Environmental Best Management Practices for Virginia's Golf Courses

SECOND EDITION

Virginia Chapter
GCSAA
Golf Course Superintendents Association of America

BMP

GCSAA
Golf Course Superintendents Association of America

BMP Best Management Practices

Best Management Practices Planning Guide & Template

GCSAA USGA

In partnership with the PGA TOUR

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EIFG | *Funded through the Environmental Institute for Golf*

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Who We Are

Golf Course Superintendents Association of America

The Golf Course Superintendents Association of America (GCSAA) is the professional association for the men and women who manage and maintain the game's most valuable resource – the golf course. Today, GCSAA and its members are recognized by the golf industry as one of the key contributors in elevating the game and business to its current state.

Since 1926, GCSAA has been the top professional association for the men and women who manage golf courses in the United States and worldwide. From its headquarters in Lawrence, Kansas, the association provides education, information, and representation to more than 17,000 members in more than 72 countries. GCSAA's mission is to serve its members, advance their profession, and enhance the enjoyment, growth, and vitality of the game of golf.

Environmental Institute for Golf

The Environmental Institute for Golf (EIFG) fosters sustainability by providing funding for research grants, education programs, scholarships, and awareness of golf's environmental efforts. Founded in 1955 as the GCSAA Scholarship & Research Fund for the Golf Course Superintendents Association of America, the EIFG serves as the association's philanthropic organization. The EIFG relies on the support of many individuals and organizations to fund programs to advance stewardship on golf courses in the areas of research, scholarships, education, and advocacy. The results from these activities, conducted by GCSAA, are used to position golf courses as properly managed landscapes that contribute to the greater good of their communities. Supporters of the EIFG know they are fostering programs and initiatives that will benefit the game and its environment for years to come.

United States Golf Association

The United States Golf Association (USGA) provides governance for the game of golf, conducts the U.S. Open, U.S. Women's Open, U.S. Senior Open, 10 national amateur championships, two state team championships, and international matches, and celebrates the history of the game of golf. The USGA establishes equipment standards, administers the Rules of Golf and Rules of Amateur Status, maintains the USGA Handicap System and Course Rating System, and is one of the world's foremost authorities on research, development, and support of sustainable golf course management practices.

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- Timothy Doran, Kingsmill Resort (Committee Chair)
- Mike Augustin, Belle Haven Country Club
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- Peter McDonough, Keswick Club
- David Norman, Virginia Golf Course Superintendents Association
- Cutler Robinson

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Virginia Chapter GCSAA
Golf Course Superintendents Association of America

Table of Contents

Tables

Figures and Photos

ACRONYMS

AAPFCO	Association of American Plant Food Control Officials
AST	above-ground storage tank
BMP	best management practice
C	carbon
Ca	calcium
CEC	cation exchange capacity
Cl	chlorine
CRN	controlled release nitrogen
Cu	copper
CWA	Clean Water Act
DCR	Virginia Department of Conservation and Recreation
DEQ	Virginia Department of Environmental Quality
DO	dissolved oxygen
DU	distribution uniformity
EC	electrical conductivity
EE	enhanced efficiency
EIFG	Environmental Institute for Golf
EPA	United States Environmental Protection Agency
ET	evapotranspiration
Fe	iron
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRAC	Fungicide Resistance Action Committee
GCSAA	Golf Course Superintendents Association of America
GDD	growing degree days
GP	growth potential
GPS	global positioning system
GWMA	Groundwater Management Area
H	hydrogen
HOC	height of cut
HRAC	Herbicide Resistance Action Committee
HVAC	heating, ventilation, and air Conditioning
IPM	integrated pest management
IRAC	Insecticide Resistance Action Committee
K	potassium
K_2O	potash
LDS	localized dry spot
LID	low impact development
Mg	magnesium
mg/L	milligrams per liter
MLSN	Minimum Level for Sustainable Nutrients
Mn	manganese
N	nitrogen
NH_4	ammonium
NO_3-N	nitrate
NO_2	nitrogen dioxide
NTEP	National Turfgrass Evaluation Program
OPS	Office of Pesticide Services
OSHA	Occupational Safety and Health Administration
P	phosphorus
P_2O_5	phosphate
PAW	plant available water
pET	potential evapotranspiration
PGR	plant growth regulator
PLC	programmable logic controllers
PPE	personal protective equipment
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
S	sulfur
SAN	slowly available nitrogen
SAR	sodium adsorption ratio
SDS	Safety Data Sheet
SDS	spring dead spot
SGN	size guide number
SWPPP	stormwater pollution prevention plan
TDR	time domain reflectometry
TMDL	total maximum daily load
TSS	total suspended solids
UNL	University Nebraska Lincoln

USACE	United States Army Corps of Engineers
USGA	United States Golf Association
UST	underground storage tank
VCE	Virginia Cooperative Extension
VDACS	Virginia Department of Agriculture and Consumer Services
VFD	variable frequency drive
VGCSA	Virginia Golf Course Superintendents Association
VPDES	Virginia Pollutant Discharge Elimination System
VSMP	Virginia Stormwater Management Program
WIN	water-insoluble nitrogen
WIN-PST	Windows Pesticide Screening Tool
WSN	water-soluble nitrogen
Zn	zinc

INTRODUCTION

With nearly 37,000 acres of land devoted to golf courses in Virginia, golf courses provide abundant recreational opportunities to the state's citizens and tourists, as well as valuable open space. Often located within large population centers such as Northern Virginia, Richmond, and the Hampton Roads areas, golf courses provide advantages over other types of development, such as habitat for birds and other wildlife, absorption of stormwater and its potential pollutants, oxygen from photosynthesis, and the cooling effect of evapotranspiration (ET).

Because 70% of the state's golf courses are located within the Chesapeake Bay watershed, protection of water quality is of particular importance in the design, construction, and management of golf courses. The golf industry also seeks to protect water quality, conserve water, and provide habitat in order to enhance the environment on and near golf courses. The use of best management practices (BMPs) helps to achieve these goals, not only within the Chesapeake Bay watershed, but also statewide.

The guidance within the 2nd edition of *Environmental Best Management Practices for Virginia's Golf Courses* was developed by the Virginia Golf Course Superintendents Association (VGCSA) in cooperation with representatives of Virginia Tech and Virginia governmental agencies. These BMPs emphasize water quality protection and water conservation and have been specifically adapted for golf courses in Virginia using current research and golf course superintendents' experiences in implementing BMPs, in accordance with state and federal regulations.

Virginia's golf course superintendents are cooperating to develop and implement BMPs adapted specifically to Virginia's climate and environment. In addition to adherence to the state's nutrient management regulations, the widespread adoption of these BMPs will result in lower nutrient loading to waterways, decreased pesticide usage and runoff, and improved water conservation. Furthermore, the voluntary adoption of these BMPs will help to achieve total maximum daily load (TMDL) goals established by the US Environmental Protection Agency (USEPA) for the Chesapeake Bay. TMDLs define the amount of a given pollutant that a body of water can accept and still meet water quality standards.

Best Management Practices

An ecosystem is a complex set of relationships among the living resources, habitats, and residents of an area, including plants, trees, animals, microorganisms, water, soil, and people. Golf courses are one type of ecosystem that can be effectively managed to sustain a healthy environment for all of the ecosystem inhabitants. Management activities can protect and enhance the ecosystem, while other practices may have negative impacts. For example, the use of vegetative buffers near surface waters can remove nutrients from stormwater runoff and thereby improve water quality. Conversely, poor vegetative cover on a slope can result in soil erosion as well as airborne dust, leading to declines in water and air quality on and around the golf course.

Pollution Prevention

Best management practices reduce the potential for sedimentation, runoff, leaching, and drift – the mechanisms that can transport contaminants and impact water quality. For example, bare ground is much more likely to erode than turf. Therefore, following grow-in BMPs during course construction or renovation to quickly establish dense turf ground cover helps minimize erosion potential. Maintaining vegetated areas, such as filter strips and buffers, to slow down stormwater or excess irrigation allows infiltration and uptake and is another key BMP. Pesticide BMPs help superintendents follow state and federal regulations related to the storage, handling, transport, and use of pesticides, preventing point source pollution and minimizing the potential for nonpoint source pollution from these chemicals.

Understanding site characteristics is another key to preventing pollution. For example, steep slopes are more prone to runoff. Areas of the state that have a shallow water table are more prone to leaching.

Water Conservation

Urbanization and severe droughts have reduced the supply of affordable and plentiful fresh water for irrigation in Virginia. Therefore, economic, social, and environmental pressures dictate that water is used wisely on Virginia golf courses. Conserving water begins with planning and irrigation system design to ensure that the golf courses do not burden public water supplies. Reducing water needs is one option for conserving water. New and existing golf courses can make an effort to convert out-of-play areas from irrigated, mowed turf to naturalized zones (tertiary management areas) that conserve water while attracting wildlife and enhancing aesthetics. Proper irrigation scheduling, careful selection of turfgrass species, and incorporation of cultural practices that increase the water holding capacity of soil are addressed through these BMPs, as well as considerations in the design, construction, and maintenance of irrigation systems.

Protecting Habitat

Golf courses can provide high quality habitat to a large and diverse population of birds, mammals, and other wildlife. These contributions are particularly important in densely populated urban areas, where golf courses can provide habitat and serve as refuges and movement corridors for wildlife in an otherwise fragmented landscape. Protecting ecosystem functions and air, water, and soil quality helps to protect wildlife habitat. In addition, wildlife habitat on golf courses can be enhanced through design features and considerations in maintenance operations.

The BMP recommendations in this publication protect ecosystem functions and therefore wildlife habitat. In addition, a number of golf courses in the state are certified through the Audubon International Cooperative Sanctuary Program for Golf Courses, a program based on site-specific enhancement of natural areas and wildlife habitats

Pollinators

Protecting bees and other pollinators is important to the sustainability of agriculture. Minimizing the impact of pesticides on bees, other pollinators, and beneficial arthropods is addressed in this document in two ways: providing specific guidance for pesticide applicators and promoting the use of integrated pest management (IPM) methods to reduce pesticide usage and minimize the potential of exposure. Superintendents can also directly support healthy pollinator populations by providing and enhancing habitat for pollinator species and by supplying food sources and nesting sites and materials.

Individual Facility BMPs

When golf courses adopt BMPs, they improve not only the environment, but also the quality of the golf course – benefits that encourage the voluntary adoption of BMPs. Specific incentives for Virginia golf courses to implement BMPs include the following:

- Reduced environmental impacts.
- Improved turf quality.
- Improved golf outing experiences.
- Improved worker safety.
- Efficient allocation of resources.
- Reduced maintenance expenditures.
- Recognition by club members and the community at large for environmental stewardship.

Because of limitations, such as budget, staff, clientele expectations, and management decisions, not all golf courses can achieve all of the best practices. Turf managers should understand that implementing BMPs will be a process that can be undertaken over time. Multiple approaches can be adopted to achieve the goals of the BMPs, such as reducing pesticide usage while maintaining turf health by implementing an integrated pest management program, using advanced technologies for precision pesticide applications, and/or spot-treating for small pest outbreaks.

In addition, planning for improvements over time and making even small changes that meet the goals of BMPs can be achieved. For example, while a sophisticated washwater recycling system may be too expensive for many facilities, blowing clippings off mowers onto a grass surface is easily achieved and markedly reduces the amount of nitrogen and phosphorus in clippings that ends up in washwater.

Conclusion

This document was developed using the latest science-based information and sources. This resource is intended to be a living document. The Virginia BMP steering committee intends to review this information periodically. Therefore, the latest version of this document will be posted on the new companion website (address TBA). At the time of publication, the information was the most recent available. Some sources are updated regularly, and the reader should try to identify the latest version. In addition, regulations may change, and the reader should identify any changes since the publication date.

1 PLANNING, DESIGN, AND CONSTRUCTION

Building a new golf course or renovating an existing golf course requires careful consideration of the health of the golf course ecosystem during planning, design, and construction. Designers can draw inspiration and develop a balanced, functional design through intense study of the onsite and neighboring ecological features, habitat documentation, terrain analysis, circulation patterns (such as air, water, wildlife, and traffic), and a variety of other constraints and attributes.

The thoughtful use of BMPs during planning, design, and construction should result in an environmentally sustainable golf course that operates efficiently and profitably. Because each golf course project is different, considerable variance in the design process exists. Therefore, the approach outlined in this guidance is general and may not be applicable to all situations. However, this approach provides a framework for good decision making throughout each project phase.

Figure 1. Bunker renovation at Magnolia Green.

1.1 Regulatory Considerations

Regulations are in place at the local, state, and national levels that impact planning, design, and construction activities on Virginia's golf courses. These laws are in place to protect and conserve the environment both during and after the construction process. Before beginning any golf course construction or renovation, consultation with the appropriate regulatory agencies is recommended. Communication between developers, designers, owners, the public, and regulatory agencies should occur early and often. In addition, if new wells must be installed, experts should be consulted for proper siting in the design plan, and all setback and other regulatory requirements.

1.1.1 Stormwater Permits

The Virginia Department of Environmental Quality (DEQ) is responsible for issuing individual and general permits that control stormwater discharges from construction activities. DEQ administers these programs through the Virginia Stormwater Management Program (VSMP) regulations, which are authorized by the Virginia Stormwater Management Act.

The following land-disturbing activities are covered by the construction general permit:

- Construction activities resulting in land disturbance equal to or greater than one acre.
- Construction activities resulting in land disturbance less than one acre that are part of a larger common plan of development or sale that ultimately disturbs one or more acres. A larger common plan of development or sale is a contiguous area where separate and distinct construction activities may be taking place at different times on different schedules. General permit coverage is required if one or more acres of land will be disturbed, regardless of the size of the individually owned or developed sites.

The construction general permit requires the operator to implement a site-specific stormwater pollution prevention plan (SWPPP). The SWPPP outlines the steps that an operator must take to comply with the permit, including water quality and quantity requirements such as reducing pollutants in the stormwater runoff from the construction site. The SWPPP also specifies all potential pollutant sources that could enter stormwater leaving the construction site and covers methods used to reduce pollutants in stormwater runoff during and after construction. More information on SWPPPs can be found on the EPA's Developing a Stormwater Pollution Prevention Plan (SWPPP) web page.

Most localities have also instituted a Virginia Stormwater Management Program. Therefore, the local regulatory authorities should be contacted regarding local stormwater management permitting requirements.

1.1.2 Wetlands and Floodplains

Activities that impact wetlands are regulated under sections 404 and 401 of the federal Clean Water Act (CWA). The U.S. Army Corps of Engineers (USACE) regulates dredging and filling of waters in the United States under Section 404 of the CWA. DEQ's role in the Section 404 permitting process entails issuing Section 401 certifications that the actions authorized by the permits do not violate state water quality standards. DEQ coordinates closely with the USACE during the certification process of Section 404 permits. Consultation with DEQ during the design phase of any construction activities expected to impact wetlands will assist in understanding the permitting process.

Development within a floodplain is generally regulated at the local government level through a floodplain ordinance based on guidance from the Federal Emergency Management Agency (FEMA).

1.1.3 Erosion and Sedimentation

Erosion and sediment control plans must be prepared by a Virginia Professional Engineer in accordance with the *Virginia Erosion and Sediment Control Handbook* and regulations (9VAC25-840). Erosion and sediment regulations require a sediment control plan to be submitted, compliance documentation, and onsite record keeping.

1.1.4 Chesapeake Bay Preservation Program

Virginia's Chesapeake Bay Preservation Act (§62.1-44.15:67 *et seq.*) specifies that the protection of the Chesapeake Bay and its tributaries will be accomplished through a cooperative state-local program. Local governments must advance the goal of protecting the bay through their zoning and land use authorities. In accordance with this premise, the Chesapeake Bay Preservation Act requires cities, counties, and towns in the Tidewater region to administer the act and the Chesapeake Bay Preservation Area Designation and Management Regulations through their local ordinances, policies, and comprehensive plans. Therefore, any facilities within this region should check with the local regulatory authorities for additional requirements related to stormwater management and erosion and control measures. More information can be found on the Chesapeake Bay Preservation Act Regulations, Guidance and Publications page of the DEQ website.

1.1.5 Listed Species

Virginia's Natural Heritage Program maintains lists of state and federal listed species that can be found in the state. In addition, before beginning a large construction project, an environmental review request must be submitted to the program to screen for the potential presence of any listed species, significant natural communities, or karst topography.

1.1.5 Invasive Species

In Virginia, 606 species have been identified as naturalized, or introduced species that reproduce outside of cultivation. Of these, 90 species (or 3 percent of the total Virginia flora) have been assessed as invasive in natural communities. Though control of invasive species is not regulated in Virginia, superintendents should be aware of the presence of any invasive species and endeavor to control and/or eradicate them from the property. Fact sheets on control of individual invasive species are published by the Natural Heritage Program.

1.1.6 Noxious Weeds

VDACS regulates the movement of noxious weeds with the Noxious Weed Law. A noxious weed is defined as any living plant, or part thereof, declared by the Board through regulations to be detrimental to crops, surface waters, including lakes, or other desirable plants, livestock, land, or other property, or to be injurious to public health, the environment, or the economy, except when in-state production of such living plant, or part thereof, is commercially viable or such living plant is commercially propagated in Virginia. Listed noxious weeds include aquatic plants, which may require special care for treatment or removal. The VDACS Office of Plant Industry Services should be consulted regarding the movement and reporting of noxious weeds.

1.2 Overview

Proper planning is the first step to any construction or renovation project, minimizing expenses from unforeseen events and maximizing long-term success. Good planning also incorporates conservation of natural resources and economic sustainability while meeting the stakeholder needs. Once a course is designed, construction must be carried out in a way that minimizes environmental impacts. Maintaining a construction progress report, as well as following regulations and coordinating with regulatory agencies as required, helps to ensure compliance. Table 1 summarizes the steps and best practices for each phase of the project.

1.3 Wetlands and Floodplains

1.3.1 Wetlands and Riparian Areas

Wetlands are transitional areas between aquatic and dry upland habitats. They are flooded or saturated by surface or groundwater at a frequency and duration long enough during the growing season to support plants and other life adapted to saturated soils where oxygen is limited and unique chemical properties form. Riparian habitats include the dense and diverse vegetation growing along streams, rivers, springs, wetlands, ponds, and lakes. They often support plants adapted to highly fluctuating water availability (from spring flooding to summer drought). In addition, wetland and riparian habitats are essential for many of Virginia’s fish, wildlife, invertebrate, and plant species. Nearly 50% of bird species rely on wetland and riparian habitats, as well as numerous other game, fish, and other wildlife species.

Conserving the state’s wetlands and riparian areas protects water quality and biodiversity, while reducing the potential for flooding and soil erosion. To protect these natural resources, wetlands should be identified in the field by qualified wetland specialists during the design phase and before the permitting process is initiated. Course design should minimize any impact to wetlands and streams tied to activities such as filling, dredging, flooding, crossings, or converting areas from one habitat type to another. In addition, natural buffers should be retained around wetlands (as with other waterbodies) to protect water quality and provide habitat.

Figure 2. Vegetated buffers, like this one at Bayville Golf Club, protect water quality and provide habitat.

Table 1. Best practices for golf course planning, design, and construction

Planning	
Step	**Description**
Assemble Team	The team should include, but not be limited to, a golf course architect, golf course superintendent, clubhouse architect, irrigation engineer, environmental engineer, energy analyst, economic consultant, civil engineer, soil scientist, golf course builder, and a legal team.
Define Objectives	Identify realistic goals, formulate a timeline, etc.
Conduct a Feasibility Study	Evaluate finances, environmental issues, water availability and sources, and energy, materials, and labor needs. Identify applicable government regulations.
Select Site	Site should meet project goals and expectations. Identify all strengths and weakness of each potential site. During site selection, any site constraints, such as the presence of listed species or valuable habitat, should be identified.
Design	
Retain a Project Manager/Superintendent	This person is responsible for integrating sustainable practices in the development, maintenance, and operation of the course.
Retain a Golf Course Architect	An experienced golf course architect is the person primarily responsible for design of the course including preservation of existing native vegetation, design of course features, and selection of appropriate turf species/varieties in conjunction with the superintendent.
	Existing native landscapes should remain intact as much as possible. Consider adding supplemental native vegetation to enhance existing vegetation alongside lengthy fairways and out-of-play areas. Nuisance, invasive, and exotic plants should be removed and replaced with native species adapted to the area.
	Greens: Should have plenty of sunlight and be well drained. Greens should be big enough to have several hole locations that can handle expected traffic. Native push-up green design can provide an adequate playing surface provided there is adequate surface drainage, sun and air movement. USGA putting greens should follow specifications in published in *A Guide to Constructing The USGA Putting Green.*
	Grass selection: Species should be selected based on climate, including winter hardiness, environmental and site conditions, and species adaptability to those conditions, including disease resistance, drought tolerance, spring greenup, and traffic tolerance.
	Bunkers: The number and size of bunkers depend on considerations, such as the resources available for daily maintenance. For each bunker consider: • The need for drainage. • Entry/exit points and how these will affect wear-and-tear patterns. • The proper color, size, and shape of bunker sands to meet needs. New bunker construction techniques can be researched to see if they satisfy stakeholders' needs.

Design Irrigation System	Hire a professional irrigation consultant/designer (preferably a member of the American Society of Irrigation Consultants), if possible, to design the irrigation system. Keep in mind the different water needs of greens, tees, fairways, roughs, and native areas. Consider the topography, prevalent wind speeds, and wind direction when spacing the heads. Choose the most efficient type of irrigation system considering available resources. The "Irrigation" chapter of this document provides detailed information on irrigation-related BMPs.
Construction	
Select Qualified Contractors	Use only qualified contractors who are experienced in the special requirements of golf course construction. Members of the Golf Course Builders Association of America make great candidates.
Safeguard Environment	Follow all design phase plans and environmental laws. Soil stabilization techniques should be rigorously employed to maximize sediment control and minimize soil erosion. Temporary construction compounds and pathways should be built in a manner that reduces environmental impacts.
Install Irrigation System	Installation should consider the need to move equipment and bury pipe while maintaining the original soil surface grade to minimize the potential for erosion.
Establish Turfgrass	Turfgrass establishment methods and timing should allow for the most efficient progress of work, while optimizing resources and preventing erosion from bare soils before grass is established.

Wetland and Streambank Restoration

In some instances, wetlands and streams can be improved or restored during golf course construction. For example, a highly degraded stream or wetland can sometimes be reshaped, rehabilitated, or replaced entirely to meet project goals and improve ecological function. Qualified environmental consultants can evaluate the overall benefit of stream enhancement or restoration and assist with permitting issues, which may include a federal 404 permit and/or state 401 certification. *The Virginia Stream Restoration & Stabilization Best Management Practices Guide* provides detailed information on stream restoration and stabilization measures.

1.3.2 Tidal Wetlands

In Tidewater regions of the state, regulations require that a vegetated buffer area not less than 100-feet wide be located adjacent to and landward of all tidal shores, tidal wetlands, certain associated non-tidal wetlands, and along both sides of all waterbodies with perennial flow.

1.3.3 Floodplains

Golf course development is often compatible with floodplains, particularly when compared with other uses such as residential or commercial development. Minimizing encroachment into floodplains to the extent possible is prudent.

Any substantial disturbance to a floodplain, including clearing and grading, generally requires an engineering analysis to demonstrate minimal impact on the base flood elevation in accordance with local ordinances. Depending on the complexity of the encroachment, this analysis may be as simple as a comparison of cut and fill quantities within the floodplain or as complex as a detailed floodplain model of the entire watershed. A complex analysis may require a FEMA review along with potential revision to the floodplain mapping.

Key course components (such as greens and tees) should be designed above the 100-year flood elevation whenever possible to avoid loss of golf play due to periodic flooding. Any effects on the floodplain and floodway should be considered, and the required offsetting adjustments should be made in grades or vegetative treatment.

1.4 Drainage

Proper golf course drainage influences the quality of every aspect of the course and therefore has a profound impact on the long-term quality of the golf course turf, the maintenance requirements, and golf course revenue. Many BMPs prolong the retention process as long as practical, retaining as much of the stormwater in surface or underground storage as is reasonable, and may even improve the quality of water leaving the property. A high-quality BMP plan for drainage addresses runoff containment, adequate buffer zones, and filtration techniques. However, drainage of golf course features is only as good as the system’s integrity. Damaged, improperly installed, or poorly maintained drainage systems negatively impact play and increase risks to water quality.

Poorly draining golf courses often fail and are at greater risk for environmental concerns. Erosion can quickly result in a stream that receives poorly defined pipe outlets. A pond will stagnate if it has a poorly shaped edge or cove that does not accept flow from either a significant drainage area or the curvilinear flow within the pond itself. Poor drainage design usually requires retrofit solutions, which result in more maintenance and more chemical and energy inputs than needed for a well-designed course.

1.5 Stormwater Management

Techniques that manage and conserve water, such as Low Impact Development (LID) philosophies, should be adopted whenever possible. LID techniques filter, infiltrate, retain, and detain stormwater runoff near its origin and mimic the natural hydrology of the site to promote infiltration whenever practical. Depending on the intent and need, methods of water management include the selective slowing and speeding of grades to move water that can be used in conjunction with one or more structural water management devices. An extensive discussion of structural water management devices is included in the 1st edition of *Environmental Best Management Practices for Virginia's Golf Courses*.

Existing golf course construction techniques can be smartly modified to assist in water quality and water quantity protection. While tradeoffs in design exist, these effects should be planned for in advance as much as possible.

1.6 Habitat Considerations

In urban and suburban environments, a golf course may provide the best habitat for many species. A number of golf course management activities can maintain and enhance habitat and provide food and shelter for numerous species, including mammals, birds, fish, amphibians, reptiles, insects, and native plants. Examples of ways to maintain and enhance habitat include:

- Identifying and preserving wildlife and migration corridors to help maintain populations at sustainable levels.
- Retaining natural buffer areas around wetlands and watercourses to preserve habitat while protecting water quality for aquatic species.
- Planting native species to provide food for animals and insects.
- Retaining dead trees to serve as nesting areas.
- Providing nest boxes for birds, bees, and bats.
- Removing exotic and invasive species to improve habitat.

The "Pollinator Protection" and "Landscape" chapters provide additional recommendations and BMPs for enhancing habitat on the golf course.

Superintendents should be aware of any invasive species that may be present on their facility and endeavor to control these species.

Figure 3. Eastern bluebird house provides nesting habitat at Kingsmill Resort.

1.7 Turfgrass Establishment

Below are summaries of the important considerations when establishing turfgrass. For detailed information on establishing turfgrass in Virginia, see Section 6-7 of the *Urban Nutrient Management Handbook* from the Virginia Cooperative Extension (VCE) and Section 6 of the *Virginia Nutrient Management Standards and Criteria* from the Virginia Department of Conservation and Recreation (DCR).

1.7.1 Cultivar Selection

Turfgrass cultivar selection should take into account variables such as drought, cold, heat, and disease resistance, as well as color, fertilization and pesticide requirements, and intended mowing heights. The National Turfgrass Evaluation Program (NTEP) provides information on the testing and adaptation of the major turfgrass species and publishes the results. The NTEP website publishes results from variety trials in four locations in Virginia. In addition, the selection of drought resistant turfgrasses for roughs/fairways can decrease irrigation needs significantly, and disease resistant turfgrasses can decrease pesticide usage. Informed turfgrass selection can greatly affect other aspects of a design, so these decisions should be made as early as possible.

1.7.2 Seedbed Preparation and Planting

Proper seedbed site preparation can help avoid long-term problems, such as weed encroachment, diseases, and drought susceptibility. Debris should be removed that could hinder root growth and limit access to water and nutrients. Any drainage issues should be corrected through grading and installation of drainage technologies. Whenever possible, soil pH should be adjusted prior to establishment as preplant incorporation greatly accelerates the neutralization of the acidity throughout the root zone.

Turfgrass establishes best when proper attention is given to:

- Preparing the site and soil.
- Understanding correct planting techniques for the material being used (seed, sod, or plugs).
- Properly caring for the grass after planting.

Appropriate establishment timing promotes more rapid establishment and better long-term turfgrass performance. Sod installations provide significant inherent advantages in water quality protection by mitigating soil erosion as well as almost immediate turf use. Sod establishment is typically successful at any time of the year for any turfgrass as long as it is not planted on frozen soils and its water needs can be met by rainfall or supplemental irrigation. However, even sod establishments benefit from favorable establishment timings that provide the most opportunity for plant maturity prior to seasons of environmental or intensity-of-use stresses.

For cool-season turfgrasses, the ideal establishment period is late summer to mid-fall, with a secondary planting window of early to mid-spring being possible. Fall establishments are vastly superior for long-term turf success since they allow for the development of a mature root system prior to the typical heat and moisture stresses of a Virginia summer. Warm-season grasses are ideally established from mid-spring to mid-summer depending on the location in Virginia. Mature plants are critical for first-winter survival of warm-season grasses.

Figure 4. Hydroseeding at Ballyhack.

1.7.3 Establishment Fertilization

The amount of N used as a supplement in grow-in programs is highly dependent on the grass, the soil, and the N source. For example, cool- or warm-season grasses on heavier textured, predominantly silt/clay soils typical of golf fairways and roughs that are unlikely to have significant physical modifications prior to planting likely have limited leaching potential. Therefore, up to 1 lb N/1,000 ft^2 can be applied in a single application at planting with a ≥ 50% slowly available nitrogen (SAN) source, which feeds the turf for up to four weeks. N sources containing predominantly water-soluble nitrogen (WSN), should be applied at no more than 1 lb N/1,000 ft^2 over the first four weeks by splitting the applications into regular intervals. At four weeks after planting, 0.25 to 0.5 lb WSN/1,000 ft^2 per week should be applied for the next four weeks.

Appropriate water management is critical for successful turf establishment and reduces soil erosion and nutrient leaching/movement potential. From a practical standpoint, granular or sprayable fertilizers can only be made to a soil that is dry enough to minimize rutting potential from either equipment or foot traffic. Large scale grow-ins on golf courses are sometimes achieved through fertigation systems that provide light and frequent nutritional supplements through the irrigation system. While not a requirement for grow-in success, properly installed and functioning fertigation systems provide an extremely efficient method of nutrient delivery for turfgrass establishment.

