

Best Management Practices
for the
Enhancement of Environmental Quality
on
Florida Golf Courses



As Secretary of the Department of Environmental Protection it is my pleasure to present the third printing of the Best Management Practices for the Enhancement of Environmental Quality on Florida Golf Courses. The FGCSA and its partners have dedicated their time to assist in the development of these criteria and the Department is convinced that their new associated training and certification programs are of the highest quality.

The importance of setting high standards and understanding how sustainable course management actions affect the environment and water resources is critical to the environmental stewardship Florida needs to maintain its pristine ecosystems. FGCSA continues to show a commitment to Florida's environment and these guidelines reflect that enthusiasm.

HERSCHEL VINYARD, SECRETARY
Florida Department of Environmental Protection



Since this manual was published in early 2007, it has been referenced in the state fertilizer rule and many local ordinances. In part because of that recognition and awareness, the Florida GCSA has recently created a voluntary Golf Course Best Management Practices Certification Program to provide golf course superintendents a way to document their understanding of these practices. This manual is also being utilized by the Golf Course Superintendent Association of America in their national program: Golf's Drive Toward Sustainability.

In addition to their social and recreational benefits, golf courses are prolific wildlife habitats in both urban and rural settings. They are valuable green spaces that have social and recreational value to the communities where they reside, and their mixture of open spaces, lakes and ponds and naturalized areas attract a variety of wildlife to be enjoyed by everyone. The scientifically documented best management practices contained in this publication help superintendents strengthen their environmental stewardship practices and protect Florida's natural resources.

NANCY MILLER, CGCS, PRESIDENT
Florida Golf Course Superintendents Association



ACKNOWLEDGMENTS

Thanks are due to the members and Board of Directors of the Florida Golf Course Superintendents Association; to Tim Hiers, Old Collier Golf Club; and to Ron Dodson and his staff at Audubon International, for their services and cooperation over more than a decade in bringing environmental stewardship to golf in Florida. Their continued assistance and counsel have been instrumental in bringing this manual, and its 1995 predecessor, to life.

Thanks are also due to the following for their efforts in making this manual a reality: Michael Thomas, FDEP, editor and BMP committee chair; subcommittee chairs Ken Ezell, Clifton, Ezell, & Clifton; David Court, FGCSA; Jerry Sartain, UF-IFAS; Bryan Unruh, UF-IFAS; Eileen Buss, UF-IFAS; and Kathy Meaux, Sarasota County; as well as members/contributors Alison Ramoy, SWFWMD; Amy Meese, Sarasota Co.; Angela Chelette, NFWFMD; Bonnie Finneran, Palm Beach Co.; Brad Nestor, PGA; Bryan Unruh, UF-IFAS; Charles Pattison, 1000 Friends of Florida; Diana Grawitch, Florida Association of Counties; Dr. William Sutton, M.D.; Eileen A. Buss, UF-IFAS; Eric Reiter, Duda; Francis Flores, NFWFMD; Gary Moyer, The Villages; Geoffrey Coggan, FGCSA; George H. Snyder, UF-IFAS; Greg Lyman, GCSAA; Greg Golgowski, Harmony; Howard Jack, Audubon International; Jane Foos (deceased), FDACS; Jan Beljan, Fazio Design; Jeff Caster, ASLA; Jerry Sartain, UF-IFAS; Jim Spratt, FNGLA; Joel Jackson, FGCSA; Joellen Zeh, Audubon International; John Cisar, UF-IFAS; John Foy, USGA; John Wildmon, LCCC; Katherine Pordeli, SJRWMD; Kathy Meaux, Sarasota Co.; Kim Fikoski, Bonita Bay Group; Laurie Trenholm, UF-IFAS; Linda Jamison, Sierra Club; Lois Sorensen, SWFWMD; Michal Eldan, MAA Task Force; Matt Taylor, FCGSA; Mark Finn, Palm Beach Co.; Mike Fiddelke; Mike Kenna, USGA; Nancy Richardson, Audubon International; Peg McPherson, SFWMD; Rebecca O'Hara, Florida League of Cities; Richard Deadman, FDCA; Ron Cohen, SWFWMD; Skip Wright, FIS; Terril Nell, UF-IFAS; Todd Lowe, USGA; Tjerk van Veen, SFWMD.

Special thanks are due to our final editor, Linda Lord, FDEP; to Lori Ann Pollgreen, Geographic Design; and especially to John and Jeannine Henebry, for permission to use her beautiful photo of the 16th hole at Old Collier Golf Club on our cover. There is no finer example of the use of both turf and natural buffers to protect lakes and enhance wildlife.

This publication was funded in part by the Florida Department of Environmental Protection with a Section 319 Nonpoint Source Management Program Grant from the U.S. Environmental Protection Agency.

DISCLAIMER

The mention of a specific product or company is for information purposes only and does not constitute an endorsement of that product or company.

Cover Photo by John and Jeannine Henebry. Copyright 2003.
All rights reserved. Reprinted by permission.

FOREWORD

This publication provides the superintendent or golf course operator with sound management strategies to maintain the golf course in a positive manner with respect to environmental protection, water quality protection, and conservation. It is also intended to provide elected officials, regulators, developers, and others with an overview of golf course management practices and how they relate to environmental issues.

This is a living document. As science and technology progress, golf industry representatives will work in conjunction with the University of Florida, staff from the Florida Department of Environmental Protection (FDEP), and other interested parties to determine the extent to which this document will be amended.

A comprehensive program of best management practices (BMPs) should include a combination of components that are properly selected, designed, operated, and maintained. BMP options should be screened for feasibility based on the following factors:

- Physical and technical limitations,
- Operational and management limitations,
- Pollutant reduction/water conservation effects,
- Profitability/cost considerations,
- Other benefits or disadvantages, and
- Public acceptance.

In the event that these BMPs are adopted by rule, as provided by Subsection 403.067(7)(c)1, Florida Statutes (F.S.), certain protection from liabilities may be established through the voluntary implementation of BMPs that have been verified by FDEP to be effective in protecting water quality.

Table of Contents

ACKNOWLEDGEMENTS.....	III	CHAPTER 5: NUTRITION AND FERTILIZATION	38
FOREWORD	IV	Overview	38
TABLE OF CONTENTS.....	V	General.....	38
LIST OF ACRONYMS AND ABBREVIATIONS	VII	Site Analysis	39
INTRODUCTION	1	Fertilizer	39
CHAPTER 1: ENVIRONMENTAL CONCEPTS	4	Terms	39
Air Quality	4	Fertilizer Analysis	39
Soil and Water Quality.....	4	Nitrogen	40
Nutrients	4	Phosphorus	44
Pesticides	4	Potassium.....	45
Wastes	5	Secondary Plant Nutrients.....	45
Wildlife Habitat	5	Micronutrients	46
Water Conservation	5	Starting a Fertilizer Program	47
CHAPTER 2: ENVIRONMENTAL MONITORING	7	Soil Acidity and Liming	47
Quality Assurance/Quality Control	7	Fertilization Program for Golf Greens.....	48
Predevelopment Monitoring	7	Tees.....	49
Monitoring During Construction.....	8	Fairways and Roughs.....	49
Postconstruction Operational Monitoring.....	8	Grow-In	50
CHAPTER 3: DESIGN AND CONSTRUCTION	9	Soil Sampling	50
Environmental Considerations	9	Tissue Testing.....	51
Site Selection and Design.....	10	Fertilizer Loading.....	53
Wetlands.....	10	Fertilizer Application	53
Drainage.....	11	Calibration	53
Stormwater, Stormwater Ponds, Lakes, Springs, and Water Hazards.....	11	Granular Application	53
Play Areas.....	14	Foliar Feeding	53
Nonplay Areas	17	Precision Application.....	54
Maintenance Facilities	20	Fertigation	54
CHAPTER 4: IRRIGATION.....	25	CHAPTER 6: CULTURAL PRACTICES FOR GOLF TURF	55
Water Sources.....	25	Mowing	55
Brackish Water	25	Mowing Height	55
Reclaimed Water	26	Mowing Frequency	56
System Design	27	Mowing Equipment	57
Irrigation for Play Areas.....	27	Mowing Patterns	58
Irrigation for Nonplay Areas and Landscape Plantings.....	29	Grass Clippings	58
Irrigation System Installation.....	30	Turfgrass Cultivation Practices	59
System Operation.....	31	Aerification.....	59
Water Restrictions	31	Vertical Mowing.....	63
Irrigation Scheduling	31	Topdressing	63
Operating Older Systems	33	Rolling	65
System Maintenance.....	34	Overseeding	65
Calibrating an Irrigation System	34	Seed Bed Preparation and Fall Transition	65
Preventive Maintenance	35	Grass Selection for Overseeding	66
Corrective Maintenance	36	Postplanting Maintenance	66
System Renovation.....	36	Shade and Tree Management	67
		CHAPTER 7: LAKE AND AQUATIC PLANT MANAGEMENT	68
		Lake Management	68
		Dissolved Oxygen	69
		Sedimentation	69
		Aquatic Plant Control	70
		Roles of Plant Life in Urban Ponds	70
		Management of Plant Life	71

CHAPTER 8: TURFGRASS PEST MANAGEMENT	74
Integrated Pest Management	74
Monitoring/Scouting	75
Sampling	75
Pests	75
Diseases	75
Arthropods	76
Nematodes	77
Weeds	77
CHAPTER 9: PESTICIDE MANAGEMENT	80
Pesticide Regulation and Legal Issues	80
Regulation	80
Licensing Requirements for Pesticide Use in Golf Course Maintenance.....	80
Record Keeping	81
Pesticides and Water Quality	82
Surface Water and Ground Water Resources.....	82
Behavior of Pesticides in Soil and Water	82
Pesticide Selection and Use	84
Pesticide Handling and Storage	86
Personal Protective Equipment	86
Pesticide Storage	86
Chemical Mixing and Loading	88
Pesticide Container Management	88
Pesticide Spill Management	89
CHAPTER 10: MAINTENANCE OPERATIONS	90
Fueling Areas	90
Equipment-Washing Facility	90
General.....	90
Pesticide Application Equipment.....	91
Equipment Maintenance Areas	92
Waste Handling	92
Hazardous Materials.....	92
Pesticides	92
Pesticide Containers	92
Used Oil, Antifreeze, and Lead-acid Batteries	92
Solvents and Degreasers.....	92
Composting	93
Paper, Plastic, Glass, and Aluminum Recycling	93

REFERENCES	94
Publications	94
Organizations	99
GLOSSARY	100
APPENDICES	105
Appendix A: Tables	105
Appendix B: Spill Reporting Requirements	109
Appendix C: Important Telephone Numbers	110
Appendix D: Details Required for an Adequate Management Plan for a Golf Course	111
Appendix E: Golf Course Best Management Practice Checklist.....	119
LIST OF TABLES	
Table 1: Irrigation spacing	29
Table 2: Suggested ranges for Mehlich-1 extractable soil nutrient levels for Florida turfgrasses	51
Table 3: Sufficiency ranges of tissue N concentration for selected turfgrasses	52
Table 4: Sufficiency concentration ranges for selected macro- and micronutrients in turfgrass tissue.....	52
Table 5: Recommended golf course mowing heights, by area	55
Table 6: Recommended mowing heights for lawn and common area turfgrasses	56
Table 7: Potential drift for various droplet sizes	83
Table 8: Persistence and partition coefficients of pesticides used on Florida golf courses.....	84

List of Acronyms and Abbreviations

AAPFCO	Association of American Plant Food Control Officials	FDACS	Florida Department of Agriculture and Consumer Services
AB-DTPA	Ammonium bicarbonate-DTPA	FDCA	Florida Department of Community Affairs
A-E method	Adams-Evans method	FDEP	Florida Department of Environmental Protection
ASABE	American Society of Agricultural and Biological Engineers	FDOH	Florida Department of Health
ASLA	American Society of Landscape Architects	FDOT	Florida Department of Transportation
ASR	Aquifer storage and recovery	Fe	Iron
ASCE	American Society of Civil Engineers	FFDCA	Federal Food, Drug, and Cosmetic Act
ASTM	American Society of Testing Materials	FFWCC	Florida Fish and Wildlife Conservation Commission
BMP	Best management practice	FGCSA	Florida Golf Course Superintendents Association
CaSO ₄	Calcium sulfate	FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
CCE	Calcium carbonate equivalent	FIS	Florida Irrigation Society
CDTA	Cyclohexanediaminetetraacetic acid	FNGLA	Florida Nursery, Growers and Landscape Association
CEC	Cation exchange capacity	FS.	Florida Statutes
Cl	Chloride	FWEA	Florida Water Environment Association
CMC	Chemical mixing center	FWS	U.S. Fish and Wildlife Service
CO ₂	Carbon dioxide	GCSAA	Golf Course Superintendents Association of America
Cu	Copper	GLPs	Good lab practices
CUP	Consumptive use permit	gph	Gallons per hour
DAP	Diammonium phosphate	gpm	Gallons per minute
DCIA	Directly connected impervious area	GPS	Global positioning system
DO	Dissolved oxygen	HOC	Height of cut
DTPA	Diethylenetriaminepentaacetic acid	IBDU	Isobutryaldehyde
EDDHA	Ethylenediaminedi (o-hydroxyphenylacetic acid)	IPM	Integrated pest management
EDTA	Ethylenediaminetetraacetic acid	IRAC	Insecticide Resistance Action Committee
EPA	U.S. Environmental Protection Agency	K	Potassium
ESTL	Extension Soil Testing Laboratory	LCCC	Lake City Community College
ET	Evapotranspiration	MAP	Monoammonium phosphate
F.A.C.	Florida Administrative Code		
FDA	U.S. Food and Drug Administration		

Mg	Magnesium	RUP	Restricted use pesticide
Mn	Manganese	S	Sulfur
Mo	Molybdenum	SCU	Sulfur-coated urea
MSDS	Material Safety Data Sheet	SFWMD	South Florida Water Management District
N	Nitrogen	SJRWMD	St. Johns River Water Management District
NELAC	National Environmental Laboratory Accreditation Conference	SMZ	Special management zone
NELAP	National Environmental Laboratory Accreditation Program	SWFWMD	Southwest Florida Water Management District
NH ₃	Ammonia (gas)	TDR	Time and frequency domain reflectometer
NH ₄ ⁺	Ammonium nitrogen	TN	Total nitrogen
NO ₂	Nitrite	TKN	Total Kjeldahl nitrogen
NO ₃ ⁻	Nitrate	TMDL	Total maximum daily load
NO ₃ -N	Nitrate nitrogen	TP	Total phosphorus
NO ₃ + NO ₂	Nitrate + Nitrite	TS	Total solids
NOAA	National Oceanic and Atmospheric Administration	TSS	Total suspended solids
NFWFMD	Northwest Florida Water Management District	TVA	Tennessee Valley Authority
OSHA	Occupational Safety and Health Administration	UAN	Urea-ammonium nitrate
P	Phosphorus	UF	Ureaformaldehyde
PAMs	Polyacrylamides	UF-IFAS	University of Florida-Institute of Food and Agricultural Sciences
Pb	Lead	USACOE	U.S. Army Corps of Engineers
PGA	Professional Golfers' Association of America	USDA	U.S. Department of Agriculture
PM	Preventive maintenance	USDA-ARS	U.S. Department of Agriculture-Agricultural Research Service
PPE	Personal protective equipment	USDA-NRCS	U.S. Department of Agriculture-Natural Resources Conservation Service
PO ₄	Orthophosphate	USGA	United States Golf Association
ppm	Parts per million	VFD	Variable frequency drive
PREC	Pesticide Registration and Evaluation Committee	VOC	Volatile organic compound
psi	Pounds per square inch	WMD	Water management district
PTO	Power takeoff	WUE	Water use efficiency
QA/QC	Quality assurance/quality control	WUP	Water use permit
RCRA	Resource Conservation and Recovery Act	Zn	Zinc

This document on best management practices (BMPs) covers many of the aspects of operating a golf course in an environmentally sound manner. Environmental stewardship begins with an understanding of the environment and how it can be harmed. From there, it is not difficult to look at each task we do, and take steps to prevent contamination, waste, and habitat loss. Then we can look at ways to correct past errors and lessen the effects of existing situations, striving to live in balance with the environment. We can never reach a point where we have no effect upon the environment; after all, as human beings we are part of it. However, we can do a lot to minimize our harmful effects.

Florida's environment is unique. It varies from the red clay hills of the Panhandle to the coral shores of the Keys; from the deep sands of the Suwannee Valley and the Central Ridge to pine flatwoods throughout the state; and it includes the vast river of grass we call the Everglades. It is truly rare to have such diversity of conditions in one state as we have in Florida. Ninety percent of Florida's drinking water comes from underground aquifers, many of which have only a highly permeable layer of sand above to protect them from contamination by chemicals we use in daily life, such as gasoline, dry-cleaning fluids, pesticides, and solvents. Nutrients, such as the nitrogen and phosphorus contained in fertilizers, may upset the balance of our waterbodies, leading to noxious weeds, algae blooms, fish kills, and the replacement of game fish with less desirable species.

Golf is one of the most popular sports in America today, for both men and women. It provides recreation, exercise, business opportunities, and a chance to get outdoors and enjoy nature for more than 9 million people every year. In 2000, golf and golf-related travel and tourism provided a \$9.2 billion boost to Florida's economy and provided 216,000 jobs¹. Almost 60 million rounds of golf were played in Florida that year. There are more than 1,300 golf courses in Florida, with more being designed and built every year. The property taxes generated by these golf courses and the increased property values they influence totaled \$214 million in 1999 alone.

Many supporters of golf, including the United States Golf Association (USGA), the Golf Course Superintendents Association of America (GCSAA), and the American Society of Golf Course Architects, are actively promoting environmentally friendly golf course design and management. Audubon International has more than 3,800 courses enrolled in the Cooperative Sanctuary Program, more than 500 of which have become certified sanctuaries.

The U.S. Fish and Wildlife Service's (FWS) Safe Harbor Program is available for courses that have crucial habitat for threatened or endangered species.

In the past, relationships within our ecosystems were not well understood, and it seemed that the capacity of the oceans, rivers, lakes, and the soil itself was limitless. We know better now, and many golf courses are leading the way through environmental stewardship of their properties.

In the mid-1990s, the Center for Resource Management brought together a diverse group of golf and environmental organizations and developed a manual titled *Environmental Principles for Golf Courses in the United States*. Sixteen organizations were involved, ranging from the U.S. Environmental Protection Agency (EPA) and the USGA, to the Sierra Club and Audubon International. Permission to use excerpts from these principles has been graciously granted, and they are used throughout this manual. The following are the basic precepts of the manual²:

- To enhance local communities ecologically and economically,
- To develop environmentally responsible golf courses that are economically viable,
- To offer and protect habitat for wildlife and plant species,
- To recognize that every golf course must be developed and managed with consideration for the unique conditions of the ecosystem of which it is a part,
- To provide important green space benefits,
- To use natural resources efficiently,
- To respect adjacent land use when planning, constructing, maintaining, and operating golf courses,
- To create desirable playing conditions through practices that preserve environmental quality,
- To support ongoing research to scientifically establish new and better ways to develop and manage golf courses in harmony with the environment,
- To document outstanding development and management practices to promote more widespread implementation of environmentally sound golf, and

¹ Haydu and Hodges, 2002.

² Center for Resource Management, 1996.



Figure 1: A typical golf course designed with the environment in mind. The yellow line shows wildlife corridors; the red lines point to water quality buffer areas.

- To educate golfers and potential developers about the principles of environmental responsibility and to promote the understanding that environmentally sound golf courses are quality golf courses.

The process begins with the site selection and initial design by the developer and golf course architect; obviously these factors cannot be changed for existing golf courses (Figure 1). However, most environmental impacts are created at least as much, if not more so, by day-to-day decisions and operations. In addition, some golf course managers rework holes and make changes over time that can allow many of those initial design decisions to be modified. Irrigation systems do not need to be torn out and replaced all at once, but state-of-the-art systems can be installed on one or two holes per year as greens are rebuilt and other changes occur. Other practices, such as the use of integrated pest management (IPM) and BMPs for turf management involving cultural practices, nutrition, and irrigation timing and duration cost little or nothing to implement. They require only education, thought, and skill on the part of golf course personnel. Best of all, these BMPs may save money and can be implemented almost immediately.

Florida golf courses average 158 acres, with 114 acres (72%) of maintained turf, down from 125 (79%) just a few years earlier. This can be attributed to newer (and many older) courses using native vegetation in nonplay areas, as suggested by Audubon International's Signature and Cooperative Sanctuary Programs.

While no one would claim that a golf course has no environmental impact, golf courses do provide environmental benefits. In an otherwise paved urban area, they provide valuable green space. Turfgrass and other, often

native, plants provide cooling evapotranspiration (ET) to an urban heat island, oxygen from photosynthesis, the absorption of stormwater and its pollutants, habitat for birds and other wildlife, and myriad more subtle advantages over other types of urban development.

These BMP measures are not regulatory or enforcement based. In some situations, however, the law may provide substantial incentives should they be formally adopted, and there are situations in which BMP use could reduce legal or regulatory exposure. Golf course operators are requested to maintain records and provide documentation regarding the implementation of all BMPs used and applied on their facilities, and to document why certain BMPs are not applicable to their specific situations. Adequate records are very important for the documentation of BMP implementation and are an integral part of any BMP program. The priorities for BMP implementation are as follows:

1. To correct any identified existing water quality/quantity problems,
2. To minimize water quality/quantity problems resulting from land use and operations,
3. To improve the effectiveness of existing BMPs implemented, and
4. To seek additional improvement of BMPs based on new, quantifiable information.

All golf course superintendents are encouraged to perform an environmental assessment of their operations. This resource allocation assessment process is a tool to aid in identifying which BMPs should be considered to achieve the greatest economic and environmental benefit based on site-specific circumstances. The incentives for adopting BMPs include the following:

- Improved turf quality,
- Improved golf outing experiences,
- Reduced environmental impacts,
- Improved worker safety,
- Efficient allocation of resources,
- Reduced maintenance expenditures,
- Reduced regulatory requirements, and
- Opportunity for industry self-regulation.

Additional research is still needed in many areas. As new knowledge is gained, these BMPs will be revised over

time to reflect changes in our level of knowledge. This is a living document. As this is published in January 2007, new technologies, such as mower-mounted sensing of water and disease stresses and computerized irrigation that is corrected for overnight rainfall, show promise of further reductions in adverse environmental effects and better, more cost-effective opportunities for golf course management.

This manual will not have all of the answers to every question that comes up. Other references are available with far more detail on almost every subject. Many are listed throughout the text and in the References section. It is hoped that the principles described in these chapters will give direction and understanding to the search for those answers. Using BMPs is an iterative process, as shown in Figure 2. To protect our state and our way of life, it is imperative that each of us uses the most powerful environmental tool we have, our brain.

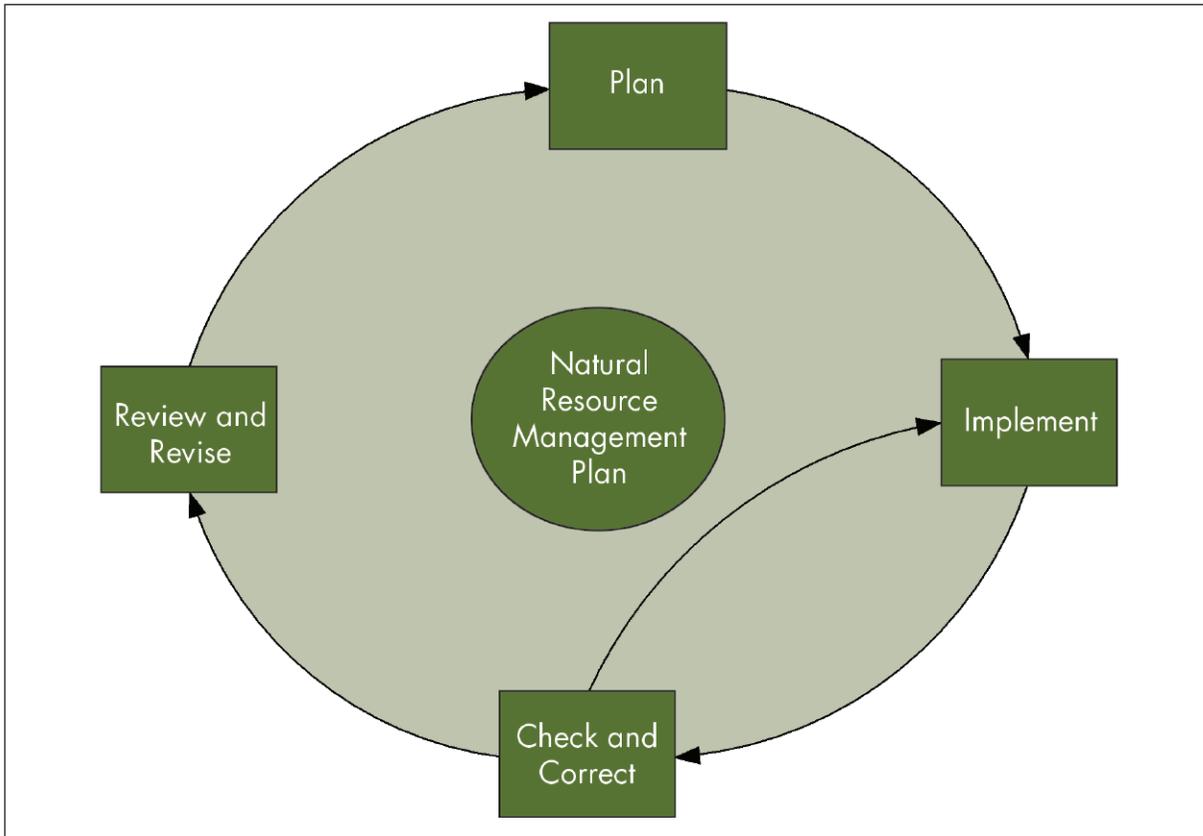


Figure 2: BMP process diagram.

Chapter 1: Environmental Concepts

To preserve healthy conditions for wildlife, plants, and humans, it is important to protect the physical environment in which all living things exist. This environment consists of the air we breathe; the water we drink and bathe in, which supports the water-based organisms we depend on to maintain higher life on earth; and the soil beneath our feet. These are completely intertwined in a complex web called an ecosystem. Soil may become airborne dust and be breathed in. The plants that we eat or feed to our livestock depend on the soil, water, and air. Air, in turn, receives its life-giving oxygen from land and sea-based plants that use sunlight to convert carbon dioxide (CO₂).

It is essential that we all do what we can to avoid disturbing ecosystem balance any more than we must. It is helpful to remember that while the situation may eventually rebalance, the swings can be unpleasant. A few hundred years ago, overcrowding and poor sanitation led to a population explosion of rats. The rats had fleas that transmitted the bubonic plague to humans. Overcrowding eased and balance was restored, but at a cost of one-third of Europe's human population. It is hard to predict the eventual effects of a substantial change in the balance of any large ecosystem.

AIR QUALITY

For the most part, golf courses have a positive impact on air quality, compared with most other urban uses. The air-purifying actions of healthy turf and plant life are offset only by impacts such as the limited air pollution of the landscape maintenance machinery, increased traffic, and the energy used to heat and cool the buildings and run the irrigation system.

Good design and proper maintenance practices can do much to minimize these effects; energy-efficient facilities can be designed, and engine-driven equipment can be kept properly tuned up and running at peak efficiency. Minimizing pesticide spray drift and solvent use, and carrying out educational efforts to remind golfers to keep their cars tuned up, can also reduce air pollution.

SOIL AND WATER QUALITY

There are several components to the issues of soil and water quality, but only a few are significant environmental concerns for golf courses. These concerns primarily relate to plant nutrients, pesticides, and the handling and disposal of waste materials.

NUTRIENTS

There are three major nutrient requirements for plants that are supplied by the addition of fertilizer: nitrogen (N), phosphorus (P), and potassium (K). While all are essential for plant growth and are normally present in

limited amounts in ground water and surface water, potassium, unlike nitrogen and phosphorus, is not normally considered an environmental problem.

Nitrates are a form of nitrogen of special concern to ground water. The federal standard for nitrate-nitrogen (NO₃-N) in drinking water is 10 parts per million (ppm). In Florida, the law considers most ground water to be potential drinking water and applies the standard to almost all ground water. Nitrates are often leached into ground water from animal wastes, septic tanks, sewage treatment plants, or the overapplication of fertilizers.

The environmental effect of contributing excess nutrients depends on the ecosystem. In many parts of Florida, where phosphate is naturally abundant in the rock and soil, algae and plant life in waterbodies are limited by the amount of nitrogen available. Too much nitrogen can lead to algal blooms, which can result in fish kills from a lack of oxygen in the water. Conversely, in the Everglades and much of south Florida, natural levels of phosphorus are very low, and it is the limiting nutrient in wetlands and surface waters. Excess phosphorus often leads to the growth of noxious aquatic plants and other damaging organisms.

For the golf course, nutrient problems are addressed by the development of proper nutrient management plans and the careful execution of those plans.

PESTICIDES

Pesticide use on golf courses may be the most publicly controversial topic of all when it comes to environmental issues. Pesticides differ in their mode of action, chemical properties, and the effects they exert on nontarget organisms such as pets, fish, and humans. Some pesticides are toxic to the bees needed for pollination, or affect birds, wildlife, fish, or other aquatic life in rivers, streams, and lakes. Some golfers or people living nearby may also be particularly sensitive to certain chemicals.

Pest control on a golf course should not begin with pesticides. The fundamental basis of an environmentally sound pest control program is a process called IPM. This focuses on the basics of identifying the pests, choosing pest-resistant varieties of grasses and other plants, enhancing the habitat for natural pest predators, scouting to determine pest populations and determining acceptable thresholds, and applying biological and other nontoxic alternatives to chemical pesticides whenever possible. Chemical pesticide applications are carefully chosen for effective and site-specific pest control that has a minimal effect on beneficial organisms and the environment, and to minimize the development of pesticide

resistance by varying the type of pesticide used so that resistant strains do not thrive.

Pesticides primarily enter our environment in three ways. Wind may move pesticides away from their target while being applied. This is called spray drift. They may also leach through the soil into ground water, or be carried in stormwater runoff to surface water. As with nutrients, proper management is the key to minimizing the adverse effects of pesticides on the environment. Many of the older, environmentally unacceptable pesticides were taken off the market decades ago. However, traces may still remain in the soil and ground water. A number of pesticides have been removed from the market more recently, and still others are undergoing review by state and federal agencies as this manual is being published.

The professional pesticide applicators on golf courses are licensed by the state only after receiving specialized training and passing state-administered examinations. In addition, they must obtain additional continuing education credits in order to renew their license every four years. This continuing education ensures that those responsible for pesticide applications on golf courses are aware of the least toxic and most environmentally sound methods of pest control.

WASTES

The disposal of waste products on golf courses presents the same sort of problems as it does throughout our society. The improper disposal of wastes can pollute soil and water, fill up landfills, and create nuisance odors and unsightly areas.

Grass clippings and other plant material can be composted and used in gardens and other landscaped areas around the course, or provided to homeowners. As at any office or home, paper, cans, glass, and many other materials can be recycled.

Mixing pesticides and cleaning equipment of residual material must be handled properly in accordance with the pesticide label. Usually, the best way is to place the diluted washwater back into the sprayer and apply it as a weak pesticide to an appropriate site.

Solvents, oils, and other regulated or hazardous wastes must be properly disposed of by recycling or by transport by a licensed transporter to an appropriate facility. In most cases, the amount of hazardous waste can be greatly reduced through the use of alternative solvents or other practices.

A superintendent can save substantial money with an aggressive pollution prevention program. Again, the key factor in determining a facility's impact on the environment is the management of a golf course by its superintendent.

WILDLIFE HABITAT

The fragmentation, destruction, or elimination of wildlife habitat and wildlife corridors through the urbanization of both natural and agricultural areas has increased the need to preserve future urban green space for wildlife habitat. In today's modern urban world, where parks and green spaces are limited, few cities have had the foresight to place large tracts off limits to development; Chicago's Grant Park, Savannah's historic squares, or New York's Central Park are examples of these large, undeveloped areas. In many of Florida's fast-growing cities, golf courses are some of the few sources of open green space. They are increasingly being recognized for their potential to provide valuable wildlife habitat. Unfortunately, the public perception of this benefit is limited.

It has been shown that most golf courses are capable of providing significant, high-quality habitat to a large and diverse population of birds, mammals, and other wildlife. Until a few years ago, when dramatic urban expansion resulted in fragmented and altered critical wildlife habitat that closed off valuable wildlife corridors, endangered wild Florida panthers were often seen in the early morning at Hole-in-the-Wall and Wilderness golf courses in Naples. Bald eagles were nesting within a hundred yards or so of the maintenance area on one course in southwest Florida until a storm took down their nesting tree. The eagles have since moved a few hundred yards away to a wooded area between fairways.

By maintaining most of the nonplay areas in varied types of native vegetation; leaving dead trees (snags) where they do not pose a hazard; winding natural areas through the course to provide movement corridors with shelter, concealment, and food; providing native shoreline and aquatic plants where play is not affected; using sound IPM, fertilization, and cultural maintenance practices; and providing nesting boxes and selecting food and cover plants for butterflies and hummingbirds, the modern golf course can truly become an urban wildlife sanctuary. Even endangered and threatened species can usually coexist if proper care is taken to avoid disturbing nesting places and dens, and if adequate food and protection from predators are provided.

WATER CONSERVATION

Potable water supplies in Florida are limited and demand continues to grow. Our challenge is to find solutions to maintain the quality of golf while using less water. BMPs and educational programs are necessary to change the public's mind-set toward the inevitable changes in water-related issues. This requires all of us to shift our thinking and develop new habits.

There are many ways to conserve water on a golf course. Ideally, only the play and practice areas should be irrigated under normal conditions. Selecting drought-tolerant

varieties of turfgrasses can help maintain an attractive and high-quality playing surface, while minimizing water use. Nonplay areas may be planted with drought-resistant native or other well-adapted, noninvasive plants that provide an attractive and low-maintenance landscape. Native plant species are important in providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation. New courses are being designed using a “target golf” concept that minimizes the acreage of irrigated turf. Existing golf courses can make an effort to convert out-of-play areas from irrigated, mowed turf to native plants and grasses to reduce water use and augment the site’s aesthetic appeal.

A well-designed irrigation system that is maintained at peak efficiency helps to ensure that the water used is not wasted. The system should be operated to provide only the water that is actually needed by the plants, or to meet occasional special needs such as salt removal. Modern irrigation systems that are computer controlled with weather stations, automatic rain- and soil moisture-sensing controls, and multiple zones can water different areas accordingly. This allows specific areas on a

course that were missed by a passing storm to be irrigated, while suspending irrigation in areas that don’t need additional water.

The source of irrigation water can also significantly reduce water use. Some sources provide lower-quality water for irrigation to conserve the dwindling potable water supply. If properly designed, rain and runoff captured in water hazards and stormwater ponds may provide most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during severe drought. Other golf courses may be located where nonpotable reuse water from a wastewater treatment plant is available. Such water is highly treated and safe to use for irrigation. In some coastal areas, nonpotable, brackish water is being successfully used for golf course irrigation. This requires the selection of salt-tolerant grasses such as seashore paspalum (*Paspalum vaginatum*) and the use of drought- and salt-tolerant plants in nonplay areas. Horizontal wells are another potential alternative water source. They are very site specific but can tap into surficial ground water sources, avoiding the use of traditional aquifers and deep wells.

Chapter 2: Environmental Monitoring

Every golf course should have a plan to monitor the state of the environment and the effects the golf course may be having on the environment, for better or for worse. Monitoring is the method used to determine if outside events are changing the water quality entering the golf course, or if the golf course is having a positive, neutral, or negative effect on water quality. It also provides a body of evidence to disprove allegations that the golf course is responsible for environmental changes for which it is not responsible. It should be noted that a single sample is rarely meaningful in isolation and that most sampling results should be reviewed as trends over time.

QUALITY ASSURANCE/QUALITY CONTROL

The purpose of quality assurance/quality control (QA/QC) is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable, and are collected and analyzed using scientifically sound procedures. To this end, Subsection 62-160.110, Florida Administrative Code (F.A.C.), defines FDEP's minimum field and laboratory quality assurance, methodological, and reporting requirements. **This rule applies to all programs, projects, studies, or other activities that are required by FDEP, and that involve the measurement, use, or submission of environmental data or reports to FDEP.**

However, even if the data are only for proprietary use and are not reported to any regulatory agency, it is strongly recommended that a certified laboratory be used and all QA/QC procedures followed. Golf course management must have good data to make good decisions, and if a golf course should ever want to produce data for an agency or in court to defend the facility from unwarranted charges, those data must meet QA/QC standards to be defensible as evidence.

The National Environmental Laboratory Accreditation Conference (NELAC) is a voluntary association of state and federal agencies with input from the private sector. NELAC's purpose is to establish and promote mutually acceptable performance standards for the operation of environmental laboratories. The EPA's National

Environmental Laboratory Accreditation Program (NELAP) office provides support to NELAC and evaluates the accrediting authority programs. In Florida, the Florida Department of Health (FDOH) provides NELAP environmental laboratory certification. More information and a list of certified laboratories are available at <http://www.dep.state.fl.us/labs/default.htm>.

PREDEVELOPMENT MONITORING

As soon as possible in the development process, preconstruction monitoring should begin, in order to establish a baseline to compare against future monitoring results. Water quality samples for the predevelopment background (baseline) study should be taken at the following locations:

- Upstream and downstream of the golf course development on adjacent major rivers, streams, or lakes, if present,
- Flowing tributaries, wetlands, and water features draining golf course development, if present,
- Any additional sites selected prior to development, and
- At upgradient and downgradient wells, as suggested by the hydrogeologist or regulatory agency.

Four rounds of samples should be taken about three months apart, so as to cover the seasonal weather patterns for an entire year. At a minimum, at least one wet season and one dry season set of samples should be taken.

Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by FDEP's Total Maximum Daily Load [TMDL] Program). Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments and suspended solids, dissolved oxygen (DO), heavy metals, and any pesticides expected to be used on the golf course. A stream or lake biodiversity analysis should also be run to characterize the predevelopment condition and every five years thereafter.

WHAT DO I SAMPLE FOR?

Physical Parameters:	Alkalinity, Conductivity, Dissolved Oxygen (DO), pH, Turbidity or Secchi depth, and Temperature
Chemical Parameters:	Chlorides (Cl) Nitrogen: Total Nitrogen (TN), Nitrate + Nitrite (NO ₃ + NO ₂), Ammonia (NH ₃), and Total Kjeldahl Nitrogen (TKN) Phosphorus: Total Phosphorus (TP) and Orthophosphate (PO ₄) Total Solids (TS) and Total Suspended Solids (TSS) Heavy Metals: Copper (Cu), Lead (Pb), and other heavy metals of concern Pesticides used or known to be used upstream
Biological Parameters:	Biodiversity Index

MONITORING DURING CONSTRUCTION

Construction site monitoring should focus on sedimentation and erosion discharges. Turbidity and suspended solids are the primary parameters at this stage. Most important are carrying out frequent visual inspections of erosion and sedimentation control BMPs on the construction site, and ensuring that the contractor makes prompt and correct repairs.

POSTCONSTRUCTION OPERATIONAL MONITORING

A water quality monitoring plan should be prepared to ensure the ongoing protection of ground water and surface water quality after construction is completed. The same sites should be monitored as during the preconstruction phase, although the monitoring plan can be modified based on site-specific conditions. The plan should include the following:

- Postconstruction surface water quality sampling should begin with the installation and maintenance of golf course turf and landscaping. Samples should be collected a minimum of three times per year, with one

sampling event scheduled during July (the beginning of the wet season), a second sampling event scheduled during October (the end of the wet season), and a third sampling event scheduled during February through May (the dry season). Should there be no discharge on the scheduled sample date, samples should be taken during the next discharge event.

- Postconstruction surface water quality sampling 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. 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.
- Sampling parameters should be determined based on golf course operation and any basin-specific parameters of concern (identified by the TMDL Program or local regulators).

ENVIRONMENTAL CONSIDERATIONS

For almost any site, local environmental issues and conditions will need to be addressed. Therefore, the careful evaluation of design criteria and proper routing/siting of golf amenities are essential during the planning process. Developers, designers, and others involved in golf course development are encouraged to work closely with local community groups and regulatory/permitting agencies during planning and siting, and throughout the development process³. Early input from these groups and agencies is very important to the development and approval process.

There are four key steps to designing, building, and operating an environmentally responsible golf course. While the following steps are very general, each is subsequently broken down into more detail as a project proceeds:

1. Consider the property and its surroundings in relationship to the local watershed and ecological community.
2. Identify biologic, agronomic, hydrogeologic, and topographic resources and features. Determine areas that merit special protection.
3. Identify those management practices that will protect environmental resources during the construction

phase and later during golf course operation. Create a natural resources management plan.

4. Implement an environmental monitoring program. This establishes a baseline for conditions when the project started and provides an early warning of potential problems that may arise, before they become serious or expensive to address. It also may defuse potential controversy later on, if problems should occur, by demonstrating the good stewardship provided by the golf course.

The design of a course should be based on the information gathered in the first three steps listed above. A good design flows in harmony with the landscape. The course should be designed and routed to preserve and enhance wildlife habitat, and the design should be environmentally proactive, with creative design used to enhance ecological sensitivity and biodiversity.

Experienced professionals should conduct the site analysis and feasibility study. They should carefully review Florida's spring watershed areas, which require additional design and BMP measures, in addition to those described below. The identification of environmentally sensitive areas and other natural resources is important, so that a design can be achieved that carefully balances environmental factors, playability, and aesthetics. From a water

DESIGN AND CONSTRUCTION BMPS

- Locate the course so that critical wildlife habitat is conserved and the development does not adversely affect viable, occupied wildlife habitat on the site.
- Identify regional wildlife corridors and configure the course to maintain and/or enhance native habitat to facilitate the use of these corridors. Any existing or proposed crossings of wildlife corridors associated with golf course operations and maintenance should be minimized, and unavoidable crossings should be designed to accommodate wildlife movement.
- Design the course to minimize the need to alter or remove existing native landscapes. The routing should identify the areas that provide opportunities for restoration.
- Design the course to retain as much natural vegetation as possible and to enhance existing vegetation through the supplemental planting of native trees, shrubs, and herbaceous vegetation next to long fairways and in out-of-play areas, and along watercourses supporting fish and other water-dependent species.
- Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance and invasive exotic plants should be removed and replaced with native species that are adapted to that particular site.
- Retain a qualified golf course superintendent/project manager early in the design and construction process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.
- Use only qualified contractors who are experienced in the special requirements of golf course construction.
- Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.
- Schedule construction and turf establishment to allow for the most efficient progress of the work, while optimizing environmental conservation and resource management.

³ Center for Resource Management, 1996.

resource standpoint, this involves protecting both ground water and surface water, and limiting the use of scarce potable water supplies for irrigation. Golf courses located in the primary or secondary protection zones of springs must take extra care to avoid leaching and should create special management zones adjacent to sinkholes or surface waters.

Although many operational and maintenance BMPs do not come into play until a golf course is fully operational, considering these BMPs up front, including the IPM program, allows the designer to get it right the first time and reduces later costs, while maximizing both environmental and financial returns. Developing comprehensive BMP and IPM plans ensures that maintenance facilities—especially chemical storage and handling areas, equipment cleaning and maintenance areas, and fueling areas—are designed with their specialized needs in mind.

Finally, the design of a golf course is only as good as the construction that makes it a reality⁴.

SITE SELECTION AND DESIGN

The site selection for a golf course and subsequent routing plan largely determine the course's environmental compatibility within the community. The involvement of a golf course architect, land use specialists, water resource managers, and geotechnical professionals is critical in selecting a site and a routing that provide environmental benefits.

Identifying the resources at a site is necessary to understand how to design the course and surrounding development, to understand the long-term maintenance pro-

cedures and associated operational costs to be incurred, and to know how best to protect the site's environmental resources.

WETLANDS

Florida law protects wetlands as waters of the state. Wetlands act both as filters for pollutant removal and as nurseries for many species in Florida. Many people do not realize the vital role they play in purifying surface waters. What fewer people realize is that wetlands are the spawning grounds and nurseries for hundreds of species of birds, insects, and many fish, shrimp, and other species important to the seafood industry. The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem.

While wetlands do pose a special concern, their mere presence is not incompatible with the game of golf. With care, many fine courses have been threaded through sensitive areas, and with proper design and management can be an acceptable neighbor. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

That said, it is usually better to avoid wetlands construction if practical. Permitting requirements can be daunting, with multiple overlapping jurisdiction of federal, state, and local agencies. At the federal level alone, the U.S. Army Corps of Engineers (USACE), EPA, FWS, National Oceanic and Atmospheric Administration (NOAA), and maritime agencies may all be involved.

IMPORTANT STEPS IN SITE SELECTION

- Topographical land maps are essential before beginning any type of design activity for a golf course. A qualified designer attempts to work with the existing landscape as much as possible, if only to reduce the costs of earthmoving and fill dirt. In addition, special conditions such as karst soil may require extra effort to avoid sinkholes, springs, and ground water contamination. Wetlands and other low-lying areas may also require special attention.
- It is essential to know the soil types that are present, in order to project costs accurately and protect the environment. Deep sands may require more fertilization and watering, and pose a high risk for leaching. Heavy soils may not drain well, may be more subject to erosion, and may create runoff into nearby waters. The types of soils present significantly affect the expense of golf course construction, especially if large quantities of topsoil must be trucked in to provide proper agronomic properties for turfgrass. As mentioned earlier, long-term maintenance costs also depend on the quality of the soils present on the site.
- Studies of water supplies are needed for irrigation systems, and studies of waterbodies or flows on, near, and under the property are needed to properly design a course's stormwater systems and water features, and to protect water resources.
- A preliminary site assessment should be conducted to identify critical habitat, natural features, wildlife corridors, environmentally sensitive areas, federal and state endangered and threatened species, and state species of special concern. Wildlife habitat conservation should play a crucial role in site analysis and selection. The site design should include the preservation of these areas.

⁴ Center for Resource Management, 1996.

DRAINAGE BMPS

- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling.
- Internal golf course drains should not drain directly into an open waterbody, but should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.

Add to this state and local agencies, and nongovernmental environmental or other citizen groups, and you can see why wetlands are usually approached with caution.

If you are considering construction along wetlands, contact your local government and/or local FDEP or water management district office before drawing up engineering plans. Staff in these agencies can give an early indication as to what may, or may not, be permitted and may be able to point out alternatives that save money and speed up the review process. Remember, most obstacles are easily avoided with enough notice.

DRAINAGE

Adequate drainage is necessary for growing healthy grass. In Florida, where 4-inch-per-hour rains are common in the summer and fall, artificial drainage may be necessary. A qualified golf course architect, working in conjunction with a stormwater engineer, reviews soils and site conditions to develop an effective stormwater management system that complies with the requirements of the water management district or other permitting agency.

A quality BMP plan for drainage addresses the containment of runoff, adequate buffer zones, and filtration techniques in the design and construction process to achieve acceptable water quality. Swales and other parts of the system must be properly maintained. Debris and unwanted plant growth can build up and clog the system, so that the required volume of water cannot be moved as designed. This may result in saturated soils, leading to oxygen deprivation in the root zone and upstream flooding.

STORMWATER, STORMWATER PONDS, LAKES, SPRINGS, AND WATER HAZARDS

Stormwater is the conveying force behind what is called nonpoint source pollution. Nonpoint pollution, which is both natural and human-created, comes not from a pipe out of a factory or sewage treatment plant, but from daily activity. Pollutants commonly found in stormwater include the microscopic wear products of brake linings and tires; oil; shingle particles washed off roofs; soap, dirt and worn paint particles from car washing; leaves and grass clippings; pet and wildlife wastes; lawn, commercial, and agricultural fertilizers; and pesticides.

Stormwater pollutants may be dissolved in the water or carried as fine particles, called suspended solids. These solids may be fine soil particles, organic material, or other kinds of particles, but all may have other chemical pollutants attached to them. One kind of stormwater treatment involves separating out these particles. Other types of treatment include biological or chemical processes, which are often used to remove dissolved materials such as pesticides or nutrients.

The control of stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance, and play areas. In addition to controlling the amount and rate of water leaving the course, it also involves storing irrigation water, controlling erosion and sediment, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns. Keep in mind that not all stormwater on a golf course originates there; some may be from adjoining lands, including residential or commercial developments.

Most golf courses in Florida plan their lakes and water hazards to be a part of the stormwater control and treatment system. This usually works out well for all concerned. However, natural waters of the state cannot be considered treatment systems and must be protected. Lakes and ponds may also be used as a source of irrigation water.

It is important to consider these functions when designing and constructing the ponds. Peninsular projections and long, narrow fingers may prevent mixing. Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation. Swales and slight berms around the water's edge, along with buffer strips, can greatly reduce the nutrients and contamination that can affect water quality. Careful design may significantly reduce future operating expenses for lake and aquatic plant management.

Stormwater Treatment Train

Stormwater treatment is best accomplished by a "treatment train" approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. For example, stormwater can be directed across a vegetated filter strip

(such as turfgrass), through a swale (Figure 3), into a wet detention pond, and then out through another swale to a constructed wetland system.



Figure 3: Swale.

Source Controls

Source controls are the first car on the BMP treatment train. They help to prevent the generation of stormwater or introduction of pollutants into stormwater. The most effective method of stormwater treatment is not to generate stormwater in the first place, or to remove it as it is generated. There are several options for accomplishing this. The most important is eliminating as much directly connected impervious area (DCIA) as possible. DCIA is any area of impervious surface that drains directly to a waterbody without treatment—for example, a roof that drains to a parking lot, down a road, and into a ditch leading to a stream.

Sedimentation Control

During construction, temporary barriers and traps must be used to prevent sediments from being washed off-site into waterbodies. **Wherever possible, keep a vegetative cover on the site until it is actually ready for construction, and then plant, sod, or otherwise cover it as soon as possible to prevent erosion.**

Golf course designers and developers should be familiar with the *State of Florida Erosion and Sediment Control Designer and Reviewer Manual*, available from FDEP or FDOT. All superintendents overseeing construction, and all construction contractors, should take the FDEP Stormwater, Erosion, and Sedimentation Control Inspector Training course. This two-day class follows the curriculum provided in the *Florida Stormwater, Erosion, and Sedimentation Control Inspector's Manual*. See the FDEP Web site (available: <http://www.dep.state.fl.us/water/nonpoint/erosion.htm>) for more information or to find a class near you.

