9. Indoor and Other Landscape Water Conservation Practices.

Water conservation and water-use efficiency are important on a whole-facility basis and not just the golf course area. Two areas for water conservation measures to be considered and reported are: a) within the various buildings, including the clubhouse, and b) on the remaining landscape areas.

3.9.1. Indoor Water Conservation Measures.

Golf course clubhouse, maintenance facilities, and other buildings can implement indoor water saving measures as part of an overall water conservation plan. Common indoor water-efficiency measures noted by Vickers (2000) are:

1. Conduct an indoor water audit to identify possible water-efficiency measures—often an outdoor water audit can be done at the same time.
2. Correct any leakage problems
3. Use water efficient devices---low volume toilets; low volume urinals; low volume showerheads; low volume faucets; high efficiency clothes washers; water efficient dishwashers and dishwashing practices.
4. Due to the size of some clubhouse and maintenance facilities, water saving measures focused on commercial kitchens and restaurants, laundries, and cooling systems can result in significant water savings (Vickers 2000). Water and energy audits can be conducted for each of these items.

3.9.2. Other Landscape Areas.

Golf courses include appreciable landscape areas beyond the bounds of the actual golf course playing area. Inclusion of water conservation practices into these areas can result in significant water savings. Many of the same concepts used on the golf course area also apply to these landscape areas, but often in a less intense manner. In such landscapes, the concepts embodied in **Xeriscape** are applicable and are presented in detail by Vickers 2000, Berle et al., (2007), Xeriscape ™ Council, 2003; and the Inter. Turf Producers Foundation 2002. Vickers (2000) has the most in-depth discussion of Xeriscape concepts, while state or regional publications will contain the best list of adapted plants to use. Typical landscape water-efficiency measures are:

1. Landscape planning and design. Careful location of plants and avoiding mixing plants with different water needs can assist in irrigation design and scheduling. Essentially, various "microclimates" are created that allow more efficient irrigation design and scheduling, while limiting high water requirement plants to confined areas.

2. Selection of low-water use turfgrasses and other landscape plants or features. The focus here is to use drought resistant and low water requiring plant materials. Also, hardscape features may be used.
3. Landscape irrigation system design and water conservation devices. Turfgrass areas, trees, shrubs, and flower beds will all require specialized design and zoning; often using a combination of different sprinkler heads and nozzles.
4. Landscape irrigation scheduling for water-use efficiency.
5. Soil improvement. The focus is toward improving the soil where possible to enhance plant performance/rooting, soil water holding capacity, and water infiltration.
6. Water harvesting at the home lawn level may be incorporated in some locations (Waterfall 1998). Harvested water can then be used for landscape irrigation, washing of equipment, or other non-potable uses.
7. Mulching where needed to conserve water.
8. Maintain the turfgrass, other water-efficient landscape plants, and irrigation system to optimize water conservation.
9. When water decorations or fountains are included consider water conservation practices appropriate to these features, such as water recirculation.
10. Practices to reduce water losses related to swimming pools, such as: use of covers when not in use to reduce evaporative losses; refilling only when needed; lowering the water level to prevent splash losses; repair of leaks; maintain a clean pool to reduce the frequency of backwashing filters; and using backwash water for other uses when the chlorine levels are sufficiently low, usually < 3 ppm chlorine. Also, pool water may be reused for irrigation of nearby landscape areas.

3.10. <u>Monitoring, Reviewing, and Modifying Conservation Strategies</u>.

In this section, monitoring and plan revision aspects should be noted as well as associated costs in time and money for these activities---including record-keeping and increases monitoring costs. For example, poor water quality necessitates much more frequent and intensive water quality assessment, soil testing, salinity monitor programs, and tissue testing. Monitoring a water conservation program may include assessing success by documenting water use (for example, by water meters) and relating it to turfgrass performance. Periodic site assessment monitoring can identify leaks, irrigation head malfunctions, design limitations, irrigation scheduling problems or other wasteful water use.

