Best Management Practices for Massachusetts Golf Courses

Golf Course Superintendents Association of Cape Cod

GCSAA
Golf Course Superintendents Association of America

Golf Course Superintendents Association of New England
Organized 1924

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*

Table of Contents

Acknowledgement 4
Additional Acknowledgement 6
Introduction 8
BMP Index 12
Best Management Practices for Massachusetts Golf Courses 15
Planning, Design and Construction 17
Irrigation 37
Water Quality Management and Protection 60
Water Quality Monitoring 70
Golf Turf Fertilization and Nutrient Management 73
Cultural Practices 85
Integrated Pest Management 97
Pesticide Management 106
Pollinators 122
Maintenance Operations 128
Sustainable Landscaping in Out of Play Areas 135
Energy Management 147
References 154
Additional References 163

Acknowledgement

Who We Are/ Acknowledgments

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 and U.S. Senior Open as well as 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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Introduction

In 2017, the Golf Course Superintendents Association of America (GCSAA) launched an initiative to create Best Management Practices (BMP) for golf course maintenance specifically for 50 States by the year 2020. As part of this initiative, GCSAA released to its members a newly developed, interactive BMP Planning Guide and Template, funded in part by the United States Golf Association. GCSAA State Chapters from each of the 50 states responded by forming steering committees dedicated to achieving this national goal. In Massachusetts, the BMP steering committee as a first step voted to join a larger, regional effort, which proposed to encompass all six New England States in a general BMP presentation. The intended goal was to further reduce the cost and labor required by each state thereafter.

The New England BMP Steering Committee formed and immediately engaged the New England Regional Turfgrass Foundation (NERTF). The NERTF trust funds education, extension, and research at local turfgrass universities. NERTF's sole purpose is to strengthen the regional turf industry by providing the latest science driven information available. NERTF generously contributed to the financing requirement of the NE BMP authors and publishers. A combination of researchers, educators and industry leaders were responsible for editing the national template to apply NE region environment and industry practices. In February 2020 the Best Management Practices for New England Golf Courses was released and adopted by all six states.

Soon thereafter, the Massachusetts BMP steering committee reconvened and endeavored to adapt BMPs for New England Golf Courses to develop a standalone Best Management Practices for Massachusetts Golf Courses product which incorporates existing state regulations and relative state adopted BMPs from the University of Massachusetts. The goal to establish a living document continually updating in the future specific for MA.

Using the funds provided to each state by GCSAA in 2018, the MA steering committee commissioned the authors to conduct their final edit and the steering committee began importing these edits, photographs and hyperlinks to create the Best Management Practices for Massachusetts Golf Courses. These research-based, voluntary guidelines have been developed specifically to help Massachusetts superintendents protect natural resources from their work practices and to have them be recognized as environmental stewards by the community at large, and state officials. Best Management Practices for Massachusetts Golf Courses is intended for day to day golf course management, golf course renovations and new golf course construction.

Massachusetts golf course superintendents, organized and represented by GCSAA, GCSA of New England (MA Based) and GCSA of Cape Cod, are dedicated to protecting the state’s natural resources. It is the explicit purpose of the steering committee to have Best Management Practices for Massachusetts Golf Courses be adopted by the Commonwealth of Massachusetts regulations, licenses and permits, as possible mitigation for state education / certification / licensing requirements for state environmental regulatory compliance.

Best Management Practices

BMPs are the latest, scientific methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing deleterious water quality impacts or reducing pesticide usage. The sciences of turfgrass and the environment will be constantly changing with research and every BMP must address the need for ongoing periodic review and updating. The turfgrass industry recognizes the preeminent importance of protecting surface and groundwater quality, thus the majority of BMPs in this document will relate to water. Many BMPs protect water quality by reducing nonpoint source pollution (such as nutrients and pesticides in stormwater runoff), stormwater volume, and peak flow. Through turfgrass retention, infiltration, filtering, and biological and chemical actions, any negative effects of golf courses on surface and groundwater resources can be prevented or minimized. In fact, several research studies have shown that implementing BMPs can improve water quality as it traverses the golf course properties. Many BMPs also can be used to conserve water and to prepare for water use restrictions that may be imposed in times of extended drought.

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 areas with established turf. Therefore, following grow-in BMPs during course construction or renovation to quickly establish dense turf ground cover helps minimize the erosion potential. Maintaining vegetated areas, such as filter strips and buffers, to slow down stormwater, 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 each golf course's unique characteristics is another key to preventing pollution. Some golf courses are in mountains and others on coastal plains. Sloped terrains will certainly be more prone to runoff water than flat plains. There are areas throughout MA that have shallow depths to the groundwater table and will be more vulnerable to leaching. Superintendents must interpret how each BMP can be modified, with the understanding of site-specific characteristics, to prevent conveyance of contaminants to surface and groundwaters.

Water Conservation

Water is a fundamental element for physiological processes in turf such as photosynthesis, transpiration, and cooling, as well as for the diffusion and transport of soil nutrients. Turf quality and performance depend on an adequate supply of water through either precipitation or supplemental irrigation. Too little water induces drought stress and weakens plants, while too much causes anaerobic conditions that stunt plant growth and promote disease. Excessive water can also lead to runoff or leaching of nutrients and pesticides into groundwater and surface water. 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 are considerations in the design, construction, and maintenance of irrigation systems.

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. It is worthy to note that many MA golf course superintendents are certified bee keepers.

State BMPs

Best Management Practices for Massachusetts Golf Courses are NOT intended to be adopted in whole by any golf course operating in this state. Instead it is an evaluation tool, offered as a tool box of proven management approaches, for the superintendent to develop a baseline of their operation and target areas/practices/products for the future. BMPs are never intended to be mandatory, unless covered by state regulation. Many golf course superintendents who review this document will, undoubtedly, learn that they are doing much of what is being recommended in the Best Management Practices for Massachusetts Golf Courses. Every golf course business will have static operating principles which will limit the amount of money, time, infrastructure and opportunity to implement change. The message of golf course superintendents as environmental stewards has been prominent for decades. There is a national pride promoted by GCSAA and its state Chapters among superintendents who are committed to minimizing environmental impact and bolstering the beneficial impacts their courses have on the natural world and the community at large.

Individual Facility BMPs

Best Management Practices for Massachusetts Golf Courses guidelines offers state superintendents the opportunity to use this document to create their own, in-house, facility-specific BMP. To adapt BMPs to an individual facility, superintendents should assess their individual site, first and foremost, for federal and state regulatory compliance as it applies to their business; consider their available resources (such as budget); and understand that implementing BMPs will be an ongoing process for the good of the game that can be undertaken over time.

Besides contributing to natural resources stewardship, the wide range of incentives for golf courses to create a facility BMP plan and to implement said BMPs include the following:

- Recognition by club members and the community at large for environmental stewardship.
- Replicate approved and supported federal Environmental Management System (EMS) and state BMP.
- Cost savings associated with applying less fertilizer and pesticide.
- Potential for more efficiently allocating resources by identifying management zones.
- Cost savings associated with more efficient irrigation and other water conservation efforts by reducing electricity needs and equipment usage.

It is not reasonable to expect every golf courses Massachusetts to achieve all of these best practices quickly. Superintendents should understand that implementing BMPs will be a process that can be undertaken over time. In addition, making even small changes that meet the goals of BMPs can easily be achieved. For example, while a sophisticated wash water recycling system may be too expensive for many golf facilities, blowing clippings off of the mowers and onto a grass surface can markedly reduce the amount of nitrogen and phosphorus from clippings that end up in the wash water.

Conclusion

This document was developed using the latest science-based information and sources and will be available for use to every golf course superintendent doing business in the Commonwealth of MA. Using Best Management Practices for Massachusetts Golf Courses guidelines, superintendents will have ready access to the most recent scientific information that can be used to inform their management activities.

BMP Index

Best Management Practices for Massachusetts Golf Courses 15
Introduction 15
Planning, Design and Construction 17
Preface 17
Planning 18
Design 21
Construction 27
Turfgrass Establishment 31
External Programs 33
Maintenance Facilities 34
Wildlife Considerations 35
Irrigation 37
Preface 37
Water Conservation and Efficient Use Planning 38
Irrigation Management Decision-Making 40
Irrigation Scheduling 42
Irrigation Water Sources 45
Irrigation Water Suitability 47
Irrigation System Design 48
Pump Station 52
Irrigation System Installation 53
Irrigation System Maintenance and Performance 54
Metering 57
Irrigation Leak Detection 58
Irrigation System Renovation 58
Irrigation Record Keeping 59
Water Quality Management and Protection 60
Preface 60
Environmental Fate and Transport 60
Pollution Prevention 61
Stormwater Management 62
Buffers 65
Wetlands 66
Lake and Pond Management 67
Water Quality Monitoring 70
Preface 70
Groundwater Monitoring 70
Surface Water Monitoring 71
Water Quality Sampling 71
Water Quality Analysis 71
Golf Turf Fertilization and Nutrient Management 73
Regulatory 73
Preface 74
Essential Elements for Turfgrass and Plant-Available Ionic Forms 74
Basis for Fertilization 75
Soil Testing 75
Plant Tissue Analysis 76

Fertilizers Used in Golf Course Management ... 77
Nitrogen ... 78
Phosphorus ... 80
Potassium ... 81
Soil pH ... 83
Cultural Practices ... 85
Preface ... 85
Turfgrass Selection ... 85
Mowing ... 87
Cultivation ... 92
Topdressing ... 94
Plant Growth Regulators ... 95
Integrated Pest Management ... 97
Preface ... 97
IPM Overview ... 97
Monitoring Pests and Recording Information ... 99
Identifying and Understanding Pests ... 99
Determining Pest Threshold Levels ... 101
Control Methods ... 102
Evaluation and Record Keeping ... 105
Pesticide Management ... 106
Preface ... 106
Human Health Risks ... 107
Environmental Fate and Transport ... 110
Pesticide Risk Assessment Tools ... 112
Pesticide Storage ... 114
Pesticide Inventory ... 116
Pesticide Mixing/Washing ... 116
Personal Protective Equipment ... 118
Pesticide Container Management ... 118
Emergency Preparedness and Spill Response ... 119
Sprayer Calibration ... 120
Sprayers and Nozzles ... 120
Pesticide Record Keeping ... 121
Pollinators ... 122
Preface ... 122
Pesticides and Pollinators ... 123
Pesticide Application Practices to Protect Pollinators ... 124
Pollinator-Related Communication ... 126
Enhancing Pollinator Habitat ... 126
Maintenance Operations ... 128
Preface ... 128
Storage and Handling of Fertilizers ... 128
Equipment Storage and Maintenance ... 129
Equipment Washing ... 130
Fueling Facilities ... 132
Waste Handling ... 133
Emergency Preparedness and Spill Response ... 133
Sustainable Landscaping in Out of Play Areas ... 135

Preface 135
Benefits of Sustainable Areas on the Golf Course 135
Sustainable Landscaping Concepts 136
Sustainable High Visibility Areas 139
Sustainable Naturalized Areas 141
Habitat Corridors 142
Meadows/Tall Grass Areas 142
Plant Selection 144
Energy Management 147
General Energy Efficiency Considerations 147
Buildings and Amenities 148
Course Management 150
Renewable Energy 152
Funding Resources 153

Best Management Practices for Massachusetts Golf Courses

Introduction

When I began my journey as a golf course superintendent fifty years ago, I did not dwell on the effect my decisions could have on the environment. My mission was to produce a well-conditioned golf course with an emphasis on aesthetics and playability. The environment was important, but not paramount.

As time went on this changed. The book Silent Spring (1962), Earth Day (1970), the establishment of the Environmental Protection Agency (EPA) (1970), and the administering of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) being transferred from the USDA to the EPA brought about tremendous awareness of human impact on the environment. It also brought about more awareness of how my actions could affect the planet. I began to realize the importance of personal and environmental safety. In other words, to care as much for the environment as for the maintenance of the golf course. My decision making became a delicate balance with the demands of golfers pulling in a direction that was focused on playability and aesthetics and managing the course in an environmentally sound and fiscally responsible way.

Golf course superintendents have been professionally organized by the Golf Course Superintendents Association of America (GCSAA) since 1926. This organization provides education, information and representation to more than 18,000 members. GCSAA has positioned itself as the global leader in the golf industry and has been tuned into environmental awareness. It has led the charge for its members to address environmental and water quality protection, learn environmentally sound cultural practices, implement Best Management Practices (*BMP), conduct on-course wildlife management, introduce native plant species, and supports the latest technological and scientific advances by funding relative research at universities throughout the country. GCSAA efforts help members create environmentally friendly properties on which to play the game.

Today's superintendents are constantly drawing on environmental science to guide them with the management of the property in their care. No one is more aware of the impacts their work can have on the environment. They take great pride in their ability to conduct this work in an environmentally beneficial manner.

BMP provide important documentation and direction for management of the golf course landscape. This landscape consists of biologically diverse habitats for plants and animals that range from large plant species to soil microorganisms. These need care and attention to thrive. Who better to provide this care than golf course superintendents? They are stewards of the property charged with the responsibility of attaining the goals of the business within the constraints of a financial budget and environmental regulations.

Golf courses in Massachusetts benefit people, wildlife and the environment. Preserving these green spaces improves the environmental quality and value of the entire community. Turfgrass provides places of recreation and leisure activities; provides cooling; reduces noise, glare and pollution; provides a substantial carbon sink in the process of returning oxygen to the atmosphere; and is one of the best “dirty” water filtration systems in nature. The local community gains beauty and wildlife habitat through the current practice of converting areas of golf courses to native plant and wildlife habitat.

This BMP document will help guide golf course superintendents to create environmentally sound practices that enhance and preserve the landscape. Not all courses are alike. Therefore, these BMP should not be considered a mold that all courses should adopt without exception. Instead, they are offered as an evaluation tool for understanding how the property measures up and provides an array of suggestions that superintendents can devote resources within the constraints of time, labor, materials and budget. If each course would implement one BMP practice per year the benefits to preserving, or in many cases improving, our natural resources would be major steps toward sustainability and the future of our game.

Don Hearn
Executive Director
Golf Course Superintendents
Association of New England

**BMP are methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing water quality impacts or reducing pesticide usage.*

Planning, Design and Construction

Preface

In the Commonwealth of Massachusetts, the development of a new golf course or the renovation of an existing facility requires consideration of numerous legal, environmental, economic and site suitability factors. These must be carefully considered during each step of planning, design, and construction to ensure that the project is permissible, viable, sustainable, and ecologically sensitive (Table 1).

Since the 1980's all golf course construction work was required, by the Massachusetts Department of Environmental Protection, to conduct an environmental impact review which would establish the existence of regulatory triggers tripped for project qualification and subsequent constraints on construction. Of particular concern was work areas that could possibly impact water quality in wetlands, surface water and groundwater. These water areas would be sampled to establish a water quality baseline. Since this time, most approved golf course construction work would require continued water quality sampling of these sources to realize the actual impact of the work.

The thoughtful use of best management practices during planning, design and construction are important to a successful result. Use of BMPs should not be considered a regulatory burden. Instead, they improve and protect natural resources for current and future generations of golfers and citizens. Furthermore, when facilities are designed and constructed to maximize sustainability, it positively impacts other topics in this document, such as maintenance operations, landscaping, and energy efficiency.

Planning

The implementation of a golf course project typically benefits from the use of professional consultants familiar with similar requirements. The consultants required depends on the scope and complexity of the proposed work, as well as the various municipal regulations governing the project site. Most projects commence with the hiring of a qualified golf course architect, a civil engineer and an environmental consultant. For most renovation projects, this may be the extent of consultants required for planning.

The first step in planning is development of an accurate existing conditions plan identifying property boundaries, topography, vegetation limits, roads, wetlands and other jurisdictional areas. A good base map is a critical tool in planning a project to avoid negative environmental impacts and to determine the feasibility of achieving project goals. The development of a constraints plan, along with identification of a suitable irrigation water source, may determine that a site is inappropriate for the intended golf project before expensive planning and permitting begins.

Once the suitability is confirmed through generation of preliminary concept plans and cost estimates, a team is generally assembled to guide the project. The golf course architect and civil engineer may be helpful in assembling the federal/state regulatory permitting team. Professional, experienced judgement is crucial when implementing BMPs in the planning, design and construction phases of the project. An experienced golf course superintendent is integral to the planning process for any golf project. For course renovation projects, with their extensive knowledge of the site, the superintendent can assist in determining the most suitable design and can inform the design team of issues that may impact maintenance of the course or player enjoyment of the facility. The superintendent's knowledge and experience with BMPs and their direct participation in planning and construction greatly affect the success of the project.

Table 1. Overview of the steps involved in golf course planning, design, and construction

Planning	
Step	**Description**
Assemble Team	The team should include, but not be limited to, fully committed golf course architect, golf course superintendent, clubhouse architect, irrigation engineer, environmental engineer, energy analyst, economic consultant, civil engineer, soil scientist, golf course builder, biologist or ecologist, and a legal team. For new golf courses, a licensed golf course designer is required by law to guide the site analysis process.
Define Objectives	Identify realistic goals, formulate a timeline, etc.
Conduct a Feasibility Study	Evaluate finances, regulatory environmental issues, water availability and sources, and energy, materials, and labor needs. Identify applicable federal, state and local regulations.
Select and Analyze 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 federal and state protected species, valuable habitat, or invasive species 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.
Design the Course	Existing native landscapes should remain intact as much as possible. Consider 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.
	Structural BMPs: Incorporate structural BMPs into the design plan. Identify opportunities to: detain stormwater and to improve water quality through stormwater volume reduction, filtering, and biological and chemical processes; reduce the amount of required water, nutrient and chemical support.
	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. Root zone material should be selected with United States Golf Association (USGA) specifications in mind, as published in A Guide to Constructing The USGA Putting Green. Physical testing of these sands by an accredited laboratory prior to use is recommended.
	Grass Selection: Species should be selected based on climate, 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
	Vegetative Filters: Managed turf should be reduced by incorporating vegetative filters (conservation buffers, vegetated filter strips, swales, etc.) can be used throughout the golf course to act as natural biofilters to reduce

	stormwater flow and pollutant load. Turf areas are also effective filters.
Design Irrigation System	Hire a professional irrigation designer, 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.
Construction	
Select Qualified Contractors	Use only qualified contractors who are experienced in the special requirements of golf course construction, such as members of the Golf Course Builders Association of America.
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. Prevent the spread of invasive species.
Install Irrigation System	Installation should consider future maintenance demands and 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.

Water Sources

Of all the environmental concerns that a golf course faces in its day to day operation, water use and quality is the most prominent. Golf courses are commonly perceived as using excessive amounts of water. Massachusetts regulates the amount of water any golf course can use for irrigation, as well as the source of that water. Regulators may require that the course utilize degraded water (if available and suitable for turf), or limit the amount of water taken from wells, streams or lakes. For some courses their only option is to purchase costly, private or municipal water sources. These requirements can severely impact the economic feasibility of a golf project. For more information on water sources, see the Irrigation chapter.

Wetlands and Streams

Wetlands are areas where water covers the soil, is present near the surface of the soil all year, regularly covers or near the surface of the soil periodically during the year, including during the growing season. The boundaries and buffer zones of any wetlands, vernal pools, coastal zones, water bodies, intermittent streams and rivers should be identified, flagged and mapped in accordance with local, state, federal regulations by a qualified specialist. Regulated activities, such as draining, dredging, clearing and filling within or in proximity to wetlands, streams, or rivers, require permits from the appropriate regulating authorities. A professional consultant and local conservation commission should be utilized to determine permitting needs and provide design assistance to reduce impacts. In some cases, the scope of a project can be changed to eliminate work in a regulated area. If not, the design may be altered to reduce impacts or generate other environmental improvements.

Floodplains

Golf courses can be a compatible use of floodplain zones, depending on the frequency and severity of flooding. When persistent floods could result in frequent course closures, turf loss and/or significant sediment removal and bunker repair, then use for golf may not be sustainable without improvements.

Listed Species and Habitats

In addition to identifying wetlands and floodplains before intensive planning, the absence of any listed species or habitats of concern should be verified with the appropriate state/local agency. The presence of either listed species or habitats of concern within the site boundaries or in proximity to the project site could limit the goals and objectives for the project. On the other hand, many times the golf course has become an asset when utilized to protect listed species or develop habitats that will increase the number of listed species common to the area.

Best Management Practices for Planning

- Assemble a qualified team with expertise in golf development and environmental permitting.
- Determine objectives and complete a feasibility study of the project.
- Select an appropriate site that is capable of achieving the needs of stakeholders and identify strengths and weakness of the selected site.
- Have a qualified specialist accurately identify wetland boundaries determine and cost likely protective or mitigation measures needed.
- Identify any listed species or habitat of concern on the site.

Design

It is important to establish clear and achievable goals and objectives at the commencement of any proposed project. The professional team can assist the course owner or developer in refining the goals and objectives by providing concept plans and cost estimates for the work in the preliminary phase of design. This information helps to determine what changes are appropriate for the site, the financial feasibility of the project and the anticipated schedule for implementation. Although the process of developing goals and objectives varies depending on the complexity of the proposed work, projects are most successful when a clear scope of work is defined and thoughtfully implemented.

A good design is legally compliant, meets the needs of the stakeholders, protects the location's environmental resources, and is economically sustainable and affordable after the construction is completed. The design should address a number of site issues, such as the ones discussed below.

Environmental Impacts

The design should avoid or minimize impacts to sensitive environmental issues that may have been identified during the site review and preliminary planning phase. When impacts are unavoidable, the design should identify the scope of the impact and provide mitigation as well as ensure that future maintenance of the course will be undertaken to lessen negative impacts.

Wetlands and Streams

When incorporated into a golf course design (or renovation), wetlands should be maintained as preserves and separated from managed turf areas with native vegetation buffers. MA Wetlands Protection Wetlands should be managed as natural areas, with their habitat structure and existing hydrology fully protected from excessive runoff discharges, temperature changes, de-watering effects from irrigation sources and from nutrients or pesticides used during golf course maintenance. The replacement of failing culverts or the installation of raised cart paths or boardwalks provides an opportunity to upgrade stream crossings and improve streamflow, wetlands and buffer areas, and provide water quality or wildlife habitat protection benefits.

Constructed Wetlands

Constructed aquatic ecosystems simulate the role of natural wetlands with respect to water purification and may be legally permitted to be an integral part of the stormwater management system. Like natural wetlands, they feature poorly drained soils and rooted emergent hydrophytes. which simulate the role of natural wetlands in water purification. These structures efficiently remove certain pollutants (carbon, nitrogen, phosphorus, metals, sediment, and other suspended solids) and can treat wastewater, such as discharges from equipment wash pads before the water enters streams, natural wetlands, or other surface water. Once these areas are constructed, however, they are considered wetlands and regulated as such.

Floodplains

Any planned 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. MA Floodplain Management 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 Federal Emergency Management Agency (FEMA) review along with potential revision to the floodplain mapping.

Floodplain restoration is the reestablishment of natural water systems to help mitigate flooding and control stormwater. During the planning and design phase, floodplain restoration activities can address vertical and lateral stream migration, which causes unstable banks, flooding, reductions in groundwater recharge, and high sediment and nutrient loads. When incorporating floodplain restoration into the course design or renovation, land use decisions and engineering standards must be based on the latest research science available. Where appropriate and if land is available, installing or enhancing stream buffers may be also help restore or enhance natural water flows and flooding controls as well as providing wildlife habitat.

Stormwater Management

Although golf courses are typically large properties ranging from 60 to 200 acres, they are just one link in a stormwater management chain. Generally, a quantity of stormwater enters the golf course area, supplemented by what falls on the golf course proper, and then the stormwater leaves the golf course. Therefore, golf courses are realistically capable of having only a small impact on major stormwater flow. That impact should be to add only small increments of water to the stormwater flow over a given period of time. Engineers call this beneficial function "detention."

When golf courses are designed, their drainage capability concept is guided by an average rainfall event of a given frequency. For example, a golf course drainage system is typically designed to detain a two- or five-year rain event. In other words, when that rain event happens, the golf course will be able to be reasonably drained in a matter of hours, as excess water not absorbed by the soil flows through the drainage system, is temporarily held, and finally leaves the property. In some instances, golf courses and other recreational facilities are mandated to be designed to handle a 20-, 50- or 100-year rain event, which means the golf course must detain more water for perhaps a longer period of time. The ability to detain large amounts of water requires accurate engineering and extensive construction to prevent physical or financial damage to the facility.

BMPs are intended to prolong the detention process as long as practical, harvest as much of the stormwater in surface or underground storage as reasonable, and to improve the quality of water leaving the property when possible. Methods of stormwater management include infiltration chambers that allow water to better enter the ground and recharge aquifers, retention basins that slow the flow of water off the property during heavy rain events while also trapping and filtering contaminants and sediments, and installation of swales with check dams to slow runoff. MA Stormwater Management

Drainage

Adequate drainage is necessary for healthy turfgrass. Good surface drainage is the most reliable method for removal of water from course play areas. On gently sloped sites, surface drainage may be adequate to remove water without concern for erosion. In general, a putting green surface should be tilted at no less than one percent (1%) slope and fairways and roughs no less than two percent (2%) to achieve adequate surface drainage.

Where the ground is very flat, subsurface drainage may be needed to assist in expedient removal. Where the ground is steep, subsurface drainage is helpful in reducing erosion by limiting the length and velocity of overland flow. Subsurface drainage is also installed to control a water table or to interrupt subsurface seepage or flow. Wherever possible, drainage should be directed into vegetative areas for biological filtration or into infiltration basins to help control the potential loss of nutrients and pesticides from the golf course.

Drainage 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. The drainage system should have many inspections portals and be routinely checked to ensure proper function. Plant roots and animal activity can easily clog drains and prevent proper functioning.

Stormwater Capture

Capture systems should be considered part of the overall treatment of stormwater. Stormwater capture is desirable where the water quality is good and allows conservation of potable water, maintains hydrologic balance, and improves water purification. This practice uses natural systems to cleanse and improve water quality naturally. Ponds often have the primary purpose of drainage and stormwater management and are also often a source of irrigation water. When the golf course is properly designed, rain and runoff captured in water hazards and stormwater ponds may provide most or all of the supplemental water necessary under normal growing season conditions, though backup sources may be needed during times of drought.

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. Therefore, the design of ponds should consider the needs of aquatic ecosystems, such as discouraging excessive growth of aquatic vegetation, supplying sufficient dissolved oxygen (DO) to support aquatic species, etc. Careful design may significantly reduce future operating expenses for pond and aquatic plant management. In addition, water resources should be managed to control or limit the spread of aquatic invasive species and infectious insects, such as submerged plants, fish, invertebrates and mosquitoes.

Habitat Conservation

In addition to adhering to regulations that protect listed species, maintaining habitat to the extent possible during all phases of planning, design, and construction helps maintain biodiversity and protect migration corridors. Natural habitats provide food and shelter for numerous species, including mammals, birds, fish, amphibians, reptiles, insects, and native plants. The "Pollinator" and " Sustainable Landscaping in Out-of-Play Areas" chapters of this document provide additional recommendations and BMPs for enhancing habitat on the golf course. Additionally, there are cases where the development of a golf course, and future management of this green space, have created a bio-diverse habitat on a barren or abused piece of property.

Best Management Practices for Design

- Involve a qualified golf course superintendent/project manager at the beginning of the design process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.
- Design the proposed changes to minimize or eliminate alteration of sensitive existing native landscapes. The plans should review alternate designs to determine the concept plan that best meets the objectives with the least disturbance.
- Design the changes to retain as many natural site characteristics as possible.
- Consider potential wear patterns in turf areas and create adequate space for ingress/egress at greens, tees, fairways and bunkers.
- Define play and non-play maintenance boundaries.
- Select a greens location that has adequate sunlight to meet plant specific needs and provides sufficient drainage, or design site improvements to reduce shade and improve drainage characteristics.
- Choose a green size and sufficient number of hole locations large enough to accommodate traffic and play damage, but not so large that it is not sustainable with your resources.
- Consider the placement of bunkers in relation to circulation patterns at greens so as not to concentrate turf wear.
- Consider the number, size and style of sand bunkers as they relate to resources available for daily maintenance.
- Be aware of bunker design as it relates to cost of construction and future maintenance. Make sure bunkers have suitable machine entry and exit points.
- Select the proper color, size, and shape of bunker sand that meets the course needs and sustainability.
- Ensure that wetlands have been properly delineated by a professional consultant before working in and around any wetlands.
- Ensure that proper permitting has been obtained before disturbing any tidal or non-tidal wetland or the regulated buffer zone.
- Establish and maintain an appropriately sized buffer around wetlands, springs, and spring runs.
- Install stream buffers to restore natural water flows and flooding controls.
- Install buffers in play areas to stabilize and restore natural areas that can attract wildlife species.
- Install detention basins to store water and reduce flooding at peak flows.
- Use a swale and berm system to allow for resident time (ponding) for water to infiltrate through the root zone to reduce lateral water movement to surface water bodies.
- When constructing drainage systems, pay close attention to engineering details such as inspection and maintenance prots, subsoil preparation, the placement of gravel, slopes, and backfilling and placement of drainage gravel.
- Discharge subsurface drainage through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- The drainage system should be routinely inspected to ensure proper function.
- Install berms and swales to capture pollutants and sediments from runoff before it enters irrigation storage ponds.

- Monitor pond water level for water loss (seepage) to underground systems. If seepage is occurring, it may be necessary to line or seal irrigation ponds or install pumps to relocate water.
- Be aware of the slope of the bottom of the pond and the maintenance requirements adjacent to the edge for personal safety.
- Install water intake systems that use horizontal wells placed in the subsoil below the storage basin. Use a post pump filter to remove particulate matter.
- Remove excess sediments in irrigation ponds to reduce irrigation system failures.
- Select an appropriate site for irrigation ponds to allow for adequate water levels to be maintained, including in times of drought.
- Design ponds so as to avoid peninsular projections and long, narrow fingers, which may prevent water mixing. Ponds that are too shallow may promote algal growth, excess sedimentation, and exhibit high temperatures and low DO levels.
- Reverse-grade around the perimeter of ponds to control surface water runoff and reduce nutrient loads.
- Provide for proper aeration with shoreline rip rap, bubblers, or fountains.
- Construct random small dips and ridges (micro topography) on shorelines of a few inches to a foot to promote diversity for the aquatic plant community and provide a healthier and more productive littoral zone.
- Consult with a professional engineer when constructing a dam.
- Protect and enhance habitat by:
  - Identifying the different types of habitat specific to the site.
  - Identifying habitat requirements (food, water, cover, space) for wildlife species.
  - Identifying and preserving regional wildlife and migration corridors by avoiding or minimizing crossings. Design unavoidable crossings to accommodate wildlife movement.
  - Designing out-of-play areas to retain or restore existing native vegetation where possible.
  - Removing nuisance and exotic/invasive plants and replacing them with native species that are adapted to a particular site.
  - Maintaining 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.
  - Retaining dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.
- Constructing and placing brush-piles, birdhouses, bat houses, bee boxes, etc. in out-of-play areas.
- Design and locate golf car paths to minimize environmental impacts. Use educational signage for the golfers. Construct the paths with permeable materials, if possible.