Once construction is completed, permanent barriers and traps can be used to control sediments. For example, depressed landscape islands in parking lots 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 “first flush” and settle out sediments, while allowing the overflow to drain away.

Water Quality Buffers

Buffers around the shore of a waterbody or other sensitive areas filter and purify runoff as it passes across the buffer (Figure 4). Ideally, **plant buffers with native species provide a triple play** of water quality benefits, pleasing aesthetics, and habitat and food sources for wildlife. As discussed above, it is important to continue these plantings into the water to provide emergent vegetation for aquatic life, even if the pond is not used for stormwater treatment. Effective BMPs in these areas include site-specific natural/organic fertilization and limits on pesticide use, primarily focusing on the control of invasive species.

A measure of protection can be achieved by instituting Special Management Zones around waterbodies. In managed areas around a golf course, the first 25 feet landward is a No Spray Zone (no pesticides used), and from 25 to 50 feet landward is a Limited Spray Zone (selected pesticide use, based on a risk assessment protective of aquatic life).

STORMWATER SOURCE CONTROL BMPs

- Ensure that no discharges from pipes go directly to water.
- Eliminate or minimize DCIA.
- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- 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 away.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.
- 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.



Figure 4: Shoreline buffer.

The No Spray Zones and buffers occupy the same space. It is important to note, however, that Limited Spray Zones and a policy of “no direct discharge” provide advantages to all wildlife by maintaining water quality. All other efforts are completely wasted if water quality is not sufficient for wildlife use. Some species, especially aquatic animals that cannot move large distances, are extremely sensitive to even trace amounts of standard fertilizers and pesticides. It is critical to have a design that incorporates protective measures to maintain water quality.

The only downside to native vegetation buffers usually concerns the play of the golf game. Sometimes a waterbody is situated such that a native buffer would take up too much space, obstruct the view, or otherwise interfere with the play of the game. In this case, a grass buffer may be used. A 25-foot buffer of turf mowed at 3 inches and only minimally fertilized with slow-release or organic-based products provides an effective buffer from a water quality standpoint, although many of the wildlife benefits are lost. Pesticides should be applied by spot treatment only, as needed.

Springs, Spring Runs, and Wet Sinks

Establish and maintain a 100 foot riparian buffer around wet sinks, springs, and spring runs.

Retention Versus Detention Ponds

Retention facilities are designed to hold all or most of the runoff from a storm event until it evaporates or soaks into the ground. Detention facilities absorb the inrush of water during a storm but release it slowly downstream. The characteristics of retention and detention facilities are as follows:

- Retention facilities allow the water to percolate through the soil into ground water. This traps most of the pollutants in the soil where they can be biologically degraded over time. They are usually designed to trap the first flush of 0.5 to 1 inch of rain and allow additional flow to bypass to another system. In many drainage watersheds, this first flush washes most of the pollutants off the surface and may carry 90% or more of the pollutants from even a large storm. These “offline” retention systems can approach 100% pollutant removal efficiency but take up a lot of space and are dry most of the year.
- Wet detention facilities are similar, in that they slow the rate of water discharge to provide flood control, but are designed to have water in them at all times. These areas are biologically active ponds that allow solids to settle. A wet detention pond should have at least 30% of its area as a shallow littoral zone; this is where much of the biological activity takes place. A properly designed and maintained wet detention pond can attain efficiencies of up to 90% solids removal, 40% nitrogen removal, and 65% phosphorus removal.
- Dry detention systems, which may be dry when they are not being used, are used primarily for flood control. Dry detention provides little water quality treatment, other than the settling of 20% to 60% of suspended solids. Nutrient removal is generally 20% or less.

Littoral Shelf Planting

The planting of littoral shelves is critical to the performance of a wet detention system. The mix of species selected must be suited to the design of the shelves and



Figure 5: Littoral zone on a south Florida golf course.

pond, depth and quality of the water, and local climate. An experienced professional should be retained to work with the engineer in designing these areas. The locations of littoral zones must be carefully planned to prevent problems with the playability and maintainability of a water hazard. In general, littoral shelves should be concentrated at a pond's inlets and outlets.

In addition to initial construction, it may be appropriate to incorporate functional littoral zones when a golf course or lake system is redesigned. Littoral zone areas should gradually slope. A minimum slope of 10-foot horizontal to 1-foot vertical is recommended. Planting on slopes less than 6-foot horizontal to 1-foot vertical may not be as successful over the long term. On the other hand, these slopes should not be perfectly graded. Random small dips and ridges of a few inches to a foot or so promote diversity within the plant community and provide a healthier and more productive littoral zone. Figure 5 shows the littoral zone on a south Florida golf course, and Figure 6 shows a cross-section of a littoral shelf.

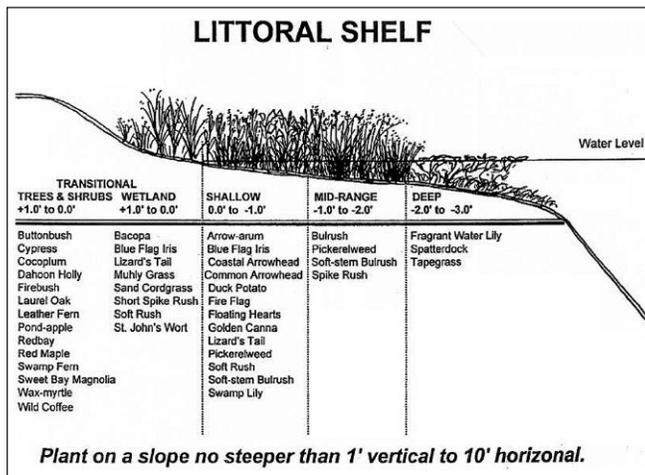


Figure 6: Cross-section of a littoral shelf.

Habitat for Aquatic Life

All or most of the out-of-play waterbodies should have shoreline buffers planted with native or well-adapted,

noninvasive vegetation to provide food and shelter for wildlife. These buffer areas not only protect water quality but provide very important habitat for many wildlife species. Birds, mammals, frogs, fish, and turtles spend some or all of their life cycles in or around the water. Many species depend on this habitat for breeding, foraging, hunting, fishing, and other essential activities. In addition to serving as habitat, shoreline buffers can also serve as wildlife corridors that connect different ecosystems and allow the movement of species with larger territories. Shoreline buffers should be coordinated with littoral shelf planting to provide as natural a habitat as possible for wildlife, with plenty of emergent vegetation in shallow areas.

PLAY AREAS

Up to 400 rounds of golf per day may be played at many courses at certain times of the year, and some public courses record up to 100,000 rounds of golf played in a year. Therefore, the sizing and placement of major playing areas should be carefully evaluated to ensure adequate wear patterns. Turf grown in the proper agronomic environment requires less-intense maintenance and fewer pesticide applications.

Greens

Greens typically occupy only about 2% of the total course area but account for about 40% of the strokes scored. Golf greens in Florida typically receive heavy use throughout the year. Careful design and very intensive turf management are required to maintain a good putting surface under these conditions. The nature of the game calls for very short mowing, usually daily, which also limits the size of the root system. As a result, frequent watering and fertilizing are necessary. This high-stress environment also makes the turf more susceptible to pests.

No procedure or method of greens construction provides an absolute guarantee of success. Success depends on the quality of the materials used, the quality of the installation, and the quality of subsequent management.

STORMWATER BMPS

- Golf course stormwater management should include "natural systems engineering" or "soft engineering" approaches that maximize the use of natural systems to treat water.
- Ensure that no discharges from pipes go directly to water.
- Eliminate or minimize DCIA.
- Use a treatment train approach.
- Institute buffers and special management zones.

Location – Locating a putting surface is almost as much an art as a science. Many elements are important in providing the aesthetic background or challenging hole play that make any round of golf a success. The natural surroundings—such as a body of water, hillside, or depression—the overview of a scenic area, and the strategic use of natural hazards such as trees, in addition to adjacent golf holes, are all incorporated into the location, shape, and size of a green. Environmental and agronomic factors such as surrounding soils or severe slopes, trees, and waterbodies must also be considered, as well as housing developments, highways, and high-population areas.

Greens require full sunlight to maximize photosynthesis and to dry out after heavy precipitation. Shade may reduce the cooling effects of air flow across a green's surface. In addition, frost on shade-covered greens melts more slowly in shade and may increase the potential for cold damage in central and north Florida.

When planning a course, remember that the sun is lower on the horizon during the fall and winter months. Trees south and southwest of the greens cast longer shadows during these months and may cause problems.

Drainage – Being able to control soil moisture is a key factor in the success or failure of a green. Drainage and runoff from surrounding areas into the desired location of a green can be key to regulating internal water content. The placement of a green downward from a hillside location can create a problem. Surface water runoff from the higher surrounding ground should not flow over the green, and water flow from slopes should be intercepted and redirected away from the green.

The surface runoff and water from these drainage lines must be directed so that it does not cause environmental harm. This may be achieved by creating swales and buffer strips using nearby fairways, rough, and out-of-play areas before allowing the water to enter a water hazard or other part of the stormwater system. **This water should never be allowed to discharge directly into a wetland, stream, or other waterbody not meant to treat stormwater.**

Size – A golf green should be large enough to allow for the adequate selection of a hole location but not so large as to become a financial and/or agronomic maintenance burden. Smaller-sized greens readily show the effects of concentrated traffic, while larger ones may have increased maintenance costs. In general, golf greens range from 3,000 to more than 7,500 square feet in size.

Profile of the Green – There are many construction techniques for greens. Again, a qualified golf architect working with experienced agronomic professionals should determine the appropriate technique and meth-

ods for greens construction. No matter what method is used, developing a consistent profile throughout all the greens is important for a golf course's maintenance practices.

The USGA has developed the following two recommendations for greens construction that attempt to create a universal standard:

1. A 12-to-14-inch root-zone medium is overlaid on a 2-to-4-inch layer of coarse (“choker”) sand that covers a 4-inch layer of gravel.
2. A 12-to-14-inch root-zone medium is overlaid on a 4-inch gravel layer that is properly graded in relationship to the root-zone mix.

With both methods, tile lines are embedded in gravel to provide outfall drainage. These methods create a “perched” water table that does not move (or percolate) readily from the finer to coarser layer until the soil water content of the finer layer is at or near saturation. Many other methods used throughout Florida provide acceptable conditions when constructed properly. However, better results can be expected from greens where the principles outlined above are used.

A BMP plan must address both surficial and internal greens drainage. This water should not be directly discharged into wetlands, streams, or other waterbodies not meant to treat stormwater. As discussed earlier, water should be allowed to filter through swales or buffer strips before entering waterbodies.

Irrigation Installation – The putting surfaces of the greens are the most intensely managed areas on a golf course. Because the most frequent mowing, cultivation, fertilization, and pest management practices are performed on greens, the irrigation system should be designed and installed so that the putting surface, and the slopes and surrounds, can be watered independently. With standard single-head coverage around the greens, either the putting surface or surrounds is often watered unnecessarily, wasting water and promoting poor root structure and fungal growth. Figure 7 shows the use of part-circle heads that conserve water.

Soil Fumigation (Optional) – Fumigation controls most undesirable weeds, insects, and nematodes present in the root-zone mix. Those unfamiliar with soil fumigants should contract with a custom applicator in circumstances that may warrant the use of fumigants.

Planting – To ensure the quality of the grass on greens, use only certified grasses from an approved grower. To ensure the survival of newly planted sprigs, it is vitally important to provide irrigation throughout the entire planting operation. Greens are typically planted using

BMPs FOR DESIGNING AND MANAGING GREENS

- The placement of bunkers and the shaping of contours surrounding a green should allow proper drainage and provide for the treatment and absorption of runoff from the green.
- Play should be spread around the green to prevent concentrated traffic in any one area. This helps to prevent turf stress and the additional use of fertilizers or pesticides.
- Adequate space should be provided around the greens, so that maintenance practices can be efficiently carried out.

sprigs but can be sodded. When sodding, ensure that the sod is grown on a similar root-zone profile to avoid the layering of soil types.

Collars – Collars have similar traffic and receive similar maintenance procedures as greens. Experience shows that constructing collars with root-zone characteristics similar to those of greens minimizes the problems encountered in maintaining these areas.

Tees

Like greens, teeing grounds receive heavy wear and tear from traffic and mowing patterns. Similarly, elements such as shade, soil, and surface drainage require careful design and placement to ensure quality turf and ease of maintenance.



Figure 7: Part-circle irrigation heads on tee conserve water.

Florida BMPs for teeing grounds ensure, at a minimum, well-drained soils graded to provide 1% fall to the rear or side of the tee as conditions warrant. Irrigation in these areas can be more site specific, and many courses are planting slopes and surrounds with native and/or ornamental grasses to reduce maintenance and long-term water requirements. The use of other grasses than bermudagrass, such as zoysia and seashore paspalums, is site specific based on design criteria.

Plant Selection: Sunlight, Shade, and Air Circulation

The fundamental principle for the environmentally

sound management of landscapes is **Right Plant, Right Place**. The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall and light patterns, insects and other pests, and endemic nutrient levels over thousands of years. As humans, we often have a need to change the natural landscape for living, working, and recreation. When we do so, our challenge becomes to use the most suitable plant materials for the new conditions that meet our design needs. The goal of the BMPs is to maintain as close to a natural ecosystem as practical, while meeting the needs of a golf course.

Bermuda and seashore paspalum grasses require full or nearly full sunlight. This is especially true on greens, where the grass is cut very short and the leaf area available for photosynthesis is minimal.

Under shaded conditions, turfgrasses have elongated leaf blades and stems as they attempt to obtain sunlight by outgrowing their neighbors. This reduces their overall health and vigor. Coverage is also reduced, and the bare ground that results is conducive to weed growth. It is generally not advisable to grow turfgrass in heavy shade. This is not usually a problem on the playing surfaces of a golf course but may be encountered in nonplay areas. Other ground covers or mulch can be used in these sites. For areas receiving moderate amounts of shade, however, certain species and cultivars are able to maintain suitable growth. Specific management practices discussed in the chapter on Cultural Practices can also encourage better turfgrass health under shaded conditions. Zoysiagrasses and, in some places, St. Augustinegrass, are good choices for partially shaded areas, although they also perform well in full sunlight.

Adequate air circulation is also important. A design in which “dead spots” are created, especially if also partially shaded, can lead to moisture problems and increased fungal or disease pressure. In these conditions, BMPs for tree pruning, understory removal, and irrigation management must be constantly reviewed.

Bunkers

A good BMP-designed golf course must focus significant

attention on bunker design and construction. Many questions must be addressed to build bunkers and bunker complexes that are successful over the long term.

Like greens, bunkers may or may not require subsurface drainage. When required, 4-inch perforated drain lines are typically installed in 8-inch-by-6-inch trenches and filled with appropriate gradation rock. A qualified golf architect determines patterns and placement to ensure that the drainage system is effective.

Bunker sand gradation and color are important considerations in the design process and should be carefully reviewed. New geotextile products are being used in heavy slope areas to minimize sand erosion, and some geotextiles are being used as separation blankets between subsurface conditions and bunker sand to avoid contamination.

A solid BMP plan addresses maintenance raking practices, entry/exit points for golfers and maintenance equipment, and any site-specific irrigation requirements that may be needed to prevent wind erosion under severe conditions. New bunker materials are being researched, such as recycled materials and limestone screenings.

Soil Amendments

Traditionally, USGA putting greens have been built using mixtures of sand and peat. Sand is used in relatively high percentages to enhance percolation rates, but high percolation rates can lead to the leaching of applied nutrients and contamination of subsurface water supplies. In addition, sands typically retain relatively small amounts of available water; thus they have low water use efficiency (WUE).

WUE is defined as the quantity of dry matter produced per unit of water applied. The addition of clays, silt, or organic matter increases cation exchange capacity (CEC) and helps to retain nutrients, but their addition may reduce the percolation rate and lead to long-term drainage problems.

Numerous other amendments have been proposed for use in putting green construction. These include clinoptilolite zeolites, polyacrylamides (PAMs), diatomaceous earths, calcined clays, porous ceramics, and iron humates. In-field tests suggest that the rankings for some of these amendments are as follows relative to their influence on soil-available water: iron humate > diatomaceous earths > calcined clays > peat > zeolites.

In recent studies, amendments with moderate levels of CEC and moderate levels of moisture retention (calcined clays and porous ceramics) produced the highest WUE. Amendments with a very high CEC but low moisture

retention (zeolites) and those with a very low CEC but high moisture retention (diatomaceous earths) produced lower WUE. All amendments, however, produced higher WUE levels than sand or sand-peat mixtures.

Iron humate has been shown to induce very high levels of WUE and significantly longer days to wilting when water is withheld than the other soil amendments listed above. An additional benefit to incorporating iron humate (2.5% V:V basis) in the root-zone mix for a USGA sand putting green is that phosphorus leaching is almost completely eliminated. No detectable levels of P were obtained in the leachate collected from a simulated USGA root-zone profile when iron humate was added as an amendment.

NONPLAY AREAS

As discussed earlier, one of the first steps in planning a golf course is to assess the site's general environment and ecology. Map any environmentally sensitive areas such as sinkholes, wetlands, or flood-prone areas, and identify federal and state endangered or threatened species, and state species of special concern. Whenever possible, habitats consisting of wetlands or other sensitive areas for wildlife should be preserved. Many difficulties associated with any development can be avoided by recognizing these issues in the beginning and managing them appropriately.

During the preconstruction process and after a course has been established, the amount of irrigated and maintained turfgrass should be looked at carefully to determine if it is functional. Many older golf courses and some new ones have more irrigated and maintained acres than are necessary. With the help of a golf course architect, golf professional, golf course superintendent, and other key personnel, the amount of functional turfgrass can be evaluated. Areas that are not in play or are not critical to the design of the course may be removed and replanted with native plant material that requires little to no maintenance after establishment. In fact, trees and shrubs may require more water than turfgrass during establishment, but once they are established, they may need very little maintenance if properly chosen and located.

It is considered a BMP for 50 to 70% of the nonplay areas to remain in natural cover. As much natural vegetation as possible should be retained and enhanced through the supplemental planting of native trees, shrubs, and herbaceous vegetation to provide wildlife habitat in nonplay areas, and along watercourses to support fish and other water-dependent species. By leaving dead trees (snags) where they do not pose a hazard, a well-developed understory (brush and young trees), and native grasses, the amount of work needed to prepare a course is reduced, while habitat for wildlife survival is maintained.

What the Florida Legislature has defined as Florida-friendly landscaping comprises nine principles. All are consistent with a well-designed and operated golf course, although the nonplay areas obviously offer the most opportunities for mulching and attracting wildlife.

NINE PRINCIPLES OF FLORIDA-FRIENDLY LANDSCAPING

1. Right Plant, Right Place.
2. Water Efficiently.
3. Fertilize Appropriately.
4. Mulch.
5. Attract Wildlife.
6. Manage Pests Responsibly.
7. Recycle.
8. Reduce Stormwater Runoff.
9. Protect the Waterfront.

Wildlife Habitat

It is important to preserve natural surroundings when developing a course. It is easier to manage wildlife if existing natural conditions and wildlife habitats are preserved. When areas that have been disturbed are replanted, native trees, shrubs, and grasses should be used when possible. Avoid exotic species, particularly invasive plants, or plants that are not well adapted to the local environment. The primary wildlife will probably be small mammals and birds.

Natural cover around a course also serves as a buffer to reduce urban traffic noise and visual distractions, and filters pesticides and nutrients from runoff entering streams or ponds. A golf course design that incorporates areas of natural cover may be less expensive to maintain and construct.

Cover provides and promotes important areas in a golf course that are significant for all species. It is a natural part of wildlife habitat and encompasses almost all the factors that wildlife need for their welfare, including shelter from weather; places to nest, loaf, and feed; and concealment from predators or prey. Providing cover for wildlife is easy to accomplish by keeping natural 50 to 70% of the nonplaying course area. Brush piles, a stand of trees, snags, riparian areas, and roughs are considered cover for some species.

Birds – Providing adequate food all year is important in establishing a healthy bird population. Appropriate trees,

plants, and grass species can be planted, or preserved if they already exist. Foods can include various types of wild fruits, plants, herbs, and seeds, and a large variety of insects.

Many bird species thrive on insects, and it is important to maintain insect populations. Fortunately, insects flourish in most areas. One of the greatest threats to insects is the application of broad-spectrum chemicals applied to a course to control specific pests. With the proper use of IPM on a wildlife-friendly course, insect populations should be adequate.

Nesting areas are important for maintaining healthy bird populations. Whenever possible, leave dead tree snags as long as they do not pose a hazard. Snags provide nesting cavities for many birds and are food sources for woodpeckers and other species that eat insects in the bark. Birdhouses and nesting boxes can be placed around a course near areas of appropriate cover and food supply. It is often possible to get members and their families interested in building and maintaining these nesting boxes at little or no cost to the golf course.

Animals – Most four-footed wildlife consists of small mammals, such as squirrels, rabbits, and opossums. These animals need concealment from predators and adequate food supplies. Small brush piles can provide cover. Food sources include nuts, berries, and grubs. Corridors should be provided when possible to allow animals to move from place to place without being exposed to predators. Therefore, perimeter fences or walls should not be installed so that wide-ranging small and large animals can traverse the site. If walls are built, they should provide a minimum clearance of 1 foot between the ground and the lowest portion of a fence or wall, except where it is necessary to exclude feral animals. The animals also need burrows and nesting/bedding places. Whenever possible, these areas should not be disturbed, especially while young are present.

Aquatic Life – A good source of uncontaminated water is important to terrestrial species and is imperative for aquatic species. Proper pesticide management and the use of water quality buffers and riparian zones are important factors in keeping the water clean. Riparian areas (streamside vegetation), which play a vital role in the terrestrial/aquatic communities, should be protected. These areas are transition zones between water and land. They provide cover and food, and also help maintain a healthy water source. Vegetation along the water's edge can stabilize surrounding soils, help in flood control, and filter sediments and chemicals that are being transferred into the system.

Assess the condition of water hazards and ponds by measuring temperature, DO, pH, conductivity, water hardness, and phosphorus and nitrogen concentrations. In addi-

tion, samples of plankton, algae, rooted aquatic plants, and terrestrial plants should be taken and identified. Observations of fish, wildlife, and general pond condition should be recorded.

The overgrowth of aquatic plants or algae is aesthetically unappealing and may lower oxygen levels in the water. As with all plants, aquatic vegetation thrives on nitrogen and phosphorus. Use natural riparian buffers or unfertilized turf buffers to minimize the entry of excessive nutrients.

As with any ecosystem, ponds and lakes require a complete food chain from bacteria to fish. These organisms cycle nutrients, control pests, and enhance the aesthetic value of water. Fish can be added to control vegetation and mosquito populations, help to balance the food chain, or fulfill other purposes.

Forested Buffers

Protecting wildlife habitat on golf courses is especially important in urban environments where highly fragmented, forested areas often provide the best, and sometimes the only, habitat for many wildlife species. Forested buffers along golf course streams and wetland areas can provide large areas of key habitat and sanctuaries for birds and other wildlife, while protecting water quality. When riparian buffers connect isolated blocks of habitat, they also serve as important travel corridors for species that may not cross large, open areas.

Forest vegetation protects aquatic habitat in several important ways. Trees and shrubs along streams provide temperature moderation through shade, which lowers

water temperature in summer and increases it in winter. Shade can also reduce the growth of filamentous green algae and promote the production of diatoms, which are an important food source for aquatic macroinvertebrates. Fallen and submerged logs and the root systems of woody streamside vegetation provide cover for fish and invertebrates, while leaves, branches, limbs, fruits, and other types of forest detritus form the base of the aquatic food chain in headwater or low-order streams.

While many Florida golf courses may not be able to devote such space throughout the golf course, maintaining a 50- to 100-foot forested buffer along watercourses can provide suitable habitat for many wildlife species, including wood ducks, herons, kingfishers, songbirds, foxes, deer, raccoons, turtles, snakes, and salamanders. Smaller buffers may still protect water quality but provide fewer wildlife benefits.

Well-designed forested buffers should contain a mixture of fast- and slow-growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife. Proper design and the selection of appropriate vegetation ensures that these buffer areas do the following:

- Trap and remove upland sources of sediments, nutrients, and chemicals,
- Protect fish and wildlife by supplying food, cover, and shade, and
- Maintain a healthy riparian ecosystem and stable stream channel.

WILDLIFE MANAGEMENT BMPS

- Identify the different types of habitat specific to the site.
- Identify the habitat requirements (food, water, cover, space) for identified wildlife species.
- Identify federal and state threatened and endangered species, and state species of special concern inhabiting the site.
- Preserve critical habitat.
- Identify and preserve regional wildlife 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.
- Perimeter fences or walls, if required, should provide a minimum clearance of 1 foot between the ground and the lowest portion of a fence or wall, 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.

Gardens

Aesthetic gardens, window boxes, and container gardens should contain a variety of plants of different heights that provide nectar for hummingbirds and butterflies. Again, Right Plant, Right Place is the key to success.

Know the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for pruning and debris removal, and lowers maintenance costs. Adding proper soil amendments in garden areas can improve the soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost. Amendments are not usually recommended for trees.

The use of organic mulches in gardens and aesthetic areas increases the moisture-holding capacity of plantings and prevents weed growth when applied in sufficient depth. Organic amendments are decomposed by soil microorganisms and add to soil tilth. **Keep mulch 2 to 3 inches away from plants, to prevent fungal growth from excess dampness.**

Excess mulch or compacted mulch may be detrimental, causing water to shed away from the root zone and encouraging overwatering. **Compaction or excessive mulch buildup should be avoided**, especially when annual remulching is performed.

Aesthetic Turf

Turfgrass may be used for purely aesthetic reasons to provide a pleasing view around clubhouses, entries, and other areas. However, while it is perfectly acceptable to use turf in this fashion, remember that turfgrasses provide minimum wildlife benefits and require considerable maintenance. Use turf as a landscape element where needed, but do not think of it as a default filler material. Garden plants, shrubbery, ground covers, or native plants may provide just as pleasing a view and also provide useful food, cover, or other environmental benefits to wildlife; they may also require less maintenance.

The addition of proper soil amendments can improve soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost.

Aesthetic turf should be maintained in accordance with the practices described in the Florida Green Industries' manual, Best Management Practices for Protection of Water Resources in Florida (available: <http://www.dep.state.fl.us/water/nonpoint/pubs.htm> or http://fyn.ifas.ufl.edu/professionals/GI-BMP_publications.htm).

Plant Selection

As discussed earlier, the fundamental guide for the environmentally sound management of landscapes is **Right Plant, Right Place**. The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall and light patterns, insects and other pests, and endemic nutrient levels over hundreds or thousands of generations. Where these factors have changed, the challenge is find other suitable plants. A BMP goal is to maintain as close to a natural ecosystem as practical, while meeting the needs of the golf course.

MAINTENANCE FACILITIES

Maintenance facilities include areas for equipment fueling, washing, storage and repair; the superintendent's office; and areas for storing, mixing, and loading fertilizers and pesticides. Building codes may be more stringent for some of these facilities, so check with local building authorities.

Pesticide Facility

The pesticide facility is one of the most important buildings on a golf course. Few other functional spaces offer the potential for such expensive liability, either for chemical contamination of the environment or for exposure to golf course workers. Proper thought and care in the design, construction, and operation of this facility can greatly reduce liability exposure, while failure to do so can greatly increase the likelihood of costly governmental or civil liability.

Pesticide Storage – 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. Locate this building at least 50 feet from other structures (to allow fire department access and space for a water curtain to protect adjacent structures). Keep pesticides in a separate facility, or at least in a locked area separate from areas used to store other materials, especially fertilizers, feed, and seed. Do not store pesticides near burning materials, near hot work (welding, grinding), or in shop areas. Do not allow smoking in pesticide storage areas.

An eyewash station and emergency shower should be provided. Provide a space for a written pesticide inventory and the MSDS (Material Safety Data Sheet) files for the chemicals used in the operation on site. Do not store this information in the pesticide storage room itself, although copies may be kept there for convenience.

Be sure that an adequate supply of personal protective equipment (PPE) and other appropriate emergency response equipment is stored where it is easily accessible in an emergency. Do not store emergency supplies

only inside the pesticide storage area, since that may be inaccessible during an emergency. **PPE is designed for mixing and application activities, and may not provide adequate protection in an emergency.** Check labels and the MSDS sheets for the safety equipment requirements.

Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides to prevent cross-contamination and minimize the potential for misapplication. Always place dry materials above liquids, never liquids above dry materials.

Use shelving made of plastic or reinforced metal. Keep metal shelving painted (unless stainless steel) to avoid corrosion. Never use wood shelving, because it may absorb spilled pesticide materials.

Construct floors of seamless metal or concrete sealed with a chemical-resistant paint. For concrete, use a water to cement ratio no higher than 0.45:1 by weight, and leave a rough finish to provide adhesion for the sealant. Equip the floor with a continuous curb to retain spilled materials. While a properly sealed sump may be included to help recover spilled materials, do not include a drain. Provide sloped ramps at the entrance to allow handcarts to safely move material in and out of the storage area.

When designing the facility, keep in mind that temperature extremes during storage may reduce safety and affect pesticide efficacy. Provide appropriate exhaust ventilation and an emergency wash area. The emergency wash area should be located outside the storage building. Local fire and electrical codes may require explosion-proof lighting and fans. The light/fan switch should be located outside the building so that both are

on before people enter and until they have left the building.

BMPs for pesticide storage often address the ideal situation of newly constructed, permanent facilities. However, the user is encouraged to apply these principles and ideas to existing facilities, and to portable or temporary facilities that may be used on leased land where permanent structures are not practical.

Plans and specifications for pesticide storage buildings are available from several sources, including the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS), the Midwest Plan Service, and the University of Florida's Institute of Food and Agricultural Sciences (UF-IFAS) Publications Office. These publications also contain recommended management practices for pesticide storage facilities. The References section of this manual contains information on how to obtain these materials.

Locating Mixing and Loading Activities – Use extreme caution when handling concentrated chemicals. Spills could result in an expensive hazardous waste cleanup. It is important to understand how mixing and loading operations can pollute vulnerable ground water and surface water supplies if conducted improperly and at the wrong site. Locate operations well away from ground water wells and areas where runoff may carry spilled pesticides into surface waterbodies. If these areas cannot be avoided, protect wells by properly casing and capping them, and use berms to keep spills out of surface waters. Areas around public water supply wells should receive special consideration and may be designated as wellhead protection areas. Before mixing or loading pesticides in such areas, consult with state and

PESTICIDE STORAGE BMPS

- 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.
- 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 PPE where it is easily accessible in the event of an emergency, but not 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.

MIXING AND LOADING BMPS

- Locate operations well away from ground water 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 PPEs required by the pesticide label.
- Assess the level of training and supervision required by staff.
- Any material that collects on the pad must be applied as a pesticide or disposed of as a (potentially hazardous) waste.
- Clean up spills immediately!

local government officials to determine if special restrictions apply.

IMPORTANT: For your own safety, always use all PPEs required by the label.

Chemical Mixing Center Design – To minimize the risk of pesticides accumulating in the environment from repetitive spills, most golf course developers construct a permanent mixing and loading facility with an impermeable surface (such as sealed concrete) so that spills can be collected and managed.

A permanent mixing and loading facility, or chemical mixing center (CMC), is designed to provide a place where spill-prone activities can be performed over an impermeable surface that can be easily cleaned and permits the recovery of spilled materials. Where feasible, the facility should be close to the pesticide storage building to reduce the potential for accidents and spills when transferring pesticides to the mixing site. Do not build new facilities on potentially contaminated sites, since subsequent efforts to clean up previous contamination may mean relocating the CMC.

In its most basic form, a CMC consists of a concrete pad treated with a pesticide-resistant sealant and sloped to a liquid-tight sump where all of the spilled liquids can be recovered. When considering a CMC, it is important to assess the level of training and supervision required by the staff using the center, so that it is operated safely and responsibly. Even the best-designed facility cannot prevent environmental contamination if it is not properly managed.

It is crucial that a CMC facility be properly designed and constructed. Mistakes can be costly and can result in unintended environmental contamination. Several publi-

cations, listed in the References section, are available to explain design, construction, and operational guidelines for permanent mixing and loading facilities. These publications should be consulted before any facility is designed.

It is very important that wherever feasible, a CMC should be located away from wells or surface waterbodies and above floodplains. The first principle of CMC management is that any material that collects on the pad must be applied as a pesticide or disposed of as a (potentially hazardous) waste. Because any water, including rain, that collects on the pad must be used as a pesticide or disposed of as a (potentially hazardous) waste, an open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides to protect against windblown rainfall.

In constructing a concrete mixing and loading pad, it is critical that the concrete have a water-cement ratio no higher than 0.45:1 by weight. This is needed to minimize cracking and to ensure that the concrete does not fail in tension near the sealant-concrete interface. Superplasticizers and/or fly ash may be added to increase the workability of the mix, but additional water must not be added. The concrete should receive a light broom finish to provide adhesion for the sealant. The 1995 Midwest Plan Service publication, *Designing Facilities for Pesticide and Fertilizer Containment*, listed in the References section, contains full concrete specifications.

Materials other than concrete, such as steel or durable synthetics, may also be used in some cases. These materials are also used for portable CMCs where a permanent facility is not practicable.

The CMC sump should be small and easily accessible for cleaning. There must be a way to pump liquid in the

sump to a sprayer or to storage tanks. Immediate application in accordance with the label instructions is usually the preferred method of handling both spills and rinsate. If rinsate storage tanks are used, there should be at least one tank for each group of compatible pesticide types. This allows rinsate to be saved and used as makeup water the next time that type of material is applied.

Fertilizer Storage and Handling

The proper storage of fertilizer is an important BMP at a golf course. Take care when storing fertilizer to prevent the contamination of nearby ground water and surface water. Fertilizer bags are often damaged in handling, sometimes even before they reach the golf course. Any spillage exposed to rain threatens nearby ground water or surface water. In addition, fertilizers are often oxidizers and may pose a serious fire threat to a maintenance area, especially where fuels and other hydrocarbons are present.

FERTILIZER STORAGE AND HANDLING

- 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 fertilizer 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. Rule 62-762, F.A.C., addresses the secondary containment of stationary liquid fertilizer tanks larger than 550 gallons. Even where not required, secondary containment is a sound practice.
- Sweep up any spilled fertilizer immediately.

Equipment Wash Areas

The first rule of equipment washing is not to wash any equipment unnecessarily. Clean equipment over an impervious area and keep it swept clean to prevent rain from carrying pollutants off the pad. **Grass-covered equipment should be brushed or blown with compressed air before being washed.** Dry material is much easier to handle and store or dispose of than wet clippings. It is best to wash equipment with a bucket of water and a rag, using only a minimal amount of water to rinse the machine. Spring-operated shutoff nozzles should be used. Freely running hoses waste vast amounts of water, and water can harm the hydraulic seals on many machines.

While there are no state requirements for a closed recycling system for washwater, the use of a well-designed system may be considered a BMP (Figure 8). Some local

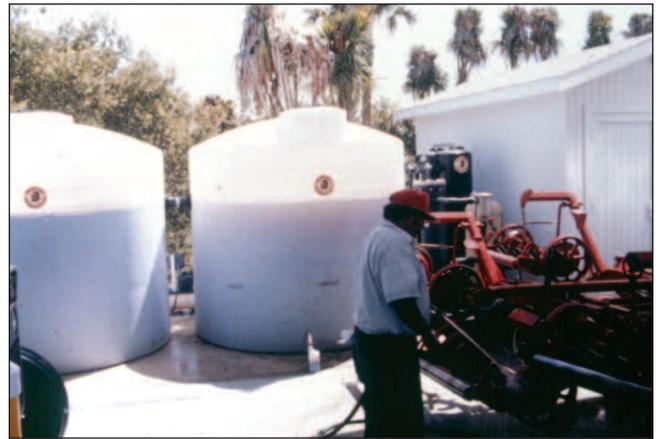


Figure 8: Recycling washdown system.

governments require such a system. The FDEP publication, *Guide to Best Management Practices for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment Wash Facilities*, provides more information on the design and operation of these facilities and the BMPs that may help you avoid the need for a permit (available: <http://www.dep.state.fl.us/water/wastewater/docs/GuideB MPClosed-LoopRecycleSystems.pdf>). A checklist for these practices is also available from FDEP (available: <http://www.dep.state.fl.us/water/wastewater/docs/ChecklistGuideClosed-LoopRecycleSystems.pdf>).

Be cautious in operating closed loop equipment where maintenance activities are involved, because the filters can concentrate traces of oils and metals that are washed off the engines and worn moving parts. In some cases, the concentrations of these substances can become high enough that the filters must be treated and disposed of as hazardous waste. Ask the recycling system manufacturer or sales representative, or your FDEP district office, for information about filter disposal. The contractor who handles oil filters, waste oil, and solvents can probably handle these filters, too.

EQUIPMENT WASH AREA BMPS

- 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 washwater and follow the FDEP BMPs.
- Recycle system filters and sludge should be treated and disposed of as hazardous waste.

Wash areas may be regulated as industrial waste facilities. Washwater systems with an overflow pipe must connect the overflow either to a sanitary sewer or to a specially designed and permitted treatment system such as a separate drainfield, or contain the discharge and have it hauled and disposed of by a licensed contractor. The overflow cannot discharge to the ground, a storm drain, or a surface waterbody. Normally, no Industrial Wastewater Permit is required as long as it can be shown that the facility is not discharging to the environment. If no permit is needed, the FDEP district sends a letter saying so. Such a letter can save a lot of expense and grief in the future, if FDEP or another agency receives a complaint because someone thinks you are operating illegally. Before designing and constructing the wash system, check with the local FDEP district office for specific rules in your area.

Fueling Areas

Design and manage fuel-dispensing areas to prevent soil and water contamination. Place fuel pumps on concrete or asphalt surfaces. Fuel pumps with automatic shutoff mechanisms reduce the potential for overflows and spills during fueling. Do not locate the pumps where a spill or leak would cause fuel to flow onto the ground, or into a storm drain or surface waterbody.

Stationary fuel storage tanks must be in compliance with FDEP storage tank regulations (Rule 62-761 or 62-762, F.A.C.). Call the nearest FDEP district office for information on these requirements. In general, underground tanks with volumes over 110 gallons and above-ground tanks with volumes over 550 gallons must be registered and located within secondary containment systems unless of double-wall construction. Local regulations may be more stringent.

While secondary containment is not usually required for smaller tanks, it is still a good practice. Also, a roof and containment for diesel engines are a good idea.

Where permitted by local fire codes, secondary containment structures should be roofed to keep out rainfall. Building a containment structure so that it is tall rather than wide helps to minimize rainfall accumulation by reducing the exposed surface area. If the structure is not roofed, water that accumulates must be managed properly. The best option is to remove the water with a portable sump pump, which ensures that the removal of water is actively managed.

If the containment structure has a discharge port (not recommended), make certain that it is closed and locked except when uncontaminated rainwater is to be drained. If a discharge port is used, a spring-loaded valve is the best way to prevent the port from being inadvertently left open. Only clean water may be discharged, to a grassy swale or other approved site. No discharge is permitted to a waterbody.

The first line of management is to minimize the possibility of a discharge and the need for disposal. For rainfall, if the containment volume is adequate, the evaporation of accumulated rainfall is often sufficient. Critical levels at which discharge is considered should be established for each facility and the levels marked on the containment wall. This prevents the frequent and unnecessary discharge of small volumes.

Equipment Repair Facilities

Many coolants, oils, and solvents are used in the equipment repair shop. These may harm water supplies and wildlife if improperly disposed of. For more information, see the FDEP publication, *A Guide on Hazardous Waste Management for Florida's Auto Repair and Paint and Body Shops* (available: http://www.dep.state.fl.us/waste/quick_topics/publications/shw/hazardous/business/Paint_and_Body8_09.pdf).

REPAIR FACILITY BMPS

- 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.

Hazardous Materials Areas

These areas should be clearly marked, have spill containment, and be secure from vandalism. Ensure that all containers are properly labeled and stored. See the FDEP Web site for current information. (available: <http://www.dep.state.fl.us/waste/categories/hazardous/pages/publications.htm>).

Parking Lots and Traffic Paths

Roadways associated with a golf course should be constructed with no curb and gutter, and vegetated swales should be used to direct water flow away from the roads. Also, no curb and gutter should be used around the clubhouse or other buildings. The pervious paving of parking lots can substantially decrease stormwater runoff from a site. This not only reduces nonpoint source pollution but also may save money by reducing the size and complexity of stormwater treatment facilities.

While some development codes require curb-and-gutter systems, it is strongly suggested that a variance or waiver be sought on the grounds of improved stormwater management and pollutant load reduction.

Various regions in Florida average between 47 and 68 inches of rainfall a year.⁵ However, there are significant seasonal variations in rainfall. Therefore, at certain times of the year rainfall is not adequate to sustain turf in a healthy enough condition to withstand the rigors of golf in Florida's subtropical weather and sandy soils.

Although golf courses use natural rainfall as the greater part of their annual water budget, irrigation with the lowest acceptable quality water is an important part of maintenance. To ensure efficient watering, courses require well-designed irrigation systems with precision scheduling based on soil infiltration rates, soil water-holding capacity, plant water use requirements, the depth of the root zone, and the desired level of turfgrass appearance and performance.

Florida's water management districts issue consumptive use permits (CUPs) or water use permits (WUPs) allowing golf courses to pump enough water to meet their annual needs from reclaimed sources, surface water, or aquifers. Permitted quantities vary by geographic location and soil type. For more specific information on water-related permits, contact your local water management district. A permitting information portal for all five districts is available at <http://flwaterpermits.com/pportal/>.

Soils contain a reservoir of water for plants. Water enters the plant through its roots, and then moves through the stem up to the leaves and then into the atmosphere through the leaf by a process termed transpiration. Transpiration serves several important functions. Water and nutrients are transported through the transpiration stream. The evaporation of water from the leaf surface results in evaporative cooling, thus moderating canopy temperature. This is important for maintaining plant cell metabolism. Humans have a similar process when perspiration evaporates and cools our bodies.

Evaporation is the flow, or loss, of water from the soil directly to the atmosphere. Collectively, evapotranspiration (ET) is the total water recycled back into the atmosphere by transpiration and evaporation. ET is largely controlled by solar radiation, humidity, wind velocity and temperature, and soil moisture content. Root system depth and cultural practices significantly affect the rate of ET.

WATER SOURCES

Developers of new golf courses should understand the reliability of water sources before construction to ensure that sufficient supplies are available for turf grow-in and survival. Course owners and developers should consider all alternative sources that are available. These include, and are not limited to, wells, existing surface water, stormwater runoff detention ponds, reclaimed water, brackish water, reverse osmosis, aquifer storage and recovery (ASR), and horizontal wells. The water management districts require that the lowest quality water appropriate to a use be considered first for water use permits.

Courses located along the state's coastal margins are likely to use reverse osmosis to remove chlorides (salts) from saline water sources, or to use brackish aquifers in conjunction with seashore paspalum turfgrass, which can be irrigated with saline water.

BRACKISH WATER

Brackish water is too salty for human consumption but not as salty as seawater. It may come from near-coastal surface waters, often tidally influenced; from shallow ground water affected by saltwater intrusion; or from very deep aquifers overlain by other freshwater aquifers. In using brackish water, special care must be taken with nonturf areas, which may be damaged by the saline content. The use of brackish water may also require the flushing of salts built up in the soil.

BMPS FOR BRACKISH WATER SUPPLIES

- Owners of courses using brackish, highly saline irrigation water should consider using varieties of seashore paspalum turf, which are more salt tolerant than bermudagrasses.
- With courses using high-saline or reclaimed water, the soil needs to be flushed regularly with fresh water to move salts out of the root zone and/or pump a higher volume of brackish water to keep salts moving out of the root zone. Ensure this is done before fertilization to prevent the leaching of recently applied nutrients.
- In some areas, it may not be desirable to use brackish water for irrigation. This is most likely to be true in an area with a shallow ground water table of fresh water, and brackish water in a deep well. In this case, the brackish water from the deep well may raise the salinity of the shallow aquifer. This issue should be discussed with the water management district.

⁵ FDEP, April 2002.

RECLAIMED WATER

The use of reclaimed water from large wastewater treatment plants for golf course irrigation is common in many areas of Florida (Figure 9). Water reuse is governed under Rule 62-610, Part III, F.A.C., and administered by FDEP's Domestic Wastewater Program. Some water management districts exempt reclaimed water from limits on watering, but this may vary with supply and demand in different areas. In 2005, 462 golf courses in Florida were irrigated with reclaimed water.



Figure 9: Reclaimed water sign.

Golf courses are efficient and effective users of reclaimed water, and the use of reclaimed water for golf course irrigation is encouraged. A research publication from the WaterReuse Foundation, *Effects of Recycled Water on Turfgrass Quality Maintained under Golf Course Fairway Conditions* (2006), may be of interest to superintendents using or contemplating the use of reclaimed water (available: <http://www.watereuse.org/Foundation/document/wrf-04-002.pdf>).

FDEP, the water management districts, and a number of other agencies have signed a Statement of Support for Water Reuse. Key factors in using reclaimed water are as follows:

- FDEP and the Florida Water Environment Association (FWEA) have developed a Code of Good Practices for Water Reuse. While this is directed primarily at reclaimed water utilities, golf course managers should discuss the contents with the utility during contract negotiations.
- Obtain information about the quality of the reclaimed water to be delivered at the time of contracting and annually, or more often if available.
- When a golf course enters into a partnership with a reclaimed water utility, the two parties need to work closely together. **The utility is in both the water supply and the wastewater disposal business**, and the golf course represents an important user. Both parties have needs, constraints, and desires. In the most successful reuse systems, both parties work together to seek mutual satisfaction. Golf courses should be recognized as excellent reclaimed water customers that provide an amenity to the community.
- When negotiating a contract with a utility for reclaimed water, pay attention to provisions related to the amounts of reclaimed water to be delivered, and to the timing of that delivery. **Avoid contract provisions that force you to overirrigate, especially during wet-weather periods.** Many wastewater treatment plants have to get rid of their water, even if a course does not need it. This often occurs during rainy periods, when courses need it least and treatment plants need to get rid of excess water the most. This can lead to very

RECLAIMED WATER BMPS

- Ensure that all cross-connection controls are in place and operating correctly. If you are converting from freshwater use to reclaimed water, or if you have a backup water source, be certain that all connections to the freshwater system have been severed and capped. A thorough cross-connection and backflow prevention setup is crucial (Section 62-610.660, F.A.C.).
- Post signs in accordance with local utility and state requirements that reclaimed water is in use. Signs may be available from the reclaimed water purveyor. Some courses also notify golfers of the use of reclaimed water on scorecards or at the first tee.
- Any course using reclaimed water must identify all nearby potable wells that could be affected by reclaimed water moving through the water table. Mandated setbacks (usually 75 feet) must be observed.
- Obtain information at the time of contracting, and at least annually, about the quality of the reclaimed water to be delivered.
- Account for the nutrients in reuse water when making fertilizer calculations. Knowing the nitrate levels in reuse water can reduce your fertilizer purchases. The application of 1 inch of reuse water containing 20 ppm nitrates adds about 1 pound of nitrogen per acre (lb. N/acre) to the soil. If you irrigate 40 inches per year, that works out to about 1 lb. per 1,000 square feet (ft²) (ppm x inches x .053 = lb. N/acre). This may save 10% or more of your annual fertilizer budget.
- Users of reclaimed water should test the water regularly for dissolved salt content. Sodium and bicarbonate buildup in the soil affect turf health and can lead to unnecessary maintenance.

soggy conditions that can damage a course and result in runoff that increases nonpoint source pollution. If a course must accept a certain quantity of water but may not have an immediate use for it, it may be possible to create storage ponds or to irrigate no-play zones to dispose of the excess water. However, one must be aware of the potentially harmful effects of irrigation on dry upland natural areas.

- A course using reclaimed water must identify any nearby potable wells that could be affected by reclaimed water moving into the water table. Setbacks from such wells are mandated by law and must be observed.

SYSTEM DESIGN

Irrigation system design is a complex issue and should be handled by trained professionals. These professionals should use existing standards and criteria such as the *FDEP Standards for Landscape Irrigation in Florida*, as well as manufacturers' recommendations, to design the most appropriate system for a location. The References section contains a list of sources for current standards and criteria. In many communities, construction and design documents and permits require the signature and seal of a licensed design professional.

The irrigation design for a site depends on a number of factors, including location, soils, landscape vegetation, water supply, and water quality. An irrigation system needs to be designed to meet a site's peak water requirements. However, it should also be flexible enough to adapt to various water demands and local restrictions.

Operating pressure must be designed not to exceed the source pressure. Design operating pressure should account for low pressure during periods of high use (i.e., mornings) and for project buildout when all of a development's landscape is in place. Irrigation systems designed to service both turf and landscape areas should have enough zones to meet each area's individual water needs. Emitter precipitation rates throughout the system must be selected so that the ability of the soil to absorb and retain the water applied is not exceeded during any one application. The irrigation design should also account for the extra water that is periodically needed to leach salt buildups caused by poor-quality irrigation water.

An irrigation system consists of four main components, as follows:

1. Water supply—this consists of a water source, pump, filters, and valves (including backflow valves).
2. Water conveyance—this is made up of a mainline, manifold, lateral lines, and spaghetti tubes and isolation valves.

3. Distribution devices—these include impact, oscillating, and rotary sprinklers; sprayheads; and microirrigation emitters. Smaller heads (sprays and small rotors) can be used for special areas such as tee tops and bunker faces to deliver extra water efficiently when it is needed.
4. A control system.

The design must account for different site characteristics and topographies. The proper design and installation of the components listed above optimizes their use and decreases any off-site impacts. To meet peak water use demands and have enough flexibility to reduce supply for different demand requirements, irrigation systems need to be designed with various control devices, including rain shutoff devices and/or soil moisture devices, and with backflow prevention to protect the water source from contamination.