Nitrogen-based establishment fertility programs for cool- or warm-season grasses on naturally occurring or modified sand-based soils require more attention in order to meet plant needs and protect water quality. In these highly leachable soils, it is important to use ≥ 50% SAN sources at up to 1 lb N/1,000 ft^2 for the first four weeks of establishment for either type of grass. For warm-season grasses, apply 0.25 to 0.5 lb WSN/1,000 ft^2 per week for the next four weeks. On cool-season grasses, up to 0.25 lb N/1,000 ft^2 per week (or 0.5 lb of a ≥ 50% SAN source every two weeks) should be applied after germination is complete for the next eight weeks.

1.7.4 Erosion and Sediment Control

The loss of topsoil from a site can be a problem for numerous reasons. Soil carried by wind and water transports contaminants with it. For example, erosion can enrich surface waters, where phosphorus and, to a lesser extent, nitrogen can cause eutrophication. When sediments and soils enter water, they can also increase turbidity, which harms aquatic plants and animals. Therefore, control measures should be documented in an erosion and sediment control plan, put in place prior to any soil disturbance, and properly maintained.

1.8 External Certification Programs

Golf-centric environmental management programs or environmental management systems, such as Audubon International's Audubon Cooperative Sanctuary Program for Golf and the Groundwater Foundation's Groundwater Guardian Green Site program, can help golf courses protect natural resources, as well as gain recognition for their environmental education and certification efforts.

1.9 Planning, Design, and Construction Best Management Practices

Planning and Design

- ❖ Maintain appropriate erosion controls during construction (e.g. silt fencing, wattles, straw bale checks) to prevent erosion and sedimentation in accordance with the SWPPP.
- ❖ Establish a low- to no-maintenance buffer along wetlands; check local ordinances for any buffer requirements.
- ❖ Establish and maintain an effective riparian buffer around wetlands, springs, and channels; check local ordinances for buffer requirements.

Wetlands and Floodplains

- ❖ Install stream buffers to restore natural water flows and flooding controls.
- ❖ Install buffers in play areas to stabilize and restore natural areas that attract wildlife.
- ❖ Install retention basins to store water and reduce flooding at peak flows.

Drainage

- ❖ Evaluate the watershed size to understand drainage needs and appropriate pipe sizing.
- ❖ Ensure that no discharges from pipes go directly to surface water.
- ❖ When constructing drainage systems, pay close attention to engineering details such as subsoil preparation and the placement of gravel, slopes, and backfilling.
- ❖ Discharge internal golf course drains through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments. Do not discharge directly into an open waterbody.
- ❖ Routinely inspect the drainage system to ensure proper function.

Listed Species

- ❖ Identify any listed species and critical habitat that may be present on the site and preserve habitat, including feeding and nesting areas, as possible.
- ❖ If any listed species are identified on site, take appropriate mitigation efforts.

Habitat Conservation

- ❖ Identify the different types of habitat specific to the site.
- ❖ Identify habitat requirements (food, water, cover, space) for wildlife species.
- ❖ Identify and preserve regional wildlife and migration corridors by avoiding or minimizing crossings. Design unavoidable crossings to accommodate wildlife movement.
- ❖ Design and locate cart paths to minimize environmental impacts. Construct the paths with permeable materials, if possible.
- ❖ Remove or treat nuisance and invasive plants safely and in a manner so as to not promote any further spread on the premises and replace them with natives.
- ❖ Maintain clearance between the ground and the lowest portion of any fences or walls to allow wildlife to pass, except in areas where feral animals need to be excluded.
- ❖ Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.

- Construct and place birdhouses, bat houses, bee boxes, etc. in out-of-play areas.
- Plant pollinator gardens around the clubhouse and out-of-play areas.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.

Turfgrass Establishment

- Select species and varieties that are adapted to the desired use, taking note of disease resistance, spring transition and greenup, drought tolerance, and other traits such as shade and wear tolerance.
- Prepare seed/sod beds to maximize success.
- Ensure erosion and sediment control devices are in place and properly maintained.
- Plant cool-season grasses from seed from mid-August to early September to allow the seed to germinate and develop well before cold temperatures significantly slow growth prior to winter.
- Plant or establish sod when the turfgrass is actively growing so the sod will root or “knit” down into the soil as quickly as possible
- Fill gaps in sod seams with soil or sand to provide a uniform surface.
- Use selective pre-emergence herbicides to reduce weed competitions and improve the chance of success with seeding establishment during the spring.
- Apply a fertilizer containing phosphorus at seeding. An additional application should be applied if turf displays symptoms of phosphorus deficiency.
- Nitrogen and sufficient water are essential during establishment. Light and frequent applications of nutrients are most desirable, unless a slow-release nitrogen source is applied.
- Allow the turfgrass to initially grow one-third to one-half higher than the desired mowing height before beginning to mow and never remove more than one-third of the turf leaf at mowing.
- Reducing watering prior to mowing will help the soil dry a bit to better tolerate the weight of the mower.
- Consider mowing with a walk-behind mower rather than a heavier riding mower to avoid making wheel track depressions in the soil.
- Keep mower blades sharp. Dull mower blades may dislodge or damage young grass.

2 IRRIGATION

The irrigation system on a golf course is critical for the maintenance of high-quality playing conditions. Throughout Virginia, various types of irrigation systems are used, ranging from basic quick connect and hose applications to advanced multi-row sprinkler systems. Advanced systems conserve water, making use of the latest in computerized central control, state-of-the-art pumping systems, sprinklers with highly efficient nozzles, soil sensors, radio communication, and weather data collection devices.

Because every golf course is different, the requirements, design, and specifications of irrigation systems differ. Therefore, irrigation recommendations should be adapted to fit the needs of a particular system and serve as a basis for determining the course-specific water conservation methods. Furthermore, using BMPs for all facets of design, construction, and maintenance operations aids in the overall conservation of water resources and quality.

Figure 5. Sprinklers set at a low angle to avoid wind drift.

2.1 Regulatory Considerations

Virginia DEQ regulates water usage in Virginia, as described below. When municipal or public potable water sources are used as a primary or secondary water source for irrigation, local governments regulate cross connection to prevent backflow.

2.1.1 Surface Water

Under the Virginia Water Protection Permit Program Regulation (9VAC 25-210), surface water withdrawals require a permit. The DEQ Surface Water Withdrawal Permitting and Fees web page provides more information on permits, including forms and checklists.

2.1.2 Groundwater

Under the Ground Water Management Act of 1992, Virginia manages groundwater through a program regulating the withdrawals in certain areas called Ground Water Management Areas (GWMA). Currently, two GWMAs exist in the state within the Coastal Plain province of Virginia: the Eastern Shore GWMA, which includes Accomack and Northampton counties, and the Eastern Virginia GWMA, which is comprised of all areas east of I-95. Any person or entity wishing to withdraw an excess of 300,000 gallons in a single month in a GWMA must obtain a groundwater withdrawal permit. The DEQ Groundwater Withdrawal Permitting and Fees web page provides more information, including permit forms and information on new well construction requirements.

2.1.3 Water Withdrawal Reporting Requirements

Virginia Water Withdrawal Reporting Requirements (9 VAC 25-200-10, et seq.) require reporting for any withdrawal with a daily average withdrawal that exceed 10,000 gallons in any single month. Each withdrawer must report to DEQ the surface water or groundwater withdrawals by January 31 in the year following the one in which the withdrawals occurred.

2.2 Water Conservation and Efficient Use Planning

Potable water supplies in many areas of the United States are limited, and demand continues to grow. The challenge is to find solutions to maintain the quality of golf play while using less water. Opportunities to conserve water exist during initial course design and renovations, during irrigation system design and use, and by incorporating the use of management zones.

Some courses are designed using a “target golf” concept that minimizes the acreage of irrigated turf. If properly designed, water hazards and stormwater ponds can capture rain and runoff that may provide supplemental water under normal conditions. Backup sources may be needed during severe drought.

In addition to utilizing well-adapted cultivars for in-play areas, existing golf courses can convert out-of-play area turf to native plants, grasses, or ground covers to reduce water use and augment the site’s aesthetic appeal. Native plant species also provide wildlife with habitat and food sources, such as native flower areas that benefit pollinators. After establishment, site-appropriate plants normally require little to no irrigation. See the "Pollinator Protection" and "Landscape" chapters for more information on native and drought-tolerant plants.

Water conservation plans should be prepared before a drought occurs, especially in the drier parts of the state. These plans should identify ways to achieve a 10% reduction in water use. Current drought reporting information is made available online for Virginia on DEQ's Current Drought Conditions in Virginia web page. Communication with golf club members and the public should be maintained to explain water conservation efforts as a proactive approach to addressing water-related issues.

2.3 Drought Resistance

Some of the areas of the golf course may be irrigated sparingly or not at all. Planning for these areas and restricting their irrigation requires knowledge of the most drought-resistant turfgrass species (Figures 6 and 7) and maximizing this resistance. Drought resistance encompasses two facets: avoidance and tolerance. Drought avoidance is preferred, since it is the ability to stay green and growing as surface soil dries and drought progresses. Drought tolerance is the ability to keep growing points alive, though not necessarily green, as drought progresses.

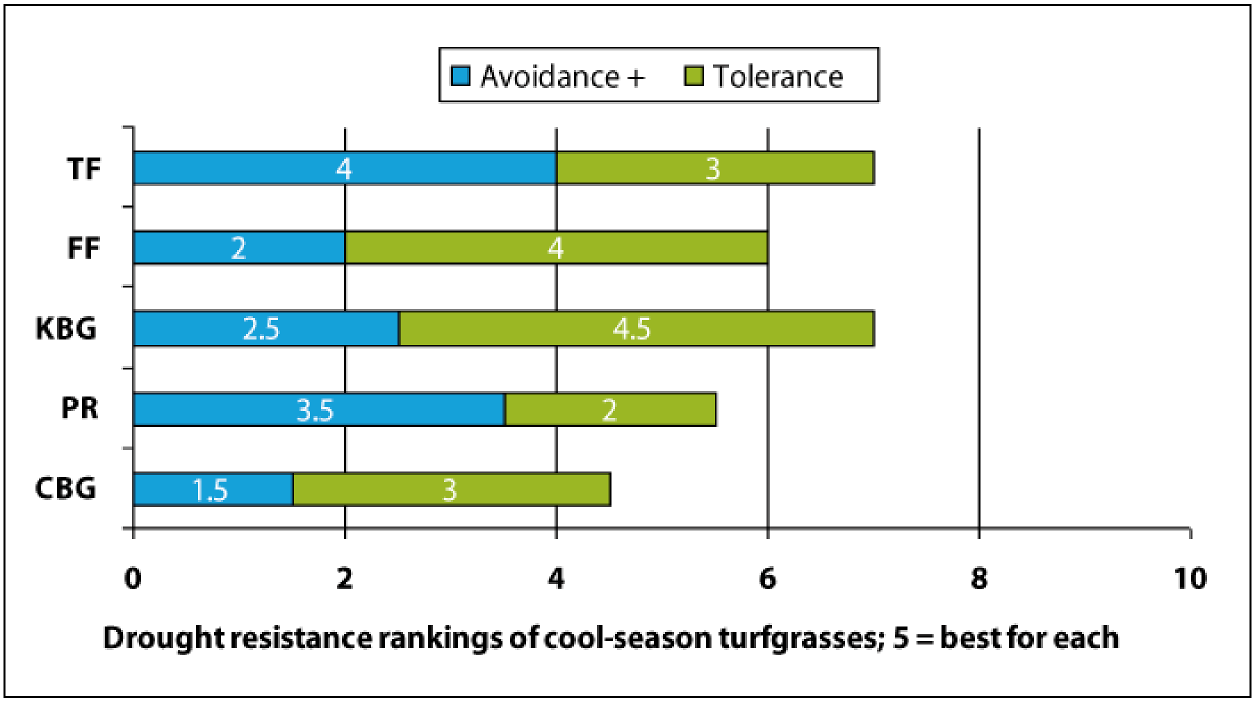

Figure 6. Drought resistance in cool-season turfgrasses.

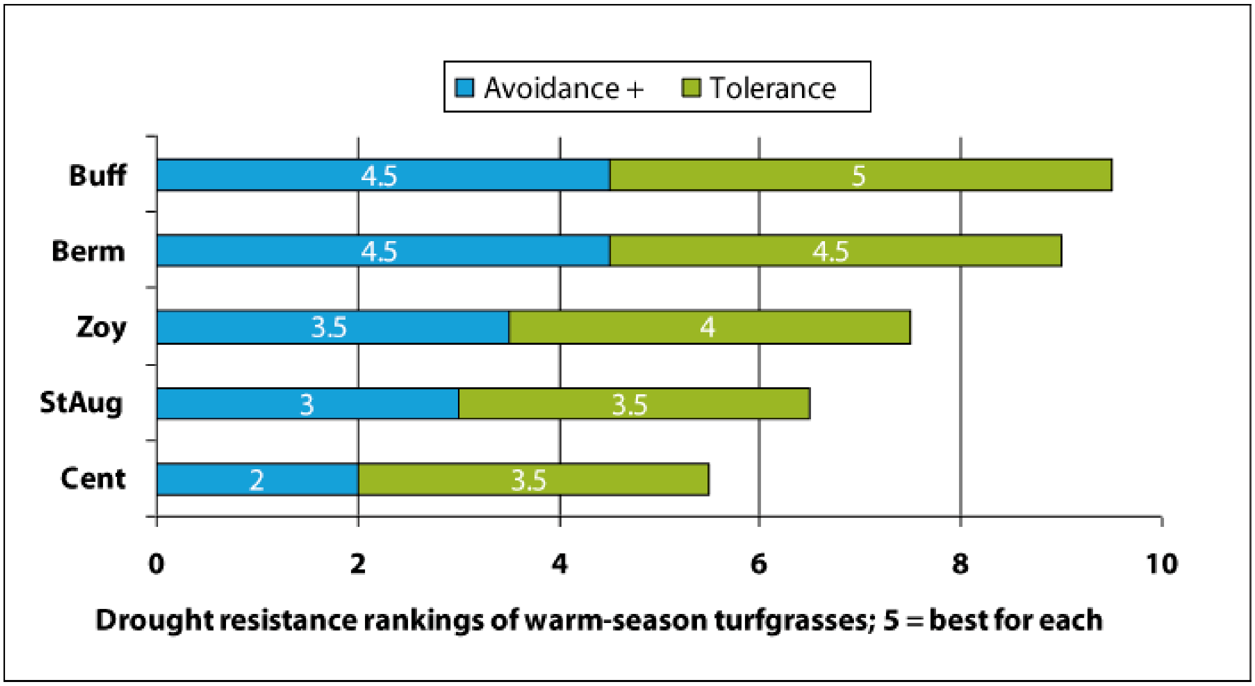

Figure 7. Drought resistance in warm-season turfgrasses.

2.4 Irrigation Water Supply

2.4.1 Irrigation Water Sources

Golf course designers and managers should identify and use alternative water supply sources to conserve freshwater drinking supplies whenever possible. The routine use of potable water is not a preferred practice. Municipal drinking water should be considered only when no alternatives exist.

2.4.2 Irrigation Water Quality

Water should be assessed to determine its suitability for irrigation and for plant growth. Non-potable water irrigation sources (such as retention ponds and recycled water) should be regularly tested to ensure that the quality is within acceptable parameters for irrigation. Commercial laboratories can analyze water samples and makes recommendations based on the electrical conductivity (EC) and sodium adsorption ratio (SAR) determined on the irrigation water and the soil series present on the land. The assessment identifies the chemical characteristics of the water and can be used to address possible issues with soil salinity and plant health caused by poor water quality.

For more information see:

- *Irrigation Water Quality Guidelines for Turfgrass Sites*, Penn State University.
- "Understanding Water Quality and Guidelines to Management," *USGA Green Section Record*.

2.4.3 Irrigation Water Requirements

An adequate water supply is essential for any planned or proposed golf course irrigation system. Water requirement analyses can be conducted to understand irrigation needs. A seasonal bulk water requirement analysis verifies the suitability of a water source and irrigation system to supply irrigation water under normal conditions. Because of the potential for drought, a maximum seasonal bulk water requirement analysis should be conducted as a worst-case scenario and calculated to not account for rainfall. For more information on calculating water requirements and example calculations, see Chapter 3 of the 1st edition of *Environmental Best Management Practices for Virginia's Golf Courses.*

It is essential that all delivery systems install and maintain accurate metering devices. Being able to measure water use allows baselines to be established and progress in water conservation efforts to be tracked. Installation of water meters will become more critical as more regulatory and compliance obligations are imposed on water for irrigation.

2.5 Irrigation System Design

2.5.1 Site Assessment

Collecting accurate site data is critical to the irrigation design process. A wide number of site-specific conditions affect the planning and efficiency of an irrigation system. During this preliminary planning stage, the golf course superintendent should seek assistance from Certified Golf Course Irrigation System designers, professional irrigation consultants, and professionals certified through WaterSense programs

In addition to assessing the site's physical characteristics (such as water sources, soil types, soil physical properties, microclimates, slopes, and sun, wind and shade exposures), the site assessment should also evaluate the impact of design elements, such as design features and concepts, planned or existing turfgrass varieties, and planned or existing drainage systems. The system design should include a general irrigation schedule with recommendations and instructions on modifying the schedule to meet these site-specific needs.

2.5.2 Design

Irrigation systems should be designed to be efficient, distribute water uniformly, conserve and protect water resources, and meet state and local code and site requirements. Site specific characteristics and incorporation of water conservation practices and technologies should be evaluated in the design.

A well-designed irrigation system should operate at peak efficiency and be designed and installed to optimize water use effectively, focusing on water placement and distribution. The design should maximize water use, reduce operational cost, conserve supply, and protect water resources. Where feasible, variable frequency drive (VFD) pumps and/or pump stations should be used. These systems only expend enough energy to meet the demands of the irrigation pump(s). VFD systems reduce water hammer to fitting, pipe, and sprinklers when systems are pressurized.

Detailed BMPs for irrigation system design are published by the Irrigation Association in *2014 Landscape Irrigation Best Management Practices*.

Design Considerations

The irrigation system design should meet the site-specific needs identified by the water quantity analyses and the site assessment. The system's capacity to deliver water should not exceed the infiltration of the soils, as that will lead to runoff. Though the design of an irrigation system is complex, some of the most important design decisions that influence the efficiency and effectiveness of water usage include those related to sprinkler and piping placement, sprinkler coverage and spacing (Table 2), and communication options.

Table 2. Sprinkler coverage and spacing considerations

Sprinkler Spacing	Advantages/Disadvantages
Manual and/or single row sprinkler coverage Typically use long radius sprinkler spacing > 90 ft.	Scheduling coefficient values are high and distribution uniformity values low. Overall, this type of fairway coverage results in inefficient irrigation.
Double row sprinkler coverage Sprinkler throw distances range from 80 to 90 ft., increasing the effective width of coverage and allowing for individual sprinkler control based on the terrain of the fairway area.	Offers an improvement in efficiency over single row coverage. However, manual hand watering or other types of supplemental watering may be needed outside the fairway area and into the extended rough.
Multi-row sprinkler coverage Incorporates three to five rows. Typically, the spacing of sprinklers ranges from 55 to 75 ft.	Offers the best method to control and conserve water and provides the user the best ability to respond to specific moisture requirements of a given fairway area.

Sprinkler layouts can be specific to each area. For example, part-circle sprinklers can be arranged to avoid overspray of impervious surfaces and to apply water only to the green surface or in heavy traffic areas. Manual quick-coupler valves can be an important conservation element and should be installed near greens, tees, and bunkers so these can be hand-watered during severe droughts. Irrigation systems strive to provide uniform water distribution and to achieve distribution uniformity (DU) values near 80%. After installation, nozzles and irrigation head runtimes should be optimized to maintain uniform soil moisture distribution. That can be easily monitored with a soil moisture probe.

Precision Irrigation Control

For precise irrigation control, courses should consider using advanced irrigation control systems that can schedule each green, tee, and fairway separately and allow course managers to adjust for differences in microclimates and root zones. Weather stations that calculate and automatically program water replacement schedules also provide opportunities for more precise irrigation, as do soil moisture sensors placed in multiple locations. Additional water conservation features may include such things as single head control and rain stop safety switches that either shut down the system in the event of rain or adjust schedules based on the amount of precipitation.

2.6 Irrigation Pumping Stations

Irrigation pumping systems play a key role in water management and life cycle management of any irrigation system. Modern pumping systems are complex arrangements of hydraulics, electronics, and communications that keep water flowing at specific rates and pressures. Properly designed and maintained, these systems can assure the user of quality service and production. Poorly designed and maintained pump systems can increase maintenance costs, create service issues, and waste energy and water. The most commonly used pump type for golf course irrigation is the vertical turbine configuration, which offers greater efficiency, less overall maintenance, and fewer loss-of-suction issues than other pump types. Major system components include a pump station, irrigation pumping station control, and intake and discharge piping networks.

Irrigation pumping system control can best be achieved by programmable logic controllers (PLC) in conjunction with VFD to efficiently determine the proper speed of the pump motor based on demand. Hydraulic system pressures can also ramp up and down relative to system flows to ensure the piping network is not compromised. These systems provide advantages over regulating valves and limit switches, which do not vary based on demand and produce non-uniform pressure strain on the piping network. Computerized irrigation central control systems and PLC also allow remote monitoring of the operation of the pump station. Pump station control software that integrates with the irrigation central control software allows remote monitoring of pump station operation and provides water use and consumption data.

2.7 Irrigation System Installation

To ensure maximum efficiency, the irrigation system must be installed per the design and specifications. The installer must ensure that there is qualified supervision of the installation process and that a qualified irrigation specialist inspects and approves the system installation.

2.8 Irrigation System Maintenance and Performance

A properly working irrigation system is critical to ensure optimum operation. System checks and routine maintenance should be done for pumps, valves, programs, fittings, and sprinklers. A schedule of inspections and a plan for record keeping should be completed. Use of photography is especially helpful in recording installations/repairs of underground systems. The publication *2014 Landscape Irrigation Best Management Practices* can be consulted for devising a schedule and a plan for record keeping.

Figure 8. Leaky o-ring identified during routine inspection.

To ensure that it is performing as intended, an irrigation system should be calibrated regularly by conducting periodic irrigation audits, such as catch-can tests and an annual irrigation audit, to check actual water delivery and nozzle efficiency. Nozzles can wear over time. This will change irrigation output and distribution. Nozzles should be replaced, depending on the manufacturer's recommendation, to ensure proper function. Inspecting and exercising isolation valves ensures their sound operation in the event of an irrigation break.

While routine inspection and audits can be performed by the golf course superintendent, a professional irrigation consultant is required for a detailed irrigation audit, which should be conducted according to the Irrigation Audit Guidelines published by the Irrigation Association. Ideally, this professional audit should be conducted at least once every five years.

Figure 9. Irrigation audit at Hermitage Country Club.

2.8.1 Winterization

Winterizing protects irrigation system pipes from damage due to water expanding and rupturing the pipe walls and fittings. Golf courses need to drain or use compressed air to remove water from lateral and mainlines pipes, sprinkler heads, and quick couplers before temperatures drop below freezing.

2.8.2 Spring Start-up

Spring start-up of the irrigation system is essentially the reverse of the steps taken to winterize the system. At the time of start-up, the system should be inspected for corrective maintenance issues.

2.9 Irrigation Management Decisions

An irrigation system should be operated based only on the moisture needs of the turfgrass – or to water-in a fertilizer or chemical application as directed by the label – not on a calendar-based schedule.

The principle of "deep and infrequent" delivery of water promotes deep rooting, gas exchange, and soil temperature moderation, while discouraging surface soil compaction. Enhanced soil gas exchange also promotes increased rooting density, improving water and nutrient absorption efficiency. In practice, for unobstructed soils of 12-18" in depth, the irrigation system applies water to fill soil pores to the depth of roots and then does not irrigate again until surface soil moisture has been depleted to near the wilting point. Soil type, effective root zone depth, and estimated ET demand determine irrigation frequency and soak cycle needs. Turfgrass species also affects irrigation frequency, since some turfgrasses more effectively resist drought than others.

2.9.1 Soil Infiltration Rate and Plant Available Water

Sandy soils, with their higher porosity, have greater infiltration rates (2-20" per hour) than silty or clay soils (0.25–1" per hour). Soil type also determines how much water per inch can be held at field capacity. Soil compaction restricts permeability but can be enhanced with regular core aerification.

Plant available water (PAW) represents the amount of water (expressed in inches) available per inch of soil depth that a plant can access for transpiration. A soil moisture probe indicates the total volumetric water content, which is greater than the PAW for a soil. The PAW can be estimated with a soil moisture meter by subtracting the current soil moisture content from the moisture content when the turf wilts. Plant available soil moisture and infiltration rates are provided in Table 3.

Table 3. Available soil moisture and infiltration rates for common soil textures

Soil Texture	Soil Type	Typical plant-available moisture per foot of soil depth (inches)	Infiltration rate (inches h^{-1})
Light, sandy	Coarse sand Fine sand	0.25 – 0.75 0.75 – 1.00	Fast (0.5 – 6+)
Medium, loamy	Loamy sand Sandy loam Fine sandy loam Silt loam	1.10 – 1.20 1.25 – 1.40 1.50 – 2.00 2.00 – 2.50	Moderate (0.25 – 0.5)
Heavy, clay	Silty clay loam Silty clay Clay	1.80 – 2.00 1.50 – 1.70 1.20 – 1.50	Slow (0.1 – 0.25)

2.9.2 Effective Root Zone Depth

Effective root zone depth is defined as the depth to which 90% of the root system penetrates and must be determined onsite with a soil probe or spade. The soil type and effective root zone depth together are used to estimate the soil water-holding reservoir available to the root system.

2.9.3 Evapotranspiration

ET is a combination of the transpirational water needs of the plant and water lost from the soil surface via evaporation. As temperatures increase and the relative humidity decreases, ET demand rises. ET requirements vary based on turfgrass species, maintenance conditions (such as intensity of use, soil type, microenvironment, and mowing height), and time of year (Table 4).

Table 4. Estimated ET replacement of various turfgrass surfaces in Virginia

Types of Turf		May	June	July	Aug	Sept
		Estimated ET Requirement (inches per week[1])				
Cool Season	Rough	0.6	1.20	1.50	1.30	0.80
	Shaded Area	0.3	0.60	0.75	0.65	0.40
	Fairway	0.55	1.10	1.35	1.20	0.75
	Green	0.50	1.00	1.10	1.10	0.80
Warm Season	Rough	0.45	0.85	1.05	1.00	0.55
	Fairway	0.35	0.75	0.90	0.90	0.50
	Green	0.30	0.70	0.80	0.80	0.70

[1] *These estimates assume that only 50% of monthly rainfall is effectively soil absorbed and becomes available for plant uptake.*

Potential ET (pET) can be calculated and should be used to help determine irrigation needs. Sources of potential ET data include onsite weather stations and the University of Virginia Climatology Office.

Figure 10. Onsite weather stations can provide potential ET data to help determine irrigation needs.

2.9.4 Soil Moisture

To accurately measure local precipitation, the proper use of rain gauges, rain shut-off devices, soil moisture sensors, and other irrigation management devices should be incorporated into the site's irrigation schedule. Monitoring of soil moisture, in addition to calculating ET rates and visual observations of turf, assists in meeting turf water needs while conserving water resources.

Figure 11. Soil moisture sensor in use at Belle Haven Country Club..

2.9.5 Irrigation Scheduling

Proper irrigation can sustain plant energy reserves, increase root mass and depth, and reduce thatch accumulation. Irrigation should be applied as necessary to prevent wilt without oversaturating the soil/root zone and without compromising playing conditions. Soils do not need to be wetted below the root zone depth, as this could potentially lead to leaching, especially in shallow soils.

The goal of successful irrigation management is to limit excessive soil moisture while preventing wilt. Golf course managers strive to precisely apply water, so PAW is only slightly greater than predicted ET. For many highly maintained turf areas, like greens, small amounts of water are applied every night to replace what was lost the prior day. Soil moisture probes can help further improve irrigation precision. These technologies can guide irrigation head run times and identify locations that might benefit from additional hand watering.

During periods of sufficient natural precipitation, stress pre-conditioning with deficit irrigation can improve tolerance to future drought, heat, and cold stress. Deficit irrigation is the practice of limiting irrigation to slowly deplete soil PAW until the soil moisture approaches wilt points.

Computerized irrigation systems provide many advantages, including allowing a superintendent to remotely cancel the program if the course has received adequate rainfall. Clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical time clocks cannot automatically adjust for changing ET rates. Therefore, frequent adjustment is necessary to compensate for the needs of individual turfgrass areas

2.10 Irrigation Best Management Practices

Water Conservation and Efficient Use Planning

- ❖ Minimize acreage of irrigated turf.
- ❖ Convert out-of-play area turf to native plants, grasses, or ground covers to reduce water use and augment the site's aesthetic appeal.

- During times of intense heat stress, syringing, or the practice of applying a small amount of water to help cool the turfgrasses as it evaporates, may be beneficial under certain conditions.
- Create a drought management plan for the facility that identifies steps to be taken to reduce irrigation/water use and to protect critical and valuable areas.
- Restrict water usage in time of drought. Use appropriate turfgrass species adapted to the location of the golf course and use drought-tolerant species whenever possible.
- Consider drought resistance when selecting turf species and varieties.

Irrigation Water Supply

- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs, if available.
- Reclaimed, effluent, and other non-potable water supply mains must have a thorough cross-connection and backflow prevention device in place that operates correctly.
- Post signs in accordance with local utility and state requirements when reclaimed water is in use.
- Use salt-tolerant varieties of turf and plants to mitigate saline conditions resulting from an alternative water source, if necessary.
- Assess the irrigation water quality.
- Account for the nutrients in irrigation water when making fertilizer calculations.
- Monitor irrigation water regularly for dissolved salt content.
- Conduct a seasonal bulk water requirement analysis and a maximum bulk water requirement analysis.
- Design and/or maintain a system to meet a site's peak water requirements under normal conditions. Be flexible enough to adapt to various water demands and local restrictions.
- Install and maintain accurate metering systems.

Irrigation System Design

- Conduct a thorough site assessment prior to designing the irrigation system.
- Develop a written, site-specific Irrigation Management Plan.
- Seek assistance from irrigation professionals, such as from Certified Golf Course Irrigation System designers and WaterSense-certified irrigation consultants, and follow established BMPs related to system design.
- Sprinkler placement should avoid interfering with the playability of the hole.
- Irrigation pipes should be installed away from the green surface to avoid substantial increases in repairs and damages should pipe failures occur.
- Update multi-head control systems with single-head control systems to conserve water and to enhance efficiency.
- Manual quick-coupler valves should be installed for site specific irrigation, so hand-watering can be used during severe droughts.
- Install part-circle heads along lakes, ponds, wetlands margins, native areas, and tree trunks.
- Use part-circle or adjustable heads to avoid overspray of impervious areas such as roadways, sidewalks, and parking areas.
- Incorporate multiple nozzle configurations to add flexibility and enhance efficiency/distribution.