Construction

Documents

Prior to starting construction, construction plans that clearly communicate the scope of work are needed to communicate all aspects of the project to stakeholders to ensure that all parties understand the project. All critical data from the environmental resource inventory as well as key notes regarding construction processes should be included in the construction documents, as well as any conditions imposed by the regulatory permit process. Documents should include sediment and erosion control or stormwater management plans that were established in the design phase.

Challenges often arise during construction that were not foreseen in the planning, design and budget stages. Development of clear and thoughtful plans and specifications can minimize costly changes during the work and will assist those involved in the project to anticipate unforeseen challenges. Proper planning can reduce the number of issues, but it is best if the contractor hired has significant experience with golf course renovation or new construction. This ensures familiarity with environmentally sound construction methods/practices.

Construction Activities

Construction should begin with a project team meeting with the contractor(s) to review construction protocols. The purpose of this meeting is to define lines of communication, review the scope of work, review methods for reducing environmental impacts and for the contractor(s) to become familiar with permit requirements. Any natural resource areas that could possibly be impacted by the project should be clearly delineated during this meeting. Field review and discussing permit conditions of these areas with the contractor will accentuate the importance of preserving natural resources.

The golf course architect, engineer, irrigation designer, golf course superintendent and other key consultants should remain involved through the entire construction phase to ensure plans and specifications are followed and permit conditions are met. The consultant's role in construction should be defined at the start of work.

During construction, the site should be kept as stable as possible to reduce erosion and stabilize sediments. For large renovation and new course projects, the contractor should attempt to "phase" work to limit the amount of disturbed area at any given time, which requires completing and stabilizing a portion of the site prior to starting on a new area. On smaller projects, rather than phasing, the best method to prevent environmental impacts may be a narrow construction window. The construction schedule and work limitations should be tailored to each site and project. With emphasis on performing quality work and minimizing the potential for future problems.

Construction Techniques

Sound construction techniques include those processes and practices that control soil erosion and stormwater runoff. Examples of such techniques include the following:

- Conduct work during permissible and reasonable hours.
- Maintain construction entrance and staging/stockpile areas. Tarp all stockpiles. Physically control the entire site for safety/trespass.
- Installation of perimeter erosion control barriers prior to any land disturbance.
- Locating construction staging and fueling operations at least two-hundred feet (200') from any water body, wetland or sensitive area.
- Checking barriers prior to a predicted rainfall and removing excess siltation and repairing barriers immediately following a storm.
- Protection of drain inlets with gravel and silt fabric.
- Monitor and log all compliance requirements.

Sediment Stabilization

The loss of topsoil from a site can be a problem for numerous reasons. Soil and sediment 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 can have harmful effects on aquatic plants and animals. Therefore, control measures need to be documented in a written erosion and sediment control plan, put in place prior to any soil disturbance, and properly maintained during the entire period, construction through stabilization. Wherever possible, a vegetative cover should be kept on the site until it is ready for construction. As soon as possible after construction activities are completed, the areas should be planted, sodded, or otherwise covered to prevent stabilize sediments and prevent erosion.

Construction Monitoring

The contractor, superintendent or a hired "clerk of the works" should be responsible for monitoring the entire construction process and provide any reports required by project permits. The level of diligence invested in monitoring can significantly influence the environmental and financial sustainability and viability of the project.

Best Management Practices for Construction

- Create a quality assurance program with proper quality control documentation.
- Conduct a pre-construction conference with stakeholders.
- Use a qualified golf course contractor, such as a member of the Golf Course Builders Association of America, or one with significant local golf course construction experience.
- Consider limiting the area of disturbance at one time. Finish and stabilize one area before starting another area.
- Construction should be scheduled to maximize turfgrass establishment and site drainage.
- Monitor construction activities, maintain a construction progress report, and communicate the report to the proper permitting agencies.
- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling to stabilize soils.
- Discharge subsurface drainage systems through pretreatment zones and/or vegetative buffers, where possible, to help remove sediments and nutrients.
- Utilize carbon filters at the end of drain pipes and cover drainage grates to avoid contamination.
- Develop and implement strategies to effectively control sediment, dust, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife and plant communities.
- Integrate hydro-mulching, erosion blankets or straw mulch into the seeding process to enhance soil stabilization. Avoid using hay as mulch which may introduce unwanted weed seeds that may become a future problem.
- Check and repair erosion control barriers after every rain event.

Turfgrass Establishment

Turfgrass establishment is a unique phase in turfgrass growth which is dependent on water and nutrient. Unlike maintaining established turfgrass with infrequent, deep irrigation and seasonal nutrient application, establishment requires light frequent applications of water and nutrient. To this end, the establishment phase should be considered carefully to minimize environmental risk. Selection of turfgrass species or cultivar is one of the most important decisions a manager can make to ensure a healthy turfgrass stand. Prior to establishing turf, turfgrass managers should select grass species and cultivars based on the existing site conditions and the intended use of the turf, as described in the Cultural Practices chapter.

Seedbed Preparation

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.

Sodding

Most grasses can be sodded during any time of the year. Soil preparation which eliminates compaction, increases infiltration and improves soil particle size distribution is critical. Sod should be topdressed to fill in the gaps between the pieces to speed establishment and create a smoother surface. During dry weather (summer or winter), light and frequent irrigation is required until the sod takes root. Check for rooting by lightly pulling the corner of the sod. Irrigation frequency can be reduced when the sod cannot be pulled from the soil surface.

Seeding

New England's cool-season turfgrass species (bluegrass, fescue, and ryegrass) should be seeded in late summer, except creeping bentgrass. This timing is generally ideal because soils are warm, nights are cool, and disease and weed pressure are reduced. However, research at the University of Connecticut has found July or early-August to be optimal for seeding creeping bentgrass to minimize annual bluegrass ("poa") competition which typically germinates during late-summer and fall. Cool-season grasses can also be dormant seeded in late fall through the winter.

Cool-season species can be seeded in the spring, especially following winterkill. However, for any spring seeding, pre-emergence herbicides should be used to vastly improve the success of bare ground grow-in. Without a pre-emergence herbicide, spring seeding success is significantly reduced because of the summer annual weed pressure. Herbicide labels should be reviewed to ensure that the product is labeled for use during establishment. A drop-type spreader should be used for uniform seed dispersal. Lightly raking the soil or using specialized "slit seeders" improves seed-to-soil contact.

During grow-in through establishment, light frequent watering is recommended. The grower's goal is to keep the soil surface moist until germination. Irrigation frequency should then be reduced, though the amount of water applied should be slightly increased until the first mowing. Turfgrasses with relatively large seeds (i.e., tall fescue, perennial ryegrass, and fine fescue) generally need fewer irrigation events during establishment than finer-textured seeds (i.e., Kentucky bluegrass and creeping bentgrass).

Soils that test deficient in phosphorous, require that this mineral be applied to the soil before seeding or sodding at a rate ranging from 0.5 to 1.5 lbs P_2O_5 per 1,000 square feet (22 to 65 lbs P_2O_5 per acre). A follow-up application of phosphorus may be required four to eight weeks after seedling germination or sodding if the turf exhibits symptoms of phosphorus deficiency (such as purple-blue color, thin canopy, poor nitrogen response). Soils tested showing a pH greater than 7.5 are also prone to phosphorus deficiency which should be addressed during establishment. Therefore, the process of turf establishment anticipates the application of supplemental phosphorous to the soil. Once the turfgrass is established it is recommended to continually monitor soil nutrient and pH by laboratory testing.

Nitrogen (N) management is essential during establishment. For highly maintained turf stands or turf growing on sand or sand-based soils, water soluble sources of N fertilizer should be applied to the turf leaf blades by spraying every 7 to 14 days. Fertilizer applications should continue until the turf canopy has achieved 100% cover. Single application rates should not exceed 0.5 lbs of N per 1,000 square feet. Slow-release nitrogen sources can also benefit establishment regardless of soil type. Higher N application rates may be used with products containing more slow-release nitrogen. Fertilizers with 50% quick-release and 50% slow-release N provide uniform nitrogen release for a period of 6 to 10 weeks, depending on the formulation.

Micronutrient fertilizers and organic matter can also be beneficial during establishment, especially on sandy or high pH soils. Nutrients such as iron and manganese can sometimes be limiting in these soil conditions. The recommendations found in soil test results are for established turfgrass. For establishing a new stand, these recommendations are not as beneficial. Instead, deficiencies can be diagnosed through small applications of fertilizer to a section of the turf. Lack of a response indicates that the nutrient is not limiting and that application to the entire area is not warranted.

Mowing should begin as soon as the turf height reaches the desired mowing height for that area. An exception may be putting greens. While some managers will start mowing to standard putting green heights immediately (0.15” or less), most managers start mowing at 0.4” and slowly reduce the height of cut as the stand matures. Regular mowing promotes new tiller formation and stimulates the transition from juvenile to mature plants.

Best Management Practices for Turfgrass Establishment

- The area to be established should be properly prepared and cleared of pests (e.g. weeds and pathogens).
- Select cultivars that are best adapted to the desired use and disease/insect resistance, drought tolerance, traffic and shade tolerance in addition to density, texture and color.
- Ensure erosion and sediment control devices are in place and properly maintained.
- Use mulch (e.g., hydromulch, loose straw from a clean source, straw mats) for soil stabilization.
- Prepare seed/sod bed to maximize success.
- Fill gaps in sod seams with soil or sand to provide a uniform surface.
- Use selective pre-emergence herbicides to reduce weed competition and improve the chance of success with seeding establishment during the spring.
- If required, apply a fertilizer containing phosphorus at seeding. An additional application should be applied if the 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 used.
- Mow turf to the desired mowing height as soon as practical to promote density and maturation. Never remove more than one-third of the turf leaf at mowing.

External Programs

Golf courses can gain valuable recognition for their environmental education and certification efforts. Examples of external designations include Audubon International's Cooperative Sanctuary Program for Golf and the Groundwater Foundation's Groundwater Guardian Green Site program.

Maintenance Facilities

Maintenance operations on golf courses include a variety of activities, such as equipment fueling and maintenance; equipment washing, storage and repair; storage, mixing and loading of fertilizers and pesticides; and handling of waste generated by maintenance operations. These activities may use chemicals such as petroleum products, pesticides, fertilizers, solvents and degreasers. Maintenance operations are based at a maintenance facility. An unintended spill or release of any products stored or used at the facility can harm human, animal and plant life, so recommended maintenance operation procedures must be followed to reduce release risk. The siting and design of the facility must consider the possibility of contamination. For instance, it would be unwise to site a maintenance facility in a shallow groundwater aquifer location, or in close proximity to a water body.

Waste reduction and pollution prevention initiatives can help streamline the storage, handling, and disposal requirements for maintenance operations. The discharge or disposal of water from the maintenance facility (such as the equipment wash water) must follow BMP's to avoid contamination of surface or groundwater. Simple steps can reduce water pollution risk, such as using only water to wash off equipment, or using only non-phosphate detergents if a cleaning chemical is required. Other steps may include using innovative water recycling systems for equipment washing and enclosed collection structures for loading and mixing of chemicals.The maintenance facilities must incorporate BMP to minimize the potential for contamination of soil and water resources. The pesticide mixing and storage facility, the equipment wash pad, and the fuel center are focal points for environmental protection.

Refer to Section 10: MAINTENANCE OPERATIONS for more detail regarding the maintenance facility and operations.

Best Management Practices

- Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment.
- Store pesticides in a roofed concrete or metal structure with a lockable door.
- Construct floors of seamless metal or concrete sealed with a chemical-resistant paint.
- Ensure that flow from floor drains does not discharge directly to the ground and that drains are not connected to the sanitary sewer line or septic system.
- Equip the floor with a continuous curb to retain spilled materials.
- Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.
- Provide storage for personal protective equipment (PPE) where it is easily accessible in the event of an emergency, but do not store in the pesticide storage area.
- Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides.
- Use shelving made of plastic or reinforced metal. Keep metal shelving painted.

- Provide appropriate exhaust ventilation and an emergency wash area.
- Always place dry materials above liquids, never liquids above dry materials.
- Never place liquids above eye level.
- Locate operations well away from groundwater wells and areas where runoff may carry spilled pesticides into surface waterbodies.
- Do not build new facilities on potentially contaminated sites.
- An open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides.
- In constructing a concrete mixing and loading pad, it is critical that the concrete have a water-to-cement ratio no higher than 0.45:1 by weight.
- The sump should be small and easily accessible for cleaning.
- Ensure that workers always use all personal protection equipment as required by the pesticide label and are provided appropriate training.
- Assess the level of training and supervision required by staff.
- Any material that collects on the pad must be applied as a pesticide according to the label or disposed of as a (potentially hazardous) waste according to state laws and regulations.
- Clean up spills immediately!
- Always store nitrogen-based fertilizers separately from solvents, fuels, and pesticides, since many fertilizers are oxidants and can accelerate a fire. Ideally, fertilizer should be stored in a concrete building with a metal or other type of flame-resistant roof.
- Always store fertilizers in an area that is protected from rainfall. The storage of dry bulk materials on a concrete or asphalt pad may be acceptable if the pad is adequately protected from rainfall and from water flowing across the pad.
- Sweep up any spilled fertilizer immediately.
- Do not wash equipment unnecessarily.
- Clean equipment over an impervious area, and keep it swept clean.
- Brush or blow equipment with compressed air before, or instead of, washing. Use spring shutoff nozzles.
- Use a closed-loop recycling system for wash water.
- Recycle system filters and sludge should be treated and disposed appropriately.
- Each piece of equipment should have an assigned parking area. This allows oil or other fluid leaks to be easily spotted and attributed to a specific machine so that it can be repaired.
- Use solvent-recycling machines or water-based cleaning machines to cut down on the use of flammable and/or toxic solvents.
- Use a service to remove the old solvents and dispose of them properly.
- Design pesticide storage to keep pesticides secure and isolated from the environment.

Wildlife Considerations

Golf courses occupy large land areas, often within urban areas. The green space of a golf course is a refuge for many species of birds and animals. With considerate maintenance, the course can provide suitable habitat and critical links between urban and rural/natural environments. Maintaining wildlife habitat on golf courses better maintains biological diversity, which is especially important in the urban environment. Most golfers enjoy observing non-threatening wildlife as they play the game.

Best Management Practices

- Identify the different types of habitat specific to the site and the natural corridors or pathways which connect the habitats
- Identify the habitat requirements (food, water, cover, space) for desired and compatible wildlife species.
- Identify species on the site that are considered threatened or endangered by the federal or state government, including species the state deems “of special concern.”
- Preserve critical habitat and their buffer zones. Habitat may be trees, brush, water, wetland or tall grass, depending on the species.
- Identify and preserve regional/local wildlife and migration corridors.
- Design and locate cart paths to minimize environmental impacts. Construct the paths of permeable materials, if possible.
- Avoid or minimize crossings of wildlife corridors. Design unavoidable crossings to accommodate wildlife movement.
- Remove nuisance and exotic/invasive plants and replace them with native species that are adapted to a particular site.
- Maintain clearance between the ground and the lowest portion of a fence or wall 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, and nesting sites in out-of-play areas.
- Plant butterfly 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.
- Minimize stream or river crossings to protect water quality and preserve stream banks.
- Retain riparian buffers along waterways to protect water quality, provide food, nesting sites, and cover for wildlife.

Irrigation

Preface

The judicious use of supplemental water keeps turfgrass and landscape plants healthy, while providing the firm, fast playing surfaces that golfers desire. BMPs that conserve and protect these water resources are integral to facility management. Conservation and efficiency-related efforts consider the strategic use of course and irrigation design, computerized and data-integrated scheduling, and alternative water supply options that support plant health and reduce the potential for negative impacts on natural resources.

Irrigation BMPs may also provide an economic, regulatory compliance, and environmental stewardship advantage to courses that integrate them into an irrigation management plan. BMPs are not intended to increase labor or create undue burden. If applied appropriately, irrigation-related BMPs can help stabilize labor costs, extend equipment life, reduce repairs, and limit overall personal and public liability while protecting and conserving natural resources. Additional comprehensive information that includes detailed irrigation-related BMPs can be found in *Best Management Practices for Golf Course Water Use* (Connecticut DEP, 2006).

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 while using less water. Opportunities to conserve water exist when courses are initially designed and during renovation, during irrigation system design and use, and by incorporating the use of management zones. For example, some new courses are designed using a “target golf” concept that minimizes the acreage of irrigated turfgrass and improves the use of the water applied. Similarly, hand-watering specific areas of stress-prone turfgrass can result in significant water savings. If properly designed, water hazards and stormwater ponds can capture rain and runoff that may provide supplemental water under normal conditions, though backup sources may be needed during severe drought.

Water Budgets

The development of a water budget establishes a benchmark for golf course water requirements that can be compared with actual water use, ultimately confirming whether water is being used efficiently or whether changes in management strategy are needed. Using a water budget to accurately estimate a course’s water requirements can translate into improved playing conditions for golfers, lower operating and maintenance costs, and improved resource management. Water budgets take into account the size of the property, historic climate data, effective rainfall, and plant factors. This helps managers make informed decisions about their current water use and the effectiveness of programs designed to reduce water use. The water-budget approach is recognized by the United States Environmental Protection Agency (USEPA) and other federal and state agencies as a science-based approach for estimating landscape water requirements. The United States Golf Association (USGA) provides an online Water Budget Calculator along with step-by-step instructions for assistance in creating a facility-specific water budget. Precision water management is one of the most important practices for maintaining high-quality golf turf while conserving water resources, as discussed in detail later in this chapter.

Precision water management can be achieved through efficient irrigation practices that replace only the amount of irrigation water needed to maintain healthy turf in playing areas. It requires an efficient and properly functioning irrigation system and regular cultural practices that increase the water-holding capacity of soil.

Turfgrass Selection

Turfgrass selection is an important component of a water conservation efforts. The increased availability of improved turfgrass species and varieties provide an excellent opportunity to select the most well adapted turf to specific site conditions. If selected for drought tolerance, some turfgrass varieties require less water to survive and maintain playability. The National Turfgrass Evaluation Program (NTEP) provides information on top performing cultivars for various desirable turfgrass traits, including tolerance to drought, traffic and diseases.

Out-of-Play Areas

In addition to utilizing well-adapted cultivars for in-play areas, existing golf courses can create out-of-play turfgrass areas to native plants, grasses, or ground covers to further reduce water requirements 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. The Native Plant Trust (formerly New England Wild Flower Society) provides information on native plants in the region, and additional lists for drought-resistant landscapes can be found through state university extension programs, including the University of Massachusetts and University of New Hampshire. See also the "Pollinators" and "Sustainable Landscaping in Out-of-Play Areas" chapters for more information on native and drought-tolerant plants.

Wetting Agents

Wetting agents can be useful for managing a number of water-related issues, such as improving irrigation efficiency, assisting in the retention of water in the soil profile, aiding in infiltration, preventing and treating localized dry spot (LDS), or serving as a spray adjuvant when applying pesticides or plant growth regulators (PGRs).

Research shows preventative applications can increase soil water uniformity and sustain high visual turfgrass quality at very low levels of irrigation (30% potential evapotranspiration) [Kostka et al., 2005]. Preventative applications of wetting agents can also increase irrigation precision, which reduces water use while maximizing playing conditions. Late fall applications may reduce water repellency in soils well into the spring, reducing the potential for LDS in the spring.

Wetting agents are especially useful in restoring the wettability of hydrophobic (water repellent) sand-based soils. Turfgrass grown on sand-based root zones can develop severe localized dry spots especially when the stand is irrigated deep and infrequently (wet and dry cycles). Wetting agents help promote water infiltration and retention in these hydrophobic areas by reducing the surface tension of water and restoring the polar attraction of water to soils.

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).

Drought Planning and Response

In Massachusetts, the term drought typically has two implications for golf course superintendents: the first being that there is an actual prolonged period of below average precipitation that will affect plant health; and the second being the regulatory action taken by the MA Executive Office of Energy and Environmental Affairs restricting non-essential water use. Most golf courses will be operating under the MA Department of Environmental Protection's Water Management Act issued permits and registrations governing the use of potable and surface water for irrigation purposes. As part of the conditions of these state permits/registrations, golf courses are mandated to submit

Annual (use) Reports and possess an MA DEP approved written Seasonal Demand Management Plan for Water Management for Golf Courses (SMDP). WMA Reporting Forms Additionally, golf course superintendents must monitor the real time MA Current Drought Status portal MA Drought Status to correctly implement their SDMP.

Besides operating the facility in a manner that promotes water conservation, superintendents should identify water-conserving measures in time of severe shortages before water usage restrictions are enacted at a state or local level. Water conservation plans should identify opportunities to achieve a 10%, 30%, and 50% reduction in water use. The USGA publication *BMPs and Water-Use Efficiency/Conservation Plan For Golf Courses: Template and Guidelines* can facilitate the creation of the plan. In addition, superintendents should monitor drought status when needed. Drought conditions for each state can be accessed through the National Integrated Drought Information System on the U.S. Drought Portal.

Communication should be maintained with water managers, golf club members, and the public to explain these water conservation efforts as a proactive approach to addressing water-related issues.

Best Management Practices for Water Conservation and Efficient Use Planning

- Develop a water budget for the course.
- Select drought-tolerant varieties of turfgrass to minimize water use.
- Utilize hand watering or targeted irrigation to conserve water.
- Control invasive plants or plants that use excessive water.
- Reduce the amount of area on the golf course that is irrigated, if possible, such as non-play areas.
- Utilize wetting agents to increase soil water uniformity, minimize localized dry spot, and sustain high visual turfgrass quality at very low levels of irrigation.
- Water-in wetting agents sufficiently.
- Identify opportunities to achieve water use reductions before mandatory water restrictions are enacted in times of drought.
- Develop a drought plan for the property based on the USGA Drought Plan Template that includes all aspects of facility management.
- During a drought, monitor the state's drought status to ensure compliance with restrictions.

Irrigation Management Decision-Making

An irrigation system should be operated based on the moisture needs of the turf-grass or to water-in a fertilizer or chemical application as directed by the label and allowed by regulations. Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excessive water use that could contribute to leaching and runoff. Plant water needs are determined by several factors including evapotranspiration rate (ET), rainfall, temperature and soil moisture. ET rates and soil moisture replacement should serve as primary factors to help determine the irrigation schedule rather than a calendar-based schedule.

Evapotranspiration

ET describes the water lost through soil evaporation and plant transpiration which is influenced by the climate conditions, such as solar radiation, temperature and relative humidity. Evaporative demand and ET increases with greater solar radiation, higher temperatures and low relative humidity. The irrigation of turf using ET replacement is effective in preventing leaching losses and therefore eliminates potential sources of waste, the most important water conservation concern. The scheduling of irrigation using ET replacement helps to quantify water in terms of the "amount" in inches to be applied to turf.

Deficit irrigation is another way ET can be used to avoid overwatering and/or reduce water consumption. In this approach, turf is irrigated with only a portion (%) of the calculated ET for a period of days until wilt becomes too difficult to manage with hand watering or a rain event occurs. In either case, soil water levels are restored to facilitate turf recovery either through irrigation or natural precipitation. In the latter case an additional water savings is accomplished by natural rainfall providing the necessary water for turf maintenance.

Accuracy of ET calculations designed to reduce water consumption can be enhanced through the use of crop deficients (Kc), the variations of water use among different plant species. Research conducted at the University of Massachusetts determined Kc values for creeping bentgrass, Kentucky bluegrass and perennial ryegrass mowed at fairway and rough mowing heights. Detailed information can be found as part of the Turf Irrigation Series, University of Massachusetts as well as information on how to correctly use ET-based irrigation scheduling for cool-season grasses.

It is important to note that because electric/mechanical clocks cannot automatically adjust for changing ET rates, frequent adjustment is necessary to compensate for the needs of individual turf-grass areas using these older systems.

The amount to irrigate is important as well. Watering plants too frequently encourages shallow rooting, increases soil compaction and favors pest outbreaks. Overwatering plants will result in leaching and runoff. For golf greens and tees the majority of roots are in the top several inches of soil. For fairways and roughs use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.

In addition to the amount of water applied as ET replacement, the scheduling of irrigation is also determined by the "timing" of an irrigation event such as "days between irrigation." The scheduling of irrigation as a timing event can be highly variable because drought resistance and precipitation efficiency vary from site-to-site. Irrigation and cultural management practices can be developed for site specific conditions and help increase drought resistance and precipitation efficiency. The presence of visual evidence of plant moisture stress is a simple way to determine when irrigation is needed and the use of a soil moisture meter can help to determine moisture needs particularly of greens and tees. In low-maintenance areas, such as golf course roughs and fairways, waiting until visual symptoms of wilt to appear before irrigating (i.e. wilt-based irrigation) is an acceptable method for determining irrigation needs.

In addition to conserving water, allowing for repeated cycles of mild soil drying between irrigation event has also been shown to promote an increase in turf-grass rooting depth, physiological stress tolerance of turf and decrease soil compaction tendencies under traffic.

During times of intense heat stress, syringing, or the practice of applying a small amount of water to turf to help cool the plants as it evaporates, may be beneficial under certain conditions. These conditions include turf with very shallow root system, turf compromised by disease, poor soils or wet-wilt. Because the cooling effect of syringing can be very brief, repeated syringing and/or use of fans to enhance evaporation will maximize the cooling effects in certain instances.

Soil Infiltration and Plant Available Water

The rate of infiltration depends on soil texture. Sandy soils, with their higher porosity, have greater infiltration rates than silty or clay soils. 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 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-grass wilts.

Rootzone Depth

The depth of effective turf-grass rooting should be determined with a soil probe or spade. Golf greens and tees have the majority of the roots in the top several inches os soil, while fairways and roughs will typically have deeper roots. Exact root depths depend on grass species and time of the year. The soil infiltration rate and root zone depth should be used together to estimate the amount of water that needs to be available to the root system to avoid wilting. The rooting depth is multiplied by the PAW to estimate the total amount of water available to the turf-grass.

Soil Moisture

To accurately measure local precipitation, the proper use of rain gauges, rain shut-off devices, soil moisture sensors (especially sensors utilizing time domain reflectometry [TDR] technology), and other irrigation management devices should be incorporated into the site's irrigation management program. Monitoring soil moisture, calculating ET rates and visual observation of turf-grass, assists in meeting all turf-grass watering needs while conserving water resources.

Irrigation Scheduling

Plant water requirements determined by ET rates, rainfall, temperature and soil moisture serve as primary factors to help determine the irrigation schedule rather than a calendar-based schedule. Evaporative demand and ET both increase with increasing solar radiation and temperatures, and decreasing relative humidity. The irrigation of turf using ET replacement is effective in preventing leaching losses and therefore eliminates potential sources of waste, which is an important water conservation strategy.

The scheduling of irrigation using ET replacement helps to quantify water in terms of the "amount" in inches to be applied to turf. Detailed information on how to correctly use ET-based irrigation scheduling for cool-season grasses can be found at Turf Irrigation Series.

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 over saturating the soil/root zone and without compromising playing conditions. In general, it is appropriate to water deeply and infrequently to promote root growth. It is also important to be mindful of how various areas of the course may require a different approach because of soil type.

The goal of successful irrigation management is to limit excessive soil moisture while limiting turf wilt. Golf course managers strive to precisely apply water so PAW is only slightly greater than predicted ET. For highly maintained turf-grass areas, like greens, small amounts of water are applied every night to replace what was lost the prior day. Soil moisture sensors can help further improve this irrigation precision. These technologies can guide irrigation run times and identify locations that might benefit from additional hand watering. During periods of sufficient natural precipitation, irrigation managers will pre-condition plants through deficit irrigation practices to improve plant tolerance to future drought, heat and cold stress.

Modern day, computerized irrigation controllers, with real time sensory feedback operating high efficiency sprinkler heads, provide many advantages and can be quickly cost justified through labor savings. Such systems can allow a superintendent to remotely cancel the program if the course has received adequate rainfall. Wi-Fi controllers connected to weather stations can adjust for changing ET. Clock-controlled irrigation systems preceded computer controlled systems; many are still in use today and do not automatically adjust for changing ET rates. Therefore, frequent adjustment is necessary to compensate for the needs of individual turfgrass areas.

Maintained Turf Areas

The irrigation system should be designed and installed so that the playing surface, slopes and surrounding areas can be watered independently. Precision irrigation scheduling of these areas is based on soil infiltration rates, soil water-holding capacity, plant water-use requirements, the depth of the root zone and desired level of turfgrass appearance and performance in order to maximize efficient watering. This design can be improved by implementing the use of remote or hand held soil moisture meters to realize the actual water requirement of the area.

Non-Play and Landscape Areas

Courses should mark any environmentally sensitive areas such as sinkholes, wetlands, or flood-prone areas, and should identify life species or habitats of concern. Natural vegetation does not require irrigation and should be retained and enhanced for non-play areas to conserve water. The most efficient and effective watering method for non-turf landscape is micro-/drip irrigation. Older golf courses may have more irrigated and maintained acres than are necessary. With the help of a golf course architect, a golf course superintendent and key personnel, the amount of functional turf-grass can be evaluated and transitioned into non-play areas. For more information of non-play area landscaping, see "Sustainable Landscaping for Out-of-Play Areas" and "Pollinator" chapters of this document.

Best Management Practices for Irrigation Scheduling

- The irrigation system should be designed and installed so that the putting surface, slopes and surrounding areas can be watered independently.
- Account for nutrients in effluent supply when making fertilizer calculations.
- Install part-circle heads to conserve water and reduce unnecessary stress to greens and surrounds.
- Avoid use of a global setting; make adjustments to watering times per head.
- Base irrigation run times on actual site conditions for each head and zone and adjust as needed based on current local meteorological data.
- Use computed daily ET rate to adjust run times and manually adjust automated ET data to address wet and dry areas on the course.
- Install rain switches to shut down the irrigation system if enough rain falls in a zone.
- Use soil moisture sensors to bypass preset irrigation schedules or to create on-demand schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Place soil moisture sensors in the root zones of representative locations within each irrigation zone and in the driest irrigation zone of the irrigation system.
- Permanent irrigation sprinklers and other distributive devices should be spaced according to irrigation design and to the manufacturer's recommendation.
- Spacing should be based on average wind conditions during irrigation.
- Triangular spacing is more uniform than square spacing.
- Periodically perform catch-can uniformity tests.
- Reducing dry spots and soil compaction improves water infiltration, which in turn reduces water use and runoff in other areas.
- When possible, irrigation should occur in the early morning hours before air temperatures rise and relative humidity drops.
- Base plant water needs on ET rates, recent rainfall, recent temperature extremes and soil moisture.
- Use cultural practices to control water loss and to encourage conservation and efficiency.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.