Also, the plan and time-line for implementing the overall BMP plan (including the monitoring and revision aspects) should be explained along with the individuals/positions responsible for these activities. As with pesticide monitoring, monitoring water-use and conservation will likely be a part of a BMP program for water conservation. Sensors used to assist in water management, can also become monitoring devices for documentation purposes. For example, obtaining detailed soil moisture data by depth from soil sensors may be necessary to justify an irrigation event during drought periods if a regulatory agency questions the need for irrigation.

PART 4. COST AND BENEFIT REVIEW AND STATEMENT.

4.l. Assessment of Costs and Benefits for All "Stakeholders".

Assessment of costs and benefits associated with developing and implementation of a long-term BMPs water conservation plan and of the benefits of turfgrass sites is necessary not only for facility planning, but also to demonstrate to regulatory agencies and possible critics of golf courses that substantial effort and cost has been involved in water conservation by the facility. For example, the USEPA incorporates a cost and benefits analysis in the EMS concept; thus it would be appropriate to include such an analysis in a BMPs for water-use efficiency/conservation (http://www.epa.gov/ems/info/costben.htm). Additionally, the BMPs document is an opportunity to state the benefits of the facility to the local/state area; and to denote potential costs to society when a rigid regulatory (command and control) approach is targeted to the industry.

Cost and benefit information is not just for golf course officials and members, but more importantly for education of other **"stakeholders".** A stakeholder is defined as anyone who could be affected by the BMPs either directly or indirectly. Examples of this wider stakeholder audience are: political decision makers, water agency personnel, environmental advocacy groups that may have an "environmental agenda", and the public (i.e. society). Many of these stakeholders do not even realize that they could be affected in a positive manner by golf courses. If the golf course officials do not take a strong role in education of stakeholders, future decisions made by these same stakeholders may well be made in the absence of essential information. Assessment of benefits and costs of implementing water conservation practices on all stakeholders is essential to understand implications of these changes. The immediate owner or manager of a turf site will naturally assess the direct costs involved to implement water conservation measures. However, other stakeholder often do not have the background to understand the benefits of water conservation measures a club is fostering nor the costs---unless they are educated with real world case situations.

1. Benefits (see Table D-1, Appendix D for "Benefits of Turfgrass")
    - Direct and indirect to the owner/manager and site customers.
    - Direct and indirect to other stakeholders, including water savings but also other benefits—economic, environmental, recreational, etc.

2. Costs. See section 2.1 "Current water-use efficiency/conservation practices" since much of this information would be in this section. It need not be repeated here except in summary form to make the point that the club have expended considerable "cost" in the past and present for BMPs related to water conservation.

- Facilities costs for past and planned implementation of water conservation strategies---irrigation system changes; water storage; pumping; new maintenance equipment; water/soil treatments; course design alterations; water harvesting, etc.
- Labor needs/costs.
- Costs associated with changes in maintenance practices; different irrigation water sources (water treatment, soil treatment, storage, posting, etc.)
- Costs that may impact the community if water conservation strategies are implemented (especially mandated ones), such as revenue loss, job loss, etc.

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APPENDIX

Appendix A. Outline of planning process and components.

Table A-1. Outline of the planning process and components of a golf course BMPs for water conservation.

A. Initial Planning and Site Assessment.

1. Identify water conservation measures that have already been implemented by a course including costs of implementation—this initial step aids in clarifying for the golf course management team and club members exactly what is entailed in BMPs water conservation measures. Also, when the final document/program is shared with regulatory agencies, this information is very valuable in pointing out that golf courses are not starting from "zero" in this arena but have been implementing BMPs for many years.

2. Determine the purposes and scope of the site assessment. Site assessment is necessary to determine the best options for the specific course.

3. Site assessment and information collection.

   - Determine current water-use profile.
   - Irrigation/water audit.
   - Additional site infrastructure assessment information---evaluation of alternative irrigation water sources; golf course design modifications; irrigation system design changes; microclimate soil/atmospheric/plant conditions affecting irrigation system design/zoning/scheduling; drainage needs for leaching of salts or any hydrological considerations that may arise from use of any particular irrigation water source.