Water conveyance systems should be designed with thrust blocks and air-release valves to prevent system damage. Water conveyance pipelines should provide the appropriate pressure required for maximum irrigation uniformity, and distribution devices should be designed for optimum uniform coverage. **Reclaimed water systems are always color-coded purple.** Isolation valves should be installed between holes, so that a leak can be repaired while the rest of the course is still being irrigated. It may seem obvious, but a distribution system should not be designed to irrigate nonplanted areas (such as driveways, cart paths, parking lots, roads, sidewalks, roof overhangs, and natural buffer zones). An irrigation system should also be designed differently for play and nonplay areas.

IRRIGATION FOR PLAY AREAS

Irrigation for play areas should contain the following elements:

- **Computerized control systems** should be installed on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head. By adjusting the watering times based on actual site conditions for each head and zone, water can be conserved and used most efficiently. Appropriate cutoff devices should be installed so that line breaks do not cause a pump to run excessively, or improper valve alignment does not cause a pump to overheat.
- **Weather stations** help superintendents adjust irrigation run times based on current local meteorological data that are recorded and downloaded to the irrigation computer. Some stations automatically compute the daily ET rate and adjust preselected run times to meet the turf's moisture needs. Weather stations, however, do not replace the human factor. Recorded ET rates can be manually adjusted to reflect wet and dry areas

on the course to ensure the maximum watering efficiency. Install rain switches, as required by Florida law, to shut down the system if enough rain falls in a zone. Soil moisture sensors will circumvent schedules if soil moisture is already adequate.

- **Pump stations** should be sized to provide adequate flow and pressure. They should be equipped with control systems that protect distribution piping, provide for emergency shutdown due to line breaks, and allow maximum system scheduling flexibility.
- **Variable frequency drive pumping systems** should be considered if dramatically variable flow rates are required, if electrical transients (such as spikes and surges) are infrequent, and if the superintendent has access to qualified technical support.
- **Heads and nozzles** should be selected to maximize the uniformity of coverage. The proper spacing of heads during course design and construction is critical. Equipment should be designed and installed following manufacturers' and professional designer specifications. Improper overlap leads to dry spots that require extra watering, so that other areas are overwatered.
- **Tee tops** may be designed so that the only maintained turf is on the tee top and slopes. Plantings of native grasses around teeing grounds, where applicable, provide an effective alternative ground cover. Such tees should have fully adjustable or part-circle heads installed to apply water only where needed. If new plant material needs irrigation to become established on the slope areas, the heads can be adjusted to provide the necessary water and then returned to tee top-only coverage. The same principle can be applied to narrow fairways, bunker complexes, and the banks of lakes, ponds, and other waterbodies.
- The irrigation of **greens and green surrounds** should be designed to provide inward and outward sprinkler coverage for maximum efficiency and turf maintenance. With single-head coverage around the greens, the slopes are often watered unnecessarily, which wastes water.
- Additionally, **operational control of each head** around the green is preferred over systems that provide total green or zone irrigation control. Individual head control increases irrigation flexibility by allowing for wind correction, watering localized dry spots, and meeting other special local needs.
- **Provide separate irrigation zones for slopes and areas surrounding greens.** Irrigation heads need to be strategically placed to minimize the amount of water applied to surrounding bunkers. The soils used for these areas may be heavier and poorly drained, compared with the modified soils in putting greens. Surrounds may hold

water better and may not need to be irrigated as frequently as a well-drained green.

- **Roughs** should be considered separate zones. At least one water management district (South Florida Water Management District [SWFWMD]) does not make an allowance for watering roughs in the permit calculations for golf courses in Water Use Caution Areas.



Figure 10: Irrigation system at green.

Figure 10 illustrates a typical irrigation set for a green. Shown from left to right are the following:

- A mist head—a small head that irrigates the green only for light cooling, syringing, or watering overseeding to keep seed damp during germination.
- The next two are greens heads—one larger inner head for irrigating the putting surface for normal night watering and one larger outer head for watering the green slope area for normal night watering.
- The single in the back is a snap (or quick coupler) valve for plugging in a 1-inch hose for hand watering hot spots.

Watering bunkers can result in sand erosion, wet shots for the players, and algae and weed encroachment, and wastes valuable water resources. Bunker slopes, however, do need to be irrigated. Some extensive sand areas, although designed as nonirrigated spaces, may have automatic sprinklers installed to wet the sand. These are used only during extreme wind conditions to prevent sand blowout.

To ensure optimum uniformity, permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations. Typically, this spacing is based on average wind conditions during irrigation. If this information is not available, guidelines such as those in Table 1 can be used. For variable wind directions, triangular spacing is more uniform than square spacing. Practical experience may suggest closer spacing than the guidelines. However, spacing should not exceed the percentages in Table 1. After the system is constructed and operating,

periodic "catch can" uniformity tests should be performed (see the chapter on Irrigation Management). Figure 11 shows two different irrigation head layouts.

Table 1. Irrigation Spacing

Wind Miles Per Hour	Square Coverage Percentage of Diameter of Coverage	Triangular Coverage Percentage of Diameter of Coverage
0-5	55%	60%
5-10	50%	55%
10+	45%	50%

IRRIGATION FOR NONPLAY AREAS AND LANDSCAPE PLANTINGS

Nonplay areas include aesthetic turf around clubhouses, landscaped garden areas, and out-of-bounds or border areas. Landscaping should follow the practices in *Florida Green Industries: Best Management Practices for Protection of Water Resources in Florida*. Consult local authorities on water restrictions for irrigation. When mature, many of these areas, if planted with the **Right Plant, Right Place** motto in mind, may require little supplemental irrigation. In these cases, temporary systems may be installed

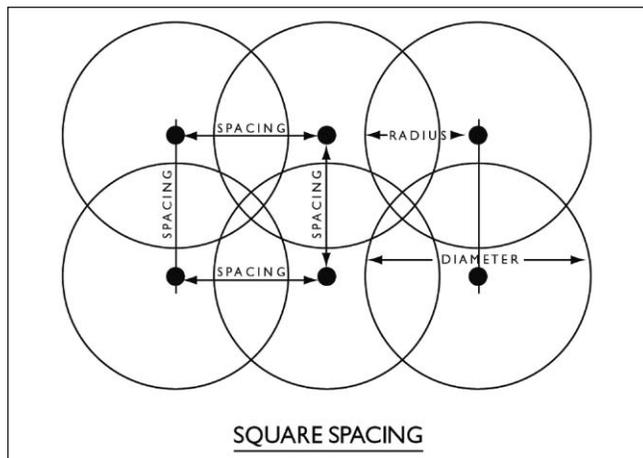
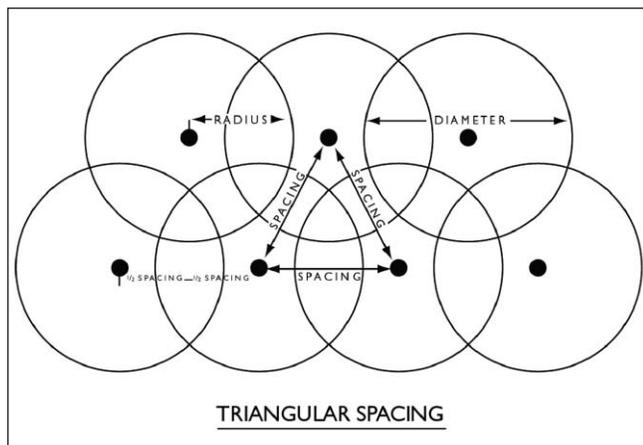


Figure 11: Irrigation head layout.



while the plants are becoming established and then removed when the plants are mature. In general, non-play areas should be irrigated like any high-quality landscape using Florida-friendly landscaping principles.

Irrigation systems operate most efficiently if they minimize evaporation during spraying and from plant foliage. Plants do not use water applied to the foliage. The most efficient and effective watering method for nonturf landscaping in Florida is microirrigation, which includes drip-and-trickle irrigation and spray jets. Microirrigation supplies small quantities of water directly to the mulch and soil through plastic tubing on or below the ground surface. Low-pressure emitters (that is, nozzles that drip, spray, or sprinkle) are attached to the plastic tubing and slowly release water into the soil around a plant. Wetting only the root zone saves water, because less water is lost through wind and evaporation.

Microirrigation equipment flow rates are given in gallons per hour (gph), rather than the gallons per minute (gpm) used for conventional irrigation equipment. Despite the difference in flow rates, caution should be used in determining zone run times. The amount of water applied can be quite high, because the water is being applied to each plant, within a small area.

When microirrigating, you need to know what kind of emitter to install in a given location. There are various types of equipment, including individual point source emitters, in-line tubing (emitters that are factory installed in tubing), or microsprays.

When drip emitters are used in some of Florida's sandier soils, water has very limited lateral movement from the emitter. For this reason, they are not practical for watering turf in Florida.

Individual drip emitters (point source) provide water to individual plants using .25-inch poly tubing. Where plantings are dense, then in-line tubing is more appropriate than individual emitters. Microsprays are appropriate for plants that require higher amounts of water, or where the emitters need to be visible for maintenance. Because drip emitters are sometimes placed under mulch or buried in the soil, if clogging occurs it is difficult to detect. Because the action of drip emitters is not readily apparent, it is also hard to know whether a system is irrigating excessively due to a hole in the tubing or some other problem. Regular inspection is required to make sure that the drip emitters, and the overall system, function as they should.

Regardless of the emitter style, clogging will likely be a problem if the water supply is not filtered before it enters the irrigation system. Filters are easily installed in any system. Water sources contain organic materials such as algae, which can dramatically increase emitter

IRRIGATION SYSTEM DESIGN BMPS

- The application rate must not exceed the ability of the soil to absorb and retain the water applied during any one application.
- The design operating pressure must not be greater than the available source pressure.
- The design operating pressure must account for peak use times and supply line pressures at final buildout for the entire system.
- Distribution devices and pipe sizes should be designed for optimum uniform coverage. The first and last distribution device should have no more than a 10% percent difference in flow rate. This usually corresponds to about a 20% percent difference in pressure.
- The system should be flexible enough to meet a site's peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions.
- Distribution equipment (such as sprinklers, rotors, and microirrigation devices) in a given zone must have the same precipitation rate.
- Heads for turf areas should be spaced for head-to-head coverage.
- Turf and landscape areas should be zoned separately.
- The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic and growing conditions, and it should include the base ET rate for the particular location.
- If required by the plant species that are present, the design should account for the need to leach out salt buildup from poor-quality water by providing access to fresh water. Otherwise, use species that tolerate these conditions.
- Water supply systems (for example, wells and pipelines) should be designed for varying control devices, rain shutoff devices, and backflow prevention.
- 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 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 between each hole.
- Nonplanted areas, especially impervious surfaces, should not be irrigated.
- Manual quick coupler valves should be installed near greens, tees, and bunkers so these can be hand watered during severe droughts.
- Install part-circle heads along lakes and ponds.

clogging. The injection of chlorine may be required to prevent the organic material from growing. For more information, consult the following sources:

- Microirrigation in the Landscape (archive: <http://ufdc.ufl.edu/fao1/results/?t=institute+of+food+agricultural+sciences>),
- Flushing Procedures for Microirrigation Systems (available: <http://edis.ifas.ufl.edu/WI013>, and
- Standards and Specifications for Turf and Landscape Irrigation Systems (available: <http://www.fisstate.org/StandardsRevision3.pdf>, or copies of the latest edition may be obtained by calling the Florida Irrigation Society at 1-800-441-5341.

IRRIGATION SYSTEM INSTALLATION

Qualified, appropriately licensed, bonded, and insured professionals should handle irrigation installation. These individuals must follow the designer's plans and use existing standards and criteria (such as the FDEP *Standards for Landscape Irrigation in Florida*, and those of the American Society of Agricultural and Biological Engineers [ASABE], Florida Irrigation Society [FIS], Irrigation Association, U.S. Department of Agriculture—Natural Resources Conservation Service [USDA–NRCS], and/or the manufacturer's recommendations). The designer must approve any changes to the design.

To prevent system failures, waste, and property damage, construction materials must meet appropriate standards

(such as the ASABE, American Society of Civil Engineers [ASCE], or American Society of Testing Materials [ASTM]). All construction practices should be planned and carried out using standard safety practices.

IRRIGATION SYSTEM INSTALLATION BMPS

- Only qualified specialists should install the irrigation system.
- Construction must be consistent with the design.
- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Acceptable safety practices must be followed during construction.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.
- Spare hydraulic tubing and electrical wiring should be installed during construction for rapid repairs in case of leaks, breaks, and short circuits.
- Remote field controllers should be grounded according to code.
- The owner should receive a copy of the as-built plans, operating manuals, and warranties, as well as written instructions on how to change the irrigation system's timers, clocks, and controllers.
- When construction is completed, the site must be cleaned of all construction materials.

SYSTEM OPERATION

Plants don't waste water, people do. Using proper irrigation system design, installation, water management, and maintenance practices provides a multitude of benefits. An efficient irrigation system translates into cost savings and protection of our water resources.

Irrigation management is the cornerstone of water conservation and reduced nutrient and pesticide movement. It includes both scheduling the amount of water applied and when, and maintaining system components, both to prevent and correct problems. Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excess water use that could lead to leaching and runoff. Plant water needs are determined by evapotranspiration rates, recent rainfall, recent temperature extremes, and soil moisture. Whenever possible, cultural practices should be used to minimize plant stress and the amount of water needed. For example, superintendents can use mowing, verticutting, nutrition, and other cultural practices to control water loss and to encourage conservation. The chapter on *Cultural Practices* provides more information on how turfgrass cultural practices influence water use rates and efficiency.

WATER RESTRICTIONS

Florida's five regional water management districts may impose water restrictions based on aquifer levels, surface water flows, and rainfall shortages. Golf course owners are legally bound to abide by any and all restrictions placed on golf course irrigation. Failure to comply can result in punitive action by the districts.

It is also important to abide by the CUP/WUP granted to your property. Overpumping can damage water resources.

Watering restrictions generally allow supplemental watering for the establishment of new plantings and new sod, hand watering of critical hot spots, and watering in of chemicals and fertilizers as prescribed by the label or good stewardship practices. **For Water Shortage Rules and Criteria, contact your local water management district (see Appendix C: Important Telephone Numbers).**

It is in everyone's best interest to document actual watering practices, especially to show savings in water use over averages. Communication with the water management districts, golf course members, and the public should be maintained to explain what you are doing and why.

IRRIGATION SCHEDULING

Before a superintendent can properly develop an irrigation schedule, the system must be audited, or calibrated, so that the rate at which water is applied in each zone is known (see the section on **System Maintenance** in this chapter). Once the water delivery rate is known, determining when and how much to water is the next important step. Irrigation should not occur on a calendar-based schedule but should be based on ET rates and soil moisture replacement. Rain gauges are necessary measurement tools to track how much rain has fallen throughout the golf course. The use of soil moisture probes, inspections for visual symptoms such as wilting turf, computer models, and tensiometers may supplement these measurements. Computerized displays (Figure 12) are available to help visualize the system.

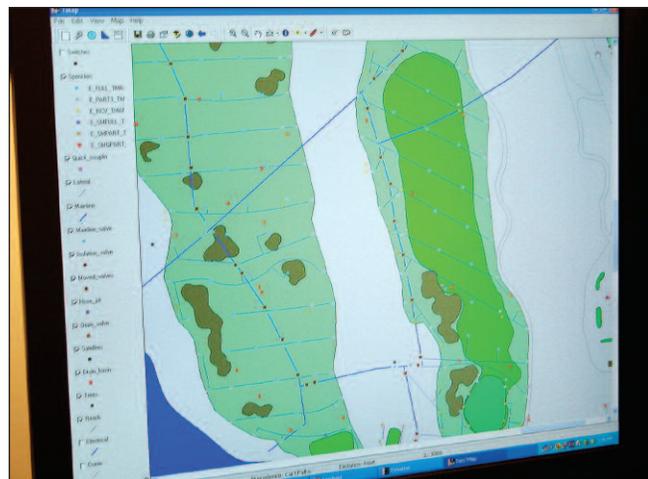


Figure 12: Computerized irrigation display.

Water loss rates decrease with reduced solar radiation, minimal wind, high relative humidity, and low air temperatures. A superintendent can take advantage of these factors by irrigating when conditions do not favor excessive evaporation. Irrigation should occur in the early morning hours before air temperatures rise and relative humidity drops. Irrigating at this time also removes dew from leaf blades and allows sufficient time for infiltration into the soil but does not encourage disease development.

Determining how much water to apply is the next step in water management. Enough water should be applied to wet the entire root zone. Wetting below the root zone is generally inefficient, since this is beyond a plant's range of access. Irrigating too shallowly encourages shallow rooting, increases soil compaction, and favors pest outbreaks. For golf greens and tees, the majority of roots are in the top 6 inches of soil. Irrigate to wet this depth unless the root zone extends deeper. For fairways and roughs, the top 12 inches of soil should become wet to supply sufficient water for plants and to encourage deep rooting. Soil moisture can be estimated by using a soil probe to feel the depth of the moisture and show the depth of the root zone.

Visual Symptoms

The presence of visual symptoms of moisture stress is a simple method used to determine when irrigation is needed. Moisture-stressed grass appears blue-green or grayish-green in color, recuperates slowly (longer than 1 minute) after one walks or drives across it, or wilts continuously. These symptoms occur when plant moisture is insufficient to maintain turgor. As a result, the plant rolls its leaves and wilts to conserve moisture. Certain areas or patches of turfgrass tend to wilt before others due to poor irrigation distribution, or to poorly developed or damaged root systems.

Waiting until visual symptoms appear before irrigating is a method best used for low-maintenance areas, such as golf course roughs and possibly fairways. Managers of golf greens cannot afford to wait until these symptoms occur, because unacceptable turf quality may result.

Predictive Models

Predictive models based on weather station data and soil types are also available. These are relatively accurate and applicable, especially as long-term predictors of yearly turf water requirements. Weather data such as rainfall, air and soil temperature, relative humidity, and wind speed are incorporated into certain model formulae, and soil moisture content is estimated. Models, however, are only as effective as the amount of data collected and the number of assumptions made. These models and programs should always be calibrated for local conditions, as they often use incorrect coefficients for Florida's climate and plant species. Accessible weather data must be available, as well as specialized computer equipment and pro-

grams. Computer programs allow for individual station settings to decrease or increase watering times for wet and dry areas. They also have "cycle and soak" features, so that water can be applied over several cycles and not puddle or run off.

Tensiometers

Tensiometers and other soil moisture sensors are used to measure soil moisture (Figure 13). Tensiometers are tubes filled with water with a porous ceramic cup at the base and a vacuum gauge at the top. As soil moisture is depleted, tension forms between the water in the soil and the water in the tube. This tension is registered by the vacuum gauge and provides a relatively accurate reading of soil moisture availability, registered in centibars. Soil field capacity (water "held" after drainage) is generally between 5 to 30 centibars, with higher values indicating decreasing soil moisture levels. Tensiometers remain accurate when tensions are less than 80 centibars. Commercial tensiometer models are available that can automatically regulate irrigation systems based on a preset tension threshold.

A drawback of tensiometers is that the reading is only accurate in the area adjacent to the placement of the ceramic tips. Tensiometers may affect play. Placing tensiometers in golf greens is not recommended, since this interferes with management practices such as aerification.



Figure 13: Tensiometer.

Irrigation Control with Feedback

Irrigation control with feedback simply means that the control system receives feedback from a sensor or sensors. These may consist of soil moisture sensors or meteorological sensors that are used to calculate the ET demands of the plants under irrigation.

Irrigation with soil moisture sensors can consist of a sensor that has a user-adjustable threshold setting where the scheduled timer-based irrigation event is bypassed if the soil moisture content exceeds the threshold. This type of control is "bypass" control. The soil moisture sensor(s) should be installed in the root zone for each irrigation zone. If the sensor system only contains one soil moisture probe, then that probe should be installed in the driest irrigation zone of an irrigation system and all other

irrigation zones should have their run times reduced to minimize over-watering. Frequent irrigation events can be programmed into the irrigation timer and the sensor will allow irrigation as conditions in the root zone dictate in response to rainfall and ET. The second type of soil moisture control is “on-demand” control where the soil moisture based irrigation control system consists of a stand-alone controller and multiple soil moisture sensors. High and low limits are set so that irrigation only occurs within those limits. Currently, the “bypass” control devices are marketed for residential irrigation and “on-demand” devices are marketed for agricultural or large commercial systems. However, both strategies could be adapted to golf course irrigation systems.

Many types of soil moisture sensors have become commercially available. Historically, tensiometers have been recommended, but these devices require more maintenance than is acceptable for golf course irrigation. Newer sensors are capacitance or dielectric-based devices and rely on the ability of the soil to conduct electricity and the fact that this property is strongly correlated to soil moisture content. It is important to place these sensors in a representative location within the irrigated root zone. Since the sensors require wires for communication and power, the wires must be buried below aeration depths and the locations of the sensors must be marked to prevent such damage. Excessive salt content in some irrigation water can also interfere with the accurate operation of some types of sensors. Other than these issues, the devices are relatively maintenance free compared with tensiometers.

Evapotranspiration-based Control Systems

ET-based control systems have been available for many years. The oldest type, consisting of a full weather station (Figure 14) that interfaces with a controller for a



Figure 14: Weather station.

large irrigated area, is fairly common in golf course irrigation systems. However, a full weather station costs several thousand dollars and requires frequent maintenance for accurate measurements. ET is calculated based on the meteorological parameters measured by the weather station, and then the controller calculates a running soil water balance. Irrigation is scheduled automatically based on the application rate of the sprinklers in a particular irrigation zone and the calculated removal of water from the root zone.

The instruments on ET control systems should be periodically checked and their accuracy verified at least annually. In addition, an accepted method for the calculation of ET should be used along with the best available crop coefficients. One of the most widely accepted methods of ET calculation is the Penman-Montieth method. A standardized form of this equation has been proposed by the ASCE-EWRI Evapotranspiration in Irrigation and Hydrology Committee (ASCE, 2005). For the most accurate calculation of irrigation water requirements, rainfall should be measured onsite. In the future, technology such as OneRain Corporation’s high-resolution, gage-adjusted Doppler radar rainfall data may be used to provide spatially distributed irrigation scheduling.

OPERATING OLDER SYSTEMS

Not all golf courses are so fortunate as to have a computerized irrigation system, variable frequency drive (VFD) pump station, or weather station. Many existing courses have pump stations that maintain pressure through the use of hydraulic pressure-sustaining valves, which operate to maintain a constant downstream pressure in the piping system.

Golf courses with hydraulic pressure-sustaining valves are much more prone to irrigation pipe and fitting breaks due to surges in the system, creating more downtime for older systems. A good preventive maintenance program for this type of station is very important to keep it operating efficiently. Maintaining the air relief and vacuum breaker valves is particularly important. The installation of a VFD system can lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.

Time clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical time clocks cannot automatically adjust for changing ET rates, and therefore staff have to adjust them frequently to compensate for the needs of individual turfgrass areas. The reliability of station timing depends on the calibration of the timing devices; this should be done periodically but at least seasonally.

It is important to keep in mind that, while new technology makes many tasks easier or less labor intensive, it is the principles discussed in this BMP manual that are

CRITICAL IRRIGATION MANAGEMENT BMPS

- An irrigation system should be operated based only on the moisture needs of the turfgrass, or to water in a fertilizer or chemical application as directed by the label.
- An irrigation system should be calibrated regularly to ensure that it is performing as designed by conducting periodic irrigation audits to check actual water delivery and nozzle efficiency.
- An irrigation system should have rain sensors to shut off the system after 1/4 to 1/2 inch of rain is received. Computerized systems allow a superintendent to call in and cancel the program if it is determined that the course has received adequate rainfall.
- An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Each day the system should be monitored for malfunctions and breaks. It is also a good practice to log the amount of water pumped each day. These data can be useful in documenting watering needs and schedules during droughts.
- Generally, granular fertilizer applications should receive 1/4 inch of irrigation to move the particles off the leaves while minimizing runoff.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- When possible, the irrigation schedule should coincide with other cultural practices (i.e., the application of nutrients, herbicides, or other chemicals).
- Proper cultural practices such as mowing height, irrigation frequency, and irrigation amounts should be employed to promote healthy, deep root development and reduce irrigation requirements.

important. These principles may be applied to any course at almost any level of technology. All of us can improve something by examining our operations from a different perspective, and the principles outlined here can help you to look at your operation from an environmental perspective.

SYSTEM MAINTENANCE

Irrigation system maintenance on a golf course involves four major efforts: calibration or auditing, preventive maintenance, corrective maintenance, and recordkeeping. The recordkeeping is an essential part of the other three, but is often overlooked. This manual also touches on system renovation.

CALIBRATING AN IRRIGATION SYSTEM

There are three levels of irrigation audits or evaluations: a visual inspection, a pressure/flow check, and a catch can test. The level chosen depends on how much detailed information is required. Irrigation audits should be performed by properly trained technicians.

First, if an irrigation system is in disrepair or coverage is obviously poor, then time is wasted doing a detailed catch can test. A visual inspection should first be conducted to identify any necessary repairs or corrective actions, and it is essential to make any repairs before carrying out other levels of evaluation. A visual inspection should be part of ongoing maintenance procedures.

Pressure and flow should be evaluated to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications. Pressure and flow rates should be checked at each head. The data can be used to determine the average application rate in an area, which is a fundamental parameter for irrigation scheduling.

Catch can tests should be run to determine the uniformity of coverage. Catch can testing provides the most detailed information on coverage and thus allows a system operator to accurately determine irrigation run times. The information gathered from this test also identifies areas where coverage is poor and a "redesign" option should be considered.

Catch can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency. However, due to time and budget constraints, this can be accomplished over an extended period. Annual testing results in a high-quality maintenance and scheduling program for the irrigation system.

Level 1—Visual Inspection

With the irrigation system on, do the following:

- Inspect for mainline breaks,
- Inspect for low pressure at the pump,
- Inspect head-to-head spacing,

- Inspect for interference with water distribution,
- Inspect for broken and misaligned heads,
- Make sure that the rain sensor is present and functioning,
- Make sure that the backflow device is in place and in good repair,
- Examine turf quality and plant health for indications of irrigation malfunction or need for scheduling adjustments,
- Schedule documentation, and
- Make adjustments and repairs on items diagnosed during the visual inspection before conducting pressure and flow procedures.

Level 2—Pressure and Flow Testing

- Measure the pressure at each rotor with a pitot tube and pressure gauge, while simultaneously recording the flow rate at the pump station,
- Identify and record the size of each nozzle,
- Use nozzle sizes and operating pressure to check the manufacturer’s specifications for the precipitation rate,
- If all heads within a zone don’t have matching precipitation rates, replace heads as needed, and
- Compute Average Application Rate (AAR) for a given area or group of heads:

$$\text{AAR (inches/hour)} = \frac{\text{Total gpm} * \times 96.3}{\text{Total Area (sq. ft.)}}$$

**Total gallons per minute of all heads in irrigated area.*

Level 3—Catch Can Testing

- Identify the areas to be tested and conduct a catch can test on all areas of each hole.
 - Identify holes that represent the worst, best, and average for the following:
 - Greens
 - Tees
 - Fairways
- Flag all heads.
- Evenly space 40 to 50 catchment containers throughout the test area.
- Testing run times:
 - 20 to 30 minutes or at least 5 rotations.
 - Set up containers at night and then collect data in the morning.
- Measure and record volumes (in milliliters [mL]) collected from each container. Catch cans with direct-read mL measurements are available from the Irrigation Association. In addition, simple plastic tumblers can be used with rubber bands and wooden dowels. Measurements can be taken with a 100mL graduated cylinder available from any scientific supply company.

After all of the measurements have been taken, determine the effective application rate using the following three steps:

1. Compute the AAR using the information gathered from the pressure flow test, or use data from the catch can test with the following formula:

Average Application Rate: (inches/hour)

$$\text{AAR} = \frac{\text{Average volume (mL)}}{\text{Diameter of catch can}^2 \text{ (inches)} \times \text{time (minutes)}} \times 4.66$$

2. Compute the distribution uniformity using the average volume of the low quarter of catch cans and divide by the average volume of all catch cans:

Distribution Uniformity (Lower Quarter):

$$\text{DU}_{\text{LQ}} = \frac{\text{Average volume of the lower quarter of catch cans}}{\text{Average volume of all catch cans}}$$

3. Compute the effective application rate by multiplying the average application rate by the distribution uniformity:

Effective Application Rate: (inches/hour)

$$\text{EAR} = \text{Average application rate} \times \text{distribution uniformity}$$

Adjust the schedule based on the effective application rate, and implement all repairs needed to improve distribution uniformity. The Florida Irrigation Society’s Urban Irrigation Auditor Certification Manual (2002) provides detailed information on calibrating an irrigation system. Copies of the manual may be obtained by calling FIS at 1-800-441-5341.

PREVENTIVE MAINTENANCE

Personnel charged with maintaining any golf course irrigation system face numerous challenges. This is particularly true for courses with older or outdated equipment. Good system management starts with good preventive maintenance (PM) procedures and recordkeeping. Maintaining a system is more than just fixing heads. It also includes documenting system- and maintenance-related details so that potential problems can be addressed before expensive repairs are needed. It also provides a basis for evaluating renovation or replacement options.

PREVENTATIVE MAINTENANCE BMPS

- System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer's recommendations.
- The system should be inspected 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 adjustments can be made.
- Systems need to be observed in operation at least weekly. This can be done during maintenance programs such as fertilizing or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation. This process detects controller or communications failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source. Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Application/distribution efficiencies should be checked annually. Implement a PM program to replace worn components before they waste fertilizer, chemicals, and water.
- Conduct a periodic professional irrigation audit at least once every five years.
- Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.
- Monitor pump station power consumption. Monthly bills should be monitored over time to detect a possible increase in power usage. Compare the power used with the amount of water pumped. Requiring more power to pump the same amount of water may indicate a problem with the pump motor(s), control valves, or distribution system. Quarterly checks of amperage by qualified pump personnel may more accurately indicate increased power usage and thus potential problems.
- Monitor and record the amount of water being applied, including both system usage and rainfall. By tracking this information, you can identify areas where minor adjustments can improve performance. Not only is this information essential in identifying places that would benefit from a renovation, it is also needed to compute current operating costs and compare possible future costs after a renovation.
- 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. Pipe failures may not only be caused by material failure, but could result from problems with the pump station. Wiring problems could be caused by corrosion, rodent damage, or frequent lightning or power surges. Control tubing problems could result from poor filtration.

CORRECTIVE MAINTENANCE

Corrective maintenance is simply the act of fixing what is broken. It may be as simple as cleaning a clogged orifice, or as complex as a complete renovation of the irrigation system. For the smaller, day-to-day failures, BMPs simply call for timely action, maintaining the integrity of the system as designed, and good recordkeeping.

CORRECTIVE MAINTENANCE BMPS

- Replace or repair all broken or worn components before the next scheduled irrigation.
- Replacement parts should have the same characteristics as the original components.
- Document all corrective actions.

SYSTEM RENOVATION

As maintenance costs increase, the question of whether to renovate arises. Renovating a golf course can improve system efficiencies, conserve water, improve playability, and lower operating costs.

System renovation starts with evaluating the current system's maintenance requirements and operating costs. Focusing on longer-term objectives may demonstrate that it is cost-effective to install a new system to reduce the accumulating and seemingly perpetual maintenance chores that older systems often require.

The process of identifying renovation needs starts with collecting as much information as possible about the system, including the following:

- Gather together all of the documentation collected as part of the PM program, along with corrective maintenance records. Correctly identifying problems and their costs helps to determine what renovations are appropriate.
- Determine the age of the system. Irrigation systems, like any asset, do not last forever. Checking the dates on any as-builts and discussing the history of the course with other golf course personnel gives you a starting point.
- Determine the age of the pump station, which is one of the single costliest items in a system. While a system's age in years provides some information, the number of operating hours is often a better indicator of life expectancy.
- Understand the operations and options of the current control system. If the system has not been renovated, it probably doesn't have a state-of-the-art control system.

By trying to maximize the efficient use of the current system, three things should occur. First, you should recognize some improvement in system performance. Second, you should begin to develop a list of things that the current system doesn't accomplish, but that you would like a new system to do. Third, you should begin to gather the site information necessary for any renovation.

Identifying ways to improve system performance is only part of the information-gathering stage. Collecting information on the cost of maintaining the system is also important. This information should include the cost of pipe repairs, sprinkler repairs, control system repairs, and power consumption. Be sure to include labor costs and the costs of lost revenue, when appropriate.

After gathering as much information as possible, you will need to identify items that are beneficial to upgrade, including the following:

- Updating control systems,
- Improving greens coverage,
- Improving tees coverage,
- Improving coverage on fairways and roughs,
- Repairing/replacing elements of the system infrastructure,
- Repairing/replacing the pump station, and
- All of the above.

As you begin to identify areas or reasons for upgrading, you will need to find appropriate professionals (such as architects and consultants) to assist in renovation planning. These professionals are necessary not only to assist in prioritizing goals, but also to develop plans, specifications, phasing recommendations, and project budgets. They can also help identify how much of the course needs to be closed and for how long, which is a crucial consideration.

After a project has started, the involvement of current staff is essential. Understanding how a system was installed provides important information for developing an effective maintenance program. The fact that renovations have been completed does not indicate that the process of gathering information has ended. Continually documenting system performance is essential to maximize the effectiveness of the renovation.

OVERVIEW

GENERAL

Proper fertilization⁶ is essential for turfgrasses to sustain desirable color, growth density, and vigor; to better resist diseases, weeds, and insects; and to provide satisfactory golf course playability. Depending on the species, plants need approximately 16 elements, which are divided into two categories: macronutrients and micronutrients. Macronutrients are further subdivided into primary nutrients (nitrogen, phosphorus, and potassium) and secondary nutrients (calcium, magnesium, and sulfur).

Macronutrients

Primary Nutrients – The primary nutrients—nitrogen, phosphorus, and potassium (N, P, and K, respectively)—receive the greatest attention because they are typically deficient in soils and must be applied regularly. These plant foods are required in the largest amounts. If not handled properly, however, nutrients can be a significant source of water pollution. Excessive nutrients can lead to algal blooms and stimulate the growth of noxious plants in lakes and streams. This can reduce the amount of oxygen available for game fish such as bass and sunfish, while promoting less-desirable fish.

Nitrate is a special health concern, because excessive levels in drinking water can cause serious health problems in infants. Florida law requires all potentially potable ground water to meet drinking water standards. Under both federal and state regulations, this standard is 10 ppm for nitrate-nitrogen.

Nitrogen influences turfgrass color, shoot and root growth, and water use. Enough N should be applied to turf to meet its nutritional needs for maintaining growth, recuperative ability, color, and quality. Nitrogen generally increases shoot growth, shoot density, and leaf width; the latter increases the leaf area exposed to the atmosphere. Excessive N application may negatively influence root growth and result in N leaching. When turfgrass is fertilized excessively with N, top growth is promoted over root growth, which may result in less drought-tolerant turfgrass in the long term. If N is applied at the recommended and required rates for optimum turfgrass growth, a strong root system can develop.

Phosphorus (P), an essential element for plant growth, is involved in the transfer of energy during metabolic processes. Unfortunately, it is often the limiting nutrient in many natural systems, such as the Everglades. As such, many areas of the state are very sensitive to excess

phosphorus. Phosphorus restrictions have been mandated in other states and could be mandated in Florida if reduction targets are not met. Many Florida soils have adequate, or even excessive, amounts of P. Always perform a soil test before adding P to the soil.

The effects of potassium (K) levels on water use are generally the opposite of those for nitrogen. Potassium nutrition increases leaf turgor, thus delaying wilting. Excessive N levels, however, can negate the positive effect of K. Optimum K fertilization has also been correlated with disease and pest resistance. Potassium is very important to root growth and a plant's overall health. With a healthy root system, turfgrass assimilates more fertilizer, and leaching is reduced.

Increased root depth increases the water available to a plant and may reduce irrigation needs. Iron (Fe) and manganese (Mn) can provide desirable turfgrass color without the excessive growth that may be produced by N. Supplemental Fe and Mn should be applied to encourage turf color and root growth without stimulating excessive shoot growth. For a detailed fertilization guide for Florida turfgrasses, see the following publication: *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: <http://edis.ifas.ufl.edu/LH014>).

Secondary Nutrients – Dolomitic limestone provides calcium and magnesium to deficient soils, while sulfur-containing fertilizers add sulfur. Sulfur is also provided by acidifying materials such as elemental sulfur that lower soil pH; by desalinization materials such as gypsum; by rainwater containing the air pollutant sulfur dioxide, or by salts of nitrogen, magnesium, potassium, and various micronutrients.

Micronutrients

Micronutrients are essential elements required in small amounts by plants. Florida's flatwoods soils, for example, may not contain enough micronutrients to sustain optimum plant growth. Due to the high sand content of many golf greens and extremes in soil pH, micronutrient management is very important for Florida superintendents. Figure 15 shows pH effects on micronutrient availability. Deficiencies in iron and manganese often occur under high soil pH (> 7.0) conditions and are sometimes mistaken for nitrogen deficiency. A number of turfgrass specialty fertilizers contain some, or all, of these micronutrients. The user should check the label before making an application.

⁶ Sartain et al., 1999a.

There are numerous fertilizer sources for many different needs. Vendors, independent soil consultants, or extension agents can provide education on particular formulations. When fertilizing putting greens or other areas with a high sand content that are subject to rapid percolation and nutrient leaching, it is important to know that **at no time should more than 1/2 lb. of water-soluble nitrogen be distributed per 1,000 ft² in a single application.** This minimizes the chance of N leaching. Additional N may be applied in a controlled-release form in the same application. Where soils contain more clay and do not drain as rapidly, higher rates of N may be applied (up to 1 lb. of soluble N per 1,000 ft²) when application equipment limitations on fairways and roughs cause inconsistent coverage at lower rates.

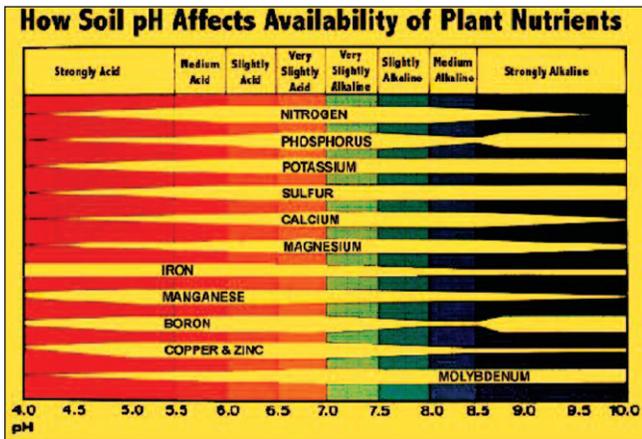


Figure 15: pH effects on the availability of plant nutrients in soil.
source: Pettinger, 1935.

Many superintendents managing new ultradwarf bermudagrasses have moved to a liquid fertilizer program on their greens. This helps to ensure that nutrients are being “spoon-fed” and minimizes the chance of nutrient loss. Liquid fertilizer pumped through an irrigation system, or fertigation, is a popular way to spoon-feed turfgrass, especially during the winter months. Fertigation reduces potential nutrient loss compared to dry fertilizers, because only small amounts of a nutrient are applied at one time. This allows the roots to quickly take up most of the nutrients, leaving little available to be leached.

SITE ANALYSIS

An overall site management plan should be established. It should be in a written format and shared with all parties associated with the management of a site. This is important so that all will understand what will happen to materials as they are applied.

Before an accurate nutrition program can be established for a golf course, a site assessment is useful. Whether a facility has yet to be built or is an established site, it is important to research soil types, water sources, drainage plans, and other special concerns on the property.

Knowing soil types can be critical in selecting specific products, because some products leach quickly through certain soils. If water is high in sodium or bicarbonates, for example, it affects a plant's ability to assimilate nutrients.

A complete water quality analysis should also be done on all waterbodies. This can be expensive, but it establishes a baseline for the site. Yearly testing and analysis help identify issues that might occur. Drainage plans should be reviewed for outfall locations. If a property has wetlands, streams, or other areas of concern, each needs to be addressed in the management plan.

If a new golf course is being built, you should identify ways to reduce potential nutrient losses. Building the greens to USGA recommendations, for example, enables you to become creative with the way in which water is discharged from the system. When designing drainage for bunkers, fairways, or roughs, you should incorporate a natural filtering system by letting the water filter through aquatic plants or through a grassed swale before it enters a waterbody or a retention area.

Soil samples help identify soil types and the elements needed for various turf types. Once the turfgrasses are established, soils should be sampled yearly. Nutrient choices and quantities are based on these results and the results of tissue samples.

FERTILIZER

TERMS

Legally, in Florida, "fertilizer" means any substance that contains one or more recognized plant nutrients and promotes plant growth. Fertilizer “grade” or “analysis” is the percent by weight of nitrogen, phosphorus, and potassium guaranteed by the manufacturer to be in the fertilizer. Nitrogen is expressed as N, available phosphate as P₂O₅, and soluble potash as K₂O. The percent sign is not used, but instead the numbers are separated by dashes, and the order is always N, P₂O₅, and K₂O (for example, 15-0-15).

FERTILIZER ANALYSIS

The Florida fertilizer label is detailed and intended to be highly informative. By law, the product label is required to provide the following basic information: the brand and grade, manufacturer's name and address, guaranteed analysis, sources from which the guaranteed primary and secondary nutrients are derived, and net weight. For additional information, see the publication, *The Florida Fertilizer Label* (available: <http://edis.ifas.ufl.edu/SS170>).

In addition to the fertilizer grade, the label also identifies the breakdown of total N as nitrate-N, ammoniacal-N, water-soluble or urea-N, and water-insoluble-N. This N breakdown supplies information on the immediate availability and/or leachability of the N in the bag. The

Association of American Plant Food Control Officials (AAPFCO) defines slow- or controlled-release fertilizer as a fertilizer containing a plant nutrient in a form that delays its availability for plant uptake and use after application, or that extends its availability to the plant significantly longer than a reference “rapidly available nutrient fertilizer” such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride.

This delay of initial availability or extended time of continued availability may occur through a variety of mechanisms. These include the controlled water solubility of the material (by semipermeable coatings; occlusion; or the inherent water insolubility of polymers, natural nitrogenous organics, protein materials, or other chemical forms), or the slow hydrolysis of water-soluble, low molecular weight compounds.

In most cases, the higher the water-insoluble N percentage in the mix, the longer-lasting the fertilizer. This is where most of the N from natural organic and slow-release sources appears. A fertilizer that contains all of its N as nitrate-N, ammoniacal-N, and/or water-soluble N is referred to as a soluble N fertilizer, which may provide a high potential for leaching. It should not be applied at rates greater than 1/2 lb. N/1,000 ft² per application on soils of high sand content that are subject to rapid water percolation.

A fertilizer label also contains a “derived from” section that identifies the materials from which the fertilizer was formulated.

For more information, see the publication, *Selected Fertilizers Used in Turfgrass Fertilization* (archive: <http://ufdc.ufl.edu/fao1/results?t=institute+of+food+agricultural+sciences>).

Secondary and micronutrients, identified in the lower portion of the label, are expressed in their elemental form. Sulfur (S) is expressed as “combined” (usually expressed as SO₄) and as “free” (elemental S form). The reason for this distinction is that “free” S is very acidifying when placed in the soil. Magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) must be expressed as total and/or soluble or water soluble, depending on the source materials formulated in the fertilizer. Chelated elements are guaranteed separately when a chelating agent is denoted in the derivation statement below the guaranteed analysis. For additional information, see the publication, *The Florida Fertilizer Label* (available: <http://edis.ifas.ufl.edu/SS170>).

NITROGEN

Nitrogen is the most important element for turfgrass maintenance due to its influence on color, growth rate, density, and stress tolerance. The total dry matter of turfgrasses consists of 1 to 5% N. It is applied in the greatest quantity and is required in larger quantities than any

other element except carbon, hydrogen, and oxygen. Excessive N, however, increases shoot growth and the incidence of certain diseases, and lowers turf’s stress tolerance of heat, cold, drought, and traffic. Most important, root and lateral shoot growth may also be reduced. Root growth suppression reduces turf tolerance of heat and drought. Additionally, excessive N fertilization may adversely affect the environment by contaminating ground water.

Origins and Losses

Turfgrasses may obtain N from the decomposition of organic matter and, to a small degree, from air as N that has been oxidized by lightning and dispersed by rainfall. In soil, the ammonium (NH₄⁺), nitrate (NO₃⁻), and nitrite (NO₂⁻) forms are the most important compounds; they originate either from the aerobic decomposition of organic matter or from the addition of commercial fertilizers. The ammonium and nitrate forms of N are the only ones used by turf plants. No matter what the N source applied (e.g., manure, crop residues, organic matter, or commercial fertilizer), it must be changed to one of these two forms for plant use.

Mineralization – Mineralization is the process through which soil microorganisms break down or transform organic matter, organic fertilizers, and some slow-release fertilizers to provide available ammonium and nitrate forms for plants. Mineralization is a three-step process involving aminization, ammonification, and nitrification. In aminization and ammonification, proteins, amines, and amino acids from organic matter or humus are converted to ammonium, a source of N used by plants. Ammonium nitrogen (NH₄⁺) is then absorbed by plants or further transformed into nitrate (NO₃⁻).

Nitrification – The transformation of ammonium nitrogen to nitrate nitrogen is referred to as nitrification. Nitrification depends on environmental conditions that favor soil microbiological activity. Warm temperatures, adequate soil moisture, and soil oxygen are necessary for this activity. However, nitrification does not readily occur under extreme temperatures (e.g., below 40°F or above 105°F), in saturated or poorly aerated soil, in excessively dry soil, or in low-pH soil (< 4.8). Under these unfavorable conditions, microorganisms do not perform nitrification, and ammonium may accumulate. Ammonium nitrogen also may become toxic to turfgrasses grown under cool, low-light conditions, such as those in late winter or early spring.

Nitrate nitrogen is readily soluble in water and may be repelled by negatively charged exchange sites of the soil components. Therefore, unless grasses rapidly use this form, it may be lost through leaching if excessive water is applied. This may especially be true during the winter months, when grass is not actively growing. In addition to nitrate and water, hydrogen ions (H⁺) also are pro-

duced during nitrification, and a reduction in soil pH may be observed. This reduction is especially acute when a high rate of N is applied on sandy soils that are low in calcium. Such soils are poorly buffered against pH changes induced through the acidifying effect of nitrification.

Denitrification and Volatilization – Besides leaching and crop removal, additional avenues of N loss are denitrification and volatilization. Denitrification is the conversion of nitrate nitrogen under anaerobic conditions to gaseous nitrogen. Low soil oxygen levels and/or high soil moisture, alkaline (high-pH) soils, and high temperatures favor denitrification. In soils that are compacted or waterlogged and a high pH (> 7.5), denitrification can result in losses of up to 70% of the applied nitrogen.

Volatilization is the conversion of ammonium nitrogen (NH_4^+) to ammonia gas (NH_3). If ammonium nitrogen comes in direct contact with free calcium carbonate in the soil, ammonium bicarbonate is formed. Upon exposure to the sun, this relatively unstable compound decomposes into ammonia, carbon dioxide, and water.

The volatilization of ammonia nitrogen can usually be avoided by incorporating the ammonium nitrogen fertilizer into the soil. In addition, the surface application of an ammonium nitrogen fertilizer to a sandy soil, free of lime or calcium carbonate, does not result in the volatile loss of ammonia nitrogen. Furthermore, irrigating with approximately .25 to .5 inch of water after fertilizer application minimizes this potential N loss.

Nitrogen Effects on Turfgrasses

Nitrogen is one of the most important elements turf managers apply to turfgrasses. In addition to affecting turf color and growth rate, N influences thatch accumulation, the incidence of diseases and insects, cold tolerance, heat and drought stress, nematode tolerance, lime requirements, and, most important to the player, putting speed. Turf managers often measure N needs based on turf color, density, and/or clipping amount. However, it is the effect of N on other aspects of turf management that often influences a superintendent's success or failure. For additional information on quickly available and slowly available forms of N, see Tables A-1 and A-2 in Appendix A.

Improper N fertilization can have an undesirable effect on turfgrass rooting. Turfgrass, in general, uses carbohydrates stored in its roots to support shoot growth. These are replenished by products resulting from photosynthesis. If heavy amounts of N are used, excessive shoot growth occurs at the expense of roots. As a result, roots may not have enough recovery time to replenish their carbohydrates before being forced to support excessive shoot growth when N is reapplied. It has been observed that

bermudagrass maintained at low N levels has up to twice as much root growth as that maintained at high levels.

In addition to forcing excessive shoot growth at the expense of root growth, improper N fertilization can also cause physiological changes such as cell-wall thinning, succulent tissue growth, and reduced root carbohydrate levels. Accordingly, increased susceptibility to stress makes the plant less hardy.

When plants are deficient in N, the initial leaf color is an overall pale yellow-green color, called chlorosis. Chlorosis reflects a reduction in chlorophyll production. Nitrogen is a part of chlorophyll and is thus essential in its manufacture. Chlorosis usually appears first on the lower (older) leaves, eventually changing to yellow as the deficiency symptoms progress to the base of the plant. In addition, the plant's growth rate and density may decrease, resulting in weak turf that has difficulty recovering from damage.

Other factors that also contribute to, or may cause, symptoms similar to those of N deficiency are a deficiency in nutrients such as iron, sulfur, or manganese. Florida's sandy soils, many of which are alkaline, often are lacking these elements. To the untrained observer, the symptoms appear similar to a lack of N. Compounding the problem are high populations of nematodes and soils with poor water-holding capacity; these can result in reduced rooting and increased water stress. Therefore, turf managers should determine the cause of chlorosis and turf thinning before indiscriminately applying an N or micronutrient fertilizer.

In general, N has a direct impact on turf growth and recovery from injuries such as divots or ball marks. However, the clipping matter produced can be a poor indicator of N needs. If adequate color and density are present, do not universally use clipping matter or weight to gauge N needs. If turf begins to thin or excessive damage occurs, turf growth and density may become relatively good indicators of N needs.

Soluble Sources

Soluble or quickly available N sources result in rapid shoot growth and greening. These occur approximately 2 to 5 days after application, peak in 7 to 10 days, and taper off to their original levels in 3 to 6 weeks, depending on the application rate and subsequent amount of water applied.