- Use predictive models to estimate soil moisture and best run time to irrigate.
- Install in-ground (wireless) soil moisture sensors (to prevent damage from aeration) in the root zone and use in conjunction with handheld moisture meters for each irrigation zone to enhance scheduled, timer-based run times.
- Designate 50% to 70% of the non-play areas to remain in natural cover according to "right-plant, right-place" principle of plant selection that favors limited supplemental irrigation and on-site practices.
- Incorporate native vegetation in non-play areas.
- Use micro-irrigation, low pressure emitters and in-line drip irrigation in non-play areas to supplement irrigation.
- Routinely inspect non-play irrigation system for problems related to emitter, clogging filter defects and overall system functionality.
- The reliability of older clock-control station timing depends on the calibration of the timing devices; this should be done periodically, but at least annually.
- An irrigation system should be shut off after 0.10 to 0.5 inches of rain fall depending on your particular soil profile.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- The irrigation schedule should coincide with other management practices, such as the application of nutrients, herbicides or other chemicals.
- Waiting until visual plant symptoms appear before irrigations is a method best used for low-maintenance areas, such as golf course roughs and possibly, fairways.
- For fairways and roughs, use “wilt-based irrigation” to supply sufficient water for plants and to encourage deep rooting.

Irrigation Water Sources

Golf course designers and managers should endeavor to identify and use alternative supply sources to conserve freshwater drinking supplies, promote plant health and protect the environment. Studies of water supplies are recommended for irrigation systems, as are studies of waterbodies or flows on, near and under the property. Water sources for irrigation must be dependable and offer sufficient resources to accommodate turf grow-in needs and continued maintenance. Environmental Best Management Practices for Virginia Golf Courses describes the methodology and provides example calculations to determine water requirements using a seasonal and maximum bulk water requirement analysis (pages 37 and 38).

The opportunity to identify and use alternative water sources may also be appropriate, depending on the availability of infrastructure and additional management costs associated with non-potable water. New course construction, existing course renovation and irrigation system upgrades offer unique opportunities for golf courses to consider innovative strategies for water capturing/harvesting, filtering, re-use onsite and reduce the amount of potable water used for irrigation purposes. The harvesting of rain water from rooftops and paved areas and the construction of lined ponds, wetlands, stormwater collection areas and sub-surface irrigation collection drains (which re-use the irrigation water applied) are some of the ways that golf courses are creating alternatives to the use of drinking water. Additionally, these man-made landscapes can be used to improve water quality by acting as bio-filters before returning the water to the aquifer. Best of all, these lined ponds and bio-filters are very beneficial to local wildlife.

When using groundwater, the area around the wellhead should be protected by practicing safe land-use to protect aquifers from accidental contamination. This includes protecting wellheads from physical impacts, keeping them secure and sampling wells according to the monitoring schedule required by the regulating authority. Before installing new wells, the local regulatory authorities should be contacted to determine the permitting and construction requirements and the isolation distances require from potential sources of contamination. New wells should be located up-gradient as far as possible from potential pollutant sources.

Best Management Practices for Irrigation Water Sources

- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- When developing new water sources, incorporate surface storage (lined ponds) with wellhead withdrawals to conserve water by conservation of rainfall, site drainage and runoff as a supplemental water source especially for conservation on dry sites.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs and follow guidelines for use.
- Ensure that all reclaimed effluent water and other non-potable water sources main lines have a certified cross-connection and back-flow prevention devices installed. Adhere to MA DEP Cross-Connection Regulations MGL 310 CMR Section 22.22.
- Post signs in accordance with local municipality and state requirements when reclaimed water is in use.
- Surround new wells in open areas with native vegetation and/or bollards to prevent impacts to the wellhead.
- 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 well depth. These factors will have an affect on how vulnerable the well is to contamination. Sample wells for contaminants according to the schedule and protocol required by various MA DEP regulations.
- Inspect wellheads and the well casing at least annually for leaks or cracks. Make repairs as needed.
- Use back-flow prevention devices at the well head and public water supplies to prevent contamination of the water source. Adhere to MA DEP Cross-Connection Regulations MGL 310 CMR Section 22.22.
- Properly plug abandoned or flowing wells.
- Account for the nutrients in reclaimed effluent water.
- Monitor (test) reclaimed water as any irrigation source with special attention to common contaminants.
- Routinely monitor (test) a shallow groundwater table of fresh water for saltwater intrusion or contamination by heavy metals and nutrients.
- Flush with fresh water or use amending materials regularly to move salts out of the root zone.

- Amend sodic water systems appropriately (with gypsum or an appropriate ion) to minimize sodium buildup in soil.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Monitor the quantity of water withdrawn to avoid impacting aquatic species.

Irrigation Water Suitability

In March 2009 MA DEP legislated MGL 314 CMR 20.00 - Reclaimed Water Permit Program and Standards. This legislation authorized a permitting program for the discharge of reclaimed water on golf courses, among other lands. Inclusive in the requirements are consideration for use, sale and distribution of reclaimed water. Any MA golf course that has access to a source of reclaimed water should consider it as a viable alternative. The Town of Yarmouth, MA Golf Department has been using reclaimed effluent water since 1998.

Irrigation water quality must be suitable for plant growth and not pose a threat to public health. Because water quality influences soil quality and turf-grass performance, it is advisable to test any irrigation source regularly for factors that can compromise the turf/soil system. This is especially true for non-potable water irrigation sources, such as natural lakes, man-made lakes and reclaimed effluent water. Water sources can contain minerals and compounds that are toxic, or otherwise influence, plant growth living in the soil or water to which it is applied. For example, irrigation water high in sodium and low in calcium and magnesium, which is applied as irrigation to a clay soil can break down soil structure, cause decomposition of organic matter and reduce soil infiltration (puddling).

Routine water analysis should provide the following information: conductivity, pH, sodium, calcium, magnesium, potassium, carbonate, bicarbonate, sulfate, chlorine, phosphorus, boron, nitrate-N, hardness and sodium adsorption ration (Landschoot, 2016). The results can be used to address possible issues with soil salinity and plant health caused by poor water quality. When necessary, sodic water system treatment options should be included in the budget to address water quality and equipment maintenance.

Best Management Practices for Water Suitability

- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- When developing new water sources incorporate surface storage (lined ponds) with wellhead withdrawals to conserve water by conservation of rainfall, site drainage and runoff as a supplemental water source.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs and follow guidelines for use.
- Ensure that all reclaimed effluent water and other non-potable water sources main lines have a shug valve and a certified cross-connection and back-flow prevention devices installed. Adhere to MA DEP Cross-Connection Regulations MGL 310 CMR Section 22.22.

- Post signs in accordance with local utility and state requirements when reclaimed water is being used for irrigation.
- Account for nutrients in reclaimed effluent water.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Monitor any fresh water supply for saltwater intrusion or contamination by heavy metals and nutrients.
- Flush turf with fresh water and/or amending materials regularly to move salts out of the root zone and/or pump brackish water to keep salts moving out of the root zone.
- Amend sodic water systems appropriately (with gypsum or an appropriate ion) to minimize sodium buildup in soil.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Monitor the quantity, as well as quality, of water withdrawn to avoid impacting aquatic and water dependent species.

Irrigation System Design

Site Assessment

An assessment of the facility should be conducted prior to developing an irrigation system design. The assessment should include site-specific features, such as water sources, soil types (see the Web Soil Survey), soil physical properties, microclimates, slopes, sun, wind, shade exposure and a seasonal and bulk water requirement analysis.

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 system. Membership need be cognizant of potential impact to the golf course designer's original intent in risk/reward play path options. The system design should include a general irrigation schedule with recommendations and instructions on modifying the schedule to meet site-specific needs.

Design Considerations

A well-designed irrigation system should operate at peak efficiency and improve water use efficiency by focusing on water placement and efficient distribution. The design should maximize water use, reduce operational cost, conserve supply and protect water resources. Detailed BMPs for general turf irrigation systems are published by the Irrigation Association in (Landscape Irrigation Best Management Practices).

The irrigation system design should meet site-specific needs identified by the water quantity analyses and a physical site assessment. The system's capability to deliver water should not exceed the infiltration rate of the soils on the site to avoid runoff. Some of the most important design decisions influencing the efficiency and effectiveness of water usage include those related to sprinkler placement, coverage and operation.

Sprinklers

Multi-row sprinkler systems provide the most efficient use of water and can respond to specific moisture requirements of selected areas. Newer sprinkler designs have multiple nozzle configurations to provide watering flexibility and improved distribution uniformity.

Single row systems do not uniformly distribute water and increase the risk of runoff. Double row systems offer improved efficiency over single-row coverage, although manual watering or other types of supplemental watering may be needed outside the covered area. The part-circle sprinklers can be arranged to avoid overspray on impervious surfaces or turf areas with varying watering needs that abut each other. Manual quick-coupler valves can be an important conservation element and should be installed near critical play areas to facilitate hand-watering. Modern irrigation systems strive to achieve distribution uniformity (DU) values near 80%. After installation the system's effectiveness should be monitored with soil moisture meters.

Communication

Computer controlled irrigation systems can schedule each playing surface separately and allow course managers to adjust for differences in microclimates and root zones. Weather stations can be added to calculate and automatically re-program water replacement schedules with more precision. Other automated control devices are in-ground moisture sensors and automatic shutoffs for rain/leaks. Most importantly computer controlled irrigation systems can be accessed remotely by their managers.

Sensor Technology

Weather stations, soil moisture and rain sensors should be installed in specific locations and maintained in order to provide the relative information necessary for making good irrigation management decisions. Rain gauges are necessary measurement tools to track how much rain has fallen at a specific site on the golf course. On some courses, more than one station may be necessary to get a complete measure of rainfall or evaporation loss. The use of soil moisture probes, tensiometers, computer models; visual inspections for symptoms such as wilting turf; may supplement these measurements.

Predictive model computer programs based on the weather station data and soil types are also available. These are relatively accurate and applicable, especially as long-term predictors of annual turf water requirements. Weather data such as rainfall, air and soil temperature, relative humidity, solar radiation and wind speed get incorporated into model formulas and adjustments can be made. Models, however, are only as effective as the amount of data collected, so it is best to have an on-site weather station monitoring conditions provided to the predictive program to get accurate ET rates that determine sprinkler site-specific water needs as described in greater detail in the Irrigation Scheduling section.

Best Management Practices for Irrigation System Design

- Seek assistance from irrigation professionals, such as from Certified Golf Course Irrigation System consultant/designer and Water Sense Certified irrigation consultants.
- Professional mapping of all irrigation components is a common design practice.
- New and upgraded irrigation system designs should deliver water with maximum efficiency, focusing on precision water placement and distribution.
- Design and/or maintain a system to meet a site's peak water requirements under normal conditions with the flexibility to adapt to various water demands and local restrictions.
- Design should account for optimal distribution efficiency and effective root-zone moisture coverage. Target 80% or better Distribution Uniformity (DU).
- Design should allow for different play surfaces, as well as physical conditions, to be watered independently.
- The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic, soil and growing conditions. It should include the base evapotranspiration (ET) rate for the particular geographical location.
- The application rate must not exceed the infiltration rate, which is the ability of the soil to absorb and retain the water applied during any one application.
- Conduct saturated hydraulic conductivity tests periodically.
- The design operating pressure cannot be greater than the available source pressure.
- Using mutiple pumps can achieve higher pressures while reducing voltage (cost).
- The design operating pressure must account for peak-use times and supply-line pressures at final buildout for the entire system.
- Turf and landscape areas should be zoned separately. Specific-use areas that should be zoned include greens, tees, primary roughs, secondary roughs, fairways, native areas, trees, shrubs and flower beds.
- Design should account for the need to leach out salt buildup from poor-quality water sources by providing access to fresh water.
- Only qualified specialists should install the irrigation system. Construction must be consistent with the design and specification.

- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Prior to construction, all underground cables, pipes and other obstacles must be identified and their locations flagged. (Dig Safe 811)
- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Spacing should be based on average wind direction during irrigation.
- Distribution devices and pipe sizes should be designed for optimal uniform coverage and flow rate.
- Distribution equipment, such as sprinklers, rotors and micro-irrigation devices, in a given zone must have the same precipitation rate.
- Heads for turf areas should be spaced for head-to-head coverage.
- Water supply systems (for example groundwater) should be designed with back-flow prevention to MGL 310 CMR Section 22.22.
- Water conveyance systems should be designed with thrust blocks and air-release valves.
- Flow velocity must be 5 feet per second or less.
- Pipelines should be designed to provide the system with the appropriate flow and pressure required for maximum irrigation uniformity.
- Pressure-regulating or compensating equipment must be used where the system pressure exceeds the manufacturer's recommendations.
- Equipment with check valves must be used in low areas to prevent low head drainage.
- Isolation valves should be installed in a manner that allow system repairs without complete system shutdowns.
- Manual quick-coupler valves (QCV) should be installed near critical playing surfaces so that these areas can be hand-watered during severe droughts. Include isolation valve at swing joint to isolate QCVs as needed for service.
- Use part-circle or adjustable heads to avoid overspray of impervious areas, surface waters and wetlands.
- Update block type sprinkler valves with single head control to conserve water and to enhance efficiency.
- Incorporate multiple nozzle configurations to enhance efficiency and distribution.
- Ensure heads are set level to the ground.
- Provide backup source for operation during power outages.
- Manual irrigation controllers/timers should be reset as often as possible to account for plant growth requirements and local climatic conditions.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices and/or other automated methods should be used to manage irrigation.
- Irrigation should never occur on a calendar-based schedule, but should be based on accurate ET rates and soil moisture replacement.
- Computerized control systems should be installed on all new course irrigation systems to help ensure efficient irrigation application that allows for individual sprinkler adjustment.
- Rain shut-off devices and rain gauges should be placed in open areas to prevent erroneous readings.
- Use multiple soil moisture sensors/meters for accuracy and to reflect soil moisture levels.

Pump Station

Pump stations should be efficient and sized to provide adequate flow and pressure. They should be equipped with control systems that protect distribution piping, provide for emergency shutdown necessitated by line breaks, and allow maximum system scheduling flexibility.

Where feasible, variable frequency drive (VFD) pumps and/or pump station 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.

Best Management Practices for Pump Stations

- The design operating pressure must account for peak-use times and supply-line pressures at final buildout for the entire system.
- Maintain the air-relief and vacuum-breaker valves by using hydraulic pressure-sustaining values.
- Install VFD systems to lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.
- An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Pumps should be sized to provide adequate flow and pressure.
- Pumps should be equipped with control systems to protect distribution piping.

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.

Best Management Practices for Irrigation System Installation

- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged. (Dig Safe 811).

Irrigation System Maintenance and Performance

Calibration and Auditing

Irrigation system maintenance on a golf course involves four major efforts: calibration and auditing; preventive maintenance; corrective maintenance; record keeping. Personnel charged with maintaining a golf course irrigation system face numerous challenges. This is particularly true for courses with older or outdated equipment. Irrigation audits can be conducted to assess the system function, ensuring that the irrigation system works reliably and is as cost effective as possible. The Irrigation Association has published irrigation audit guidelines.

Maintenance

Good system management starts with good preventive maintenance procedures and record keeping. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required; or the heads can be brought on-line for a few seconds to be observed for proper operation. However, maintaining a system is more than just fixing heads. It also includes documenting system and maintenance related details so potential problems can be addressed before expensive repairs are needed. Documentation also provides a basis for evaluating renovation or replacement options. Being proactive includes addressing larger issues if the system requires frequent repairs and determining the cause of failures. For example, pipe failures may be caused not only by material failure, but also by problems with the pump station; wiring problems may be caused by corrosion, rodent damage or frequent lightning/power surges; control tubing problems can result from poor filtration.

Irrigation systems degrade with use over time. Corrective maintenance is simply the act of fixing what is broken and may be as simple as cleaning a clogged orifice or as complex as a complete renovation of the irrigation system. As maintenance costs increase with time, a replacement evaluation should be anticipated and budgeted for with proper expectations and planning.

Winterization

Winterizing protects irrigation system pipes for damage due to water expanding and rupturing the pipe walls and fittings. Golf courses need to drain or use compressed air to remove the water from all piping/pumps/sprinklers before temperatures drop below freezing. Some golf facilities operate an independent irrigation system below the frost line that allows the application of water to turf throughout the winter and prevent plant desiccation.

Spring Start-up

Spring start up of the irrigation system is essentially filling and pressurizing the system. It also the best to inspect the entire system for corrective maintenance/adjustment issues.

Best Management Practices for Irrigation System Maintenance – Calibration and Auditing

- Examine turf quality and plant health for indications of irrigation malfunction or the need for scheduling adjustments.
- Evaluate pressure and flow to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications.
- Visually inspect the entire system to identify necessary repairs/corrective actions and make these repairs before carrying out other levels of evaluation.
- Conduct an annual irrigation audit to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- Conduct an annual pump test/inspection.
- Submit required reports as included in the MA DEP annual water withdrawal reporting.

Best Management Practices for Irrigation System Maintenance – Preventive Maintenance

- Routinely inspect the system daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers and irrigation heads. A visual inspection should be carried out for leaks, misaligned or inoperable heads and chronic wet or dry spots so that repairs can be made.
- Observe the system in operation regularly to detect controller or communication failures, stuck or misaligned heads and clogged or broken nozzles.
- Clean and maintain filtration equipment.
- Check filter operations frequently. Keeping filters operating properly prolongs the life of an existing system and reduces pumping costs. An unusual increase in the amount of debris may indicate problems with the water source.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems or declining irrigation water quality.
- Monitor the power consumption of pump stations for problems with the pump motors, control valves and distribution system
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.
- Inspect irrigation pipes and look for fitting breaks caused by surges in the system.
- Install thrust blocks to support conveyances.
- Maintain air-relief and vacuum-breaker valves.
- Have qualified pump personnel perform regular checks of amperage to accurately identify increased power usage that indicates potential problems.
- Check application/distribution efficiencies annually.
- Winterize the irrigation system to prevent damage.
- Document equipment run-time hours.
- Document and periodically review the condition of infrastructure such as pipes, wires, valves and housings.
- Follow the manufacturer's recommendations for system checks and routine maintenance.

- Record rotation speed of all sprinklers and monitor for any increase or decrease in rotation time for an early indication of sprinkler malfunction issues. Good record keeping often identifies a problem before visual inspection will observe.
- Check sprinkler discharge nozzles for wear and replace nozzles as needed to maintain design intent.
- Keep turf around sprinklers trimmed to ensure proper distribution.
- Adjust sprinkler head height with grade as needed.
- Flush irrigation lines regularly to minimize emitter clogging in non-play areas, sediment buildup and prevent microbial growth caused by fertigation.
- In older systems document precipitation rate (Pr), compare to soil intake rate and adjust scheduling accordingly.

Best Management Practices for Irrigation System Maintenance – Winterization

- Flush and drain above-ground irrigation system components.
- Remove water from all conveyances and supply and distribution devices that may freeze. Use compressed air and/or open the drain valves at the lowest point on the system.
- Set compressor a highest point in the system and drive water downward wherever possible.
- Change filters, screens and housing: remove drain plugs and ensure any water is removed from the system. Secure system with rodenticide and closing/locking all covers/doors.
- Drain any above-ground pump casings that may have "trapped' water.
- Record metering data. Perform pump and engine servicing/repair before winterizing.
- Remove air/vacuum relief valves as/if recommended by the manufacturer.
- Never activate or close down the compressor without an open port.

Best Management Practices for Irrigation System Maintenance – Spring Start Up

- Power up the pump station and pump motors prior to using system. By completing this task ahead of recharging the system, the coils inside the motor heats up and removes any moisture that collected during the offseason.
- Re-install air and vacuum relief valves if removed during winterization and check functionality.
- Keep the water pressure at 60 PSIG or lower when priming lines.
- Operate each of the sprinklers until all excess air is flushed from the irrigation system.
- Inspect the entire system for any corrective maintenance issues.

Metering

As mentioned earlier (Sub-section Water Conservation and Efficient Use, Drought Planning and Response) all MA golf courses are responsible for being knowledgeable of every federal, state and local regulation applicable to their business, including irrigation practices. Unless a golf course operating in MA purchases their irrigation from a water supplier, then the Water Management Act governs every aspect of golf course irrigation. Metering is one the most stringent aspects of MGL c. 21G.

Metering is recommended at the discharge pipe for the golf course's irrigation water to track the total volume provided during the growing season. Annually calibrated metering is mandated by state permit/registration at any withdrawal pipe of ground or surface water sources used for irrigation purposes. Fact Sheet: WMA Registration and Permitting

Rainfall may vary from location to location on a course. The proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors and/or other irrigation management devices should be incorporated into the site's irrigation schedule. It is also important to measure the amount of water that is actually delivered through the irrigation system using a certified, calibrated water meter or acceptable, calibrated measurement device. Knowing the flow or volume will help determine how well the irrigation system and irrigation schedule are working.

Best Management Practices for Metering

- Calibrate equipment annually to compensate for wear in pumps, pipes and nozzles.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods should be used to manage irrigation.
- Flow meters should have a run of pipe that is straight enough — both downstream and upstream according to manufacturer's requirements — to prevent turbulence which creates inaccurate readings.
- Flow meters can be used to determine how much water is used for irrigation.
- Ensure that all filing and registrations requirements are followed as per MA DEP.

Irrigation Leak Detection

Irrigation systems are complex systems that should be closely monitored to ensure leaks are quickly detected and corrected. An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions. Golf courses without hydraulic pressure-sustaining valves are much more prone to irrigation pipe and fitting breaks because of surges in the system, creating more downtime for older systems.

Best Management Practices for Irrigation Leak Detection

- Monitor water meters or other measuring devices for unusually high or low readings to detect possible leaks or other problems in the system. Make any needed repairs.
- Monitor the system daily for malfunctions and breaks. Log water usage daily.
- Ensure that control systems provide for emergency shutdowns caused by line breaks and allow maximum system scheduling flexibility.

Irrigation System Renovation

Renovating a golf course irrigation system can improve system efficiencies, conserve water, improve playability, and lower operating costs.

Best Management Practices for Irrigation System Renovation

- Determine the age of the system to establish a starting point for renovation.
- Identify problems and their costs to determine which renovations are appropriate.
- Identify system performance improvements that maximize the efficient use of the current system.
- Irrigation systems are short lived and should be maintained as a regular line item of long term plans. Real time evaluation for the cost of such renovation and the return on it's financial and management benefits is mindful.

Irrigation Record Keeping

In the Commonwealth of Massachusetts MGL c. 21G is very specific with record keeping and reporting forms for large volume water users. MA DEP requires monthly and annual record keeping from all permittees, especially golf course irrigation. WMA Reporting and Forms Not only is careful record keeping an important, practical part of managing a golf course irrigation system, it is legally mandated.

Best Management Practices for Record Keeping

- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.
- Monitor and record the amount of water being applied, including system usage and rainfall and identify areas where minor adjustments can improve performance.
- Document and periodically review the condition of infrastructure, such as pipes, wires, and fittings. If the system requires frequent repairs, it is necessary to determine why these failures are occurring.
- Document all corrective actions.
- Adhere to all regulatory reporting requirements for water withdrawal.

Water Quality Management and Protection

Preface

A golf course business presents a unique opportunity to enhance and preserve water quality and the local wildlife which it supports. Protecting water quality involves recognizing the potential fate and transport mechanisms that can carry contaminants into natural water resources. If water quality contaminants reach surface or groundwater, the potential water quality impacts can include:

- Drinking water impairment if nitrogen as either nitrate (NO_3) or nitrite (NO_2) exceeds risk values that may adversely affect health.
- Nutrient enrichment of surface water.
- Sedimentation due to eroding soils.
- Toxicity to aquatic life.

Therefore, aligning water quality management efforts, such as stormwater management/retention and management of natural/manmade (linden-impervious) ponds and lakes with established, research-based BMPs protects water quality. A water quality monitoring program can be used to verify that water resources are being adequately protected. In addition, monitoring may demonstrate the presence of issues in water before enters a golf course such as upstream contamination.

Overall, protecting water quality includes not only implementing what is contained in this chapter, but what is discussed throughout this document, including:

- Design considerations such as establishing vegetative buffers around surface waters or creating artificial wetlands.
- Fertilization strategies near surface waters.
- Pesticide usage.
- Erosion control

A water quality monitoring program (covered at length in the next section) can be used to verify that water resources are being adequately protected. In addition, monitoring may demonstrate the presence of problems with the water before it enters a golf course, such as upstream contamination, which can be corrected by instituting Water Quality BMPs by the golf course.

Environmental Fate and Transport

Understanding contaminant fate and transport mechanisms will help superintendents protect water quality by minimizing the risk of off-movement of nutrients and pesticides applied to golf courses. Nonpoint sources pollution, which comes from many diffuse sources (as opposed to point source pollution that results from a single source), can occur due to the following fate and transport mechanisms of concern to golf course superintendents:

- Runoff, or the movement of water across the turf and soil surface, typically following a storm event or heavy irrigation. The potential for runoff is greatest on steep slopes.
- Leaching, or the downward movement of water through the soil and potentially into groundwater. Several variables influence the probability and rate of leaching, such as soil type and structure, vegetation, chemical properties, rate of precipitation, and depth to groundwater.
- Spray drift, or the movement of fine particles, or droplets, through the air while the pesticide is being applied. Droplet size and wind and weather conditions affect the potential for spray drift during pesticide applications.
- Vapor drift, or the movement of pesticide in the form of a gas or vapor during or after application. Pesticide formulation, wind, and atmospheric conditions affect the potential for vapor drift during pesticide applications.
- Volatilization, or the transformation of a pesticide from a solid or liquid to a gas or vapor after a pesticide application. Once airborne, volatile pesticides can come into contact with pesticide applicators or move long distances off-site.
- Spills, or unintended releases of chemicals, such as fertilizers, pesticides, hazardous materials, or petroleum products during transportation, storage, routine maintenance, and facility operations.

While most of the fate and transport mechanisms of concern can contribute to nonpoint sources of pollution, spills can be a point source of pollution. On golf courses, point sources of pollution can originate from:

- Storage and maintenance facilities.
- Unintended release of chemicals, such as pesticides, fertilizers, or fuel, during transportation, storage, or handling.
- Drainage discharge outlets (e.g., the end of a drainage pipe).
- Improper sprayer/spreader calibration.

Designed containment measures can easily prevent chemicals from becoming point sources of pollution during storage and handling. To prevent contamination of surface water, any accidental spills of chemicals must be diverted from surface water.

One additional potential contaminant is sediments, though primarily only a concern when bare soil is exposed, as during construction or renovation. Sedimentation is a concern when precipitation and irrigation carry soil particles (sediment) in runoff and deposit them into surface water. Too much sediment can cloud surface water, reducing the amount of sunlight that reaches aquatic plants and impairing aquatic species habitat. In addition, sediments can carry fertilizers, pesticides, and other chemicals attached to soil particles and transport them into waterbodies, causing algal blooms that lead to oxygen depletion. Sedimentation is handled through BMPs that control the volume and flow rate of runoff water, maintain adequate turf density, and reduce soil transport.

Pollution Prevention

Implementing BMPs can prevent or minimize the effects of a golf course on surface and groundwater, while ensuring and even enhancing public health and environmental quality. Pollution prevention is easier, less expensive, and more effective than addressing problems after they happen. An integrated water quality protection system that incorporates the BMPs found throughout this document is based on a tiered concept as follows:

- Personnel Training – Incident response action and reporting.
- Prevention – Stopping problems from occurring.
- Control – Having safeguards in place to handle any problems.
- Detection – Using a monitoring program to detect changes in environmental quality.

At any golf facility, preventive strategies should include combinations of land use controls and source prevention practices. Land use BMPs are engineered and incorporated into the course during golf course design and construction. They protect natural resources through primarily mechanical methods, such as retention basins, vegetated swales, manmade lined, impervious ponds and lakes and buffer areas around water courses.

Source prevention BMPs are implemented during golf course management operations to prevent sediment, nutrients, or pesticides from being introduced into ecologically sensitive areas. For example, pesticide management BMPs reduce the potential for drift and volatilization during pesticide applications. Irrigation BMPs prevent over-watering and are especially important for minimizing pollutant transport via runoff or leaching. Cultural practices BMPs maximize the water infiltration and water holding capacity of soils. Safeguards should be incorporated into the facility management to control any problems should they arise to prevent the contamination of water from spills. For example, many of the BMPs related to pesticide storage and handling as well as maintenance operations can prevent accidental releases of contaminants (pesticides, fertilizers, fuel, etc.) from becoming a point source of contamination.

Aligning golf course management practices with BMPs protects water quality on and downstream (leaving the golf course) from the facility. While water quality monitoring on golf courses is typically voluntary, monitoring results demonstrate a commitment to water quality. Furthermore, providing monitoring information to local, regional, and state regulatory authorities and watershed groups can help foster positive relationships with these stakeholders.

Stormwater Management

Runoff, or the movement of water across the land surface from either precipitation or irrigation that does not infiltrate into the ground, is the conveying force behind nonpoint source pollution. Stormwater management refers to runoff from precipitation but applies to irrigation runoff as well. Stormwater management is the control and use of runoff and includes planning for runoff, maintaining stormwater systems, and regulating the collection, storage, filtration and movement of stormwater.

BMPs reduce stormwater volume, peak flow, and nonpoint source pollution by promoting evapotranspiration, infiltration, detention, and filtering, as well as biological and chemical actions. BMPs help achieve such goals by:

- Keeping stormwater close to where it falls.
- Slowing down stormwater runoff.
- Allowing stormwater to infiltrate into the soil.

Stormwater management is best accomplished by a “treatment train” approach in which water is moved from one treatment to another by conveyances that themselves contribute to the treatment. These treatments include source controls, structural controls, and non-structural controls. An example of this treatment train approach is as follows: Stormwater is directed across vegetated filter strips, through a swale, into a retention pond, then out through another swale to a constructed wetland system.

Golf course owners and superintendents in Massachusetts should review and comply to the extent practicable with the applicable standards of the Massachusetts Stormwater Handbook and local stormwater management and wetlands protection regulations and bylaws. Massachusetts Stormwater Handbook

Source Controls

The first car of the BMP treatment train are source controls to help prevent the generation of stormwater runoff or the introduction of pollutants into stormwater runoff. For example, during construction or redesign activities, strict adherence to erosion and sedimentation controls helps to prevent, or at least minimize, the possibility for sediment and nutrients to impact water quality through runoff. After construction, implementation of BMPs can reduce the potential for off-site movement of contaminants such as nutrients and pesticides.