4. Determine future water needs and identify an initial water conservation goal.

B. Identify, evaluate, and select "water conservation strategies" and options.

1. Selection of turfgrasses and other landscape plants.
2. Use of non-potable water sources for irrigation---alternative water sources; water harvesting/reuse.
3. Efficient irrigation system design and devices for water conservation.
4. Efficient irrigation system scheduling/operation. Both irrigation system design and irrigation scheduling in the future will requires much more site-specific information. Sensor technology integrated into a GPS/GIS approach will assist in development and interpretation of information for improved irrigation systems and scheduling.
5. Golf course design for water conservation.
6. Altering management practices to enhance water-use efficiency---soil amendments; cultivation; mowing; fertilization; etc.
7. Indoor water conservation measures in facility buildings. Conservation strategies for landscape areas other than the golf course and

8. Education. Plan for initial and continuing education on water conservation/management by golf course superintendent, crew, club officials, etc. BMPs for turfgrass water conservation is complex and when poor irrigation water quality is involved the level of costs and complexity greatly increases ---i.e., fertilization, leaching of salts, salt disposal/hydrological issues, complex irrigation systems and scheduling of irrigation, these are some of the complex issues.
9. Development of conservation and contingency plans. A formal BMPs document should be developed and agreed on by all club officials and members so that the golf course superintendent has support for any reasonable science-based measures to be taken. Also, a written plan may be required by regulatory agencies.
10. Monitor and revise plans.

C. Assess benefits and costs of water conservation measures on all stakeholders.

Assessment of costs and benefits associated with developing and implementation of a long-term BMPs water conservation plan is necessary not only for facility planning, but also to demonstrate to regulatory agencies and possible critics of golf courses that substantial effort and cost has been involved in water conservation by the facility.

1. Benefits.
    - Direct and indirect to the owner/manager and site customers.
    - Direct and indirect to other stakeholders, including water savings but also other benefits—economic, environmental, recreational, etc.

2. Costs.
    - Facilities costs for past and planned implementation of water conservation strategies---irrigation system changes; water storage; pumping; new maintenance equipment; water/soil treatments; course design alterations; water harvesting, etc.
    - Labor needs/costs.
    - Costs associated with changes in maintenance practices; different irrigation water sources (water treatment, soil treatment, storage, posting, etc.)
    - Costs that may impact the community if water conservation strategies are implemented (especially mandated ones), such as revenue loss, job loss, etc.

Appendix B. State or Water District BMPs. **See:** Carrow, R. N., C. Waltz, and M. Esoda. 2008a. Beyond site-specific best management practices for water conservation. Golf Course Manage. 76(1): 164-169. http://archive.lib.msu.edu/tic/gcman/article/2008jan164.pdf

Table B-1. This table contains an outline of common State BMPs for an urban water conservation plan. Adapted from CUWCC (2007); Finch (2007); CreenCO (2004); TWBD (2004); Vickers (2002); US EPA (1998);

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1. Identify water conservation goals.
2. Develop water-use profiles for water users and forecasting for future needs.
3. Identify and evaluate all water conservation measures.
4. With consideration of items 1-3, develop a community or water district BMPs plan including well-defined, logical water restriction levels with stated triggers to move from one level to another. Usually 1-2 triggers are used and these are well publicized. Both water restriction levels and the requirements for triggers should be consistent with state and water district BMPs practices.
5. Infrastructure improvements. Public system water audits, leak detection and repair. Public water delivery systems are often the source of major water loss in many urban areas. For golf courses and other water users, water audits, leak detection, and repairs would be part of their site-specific BMPs.
6. Indoor water conservation measures, including all public buildings and facilities.
7. Conservation pricing with water costs rising above the normal use level for a user that is operating under site-specific BMPs.
8. Stakeholder cost and benefits. Evaluation of voluntary and regulated water conservation measures on all stakeholders – i.e., community jobs, economy, environmental. This evaluation should be not only when selecting initial conservation practices but also in terms of how fairly and uniformly different businesses are treated, especially in times of water crisis.
9. Encourage alternative irrigation water sources especially by large landscape areas such as golf courses.
10. Consider potential for water conservation incentives such as rebates for conservation devices, systems, and measures.
11. Develop an on-going public information and education program based on a positive attitude that fosters voluntary actions by individuals to achieve water conservation. Avoid making every citizen a "water cop". Conservation plans and programs are long term and their nature influences the community attitudes and actions.
12. School based educational programs that foster understanding of BMPs.
13. Foster development of site-specific BMPs for all industrial, commercial, institutional, agricultural, and irrigation landscape water users. See Table 2 and Carrow et al. (2005b; 2007) for components or strategies within a site-specific BMPs plan. All public owned sites that are irrigated should be models for development and use of site-specific BMPs.
14. Develop a monitoring and reporting program that entails all water users. Monitoring requirements should focus on the essential information and not become burdensome for water users by requiring unnecessary information. Overall water-use efficiency and conservation are the important aspects and not monitoring every component within a site-specific BMPs plan. Public facilities should not be exempt from monitoring and reporting.