- ❖ When possible, use precise irrigation control technologies.

Irrigation System Installation

- ❖ The designer must approve any design changes before construction.
- ❖ Prior to construction, all underground cables, pipes, and other obstacles must be identified, and their locations flagged.
- ❖ Only qualified specialists should install the irrigation system.
- ❖ Construction and materials must meet existing standards and criteria.
- ❖ Construction must be consistent with the design.
- ❖ Installers must provide an accurate and comprehensive As-Built map.

Irrigation System Maintenance and Performance

- ❖ Visual inspections should be conducted to identify necessary repairs or corrective actions, which should be completed before further evaluation of system performance.
- ❖ Pressure and flow should be evaluated to determine that the correct nozzles are being used and that heads are performing according to the manufacturer's specifications.
- ❖ Pressure and flow rates should be checked (ideally annually) at each head to determine the average precipitation rates.
- ❖ Catch-can tests should be run to determine the uniformity of coverage and to accurately determine irrigation run times.
- ❖ Catch-can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency.
- ❖ Conduct an irrigation audit annually to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- ❖ Inspect for water distribution interferences, such as trees and other obstructions.
- ❖ Inspect for broken and misaligned heads.
- ❖ Check that the rain sensor is present and functioning.
- ❖ Inspect the backflow device to determine that it is in place and in good repair.
- ❖ Examine turf quality and plant health for indications of irrigation malfunction or a need for scheduling adjustments.
- ❖ Periodically conduct a professional irrigation audit that follows established guidelines.
- ❖ Record any modifications to the As-Built map, including head and nozzle choices.
- ❖ Use photography to record and document any major underground installations/repairs.
- ❖ Review efficiency of above-ground electric motors annually.
- ❖ Licensed professionals should routinely inspect the well housing.

Irrigation System Winterization

- ❖ Flush and drain above-ground irrigation system components that could hold water as part of winter preparation.
- ❖ Remove water from all conveyances and supply and distribution devices that may freeze. Use compressed air or open the drain valves at the lowest point on the system.
- ❖ Change filters, screens, and housing; remove drain plugs and ensure any water is removed from the system. Secure systems and close and lock covers/compartment doors to protect the system from vandalism and from animals seeking refuge.
- ❖ Drain any above-ground pump casings that may have trapped water.
- ❖ Record metering data before closing the system.

- Secure or lock any remote irrigation components, including satellites.
- Perform pump and engine servicing/repair before winterizing.

Irrigation System Spring Start-up

- Power up the pump station and pump motors before using the system. By completing this task ahead of recharging the system, the coils inside the motors heat up and will therefore remove any moisture that collected during the offseason.
- Keep the water pressure at 60 PSI or lower when priming the lines.
- Operate each of the sprinklers until all excess air is flushed from the irrigation system.
- Check the functionality of air pressure relief valves.
- Inspect the entire system for any corrective maintenance issues.

Irrigation Management Decisions

- Evaluate root zone depth on the course and do not irrigate beyond this depth.
- Monitor potential ET and calculate plant available water to improve irrigation precision.
- Utilize soil moisture technologies and techniques consistently.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Place soil moisture sensors in a representative location within an irrigation zone.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Use a journal to record the "indicator zones" that should be more closely monitored.
- Calibrate older clock-control station timing devices periodically, and at least seasonally.
- Install control devices to allow for maximum system scheduling flexibility.
- Base plant-water needs should be determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.
- Avoid use of a global setting; adjust watering times per head.
- Adjust irrigation run times based on current local meteorological data and computed daily ET rate to meet the turf's moisture needs.
- Manually adjust automated ET data to reflect wet and dry areas on the course.
- Irrigation quantities and rates should not exceed the available moisture storage in the root zone.
- Use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting in fairways and roughs.
- To maximize turf health during summer, irrigate to the depth of the turf root in early morning.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.
- The irrigation schedule should coincide with other cultural practices (for example, the application of nutrients, herbicides, or other chemicals).
- Generally, granular fertilizer applications should receive 0.25" of irrigation to move the particles off the leaves while minimizing runoff.
- Lightly irrigate high value turf on dry, sunny winter days when the air temperatures are well above freezing to rehydrate plant crowns back to a survivable level and restore moisture at the surface.

3 WATER MANAGEMENT

Whether natural or manmade, surface water in the form of lakes, ponds, and streams has long been associated with golf courses. Natural lakes and ponds are usually connected to existing water sources, such as wetland areas. Irrigation impoundments (lakes, ponds, and constructed wetlands) can be incorporated into the design of a course and used both to manage stormwater and to function as a source for irrigation.

Overall, water management incorporates not only the information contained in this chapter, but many of the issues discussed throughout this document, including:

- Design considerations such as the use of vegetated buffers.
- Fertilization strategies near surface waters.
- Pesticide usage.
- Water quality monitoring.

In addition to planning for stormwater issues and protecting groundwater, water management should focus on lakes and ponds. Important parts of aquatic maintenance include managing components of aquatic habitats, such as algae and plant growth; reducing or preventing nutrient and sediment enrichment especially through the use of vegetated buffers; and ensuring that dissolved oxygen levels can sustain aquatic life.

Proper surface water management as discussed in this chapter and referenced in other chapters preserves the environmental quality of these water features, protects water quality downstream of the golf course, and conserves water.

3.1 Regulatory Considerations

3.1.1 Surface Water Quality

The EPA administers the protection of streams and lakes under the CWA. At the same time, DEQ creates state-specific regulations and water quality standards based on federal recommendations. Surface water quality is regulated under the CWA. DEQ is the state’s lead agency with regulatory authority for surface and groundwater quality.

The CWA requires states to prepare a list of impaired surface waters every other year. Impaired waters are those that do not meet the state water quality standards. From this list of impaired waters, states prepare TMDLs that include pollution control goals and strategies necessary to improve the quality of impaired waters and remove the identified impairments. TMDLs can include goals for nutrient loading (e.g. nitrogen or phosphorus). DEQ provides information on the TMDLs and a list of finalized TMDLs in the state.

In addition to developing TMDLs, DEQ is required to provide Congress with surface water quality reports every two years that describe the status and trends of existing quality of all waters in the state. The report also provides information about the extent to which designated uses are supported. DEQ combines this report with the impaired waters report into one integrated report, the Virginia Water Quality Assessment 305(b)/303(d) Integrated Report.

3.1.2 Dams

Impounding Structure Regulations (Dam Safety) (4 VAC 50-20) regulates dams in Virginia, unless a dam is specifically excluded from the regulations. These regulations cover construction, alteration of an existing impoundment structure, and operation and maintenance of the impoundments. For more information, see the Virginia Department of Conservation and Recreation (DCR) Dam Safety web page.

3.1.3 Aquatic Pesticides

Aquatic pesticides that control nuisance aquatic plants like Eurasian milfoil, as well as algaecides that control algae, are available from commercial distributors. Any herbicide used must be labeled for aquatic sites and registered with the Virginia Department of Agriculture and Consumer Services (VDACS) for use in Virginia. See the “Pesticide Management” chapter for more information on pesticide regulations.

In addition, a Virginia Pollutant Discharge Elimination System (VPDES) permit is required for the direct application of pesticides to surface waters. A general permit issued by the DEQ is available to operators who discharge pesticides to surface waters from the application of either biological pesticides or chemical pesticides that leave a residue, including pesticides used for weed and algae control. Applicators must be certified by the VDACS Office of Pesticide Services (OPS).

As with any pesticide application, the label must be followed. Labels on aquatic herbicides for algae control may specifically state that only a portion of the surface water area can be treated at one time to prevent massive algae and other plant die-offs and to avoid the low dissolved oxygen (DO) conditions that result from decaying organic matter.

3.1.4 Grass Carp

Biological practices such as the introduction of triploid (sterile) grass carp can be a useful component of a lake management strategy. Under state regulations (4 VAC 15-30-40), the introduction of grass carp requires a permit from the Virginia Department of Game and Inland Fisheries' Triploid Grass Carp Program, which typically involves an onsite inspection following submission of an application. Impoundments are usually approved if little chance exists for the fish to escape.

3.1.5 Buffers

In Tidewater regions of the state, regulations require that a vegetated buffer area not less than 100 feet wide be located adjacent to and landward of all tidal shores, tidal wetlands, certain associated non-tidal wetlands, and along both sides of all waterbodies with perennial flow.

3.2 Stormwater Management

Best practices related to protecting the quality of surface waters center on preventing nutrients, chemicals, and sediments from reaching waterbodies and wetlands. Superintendents can effectively protect Virginia's water resources by managing stormwater effectively, maintaining buffers, and considering the special needs of wetlands, floodplains, lakes, and ponds.

The control of stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance sites, and play areas. Proper management of stormwater controls the amount and rate of water leaving the course, controls erosion and sedimentation, stores irrigation water, removes waterborne pollutants, enhances wildlife habitat, and addresses aesthetic and playability concerns. Stormwater runoff (also called surface runoff) is the conveying force behind what is called nonpoint source pollution. Nonpoint source pollution is caused by water moving over and through the ground, picking up and carrying away natural and human-made pollutants, and finally depositing them into surface waters (lakes, rivers, wetlands, coastal waters) and groundwater. On golf courses, pollutants that might be found in surface runoff include, but are not limited to, pesticides, fertilizers, sediment, and petroleum.

Treating stormwater to avoid impacts to water quality is best accomplished by a treatment train approach in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. These treatments include source controls, structural controls, and non-structural controls. Source controls are the first car of the BMP treatment train. They help prevent the generation of stormwater runoff or the introduction of pollutants into stormwater runoff. The most effective method of stormwater treatment is to prevent or preclude the possibility of movement of sediment, nutrients, or pesticides into runoff.

The next car in the treatment system is often structural controls, which are design and engineering features of the course created to remove, filter, detain, or reroute potential contaminants carried in surface runoff. Examples of structural BMPs include ponds, constructed wetlands, and filters to address water quality, water recharge, and stream channel protection. Non-structural controls mimic natural hydrology and minimize the generation of excess stormwater and include vegetated systems. Vegetated systems such as stream buffers act as natural biofilters, reducing stormwater flow, removing sediments from surface water runoff, and preventing nutrient and pesticide discharge in runoff from reaching surface waters. The treatment train approach combines these controls, as in the following example: Stormwater can be directed across vegetated filter strips (such as turfgrass), through a swale into a wet detention pond, and then out through another swale to a constructed wetland system.

During any construction or redesign activity, proper erosion and sedimentation control must be followed (as discussed in the "Planning, Design, and Construction" chapter) to ensure that stormwater runoff does not impact water quality. Properly designed golf courses capture rain and runoff in water hazards and stormwater ponds, providing most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during drought conditions.

3.2.1 Preventing Surface Runoff

Factors that affect nutrient mobility, availability, and accessibility can be evaluated to predict where and when nitrogen (N) contamination can potentially occur. BMPs related to this are designed to prevent the transportation of N to surface waters (Table 5). Soils data is needed for this assessment and is available from Web Soil Survey data for Virginia published by the USDA Natural Resources Conservation Service (NRCS).

Table 5. Criteria for high potential to affect N transport to surface water as related to natural factors

Natural Factors	Criteria
Surface water proximity	Adjacent land within 500 feet that slopes into the drainage network.
Soil aeration	Excessive, somewhat excessive, and well drained soils
Mobilization in solution	Soil hydrogeologic group C and D
Mobilization with sediment	K factor near 0.69 combined with soils in hydrogeologic groups C and D
Land slope	Slopes > 9%
Flooding frequency	Frequent flooding as defined by NRCS

3.2.2 Buffers

Buffers around the shore of surface waters, wetlands, or other sensitive areas filter runoff as it passes across the buffer. Buffers can be vegetated filter strips, such as those used as part of a stormwater treatment system. When used as a buffer along shorelines, stream banks, and wetland boundaries, filter strips are the last line of defense to keep sediment out of streams and to filter out fertilizers and pesticides that might otherwise reach waterways.

Depending upon site-specific conditions, including the amount of available space and in-play versus out-of-play considerations, a range of buffer widths can be considered. Buffer widths from 10 to 656 feet have been shown to be effective. In most cases, a buffer of at least 100 feet is necessary to fully protect aquatic resources. Smaller buffers (toward the lower end of this range) still afford some level of protection to the surface waters and are preferable to no buffer at all. Protection of the biological components of wetlands and streams typically requires buffer widths toward the upper end of the range.

For vegetated buffer zones, the installation of ornamental grasses, wetland plants, or emergent vegetation around the perimeter and edges of surface waters serves as both a buffer and wildlife habitat for many aquatic organisms, as well as being aesthetically pleasing. Use native plants for these plantings whenever possible. See the DCR publication *Native Plants for Conservation, Restoration & Landscaping* for more information.

Riparian buffers along streams and rivers can be up to three different plant assemblages, progressing from sedges and rushes along the water's edge to upland species. Riparian buffers of sufficient width intercept sediment, nutrients, and pesticides in surface runoff and reduce nutrients and other contaminants in shallow subsurface water flow. Woody vegetation in buffers provides food and cover for wildlife, stabilizes stream banks, and slows out-of-bank flood flows. The DCR publication *Riparian Buffers Modification & Mitigation Guidance Manual* provides extensive guidance on riparian buffers.

Maintenance considerations for buffers to protect water quality include the following:

- Maintain healthy turf cover adjacent to surface waters to slow sediment accretion and reduce runoff flow rates.
- Plant shrubs and trees far enough from water edges so that leaves stay out of the water.
- Mow and clip vegetated filter strips, buffers, and riparian shrubs to avoid contributing nutrient inputs into surface waters. Return clippings away from the water or collect them (such as for composting in a designated area) so that runoff does not carry vegetation into the water.
- Mow buffers in-play areas situated in riparian areas to heights up to 4 inches.
- Use imaginative plant selection to help reduce nutrient content, such as small floating hydroponic rafts of plants whose roots draw nutrients from the water. These plants can be periodically harvested and composted, which removes nutrients from the water permanently.
- Periodically clean small basins, ponds, and forebays to remove sediments. Be aware that the effort, disruption, and financial outlay for this effort is less than that for dredging an entire body of water.
- As a general practice, all chemical applications should be kept 10 to 15 feet away from the water’s edge when using rotary spreaders and/or boom sprayer applications. When fertilizers or pesticides are needed, spot-treat weeds or use drop spreaders or shielded rotary spreaders and boom sprayers to minimize the potential for direct deposition of chemicals into the water.

3.3 Flood Recovery

When floods occur and turf is submerged for any length of time, the potential for turf death depends upon a number of factors, including the time of year; the length of time the turf is submerged; the depth of submersion; water temperature; and light intensity. Actively growing turf is most vulnerable; substantial loss can be expected after 4 days of continued submersion whereas dormant turf can be expected to survive longer submersion. If any of the leaf tissue is above the water line, the potential for survival is greater. Cooler temperatures also increase survival rates, due to lower water temperatures and lower light intensity.

Following a flood, turf injury can be evaluated by inspecting the turf crown and cross-sectioning. If the majority of the crown is alive, recovery can be monitored. If the majority of the crowns are dead (brown and mushy), aggressive over-seeding is called for.

3.4 Wetlands

The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem. Wetlands should be maintained as preserves and separated from managed turf areas by means of native vegetation, structural controls to protect water quality, and low/no maintenance activities to avoid nutrient or pesticide contamination.

3.5 Floodplains

Control structures located near floodplains, such as retention basins, store water and thereby reduce flooding and protect stream banks. These structures should be regularly inspected and maintained to ensure their proper function. Vegetated buffers along floodplains should be maintained to mitigate flooding, control stormwater, and protect water quality.

3.6 Lakes and Ponds

The management of lakes and ponds should include a clear statement of goals and priorities to guide the development of the BMPs necessary to meet those goals. Some of the particular issues superintendents should address to maintain the water quality of golf course lakes and ponds include:

- Pond design.
- Dissolved oxygen (DO) levels.
- Aquatic plant management.
- Near-shore management zones.

3.6.1 Pond Location and Design

Designing a new pond requires considerations such as the size of the drainage area, water supply, soil types, and water depth. In addition to potentially serving as an irrigation water source, ponds support aquatic life. The construction of ponds should consider the needs of aquatic ecosystems (e.g. DO needs for aquatic species and discouraging excessive growth of aquatic vegetation). Careful design may significantly reduce future operating expenses for pond and aquatic plant management.

3.6.2 Dissolved Oxygen

Dissolved oxygen is the amount of oxygen present in water and is measured in milligrams per liter (mg/L). Adequate DO levels are required to sustain life in aquatic organisms and vary by species, the organism's life stage, and water temperature.

The amount of DO that water can hold depends on the physical conditions of the body of water (water temperature, rate of flow, oxygen mixing, etc.) and photosynthetic activity. Colder water has higher DO levels than warmer water. Dissolved oxygen levels also differ by time of day and by season as water temperatures fluctuate. Similarly, a difference in DO levels may occur at different depths in deeper surface waters if the water stratifies into thermal layers. Fast-flowing streams hold more oxygen than impounded water. Lastly, photosynthetic activity also influences DO levels. As aquatic plants and algae photosynthesize during the day, they release oxygen. At night, photosynthesis slows down considerably or even stops, and algae and plants pull oxygen from the water. In impoundments with excessive plant and algae growth, several cloudy days in a row can increase the potential for fish kills due to low DO during warm weather. Therefore, preventing excessive aquatic growth helps to maintain DO levels. The use of artificial aeration (diffusers) can also be used to maintain adequate DO, especially in small impoundments or ponds.

Figure 12. Solar-powered artificial aeration at Army Navy Country Club helps to maintain adequate dissolved oxygen.

3.6.3 Aquatic Plants

Aquatic plants include algae and vascular plants. Phytoplankton, or algae, give water its green appearance and provide the base for the food chain in ponds. Tiny animals called zooplankton use phytoplankton as a food source. Large aquatic plants (aquatic macrophytes) can grow rooted to the bottom and supported by the water (submersed plants), rooted to the bottom or shoreline and extended above the water surface (emerged plants), rooted to the bottom with their leaves floating on the water surface (floating-leaved plants), or free-floating on the water surface (floating plants). The Virginia Department of Game and Inland Fisheries provides information on its Aquatic Plant ID and Treatment web page.

Aquatic plants are part of aquatic ecosystems. They provide a number of benefits, such as:

- Habitat for aquatic organisms (e.g. food and nesting sites).
- Oxygenation.
- Shoreline stabilization.
- Aesthetic appeal.

Aquatic plants growing on a littoral shelf may help protect receiving waters from pollutants present in surface water runoff. Ideally, littoral zones should have a slope of about 1 foot vertical to 6-10 foot horizontal to provide the best substrate for aquatic plant growth. In open areas, floating-leaved and floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade.

Particularly in shallow or nutrient-enriched ponds, aquatic plant growth can become excessive. Non-native plants, in particular, can aggressively colonize aquatic environments. The excessive growth of any aquatic plant requires management. Following the principles laid out in the "Integrated Pest Management" chapter, a number of controls should be considered to deal with excessive aquatic plant growth, including:

- Prevention, such as reducing nutrient enrichment and avoiding the introduction of invasive species.
- Cultural practices, such as benthic barriers to prevent vascular plant growth.
- Mechanical removal.
- Chemical control.

Triploid (sterile) grass carp are allowed in Virginia with a permit and are sometimes used as a biological control for aquatic plants.

3.6.4 Shoreline Management

Special management zones should be established around the edges of lakes and ponds. The management specifications should include a setback distance when applying fertilizers, as well as reduced mowing. Grass clippings should be collected near shorelines, as the phosphorus and nitrogen in clippings can impact water quality when transported into waterbodies. Similarly, tree leaves near waterways should also be collected and not blown into or disposed of near surface waters.

Figure 13. Before: Storm water management pond using water lettuce to remove nutrients.

Figure 14. After: Storm water management pond using bubblers and floating wetlands to control nutrient enrichment and aquatic plant growth.

3.6.5 Waterfowl

The deposits of fecal matter by resident and migrating waterfowl (such as Canada geese) can substantially impact water quality through nutrient enrichment. On golf courses, shallow ponds with significant populations of waterfowl are most likely to be affected. In addition, large numbers of Canada geese can erode shorelines and thin the grass cover on greens and fairways, contributing to the potential for erosion. Efforts to control waterfowl have met with mixed success. Loud sounds, dogs, and hunting have been tried in order to deter them. However, many of these efforts do not lend themselves to golf courses, especially in more urban areas. For more information, see *Managing Wildlife Damage: Canada Goose (Branta canadensis)*, VCE.

3.7 Groundwater Management

Protection zones around water supply wells and safe land-use practices that prevent leaching help protect aquifers from accidental contamination.

3.7.1 Preventing Leaching

Leaching refers to the loss of water-soluble plant nutrients or chemicals from the soil as water moves through the soil profile and reaches the saturated zone. Some of the factors that can influence leaching potential include the depth to groundwater, soil type and structure, geology, rate of precipitation, and amount of irrigation. When applying fertilizers or pesticides, the rate, timing, and location of applications should be considered to minimize the potential for losses due to leaching. Sandy soils, for example, have a low potential to fix phosphorus (P) and therefore are more likely to leach phosphorus, as well as nitrogen, than other soil types.

Nitrogen, in the form of nitrate (NO_3-N), presents leaching concerns for groundwater quality. In Virginia, nitrate is one of the most widespread groundwater contaminants. Sandy or gravelly textured soils, excessively drained soils, and areas with shallow groundwater tables are most likely to leach nitrogen (Table 6). Fertilizers with a solubility of more than 30 mg/L (or 30 ppm) can pose a risk for leaching.

Table 6. Criteria for high potential to affect N translocation to groundwater as related to natural factors

Natural Factors	Criteria
Soil aeration	Excessive, somewhat excessive, or well drained soils
Soil texture	Sandy, sandy-skeletal, or fragmental family particle size
Depth to aquifer	Less than 50 feet to the top of the saturated aquifer
Hydrologic recharge area	>20 inches to accumulations of calcium carbonate ($CaCO_3$)

3.7.2 Protecting Wellheads

Protecting wellheads from physical impacts and contaminants, keeping them secure, and sampling wells are all best practices for ensuring groundwater supplies of drinking water are adequately protected.

Before installing new wells, the well construction permit should be reviewed to determine any permitting and setback requirements. New wells should be located in areas that will maximize yield but also minimize potential contamination of source water such as being located up-gradient as far as possible from potential pollutant sources, such as petroleum storage tanks, septic tanks, chemical mixing areas, and fertilizer storage facilities. The completion of a preliminary wellhead protection area delineation and source inventory is therefore desirable prior to the installation of new wells. Once installed, activities that could contaminate the well should be prohibited in the protected area. In addition, most pesticide labels now prohibit mixing/loading pesticides within 50 feet (or other specified setback distances) from any well.

3.8 Water Management Best Management Practices

Stormwater Management

- Design stormwater treatment trains.
- Install berms and vegetated swales to capture pollutants and sediments from runoff before it enters irrigation storage ponds or other surface waters.
- Implement no- or low-maintenance vegetated buffer strips around surface waters.
- Utilize vegetated filter strips in conjunction with water filtration basins.
- Eliminate or minimize directly connected impervious areas.
- Use depressed landscape islands in parking lots to catch and filter water and allow for infiltration. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediment, while allowing the overflow to drain away.
- When possible, maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and plants.

Flood Recovery

- After a flood, if turf has been submerged for any length of time, inspect the crowns and either monitor recovery or aggressively overseed as needed.

Wetlands

- Maintain appropriate silt fencing on projects upstream to prevent erosion and sedimentation.
- Natural waters cannot be considered treatment systems and must be protected. (Natural waters do not include treatment wetlands.)
- Establish a low- to no-maintenance buffer along wetlands, springs, and spring runs.

Floodplains

- Maintain stream buffers to restore natural water flows and flooding controls.
- Install buffers in play areas to stabilize and restore natural areas that also attract wildlife species.
- Install detention basins to store water and reduce flooding at peak flows.

Lakes and Ponds

- Maintain an unmowed, vegetated buffer strip (riparian buffer) to filter the nutrients and sediment in runoff, mowing only once or twice a year at most so that grasses and plants grow knee-high.
- If mowing near a pond or lake, collect clippings or direct them to upland areas so they do not increase nutrient loading to waterbodies.
- Maintain the required setback distance when applying fertilizers near waterways.
- Encourage clumps of native emergent vegetation at the shoreline.
- Maintain water flow through lakes if they are interconnected.
- Establish wetlands where water enters lakes to slow water flow and trap sediments.

- Maintain appropriate erosion and sedimentation controls on projects upstream to prevent sedimentation and nutrient enrichment to waterbodies.
- Dredge or remove sediment before it becomes a problem.

Dissolved Oxygen

- Establish DO thresholds to prevent fish kills, which occur at levels of 2-3 mg/L.
- Reduce stress on fish by keeping DO levels above 5 mg/L.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels.
- Use artificial aeration (diffusers), if needed, to maintain adequate DO.

Aquatic Algae and Plants Management

- Develop a comprehensive management plan that includes strategies to prevent and control the growth of nuisance aquatic vegetation.
- Keep phosphorus rich material (e.g. natural or synthetic fertilizers, organic tissues like grass clippings, or unprotected topsoil) from entering surface water.
- Install desirable native plants to naturally buffer DO loss and fluctuation.
- To control excessive aquatic plant growth, use an IPM approach that incorporates prevention, cultural practices, and mechanical removal methods in addition to chemical control.
- To reduce the risk of DO depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.
- Dredge or remove sediment as needed to improve aquatic habitat.
- Reverse-grade around the waterbody perimeters to control surface water runoff and to reduce nutrient loads.
- Discourage large numbers of waterfowl from colonizing golf course waterbodies.

Preventing Leaching

- Identify areas on the course that may be prone to leaching (shallow depth to groundwater, sandy soils, etc.)
- Manage irrigation to avoid over-watering.
- Consider the potential for fertilizers or pesticides to leach before applying.

Wellhead Protection

- Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of water sources.
- Follow pesticide labels for setback distance requirements (typically a minimum of 50 feet).
- Properly decommission illegal, abandoned, or flowing wells.
- Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.
- Inspect wellheads and the well casing routinely for leaks or cracks; make repairs as needed.
- Maintain records of new well construction and modifications to existing wells.
- Obtain a copy of the well log for each well to determine the local geology and the well's depth; these factors will have a bearing on how vulnerable the well is to contamination.
- Develop a written Wellhead Protection Plan that minimizes environmental risk and potential contamination.

4 WATER QUALITY MONITORING

Regularly scheduled water quality monitoring can be both preventive and curative in terms of environmental impact. The public perceives that water sources on golf courses are contaminated with nutrients and chemicals applied in turf management. However, as demonstrated in a high-profile research project conducted at Purdue University's North Golf Course, a properly designed and managed golf course can actually improve the quality of the water entering golf courses from stormwater runoff originating from neighboring farmland and residential development (Kohler et al. 2004).

Water quality monitoring measures the likely origin and extent of sedimentation and nutrient inputs and impacts to surface water and groundwater. Using monitoring data, management strategies can be altered if the need for corrective action is identified. In addition, water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can inform nutrient and liming programs.

If budgetary concerns limit the scope or frequency of sampling, water quality monitoring should concentrate on the water sources with the most significant impacts on the surrounding environment. In addition, a group of area golf courses can purchase water sampling equipment to share among their facilities.

In addition to monitoring water quality from golf course management operations, superintendents will want to regularly test irrigation water, such as that from retention ponds. Information on irrigation water quality testing is provided in Section 2.4.2: "Irrigation Water Quality."

4.1 Existing Water Quality Information

Several sources of existing surface water and groundwater monitoring data may be available that can provide baseline information for a course-based water quality monitoring program. These potential data sources include:

- DEQ VEGIS datasets.
- United States Geological Survey (USGS) Surface-Water Data for Virginia.
- EPA's How's My Waterway tool.

4.2 Developing a Water Quality Monitoring Program

A water quality program begins with the development of a monitoring plan. The plan should identify specific conditions such as the presence of a watershed, stream flows, soil type, topography, drainage, and vegetation. In addition, the plan needs to document the hydrologic conditions and drainage, monitoring objectives, monitoring locations and frequency, and monitoring parameters. Baseline reference conditions can be established by collecting upstream water samples and comparing them with collection sites downstream of the areas influenced by golf course management practices.

Surface water collection sites can include streams, rivers, ponds, wetlands, etc., with the number and location of collection sites dependent upon the monitoring objectives. For example, a simple monitoring program can consist of the collection of DO data in surface waterbodies to ensure that these waterbodies can support aquatic life. Regardless of the extent of the monitoring program, the location of monitoring sites should remain consistent over time to establish trends in data.

A more comprehensive monitoring program should include both field measurements at the time of sampling and analytical testing. Field measurements include pH, temperature, specific conductance, and DO. Lab testing should be conducted by a certified laboratory. Typical testing parameters include nutrients (such as nitrates and phosphorus), total dissolved solids (TDS), alkalinity, sediments, and selected pesticides used on the course. For more information on surface water monitoring programs, sampling procedures, and parameters specific to golf turf, the 1st edition of *Environmental Best Management Practices for Virginia's Golf Courses* can provide detailed guidance.

Developing a water quality monitoring program on golf courses is often limited to surface water monitoring. Sampling of stream with benthic macroinvertebrates is a useful addition to a monitoring program, as composition and diversity of these species can be used as a relative assessment tool for stream health. For more information, see New Mexico State University's *Stream Biomonitoring Using Benthic Macroinvertebrates*. Such sampling can often be undertaken by university students in fulfillment of course work, by watershed association volunteer groups, or by other volunteer monitoring efforts.

In some instances, groundwater monitoring may be desired. Groundwater monitoring from wells located at the hydrologic entrance and exit of the course may be the best way to evaluate a golf course's impact on water quality. If groundwater monitoring data from these locations are not available from existing sources, monitoring wells at the hydrologic entrance and exit of the course can be installed by private installers. Groundwater quality parameters can be limited to test only the ones directly influenced by course management, such as levels of pesticides and organic and inorganic nitrogen.