Structural Controls

Structural controls are often the next car in the treatment train and are design and engineering features on the course created to remove, filter, retain, or reroute potential contaminants (e.g., nutrients, pesticides, sediments) carried in surface runoff. They may also be combined to increase the treatment of stormwater. For example, sediment forebays can be used to pretreat stormwater before it is discharged to a dry extended detention basin, wet basin, constructed stormwater wetland, or infiltration basin. Periodic inspection and maintenance of all structural controls are essential to ensure they function as designed. Maintenance includes periodic cleaning of small basins, ponds, and forebays to remove sediments. The disruption and financial outlay of this effort is less than that for dredging an entire body of water.

In and around the clubhouse and other structures, opportunities should be identified to slow down the movement of water from impervious surfaces and allow for infiltration. For example, runoff from gutters and roof drains should flow into permeable areas. Rain gardens near these areas can be incorporated into the landscape design. Maximizing the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass, allows stormwater to infiltrate into the soil as opposed to running off. Crushed stone and other permeable products are available for cart paths or parking lots.

Non-Structural Controls

Non-structural controls are the last car in the treatment train. Non-structural controls often mimic natural hydrology (e.g., constructed wetlands), hold stormwater, and filter stormwater via vegetative practices (e.g., filter strips and grassed swales). Turfgrass areas are extremely effective in reducing soil losses compared with other cropping systems, due to the architecture of the turf canopy, the fibrous turf root system, and the development of a vast macropore soil structural system that encourages infiltration rather than runoff. Additionally, turf density, leaf texture, rooting strength, and canopy height physically restrain soil erosion and sediment loss by dissipating impact energy from rain and irrigation water droplets.

Best Management Practices for Stormwater Management

- Design stormwater control structures to hold stormwater for appropriate residence times to help remove total suspended solids (TSS).
- Use a stormwater treatment train (in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment).
- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally broken down by soil organisms.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. (Special high-permeability concrete and asphalt products are available for cart paths or parking lots.) Pervious Pavement
- Minimize directly connected impervious areas to the extent practical.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.
- If capturing water utilize a first-flush diverter.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain.
- Ensure that no untreated discharges from pipes go directly to waterbodies.
- For any of the above practices that are instituted, be certain to create/add an inspection and maintenance protocol for your annual management plan.

Buffers

Buffers around the shore of surface waters, wetlands, or other sensitive areas filter runoff as it passes across. Buffers 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 as narrow as 10 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 significantly greater buffer widths.

For vegetated buffer zones, ornamental grasses, wetland plants, or emergent vegetation around the perimeter and edges of surface waters serve as a buffer and wildlife habitat for many aquatic organisms and can be aesthetically pleasing. Use native plants for these plantings whenever possible. See the “Landscaping” chapter for more guidance on plant selection and the benefits of utilizing native plants. 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.

Best Management Practices for Buffers

- Maintain healthy turf cover adjacent to surface waters to slow sediment accretion and reduce runoff flow rates.
- Vary the width, height, and type of vegetation to meet the specific functions of the buffer and growing conditions at the specific location.
- Encourage clumps of native emergent vegetation at shorelines.
- Plant shrubs and trees far enough from water edges so that leaves stay out of the water.
- Mow buffers on in-play areas in riparian areas to heights up to 4 inches.
- When mowing near buffer areas, 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.
- As a general practice, keep all chemical applications 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 in the buffer area, spot treat weeds or use drop spreaders or shielded rotary spreaders and boom sprayers to minimize the potential for direct deposit of chemicals into the water.

Wetlands

Wetlands, whether natural or made, serve as filters for pollutant removal and as habitat for many species of birds, insects, fish, and other aquatic organisms. Vegetated buffers around the shore of a waterbody or another sensitive area slow, filter, and purify runoff before it can reach surface waters. Buffers may increase infiltration and ground water recharge. Existing wetlands on golf course properties must be maintained as a protected area and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may require a permit to be an integral part of the stormwater system. Many Massachusetts municipalities have local regulations in place that are community-specific and often more restrictive than state or federal regulations. As such, local coordination is typically the best first step before addressing a wetland or water-related project. Massachusetts Wetlands Protection Act Regulations

Best Management Practices for Wetlands

- Protect and maintain existing vegetation as natural buffers, to the maximum extent possible, during new course design and construction or during course renovation or general maintenance.
- Develop, enhance, restore, and protect wetland buffers. Manmade buffers should be designed to improve habitat diversity and include a mixture of fast and slow-growing native trees, shrubs, or grasses to provide a diverse habitat for wildlife.
- Encourage robust coastal and riparian vegetated buffers along the banks of golf course wetlands, perimeters of storage ponds and other waterbodies, and undeveloped uplands.
- Do not fertilize riparian buffer areas above the high-water mark. Leave them in a natural state.
- Reduce the frequency of mowing at a waterbody edge. Take clippings to upland areas.

Lake and Pond Management

The management of natural and manmade lakes and ponds golf courses 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:

- Proper location and design.
- Dissolved oxygen (DO) levels.
- Aquatic plant management.
- Near-shore management zones.

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 and wildlife. The construction of ponds should consider the needs of aquatic ecosystems, such as discouraging excessive growth of aquatic vegetation and the DO needs for aquatic species. Careful design may significantly reduce future operating expenses for pond and aquatic plant management.

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. Dissolved oxygen levels also differ by time of day and by season as water temperatures fluctuate, with warm water holding less DO than colder water. 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.

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).

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 the pollutants present in 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 can aggressively colonize aquatic environments. The excessive growth of any aquatic plant requires management. Following integrated pest management, 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 grass carp are allowed in some states (typically with a permit) and are sometimes used as a biological control for aquatic plants.

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.

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.

Best Management Practices for Lake and Pond Management

- Maintain and improve (add falls/rocks) with 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.
- Establish and monitor 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.
- 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.
- Use a multi-faceted, IPM approach to control nuisance animals, such as Canada geese.

Water Quality Monitoring

Preface

Monitoring can be used to set a pre-construction baseline for water quality. Routine monitoring can be used to measure water quality improvements and identify any areas where corrective actions should be taken. Monitoring can also demonstrate the presence of issues in water as it enters a golf course property not related to any impacts from facility management.

Golf course superintendents wanting to develop and implement a water quality monitoring program should first review available baseline water quality data, which can include both groundwater and surface water monitoring. Baseline data can be assessed to determine the likely origin of contaminants, measure the extent of sedimentation and nutrient inputs, and estimate the potential impacts to surface water and groundwater. In addition to monitoring surface and/or groundwater, water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can inform nutrient and liming programs.

Groundwater Monitoring

Groundwater monitoring from wells located at the hydrologic entrance and exit from the course may be the best way to evaluate a golf course's impact on water quality. If groundwater monitoring data from these locations is not available from existing sources, monitoring wells can be installed by private companies. Installing groundwater monitoring wells can be relatively expensive, but the expense may be justified in certain cases where the origin of contamination can only be determined through comparison of water quality entering and exiting the property. To identify the appropriate site for monitoring wells, groundwater flow information is required. If this information is not available, experienced environmental engineering firms or the United States Geological Survey (USGS) can assist in determining suitable monitoring well locations.

Surface Water Monitoring

For new golf courses or renovation projects in the planning stage, baseline water quality levels should be measured prior to construction at points of entry and exit of flowing water sources on or surrounding the golf course and on any surface water. This information can be used to form a baseline of flow and nutrient/chemical levels. For established courses, ongoing, routine water sampling provides meaningful trends over time. Post-construction surface-water quality sampling should begin with the installation and maintenance of golf course turf and landscaping and should continue through the first three years of operation and during the wet and dry seasons every third year thereafter, provided that all required water quality monitoring has been completed and the development continues to implement all current management plans. A single sample is rarely meaningful in isolation. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality.

Water Quality Sampling

The number of monitoring samples is highly variable and depends on the size, location, and number of water sources on or near the golf course. The entry and exit points of golf course water sources are logical sampling points. However, sampling and analysis of standing water sources (i.e. ponds), springs, and any other irrigation sources should also be included. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality.

Developing a water quality monitoring program on golf courses is often limited to surface water monitoring and sometimes groundwater monitoring. Stream biomonitoring is a method to evaluate the condition of a stream or river using biological surveys of the living organisms that inhabit the waters. It is a way of inferring the water quality based on what organisms are present. Sampling of stream macrobenthic invertebrates (macrobenthic invertebrates are relatively large organisms that inhabit bottom substrates of streams and lakes for at least part of their life cycles) is a useful addition to a monitoring program, as the composition and diversity of these species can be used as a relative assessment tool for stream health. Such sampling can often be undertaken by university students in fulfillment of course work.

Water Quality Analysis

Testing protocols can be simplified to test only those parameters that are directly influenced by course management, including organic and inorganic levels of nitrogen and phosphorus and a pesticide screen for selected pesticides used on the course. Additional analytes can include watershed basin-specific parameters of concern, such as sediments, suspended solids, and heavy metals. During measurements of dissolved oxygen, pH and alkalinity can also be sampled.

Samples should be analyzed by a certified laboratory, and all quality assurance/quality control (QA/QC) procedures must be followed. The purpose of QA/QC is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable. If a golf course should ever need to produce data for an agency or go to court to defend the facility, the data must meet QA/QC standards to be defensible as evidence.

Interpreting Water Quality Results

Water quality can be analyzed by private companies or by university laboratories. 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 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.

Best Management Practices for Water Quality Monitoring

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

Golf Turf Fertilization and Nutrient Management

Regulatory

If your business is operating in the "Cape Cod" Counties of Barnstable, Dukes or Nantucket, MA understand that there are more stringent fertilizer regulations enforced in those counties than the following statewide legislation.

In 2012, the Commonwealth of Massachusetts Legislature passed An Act Relative to the Regulation of Plant Nutrients (Act): Plant Nutrient Management

The following link leads to the entire regulation: MA State 330 CMR 31.00

MA State 330 CMR 31.00 established standards for the applications of plant nutrients to non-agricultural land, **including golf courses**, effective June 5, 2015. Section 2 of chapter 128 of this law was most recently amended by section 36 of chapter 194 of the acts of 2011, and is hereby amended by adding the following subsection:

(k) Maintain authority to regulate and enforce the registration and application of plant nutrients put on or in soil to improve the quality or quantity of plant growth, including, but not limited to, fertilizer, manure and micronutrients in the commonwealth. The department shall promulgate regulations that specify when plant nutrients may be applied and locations in which plant nutrients shall not be applied. Subject to appropriation, the department may also develop regulations regarding the use of plant nutrients designed to mitigate significant risks to human health and the environment. The department may limit the scope of those regulations regionally as appropriate (*ie Cape Cod and the Islands*). The department shall work in conjunction with the University of Massachusetts Amherst Extension to ensure any regulations of the department relative to plant nutrients are consistent with the program's published information, educational materials and other public outreach programs relative to nutrient management and fertilizer guidelines.

By law, if you are applying fertilizer to grass plants growing within the Commonwealth of Massachusetts "homeowners and professionals are required to obey plant nutrient application restrictions and follow the University of Massachusetts Amherst Extension Guidelines (UMass Guidelines) for nutrient management when applying plant nutrients on non-agricultural turf and lawns". The state regulatory expert is The University of Massachusetts.

On web page MA State 330 CMR 31.00 click UMass Guidelines for Nutrient Management
On web page UMass Guidelines for Nutrient Management click Turf

ALERT for businesses on Cape Cod and The Islands: At the bottom of this web page there are additional links specifically for Barnstable, Dukes and Nantucket Counties. The UMass Extension Service has included these links as necessary to provide an accurate statewide accounting of nutrient limitations. Please be certain to connect to the link for your town if it is displayed.

On web page UMass Guidelines for Nutrient Management you can also find the Commonwealth of Massachusetts adopted BMP's for Turf click [Best Management Practices for Soil and Nutrient Management in Turf Systems]

Preface

Fertilization is the key cultural practice that supplies essential nutrients to turfgrass plants. A sound fertilization program ensures turfgrass persistence, performance, and quality while safeguarding against environmental pollution. Proper fertilization, combined with appropriate mowing, irrigation, and pest control, produces healthy and attractive turf that withstands the wear and tear of its intended use. This requires a high level of cultural expertise including knowledge of plant nutrition, soils, and fertilizer technology and application. Variables to consider when developing a fertilizer program include turfgrass species, mowing height and frequency, soil type and structure, irrigation, intended use of the turfgrass, temperature, environmental factors such as shade or sun, and whether clippings are returned.

The Commonwealth of Massachusetts established a federal land grant college in 1863 and offered degrees in landscape horticulture and turfgrass management. In 1918 the Stockbridge School of Agriculture grew out of the Massachusetts Agricultural College offering two year degree programs in the same disciplines. The two year institution was named in honor of the first agricultural professor hired by Mass Aggie in 1863, Levi Stockbridge. In 1927 Professor Lawrence Dickinson established the Winter School for Greenkeepers, the first of its kind, which continues to successfully train turf managers to this day. That's 157 years of the science and research of turf.

The scientific expert for the Legislature of the Commonwealth of Massachusetts is the state's own university system. Therefore, it is imperative that you are ALSO directed to the UMass Extension Service's latest version of the Nutrient Management for Turf to get the most relevant information for our state.

Essential Elements for Turfgrass and Plant-Available Ionic Forms

At least 17 elements are considered essential for turfgrass growth. These elements are identical whether they are provided through a synthetic or "organic" fertilizer product. When considering environmental protection concerns, such as controlling runoff or leaching, the single most important consideration for any fertilizer application is the rate of release. Both types of fertilizer products have special inherent values and the use of both forms is the most efficient means for a turfgrass fertilizer management program with an eye towards environmental conservation and protection.

Macronutrients, the nutrients required in relatively large amounts, include carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). Micronutrients, nutrients required in relatively smaller amounts, include iron (Fe), manganese (Mn), zinc (Zn), boron (B), molybdenum (Mo), copper (Cu), chlorine (Cl), and nickel (Ni). Turfgrasses obtain C, H, and O from the atmosphere and water; the remainder are obtained primarily by roots from the soil. For turfgrasses to take up an essential element from the soil solution, it must be present in a plant-available ionic form, and water must be moving into the plant from the soil. Micronutrients are rarely deficient in Massachusetts soils, and therefore, applying them on a routine basis is generally not necessary. Soil pH will affect all nutrient availability to plants. Try to maintain a neutral, to slightly less than neutral, soil pH for optimum availability and uptake of all plant nutrients required for healthy turf.

Basis for Fertilization

Soil test results should be the foundation of a turfgrass fertilization program. Soil tests are used routinely to determine the availability of essential nutrients. Past fertilization practices and responses are useful guides for N fertilization. Tissue tests are becoming more widely utilized but are expensive compared with soil tests. Reflectance meters and digital image analysis may prove to be useful in a turfgrass N management program in the near future (Karcher and Richardson, 2013; Bell et al., 2013; Guillard et al., 2016; Inguagiato and Guillard, 2016).

Common sense should provide a guiding influence on nutrient management programs for turf. When the potential for water quality impacts exist, turfgrass fertilizer applications need to be closely managed. For example, fertilization (especially excess nutrient application) near open waterbodies or on sites with high leaching potential may contribute to contamination of receiving waters. In these cases, the solubility and release rates of N formulations, timing of application, and application rate need to be carefully considered.

Soil Testing

Soil testing plays an important role in a turfgrass nutrient management program. Soil tests measure the soil pH (how acidic or alkaline the soil), amounts of available macro- and micronutrients, and other chemical or physical properties such as soil texture, bulk density, porosity, CEC, soluble salts, and organic matter. A turf manager needs to know about the various soil properties to apply the proper amount of fertilizer and lime. Too little fertilizer and lime may result in reduced turf quality, vigor, stand persistence, performance, and tolerance to biotic and abiotic stresses. Too much fertilizer may increase problems with diseases and insects, reduce environmental stress tolerances, deplete plant storage carbohydrates (i.e., food energy), increase the potential for nutrient losses off-site, and increase economic losses due to unneeded nutrients.

Soil Testing Frequency

Newly established turf areas should be tested annually for a few years until the nutrient status of the soil becomes stable. For established turf without problems, a soil sample every two to three years should be adequate. Problem turf areas should be sampled annually until problems are corrected. High-value turf areas probably should be sampled annually because the margin for error in these systems is so low.

Soil samples can be analyzed by commercial laboratories, land-grant university systems, or agricultural experiment stations such as:

- Connecticut – University of Connecticut Soil Nutrient Analysis Laboratory and the Connecticut Agricultural Experiment Station.
- Maine – University of Maine Agricultural and Forest Experiment Station's Analytical Laboratory and Maine Soil Testing Service.
- Massachusetts – University of Massachusetts Soil & Plant Nutrient Testing Laboratory.
- New Hampshire – University of New Hampshire Cooperative Extension Soil Testing Services.
- Rhode Island (soil pH only) – University of Rhode Island Master Gardener's Program.
- Vermont – University of Vermont Agricultural and Environmental Testing Lab.

Best Management Practices for Soil Testing

- Divide the course into logical sampling components such as greens, fairways, tees, roughs, etc., for each hole.
- Take 10 to 15 soil samples randomly from each respective section of the golf course and blend them together to provide a representative, uniform soil sample (separately for greens, tees, fairways, and roughs).
- Take each soil sample at the same depth.
- Use an extractant appropriate for the course's soils (historically, the Morgan and modified-Morgan extractants are best for New England soils).
- Ensure that the same extractant is used for each test in order to compare soil test results over time.
- Keep soil tests from prior years and review to observe changes over time. This practice can provide good evidence of the impact of the nutrient management plan.

Plant Tissue Analysis

Turfgrass fertilization recommendations can also be based on tissue testing. With tissue testing, the clippings are analyzed for nutrient concentration and this value is compared to a critical range indicating deficiency, sufficiency or excess. Some believe that this method is more accurate than a soil test because it measures the concentrations of nutrients actually taken up by the grass rather than estimated from extractable soil values.

Best Management Practices for Plant Tissue Analysis

- Tissue samples may be collected during regular mowing.
- Do not collect tissue after any event that may alter the nutrient analysis such as fertilization, topdressing, and pesticide applications.
- Place tissue in paper bags, not plastic.
- If possible, allow tissue samples to air-dry before mailing them.
- Poor-quality turfgrass that is of concern should be sampled separately from higher-quality turfgrass.
- When turfgrass begins to show signs of nutrient stress, a sample should be collected immediately.

- More frequent tissue sampling allows a more accurate assessment of turfgrass nutrient status changes over time.
- The frequency of tissue analysis is dependent on individual course needs. Two to four tests per year are common on greens and one to two tests per year are common on tees and fairways.
- Keeping tissue test results from prior years allows for observation of changes over time.
- Tissue testing can provide good evidence of the impact of the nutrient management plan.

Fertilizers Used in Golf Course Management

The most important thing to realize about the modern agricultural fertilizers is that the scientific and technological advancements achieved over the last thirty years is as much a direct response to environmental protection as it is to maintaining plant health. The time and effort committed to university research continues to grow and manufacturers strive to create sound and sustainable products and practices for our industry. Fertilizer managers must stay abreast of these changes.

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. By law, all fertilizers include a grade or analysis stating the percent by weight of nitrogen (N), phosphorous (as P_2O_5) and potassium (as K_2O) that is a guaranteed minimum in the fertilizer. A complete fertilizer contains N, P_2O_5, and K_2O. However, additional laws that govern fertilizer labeling vary greatly among states. Consult the land-grant university or the appropriate state agency (usually the Department of Agriculture) regarding state laws.

Label

The label is intended to inform the user about the contents of the fertilizer that, if understood and followed, will minimize environmental risk. The fertilizer label may contain the following information:

- Brand
- Size guide number (SGN)
- Manufacturer’s name and address
- Guaranteed analysis/Grade
- “Derived from” statement
- Net weight
- Application and irrigating recommendations
- Personal Protective Equipment

Macronutrients

Macronutrients are required in the greatest quantities and include N, P, and K. Understanding the role of each macronutrient within the plant should provide you with a greater understanding of why these nutrients play such a key role in proper turfgrass management.

Nitrogen

Nitrogen is typically the nutrient required in the greatest quantity by turfgrasses aside from C, H, and O. Concentrations of N within tissues at sufficiency levels usually range from 2% to 6% N on a dry weight basis. When turf soils do not provide an adequate amount of N, persistence, performance, and quality of the turf suffers. This is usually expressed by reduced turf growth and development, reduced shoot and tiller density, reduced stolon or rhizome growth, increased weed infestations, and a yellowing of the leaf blades that reduces visual quality and resilience to abiotic and biotic stresses. It is critical that correct amounts be supplied at appropriate times in appropriate amounts. It is easy to see when turf is lacking N, but much harder to determine when N availability is beyond adequate and excessive.

It is commonly known that N fertilization results in a darker green leaf color, but consistent excessive N fertilization for a dark green turf color may not be beneficial in the long run. Under consistent and high N rates, turfgrass health may be compromised. Excessive N availability can result in the following:

- Poor root growth because shoot growth is stimulated at the expense of the roots.
- Poor rhizome and/or stolon development resulting in a weak sod.
- Higher incidence with hot- and cold-weather diseases.
- Reduced storage of food carbohydrates needed for regrowth following stress periods and overwintering; reduced recuperative ability.
- Poor tolerance to heat, cold, traffic, and drought stresses.
- Shifts of the turf community to species that are favored by high N (e.g., annual bluegrass).
- Higher succulence resulting in less wear tolerance and disease.
- More frequent mowing.
- Higher burn potential with certain types of N fertilizers.
- Environmental and economic losses of N.

Conversely, insufficient N fertility also can negatively affect performance of turfgrasses and the environment. Adequate N fertility enables turf to resist and/or recover from abiotic and biotic stresses. Maintaining sufficient N fertilization also increases turf density that can minimize weed infestation and the runoff of sediment, nutrients, and pesticides.

Fate and Transformation of N

The goal of all applied nutrients is to maximize plant uptake while minimizing nutrient losses. Understanding each process increases the ability to make sound management decisions and ultimately leads to an increase in course profitability and a reduction in environmental risk. Nitrogen management is more complicated than other required essential elements because of the multiple transformations that can occur in the soil with N. Nitrogen processes are shown in Figure 5-1 and include:

- Mineralization, the microbial mediated conversion of organic N into plant-available NO_3^- and ammonium NH_4^+.
- Nitrification, the microbial-mediated conversion of NH_4^+ to NO_3^-.
- Denitrification, the microbial mediated conversion of NO_3^- to N gas (NO, N_2O, or N_2); this primarily occurs in low-oxygen environments and is enhanced by high soil pH.
- Volatilization, the conversion of NH_4^+ to ammonia (NH_3) gas; this is enhanced by high soil pH.
- Leaching, the downward movement of an element through and below the rootzone.
- Runoff, the lateral movement of an element beyond the intended turfgrass location.

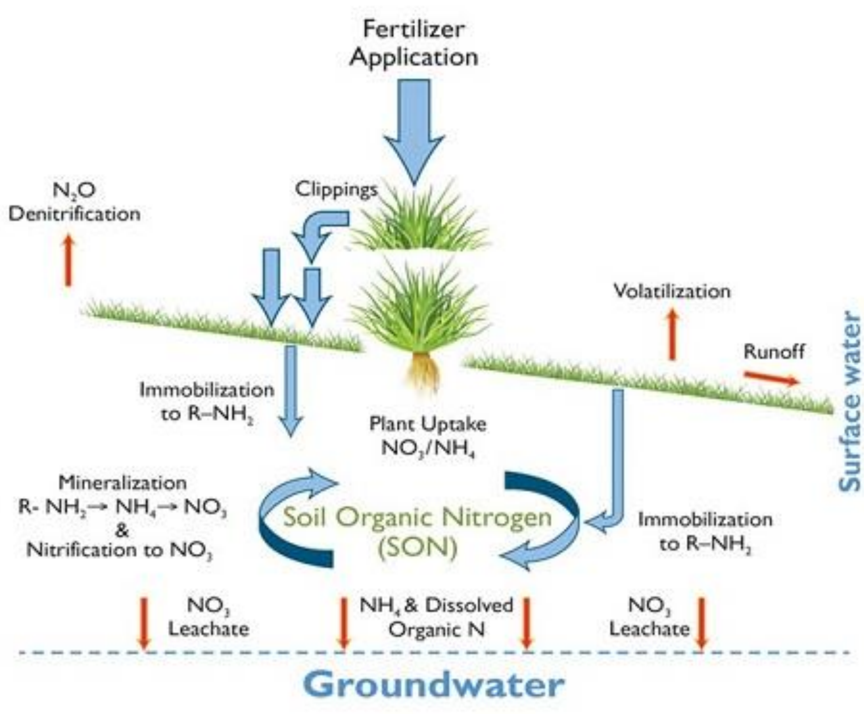


Figure 5-1. Fate and transport of nitrogen in fertilizers applied to turfgrass.

Nitrogen Fertilization Rate

The maximum amount of N that may be safely applied at any one time depends on the form and carrier of N, temperature, time of year, mowing height, species, and turf use. Here are examples of application rates:

- Under favorable conditions in Massachusetts, soluble N-containing fertilizers can be applied on short-cut turf at 0.10 to 0.25 lb N/1,000 ft^2/application. For higher-cut turf, N should be applied to provide no more than 1 lb N/1,000 ft^2 in any one application. Apply soluble N fertilizers only when turf is dry and when temperatures are below 80˚F. After application, apply water to wash the fertilizer off the foliage. Under hot temperatures, higher rates of soluble N may cause burn or excessive shoot growth.
- Under hot temperatures, N application should be avoided or limited to no more than 0.10 lb N/1,000 ft^2/application on lower-cut turf, and 0.5 lb N/1,000 ft^2 in any one application for higher-cut turf.
- With the natural organic materials, slightly higher rates may be used. However, no more than 1 lb N/1,000 ft^2 on lower-cut turf and no more than 3 lbs N/1,000 ft^2 on higher-cut turf should be applied at any one time. Reduce the number of applications by half when natural organic sources are applied at rates greater than 1 lb N/1,000 ft^2.
- In Massachusetts, an annual total of 2 to 3 lbs N/1,000 ft^2 is usually sufficient for good growth of short-cut turf. For higher-cut turf, up to 2 to 4 lbs of N/1,000 ft^2 per year is often applied. Reduce rates when clippings are returned.

Nitrogen Fertilization Timing

Fertilizer applications should be timed to maximize growth and vigor in the grass plant. Key times to apply fertilizer are spring, late spring, late summer, or early fall. Timing of fertilizer application should be based on environmental conditions and coincide with turfgrass needs. Therefore, time fertilizer application to provide nutrients at the beginning of periods when temperature and moisture conditions favor active turfgrass growth. Higher rates of N fertilization should be avoided when turf is stressed or with shaded turf. Summer application of fertilizer is generally not recommended unless recovery is required from traffic or wear, or where spoon-feeding programs are implemented. Excessive midsummer N fertilization promotes certain hot-weather diseases such as brown patch, summer patch, and pythium. It also stimulates shoot growth at a low-growth period, which depletes the food carbohydrates in the grass. This reduction in carbohydrates is detrimental to root growth. A rapid reduction in root growth leads to decreased heat, drought, wear, and pest tolerance.

Phosphorus

The application of phosphorous, or any fertilizer product containing phosphorous, as a plant nutrient is strictly regulated by the Commonwealth of Massachusetts. The role of P contained in sedimentation/erosion is a dominant factor in eutrophication. One poorly maintained construction project can undo decades of P management. As a consequence of this fact, any turf establishment on bare ground, or an existing turf stand with a "current" soil test exhibiting a phosphorous deficiency, in Massachusetts may receive a maximum application amount of P/1,000 ft^2 each year. MDAR Plant Nutrient Regulations

Turfgrasses take up P primarily as orthophosphate (H_2PO^{4-}). Phosphorus forms high-energy compounds that are used to transfer energy within the plant. Although many mineral soils contain relatively large amounts of P, it occurs in forms not available to turfgrass plants. Phosphorus is readily fixed by Ca, Fe, or Al. At a pH below 5.5, Fe and Al form an insoluble complex with P that makes P less available to turfgrass. At a pH above 7.5, Ca complexes with P to form an insoluble complex that makes P less available to turfgrass. It is commonly believed that P is most available to turfgrass when soil pH is between 6 and 7.

Physical soil characteristics are equally important to P availability to the plant. P transfer in soil Therefore, understanding the physical characteristics favorable to P availability and implementing the proper strategy for the timing and rate of any application are critical to achieve plant uptake and reduce the risk of off-site movement of P.

The role of P in turfgrass culture is important in seed germination, seedling vigor, and rooting responses. Therefore, P is critical during turfgrass establishment. Fertilization of P should be based on soil tests or tissues tests. When establishing new turf, P should be applied when extractable P levels in a soil test indicate a need. The P-containing fertilizer should be incorporated into the soil before seeding or sodding to a depth of 4 to 6 inches to provide at least 2 lbs P_2O_5 /1,000 ft^2. On low P sites, the new seedlings or sod should be additionally topdressed to provide at least 1 lb P_2O^5 /1,000 ft^2 after emergence. With tissue tests, adequate P is available when leaf P concentrations are 0.2% or above on a dry weight basis. For mature turf, P should be applied as a maintenance fertilizer only when soil test extractable P levels read low to provide at least 1 lb P_2O^5 /1,000 ft^2.

Lastly, our concern for P in the environment and subsequent federal, state and local regulations controlling fertilizer formulations and practices makes it imperative that every agriculutural manager understand that zero P is only possible in man made fertilizers. Organic based fertilizer products will always have P contained in them. Recently, manufacturers of these organic based products are trying to display P content on their product labels.

Potassium

Turfgrasses take up large amounts of potassium as the cation K^+. Turfgrass leaf concentrations of K can range from 2% to 5% of the dry matter. High K concentrations in turfgrass leaf tissue have been reported to improve tolerance of heat, drought, cold, disease, and wear. It is common to see high-K containing turf fertilizers, which are often called winterizers, promoted for late-season application. However, the effects of high K applications have been inconsistent and not observed in all cases.