Appendix C. Drought Characteristics of Turfgrasses.

Table C-1. Drought avoidance and tolerance capabilities of turfgrasses.

Type of grass	Avoidance	Tolerance/ Recoverability	Overall Drought Resistance
Cool Season grasses*			
Kentucky bluegrass	fair	medium	**medium**
Tall fescue	excellent	good	**good/excellent**
Fine fescues	fair	good	**medium**
Perennial ryegrass	medium	poor	**fair**
Creeping bentgrass	fair	poor	**fair**
Annual bluegrass	very poor	very poor	**very poor**
Rough bluegrass	very poor	very poor	**very poor**
Colonial bentgrass	poor	poor	**poor**
Warm-season grasses			
Bermudagrass	superior	excellent	**superior**
Buffalograss (Amer.)	excellent	excellent	**excellent**
Zoysiagrass	excellent	good	**good/excellent**
Kikuyugrass	excellent	excellent	**excellent**
St. Augustinegrass	good	good	**good**
Centipedegrass	good	medium	**good**
Bahiagrass	excellent	good	**excellent**
Seashore paspalum	excellent	good	**good/excellent**

From: Brede (2000); Kenna and Horst (1993); Siefers and Beard 1999; Carrow 1996

APPENDIX D. Benefits of turfgrass and turfgrass sites.

Table D-1. Benefits that turfgrasses and turfgrass sites contribute to the environment, society, and economics.

Functional/Environmental

Prevent soil loss from wind erosion
Protect from soil loss by water erosion
Reduce air borne dust
Reduce sediment movement into water features
Capture water from runoff for soil moisture recharge
Reduces climatic temperature
Reduces sod/soil surface temperatures on sports fields and turf areas used for enjoyment
Entrapment of organic chemical pollutants and enhances degradation
Contributes soil organic matter and enhances soil quality
Fire protection by providing a green zone that is not combustible
Glare reduction
Air pollution control
Many turfgrass sites incorporate wetlands, other water features, trees, shrubs, and natural areas for diversity of flora and fauna.

Recreational

Integral part of many community, school, college, and professional sports---soccer, golf, football, baseball, field hockey, etc.
Enhances participation in outdoor activities and sports
Contributes to a safe playing environment for athletes---cushioning and surface stability, smoothness
Contributes to spectator enjoyment
Low cost, natural, living surface that can be self-repairing

Aesthetic

Beauty contributes to quality of life
Feeling of mental well-being---horticulture therapy
Community pride
Ornamental compliment to trees, shrubs, and flowers---
Allows individuals to express themselves and influence their surroundings through individualized landscapes

Economic

Direct revenues, taxes, jobs from sports events and golfing in the local economy
Enhancement of tourism---in some cases regional tourism is built around the golf industry
Parks, sports venues, golf courses, and landscape industry contribute jobs, money, and taxes
Manufacturers and suppliers of turfgrass equipment, supplies, and services contribute jobs, money, and taxes in the economy
Enhanced home and properties values and, therefore, greater tax revenues
Contributes to purchase of non-turf items goods and services in the community ---restaurants, dry cleaners, service stations, etc

After Beard and Green 1994; Parsons et al. 1998; Inter. Turf Producers 2002; Gibeault 2002; Beard and Kenna, 2008.