Water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can influence nutrient programs. Immunoassay analysis may be a possible and cost-effective method for monitoring, depending on the analytical goals and the number of samples. To save money, several golf courses could pool resources and share immunoassay analyzer equipment and kits. See the "Irrigation" chapter of this document for more information on irrigation water quality issues.

4.3 Interpreting Water Quality Testing Results

Interpretation and use of water quality monitoring data depends to a large extent on the goal of the monitoring program. For example, the results may be analyzed to compare:

- Values over time.
- Values following implementation of BMPs, such as IPM measures.

- Monitoring points entering the site and leaving the site.

Results should also be interpreted and compared with the state's water quality standards, if water quality standards have been established for the parameter being evaluated. Data analysis can also be used to identify issues that may need corrective action, based on findings such as a spike in nutrient levels. For example, operator error in nutrient applications, an extreme weather event, or some combination of factors may be responsible. Water quality problems can often be addressed by simple changes to a course's existing nutrient management program.

4.4 Water Quality Monitoring Best Management Practices

Developing a Water Quality Monitoring Program

❖ Review existing sources of groundwater and surface water quality information.
❖ Develop a water quality monitoring program.
❖ Establish baseline quality levels for water.
❖ Identify appropriate sampling locations and sample at the same locations in the future.
❖ Visually monitor/assess any specific changes of surface waterbodies.
❖ Follow recommended sample collection and analytical procedures.
❖ Conduct seasonal water quality sampling. The recommendation is four times per year.
❖ Partner with other groups or volunteer water quality monitoring programs if possible, to share data and monitoring costs.

Interpreting Water Quality Testing Results

❖ Compare water quality monitoring results to benchmark quality standards.
❖ Use corrective measures when necessary.

5 NUTRIENT MANAGEMENT

Proper nutrient management plays a key role in the reduction of environmental risk and also increases course profitability. Among other benefits, applied nutrients increase the available pool of nutrients and allow turfgrass to recover from damage, improve its resistance to stress, and increase its playability. However, an increase in available nutrients also raises the potential risk of environmental impact. Nutrients may move beyond the turfgrass via leaching or runoff, which may directly impact water quality. Other organisms also respond to increases in nutrients and, in some cases, these organisms may deleteriously alter the ecosystem. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant uptake.

5.1 Regulatory Considerations

Virginia regulations (4 VAC 50-85) serve as the basis for developing certified Nutrient Management Plans (NMPs) to limit nutrient (primarily N and P) and sediment pollutants from reaching water and entering watersheds. DCR certifies individuals to write NMPs for turf and landscape. These regulations provide the basis for developing environmentally responsible NMPs that consider both warm-season and cool-season grasses, the turf use, soil type, and nutrient application levels and frequencies for both grow-in and general management purposes. A certified nutrient management planner uses these recommendations in developing a site-specific nutrient management plan. For more information, see the Urban Nutrient Management page on the DCR website.

5.2 Soil Testing

Soil testing provides the basis for sound nutrient management and water quality protection programs in golf turf management, especially given the dynamic nature of the sandy soils of many putting greens and tees. A standard soil test provides information on soil pH and the levels of the macronutrients P, potassium (K), calcium (Ca), and magnesium (Mg) and typical micronutrients iron (Fe), zinc (Zn), copper (Cu), and boron (B). Soil test results do not provide N levels because N constantly fluctuates between plant available and unavailable forms. However, soil test results typically provide a recommendation for N levels and timing of applications.

General soil test sampling and analytical testing recommendations include the following:

- Conduct soil sampling at a 2-4” depth from representative areas of similar management.
- Exclusively use one trusted soil testing laboratory.
- Verify whether the lab uses Mehlich-3 or Mehlich-1 extractions and use appropriate conversion factors for developing and implementing a nutrient management plan.

One of the best ways to utilize soil testing is to monitor changes in the nutrients over time. Declining soil test P and K, for example, indicates that fertilization with P_2O_5 and K_2O should be increased relative to N fertilization rate, unless the values for those nutrients are deemed to be sufficient. Nitrogen fertilizer drives the uptake of all other nutrients in turf. Therefore, P_2O_5 and K_2O should be looked at relative to N fertilization rate and not just the total amount applied.

For more detailed information on soil testing, see Chapter 5 of the *Urban Nutrient Management Handbook*, VCE.

5.3 Soil pH

Soil pH is an assessment of the total amount of hydrogen ions (H^+) in soil solution ("active acidity") and those ions attracted to soil colloids ("reserve acidity"). Nutrients may be present in the soil but not available to plants because nutrient availability to plants is governed primarily by pH. Figure 15 shows that slightly acidic soils are optimal for nutrient availability (typically a pH of 6.2 to 6.8 for golf turf management). Extremes in soil pH result in nutrient deficiency or toxicity, both of which can cause suboptimal growth conditions and ultimately lead to turf loss.

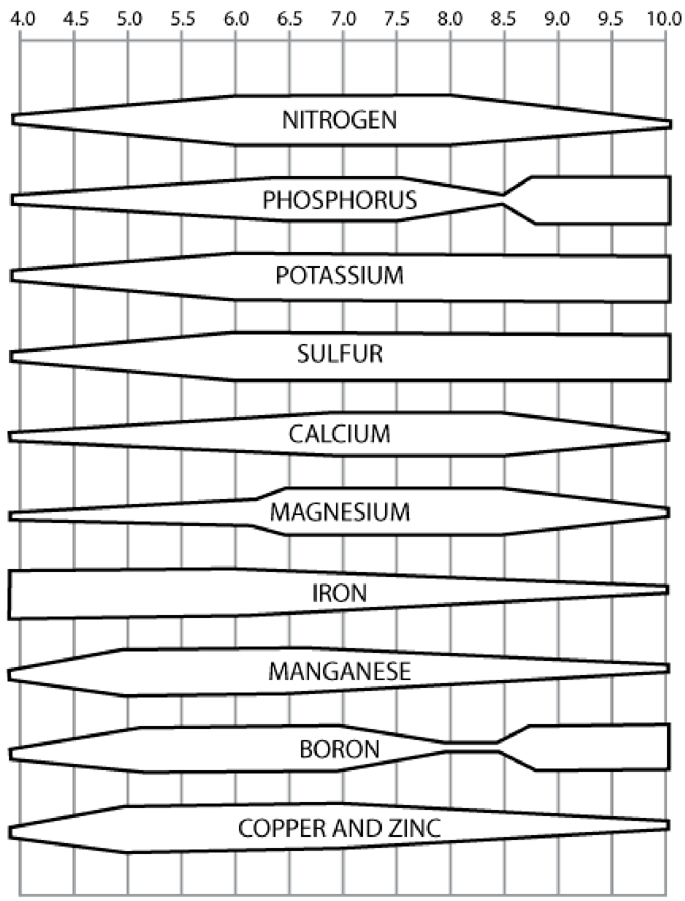

Figure 15. Relationship between soil pH and nutrient availability.

5.4 Plant Tissue Analysis

Visible plant symptoms can offer helpful clues in diagnosing nutrient deficiencies, but can also be easily confused and misinterpreted, especially where micronutrients or sulfur compounds are involved. Tissue testing can help to adjust nutrient management programs in these ways:

- To confirm a suspected nutrient element deficiency when visual symptoms are present

- To monitor plant nutrient element status in order to determine whether each tested nutrient is in sufficient concentration for optimum performance

Recent soil test results should be used to assist in the interpretation of the results of a plant tissue analysis. If none are available, a soil sample should be submitted along with the tissue sample.

5.4.1 Nutrient Monitoring

Tissue tests can indicate ranges in possible nutrient excesses or deficiencies, but the data does not explain the cause of the nutrient deficiency (such as unsuitable pH, or deficiency or excess in nutrient application).

A routine monitoring program and the resulting recommendations provide a basis for effective nutrient management practices. Some golf course superintendents submit samples to testing labs every month or every other month, especially for creeping bentgrass grown on completely modified sand-based putting greens. Trends in tissue nutrient status can be observed, and in conjunction with soil test data, can be used to make adjustments in lime and fertilizer treatments before deficiencies or excesses develop. In addition, by comparing plant analysis results with turf quality, nutrient applications, and soil test data over time, the nutrient sufficiency ranges and nutrient management practices required to maintain site-specific turf quality under varying climatic conditions and management constraints can be refined. If regular sampling is cost prohibitive, then prioritized sampling is recommended and should include areas that are representative of the turf quality, use, composition, and soils.

5.4.2 Plant Sampling

Plant samples should be taken at regular intervals from each representative area prior to and during growth cycles. Turf quality (clipping yields if available), weather conditions, and any known problems at the time of sampling should be recorded. Nutrient additions on each monitored site should be documented and routine soil samples collected at least once a year (prior to P and K fertilization) to supplement nutrient management records.

For diagnostic samples, plant tissue samples should be collected as soon as symptoms appear. Plants showing severe deficiency symptoms are often the most difficult to interpret correctly, since a deficiency of one element may result in deficiencies or excess accumulation of other elements if uncorrected. Plants under prolonged stress of any kind (temperature or moisture extremes, pests, flooding, mechanical damage, etc.) can have unexpectedly high or low nutrient levels due to the stress.

Comparative sampling can improve the accuracy of diagnosis by collecting both plant and soil samples from “good” and “bad” areas that are close proximity to each other and have similar soil types, similar species composition, and similar management (mowing height, irrigation, etc.). Since the recommended ranges of plant nutrient content are general, a sample should represent general site and management conditions. Differences in nutrient concentrations can then be compared with soil samples to determine if the problem is related to fertility management or is an uptake problem (such as disease, water, compaction, or root damage). For example, differences in Mg and Mn between plants could be related to differences in soil pH.

Samples should be collected from the above-ground portion of the plant, clipped just above ground level no more than two days after mowing. As a general rule, monitoring samples can be taken from turfgrass clippings collected in buckets, as long as the bucket is clean and the clippings are not contaminated from chemical applications (fertilizers, pesticides, reel-sharpening compounds, etc.). When whole plants are sampled, the roots should be cut off and discarded and shoots washed to remove soil particles. Under normal conditions, rainfall is frequent enough to keep leaf surfaces fairly free from dust and soil particles. If recently sprayed, or if Fe is of primary interest, a quick wash in a dilute (0.3%) detergent solution followed by a quick rinse in a strainer or colander removes residues and soil particles that could bias the sample. To prevent decay during transport to the lab, excess moisture should be reduced by partially air drying plant tissue samples before shipment to the laboratory. Fresh samples should not be put in a tightly sealed or plastic bag unless they will be kept cold during transport.

5.5 Fertilizers Used in Golf Course Management

Understanding the components of fertilizers, the fertilizer label, and the function of each element within the plant are all essential in the development of an efficient nutrient management program. In Virginia, VDACS analyzes samples of fertilizer and agricultural lime sources to ensure that labeling guarantees are met and that the product is safe for the environment.

5.5.1 Terminology

Grade or analysis is the percent by weight of N, P_2O_5, and K_2O that is guaranteed to be in the fertilizer at minimum. Complete fertilizers contain N, P, and K.

5.5.2 Label

The label is intended to inform the user about the contents of the fertilizer. When applied according to the label, the use of fertilizer presents little to no environmental risk. Fertilizer labels generally provide the following information:

- Manufacturer’s name and address.
- Brand name.
- Website.
- Nutrient guarantee (i.e. guaranteed minimum amounts of nutrients, given as a ratio).

Additional information that may be found on the label includes characteristics such as size guide number (SGN), water-insoluble nitrogen (WIN), WSN, and release characteristics.

5.6 Nitrogen

Nitrogen sources get the most scrutiny in a management program because of the intensity of golf turf management and the highly variable grass requirements, based on the turfgrass species, turf use, maintenance requirements, and soil type. A wide variety of N sources are available, but only two forms of N are plant available: the ammonium cation (NH_4^+) and the nitrate anion (NO_3^-). Regardless of the source, N must be transformed into one of these two forms to become plant available. Given its positive charge, NH_4^+ can be temporarily bound in the soil by cation-exchange capacity (CEC) reactions. NO_3^- is highly prone to leaching and can quickly contribute to water quality issues, particularly for sand-based soils with very low CEC.

The first selection criterion in choosing an N fertilizer source is often its water solubility. Readily available N sources, such as WSN, provide rapid turfgrass growth and color responses and are more prone to leaching, particularly in sand-based soils often used for golf putting greens or tees. SAN sources, often referred to as WIN or controlled release N (CRN), are highly variable in N content and release characteristics.

The latest generation of “stabilized” N sources cannot be adequately described on the basis of N solubility. The Association of American Plant Food Control Officials (AAPFCO) adopted the term “enhanced efficiency” (EE) to better describe fertilizer products that minimize the potential of nutrient losses to the environment, as compared with a “reference soluble” product such as WSN or SAN. This term distinguishes between two categories of EE fertilizer products:

- “Slow release” fertilizer sources release or convert nutrients to a plant-available form at a slower rate relative to a “reference soluble” product. For these products, the release of soluble nutrients is governed by either a coating or occluded materials (such as polymer or sulfur-coating, urea form and derivatives, and isobutyraldehyde diurea).

- “Stabilized” N sources are amended with an additive that reduces the rate of transformation of fertilizer compounds, resulting in extended time of availability in the soil, such as nitrification inhibitors, nitrogen stabilizers, and urease inhibitors. Stabilized sources are subject to the rates governing WSN applications.

Both categories of products improve nutrient use efficiency and minimize the potential of nutrient losses to the environment. AAPFCO is refining the definition of these products and their labeling characteristics as technologies evolve.

Nitrogen solubility and stabilization are highly variable, depending on the source and possible combinations with readily available materials. While SAN and stabilized sources are significantly more expensive on a cost per pound of N basis as compared with WSN materials, their release characteristics fit well given the precision required in golf turf management and their use is encouraged whenever possible.

5.6.1 Nitrogen Application

As a rule of thumb, no more than 0.7 lb of readily available N per 1,000 ft^2 per growing month or 0.9 lb of slowly available N per 1,000 ft^2 per growing month for cool-season grasses should be applied in a single application. For warm-season grasses, no more than 1 lb of N per 1,000 ft^2 per growing month should be applied in a single application. When possible, these should be split into two or more applications. This strategy meets turfgrass nutritional needs and regulatory requirements while minimizing potential water quality concerns. Restricting N application levels is especially important on sand-based putting greens and is easily adapted into green management programs, where it is commonplace for superintendents to "spoon-feed" (0.05 to 0.15 lb N/1,000 ft^2) the turf, making numerous light applications of nutrients on a frequent basis. This strategy balances turfgrass growth and color with requirements for turf health, recovery, and playability, in addition to reducing nutrient leaching potential.

Spoon-feeding can be accomplished with both granular and liquid applications. The practice of liquid feeding or foliar feeding is popular for facilities with spraying equipment. Liquid feeding uses greater than 45 gallons per acre (gal/A) of water and most nutrient uptake occurs at the root system. Foliar feeding uses less than 45 gal/A water carrier in order to keep the majority of the nutrients on the leaf surface for foliar absorption.

Applying fertilizer in water improves the uniformity of distribution and allows small amounts of nutrients to be accurately applied with water as the carrier. Fertigation (delivery through an irrigation system) is another specialized means of delivering nutrients and is especially effective during a grow-in when wet soils are not conducive to spreader and/or sprayer operation. Fertigation performance is only as good as the distribution and uniformity capabilities of the irrigation system. Dispersible granule fertilizer formulations provide enhanced turf coverage that mimics foliar or liquid feeding. Upon contact with water, a single fertilizer granule separates into several thousand particles, thus coating the turfgrass foliage.

5.7 Phosphorus

Phosphorus is a critical nutrient for turfgrass growth and development, playing important roles in energy transformations in plant cells and root development. P enhances turfgrass establishment and is the most important nutrient in "starter fertilizers." In the soil, P is generally in complex with other elements and is an insoluble (plant unavailable) nutrient.

Phosphorus is slowly made available to plants on an as-needed basis by chemical reactions in the soil that convert it to either of two anionic forms: HPO_4^{2-} or $H_2PO_4^-$. In these anionic forms, phosphorus is highly leachable and is a concern for water quality issues since it contributes to eutrophication. However, the complexing of P with other elements greatly minimizes P leaching as compared with NO_3^- leaching potential. Phosphates are a potential leaching concern during the grow-in of turfgrass on sand-based systems that inherently have very low nutrient holding capacity and are subject to frequent irrigation when the turfgrass has a very limited root system.

Leaching can also be a concern where P is overapplied to established turf, especially on sand-based systems. In native soils, P leaching is typically of minimal concern unless P has been overapplied for many seasons. P leaching potential is best managed by applying it on the basis of a soil test. Applying fertilizers near water resources and/or impervious surfaces that move stormwater contribute to water quality concerns and should be avoided.

The standard P fertilizer sources are provided in Table 6-3 in the 1st edition. Recent changes in fertilizer manufacturing include the production of "P-free" fertilizer sources. In addition, interest in natural organic fertilizers has grown, but these are not "P-free" and are typically 0.5 -2% P_2O_5 by weight. Phosphonate (phosphite) is a unique form of P used in the golf turf industry primarily for its activity on Pythium induced turf diseases (Landschoot and Cook, 2009). Numerous labeled phosphonate fungicides have been shown to be low cost, extremely effective Pythium control products when used on a preventive basis. Phosphonates are most often referred to in the golf turf industry as "plant health products" since they have such low nutrient value, but can be converted to plant available phosphate by soil-borne bacteria over time (three to 12 months). Hence, their use warrants some consideration by golf turf managers and nutrient management planners. The normal use rates for *Pythium* disease suppression are so low compared with standard phosphate-containing fertilizers that they would not be anticipated to contribute to excessive soil loading of P that might ultimately lead to phosphate leaching.

5.8 Potassium

Potassium is not a direct component of any organic compound within a plant but is heavily involved in many biochemical responses. In particular, K is the nutrient that most impacts water relations within the plant, sometimes referred to as the "antifreeze" and "coolant" nutrient of the plant world. The most common forms of potassium fertilizer sources are presented in Table 6-4 in the 1st edition. Because the last of the three numbers that appear in the fertilizer grade represents potash (K_2O), this value must be converted to elemental K by multiplying by 0.83.

Although many unrefined and manufactured sources of potassium exist, plants always absorb potassium in the same form, the K^+ cation. K is required in the second highest quantities by plants after N. As a cation, K^+ can be temporarily bound and exchanged for other cations (i.e. cation exchange) in soils that contain significant anionic (negatively charged) exchange sites (i.e. soils with significant amounts of clay and/or organic matter). Even as a cation, K^+ can still leach depending on soil type (especially sand-based soils) and under heavy rainfall or irrigation. Potassium is not considered to be an environmental concern that negatively impacts water quality and therefore does not receive as much attention as N and P from this perspective

5.9 Calcium, Magnesium, and Sulfur

While much time is spent on N, P, and K, when it comes to nutrient management programs for golf turf, Ca, Mg, and sulfur (S) are equally important for plant growth and development. In addition to the common sources listed in Table 7, other materials such as bone meal, wood ash, manures, and sludge can contain significant amounts of these elements.

Many of these sources also alter pH (i.e. liming materials that raise pH, sulfur-based materials that lower pH). Therefore, if Ca, Mg, or S is limiting in the soil, but a pH change is not desired, standard liming sources and elemental S should be avoided and gypsum ($CaSO_4$), magnesium sulfate, or potassium-magnesium-sulfate used to supply these nutrients.

Table 7. Secondary macronutrients

Nutrient	Role	Sources
Calcium	Primarily a component of cells walls and structure.	Gypsum Limestone Calcium chloride
Magnesium	Central ion in the chlorophyll molecule and chlorophyll synthesis.	S-Po-Mg Dolomitic limestone Magnesium sulfate
Sulfur	Metabolized into the amino acid cysteine, which is used in various proteins and enzymes.	Ammonium sulfate Elemental sulfur Gypsum Potassium sulfate

5.10 Micronutrients

Micronutrients are just as essential for proper turfgrass health as macronutrients but are required in very small quantities compared with macronutrients. Micronutrients include iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl). They play a variety of roles in turf biology, including roles in photosynthesis, nitrogen fixation, and protein synthesis. Micronutrient deficiencies can be confirmed by tissue testing or small fertilizer applications to turf to verify fertilizer response. Soil testing for micronutrients is not recommended, and soil interpretations for these nutrients can be ignored.

Fe and Mn deficiency symptoms can be common in bluegrasses and bentgrass during summer. Deficiency symptoms include yellow colored (chlorotic) turf that does not respond to N fertilization. In many instances, nitrogen fertilization will intensify the chlorosis. The chlorosis is most severe when soils are warm, wet, and have high pH (>7.3). It is believed that root function is lost under these conditions. As a result, foliar Fe and Mn applications will effectively correct the deficiency. Deficiency symptoms subside as the soil cools into the fall.

5.11 Managing Soil pH

Most of the native soils of Virginia essentially act as weak acids, with only a small portion of their potential acidity present in the active, or soil solution form. Acidic soil (with a low pH) must be limed based on a soil test recommendation to make the rooting environment hospitable for root exploration and development. Golf turf soils are rarely too alkaline (with a high pH) in this region. High alkalinity is typically due to excessive lime applications made without soil test recommendations. High alkalinity should be avoided due to the difficulty of managing high pH soils as compared with low pH soils.

Selection of liming materials is typically based on the ability to neutralize soil acidity, chemical composition, fineness of grind, ease of handling, and cost (Little and Watson, 2002). Whenever possible, soil pH should be adjusted prior to establishment as preplant incorporation greatly accelerates the neutralization of the acidity throughout the root zone. For more information on liming materials and rates, see Chapter 6 in the 1st edition of *Environmental Best Management Practices for Virginia's Golf Courses*.

5.12 Nutrient Application Programs and Strategies

Defining an ideal nutrient application strategy given all of the variables (grass, grass use, soil, climate, budget, equipment available, etc.) is impossible for golf turf management fertility programs. However, four general management principles apply:

- Apply the right rate of fertilizer.
- Apply fertilizer at the right time.
- Apply fertilizer in the right place.
- Use the most appropriate type of fertilizer.

The required Nutrient Management Plan provides the basis for developing a nutrient management strategy that optimizes plant health in an environmentally responsible manner.

To improve application efficiency, a spatial assessment of nutrient requirements that calibrate nutrient applications to plant growth can be performed. Using *Minimal Levels for Sustainable Nutrition Soil Guidelines* soil nutrient interpretation guidelines and the turfgrass growth potential (GP) model, nutrient needs can be predicted based on variable plant demand through the growing season. This approach ensures nutrients are applied in amounts and at times when plants are most capable of uptake and utilization and can effectively reduce costs in nutritional programs through reduced applications. For more information on Minimum Level for Sustainable Nutrition (MLSN) guidelines, see also the *MLSN Cheat Sheet*.

5.12.1 Fertilizer Application Timing

The timing of fertilizer applications (N in particular) is one of the most critical aspects for protecting water quality. The vast array of slowly available N sources, many of which are extremely immobile in soils, provides some flexibility in N application timing.

N should be applied during periods of optimal turfgrass growth. For cool-season grasses, typical management programs result in two-thirds to three-fourths of a seasonal N application applied in the fall, with the remaining one-fourth to one-third applied in early to mid-spring. For warm-season grasses, the N application period typically extends from mid-spring through late summer.

The DCR Nutrient Management Standards and Criteria recommends the application for N fertilizers to cool-season turfgrass beginning six weeks prior to the last spring average killing frost date and ending six weeks after the first fall average killing frost date. For non-overseeded warm-season turfgrasses, N applications should begin no earlier than the last spring average killing frost date and end no later than one month prior to the first fall average killing frost date. Utilizing lower N application levels during the early and late periods of the application window further promotes nutrient use efficiency and less potential for water quality impacts. Combining these timing recommendations with sound agronomic decision making minimizes the likelihood of potentially mobile (both surface and subsurface) nutrients entering water sources during non-active growing periods.

5.12.2 Maintenance Fertilization

Given the diversity in grasses and their intended uses on Virginia golf courses, maintenance fertility programs are also highly diverse in terms of fertility source, application rate, and frequency. Highly leachable sand-based soils and regular clipping removal, two characteristics associated with the putting green and tee management, further increase the intensity of nutrient management under these conditions.

Table 8 presents general seasonal N applications for all aspects of golf turf management developed from VA regulations. Maximum N levels are not intended to be interpreted as "optimal" N levels for single applications. Every putting green, tee, etc. has its own site-specific nutritional requirements, and it is highly likely (and probably desirable from a plant health and environmental perspective) that the applications are split into frequent, light applications of nutrients, especially for putting green management. As with establishment fertilization, fertilization applications should be timed during periods of active turfgrass growth and the percentages of readily- and slowly-available N in products should be used to determine application rates, with typically no more than 0.7 lb of N per 1,000 ft^2 applied per growing month.

Table 8. General seasonal N strategies for golf turf management

Turf Use	Grass Type	Maximum N Rate Per Application – WSN	Total Annual N Rate – SAN
		(lbs/1,000 ft^2)	
Greens		0.7 (b)	3 – 6
Tees		0.7 (b)	2 – 5
Overseeded Tees	Warm-season	0.5	1.25
Fairways (normal management)	Cool-season Warm-season	0.7 (c) 0.7 (c)	2 – 3 3 – 4
Fairways (intensive management)	Cool-season Warm-season	0.5 (d) 0.5 (d)	3 – 4 3.5 – 4.5
Overseeded fairways	Warm-season	0.5	1.25
Roughs		0.7 (e)	1 – 3

(b) Greens and Tees – Per application timing must be a minimum of 30 days between applications. A rate of 0.9 lbs/1,000 ft^2 of total N may be applied for cool season grasses or 1.0 lbs/1,000 ft^2 of total N may be applied for warm season grasses using a material containing slowly available forms of N.

(c) Fairways (normal management; non-irrigated or irrigated) – Per application timing must be a minimum of 30 days between applications. Total N application rates of 0.9 lbs/1,000 ft^2 of total N may be applied for cool seasons grasses or 1.0 lbs/1,000 ft^2 of total N may be applied for warm season grasses using a material containing slowly available forms of N.

(d) Fairways (intensive management; irrigated) – Per application timing must be a minimum of 15 days between applications. This option requires optimized timing of more frequent applications of N with lesser rates per application. Alternatively, a maximum application rate of 0.9 lbs/1,000 ft^2 of total N for cool season grasses or 1.0 lbs/1,000 ft^2 of total N for warm season grasses using a material containing slowly available forms of N may be applied with a minimum of 30 days between applications.

(e) Foliar fertilizer may be applied to warm season grasses within 30 days prior to the first killing frost in the fall, at a rate not to exceed 0.1 lbs/1,000 ft^2 of N per application. This application must be accounted for tin the total annual N rate.

5.12.3 Site-Specific Considerations

Additional considerations for fertilization management depend on weather forecasts and site-specific characteristics within each area of a golf course. For example, the following are recommendations for topographic, geologic, soils, climate, and cultural considerations that should be accounted prior to fertilization applications. Following these recommendations minimizes the amount of nutrients in runoff and/or groundwater:

- Minimize fertilizer application rates on slopes.
- Use N levels of 0.25-0.5 lb per 1,000 ft^2 per application on deep sandy soils or near shallow water tables.
- Avoid applying fertilizers prior to anticipated intensive, heavy rainfall.
- Ensure all fertilizers are applied or are moved into turfed areas so that they do not remain on impervious surfaces where they can move in stormwater.
- Establish minimal maintenance buffer zones around stream and lake boundaries.

5.13 Application Equipment

The selection and calibration of application equipment is another important aspect of nutrient management. Not all fertilizers can be spread with every spreader. For example, if sulfur-coated urea is spread through a drop spreader, the sulfur coating could be damaged, essentially leading to an application of soluble urea. Therefore, choosing the appropriate spreader for a given material (walk-behind rotary drop spreader, bulk rotary, or spray) is important.

Accurately calibrated sprayers or spreaders are essential for proper application of fertilizers. Incorrectly calibrated equipment can easily apply too little or too much fertilizer, resulting in damaged turf, excess cost, and greater potential of nutrient movement off-site. An excellent resource for spreader care and calibration can be found at Penn State's Department of Plant Science website. Spreaders should also be thoroughly cleaned after use due to the high salt content that corrodes metal parts and in keeping with the BMPs for equipment washing.

5.14 Nutrient Management Best Management Practices

- ❖ Because turf is extremely responsive to soil N status, evaluate changes in clipping yield during the growing season to estimate N availability.
- ❖ Reduce N inputs on more mature turfgrass stands.

- Adapt N fertilizer programs to provide turfgrasses with an even growth rate. This increases golf course playability and minimizes the risk to the environment, while excessive fertilization reduces playability and increases the risk of N leaching.
- Use soluble N sources (0.05-0.50 lb N per 1,000 ft^2) to fine-tune clipping yield on highly managed turf surfaces.
- Fertilizer products with a blend of quick and slow-release fertilizer are frequently applied to non-intensively managed areas. Optimum timing for cool-season species is late summer through mid-fall; a secondary application can take place in mid-spring to early summer.
- Summer fertilizer applications can benefit young turf stands or stands growing on poor soils.
- Apply fertilizer when turf is actively growing to minimize loss.
- Light irrigation after P application has been shown to reduce P runoff.
- Maintain dense turf stand through proper nitrogen fertilization to reduce soil runoff.
- Monitor K and P by testing soil regularly.

Fertilizer Applications

- Prevent fertilizers from being deposited onto impervious surfaces.
- Avoid applying fertilizer to soil at or near field capacity or following rain events that leave the soil wet.
- Do not apply fertilizer when heavy rains are likely.
- Do not apply fertilizers to dormant turf or when ground is frozen.
- Maintain buffer areas around waterbodies. The buffer areas should not be fertilized.
- Choose the appropriate type of spreader for a given fertilizer.
- Calibrate application equipment regularly.

6 CULTURAL PRACTICES

Golf cultural practices, which include mowing, cultivation practices, and overseeding, maintain a turfgrass system (i.e. putting greens, tees, fairways, or roughs) for the desired use or function. For example, mowing creeping bentgrass and ultra-dwarf bermudagrass putting greens to a low height of cut (HOC) with well-adjusted and sharp blades – in addition to proper implementation of cultivation practices such as aerification and topdressing – maintains a uniform surface over time for smooth ball roll. In addition to the playability benefits of implementing cultural practices BMPs, these practices help to avoid sediment and nutrient runoff by maintaining the health of the turf and decreasing soil compaction.