Fertilization of K should be based on soil tests or tissues tests. Potassium should be applied only when the soil test extractable levels are low and at a rate to provide at least 1 lb K_2O /1,000 ft^2. Tissue concentrations below 1% are considered deficient (Jones,

1980) and a N:K ratio of 2:1 in the tissue is considered optimum. There is little turfgrass response to K fertilizers when soil test extractable K levels are medium or above. Potassium is a constituent of many soil minerals and weathering of nonexchangeable forms may provide a significant amount of K to turfgrasses in Massachusetts soils during the growing season. Similar to temperature tolerance, there has been little to no effect found in wear tolerance and traffic recovery (Hoffman et al., 2010). However, K fertilization beyond what is recommended for optimum shoot growth may increase the winter hardiness of annual bluegrass (Schmid et al., 2016) and perennial ryegrass (Webster and Ebdon, 2005).

Best Management Practices for Fertilization

- The overuse of poor quality fertilizer products will change soil chemistry by increasing salt content.
- Apply nutrients when soil tests dictate and turfgrass is actively growing.
- Apply N at rates and intervals to maintain moderate turf growth and recuperative potential.
- Use light, frequent N applications (spoon-feeding) to provide turf consistent nutrition and minimize potential for leaching and runoff.
- Apply slow-release N fertilizer at the appropriate time of year to maximize the products' release characteristics.
- N application rates from slow-release materials should take into consideration the release rate of the chosen material.
- Select a N:K fertility ratio based on turf use, rootzone, and clippings management.
- Exercise caution when applying nutrient applications during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff.
- Practice the" 5" R's of nutrition: Right Reason and 4 R's to minimize N loss without reducing turfgrass goals.
- Be aware of the different types of spreaders and understand the advantages and disadvantages of each.
- Calibrate spreaders regularly to reduce environmental risk and increases profitability. FertAdvisor is a free smartphone application that assists in spreader calibration developed by the University of Connecticut and available for both iPhone and Android users.
- Reduce environmental risk by properly storing and loading fertilizer and cleaning up any spills and unintended applications on hardscapes.
- Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave the soils wet.
- Do not apply fertilizer when the National Weather Service has issued a flood, tropical storm, or hurricane watch or warning, or if heavy rains that will produce runoff.

Soil pH

Maintaining soil pH within certain tolerances plays an important role in turfgrass growth and quality. Nutrient availability and soil flora and fauna activities are closely associated with the pH of the soil. These activities are important for mineralization of soil organic matter, thatch, and grass clipping decomposition, severity and incidence of certain turfgrass pests, and influences on pesticide efficacy. Liming does not replace a sound fertilization program, but enhances one. Therefore, the turfgrass manager must understand and appreciate how pH influences the persistence, growth, and quality of turf.

Soil pH is the result of the chemical reactions that occur in the soil, and these reactions affect the degree of acidity or alkalinity of a soil solution. The pH scale is used to measure the effects of these soil reactions. This scale is related to the amount or concentration of hydrogen ions $[H^+]$ present in the soil solution, and then transformed into a value that is easily understood. Mathematically, the pH value is calculated as the negative logarithm (base 10) of the hydrogen ion concentration $[H^+]$, and ranges from 0 to 14.

Because the scale is measured using logarithms (base 10), it increases or decreases 10 times for each unit change of pH. For example, even though a pH of 5 does not seem that much lower than a pH of 6, the pH of 5 is 10 times more acidic than the pH of 6. A pH of 4 is only two units lower than 6, but 100 times more acidic.

Optimum Ranges of Soil pH for Turfgrasses

Although most turfgrasses can tolerate a wide range of soil pH values, a pH range of 6 to 7 is generally recommended for Massachusetts' turf. Kentucky bluegrass, a popular turf species, does best when soil pH is between 6.5 and 7.2. Ryegrasses and bentgrasses are somewhat more tolerant of lower soil pH values than Kentucky bluegrass, but they also perform best under a neutral or slightly alkaline pH. The fine fescues and turf-type tall fescues can tolerate fairly acidic soil conditions, but their growth is also better under a neutral or slightly alkaline pH.

Rates of Lime Application

Soil tests are the only way to determine if the turf soil requires lime. The rate for liming materials is partly determined by soil texture. Soils with more clay and silt require more lime to neutralize acidity than sandier soils. Soils with higher organic matter may require more lime than the same soil type with lower organic matter content.

Because most Massachusetts soils contain an appreciable amount of sand, it is best to limit each application of ground limestone to 50 lbs/1,000 ft^2 when applied to established turf. Higher rates may result in excessive alkalinity near the soil surface before the lime eventually moves downward. This is especially the case with turf containing a thick thatch layer. If more than 50 lbs limestone/1,000 ft^2 are recommended based on a soil test, the applications should be split at least a few months apart. When establishing new turf, the total limestone requirement may be applied in a single application provided that it is thoroughly mixed into a 4- to 6-inch depth before seeding or sodding.

Best Management Practices for Soil pH

- Maintain pH near 6.8 to optimize nutrient availability and reduce fertilization requirements.
- To increase soil pH, apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca^{2+} or Ca^{2+}/Mg^{2+} and neutralizes acidity.
- To lower soil pH, products containing elemental sulfur should be applied.
- In some cases, utilizing injection pumps into irrigation water to address pH can be beneficial.

Cultural Practices

Preface

Cultural practices play a large role in turfgrass quality. In addition to selecting appropriate turfgrass species or cultivar, proper cultural management can help produce a dense, healthy playing surface. These practices are used on all areas of a golf course, including putting greens, fairways, tee boxes and roughs; and include a variety of methods, such as mowing, cultivation, cultivar selection and rolling. These practices typically manage the top 3 to 4 inches of soil to improve nutrient and water uptake and the overall health of the plant.

The Commonwealth of Massachusetts established a federal land grant college in 1863 and offered degrees in landscape horticulture and turfgrass management. In 1918 the Stockbridge School of Agriculture grew out of the Massachusetts Agricultural College offering two year degree programs in the same disciplines. The two year institution was named in honor of the first agricultural professor hired by *Mass Aggie* in 1863, Levi Stockbridge. In 1927 Professor Lawrence Dickinson established the Winter School for Greenkeepers, the first of its kind, which continues to successfully train turf managers to this day. That's 157 years of the science and research of turf.

The scientific expert for the Legislature of the Commonwealth of Massachusetts is the state's own university system. Therefore, it is imperative that you are ALSO directed to the UMass Extension Service's latest version of the Best Management Practices for Lawn and Landscape Turf to get the most relevant information for our state.

Turfgrass Selection

Selection of turfgrass species or cultivar is one of the most important decisions a manager can make to ensure a healthy turfgrass stand. Selecting the wrong species can lead to turfgrass failure, resulting in poor density, poor playability, increased water use, and increased likelihood of pesticide application. Turfgrass managers should select grass species and cultivars based on the existing site conditions and the intended use of the turf. Criteria include the selection of:

- Drought-tolerant species and cultivars where water is limited or not available.
- Wear- and compaction-tolerant species and cultivars for heavy play and high traffic areas.
- Disease-tolerant and endophytic cultivars to reduce pest damage and pesticide use.
- Shade-tolerant species and cultivars for areas with limited or restricted light.

Breeding programs have made tremendous advances in the development of improved turfgrass cultivars. Within each turfgrass species, cultivars can now be selected for improved characteristics such as denser playing surfaces, tolerance of lower mowing heights, increased drought tolerance, improved wear tolerance, improved pest resistance, improved shade tolerance, and improved salinity tolerance. As a result of these improvements, managers can select cultivars or species appropriate for the site that require less water, pesticide, and fertilizer.

When planning new seeding or overseeding projects for the golf course, it is recommended that turfgrass mixtures (two or more species) or blends (two or more cultivars of the same species) be used to improve genetic diversity of the turfgrass stand. Consideration should be given to match turfgrass characteristics such as color, texture, growth rate, and mowing height requirement of grasses in the mix or blend. Examples of typical grass species and blend or mixture recommendations for cool-season grasses in Massachusetts can be found in Table 6-1.

Table 6-1. Recommended turfgrass species for Massachusetts Golf Courses

Area of Golf Course	Species	Recommended Mixture or blend
Putting Greens	Creeping bentgrass	Single Cultivar[1] or Blend
	Velvet bentgrass	Single Cultivar[1] or Blend
Tees and Fairways	Creeping bentgrass	Blend
	Perennial Ryegrass	Blend
	Compact Kentucky bluegrass	Blend
	Compact Kentucky Bluegrass/Perennial ryegrass	Mixture
	Compact Kentucky Bluegrass/Fine fescue	Mixture
	Fine leaf fescue/colonial bentgrass[2]	Mixture[2] Minimally irrigated areas
Roughs[3]	Kentucky bluegrass	Blend
	Kentucky bluegrass/ Perennial Ryegrass/fine fescue	Mixture
	Turf-type Tall fescue[4] (minimally irrigated roughs)	Blend

When considering new turfgrasses, managers can consult the National Turfgrass Evaluation Program, the Alliance for Low-input Sustainable Turf (A-List Turf), or the Turfgrass Water Conservation Alliance to select cultivars that perform well in their region. Attending educational conferences, seminars, and turfgrass field days are other ways turfgrass managers can learn about new and improved cultivars (Figure 6-1).

Figure 6-1. National Turfgrass Evaluation Program fine fescues traffic trial for University of Connecticut. The study evaluated the use of low input (low water and fertility) for fine fescue species and cultivars maintained at golf course fairway mowing heights.

Best Management Practices for Turfgrass Selection

- Identify site characteristics and use requirements that may impact turfgrass growth and performance.
- Select appropriate grass species and improved cultivars for the site and intended use with the following characteristics as needed:
  - Lower mowing height of cut o Increased density
  - Improved shade tolerance o Improved heat tolerance
  - Improved drought tolerance o Reduced disease susceptibility
  - Reduced insect susceptibility o Improved traffic (wear + compaction) tolerance

Mowing

Mowing is the most common cultural practice of managed turfgrass systems. Turfgrasses are unique in that they tolerate routine mowing at heights from 0.09 to 4 inches depending on the turfgrass species and/or cultivars. When considering mowing, five areas of interest affect turfgrass quality and playability: height of cut (HOC), mowing frequency, clipping management, mower selection, and mowing direction. Additionally, the type of roller (i.e. smooth or grooved) on the front of the mower can also affect mowing quality.

Mowing Height

Turfgrass HOC is determined by several factors, including, but not limited to, the following: species and cultivar, area of play (tee, green, fairway, etc.), budget, number of rounds, and tournament or non-tournament conditions. Examples of typical mowing heights and desirable ranges for Massachusetts golf turfgrass, are provided in Table 6-2. In general, no more than 30% to 40% of the leaf blade should be removed in a single mowing (Crider, 1955). On turf stands that have been previously maintained at a higher mowing height, or turf that has not been mowed for an extended length of time (i.e. too wet to mow), the HOC should be lowered gradually and in weekly intervals.

Table 6-2. Mowing heights* commonly utilized for golf course playing surfaces in Massachusetts

Species	Greens Regular Membership play	Greens Tournament conditions	Collars, Tees, and Approaches	Fairways	Rough (primary)
	------------------------------------- inches -------------------------------------				
Creeping bentgrass	0.1 - 0.14	0.09 - 0.125	0.25 - 0.4	0.35 - 0.5	-
Velvet bentgrass	0.1 - 0.14	0.09 - 0.125	0.25 - 0.4	-	-
Perennial ryegrass	-	-	0.4 - 0.5	0.4 - 0.5	1.5 - 3
Kentucky bluegrass **	-	-	0.5	0.5 - 0.14%	1.5 - 3
Fine Fescue	-	-	0.4 - 0.5	0.4 - 0.5	-
Tall fescue (turf-type)	-	-	-	-	1.5 - 3

Mowing heights may need to be adjusted based on weather conditions, time of year, turfgrass health, the presence of abiotic or biotic stresses, and the growing environment. For example, mowing HOC should be raised for turf grown under shade conditions. Doing so allows for increased leaf area that maximizes photosynthesis (Gardner and Goss, 2013).

Maintaining an optimal root-to-shoot ratio is critical for plant health. Mowing at an HOC less than the desirable range negatively affects the plant (Figure 6-2). Lower mowing heights often result in decreased root growth (Liu and Huang, 2002) as well as decreasing rhizome production (Juska et al. 1955).

When this occurs, drought tolerance is reduced, susceptibility to root-feeding insects and pathogens can potentially increase, and overall plant vigor decreases (Steinke and Ervin, 2013). Turfgrasses maintained below their optimum HOC can also result in increased weed pressure (Calhoun, et al. 2005). To maintain plant health when mowing turfgrasses below their range of adaptation, greater inputs of water, fertilizer and pesticide may be needed.

Figure 6-2. Operator error resulted in scalped turf.

Mowing Frequency

Mowing frequency is primarily a function of mowing height. Turf maintained at lower mower heights should be mowed more frequently to avoid removing too much leaf tissue in a single cutting. Frequent mowing increases shoot density and tillering, which can improve playability.

Mowing frequency has been shown to have an impact on root to shoot ratios. Krans and Beard (1985) reported that root:shoot ratios were greater for Merion Kentucky bluegrass plants that were clipped semiweekly compared with plants that were cut weekly or biweekly. Mowing strategies that can help maintain optimal root to shoot ratios are as follows:

- When possible, reduce mowing frequency when grasses are suffering from biotic or abiotic stresses, or from mechanical damage as a result of cultural practices.
- Do not remove more than 30% to 40% of the leaf area with a single mowing (Crider, 1955). In order to follow this rule, mowing frequency should be based on factors such as time of year, fertility level, water availability, and, ultimately, the rate of grass growth.

Mowing Equipment

Reel and rotary mowers are the two main types of mowers used on the golf course for maintaining areas of play (Figures 6-3 and 6-4). Quality of cut for both reel and rotary mowers depends upon sharp, well-adjusted blades. Dull blades increase the likelihood of wounding leaf tissue, increased water loss, and increased potential for infection or disease (Figure 6-5). Reel mowers provide the best quality of cut at mowing heights less than 1.5 inches. Generally, the lower the HOC the more blades there are on the reel cylinder. The combination of the number blades on the reel, the reel speed (rotational velocity), and the forward speed of the mower make up the clipping rate. It is critical that the clipping rate matches the HOC to provide the most uniform playing surface. Rotary mowers provide acceptable mowing quality when used at mowing heights equal to or greater than 1 inch.

Figure 6-3. Reel mowers are used on greens, collars, tees, approaches, and fairways. Proper reel to bed knife adjustment is necessary to maintain plant health.

Figure 6-4. Rotary mowers are used for rough and surrounds (bunker, green, and tee). Sharp rotary blades are necessary for a quality cut and plant health.

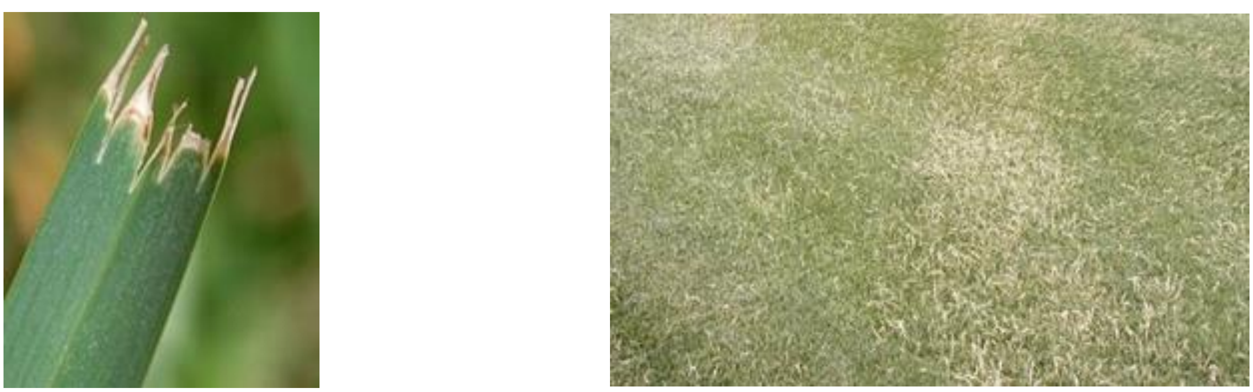


Figure 6-5. Dull mower damage to turfgrass. Properly adjusted mowers minimize turf stress.

Clipping Management

Turfgrass clippings are a source of nutrients. Research has shown that nitrogen fertilization rates can be cut by as much as one-half when clippings are returned (Kopp and Guillard 2002). Therefore, clippings should be returned to the site during the mowing process unless the presence of grass clippings will have a detrimental impact on play. The nutrient values of returned clippings can be deducted from your annual fertility needs on these areas and save money. Clippings should be removed during disease outbreaks, when practicing Poa annua control strategies (Gaussoin and Branham, 1989), or when weed seed production is high.

In areas where clippings cannot be returned, such as putting greens, they may be collected and either composted for future use or dispersed in areas such as roughs or practice ranges. On fairways and tees, clippings can be dragged back into the turf canopy with the use of a metal chain pulled between two golf carts or blown into the rough (Figure 6-6). Because nutrients contained in clippings can be a source of pollution, they should be handled properly and care taken to avoid depositing clippings into wetlands, ponds, and streams.

Figure 6-6. To return nutrients back to the soil, collected clippings should be composted, blown, or spread into roughs and out of play areas on the golf course.

Rolling

Rolling putting greens has proven to be beneficial in maintenance programs (Figure 6-7). It provides for a smoother ("truer") putting surface and increases putting green speeds. Both benefit playability. Rolling allows managers to either reduce mowing frequency or raise mowing heights while maintaining acceptable putting green speeds. Rolling has also been shown to reduce incidence of dollar spot (Nikolai et al., 2001). To reduce the potential of compaction, rolling should be avoided when soils are saturated.

Figure 6-7. Rolling putting green surfaces can allow managers to reduce mowing frequency or raise mowing heights while maintaining putting green speeds.

Best Management Practices for Mowing

- Maintain turfgrass mowing heights within the ranges of adaptation for the species and cultivars being grown.
- Avoid removing more than 30% to 40% of the total leaf area in a single mowing.
- Reduce mowing frequency when turf is suffering from biotic and abiotic stresses.
- Alternate between rolling and mowing when turf shows signs of stress.
- Increase mowing height and roll greens routinely (e.g., every other day) to maintain ball roll distance and turf health.
- Properly adjust mowers and sharpen blades to maintain mowing quality and reduce the possibility of disease or infection through wounded plant tissue.
- Return clippings to the turf when possible and account for the nutrients they contribute to the fertility program.
- Remove clippings during periods of weed seed production, to reduce disease spread, to eliminate potential smothering of turfgrass plants from excessive clipping volume, or when clippings interfere with functional use of the turf.
- Do not dispose of or compost clippings near ponds, streams, and water ways or on impervious surfaces.

Cultivation

Turfgrasses are unique in three ways: they tolerate frequent close mowing; they persist under traffic conditions; and they form a dense, contiguous community. These characteristics make turfgrasses ideal for functional outdoor spaces like golf courses.

However, high traffic areas such as fairways, tees, and putting greens can deteriorate with routine use.

The negative impacts of soil compaction and high wear will be evident in concentrated traffic areas. Thatch accumulation can be problematic in less trafficked areas. The surface of the soil profile (top 3 inches) needs to be actively managed to enhance turfgrass health by improving water movement, increasing atmospheric gas exchange, reducing root penetration resistance, and removing thatch accumulation. Accumulation of excessive thatch and organic matter will reduce root growth, reduce water infiltration, cause scalping, create an undesirable playing surface, and encourage disease and insect activity

Cultivation involves disturbing the thatch and/or soil through the use of various methods such as hollow-tine cultivation, solid-tine cultivation, slicing, spiking, water injection, air injection, verticutting, drill aerification, and deep-tine cultivation (Figure 6-8).

Depending on equipment used, goals, and turfgrass growth rate, cultivation techniques can result in disturbance of the playing surface that can require significant time for recovery. The level of disruption depends on the type of cultivation selected. Type and frequency of cultivation should be based on traffic intensity, growing conditions, degree and depth of soil compaction, and the amount of thatch accumulation.

Figure 6-8. Hollow-tine cultivation on a tee at West Point Golf Course in West Point, NY.

Best Management Practices for Cultivation

- Conduct more aggressive techniques such as hollow-tine cultivation only when grasses are actively growing to aid in quick recovery of surface density (typically during or just before periods of rapid root growth such as spring and fall).
- Design core cultivation programs to remove 15% to 20% of the surface area per year on sand-based putting greens. This typically will require two core cultivation treatments annually.
- Vary depth of aerification events every two to three years to prevent compacted subsurface layers in the soil profile. This can include varying the length of tines used, but ideally deep-tine equipment that can reach depths of 6 inches or more should be used.

- Use less aggressive types of cultivation such as small solid tines (needle tines), water injection, or air injection during more environmentally stressful periods to vent the surface (maintain gas exchange) and maintain infiltration rates (Murphy and Rieke, 1994; Carrow, 2003).
- Conduct shallow vertical mowing (blades do not penetrate the soil surface) monthly to prevent thatch accumulation and stimulate new growth to increase shoot density by cutting stolons.
- Only use more aggressive vertical mowing (blades reach the bottom of the thatch layer into the immediate soil surface) as a curative approach for thatch removal once the thatch layer reaches a 0.25 inch depth.
- Apply sand topdressing concurrently with more aggressive forms of cultivation such as hollow-tine cultivation (cores harvested, holes filled with topdressing) or aggressive vertical mowing to help maintain macroporosity at the surface, fill voids to smooth the playing surface, and reduce organic matter accumulation (Carrow, 2003).

Topdressing

The objectives of sand topdressing are to 1) dilute thatch accumulation, 2) smooth the playing surface, 3) maintain surface drainage, 4) increase infiltration, 5) increase soil macroporosity at the surface by increasing the sand content of the soil, and 6) increase surface firmness (Figure 6-9).

The goal of topdressing is to keep the crown of the turfgrass plant as close to the soil surface as possible by physically removing organic matter and thatch through cultivation and adding desirable rootzone material to the surface by sand topdressing. Obtaining this goal through proper management enables the turfgrass plant to maximize root development, minimize any disruption in water or air movement, and minimize pest pressure (disease/insect).

The particle size of topdressing material must be compatible with and appropriate for improvement of the existing rootzone material. Topdressing materials should have the same particle size distribution as the construction mix or be coarser in texture. Topdressing materials finer in texture than the original construction sand can negatively impact rootzone infiltration rates and result in excessive moisture retention in the topdressing layer. Soil modification with sand of the top 3 inches results in higher infiltration rates and reduced runoff.

Figure 6-9. Topdressing can help maintain good soil physical properties in high traffic areas.

Best Management Practices for Topdressing

- Apply higher rates of topdressing to putting greens in the spring and fall in conjunction with more aggressive forms of cultivation, harvest cores and fill holes with topdressing (Carrow, 2003). Apply lighter, more frequent sand applications (every seven to 14 days) throughout the growing season.
- Laboratory test prospective topdressing materials using ASTM F1632, also known as the Standard Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sport Field Rootzone Mixes. Compare the results to USGA guidelines for particle size distribution to determine the suitability as potential topdressing materials.
- Laboratory test prospective topdressing materials using ASTM F1815, also known as the Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Putting Green and Sports Turf Rootzones, to ensure they meet USGA guidelines for hydraulic conductivity.
- Sample existing greens on the golf course (15 to 20 subsamples at 4 inch depth or to the current topdressing layer depth if previously topdressed) and laboratory test using ASTM F1632, and compare the results with prospective topdressing materials to ensure compatibility.

Plant Growth Regulators

Plant growth regulators (PGRs) are frequently used to reduce clipping yield, improve stress tolerance, and improve turfgrass quality and performance. An additional benefit of using PGRs is a reduction in the use of other inputs (e.g. fertilizers). Plant growth regulators 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 can include mild discoloration, stressed turfgrass, and segregation of grasses. These effects can be confused with disease, can slow recovery, 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. Tools are available online for assistance in using GDD information to schedule PGR applications, such as the web-based app GreenKeeper and Cornell University's ForeCast web site.

Best Management Practices for PGRs

- Use GDD to plan PGR use.
- Plant growth regulators should not be applied too early or too late in the growing season to avoid stressing turfgrass.

Integrated Pest Management

Preface

When Massachusetts turfgrasses face stresses such as the heat, humidity, and occasional drought in the summer, pests can become a problem. Pesticides alone will not control pests. A more effective approach is to develop an integrated pest management (IPM) program to reduce pest damage and reliance on pesticides. The United States Environmental Protection Agency (USEPA) 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 number 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.

The Commonwealth of Massachusetts established a federal land grant college in 1863 and offered degrees in landscape horticulture and turfgrass management. In 1918 the Stockbridge School of Agriculture grew out of the Massachusetts Agricultural College offering two year degree programs in the same disciplines. The two year institution was named in honor of the first agricultural professor hired by Mass Aggie in 1863, Levi Stockbridge. In 1927 Professor Lawrence Dickinson established the Winter School for Greenkeepers, the first of its kind, which continues to successfully train turf managers to this day. That's 157 years of the science and research of turf.

The scientific expert for the Legislature of the Commonwealth of Massachusetts is the state's own university system. Therefore, it is imperative that you are ALSO directed to the UMass Extension Service's latest version of the Protocols for an IPM System for Golf Courses to get the most relevant information for our state. This workbook publication is the result of a three year collaboration between the university and the Golf Course Superintendents Association of New England and may be purchased for $20.00.

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 basic 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 not: a ban on synthetic pesticides; low input or low yield; an organic program; a government regulated program. It is flexible, and superintendents can usually balance course quality and environmental goals through its responsible implementation. Growing healthy turf is the best and first line of defense against all pest problems. IPM is a series of evaluations by superintendents to arrive at the least impactful approach for a given situation which is governed by the constraints of the practitioner's program. It is uniquely tailored, by you, for you.

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 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.

Best Management Practices for IPM

- Work with all stakeholders to 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 application strategy with the lowest overall impact when considering toxicity and potential for off-target movement. Understand that a low impact, low efficacy approach may be more harmful than a single highly effective application.
- Designate an IPM Coordinator to document all IPM goals and related activities, including non-chemical control methods and pesticide usage.
- Train your people in the elements of the IPM and how to conduct the evaluations of pest identification and thresholds.

Monitoring Pests and Recording Information

In an 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 for 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:

- Is the host human or plant?
- 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.

Best Management Practices for IPM Monitoring

- 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

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 are recognizing and understanding beneficial organisms and their life cycles so their populations are not unduly 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.

Diseases

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 can often be 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 will 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, which are often available from a state land grant university's plant disease clinic or from private laboratories, can help prevent choosing the wrong products or management tactics.

Weeds

Weeds are unwanted plants that are unsightly, disrupt playability, harbor pests, and competitively displace desirable turfgrass. Weeds exploit openings in the turfgrass canopy, where seedlings germinate and survive to become a persistent colony of perennials or seed producing annuals. Allowed to run out of control, even for a short period, they can produce an enormous seed bank in the soil that may persist for years and be far more difficult to control and requiring greater imput.

The potential for invasive weeds can be limited through implementation of the BMPs 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 and frequency can also impact turf weed populations. For example, mowing too low 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.

Nematodes

In Massachusetts, high populations of plant-parasitic nematodes are generally restricted to golf greens, which provide an ideal environment for nematodes. The pore spaces of sandy soils provide a favorable environment to support nematodes: adequate oxygen levels, room to accommodate nematode mobility, and water availability.

Plant-parasitic nematodes adversely affect turfgrass health by debilitating the root system of susceptible species, thus decreasing the efficiency of plant 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 such as drought, high or low temperatures, and wear.

Insects/Arthropods

Annually recurring insect pest groups common to Massachusetts golf courses include numerous species, including billbugs, chinch bugs, and Lepidoptera order members such as armyworms, cutworms, and sod webworms.

Several species of grubs occur in Massachusetts, including the Japanese beetle, European chafer, Oriental beetle, annual bluegrass weevil, and black turfgrass ataenius. 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. Natural grub predators (skunks, birds) will destroy turf rummaging for the insects. Management of white grubs is most efficient when the specific population causing turf damage is identified. Because some insecticides are less effective against Oriental beetle or European chafer, species identification has become increasingly important for management decisions.

Best Management Practices for 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 Pest 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.

Best Management Practices for Identifying and Understanding Pests

- Establish injury and treatment thresholds levels for key pests.
- Document pest thresholds in an IPM plan.

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.

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.

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.

Prescribed Burns

As many golf courses convert maintained turfgrass areas to native grassed areas, 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 non-native species and woody plant materials and can be used to create a links-style course that resembles a tallgrass prairie.

Any local notification requirements should be followed as required and all fire danger information should be reviewed before conducting a prescribed burn.

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.

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.
- The pesticide should be effective in treating the pest problem.
- The timing of the pesticide application should be based on growing degree day (GDD) information for the pest to be controlled. GDDTracker is an example of a tool that can assist in timing applications; Cornell University's ForeCast website also has GDD information.
- Pesticide rotation, 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 risks, particularly potential for product drift, applicator health and water quality impacts must be evaluated. Tools to evaluate risk are described in the Pesticide Risk Assessment Tools section of the "Pesticide Management" chapter of this document.
- Knowledge of the total number of applications required for effective control needs to be considered in terms of potential damage, cost, time, and the aggregate environmental impact.
- Any restrictions on the pesticide label must be reviewed and rigorously followed.

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 USEPA registers reduced-risk pesticides through its Conventional Reduced Risk Pesticide Program. These reduced-risk pesticides are commercially viable alternatives to conventional pesticides.

The USEPA 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.

Table of Reduced risk pesticides labeled for use on golf course turf.

Fungicides	Herbicides	Insecticides
boscalid	penoxsulam	clothianidin
penthiopyrad	carfentrazone-ethyl	chlorantraniliprole
trifloxystrobin	mesotrione	cyantraniliprole
fudioxonil	bispyribac-sodium	fipronil
azoxystrogun		spinosad

Biopesticides, which are derived from such natural materials as animals, plants, bacteria, and certain minerals, are classified separately by the USEPA. For more information on biopesticides (part of the USEPA Reduced Risk Pesticide Program) go to Biopesticide Registration.

Best Management Practices for IPM 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 materials, such as topdressing, are pest-free.
- Apply a preventative 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 guidelines and advice provided by the FRAC, HRAC, and IRAC.
- Evaluate use of reduced-risk pesticides and biopesticides to treat the problem.
- Track and document results so they can be repeated or modified in the future.

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 restricted-use pesticides. For IPM purposes, records should be kept for all pesticide applications and should include additional information, such as monitoring records, weather records, cultural management logs, and pest response.

Best Management Practices for IPM 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.