Soluble N sources have saltlike characteristics. They dissolve readily in water to form cations and anions. The greater availability of these ions corresponds to a greater burn potential for the fertilizer. Burn potential can be lowered by making applications only to dry turf surfaces when air temperatures are cooler than 80° F. Watering in soluble N immediately following application further

reduces the chance of burning plant tissue. Other disadvantages of using soluble N sources can be minimized by applying small amounts frequently. Rates at or below 1/2 lb. N per 1,000 ft² minimize these problems but increase application frequency and treatment costs.

ADVANTAGES AND DISADVANTAGES OF SOLUBLE NITROGEN SOURCES

Advantages:

- Rapid initial color and growth response,
- High in total nitrogen,
- Odorless,
- Help to maintain satisfactory nitrogen levels if applied frequently in small amounts,
- Minimum temperature dependence for availability,
- Low cost per unit of N, and
- Versatile—can be applied in granular or liquid forms.

Disadvantages:

- High potential for foliar burn, especially at higher rates and temperatures,
- Potential undesirable growth surge,
- Relatively short residual plant response, so frequent applications are needed, which increases labor costs, and
- Greater potential for N loss from volatility, leaching, and runoff.

Urea – Urea is one of the most widely used N sources due to its relatively low cost and solubility. It is formed by reacting ammonia gas and carbon dioxide. Once applied, urea is hydrolyzed and in the presence of urease is converted to ammonium carbonate. This ammonia form of N is prone to volatilization. If left on the surface and exposed to the sun's heating action, the ammonium carbonate decomposes into ammonia and carbon dioxide, and the applied N volatilizes. Research has shown that as much as 70% of surface-applied urea can be lost through volatilization. The easiest and simplest way to avoid this volatile N loss is to irrigate with .25 to .5 inch of water shortly after urea application. Urea is nonionic when solubilized. Nitrogen from urea is prone to leaching, and if excessive irrigation or rainfall occurs shortly after application, it may leach below the root zone.

Urea has a quick initial release rate of short duration and a low foliar burn potential. Urea-based fertilizer programs for putting greens should therefore involve light applications (< 1/2 lb. N per 1,000 ft²) made frequently (e.g., every 2 to 4 weeks) to reduce these potential losses.

Ammonium or Nitrate Salts – Ammonium sulfate, ammonium nitrate, ammonium phosphate, potassium nitrate, and calcium nitrate are other commonly used, water-soluble N sources, collectively referred to as inorganic salts. Once the ammonium fertilizers solubilize in soil, ammonium ions can be adsorbed by the negatively charged clay or organic matter. As with urea, soil bacteria convert this ammonium to nitrate, which is the main form available to plants. Unlike ammonium sulfate and phosphate, potassium nitrate and calcium nitrate fertilizers do not need to undergo conversion by bacteria, since their N source is already in nitrate forms.

Slow-release Nitrogen Sources

In an attempt to overcome some of the disadvantages of soluble N sources, fertilizer manufacturers have developed an array of slow- or controlled-release products. These generally provide a more uniform growth response and longer residual plant response. They also have less potential for N loss and allow a higher application rate than readily soluble sources. In addition, their burn potentials are lower because of their low salt index values. The application rate at which these sources release N may vary with fertilizer timing, source, temperature, moisture, pH, and particle size.

The drawbacks of slow-release N sources include high per-unit cost and slow initial plant response. Most sources also are not adaptable to liquid application systems. Turf managers should understand the various N sources and conditions favoring N release before formulating their yearly fertilizer program.

Coated N fertilizers consist of urea or other soluble sources that are coated with a semipermeable barrier. Their release rate is slow because the coating prevents the wetting of the soluble N source. Release rates depend on coating degradation or the physical integrity of the coating. Other controlled-release fertilizers are created by a reaction between urea with isobutryaldehyde (IBDU) or formaldehyde (urea-formaldehyde). Release rates depend on water hydrolysis or the microbial degradation of the product.

Sulfur-Coated Urea – Sulfur-coated urea (SCU) is formulated by moving granulated or prilled, preheated urea pellets through a stream of molten sulfur using a rotating drum. Urea gradually diffuses through the coating through cracks, pinholes, and imperfections that naturally occur in the surface as the particles cool.

Because of the nonuniformity and lack of integrity in the coating process, the urea granules crack at differing times, thus exhibiting variable N release rates. The granules also may be damaged during transportation, blending, and application, or by the weight of mower reels, rollers, or wheels. Therefore, handling should be kept to a minimum and drop spreaders avoided when applying SCU.

The rate of urea diffusion from SCU depends on the coating's thickness and integrity. Nitrogen release from SCU increases with warm temperatures, moist soils, and neutral soil pH. Heavy sulfur coatings result in larger fertilizer granules, which release the N more slowly. Problems with mower crushing or pickup may occur with these larger granules. To minimize this, a fine prilled product is produced for greens application that has a more rapid N release rate.

SCU applied during the winter months may produce a mottled turfgrass appearance. The intensity of this mottling is correlated with coating thickness and granule size. It normally dissipates in two to four weeks, depending on the N application rate and weather conditions.

SCU has little effect on soil salinity but can reduce soil pH slightly due to the sulfur coating. The sulfur coating also is a sulfur source for plants. Sulfur-coated urea is less costly than many other coated, slow-release N sources. Leaching and volatilization losses generally are low, assuming that excessive moisture is not applied. The N content of SCU ranges from 32 to 38%, depending on the thickness of the sulfur coating.

Plastic/Resin-Coated Urea – A relatively new but similar technology to SCU is a resin-coating (or polymer-coating) process that coats a soluble N source, such as urea, nitrate, or ammonium, with resin or a plastic. Resin-coated fertilizers rely on osmosis rather than coating imperfections to release N. Low concentrations of salts on one side of the resin or plastic membrane allow the diffusion of high salt concentrations to the other side through the coating. As the fertilizer particle swells, internal pressure either causes the pellet to crack open, releasing the urea, or the urea is forced out through the pores. Since the coating is semipermeable, N is time released.

Release rates generally vary from 70 to 270 days, depending on the thickness of the coating and dissolution of water into the prill. Soil temperature also influences the release rates of coated materials, since the release is by diffusion. The diffusion rate is temperature mediated. Thus, the polymer-coated materials tend to release N more slowly in the cool season than in the warm season. The major disadvantage of polymer coating is that it costs more other slow-release fertilizers.

The multiple coating of urea is a recent development. Urea is first coated with sulfur to form one layer and then coated with a polymer that further protects the nutrients and, in combination with the sulfur layer, determines the rate of release. The N is released through diffusion, which can be regulated by varying the levels of each of the coating components. One advantage, in addition to the controlled release rate, is better resistance

to abrasion than SCU. Dust problems when handling the material are also minimal.

Another coating process involves two coats of resin instead of one, plus one coat of sulfur. The first resin coating reacts with the urea, and the second coating reacts with the first to form a hard coating that does not break easily on handling. The coatings are very thin but effective. The thickness of the coating can be controlled to produce varying release rates. The dissolution of water into the prill also controls the N release rate.

Isobutylidene Diurea – Isobutylidene diurea (IBDU) is formed by reacting isobutyraldehyde with urea in an acid solution. The resulting product contains 31% N, 90% of which is water insoluble. In the presence of water, IBDU hydrolyzes back to urea and butyric acid. IBDU's nitrogen release rate is predominantly affected by soil moisture and particle sizes, and is not as dependent on temperature. With IBDU, an optimum pH range for N release is between 5 and 8, with a significant rate reduction occurring outside these ranges. Nitrogen release is independent of microbial activity. Therefore, IBDU nitrogen is released more readily during cool weather compared with other slow-release sources. The influence of IBDU on soil salinity and pH is minimal.

Ureaformaldehyde – Ureaformaldehyde (UF) is a generic designation for several methylene urea polymers that are formed by reacting urea with formaldehyde. These products have varying-length polymers of methylene urea, ranging from water-soluble molecules to highly water-insoluble molecules, to provide controlled N release. The smaller the ratio of urea to formaldehyde, the longer the chain of polymers formed. As polymer lengths and the number of longer polymers increase, solubility decreases, and N is released more slowly. Ureaform fertilizers contain a minimum of 38% N and are commercially available as Nitroform™, Nutralane™, Ureaform™, and Blue-Chip™; several additional methylene urea materials are marketed under other trade names.

All UF products depend on microbial breakdown for N availability. Therefore, environmental conditions favoring microbial activity (e.g., warm temperatures (> 55° F), neutral soil pH, and adequate soil moisture and oxygen) promote N release. Conversely, low temperatures, acid soils, and low soil oxygen inhibit N release from UF. Unlike IBDU and SCU, where N is released into soil as urea, N from UF is released as ammonium.

Shorter-chained, water-soluble polymers are readily digestible by soil microorganisms and release N in a relatively short time. Longer-chained polymers contain water-insoluble N, which is more slowly digested by soil bacteria. A lag in N availability may occur when using UF.

As with any N source, UF losses by mower pickup can be significant, especially immediately after application. Grass catcher boxes can be removed to allow clippings and fertilizer granules to return to the soil surface.

The losses of N by leaching and volatilization are less for UF than for readily available N sources. Over time, UF sources are about equal to soluble sources in terms of N use efficiency. Under conditions favoring leaching and volatilization, however, UF sources often are more efficient. Labor costs for applying fertilizer also must be weighed, since UF applications are less frequent. Soil pH or salinity are little affected by UF, and its burn potential is low.

Several new liquid materials that have better slow-release characteristics are now commercially available for foliar feeding and fertigation. These allow heavier rates to be applied less frequently without undesirable surges in growth or color. In addition, these slow-release materials minimize turf foliar burn potential. These solutions are generally composed of mixtures of short-chain methylene ureas, triazones, amines, and soluble urea. They are generally marketed as 28 to 30% N solutions containing about 30% soluble urea. In general, the responses observed for the various materials are very similar and generally last for no more than 60 days.

Natural Organic Nitrogen Sources

Natural organic N sources usually involve various levels of compost or waste (either human or animal) materials. Manure, biosolids, bone meal, humates, and composted plant residues are traditional sources of natural organic N. The advantages of these substances include a low burn potential due to limited water-soluble N, little effect on pH, low leaching losses, and the presence of other nutrients in the materials. The physical condition of soils, especially sandy ones, may improve with their use. Depending on the local source, natural organic N sources may be readily available at competitive prices.

Some considerations before using these sources include their low N content and slow N release during cool weather due to reduced microbial activity. Large amounts of material may need to be applied. These materials may be more costly per pound of nutrients than soluble sources. Natural organic N sources may be difficult to store and to apply uniformly, especially when the turf is already established. Some natural organic sources produce objectionable odors after application and contain undesirable salts, heavy metals, and weed seeds. Natural organic sources such as manures and composted crop residues should not be used on golf greens because of potential hindrances to soil drainage resulting from the large amounts of material applied.

For more information on N fertilizer sources for turfgrasses, see the publication, *Selected Fertilizers Used*

in *Turfgrass Fertilization* (archive: <http://ufdc.ufl.edu/fa01/results/?t=institute+of+food+agricultural+sciences>).

PHOSPHORUS

Phosphorus is an essential element for plant growth. Unfortunately, it is often the limiting nutrient in many natural systems, such as the Everglades. As such, many areas of the state are very sensitive to excess P. Phosphorus is abundant in some soils and should never be added to turf without a specific reason. Soil or tissue should almost always be tested before fertilizing with P.

Phosphorus is involved in the transfer of energy during metabolic processes. P content may range from 0.10 to 1% by weight, with sufficiency values from 0.20 to 0.40% in newly mature leaf tissue. Phosphorus is considered deficient when levels are below 0.20% and excessive above 1%. The highest concentration of P is in new leaves and their growing points, but it is readily mobile in plants.

The symptoms of P deficiency include slow growth and weak, stunted plants with dark-green lower (older) leaves. These older leaves eventually turn a dull blue-green color, with reddish-purple pigmentation along the leaf blade margins. Eventually, the leaf tips turn reddish and may then develop with streaks down the blade. Since P is fairly mobile in plants, deficiency symptoms initially occur in older tissue.

Phosphorus deficiency symptoms normally occur when the root growth of turf plants is restricted. Similarly, deficiencies often occur during cool-season turfgrass establishment, resulting from the initial restricted rooting of new seedlings. Cool-season turfgrasses (ryegrass) tend to respond positively to P fertilizer applications, even in soils with high P levels. The growth rate of bermudagrass, meanwhile, declines as a result of excessive P application. A reduction in tissue nitrogen content appears to result from applying P to a soil containing high levels of extractable P. In light of these findings, the majority of yearly fertilizer P should be applied to cool-season turfgrasses (ryegrass).

The most common P fertilizers used in turf include triple (or treble) superphosphate, and monoammonium and diammonium phosphate (MAP and DAP, respectively). Triple superphosphate is formed when rock phosphate is treated with phosphoric acid, while ammonium phosphates are produced by reacting ammonia with phosphoric acid.

A soil test is probably the best indicator of the P fertilization requirement. Indiscriminate P application can result in high levels. Phosphorus is most readily available to plants with a soil pH range of 5.5 to 6.5. At low pH (< 5.0), soils containing iron and aluminum form an insoluble complex with P; as a result, neither nutrient is easily available to the grass.

Sandy soils, such as those under many golf greens, lack iron or aluminum and do not form insoluble P complexes. Under these conditions, P is more available at a lower pH. However, one must be very careful to avoid leaching or runoff when adding P to low-pH, uncoated, sand putting greens.

In alkaline soils (pH > 7.5), calcium forms insoluble complexes with P to render it unavailable as dicalcium phosphate [CaHPO₄]. Applied P becomes less soluble over time and thus unavailable to the turf.

For more information on P sources for turfgrasses, see the publication, *Selected Fertilizers Used in Turfgrass Fertilization* (archive: <http://ufdc.ufl.edu/fa01/results/?t=institute+of+food+agricultural+sciences>).

POTASSIUM

Potassium is an essential element not usually associated with a prominent, easily seen response in a plant's shoot color or density. It does help a plant overcome some of the negative effect of excessive nitrogen fertilization, such as decreased stress tolerance to cold, heat, drought, diseases, and wear. It often is called the "health" element, since an ample supply of K increases a plant's tolerance of these stresses. Potassium is directly involved in maintaining the water status of a plant, the turgor pressure of the cells, and the opening and closing of the stomata. As the P concentration increases in a plant, the tissue water content increases and the plant become more turgid, since K regulates the stomatal opening. This is because K provides much of the osmotic pressure necessary to pull water into plant roots and thus improves a plant's drought tolerance. Cold tolerance is influenced by a plant's P-to-K relationship.

The dry matter of turfgrass leaf tissue consists of 1 to 3% K. Sufficient values range from 1 to 3% in recently matured leaf tissue. K deficiency occurs when levels are less than 1% and amounts greater than 3% are excessive. An inverse relationship also exists between K, magnesium, and calcium in plants. As K levels increase, magnesium deficiencies are the first to show, while at higher concentrations, calcium deficiencies occur. An inverse relationship can occur in saline soils, where calcium, magnesium, or sodium ions compete with K for plant uptake.

Potassium deficiency symptoms include the interveinal yellowing of older leaves and the rolling and burning of the leaf tip. Leaf veins finally appear yellow, and margins look scorched. The turf stand loses density, with spindly growth of individual plants. Potassium is a mobile element within plants and thus can be translocated to younger, meristematic tissues from older leaves if a shortage occurs.

Potassium fertilizer often is referred to as "potash." The soluble K content of a fertilizer is expressed as K₂O.

Early settlers coined the name from producing potassium carbonate needed to make soap by evaporating water filtered through wood ashes. The ashlike residue in the large iron pots was called potash, and this process was the first U.S.-registered patent.

Muriate of potash (potassium chloride), the most often used K-containing fertilizer, originates from potassium salt deposits that have been mined and processed. Potassium sulfate has a lower salt index than muriate of potash and should be used in high-salt situations.

The available form for plant use, the potassium ion (K⁺), is absorbed primarily from the soil solution. Potassium is not readily held in sandy soils (low-CEC soils) and can be lost by leaching. This problem is not always appreciated, especially when growing grass subjected to heavy rainfall or watering. Soils containing appreciable clay retain more K, because clay particles hold this element.

There is competition in plant uptake between K and calcium and magnesium. Soils high in either calcium or magnesium, or both, need additional K fertilization in order to satisfy plant needs. In sandy soils, or where turf clippings are not returned, research shows that K application equal to or in excess of the N rate does not result in additional growth or K in turfgrass tissue. Frequent light applications of K may be beneficial due to the high leaching potential of K in sand-based greens. High rates of K application may induce tissue magnesium deficiencies on soils where exchangeable magnesium levels are marginal. On fairways where clippings are returned, optimum tissue K levels can be maintained when a 2-to-1 N-to-K fertilization ratio is used.

SECONDARY PLANT NUTRIENTS

The elements calcium (Ca), magnesium (Mg), and sulfur (S) are required in almost the same quantities as phosphorus. Calcium's functions include strengthening cell walls to prevent their collapse; enhancing cell division; encouraging plant growth, protein synthesis, and carbohydrate movement; and balancing cell acidity. Calcium also improves root formation and growth. Contrary to other nutrient elements, most plant calcium is obtained by mass flow created by the transpiration stream. Deficiencies may occur in sandy soils, acidic soils (pH < 5.0), or soils saturated with sodium. Deficiency symptoms include young leaves that are distorted in appearance, leaves that turn reddish-brown along their margins before becoming rose-red, and leaf tips and margins that wither and die. Roots also are short and bunched. Excessive calcium may tie up other soil nutrients, especially phosphorus, magnesium, manganese, iron, zinc, and boron.

Calcium is an immobile element within plants. It does not move from older leaves to new ones and must be supplied continuously. Calcium is usually added in a liming

program or by irrigation with water containing high levels of calcium. Florida's high-pH soils naturally contain calcium. Commercial sources include calcitic and dolomitic limestone, gypsum, superphosphates, shells, slags, and water treatment residue.

Magnesium is essential for chlorophyll production in plants. Chlorophyll molecules contain approximately 7% magnesium. Magnesium also is essential for many energy reactions, such as sugar formation; acts as a carrier of phosphorus; and regulates the uptake of other plant nutrients. Deficiencies occur mostly in sandy soils (low CEC) or soils with extremely high pH, especially when clippings are continuously removed. Deficiencies can occur in soils with less than 40 lbs. per acre of Mehlich-1 extractable magnesium. High calcium and phosphorus levels also tend to reduce magnesium uptake.

Magnesium is a mobile element in plants and is easily translocated from older to younger plant parts as needed. Symptoms of deficiency include a general loss of green color starting at the bottom leaves. Veins remain green. Older leaf margins turn a blotchy cherry-red, with stripes of light yellow or white between the parallel veins. Necrosis eventually develops. Sources of magnesium include dolomitic limestone, sulfates of potash and magnesium, magnesium sulfate (Epsom salt), oxide, and chelates.

Sulfur is essential for selective amino acid production. It is used for building blocks of proteins and also reduces the incidence of disease. Sulfur content in leaf tissue ranges from 0.15 to 0.50% of the dry weight.

The sulfate anion (SO_4^{-2}) is the primary available form found in soil solution. Like nitrate, the sulfate ion can leach from soil. Deficiencies may occur where grass clippings are removed, excessive watering occurs, and sandy soils predominate. Deficiency symptoms include an initial light yellow-green color in the leaves, with the yellowing most pronounced in younger leaves, as sulfur is mobile in plants. Older leaves become pale and then turn yellowish-green in interveinal areas. Leaf tips are scorched along the margins. Bermudagrass grown in sandy soils has been shown to respond to sulfur applications.

Over 90% of available sulfur exists in the organic matter, which has a nitrogen-to-sulfur ratio of approximately 10 to 1. Deficiencies may occur when the ratio is greater than 20 to 1 or at a high soil pH (> 7.0). Sulfur may be precipitated as calcium sulfate (CaSO_4), while at lower pH levels (< 4.0), the sulfate anion may be adsorbed by aluminum and/or iron oxides. Turf clippings with a high nitrogen-to-sulfur ratio (> 20 to 1) decompose slowly and may slow thatch biodegradation. Microorganisms require sulfur to decompose plant residues. Sulfur is supplied as a contaminant in some fertilizer sources, such as super-

phosphate. However, many new high-analysis fertilizers frequently do not contain appreciable sulfur.

In poorly drained, waterlogged soils where soil oxygen is exhausted, sulfate-reducing bacteria can convert SO_4^{-2} and sulfur-containing organic matter to toxic hydrogen sulfide (H_2S). Excessive applications of elemental sulfur also may encourage the buildup of hydrogen sulfide in greens where excessive irrigation is practiced or drainage is poor. Insoluble sulfides also may form by reacting with soil iron.

Turf soils containing toxic levels of hydrogen sulfide or iron sulfate are acidic and commonly form a black layer several inches below the soil surface. They typically are characterized by a distinct hydrogen sulfide (e.g., sewer or rotten egg) smell. Low soil oxygen also can reduce levels of manganese, copper, and iron, resulting in gray and blue colored subsoils. This often occurs in poorly drained soils and in greens receiving excessive irrigation. The black layer can usually be controlled by proper water management.

MICRONUTRIENTS

Micronutrients are essential elements needed in relatively small amounts (e.g., < 50 ppm). Many soils in the United States supply sufficient levels of micronutrients. In other cases, enough micronutrients are supplied in fertilizers as impurities. In Florida, however, with its sandy and peat or muck soils, pockets of high-pH and phosphorus-containing soil, poor drainage, and periods of extended, heavy rainfall, deficiencies in micronutrients can become a problem. For example, as soil pH increases, iron changes from its available (soluble) ionic form to hydroxy ions and finally to insoluble or unusable hydroxide, or oxide forms.

Soil pH has many effects on plants but probably influences them most by affecting the availability of important nutrients. Figure 15 shows the relative availability of some nutrients as a function of pH. A wider bar indicates more availability. For example, at lower pH values (< 5), aluminum, iron, and manganese are highly soluble. High levels of aluminum can reduce plant uptake of phosphorus, calcium, magnesium, and iron. At higher pH values (> 7.0), nutrients such as iron, manganese, copper, and zinc are less soluble and therefore relatively unavailable for plant uptake—although molybdenum (Mo) availability actually increases with high pH. The availability of phosphorus and boron also may be hindered by a soil pH value greater than 7.

In parts of south Florida, marl may become mixed with surface organic soils or peat. These normally acidic organic soils thus become neutral or even alkaline due to the liming action of the marl. Many of the peat or muck sod farms in south Florida are on soils with marl intermixing. These soils are almost always low in magnesium, potassium, phosphorus, copper, and zinc.

A balance of micronutrients is particularly important, because many plant functions require more than one element. Regular tissue testing is the best approach to preventing nutrient deficiency problems. Iron and manganese are two of the most common micronutrient deficiencies that Florida turf managers experience. Micronutrient deficiency symptoms can easily be confused with pest occurrences or other stresses. These problems, however, usually are more localized and appear as irregular spots or in circular patterns.

Chelates

Chelates, chelating agents, or sequestering agents are cyclic structures of a normally nonsoluble metal atom bonded with an organic component. They are soluble in water. Commercially available sequestered metallic ions are iron, copper, zinc, and manganese. Organic compounds with the ability to chelate or sequester these metallic ions include ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), cyclohexanediaminetetraacetic acid (CDTA), and ethylenediamine di(o-hydroxyphenylacetic acid) (EDDHA). A plant can absorb the soluble chelate forms of the metal ions.

Beneficial Elements

Recent research suggests that silicon may be beneficial to the growth of turfgrasses. Disease incidence, particularly grey leaf spot, may be reduced and wear tolerance may be improved by the application of silicon to turfgrasses growing in soils low in soluble silicon. In some countries—but not in the United States—silicon is recognized as an essential element for some plants. See the comment on sodium below regarding C₄ plants, and keep up on potential changes in the research on this issue.

Nonessential Elements

Aluminum, arsenic, and sodium are generally considered nonessential elements for turfgrass growth and development. They become toxic when levels are excessive and should not normally be applied in supplemental fertilizers. However, some published research indicates that sodium may be essential at some level for bermudagrass and other C₄ plants.

STARTING A FERTILIZER PROGRAM

Fertilization programs⁷ for golf course grasses require ample nutrients for optimum growth and performance quality but must also protect Florida's fragile environment. Trying to improvise one fertilization schedule that encompasses all courses within the state is unrealistic. Players' expectations, budget constraints, the soils used in construction, and location all influence the inputs each course must use when determining a sound

fertility program. Many times this is intensified by the high, and often excessive, standards demanded by professional players. Club members often place undue pressure on their superintendents to provide lush conditions that drive up costs and waste or harm natural resources.

The state is very concerned about nitrate-nitrogen leaching into ground water and the phosphorus and nitrogen impacts on surface waters in many areas. Both local and state agencies have been examining the fertilization practices of golf courses. Excessive and unnecessary fertilization should be avoided to prevent water contamination and the possible penalties faced by those deemed to be the source of water pollution.

The following provides an overview of fertility recommendations for most courses and special situations in the state. Each course, however, should follow the fertility program that best suits its situation. For general information on the fertilization of Florida turfgrasses, see the publication, *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: <http://edis.ifas.ufl.edu/LH014>).

SOIL ACIDITY AND LIMING

Except in some coastal areas, most Florida soils are naturally acidic. Liming acidic soils to a pH of 6.5 has numerous positive effects on the soil and on turfgrass growth and quality. The beneficial effects of liming acidic soils include the following:

- Increased turfgrass growth and quality,
- Decreased thatch buildup,
- Increased retention and reduced leaching of fertilizer elements,
- Increased rooting density and depth,
- Optimum availability of nutrients,
- Increased activity of beneficial soil organisms,
- Amelioration of toxic elements in the soil, and
- Better soil structure and tilth.

Soil pH should be monitored by annual soil testing. Intensively managed and artificially constructed areas such as putting greens may require more frequent testing. Whenever soil pH drops below 6.0, lime should be applied in sufficient quantity to raise the pH to 6.5. A general rule of thumb for liming sandy soils with low

⁷Sartain, Miller, Snyder, Cisar, and Unruh, 1999.

buffering capacity, such as those in Florida, is to apply 1 ton of lime per acre to raise the pH 1 unit (Figure 16). However, liming based on laboratory recommendations is more precise and should be used whenever possible. Samples should be sent to a soils lab that uses the Adams-Evans (A-E) method for predicting liming requirements. The UF-IFAS Extension Soil Testing Laboratory (ESTL) uses the A-E method and recommends it. Ideally, the pH of Florida soils should never be allowed to drop below 5.5 unless recommended by the ESTL for the specific crop being grown.

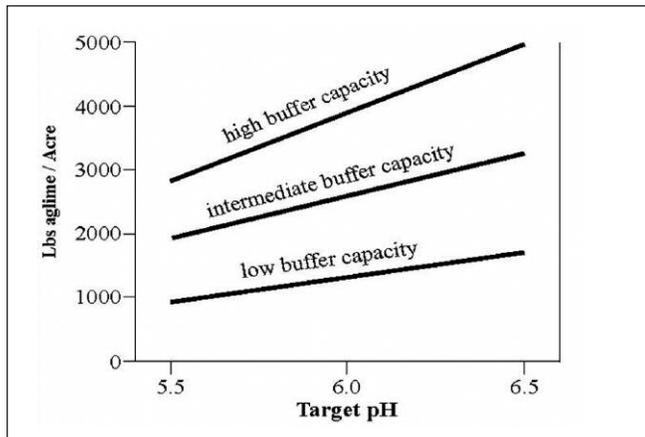


Figure 16: Effects of buffering capacity on lime requirements.

Pulverized calcitic or dolomitic limestone with a calcium carbonate equivalent (CCE), or neutralizing power, of 90 or greater is recommended for liming golf turf. Dolomitic limestone is the preferred product for soils that are low in magnesium. Pelletized products reduce the dust associated with the application of liming materials and flow more easily.

FERTILIZATION PROGRAM FOR GOLF GREENS

Timing

Determining how much and how often fertilizer should be applied depends on several factors. Each golf course superintendent should consider the quantity and scheduling of fertilizer to be applied during the year. Fertilization programs should provide adequate levels of essential nutrients to sustain growth and acceptable turf quality and color. Improper timing and/or rates of fertilizer application influence the stress tolerance and recuperative ability of turfgrasses. In addition, disease occurrence and severity often are closely linked to the amounts and timing of fertilization programs. For example, dollar spot (*Moellerodiscus* and *Lanzia* spp.) disease often is associated with low nitrogen levels. A fertilizer application containing quick-release nitrogen often allows the turfgrass to outgrow these disease symptoms, thus eliminating the need for fungicide applications. In contrast, the excessive fertilization of overseeded grasses such as ryegrass (*Lolium* spp.), roughstalk bluegrass (*Poa*

trivialis), and bentgrass (*Agrostis* spp.) often promotes the occurrence of brown patch (*Rhizoctonia* spp.) and pythium (*Pythium* spp.) diseases.

Proper fertilization not only provides disease- and stress-free turf, but also an acceptable playing surface.

Excessive fertilization with nitrogen is not only agronomically detrimental but drastically slows ball roll and draws complaints from players. Exceptions, such as certain high-traffic greens and tees (e.g., Par 3) or newly constructed greens, require more nitrogen fertilization to promote turf recovery from ball marks and concentrated traffic, and to facilitate more rapid grow-in.

The timing of fertilization may be based on the minimum and optimum temperatures necessary for turfgrass growth. Minimum temperatures for warm- and cool-season shoot growth are about 55° and 40° F, respectively, while warm- and cool-season roots may grow at temperatures as low as 50° and 33° F, respectively. Optimum temperatures for warm- and cool-season shoot growth are about 80° to 95° F and 60° to 75° F, respectively, while optimum temperatures for warm- and cool-season roots are 75° to 85° F and 50° to 65° F, respectively. If temperatures are outside the growth range of the grass, slow-growing plants use fertilizer applications inefficiently.

Nitrogen Rates

Because of year-round play, the range of N needs for Florida golf greens is higher than that typically used in many other settings. However, quality putting surfaces can be maintained without excessive N rates. Courses with high traffic and elevated demands from serious amateur and tournament players use more N than public courses with modest traffic. The most important factor in the environmental fate of N application to turfgrass is not the total amount applied annually but rather, the amount applied in any single application and therefore available to leach or run off to surface waters before being used by the plants. Frequent “spoon-feeding” of greens is the most effective method of avoiding accidental N losses to the environment. The nitrogen content in reclaimed water used for irrigation should be included in these calculations.

Frequency

To maintain optimum color and density during periods of active growth, sand-based bermudagrass golf greens need approximately 1/2 lb. soluble N per 1,000 ft² every 7 to 14 days. For courses without these resources and for those with lower expectations, adequate bermudagrass can be maintained with 1/2 lb. N per 1,000 ft² applied every 2 to 3 weeks. On intensively maintained courses, higher rates (e.g., up to 1/2 lb. every 3 to 7 days) may be necessary for up to 4 weeks to encourage quicker turf recovery during times of heavy play. The failure of the turf to recover in 4 weeks may indicate problems other than N.

In addition, higher application rates can lead to other problems. Excessive thatch can quickly accumulate, putting speeds are slower since more leaf area is produced, and a decrease in turfgrass rooting may result. During the rainy season, these rates may cause excessive leaching and runoff due to the severity of Florida's frequent (often daily) thunderstorms. When possible, take advantage of breaks in the rainy weather to apply nutrients so they may be absorbed before the rains start again.

Prescription Fertilization

Whenever practicable, fertilization should be based on the specific needs of each green at a given time. Soil and tissue testing can help devise a prescriptive approach to each area.

Nitrogen Sources

The source of N used to fertilize golf greens affects the amount applied. Usually, a combination of soluble and insoluble sources is recommended to provide uniform grass growth and reduce N leaching. Ureaformaldehyde (Nitroform), IBDU, and SCU often are used to provide slow-release, residual N, while a soluble source is used for rapid response. During cold temperatures, IBDU or soluble sources provide the fastest turf response, because they are less dependent on microorganisms for N conversion and release. Other considerations involving N sources include higher costs for slow-release and natural organic sources compared with soluble ones, the salinity hazard of ammonium nitrate and ammonium sulfate, and the acidifying effects of ammonium sulfate and ammonium phosphate.

Except for slow-release (water-insoluble) materials, actual N should never be applied in excess of 1 lb. per 1,000 ft² in any one application, and then only when appropriate soils and healthy turf preclude leaching. Small amounts (1/2 lb/1,000 ft² soluble N) frequently applied are preferred, since this produces a higher-quality turf, reduces growth flushes, and minimizes leaching potential. In most cases, a high-quality turfgrass can be maintained for a 90-day period without flushes of growth or drastic changes in color when slow-release sources are used. Additionally, slow-release N sources leach less than soluble ones.

Other Elements

Potassium (K) often is called the "health" element. Without a readily available supply of K, turfgrasses may be more susceptible to environmental and pest stresses. Root growth also is related to K availability. Unfortunately, K does not readily remain in the turfgrass root zone, especially in greens constructed predominately with sandy soils. Therefore, it should be applied to golf greens nearly as frequently as N, at between one-half to equal the N rate.

Soil phosphorus (P) levels tend not to fluctuate as readily as N or K. Soil test results should be used to determine the amount needed for a particular golf course. Golf

greens constructed of uncoated sands, and sand greens that have a pH less than 5.0, may leach P readily. In such situations, soil P levels should be monitored frequently and P source fertilizers applied only when soil P levels become deficient.

Micronutrients

Regular soil and tissue testing is the best preventive approach to avoiding many of the micronutrient deficiency problems. Iron and manganese are two of the most common micronutrient deficiencies that Florida turf managers experience. The symptoms can easily be confused with other stresses. These problems, however, usually are more localized and appear as irregular spots or in circular patterns.

TEES

Tees, like greens, should be fertilized sufficiently to sustain vigorous recuperative growth, but not to the point that wear tolerance is sacrificed. Tees, in general, are maintained almost as intensively as golf greens. This is especially true for tees constructed with a sand-based profile and for Par 3 tees that receive excessive traffic and damage from club divots. For most Par 4 and Par 5 tees, the fertilization program can be reduced to approximately one-half that for golf greens. For Par 3 tees, the fertilization program should range between three-fourths of or equal to that for greens. K applications should be approximately one-half of N applications, except where clippings are removed or when sand-based tees are constructed. In such cases, K application rates may need to equal those of N.

FAIRWAYS AND ROUGHS

Fairways generally are maintained with lower fertilizer inputs than golf greens. Clippings are not removed during mowing, resulting in the recycling of more nutrients, and heavier soils are usually used for fairways. In addition, higher mowing heights promote deeper rooting, and less irrigation is applied that may leach soil nutrients. N fertilization rates should range between 130 and 260 lbs. per acre per year. P and K needs should be based on yearly soil tests.

Applications should begin in late winter during the flush of new turf growth. In general, one application of a complete fertilizer during this period and another in the fall are needed. These are supplemented throughout the year with N and K, as needed, to maintain desirable color, leaf texture, density, and recuperative ability. In general, applications are made every 5 to 8 weeks on high-maintenance courses and every 10 to 12 weeks on low-maintenance courses through the spring and summer. The last fertilization should be made approximately 1 month before anticipated frost in north Florida and should consist of a 1-to-1 or 1-to-2 N-to-K ratio to encourage desirable carbohydrate formation. Fertilization should continue in south Florida or on overseeded fairways to maintain desirable color.

Be careful not to overapply, because the slower-growing turf is less able to use the applied material.

Since roughs are mowed higher than fairways, may have less traffic, and clippings are returned, fertilization requirements for roughs are much lower than for fairways and greens. Roughs should usually be fertilized 2 to 4 times a year to provide color and recuperation from pest or traffic damage. Twenty pounds of N from a soluble source, or 40 pounds from an insoluble source, should be applied per acre per application.

For specific information on the fertilization of different turfgrass species grown on golf courses and athletic fields, see the publication, *Recommendations for N, P, K, and Mg for Golf Course and Athletic Field Fertilization Based on Mehlich I Extractant* (available: <http://edis.ifas.ufl.edu/SS404>).

GROW-IN

Grow-in, or the establishment of turfgrass, is one of the most intensive phases in turfgrass management. Typically, in order to promote rapid establishment, large amounts of N and water are applied during the 10- to 12-week grow-in period, when the largest amount of environmental impairment may take place. Research has shown that this does not have to be the case. By regulating the rate of N applied according to the level of establishment of the turfgrass—i.e., applying less when the turfgrass coverage is less and gradually increasing the rate of N application as more of the ground is covered—one can reduce N leaching losses by as much as 25%. Also, by properly selecting the N source—i.e., including some slow-release or organic N sources in the fertilizer mixture—the rate of N loss through leaching can also be reduced. For installation of fresh-cut sod which has been fertilized within 45 days of harvest, nitrogen or phosphorus fertilizer should not be applied until at least 14 days after sodding. This does not apply to grow-in from seeding or sprigging.

These practices delay the full establishment of the turfgrass by as much as 14 days, but through the proper selection of application rates and N fertilizer sources, N leaching losses can be reduced to less than 10% of the applied N during the entire 12-week grow-in period, even with the high rates of irrigation that are normally applied. Combinations of soluble, organic, and slow-release N sources produce high quality turfgrass during grow-in. The incorporation of fertilizer nutrients in the grow-in root-zone sand/peat mixture does not result in more rapid establishment of turfgrass but does result in more total N, P, and K leached. Recently, some golf course construction firms have used sand only as a root-zone mix. Sand-only greens have a higher propensity to leach N and P, and are slower to become established. Great care should be exercised when establishing turfgrasses on sand-only greens.

P and K fertilization are also very important during grow-in. In general, turfgrasses respond better to

P fertilization during grow-in than at any other time during their growth cycle. If the root-zone mix does not contain adequate levels of P for root development, the turfgrass establishes slowly and has a poor root system. Extreme care should be exercised when fertilizing with P during grow-in, because the turfgrass coverage area may be small and the roots poorly developed. When establishing turfgrass on sands containing low levels of P and sesquioxide/clay coatings, P may leach. Apply P when dictated by a soil test and at the recommended rates for good turfgrass growth.

K is also very important during turfgrass establishment for good root growth and healthy turfgrass growth. Sandy soils are typically low in K and require K fertilization. Fortunately, K is not considered an element of environmental impairment; thus, K fertilization may not have an environmental impact, but salt buildup in the root-zone mix and the depletion of a natural resource are two reasons to monitor the soil test K level and apply only the amount required for optimum turfgrass growth. Maintaining an optimum soil pH for turfgrass growth through proper liming results in maximum K retention by media cation exchange sites in the root zone.

SOIL SAMPLING

Although it may not be an essential practice for the everyday maintenance of a healthy landscape, testing to determine the soil's chemical properties before installing turfgrass or landscape plants is recommended. Through soil testing, the initial soil pH and P level can be determined. Soil pH is important in determining which turfgrass is best adapted to the soil. After initial soil testing, additional testing may be required only when fertility problems arise and the responses to fertilization are poor.

Soil testing is an applied science and can be used as a tool in maintaining healthy turfgrass and landscapes. For the effective management of nutrients, soil testing should be used in conjunction with tissue testing. Soil test recommendations are based on a correlation between the level of a given nutrient extracted from the soil and the anticipated plant response. The amount of nutrients extracted by a particular extractant is only an index relative to crop response. It is not a direct measure of actual plant nutrient availability.

The levels of extracted P, K, and Mg are divided into five categories: very low, low, medium, high, and very high. For more information, see your county Cooperative Extension Service agent or the publication, *Soil Testing and Interpretation for Florida Turfgrasses* (available: <http://edis.ifas.ufl.edu/SS317>); for specific information on the fertilization of different turfgrasses species grown on golf courses and athletic fields, see the publication, *Recommendations for N, P, K, and Mg for Golf Course and Athletic Field Fertilization Based on Mehlich I Extractant* (available: <http://edis.ifas.ufl.edu/SS404>).

Methodology

The soil test and resulting recommendations are only as representative as the sample itself. Therefore, it is imperative that the soil sample be taken and handled properly. The sample should be obtained by taking 15 to 20 small plugs at random over the entire area where information is desired (Figure 17). Avoid any unusual areas or areas with specific, identifiable characteristics; these should be sampled separately. For turfgrass, since most of the roots are in the top 4 inches of soil, limit the sampling depth to 4 inches. For landscape plants, the sampling depth should be no more than 6 inches.



Figure 17: Soil Core

Place the plugs that have been collected into a plastic container, mix them thoroughly, and send approximately 1 pint of the mixed sample to the ESTL for chemical analysis. Several commercial laboratories also offer the same service in Florida. You should use the same laboratory on a continued basis to establish a historical log of your soil properties. Laboratories across the state do not use the same extractant, and so if you change labs often you may be comparing results obtained by different methods.

Soil Test Interpretation

A soil analysis supplies a wealth of information on a soil's nutritional status and can detect potential problems that limit plant growth. A routine soil analysis supplies information on soil pH and the extractable phosphorus, potassium, calcium, and manganese status of the soil. The ESTL currently uses Mehlich-1 as an extractant on all the acidic mineral soils in the state and AB-DTPA (ammonium bicarbonate-DTPA) extractant on soils with a pH above 7.3 (calcareous soils).

Table 2 presents interpretation ranges for soil test levels of P, K, Mg, Mn, Zn, and Cu. For detailed explanations of soil tests and interpretation, see the publication, *Soil Testing and Interpretation for Florida Turfgrasses* (available: <http://edis.ifas.ufl.edu/SS317>).

Note that there is no interpretation made for soil test calcium or iron. No interpretation is made for Mehlich-1 extractable calcium levels because the extractant dissolves calcium compounds, which may not be readily plant available. Thus, the amount of plant-available calcium can be erroneously interpreted. In most cases, calcium levels are adequate for turfgrass growth because Florida soils are inherently high in calcium, have a history of calcium fertilization, or receive calcium regularly through irrigation with high-calcium water. The soil test level for Mehlich-1 extractable calcium is used only to determine the type of limestone needed when lime is recommended. For most soils and turfgrasses, liming to ensure an adequate soil pH ensures more than adequate calcium. Research has shown no turfgrass response to added calcium, from either liming materials or gypsum, when the Mehlich-1 extractable calcium level is above 250 ppm.

The ESTL does not analyze for extractable iron because definitive data on interpretation are lacking. Significant correlation of soil test iron levels with plant tissue levels is also lacking. The testing procedures tend to produce highly variable results. Most soils, except those with a pH greater than 7.0, generally contain adequate levels of iron for optimum growth. Turfgrasses grown on soils with a pH greater than 6.5 exhibit a greening response to iron applied as a foliar spray. Unfortunately, frequent reapplications may be required to sustain the desired color.

For more information on fertilizing landscape plants, see the publication, *IFAS Standardized Fertilization Recommendations for Environmental Horticulture Crops* (archive: <http://ufdc.ufl.edu/fao1/results/?t=institute+of+food+agricultural+sciences>).

TISSUE TESTING

Because of the mobility of most essential nutrients for landscape plant and turfgrass growth in Florida soils, one of the best indicators of appropriate fertilization and plant

Table 2: Suggested ranges for Mehlich-1 extractable soil nutrient levels for Florida turfgrasses

Macronutrients*			Micronutrients**		
P	K	Mg	Mn	Zn	Cu
Parts per million (ppm)					
16–30	36–60	20–30	3–9	0.5–3	0.1–0.5

* Medium ranges of Mehlich-1 extractable P, K, and Mg when in 25% of the cases a response to applied fertilization would be expected.

** Soils testing below these levels of micronutrients are expected to respond to applied micronutrients. The interpretation of soil test micronutrient levels is based on soil pH. The smaller number is for soils with a pH of less than 6.0, and the larger number is for soils with a pH of 7.0 or greater. Mehlich-1 extractable micronutrient levels are only determined when requested and require an additional charge.

health is tissue analysis. Since turfgrass is a perennial crop, historical logs of tissue composition can be used to fine-tune a turfgrass fertilization program for optimum plant growth and minimum environmental impact. Leaf analysis, along with appearance and soil analysis, can be used to diagnose the problems and the effectiveness of a fertilization program, especially for micronutrient deficiencies. Soil analysis for some nutrients, because it is a snapshot of what is present at the time of sampling, does not always indicate their availability to plants. Potential nutrient deficiencies can be detected with leaf analysis before visual symptoms appear. Leaf analysis may provide information on induced deficiencies and inferences on plant uptake.

Methodology

Clippings can be collected for tissue analysis during regular mowing. It is essential that the clippings be free of sand and fertilizer contamination. Do not harvest clippings immediately after fertilization, topdressing, or any other cultural practice that results in significant mower pickup. Place approximately a handful of well-mixed clippings in a paper bag. Do not place the clippings in a plastic bag because the clippings may begin fermenting prior to drying.

If facilities exist at your location, dry the collected clippings at approximately 70° C. (158° F) for 24 hours, and then mail them to your favorite analytical laboratory for analysis. If you do not have drying facilities, ship the samples, preferably overnight, to the analytical laboratory. Even if placed in a paper bag, if a sample is allowed to sit for more than a couple of days the tissue begins to ferment and the value of the sample for analytical purposes is lost.

Sample Contamination

Turfgrass clippings that have been recently sprayed with micronutrients for fungicidal or nutritional purposes should not be used for micronutrient analysis. Washing recently unsprayed clippings to remove soil and dust particles is recommended prior to sending the samples to the lab for analysis. If you wash one collection of clippings

and not all, the nutritional analyses may not be comparable because the concentration of some nutrients, such as K, in tissue is highly mobile and a portion of the K may be removed during washing. Unwashed samples may appear to have a much higher concentration than the washed samples, and you may suspect a deficiency in the washed samples when in fact an adequate supply of K exists.

Interpretation of Results

Sufficiency levels of essential nutrients do not vary much among the various turfgrass species, except for N. The sufficiency tissue N concentration can vary from a low of 1.5% for centipede grass or bahiagrass to a high of 5.5% in cool-season, overseeded ryegrass. **Table 3** lists the sufficiency ranges for tissue N concentration for the various turfgrasses used in lawns. In most cases, tissue N concentrations below the minimum of the range are deficient and above the range are excessive.

The concentration of other macro- and micronutrients in tissue does not vary greatly among the various species of turfgrasses. The sufficiency ranges in **Table 4** are applicable to most of Florida's turfgrass species. All of these values are based on dry weight. The values represent the range over which a particular nutrient might vary across the various turfgrass species. They represent sufficiency ranges, which suggest that levels below the range may indicate a deficiency or above the range may represent excessive fertilization or toxicity.

The sufficiency ranges in the tables show the most current interpretation for nutrient concentrations in turfgrass tissue. If analytical test results are in the deficiency range or below the sufficiency range, an increase in fertilization for that nutrient may be appropriate. Alternatively, if test results fall outside the sufficiency range, the fertilization program may need adjustment. However, other causes may need to be considered. If a change in fertilization is indicated, the adjustment should be reasonable. The intent is to find the correct nutrient management level that maintains nutrient concentrations in turfgrass tissue within the optimum range, but does not lead to overfertil-

Table 3: Sufficiency ranges of tissue N concentration for selected turfgrasses

	St. Augustine	Zoysia	Bermuda	Centipede	Bahia	Rye
N (%)	2.0–3.0	2.0–3.0	2.5–3.5	1.5–2.5	1.5–2.5	3.5–5.5

Table 4: Sufficiency concentration ranges for selected macro- and micronutrients in turfgrass tissue

P	K	Ca	Mg	Fe	Cu	Mn	Zn	B
Percent (%)				ppm				
0.15–0.50	1.00–2.00	0.5–1.0	0.20–0.50	50–500	5–30	25–100	20–100	5–20

ization and possible adverse environmental and economic results.

FERTILIZER LOADING

Load fertilizer into application equipment away from wells or surface waterbodies. A concrete or asphalt pad with rainfall protection is ideal, as it permits the easy recovery of spilled material. If this is not feasible, spread a tarp to collect spillage. Where dedicated facilities are not available, loading at random locations can prevent a buildup of nutrients in one location. **It is not recommended to load fertilizers on a pesticide CMC because of the potential for cross-contamination.** Fertilizers contaminated with pesticides may cause turf damage or generate hazardous wastes. Many pesticide carriers are hydrocarbon-based and they may react with oxidizers in spilled fertilizer materials.

Clean up spilled material immediately. Collected material may be applied as fertilizer. The area can be cleaned by sweeping or vacuuming (or by using a shovel or loader, if a large spill), or by washing down the loading area to a containment basin specially designed to permit recovery and reuse of the washwater. Washwater generated should be collected and applied to the turf.

Discharging this washwater to waterbodies, wetlands, storm drains, or septic systems is illegal.

Figure 18 shows unsafe and safe fertilizer storage practices (top and bottom photos, respectively).



Figure 18: Fertilizer: top, no cover, open spills; bottom: good practices, inside storage.



FERTILIZER APPLICATION CALIBRATION

The only way to accurately know how much fertilizer is actually being applied is to calibrate your application equipment. Calibration should be done in accordance with the manufacturer's recommendations, or whenever wear or damage is suspected to have changed the delivery rate. For granular materials, it may be necessary to recalibrate whenever using a new material with different flow characteristics. Sprayers and metering pumps on liquid systems also need to be calibrated regularly.

GRANULAR APPLICATION

Granular fertilizer is usually applied with a rotary spreader. When applying it near waterways, cart paths, or other nontarget areas, always use a deflector shield to prevent inappropriate fertilizer distribution. Maintain a "Ring of Responsibility" of at least 3 feet when using a deflector shield, 10 feet if no shield is used, even if no other Special Management Zone is defined. If fertilizer is deposited on cart paths, parking lots, or other impervious surfaces, sweep the material into the turf where it can be properly absorbed and will not run off into storm drains or waterbodies. Drop spreaders may be used occasionally, but they may cause mechanical damage to the coatings of slow-release fertilizers.

FOLIAR FEEDING

Foliar feeding⁸ and liquid fertilization involve the use of a soluble nutrient form for plants. Nutrients are used more rapidly and deficiencies corrected in less time than conventional soil treatments. However, the response is often temporary. Due to the small amounts required, micronutrient applications have traditionally been the most prominent use for foliar sprays.

Foliar feeding involves using low fertilizer rates (e.g., 1/8 lb. nitrogen or iron per 1,000 ft²) at low spray volumes (e.g., 1/2 gal. per 1,000 ft²). Low nutrient and spray volumes minimize costs and supplement the normal fertilization program with nutrients absorbed directly by turf-grass leaves.