6.1 Mowing

Mowing, the most commonly used cultural practice on golf courses, impacts turf density, texture, color, root development, and wear tolerance. Failure to mow properly results in weakened turf with poor density and quality. Mowing height decisions are typically based on the turf species and location on the course. Other factors affect mowing as well, such as frequency, shade, equipment, time of year, root growth, and abiotic and biotic stress. Mowing should promote tillering and shoot density while not decreasing root and rhizome growth as much as possible (Figure 16).

take the impact on reduced stress tolerance into consideration

Figure 16. Mowing HOC decision-making should consider the impact on root and rhizome development and stress tolerance.

6.1.1 Height of Cut

Height of cut is important for a healthy playing surface. Setting a desired HOC is a function of the species/cultivar being managed and the intended use of the site. While taller grown turf is more likely to withstand pests and stresses, a well-groomed turf stand is preferred by many golfers for playability and aesthetic appeal.

Various heights of cut are used on different locations on a golf course. The tables shown below shows recommended HOC for turf species (Table 9 and Table 10). These HOC ranges maximize turf density, assuming water, nutrient, and cultivation needs are being met. Following a rule of thumb that no more than one-third of the plant should be removed at one time avoids scalping, which reduces turf density and can result in a dramatic reduction in root growth.

Table 9. Mowing HOC recommendations by species and location

Turf Species	**Greens (Healthy Maintenance)**	**Greens (Tournament Play)**	**Tees, Collars, Approaches**	**Fairways**
	(in inches)			
Creeping bentgrass	0.125 – 0.180	0.090 – 0.135	0.250 – 0.500	0.350 – 0.625
Hybrid bermudagrass	0.125 – 0.180	0.100 – 0.140	0.375 – 0.500	0.375 – 0.625
Common bermudagrass	N/A	N/A	0.500 – 0.625	0.500 – 0.750
Zoysiagrass	N/A	N/A	0.400 – 0.625	0.500 – 0.750
Perennial ryegrass	N/A	N/A	0.375 – 0.500	0.375 – 0.625
Kentucky bluegrass	N/A	N/A	0.500 – 0.750	0.625 – 1.00

Table 10. Recommended mowing heights for roughs

Kentucky bluegrass	**P. ryegrass**	**Tall fescue**	**Fine fescues**	**Bermudagrass**
(in inches)				
1.0 – 6.0	1.0 – 6.0	2.0 – 6.0	2.5 – 6.0	0.75 – 2.5

For intermediate, primary and secondary roughs. Intermediate rough cuts are defined as a narrow (<10') step-up cut immediately adjacent to the fairway. HOC for intermediate roughs are usually in the lower part of the specified ranges, typically 1.0–1.75".

6.1.2 Seasons

Mowing height can be varied seasonally to improve responses such as spring greenup, summer stress tolerance, and cold hardening. In spring through mid-summer, longer days result in a more prostrate growth habit for warm-season grasses. During this time, bermudagrasses and zoysiagrasses can be mowed closer to enhance density without negatively affecting overall plant health. Close mowing in early spring can remove dead tissue, open the canopy to greater solar radiation, and promote faster spring greenup. For example, if the intended maintenance HOC for a bermudagrass fairway is 0.5", begin spring mowing at 0.35", returning to 0.5" as 80–100% spring greenup occurs.

The shorter days of late summer to autumn promote a slightly more upright growth habit for warm-season grasses. Raising HOC by 30% during this time reduces scalping potential while allowing more light interception by lower leaves. Overall, the result should be plants with greater carbohydrate storage for improved winter hardiness and canopies with greater biomass to protect crowns against winter traffic.

A similar approach could be taken with a tall fescue rough, but the first cleanup mowing should occur before active shoot growth resumes to avoid deleterious effects on spring root growth. For example, if the intended maintenance HOC for a tall fescue rough in spring is 2.75”, the first mowing should be at 1.75”, or about 40% below the intended maintenance height. This removes the upper brown leaf tissue and exposes the newer green growth to incoming radiation, enhancing soil warming, and speeding greenup. As the spring shoot growth flush begins, HOC should be returned to 2.75”. As the spring flush of shoot growth subsides and the heat of summer is looming, consider raising the height to 3” to better insulate the crown from high temperature stress, reduce weed competition, and increase late spring rooting potential for improved summer drought avoidance. With cooler temperatures of October, HOC can be lowered to 2.5” to encourage lateral growth and more efficiently mulch tree leaves into the rough. A similar seasonal approach to mowing heights for creeping bentgrass and *Poa annua* putting greens is recommended.

6.1.3 Frequency

Leaf growth in response to factors such as nutrient availability, environmental conditions, and plant growth regulator (PGR) use dictates mowing frequency. Maximum mowing frequency is required in the spring for cool-season grasses and in the summer for warm-season grasses.

For most turfgrasses, shoots have priority over roots for carbohydrate allocation for maintaining enough leaf area for photosynthetic energy production. Repeated removal of > 40% leaf area initially stops energy from being stored in the roots and eventually stops root growth, reducing overall root viability. Coupled with summer stress, excessive mowing often results in shoot thinning, weed invasion, and sometimes, death. If rainfall results in turf of excessive height between clips, the height of cut should be lowered in small (25–40%) increments until the desired HOC is reached. Also, the lower a turf is mowed, the more frequent the need to be cut so as to protect healthy growth while not breaking the one-third rule, which is a rule based partly on Virginia Tech research in the 1950s which states the following: Do not remove more than 30–40% of the leaf blade with any mowing.

6.1.4 Mowing Patterns and Direction

Mowing patterns influence both the aesthetic and functional characteristics of a turf surface. While patterns should be varied regularly throughout the course, the direction of cut should be changed on putting greens every time it is mowed, including changing the direction of clean up and skipping some clean-up mows. Varying mowing patterns also provides aesthetic value.

Mowing in alternating lines to create various aesthetically pleasing striping effects is most easily accomplished with cool-season rather than warm-season grasses because cool-season grass blades lay over easier and reflect light more strongly due to their waxier cuticles. Dark-colored stripes result when the rollers on the back of the mower blades have laid the turf toward the viewer's eye; light colored stripes result when the turf is laid down away from the viewer's eye.

Warm-season grasses such as bermudagrasses and zoysiagrasses must be repeatedly reel-mowed in the same direction to "burn-in" or train the stiffer blades to lay in a certain direction for a pronounced striping effect. This mowing approach must be used cautiously because compaction, rutting, excessive wear from turning at the same location, and formation of grain that disrupts proper ball roll can occur. Varying the striping pattern on putting greens prevents grain, encourages more upright growth, and varies wear patterns. A rotating clock pattern is recommended so that mowing direction is changed daily. Cleanup laps should be routinely reversed or skipped two to three times per week to lessen wear damage.

6.1.5 Clipping Management

Turfgrass clippings are a source of nutrients, containing 2% to 4% nitrogen on a dry-weight basis, as well as significant amounts of phosphorus and potassium. These nutrients can be sources of pollution, and therefore should be handled properly to avoid contaminating water resources. Clippings should be returned to the site during mowing unless the presence of grass clippings will have a detrimental impact on play (e.g. on greens) or when the volume of clippings is so large that it could smother the underlying grass. When possible, collecting and measuring clipping yield can assist in determining growth rates, the need for fertilization, and scheduling PGR applications. Collected clippings should be disposed of properly to prevent undesirable odors near play areas and to prevent a fire hazard due to the heat generated by composting that can occur when clippings accumulate. Consider composting clippings or dispersing them evenly in natural areas where they can decompose naturally without accumulating in piles, though care should be taken to ensure that clippings are free from pesticides.

6.1.6 Mowing Equipment

Different mowing equipment is typically used on different locations of a golf course. For example, reel mowers are ideally suited for maintaining turfgrass stands that require HOC below 1.5" and provide the best quality cut when compared with other types of mowers. Rotary mowers, when sharp and properly adjusted, deliver acceptable cutting quality for turf cut above 1" in height. Flail mowers are most often used to maintain infrequently mowed areas. Maintaining blades by sharpening and adjusting them regularly provides the best quality cut. Dull blades shred leaf tissue, increase water loss, and increase potential for disease development.

6.2 Aeration

Cultivation practices – aeration practices and surface cultivation practices – disturb the soil or thatch through the use of various implements to achieve important agronomic goals that include relief of soil compaction, thatch/organic matter reduction, and improved water and air exchange. Aeration practices consist of core aeration, deep drilling, solid tining, and high-pressure water injection. Light and frequent sand topdressing applications are also beneficial for smoothing the surface, diluting organic matter, and improving playability. Aeration frequency depends upon traffic intensity, thatch/organic matter buildup, black layer and level of soil compaction. Even though aeration is very beneficial, it disturbs the playing surface and takes some time to heal. Table 11 shows advantages and disadvantages of multiple aeration practices.

Table 11. Aeration practices

Method	Compaction relief	Surface disruption	Water/air movement	Disruption of play
Hollow-tine aeration	High	Medium	High	Medium to High
Solid-tine aeration	Low	Low	Low to Medium	Low to Medium
Deep-tine aeration	Medium	Medium	High	Low to Medium
Deep drilling	Medium	Medium	High	High
Sand injection	Medium	Low	High	Low
High-pressure water injection	None	Low	Medium	Low
Air injection	Low-Medium	Low	Medium-High	Low

Figure 17. Solid tine aeration at Hermitage Country Club.

6.2.1 Hollow-tine Aeration

Hollow-tine (or core) aeration is effective at relieving soil compaction, improving internal soil drainage, and increasing oxygen in the soil. Aeration involves physically removing cores, varying in depth, diameter, and distance apart. Table 11 shows different core sizes used for aeration.

The USGA recommends organic matter dilution (OMD) programs as follows: core aerating to achieve annual surface removal of 15-20% with enough topdressing to fill all holes plus extra sand (50-200 lbs/1,000 ft^2 every two to four weeks) for putting green conditioning between major cultivation events. Virginia Tech researchers implemented various iterations of the OMD program for three years on mature sand-based Penn-A4 greens at a course near Richmond and confirmed a minimum of 15% removal was required to meet this BMP (Ervin and Nichols 2011). Achieving this BMP should also result in the maintenance of 10-20% aeration porosity needed for the healthy root growth and surface water infiltration required to prevent summer bentgrass decline.

Table 12. Core size options for aeration

Tine Size (in.)	Spacing (in.)	Holes/ft^2	Surface Area of One Tine (in.)	Percent Surface Area Affected (Outside tine)
1/4	1.252	100	0.049	3.4%
1/4	2.52	25	0.049	0.9%
1/2	1.252	100	0.196	13.6%
1/2	2.52	25	0.196	3.4%
5/8	2.52	25	0.307	5.3%

6.2.3 Deep-tine Aeration

Deep-tine aeration loosens soils and creates aeration channels to a depth well below that of conventional core aerification. It is also used to improve air, water and nutrient movement through layered, poorly drained soils. Following deep-tine aeration, relatively large amounts of topdressing soil or organic matter can be added to the turfgrass root zone.

Either hollow tines or solid tines may be used in deep-tine aeration; solid tines are often preferred when cultivating heavily compacted clay soils or gravelly soils for the first time. Cultivating with a conventional aerifier before using a deep-tine aerifier with solid tines may prove very beneficial as the aeration channels created by the conventional core aerifier receive some of the soil displaced by deep-tine, solid-tine aerification and lessens the disruption of the turf surface with fewer turfgrass plants lifted from the soil.

6.2.4 Deep Drilling

Deep-drill aeration creates deep holes (8-10”) in the soil surface profile through use of drill bits. Soil is brought to the surface and distributed into the canopy. Holes can be backfilled with new root zone materials if a drill-and-fill machine is used. These machines allow replacement of heavier soils with sand or other materials in an effort to improve water infiltration into the soil profile.

The process is slow and the equipment expensive, requiring most golf courses to hire a contractor. Moreover, going over the green once (with a 6” spacing between holes) renovates only approximately 5% of the root zone. Therefore, the process must be repeated multiple times for best effect.

6.2.5 Root Zone Injection

Sand Injection

Sand injection, which injects small columns of sand into the root zone without removing cores, has been used recently as a supplement to traditional core aeration. The injection depth should be adjusted so the majority of sand is injected where it is needed most, often in the upper root zone.

High-Pressure Water Injection

A more effective and slightly longer lasting summer approach for promoting water penetration and air exchange is high-pressure water injection. Fine streams of high-velocity water are injected, creating channels that are 1/8-1/4" diameter to a depth of 4-8". These small diameter holes do not disrupt play and have been shown to improve water infiltration for three to four weeks. Thus, high-pressure water injection, conducted every three to four weeks in the summer, serves as an excellent supplement to hollow-tine aerification to prevent summer putting green decline.

Air Injection

Air injection, which is a new technology that laterally injects pressurized air beneath the surface of the soil, is used to relieve compaction, and increase porosity. A benefit of this technology is that the turfgrass surface has little to no disturbance.

6.3 Surface Cultivation

The goals of surface cultivation are to manage organic matter accumulation above the soil, reduce the formation of leaf grain, improve infiltration, and improve surface consistency (Table 13). These methods are generally less disruptive than traditional aeration practices and can quickly impact a large percentage of the turfgrass canopy. They usually have low to no impact on soil compaction.

Table 13. Surface cultivation practices

Method	Compaction relief	Surface disruption	Water/air movement	Disruption of play
Vertical mowing	Low	Medium to High	Medium	Low to High
Spiking/slicing	None	Low	Low	None

Figure 18. Vertical mowing at Hermitage Country Club.

6.3.1 Vertical Mowing

Vertical mowing can be incorporated into a cultural management program to achieve a number of goals. The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Frequent, light vertical mowing minimizes grain formation. Deeper penetration of knives stimulates new growth by cutting through stolons and rhizomes while removing accumulated thatch. A more aggressive, deep vertical mowing can reach a depth of 0.5-1", removing a greater amount of thatch compared with other cultivation practices. Even though this is beneficial, deeper vertical mowing should not be used when the grass is growing slowly because aggressive growth is needed to fill in disturbed areas.

6.4 Topdressing

The primary goal for any sand topdressing program is to dilute organic matter and produce smooth, firm putting surfaces while minimizing golfer and mower impact. As part of a program, sand topdressing improves the soil structure and can relieve surface compaction, improve drainage, increase water and air infiltration, and protect turf crowns. The important considerations for a sand topdressing program include sand type, application rate, and application frequency.

6.4.1 Sand Type

When purchasing sand for topdressing, it is important to consider the source, cost, texture, and overall quality of the sand. For example, angular sand performs better than spherical shaped sand for topdressing. Two or more sand materials can be used for a topdressing program; a coarse type for aeration and topdressing when playability is less important (e.g. as part of winterization preparation), and another less-coarse sand that can be used for routine topdressing to minimize disruptions to play.

Similarly, topdressing with sand with greater than 25 percent fine material (0.15-0.25 mm) could potentially lead to problems associated with layering, such as increased moisture at the surface of the greens. Collecting soil cores and analyzing for physical characteristics every few years can be used to monitor putting green performance.

6.4.2 Application Rate and Frequency

Two application rates must be considered in a topdressing program: the rate for each topdressing event and the annual rate achieved from the sum of all topdressing events. An annual rate of 25-35 cubic feet of sand per 1,000 ft^2 is a typical range for dilution of organic matter. Factors to consider in determining optimal topdressing rates include the length of the growing season, quality of the growing environment, turfgrass species and cultivar, nitrogen fertilization program, and traffic intensity.

Individual application rates must be considered in conjunction with the application frequency, as increasing application frequency decreases the topdressing rate. Light and frequent topdressing (e.g. on the order of every one to three weeks) is usually recommended, which reduces the disruption to playing surfaces and is easier to apply and incorporate. See Table 14 for application rates for light and frequent topdressing. When necessary, an accelerated program can be followed to quickly improve root zone conditions and playability.

For more information on topdressing recommendations, see the USGA article "Light and Frequent Topdressing Programs."

Table 14. Light and frequent topdressing rates

Quantity (ft^3/1,000 ft^2)	Quantity (lbs/1,000 ft^2)	Quantity (tons/acre)	Depth of Application (inches)
0.50	50	1.1	0.006
0.75	75	1.7	0.009
1	100	2.2	0.012

Figure 19. Sweeping topdressing at Heritage Oaks Golf Club.

6.4.3 Topdressing with Compost

While the most frequent material for topdressing golf turf is a specified sand, topdressing with compost has a number of advantages. Virginia has a wide variety of quality compost materials available. While it is highly unlikely a compost source would be used on putting greens because the focus is on keeping water moving into and through these soils, regular compost applications on heavier textured, naturally occurring soils such as fairways and roughs can enhance soil structure and improve overall soil health. Research at Penn State reported that as little as 0.25 inch depth of topdressed compost applied one to two times per year vastly improves soil health within a few years and improves soil properties more quickly when linked to core aeration events. Improving the soil physical and chemical properties with compost can ultimately reduce overall irrigation, fertility and pesticide inputs.

6.5 Overseeding

Overseeding is the process of seeding a cool-season grass, primarily perennial ryegrass, into a dormant bermudagrass canopy to provide a green late fall to early spring playing surface. Overseeding is not considered a BMP as it may negatively affect the underlying bermudagrass.

Additional late fall to early spring fertilizer applications are often required to ensure proper growth and development of the overseeded perennial ryegrass, which increases the chance of N and P runoff during the winter. The main reasons for overseeding bermudagrass are almost always aesthetics and the potential for increased winter golf revenue. This common Virginia scenario may have a number of disadvantages, including:

- Poor aesthetics.
- Poor playability (i.e. ground-under-repair).
- Added costs for re-establishment (fertilizer, aerification, seeding, sprigging, sodding, irrigation, labor).
- Greater weed pressure.
- Open soil susceptible to loss of sediment-bound N and P.
- Resource-depleted bermudagrass stand more susceptible to winter-kill.

Thinning of the bermudagrass stand occurs due to competition. In the spring, perennial ryegrass competes very aggressively with the greening-up bermudagrass until air temperatures consistently reach the high 80 degrees F, which may not occur until late June in many parts of Virginia. Such competition delays total bermudagrass fill-in and, if a heat wave causes the overseeding to quickly die, results in a thin, soil-exposed stand of bermudagrass. For courses that still choose to overseed, gradual transitions from bermudagrass to perennial ryegrass in the fall and back to bermudagrass in late spring are necessary to maintain consistent turf playability.

For superintendents who do chose to seed, a number of considerations apply. For example, seeding too early can result in excessive bermudagrass competition and disease pressure (gray leaf spot and Pythium damping-off) that thins the perennial ryegrass seedlings to the point where re-seeding is necessary. Seeding too late may result in reduced seedling vigor and thin perennial ryegrass cover through the winter. Consistent night temperatures of around 50 degrees F are one of the most dependable indicators for overseeding timing. In addition, overseeding should be completed two to three weeks prior to the first killing frost. These timings minimize bermudagrass competition and still provide sufficient soil and air temperatures for perennial ryegrass germination and development.

Figure 20. Overseeding at Hermitage Country Club.

6.5 Rolling

Rolling can help smooth the putting surface and maintain speeds at higher HOC. Even with a raised HOC, rolling can increase ball roll by 10 percent. Light-weight rollers typically have little negative impact on soil compaction unless the practice is overutilized or is used on high silt and clay soils when saturated with water. Rolling can also be used to remove dew from the playing surface, which reduces the possibility of dollar spot.

Figure 21. Rolling at Heritage Oaks Golf Club.

6.6 Wetting Agents

Wetting agents have the general purpose of reducing the surface tension of water and increasing the distribution or penetration of water or solution on plants or in soils. They can be used for a number of reasons, such as treating dry spots; preventing dry spot development; to move water into and through the soil; improve irrigation efficiency; or as a spray adjuvant when applying pesticides or PGRs. Wetting agents are especially helpful when applied to sandy soils that can become hydrophobic (water repellent). Turf grown on sand-based root zones can develop severe localized dry spots (LDS) especially when the stand is irrigated deep and infrequently. Surfactants help promote water infiltration into these hydrophobic areas which prevents and alleviates LDS.

Research shows preventive applications can increase soil water uniformity and sustain high visual turfgrass quality at very low levels of irrigation (30% pET). Preventive applications of wetting agents can also increase irrigation precision, which reduces water use while maximizing playing conditions. In addition, their use can reduce electrical usage and wear and tear on pumps associated with irrigation systems. Late fall applications may reduce water repellency in soils well into the spring after being applied in the late fall, reducing the potential for LDS in the spring. In Virginia, the benefits of a late fall application will typically last until April.

For more information on wetting agents, see the USGA publication *Understanding Wetting Agents*.

In addition to a variety of chemistries available for wetting agent products, natural options to improve water movement in the soil include yucca extracts and gypsum (calcium sulfate).

6.7 Plant Growth Regulators

There are two broad categories of PGRs used in fine turf: Type I (products that disrupt cell division, suppressing both vegetative growth and seedhead formation) and Type II (products that reduce cell elongation and have little to no effect on seedhead formation). PGR selection for golf turf changes throughout the growing season depending on the turf to be treated (greens, tees, fairways, or roughs), the turfgrass itself, and the desired response. Plant growth regulators are frequently used to reduce clipping yield, improve stress tolerance, and improve turf quality and performance. Additional benefits of using PGRs is a reduction in the use of other inputs (e.g. labor, fuel, fertilizers, pesticides).

PGRs require frequent reapplication during the growing season to maintain consistent growth suppression, but excessive PGR use can result in a number of undesirable side effects. These side effects might include mild discoloration, stressed turf, and segregation of grasses like creeping bentgrass and annual bluegrass. These effects can be confused with disease and can intensify damage from pests and traffic.

The best approach to planning PGR applications is to use growing degree day (GDD) thresholds instead of a calendar-based schedule. Free tools are available online for assistance in using GDD information to schedule PGR applications. For more information on using GDD to schedule PGR applications, see the Golfdom article "Looking at GDD: The Perils of PGR Over-Regulation."

6.9 Cultural Practices Best Management Practices

Mowing

- Follow the recommended HOC for different turf species.
- Raise HOC by at least 30% in heavily shaded areas to improve turf health.
- Routinely use plant growth regulators, if needed, to improve overall turf health in shaded environments.
- Increase HOC in times of stress such as heat, drought, or prolonged cloudy weather to increase photosynthetic capacity and rooting depth of plants.
- If turf becomes too tall, it should not be mowed to the desired height all at once. Tall grass should be mowed frequently and HOC gradually decreased until the desired HOC is achieved.
- Mowing frequency should increase during periods of rapid growth and decrease during dry, stressful periods.
- Decrease mowing frequency and increase HOC when the turf is stressed.
- Change mowing patterns on all locations of the golf course.
- Change direction of mow on greens every time the turf is mowed.
- Rarely use inefficient mowing patterns (e.g. 9-3) on areas other than putting greens to save time, fuel, and labor.

- Return clippings to the canopy whenever possible.
- Use compressed air to blow off clippings from mowing equipment over grassed areas and before washing equipment.
- Collect pesticide-free clippings and compost or distribute them in natural areas, away from surface waters.
- Use proper mowing equipment.
- Regularly sharpen and adjust blades.

Aeration

- When thatch levels are excessive, core aeration programs should be designed to remove 15% to 20% of the surface area and to minimize grain formation.
- High traffic areas may require a minimum of two to four core aerations annually.
- Core aeration should be conducted only when grasses are actively growing in the spring and fall to aid in quick recovery of surface density.
- Aeration events should be as deep as practical to prevent development of compacted layers in the soil profile as a result of cultivation.
- Consider timing of core aeration to avoid the period of *Poa annua* (annual bluegrass) seed head formation.
- Backfill holes with new root zone materials if a drill-and-fill machine is used.
- High-pressure water injection can be applied once every three to four weeks throughout the summer.

Surface Cultivation

- Initiate vertical mowing when thatch level reaches 0.25-0.5" in depth. Shallow vertical mowing should be done at least monthly on putting greens to prevent excessive thatch accumulation.
- Vertical mowing depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.
- Aggressive or deep vertical mowing should not be used when the turf is growing slowly.
- Frequent shallow vertical mowing on putting greens prevents excessive thatch buildup and grain formation.

Topdressing

- Assess root zone physical characteristics regularly by analyzing core samples to determine topdressing needs and evaluate the topdressing program.
- Know the sand source and ensure that sand is weed-free, uniform, and of appropriate quality.
- Use silica sand if possible because of its tolerance to weathering.
- Determine a rate and frequency for each topdressing event based on an annual topdressing goal, adjusting if needed to match growth and organic matter accumulation.
- Use light and frequent topdressing applications with or without aeration, according to Table 14.
- Aeration backfill should closely match the physical characteristics of the sand used at construction, but routine topdressing sand can be somewhat less coarse to ease incorporation and reduce wear on mowers.
- Light sand topdressings can be effectively brushed, rolled, or irrigated into the turf canopy.

- ❖ Double-mowing and increasing the frequency of clip should be avoided following topdressing to reduce sand harvesting and wear on mowers.

Rolling

- ❖ Roll putting surfaces following mowing to increase putting speeds and allow for improved ball roll without lowering HOC.
- ❖ Avoid rolling on saturated soils to avoid compaction.
- ❖ Use lightweight rollers to minimize potential compaction.

Overseeding

- ❖ Time overseeding to minimize bermudagrass competition, ensuring that soil and air temperatures are sufficient for perennial ryegrass germination and development.
- ❖ Open up and remove much of the slow-growing bermudagrass canopy by lowering the HOC for a slight scalping to improve seed to soil contact and improve establishment.
- ❖ For best uniformity and to avoid skips, spread seed in at least two directions.
- ❖ Seed fairways and tees at 250-800 pounds of pure live seed per 1,000 ft^2; the specific rate chosen depends on the experience and expectations of the golf course superintendent.
- ❖ Consider sand topdressing (5-10 tons/acre) and dragging following seeding for greater establishment.
- ❖ Apply a starter fertilizer at seeding to supply 0.5 lb N per 1,000 ft^2 to provide adequate N and P for seedling development.
- ❖ In dry conditions, irrigating lightly 3-4 times daily keeps the surface moist but not puddled.
- ❖ When seedlings reach about 1”, approximately 14-28 days after seeding, mow at a 0.75” HOC to allow seedlings to root.
- ❖ Fertilize after the first or second mowing and continue until cold weather at a rate of 0.25–0.5 lbs N per 1,000 ft^2 every three to four weeks with a soluble N source.
- ❖ Apply P and K application based on need established solely by soil test results.
- ❖ Control perennial ryegrass as summer approaches. In the hottest areas of Virginia, encourage it to die out by scalping, increasing application rates of soluble N, aggressive vertical mowing, and reducing irrigation.

Wetting Agents

- ❖ Preventive applications of wetting agents should be made to high risk (sandy) soils.
- ❖ Frequent preventive applications prevent development of localized dry spot and increases soil water uniformity.
- ❖ Water-in wetting agents sufficiently.
- ❖ Apply wetting agents in the late fall to reduce water repellency in soils and reduce the potential for localized dry spot.

PGRs

- ❖ Use GDD to plan PGR use.
- ❖ Consider the selection and timing of PGR applications, which is critical to achieve desired turfgrass responses.

7 INTEGRATED PEST MANAGEMENT

When turfgrasses face stresses such as the heat and drought found in Virginia's transition zone climate, pests can become a problem. Pesticides alone will not control pests; a more effective approach is to develop an IPM program to reduce pest damage and reliance on pesticides. The EPA defines IPM as "an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices."

The primary objective of an IPM program is to reduce the total pesticide load on the golf course by using a combination of tactics to control or manage pests. This approach considers all strategies to reduce pest damage to acceptable levels in the most economical means, while simultaneously accounting for impacts on humans, property, and the environment.

7.1 Regulatory Considerations

7.1.1 Pesticide Usage

As described in detail in the next chapter ("Pesticide Management"), pesticide usage needs to follow state and federal regulatory requirements. The label is the law and must be followed at all times.

7.1.2 Prescribed Burns

Prescribed burns can be part of an IPM program to control weeds and other growth. State law (9VAC5-13) allows open burning for forest management and agricultural practices, provided the burn is at least 1,000 feet from any occupied building unless the occupants have given prior permission, other than a building located on the property on which the burning is conducted. The burn must also be attended at all times. Some local ordinances may supersede state laws and regulations, so local government should be contacted prior to initiating a prescribed burn.

7.2 IPM Overview

IPM is comprised of a range of pest control methods or tactics designed to prevent pests (insects, pathogens, nematodes, weeds, etc.) from reaching economically or aesthetically damaging levels while creating the least risk to the environment. IPM programs have basic components that provide the opportunity to make informed decisions on the control of pests at a golf course. Five steps for an effective IPM program for turf are as follows:

Step 1: Monitor pests and their damage and record information.

Step 2: Identify pests and understand their biology.

Step 3: Determine threshold levels.

Step 4: Consider a variety of control methods.

Step 5: Evaluate the IPM program.

IPM is flexible, and superintendents can usually balance course quality and environmental goals through its implementation. Growing healthy turf is the best and first line of defense against pests. For example, cultural conditions that predispose turfgrass to diseases include close mowing, inadequate or excessive nitrogen fertility, frequent or excessive irrigation, inadequate thatch management, poor drainage, and shade. Following cultural BMPs and nutrient BMPs can help alleviate these conditions. However, under the right conditions, pests can sometimes cause excessive damage to highly managed turfgrass.

A number of non-chemical and chemical control options are available. When chemicals are needed, selection of an appropriate pesticide should follow an evaluation process that considers potential impacts on beneficial organisms and the environment, as well as the potential for development of pesticide resistance. Pesticide products should be rotated, based on their resistance classification.

7.3 Monitoring Pests and Recording Information

In the IPM plan, pest monitoring or "scouting" efforts should be described for all areas of the course such as putting greens, tees and fairways, roughs, and landscaped areas. Scouting methods include visual inspection, soil sampling, soap flushes, and trapping of insects. Additional monitoring efforts can include weather tracking, which is especially helpful for predicting potential disease outbreaks. Here is one potential scouting schedule: daily on putting greens, at least weekly on tees and fairways, twice a month on roughs, and whenever the potential for pests increases due to weather. For example, warmer temperatures combined with high humidity favor the development of diseases such as dollar spot and brown patch.

When pests are discovered during monitoring, the pest pressure should be quantified with measurements such as:

- Number of insects per unit area.
- Disease patch sizes.
- Percent of area affected.