Pesticide Management

Preface

The judicious use of pesticides is generally required, as part of an integrated pest management (IPM) program, to minimize damage to golf course playing surfaces caused by disease, insects, and weeds throughout Massachusetts. The term pesticide is inclusive of fungicides, insecticides, and herbicides among others, and is defined by the U.S. Environmental Protection Agency (USEPA) as any substance or mixture of substances intended to prevent, destroy, repel, or mitigate a pest; or any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

The use of pesticides can pose a risk to human and environmental health. However, the relative risk of pesticides is largely mitigated through governmental regulation of pesticides and their use, and through responsible decision-making and actions of licensed or certified pesticide applicators. The US Federal Government has regulated pesticides since 1947 through the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). This law empowers the USEPA to register pesticides and to regulate the use, storage and disposal of containers and manufacturing wastes. FIFRA also allows states to have primary enforcement responsibility. FIFRA

Massachusetts regulates pesticides under the authority of the Massachusetts Pesticide Control Act (MPCA, Chapter 132B of the Massachusetts General Laws). This law, enacted in 1978, places the power of pesticide regulation with the Massachusetts Department of Agricultural Resources. The regulations are Chapter 333 of the Code of Massachusetts Regulations (333 CMR).MPCA Chapter 132B

The Pest Management branch within the Department of Agricultural Resources carries out these regulatory responsibilities. Pesticide Program All of the topics covered in the individual sub-sections of this BMP category are regulated by this program.

The most significant regulation from the federal and state level is that any person involved in the business of working with pesticides must be licensed or certified by the Commonwealth of Massachusetts and participate with an accredited, three year Pesticide License Recertification and Audit Program to renew a license or certification. License/Certification Renewal

When a pest application is deemed necessary by the licensed golf course superintendent, pesticide selection should be based on effectiveness, toxicity to non-target species, site characteristics, solubility and persistence in the environment, and cost. This section focuses on many of these topics, which golf course superintendents should consider to minimize human and environmental risk associated with pesticide use.

Human Health Risks

In addition to the US EPA FIFRA regulations mentioned in the previous section, the US EPA provides a wealth of information to the public concerning its multi-layered risk chemical risk assessment programs. US EPA Risk Assessment "*EPA's mission is to protect human health and the environment."* Not to oversimplify their work, when setting acceptable levels of risk EPA tests for effectiveness of the pesticide's intended use and then consider its safety to human and environmental health. They reduce the amount of allowable concentration for use to account for sensitive groups: children and pregnant women. This is followed by discussing and deciding the fate of the pesticide and the route of exposure.

Pesticides belong to numerous chemical classes developed by EPA that vary greatly in their toxicity. Toxicity is a measure of a substance's potential to cause injury, illness, or death. It is characterized through laboratory studies to determine the dose or concentration of a chemical that results in 50% mortality of an animal test population (i.e., lethal dose or LD50). All pesticide labels contain a "Signal Word" (Table 8-1) to characterize their relative risk to human health based on acute toxicity of six studies of oral, dermal, inhalation, and eye and skin irritation (USEPA, 2014).

Table 8-1. Pesticide signal words

Signal Word	Toxicity Level
Danger	Toxicity Category I
Warning	Toxicity Category II
Caution	Toxicity Category III
None required (or Caution as optional)	Toxicity Category IV

However, the risk to human health associated with pesticide use depends on both pesticide toxicity and the level of exposure. Exposure is related to how much an individual is exposed to a pesticide. Thus, the risk of a very highly toxic pesticide may actually be very low, if the exposure is sufficiently small.

To minimize human health risks associated with golf course pesticide use, superintendents should select effective pesticides with lower toxicities, including reduced risk pesticides, and adopt practices that reduce exposure to applicators, staff, and their clientele.

Reduced Risk Pesticides

Special designation is given by the USEPA to pesticides meeting the following criteria: low impact on human health, lower toxicity to non-target organisms (birds, fish, plants), low potential for groundwater contamination, low use rates, low pest resistance potential, and compatibility with IPM (USEPA, 2018). Several reduced risk pesticides are labeled for use in turf (Table 8-2). Some of these have been demonstrated to reduce hazard to golfers due to the reduced toxicity and use rates (Doherty, 2017).

Table 8-2. Reduced risk pesticides labeled for use on golf course turf.

Fungicides	**Herbicides**	**Insecticides**
boscalid	penoxsulam	clothianidin
penthiopyrad	carfentrazone-ethyl	chlorantraniliprole
trifloxystrobin	mesotrione	cyantraniliprole
fludioxonil	bispyribac-sodium	fipronil
azoxystrobin		spinosad

List as of June 2018. https://www.epa.gov/pesticide-registration/reduced-risk-and-organophosphate-alternative-decisions-conventional.

Re-entry Interval (REI)

This is a period of time in which entry into a pesticide-treated area is restricted. Several pesticides used in production agriculture have specifically stated “re-entry intervals” on the label, preventing workers from entering a treated field for the stated period of time after application unless they use the required personal protective equipment (PPE). The purpose of this restriction is to protect farm workers from exposure to residues of pesticides while they work in the fields. Re-entry intervals are not required following applications made on golf courses, based on current pesticide labels. However, a one-hour re-entry period following golf course pesticide applications reduces worker and golfer pesticide exposure (Putnam et al., 2008; Doherty, 2017).

Research conducted at the University of Massachusetts has demonstrated that pesticide residue transfer from treated turf is greatest within the first hour after application (Figure 8-1 and 8-2) (Putnam et al., 2008; Doherty, 2017). Thus, pesticide exposure to golfers and staff can be reduced by limiting entrance into treated areas for one hour following an application. However, applying pesticides at night to provide a re-entry period before the following day does not effectively reduce pesticide transfer, and can actually increase pesticide exposure compared with daylight applications (Putnam et al., 2008).

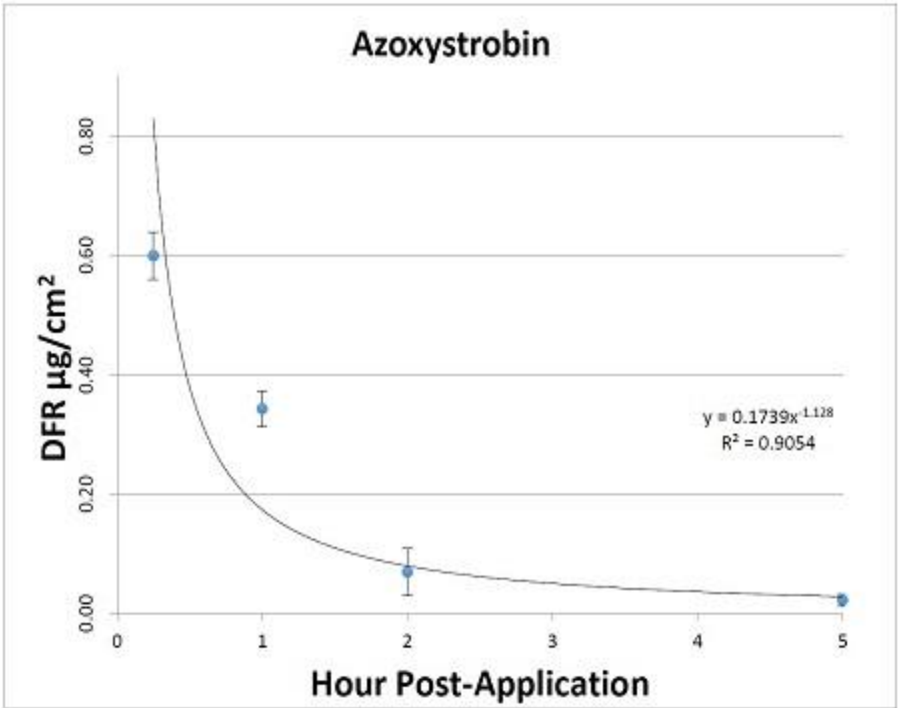


Figure 8-1. Azoxystrobin dislodgeable foliar residues were measured over the first 5 hours following application. Residues of azoxystrobin declined rapidly within the first two hours post application with a 43% reduction of residues 1 hour after application. From Doherty, 2017.

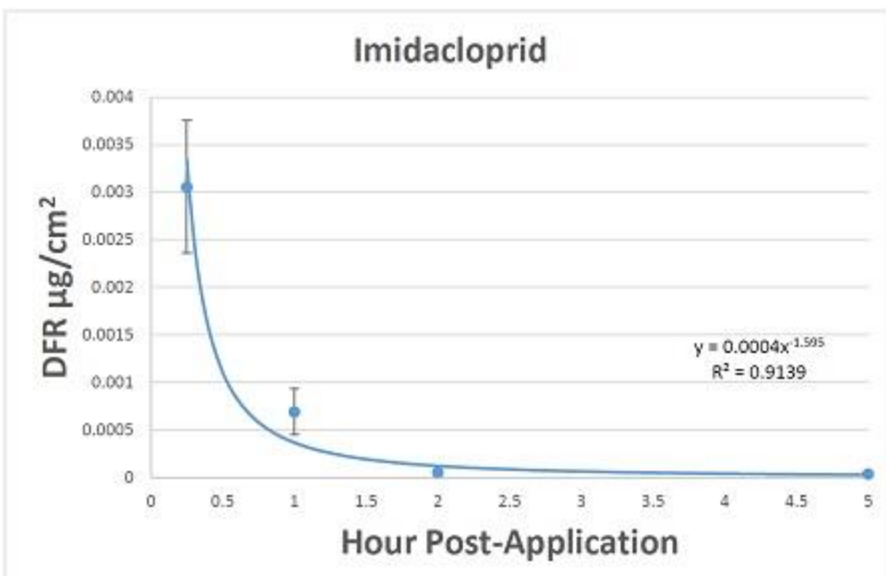


Figure 8-2. Imidacloprid dislodgeable foliar residues were measured over the first 5 hours following application. Residues of imidacloprid declined very rapidly with a 4.3-fold reduction within the first hour after application. From Doherty, 2017.

Post-application Irrigation

In some instances, irrigating pesticide-treated turf immediately following an application is recommended by the product label. In Massachusetts pesticide regulations an oft-repeated proverb is "the label IS the law". Following its instructions is required for regulatory compliance. Irrigating after application can move some pesticide residues from the foliage into the lower canopy, or to the thatch and soil. This practice can reduce dislodgeable foliar pesticide residues 9 to 30-fold compared with turf that is not irrigated after pesticide application (Doherty, 2017). Post-application irrigation may be an effective way to reduce pesticide exposure and may help target some turf pests (e.g., grubs, root pathogens, pre-emergent weeds). It can also delay volatilization of chemicals. However, irrigating treated turf can reduce efficacy of some pesticides, particularly contact materials.

Best Management Practices for Reduce Human Health Risks

- The pesticide label is the law in Massachusetts.
- Select the least toxic pesticide with the lowest exposure potential.
- Use Reduced Risk Pesticides when appropriate.
- Applicator should wear PPE.
- Only apply pesticides if weather conditions are favorable to achieve the goal of the application.
- Restrict staff and golfer entry to pesticide treated areas for at least one hour following application.
- Irrigate pesticides after application as recommended by the label.
- In case exposure occurs: applicator must know the symptoms and emergency response procedure.

Environmental Fate and Transport

Pesticides applied to any environment have the potential to interact with wildlife or migrate into surface and subsurface waters. Environmental implications of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. The “Environmental Hazards” statement, found under the general heading “Precautionary Statements,” provides language advising the user of the potential hazards to the environment from the use of the product. The environmental hazards generally fall into three categories: general environmental hazards, non-target toxicity, and endangered species protection.

While pesticides can pose risks to the environment, it is important to recognize that turfgrass systems are particularly well suited to capturing and degrading pesticides due to their high plant density and sub-surface thatch layer (Branham, 2006). In fact, BMPs for minimizing pesticide and nutrient runoff from agricultural fields recommend use of turfgrass between fields and waterways as vegetative filter strips to minimize runoff (Krutz et al., 2005). Pesticides applied to turfgrass systems are often strongly adsorbed to thatch and soil, limiting their movement (Dell et al., 1994; Lickfeldt and Branham, 1995). Moreover, naturally occurring processes including chemical and microbial degradation and photodegradation dissipate pesticides in the environment (Figure 8-3).

Environmental fate and transport of pesticides is largely dependent on their physical and chemical properties (Table 8-3). Consideration of these properties can help guide golf course superintendents’ selection of pesticides to reduce environmental impacts.

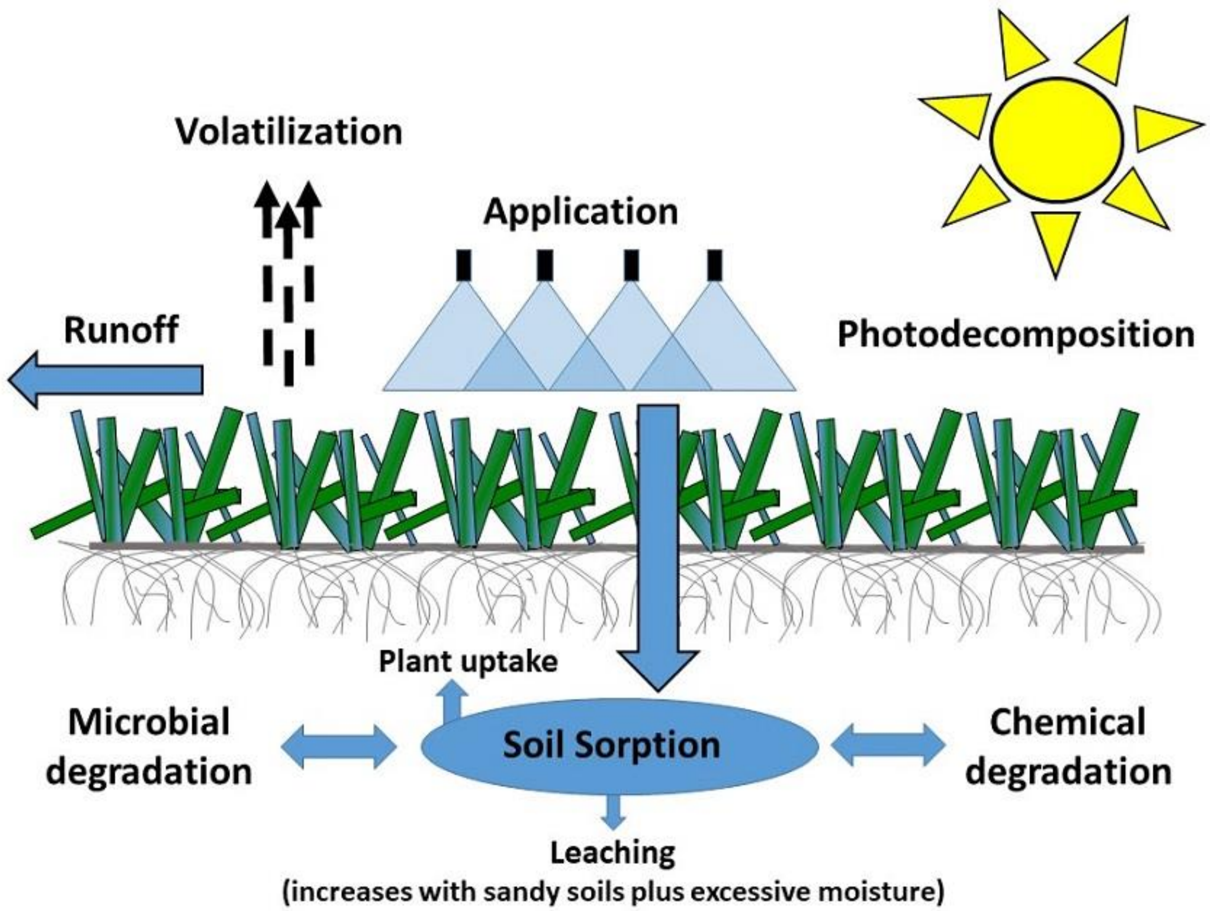


Table 8-3. Pesticide characteristics associated with increased risk of groundwater and surface water contamination.

Chemical Characteristic	Range for Potential Contamination
Water solubility	greater than 30 ppm (= mg/L)
K_d	less than 5, usually less than 1
K_{oc} (mL/g)	less than 300 to 500
Henry's law constant	less than 10^{-2} atm per m^{-3} mol
Hydrolysis half-life	more than 175 days
Photolysis half-life	more than 7 days
Field dissipation half-life	more than 21 days

Persistence (Half-life)

Pesticide active ingredients are carbon-based molecules that degrade over time. The persistence of any pesticide is characterized by its half-life (DT_{50} or t1/2), or the amount of time required for an initial amount to be reduced by half. The half-life of most pesticides is less than 120 days (McCarty et al., 2003). Half-life is independent of the amount of pesticide applied, although the amount applied does affect how many half-life intervals are necessary for a pesticide to be completely degraded. Using pesticides with a shorter half-life can reduce their overall persistence in the environment. Additionally, selecting pesticides with lower use rates, or applying products at lower rates, can also reduce persistence, since less pesticide is initially applied.

Solubility

A chemical's ability to dissolve in water is known as its solubility and is reported as parts per million (ppm), milligrams per liter (mg/L), or grams per liter (g/L). A high solubility denotes a highly soluble chemical. More soluble pesticides have a greater potential of moving in surface or soil water and can be associated with greater risk of runoff or leaching. Pesticides with solubility greater than 30 ppm or mg/L are at increased risk for groundwater and surface water contamination.

Organic Carbon Sorption Coefficient (Koc)

The affinity for various pesticides to adsorb to organic matter is commonly expressed as Koc (mL/g). Mature turfgrass stands typically contain a layer of organic matter, referred to as thatch, underlying the canopy. Pesticides with a small Koc value do not strongly adhere to thatch and soil organic matter and are therefore more likely to leach through the soil and reach groundwater. Conversely, pesticides with large Koc values tend to remain near the soil surface, reducing the likelihood of leaching, but can be carried to surface water via runoff or soil erosion.

Pesticide Risk Assessment Tools

USEPA is charged with providing risk assessments of all federally registered pesticides on an ongoing basis. When used according to label recommendations, registered pesticides have an acceptable amount of risk. Despite this, golf courses that may want to further understand and characterize the pesticides they use can consider one or a combination of several available pesticide risk assessment indices. These tools exist to assess the potential risk of pesticide transport and impact on human and environmental health. They synthesize several characteristics described in the preceding sections to assign a single value to pesticides for comparison. Superintendents may use these values, in addition to efficacy and cost, to select pesticides that further minimize hazards. In all cases, these tools are estimates for how a pesticide may respond in the environment.

Groundwater Ubiquity Score (GUS)

The groundwater ubiquity score is a value used to describe the potential for a pesticide to leach to groundwater based on half-life and Koc plotted on a log-scale (Gustafson, 1989). Pesticides with GUS values greater than 2.8 are considered "leachers," while those with GUS values less than 1.8 are "non-leachers." GUS is a convenient tool to assess and compare pesticide leachability. However, in some cases it may overstate (e.g., soils with high organic matter) or understate (e.g., coarse soils) the leaching potential since it does not consider site conditions.

Windows Pesticide Screening Tool (WIN-PST)

WIN-PST is a free software-based tool developed by the U.S. Department of Agriculture's Natural Resources Conservation Service that can be used to evaluate the potential movement of pesticides in water or eroded soil/organic matter and to estimate the toxicity risk to non-target organisms. It uses soil survey databases with information such as soil type, organic matter content, and water table depth, along with pesticide characteristics, to provide site-specific risk estimates. Users can specify application method, relative application rate (i.e., standard, low, ultralow), and rainfall probability. Long-term human and fish toxicity data and ratings are also included in WIN-PST. Toxicity ratings can be combined with the off-site movement potential ratings to provide an overall estimate of the potential risks from pesticide movement below the root zone and past the target application area.

Environmental Impact Quotient (EIQ)

Environmental impact quotient is a comprehensive pesticide assessment tool that synthesizes risk factors affecting applicator/golf course workers, indirect human hazards, groundwater, and ecological toxicities into a single EIQ value (Kovach et al., 1992). An advantage of EIQ is the ability to compare the potential environmental impact of pesticides based on their formulation and application rates by calculating a “Field Use EIQ” (FUEIQ) (Table 8-4). FUEIQ values can be calculated using the formula below, or determined online using the “Calculator for Field Use EIQ.” New York State golf course BMPs (2014) recommend a desirable single application FUEIQ to be less than 25. A value greater than 100 is considered an increased risk.

$$\text{FUEIQ} = \text{EIQ} \times \text{Rate (lbs/acre)} \times \%\ \text{Active Ingredient}$$

Using FUEIQ, it is also possible to quantify the cumulative risk of pesticide management programs by totaling all single application FUEIQs over the course of the season. FUEIQ can also be used to characterize pesticide risk of a treated area (e.g., fairway in an environmentally sensitive area) by multiplying the FUEIQ of an application by the total treated acreage. One disadvantage of EIQ compared to WIN-PST is that it does not use site-specific data in its risk assessment.

Table 8-4. Comparison of EIQ and FUEIQ of three contact fungicides applied for dollar spot control in fairway turf.

Active ingredient	% Active ingredient	Application rate	EIQ	FUEIQ
chlorothalonil	54.0%	2.0 fl.oz. / 1,000 ft^2	37.4	110.0
iprodione	23.3%	2.0 fl.oz. / 1,000 ft^2	24.2	61.5
fluazinam	40.0%	0.5 fl.oz. / 1,000 ft^2	23.3	12.7

Best Management Practices for Pesticide Risk Assessment

- Know what and where the target pest is and select an efficacious pesticide and application method.
- Understand pesticide sorption principles so that appropriate decisions can be made.
- Avoid using highly water-soluble pesticides when possible.
- Select pesticides that have a low runoff and leaching potential.
- Before applying a pesticide, evaluate the impact of site-specific characteristics (e.g., proximity to surface water, water table, and well-heads; soil type; prevailing wind) and pesticide-specific characteristics (e.g., half-lives and Koc).
- Identify label restrictions that may pertain to your facility (e.g., additional restrictions for sites with sandy soils).
- Select pesticides with reduced impact on pollinators (see "Pollinator Protection" chapter).
- Select pesticides on the basis of effectiveness, rate, safety, and other real assessment variables that, when applied according to the label, have no known effect on endangered species present on the facility.
- Document your decision making process.

Pesticide Storage

Storage and handling of pesticides in their concentrated form poses the greatest potential risk to ground or surface waters. For this reason, facilities that store and handle these products must be properly sited, designed, constructed, and operated. Storage facilities should facilitate the secure, dry storage of pesticides; provide safe working conditions for personnel with easy access to PPE; and provide secondary containment of incidental spills due to normal mixing/loading practices and secondary containment of large accidental spills. The following suggestions in this document are offered for consideration, as well more detailed information in Storing, Mixing and Loading of Pesticides from the Massachusetts Department of Agricultural Resources (MDAR).

Storage Location

Storage areas should be located to minimize risk to human health and the environment associated with potential spills, contaminated runoff, or fire. The location should be easily accessible to service vehicles in case of an emergency. Pesticide storage facilities should be at least 400 feet downhill from drinking water supplies and 200 feet from surface water. They should not be placed within a 100-year floodplain, and storm runoff should be diverted around them.

Engineering Controls

Walls and doors: Storage buildings should be built to contain and resist potential fire. Fire rating of walls influences suggested building setbacks (Table 8-5.) Interior walls should be impervious to pesticides (e.g., painted steel, aluminum, fiberglass). Doors should be lockable, steel (solid core), and set in a steel frame that opens to the outside.

Floors and concrete specifications: Concrete floors with impervious sealant or comparable surface should be used for pesticide storage facilities. Type I or Type II cement is suggested. Epoxy, urethane, polyester, vinyl, chlorosulfonated polyethylene, and polyurea coatings prevent corrosion of floors due to fertilizers and pesticides. Coating efficacy varies and should be selected based on types of products stored in the facility. A continuous sill should surround the floor to contain 125% of the volume of the largest container in storage.

Lights and ventilation: Storage facilities should include enough light to clearly read pesticide labels. A ventilation system should be installed to dissipate potential chemical vapor and ensure a safe workspace. Fans should be wired to turn on with lights and displace six air changes per hour.

Table 8-5. Fire rating and suggested building setback for various wall fireproofing materials. Adapted from: Pesticide Storage Mixing and Loading Guidelines for Applicators. MDAR.

Fire Rating	Gypsum Wallboard†	Hollow Masonry	Solid Masonry	Solid Concrete	Building Setback
1-hour wall	1 layer	3 inch	4 inch	3 inch	50 feet
2-hour wall	2 layer	4 inch	6 inch	4 inch	25 feet
4-hour wall		6 inch	10 inch	6 inch	none

Storage Conditions

Pesticides should be stored in their original container with the label clearly visible. Pesticides within the storage facility should not be exposed to direct sunlight, freezing temperatures, or extreme heat. Flammable materials should be stored in fireproof containment. Separate the fungicides, insecticides, and herbicides within the storage area to prevent unintended usage. Dry pesticides should be stored separately from liquid formulations to prevent contamination in case of leakage. Place pesticide containers within chemical-resistant bins or on shelves with a raised lip to contain leaks. Food, feed, potable water, seed, and personal protective equipment should not be stored within pesticide storage areas.

Best Management Practices for Pesticide Storage

- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
- Whenever possible, store pesticides in a lockable concrete or metal building that is separate from other buildings.
- Locate pesticide storage facilities away from other types of structure to allow fire department access.
- Storage facility floors should be impervious and sealed with a chemical-resistant paint.

- Floors should have a continuous sill to retain spilled materials and no 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.
- 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.
- 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 can be turned off after they leave the building.
- Avoid temperatures less than 40°F or greater than 100°F inside the pesticide storage facility.
- Personal protective equipment should be easily accessible and stored immediately outside the pesticide storage area.
- Regular training in the use and fit of PPE and spill containment.
- Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.
- Know the consequences of the pesticides burning or mixing with other chemicals stored nearby

Pesticide Inventory

Pesticides degrade over time. Do not store large quantities of pesticides for long periods. Adopt the “first in–first out” principle, using the oldest products first to ensure that the product shelf life does not expire. Avoid storing pesticides more than two years old and make sure temperatures do not exceed 100º F or drop below 40º F at any time. Utilize computer software systems to record inventory and use. Safety Data Sheets (SDS) for all pesticides on hand should be kept in an easily identifiable location, outside the pesticide storage facility.

Best Management Practices for Pesticide Inventories

- Avoid purchasing large quantities of pesticides that require storage for greater 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.
- Ensure labels are on every package and container.
- Consult inventory when planning and before making purchases.
- Control temperature to avoid extreme hot or cold.
- Never re-use containers and always dispose of responsibly.

Pesticide Mixing/Washing

Pesticide leaks or spills, if contained, will not percolate down through the soil into groundwater or run off the surface to contaminate streams, ditches, ponds, and other waterbodies. One of the best containment methods is the use of a properly designed and constructed chemical mixing center (CMC).

These chemically impervious areas prevent seepage of pesticides into soil and facilitate easier clean-up and containment of spills or overflows. Although there are many alternatives, suggestions for CMC building specifications are noted below, and are available in Storing, Mixing and Loading of Pesticides published by MDAR.

Mixing Pad

Chemical mixing centers should be located at similar distances from drinking water sources and surface waters as pesticide storage facilities, and preferably adjacent to them. An impervious, sealed concrete pad should be constructed to accommodate the sprayer size/weight and tolerate winter freeze/thaw cycles. Edges of the pad should be curbed to contain spills and discharges.

Containment Volume

The CMC should be built large enough to contain a volume 1.25 times the size of the largest spray tank loaded on the pad. Preferably, the area would have a roof to protect the containment area from precipitation. A greenhouse frame covered with a three-year co-polymer film can be a low cost alternative to a roof. In the absence of a roof, the containment volume should be increased to accommodate a two-year, 24-hour storm event (2.9 to 3.6 inches of rain).

Sump Design

The pad should slope to a sump to collect all spills, rinsate, and discharges. Chemically impervious materials should be used for the sump. Minimize dirt, clippings, rocks, and other debris from entering the containment pad and sump. Keep sump clean of solids. A pump should be installed to transfer the liquid collected in the sump to a holding tank for use in subsequent tank filling or applied as a pesticide to appropriate turf areas.

Pesticide Mixing and Handling

Handling open pesticide containers, measuring pesticide materials, or working with pesticide application equipment presents an exposure risk to the handlers and the environment. Applicators and handlers must put on label-recommended PPE prior to opening pesticide packages. All pesticide handling should be restricted to the appropriate storage area or CMC.

Best Management Practices for Pesticide Mixing/Washing Stations

- Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface, so that spills can be collected and managed.
- The mixing station surface should offer easy cleaning and the recovery of spilled materials.
- Pump the sump dry and clean it at the end of each day.
- Liquids and sediments should 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).

- Apply liquids and sediments from the sump as you would a pesticide, strictly following label instructions.
- Absorbents such as speed dry products for disposal or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates or disposed of as a hazardous waste.
- Sweep up solid materials and use as intended.
- Collect wash water (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.
- The rinsate may be applied as a pesticide (preferred) or stored for use as makeup water for the next compatible application.

Personal Protective Equipment

Based on exposure, pesticide handlers and applicators are at the greatest risk for potential adverse health effects. 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. PPE statements on pesticide labels provide the applicator with important information about protection.

Best Management Practices for PPE

- Provide adequate PPE and training 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.
- Make certain that PPE is appropriate for the chemicals used.
- Ensure that PPE meets rigorous testing standards and is not just the least expensive.
- Store PPE where it is easily accessible but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home where they may come into contact with family.
- Provide laundering facilities or uniform service for employee uniforms.
- The federal Occupational Safety and Health Administration (OSHA) requires employers to fit-test workers annually who must wear tight-fitting respirators.
- Meet requirements for OSHA 1910.134 Respiratory Protection Program.

Pesticide Container Management

The containers of some commonly used pesticides are classified as hazardous waste if not properly rinsed, and as such, are subject to the many rules and regulations governing hazardous waste. The improper disposal of a hazardous waste can result in high fines and/or criminal penalties. However, pesticide containers that have been properly rinsed can be handled and disposed of as nonhazardous solid waste. Federal law (Federal Insecticide, Fungicide, and Rodenticide Act, or FIFRA) and some state laws require pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. Under federal law (Resource Conservation and Recovery Act, or RCRA), a pesticide container is not empty until it has been properly rinsed.

Best Management Practices for 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.
- Puncture empty, rinsed pesticide containers and dispose of them according to the label.
- Use manufacturer/distributor recycle programs when available and reasonable.

Emergency Preparedness and Spill Response

Accidents can happen. Advance preparation on what to do when an accident occurs is essential to mitigate the human health effects and the impact on the environment. A spill containment kit containing absorbent materials (e.g., reusable gelling agents, cat litter, clay, soil, or sand), garbage can, and a shovel should be available for small spills. Hydrated lime or bleach can be used to neutralize and clean surfaces where spills occur. Spill containment kits should be easily accessible within the pesticide storage area. Ensure that PPE, a first-aid kit, and eye-wash stations or eye-wash bottles are accessible outside the pesticide storage and mixing area.