At higher spray volumes, (e.g., 3 to 5 gals. per 1,000 ft²), the fertilizer is washed off the leaves. This is called liquid fertilization. With liquid fertilization, fertilizers and pesticides often are applied together. Although the initial spray equipment for liquid application costs more, it usually is less expensive to apply in the long run than granular fertilizer.

The application of micronutrients, iron being a notable example, is commonly employed with foliar fertilization. All micronutrients are metals except boron and chloride. With the exception of molybdenum, the availability of most micronutrients declines with increasing soil pH.

⁸Sartain et al., 1999b.

Chloride is unaffected by soil pH. Micronutrient fertilizers are generally more expensive than macronutrient materials. The application rates for micronutrients usually are low enough so that foliar applications are feasible. One potential problem when zinc, iron, manganese, and copper are added to clear liquid fertilizers is that precipitation often occurs as a reaction with phosphates. Chelates of the metal micronutrients can be mixed with liquids without causing precipitation.

Nitrogen also is added to many micronutrient products to stabilize the solution. Micronutrient solutions can retain elements at higher temperatures and become supersaturated. Upon cooling, micronutrients in the solution may precipitate out, forming insoluble compounds. Urea has been shown to help prevent precipitation, and it also gives the turf a small color boost.

ADVANTAGES AND DISADVANTAGES OF FOLIAR FERTILIZATION

Advantages:

- There is no segregation of particles, as is common with granular fertilizers.
- The process provides nutrients directly to plants and is not influenced by soil properties.
- Fertilization provides water-soluble forms of nutrients.
- Coapplication with pesticides is possible.
- The fertilizer is generally easier to handle and quicker to apply.

Disadvantages:

- There are problems with sufficient application without severe leaf burn.
- The number of bags cannot be counted.
- Some solutions may salt out at lower temperatures.
- Frequent applications at low rates may be necessary because turf response is temporary and low rates prevent leaf burn.

PRECISION APPLICATION

Precision application refers to the use of automated application equipment using global positioning system (GPS) data and detailed mapping to apply just the right amount of a chemical to a specific area. This may reduce overall fertilizer (or pesticide) use by customizing the application to the particular characteristics at a given location, and may be accurate to within one or two feet. Typically, standard spreading equipment applies the same amount everywhere. In order to ensure that enough is applied to troublesome spots, overapplication may occur in many other areas.

FERTIGATION

Fertilizer application through an irrigation system is termed fertigation. This ideally combines the two operations to use resources and labor more efficiently. Frequent light applications (e.g., spoon-feeding) of fertilizer are metered into irrigation lines and distributed along with irrigation water through sprinkler heads. Since most of the applied irrigation water and fertilizer enters the soil and is not retained on the foliage, fertigation is not synonymous with foliar fertilization. Nitrogen, potassium, and micronutrients are often applied in this manner. Fertigation is usually considered a BMP in Florida because it minimizes the potential for leaching. It helps maintain even color and growth, minimizes color surges that result after heavy granular applications, and reduces the labor costs associated with frequent applications of granular forms.

Application through a simple irrigation delivery system is probably the best. This consists of a fiberglass or plastic storage tank with a visual volume gauge, a filter, and an adjustable, corrosive-resistant pump to inject fertilizer into the main irrigation line. If a centrifugal pump is used for irrigation, drawing fertilizer into the suction side of the irrigation pump can eliminate the injector pump, so that some fertilizer is applied at each irrigation event. If the injection pump supplies fertilizer at a constant rate, it is important that the irrigation system is well balanced, with each zone covering approximately the same amount of land area so the fertilization rate is also constant—except for areas where it is desirable to fertilize at a heavier rate. Proportioning systems have been developed that keep a constant ratio between the volume of liquid fertilizer injected and the volume of irrigation water applied.

To operate the system, the amount of N and other nutrients that are desired per unit of turf area per unit of time (e.g., lbs. N per 1,000 ft² or per acre applied per month) must be determined. Then, by knowing the concentration of the fertilizer solution, the rate at which the injection pump must operate can be determined. This rate can be adjusted if necessary to compensate for unusually high or low amounts of rainfall that affect irrigation needs. The visual gauge on the fertilizer tank helps determine how well the fertilization schedule is being maintained, since the period needed to empty the tank (e.g., a week, a month) can be determined in advance. Heavily used areas such as tees and greens often require higher N rates than fairways. Various methods can be devised to increase the rate of fertilizer applied by irrigation systems on these areas. Such complications, however, may cause excessive work and problems. In most cases, it seems best to use fertigation to supply a uniform rate of N to the entire golf course and traditional granular means to augment fertilization on the relatively small, heavily used green and tee areas.

Chapter 6: Cultural Practices for Golf Turf

Cultural practices have a significant impact on turfgrass growth and playability. Certain cultural practices such as mowing, verticutting, and rolling are necessary to provide good playability, while others, such as aerification, are needed to enhance turf health. This chapter discusses the need for each practice and lists methods for cultivating turf for improved playability while decreasing water loss and encouraging environmental protection.

MOWING

Mowing⁹ is the most basic yet most important cultural practice a superintendent can use to provide desirable turf. Mowing affects other cultural practices and many aspects of turf quality, such as density, texture, color, root development, and wear tolerance. Failure to mow properly usually results in weakened turf with poor density and quality.

Turfgrasses used on golf courses can be mowed close to the ground, since their terminal growing points (crowns) are located at or just below the soil surface. Regrowth from cell division and elongation takes place from growing points located below the height of the mower blade. In contrast, upright-growing dicot plants have their meristematic (growth points) tissue at the top or tip of their stems. Consequently, mowing removes this growing point, and many upright dicot weeds are thus easily eliminated from frequently mowed turf.

Mowing affects turfgrass growth habit. Frequent mowing increases tillering and shoot density. Mowing decreases root and rhizome growth, because after mowing, food reserves are used for new shoot tissue development at the expense of root and rhizome growth. Improper mowing exacerbates this problem. If the correct mowing height and frequency are used, then the turf does not go through a stress period from the immediate loss of top growth and can recover more quickly. Infrequent mowing results in alternating cycles of elevated crowns followed by scalping, depleting food reserves further. Remember, stressed turf means a weaker plant that is more vulnerable to

drought, insects, and disease, and that needs more pesticides.

MOWING HEIGHT

Mowing height refers to the height of top growth immediately after the grass is cut. Determining this height accurately can be misleading to inexperienced mower operators. Often height is adjusted and checked on a level surface such as a worker's bench or roadway, and is thus referred to as the "bench setting." However, when operated, the mower wheels are forced down on grass shoots; as a result, the unit rides on top of them and the mower is actually raised higher than the bench setting.

Conversely, when a mower is operated on soft ground or when a thick, spongy thatch layer is present, the mower cuts lower than the bench setting, often resulting in undesirable scalping.

Variables Influencing Mowing Height

Many factors influence the mowing height of grasses. Mowing heights for golf course turf are governed by the grass variety and its use. For example, golf greens are mowed below .25 inch to provide the smooth, fast, and consistent playing surface that golfers desire. Tifdwarf bermudagrass tolerates closer mowing than Tifgreen bermudagrass. Likewise, the new ultradwarf bermudagrass cultivars appear to tolerate a closer mowing height than Tifdwarf. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and stress.

Table 5 lists the recommended mowing heights for the different areas of a golf course, and Table 6 shows the recommended mowing heights for lawn and common area grasses. Shoot and leaf tissue is the site of photosynthesis. Any removal of this tissue strongly influences the physiological and developmental condition of a turfgrass plant. If grass is mowed too low or too infrequently, crown damage can occur, and excessive photosynthetic tissue is removed. This results in off-colored turf with a low recuperative potential.

Table 5: Recommended golf course mowing heights, by area

	Greens Regular Maintenance	Greens Tournament Play	Collars and Approaches	Tees	Fairways	Roughs
Bermudagrass Range	0.110"–0.250"	0.090"–0.125"	0.375"–0.500"	0.250"–0.500"	0.375"–0.600"	0.750"–2.000"
Seashore paspalum	0.110"–0.125"	0.090"–0.125"	0.375"–0.500"	.375"–.500"	.375"–.500"	1.00"–1.500"

* Golf course mowing heights vary within these ranges and may temporarily vary outside these ranges due to numerous factors, including weather, budget, season, tournaments, member expectations, and a variety of other agronomic considerations such as the turf growth rate, cultivar being grown, soil type, age of turf, shading, pest outbreaks, rooting depth, thatch management, grow-in, and overseeding.

⁹Unruh, Cisar, and Miller, 1999.

Table 6: Recommended mowing heights for lawn and common area turfgrasses

Zoysiagrass	St. Augustinegrass	Bahiagrass	Centipedegrass	Carpetgrass
0.5"-2.5"	2.5"-4"	2.5"-4"	1.5"-3"	2"-3"

Root-to-Shoot Ratio – If plants are mowed too low, their roots require a substantial amount of time to provide the food needed to produce shoot tissue for future photosynthesis. Turfgrasses have a ratio of root-to-shoot tissue that is optimum to support growing grass. If turf is mowed too low all at one time, the ratio becomes imbalanced, with more roots available than the plant physiologically requires. This excessive root mass is then sloughed off. Until the plant has time to regenerate new shoot tissue, it becomes weak and more susceptible to environmental and pest stresses. Root growth is least affected when no more than 30 to 40% of the leaf area is removed at one mowing.

Root Growth – A direct relationship exists between mowing height and root depth. As the mowing height is reduced, a corresponding reduction in root depth occurs. Less root depth is needed to support less top growth when the mowing height is lowered. This is why golf greens need to be watered and fertilized more frequently than other playing surfaces. Shallow roots have a decreased depth from which they can obtain moisture and nutrients from the soil. Roots (plus lateral stems) are where carbohydrate reserves are stored. Therefore, shallow roots on a putting green also mean that leaves and shoots have minimal carbohydrate reserves to draw from when the plants are stressed.

Shade – Under shady conditions, grass leaves grow more upright to capture as much of the filtered sunlight for photosynthesis as possible. As a result, the mowing height for grasses grown under these conditions needs to be raised at least 30%. If mowed continuously short, grasses grown under shaded conditions gradually thin due to the lack of sunlight needed for photosynthesis. To reduce irrigation, fertilization, and pesticide inputs, it is recommended that greens be mowed as high as the clientele will allow. Also, research suggests that applying the plant growth regulator Primo (trinexapac-ethyl) to shaded turf improves overall turf health.

Mower Type – Mowing height is also influenced by the mower type being used. Rotary and flail-type mowers cut best at heights above 1 inch and are used primarily in roughs and out-of-play areas. Conversely, reel mowers cut best at heights below 1 inch and are used on most golf course play areas.

Season – The season of the year may also influence mowing height. In early spring, turfgrasses have a more

prostrate (decumbent) growth habit. They can be mowed closer without serious consequences than in other seasons. Close mowing in early spring controls thatch, increases turf density, removes excess residues or dead leaf tissue, and promotes earlier green-up. Green-up is hastened because close mowing removes top growth and dead tissue that shade, and thus cool, the soil surface. If more solar radiation reaches the soil surface, it warms up more quickly than if the top growth is allowed to remain tall. In summer, when days are longer, grasses have a more upright growth habit and are healthier if the mowing height is raised to compensate for it. A higher mower setting at this time also increases turf rooting, reducing water needs and stresses imposed by increased nematode activity. In fall, the mowing height may also need to be raised to reduce the chance of low-temperature damage during winter (in north Florida) and to provide a cushion for grass crowns in winter where bermudagrass is dormant.

Environmental Stresses – Mowing heights should be increased during more stressful periods, particularly during prolonged cloudy weather. Increase mowing heights as high as the golfing clientele will allow. If cutting heights are selected based strictly on desired green speed, consider a higher height and rolling. Even an increase of 0.06 inch provides extra leaf tissue to maintain photosynthetic capability. It is also important to raise mowing heights on all playing surfaces during periods of drought. Higher mowing increases root depth and improves the turf's ability to take up water and nutrients.

MOWING FREQUENCY

Mowing frequency often is a compromise between what is best for the turf and what is practical for the sport. The growth rate of the grass should determine the frequency of cut. The growth rate is influenced primarily by mowing height, the amount and source of nitrogen fertilizer applied, and the season or temperature. Higher amounts of nitrogen result in faster top growth, necessitating an increased mowing frequency. Raising the mowing height reduces cutting frequency, helping to compensate for faster-growing turf.

One-Third Rule

The traditional rule is to mow often enough so that no more than one-third of the top growth is removed at any one time. Removing more than this amount decreases the recuperative ability of grass due to the extensive loss of leaf area needed for photosynthesis. A reduction in

photosynthesis can result in the weakening or death of a large portion of the root system, since carbohydrates in roots are then used to restore new shoot tissue. Consequently, root growth may stop for a while, since the regeneration of new leaves (shoots) always takes priority over sustaining roots for food reserves following severe defoliation.

To determine how much growth to allow, multiply the height of cut (HOC) by 1.5. For example, if the HOC is 0.5 inch, the calculation is as follows:

$$0.5" \times 1.5 = 0.75"$$

The grass should be allowed to reach 0.75 inch and then mowed. Thus, 0.25 inch of clippings is removed (one-third) and 0.5 inch of verdure remains (two-thirds).

Scalping

If turf becomes too tall, it should not be mowed down to the intended height all at one time. Such severe scalping may stop root growth for extensive periods. Also, scalping reduces turf density, increasing weed establishment. Tall grass should be mowed frequently and the height gradually reduced with each mowing until the desired height is reached. The exception is when scalping is performed as a summertime cultivation practice, particularly on golf course roughs. Like verticutting, scalping is implemented to remove excess stem/leaf material and improve turf uniformity, but if the one-third rule is frequently violated, the result is usually gradual thinning and a disappointing reduction in turf quality.

MOWING EQUIPMENT

Mowing equipment has continued to increase in sophistication since the scythe was invented. The first reel mower was developed in 1830 by Edwin Budding, a textile engineer, who adapted the rotary shear that was used to cut carpet nap. Early mowers were operated using hand or animal power, but these were eventually replaced by gasoline- and diesel-powered units. Today a vast array of mower types is available, with varying levels of sophistication and a wide range of costs.

Reel Mowers

Reel mowers consist of blades attached to a cylinder known as a reel. As this cylinder rotates, grass leaves are pushed against a sharp, stationary bedknife and clipped. A reel mower that is properly adjusted cuts grass as cleanly as a sharp pair of scissors and produces better-quality results than other types of mowers. Reel mowers also require less power, consume less fuel, and, therefore, are more efficient to operate than rotary or flail mowers. In fact, reel mowers use up to 50% less fuel per acre of cut than rotary mowers when used at the same mowing speed.

Reel mowers do have some disadvantages, most notably their inability to mow grass maintained above approxi-

mately 1.5 inches and to cut coarse-textured turf. Similarly, tall seedheads, weeds, and tough seed stalks are not cut efficiently with reel mowers. Reel mowers, especially hydraulically driven ones, are more expensive than other mowers and usually require a higher level of maintenance and skill to adjust and operate.

Rotary Mowers

Rotary mowers are an impact-type cutting mower. They have blades that are horizontally mounted to a vertical shaft that cuts grass by impact at a high rate of speed. The key to success with rotary mowers is to maintain a sharp, balanced blade. Rotary mowers cut grass like a machete. As long as the blade is sharp and balanced, the quality of cut is acceptable. A dull mower blade shreds leaf blades instead of cutting them, and leaf tips become jagged and frayed. When leaf tissue is mutilated by an unsharpened rotary blade, wounds heal slowly and greater water losses occur through evaporation, since the leaf area exposed to the environment is increased. Mutilated tissue also provides invasion points for diseases. This can increase the need for pesticides or fertilizers. If blades are nicked from hitting hard objects, they should be ground or filed to restore the original cutting edges.

Rotary mowers have the advantage of being relatively inexpensive and more versatile than reel mowers. They can be used to cut very tall or coarse-textured grass and tough weeds and seed stalks, while reel mowers cannot. Rotary mowers may also decrease herbicide use in golf course roughs by making weed seedheads less conspicuous. They also can be more easily maneuvered than reel mowers to trim around trees and buildings, and generally have lower initial costs and simpler maintenance requirements.

The disadvantages of rotary mowers include their inability to provide a quality turf at heights lower than 1 inch. Rotary mowers are dangerous if hands or feet are accidentally placed under the mowing deck while the blade is operating. Because the blades rotate at a high speed, they can turn any rocks or tree limbs that they encounter into dangerous projectiles. Rotary mowers are not usually designed to follow the surface contour as exactly as a reel mower. Therefore, at close mowing heights, the rotary mower is more likely to scalp turf as it travels across small mounds or ridges that often compose the turf surface.

Flail Mowers

Flail mowers, another impact-type cutting unit, have a number of small blades (knives) attached to a horizontal shaft. As the shaft rotates, the knives are held out by centrifugal force. Cut debris from flail mowers is recut until it is small enough to escape the close clearance between the knives and mower housing.

The advantages of flail mowers include their ability to cut tall grass into finely ground mulch and the ability of each blade to recoil without damage to the mower. Unlike rotary mowers, they do not create a dangerous projectile if they strike a hard object such as a rock or tree limb. The disadvantages include the flail mower's inability to provide a close, quality turf surface and the difficulty of sharpening the small, numerous knives. Flail mowers are most often used on low-maintenance utility turf, such as roughs or out-of-play areas, that is mowed infrequently and does not have a high aesthetic requirement.

Equipment Care

Equipment care is almost as important as initially choosing the right mower. Routine maintenance such as lubrication, oil changes, blade sharpening, tune-ups, belt adjustments, and proper cleaning are important in extending the useful life of equipment and in lowering operating costs. Adequate, accurate records need to be maintained and observed to help pinpoint the costs of operation and to justify the purchase of new equipment. In addition, proper storage should be available to minimize the exposure of equipment to weather, to prevent accidents, and to maintain security. When a job is finished, the unit should be cleaned and stored in a clean, dry, and secure area.

MOWING PATTERNS

The mowing patterns imposed by operators can influence both the aesthetic and functional characteristics of a turf surface (Figure 19). Aesthetic qualities are influenced by differing light reflections that occur in response to shifts in mowing direction. These shifts often result in alternating light- and dark-green strips that are generally more pronounced when walk-behind reel mowers are used, compared with triplex-riding mowers. Double-cutting at right angles produces a checkerboard appearance of light- and dark-green strips, as if two different nitrogen fertility levels or grasses had been used.

Mowing directions should not be repeated over the long term, even though this may produce alternating color



Figure 19: Mowing pattern (courtesy USGA).



Figure 20: Grain on putting green (courtesy USGA).

differences. If turf is mowed repeatedly in the same direction, the grass leans or grows in the direction in which it is cut. This horizontal orientation of grass foliage in one direction is called “grain” (Figure 20). Grain results in an uneven cut, a streaked appearance, and a poor-quality putting surface on golf greens. The ball tends to follow the grain. When a different grain is encountered, the ball reacts by altering its path slightly.

Varying the pattern of successive mowings easily prevents grain, encourages the upright growth of the shoots, minimizes the amount of leaf surface that the rolling golf ball encounters, and increases a green's putting speed and accuracy. The mowing patterns or directions of golf greens should be changed daily and cleanup laps routinely reversed or skipped. Often a rotating clock pattern is followed for mowing directions and is changed daily. Similarly, fairways should be mowed side to side and diagonally as well as longitudinally to minimize wear, compaction, and grain development.

Mowing continually in the same direction also scalps the same high spots and increases compaction and rutting by mower wheels. In addition, turning the mower at the same location and in the same direction encourages severe wear and soil compaction.

GRASS CLIPPINGS

Clippings are a source of nutrients. They contain 2 to 4% nitrogen based on dry weight and also significant amounts of phosphorus and potassium. If clippings are removed, additional fertilizer must be applied to compensate for these nutrients. Removing clippings can pose environmental and budgetary concerns, since municipal landfills no longer accept them. Emptying the catcher or raking the clippings also requires additional time and labor. Under normal conditions, clippings should be allowed to fall back to the turf. They should be removed only when they are so heavy that they smother the grass or interfere with the playing surface, such as on golf greens.

By following the one-third rule on mowing frequency, large amounts of clippings are not deposited at one time. Soil organisms that naturally break down grass clippings have enough time to decompose them before the clippings accumulate. If excessive growth occurs because of heavy nitrogen fertilization or excessive scalping, natural decomposition may not be able to keep up with the amount of clippings deposited. A thatch problem may develop under these conditions.

Clippings collected from golf greens should be disposed of properly to prevent undesirable odors near play areas and to prevent fire hazards that can occur when clipping piles accumulate. One option is to compost the clippings. Develop compost piles by alternating layers of clippings with a mixture of soil and nitrogen fertilizer. When composted, the clippings can then be used as ground mulch in flower beds or inaccessible mowing areas. If not composted, the clippings should be dispersed so that piles do not form.

TURFGRASS CULTIVATION PRACTICES

Cultivation practices are an important part of turf management.¹⁰ Heavily used areas such as golf course greens often deteriorate due to compacted soil, thatch development, and excessive use. Soil problems from active use are usually confined to the upper 3 inches of the turf.

Unlike annual crops, which are periodically tilled to correct such problems, turf managers do not have the opportunities for such physical disturbances without destroying the playing surface. Over the years, however, a number of mechanical devices have been developed that provide a degree of turf cultivation with minimum disturbance to the turf surface. Cultivation is accomplished by aerification, vertical mowing, spiking, and topdressing.

AERIFICATION

Aerification, or “coring,” is the removal of small soil cores or plugs from the turf surface, leaving a hole in the sod (Figure 21). By reducing dry spots and soil compaction, it improves water infiltration, which in turn reduces water use and runoff in other areas.

Holes are normally 0.25 to 0.75 inches in diameter; their depth and distance vary depending on the type of machine used, forward speed, degree of soil compaction, and amount of soil moisture present. Traditional aerifying machines penetrate the upper 2 to 4 inches of soil surface, with cores spaced on 2- to 6-inch centers. Recent innovations in aerification equipment provide options for creating holes to depths greater than 10 inches and diameters ranging from 0.125 to 1 inch. In addition, options are now available for creating the hole and core spacing.



Figure 21: Aerification (courtesy USGA).

Generally, the benefits of aerification far outweigh any detrimental effects. Turf managers must decide which option is best to solve the existing problem. The following common problems limiting turf growth may be improved by aerification:

- Excessive soil compaction,
- Waterlogged soils,

ADVANTAGES & DISADVANTAGES OF AERIFICATION

Advantages:

- Relieves soil compaction.
- Allows deeper, faster penetration of water, air, fertilizer, lime, and pesticides into the root zone.
- Allows for the atmospheric release of toxic gases (e.g., carbon dioxide, carbon monoxide) from the root zone.
- Improves drainage, helping to dry out saturated soils and prevent the formation of puddles.
- Improves water penetration into dry or hydrophobic soils (e.g., relieves localized dry spots).
- Penetrates the soil layers that develop from topdressing with dissimilar materials.
- Provides thatch control by stimulating the environmental conditions that promote healthy soil microorganism activity for thatch decomposition.
- Increases rooting by constructing a medium more conducive to active root growth.

Disadvantages:

- Temporarily disrupts or damages playing surfaces.
- Increases turf surface desiccation as roots are exposed.
- Produces coring holes that provide a better habitat for cutworms and other insect pests.

¹⁰Unruh, Dudeck, Cisar, and Miller, 1999.

- Black layer development,
- Standing surface water,
- Dry spots,
- Excessive thatch development, and
- Poor root growth.

Soil Compaction

One of the primary goals of core aeration is to relieve soil compaction, which occurs when mineral particles are pressed close together. This results from excessive or concentrated traffic, especially when soil is wet. Soil compaction reduces oxygen (porosity) levels in the soil. A soil should be composed of at least 25% air, on a volume basis, but compacted soil has as little as 5% (Figure 22).

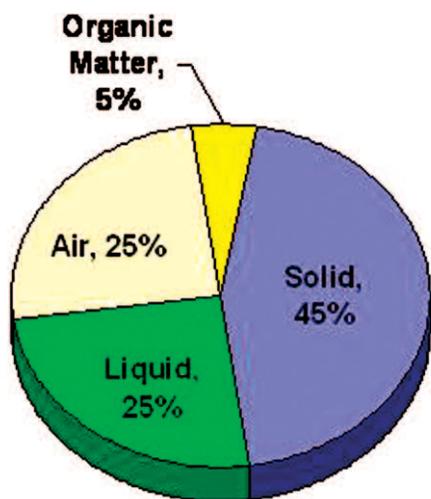


Figure 22: The four components of soil

Root function decreases under compaction due to the lack of oxygen needed for respiration and the buildup of toxic gases such as carbon dioxide. Also, roots may be unable to physically penetrate such a tightly packed soil mass. New roots are often abundant along the sides of the aeration holes, indicating the need for increased soil oxygen.

Compacted soil surfaces also reduce water infiltration and percolation. Dry soils in compacted areas are difficult to rewet. Conditions such as localized dry spots often develop, especially in areas with a high sand content. This encourages the overwatering of adjacent areas. On the other hand, compacted, saturated soils may not drain excessive water and often turn into mud with continued use. Such soils often remain wet for extended periods and become covered with an undesirable layer of algae or moss. The success of highly maintained turf areas such as golf greens depends on the superintendent's control of soil moisture content.

The best method for preventing compaction is to build greens and tees with a predominately sandy soil and with proper surface drainage. Compaction is much more likely on fine-textured clay soil than on a coarser, sandy soil. Usually a coarse-textured soil consisting of 80% or more sand is necessary to achieve the desired results. Soil containing a significant amount of clay (> 30%) or silt (> 5%) is unacceptable for golf green construction. All soils should be tested by an accredited soil laboratory before use. Proper surface contouring and subsurface drainage in the form of tile lines also hasten the removal of excessive surface water. For putting greens, the USGA formulated a construction method that provides good drainage and resistance to compaction. Created in 1960, it is still one of the most prevalent methods for constructing golf course putting greens today. This method is discussed in the USGA publication, *Recommendations for a Method of Putting Green Construction* (available: http://www.usga.org/course_care/articles/construction/greens/Green-Section-Recommendations-For-A-Method-Of-Putting-Green-Construction/).

Reducing or redirecting traffic also relieves soil compaction. For example, the correct placement of cart paths and sidewalks is important. Cart paths should normally be a minimum of 8 feet wide to allow two-way cart traffic and larger maintenance vehicles, such as tractors and trucks, an adequate passageway. Barriers such as curbs should be used adjacent to high-traffic areas such as tees and greens to prevent carts straying from the path.

Traffic should be minimized or prevented when soil is wet. Water in the soil acts as a lubricant. Traffic during these periods further increases soil compaction, reducing turfgrass growth and vigor. Regulate traffic after heavy rains, and mow with large, heavy units. Use wide turf tires on all equipment to help distribute the weight of the vehicles over a larger area than is allowed by regular tires.

Core aeration usually softens hard, compacted turf surfaces. This is especially true when the spacing between holes does not exceed 2 inches. Aerifier tines should penetrate a minimum of 3 inches deep. This depth should be varied between aerifications to minimize the development of any compacted layering. Coring is most effective when soils are moist but should never be performed when soils are saturated.

Thatch Management

Bermudagrass can accumulate thatch and organic matter quite aggressively in Florida's warm climate (Figure 23). Some thatch and organic matter are necessary for nutrient/water retention and good playability, but excessive amounts reduce root growth, encourage disease, and create undesirable playing conditions.

Aerification removes small cores of thatch and organic matter, and subsequent sand topdressing is incorporated to dilute the existing material. Bermudagrass putting



Figure 23: Thatch from putting green root zone (courtesy USGA).

greens must be core aerified several times each summer. Various aerifier tine diameters and spacings affect the percentage of putting surface affected.¹¹

Dry Spots

Localized dry spots are areas—usually ranging from 1 to several feet in diameter—that become very hydrophobic and repel water. This is most pronounced during hot, dry weather and with sand-based greens with excessive thatch. Aerifying with small-diameter tines (< 0.5 inch) on close spacing (< 2 inches) allows better water infiltration. The routine use of granular or liquid wetting agents or surfactants applied to the dry spots in combination with aerification is also helpful. Solid “quad-tines,” followed by wetting agent treatments, can alleviate dry spots with minimal disruption to the putting green surface.

Types of Aerifiers – Many types of core aerifiers or cultivators are available. Most fall into one of two categories: vertical- or circular-motion units. Vertical-motion core cultivators provide minimal surface disruption and are the preferred choice on closely mowed turf surfaces such as golf greens. Vertical units have the drawback of being relatively slow due to the linking of vertical and forward operations. However, their speed and ease of operation have improved in recent years.

Circular-motion cultivators have tines or spoons mounted on a drum or metal wheels. The tines or spoons are forced into the soil as the drum or wheels turn in a circular motion. Hollow drum units remove extracted cores from the soil surface, while other units deposit cores back directly onto the surface. Circular-motion cultivators are preferred for aerifying large areas, since the rotating units can cover more ground in a given period than vertical-motion cultivators. However, they disrupt the turf surface more and do not penetrate as deeply

as vertical-motion cultivators. Weights are often placed on top of these cultivators to increase penetration depth.

Core Removal

Aerifiers with hollow tines cut and bring a soil core to the surface, leaving a hole or cavity in the turf. A commonly asked question is whether to remove the cores that result from aerifying (Figure 24). For turf areas other than golf or bowling greens, it is most practical to leave the holes open. Cores also do not have to be removed if thatch control, temporary compaction reduction, or air and chemical entry are desired and the underlying soil is acceptable.



Figure 24: Harvester picking up cores (courtesy USGA).

If the root-zone mixture (soil) present is acceptable, then the cores should be broken up by lightly verticutting or dragging the area with a mat, brush, or piece of carpet. The remaining debris should be blown off or picked up with a follow-up mowing. Before the soil cores are matted, they should be allowed to dry enough so that they easily crumble between the fingers. If the cores are too dry when matted, they are hard and not easily broken up. If too wet, they tend to smear and be aesthetically undesirable. Recent advances in mechanization allow the quick and easy windrowing of soil cores and their subsequent mechanical removal. Cores should be removed on putting greens, since organic matter removal/dilution is much more important on greens than on other playing surfaces.

Frequency of Cultivation

The frequency of core cultivation should be based on the traffic intensity that the turf is exposed to, and on the soil makeup, hardness of the soil surface, and degree of compaction. Areas receiving intense daily traffic—such as golf greens, approaches, landing areas, aprons, and tees—require a minimum of 2 to 4 core aerifications annually. Additional aerifications may be needed on exceptionally

¹¹ O'Brien and Harwiger, March/April 2003.

small greens where traffic is more concentrated, on areas of heavy soils high in silt and/or clay that do not drain well, or on soils exposed to saline or effluent water. Such areas may need aerification with smaller-diameter tines (0.38 inch or less) every 4 to 6 weeks during the active bermudagrass growing months. Failure to maintain an aggressive aerification program in these situations will probably result in poorly drained soils, thin grass stands, and continued problems with algae.

Less-intense traffic areas should be aerified as needed. Most golf course fairways should be aerified twice yearly, with the first aerification timed in mid-spring once the grass is actively growing and the chance of a late freeze has passed. The second aerification should be in late summer. If the area is to be overseeded with ryegrass, then the second aerification should be timed approximately 4 to 6 weeks prior to seeding. Aerification is not recommended within 6 to 8 weeks before the first expected frost in north Florida, in order to allow enough time for bermudagrass to recuperate before cold weather ceases its growth.

Solid tines are sometimes used for coring instead of hollow tines. Creating holes by forcing solid tines into the turf is called “shatter-coring.” Solid tines do not remove soil cores and may compact soil along the sides and bottoms of the holes more severely than hollow tines. Areas receiving solid tine aerification will probably benefit only temporarily.

Solid tines do not disrupt the playing surface as much as hollow tine cultivation. This is an advantage during the winter months, when the growth rate of bermudagrass has ceased or been reduced. Using solid tines in overseeded turf temporarily reduces compaction and softens the green with a minimal disruption of the putting surface.

Bermudagrass should only be aerified with hollow tines when the turf is actively growing and is not subjected to heat, cold, and water stress. Topdressing and irrigation immediately following aerification may reduce desiccation potential but may not be totally effective during periods of hot temperatures.

Recent Developments

Several recent developments in aerification technology provide turf managers with a wider choice of aerification strategies. One involves deep tine cultivators that are able to extract a 0.75- to 1-inch diameter core to a depth of 8 to 12 inches. Deep cultivator units enable the superintendent to relieve the soil compaction layer that develops when traditionally used aerifiers penetrate constantly to 3 inches. Soil profiles consisting of many undesirable layers that develop with the use of different materials for topdressing are also penetrated. This enhances water penetration, soil aeration, and rooting. For greens, an

undesirable soil profile can be improved by topdressing with desirable soil following deep aerification.

Another development is the deep drill aerifier. Drill bits of varying lengths and diameter are drilled into the turf, leaving a small cast of soil on the surface around each hole. This soil is usually then matted back into the turf. The biggest advantage of the deep drill aerifier is the ability to provide a deep hole with the least disruption to the playing surface. These units, however, are relatively slow running and are generally more expensive to operate, since a high degree of mechanization and numerous drill bits are needed. Since a core is not physically extracted, the soil brought to the surface is difficult to remove.

Deep aerification creates more surface damage than shallow depth models. The initial expense also prevents many clubs from purchasing a unit, since it is more of a renovation tool than a regularly scheduled maintenance practice. These units are generally available for rental or contract use, however, or several clubs may choose to share the cost of purchasing a unit. Care must be used when aerifying golf greens built to the specifications outlined by the USGA, so as not to penetrate the 2- to 4-inch coarse sand layer, or 4-inch gravel layer, that is located 12 to 14 inches deep. This violates the concept that greens maintain a “perched” water table for the turf to be grown in.

Another aerification technique is high-pressure water injection. Fine streams of high-velocity water are injected over the turf surface, resulting in minimal surface disruption. Play is not disrupted by aerification holes as it is by traditional machines. These high-pressure units are also beneficial, because they wet hydrophobic soils, such as localized dry spots. The disadvantages are the initial high cost and the need for a water source at all aerification sites. The units may be less effective on heavy soils where the high-pressure water stream cannot adequately penetrate. In addition, thatch control is minimal and sand cannot be incorporated back into the green's profile, since the holes produced are not large enough. The hole spacing and penetration depth are, however, adjustable through multiple pulses, the changing of nozzle spacing, or varying speed. Water injection cultivation should supplement, not replace, traditional core aerification.

Slicing and Spiking

Two other cultural practices, slicing and spiking, help relieve surface compaction and promote better water penetration and aeration. A slicer has thin, V-shaped knives bolted at intervals to the perimeter of metal wheels that cut into the soil. The turf is sliced with narrow slits about 0.25 inch wide and 2 to 4 inches deep. Slicing can be performed much faster than coring and does not interfere with turf use, since there is no removal of soil cores; thus, no cleanup is necessary after the operation. Slicing is also performed on fairways and other large, heavily trafficked areas during midsummer stress periods, when

coring may be too injurious or disruptive. However, it is less effective than coring and is most effective when used in conjunction with coring. As with coring, slicing is best accomplished on moist soils.

A spiker has an effect similar to that of a slicer, but penetration is limited to approximately 1 inch, and the distance between perforations along the turf's surface is shorter. For these reasons, and because spiking causes less surface disruption than coring, spiking is practiced primarily on greens and tees. A spiker is used to break up soil surface crusting, break up algae layers, and improve water penetration and aeration. Solid tines are associated with a spiker, and holes are punched by forcing soil downward and laterally. This results in some compaction at the bottoms and along the sides of the holes. Since only minor disruptions of soil surfaces occur, spiking and slicing can be performed more often (e.g., every 7 to 14 days) than core aeration (e.g., every 4 to 8 weeks).

VERTICAL MOWING

A vertical mower has a series of knives vertically mounted on a horizontal shaft. The shaft rotates at high speeds, and the blades slice into the turf and rip out thatch and other debris.

Depth

Vertical mowing meets different objectives, depending on the depth of the penetrating knives. Grain is reduced on putting greens when the knives are set just to nick the surface of the turf. Shallow vertical mowing on tees and fairways breaks up cores following aeration, facilitating a topdressing effect. The deeper penetration of knives stimulates new growth when stolons and rhizomes are severed and removes accumulated thatch. Vertical mowing is also used to prepare seedbeds before overseeding.

The desired depth of thatch removal determines blade depth when dethatching is the objective. Vertical mowing should reach the bottom of the thatch layer, and preferably the soil surface beneath the thatch layer should be sliced. Dethatching is an aggressive practice that is not recommended on most golf course putting greens, due to increased disease susceptibility and time needed for recovery. There is a limit to the depth that blades should be set, or excessive removal of turf roots, rhizomes, stolons, and leaf surface may occur. For example, blades should be set at a depth to cut just stolons and no deeper if new growth stimulation is the objective. Vertical blade spacing for thatch removal in bermudagrass should range from 1 to 2 inches for maximum thatch removal with minimal damage.

Frequency

The rate of thatch accumulation dictates the frequency of vertical mowing. Vertical mowing should begin once the thatch layer on golf greens exceeds .25 to .5 inch.

Shallow vertical mowing should be completed at least once per month for nonoverseeded bermudagrass greens. Some of the new ultradwarf bermudagrasses may require even more frequent shallow vertical mowing to prevent excessive thatch accumulation. Be sure to verticut in different directions, just as with regular mowing.

Interchangeable vertical mower units are now available for many of today's triplex greens mowers. This equipment allows for frequent vertical mowing and simultaneous debris collection. For light surface grooming, the vertical blades on greens mowers should be set only to nick the surface of the turf so the surface is not impaired. By conducting frequent vertical mowing, the severe vertical mowing needed for renovation may be avoided. Large turf areas are vertically mowed by using units that operate off a tractor's power takeoff (PTO). Such units have heavily reinforced construction and large, thick (approximately .25-inch) blades that can penetrate to the soil surface.

Grooming and Brushing

A miniature vertical mower can be attached in front of the reel cutting unit of greens mowers to lightly groom putting green turf. Likewise, brush attachments can be used in conjunction with daily mowing (Figure 25). These units improve the playing surface by standing up leaf blades before mowing, thus reducing surface grain. Slicing stolons also stimulates new shoot development, and thatch near the surface is removed.



Figure 25: Brush attachment on mower (courtesy USGA).

TOPDRESSING

Topdressing adds a thin layer of sand to the turf surface that is then incorporated by dragging or brushing it in. On newly established turf, topdressing partially covers and stabilizes the newly planted material, smooths gaps that result from sodding, and minimizes turfgrass desiccation. Topdressing is performed on established turf to smooth the playing surface, control thatch and grain, promote recovery from injury, and possibly change the physical characteristics of the underlying soil. Unfortunately,

many superintendents have reduced the number of coring and topdressing procedures in recent years due to member complaints that these practices disrupt play. However, these are sound, fundamental agronomic practices that are necessary to maintain an optimal bermudagrass putting surface. If eliminated, the quality of the putting green will diminish over time.

Topdressing Frequency and Amounts

The frequency and rate of topdressing depend on the objective. Following coring and heavy verticutting, moderate to heavy topdressing helps to smooth the surface, fill cored holes, and cover exposed roots resulting from these two processes. Irregular play surfaces or soil profile renovation require frequent and relative heavy topdressing. Rates ranging from 0.125 to 0.25 inch (2 to 4 cubic yards of soil per 5,000 ft²) are suggested. However, if the capacity of the turf to absorb the material is limited, less material should be used to prevent smothering the turf.

If the objective of topdressing is to change the characteristics of the underlying soil, then a heavy topdressing program following numerous deep core removal operations over a period of years is required. If thatch management is the main objective, then the rate of thatch accumulation governs the amount and frequency of topdressing. Thatch layering of 0.25 to 0.5 inch on golf greens is desirable, but it is necessary to dilute this layer with sand. The relatively thin thatch layer cushions (holds) the approaching golf shot better and also helps to protect bermudagrass crowns from traffic. When thatch is not excessive (≤ 0.5 inch), approximately 1 cubic yard per 5,000 ft² of topdressing is suggested at least once per month during the bermudagrass growing season. If over time this relatively light rate is not maintaining or reducing the thatch layer, then the frequency of application and the topdressing rate should be increased.

If the thatch layer exceeds 0.5 inch, then coring or deep verticutting is required to remove a portion of the thatch material. This should be followed with heavy topdressing. A distinct thatch (stem) layer greater than 0.5 inch that does not contain any sand must be prevented or eliminated. Such thatch layers either become hydrophobic (repel water) or create a perched water table at the surface that encourages roots to remain in the thatch layer and not grow down into the soil. In either situation, the turf is more susceptible to pests, mechanical damage, and environmental stresses.

If the objective of topdressing is only to provide routine smoothing of the playing surface, then light, frequent topdressings are suggested. The surface irregularities of the green are reduced and the area is somewhat leveled when a mat is used to drag sand into the turf canopy following topdressing. Topdressing with 0.5 to 1 cubic yard per 5,000 ft² of green surface every 2 to 4 weeks provides a smoother, truer playing surface. Light topdressing is also

performed approximately 10 to 14 days prior to major club tournaments to increase green speed and provide a smoother putting surface. In addition, frequent, light topdressing should be applied to new greens every 2 to 4 weeks to cover stolons and to smooth the surface, until complete coverage or the desired smoothness is achieved.

Topdressing Materials

Deciding what material to use for topdressing is one of a superintendent's most important long-term management decisions. Using undesirable materials can be disastrous and can ruin the integrity of initially well-built facilities. This usually occurs when the topdressing material used is finer in particle size than the size used in constructing the green.

Only weed-free materials should be used for topdressing. If the material's origin is not known, or if it has been piled and exposed over time, fumigation is highly recommended before use. Washed sands may not need sterilization before use but should be closely inspected to determine whether this is needed. Excess topdressing material should be properly stored to keep it dry and uncontaminated. Covered soil bins, sand solos, or polyethylene covers provide good storage conditions until the material is used.

When the underlying soil of the play surface (green or tee) is unsatisfactory, it must be determined whether to rebuild the facility or try to slowly change its composition through aggressive coring and topdressing. If the soil problem is severe, then reconstruction should be considered. With the introduction of deep core aerifiers, the process of changing the underlying soil characteristics may be expanded. Deep coring once per year followed by heavy topdressing with desirable sand should be practiced to improve poorly draining greens. Between these corings, conventional aeration and topdressing should still be performed. Over several years, the use of this technique can radically improve the soil characteristics of the playing area.

If a topdressing program is chosen to improve the soil, then the next question is what material to use. Fine-textured soils high in clay and/or silt predominate on most undesirable playing surfaces. A coarser soil texture, most notably sand, is introduced to improve water percolation and aeration. Current trends involve frequent topdressing with medium-fine (0.25 to 1.0 millimeter [mm]) sand. This size is usually coarse enough to change soil texture and fine enough to be easily worked into the turf surface. It is not so fine, however, as to seal the surface and impede air and water movement. A competent soil-testing laboratory should test the sand in question before a superintendent attempts to slowly change the root zone of a green or tee by this method.

The most commonly observed problem is the formation of various alternating layers of soil when different top-

dressing materials are used over time. The differences in textural characteristics between layers of sand and organic matter result in poor root growth, caused by physical barriers, the lack of oxygen, the entrapment of toxic gases, micropatched water tables, and dry zones. Once these layers have formed, aggressive vertical mowing and coring are required to correct the problem. Aerification holes should extend at least 1 inch below the depth of the deepest layer. The use of one of the new deep-tine or deep-drill aerifiers often is required to reach these desirable depths. Shallow spiking or coring above the layering is of questionable benefit.

If conveyor-type topdressers are used, applied topdressing should be incorporated into the turf canopy by dragging a piece of chain-link fence, brush, or piece of carpet over the area in several directions to evenly distribute the material. This should immediately be followed by watering to reduce soil drying and to encourage the material to settle.

ROLLING

An older practice that has recently resurfaced consists of rolling greens prior to a tournament to provide a smoother, faster playing surface. Two types of rollers are used today: first, a set of three that replaces the mowing units on a triplex mower, and second, a stand-alone unit that has a driver facing perpendicular to the direction the machine moves (Figure 26). This machine must be loaded and unloaded from a trailer at each green and requires a small tractor to pull it around.



Figure 26: Rolling a green (courtesy USGA).

Benefits

Limited research on bentgrass provides some guidelines on the expected increase in ball speed after rolling. Rolling once the morning before a tournament increases the speed of a green approximately 10%. However, to increase the speed by 20%, greens need to be rolled a total of four times. Rolling two or three times increases the speed between 10% and 20%. Rolling once per green per day is sufficient. Again, this research was performed

on bentgrass, and it is not known if the results are similar for overseeded or nonoverseeded bermudagrass greens. It is interesting to note that the roller weight had no influence on the resulting green speed.

Limitations

Any time pressure is applied to a soil surface, compaction may result. Therefore, to minimize the potential of compaction from rollers, use the lightest roller(s) available. As mentioned above, roller weight does not appear to influence resulting ball speed but may influence the degree of resulting compaction. Rollers also should be used only on greens consisting primarily (80%) of sand and less than 10% silt or clay.

To further prevent compaction problems and to reduce labor costs, roller use is encouraged only during major tournament play and not as a routine daily practice. Rolling should also never be attempted when the soil is saturated, because moisture acts as a lubricant and allows the closer association of soil particles. Extra aerification to relieve any soil compaction may be required.

OVERSEEDING

Overseeding is the practice of establishing a temporary cool-season grass into the base bermudagrass for improved color and playability. Bermudagrass becomes completely dormant in some regions of north Florida, and the turf is overseeded to provide green color and a more cushioned ball lie. In central to south Florida, bermudagrass rarely goes completely dormant, and the need for winter overseeding decreases.

Overseeding increases the need for daily watering and routine mowing, and can also cause significant thinning of the base bermudagrass during the spring transition. Each particular golf course should evaluate whether overseeding is worth the increased requirements for natural resources and labor. Some golf courses paint their putting greens instead of overseeding them, as it requires fewer resources than overseeding and is a more environmentally responsible alternative. This section discusses BMPs for courses that choose to overseed for the winter season.

Fertilizers used 4 to 6 weeks prior to overseeding should be low in nitrogen and high in potassium. Maintaining low nitrogen levels at this time minimizes bermudagrass's competitiveness with overseeded grasses but allows it to retain enough vigor to withstand the overseeding process. Adequate potassium promotes tolerance to cold, wear, and diseases.

SEED BED PREPARATION AND FALL TRANSITION

Proper seedbed preparation ensures that seedling roots are in contact with the soil and not perched above it, where they are susceptible to drought and temperature stress. Thatch greater than 0.5 inch associated with the

bermudagrass base prevents good seed-to-soil contact and therefore should be reduced **before** overseeding.

Nitrogen fertilization should be reduced or completely stopped 3 to 4 weeks before overseeding to minimize competitive bermudagrass growth. Excessive bermudagrass growth at the time of overseeding provides competition for the germinating seed. It may also predispose the bermudagrass to winter injury.

Cultivate the soil by coring 4 to 6 weeks prior to overseeding to alleviate soil compaction and to open the turf. If growing an ultradwarf bermudagrass, cultivate no less than 6 weeks prior to overseeding to allow adequate time for recovery. Allow the cores to dry and pulverize them by verticutting, power raking, or dragging. Coring is performed in advance of the actual overseeding date to allow the coring holes to heal over, thus preventing a speckled growth pattern of winter grass.

GRASS SELECTION FOR OVERSEEDING

The primary grasses used for overseeding in Florida are perennial ryegrass and roughstalk bluegrass (*Poa trivialis*) (Figure 27). Annual ryegrass, intermediate ryegrass, creeping bentgrass, and fine (chewings, creeping red, or hard) fescue are used to a lesser extent. The grasses and mixtures most widely used on golf greens and tees are improved cultivars of roughstalk bluegrass seeded alone, or in mixtures with perennial ryegrass or fine fescue. Fairways are seeded predominately with a perennial ryegrass cultivar. Each grass has advantages and disadvantages.

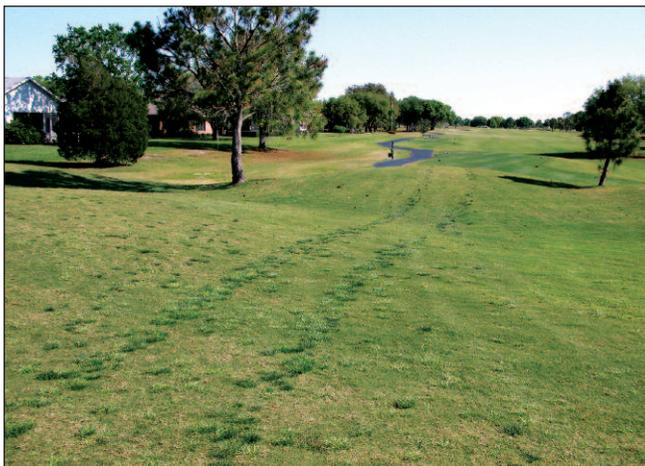


Figure 27: "Volunteer" ryegrass around overseeded area (courtesy USGA).

POSTPLANTING MAINTENANCE

Irrigate lightly to carefully moisten the soil surface without puddling or washing the seed into surrounding areas. Three or four light irrigations per day may be needed until the seedlings become established. Once germination begins, the seed cannot be allowed to dry out or the stand will be thinned. If seed washes into concentrated

drifts following intense rains or heavy irrigation, a stiff-bristled broom should be used to redistribute it. Once grass is established, gradually reduce watering frequency to decrease disease potential.

Mow greens at a 0.5-inch height when the new stand reaches 0.67 to 0.75 inches. Gradually lower the cutting height to 0.31 inch over a 2- to 3-week period. Use a sharp mower that does not pull up seedlings. On golf greens, walk-behind reel mowers are preferable to triplex mowers, which are heavy. Once the grass is well established, mowing heights gradually can be reduced to the desired height, and the heavier triplex mowers then can be used. On tees and fairways, initiate mowing when the grass reaches 1 to 2 inches. This allows time for seedling turf to root. Tees and fairways usually are maintained at 0.5 inch and 0.75 inch in height, respectively.