Documentation should include useful information, such as photographs, delineation of pest boundaries on an area map, outbreak date, description of the prevailing weather conditions, and recent management practices. This information can be used to build a database for reference in future seasons and for updating the IPM plan.

7.4 Identifying and Understanding Pests

Once detected, pests must be properly identified. Understanding the biology of pest species and their vulnerable life stages assists in later control efforts. Just as important as identifying pests is recognizing and understanding beneficial organisms and their life cycles so their populations are not unduly negatively affected while managing pests. Superintendents and staff should continually hone their diagnostic skills by attending training seminars and field days, obtaining reference materials, and providing peer-to-peer training.

7.4.1 Diseases

Both warm- and cool-season turfgrasses are susceptible to a number of diseases. In many cases, diseases develop when conditions are favorable, regardless of management strategies. However, the severity of disease is often greatly reduced by using cultural, biological, and genetic techniques. As a rule, healthy, well-managed turf better withstands disease outbreaks and recovers more rapidly than unhealthy turf.

In order to effectively treat turf diseases and implement an IPM program, it is important to know which disease is most likely to be active. Managers who do not understand disease pathology risk treating the symptom, rather than the underlying disease. Turf diseases are typically most common in the summertime for cool-season grasses and in the spring and fall for warm-season grasses. These diseases occur largely due to the shift in growth habits of the grasses from active growth to survival, giving a competitive advantage to disease pathogens.

Understanding the potential diseases for a given species or cultivar and the environmental conditions associated with them is essential. In situations where diseases develop, proper diagnosis assists with decisions on how best to proceed. Diagnostic services are available from the Plant Disease Clinic at Virginia Tech and private laboratories and can help prevent choosing the wrong products or management tactics. Some of the more common golf turfgrass disease problems are described in Table 15.

Table 15. Common golf turfgrass diseases

Conditions Favoring Disease Development	Disease (Common Names)
Cool-season turfgrasses	
Low N	• dollar spot • anthracnose • brown ring patch
High N	• brown patch • Pythium diseases • snow molds (*Microdochium* patch and *Typhula* blight)
General	• Fairy ring caused by various basidomycete fungi (both cool- and warm-season grasses) • leaf spots and melting out
Warm-season turfgrasses	
Low N	• dollar spot
High N	• large patch • leaf spots
General	• spring dead spot

7.4.2 Weeds

Weeds are unwanted plants that are unsightly, disrupt playability, harbor pests, and competitively displace desirable turfgrass. Bermudagrass may be a desirable turfgrass on a golf fairway but be a serious weed in the neighboring golf rough, tees, or putting greens. Weeds exploit openings in the turfgrass canopy, where seedlings germinate and survive to become a persistent colony of perennials or seed-producing annuals.

The potential for invasive weeds can be limited through implementation of the BMPs identified in this document related to turfgrass selection, nutrient management programs, irrigation, and cultural practices. For example, sites that are over-irrigated may have higher densities of weeds, such as green kyllinga or yellow nutsedge. Cultural practices, such as mowing height, frequency, and maintenance, can also impact turf weed populations. For example, not following the one-third mowing rule and mowing too short can open the canopy and provide a competitive advantage to germinating weeds. Because of the importance of soil quality in growing healthy turf, emphasis should be placed on soil testing for the maintenance of turf that can withstand pressure from weeds.

Virginia Tech's Weed Identification web page offers identification images and text on hundreds weeds of Virginia and surrounding areas. VCE also offers free weed identification and control recommendations though its county agents. Fresh plant samples can be placed in a re-sealable storage bag and mailed to the Virginia Tech Weed Clinic or a County Extension Office.

7.4.3 Nematodes

Plant-parasitic nematodes adversely affect turfgrass health by debilitating the root system of susceptible species, thus decreasing the efficiency of water and nutrient uptake. Turf weakened by nematode infestations favors further pest infestation, especially weeds. Over time, turf in the affected areas thins out and, with severe infestations, may die. Turfgrass often begins showing signs of nematode injury during additional stresses, including drought, high or low temperatures, and wear. Sampling is recommended to identify nematodes and to develop threshold levels and treatment strategies.

7.4.4 Insects/Arthropods

Annually recurring insect pest groups on Virginia golf courses include numerous species:

- Billbugs.
- Grubs.
- Armyworms, cutworms, and sod webworms (Lepidoptera).
- Nuisance ants and red imported fire ant (Hymenoptera).

Occasional pests include the northern mole cricket (Orthoptera) in sandy soils and common chinch bug (Hemiptera).

White grubs are the larval stage of a group of beetles collectively known as scarabs (family Scarabaeidae). Among the white grub species causing turf injury in Virginia are:

- Several annual white grub species.
- Black turfgrass ataenius, *Ataenius spretulus*.

- Annual bluegrass weevil (Coleoptera).

White grubs can destroy significant areas of turfgrass, with damage appearing in summer. Summer drought stress and insufficient irrigation may compound the damage to turf by grubs burrowing into grass stems. For more information on IPM methods and control methods specifically for annual bluegrass weevils, see *Diagnosis and Decision Making for Sustainable Annual Bluegrass Weevil Management*, New York Golf Course Foundation and Cornell University.

Figure 22. Soap flushes are an IPM scouting technique in use at Heritage Oaks Golf Club.

7.5 Determining Threshold Levels

A key feature of IPM programs is the identification of tolerance thresholds. Thresholds are based on the pest population, the stage of the pest, and the life stage of the plant. Injury thresholds represent the pest level population that causes unacceptable injury. Treatment thresholds are less than the injury threshold and indicate the number of pests or level of damage that would justify treatment to prevent the pest population from causing unacceptable turf loss.

7.6 Control Methods

Once a pest problem reaches the established treatment threshold, different methods can be used to control the problem, including cultural, mechanical, biological, and chemical. Selecting the most appropriate approach depends on a number of factors, including the site-specific location on the golf course, efficacy of non-chemical controls for the particular situation, economics, and pest populations.

7.6.1 Cultural Controls

Cultural practices, especially irrigation, mowing, topdressing, core cultivation, and venting, greatly affect both short- and long-term plant health. Using and/or altering cultural practices, especially in times of stress, to keep plants and soil healthy helps turf to better withstand pest pressure. It is important to recognize that turfgrass management practices such as core aeration and sand topdressing, while beneficial, can also stress turfgrass.

7.6.2 Mechanical or Physical Controls

Mechanical methods, such as vacuuming, or physical control methods, such as hand pulling weeds, exclude or remove pests, though these methods may be time consuming and work best when pest populations are low.

7.6.3 Prescribed Burns

As golf courses convert maintained turfgrass areas to native-grassed sanctuaries, many facilities use prescribed or controlled burns to reduce undesirable plants, including noxious weeds, and to encourage desirable species, enrich wildlife, and remove excessive plant debris. Prescribed burns are especially effective in suppressing cool-season grasses and woody plant materials to create a more desirable stand of a links-style course that resembles a tallgrass prairie. Use of a prescribed burn, along with other control methods, is an IPM approach to effectively manage these eco-sensitive areas. For more information, see "Beyond the Bonfire: A Primer on Prescribed Fire for Virginia's Private Landowners."

As noted in the "Regulatory Considerations" section of this chapter, any local notification requirements should be followed as required and all fire danger information reviewed before conducting a controlled burn.

7.6.4 Biological Controls

The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms. Several organisms known to have some efficacy against turfgrass pests have been marketed as pest control products, such as such as *Bacillus licheniformis.* Natural enemies (e.g. ladybird beetles, green lacewings, and mantids) of some insect pests may be collected or purchased and released near pest infestations. Areas on the golf course can also be modified to better support natural predators and beneficial organisms, especially in landscaped areas.

7.6.5 Pesticides/Chemical Controls

Chemical control is an acceptable IPM practice when other methods will not alleviate the pest problem. In addition to traditional chemical control, reduced-risk pesticides and biopesticides provide a number of advantages over conventional pesticides and should be considered if applicable. The selection and use of conventional pesticides should follow a selection process and these criteria:

- Use a recommended product to treat a correctly identified pest. See Chapter 7 of the *2020 Pest Management Guide: Horticultural and Forest Crops*, VCE.
- The pesticide should be effective in treating the pest problem.
- The timing of the pesticide application should be based on GDD information for the pest to be controlled. GDDTracker is an example of a tool that can assist in timing applications.
- Pesticides should be rotated, based on resistance classification, as classified by the Fungicide Resistance Action Committee (FRAC), Herbicide Resistance Action Committee (HRAC), and Insecticide Resistance Action Committee (IRAC).
- Costs should be considered.
- Environmental risk and potential for water quality impacts must be evaluated.
- Any restrictions on the pesticide label must be reviewed and rigorously followed.

Evaluating the environmental risk and potential for impact on water quality can include the use of software, such as the Windows Pesticide Screening Tool (WIN-PST), which was developed by the NRCS to evaluate the potential of pesticides to move with water and eroded soil/organic matter and to affect non-targeted organisms. WIN-PST users can select combinations of active ingredient, soil type, and growing conditions to select an active ingredient that has less potential to leach and/or run off into surface water.

The use of all pesticides must follow the label and adhere to state and federal regulations, as described in the "Pesticide Management" chapter.

Reduced Risk Pesticides and Biopesticides

The EPA's Conventional Reduced Risk Pesticide Program registers reduced-risk pesticides, which are commercially viable alternatives to conventional pesticides. The EPA characterizes the advantages of reduced-risk pesticides as follows:

- Low impact on human health.
- Lower toxicity to non-target organisms (birds, fish, and plants).
- Low potential for groundwater contamination.
- Low use rates.

- Low pest-resistance potential.
- Compatibility with IPM practices.

Biopesticides, which are derived from such natural materials as animals, plants, bacteria, and certain minerals, are classified separately by the EPA. For more information on biopesticides, see EPA's Biopesticide Registration page.

7.7 Evaluation and Record Keeping

It is essential to record the results of IPM-related efforts to develop historical information, document patterns of pest activity, and evaluate successes and failures. Records of pesticide use are required for all general and restricted use pesticide applications and maintained for two years following applications. (2VAC5-685-210). For IPM purposes, records should include additional information, such as monitoring records, weather records, cultural management logs, and pest response.

7.8 IPM Best Management Practices

- ❖ Develop a facility-specific, written IPM plan. Available resources for writing an IPM plan include the Golf Course Superintendents Association of America's IPM information and online tools.
- ❖ Select turfgrass cultivars and species recommended for use in areas with similar climate and best suited for the intended use and environmental conditions of the specific site.
- ❖ Correct the soil's physical and chemical properties that may impact turfgrass health and its ability to resist pests.
- ❖ Evaluate the potential impact of the timing of cultural practices and nutrient applications on the incidence of pest problems.
- ❖ Use a defined pesticide selection process to select the most effective pesticide with the lowest toxicity and least potential for off-target movement.
- ❖ Document all IPM-related activities, including non-chemical control methods and pesticide usage.

Monitoring Pests and Recording Information

- ❖ Monitor prevailing environmental conditions for their potential impact on pest problems.
- ❖ Train personnel how to regularly monitor pests by scouting or trapping.
- ❖ Identify alternative hosts and overwintering sites for key pests.
- ❖ Assess pest damage when it occurs, noting particular problem areas, such as the edges of fairways, shady areas, or poorly drained areas.
- ❖ Document when the damage occurred. Note the time of day, date, and flowering stages of nearby plants.
- ❖ Map pest outbreak locations to identify patterns and susceptible areas for future target applications.

Identifying and Understanding Pests

- ❖ Identify key pests in the IPM plan.

- ❖ Determine the pest's life cycle and know which life stage to target (e.g. for insect pests, whether it is an egg, larva/nymph, pupa, or adult).
- ❖ Identify pests accurately. For diseases, correctly identifying the disease pathogen often involves sending samples to a diagnostic laboratory.

Determining Thresholds

- ❖ Establish injury and treatment thresholds levels for key pests and document them in the IPM plan.

Control Methods

- ❖ Implement proper cultural, irrigation, and turf management practices to reduce stress and pressure of pest establishment.
- ❖ Maintain a proper fertilization schedule to improve turf density and quality and reduce pest populations.
- ❖ Make sure your materials, such as topdressing, are pest-free.
- ❖ Apply a preventive pesticide to susceptible turfgrass when unacceptable levels of disease are likely to occur.
- ❖ Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- ❖ Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- ❖ When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem.
- ❖ Release insect-parasitic nematodes to naturally suppress insect pests such as white grubs.
- ❖ Identify areas on the golf course that can be modified to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- ❖ Install flowering plants that can provide parasitoids with nectar or sucking insects (aphids, mealybugs, and soft scales) with a honeydew source.
- ❖ Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.
- ❖ Follow a selection process when conventional pesticide use is warranted.
- ❖ Follow guidelines and advice provided by the FRAC, HRAC, and IRAC to reduce the likelihood of pesticide resistance.
- ❖ Evaluate use of reduced-risk pesticides and biopesticides to treat the problem.

Prescribed Burns

- ❖ Follow local permitting requirements.
- ❖ Notify the following of when/where an open burn will occur: local fire department, municipality nearest the burn, the county sheriff's department, and any military, commercial, county, municipal or private airport or landing strip that may be affected by the open burn.
- ❖ Make sure the burn area is free of any debris.
- ❖ Ensure that the prevailing winds during the burn are away from any town/city or any occupied residence likely to be affected by the smoke to the best extent possible.
- ❖ Minimize the amount of dirt in the material being burned to reduce smoldering.

- Conduct open burns between three hours after sunrise and three hours before sunset to allow for smoke dispersion and to avoid air inversions that can trap the smoke at breathing level. Additionally, fuel should not be added outside the timelines listed above.
- Extinguish an open burn completely to ensure smoldering of material does not persist.
- Do not create a traffic hazard on any public road or airport right of way or obscure visibility.
- Use common sense precautions, such as having someone watching the fire until it is extinguished and assuring smoke does not impact residences or impair vehicular travel on highways.

Evaluation and Record Keeping

- After treatment, determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.
- Observe and document turf conditions regularly, noting which pests are present, so that informed decisions can be made regarding the damage the pests are causing and what control strategies are necessary.

8 PESTICIDE MANAGEMENT

Pesticide use should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices. When a pesticide application is deemed necessary, its selection should be based on effectiveness, toxicity to non-target species, cost, site characteristics, and its solubility and persistence in the environment.

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater, surface water, and human health. For this reason, it is essential that facilities for storing and handling pesticides be properly sited, designed, constructed, and operated in accordance with federal and state regulations.

8.1 Regulatory Considerations

8.1.1 Federal Regulations

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is the federal law regulating the manufacture, distribution, sale, and use of pesticides. USEPA regulates pesticides under broad authority granted by FIFRA. The process of registering a pesticide includes scientific, legal, and administrative procedures to ensure the company meets all scientific and regulatory requirements, as described below. Only after the company applying for registration meets the scientific and regulatory requirements is a pesticide approved for distribution, sale, and use.

<u>Pesticide Labels</u>
FIFRA and its implementing regulations govern what must be included on pesticide labels. Pesticide product labels provide critical information about how to safely and legally handle and apply pesticides. Unlike other types of product labels, pesticide labels are enforceable and must include the statement, “It is a violation of Federal law to use this product in a manner inconsistent with its labeling.” In other words, the pesticide label is the law.

<u>Storage Areas</u>
All pesticide storage areas must meet federal minimum requirements set by USEPA:

- The storage area must be secured or locked to prevent unauthorized access.
- Pesticides must be stored in a separate building or, at a minimum, must be separated by a physical barrier from living and working areas and from food, feed, fertilizer, seed, and safety equipment.
- A warning sign must be placed on the exterior of the storage area.
- Pesticides must be stored in a dry, ventilated area.
- The pesticide storage area must be kept clean.
- A supply of absorbent material sufficient enough to absorb a spill equivalent to the capacity of the largest container in storage must be kept in the storage area.
- The storage area must contain only pesticide containers that are properly labeled and are free of leaks.

- Routinely inspect storage areas and products checking for leaking/damaged containers and containers with illegible/missing labels.
- The storage area must have an appropriate fire extinguisher available.
- Pesticides must be stored in an area located at least 50 feet from any water well or stored in secondary containment.

8.1.2 State Regulations

In Virginia, VDACS Office of Pesticide Services enforces the Virginia Pesticide Control Act regulations (2 VAC 5-670). Under these regulations, VDACS certifies applicators, registers pesticide products, and issues pesticide business licenses in order to permit the safe and effective control of pests. These regulations also cover all aspects of pesticide usage, such as storage and handling, disposal, application and equipment, service container labeling, disposal, etc.

Most occupational pesticide users, including turf managers and their employees, must be certified as either a Commercial Applicator or a Registered Technician. Legal obligations are described in the VDACS fact sheet Responsibilities of Commercial Pesticide Applicators and Registered Technicians in Virginia. In addition to complying with the pesticide regulations and certification requirements, pesticide applicators must adhere to requirements of a VPDES permit issued by DEQ that covers pesticide discharges to surface waters.

8.1.3 Local Regulations

Local Fire Marshalls enforce the State of Virginia's Fire Prevention Code, which addresses the storage of hazardous materials, such as pesticides. Depending on the type and quantity of products stored, local ordinances may influence storage location or require fire department inspection. If not required, local emergency responders should be notified of the pesticide storage area location. Additionally, local governments regulate and dictate the required code and methods for backflow prevention. Backflow prevention requirements are discussed in more detail in the “Irrigation” chapter.

8.2 Human Health Risks

Pesticides belong to numerous chemical classes that vary greatly in their toxicity. Acute toxicity refers to a single exposure by mouth, skin, or inhalation, or repeated exposures over a short time. Chronic toxicity effects are associated with long-term exposure to lower levels of a toxic substance, such as ingestion in drinking water. Pesticide toxicity and level of exposure can be a risk to human health. This idea is expressed by the formula: Risk = Toxicity x Exposure. To manage toxicity, pesticide usage should be minimized as part of an IPM strategy, and the least toxic yet effective pesticide should be selected. Exposure can be limited through good work habits, engineering controls (when possible), and protective clothing, Therefore, risk can be held to an acceptably low level if the amount of exposure is kept low.

Pesticide labels provide information on personal protective equipment (PPE) and first-aid information specific to the product. Therefore, applicators should always read and follow the label before using a pesticide, in addition to following standard safety practices. Safety Data Sheets (SDS) provide important information on hazardous chemicals. In addition, exposure to pesticides can be mitigated by practicing good work habits and adopting modern pesticide mix/load equipment (e.g. closed loading) that reduce potential exposure. SDS for pesticides can be found in an online database of U.S. registered pesticide labels.

Potential routes of exposure to golfers include ones via shoes, clothing, and equipment. Pesticide labeling addresses re-entry restrictions, and any application should be allowed to thoroughly dry before play resumes.

More information on pesticide toxicity and exposure can be found in Chapter 1 of *2020 Pest Management Guide: Horticultural and Forest Crops*, VCE.

8.3 Personal Protective Equipment

PPE protects workers from exposure through one or more pathways: skin, eyes, oral ingestion, or respiratory tract. Pesticide labels list legal requirements for minimum PPE, such as specific types of clothing, goggles, and respirators. The type of PPE needed depends both on the toxicity of the pesticide and the formulation. If a pesticide label does not have specific PPE requirements, the route of entry and other information on the label can be used to determine the type and degree of appropriate protection. To avoid contamination, PPE should not be stored in a pesticide storage area.

More information on PPE and laundering pesticide-contaminated clothing can be found in Chapter 1 of *2020 Pest Management Guide: Horticultural and Forest Crops,* VCE.

8.4 Environmental Fate and Transport

Environmental characteristics of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. The environmental hazards statement (referred to as “Environmental Hazards” on the label and found under the general heading “Precautionary Statements”) advises the user of product specific concerns. Potential environmental impacts include toxicity to non-target organisms (such as pollinators) and contamination of surface water or groundwater. If endangered species are present on or near the course, labeling on applicable pesticide products directs users to the limitations found in the EPA's Endangered Species Protection Bulletins.

The key to preventing pesticide impacts to water quality is an understanding of the physical and chemical characteristics that determine a pesticide's interaction with the environment: solubility, adsorption, persistence, and volatilization. Pesticide characteristics influence the potential for runoff, leaching, or drift. Once applied, pesticides can move off-site in several ways: in water, in air, attached to soil particles, and on or in objects, plants, or animals.

To prevent pesticides from moving off-site, pesticide characteristics, site-specific characteristics, and prevailing weather conditions should all be evaluated. Pesticide characteristics, such as solubility, and site-specific characteristics, such as soil type, depth to the water table, geology, and proximity to surface water, should be considered before selecting and applying pesticides.

Prevailing weather conditions, such as the chance of precipitation, the prevailing wind, and humidity, should be evaluated with respect to the timing of pesticide applications.

A detailed discussion of environmental fate and transport topics is available in Chapter 9 of the 1st edition of *Environmental Best Management Practices for Virginia's Golf Courses*.

8.4.1 Leaching and Runoff

Most pesticide movement in water is either by surface movement off the treated site (runoff) or by downward movement through the soil (leaching). Runoff and leaching may occur when:

- Too much pesticide is applied or spilled onto a surface.
- Too much rainwater or irrigation water moves pesticide through the soil off-site or into groundwater.
- Highly water-soluble or persistent pesticides are used.

Pesticide movement in soil and water is affected by its water solubility, adsorption by soil, and persistence. Pesticides with greater adsorption by soil are less likely to be moved by leaching or surface runoff but can be carried to surface water with eroding soil. In addition to following the pesticide BMPs to reduce the likelihood of pesticides moving off-site in surface runoff, the use of buffer strips (as discussed in the "Water Management" chapter of this document) slow down runoff and allow pesticides to adhere to soil particles and plant tissue, preventing contamination of surface water.

Pesticides with less adsorption by soil are more likely to leach through the soil and reach groundwater. For example, if rainfall is high and soils are permeable, water that carries dissolved pesticides may take only a few days to percolate down to the groundwater.

8.4.2 Drift

Air movement causing pesticide transfer away from the application site is called drift. Pesticides may be carried off-site in the air as spray droplets, vapors, or even on blowing soil particles, as follows:

Spray drift: Airborne movement of pesticide particles to non-target sites during application.

Vapor drift: Volatilization of particles from plant and other surfaces during and after application and movement as a gas or vapor to a non-target site in sufficient concentrations to affect plant processes.

The potential for spray drift is strongly related to droplet size; smaller droplets have smaller mass and remain airborne and exposed to air movement longer than larger droplets. Equipment selection and operation characteristics, such as nozzle type, spray pressure, nozzle spray angle, and spray volume, impact the potential for spray drift. Weather-related considerations that can influence the potential for spray drift include wind speed, wind direction, air stability, relative humidity, and temperature.

The formulation of combination products as an amine or ester can also impact the potential for drift. Esters have higher vapor pressures than amines, but typically provide better weed control. In cooler weather, ester formulations can often be used safely. In higher temperatures, the risk of volatilization increases and calls for switching to an amine formulation if drift is a concern.

Vapor drift can sometimes be difficult to predict and depends on the factors such as the pesticide's chemical characteristics and weather, even days after the application. Volatility increases as the pesticide's vapor pressure increases and as air temperature and wind speed increase. Irrigating shortly after surface application of volatile pesticides reduces the potential for vapor drift.

8.4.3 Preventing Drift

Drift management tank additives, as well as nozzle selection and application method, can reduce potential for drift. In addition, weather conditions at the time of application should be considered. Wind speeds of 3-10 mph are best for applying pesticides. More than 10 mph indicates an increasing potential for particle drift while less than 3 mph indicates stagnant air and the potential for temperature inversions. Temperature inversions can result in long-distance drift, which occur when lighter warm air rises upward into the atmosphere and heavier cooler air settles near the ground. Under these conditions, air does not mix, and spray droplets do not disperse and any subtle airflow can move this mass of pesticide spray droplets off-target. Temperature inversions typically start at dusk and break up around sunrise as air mixes vertically.

Drift management directions are typically an integral component of product labeling. Therefore, the pesticide label should be reviewed for specific information on drift reduction techniques or requirements. Weather-related instructions on the label must be followed as well.

For more information on preventing drift, see the University Nebraska-Lincoln Extension publication *Spray Drift of Pesticides*. Some specialty crops are especially sensitive to pesticides. Therefore, pesticide applicators can check the FieldWatch online mapping tools, which includes DriftWatch and BeeCheck that allow those with commercial specialty crops, organic crops, beehives, and other sensitive crops to report their field locations. All applicators applying pesticides outdoors are encouraged to sign up for free access to FieldCheck app and/or free email notices.

8.5 Water Quality

Water is the major component of pesticide spray solutions. Research indicates that the quality of the water can impact pesticide performance. Therefore, performing a water quality test can indicate whether or not water conditioners may be needed to maximize pesticide effectiveness. For example, water conditioners can be added to the spray solution or tank-mix to eliminate problems associated with water hardness. A pH buffer can be used to raise or lower the pH, depending on the desired range needed for optimum performance. Some pesticide formulations already contain water conditioners that make them compatible within a wide range of water conditions. Other products, however, perform better when adjuvants are added to overcome water quality issues. For more information, see the Purdue Extension publication *The Impact of Water Quality on Pesticide Performance*.

8.6 Pesticide Application Equipment and Calibration

Application equipment must apply the pesticide to the intended target at the proper rate. Information on the pesticide label specifies the legal application rate and sometimes suggests the appropriate equipment for use with the product.

Figure 23. Pesticide application at Hermitage Country Club.

8.6.1 Application Equipment Selection

For spray applications, the size of the equipment (tank size, boom width, etc.) should be matched to the scale of the facility. Nozzle selection and coverage, in particular, are important in the control of drift as well as product performance. The type of nozzle, nozzle orifice size, sprayer pressure, and the height or distance of the nozzles from the target affect the potential for off-site movement of pesticides. A nozzle that primarily produces coarse droplets is usually selected to minimize off-target drift. Boom covers can also be incorporated to minimize the potential for drift.

For more information on equipment selection to reduce drift, see the *Spray Drift of Pesticides*, UNL Extension.

8.6.2 Equipment Calibration

To apply liquid or granular pesticides at the proper rate, properly calibrated application equipment is essential. Such equipment mitigates environmental and human health concerns, reduces the chances of over- or under-applying pesticides, and optimizes pesticide efficacy. In addition, applicators must be especially careful to avoid exposure through inhalation when applying granular products. Equipment should also be checked frequently for leaks and malfunctions.

For more step-by-step instructions for calibrating boom sprayers, see Chapter 1 of *2020 Pest Management Guide: Horticultural and Forest Crops*, VCE.

8.6.3 Emerging Technologies

The technological advancements of the 21st century will further enhance the golf turf manager's abilities to deliver a high quality, healthy golf turf. The first generation of soil sensors monitoring moisture, temperature, and salt levels are already in use at many facilities, but their functionality is somewhat limited by data transmission capabilities and their size when placed in the soil. The expansion of 5G (fifth generation) wireless networks will provide for data collection and exchange capabilities that could only recently be imagined, and coupling this with "smart technology" utilizing artificial intelligence, remote sensing, global positioning radio navigation systems (GPS), and robotics, the opportunities for further refining golf turf management are seemingly endless.

Drones are regularly being used as a means of routine course inspections. Incorporating remote sensing devices will further refine opportunities for monitoring and managing plant stress. Robotic mowers are already making waves in golf turf management, offering mowing precision suitable for mowing putting greens. Unit costs are obviously significant for early generation technology. But with labor being one of the largest challenges in golf turf management, the ability for a crew to engage the robotic mowers and then complete other tasks is offering valid economic arguments for these units, and it is anticipated that prices will come down in the future.

Figure 24. Drone technology can be used to refine the monitoring of plant stress.

The research program of Dr. David McCall and Jordan Booth, CGCS, at Virginia Tech has already demonstrated the potential environmental and economic benefits of using site specific disease management with a TORO 5800 Spray System equipped with Geo-Link GPS technology. After developing disease incidence maps utilizing drones to fly over the golf course fairways in the spring to assess the location and size of spring dead spot (SDS) areas, the sprayer combines the map data with the GPS technology to apply the fungicide the following fall only to the areas where the disease has previously occurred. (SDS is a monocyclic, recurrent soil-borne disease on bermudagrass that infects stems and roots in the fall.)

This treatment strategy has been demonstrated to provide comparable control to traditional blanket-spray approaches in SDS management and to reduce fungicide inputs by 50-65% compared with blanket-spraying. Thus, significant environmental and economic enhancements are gained and playing quality is improved/maintained with the site-specific control of this pest. McCall's research program is expanding into other areas of remote sensing for turfgrass stress (moisture, pests, traffic/compaction etc.) in the utilization of sensors attached to drones and ground-driven recorders. None of these technological tools will eliminate the need for qualified golf turf management staff, but they will further increase the opportunities to improve turf performance and health while enhancing the efficacy of pesticides and/or reducing the amounts of chemical inputs required for a healthy turf.

8.7 Pesticide Record Keeping

Maintaining accurate records of pesticide-related activities (e.g. purchasing, storage, inventory, and applications) is essential and required by state law for all pesticides applied by certified professional applicators and private applicators.

Virginia regulations require Registered Technicians and Commercial Applicators to record all pesticide applications and maintain application records for two years. No specific form or format is required, but records must contain the information that includes, but is not limited to, the following:

- Name, address, and telephone number of the property owner, and address or location of the application site, if different.
- Name and certification number of the person making or supervising the application.
- Date of application (day, month, and year).
- Type of plants, crop, animals, or sites treated.
- The brand or product name of the federally restricted-use pesticide and the product's EPA Registration number.

In addition to record keeping as required by Virginia regulation, additional information increases the effectiveness of pesticides usage as part of an IPM program, such as:

- Stage of development of the treated turfgrass or plant material.
- Life cycle stage of target pest.
- Severity of infestation.
- Beneficial species present.
- Site conditions, such as air temperature, relative humidity, wind speed and direction, rainfall (date and amount), and soil moisture level.
- Other pertinent environmental conditions, such as recent previous attempts to control, basis of selection for treatment(s), and results.
- Pesticide manufacturer, formulation, percent active ingredient, and EPA Establishment Number.

A sample record keeping form is also available found in Chapter 1 of *2020 Pest Management Guide: Horticultural and Forest Crops*, VCE

8.8 Pesticide Storage and Handling

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater or surface waters. For this reason, it is essential that care be taken in transporting pesticides and that the facilities for storing and handling these products be properly sited, designed, constructed, and operated.