An emergency response plan containing actions to take and personnel to contact in the event of a spill or accident should be in place. The plan should include the following information:

- Names and quantities of pesticides in inventory.
- Location of property, including a map and directions (to relay over phone in emergency).
- Names, addresses, and phone numbers of the designated spokesperson, superintendent, and key employees.
- Plan of facility showing pesticide storage locations, flammable materials, electrical service, water supply, fuel storage tanks, fire hydrants, storm drains, and nearby wetlands, ponds, or streams.
- Location of emergency equipment supplies.
- Know the applicable regulations concerning spill trigger amounts and deadlines for reporting.
- Contact information for fire, police, hospital, pesticide bureau, spill clean-up firm, board of health, and facility owner.

Ensure that copies of the plan are located near the pesticide storage facility and the office and distributed to local police and fire departments. Maintain copies in English and any other language commonly used by employees. Be sure to update the information regularly for local police and fire departments.

Best Management Practices for Emergency Preparedness and Spill Response

- Develop a golf course facility emergency response plan that includes procedures to control, contain, collect, and store spilled materials and train/cerify employees annually.
- An inventory of the pesticides kept in the storage building and the SDS for the chemicals used in the operation should be accessible on the premises, but not kept in the pesticide storage room itself.
- Prominently post “Important Telephone Numbers” including CHEMTREC, for emergency information on hazards or actions to take in the event of a spill.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.
- Host a tour for local emergency response teams (e.g., firefighters) to show them the facilities and to discuss the emergency response plan. Seek advice on ways to improve the plan.

Sprayer Calibration

Properly calibrated application equipment is paramount to mitigating environmental and human health concerns. it will also improve sustainability by applying less, getting the most benefit (spray dispersion and uniformity) and making the application more cost effective. Sprayer output is dependent on several variables (e.g., speed, nozzle size, pressure). Spray coverage is often reduced at greater application speeds, regardless of nozzle size. To maximize efficacy of pesticide applications, applicators should consider optimization of spray coverage versus efficiency of labor when choosing spray speeds.

Best Management Practices for Sprayer Calibration

- Ensure that the spray technician is experienced, licensed (or certified), and properly trained.
- Minimize off-target movement of pesticides by using properly configured application equipment.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) and 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 their walking speed and other variables.

Sprayers and Nozzles

Various types and sizes of application equipment are readily available. The size of the equipment (tank size, boom width, etc.) should match the scale of the target area. Larger ride-on sprayers are more efficient for large areas, while small walk-behind boom sprayers are well suited for smaller areas. Smaller boom lengths may increase the accuracy of applications, minimizing overspray on non-target areas.

Individual nozzle control on global positioning system (GPS) assisted boom sprayers can further minimize overspray of non-target areas and has resulted in 25% less pesticide applied at some golf courses (USGA Green Section, 2016).

Spray nozzle size and design affect the spray drop size. This can be an important factor influencing the potential for drift and off-target movement of pesticides. Smaller droplet sizes can improve the efficacy of some pesticides, although they are more susceptible to drift. Larger droplets are more resistant to drift, although may reduce the efficacy of some pesticides due to reduced coverage. Nozzles designed to encapsulate an air bubble within the droplet (e.g., air induction nozzles) provide a good compromise between drift reduction (larger droplet size) and coverage and efficacy (drop bursts into small drops on impact). Additionally, nozzles designed with a wider spray angle (i.e., 110° versus 80°) enable booms to be set lower to the ground where they are less susceptible to drift. To really get down into the "nitty gritty" measure flow rate, measure nozzle pressure, and change worn or damaged nozzles.

Best Management Practices for Sprayers and Nozzles

- Use an appropriately sized applicator for the size of area being treated.
- Equipment too large in size requires greater volumes to prime the system. This can result in significant waste that must be properly handled.
- Use wide-angle, air-induction, flat-fan nozzles to minimize spray drift to non-target areas.
- Guarantee spray coverage with test products.
- Measure and monitor travel speed.

Pesticide Record Keeping

FIFRA is the federal statute that governs the registration, distribution, sale, and use of pesticides in the United States. Through this statute the Commonwealth of Massachusetts is empowered with regulation of the same. Massachusetts mandates the creation and maintenance of accurate records of any pesticide-related activities (for example, purchases, storage, inventory, applications, spills, etc.) and to report the same to the MDAR Pesticide Program annually. The burdened of reporting is assigned to the state licensed and certified pesticide applicators. This annual report will detail the quantities and nature of all pesticides used. Failure to submit a use report will result in the loss of eligibility for renewal of your license. Annual Pesticide Report

Best Management Practices for Pesticide Record Keeping

- Keep and maintain records of all pesticides used to meet legal (federal, state, and local) reporting requirements.
- Use records to monitor pest control efforts and to plan future management actions.
- Use electronic or hard-copy forms and software tools to properly track pesticide inventory and use.
- Keep a backup set of records in a safe but separate storage area.

Pollinators

Preface

Most flowering plants need pollination to reproduce and grow fruit. While some plants are pollinated by wind, many require assistance from insects and other animals. In the absence of pollinators, many plant species, including many of the fruits and vegetables we eat, would fail to survive. In fact, 35% of the fruits and vegetables that make up our diet require pollination by honey bees and other insect pollinators.

The western honey bee (*Apis mellifera*), a very important pollinator in the United States, is maintained in commercial and residential bee hives all around the country. Recent controversies have arisen regarding honey bee health. Some people believe honey bee hives are struggling and that improper pesticide applications are to blame for their decline. Others believe that honey bee colonies are performing at levels similar to the past 20 or 30 years, and that many factors are contributing to any decline in honey bee colony health. The truth is probably somewhere in the middle. Meanwhile, many other insect pollinators, including many bumble bee species, solitary bees, flower flies, and butterflies play a critical role in our food supply.

One thing that everyone agrees on is that honey bee colonies face many stresses, one of which is the use of insecticides in pollinator foraging areas. Other factors that can impact honey bee health are:

- Stress of being moved from one location to another.
- Stress of moving from one crop to another every five to eight weeks for several months at a time, adapting to a new habitat and diet with each move.
- Stress from tracheal mites and *Varroa* mites, both of which invade colonies and compromise the health of the colony.
- Presence of American foulbrood, a fatal disease caused by *Paenibacillus* larvae, that is not a stress-related disease.
- Stress of other pathogens, which are often stress-related, including *Nosema bombi* and *Crithidia bombi*.
- Food sources and habitat loss from extreme weather events and climate change.
- Exposure to insecticides applied when bees are foraging.
- Stress from high fructose diet (which is provided as a supplement when honey is harvested from the hive).
- Winter mortality (e.g., from cold temperatures or desiccating winds).

For more on pollinator basics, see the University of Maryland webpage Pollinator Basics.

Pesticides and Pollinators

The purpose of this section is to discuss methods to minimize any possible harmful impact of pesticides (especially insecticides) on honey bees and other insect pollinators. Pesticides are products designed to control pests (e.g., insects, weeds/flowering plants, diseases or nematodes). Pesticides and other plant health products, including plant growth regulators, surfactants, and biostimulants, are often used in golf course management. The unintended non-target effects of products used in golf course management are of increasing concern. Therefore, pesticide applicators – and the people making the decisions about pesticide applications – must be mindful of the impact that pesticides can have on pollinator species and their habitats.

Pollinator-protection language is found on labels of all pesticides that can be harmful to pollinators. Some insecticides that are particularly toxic to honey bees have a bright yellow, diamond-shaped box ("bee box") outlining restrictions on applications (Figure 9-1). Several classes of insecticides, including neonicotinoids and pyrethroids, are known to be toxic to honey bees and other pollinators. Toxicity data for several turf insecticides commonly used in Massachusetts are summarized in Table 9-1. The data for bees is given in micrograms per bee. Note that several insecticides (including all the neonicotinoids, most of the pyrethroids, chlorpyrifos, and spinosyn) have a honey bee LD_{50} of 0.01 microgram per bee or less. This means that each of these products has the potential to be harmful to honey bees, and therefore every possible step must be taken to minimize the likelihood of exposure of bees to the product.

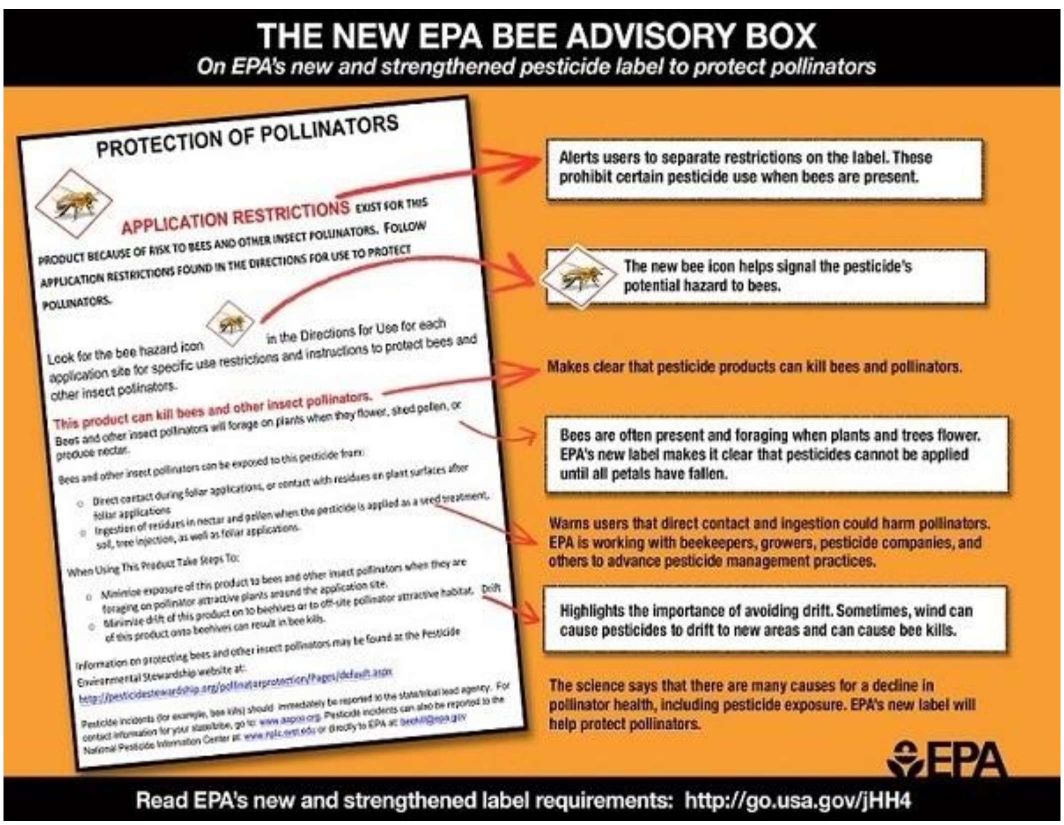


Figure 9-1. The USEPA Bee Advisory Box can be found on new insecticide labels that may pose a risk to pollinators.

Note that no correlation exists between mammalian toxicity and bee toxicity. While several insecticides have very low toxicity to mammals (e.g., dinotefuran, thiamethoxam, or spinosad), each of these products is highly toxic to honey bees. Also, note the considerable variation in honey bee toxicity within some chemical classes. For example, chlorantraniliprole (an anthranilic diamide) is virtually non-toxic to honey bees, while cyantraniliprole is moderately toxic to bees.

Licensing of and recordkeeping by pesticide applicators is required by law in Massachusetts to use pesticides. IPM principles suggest that you keep records of all pest control activity so that you can refer to previous outbreaks to determine what worked or did not work, and to select the best course of action in the future.

Table 9-1. Ecotoxicology of several common turf insecticides in several different animal species.

Insecticide class	Insecticide	Mammal LD_{50} *mg kg*$^{-1}$	Bird LD_{50} *mg kg*$^{-1}$	Fish LC_{50} *mg L*$^{-1}$	Honey bee LD_{50} *µg bee*$^{-1}$
Neonicotinoid	chlothianidin	>500	430	104	0.004
	dinotefuran	>2,000	>2,000	>100	0.023
	imidacloprid	424	152	211	0.0037
	thiamethoxam	>1,563	576	>125	0.005
Pyrethroid	beta-cyfluthrin	77	>2,000	0.000068	0.001
	bifenthrin	54	1,800	0.00026	0.1
	lambda-cyhalothrin	56	>3,950	0.00021	0.038
Organophosphate	chlorpyrifos	64	13	0.0013	0.059
	trichlorfon	212	37	0.7	>0.4
Carbamate	carbaryl	614	>2,000	2.6	0.14
Avermectin	emamectin benzoate	24	23	0.174	0.0035
Spinosyn	Spinosad	>5,000	>2,250	2.69	0.024
Anthranilic diamide	chlorantraniliprole	>5,000	>2,250	>12	>4
	Cyantraniliprole	>5,000	>2,250	>12.6	>0.1

Pesticide Application Practices to Protect Pollinators

Pesticide applicators must make careful decisions about what materials to use and when to apply them to minimize the impacts of pesticides on bees, other pollinators, and beneficial arthropods. While integrated pest management BMPs address decision-making considerations for determining whether to use a pesticide to manage a pest (and which pesticide would be least disruptive to bees and other pollinators), countless other factors must also be considered when deciding on a course of action.

Superintendents must determine what is best for a specific facility based on local agronomics (e.g., turf species and cultivars, fertility practices), local geographic conditions (e.g., underlying soils, slopes, surface water, groundwater), cost of materials and labor, availability of application equipment, expectations of the membership, and budget.

Turf entomologists collaborated to create the national BMPs for protecting pollinators (Larson et al., 2017) listed below that can be implemented at golf facilities to protect pollinators. These BMPs provide guidance for decision-making, but the superintendent – and golfers – must recognize that there often are challenging circumstances that limit a superintendent's options.

Best Management Practices for Pesticide Application Practices

- Before applying a pesticide, scout the area for pest and beneficial insect populations (including pollinators), and only apply a pesticide when a pest damage threshold has been reached. Pest thresholds vary from one part of a golf course to another; for example, little or no damage is typically acceptable on putting greens, while golfers and turf managers are more tolerant of pest activity in roughs.
- Use other pest management approaches (e.g., lures, pheromones, cultural manipulations) to manage pest insect populations.
- When pesticides must be used to manage a pest insect population, select one – when possible – with a lower impact on pollinators.
    - Several classes of insecticides are known to be toxic to honey bees, including neonicotinoids, pyrethroids, carbamates, and spinosyns.
    - Chlorantraniliprole has no activity against bees, ants, or wasps.
    - Granular formulations generally reduce pollinator exposure, compared with a sprayable formulation of the same active ingredient.
    - Apply water after the application to move the residue off the surface and reduce exposure.
- Avoid applying pesticides when plants (including flowering weeds) are in bloom or bees are foraging.
- Whenever possible, schedule pesticide applications early in the morning or late in the evening, when few bees are foraging.
- Mow the area immediately before application to remove blossoms from flowering weeds or use herbicides to reduce weed populations (Larson et al., 2013).
- Avoid applications during unusually low temperatures or when dew is forecast.
- Use spray technology (e.g., drift-reduction nozzles, larger droplet sizes) to reduce off-site drift of a pesticide.
- Remember that systemic insecticides (e.g., neonicotinoids) may be absorbed through the roots of nearby ornamental plants and translocated to flowers, so be very careful to avoid applying pesticides in a way that results in translocation of the active ingredient to flowers of nearby ornamental trees and shrubs.

Pollinator-Related Communication

In addition, several steps can be taken to protect pollinators by increasing communication and interaction with people in the community. Recommendations include the following:

- Consider joining a local beekeeper association to become connected with local educational events and mentoring opportunities.
- Consider setting up a couple of hives within a natural area of the golf course, to be maintained by an interested staff member or possibly a nearby beekeeper seeking another suitable location.
- Check with state or local agricultural and natural resource agencies and obtain a list of registered beekeepers within a three-mile radius of the golf course. Let them know of pending applications that could affect honeybees. This advance notice enables beekeepers to temporarily close hive entrances, keeping bees inside until pesticides have dried on the foliage.
- Attend workshops or online seminars to learn more about pollinators and other beneficial arthropods.
- Use signage, social media and local news media to explain course management practices and educate golfers, course walkers and the general public about the steps taken to minimize impact on pollinators.
- Invite local master gardeners, garden clubs, or student groups to visit the golf course or host workshops at local garden centers to demonstrate how you use the information on a pesticide label to minimize impact on pollinators.

Enhancing Pollinator Habitat

Pollinators face challenges related to the loss of natural habitat, as suburban areas encroach into more rural settings. Habitat for pollinators includes foraging habitat and nesting sites. One way to encourage pollinator activity on golf courses is to provide pollinator habitat in non-play areas with a diversity of wildflower species to provide a variety of food sources. General considerations for pollinator-friendly plantings include the following:

- Enlist the services of local conservation/native plant trust groups.
- Plants with a variety of colors.
- Flowers with different shapes and sizes.
- Plants with different flowering times to provide forage throughout the growing season.
- Plants with different heights and growth habits.

Creating pollinator-friendly gardens and native grass or tall meadow areas on the property can provide opportunities for superintendents to reach out to the community. Organizing field trips for primary school-aged children can provide a tremendous opportunity to educate the community about the ecological and environmental benefits of golf courses.

Some pesticide manufacturers have developed pollinator programs and provide flower seed blends that have been developed for different regions of the United States. These include Operation Pollinator(Syngenta),Bee Care (Bayer), Living Acres Monarch Challenge, and Monarchs in the Rough. Many environmental organizations provide resources to identify good native plants to enhance pollinator health, as described in the "Landscaping" chapter. Other simple steps for providing nesting sites for native species can include leaving stems, coarse, woody debris, and exposed patches of sand or well-drained soil in out-of-play areas. In addition, nesting boxes or hollow bamboo sticks can be provided for solitary nesting species.

Best Management Practices to Enhance Pollinator Habitat

- Plant a diversity of flowering pollinator-friendly plants when renovating out-of-play areas.
- Leave nesting materials and sites in out-of-play areas whenever possible.
- Mow natural or pasture areas just once per year – late in the season when plants are going dormant – to control woody plants or other growth at a time that minimizes effect on pollinators.
- Consider providing man-made nesting sites for solitary nesting species.

Maintenance Operations

Preface

Facilities created to store and handle equipment, inventory, fuels and oils, fertilizers, and other chemicals, especially in their most concentrated forms, pose the highest potential risk to water and other environmental sources if accidentally released in quantity. Therefore, any business storing, mixing, or loading potentially hazardous chemicals should treat all leaks, spills, and fires as emergencies and be prepared to respond to these emergencies promptly and correctly. For unintended releases of any chemicals, an emergency response plan, spill kit, and first-aid kit should be readily available.

In the Commonwealth of Massachusetts the operating nature of these facilities are regulated by the Comprehensive-Fire-Safety-Code. However, enforcement of these regulations is assigned to the local municipality in which the business is operating. Be sure to reach out to local regulators and fire departments to guide your business through compliance.

This section provides additional guidance for maintenance operations and points out differences between managing fertilizer equipment and pesticide equipment.

Storage and Handling of Fertilizers

Storage facilities that are well designed and well maintained protect people from exposure, reduce the potential of environmental contamination, protect chemicals from extreme temperatures and excess moisture, and, in general, reduce liability concerns and potential environmental risks. The storage area should be secure and provide containment features as recommended by The University of Massachusetts Extension Service for agricultural business operations.

UMass Fertilizer Storage and Handling

UMass Pesticide Storage, Handling and Disposal

Best Management Practices for Storage and Handling of Fertilizers

- This facility should be used only for storing fetilizers and/or pesticides - not equipment, fuel, or other chemicals.
- 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 natural/manmade flooding.
- Locate dry fertilizer storage buildings or liquid fertilizer secondary containment away from wells, water supplies, 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 non-liquid 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 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 and no smoking signs on chemical storage buildings, especially near entry or exit areas.
- Storage facilities should be bollard for exterior damage and secured to allow access only to authorized staff.
- Replace worn or faulty valves, plugs, and threaded fittings in storage containers.
- Install a backflow prevention device on water supply lines used for fertilizer or pesticide 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.
- Physically separate incompatible materials and store liquid materials below dry materials to prevent any contamination from a leaking container.
- Train staff and other management on how to access and use the facility's SDS database.
- Maintain accurate inventory lists.

Equipment Storage and Maintenance

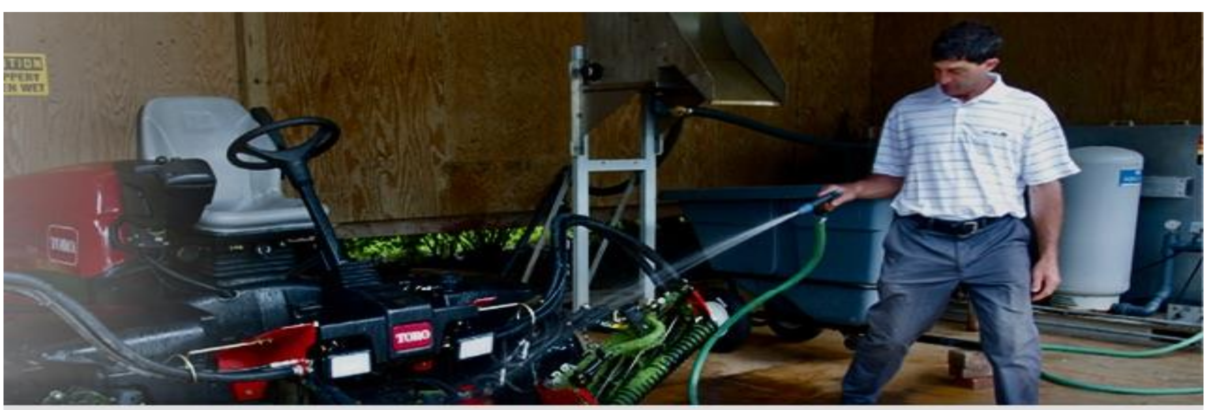
Equipment storage and maintenance facilities should be designed to prevent the accidental discharge of chemicals, fuels, or contaminated wash water from reaching water sources. Properly storing and maintaining equipment also extends the useful life of machines and reduce repairs.

Best Management Practices for Equipment Storage and Maintenance

- Store and maintain equipment in a covered area complete with a sealed impervious surface to limit risk of fluid leaks contaminating the environment and to facilitate the early detection of small leaks that may require repair before causing significant damage to the turf or the environment.

- Seal floor drains unless they are connected to a holding tank or sanitary sewer with permission from the local wastewater treatment plant.
- Provide fire suppression equipment or extinguishers as mandated by insurer and local regulators to be readily available and comply with annual inspection/cerification requirements.
- Store pesticide and fertilizer application equipment in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment and possibly contaminate soil or water.
- Store solvents and degreasers in lockable metal cabinets away from ignition sources in a well-ventilated area. These products are generally toxic and highly flammable. Never store them with fertilizers or in areas where smoking is permitted.
- Keep an inventory of solvents and Safety Data Sheets (SDS) for those materials on-site but in a different location where they will be easily accessible in case of an emergency.
- Keep basins of solvent baths covered to reduce emissions of volatile organic compounds.
- When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Always use appropriate personal protective equipment (PPE) when working with solvents.
- Never allow solvents or degreasers to drain onto pavement or soil, or to discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date. Schedule collection by a commercial service.
- Blow off all mowing equipment with compressed air to reduce damage to hydraulic seals.

Equipment Washing



Equipment washing should be conducted under controlled conditions in an appropriate contained area with minimal risk to the environment to prevent adverse wash water runoff impacts whenever possible. Equipment washing guidelines and restrictions should be established that reduce the potential for pollutants to reach surface water, or groundwater.

Proper cleaning of equipment helps prevent residues from reaching surface waters, groundwater, drainage pipes, or storm sewers. The residues from washing equipment include grass clippings, soil, soap, oil, fertilizer, and pesticide.

A primary concern when washing mowing equipment is the nitrogen and phosphorus nutrients in grass clippings. Using compressed air to blow clippings off mowers before washing can help reduce the amount of nutrients that enter drains via wash water. The best practice is to have a dedicated wash area with a catch basin to collect remaining grass clippings. Clippings can be collected, then composted or removed to a designated debris area. When formal washing areas are not available, a “dog leash” system using a short, portable hose to wash off the grass at random locations, away from surface waters, wells, or storm drains, is an option.

For equipment with possible pesticide residue, BMPs should be followed to ensure that wash water does not become a pollution source. Captured wash water can be used as a dilute pesticide per label, or it may be pumped into a rinsate storage tank and identified for use in the next application and used as a dilute pesticide per the label.

Best Management Practices for 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 wash water 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 wash water 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.

Fueling Facilities

Fueling areas should be properly sited, designed, constructed, maintained, and monitored to prevent petroleum products from being released into the environment through spills or leaks. One gallon of gasoline can contaminate up to one million gallons of water making a gasoline spill VERY expensive to remediate. An aboveground storage tank (AST) is easier to monitor for leakage and is therefore the preferred storage method. Because of the potential for groundwater contamination from a leaking underground storage tank (UST), 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.

MassDEP Fuel Storage and Fueling

Best Management Practices for Fueling Facilities

- Locate fueling stations under roofed areas with concrete pavement whenever possible.
- Employ a rigid maintenance and corrosion prevention system.
- Ensure that fueling stations have spill containment and recovery facilities located nearby.
- Develop a record-keeping process to monitor and detect leakage in USTs and ASTs.
- Visually inspect ASTs for leakage and structural integrity.
- Secure the fuel storage facilities and allow access only to authorized and properly trained staff.
- Ensure that fuel tanks and pumps are properly labeled.
- Post "No Smoking" signs near fueling facilities.
- Consideration for alternative energy equipment purchases may reduce the risk of fuel stored on site.

Waste Handling

By definition of the Commonwealth of Massachusetts all golf course maintenance operations are Waste Generators. Hazardous Waste Generation & Generators is a complete guide to help any business develop their size and subsequent legal obligations established under the Massachusetts Department of Environmental Protection Hazardous Waste Regulations.

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, fluorescent light tubes, 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 more detail in the “Pesticide Management” chapter.

Best Management Practices for 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.

Emergency Preparedness and Spill Response

As discussed in the “Pesticide Management” chapter, enough absorbent material must be available to handle a spill of the largest container in storage areas. Sorbent materials include booms, socks or mini booms, pillows, pads and rolls, and loose sorbents. These sorbent materials may be universal or more specific (such as for petroleum products). Having a readily accessible spill kit is a necessity at any facility where chemicals are used or stored. The spill kit should contain, at a minimum, the following:

- Proper clothing and PPE.
- A supply of neutral absorbing materials that may include activated charcoal, clay, or vermiculite.
- Clean water.
- Class B fire extinguisher for chemical fires.
- Detergent for deactivation of spill site.
- Salvage drum for waste cleanup.
- Cleanup tools such as brooms, shovels, and dust pans.

Best Management Practices for Spill Response

- One person should NEVER be cleaning a chemical spill alone due to inhalation or other exposure risks.
- Staff training is the key to developing a golf course facility emergency response plan that includes procedures to control, contain, collect, and store spilled materials.
- Know the legally reportable quanities and timelines triggered by a spill.
- Prominently post "Important Telephone Numbers," including the hotline number for emergency information on hazards or actions to take in the event of a spill.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.

Sustainable Landscaping in Out of Play Areas

Preface

During play, golf competitors often become immersed in their landscaped surroundings. While care of tees, greens, and fairways will always be the highest priority for golf course superintendents, out-of-play areas are also an important component of superintendents' responsibilities. Landscaped and "non-play" areas help delineate in-play areas and contribute to the overall beauty of the golf course design. They enhance course aesthetics, provide wildlife habitat, and add a natural buffer that moderates external noise. Maintaining these aesthetically pleasing areas as sustainably as possible is economically advantageous and supports the biodiversity of pollinators and other wildlife. Developing or expanding naturalized areas may reduce dependence on water, chemical, and fuel inputs, while allowing more intensive maintenance to be reserved for areas dedicated to play (Lyman et al., 2007; Gross and Eckenrode, 2012).

The substantial acreage of golf course properties provides an ideal opportunity for environmental stewardship and conservation. Converting grassed out-of-play areas into vegetated areas with a greater diversity of plant species that support wildlife by providing forage and habitat for pollinators and other beneficial insects (Tallamy, 2009). Less intensively managed vegetation (e.g., tall grass and naturalized areas) directly correlates with a higher biodiversity of plants and pollinators (Colding and Folke, 2009; Dobbs and Potter, 2013). Golf courses can contribute to the environmental goal of plant and pollinator diversity by converting grass to natural habitat throughout the course – in the rough and other out-of-play areas, as well as in high-visibility areas, such as the property surrounding the clubhouse and other outbuildings.

Benefits of Sustainable Areas on the Golf Course

An ecosystem with a healthy variety of plants fosters a robust biodiversity of animal and insect species. Plants provide a primary food source and habitat, yield nutrients, improve soil health, and produce oxygen. Golf courses can provide a critical link that connects wildlife corridors by increasing naturally vegetated habitat, including unmown grass and native wildflower out-of-play areas. Benefits of increasing the sustainability of out-of-play areas include:

- Attracting beneficial wildlife, supporting pollinator habitat, enhancing biodiversity, and creating aesthetic interest that provides year-round visual pleasure for golfers on the course (Figure 11-1).
- Providing an option for out-of-play areas that requires fewer non-renewable inputs (fertilizer, water, and gasoline) to maintain.
- Protecting soils, natural vegetative cover, water resources, and water quality.
- Greater carbon sequestration potential than high maintenance areas because of greater plant biomass production (Wissman, 2016).

Figure 11-1. Tall grass areas add to the beauty of golf course landscapes.

Sustainable Landscaping Concepts

What is sustainable landscaping? According to the American Society of Landscape Architects, “sustainable landscapes sequester carbon, clean the air and water, increase energy efficiency, restore habitats, and create value through significant economic, social, and environmental benefits.”

Dense, healthy turfgrass plays an important function in sequestering carbon. However, frequent maintenance practices contribute to carbon emission, which diminish the carbon sequestering benefits of turfgrasses. The leading cause of increased carbon dioxide (CO_2) emissions is the direct result of fossil fuel use (Gillette et al., 2011). By reducing frequently mown acreage and expanding sustainable areas that are managed with fewer inputs, golf courses can potentially be valuable net carbon sinks (natural systems that absorb and store carbon dioxide from the atmosphere). Naturalized areas can offset the higher carbon demands of intensively managed, priority areas.