Do not fertilize with nitrogen (N) immediately before or during overseeding and grass establishment, because excessive N may encourage excessive bermudagrass competition and increase disease potential. Nitrogen fertilizer also influences the appearance of overseeded grass and the spring recovery of bermudagrass. Adequate levels of phosphorus and potassium, however, should be maintained for good plant growth. Begin to fertilize shortly after shoot emergence (2 to 3 weeks after seeding for perennial ryegrass) and continue until cold weather halts bermudagrass growth. Normally, 0.25 to 0.5 lb. N per 1,000 ft² every 2 to 3 weeks with a soluble N source (e.g., ammonium nitrate/sulfate), or 1 lb. N per 1,000 ft² per month with a slow-release N source (e.g., IBDU, Milorganite, SCU) is adequate to promote desired growth without overstimulating growth and encouraging disease. More frequent applications may be needed if the recovery time from traffic or weather damage is slow. Whenever possible, traffic should be minimized during grass establishment. Hole locations and tee markers on golf greens should be moved daily.

Applications of phosphorus, potassium, manganese, and iron should be considered during winter. All of these provide desirable color without stimulating excessive shoot growth. In addition, potassium helps in carbohydrate formation. Soil phosphorus and potassium levels and rates should be determined by soil testing. Iron generally is applied every 3 to 4 weeks as ferrous sulfate at 2 oz. per 1,000 ft². Manganese can be applied as manganese sulfate at 0.5 to 1 oz. per 1,000 ft² in 3 to 5 gallons of water.

Once the overseeded grass becomes established, the chance of severe disease is reduced. Dollar spot often occurs when N levels are too low. It is easily controlled by applying a small amount (0.125 to 0.25 lb. N per 1,000 ft²) of a quick-release N source. Brown patch and pythium blight may occur on greens that drain poorly, or during continuous wet periods (Figure 28). Excessive



Figure 28: Pythium blight on overseeded green (courtesy USGA).

amounts of soluble nitrogen also can trigger these diseases. This is especially true during the periods of heavy, uninterrupted foggy weather that often occur in Florida during the winter. Turf managers should constantly check the weather forecast and be ready to use a fungicide if these conditions are forecast.

Maintain low fertilizer application rates in late winter through early spring to reduce overseeded grass growth.

When bermudagrass growth is apparent, restore fertilizer applications. Approximately 2 weeks after the initiation of spiking, fertilize with 0.5 lb. of soluble N per 1,000 ft² to help stimulate new bermudagrass growth. Fertilize weekly until an adequate bermudagrass cover is achieved.

SHADE AND TREE MANAGEMENT

In general, most turfgrasses do best in full sun. Excessive shade reduces photosynthesis, and moisture does not evaporate as quickly. Also, trees reduce air circulation, resulting in stagnant air. High heat and humidity quickly build in such areas. Whether from decreased sunlight or air circulation, the result is weaker turf that is more prone to disease and pest problems than turf in sunnier areas. Tree limbs and roots should be pruned yearly to reduce competition for sunlight, water, and nutrients with bermudagrass turf. A UF-IFAS Web site dedicated specifically to pruning is <http://hort.ufl.edu/woody/pruning.shtml>. Where possible, trees should be removed from around closely mown areas such as tees and greens to maintain good turf growth. A UF-IFAS Web site on landscape plants, at <http://hort.ufl.edu/woody/>, is a good source of information on all aspects of tree and shrub care.

BMPS FOR TURFGRASS GROWTH IN SHADE

- Increase mowing height: This allows for more leaf area to intercept as much available light as possible. In addition, leaf blades are longer and narrower in the shade, and a lower cutting height excessively reduces leaf length, which is not good for the grass. Increased mowing height also promotes deeper rooting, which is one of the key mechanisms of stress tolerance for turfgrasses.
- Reduce fertilizer applications: Grass grows more slowly in a shaded environment, reducing its fertility needs. Too much nitrogen fertilizer depletes carbohydrates and produces a weaker turf system. If a normal yearly application is 4 lbs. N per 1,000 ft², apply only 2.5 to 3 lbs. to turf growing in the shade. Limit any single fertility application to no more than 0.5 lb. N per 1,000 ft² at any one time.
- Adjust irrigation accordingly: If the irrigation system covers an area that is partially shaded and partially in sun, consider removing the sprinkler heads from the shaded areas and irrigate by hand when rainfall is inadequate. Not only does overirrigation waste water and potentially leach pollutants, but the slower evapotranspiration (ET) rate in shaded areas can lead to fungal or other disease and pest problems.
- Reduce traffic: Shaded turf is more easily injured by traffic and may not be able to recover adequately. Also, traffic in shady areas may damage a tree's roots, causing the tree to decline or die.
- Increase air circulation: Very few fungi can infect dry leaves. Where a green is "boxed" or "pocketed" by trees or other obstructions to the point where air circulation is inhibited, surface moisture builds up. This may lead to increased fungal disease, algae, or other problems. Both the root zone and the leaf tissues are susceptible to excessive moisture problems. To address this on an existing course, fans¹² are often used to dry out the soil and increase ET by providing a 3- to 4-mile-per-hour breeze at the surface.

¹²O'Brien July/August, 1996.

Golf course lakes are present for many reasons. They may be natural or man-made. They may have been sited as water hazards for the game, for aesthetic pleasure, to provide irrigation, or because of regulatory requirements for stormwater treatment. Most fill many purposes at the same time.

In its natural state, a lakeshore supports a variety of herbaceous and woody vegetation, has emergent and submergent shoreline plants, and experiences increases and decreases in algae populations. Traditional Florida golf courses favor pond banks with open views of sparkling clear water, distinguished by neat edges of closely cropped sod or hardscape retaining structures. Maintaining such a highly artificial edge requires intensive management. Understanding natural lake processes and accommodating them in the design and management of a pond can create significant aesthetic value and reduce operational costs.

Lakes and ponds have several distinct defining characteristics. Their size, shape, and depth may all affect how they respond to various environmental inputs. Most lakes on a golf course are relatively small and somewhat shallow. This can lead to rapid changes in temperature and a lack of oxygen in the water, resulting in dying plants and fish and bad odors. In shallow or nutrient-impacted ponds, aeration may be required to maintain acceptable dissolved oxygen (DO) levels in the water.

No matter what their purpose, golf course ponds can still provide sustainable aquatic ecosystems for aquatic insects, fish, frogs, turtles, birds, and other wildlife. It is, therefore, important to develop a comprehensive lake management plan that not only allows a pond to continue to function as it was originally designed, but also protects water quality and prevents undesirable changes that could lead to significant restoration costs.

Successful pond management must include a clear statement of goals and priorities to guide the development of the BMPs necessary to meet those goals. Some of the challenges facing superintendents in maintaining the quality of golf course ponds are as follows:

- Low DO,
- Sedimentation,
- Changes in plant populations,
- Nuisance vegetation, and
- Maintenance of littoral shelves and vegetation on the lakeshore.

LAKE MANAGEMENT

Each pond has regions or zones that significantly influence water quality and are crucial in maintaining the ecological balance of the system. It is important for the manager to understand their function and how good water quality can be maintained if these zones are properly managed. The four zones of a lake are the riparian zone, littoral zone, limnetic zone, and benthic zone.

Riparian zones (buffers) are strips of grass, shrubs, and/or trees surrounding a pond and separating it from upland areas (Figure 29). They filter pollutants and trap sediment from stormwater runoff and also slow the velocity of the water, allowing it to filter into the soil and recharge the ground water aquifer. They also offer valuable wildlife habitat. These upland areas are above the high-water mark and should be unfertilized and left in a natural state if possible; otherwise they should be mowed to 2 to 3 inches to act as a filter and buffer to nutrients moving toward the water. A slight swale and berm system also helps by requiring most of the water to infiltrate through the root zone rather than running overland to reach the lake.



Figure 29: Both turf and native plantings can be effective buffers. Properly selected plantings may also provide wildlife habitat. Notice the crane nesting in the buffer above. (Top photo courtesy Harmony Golf Preserve, bottom photo courtesy USGA.)



The littoral zone is the transitional area between the upland and the open water where sunlight penetrates to the bottom of the lake and emergent plants thrive. Ideally, it should have a slope of about 1 foot vertical to 6 to 10 feet horizontal, but this may vary with the size, shape, and morphology of the pond. This zone is crucial to a pond's health, because the macrophytes in this area not only take up nutrients themselves but provide a habitat for other nutrient-removing organisms.

The limnetic zone, or open water, is usually the largest volume of water. In this area, light can penetrate several feet if the water is clear, allowing submergent plants and algae to photosynthesize oxygen during the day and respire carbon dioxide at night. Aerobic bacteria in the water use the oxygen to decompose organic matter and keep nutrients at a low level. This zone is typically easier to manage.

The benthic zone, the area at the bottom of the pond, comprises sediment and soil. It is typically nutrient enriched and has a high demand for DO. The benthic zone functions as habitat for epifaunal organisms that live on the sediment surface and infaunal organisms that spend all or part of their life cycle within the sediments. These organisms are important because they consume plankton and are the basis of the food web, as they are a source of food for bottom-feeding fish and aquatic organisms.

DISSOLVED OXYGEN

As stated previously, maintaining levels of DO that are adequate to sustain a healthy lake ecosystem is a challenge to a lake manager, but may be the single most important water quality factor to understand. The air over a pond is roughly 20% or 200,000 ppm oxygen, but rarely does a pond contain more than 20 ppm oxygen. Most fish show stress if levels reach 3 ppm, with fish kills occurring at levels of 2 ppm. The maximum amount of DO in the water (saturation) primarily depends on water temperature, with warm water able to hold less oxygen than colder water.

Oxygen enters the water from two sources: as an exchange from the atmosphere and as a result of photosynthesis from green plants in the water. It is consumed most significantly by the respiration of plants and decomposition of decaying organic matter. Oxygen levels naturally rise during the day as sunlight drives the photosynthesis process and decline at night as plants consume oxygen through respiration. Excessive oxygen depletion and resulting fish kills, bad odors, and generally unpleasant conditions are usually caused by one or more of the following factors:

- Blooms of algae and other phytoplankton, characterized by very green water, usually result from increased loadings of nutrients coming from excessive fertiliza-

tion or runoff from human activities. Heavy blooms consume large amounts of oxygen at night, and when the wind is low (minimizing atmospheric exchange) and there are cloudy days (minimizing photosynthesis), the risk of serious oxygen depletion is high. When phytoplankton levels are high enough to limit visibility to a foot or less, there is a danger of oxygen depletion. See the discussion of phytoplankton below.

- Being fairly simple plants, phytoplankton populations can expand rapidly and also die rapidly. Such die-offs cause rapid oxygen depletions as oxygen production from the loss of these plants ends and as anaerobic bacteria and fungi working to degrade the now-dead plankton consume the water's remaining oxygen. Die-offs can be caused by sudden drops in temperature and other natural factors, and by heavy herbicide applications to a pond.
- A pond "turnover" can result in low oxygen levels. Turnovers occur most frequently in the spring, when the sun starts warming the surface water while the lower depths remain cool from winter conditions. This stratification causes the bottom water to lose its oxygen to decomposition, and the oxygen is not replaced by surface exchange or photosynthesis. A sudden cooling of the surface—perhaps by a cold wind or rain—can break down this stratification and bring the oxygen-poor water to the surface, where fish become starved for air. Such turnovers occur most frequently in deeper (over 8 feet) ponds and in colder climates but can still be a factor in Florida ponds.

In Florida, lakes less than 6 feet in depth can be difficult to keep oxygenated. Because they are shallow, light penetrates the entire water column and promotes plant and algae growth. They also heat up quickly, often reaching more than 85°, limiting the maximum amount of oxygen they can hold during the day. Hot and humid summer weather provides a worst-case situation. Artificial aeration, particularly at night, for as long as the depleting factors are at work can help to control oxygen depletion in any pond. Encouraging the establishment of desirable plants in an effort to establish a natural balance also buffers a pond from wide swings in oxygen levels.

SEDIMENTATION

Excess sedimentation usually results from upstream erosion or the buildup of decaying organic matter. Excessive nutrients can result in excessive floating plant growth, algal growth, and other problems. As aquatic plants and algae die, they sink to the bottom and form an organic sludge. If this occurs faster than bacteria can degrade the material, the sludge can build up over time, leading to odors and clumps of floating sludge buoyed by gases. The sludge may be sucked into irrigation systems. These sediments can build up to the point where a pond's capacity is significantly reduced, and dredging may be

necessary. If used on a golf course, this “black layer” may seal the soil pores and cause considerable harm to the turf. Excess sediments also smother benthic organisms, inhibiting nutrient reduction and reducing food resources available to other aquatic species. In addition, sediments often build up high levels of cadmium, lead, nickel, and other toxic substances, including herbicides and other pesticides. The disposal of these sediments may be subject to regulation, and application to turf may cause damage from residual herbicides.

AQUATIC PLANT CONTROL

Soon after a pond is constructed, unforeseen problems may arise—e.g., it becomes clogged with floating or submersed aquatic plants. The degree to which an aquatic plant becomes a weed problem depends on a pond's intended use. For example, shoreline grasses can help stabilize and prevent bank erosion, but out-of-control grasses may encroach into the water, restricting access and usability.

Plants are vital to the functioning of lakes and wetlands and serve various roles, such as producing oxygen and providing wildlife habitat. Ponds may be constructed on golf courses simply as water hazards but usually have additional purposes such as stormwater management (wet detention ponds) and irrigation. Stormwater management is often a pond's primary purpose. Wet detention ponds may be constructed with shallow sloping areas, called littoral shelves, which provide habitat for rooted plants. Plants in ponds need to be managed, and management goals depend on a pond's intended purposes.

In developing an aquatic plant management strategy, it is important to know the intended uses of a waterbody, the site's physical attributes and location, the invasive or weedy species present, aesthetics, and other environmental considerations. Preventing the introduction and spread of non-native plants in Florida's waterways is the best and least expensive means of restoring natural freshwater habitats. In addition, preventive measures such as properly locating and constructing a pond help to reduce the risk of a takeover by invasive aquatic weeds.

As with other pest problems, the principles of IPM should be used. Prevention is better than cure, and the first steps in prevention are the use of proper fertilization practices, along with proper mowing, unfertilized buffer strips, and good pond design and littoral shelf plantings. The use of lake colorants and dyes, aeration, mechanical removal, and biological controls also has a place in a lake IPM system.

Chemical maintenance control may be necessary to reduce invasive or noxious plant or algae populations, herbicide use, and management and environmental costs. Florida law (Chapter 369.22, F.S.) defines maintenance control as “a method of managing exotic plants in which

control techniques are utilized in a coordinated manner on a continuous basis in order to maintain a plant population at the lowest feasible level.”

In a maintenance control program, even though herbicide applications occur more frequently, the overall amount of herbicide used is much lower than what would be used to treat an out-of-control infestation and the stress on the pond is much less. Maintenance control also reduces sediment deposition. Plant managers choose the aquatic herbicide for each job according to the target plant, waterbody type and uses, wind, temperature, water depth, and other factors such as efficiency and cost-effectiveness.

It is important to consider the types of chemicals used in an aquatic environment. Copper products are a concern to environmental agencies because copper is persistent in the environment and highly toxic to many fish and other aquatic animals at exposure levels near those used to control algae, especially in water with low alkalinity. Many surface waters in Florida are impaired due to high levels of copper, and many others are being investigated. In general, chelated copper compounds are safer to use than copper sulfate. The Virginia Cooperative Extension Service has published an excellent reference for pesticide use in aquatic environments: *Pesticides and Aquatic Animals: A Guide to Reducing Impacts on Aquatic Systems* (available: <http://www.ext.vt.edu/pubs/waterquality/420-013/420-013.html>).

ROLES OF PLANT LIFE IN URBAN PONDS

Phytoplankton, which give water its green appearance, provide the base for the food chain in ponds. Tiny animals called zooplankton use phytoplankton as a food source. Larger animals, including small fish, use the zooplankton for food, and other, larger animals such as fish and birds feed on these to make up the higher levels of the food chain. Phytoplankton also produce oxygen, needed by fish and other animals in pond water, through the process of photosynthesis.

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 (emersed 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). Different types of aquatic macrophytes have different functions in ponds. Plant life growing on littoral shelves may help to protect receiving waters from the pollutants present in surface water runoff, and a littoral shelf is often required in permitted surface water retention ponds. Floating plants suppress phytoplankton because they absorb nutrients from the pond water and cause shading.

All types of aquatic macrophytes harbor insects. These may feed directly on plants (phytophagous), or they may

be predatory insects that prey on other insects or small fish. In turn, these insects provide food for fish and birds.

The presence or absence of plants, and the types of plants, may affect the bird life that frequents ponds. Birds use large aquatic plants, including adjacent shrubs and trees, such as wax myrtles, willows, salt bush, and red maples for nesting, feeding, and refuge sites. They also use macrophytes as food, and the plants provide habitat for other species eaten by birds. For example, bulrush (*Scirpus* spp.) is a primary habitat for least bitterns, red-winged blackbirds, and boat-tailed grackles. Wading birds, rails, and ducks may avoid tall and medium-height vegetation such as arrowhead (*Sagittaria* spp.), duck potato (*Sagittaria* spp.), and pickerelweed (*Pontederia* spp.), while moorhens use them frequently for cover. Domestic ducks can be a nuisance and are often associated with lakes that contain open, sodded edges or hydrilla (*Hydrilla verticillata*), a major food source for these birds. Trees such as cypress (*Taxodium* spp.) and black gum (*Nyssa* spp.) provide perches and resting places for cormorants, anhingas, herons, osprey, and a variety of other birds that hunt for food in ponds. Establishing a broad littoral shelf of spikerush or other grasslike plants can provide space for sandhill cranes, a frequenter of fairways, to build nests. Dead trees that do not create a safety hazard provide insect populations for woodpeckers, whose holes offer nesting opportunities for a number of birds.

Certain plants have ornamental or aesthetic value in ponds. Plants such as duck potato and pickerelweed provide showy flowers. Plants such as bulrush have bright-green stems and foliage. All plants provide interesting shapes and screens that add aesthetic variety to a pond. For the butterfly enthusiast, butterfly gardens can be created on pond margins and littoral shelves, with the proper selection of planting material. The use of aquatic plants to improve the appearance of a pond (aquascaping) can be included as part of the overall landscape design.

Additional information on aquatic plants can be obtained from the FFWCC Invasive Plant Management Circular #4, *Plants for Lakefront Revegetation* (available: <http://www.dep.state.fl.us/lands/invaspec/2ndlevpgs/pdfs/Circular4.pdf#search=%22Plants%20for%20Lakefront%20Revegetation%22>), the UF-IFAS Center for Aquatic and Invasive Plants, Information Office, at (352) 392-1799 (available: <http://plants.ifas.ufl.edu/>), and the UF-IFAS Extension Electronic Data Information Source (available: <http://edis.ifas.ufl.edu>).

MANAGEMENT OF PLANT LIFE

Aquatic plants growing in and around a pond provide many benefits. They help maintain good water quality by reducing shore erosion and absorbing nutrients. Plants provide cover for fish and a substrate for the colonization of minute organisms used by small fish. Wildlife use

shoreline vegetation for concealment and as areas to search for food.

Properly designed ponds with a narrow fringe of vegetation along the edge are much more resistant to problems than those with highly maintained sod. Still, plant life needs to be managed to ensure that a pond functions as it was intended. Ponds may be constructed on golf courses strictly as water hazards or for landscape purposes, but they often have the primary purpose of drainage and stormwater management, and are also often a source of irrigation water. Wildlife habitat is an ancillary benefit, and aesthetic value can also be derived from a pond whose primary purpose is stormwater detention.

Stormwater management ponds in which aquatic plants grow and need management are referred to as wet detention ponds, and the maintenance of plant life may be regulated under the construction permit issued by a water management district or other agency. The ponds are often constructed with a littoral shelf that is required by the permit and with requirements for maintaining certain densities of certain plants on the littoral shelf.

Vegetation is managed differently for different purposes. Special practices may be required in permitted stormwater management ponds. In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves. Some permits stipulate certain control methods that may not be used. Therefore, before using an algicide, herbicide, or grass carp in a permitted surface water detention pond, it may be necessary to check with a water management district official to determine permit requirements. If water from the pond is used for irrigation, waiting periods for using the water for irrigation required by the herbicide label must be followed. The herbicide label must be consulted as the legal guideline. The management of vegetation for certain combinations of benefits may be mutually exclusive, and certain compromises may have to be made. The removal of aquatic weeds from state waters requires an aquatic plant removal permit from FFWCC (additional information is available at: <http://www.myfwc.com/license/aquatic-plants/>).

Practices commonly used to manage plant life in ponds include the modification of cultural practices surrounding the pond (e.g., fertilization practices), the introduction of desirable plants, the hand removal of plants or mechanical harvesting, the introduction of triploid grass carp (a plant-eating fish), biological controls, aeration, and chemical controls.

Biological controls for some plants, including predatory insects, may be obtained from the USACOE in Jacksonville (available: <http://www.saj.usace.army.mil/Missions/Environmental/InvasiveSpecies.aspx>). Research on biological controls is also being done on several invasive plants at

the USDA–ARS Invasive Plant Research Laboratory in Ft. Lauderdale (available: http://www.ars.usda.gov/Main/site_main.htm?modecode=66-29-00-00).

A permit is required to stock triploid grass carp. Permit forms and additional information can be obtained from the FFWCC (available: <http://myfwc.com/wildlifehabitats/invasive-plants/grass-carp/>).

Herbicides (and algicides) that are registered by the EPA and the Florida Department of Agriculture and Consumer Services (FDACS) for use in water are also an option. A commercial aquatic plant restricted use pesticide applicator license from FDACS is required to use them. Another option is to contract a reputable pond management company. As mentioned earlier, many surface waters are impaired due to high levels of copper in the water. Superintendents should be aware of any such designated waters in their area.



Figure 30: Pesticide application may be necessary to control noxious plants (courtesy USGA).

The method or combination of methods to be used depends on the management objectives for a pond. Selectivity (the ability of a practice to control certain plants and not others), secondary environmental effects on the pond, irrigation considerations, and permit restrictions are important considerations when determining the vegetation management practices to be used.

Types of Plant Life

A comprehensive lake management plan should include strategies to control the growth of nuisance vegetation that can negatively affect a pond's water quality and treatment capacity. These plants fall into two categories: phytoplankton (suspended algae) and filamentous algae, and plants (floating, submersed, and emersed).

Phytoplankton – Green and turbid water caused by abundant phytoplankton results from high levels of nutrients,

particularly nitrogen and phosphorus, in pond water. Fertilizers and reclaimed water are common sources of nutrients on golf courses. The reduction of nutrient inputs to pond water is the best long-term solution to chronic phytoplankton problems. Irrigation should not directly strike or run off to waterbodies, and no-fertilization buffers should be maintained along the edges.

A dense and active littoral zone may reduce nutrient inputs before they reach open water. EPA-approved lake dyes that reduce light infiltration and algal photosynthesis may be helpful. Bacteria-containing pond clarifiers are available that reportedly reduce algae in water. These must be continually added to a pond, and the water must be aerated. Aeration alone may help correct certain problems associated with phytoplankton.

If other methods are not feasible, an algaecide containing endothall, copper, or hydrogen peroxide can be used to temporarily reduce phytoplankton blooms. Fish mortality is likely to occur after algaecide application, because the decay of treated phytoplankton consumes oxygen, and oxygen is no longer being produced by phytoplankton, which are the primary source of oxygen in pond water. There is a greater potential for fish mortality when water temperatures are high. Oxygen depletion is less likely to be a problem with an algaecide containing hydrogen peroxide than one with copper or endothall. Phytoplankton are very resilient and will quickly reoccur if suitable conditions for growth prevail.

Filamentous Algae – Filamentous algae are one of the most common and difficult problems in ponds. Like phytoplankton, filamentous algae obtain nutrients from pond water. Therefore, these algae may be reduced if nutrient inputs to pond water can be reduced, and problems may be fewer if the pond is heavily vegetated with macrophytes. As with phytoplankton, dyes and aeration may help. However, some problems with filamentous algae may still occur.

It is best to keep filamentous algae to a minimum by frequent hand removal and/or the frequent application of algaecide to small areas of algae (spot treatment). Treating an entire pond with an algaecide is likely to cause fish mortality due to the lowering of oxygen in the water. If this phenomenon is suspected, a specialist should identify a sample of the algae to determine if this is the case, so that alternative methods can be used.

Floating Plants – The most common floating plants that can become problems include water-hyacinth (*Eichhornia crassipes*), water-lettuce (*Pistia stratiotes*), duckweed (*Lemna* sp., *Spirodela* sp., *Landoltia* spp.), watermeal (*Wolffia* sp.), water fern (*Salvinia minima*), and mosquito fern (*Azolla caroliniana*). Floating plants, like algae, are the greatest problem under high-nutrient conditions. Therefore, limiting nutrient runoff from artificial sources

may reduce the problem. Small amounts of invasive, non-native plants such as water-hyacinth and water-lettuce can be hand removed or spot treated with herbicide.

Triploid grass carp can be used to help keep duckweed, water fern, and mosquito fern under control in ponds, but their effectiveness is unpredictable and they may damage littoral plantings over time. Therefore, if grass carp are used, they should be stocked at low rates initially, and littoral shelves should be monitored so that these fish can be removed if necessary.

Submersed Plants – While submersed plants, such as bladderwort, provide certain wildlife benefits, they can become objectionable in small urban ponds if allowed to grow out of control. Because they can derive nutrients from both the water and hydrosol, rooted submersed plants can proliferate under all but very low-nutrient conditions.

Most submersed plants can be selectively controlled with herbicides without permanently damaging littoral shelves. Grass carp can be used to some extent to keep submersed weeds under control with minimal damage to desirable emersed plants, but it is usually best to get the problem under control with at least one herbicide application and then maintain control using grass carp.

However, the effects of stocking grass carp in ponds are unpredictable. Desirable vegetation may be damaged, or acceptable control may not be achieved. It is difficult to remove fish from a lake, but it may be necessary to remove some grass carp if beneficial plant loss is noted. Thus it is prudent to begin by stocking the fish in low numbers and adding more if needed. While triploid grass carp are sterile, so that uncontrolled population expansions should not be an issue, barriers are required at pond outfalls to ensure that the fish stay where they are stocked.

Nuisance Plants – A newly created pond offers a welcome mat for colonizing plants. Unfortunately, many are not native to Florida, and without natural enemies find conditions ideal for rapid expansion, to the detriment of native species. Some plants that are considered native—such as cattails and primrose willow or even duck potato—also find an open pond bank a great place to become established and expand, reducing the plant diversity that a healthy system requires. Even in established ponds, a drawdown of water levels can expose the pond bottom and create the kind of disturbed habitat that these colonizers love. Maintaining a pond with a diversity of desirable plants requires the selective removal of weedy plants. In ponds containing dense emergent vegetation, the appearance of the pond improves and the rate of detrital accumulation decreases if dead vegetation is removed in the fall or spring.

If cattails are allowed to become the dominant vegetation on a littoral shelf, reducing their population to a manage-

able level is very labor intensive and damaging to littoral shelf plantings. If possible, any regrowth from the rhizome fragments that are left after pulling or cutting should be treated when the shoots are no more than 1 foot tall.

Once allowed to proliferate, torpedograss is the most difficult-to-control emergent weed in ponds. The careful application of appropriate herbicides is needed to minimize damage to nontarget littoral plantings. As torpedo grass can often begin in upland turf areas and extend into the water, one effective control strategy may be to maintain a narrow band of open water at the pond edge to control the expansion of this plant into more desirable littoral plantings.

Additional information on aquatic plant management can be found in the following publications. *Weed Control in Florida Ponds* (archive: <http://ufdc.ufl.edu/fao1/results/?t=institute+of+food+agricultural+sciences>) and *Aquatic Plant Management in Lakes and Reservoirs* (available: <http://plants.ifas.ufl.edu/hoyerapm.html>), and *Pond and Lake Management* (available: <http://www.otterbine.com/assets/base/resources/PondAndLakeManual.pdf>).

LAKE MANAGEMENT BMPs

- Maintain a riparian buffer to filter the nutrients in stormwater runoff,
- Reduce the frequency of mowing at the lake edge and collect or direct clippings to upland areas,
- Practice good fertilizer management to reduce the nutrient runoff into ponds that causes algae blooms and ultimately reduces DO levels,
- Establish a 25-foot-wide no-fertilizer special management zone around pond edges,
- Dispose of grass clippings where runoff will not carry them back to the lake,
- Encourage clumps of native emergent vegetation at the shoreline,
- Maintain water flow through lakes, if they are interconnected,
- Establish wetlands where water enters lakes to slow water flow and trap sediments,
- Reverse-grade around the perimeter to control surface water runoff into ponds and reduce nutrient loads,
- Maintain appropriate silt fencing and BMPs on projects upstream to prevent erosion and the resulting sedimentation,
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels,
- Aerate ponds, and
- Dredge or remove sediment before it becomes a problem.

Pest management is a year-round activity on Florida's golf courses. The state's temperate to subtropical/tropical climate—which is marked by high temperatures, abundant moisture, and year-round growing conditions—makes it prone to increased pest activity. To grow healthy turfgrass in Florida, it is important for golf course superintendents to know what IPM is and how to implement it for each pest group (arthropods, nematodes, diseases, and weeds). They must be well-versed in pest identification, understand pest life cycles and/or conditions that favor pests, and know about all possible methods of controlling pests.

INTEGRATED PEST MANAGEMENT

IPM is a method of combining proper plant selection, correct cultural practices, the monitoring of pest and environmental conditions, the use of biological controls, and the judicious use of pesticides to manage pest problems. Under Florida law (Chapter 482, F.S.), IPM is defined as the following:

... the selection, integration, and implementation of multiple pest control techniques based on predictable economic, ecological, and sociological consequences, making maximum use of naturally occurring pest controls, such as weather, disease agents, and parasitoids, using various biological, physical, chemical, and habitat modification methods of control, and using artificial controls only as required to keep particular pests from surpassing intolerable population levels predetermined from an accurate assessment of the pest damage potential and the ecological, sociological, and economic cost of other control measures.

The philosophy of IPM was developed in the 1950s because of concerns over increased pesticide use, environmental contamination, and the development of pesticide resistance. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of exposure to people, animals, and the environment. Its main goal, however, is to reduce pesticide use by using a combination of tactics to control pests, including cultural, biological, genetic, and chemical controls, as follows:

- **Cultural controls** consist of the proper selection, establishment, and maintenance (such as mowing/pruning, fertilization, and irrigation) of turf and landscape plants. Keeping turf healthy reduces its susceptibility to diseases, nematodes, and insects, thus reducing the need for chemical treatment.

- **Biological controls** involve the release and/or conservation of natural enemies (such as parasites, predators, and pathogens) and other beneficial organisms (such as pollinators). Natural enemies (including ladybird beetles, green lacewings, and insect-parasitic nematodes) may be purchased and released near pest infestations. However, the golf course landscape can also be modified to attract natural enemies, provide habitat for them, and protect them from pesticide applications. For example, in nonplay areas, flowering plants may provide parasitoids with nectar, or sucking insects (aphids, mealybugs, or soft scales) growing on less-valuable plants may provide a honeydew source for natural enemies.
- **Genetic controls** rely on the breeding or genetic engineering of turfgrasses and landscape plants that are resistant to key pests. Such resistance may increase a plant's tolerance of damage, or weaken or kill the pests. Pests may also develop more slowly on partially resistant plants, thus increasing their susceptibility to natural enemies or “softer” pesticides. Selecting resistant cultivars or plant species when designing a golf course is a very important part of IPM. Although superintendents often work with established plant material, they can still recommend changes. Every opportunity should be taken to educate builders, developers, landscape architects, plant producers, and others on which plants are best suited to golf courses.
- **Chemical controls** include a wide assortment of conventional, broad-spectrum pesticides and more selective, newer chemicals, such as microbial insecticides and insect growth regulators. IPM is not antipesticide, but it does promote the use of the least toxic and most selective alternatives when chemicals are necessary. Pesticides are only one weapon against pests and should be used responsibly and in combination with other, less-toxic control tactics.

When determining which products are available for use by turfgrass managers, and when and how to use them, the most comprehensive pesticide guide in Florida is the *University of Florida's Pest Control Guide for Turfgrass Managers*. This publication is updated annually (available: <http://turf.ufl.edu>). Other relevant publications include *Spray Additives and Pesticide Formulations* (archive: <http://ufdc.ufl.edu/fa01/results/?t=institute+of+food+agricultural+sciences>) and *Pesticide Calibration Formulas and Information* (available: <http://edis.ifas.ufl.edu/WG067>). Online searches for University of Florida extension publications can be made at <http://edis.ifas.ufl.edu/advsearch.html>. Also, consult with UF-IFAS turfgrass agents or faculty, chemical distributors, product manufacturers, or independent turf or golf course maintenance consultants.

The basic steps of an IPM program are as follows:

- Identify key pests on key plants.
- Determine the pest's life cycle, and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- Use cultural, mechanical, or physical methods to prevent problems from occurring (for example, prepare the site and select resistant plant cultivars), reduce pest habitat (for example, practice good sanitation and carry out pruning and dethatching), or promote biological control (for example, provide nectar or honeydew sources for natural enemies).
- Decide which pest management practice is appropriate and carry out corrective actions. Direct control where the pest lives or feeds. Use properly timed preventive chemical applications only when your professional judgment indicates that they are likely to control the target pest effectively, while minimizing the economic and environmental costs.
- Determine if the “corrective actions” actually reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.

MONITORING/SCOUTING

Monitoring, or scouting, is the most important element of a successful IPM program. It enables you to monitor for the presence and development of pests throughout the year. By observing turf conditions regularly (daily, weekly, or monthly, depending on the pest) and noting which pests are present, intelligent decisions can be made regarding how damaging they are and what control strategies are necessary. Keep in mind that pests may be present for some time before damage occurs or is noticed. It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures.

Look for the following when monitoring:

- **What are the signs?** These may include mushrooms, animal damage, insect frass, or webbing.
- **What are the symptoms?** Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.
- **Where does the damage occur?** Problem areas might include the edges of fairways, shady areas, or poorly drained areas.
- **When does the damage occur?** Note the time of day and the year, and the flowering stages of nearby plants.

- **What environmental conditions are present at the time of damage?** These include air temperature and humidity, soil moisture, soil fertility, air circulation, and amount of sunlight.

SAMPLING

Common sampling methods for pests include soil samples; soap flushes or drenches; and blacklight, pheromone, and pitfall traps. Before collecting and submitting turf samples for identification, visit the following UF–IFAS Web sites for additional information: Plant Disease Clinic (available: <http://edis.ifas.ufl.edu/sr007>), Insect Identification Service (available: <http://edis.ifas.ufl.edu/SR010>), and Nematode Assay Laboratory (available: <http://edis.ifas.ufl.edu/SR011>). The Rapid Turfgrass Diagnostic Service was designed and implemented for managers of high quality turfgrass in Florida for very fast turn-around (available: <http://turf.ufl.edu/rapiddiag.shtml>).

PESTS DISEASES

Several fine-bladed turfgrasses are managed at the edge of their adaptations to create suitable surfaces for playing golf in Florida. Various groups of plant pathogens can disrupt play by marring and destroying all species and cultivars of this intensely managed turf, if conditions are conducive to disease. As some superintendents note, the tolerance of golfers for disease damage is generally inversely proportional to what they pay to use the course. In other words, the more they pay, the better they expect the turf to look.

No measure can completely eliminate the threat of turfgrass disease on a golf course. However, turfgrass managers have several tactics and tools that can reduce the likelihood of disease. A superintendent's budget, turfgrass species and cultivars, and membership expectations dictate what options are available.

The first rule is to minimize plant stress by optimizing cultural management programs. Cultural factors that can influence turfgrass stress and the likelihood of disease problems include organic layer management, fertility programs, water management, and mowing height selection. Healthy, well-managed turfgrass is less likely to develop disease problems. Diseases that do occur are less likely to be severe because healthy turf has better recuperative potential than stressed, unhealthy turf. Successful superintendents find a balance between membership expectations and the edge of their turf's adaptation.

Many excellent fungicide products are labeled for use on golf courses and marketed to superintendents. Fungicide use should be integrated into an overall management strategy for a golf course. In general, plant diseases are difficult to manage once symptoms are severe in an area, and fungicides are most effective when used in preventive

programs. The appropriate (most effective) preventive fungicide should be applied to susceptible turfgrasses when unacceptable levels of disease are likely to occur.

Determining when and where diseases are likely to occur requires an understanding of the potential disease problems for a particular turfgrass cultivar and knowledge of the impact that environmental variables such as temperature, relative humidity, and leaf wetness have on disease outbreaks. Because this type of prediction is difficult, and even veteran superintendents and plant pathologists cannot predict all disease outbreaks, curative treatments are sometimes necessary. Fungicide labels generally call for higher rates and shorter intervals when treating diseased turfgrass curatively. Selecting the appropriate fungicide product is very important for efficient and effective curative treatment and depends on a correct disease diagnosis.

No one fungicide product is effective against all common turfgrass pathogens. Also, for some turfgrass injuries and disorders (not caused by a pathogen), the symptoms are identical to those of disease. Some turfgrass diseases are fairly obvious, and others can cause a range of overlapping symptoms that makes correctly diagnosing the problem difficult. Diagnostic services are available from the University of Florida and private laboratories. To avoid using the wrong product, ask your fungicide company sales representative, turfgrass consultant, or county agent for diagnostic lab confirmation to make sure the best fungicide product for your situation is applied. For a list of potential fungicides, see the publication, *Turfgrass Disease Management* (available: <http://edis.ifas.ufl.edu/LH040>).

The most common golf turf disease problems are as follows:

- Rhizoctonia diseases, including brown patch, leaf spot, and sheath spot,
- Dollar spot caused by *Sclerotinia homoeocarpa*,
- Pythium blight of cool-season grasses used as overseed,
- Pythium root rot of warm-season turfgrasses,
- Bermudagrass decline and take-all patch caused by *Gaeumannomyces graminis* var. *graminis*,
- Helminthosporium leaf spot and melting out,
- Fairy ring caused by various basidiomycete fungi, and
- Fusarium leaf spots and blight.

ARTHROPODS

Many arthropods (especially insects and mites) occur in the turfgrasses and ornamental plant beds located on golf courses. Some are beneficial (e.g., pollinators, decom-

posers, and natural enemies) or aesthetically attractive (e.g., butterflies), while others may be nuisance pests or negatively affect plant health. Arthropods can cause various types of damage to turfgrass, depending on where they attack the plant. Major root-feeding pests in Florida include mole crickets, white grubs, billbugs, and ground pearls. Arthropods that commonly feed on leaves or stems include tropical sod webworms, armyworms, grass loopers, greenbug aphids, chinch bugs, spittlebugs, some scales, and bermudagrass mites. Insects with piercing-sucking mouthparts (e.g., aphids, chinch bugs, and spittlebugs) withdraw liquids from plants and may cause some leaf streaking, while chewing insects (e.g., mole crickets, white grubs, billbugs, and caterpillars) partially or completely remove above- or below-ground plant tissue. Nuisance pests may not directly damage turfgrass but can be abundant during short periods, make mounds or castings (e.g., earthworms), nest in sand traps or electrical equipment, or affect human or animal health (e.g., red imported fire ants, stinging wasps, fleas, and ticks).

Florida's warm and humid climate, long growing season, and plant diversity are ideal for arthropod growth and development. Several insects that have only one generation per year in the northern United States may have multiple generations in Florida. Thus, pest management decisions should be made with more localized information on pest life cycles and susceptible life stages. Early pest detection and identification are vital to any IPM program. Turf should be inspected as often as practical, especially in areas that tend to become reinfested each year. All employees should be trained to spot potential problems while performing their assigned duties. Specimens can be sent to several different University of Florida and private identification labs.

IPM is useful against most arthropod pests of turfgrass. It is both a practice and strategy to keep pest populations below damaging levels with minimal nontarget effects. When possible, it is important to identify which factors might predispose areas to unwanted arthropod pests and then modify those factors before using pesticides. For example, some golf course practices that enhance playability (e.g., using floodlights at night) or plant growth (e.g., fertilization during grow-in or in late summer) can attract flying beetles or moths that lay eggs on grass blades or in the soil. Cultural practices, such as mowing, dethatching, and aerating may help to mechanically kill some pests or reduce their habitats. Leaving roughs and driving ranges as untreated refuges for natural enemies, providing flower or nectar sources for parasitic flies or wasps, or applying insect-parasitic nematodes or pathogens to infested turfgrass may provide more sustainable pest suppression than a pesticide program.

Insecticides are effective tools if they are accurately selected, timed, and targeted against a pest's appropriate life stage. Products within several chemical classes are avail-

able to superintendents, and product manufacturers continue to create new chemical classes for use in turf and ornamentals. However, the potential for a pest to develop resistance to a pesticide is real and needs to be considered. Resistance is likely to develop if products in the same chemical class are repeatedly used without rotation, the insect has several generations a year, it has limited dispersal, and it can reproduce and develop quickly. For these reasons, chinch bugs, aphids, or mites are more likely to become resistant than mole crickets or white grubs.

For more information, see the publication, *Insect Pest Management on Golf Courses* (available: <http://edis.ifas.ufl.edu/IN410>) or see the *Insecticide Resistance Action Committee* (IRAC) Web site (available: <http://www.irac-online.org/>).

NEMATODES

Plant parasitic nematodes have long been known to adversely affect turfgrass health. However, as many of the highly effective nematicides used in the past 25 years have been withdrawn from the market, nematode management on turfgrasses has become increasingly difficult. Plant parasitic nematodes are microscopic roundworms (unsegmented), usually between 1/64th and 1/8th inch (0.25 and 3 mm) in length. These obligate parasites feed on living plant tissue using a hollow stylet (mouth spear), with which they puncture cell walls, inject digestive juices into the cells, and draw the liquid contents from the cells. By debilitating the root system, plant parasitic nematodes cause turf to be less efficient at removing water and nutrients from the soil and make it much more susceptible to environmental stresses. Additionally, weakened turf favors pest infestation, especially troublesome weeds that necessitate herbicide applications.

Plant parasitic nematodes are classified according to their feeding habit as ectoparasitic or endoparasitic. Ectoparasitic nematodes always live outside roots and feed only on tissues they can reach from outside the roots. Because they are exposed in the soil, ectoparasites generally respond much better to nematicides than endoparasites. Endoparasitic nematodes spend at least part of their life cycles inside the roots on which they feed and are either migratory or sedentary. Migratory nematodes move freely in, through, and out of root tissues, while sedentary nematodes spend most of their life cycles in a single permanent feeding site within a root. Because they are protected within roots, endoparasites are typically more difficult to manage with nematicides and are easily spread in infested plant material.

Because they have a clumped distribution, areas of nematode-damaged turf usually are irregular in shape and vary in size. Affected turfgrass plants often appear wilted, and the shoots often turn yellow and eventually brown. Over time, turf in the affected areas thins out and, with severe infestations, may die. The roots of turfgrasses under

nematode attack may be very short, with few, if any, root hairs, or they may appear dark and rotten.

Although plant parasitic nematodes may be active, healthy turfgrass growing in fertile, moist soil during favorable weather often perseveres. Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses, including drought, high temperatures, low temperatures, and wear. When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem. Often, tolerance to nematodes can be promoted by reducing additional stresses on the turf (see the box on **BMPs for Pest Management**). However, in many cases nematicides need to be applied to achieve the desired turf quality. The application of a nematicide on golf course turf should always be based on assay results.

For more information, see the publication, *Nematode Management for Golf Courses in Florida* (available: <http://edis.ifas.ufl.edu/IN124>).

WEEDS

A weed is any plant out of place or growing where it is not wanted. For example, bahiagrass is considered a weed when growing in a pure stand of bermudagrass but is highly desirable when grown in a monoculture such as a golf course rough. In addition to being unsightly, weeds compete with turfgrasses for light, soil nutrients, soil moisture, and physical space. Weeds also are hosts for other pests such as plant pathogens, nematodes, and insects, and certain weeds can cause allergic reactions in humans.

The most undesirable characteristic of weeds in turf is the disruption of visual turf uniformity that occurs when weeds with a different leaf width or shape, growth habit, or colors are present. Broadleaf weeds such as yellow woodsorrel, spotted spurge, and dollarweed have leaves with a different size and shape than the desirable turf species. Smutgrass, goosegrass, vaseygrass, and thin paspalum grow in clumps or patches that also disrupt turf uniformity. In addition, large clumps are difficult to mow effectively and increase maintenance problems. The lighter-green color typically associated with certain weeds, such as annual bluegrass, in a golf green often distracts from the playing surface.

Weed control for turf managers can be a difficult chore for several reasons. Florida, unlike most areas of the country, has a very mild climate with few freezes. As a result, many weeds traditionally thought of as annuals often behave as short-lived perennials, especially in central and south Florida. For example, year-round weed pressure can occur in Florida from annuals such as crabgrass and goosegrass, which in most sections of the country are killed by freezing temperatures. Florida's mild climate is also suitable for the growth of many subtropical

and tropical weeds that are not found in other regions of the country.

Weed management is an integrated process where good cultural practices are employed to encourage desirable turfgrass ground cover, and where herbicides are intelligently selected and judiciously used. A successful weed management program consists of (1) preventing weeds from being introduced into an area, (2) using proper turfgrass management and cultural practices to promote vigorous, competitive turf, (3) properly identifying weeds, and (4) properly selecting and using the appropriate herbicide, if necessary.

Weeds often are the result, but never the cause, of a weakened turf. The major reasons for weed encroachment are reduced turfgrass quality and low density. Weakened turf or bare areas results from (a) the selection of turf species or cultivars not adapted to the prevalent environmental conditions; (b) damage from turfgrass pests such as diseases, insects, nematodes, and animals; (c) environmental stresses such as shade, drought, heat, and cold; (d) improper turf management practices, such as the misuse of fertilizer and chemicals, improper mowing height or mowing frequency, and improper soil aeration; and (e) physical damage and compaction from excessive traffic. Unless the factors that contribute to the turf decline are corrected, continued problems with weed encroachment can be expected.

Proper weed identification is essential for effective management and control. Turf managers should be able to correctly identify at least the most common species for their geographic area. Since weeds often indicate fertilizer, drainage, traffic, or irrigation problems, correct weed identification can help turf managers to determine the underlying causes of certain infestations and correct them. For example, goosegrass indicates compacted soil, nutsedge suggests drainage problems, while sorrel indicates low pH.

Identification begins with classifying the weed type. Broadleaves, or dicotyledonous plants, have two seed cotyledons (young leaves) at emergence and have netlike veins in their true leaves. They often have colorful flowers. Examples include clover, spurges, lespedeza, plantain, henbit, pusley, dollarweed, and matchweed. Grasses, or monocots, have only one seed cotyledon present when seedlings emerge from the soil. They also have hollow, rounded stems with nodes (joints) and parallel veins in their true leaves. Examples include crabgrass, goosegrass, dallisgrass, thin (bull) paspalum, and annual bluegrass. Sedges and rushes generally favor a moist habitat and have stems that are either triangular shaped and solid (sedges), or round and solid (rushes).

Weeds complete their life cycles in either one growing season (annuals), two growing seasons (biennials), or three or more years (perennials). Annuals that complete their life cycles from spring to fall are referred to as summer annuals. Those that complete their life cycles from fall to spring are winter annuals.

In the past, proper weed identification was difficult due to the lack of a suitable guide. Most guides pictured weeds in unmowed conditions or did not list all the important turf weeds. *Weeds of Southern Turfgrasses*, a publication jointly produced by the University of Florida, University of Georgia, and Auburn University, provides color photographs (most taken in mowed turf situations) of nearly 200 major weeds, with detailed descriptions and information on their life cycles and worldwide distribution (available: <http://www.ifasbooks.com>).

For more information on weed management, see the publication, *Response of Turfgrass and Turfgrass Weeds to Herbicides* (available: <http://edis.ifas.ufl.edu/WG071>).

Cultural and Physical Controls

- Prevent introducing pests by using certified plant material, destroy infested/infected plants (sanitize), and exclude pests.
- Increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed seed germination.
- Stimulate or increase root growth if root-feeding pests are detected (e.g., through aeration, fertilization).
- Time irrigation to avoid excess moisture or drought stress, and minimize the duration of leaf wetness.
- Remove dew on nonmowing days during disease-conducive periods.
- Wash mowers to avoid spreading pathogens and weeds.
- Allow turf to dry before mowing.
- Manage thatch by adjusting fertility levels, mechanical removal, topdressing, or other means.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- Avoid outdoor lighting or use sodium-vapor lightbulbs during peak mole cricket flight, from dusk to 2 hours after dusk between late February and early May.
- Select endophyte-enhanced cultivars for overseeding.

Biological Controls

- Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide beneficial organisms a refuge.
- Install flowering plants that can be nectar food sources for parasitic insects.
- Release insect-parasitic nematodes to naturally suppress mole crickets and white grubs.

Pesticide Controls

- Integrate pesticide use into a pest management plan that is based on the proper diagnosis and identification of pest problems, documents pest abundance, ensures that the pest is in a susceptible life stage, and considers feasible cultural management options first.
- Especially for insecticides aimed at soil insects, irrigate turfgrass before and/or after an application, in accordance with the label.
- Avoid broad-spectrum pesticides when possible to conserve beneficial insects.
- Test the pH of spray water regularly and buffer if necessary.
- Test new pesticides on a small area on the golf course before widely using them.
- Manage pesticide resistance by rotating pesticides with different modes of action, as appropriate.
- Preventively apply appropriate fungicides where diseases are likely to occur and when conditions favor disease outbreaks.
- Preventively apply pesticides only in areas where severe damage previously occurred, was documented, and can be reasonably expected again.
- Avoid applying herbicides when they could contribute to plant stress and lead to greater damage from a secondary pest problem.

¹³ Modified from Peterson, 2000.

PESTICIDE REGULATION AND LEGAL ISSUES

Before any pesticide product is sold or distributed in Florida, it must be registered by the EPA and FDACS. In any commercial pesticide product, the component that actually kills, or otherwise controls, the target pest is called an active ingredient. The product may also contain inert ingredients such as solvents, surfactants, and carriers. However, not all inert ingredients are harmless, and they may be controlled or regulated because of environmental or health concerns. The EPA regulates the use of pesticide products based on their active ingredients, but also reviews and limits the use of inert ingredients based on their toxicity.