Regulatory requirements (2 VAC 5-670-150) for pesticide storage and handling state the following:

> *No person shall handle, transport, store, display, or distribute pesticides in a manner that may endanger humans and the environment, or food, feed, or any other products that may be transported, stored, displayed, or distributed with the pesticides.*

In addition to these general regulatory requirements, guidelines for storage of bulk pesticides include the following:

- Avoid the problem of storing pesticides by purchasing only the amount needed for the current season.
- Store pesticides in their original container with the original label attached. Read each label to determine suitable storing conditions.
- Do not store pesticides with food, feed, seed, planting stock, fertilizers, veterinary supplies, or pesticide safety equipment. Also, avoid storing them next to a water supply.
- Date containers as they are purchased and keep an inventory list so outdated material can be disposed of.
- Designate a building, room, or cabinet specifically for pesticide storage and nothing else. The optimum storage facility should have a concrete floor, which is impermeable and easy to wash; adequate ventilation to avoid extreme heat and to reduce the concentration of toxic or flammable vapors; insulation and supplemental heating if required to meet label specifications; good lighting; and access to water to handle accidental spills.
- Always keep the building, room or cabinet where pesticides are stored locked when the area is unattended.
- Post caution signs at all entrances or doors that warn the area is used for pesticide storage.
- Routinely examine pesticide containers for leaks, corrosion, breaks, and tears, and illegible/missing labels. Clean up spills immediately and properly dispose of containers and cleaning materials. Sawdust, industrial absorbent, cat litter, or dry soil may be used to soak up liquid spills. Sweeping compound can be used with dry spills. Keep cleaning materials in the storage area for quick access.

8.9 Transportation

According to state law, it is a violation to transport pesticides in any manner that will endanger humans, animals, or the environment. Pesticide transport should follow these recommendations:

- Use a ratchet-type tie-down strap or chain binder to secure tanks to the vehicle. Make sure that the strap or chain/chain binder is of sufficient strength to secure the load.
- Inspect all plumbing and secure hoses and other equipment to avoid damage and potential spills.

- Ensure that the transport vehicle is capable of transporting the weight of the container and contents.
- When transporting small containers:
    - Do not transport them inside the passenger compartment.
    - It is suggested that small pesticide containers be placed within a leak-proof container such as a covered plastic container.
    - Never leave pesticides unattended in an unlocked vehicle or an unsecured area where they can be tampered with or stolen.
    - Secure pesticide containers in an area of the vehicle to avoid significant movement or breakage from movement of other items in the vehicle.
- When transporting concentrates in containers other than the original container ensure that the container is labeled with the following:
    - Product name (brand names from product label).
    - EPA registration number (from product label).
    - Name and percentage of active ingredient(s) from the product label.
    - Appropriate signal word; i.e., Poison, Danger, Warning, Caution (from product label).
- When transporting tanks containing end-use dilutions exceeding 3 gallons ensure the tank is labeled with the following:
    - Product name (brand names from product label).
    - EPA registration number (from product label).
    - Name and percentage of active ingredient(s) from the product label.
    - Appropriate signal word; i.e., Poison, Danger, Warning, Caution (from product label).

8.10 Mixing/Washing Station

8.10.1 Mixing

Procedures for mixing of pesticides and washing of pesticide application equipment should prevent the transport of pesticides or pesticide residues into surface waters, groundwater, or down drains. Loading and mixing of pesticides should be over an impermeable surface, such as a concrete pad. In addition, maintain at downslope distance of at least 150 feet from any well when mixing pesticides.

Some herbicide labels list a specific mixing sequence. In absence of specific directions, the recommended sequence for adding pesticide formulations to a tank partially filled with water follows the A.P.P.L.E.S. method:

- Agitate
- Powders soluble
- Powders dry
- Liquid flowables and suspensions
- Emulsifiable concentrates
- Solutions

Each ingredient must be uniformly mixed before adding the next component, e.g. a soluble powder must be completely dissolved before adding the next component. Adjuvants are added in the same sequence as pesticides, e.g. ammonium sulfate is a soluble powder, oil adjuvants are emulsifiable concentrates, and most surfactants are solutions. Within each group, the pesticide is usually added before the adjuvant, e.g., a soluble-powder pesticide before ammonium sulfate.

8.10.2 Cleaning Equipment

Cleaning pesticide equipment is a vital step in the process of applying pesticides. Each and every component of a sprayer system must be thoroughly cleaned. Following cleaning procedures, including those that may be found on the pesticide label, and developing rig- specific standard operating procedures ensures that future pesticide applications go as planned. General cleaning procedures for different types of application equipment can be found in the UNL Extension publication *Cleaning Pesticide Application Equipment*.

Rinsate can be used as a diluent for another batch of finished spray mix or applied to a labeled site following all label directions.

8.11 Disposal

The safest way to dispose of leftover pesticide from professional applications is to use all of the chemical according to directions on the label. This includes the washwater from pesticide equipment washing, which must be used in accordance with the label instructions.

Unusable or unwanted pesticides can sometimes accumulate in the pesticide storage area. Simply keeping them in storage eventually becomes problematic when packaging inevitably deteriorates or corrodes and creates a hazard. Yet disposing of these stockpiles properly can be challenging. The best strategy for dealing with unwanted pesticides is to minimize or eliminate them by buying only enough pesticide for one season, calibrating equipment correctly, mixing only the amount of pesticide needed per application, and selecting pesticides that are easy to measure or ready to use. Disposal options for unwanted or unusable concentrate or product include:

- Legal use.
- Valid label disposal directions.
- Return to point-of-sale or manufacturer/registrant.

- Indemnification.
- Professional waste disposal firm.
- Local, state, or federal waste disposal program.
- Indefinite proper storage.

Rinsate can be used as a diluent for another batch of finished spray mix or applied to a labeled site following all label directions.

Pesticide container management can reduce leftover packaging. Minimizing container disposal efforts can be achieved by the following practices:

- Choosing low-rate products (which reduces container volume).
- Selecting products packaged in a manner that eliminates the need for container disposal (such as water-soluble packaging).
- Using returnable/refillable containers.
- Recycling or reconditioning containers.
- Choosing products packaged in containers that can be disposed of legally and conveniently.

Unused pesticides, pesticide containers, equipment washwater, and container rinsate should be disposed of properly. Virginia's Pesticide Collection Program assists in the proper disposal of unwanted pesticides. The program is an effort by the VDACS OPS.

8.12 Pesticide Container Management

Handling of empty pesticide containers must be done in accordance with label directions as well as with all laws and regulations. Under the federal Resource Conservation and Recovery Act (RCRA), a pesticide container is not empty until it has been properly rinsed. Non-refillable pesticide containers that have been properly rinsed can be handled and disposed of as non-hazardous solid waste; some plastic containers can be recycled. Refillable containers may be returned to the supplier unrinsed.

Proper procedures for cleaning pesticide containers, such as pressure rinsing and triple rinsing, and for storing empty containers must be followed. Following proper rinsing procedures, the container must be punctured or cut in order to render the container unusable. Pesticide containers can be either recycled through participation in a container recycling program or disposed of by depositing them in a licensed sanitary landfill after pressure rinsing or triple rinsing. Ways to reduce the amount of waste that requires handling include identifying and implementing waste-reduction practices and purchasing bulk packaging when possible.

8.13 Emergency Preparedness and Spill Response

Pesticide leaks or spills, if contained, will not percolate down through the soil into groundwater or be carried away in runoff. All accidents or incidents involving pesticides that constitutes a threat to any person, to public health or safety, or to the environment must be reported to VDACS OPS within 48 hours of the accident or incident's occurrence. Further guidance will be provided by the office as to further reporting procedures. Within ten days of initial notification a written report must be submitted that includes all of the required information.

Following an accidental release, spills should be controlled, contained, collected, and stored, as follows:

- Control actively spilling or leaking materials (for example, by setting the container upright, plugging leaks, or shutting the valve) using the appropriate PPE as indicated on the label.

- Contain the spilled material. Barriers and absorbent material should be used for liquids. For dusts, the material should be misted to avoid drift. Containment is usually not necessary for granules and pellets.

- Collect spilled material, absorbents, and leaking containers. These items should be placed in a secure and properly labeled container.

- Store the containers before applying as a pesticide or disposing of properly.

Small liquid spills may be cleaned up by using an absorbent such as cat litter or mulch, diluting with soil, and then applying the soil and absorbent as a pesticide in accordance with label instructions or disposing as a waste. Solid materials can be swept up and reused.

If spills are not contained, controlled, and cleaned up properly, they can harm human health, the environment, or both through leaching or runoff. In the case of an uncontained spill, call CHEMTREC at (800) 424–9300. CHEMTREC is a service of the Chemical Manufacturers Association and can provide emergency response information. DEQ should also be notified if water resources are impacted.

In addition to having a spill kit, emergency preparedness includes having appropriate and readily accessible PPE, SDS sheets on all pesticides used and stored onsite, and reporting notification information.

8.14 Pesticide Management Best Management Practices

Human Health Risks

- ❖ Follow the pesticide label for re-entry period requirements or recommendations following application.
- ❖ Allow all pesticide applications to dry thoroughly before allowing play to resume.
- ❖ Prioritize using lower risk products whenever possible.

Personal Protective Equipment

- ❖ Follow pesticide labels for appropriate PPE.
- ❖ Provide adequate PPE for all employees who work with pesticides, including equipment technicians who service pesticide application equipment.
- ❖ Ensure that PPE is sized appropriately for each person using it.

- Ensure that respirators are seal- and fit-tested properly and that the person is thoroughly trained and has no medical limitations to respirator use.
- Store PPE where it is easily accessible, but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home by providing laundering facilities or a uniform service.
- Meet requirements for the OSHA 1910.134 Respiratory Protection Program.

Pesticide Applications

- Consider pesticide characteristics in the chemical selection process.
- Identify any areas on the course prone to leaching losses (e.g. shallow water tables, sand-based putting greens, coarse-textured soils, etc.). Do not use highly soluble pesticides in these areas.
- Select low- or non-volatile pesticides.
- If listed species or species of concern are present, specifically select pesticides that have no known effects on these species.
- Check the forecast before applying pesticides and apply when conditions are favorable, such as minimal wind velocity, temperature inversions not forecast, rain not forecast, etc.
- Follow the pesticide label to avoid drift.
- Use spray additives (adjuvants, acidifiers, buffers, drift, retardants, compatibility agents, water conditioners, dyes, foamers, etc.) to improve the efficiency of pesticide applications and use within label guidelines.
- Schedule the timing and amount of irrigation needed to water-in products (unless otherwise indicated on label) without over-irrigating.
- If sites adjacent to the application area are planted with susceptible plants or crops, allow a buffer area between the two, or wait until winds are blowing away from the area of concern.

Pesticide Application Equipment

- Use an appropriately sized applicator for the size of area being treated.
- Ensure the spray technician is experienced, certified, and properly trained.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications.
- Check equipment daily when in use.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Calibration of walk-behind applicators should be conducted for each person making the application to take into consideration walking speed, etc.
- Avoid high spray boom pressures; consider 45 PSI a maximum for conventional broadcast ground spraying.
- Use drift-reduction nozzles that produce larger droplets when operated at low pressures.
- Use wide-angle nozzles and low boom heights and keep boom stable.
- When possible, use lower application speeds to avoid drift.
- Use spray additives within label guidelines to improve effectiveness of pesticide and reduce potential for drift.
- Use shielded booms. When banding, use shroud covers.

Pesticide Record Keeping

- Use electronic or hard-copy forms and software tools to properly track pesticide inventory.

- ❖ Keep and maintain records of all pesticides for two years.
- ❖ Use records to monitor pest control efforts and to plan future management actions.

Pesticide Storage and Handling

- ❖ Routinely undergo a “risk assessment” to identify any potential risks to the applicator or environment.
- ❖ Do not transport pesticides in the passenger section of a vehicle.
- ❖ Never leave pesticides unattended during transport.
- ❖ Maintain an inventory of all pesticides used and the SDS for each chemical.
- ❖ Avoid purchasing large quantities of pesticides that require storage for more than six months.
- ❖ Adopt the “first in-first out” principle, using the oldest products first to ensure that the product shelf life does not expire.
- ❖ Locate pesticide storage facilities away from other structures to allow fire department access.
- ❖ Store, mix, and load pesticides away from sites that directly link to surface water or groundwater (e.g. wells).
- ❖ Store pesticides in a lockable concrete or metal building separate from other buildings.
- ❖ Shelving should be made of sturdy plastic or reinforced metal.
- ❖ Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used because it may absorb spilled pesticides.
- ❖ When storing pesticides on shelves, place liquid pesticides on lower shelves and dry formulations above them.
- ❖ Store herbicides, insecticides, and fungicides in separate areas within the storage unit.
- ❖ Storage facility floors should be impervious and sealed with a chemical-resistant paint.
- ❖ Floors should have a continuous sill to retain spilled materials and should not have drains, although a sump may be included.
- ❖ Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- ❖ Automatic exhaust fans and an emergency wash area should be provided. Light and fan switches should be located outside the building, so that both can be turned on before employees enter the building and turned off after they leave the building.
- ❖ Avoid temperature extremes inside the pesticide storage facility.

Mixing/Washing Station

- ❖ Load and mix pesticides over an impermeable surface, such as a concrete pad.
- ❖ Mix pesticides at least 150 feet downslope from any well.
- ❖ Mix materials according to label directions and in amounts that will be used for the application to avoid excess that will need disposal.
- ❖ Either use anti-backflow devices when mixing pesticides or maintain a 6” air gap between mixing container and water source.
- ❖ Pump the sump dry and then clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (i.e. one that cannot be legally applied to the same site).
- ❖ Develop standard operating procedures for the washing and cleaning of different types of pesticide application equipment.

Disposal

- ❖ Collect washwater (from both inside and outside the application equipment) and use as a pesticide in accordance with the label instructions.
- ❖ Apply rinsates as a pesticide (preferred) or stored for use for the next compatible application.
- ❖ Annually review pesticide inventories and properly dispose of unusable and unwanted pesticides.

Pesticide Container Management

- ❖ Rinse pesticide containers immediately in order to remove the most residue.
- ❖ Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.
- ❖ Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.
- ❖ Use refillable pesticide containers only for pesticides.
- ❖ Recycle non-refillable containers when possible.
- ❖ Puncture empty and rinsed pesticide containers prior to disposal.
- ❖ Dispose of containers according to the label.

Emergency Preparedness

- ❖ Keep a written pesticide handling and discharge response plan as required that outlines the procedures to control, contain, and clean up spilled materials.
- ❖ Train all employees on the emergency response plan and emergency procedures.
- ❖ Provide a copy of the written handling and discharge response plan to local authorities.
- ❖ Keep an appropriate spill containment kit in a readily available space.
- ❖ For small liquid spills, use absorbents such as cat litter or sand and apply as a topdressing in accordance with the label rates, or dispose of as a waste.
- ❖ For small solid spills, sweep up and use as intended.
- ❖ Ensure that SDS documents are present and that all employees have been properly trained on their location and contents.
- ❖ Report releases as required.

9 POLLINATOR PROTECTION

Pollination is an essential need for seed-bearing plants. Of the 1,400 crop plants grown around the world, almost 80% require pollination by invertebrates or animals. Pollinating visits from bees and other insects, birds, bats, etc., are a critical component of a stable food supply. In the United States alone, pollination of agricultural crops is valued at billions of dollars annually.

Many pollinator species have experienced significant population declines over the last several decades. While a number of factors have contributed to this decline, the most critical may be habitat loss, largely from large scale agricultural operations and urbanization. The monarch butterfly (*Danaus plexippus*) is an example of one of a pollinator species that resides in Virginia for part of the year that has experienced habitat loss throughout its range. Other issues, such as colony collapse disorder of bee species have also exerted pressure on pollinator populations. Human interaction and the indiscriminate use of certain pesticides is also a factor influencing pollinator populations and biodiversity.

Golf courses are an ideal opportunity to re-establish pollinator habitat and can offer food, nesting, and water resources to meet the needs of pollinators. In addition to enhancing or creating pollinator habitat, superintendents need to be mindful of the potential impact of the use of pesticides on pollinator health. However, superintendents can maintain high quality turf on playing surfaces while protecting pollinators by being mindful of the potential impact of pesticides by using IPM methods, following label requirements related to pollinators, and implementing BMPs that protect pollinators.

Figure 25. Pollinator meadow at Bayville Golf Club.

9.1 Regulatory Considerations

Pollinator protection language is a requirement for pesticide labels, and following the label is mandatory. Pesticide applicators must be aware of honey bee toxicity groups and be able to understand precautionary statements. In addition to following legal requirements, pesticide applicators should understand the effects of pesticides on bees and other pollinators and the routes of potential exposure.

The USGA publication *Making Room for Native Pollinators*, U.S. Department of Agriculture's Forest Service and Pollinator Partnership publication *Bee Basics: An Introduction to Our Native Bees*, and VCE’s publication *Native and Solitary Bees in Virginia* provide basic facts about pollinator biology that are useful to pesticide applicators. In addition, record keeping may be required by law to use some pesticides. Many of the IPM best management practices, such as record keeping, are valuable tools for protecting pollinators.

Some golf courses maintain beehives onsite as a way to increase their environmental stewardship efforts. VDACS has formulated *Virginia’s Voluntary Plan to Mitigate the Risk of Pesticides to Managed Pollinators* with voluntary guidance on protecting pollinators in the state.

9.2 Pest Management Practices

Protecting pollinators on the golf course does not preclude the use of pesticides, but instead minimizes any potential impact from these chemicals. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans.
Using IPM best management practices is an important key to protecting pollinators because they reduce pesticide usage and minimize the potential of exposure. Superintendents can utilize IPM best management practices for turf that protect pollinators by following these simple steps:

- Identifying what is truly a pest. (For example, solitary ground-nesting bees and wasps might be alarming, but most are harmless.)
- Setting higher weed thresholds in low-use areas.
- Monitoring bee activity to avoid applying pesticides during peak activity times (i.e. apply pesticides in the early morning or evening).

When the use of pesticides is necessary, being mindful of pollinators includes selecting chemicals with low toxicity to bees, short residual toxicity, or properties repellent to bees; using caution when applying near flowering plants, including flowering weeds (mow first whenever possible); and avoiding drift. Tables of pesticides based on relative toxicity to honey bees can be found on pp. 32 to 34 of Chapter 1 in the *2020 Pest Management Guide: Horticultural and Forest Crops*, VCE.

Pesticide applicators are also encouraged to check the Virginia BeeCheck website, which is an online mapping system providing apiary location and beekeeper contact information. All applicators applying pesticides outdoors are encouraged to sign up for free access to the system.

9.3 Preserving and Enhancing Habitat on the Course

Habitat for pollinators includes foraging habitat with food sources for the various stages of pollinators' lifecycles, nesting sites, and water sources. Increasing habitat to meet pollinator needs can be accomplished simply by adding to existing plantings or through more intensive efforts to establish a larger native area. Pollinator habitat on the golf course includes existing out-of-play areas (such as buffer strips around water courses and bodies of water) and areas renovated specifically with pollinators in mind that include native plants, wildflowers, and flowering trees and shrubs, nesting sites, and water sources.

To convert an existing out-of-play area to a new native area, site preparation is key and may require more than one season of effort to reduce competition from invasive or other undesirable plants prior to planting. For more information on establishing a native area, see the USGA publication *Making Room for Native Pollinators*. For information on plant selection in the mid-Atlantic that specifically includes plants for monarch butterflies, a species in decline, see the *Monarch Nectar Plants: Mid-Atlantic* and the Monarchs in the Rough website.

Pollinator-friendly habitat contains a diversity of blooming plants of different colors and heights, with blossoms throughout the entire growing season. An ideal plant mix consists of nine species: three that bloom early in the season, three in mid-season, and three in late season. Native plants are best for providing the most nutritious food source for native pollinators. Though wildflowers are most often thought of as pollinator-friendly plants, grasses, sedges, forbs, shrubs, and trees also provide habitat. For example, many sedge species are larval hosts; hollow stem grasses provide nesting habitat; and sturdy grasses shelter insects from harsh weather. Herbs also can be beneficial to bees and other pollinators. For example, borage is an underutilized herb that is extremely attractive to pollinators. Milkweed provides habitat specifically for monarch butterflies.

The Xerces Society provides information on plants and plant mixes for pollinators appropriate for the mid-Atlantic in *Pollinator Plants: Mid-Atlantic Region*.

Providing nesting sites for native species can be accomplished by taking simple steps in out-of-play areas, such as:

- Leaving exposed patches of bare soil, surrounded by erosion-trapping vegetation.
- Leaving dead trees, stumps, and posts.
- Planting hollow stem grass species.
- Creating stem bundles of hollow plant stems like bamboo.
- Creating bee blocks for solitary nesters such as mason and leafcutter bees.
- Creating artificial boxes for bumble bees.

Bee boxes can be purchased or constructed following simple instructions. The USGA publication *Making Room for Native Pollinators* offers instructions for constructing a simple bee box.

A clean, reliable source of water is another essential habitat consideration for pollinators. Pollinators can use natural and human-made water features such as running water, pools, ponds, small containers of water, and mud puddles. Water sources should have a shallow or sloping side so the pollinators can easily approach the water without drowning. In addition, irrigation management practices that preserve ground-nesting pollinators include irrigating at night and avoiding flooding any areas.

Figure 26. Monarchs, a species in decline, is the subject of a number of efforts to increase habitat, including on golf courses.

9.4 Managed Hives

Hosting honey bee hives on the golf course provide bees with valuable green space, especially in urban areas, and can be a positive public-relations tool. If embarking on this effort, consider:

- Partnering with an experienced local beekeeper. Proper beekeeping is time and knowledge intensive. If not partnering with an experienced beekeeper, superintendents or other responsible staff should attend a beekeeping course.
- Ensuring enough food sources are available for both honey bees and wild pollinator species.
- Placing hives away from areas where golf course workers or golfers are active to avoid stings.
- Facing the hive exit in a direction away from in-play areas of the course.
- Educating golfers via explanatory signs, newsletters, and sales of honey and other bee products.
- Calling in an experienced beekeeper if disease or parasites are suspected in order to

identify and mitigate any health issues.

Figure 27. Honey bee hives at Twin Lakes Golf Course.

Figure 28. Monitoring hives at Magnolia Green Golf Club.

9.5 Pollinator Protection Best Management Practices

Pest Management Practices

- ❖ Before applying a pesticide, inspect the area for both harmful and beneficial insect populations, and use pesticides only when a threshold of damage has been indicated.
- ❖ Consider biological control agents, lures, baits, and pheromones as alternatives to insecticides for pest management.
- ❖ When pesticides are needed, select those with a lower impact on pollinators, such as chlorantraniliprole.
- ❖ If a granular formulation will control the pest, choose it over liquid formulations. Granular versions of pesticides are known to be less hazardous to bees.
- ❖ Restrict applications to early morning or evening when pollinators are not as active.

- Follow the pesticide label regarding blooming season applications and restrictions.
- Avoid application during unusually low temperatures or when dew is forecast.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site translocation of pesticide.

Habitat Protection and Enhancement

- Follow site preparation guidelines when renovating areas to ensure success.
- Choose south-facing sites whenever possible for establishing native areas.
- Place plants in masses (three or more) to attract pollinators.
- Select plants of different shapes, sizes, and colors and ones that bloom at different times of the year.
- Select native grasses that provide foraging and nesting habitat.
- Use both perennials and annuals.
- Leave stems and coarse, woody debris in native areas for pollinator nesting.
- Leave exposed patches of well-drained soil in native areas for pollinator nesting.
- Provide water sources with shallow sides for pollinators.
- Provide food sources for the various stages of pollinators' lifecycles.

10 MAINTENANCE OPERATIONS

It is the objective to manage the potential environmental risks associated with golf course maintenance operations. Our industry has a need and responsibility to implement, manage, measure, and improve all aspects of environmental stewardship. It is imperative that hazardous materials be handled, stored, recycled, and disposed in a safe, healthy, and environmentally sound manner.

Pollution prevention includes the proper delivery, storage, handling, and disposal of all chemicals, washwater, and wastewater. For example, washwater from pesticide application equipment must be managed as a pesticide. Conversely, wastewater not contaminated with harmful chemicals can be reused or discharged to a permitted stormwater treatment system. The "Pesticide Management" chapter offers maintenance operations-related BMPs specifically for pesticides.

For unintended releases of any chemicals, an emergency plan, spill kit, and first-aid kit should be readily available.

10.1 Regulatory Considerations

10.1.1 Hazardous Waste

Hazardous wastes are regulated by EPA under RCRA. Hazardous waste has properties that make it dangerous or potentially harmful to human health or the environment. These wastes could include some chemicals used in golf course maintenance operations such as solvents and pesticides. (See the "Pesticide Management" chapter for regulatory considerations for pesticides.)

In Virginia, DEQ has implemented a hazardous waste program and therefore has primary responsibility for enforcing hazardous waste regulations. Hazardous waste releases may be regulated under SARA Title III (42 CFR 103), also known as the Emergency Planning and Community Right-to-Know Act, depending upon the chemical hazard and the volume released.

10.1.2 Petroleum Storage Tanks

Virginia DEQ's Tank Compliance Program regulates underground storage tanks (USTs) and above-ground storage tanks (ASTs). Guidance is available from DEQ to assist with regulatory compliance.

USTs are regulated in Virginia under two regulations: the Technical Standards and Corrective Action Requirements Regulation (9 VAC 25-580-10 et seq.) and the Petroleum UST Financial Responsibility Requirements Regulation (9 VAC 25-590-10 et seq.). Some differences exist between the federal UST regulation and Virginia's UST regulations; state regulations are sometimes more stringent or implemented differently from the federal regulations. For example in Virginia, tank owners and operators are required to show that they have complied with the

Uniform Statewide Building Code by obtaining a permit issued by the local code official and any required inspections for UST installation, upgrade, repair, or closure.

ASTs are regulated in Virginia under the Facility and Aboveground Storage Tank Regulations (9 VAC 25-91-10 et seq). Other state laws apply to ASTs and are included in the statewide building and fire codes, which local code officials administer.

10.1.3 Local Regulations

Local building and fire codes should be reviewed with respect to the siting, construction, and operation of maintenance facilities, such as fueling areas and pesticide storage areas. In addition, USTs in Virginia must be permitted by the local code official and inspected as required. Finally, any discharges to sanitary sewer systems require a permit from the local wastewater treatment facility.

10.2 Storage and Handling of Fertilizers

The nutrients in fertilizers, particularly nitrogen and phosphorus, can present water quality issues if not handled properly. Fertilizers also must be stored properly because their oxidizing properties pose fire hazards.

Fertilizers should be stored in a dry area and, ideally, in a concrete building with a metal or other flame-resistant roof. At the least, fertilizers should be stored on a concrete pad and covered from the elements. Nitrate-based fertilizers, while stable themselves, act as an oxidizer and can react with combustible and reducing materials. The presence of a fire hazard depends on other general combustible materials in the vicinity of nitrate-based fertilizers, which can accelerate a fire. Therefore, nitrate-based fertilizers must be stored separately from pesticides, solvents, and fuels.

Fertilizers should be loaded into or unloaded from application equipment away from surface waters or drinking wells. To minimize accidental release and allow for easy cleanup of spilled fertilizer, a covered impervious surface (for example, a concrete pad) is ideal. The surface area should be cleaned after loading or unloading to further control dust and spills and prevent accidental off-site release.

10.3 Equipment Washing

Equipment washing areas are primarily used to wash mowing equipment, which can transport organic matter such as grass clippings or soil into surface waters with runoff. Washing procedures should incorporate the minimal use of water and spring-operated shutoff nozzles to conserve water resources. In general, unless the washwater contains contaminants such as petroleum products, pesticides, solvents, or degreasers, it may not need to be collected before being discharged. However, even uncontaminated washwater should never be allowed to discharge directly into, or in the vicinity of, surface waters and storm drains.

Washing areas can be simple or more complex. The simplest system is a “dog leash” system that uses a short, portable hose to wash off the grass over a turfed area. The washwater infiltrates into the soil. The washing location should be moved around, depending upon the amount of water used and the percolation rate of the soil, to avoid any potential problems with mud and surface runoff.

Well-designed equipment washing areas incorporate an impervious surface and a system to recycle, discharge, or divert washwater and minimize the potential for environmental impacts.

Clippings should be brushed or blown off equipment with compressed air prior to washing since dry clippings are easier to handle, store, and dispose of than wet ones. In addition, this practice decreases the possibility of nutrients, such as N and P, leaching out of wet clippings and into the washwater. Any remaining grass clippings can be separated from the washwater using an above-ground screening system or a tank containing separation baffles that trap the clippings to separate them from the water. Collected wet clippings can be composted or used as mulch if they are not contaminated with pesticides or petroleum.

10.3.1 Washwater Disposal and Recycling

Disposal of washwater depends on a number of variables, including the volume of washwater generated, the nature of the surrounding area, and the frequency of the operations. For limited washdown of ordinary field equipment, it may be legal to allow the washwater to flow to an area for infiltration, such as a grassed retention area or swale. Discharge to a septic system is illegal. Other options for managing washwater include:

- Discharge to a sanitary sewer system.
- Treatment onsite.
- Recycling.

Discharges to a wastewater treatment system require a permit and may require pretreatment, such as the use of an oil/water separator and separation of grass clippings or other solids.

10.3.2 Onsite Treatment

Onsite treatment uses separation systems to separate clippings from the water. Soaps or degreasers can be used in washing equipment that is treated onsite. Separation systems can use an above- or below-ground catch-and-release system to capture clippings and discharge washwater.

Above-ground systems capture clippings through a screening mechanism and discharge washwater to the ground surface for infiltration. There must be no connection to surface water in this system. Clippings must be collected regularly and returned to a turfed area or composted.

Below-ground catch-and-release systems capture clippings by an above-ground screening mechanism or a below-ground tank before discharging the washwater to an underground infiltration network. If a tank is used to capture clippings, the clippings must be disposed of by a licensed liquid industrial waste hauler.

10.3.3 Recycle Wash Systems

Two types of recycling systems are available to purify wastewater and pipe it back for reuse: 100% closed-loop recycle and partial recycle systems. Although expensive, recycle systems conserve water resources and lower water bills and sewer discharge fees.