When designing a sustainable landscape, plants are selected for much more than simple aesthetic value. Plants should be selected because they are already adapted to the existing soil conditions, available water, and the microclimate, so additional inputs of irrigation, fertilizer, and soil amendments can be reduced or eliminated.

Native plants are prioritized because they have evolved in concert with native wildlife and pollinators, providing the foundation of local food webs that enable butterflies, birds, and other wildlife to survive. Most herbivorous insects and pollinators are specialists that cannot survive on introduced or exotic plant species.

The population of many beneficial insects and pollinators has declined due to a variety of factors, including loss of natural habitat, lack of forage opportunities, diseases, predatory insect infestations, stress, and exposure to pesticides (Mader et al. 2011). Native plants in the landscape contribute to the restoration of local ecosystems and create conditions that support a wide variety of indigenous, beneficial animal and insect species. Therefore, in naturalized or less intensively managed areas of the landscape, where tolerance of potential pest damage is higher, native plants should be prioritized to support pollinators, food chains, and native ecosystems.

Two distinct approaches to sustainable landscape design are as follows:

> **Traditional design**, which uses native plants as an alternative for introduced or exotic ornamental species in a formal garden, often including mulched landscape beds and lawn areas (Figure 11-2). Required maintenance is the same as any typical garden area, with possibly reduced irrigation if drought tolerant plants are used. This type of design is best suited for priority areas of high visibility around the clubhouse or other out-buildings that provide aesthetic focal points.
>
> **Naturalized design**, which uses maturing and evolving native plant communities, such as tall grass, meadow, and forested areas. This style is a more viable and cost-effective option in the long term for large out-of-play areas. Required maintenance is consistent with meadows and periphery areas.

Facility managers seeking to conserve water and protect ecosystems on the course can employ a type of sustainable landscaping known as Green Infrastructure (GI). GI is effective and economical and improves the safety and quality of life (USEPA, 2017) through the intentional use of the ecosystem services provided by plants in the managed landscape. GI conserves, restores, or replicates the natural water cycle by reducing and treating stormwater runoff, thus turning a potential pollutant into an environmental and economic benefit. Green roofs, rain gardens, bioswales, cisterns, and permeable pavements are examples of GI. Learn more about how to incorporate GI into the golf course in the fact sheet “Sustainable Landscaping in Out-of-Play Areas on Golf Courses.”

Figure 11-2. A traditional garden design that incorporates native plants.

Sustainable High Visibility Areas

Landscape design on the golf course should meet the needs of the customers, protect the course's environmental resources, and remain economically sustainable. It is important that high visibility areas of the golf course (around the clubhouse and other out-buildings) are aesthetically pleasing focal points that enhance the overall course aesthetics (Figure 11-3). The landscaping around buildings makes a lasting impression on customers, which can influence any course's popularity with the non-golfing customers, increasing annual rounds and bookings for functions and golf outings, as well as support playability of the course. Sustainable landscaping concepts can be incorporated into these landscaped areas to fulfill both the course's environmental commitment and its aesthetic goals in high-priority areas.

Figure 11-3 Native perennials used in a traditional, formal border planting.

Sound design includes the selection of site-appropriate plant cultivars that permit reduced maintenance to remain healthy and attractive. National Turf Evaluation Program, Alliance for Low Input Sustainable Turf, and Turfgrass Water Conservation Alliance can provide information on improved cultivars of turfgrasses for non-golf areas with improved drought tolerance and pest resistance. Whenever new construction or renovation occurs, landscaped areas should be amended to include more native plant material. Native plants are best adapted to the local soils, site conditions, and pests. Incorporating native plants supports a reduced maintenance program that requires less time and expense to maintain.

Establishing strong, healthy plants is key for weed management in sustainable landscapes.

Any changes to the landscape design should blend in with existing site features. Changes should be made slowly and with significant investment in customer buy-in. For example, many native plants grow more slowly than the introduced exotic plants common to contemporary landscapes. Therefore, communicating plans and progress to the customers will improve their response to these changes.

Best Management Practices for Landscaping High-Visibility Areas

- Integrate low-maintenance turf and native plant species into landscape areas around the clubhouse, service buildings, and other out-of-play areas and design these areas for ease of maintenance required.
- Consider the soil characteristics, climate, sun exposure, water conditions, and pest possibilities when selecting plants. Select plant material not regularly browsed by deer. (Refer to fact sheet “Sustainable Landscaping in Out-of-Play Areas on Golf Courses” for more information.)
- Group plants with similar watering, pH, and fertilizer requirements together to allow for the most efficient use of resources.
- Select each plant based on its unique contribution to the overall project, including blooming schedules, bark, fruit, texture, and habit.
- Utilize native plants wherever possible, integrating them into the landscape along with annuals to maintain season-long color and aesthetic interest.
- Use plants that will perform well over time. Ensure that the mature height and spread of each plant is considered in the landscape design to avoid the need for excessive pruning or regular replacement. For an immediately full, dense landscape, plant annuals or perennial species that can be relocated or divided as plants mature. Quick-growing, short-lived “filler” plants may also help to temporarily embellish a planting bed as it develops.
- Where feasible, design with drought-tolerant and low-water-use plants.
- Use native drought-tolerant plants around buildings, parking areas, or other appropriate places.
- Where irrigation is necessary, utilize high-efficiency irrigation systems (e.g., drip irrigation) in all landscaped areas for maximum efficiency. If possible, design recycling water features, such as collecting rainwater for graywater use.
- Perform a soil test and analysis when analyzing problems or when renovating landscapes.
- Use organic amendments (e.g., compost, compost tea, or leaf mulch), calibrated as part of the overall nutrient management plan, to build healthy soils, establish beneficial soil organisms, and release nutrients over the long term.
- Where necessary, maintain 2-4 inches of organic mulch over the surface of soil, applied a few inches from the base of trees and plants, to keep soil moist and minimize weeds.
- Minimize the use of impervious surfaces and increase permeable features.
- Replenish groundwater by adding rain gardens, green roofs, bioswales, and other permeable surfaces. Install gravel pathways or borders that permit water infiltration, but have low evaporation potential.
- Where possible, recycle, reuse, or use locally sourced materials for plants and hardscapes.
- Use signage and other media to promote your sustainability goal.

Sustainable Naturalized Areas

Sustainable naturalized areas can help golf superintendents' meet their goals to improve both environmental protection and economic sustainability. While tees, greens, and fairways normally require sufficient irrigation for overall plant health (which contributes to visual impact and recovery from traffic), not all areas of a golf course must be maintained as intensely. In particular, facilities that experience increased seasonal water limitations may consider design alterations to reduce the expanse of maintained turfgrass areas.

Using alternative landscape features in selected areas that do not naturally impact the game of golf can result in substantive water, nutrient, labor, and other maintenance cost savings. They can also restore habitat and increase biodiversity. Conventional landscapes use less than 15 species in an average landscaped lot, while the average undisturbed forest or meadow can support 100 species in the same area. In addition, diverse, multi-storied plantings store more carbon than mown turf areas (Selhort, 2012).

A change in design must be carefully implemented in a manner that does not interfere with game play. While developing a plan to improve and expand wildlife habitat, existing native habitats should be protected and existing natural amenities expanded or enhanced. Retain or restore existing native vegetation, where possible. Where appropriate, existing vegetation should be enhanced through the supplemental planting of native species around tee complexes, out-of-play areas, and water sources. Construct or modify any existing storage ponds with shallow margins (vegetated buffers) planted with native wetland vegetation utilized by many wildlife species. Nuisance, invasive, and exotic plants should be removed and replaced with native species adapted to the site.

Best Management Practices for Sustainable Naturalized Areas

- Manage natural areas to encourage wildlife diversity, by increasing habitat for locally threatened or endangered species, and to provide habitat connectivity by linking natural areas.
- Manage player expectations through educational outreach, newsletters, and signange.
- Actively manage open-space areas to support native habitats, provide brush piles for habitat and avoid introduction and establishment of invasive species.
- Utilize a diverse range of species in plant selection.
- Ensure that the areas selected for low-maintenance modification will not significantly impact the pace of the golf game or game satisfaction. Use of GPS data trackers will correctly identify placement of these landscapes by identifying and delineating areas that are not in play for golfers.
- Use unmown turf as a landscape element to help focus the design of formal areas.
- Allow beneficial "weeds" (e.g., milkweed, which supports the survival of monarch butterflies) to grow and mature in out of the way areas where they will not interfere with integral in-play areas.

Habitat Corridors

Golf courses can make a positive and significant impact on wildlife diversity by creating new habitat corridors, which provide a safe haven for many species while simultaneously enhancing the golfing experience. Corridors are areas of habitat that physically connect plant and animal populations that cannot maintain healthy, genetically diverse populations when highly fragmented by human activities or structures (UC-Davis, 2008).

Best Management Practices for Habitat Corridors

- Establish wildlife corridors that connect areas of habitat, enabling animals to travel and forage for food.
- Maintain habitat corridors as contiguous and unbroken as possible. Joining a water way or power line right of way opens the pathway to other areas.
- Corridors should be made as wide as possible and located away from roads, trails, and golf car paths, to minimize human interactions with wildlife.
- Maintain the edge habitat without an abrupt transition such as grasses to taller grasses, to short bushes, taller shrubs, dwarf or immature trees.
- When establishing or renovating out-of-play areas, include a diversity of pollinator-friendly plants in areas where they will not interfere with routine play.
- Remove invasive exotic plants and replace them with native species adapted to the particular ecological conditions prevalent at the site.
- Protect existing ponds and streams by increasing surrounding vegetative cover height (including turfgrass).
- Incorporate well-adapted, drought-resistant plants, including low-growing ground covers, shrubs, and trees that require little, if any, supplemental irrigation once established.
    - Identify and preserve the habitat requirements (food, water, cover, space) for local wildlife species. Preserve existing areas of critical habitat. Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.
    - Preserve available nesting materials and sites in out-of-play areas when possible.
    - Construct and place birdhouses, bat houses, nesting boxes, or bee houses in out-of-play areas; leave dead tree snags, coarse woody debris, and exposed patches of sand or well-drained soil for nesting and feeding sites, provided they pose no danger to people or property.
    - Maintain clearance between the ground and the lowest portion of a fence or wall to allow wildlife to pass, except in areas where animals need to be excluded (BMP-Maryland, 2017).

Meadows/Tall Grass Areas

Replacing supplemental areas of turf with native vegetation, such as in meadows or tall grass areas, provides essential habitat for many species threatened by encroaching development. A meadow is an area of natural grasses and/or native wildflowers that, over time, becomes self-sustaining. Native meadow plants are resilient, accustomed to the regional climate and can survive adverse conditions.

Meadow plants have adapted to the existing soil conditions, water availability, and microclimate challenges. Remediated areas improved by human input, through changes to irrigation, fertilizer, and soil amendments, can successfully be reduced or eliminated, over time.

Meadows that are successfully incorporated into landscape management programs can reduce the burden of some property maintenance expenses. Meadows incorporated into golf environments must be maintained as low-growing and thinly vegetated to give players the ability to easily locate and retrieve balls that have made their way out of the fairway. However, meadows should be signed for golfers to consider noxious weeds (poison ivy), stinging insects and ticks.

Proper site selection, plant selection, site preparation, and maintenance is critical to designing, establishing, and sustaining a flourishing, beautiful meadow (Figure 11-4). Refer to fact sheet "Sustainable Landscaping in Out-of-Play Areas on Golf Courses" for a list of recommended meadow plants. Most meadow plants prefer full sun. A substantial portion (about 40%) of a meadow should be comprised of grasses (Zimmerman, 2010), in order to sufficiently proliferate between perennial forbs to prevent weed seed germination and development. Time spent on site preparation that eliminates competing vegetation leads to fewer weeds in the meadow in subsequent years. Soil surface disturbance during site preparation should be minimized whenever possible, to prevent unnecessary weed germination at the soil surface. Less disturbance to the site will also maintain soil structure and integrity.

As part of the overall meadow establishment protocol, an effective maintenance plan should be developed before planting and implemented at planting for the successful longevity of the meadow. The initial three years of meadow establishment require both patience and focused effort. During establishment, a nurse crop such as a quick-establishing, clump-forming grass can be used to reduce weed invasion, hold the seed or young plants in place, and protect the soil from erosion.

In the first growing season, perennial meadow plants grow slowly, with an average overall height of 2-6", depending on the species. Annual weeds will proliferate and grow quickly if given the opportunity. Regular mowing and spot treating weeds can prevent weeds from growing too tall and outcompeting the desired perennials. In the second and subsequent years, the meadow should be mowed annually in late winter or early spring, before the next year's growth begins.

Best Management Practices for Meadows/Tall Grass Areas

- Select an area for a meadow that receives no less than half a day of direct sunlight to ensure success with sun-loving plants.
- For multi-year health of the meadow, include both short-term species (nurse grasses, annuals, and biennials) and long-term perennial species that take multiple years to establish.
- Select grasses to comprise a substantial portion of the plants to populate the meadow in addition to pollinator plants.
- Prepare the site by removing competing vegetation, while avoiding unnecessary disturbance to the soil to maintain soil structure and integrity.

- Where meadows are begun by seed in bare soil areas, utilize an annual "nurse" crop in the first year to aid in establishment.
- Mow every 4 to 6 weeks to a height of 4-6" during the first growing season to control weeds, along with spot treating noxious and invasive weeds as needed.
- Mow established meadows annually either in late winter or early spring before the next year's growth begin.
- Promote with signage.

Figure 11-4. A successfully established meadow with thriving grasses and perennials.

Plant Selection

The fundamental principle for the environmentally sound management of landscapes is "right plant, right place." Proper plant selection is the most important step in designing a sustainable landscape planting. Use a detailed, completed site analysis as described in fact sheet "Sustainable Landscaping in Out-of-Play Areas on Golf Courses " to select appropriate plants for the site and ensure successful establishment based on sunlight requirements, soil conditions, and water availability. Native plants recommended by local native plant trusts or the University of Massachusetts Native Plants should be an integral component of the landscape design throughout the course and at key focal points.

Native plants are best adapted to the local soils, site conditions, and pests. The goal of species selection in a sustainable landscape is to maintain as close to a natural ecosystem as practical. Whenever possible, 50-70% of the non-play areas should remain in natural cover (Gross and Eckenrode, 2012). As much natural vegetation as possible should be retained and enhanced through the supplemental planting of native trees, shrubs, and herbaceous vegetation to provide active wildlife habitat.

Over time, incorporating native plants not only enhances the ecosystem function of a landscape by supporting a wide variety of indigenous, beneficial animal and insect species, it can also reduce the time and expense spent on maintenance. Planting, or preserving, habitat with native plant species provides the greatest benefit to wildlife and increases biodiversity on the golf course property. Prioritize the planting of species that provide the greatest benefit to wildlife diversity. For example, native species such as oak and aster best sustain species of native butterfly and moth caterpillars (Table 9-1), while non-native species such as Ginkgo or Zelkova support none. Planting these species will be the most effective means to maintain and improve biological diversity of butterflies, moths, and the higher life forms that they sustain such as birds.

Table 11-1. Species that provide the greatest support to native butterfly and moth caterpillars (Tallamy, 2009).

TREES		**PERENNIALS**	
COMMON NAME (BOTANICAL NAME)	**BUTTERFLY/MOTH SPECIES SUPPORTED**	**COMMON NAME (BOTANICAL NAME)**	**BUTTERFLY/MOTH SPECIES SUPPORTED**
Oak (*Quercus*)	534	Goldenrod (*Solidago*)	115
Black Cherry (*Prunus*)	456	Aster (*Symphyotrichum*)	112
Willow (*Salix*)	455	Sunflower (*Helianthus*)	73
Birch (*Betula*)	413	Joe Pye Weed (*Eutrochium*)	42
Poplar (*Populus*)	368	Blue Grass (*Poa*)	42
Crabapple (*Malus*)	311	Sedge (*Carex*)	36
Blueberry (*Vaccinium*)	288	Lupine (*Lupinus*)	33
Maple (*Acer*)	285	Rye, Blue Wild (*Elymus*)	31
Elm (*Ulmus*)	213	Violet (*Viola*)	30
Pine (*Pinus*)	203	Wild geranium (*Geranium*)	24

Best Management Practices for Plant Selection

- Create a record of your as built plant selections for performance evaluation and future considerations.
- Whenever possible, retain 50-70% of the non-play areas in natural cover.
- Choose each plant based on the soil characteristics, climate, sun exposure, water conditions, and existing wildlife.
- Select more stress-tolerant species or cultivars to manage periodic dry/wet conditions.

- Use plants that will perform well over time. Ensure that the mature height and spread of each plant is accounted for to avoid the need for excessive pruning or regular replacement.
- Select plants that don't require excess care to maintain (deadheading, frequent pruning, etc.).
- Group plants with similar water, pH, and nutrient requirements together to allow for the most efficient use of resources.
- Choose plants that are known to occur together naturally to significantly increase the odds of survival and provide the most benefit to wildlife.
- Select each plant based on its unique contribution to the overall design, including flower blooming schedules, bark, fruit, texture, and habitat.
- Where feasible, leave in place the existing understory (brush and young trees) and native grasses and communicate the value of these natural ecosystems to customers.
- The design should look "natural." Replicate the natural system of layers to create harmony and provide year-round interest: a canopy of large shade trees, a medium understory of large shrubs and small flowering trees, a smaller shrub layer, and an herbaceous layer.
- Group plants in odd, spacious quantities (1, 3, 5, 7, 9…) for aesthetic appeal.

Energy Management

General Energy Efficiency Considerations

Energy, in the form of electricity, natural gas, diesel, propane, heating oil, gasoline and other fuels, is a significant expense on the golf course. According to the Golf Course Superintendents Association of America (GCSAA), the average 18-hole golf course uses nearly 450,000 kilowatt-hours in electricity alone (Golf Course Environmental Profile, 2012). At an average New England electric rate of $0.16/kWh, that's $72,000 in annual electricity costs. Fortunately, golf course managers have many opportunities to reduce energy consumption in many areas of course operations. Making investments in energy efficiency saves money for the golf course and positions the course to be more resilient to future increases in energy prices or regulatory changes. An energy-efficient golf course is also a good steward of natural resources and can enhance its standing in the community by publicizing its efforts to reduce energy consumption and carbon emissions.

Energy Audit

Massachusetts golf course managers should consider having an energy audit performed for the golf course as a preliminary step before making large capital investments.Mass Save Program will conduct an energy audit analysis of the energy use of the facility to uncover areas of greatest potential energy savings, allowing a golf course manager to prioritize energy improvements based on return-on-investment. They also can provide financing for relative work.

Other qualified auditing firms include those holding the Certified Energy Manager (CEM), Certified Energy Auditor (CEA), or Certified Golf Irrigation auditor certifications. The contract with the auditing firm should be clear with respect to the costs and scope of the audit. Some auditors only look at electrical use, while others may only look at the stationary equipment and not the mowing or maintenance equipment. An irrigation audit may be conducted separately by an irrigation specialist. The golf course's utility company or state energy office is a good source for names of reputable auditors, and many states have programs that provide free or reduced-cost audits or other technical assistance. An energy audit can also identify available incentives and financing to reduce the initial investment of energy efficient equipment.

Establish an Energy Management Plan

Once an energy audit has identified areas of greatest concern the audit's recommendations can be utilized to create an energy management plan with specific goals for reducing energy consumption over time. The manager can prioritize the capital expenditures and make a plan to invest in energy efficient equipment as the budget allows. Management can also ensure that staff members are following best practices for energy efficiency and provide training on energy efficient practices. To track energy consumption, managers can make use of online portals from the electric utility as well as monitoring tools supplied by electronic control systems.

Employee Training

A facilities' employees are on the front lines of energy conservation, as their daily choices can contribute to the facility's energy efficiency. Even simple activities such as turning off lights in empty rooms, following a maintenance checklist to keep equipment clean, and keeping equipment properly calibrated can all contribute to energy savings. Management can consider developing a checklist of employee-led maintenance activities and energy conservation behaviors. Staff training allows the employees to buy in to the energy conservation goals and take ownership of their role in energy management.

Buildings and Amenities

Lighting is used throughout the golf course in both for interior and exterior spaces. Lighting represents one of the easier cost-effective ways to save energy. In the past decade, light-emitting diode (LED) technology has rapidly advanced while costs for these products have decreased by approximately 90%. LED lighting is quickly making other types of lighting obsolete due to the sharp increase in efficiency, decrease in cost, long life and marrying them to timers or motion detectors. LEDs can replace not only indoor lighting, but also older mercury vapor or metal halide exterior lighting.

Clubhouse

In a clubhouse, energy efficiency and water conservation measures can be implemented to save energy, including those associated with kitchen equipment, swimming pools, heating, ventilation and air conditioning (HVAC) equipment, bathrooms, and offices.

Best Management Practices for Building & Amenities

- Pick LED lights that come with at least a three-year warranty and consult third-party listings like the Design Lights Consortium to evaluate options.
- Install timers or photocells on outdoor lighting and consider the use of motion/occupancy sensors where appropriate.
- Where motion/occupancy sensors are not workable, train staff to turn off lights when not in use.
- When considering a lighting retrofit, prioritize the oldest lights that also have the longest run time (hours in use per day).
- Utilize translucent wall panels to provide natural lighting in areas such as equipment maintenance/storage and irrigation pump houses.
- Consider solar energy and other renewable energy sources to reduce overall electric costs for lighting.
- Look for EnergyStar-certified kitchen equipment such as dishwashers, refrigerators, and walk-in coolers. EnergyStar is a joint program of the U.S. Department of Energy and U.S. Environmental Protection Agency that labels energy-efficient appliances and allows the consumer to easily compare the energy consumption of various equipment.
- Ensure kitchen equipment is clean and in good working order. Dirt and dust build-up can lead to wasted energy use and premature equipment failure, so staff should adhere to a maintenance/cleaning checklist.
- Turn off equipment such as burners and broilers when not in use.
- Ensure seals and gaskets around ovens, steamers, refrigerators, and freezers are aligned properly.
- Heat water to the proper setting (120 degrees Fahrenheit) and insulate hot water lines.
- User proper dishwasher setpoints and operation mode. Set rinse pressure to 15 to 25 pounds per square inch to avoid excess water use.
- Set the wash tank temperature to 160 degrees Fahrenheit and the booster heater setpoint to 180 degrees Fahrenheit in accordance with guidelines from NSF International, an organization that develops standards for public health and safety.
- Run the dishwasher only when full and do not run in manual mode.
- Upgrade to low-flow pre-rinse sprayers. Replace sprayers that take less than 30 seconds to fill a one-gallon pail.
- Use a high-efficiency pool heater and consider the use of a solar pool heating system.
- Ensure pool pumps and motors are properly sized and are the most energy-efficient model available.
- Maintain an appropriate water temperature when the pool is in use and turn down the pool heater when not in use.
- Use a pool cover to decrease evaporation when the pool is closed.
- Add windbreaks (trees, shrubs, fencing) around the pool to further reduce evaporation.
- Consider installing EnergyStar-certified commercial boilers with a thermal efficiency of 94% or greater and a turndown ratio of 5:1.
- Change HVAC filters on a regular basis, typically every one to three months.

- Find an HVAC technician to perform regular check-ups to ensure the HVAC equipment is working properly.
- Consider installing EnergyStar air conditioning equipment, especially if the air conditioner is over 10 years old.
- Use a programmable thermostat in conditioned spaces to reduce heating and cooling costs during periods of low use.
- Properly seal heating and cooling ducts and ensure the ducts are insulated.
- Ensure all new building construction meets current state and federal energy codes
- Ensure that buildings are properly insulated and that leaks are sealed.
- Consider adding advanced variable speed drives and digital economizer controls to an existing rooftop HVAC unit. These controls bring in ventilation only when needed, reducing the overall energy consumption of the HVAC unit.
- Consider use of a commercial geothermal or water-source heat pump for heating and cooling. A qualified HVAC technician can inform course managers if this technology is applicable for the golf course's buildings.
- Efficient wood boilers can be an effective way to provide supplemental heat. Burning wood may also eliminate or reduce disposal problems on golf courses that generate wood debris.
- Install low-flow faucets and showerheads.
- Install dual-flush, low-flow toilets.
- Install water-free urinals.
- If the golf course does laundry on the premises, ensure washers and dryers are the most efficient models available. Consider ozone laundry systems as an alternative to large commercial washers. Ozone machines use cold water and ozone gas, instead of hot water and chemicals, to clean and disinfect laundry.
- Look for the EnergyStar label when purchasing office equipment such as computers and photocopiers; set the equipment to power down automatically after a period of inactivity.
- Install energy-efficient vending machines and retrofit older vending machines with a controller that reduces the machine's run time.
- Consider pursuing LEED Certification

Course Management

Pumping and Irrigation

Irrigation is one of the largest energy users on a golf course, with irrigation pumping contributing about 30% of the electricity use in the average course (2015 Golf Course Environmental Profile). Fortunately, ample opportunities exist for energy savings by optimizing the design of the irrigation system, ensuring pumps and other system components are properly maintained, and utilizing automated sensors and controls. Regular monitoring and maintenance, as described in the "Irrigation" chapter, is the key to uncovering leaks, waste, and problems that could lead to expensive repairs and wasted energy in the future. Golf course managers should implement a daily, weekly, and monthly maintenance plan with help from their irrigation designer.

Golf Car Charging

Golf car charging can use a lot of electricity. Some of that electric use can be saved by moving the charging time to off-peak hours to reduce demand charges from the utility, as many utilities charge their larger energy users a demand charge for energy used during times of highest electric demand. A golf course with a demand charge can save energy and money by switching certain activities from high-peak times to off-peak times. Typically, off-peak times are early morning and late at night.

Mowing

Conventional commercial lawnmowers use gasoline or diesel fuel. Many innovations in alternative-fuel turf equipment can lower emissions and provide other benefits such as extended life, decreased maintenance, and eliminating the risk of fuel theft or spillage. Alternative-fuel turf equipment has a wide range of price points and features. Golf course managers should thoroughly research the specifications of alternative fueled equipment to make the best decision.

Best Management Practices for Efficient Course Management

- Consider switching golf car charging to off-peak hours. If it is not possible to switch the entire fleet to off-peak times, see if charging can be staggered to minimize the number of cars being charged in the peak hours.
- New national standards for battery charger energy efficiency took effect in 2018. Consider replacing an older battery charger with a model manufactured according to the new standard to save the most energy.
- Consider solar-charged golf cars. These cars work by using a solar panel on the roof of the car and can reduce electricity consumption of car charging by 50% to 75%.
- Compressed natural gas requires less maintenance, extends equipment life, and does not spoil or clog the fuel system during storage.
- Propane has many of the same benefits of compressed natural gas. New propane-powered equipment can be purchased, or some gasoline equipment can be converted to propane using a conversion kit.
- Biodiesel, which can be blended with petroleum diesel without modifying the equipment, reduces emissions. Check with the equipment manufacturer to see if a biodiesel blend is approved for use.
- Commercial electric equipment is powered with rechargeable electric batteries. Recent innovations have improved battery life, enabling extended use of commercial equipment between charges. Solar-powered electric equipment is another recent addition to the market that golf courses can consider.
- Hybrid equipment, using a combination of alternative and traditional fuels, is also available for many fuels and offers improved fuel efficiency and emissions reductions.

Renewable Energy

Maximizing energy efficiency is the first step in reducing a facility’s carbon footprint. To further reduce the carbon footprint and reduce energy costs, facilities can invest in renewable energy sources. Some types of renewable energy, such as solar and wind, are highly visible to a golf course’s guests and the public and can enhance the golf course’s environmental image.

Solar PV

Solar photovoltaic (PV) systems have decreased in price dramatically in recent years, making solar system installation an economically viable option for many golf courses, especially when coupled with federal and state incentives. Some considerations for solar include the size of the system, whether to install a ground or roof-mounted system, and whether to lease or own the system. With multiple companies able to install a solar project, golf courses should consider the services of a third-party consultant to help evaluate which solar company offers the best terms.

Solar Hot Water

A solar hot water heater can be a cost-effective way to provide hot water for the golf course. A solar hot water heater can cut water heating expenses by 50% to 80% in some instances. Golf courses should check with a reputable installer to ensure the system makes sense for the needs of the course.

Geothermal Heat Pump

A geothermal, or ground-source heat pump uses the Earth’s heat in cold weather by drawing up the warmer air from below ground. In warm weather, the heat pump sends warm air back into the Earth to provide cooling. A geothermal heat pump can save 40% to 70% in heating and cooling costs, according to a geothermal industry trade group. Golf courses should check with a qualified heat pump installer to understand whether a geothermal heat pump is a viable option.

Wind

Smaller-scale wind turbines are available for individual facilities to offset some of their electric use. Golf courses interested in wind power should get a professional evaluation of wind energy potential to make sure the wind speed is sufficient to make a turbine economically viable.

Biomass

Biomass is any renewable organic matter that can be used for fuel, with the most common fuel source being biogas created by anaerobic digesters. Another type of biomass heating source is a wood-pellet boiler, which can work in some commercial applications. A golf course that produces a large volume of biomass or organic wastes may find biomass energy generation to be a viable option. Check with a qualified consultant to better understand the costs and benefits of biomass energy.

Funding Resources

The U.S. Department of Agriculture administers the Rural Energy for America Program (REAP) through its Rural Development office. REAP offers grants of up to 25% of project cost and loan guarantees of up to 75% of the project cost to rural businesses that install energy-efficient or renewable-energy projects. To qualify as rural, a golf course must be located in an area with less than 50,000 inhabitants. Grants range from $1,500 to $2,500 for energy efficiency and $2,500 to $500,000 for renewable energy. Loans range from $5,000 to $25 million.

The Federal Business Energy Investment Tax Credit and Modified Accelerated Cost Recovery System offer tax benefits to businesses that install renewable energy projects. The 30% tax credit for renewable energy significantly lowers the cost of many renewable energy projects.

The Section 179D Commercial Buildings Energy Efficiency Tax Deduction provides a deduction of $1.80 per square foot for installations of lighting, building envelope, and HVAC or hot water systems that reduce the building's total energy use by 50% or more. Facilities can receive a deduction of $0.60 per square foot for meeting a partial qualification. Tax deductions can be retroactively applied to projects installed since January 1, 2006. Golf course managers should check with their accountants to ensure compliance and can work with a qualified energy consultant to develop the documentation for the tax deduction.

The MassSave program offers a range of incentives for electric and natural gas efficiency projects.

To search additional opportunities for Massachusetts, the Database of State Incentives for Renewables & Efficiency (DSIRE) offers a customizable listing of applicable incentives based on business type, funding source, and other factors. Visit https://www.dsireusa.org/ and select Massachusetts under "Find Policies & Incentives by State" to get started.

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