REGULATION

The U.S. Congress has mandated that the EPA regulate the use and disposal of pesticides in this country. Through its Office of Pesticide Programs, the EPA regulates pesticide use and disposal under two federal statutes. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), administered by the EPA, governs the licensing or registration of pesticide products. This act was last amended by Congress in 1988. FIFRA, as amended in 1972, authorizes cooperative enforcement agreements between the EPA and the state's lead pesticide regulatory agency. In 1978, FIFRA was amended to give state governments the primary enforcement responsibility, subject to oversight by the EPA, for pesticide-use violations.

The Federal Food, Drug, and Cosmetic Act (FFDCA) authorizes the EPA to establish tolerances for pesticide residues in raw and processed foods. The Food and Drug Administration (FDA) of the U.S. Department of Health and Human Services monitors and enforces these tolerances.

State regulatory agencies may set local standards, but they can be no less stringent than those established by the EPA. Because of the unique environmental conditions present in Florida, state regulations have been adopted that are more strict than the federal guidelines for the use of certain pesticides. FDACS is the lead state agency that, in cooperation with the EPA, enforces existing state and federal statutes to ensure that pesticides are registered, used, and disposed of properly. FDACS also analyzes field samples of soils and water to determine if pesticide residues are at acceptable levels in environmental samples. Four main programs within FDACS carry out these responsibilities: (1) pesticide registration, (2) pesticide enforcement, (3) scientific evaluation, and (4) laboratory analysis.

Depending on the specific pesticide use, a registrant must supply the EPA with the results of a battery of environmental fate and toxicity studies. These studies are performed primarily by private laboratories that follow strict good lab practices (GLPs) and QA/QC measures. Only

after the registrant has met all the EPA guidelines and the risk assessment is complete can a registrant receive a federal registration for a pesticide product.

Several states, including Florida, require an additional review before a pesticide can be sold and distributed within the state. FDACS scientists review the behavior of a pesticide under Florida conditions which may be atypical compared with much of the rest of the United States. Florida's high annual rainfall, year-round cropping, karst topography, and sandy soils are only a few of the conditions that must be considered in evaluating a pesticide's risk to surface water and ground water quality, threatened and endangered species, and Florida citizens. All new pesticides are reviewed before the Pesticide Registration and Evaluation Committee (PREC) for registration. This committee includes members from the FDOH, FDEP, FFWCC, and FDACS. If unreasonable risks are suspected, the manufacturer may be required to provide additional data, perform field tests under Florida-specific conditions, and/or impose risk mitigation measures.

Pesticides registered for use in Florida carry a label that provides, among other information, the maximum allowed application rates; approved application methods and times, crops, and pests; and directions for safe and effective use. State and federal laws require the use and disposal of pesticides according to the label.

LICENSING REQUIREMENTS FOR PESTICIDE USE IN GOLF COURSE MAINTENANCE

Some federal or state regulation covers practically anyone who manufactures, formulates, markets, and uses any pesticide. Laws regarding pesticide use (Chapter 487, F.S.) require that golf course superintendents using restricted use pesticides (RUPs) obtain a RUP applicator license from FDACS. Application of soil fumigants requires a special additional RUP license. County Cooperative Extension Service offices statewide provide training and exams, and most manuals are available at a nominal cost from the UF-IFAS Publications Office at (800) 226-1764 or at <http://www.ifasbooks.com>. A list of counties that offer all exams is available at <http://www.flaes.org/complimonitoring/pesticidecertification.html>. To find out the exam schedule for a specific county Cooperative Extension Service office, contact that particular office. A list of the offices with telephone numbers, addresses, and maps is available at <http://directory.ifas.ufl.edu/>. For more information contact the Pesticide Certification Section at (850) 617-7870.

Continuing Education and Applicator Training

Once an applicator has successfully passed the examination, continuing education credits or retesting are necessary for renewal. UF-IFAS and industry associations such as the Florida Golf Course Superintendents

Association and the Florida Turfgrass Association offer many training opportunities each year. These events provide learners with practical information on pesticide safety, scouting, cultural practices and IPM, equipment calibration and maintenance, and record keeping. Pesticide application is where the rubber meets the road, so to speak, and applicator training is key to safe and effective use. For training information, contact your local extension agent or the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392-4721 (available: <http://www.pested.ifas.ufl.edu>).

RECORD KEEPING

The Florida pesticide law requires certified applicators to keep records of all RUPs. To meet your legal responsibility and to document your management practices, you need to maintain accurate pesticide application records. Florida regulations require that information on RUPs be recorded within two working days of the application and maintained for two years from the application date. The required records must be made available upon request to FDACS representatives, USDA authorized representatives, and licensed health care professionals. A simple-to-use record-keeping form is available at <http://www.flaes.org/complimonitoring/databasearch/pesticidecertlicensingformsanddocuments.html>.

Florida law requires that you record the following items to comply with the RUP record-keeping requirement:

- Brand or product name,
- EPA registration number,
- Total amount applied,
- Location of application site,
- Size of area treated,
- Crop/variety/target site,
- Month/day/year and start and end times of application,
- Name and license number of applicator (if applicator is not licensed, record his/her name and his/her supervisor's name and license number),
- Method of application, and
- Name of the person authorizing the application, if the licensed applicator does not own or lease the property.

Subsection 487.051(1)(b), F.S., and Section 5E-2.033, F.A.C., also require application information on organo-auxin herbicides (e.g., 2,4-D) and plant growth regulators (general or restricted use) to a land or surface area greater than 5 cumulative acres with a 24-hour period. For a land or surface area less than 5 cumulative acres within a

24-hour period, only wind speed and direction readings are required. The suggested format for recording this information is available at <http://www.flaes.org/complimonitoring/databasearch/pesticidecertlicensingformsanddocuments.html>.

The publication, *Pesticide Record Keeping* (available: <http://edis.ifas.ufl.edu/PI012>), provides additional information on pesticide record keeping.

In addition to the records required by law for RUP use, IPM principles suggest that you keep records of all pest control activity, so that you may refer to information on past infestations or other problems to select the best course of action in the future. There is no time limit on these records, because the longer they go back, the more helpful they are. These records will help you to do the following:

- Evaluate past pest control practices,
- Improve pest control practices,
- Predict future pest problems,
- Predict future results,
- Develop more accurate pest control budgets,
- Minimize pesticide use and costs,
- Maximize pest control efficiency,
- Avoid pesticide misuse,
- Reduce pesticide inventory and storage requirements, and
- Provide proof of label and IPM compliance in the event of a lawsuit.

Such records should include the following:

- Plant being treated,
- Location and area treated,
- Stage of plant development,
- Pest being treated,
- Stage of pest development,
- Severity of infestation,
- Beneficial species present,
- Air temperature,
- Wind speed and direction,

- Rainfall and soil moisture level,
- Other pertinent environmental conditions,
- Time of day and date,
- Recent previous attempts to control,
- Basis of selection for treatment used,
- Pesticide name (if used),
- Trade name and manufacturer,
- Type of formulation,
- Lot number,
- Percent active ingredient,
- Application rate (per acre or 1,000 ft²),
- Type of equipment used, and
- Results of treatment.

PESTICIDES AND WATER QUALITY

Because Florida's climate favors the growth of many harmful insects, nematodes, weeds, and plant diseases, golf courses are typically dependent on pesticides for turfgrass management. In Florida, concern about the presence of pesticides in the environment and the threat they pose to surface water and ground water quality is significant. The careful use of pesticides to avoid environmental contamination is an important aspect of golf course management and is desired by both superintendents and the general public. This section discusses factors affecting the behavior of pesticides in soil and water, and how pesticides should be selected and used to prevent environmental contamination.

SURFACE WATER AND GROUND WATER RESOURCES

Surface waters are those we can see on the surface of the earth, including lakes, rivers, streams, wetlands, estuaries, and even the oceans. They are replenished by rain, runoff, the upwelling of ground water, and the lateral discharge of ground water. Ground water, the source of water for wells and springs, is found underground, within cracks in bedrock or filling the spaces between particles of soil and rocks. The ground water layer in which all available spaces are filled with water is called the saturated zone. The dividing line between the saturated zone and overlying unsaturated rock or sediments is called the water table.

Water entering the soil gradually percolates downward to become ground water if it is not first taken up by plants, evaporated into the atmosphere, or held within soil pores. This percolating water, called recharge, passes downward

through the root zone and unsaturated zone until it reaches the water table. Effective programs for ground water protection focus primarily on the recharge process, because this controls both the quantity and the quality of water reaching the saturated zone.

The quantity of recharge in any particular location depends on the amount of precipitation or irrigation, runoff soil storage, evapotranspiration, the type of soil, and the site's topography and geology. Seasonal fluctuations occur in the quantity of recharge, leading also to fluctuations in the depth of the water table. Florida is known for its high annual rainfall; however, these rain events are often seasonal. During the dry season, shallow wells can run dry and also cause some springs, wetlands, and small streams to dry up due to a falling water table. Recharge is the only natural means of replenishing ground water supplies, and the water table drops if the amount of water lost exceeds the amount of recharge.

BEHAVIOR OF PESTICIDES IN SOIL AND WATER

Once a pesticide is applied to turfgrass, a number of things may happen (Figure 31). The pesticide may be taken up by plants, or ingested by animals such as insects and earthworms or by microorganisms in the soil. It may move downward in the soil and either adhere to particles or dissolve. The pesticide may volatilize and enter the atmosphere, or break down via microbial and chemical pathways into other, less toxic compounds. Pesticides may be leached out of the root zone or washed off the land surface by rain or irrigation water. Although the evaporation of water at the ground surface can lead to the upward flow of water and pesticides, in most Florida soils, this process is likely not to be as important as downward leaching from irrigation and/or rainfall.

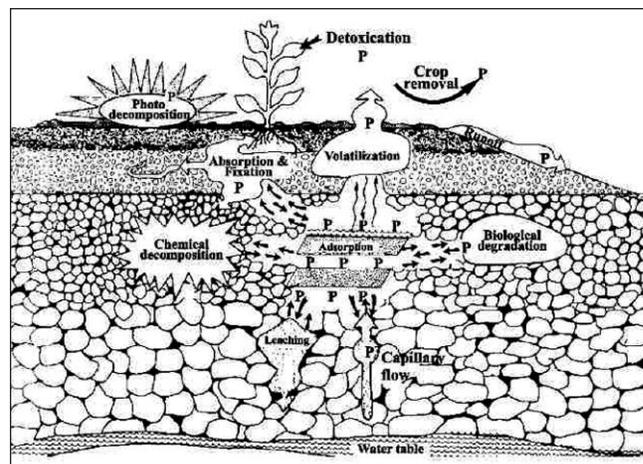


Figure 31: Pathways of pesticide loss
(Rao and Hornsby, 1993; adapted from Skrotch and Sheet, 1981).

Nontarget Effects

Although pesticides can effectively control pests, they can also be dangerous when misused. Fish kills, reproductive failure in birds, and acute illnesses in people have all

Table 7: Potential drift for various droplet sizes

Droplet Diameter in Microns	Droplet Type	Time Required to Fall 10 Feet in Still Air	Distance Covered Falling 10 Feet in a 3-mph Breeze
5	Fog	66 minutes	3 miles
100	Mist	10 seconds	409 feet
500	Light rain	1.5 seconds	7 feet
1,000	Moderate rain	1 second	4.7 feet

been attributed to exposure to or the ingestion of pesticides—usually as a result of misapplication, spray drift or the careless disposal of unused pesticides and containers. In addition to obvious nontarget organisms such as people, pets, birds, and wildlife, other important organisms that can be affected by pesticides include earthworms, honeybees and other beneficial arthropods, and fungi or other microorganisms that might degrade thatch or control pathogens, or are important to nutrient dynamics and overall soil health.

There are three principal ways in which pesticides can leave their application site: runoff, leaching, and spray drift during application. Runoff is the physical transport of pesticides over the surface of the ground with rainwater or irrigation water that does not penetrate the soil. Florida often experiences rainfall events with very high precipitation rates, resulting in significant amounts of runoff. Leaching is a process where pesticides are flushed through the soil by rain or irrigation water as it moves downward. Many of Florida’s soils are sandy, making them more susceptible to leaching of dissolved nutrients and pesticides. Drift is the airborne movement of pesticide particles into nontarget areas during application. Droplet size, which is affected by nozzle type and spray pressure, wind speed, and application height are the most important factors influencing spray drift. Drift is one of the most likely causes of neighborhood complaints and may result in injury to greens or neighboring properties, pets, or people. It may also contaminate surface water if the pesticide settles on a waterbody. Table 7 lists the potential drift for various droplet sizes under different wind conditions. In addition, secondary drift may occur when a pesticide volatilizes from the soil or leaf blade and moves with the air.

Due to Florida’s soils and geology, there are also significant surface water–ground water interactions, which allow pollutants to move from one to the other. Sinkholes and springs are the most obvious, but equally important are the coarse soils, shallow water tables, and drainage ditches and canals.

Persistence and Sorption

The fate of a pesticide applied to soil depends largely on two of its properties: persistence and sorption. Persistence defines the stability of a pesticide. Most mod-

ern pesticides are designed to break down or “degrade” relatively rapid over time as a result of chemical and microbiological reactions in soils. Sunlight breaks down some pesticides, and soil microorganisms can break down others. Some pesticides are degraded or metabolized to intermediate substances, called degradates, as they break down. Degradation time is expressed as half-life ($T_{1/2}$), the amount of time it takes for the concentration of a pesticide in soil to be reduced by one-half. For example, if the half-life of a pesticide is 10 days in the topsoil, then theoretically, the concentration would decrease from 100% to 50% over 10 days. It would take an additional 10 days for the concentration to be further reduced from 50% to 25%. In the soil, a pesticide’s half-life may be affected by soil type, soil horizons, sediments, temperature, and pH.

Table 8 lists examples of pesticides used on Florida golf courses and their persistence based on their degradation in surface soils. Of the pesticides listed, atrazine takes the longest time to degrade, with a half-life of 60 days.

As a pesticide moves through soil, some of it sticks to soil particles, particularly organic matter or clay particles, through a process called sorption, and some dissolves in soil water. As more water enters the soil through rain or irrigation, the sorbed pesticide molecules may be detached from soil particles through a process called desorption. The solubility of a pesticide and its sorption to soil are two critical factors affecting the fate of a pesticide.

A useful index for quantifying pesticide sorption on soils is the partition coefficient (K_{oc}) which is defined as the ratio of pesticide concentration in the sorbed state (i.e., bound to soil particles) and the solution phase (i.e., dissolved in the soil water). Thus, for a given amount of pesticide applied, the smaller the K_{oc} value, the greater the tendency to move into solution. Pesticides with small K_{oc} values are more likely to leach, compared with those having large K_{oc} values, which are more likely to bind with soil and organic matter. For example, in the table, glyphosate, which has a K_{oc} value of 24,000, does not leach because it binds very tightly to soil. In contrast, dicamba, which has a K_{oc} value of 2, can readily leach. This explains why dicamba should never be sprayed under the drip line of a tree, because it can readily move into the roots. Glyphosate, on the other hand, is

Table 8: Persistence and partition coefficients of pesticides used on Florida golf courses

Common Name	Trade Name(s)	T _{1/2} (days)	K _{oc} (mL/g OC)
Dicamba	various	14	2
Metsulfuron-methyl	Manor, Blade	30	35
Iprodione	Chipco 26GT	14	700
Atrazine	various	60	100
Glyphosate	various	47	24,000

frequently sprayed as an edging material around the trunk of a tree without causing damage. Dicamba is not bound to the soil, and glyphosate is strongly bound.

An added complexity in turf is thatch. When washed off turfgrass leaves, a pesticide encounters the thatch layer that accumulates on top of the soil. This layer of living and dead leaves, stems, and other organic matter provides sites for pesticides to attach and become immobilized. This process often explains the poor efficacy of certain pesticides on their target organisms (e.g., insecticides on controlling grub worms).

Turf also supports an abundant population of microorganisms. Once in the soil, a pesticide may be metabolized and rendered ineffective by these microorganisms. The role and impact that thatch sorption and degradation have on pesticide mobility is an important area of ongoing research.

Estimating Pesticide Losses

When estimating pesticide losses from soils and their potential to contaminate ground water or surface water, it is essential to consider both persistence and sorption. In general, strongly sorbed pesticides (that is, compounds with large K_{oc}) are likely to remain near the ground surface, reducing the likelihood of leaching but increasing the chances of being carried to surface water via runoff or erosion. In contrast, weakly sorbed pesticides are more likely to leach through the soil and reach ground water.

For nonpersistent pesticides with a short half-life, the possibility of surface water or ground water contamination depends primarily on whether heavy rains (or irrigation) occur soon after pesticide application. Without water for movement these pesticides are more likely to remain within the biologically active turf root zone where they may be degraded. In addition, the depth to the water table and the type of subsoil and surficial geology may also affect a pesticide's ability to reach ground water. Therefore, pesticides with intermediate K_{oc} values and short T_{1/2} values may be considered lower risk with respect to water quality, because they are not readily leached and degrade fairly rapidly, reducing their potential impact on nearby waterbodies. Soils with hard pans (i.e., spodic horizons) or finer textured horizons in the

subsoil may have a greater ability to adsorb a pesticide as it leaches through the surface horizons. The worst-case scenario with respect to ground water vulnerability is where sandy soil overlies porous limestone with a shallow water table.

PESTICIDE SELECTION AND USE

The use of pesticides should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, referred to altogether as IPM. When a pesticide application is deemed necessary, its selection should be based on effectiveness, toxicity to nontarget species, cost, and site characteristics, as well as its solubility and persistence. Half-lives and partition coefficients are particularly important when the application site of a pesticide is near surface water or underlain with permeable subsoil and a shallow aquifer. Short half-lives and intermediate to large K_{oc} are best in this situation. Many areas of Florida have impermeable subsoils that impede the deep leaching of pesticides. On such land, pesticides with low K_{oc} and moderate to long half-lives should be used cautiously to prevent rapid transport in drainage water to a nearby waterbody. Non-erosive soils are common to much of Florida, and pesticides with large K_{oc} remain on the application site for a long time. However, the user should be cautious of pesticides with long half-lives, as they are more likely to build up in the soil.

Environmental characteristics of a pesticide can often be ascertained (without any additional information on environmental fate and/or non-target effects) by the environmental hazards statement found on pesticide product labels. The environmental hazards statement (referred to as "Environmental Hazards" on the label and found under the general heading "Precautionary Statements") provides the precautionary 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: 1) general environmental hazards, 2) non-target toxicity, and 3) endangered species protection. Advisories specific to these general categories include:

- General Environmental Hazards
 - > Generic water advisory (for terrestrial pesticides) – "Do not apply directly to water"

- > Ground water advisory – for pesticides (or major degradates) that are mobile and persistent in the environment
- > Surface water advisory – for pesticides with the potential to contaminate surface water via spray drift and/or potential for runoff for several months after application (i.e., persistent in soil)
- Non-Target Toxicity
 - > High toxicity to aquatic organisms (i.e., fish and/or aquatic invertebrates)
 - > High toxicity to wildlife (i.e., birds and mammals)
 - > High toxicity to beneficial insects (i.e., honey bees)
- Endangered Species Protection
 - > Product may have effects on endangered species – instructions are provided to users on mitigating potential effects (i.e., on the label or Endangered Species Protection Bulletin)

Several factors should be considered when applying pesticides with potential environmental impacts specified on the label (Environmental Hazards statement) including:

- Groundwater Hazards
 - > Proximity to sinkholes, wells, and other areas of direct access to ground water, such as karst topography
 - > Highly permeable soils
 - > Soils with poor adsorptive capacity
 - > Shallow aquifers
 - > Wellhead protection areas
- Surface Water Hazards
 - > Proximity to surface water
 - > Runoff potential
 - > Rainfall forecast
 - > Prevailing wind direction and speed (drift)
 - > Wind erosion
- Non-Target Hazards
 - > Proximity to surface water
 - > Proximity to wildlife
 - > Potential for the presence of foraging bees and beneficial insects
- Endangered Species Protection
 - > Proximity to federally listed species and/or habitat

More information can be found in the following publications:

- *Behavior of Pesticides in Soils and Water* (archive: <http://ufdc.ufl.edu/faol/results?t=institute+of+food+agricultural+sciences>).
- *A Review of Turfgrass Pesticide Environmental Fate: Sorption and Degradation in Thatch* (archive: <http://ufdc.ufl.edu/faol/results?t=institute+of+food+agricultural+sciences>).

- *Pesticides and Their Behavior in Soil and Water* (available: <http://psep.cce.cornell.edu/facts-slides-self/facts/gen-pubre-soil-water.aspx>).
- *Pesticide Management Practices* (available: <http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2d.html>).
- *Management Practices to Protect Surface Water from Agricultural Pesticides* (archive: <http://ufdc.ufl.edu/faol/results?t=institute+of+food+agricultural+sciences>).
- *Pesticides and Groundwater: A Guide for the Pesticide User* (available: <http://psep.cce.cornell.edu/facts-slides-self/facts/pest-gr-gud-grw89.aspx>).
- *Factors Influencing Pesticide Movement to Ground Water* (archive: <http://ufdc.ufl.edu/faol/results?t=institute+of+food+agricultural+sciences>).
- *Pesticide Management for Water Quality* (available: <http://psep.cce.cornell.edu/facts-slides-self/facts/pestmgt-water-qual-90.aspx>).
- *Managing Pesticides for Sod Production and Water Quality Protection* (available: <http://edis.ifas.ufl.edu/SS053>).
- *Improved Pesticide Application BMPs for Groundwater Protection from Pesticides* (available: <http://www.ext.nodak.edu/extpubs/h2oqual/watgrnd/ae1113w.htm>).
- *Agricultural Chemical Drift and Its Control* (available: <http://edis.ifas.ufl.edu/AE043>).
- *Sprayer Nozzles* (available: <http://psep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-spray-nozz.aspx>).
- *Agricultural Spray Adjuvants* (available: <http://psep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-adjuvants.aspx>).
- *Spray Additives and Pesticide Formulations* (archive: <http://ufdc.ufl.edu/faol/results?t=institute+of+food+agricultural+sciences>).

Pesticide Risk and Applicator Safety

Pesticides belong to numerous chemical classes that vary greatly in their toxicity. The human health risk associated with pesticide use is related to both pesticide toxicity and the level of exposure. The risk of a very highly toxic pesticide may be very low if the exposure is sufficiently small. Conversely, pesticides having low toxicity may present a

potential health risk if the exposure is sufficiently high. Toxicity is measured using an LD₅₀ value, which is the dose that is lethal to 50% of the test animal population. Therefore, the lower the LD₅₀ value, the more toxic the pesticide.

Pesticide exposures are classified as acute or chronic. **Acute** refers to a single exposure or repeated exposures over a short time, such as an accident during mixing or applying pesticides. **Chronic** effects are associated with long-term exposure to lower levels of a toxic substance, such as the ingestion of pesticides in the diet or ground water.

Additional information can be found in the publication, *Toxicity of Pesticides* (available: <http://edis.ifas.ufl.edu/pdf/files/PI/PI00800.pdf>). Specific information on using herbicides safely and herbicide toxicity can be found in the publication, *Using Herbicides Safely and Herbicide Toxicity* (archive: <http://ufdc.ufl.edu/faol/results/?t=institute+of+food+agricultural+sciences>).

Pesticide labels contain signal words that are displayed in large letters on the front of the label to indicate approximately how acutely toxic the pesticide is to humans. The signal word is based on the entire contents of the product, not the active ingredient alone, and therefore reflects the acute toxicity of the inert ingredients. The signal word does not indicate the risk of chronic effects.

Pesticide products having the greatest potential to cause acute effects through oral, dermal, or inhalation exposure have DANGER as their signal word, and their labels carry the word POISON printed in red with the skull-and-crossbones symbol. Products that have the DANGER signal word due to their potential for skin and eye irritation only do not carry the word POISON or the skull-and-crossbones symbol. Other signal words include WARNING for moderately toxic pesticides and CAUTION for slightly to relatively nontoxic pesticides. Additional information on pesticide labels can be found in the following publications:

- *Interpreting Pesticide Label Wording* (available: <http://edis.ifas.ufl.edu/PI071>), and
- *National Pesticide Telecommunications Network fact sheet, Signal Words* (available: <http://npic.orst.edu/factsheets/signalwords.pdf>).

Other sources of information include the following publications:

- *Pesticide Safety* (available: <http://edis.ifas.ufl.edu/pdf/files/CV/CV10800.pdf>), and
- *Managing Heat Stress when Mixing, Loading, and Applying Pesticides* (archive: <http://ufdc.ufl.edu/faol/results/?t=institute+of+food+agricultural+sciences>).

PESTICIDE HANDLING AND STORAGE

The proper handling and storage of pesticides is important. Failure to do so correctly may lead to the serious injury or death of an operator or bystander, fires, environmental contamination that may result in large fines and cleanup costs, civil lawsuits, the destruction of the turf you are trying to protect, and wasted pesticide product.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) statements on pesticide labels provide the applicator with important information on protecting himself/herself. PPE provides a barrier between the applicator and a pesticide. PPE statements on pesticide labels dictate the minimum level of protection that an applicator must wear; additional protection is encouraged but is up to the discretion of the applicator. Some pesticides require additional garments during high-risk tasks such as mixing, loading, and cleaning. Note also that PPE may not provide adequate protection in an emergency situation.

Store PPE where it is easily accessible but not in the pesticide storage area (where it may become damaged or contaminated). Check the label and the Material Safety Data Sheet (MSDS) for each pesticide for the safety equipment requirements.

Additional sources of information on PPE include the following:

- *Interpreting PPE Statements on Pesticide Labels* (available: <http://edis.ifas.ufl.edu/pdf/files/CV/CV28500.pdf>),
- *Personal Protective Equipment: OSHA Standards 1910.132-1371* (available: <http://edis.ifas.ufl.edu/OA034>),
- *Pesticide Applicator Update: Choosing Suitable Personal Protective Equipment* (available: <http://edis.ifas.ufl.edu/PI061>), and
- *Guidelines for Safely Laundering Pesticide-contaminated Clothing* (available: <http://www.ext.nodak.edu/extpubs/yf/textile/he382w.htm>).

PESTICIDE STORAGE

The storage and handling of pesticides and fertilizers in their concentrated forms pose the highest potential risk to ground water or surface water from agricultural chemicals. For this reason, it is essential that facilities for storing and handling these products be properly sited, designed, constructed, and operated.

Community Right-to-Know Laws

Florida law (Chapter 487, F.S.) allows local governments to control the locations of pesticide storage facilities.

Some of Florida's counties/cities choose to write such zoning ordinances, while others do not. Before you site a pesticide-storage facility, check to see if your local government has a zoning ordinance that influences the locations of these types of facilities. If so, it must be obeyed. Similarly, depending on the kinds of products stored and their quantity, you may need to register the facility with the FDCA and your local emergency response agency. Check with your dealer about community right-to-know laws for the materials that you purchase.

Every golf management facility should have an emergency response plan in place, and golf course personnel should be familiar with the plan before an emergency occurs, such as a lightning strike, fire, or hurricane. Individuals conducting emergency pesticide cleanups should be properly trained under the requirements of the federal Occupational Safety and Health Administration (OSHA). For additional information on reporting chemical spills, see **Appendix B: Spill Reporting Requirements** and **Appendix C: Important Telephone Numbers**.

Storage Facilities

Pesticides should be stored in a lockable concrete or metal building. The secure storage of pesticides benefits everybody. It both helps to protect Florida's environment and reduces the risk of pesticide theft. It also reduces the chance of pesticides getting into the hands of vandals and terrorists. Secure storage is equally important for all pesticides—not just those that are highly toxic.

The pesticide storage area should be separate from other buildings, or at least separate from areas used to store other materials, especially fertilizers. These facilities should be located at least 50 feet from other types of structures to allow fire department access.

Floors should be impervious and sealed with a chemical-resistant paint. They 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. Explosion-proof lighting may be required. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building. PPE should be easily accessible and stored immediately outside the pesticide storage area. An inventory of the pesticides kept in the storage building and the MSDSs for the chemicals used in the operation should be accessible on the premises but not kept in the pesticide storage room itself (since that would make them unavailable in an emergency).

Maintaining a Pesticide Inventory

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.

Store pesticides in their original containers. Never put pesticides in containers that might cause children and others to mistake them for food or drink. Keep the containers securely closed and inspect them regularly for splits, tears, breaks, or leaks. All pesticide containers should retain their original labels. Arrange the containers so that the labels are clearly visible, and make sure the labels are legible. Refasten all loose labels, using nonwater-soluble glue or sturdy, transparent packaging tape. Do not refasten labels with rubber bands (these quickly rot and break) or nontransparent tape, such as duct tape or masking tape (these may obscure important product caution statements or label directions for product use). If a label is damaged, immediately request a replacement from the pesticide dealer or formulator. As a temporary substitute for disfigured or badly damaged labels, fasten a baggage tag to the container handle. On the tag write the product name, formulation, concentration of active ingredient(s), and date of purchase. If there is any question about the contents of a container, set it aside for proper disposal.

Flammable pesticides should be separated from those that are nonflammable. Dry bags should be raised on pallets to ensure that they do not get wet. Liquid materials should always be stored below dry materials, never above them. Labels should be clearly legible. Herbicides, insecticides, and fungicides should be separated to prevent cross-contamination and minimize the potential for misapplication.

Storage building plans are available from several sources, including the Midwest Plan Service, UF–IFAS, and the USDA–NRCS.

Additional sources of information on maintaining a pesticide inventory include the following:

- *Secure Pesticide Storage: Facility Size and Location and Secure Pesticide Storage: Essential Structural Features of a Storage Building* (archive: <http://ufdc.ufl.edu/fa01/results/?t=institute+of+food+agricultural+sciences>).

Operation Cleansweep provided a free, one-time disposal service for pesticide end users—specifically, in agricultural, nursery, golf course, and pest control operations—in order to eliminate potential public health and environmental hazards from cancelled, suspended, and unusable pesticides that are being stored. The program ended in 2010. Operation Cleansweep offered an opportunity to avoid the formidable regulatory barriers to legal disposition of these materials and to promote safe and environmentally sound pesticide use,

handling and disposal (available: <http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides/default.htm>).

CHEMICAL MIXING AND LOADING

Pesticide leaks or spills, if contained, will not percolate down through the soil into ground water 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). The Midwest Plan Service book, *Designing Facilities for Pesticide and Fertilizer Containment* (revised 1995), the Tennessee Valley Authority (TVA) publication, *Coating Concrete Secondary Containment Structures Exposed to Agrichemicals* (Broder and Nguyen, 1995), and USDA–NRCS Code 703 contain valuable information about constructing CMC facilities. One point to remember is that the sump is only a point of collection and pump suction; the containment volume is the entire volume of the bermed and sealed pad. The sump should be small enough to provide for rapid and easy cleaning.

Although the use of a CMC is not mandatory, adherence to the practices in the publications listed above is strongly encouraged. A CMC provides a place for performing all operations where pesticides are likely to be spilled in concentrated form—or where even dilute formulations may be repeatedly spilled in the same area—over an impermeable surface.

Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed. This surface should provide for easy cleaning and the recovery of spilled materials. In its most basic form, a CMC is merely a concrete pad treated with a sealant and sloped to a liquid-tight sump where all of the spilled liquids can be recovered. Pump the sump dry and clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (i.e., one that cannot be legally applied to the same site). Liquids and sediments can then be applied as a pesticide, provided the label instructions are followed, instead of requiring disposal as a (possibly hazardous) waste.

Absorbents such as cat litter 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 waste. Solid materials, of course, can be swept up and reused.

Washwater from pesticide application equipment must be managed properly, since it contains pesticide residues. The BMP for this material is to collect it and use it as a pesticide in accordance with the label instructions. This applies to washwater from both inside and outside the application equipment. The rinsate may be applied as a pesticide (preferred) or stored for use as makeup water

for the next compatible application. Otherwise, it must be treated as a (potentially hazardous) waste. After the equipment is washed and before an incompatible product is handled, the sump should be cleaned of any liquid and sediment.

Additional information on handling pesticide wastewater can be found in the publication, *Proper Disposal of Pesticide Waste* (available: <http://edis.ifas.ufl.edu/PI010>).

PESTICIDE CONTAINER MANAGEMENT

The containers of some commonly used pesticides are classified as hazardous wastes 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 very high fines and/or criminal penalties. However, pesticide containers that have been properly rinsed can be handled and disposed of as nonhazardous solid waste. Both federal law (FIFRA) and the Florida Pesticide Law (Chapter 487, FS.) require pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. **Under federal law (the Resource Conservation and Recovery Act, or RCRA), A PESTICIDE CONTAINER IS NOT EMPTY UNTIL IT HAS BEEN PROPERLY RINSED.** Additional information on pesticide container management can be found in the publication, *The Florida Agricultural Handbook of Solid and Hazardous Waste Regulation: Federal Legislation* (available: <http://edis.ifas.ufl.edu/fe761>) and from the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392–4721 (available: <http://www.pested.ifas.ufl.edu>).

Immediate and proper rinsing removes more than 99% of the container residues typically left by most liquid pesticide formulations. Properly rinsed pesticide containers pose a minimal risk for the contamination of soil and water resources, and preventing contamination is an important part of pesticide management. Containers holding liquid pesticides should be rinsed as soon as they are empty; thus, the time to rinse is during the mixing and loading process. Immediate rinsing has several advantages. A freshly emptied container is easier to clean, because the formulation residues have not had time to dry and cake on the inside of the container. Also, rinsing containers during the mixing and loading process solves the problem of what to do with the container rinse water, as it is added to the water used to prepare the finished spray mix. Newly emptied pesticide containers can be properly rinsed by either triple rinsing or pressure rinsing—both methods work. The steps for triple rinsing and pressure rinsing a container are as follows:

Triple Rinsing a Container

1. Put on the PPE listed on the product's label.
2. Allow the formulation to drip drain from its container into the sprayer tank for at least 30 seconds.

3. Partially fill the container with clean diluent, usually water (about 20% of its capacity).
4. With the container cap placed back on, swirl the water so that all sides are rinsed.
5. Pour the rinse water back into the sprayer tank and allow the container to drip drain for at least 30 seconds.
6. Repeat Steps 2 through 5 twice more.

Pressure Rinsing a Container

1. Put on the PPE listed on the product's label.
2. Install a pressure-rinse nozzle on a hose connected to a water supply capable of delivering 35 to 60 pounds per square inch (psi) of water pressure.
3. Allow the formulation to drip drain from its container into the sprayer tank for at least 30 seconds.
4. Firmly press the pressure-rinse nozzle tip into the side of the pesticide container until the probe is inserted and seated, and then turn on and rinse the container for at least 30 seconds with it draining into the sprayer tank (Figure 32). For containers that are larger than 5 gallons, insert the pressure-rinse nozzle into the tank's bottom.
5. Allow the container to drip drain for at least 30 seconds.



Figure 32: Pressure rinsing.

Additional information can be found in the publication, *Pesticide Container Rinsing* (available: <http://edis.ifas.ufl.edu/PI003>).

Recycle rinsed containers in counties where a program is available. For information about pesticide container recycling programs in your area, contact the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392-4721.

PESTICIDE SPILL MANAGEMENT

Clean up spills as soon as possible. The sooner you can contain, absorb, and dispose of a spill, the less chance there is that it will cause harm. Always use the appropriate PPE as indicated on the MSDS and the label. In addition, follow the following four steps:

1. **CONTROL** actively spilling or leaking materials by setting the container upright, plugging leak(s), or shutting the valve,
2. **CONTAIN** the spilled material using barriers and absorbent material,
3. **COLLECT** spilled material, absorbents, and leaking containers and place them in a secure and properly labeled container, and
4. **STORE** the containers of spilled material until they can be applied as a pesticide or appropriately disposed of.

Small liquid spills may be cleaned up by using an absorbent such as cat litter, diluting with soil, and then applying the absorbent to the crop as a pesticide in accordance with the label instructions.

Golf course managers and landowners must comply with all applicable federal, state, and local regulations on spill response training for employees, spill-reporting requirements, spill containment, and cleanup. Keep spill cleanup equipment available when handling pesticides or their containers. If a spill occurs of a pesticide covered by certain state and federal laws, you may need to report any accidental release if the spill quantity exceeds the "reportable quantity" of active ingredient specified in the law. Large spills or uncontained spills involving hazardous materials may best be remediated by hazardous material cleanup professionals. For additional information on reporting spills, see **Appendix B: Spill Reporting Requirements** and **Appendix C: Important Telephone Numbers**.

For emergency (only) information on hazards or actions to take in the event of a spill, call CHEMTREC, at (800) 424-9300. CHEMTREC is a service of the Chemical Manufacturers Association. For information on whether a spilled chemical requires reporting, call the CERCLA/RCRA help line at (800) 424-9346.

FUELING AREAS

The first line of management is to minimize the possibility of a discharge and the need for disposal. For rainfall, if the containment volume is adequate, the evaporation of accumulated rainfall is often sufficient. Critical levels at which discharge is considered should be established for each facility and the levels marked on the containment wall. This prevents the frequent and unnecessary discharge of small volumes.

The water to be discharged must always be checked for contamination, by looking for an oil sheen, observing any smell of fuel or oil, or by using commercially available test kits. Never discharge to the environment any water that is contaminated.

Treat contaminated water on site by using commercially available treatment systems, discharging it to an FDEP-permitted off-site industrial wastewater treatment system, or transporting it by tanker truck to a treatment facility. Never discharge to a sanitary sewer system without written permission from the utility. Never discharge to a septic tank. For more information on disposal options, contact the appropriate FDEP district office.

If the water is not contaminated, it can be reused or discharged to a permitted stormwater treatment system, such as a retention area, grassed swale, or wet detention pond, although this practice is not encouraged. Do not discharge it during or immediately after a rainstorm, since the added flow may cause the permitted storage volume of the stormwater system to be exceeded.

EQUIPMENT-WASHING FACILITY

GENERAL

An equipment-washing facility can be a source of both surface water and ground water pollution, if the washwater generated is not properly handled. All equipment used in the maintenance of golf courses and associated developments should be designed, used, maintained, and stored in a way that eliminates or minimizes the potential for pollution. Washwater generated from the general washing of equipment, other than pesticide application equipment, may not have to be collected. **Always check with local authorities to determine which BMPs are accepted in your jurisdiction.**

BMPs for the disposal of washwater (from other than pesticide application equipment, and with no degreasers or solvents) depend on several factors, such as the volume of washwater generated, the nature of the surrounding area, and the frequency of the operations. For limited washdown of ordinary field equipment, it may be legal to allow the washwater to flow to a grassed retention area or swale. **Do not allow any washwater to flow directly into**

surface waters. Always check with local authorities to determine whether other requirements may apply. Discharge to a septic system is illegal.

Figure 33 provides examples of unsafe and safe equipment-washing work areas, respectively.



Figure 33: above: unsafe work area, runoff, erosion. below: Safe and clean, curbed, water captured by drain for proper disposal.



Other options include the following:

- Use a closed-loop washwater recycling system and follow FDEP BMPs.
- Discharge to a treatment system that is permitted under FDEP industrial wastewater rules.
- Use the washwater for field irrigation.

Grass-covered equipment should be brushed or blown with compressed air before being washed. Dry material is much easier to handle and store or dispose of than wet clippings. It is best to wash equipment with a bucket of water and a rag, using only a minimal amount of water to

EQUIPMENT-WASHING BMPS

- Wash equipment over a concrete or asphalt pad that allows the water to be collected, or for some limited operations, to run off onto a grassed area to soak into the ground, but never into a surface waterbody or canal. After the residue dries on the pad, it can be collected and composted or spread in the field.
- Use compressed air to blow off equipment. This is less harmful to the equipment's hydraulic seals, eliminates wastewater, and produces dry material that is easier to handle.
- Handle clippings and dust separately. After the residue dries on the pad, it can be collected and composted or spread in the field.
- Minimize the use of detergents. Use only biodegradable nonphosphate detergents.
- Minimize the amount of water used to clean equipment. This can be done by using spray nozzles that generate high-pressure streams of water at low volumes.
- Do not discharge washwater to surface water or ground water either directly or indirectly through ditches, storm drains, or canals.
- Do not conduct equipment wash operations on a pesticide mixing and loading pad. This keeps grass clippings and other debris from becoming contaminated with pesticide.

rinse the machine. Spring-operated shutoff nozzles should be used. Freely running hoses waste vast amounts of water, and water can harm the hydraulic seals on many machines. Where formal washing areas are not available, a “dog leash” system using a short, portable hose to wash off the grass at random locations with syringing valves may be an option. **Do not allow any washwater to flow directly into surface waters or storm drains.**

While there are no state requirements to have a closed recycling system for washwater, the use of a well-designed system is considered one of the available BMPs to deal with this issue. Some local governments require such a system. The FDEP publication, *Guide to Best Management Practices for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment Wash Facilities* (available: <http://www.dep.state.fl.us/water/wastewater/docs/GuideBMPClosed-LoopRecycleSystems.pdf>), provides additional information on the design and operation of these facilities, and the BMPs that may help you avoid the need for a permit. A checklist for these practices is also available from FDEP. Be cautious in operating a system where maintenance activities are involved, because the filters can concentrate traces of oils and metals that are washed off the engines and worn moving parts. In some cases, the concentrations of these substances can become high enough that the filters must be treated and disposed of as hazardous waste. Ask the recycling systems manufacturer or sales representative, or your FDEP district office, for information on filter disposal. The contractor who handles oil filters, waste oil, and solvents can probably handle these filters, too.

Oil/water separators can be used but must be managed properly to avoid problems. **Do not wash equipment used to apply pesticides on pads with oil/water separa-**

tors, since the pesticide residues will contaminate the oil that is salvaged. Be aware that the oil collected in these systems may be classified as a hazardous waste (due to the high concentrations of heavy metals from engine wear), making disposal expensive. Usually, filters from these systems may be disposed of at an approved landfill. Keep all records on the disposal of these materials to prove that you disposed of them properly.

Oil/water separators are generally not necessary, unless the water from the system is to be reclaimed for some particular end use, or large volumes of water are generated and the industrial wastewater permit, local government, or receiving utility requires such a system.

PESTICIDE APPLICATION EQUIPMENT

Washwater from pesticide application equipment must be managed properly, since it contains pesticide residues. The BMP for this material is to collect it and use it as a pesticide in accordance with the label instructions for that pesticide. **This applies to washwater from both the inside and the outside of the application equipment.** Often, the easiest way to do this is to wash the equipment in the CMC. The pad should be flushed with clean water after the equipment is washed, and the captured washwater should be applied to the labeled site as a dilute pesticide, or it may be pumped into a rinsate storage tank for use in the next application. FIFRA, Section 2(ee), allows the applicator to apply a pesticide at less than the labeled rate. **The sump should then be cleaned of any sediment before another type of pesticide is handled.**

Clean the tires and particularly dirty areas of the equipment's exterior with plain water before bringing it into the pad area. This practice prevents unwanted dirt from getting on the mix/load pad and sump, or from being

recycled into the sprayer. **Avoid conducting such washing in the vicinity of wells or surface waterbodies.** It may be necessary to discharge the washwater to an FDEP-permitted treatment facility.

EQUIPMENT MAINTENANCE AREAS

Equipment used to apply pesticides and fertilizers should be stored in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment, and these residues can contaminate soil or water. Pesticide application equipment can be stored in the CMC, but fertilizer application equipment should be stored separately. **Blow or wash loose debris off the equipment to prevent dirt from getting on the CMC pad, where it could become contaminated with pesticides.**

Other equipment should be stored in a clean, safe and protected area when not in use. One BMP is to use paint to delineate parking areas for each piece of equipment. This makes it easy to notice fluid leaks and take corrective action.

WASTE HANDLING HAZARDOUS MATERIALS

Ensure that all containers are sealed, secured, and properly labeled. Use only FDEP-approved, licensed contractors for disposal.

PESTICIDES

Remember, pesticides that have been mixed so they cannot be legally applied to a site in accordance with the label must be disposed of as a waste. Depending on the materials involved, they may be classified as hazardous waste. Operation Cleansweep staff may be able to provide additional information (available: <http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides/pages/contacts.htm>).

PESTICIDE CONTAINERS

Rinse pesticide containers as soon as they are empty. Pressure rinse or triple rinse containers, and add the rinse water to the sprayer. Shake or tap nonrinseable containers, such as bags or boxes, so that all dust and material fall into the application equipment. **Always wear the proper PPE when conducting rinse operations.** See the section on pesticide container management in Chapter 9 for more details.

After cleaning them, puncture the pesticide containers to prevent reuse (except glass and refillable minibulk containers). Keep the rinsed containers in a clean area, out of the weather, for disposal or recycling. Storing the containers in large plastic bags is one popular option to protect the containers from collecting rainwater. **Recycle rinsed containers in counties where an applicable program is available,** or take them to a landfill for disposal. Check with your local landfill before taking containers

for disposal, as not all landfills will accept them. For information about pesticide container recycling programs in your area, contact the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392-4721 (available: <http://www.pested.ifas.ufl.edu>).

USED OIL, ANTIFREEZE, AND LEAD-ACID BATTERIES

Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them. In Florida, recycling is the only legal option for handling used oil. Oil filters should be drained (puncturing and crushing helps) and taken to the place that recycles your used oil, or to a hazardous waste collection site. Many gas stations or auto lube shops accept small amounts (including oil filters) from individuals.

Antifreeze must be recycled or disposed of as a hazardous waste. Commercial services are available to collect this material.

Lead-acid storage batteries are classified as hazardous wastes unless they are recycled. All lead-acid battery retailers in Florida are required by law to accept returned batteries for recycling. Used acid from these batteries contains high levels of lead and must be disposed of as a hazardous waste, unless the acid is contained within a battery being recycled. Make sure that all caps are in place to contain the acid. **Store batteries on an impervious surface and preferably under cover. Remember, spent lead-acid batteries must be recycled if they are to be exempt from strict hazardous waste regulations.**

Do not mix used oil with used antifreeze or sludge from used solvents.

SOLVENTS AND DEGREASERS

One of the key principles of pollution prevention is to reduce the unnecessary use of potential pollutants. Over time, the routine discharge of even small amounts of solvents can result in serious environmental and liability consequences, due to the accumulation of contaminants in soil or ground water. **As little as 25 gallons per month of used solvents to be disposed of can qualify you as a “small quantity generator” of hazardous waste, triggering EPA and FDEP reporting requirements.**

Whenever practical, replace solvent baths with recirculating aqueous washing units (which resemble heavy-duty dishwashers). Soap and water or other aqueous cleaners are often as effective as solvent-based ones. Blowing off equipment with compressed air instead of washing with water is often easier on hydraulic seals and can lead to fewer oil leaks.

Storage

Store solvents and degreasers in lockable metal cabinets in an area away from ignition sources (e.g., welding areas or grinders), and provide adequate ventilation.

They are generally toxic and highly flammable. Never store them with pesticides or fertilizers, or in areas where smoking is allowed. **Keep basins or cans of solvent covered to reduce the emissions of volatile organic compounds (VOCs) and fire hazards. Keep an inventory of the solvents stored and the MSDSs for these materials on the premises, but not in the solvent storage area.** Keep any emergency response equipment recommended by the manufacturer of the solvent in a place that is easily accessible and near the storage area, but not inside the area itself. Follow OSHA signage requirements.

Use

Always wear the appropriate PPE, especially eye protection, when working with solvents. **Never allow solvents to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems, even in small amounts.** Solvents and degreasers should be used over a collection basin or pad that collects all used material. Most solvents can be filtered and reused many times. **Store the collected material in marked containers until it can be recycled or legally disposed of.**

Solvent disposal

Private firms provide solvent washbasins that drain into recovery drums and a pickup service to recycle or properly dispose of the drum contents. **Collect used solvents and degreasers, place them into containers marked with the contents and the date, and then have them picked up by a service that properly recycles or disposes of them. Never mix used oil or other liquid material with the used solvents.** Use only FDEP-approved, licensed contractors.

COMPOSTING

Grass clippings and routine, healthy landscape trimmings should be composted and used to improve the soil. Do not compost diseased material, as this may spread disease.

PAPER, PLASTIC, GLASS, AND ALUMINUM RECYCLING

Office paper, recyclable plastics, glass, and aluminum should be recycled. Place containers for recycling aluminum cans and glass or plastic soft drink bottles at convenient locations on the golf course.

PUBLICATIONS (Note: URLs are as of January 2007)

- Aerts, M.O., N. Nesheim, and F. M. Fishel. April 1998; revised September 2006. *Pesticide recordkeeping*. PI-20. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI012>.
- ASCE, January 2005. *The ASCE standardized reference evapotranspiration equation*. Final report of the Task Committee on Standardization of Reference Evapotranspiration, Environmental and Water Resources Institute of the American Society of Civil Engineers. 1801 Alexander Bell Drive, Reston, VA 20191 Available: <http://www.kimberly.uidaho.edu/water/asceewri/ascestzdetmain2005.pdf>.
- Audubon International, 2006. *Maintenance facility BMPs- A self-assessment checklist*. Audubon International, 46 Rarick Rd., Selkirk, NY 12158 Available: <http://www.auduboninternational.org/e-source/>.
- Augustijn-Beckers, P.W.M., T.M. Buttler, A.G. Hornsby, L.B. McCarty, D.E. Short, R.A. Dunn, and G.W. Simone. May 1991; revised January 1998. *Managing pesticides for lawn care and water quality protection*. Circular 1013. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/pdffiles/SS/SS05200.pdf>.
- Bohmont, B. 1981. *The new pesticide users guide*. Fort Collins, Colorado: B & K Enterprises.
- Braaten, A.W. May 1996. *Guidelines for safely laundering pesticide-contaminated clothing*. HE-382. Fargo, ND: North Dakota State University Extension Service. Available: <http://www.ext.nodak.edu/extpubs/yf/textile/he382w.htm>.
- Brecke, B.J., and J.B. Unruh. May 1991; revised February 25, 2003. *Spray additives and pesticide formulations*. Fact Sheet ENH-82. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH061>.
- Broder, M.F., and D.T. Nguyen. 1995. *Coating concrete secondary containment structures exposed to agrichemicals*. Circular Z-361. Muscle Shoals, Alabama: Tennessee Valley Authority, Environmental Research Center. Tel. (205) 386-2714.
- Broder, M.F., and T. Samples. 2002. *Tennessee handbook for golf course environmental management*. Tennessee Department of Agriculture.
- Buss, E.A. January 2002; revised July 2003. *Insect pest management on golf courses*. ENY-351. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/IN410>.
- Butler, T., W. Martinkovic, and O.N. Nesheim. June 1993; revised April 1998. *Factors influencing pesticide movement to ground water*. PI2. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI002>.
- California Fertilizer Association. 1985. *Western fertilizer handbook*, 7th ed. Sacramento, California.
- Carroll, M. [2005]. *A review of turfgrass pesticide environmental fate: Sorption and degradation in thatch*. University of Maryland. Available: http://www.pestfacts.org/turfconf_05/papers/carroll.pdf.
- Center for Resource Management. 1996. *Environmental principles for golf courses in the United States*. 1104 East Ashton Avenue, Suite 210, Salt Lake City, Utah 84106. Tel: (801) 466-3600, Fax: (801) 466-3600.
- Clark, G.A. July 1994. *Microirrigation in the landscape*. Fact Sheet AE254. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/AE076>.
- Cromwell, R.P. June 1993; reviewed December 2005. *Agricultural chemical drift and its control*. CIR1105. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/AE043>.
- Crow, W.T. February 2001; revised November 2005. *Nematode management for golf courses in Florida*. ENY-008 (IN124). Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/IN124>.
- Daum, D.R., and T.F. Reed. n.d. *Sprayer nozzles*. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-spray-nozz.html>.
- Dean, T.W. February 2003. *Pesticide applicator update: Choosing suitable personal protective equipment*. PI-28. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI061>.