Closed-loop recycle systems recycle both washwater and rinse water with no discharges of wastewater to ground or surface waters. These systems must be properly operated and maintained to prevent accidental discharges. Florida DEP has published BMPs for the use of closed-loop recycle systems in *Guide to Best Management Practices: 100% Closed-Loop Recycle Systems at Vehicle and Other Equipment Wash Facilities*. In some cases, the use of closed-loop systems may require an industrial wastewater permit. Partial recycle systems separate washwater from rinse water and recycle the washwater. Excess rinse water may be disposed of onsite. More information on partial recycle systems is also available in the Florida DEP's guidance on closed-loop recycle systems referenced above.

10.3.4 Oil/Water Separators

Oil/water separators are generally not necessary, unless the water from the system is to be reclaimed for some particular end use (such as recycle systems), or as required by an industrial wastewater permit, local government, or receiving utility. If used, the oil collected in these systems may be classified as a hazardous waste, making disposal expensive. Usually, filters from these systems may be disposed of at an approved landfill. Keep all disposal records to document proper disposal of this waste.

10.4 Equipment Storage and Maintenance

All equipment used in the maintenance and operation of golf courses should be stored, maintained, and cleaned in a way that eliminates or minimizes the potential for pollution. When not in use, equipment should be stored in a clean, safe, and protected area, such as covered and sealed impervious areas. Fluid leaks from stored equipment should be identified and the equipment repaired. Assigned parking areas aid in the identification of equipment with fluid leaks.

Figure 29. Checking mower reel sharpness at Belle Haven Country Club.

Application equipment must be stored in covered areas protected from rainfall because of the potential for pesticide or fertilizer residue to wash off the exterior of this equipment. Pesticide and fertilizer equipment should be stored separately from other equipment.

10.5 Fueling Facilities

Fueling areas should be properly sited, designed, constructed, and maintained to prevent petroleum products from being released into the environment through spills or leaks. Above-ground tanks are easier to monitor for leakage and are therefore the preferred storage method. Because of the potential for groundwater contamination from leaking USTs, leak detection monitoring is a critical aspect of UST compliance. Any leaks or spills must be contained and cleaned immediately.

Fueling areas should be sited on impervious surfaces, equipped with spill containment and recovery facilities, and located away from surface waters and water wells. Catch basins in fueling areas should be directed toward an oil/water separator or sump to prevent petroleum from moving outside any containment structure. Floor drains in fueling areas should be eliminated unless they drain to containment pits or storage tanks.

10.6 Waste Handling

Facilities need to regularly review how they handle the disposal of unwanted, expired, or accumulated items, including chemicals, paints, pesticides, tires, batteries, used oils, solvents, paper products, plastic or glass containers, and aluminum cans. Developing recycling programs reduces waste and minimizes the quantity of waste reaching landfills. In some cases, recycling of some wastes may be required locally, and superintendents should be aware of these requirements.

All packaging from chemicals, their containers and other wastes should be properly disposed of. Pesticide-specific waste handling requirements are identified on the pesticide label and are discussed in the “Pesticide Management” chapter.

10.7 Maintenance Operations Best Management Practices

Fertilizer Storage

- Review groundwater sensitivity information before constructing any fertilizer storage facilities or handling areas.
- Storage facilities should not be located in areas with high probability of flooding.
- Locate dry fertilizer storage buildings or liquid fertilizer secondary containment over 500 feet away from a well, water supply, or surface water runoff area.
- Construct storage buildings to prevent seepage or spillage of fertilizer under normal conditions.
- Unless stored in a totally enclosed building, all nonliquid fertilizer materials should be covered and stored within an appropriate secondary containment storage structure.
- Construct liquid fertilizer secondary containment capable of holding 125 percent of the volume of the largest container plus the volume of the butts of all other containers inside the liquid containment area.
- Construct dry storage for secondary containment that is of sufficient thickness and strength to withstand loading conditions.
- Design loading areas to prevent spillage onto unprotected areas and create a proper cleanup area by installing curbed containment.

- Post warning signs on chemical storage buildings, especially near entry or exit areas.
- Storage facilities should be secured and allow access only to authorized staff.
- Replace worn or faulty valves, plugs, and threaded fittings in storage containers.
- Install backflow prevention devices or use air gap separation on water supply lines used for fertilizer mixing or equipment rinsing.
- Lock valves and shutoff devices while storage containers and facilities are not in use.
- Follow hazard safety rules, worker protection laws, and fire prevention rules while handling and storing fertilizer.
- Apply appropriate sealant to seams and cracks in all storage facilities and load/wash/rinse pad areas.
- Use approved containers designed for and compatible with the fertilizer being stored.
- Shelves should be made of plastic or reinforced metal. Metal shelving should be coated with paint to avoid corrosion. Wood shelving should not be used due to its ability to absorb spilled chemicals.
- Exhaust fans and an emergency wash station should be provided.
- Light and fan switches should be located on the exterior of the storage facility.
- Store liquid materials below dry materials to prevent contamination from a leak.
- Train staff and other management on how to access and use the facility's SDS database.
- Maintain accurate inventory lists.

Equipment Washing

- Brush or blow off accumulated grass clippings from equipment using compressed air before washing.
- Wash equipment on a concrete pad or asphalt pad that collects the water. After the collected material dries, collect and dispose of it properly.
- Washing areas for equipment not contaminated with pesticide residues should drain into oil/water separators before draining into sanitary sewers or holding tanks.
- Do not wash pesticide-application equipment on pads with oil/water separators. Do not wash near wells, surface water, or storm drains.
- Use spring-loaded spray nozzles to reduce water usage during washing.
- Minimize the use of detergents. Use only biodegradable, non-phosphate detergents.
- Use non-containment washwater for irrigation.
- Do not discharge non-contaminated wastewater during or immediately after a rainstorm, since the added flow may exceed the permitted storage volume of the stormwater system.
- Do not discharge washwater to surface water, groundwater, or susceptible/leachable soils either directly or indirectly through ditches, storm drains, or canals.
- Never discharge to a sanitary sewer system without written approval from the appropriate entity.
- Never discharge to a septic tank.
- Do not wash equipment on a pesticide mixing and loading pad. This keeps grass clippings and other debris from becoming contaminated with pesticides.
- Solvents and degreasers should be used over a collection basin or pad that collects all used material.

Equipment Storage and Maintenance

- Store equipment in areas protected from rainfall. Rain can wash residues from equipment and potentially contaminate the surrounding soil or water.
- Perform equipment maintenance activities in a completely covered area with sealed impervious surfaces.
- Drains should either be sealed or connected to sanitary sewer systems with the approval of local wastewater treatment plants.
- Solvents and degreasers should be stored in locked metal cabinets away from any sources of open flame.
- Complete a chemical inventory and keep SDS of each on site. A duplicate set of SDS should be kept in locations away from the chemicals, but easily reached in an emergency.
- Use PPE when working with solvents.
- Use containers with dates and contents clearly marked when collecting used solvents and degreasers.

Fueling Facilities

- Above-ground fuel tanks are preferred as they are more easily monitored for leaks as compared with underground tanks.
- Fueling stations should be located under roofed areas with concrete pavement whenever possible.
- Fueling areas should have spill containment and recovery facilities located near the stations.
- Develop a record-keeping process to monitor and detect leakage in USTs and ASTs.
- Visually inspect any AST for leakage and structural integrity.
- Secure fuel storage facilities and allow access only to authorized and properly trained staff.

Waste Handling

- Label containers for collecting used solvents, oils, and degreasers.
- Recycle lead-acid batteries. If not recycled, batteries are classified as hazardous waste.
- Store old batteries on impervious surfaces in areas protected from rainfall.
- Recycle used tires, paper products, plastic or glass containers, aluminum cans, and used solvents, oils, and degreasers.
- Provide a secure and specifically designated storage for the collection of recyclable waste products.
- Recycle or properly dispose of light bulbs and fluorescent tubes.

11 LANDSCAPE DESIGN AND MANAGEMENT

The fundamental principle for the environmentally sound management of landscapes is "choose the right plant, in the right place." Ideal landscape plants are native and adapted specifically to the soil, degree and direction of slopes, precipitation type and amounts, wind direction and speed, light patterns, and microclimate. Susceptibility to major damage by insects and other pests is another selection criterion, as are the nutrient levels of the area. Because native and/or adapted plants can mimic natural ecosystems, their use in the landscape can reduce overall management inputs, attract pollinators, provide multi-season interest, and enhance out-of-play areas.

Figure 30. Native grass areas at Bayville Golf Club.

11.1 Planning and Design

Planning begins with a careful assessment of existing conditions. Slopes and drainage patterns impact not only the playability of the course, but the survival of existing and proposed plants. A majority of the non-play areas on the golf course should remain in natural cover. Supplemental planting of native or adapted trees, shrubs, and herbaceous vegetation can limit soil erosion, protect stream banks, and enhance wildlife habitat, including non-game species, birds, and pollinators, in non-play natural areas. Mimicking natural ecosystems by leaving dead trees (snags), brushy understory plants, and native grasses and forbs in these areas also reduces maintenance work by minimizing or eliminating the need to mow or apply fertilizer or pesticide.

Higher-impact, higher-use landscape areas, such as around the clubhouse, should be designed to utilize natural drainage patterns and channel runoff away from impervious surfaces (e.g. paved areas), conserve water, and lower nutritional input requirements once mature. Installing rain gardens in locations where they catch and temporarily hold water (such as near roofs and other impervious surfaces) helps control stormwater runoff, remove contaminants before releasing water into the surrounding soil or aquifer, and conserve water by reducing supplemental irrigation needs. For more information on rain gardens, see the NRCS publication *Rain Gardens*.

Golf courses are excellent facilities for zoning the landscape, using designations of high-impact zones, transition zones, and perimeter zones, and matching high-use and high-impact areas to plants that need more water and likely more-intense management. Taking into consideration the lay of the land, including differences in soil and changes in sunlight levels throughout the day, planning for landscaped areas should include consideration of the water needs in each area. A zoned approach is an efficient way to plan, as follows:

- High-use and high-impact zones: Match plants that need the most water to small, highly visible areas that will be watered as needed.
- Transition zones: Choose plants that require moderate amounts of water to be applied only when they show signs of moisture stress, such as wilting.
- Perimeter zones: Use plants with minimal water requirements. Water during establishment and in periods of extreme drought.

Ideally, 10% or less of the landscaped areas should be zoned for high water use, 30% or less of the area should be zoned for moderate water use, and 60% or more of the landscape should be zoned for low water use.

11.2 Site Inventory and Assessment

Before developing a landscape plan, an inventory should be conducted of existing plants, their condition and quality, their contribution to the overall style of the course, and how they've been managed. For landscaped areas, a soils analysis and a soil test should be conducted. The soils analysis evaluates the structure and texture of the soil. The addition of soil amendments can improve the structure and texture of soil, increase its water-holding capacity, and reduce the leaching of fertilizers. Soil amendments, such as compost from clippings, can contribute to an overall healthier plant environment, allowing easier root development and fewer soil-related problems. The use of peat as an amendment should be very limited (such as in containers), as it is both expensive and originates from peat bogs, which are non-renewable. Fertilizers should be applied on the basis of the results of soil tests that have been conducted to identify plant nutritional needs and pH, as described in the "Nutrient Management" chapter.

11.3 Plant Selection

Selection of specific plants should be based to the extent possible on natural ecosystems in the area. This is particularly true for the perimeter zones and out-of-play areas. Additional considerations for species selection and placement include plant hardiness, design intentions and knowing the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for future pruning and debris removal. In addition, the adaptability of plants to a specific site is important. Site-specific characteristics to consider include sun exposure, light intensity, wind conditions, drainage, and temperatures.

With respect specifically to trees, the distance to tees and greens requires additional consideration because the shade from trees prevents turfgrass from growing the best during the summer due to shade and reduced airflow, causes more frost or cold damage on the grasses in winter, and competes with turf for water and nutrients during the growing season. Because trees can impact the health of turf, their careful addition to the landscape when desired and/or selective removal from the landscape when too close to tees and greens should be a component to the landscape management program. See the short USGA article "When Trees and Grass Compete, Trees Win" for a summary of the issues associated with trees near tees and greens.

For more information on plant selection in Virginia, see the following:

- Plant Virginia Natives website for native plants listed by each region in the state
- *Problem-free Shrubs for Virginia Landscapes*, VCE
- *Selecting Landscape Plants: Shade Trees*, VCE
- *Selecting Landscape Plants: Groundcovers*, VCE

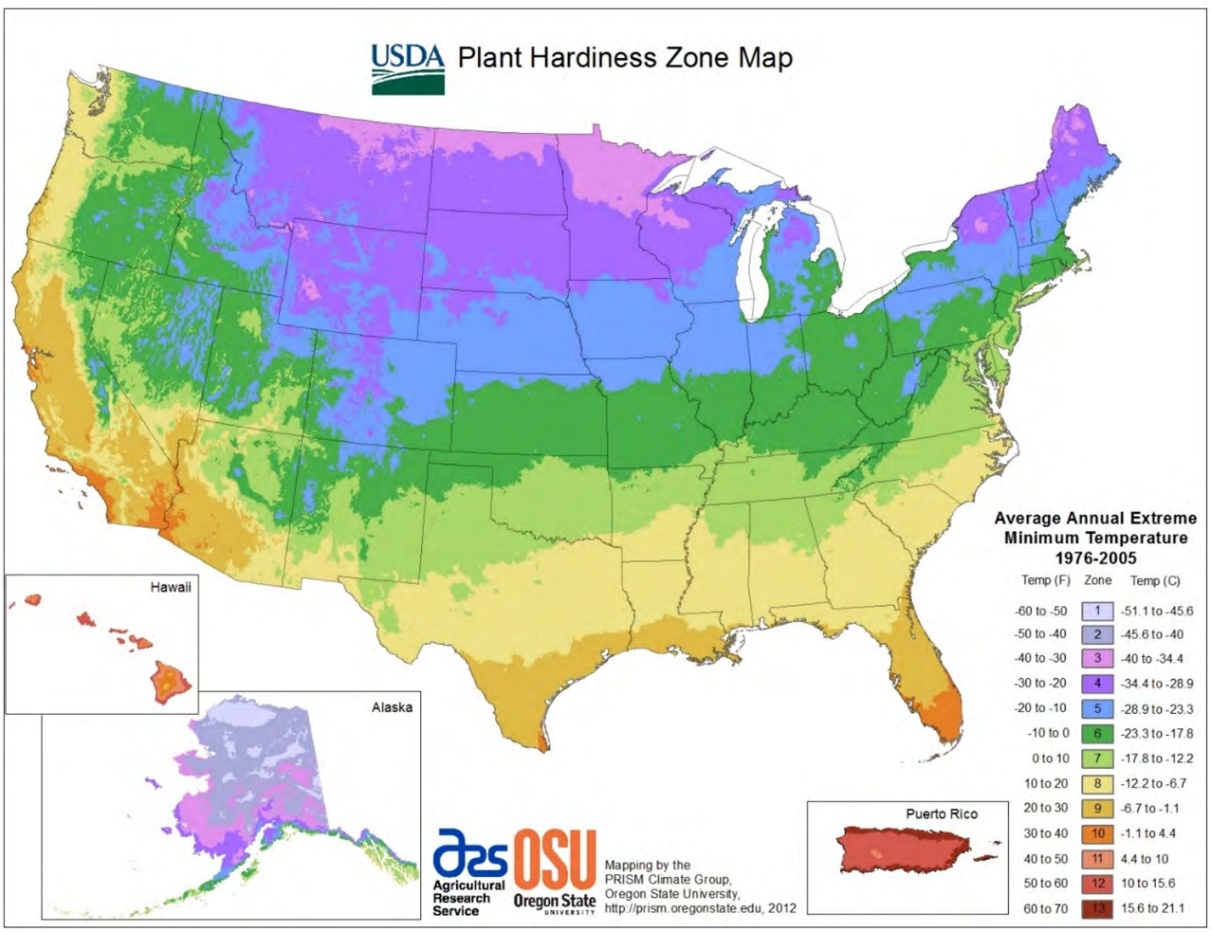

Figure 31. Plant Hardiness Zone Map of the United States.

11.4 Installation

During landscape bed construction, native soil should be used and any hardpan or compaction from construction should be resolved. The beds should be sloped away from buildings, with a minimum percent slope away from buildings of at least 2% for at least 10 feet. Resolve drainage issues and establish clear drainage patterns prior to installing plants. Plants with higher moisture requirements can be planted at lower elevations and drought-tolerant plants at higher elevations.

In general, the best times to plant trees and shrubs in Virginia is in the fall. Bare-root trees can be planted only when they are dormant, limiting their planting time to early spring or late fall. These times reduce the stress on the plants by capitalizing on periods of cooler (but not cold) temperatures and more moisture. When planting, the soil ball should be kept together and the fine roots kept moist.

11.5 Irrigation

Regardless of their ability to tolerate drought, all plants require supplemental irrigation during establishment. To increase water-use efficiency and improve plant establishment in landscaping, consider hand-watering individual plants for the first several months of the growing season. If the plants have been selected and placed in zones that match their water requirements, irrigation can be scheduled to help efficiently meet the water needs of the entire landscape, thus eliminating regular hand-watering. When needed, plants should be watered in the early morning to conserve water by avoiding water loss due to evaporation. Careful assessment of landscape watering patterns minimizes spray on impervious surfaces, blockage of spray by plants or other obstructions, and runoff on slopes, clay soils, or compacted sites. Focusing the irrigation of woody plants at or beyond the dripline promotes extensive rooting. Additional water conservation ideas in landscaped areas include using quick couplers in landscaped areas to meet water needs (note, placement is key when using quick couplers) and using planters in areas that need color, as planters require less water than landscaped beds. Self-watering planters can be used to reduce labor requirements as well.

For existing irrigation systems, assess the coverage to determine whether changes should be made to identify areas where efficiency can be improved. Ideally, the irrigation system for the landscape beds should be zoned. Periodically throughout the growing season, the performance of the landscape irrigation system should be checked.

11.6 Use of Mulch

Mulch conserves soil moisture, mitigates temperature extremes, and reduces weed competition. In winter, mulch helps prevent soil cracks from forming and exposing roots to cold temperatures and winter desiccation. Organic mulches include herbicide-free grass clippings (though avoid applying too deeply to prevent matting and heating the soil) and wood chips of varying dimensions. Organic mulches are preferred, as non-organic mulches such as stone may add heat stress around annuals and perennials.

Annuals and perennials grow best with no more than 2” of mulch; mulch around trees and shrubs should be no more than 3-4” deep. With any planting, mulch should be placed between the plants and not on top of the crown or against tree trunks or shrub canes. In winter after the ground freezes, a deeper layer of coarse mulch (evergreen branches) over bulbs and other perennials can delay or prevent early growth.

For more information, see the VCE publication *Mulching for a Healthy Landscape*.

11.7 Pruning

Correctly pruning trees, shrubs, and herbaceous perennials has multiple benefits throughout a landscape or golf course. Trees and shrubs are pruned first for safety. Pruning in some cases can increase plant health and result in better growth in future seasons. Typically, the ideal time to prune deciduous shade trees and conifers in Virginia is in late winter/early spring, except in times of drought and except for trees with heavy sap flow (e.g. maples and birches), which can be pruned after fully leafed out. Shrubs should be pruned based on their season of bloom (if the flowers are significant). Plants that bloom on second-year or old wood set their flower buds immediately after flowering and can be pruned for the month following bloom. Plants that bloom on new wood, or current-season wood, can be pruned in early spring prior to dormancy break.

11.8 Pest Management

The same principles and methods identified in the IPM chapter can be applied to landscaped areas. The UNL Extension’s *Integrated Pest Management for Landscapes* provides guidance specifically for these areas.

Additional publications related to pest management of landscaped areas in Virginia include the following:

- *2020 Pest Management Guide: Horticultural and Forest Crops,* VCE.
- *Diagnosing Plant Problems*, VCE.
- *Managing Invasive Alien Plants in Natural Areas, Parks, and Small Woodlands*, DCR.

11.9 Native Areas Establishment and Maintenance

Native areas can serve multiple functions on the golf course such as: buffers near surface waters; wildlife habitat by providing forage and nesting sites for different game and non-game species; and pollinator habitat. Establishing a native area can include plantings of grasses, forbs, and shrubs. Selection of species to be planted should be based on the site’s climate, soils, intended use and planned management. Once established, native areas require little in the way of supplemental irrigation.

The following NRCS publication can provide additional information on species selection, seeding rates, and establishment: *Five Keys to Successful Grass Seeding*, NRCS.

11.10.1 Native Area Establishment

To establish native areas with grasses, transplanting will result in much quicker establishment but will be much more expensive than direct seeding. Direct seeding, by contrast, is much less expensive but requires two to five years to reach maturity, depending upon the species.

Prior to seeding, the area should be prepared. The primary preparation will be related to weed control. Eliminating all existing perennial weeds, especially aggressive and noxious weeds, yields the best results and will require less labor later in managing the native areas. Eliminating weeds may require a full year or possibly longer prior to planting or transplanting natives, depending upon the existing site conditions. Annual and biennial weeds are often a problem in the first two years during establishment as they compete with seedlings for sunlight and/or moisture. Competitive weeds can be controlled either mechanically, chemically, or a combination of the two, and should be performed prior to weed seed maturity.

11.10.2 Native Area Maintenance

Native areas require management that mimics natural disturbance processes (such as grazing and periodic fires) to invigorate and maintain desirable species in an optimum condition. On a golf course, these managed practices can include mowing, haying and using prescribed burns, which reduce unwanted woody vegetation and invasive plant species.

Burning reduces plant litter and stimulates new plant growth. It must be timed to negatively impact the targeted invasive species. For example, burning should be timed in early spring after invasives like smooth bromegrass have greened up but prior to native green up. Burning to control invasives should be done on a three- to five-year rotation. However, annual burning may be needed in the beginning for native grassland heavily invaded by smooth bromegrass or Kentucky bluegrass. For more information on prescribed burns, see the “Prescribed Burns” section of the “Cultural Practices” chapter.

Mowing or haying should be delayed until after the primary nesting season for grassland bird species (mid-spring through early August) and be done on a rotational basis, such as once every three to five years. Haying should be done with a sickle bar mower and rake in order to remove plant litter; swathers or conditioners do not remove plant litter build-up and may shade native plants and inhibit growth. Haying should be done from the center outward or toward undisturbed habitat. Selective use of herbicides may be needed, in conjunction with mowing, to control invasives.

11.10 Landscape Best Management Practices

Planning and Design

- ❖ Leave the majority of non-play areas in natural vegetation – the perimeter zone.
- ❖ Enhance natural areas with supplemental plantings of native and adapted species.

- ❖ In landscaped areas, use natural drainage patterns and directional site grading to channel runoff away from impervious surfaces onto planted areas such as grass swales, filter strips, or rain gardens.
- ❖ Install rain gardens in locations where they can catch and temporarily hold runoff.
- ❖ Minimize the amount of area covered by paved surfaces. Where feasible, use permeable materials such as bricks laid on sand, interlocking pavers or pervious pavers, porous concrete, mulch, or plants.
- ❖ Use a zoned approach to plant management and water needs and minimize the areas zoned for high water use.

Site Inventory and Assessment

- ❖ Conduct an inventory of existing plants, their condition and quality, and their contribution to the overall style of the course.
- ❖ Conduct a soil analysis before choosing specific plants for landscape areas.
- ❖ Conduct a soil test before applying fertilizers. Modify pH if needed, based on results.
- ❖ Amend the soil to improve soil texture and increase water infiltration.

Plant Selection

- ❖ Select native species whenever possible; use adapted species or cultivars of native plants where appropriate.
- ❖ Select trees, plants, and grass species to attract birds seeking wild fruits, herbs, seeds, nesting materials, cover, and insects.
- ❖ Know the ultimate sizes and growth rates of trees, shrubs, herbaceous plants, and ground covers.
- ❖ Select plants recommended for your specific location.
- ❖ Choose the most stress-tolerant species for a particular area.
- ❖ Do not introduce invasive species into the landscape.
- ❖ Control or remove existing invasive species and noxious weeds.

Irrigation

- ❖ Irrigate frequently during establishment.
- ❖ Water established plants based on their needs and, when necessary, deeply and infrequently.
- ❖ Irrigate in the early morning to conserve water.
- ❖ Avoid water runoff onto impervious surfaces or slopes.
- ❖ Evaluate landscape irrigation performance periodically.

Use of Mulch

- ❖ Use mulch in landscaped beds.
- ❖ Use organic mulches whenever possible.
- ❖ Use only herbicide-free grass clippings for mulch.
- ❖ Protect bulbs and other perennials in winter with a layer of coarse mulch (evergreen branches) to delay or prevent early growth.

Pruning

- Hire a certified arborist to prune trees as the correct pruning cuts are essential to good tree health.
- Maintain pruning equipment to ensure clean cuts and less risk of damage to the plant.
- Prune deciduous shade trees in March and early April, except in times of extreme drought.
- Prune shrubs based on their season of bloom.

Pest Management

- Use IPM for landscaped areas.

Native Areas Establishment and Maintenance

- Eliminate weeds prior to establishment.
- Use native species, and select species based on the site's climate, soils, intended use, and planned management.
- Seed native areas at the recommended rates for that species.
- Maintain weed control, especially during establishment phase, and time weed control efforts prior to weed seed maturity.
- Maintain native areas through prescribed burns, mowing, or haying.

12 ENERGY

The use of energy for all activities in society is of great interest worldwide. Golf courses use a variety of energy sources, primarily electricity, gasoline, diesel, natural gas, propane, and heating oil. Renewable sources, such as solar, wind, and geothermal, are being considered and used by more small business as the return on investment increases. These newer technologies offer opportunities to reduce dependencies on fossil fuels and to decrease our carbon footprint.

To establish effective energy BMPs, the facility's existing energy consumption should be evaluated, and improvements should be achieved through energy reduction, conservation, and new technologies. Energy audits allow for identification of deficiencies. A written energy conservation plan is key to ensuring improvement, and includes an evaluation of current conservation practices in these categories:

- Buildings, infrastructure, and facility amenities such as the clubhouse, restaurant, kitchen, swimming pool, parking lot, offices, maintenance building(s), tennis courts, and restrooms.
- Golf course, surrounding landscapes, and related agronomic operations (playing surfaces, equipment, turfgrass maintenance, etc.).
- Irrigation system and pump station.

The irrigation system and pump station are the largest consumers of energy on the golf course and should be evaluated. Conserving and reducing water through irrigation BMPs also reduces energy consumption.

Some policies, financial incentives, and loan opportunities exist at the state and local level for renewables and energy efficiency measures at commercial enterprises such as golf courses. Energy providers can provide information, expertise, and incentives to help achieve these goals.

Figure 32. Solar panels installed at a golf course facility can be a renewable energy source.

12.1 Energy Audits and Evaluation

An energy audit of the facility should be done if one has not been conducted previously. Energy audits identify areas most in need of conservation. Utility providers can be a source of expertise in conducting an audit. An energy audit should include these steps:

- Evaluate insulation in heated buildings.
- Evaluate heating, ventilation, and air conditioning (HVAC) system efficiency.
- Determine annual energy usage.
- Itemize usage according to various categories.
- Determine if energy usage during non-peak hours are maximized.
- Compare usage with similar small businesses.
- Identify areas of improvement.

Determining energy conservation goals and establishing an environmental plan is a first step in addressing energy efficiency. An energy management plan sets a baseline related to current energy use and incorporates quality management elements (plan, do, check, and act) for continual improvements. Once goals for energy conservation are established and documented, this policy should be communicated to all staff.

Evaluating the performance of an energy conservation program requires tracking and measuring energy use at the facility based on energy assessment units (e.g. kilowatt hour or BTU). Monitoring energy usage can be accomplished with energy management software or programs such as EPA's Portfolio Manager, which also incorporates features such as reporting, savings calculations, and carbon footprint calculations. To benchmark performance, energy consumption can be compared with other local golf facilities of similar size or more generally to buildings of similar size.

12.2 Energy Efficiency Improvements

The audit will identify opportunities to increase energy efficiency in buildings, amenities, and operations. For example, ground-based heat pumps conserve energy as compared with conventional heating sources and could be considered for new building construction or replacement for existing heat sources when the opportunities arise. Developing and implementing a viable energy conservation plan will lead to improvements over time.

12.3 Green and Alternative Energy

Green and alternative energy can be incorporated into golf course operations. Golf courses can become small-scale generators of energy through wind, solar installations, and geothermal heating and pumping. Golf courses normally have the land, space, and natural resources available on the property to lend themselves to energy generation as newer technologies become more affordable. Financial and tax incentives may be available for installing these energy generators.

Figure 33. Solar energy powered pond aerator at the Federal Club.

12.4 Energy Best Management Practices

Energy Audits and Evaluation

- ❖ Conduct an energy audit, including lighting, insulation, and HVAC systems.
- ❖ Monitor energy use by tracking statistics and "time of use" data.
- ❖ Install precision meters, gauges, etc.
- ❖ Develop an equipment inventory that documents individual equipment's energy use, traffic patterns, maintenance records, operation hours, etc.
- ❖ Benchmark performance against similar-sized facilities.
- ❖ Educate, train, and motivate employees on energy efficiency practices pertaining to golf course operations.

Energy Efficiency Improvements

- ❖ Evaluate and monitor all energy sources, tracking both costs and any usage trends.
- ❖ Add insulation where needed.
- ❖ Use non-peak electrical hours for charging golf carts and maintenance equipment.
- ❖ Prioritize pump station usage during non-peak hours.
- ❖ Limit high-consumption activities when demand is high.
- ❖ Install LED lighting and other high-efficiency alternatives.
- ❖ Install motion sensors for lights where appropriate.
- ❖ Install low-flow faucets.
- ❖ Install programmable thermostats.
- ❖ Consider energy management software.
- ❖ Utilize the EPA's Energy Star and Portfolio Manager programs.
- ❖ Utilize the EPA's WaterSense program.
- ❖ Maintain good record-keeping practices.

- ❖ Prioritize energy consumption as part of decision-making when making purchases concerning all aspects of facility management.
- ❖ Evaluate effectiveness of upgrades according to efficiency and conservation goals for energy use.

Green and Alternative Energy

- ❖ Consider pursuing the U.S. Green Building Council's LEED certification for new buildings and existing building retrofits.
- ❖ Use alternative energy from natural sources, such as solar, geothermal, and wind energy generation when possible.
- ❖ Assess the viability of small-scale wind and solar installations.
- ❖ Install geothermal heating and cooling systems.

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