- . April 2004; revised November 2004. *Secure pesticide storage: Facility size and location*. Fact Sheet PI-29. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI064>.
- . April 2004; revised November 2004. *Secure pesticide storage: Essential structural features of a storage building*. Fact Sheet PI-30. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI065>.
- Dean, T.W., O.N. Nesheim, and F. Fishel. Revised May 2005. *Pesticide container rinsing*. PI-3. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI003>.
- Elliott, M.L., and G.W. Simone. July 1991; revised April 2001. *Turfgrass disease management*. SS-PLP-14. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH040>.
- Ferrell, J.A., G.E. Macdonald, B.J. Brecke, A.C. Bennett, and J.T. Ducar. Reviewed January 2005. *Using herbicides safely and herbicide toxicity*. SS-AGR-108. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/pdf/WG/WG04800.pdf>.
- Fishel, F.M. March 2005. *Interpreting pesticide label wording*. Gainesville, Florida: Institute of Food and Agricultural Sciences. Available: <http://edis.ifas.ufl.edu/PI071>.
- Fishel, F.M., and Nesheim, O.N. November 2006. *Pesticide safety*. FS11. Gainesville, Florida: Institute of Food and Agricultural Sciences. Available: <http://edis.ifas.ufl.edu/pdf/CV/CV10800.pdf>.
- Florida Department of Agriculture and Consumer Services. n.d. *Pesticide recordkeeping—benefits and requirements*. Available: <http://www.flaes.org/pdf/Pesticide%20Recordkeeping%20Pamphlet%205-05.pdf>.
- Florida Department of Agriculture and Consumer Services. Division of Agricultural Environmental Services. *Suggested pesticide recordkeeping form*. Available: <http://www.doacs.state.fl.us/onestop/forms/13340.pdf>.
- . Division of Agricultural Environmental Services. *Suggested pesticide recordkeeping form for organo-auxin herbicides*. Available: <http://www.doacs.state.fl.us/onestop/forms/13328.pdf>.
- Florida Department of Agriculture and Consumer Services and Florida Department of Environmental Protection. 1998. *Best management practices for agricultural handling and farm equipment maintenance*. Available: <http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/agbmp3p.pdf>.
- Florida Department of Environmental Protection. 1999. *Florida stormwater, erosion, and sedimentation control inspector's manual*. Tallahassee, Florida: Nonpoint Source Management Section, MS 3570, 2600 Blair Stone Rd., Tallahassee, Florida 32399-2400. Available: http://www.dep.state.fl.us/water/nonpoint/ero_man.htm.
- . December 27, 2002. *Environmental risks from use of organic arsenical herbicides at south Florida golf courses*. FDEP white paper. Available: <http://fdep.ifas.ufl.edu/msma.htm>.
- . April 2002. *Florida water conservation initiative*. Available: http://www.dep.state.fl.us/water/water/policy/docs/WCI_2002_Final_Report.pdf.
- . June 2002. *Florida Green Industries: Best management practices for protection of water resources in Florida*. Available: <http://turf.ufl.edu/BMPmanual.pdf> or <http://www.dep.state.fl.us/water/nonpoint/pubs.htm>.
- . Revised June 2002. *A guide on hazardous waste management for Florida's auto repair shops*. Available: http://www.dep.state.fl.us/waste/quick_topics/publications/shw/hazardous/business/autorepair02.pdf.
- . October 2005. *Checklist guide for 100% closed loop recycle systems at vehicle and other equipment wash facilities*. Available: <http://www.dep.state.fl.us/water/wastewater/docs/ChecklistGuideClosed-LoopRecycleSystems.pdf>.
- . October 2005. *Guide to best management practices for 100% closed-loop recycle systems at vehicle and other equipment wash facilities*. Pollution Prevention Program and Industrial Wastewater Section. Available: <http://www.dep.state.fl.us/water/wastewater/docs/GuideBMPClosed-LoopRecycleSystems.pdf>.
- . 2006. *State of Florida erosion and sediment control designer and reviewer manual*. Nonpoint Source Management Section. Available: <http://www.dep.state.fl.us/water/nonpoint/erosion.htm>.
- . 2006. *Operation Cleansweep for Pesticides Web site*. Available: <http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides/default.htm>.

- . October 2006. *Standards for landscape irrigation in Florida*.
- Florida Irrigation Society. 2002. *Urban irrigation auditor certification manual*. 9340 56th Street N., Suite 105, Temple Terrace, FL 33617. Available: <http://www.fisstate.org/index.htm>.
- . December 1, 2005. *Standards and specifications for turf and landscape irrigation systems*, 5th Ed. Available: <http://www.fisstate.org/StandardsRevision3.pdf>.
- Gilman, E. 2006. *Pruning shade trees in landscapes*. Available: <http://hort.ufl.edu/woody/pruning/index.htm>.
- Havlin, J.L., et al. 2004. *Soil fertility and fertilizers*, 7th Ed. Prentice Hall.
- Haydu, J.J., and A.W. Hodges. 2002. *Economic impacts of the Florida golf course industry*. UF-IFAS Report EIR 02-4. Available: <http://economicimpact.ifas.ufl.edu/publications/EIR02-4r.pdf>.
- Helfrich, L.A., et al. June 1996. *Pesticides and aquatic animals: A guide to reducing impacts on aquatic systems*. Virginia Cooperative Extension Service. Publication Number 420-013. Available: <http://www.ext.vt.edu/pubs/waterquality/420-013/420-013.html>.
- Hornsby, A.G., T.M. Buttler, L.B. McCarty, D.E. Short, R.A. Dunn, G.W. Simone. Revised September 1995. *Managing pesticides for sod production and water quality protection*. Circular 1012. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS053>.
- Insecticide Resistance Action Committee Web site. Available: <http://www.irac-online.org/>.
- Kidder, G., E.A. Hanlon, T.H. Yeager, and G.L. Miller. April 1989; reviewed September 2003. *IFAS standardized fertilization recommendations for environmental horticulture crops*. Fact Sheet SL-141. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.
- King, K.W., and J.C. Balogh. 2001. Water quality impacts associated with converting farmland and forests to turfgrass. In: *Transactions of the ASAE*, Vol. 44(3): 569-576.
- Lehtola, C.J., C.M. Brown, and W.J. Becker. November 2001. *Personal protective equipment*. OSHA Standards 1910.132-137. AE271. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/OA034>.
- McCarty, L.B., and D.L. Colvin. 1990. *Weeds of southern turfgrasses*. Gainesville, Florida: University of Florida.
- Midwest Plan Service. Revised 1995. *Designing facilities for pesticide and fertilizer containment*. MWPS-37. Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, IA 50011-3080. Tel.: (515) 294-4337.
- Mitra, S. 2006. *Effects of recycled water on turfgrass quality maintained under golf course fairway conditions*. WaterReuse Foundation, 1199 North Fairfax Street, Suite 410, Alexandria, VA 22314. Available: <http://www.watereuse.org/Foundation/documents/wrf-04-002.pdf>.
- National Pesticide Telecommunications Network. December 1999. *Signal words*. Fact Sheet. Available: <http://npic.orst.edu/factsheets/signalwords.pdf>.
- Nesheim, O.N. April 1998; reviewed April 2003. *Management practices to protect surface water from agricultural pesticides*. PI22. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI014>.
- . April 1998; reviewed April 2003. *Managing heat stress when mixing, loading, and applying pesticides*. PI117. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI009>.
- . n.d. *Interpreting PPE statements on pesticide labels*. PI116. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/CV285>.
- Nesheim, O.N., and F.M. Fishel. March 1989; revised November 2005. *Proper disposal of pesticide waste*. PI-18. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI010>.
- Nesheim, O.N., F.M. Fishel, and M. Mossler. July 1993. *Toxicity of pesticides*. PI-13. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/pdf/PI/PI00800.pdf>.
- North American Lake Management Society and the Aquatic Plant Management Society. 1997. *Aquatic plant management in lakes and reservoirs*. Prepared for

- the U.S. Environmental Protection Agency, Office of Water Assessment and Watershed Protection Division, Washington, D. C. Available: <http://plants.ifas.ufl.edu/hoyerapm.html>.
- O'Brien, P. July/August 1996. *Optimizing the turfgrass canopy environment with fans*. USGA Green Section Record, Vol. 34(4), 9-12 Available: http://www.usga.org/turf/articles/management/greens/optimizing_turfgrass.html.
- O'Brien, P., and C. Hartwiger. March/April 2003. *Aerification and sand topdressing for the 21st century*. USGA Green Section Record, Vol. 41(2), 1-7. Available: <http://turf.lib.msu.edu/2000s/2003/030301.pdf>.
- Olexa, M.T., A. Leviten, and K. Samek. December 2003. *Florida solid and hazardous waste regulation handbook: Table of contents*. FE440. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/fe440>.
- Otterbine Barebo, Inc. 2003. *Pond and lake management*. 3840 Main Road East, Emmaus, PA 18049. Available: <http://www.otterbine.com/assets/base/resources/PondAndLakeManual.pdf>.
- Peterson, A. 2000. *Protocols for an IPM system on golf courses*. University of Massachusetts Extension Turf Program.
- Pettinger, N.A. 1935. Useful chart for teaching the relation of soil reaction to availability of plant nutrients to crops. *Virginia Agri. Ext. Bul.* 136, 1-19.
- Rao, P.S.C., and A.G. Hornsby. May 1993; revised December 2001. *Behavior of pesticides in soils and water*. Fact Sheet SL40. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS111>.
- Rao, P.S.C., R.S. Mansell, L.B. Baldwin, and M.F. Laurent. n.d. *Pesticides and their behavior in soil and water*. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/gen-pubre-soil-water.html>.
- Rodgers, J. n.d. *Plants for lakefront revegetation*. Bureau of Invasive Plant Management, Florida Department of Environmental Protection, South Gulf Office, 8302 Laurel Fair Circle, Suite 140, Tampa, FL 33610. Circular 4. Available: <http://www.dep.state.fl.us/lands/invaspec/2ndlevpgs/pdfs/Circular4.pdf#search=%22Plants%20for%20Lakefront%20Revegetation%22>.
- Sartain, J.B. 2000. *General recommendations for fertilization of turfgrasses on Florida soils*. Fact Sheet SL-21. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH014>.
- . 2001. *Soil testing and interpretation for Florida turfgrasses*. SL-181. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS317>.
- . 2002. revised October 2006. *Recommendations for N, P, K, and Mg for golf course and athletic field fertilization based on Mehlich-I extractant*. SL-191. Available: <http://edis.ifas.ufl.edu/SS404>. Gainesville, Florida.
- Sartain, J.B., and W.R. Cox. 1998. *The Florida fertilizer label*. SL-3. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS170>.
- Sartain, J.B., and J.K. Kruse. 2001. *Selected fertilizers used in turfgrass fertilization*. CIR-1262. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Archive: <http://ufdc.ufl.edu/fao1/results/?t=institute+of+food+agricultural+sciences>.
- Sartain, J.B., G.L. Miller, G.H. Snyder, and J.L. Cisar. 1999a. Plant nutrition and turf fertilizers. In: J.B. Unruh and M. Elliott (Eds.). *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.
- . 1999b. Liquid fertilization and foliar feeding. In: J.B. Unruh and M. Elliott (Eds.), *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.
- Sartain, J.B., G.L. Miller, G.H. Snyder, J.L. Cisar, and J.B. Unruh. 1999. Fertilization programs. In: J.B. Unruh and M. Elliott (Eds.). *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.
- Schueler, T.R. 2000. Minimizing the impact of golf courses on streams. Article 134 in: *The practice of watershed protection*. T. R. Schueler and H. K. Holland (Eds.). Ellicott City, Maryland: Center for Watershed Protection. Available: <http://www.stormwatercenter.net/>.
- Schumann, G.L., et al. January 1998. *IPM handbook for golf courses*. Indianapolis, Indiana: Wiley Publishing, Inc.

- Seelig, B. July 1996. *Improved pesticide application BMPs for groundwater protection from pesticides*. AE-1113. Fargo, North Dakota: North Dakota State University Extension Service. Available: <http://www.ext.nodak.edu/extpubs/h2oqual/watgrnd/ae1113w.htm>.
- Skrotch, W.A. and Sheet, T.J. (Eds.) 1981. *Herbicide Injury and Diagnosis*. North Carolina Agricultural Extension Service, AG-85.
- Smajstrla, A.G., and B.J. Boman. April 2000. *Flushing procedures for microirrigation systems*. Bulletin 333. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/WI013>.
- Thayer, D.D., K.A. Langeland, W.T. Haller, and J.C. Joyce. October 1986; revised June 2003. *Weed control in Florida ponds*. CIR 707. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/aa238>.
- Trautmann, N.M., K.S. Porter, and R.J. Wagenet. n.d. *Pesticides and groundwater: A guide for the pesticide user*. Fact Sheet. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/pest-gr-gud-grw89.html>.
- University of Florida—Institute of Food and Agricultural Sciences Web site. *Welcome to landscape plants*. Available: <http://hort.ufl.edu/woody/index.htm>.
- University of Florida—Institute of Food and Agricultural Sciences. Center for Aquatic and Invasive Plants Web site. Available: <http://plants.ifas.ufl.edu/>.
- . Insect Identification Service Web site. Available: <http://edis.ifas.ufl.edu/SR010>.
- . Nematode Assay Laboratory Web site. Available: <http://edis.ifas.ufl.edu/SR011>.
- . Pesticide Information Office Web site. Available: <http://www.pested.ifas.ufl.edu/>.
- . Plant Disease Clinic Web site. Available: <http://edis.ifas.ufl.edu/LH041>.
- . Rapid Turfgrass Diagnostic Service Web site. Available: http://turfpath.ifas.ufl.edu/turfgrass/rapid_diag.shtml.
- Unruh, J.B. November 1993. *Pesticide calibration formulas and information*. Fact Sheet ENH-90. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/WG067>.
- Unruh, J.B. 2006. *2006 University of Florida's pest control guide for turfgrass managers*. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://turf.ufl.edu>.
- Unruh, J.B., and B.J. Brecke. Revised January 1998. *Response of turfgrass and turfgrass weeds to herbicides*. ENH-100. Gainesville, Florida: Department of Environmental Horticulture, University of Florida. Available: <http://edis.ifas.ufl.edu/WG071>.
- Unruh, J.B., and M. Elliot. 1999. *Best management practices for Florida golf courses*, 2nd ed. UF-IFAS Publication SP-141. Gainesville, Florida.
- Unruh, J.B., J.L. Cisar, and G.L. Miller. 1999. Mowing. In: J.B. Unruh and M.L. Elliot (Eds.). *Best management practices for Florida golf courses*, 2nd ed. Gainesville, Florida: University of Florida Institute of Food and Agricultural Sciences.
- Unruh, J.B., A.E. Dudeck, J.L. Cisar, and G.L. Miller. 1999. Turfgrass cultivation practices. In: J.B. Unruh and M.L. Elliot (Eds.). *Best management practices for Florida golf courses*, 2nd ed. Gainesville, Florida: University of Florida Institute of Food and Agricultural Sciences.
- U.S. Environmental Protection Agency. n.d. *Pesticide management*. Washington, D. C. Office of Wetlands, Oceans, and Watersheds. Available: <http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2d.html>.
- U.S. Environmental Protection Agency, Region 3. n.d. *Green communities, beneficial landscaping*. Available: <http://www.epa.gov/greenkit/landscap.htm>.
- United States Golf Association. 2004. *Recommendations for a method of putting green construction*. Available: http://www.usga.org/turf/course_construction/green_articles/putting_green_guidelines.html.
- van Es., H.M. October 1990. *Pesticide management for water quality: Principles and practices*. October 1990. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/pestmgt-water-qual-90.html>.
- Witt, J.M. n.d. *Agricultural spray adjuvants*. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-adjuvants.html>.
- Yergert, M.B. Austin, and R. Waskom. June 1993. *Best management practices for turfgrass production*. Turf BMP Fact Sheet. Available: <http://www.ag.state.co.us/csd/groundwater/turfbmp.pdf>. Colorado Department of Agriculture. Agricultural Chemicals and Groundwater Protection Program.

Organizations

American Society of Golf Course Architects (ASGCA)

125 N. Executive Dr., Suite 106
Brookfield, WI 53005
(262) 786-5960 (ph)
(262) 786-5919 (fax)
<http://www.asgca.org>

Audubon International

46 Rarick Road, Selkirk, NY 12158
(518) 767-9051 (ph)
(518) 767-9076 (fax)
<http://www.audubonintl.org/>

Florida Golf Course Superintendents Association (FGCSA)

1760 NW Pine Lake Dr., Stuart, FL 34994
(772) 692-9349 (office)
(800) 732-6053 (toll free)
(772) 692-9654 (fax)
<http://www.floridagcsa.com/>

Florida Turfgrass Association (FTGA)

5104 North Orange Blossom Trail, Suite 104
Orlando, FL 32810
(800) 882-6721 (toll free)
(407) 291-9415 (ph)
(407) 291-4852 (fax)
<http://www.ftga.org/>

Golf Course Builders Association of America (GCBAA)

727 "O" Street, Lincoln, NE 68508
(402) 476-4444 (ph)
(402) 476-4489 (fax)
<http://www.gcbaa.org/>

Golf Course Superintendents Association of America (GCSAA)

1421 Research Park Drive
Lawrence, KS 66049
(785) 841-2240 (ph)
(800) 472-7878 (toll free)
<http://www.gcsaa.org>

National Golf Course Owners Association

291 Seven Farms Drive, Charleston, SC 29492
(843) 881-9956 (ph)
(800) 933-4262 (toll free)
(843) 881-9958 (fax)
<http://www.ngcoa.org>

United States Golf Association (USGA)

P.O. Box 708, Far Hills, N.J. 07931
908-234-2300 (ph)
908-781-1736 (fax)
<http://www.usga.org>

The following glossary is adapted with permission from the GCSAA "Turfgrass Terminology" Web site.

annual grasses

Grasses that normally complete their life cycles in one year.

apron

The fairway area close to and in front of the putting green, adjoining the putting green collar. This area is normally mowed at fairway height but sometimes is mowed slightly closer.

bentgrass

Generally speaking, bentgrasses are tolerant of cold weather, extremely fine-bladed and very popular among golfers, especially for greens. Bentgrasses are even in demand in the South, but it is difficult and costly to maintain them in warm climates.

biennial

A term applied to plants that normally complete their life cycles in two years.

biological control

Control of turfgrass pests by the use of living organisms.

blend

A combination of two or more varieties of the same grass species.

blight

A general term used to describe symptoms of plant disease that may include sudden wilting or the death of leaves, flowers, stems or entire plants. The most common blight of golf course turfs is Pythium.

broadleaved

Any of the dicotyledonous plants that grow in a turfgrass stand (e.g., dandelion, plantain, clover, chickweed, or knotweed.)

brushing

The practice of lifting excessive leaf and stem growth off grasses before mowing. Usually accomplished with brushes affixed to mowers ahead of the cutting reel.

calibrate

To determine or mark the graduation of, or to determine and control the amount of material delivered by a sprayer or spreader on a given area or in a given time.

chlorosis

As commonly used, the condition in plants relating to the loss or lack of green color. May be caused by disease activity, albinism or nutritional deficiency.

collar

An area of turf adjoining the putting green that is mowed at an intermediate height between the fairway and the green.

compaction

The reduction in the number and size of airspaces caused by compression, most often the result of traffic. Compaction prevents adequate water and air penetration, and reduces turfgrass root growth.

complete fertilizer

A fertilizer that contains nitrogen, phosphorus and potassium.

contour mowing

To shape the border between the fairway and rough to add interest, direction or strategy to the golf hole.

cool-season grasses

Among the best known are colonial bentgrass, creeping bentgrass, Kentucky bluegrass, perennial ryegrass, fine fescue and tall fescue. They grow best between 55° F and 85° F.

coring

The removal of a core from a turfgrass area with a soil probe or hollow metal tines, usually to provide aeration.

cultivar

A term used to distinguish cultivated varieties of plants from the naturally occurring varieties e.g., Penncross creeping bentgrass.

cultivation

A mechanical procedure such as spiking, grooving or core removal on established turf without destroying its sod characteristics.

cutting height

The distance above the soil line that grasses are clipped.

bench setting - The height at which the bedknife is set above a firm, level surface. This is generally the accepted measure for determining cutting height.

effective cutting height - The actual height at which grasses are cut. It varies from the bench setting, depending on the degree of thatch and flotation of the cutting unit.

damping off

A disease of seeds or young seedlings caused by fungi, usually occurring under wet conditions.

desiccation

Drying up. A type of winter injury that exposed turf areas suffer when subject to high winds and inadequate moisture or snow cover.

dethatching

The procedure of removing an excessive thatch accumulation either mechanically, by practices such as vertical mowing, or biologically, such as by topdressing with soil.

disease

A disturbance in normal functioning and growth, usually caused by pathogenic fungi, bacteria or viruses.

dormant

In a resting, or nonvegetative, state.

drainage

The rapid removal of water by surface contouring (swales or ditches) or the installation of subsurface tile.

erosion

The wearing away of the land by running water, wind or other geological agents.

evapotranspiration

The combination of soil evaporation and transpiration from a plant; total water loss from plant and soil.

facing

The slope or incline of a bunker constructed in the direction of the putting green, intended to create an added obstacle for a player to negotiate.

fairway

No precise definition exists in the Rules of Golf for “fairway.” It is deemed to be an area between the tee and putting green included in the term “through the green.” In terms of maintenance, fairways are those areas of the course that are mowed at heights between 0.5 and 1.25 inches, depending on the grass species and the cultural intensity desired. Fairways normally are about 50 yards wide but vary from about 33 yards to more than 60 yards, depending on the caliber of the golf course and the limitations imposed by architecture or terrain.

fertigation

The application of fertilizer through an irrigation system.

fertilizer

A nutrient applied to plants to assist growth.

foliar fertilizers

Soluble plant nutrients applied to the leaf and capable of being absorbed through leaves.

foot printing

Temporary foot impressions left on a turf because the flaccid leaves of grass plants have insufficient water to spring back.

friable

Easily crumbled in the fingers. Most often used when describing soils.

fumigant

A liquid or solid substance that forms vapors that destroy pathogens, insects, or other pests. Fumigants are usually used in soils or closed structures.

fungicide

A chemical that kills or inhibits the growth of fungi.

fungus

A low form of plant life that, lacking chlorophyll and being incapable of manufacturing its own food, lives off dead or living plant and animal matter.

germination

The beginning of growth in a seed, plant bud or joint.

grain

As applied to putting greens, the tendency for grass leaves to lie down in one direction and interfere with the natural roll of the ball.

ground covers

Plants used to provide a low-maintenance, vegetative cover that is not necessarily turf.

herbaceous

Nonwoody plants.

herbicide

A chemical used to kill weeds or herbaceous growth.

humus

A dark, well-decomposed material formed from decayed vegetable or animal matter in the soil.

hydroseeding

A technique for applying seed, mulch and fertilizer in a water slurry over a seedbed.

infiltrate

To filter into; the penetration of water through soils.

inorganic fertilizer

Plant nutrients derived from mineral rather than organic sources.

insecticide

A chemical used to destroy insects.

internode

The portion of a stem between the nodes or joints.

lip

An abutment of sod raised 3 to 4 inches above the sand level of a bunker. It faces the putting green and prevents a player from putting out.

lime

Materials containing calcium and magnesium used to neutralize soil acidity and to supply calcium and magnesium as plant nutrients. Lime materials include limestone, shell, marl, slag and gypsum.

localized dry spot

A dry area of sod and soil that resists water as normally applied; caused by various factors such as heavy thatch, soil or fungal organisms.

mat

In turf, an undecomposed mass of roots and stems hidden underneath green vegetation. Associated with sponginess or fluffiness in turf.

matting

The process of working topdressing, fertilizers or other materials into a turfgrass area with drag mats.

microenvironment

The area in the immediate vicinity of the turfgrass plant from the surface to the depth of root penetration into the soil.

micronutrient

An element needed in small amounts for turfgrass growth.

mildew

A disease in which the causal fungus forms a coating over the surface of plant parts. The coating, which is a mycelial growth, is usually thin and whitish. There are two types of mildew: downy and powdery.

mulch

A material such as wood chips, straw, netting, or burlap spread over seeded or stolonized areas to protect them from erosion, moisture loss and temperature extremes and to enhance germination and growth.

native grasses

Grasses that are indigenous or that occur naturally in a particular region.

nematicide

A substance used to destroy nematodes.

nematode

A small, round worm, usually microscopic and colorless,

that lives free in moist soil, water or decaying or living organic matter. Parasitic forms puncture plant tissues and live by sucking the juice of the plant.

node

The joint of a grass stem from which leaves and buds arise.

nutrients, plant

The elements taken in by the plant, essential to its growth and function.

organic matter

Decomposed material derived from plant or animal sources. An important component of topsoil often added to topdressing soil mixtures to give added water-holding capacity and exchange capacity to the soil.

organic soil

A general term used in reference to any soil that is at least 20% organic matter.

overseed

To sow seed over an area that is sparsely covered or to plant cool-season grasses into dormant warm-season turfgrass swards for a temporary, green winter cover.

pathogen

An organism causing disease.

peat

Unconsolidated soil material consisting largely of undecomposed or only slightly decomposed organic matter accumulated under conditions of excess moisture.

permeability

A measure of the ease with which air, roots and water penetrate the soil.

perennial grasses

Lasting or continuing from year to year in areas where adapted.

pH

A measure of the acidity or alkalinity of a material or solution. pH ranges from 0 to 14. Values below 7 are increasingly acid; above 7, increasingly alkaline.

phytotoxic

Harmful to plants.

plant growth regulator

A chemical that can slow the growth of turfgrass.

plugging

The vegetative propagation of turfgrass by means of plugs or small sod pieces. A method of establishing vegetatively propagated turfgrasses, and repairing damaged areas.

Poa

The genus of all bluegrasses.

pore space

The space between solid soil particles or aggregates that is normally filled with water, air or grass roots.

postemergence

A term used to refer to herbicide treatment made after weed seedlings have emerged from the soil.

preemergence

A term used to refer to herbicide treatments made before weed seedlings emerge from the soil.

profile, soil

A cross-section of soil that shows the layers or horizons lying above the unweathered parent material.

Pythium blight

A highly destructive turfgrass disease that can totally destroy a turfgrass stand in less than 24 hours. Pythium blight most commonly occurs under conditions of high temperature and humidity.

rebuilding

A term that refers to practices involving complete changes in the total turf area, i.e., the reconstruction of a green, tee, fairway, rough or any other area of the golf course.

renovation

Turf improvement carried out by replanting into existing live and/or dead vegetation.

resiliency

The capability of the turf to spring back when balls, shoes or other objects strike the surface, thus providing a cushioning effect.

rhizome

An underground, root-like stem; underground creeping stem.

saline soils

Soils in which there is a heavy accumulation of salts.

scald

Turf damage occurring under conditions of excessive water, high temperatures and intense light.

scalping

Cutting into or below the crown of the grass plant while mowing. Continued scalping will weaken or kill the turf.

seed bed

An area of soil prepared for seeding.

seedling

A plant grown from seed; usually refers to a young plant.

selective herbicide

One that can be applied to a mixed stand of turfgrass and weeds that will selectively kill certain weeds without injuring the turfgrasses.

soil modification

The alteration of soil characteristics by adding soil amendments such as sand, peat, lime, or other material; commonly used to improve physical and chemical conditions.

soil texture

The coarseness or fineness of the soil. Sand is coarse-textured; clay is fine-textured.

species

An established classification into which similar individuals in the plant or animal kingdom are placed. A species is described as a morphologically distinctive and genetically isolated natural population.

spray drift

The movement of small spray particles away from the target area.

sprigging

The planting of stolons (runners), rhizomes or vegetative segments of plants.

sterilize

To treat soil chemically or by heat to kill disease organisms, weed seeds and insects.

stolons

Creeping stems or runners aboveground that may produce roots and new stems and become independent plants.

striping

A pattern left on turfgrass, usually a fairway or green, using lightweight mowing equipment. Its main purpose is a pleasing appearance. Patterns are the result of light reflected from blades of grass lying in different directions because they have been mowed in different directions.

subsoil

That part of the soil profile below plow depth, usually considered unsatisfactory for plant growth.

surfactant

An agent that reduces the surface tension of liquids on plant materials or in the soil. Wetting agents are common examples.

susceptible

Lacking an inherent ability to resist. Turf may be susceptible to diseases, insect damage or weed encroachment.

synergistic

The action of one chemical upon another causing an accelerated action or a result that neither one alone could produce.

syringing

The light sprinkling of water on turf, usually done during the hot part of the day to prevent wilting. Only enough water is applied to wet the leaves, not the soil.

texture, grass

The width of individual leaves. A narrow-leaved grass, such as creeping bentgrass, is considered fine-textured. A wide-leaved grass, such as some tall fescues, is considered coarse-textured.

thatch

A tightly intermingled layer of dead and decaying roots, stolons, shoots and stems that develops between the green vegetation and soil surface.

tolerance

The ability of a plant to withstand the effects of adverse conditions, chemicals or parasites.

topdressing

A prepared mixture usually containing sand and organic matter used for leveling and smoothing the playing surface. It aids in controlling thatch and in maintaining biological balance. Topdressing is also used to cover stolons or sprigs in vegetative planting.

topsoil

A general term applied to the top natural layer of soil.

toxicity

Quality, state or degree of being toxic; poisonous.

transpiration

The movement of water vapor out of a plant through leaf openings.

variety

In classification, a subdivision of species. Differing from the remainder of the species in one or more recognizable and heritable characteristics.

vegetative propagation

Propagation by means of pieces of vegetation, i.e., sprigs or sod pieces.

verdure

The green, living plant material remaining after mowing.

warm-season grasses

Among the best known are bermudagrass, St. Augustinegrass, zoysiagrass, bahiagrass, carpetgrass and centipedegrass. Bermudagrass is the most popular for greens. Warm-season grasses grow at their optimal rate between 75 F and 95 F.

weeds

Plants out of place; undesirable or unwanted plants.

wettable powder

A dry powdered formulation of a pesticide that is applied as a suspension in water.

winterkill (injury)

The general term applied to injuries of turf from a variety of causes that occur during the winter and become evident in spring.

APPENDIX A: TABLES

Table A-1: Sources of quickly available nitrogen in turfgrass fertilizers

Source	~ Content(%) ^a			Salt Index per Unit ^b	Acidifying Effect ^c	Cold-water Solubility (lbs./gal.)	Comments
	N	P ₂ O ₅	K ₂ O				
Ammonium nitrate	34	0	0	2.99.0 H	62	11	Contains both ammonium ions that are adsorbed by soil colloids and nitrate ions that may be mobile in soils.
Ammonium sulfate	21	0	0	3.25 H	110	5.7	Contains 24% sulfur and has the greatest acidifying effect of the materials listed.
Calcium nitrate	15.5	0	0	4.41	20 Base	6.6	Contains 21% calcium in addition to nitrogen; absorbs moisture very rapidly.
Diammonium Phosphate (DAP)	18	46	0	1.6 M	75	3.4	Provides both nitrogen and phosphorus; very soluble phosphate source.
Monoammonium Phosphate (MAP)	11	48	0	2.4 H	58	1.9	Although less soluble than DAP, MAP has a greater salt index per unit.
Potassium nitrate	13	0	44	5.3 H	26 Base	1.0	May slightly increase soil pH as it rapidly releases nitrogen.
Urea	46	0	0	1.6 M	71	6.2	This highly water-soluble nitrogen source contains the highest nitrogen concentration of any granular fertilizer.

^a To calculate the phosphorus content (percent) of each fertilizer, multiply percent P₂O₅ by 0.44; to calculate the potassium content (percent), multiply percent K₂O by 0.83.

^b Partial salt index expressed as the relative salinity of mineral salts per unit of nutrient compared with sodium nitrate (6.3). High (H) = 2.6 or greater; moderate (M) = 1.0 to 2.5; and low (L) = less than 1.0.

^c Units of CaCO₃ required to neutralize 100 units of fertilizer (by weight).

(Source: California Fertilizer Association, 1985)

Table A-2: Sources of slowly available nitrogen and nitrification inhibitors used in turfgrass fertilizers

Source	Formula	~ Content			(%)Salt Index per Unita	Cold-water Solubility ^b	Comments
		N	P ₂ O ₅	K ₂ O			
IBDU (isobutylidene diurea)	[CO(NH ₂) ₂] ₂ C ₄ H ₈	31	0	0	0.2 L	SS	Two urea molecules are linked by a carbon group, resulting in a source of nitrogen dependent on hydrolysis for release.
Milorganite	organic-N complex	6	2	0	0.7 L	SS	Nitrogen in this activated sewage sludge is released by microbial activity.
NBPT	N-butyl-thiophosphoric triamide						A urease inhibitor used on urea granules and urea-ammonium nitrate (UAN) solutions. Slows the volatile loss of nitrogen from the surface application of urea.
Polymer/ Resin-coated Urea	CO(NH ₂) ₂ + polymer or resin	40-44	0	0		SR	Nitrogen release depends on diffusion coating thickness and temperature and, to a much lesser degree, Hydrolysis.
SCU (sulfur-coated urea)	CO(NH ₂) ₂ + sulfur	35-39	0	0	0.7 L	SR	Permeable sulfur (molten) coating allows water to slowly move through the barrier dissolving the enclosed urea; nitrogen release depends on coating thickness and hydrolysis.
Slow-release Nitrogen Solutions							
Methylene-urea	[CO(NH ₂)CH ₂] _n CO(NH ₂) ₂	28	0	0			Solution short chain methylene urea that can be used in fertigation.
Triazone	C ₆ H ₃ O ₃ N ₃ + CO(NH ₂) ₂	28	0	0			Solution of ring structure nitrogen compound. Nitrogen release by microbial action
UF (urea formaldehyde or methylene ureas)	[CO(NH ₂)CH ₂] _n CO(NH ₂) ₂	38-40	0	0	0.3L	SS	Nitrogen is released from these various-sized, chainlike polymers of urea as a result of soil microorganism activity.

^a Partial salt index expressed as the relative salinity of mineral salts per unit of nutrient compared with sodium nitrate (6.3). High (H) = 2.6 or greater; moderate (M) = 1.0 to 2.5; and low (L) = less than 1.0.

^b SS = slowly soluble; SR = slow release.

(Source: Information combined from Havlin et al., 2004; and Sartain and Kruse, 2001.)

Table A-3: Sources of phosphorus and potassium in turfgrass fertilizers

Source	Formula	~ Content (%) ^a			Salt Index per Unit ^b	Acid Acid Effect ^c	Cold-Water Solubility (lbs./gal.)	Comments
		N	P ₂ O ₅	K ₂ O				
Diammonium phosphate								See Table A-1.
Monoammonium phosphate								See Table A-1.
Muriate of potash	KCl	0	0	60	1.9 M	0	2.8	Very common source of potassium.
Potassium magnesium sulfate	K ₂ SO ₄ .2 (MgSO ₄)	0	0	22				Releases nutrients rapidly; also contains about 18% magnesium and 23% sulfur.
Potassium nitrate								See Table A-1.
Sulfate of potash	K ₂ SO ₄	0	0	50	0.9 L	0	0.9	Often used in place of muriate of potash, sulfate of potash has a low salt index and contains 18% sulfur.
Superphosphate	Ca _n (H _n PO ₄) ₂ + CaSO ₄	0	20	0	0.4 L	0	0.2	Decreases soil acidity; contains calcium and sulfur in the gypsum (CaSO ₄) component that acts as a drying (dehydrating) agent
Treble superphosphate	Ca _n (H _n PO ₄) ₂ H ₂ O	0	44	0	0.2 L	0	0.3	Concentrated source of phosphorus

^a To calculate the phosphorus content (percent) of each fertilizer, multiply percent P₂O₅ by 0.44; to calculate the potassium content (percent), multiply percent K₂O by 0.83.

^b Expressed as the relative salinity of mineral salts per unit of nutrient compared with sodium nitrate (6.3). High (H) = 2.6 or greater; moderate (M) = 1.0 to 2.5; and low (L) = less than 1.0.

^c Units of CaCO₃ required to neutralize 100 units of fertilizer (by weight).

(Table from Broder and Samples, 2002)

Table A-4: Pesticide Leaching Potential Index

HERBICIDES			
Common Name	Trade Name	Rate*	Index**
Fenoxaprop	Acclaim	0.18	0
Prodiamine	Barricade	0.75	1
Diclofop	Illoxan	1.50	10
Pendimethalin	Pre-M	3.00	18
Dithiopyr	Dimension	0.50	20
Metolachlor	Pennant	4.00	22
Sethoxydim	Vantage	0.28	26
MSMA	MSMA	3.00	27
Trifluralin	Treflan	3.00	32
Pronamide	Kerb	1.50	34
Glyphosate	Roundup	4.00	36
Oxadiazon	Ronstar	3.00	36
Benefin	Balan	3.00	36
Bentazon	Basagran	2.00	36
DCPA	Dacthal	10.50	38
Ethofumasate	Prograss	1.00	41
2,4-D	2,4-D	0.75	41
DSMA	Methar	5.00	41
Metsulfuron	DMC	0.10	42
Isoxaben	Gallery	1.00	44
Bensulide	Betasan	10.00	44
Oryzalin	Surflan	3.00	44
Napropamide	Devrinol	3.00	46
Asulam	Asulox	2.00	47
Metribuzin	Sencor	0.50	48
Atrazine	Aatrex	2.00	52
Triclopyr	Turflon	2.00	53
Simazine	Princep	2.00	54
Dicamba	Banvel	0.50	54
Imazaquin	Image	0.50	58
Mecoprop	MCP	1.75	61
Siduron	Tupersan	10.00	64

FUNGICIDES			
Common Name	Trade Name	Rate*	Index**
Vinclozolin	Curlan	2.70	20
Fosetyl-AI	Aliette	17.40	25

Thiophanate methyl	Clearys 3336	2.70	31
Anilazine	Dyrene	5.40	31
Iprodione	Chipco	2.50	33
Mancozeb	Fore	8.70	36
Triadimefon	Bayleton	1.30	43
Propiconazole	Banner	1.50	45
Chlorothalonil	Daconil	19.60	46
Metalaxyl	Subdue	1.36	50
Propamocarb	Banol	7.24	51
Fenarimol	Rubigan	2.00	51
Chloroneb	Terraneb	7.00	51
Benomyl	Tersan	2.70	55
Maneb	Manzate	13.00	56
Etridiazole	Koban	6.50	65

INSECTICIDES			
Common Name	Trade Name	Rate*	Index**
Cyfluthrin	Tempo	0.09	0
Permethrin	Astro	0.90	12
Fenoxycarb	Award	1.50	19
Chlorpyrifos	Dursban	1.00	19
Fenamiphos	Nemacur	10.00	36
Acephate	Orthene	3.00	36
Fonofos	Crusade	3.90	37
Bendiocarb	Turcam	4.10	38
Carbaryl	Sevin	2.10	39
Diazinon	Diazinon	4.30	41
Isofenphos	Oftanol	1.90	44
Isazofos	Triumph	2.00	44
Methomyl	Lannate	1.90	51
Trichlorfon	Proxol	8.16	52
Ethoprop	Mocap	4.90	55
Propoxur	Baygon	8.10	76

(Courtesy North Carolina State University Extension Service)

* Maximum recommended application rate (lb A.I./acre).

** Pesticide Leaching Potential Index (0-100), where 0 = very low leaching potential and 100 = very high leaching potential.

APPENDIX B: SPILL REPORTING REQUIREMENTS

Public Law 96-510 and Public Law 92-5000 (CERCLA) require immediate notification of the appropriate agency of the United States Government of a discharge of oil or hazardous substances. *Any such person who fails to notify immediately such agency of such discharge shall, upon conviction, be fined not more than \$10,000 or imprisoned for not more than one year, or both.*

Pursuant to Chapters 376 and 403, Florida Statutes:

—Any owner or operator of a facility who has knowledge of any release of a hazardous substance from a facility in a quantity equal to or exceeding the reportable quantity (see MSDS sheet) in a 24 hour period shall immediately notify the **State Warning Point**.

—The owner or operator having a discharge of petroleum products exceeding 25 gallons on a pervious surface (or any amount in a water body) must report such discharge to the Department of Environmental Protection or the **State Warning Point**.

The penalty is not in reporting a spill; it is in failing to report a spill.

REPORT THE FOLLOWING INFORMATION:

1. Name, address, and telephone number of person reporting,

2. Name, address, and telephone number of person responsible for the discharge or release, if known,
3. Date and time of the discharge or release,
4. Type or name of substance discharged or released,
5. Estimated amount of the discharge or release,
6. Location or address of discharge or release,
7. Source and cause of the discharge or release,
8. Size and characteristics of area affected by the discharge or release,
9. Containment and cleanup actions taken to date, and
10. Other persons or agencies contacted.

In addition to state and federal spill-reporting requirements, local governments may also impose their own requirements. For example, Palm Beach County includes the following language in its wellfield protection ordinance: *“Reporting of Spills: Any spill of a Regulated Substance in excess of the non-aggregate quantity thresholds identified in the definition of “Regulated Substance” shall be reported by telephone to PBCHD and the designated public utility within 1 hour, and to ERM within 24 hours of discovery of the spill. Clean-up shall commence immediately upon discovery of the spill. A full written report including the steps taken to contain and clean up the spill shall be submitted to ERM within 15 days of discovery of the spill.”*

Superintendents must be aware of all local ordinances and permit requirements.

APPENDIX C: IMPORTANT TELEPHONE NUMBERS

EMERGENCY REPORTING

For Ambulance, Fire, or Police,
DIAL 911

State Warning Point
(Florida Department of Community Affairs, Division of Emergency Management)
24 hrs. toll-free • 1-800-320-0519
or (850) 413-9911

National Response Center
24 hrs. toll-free • 1-800-424-8802

(Federal law requires that anyone who releases into the environment a reportable quantity of a hazardous substance [including oil when water is or may be affected] or a material identified as a marine pollutant, must immediately notify the NRC).

HELP LINE NUMBERS

(for chemical hazard information and regulatory questions)

CHEMTREC HOT LINE (Emergency only)
24 hrs. toll-free • 1-800-424-9300

CERCLA / RCRA help line
Toll-free • 1-800-424-9346

NON-EMERGENCY NUMBERS

State Emergency Response Commission
(NOT a 24-hr. number) 1-800-635-7179
(This is for follow-up reporting for state spill-reporting requirements. In an emergency, call the State Warning Point. If federal reporting is required, also call the National Response Center.)

Florida Department of Agriculture and Consumer Services
Bureau of Compliance Monitoring (850) 617-7870
Bureau of Pesticides (850) 617-7917

Florida Department of Environmental Protection
FDEP Nonpoint Source Management Section (Tallahassee) (850) 245-7508

FDEP Stormwater/NPDES Section (Tallahassee) (850) 245-7522

FDEP Hazardous Waste Management Section (Tallahassee) (850) 245-8707

FDEP District offices:
Northwest (Pensacola) (850) 595-8300

Northeast (Jacksonville) (904) 448-4300

Central (Orlando) (407) 894-7555

Southeast (West Palm Beach) (561) 681-6800

Southwest (Tampa) (813) 744-6100

South (Ft. Myers) (941) 332-6975

Water Management Districts

	Local phone	Toll-free
Northwest Florida (Tallahassee)	(850) 539-5999	

Suwannee River (Live Oak)	(904) 362-1001	1-800-226-1066
---------------------------	----------------	----------------

St. John's River (Palatka)	(904) 329-4500	1-800-451-7106
----------------------------	----------------	----------------

Southwest Florida (Brooksville)	(352) 796-7211	1-800-423-1476
---------------------------------	----------------	----------------

South Florida (West Palm Beach)	(561) 686-8800	1-800-432-2045
---------------------------------	----------------	----------------

APPENDIX D: DETAILS REQUIRED FOR AN ADEQUATE MANAGEMENT PLAN FOR A GOLF COURSES¹⁴

IN GENERAL

The purpose of the Management Plan (Plan) is to detail how the golf course design, construction, and maintenance will protect natural resources and the environment, focusing on the areas of water quality (including monitoring program), water conservation, IPM, waste management, and wildlife habitat management. As a general matter, the level of detail in the Plan must be sufficient to identify scientifically based environmental approaches to be used in design, construction, and management. The Plan must integrate prevention, control, and detection in golf course design, golf course cultural practices, best management practices, IPM, environmental monitoring, and maintenance facility planning and operations.

ESTABLISH THE ENVIRONMENTAL CONTEXT

The Plan should be developed based on existing site conditions and resources to protect natural resources. The first step is to examine the golf course property in terms of natural resources; the second step is to identify environmentally and ecologically sensitive areas at the site; and the third step is to identify management practices that are appropriate to ensure protection of these sensitive areas.

To make the Plan understandable on a self-contained basis for readers, both regulatory reviewers and the design, construction, and management personnel for the golf course, it must provide details about the site and its resources that establish the environmental context.

Site Description and Evaluation

Examine the site relative to environmental characteristics, including location of surface waters and proximity of environmentally sensitive areas to golf hole locations. Include the following:

- Identify the physical setting.
- Discuss topography and how it affects protection of resources.
- Identify surface water resources (lakes, ponds, streams, wetlands, and other types, natural and manmade). Discuss how they are susceptible to adverse construction and management impacts from golf course development. Provide data on existing water quality.
- Identify groundwater resources. Discuss how they are susceptible to adverse construction and management

impacts from golf course development. Provide data on existing water quality.

- Climate: discuss temperature ranges, frost dates, rainfall.
- Identify areas that require special protection and include areas that exhibit any of the following characteristics: habitat that supports a rare, threatened, or endangered species; area particularly valuable because of its maturity, density, or diversity of plant or animal species; highly productive habitat; area of special commercial, economic, or recreational value.

Drawings

At a minimum, this part of the Plan should include maps or drawings with the following information:

- Map showing the golf course.
- Topographic map of the site.
- Vegetation and habitat map of the site.
- Soils map of the site.
- Surface water map of the site.
- Groundwater map of the site.

WATER QUALITY MANAGEMENT

This part of the Plan should include identification of best management practices (BMPs), management zones, fertilizers, and pesticides that can be used at the golf course. BMP are those drainage facilities or cultural approaches to golf course management that serve to prevent the movement of sediments, nutrients, or pesticides into water resources and other environmentally sensitive areas.

This part of the Plan should clearly identify preventive and structural controls and show all construction, stormwater, management and other types of BMPs on site plans or drawings. BMPs must be detailed for each green, tee, fairway, out-of-play area, and other area of a golf course. A BMP “train” approach must be followed. The Plan must identify the types of BMPs and the effectiveness of each. It should determine the effectiveness of each BMP through a modeling exercise that uses at least the SIMPLE model for evaluation. Results of the modeling must be shown in a table that identifies the variable

¹⁴ Copyright 2005-06, Audubon International. Used with permission.

of interest, watershed size, pollutant reduction, and other relevant information. All maintenance practices, short or long term, potentially affecting water resource quality must be identified and evaluated for their impacts.

Surface Water and Golf Course Construction and Grow-in

Describe in detail separate plans and measures (with appropriate maps or drawings) to protect surface waters during: (a) construction and (b) grow-in.

Golf Course and Post Construction Effects

Describe in detail plans and measures (with appropriate maps or drawings) to control all runoff from impervious surfaces by filtering through areas which have a vegetative cover.

Subsurface Drainage

Describe in detail all plans and measures (with appropriate maps or drawings) to ensure that all subsurface drainage is directed into buffer areas, or other vegetative filters, and not directly into water. The entire drainage system for the golf course must be mapped.

Wetlands and littoral areas

An active wetland/littoral area management program must be developed and implemented. It must include: 1) regular periodic monitoring, at least four times per year, 2) maintenance of vegetative conditions, 3) restoration or repair of damaged areas, and 4) record keeping.

Management Zones

This part of the Plan should also establish and identify (with appropriate maps or drawings) the following management zones on the golf course property:

No Spray Zones. No spray zones should be established around each water body (e.g., ponds, wetlands) extending to a minimum of 25 feet landward from normal water elevation. No pesticides should be used in these areas, and only organic fertilizers should be used in them.

Limited Spray Zones. Limited spray zones should be established around each water body, beginning from the outer edge of the No Spray Zone (at least 25 feet landward from normal water elevation) and extending to at least 50 feet landward from normal water elevation. A limited set of pesticides may be used in this zone, and only organic fertilizers or “spoon feeding” may be used. Additionally, when wind speed is greater than 10 mph, a shroud should be used on spray equipment to avoid drift.

Bridge Construction Zones. Cart and foot bridges that cross environmentally sensitive areas must be built from the deck with only pilings disturbing the sensitive areas.

WATER QUALITY MONITORING PROGRAM

The Water Quality Monitoring Program must include monitoring of surface water, ground water, and pond sediments. It should be implemented in three phases: Background, Construction, and Long Term Management. For each phase, identify the following:

- Specific Sample Locations in surface water, sediments, and groundwater.
- Sample Frequency - at least quarterly.
- Sample Variables, including at least dissolved oxygen, pH, specific conductance, total phosphorus, total nitrogen, nitrate nitrogen, chloride, total dissolved solids, turbidity, and pesticides that are identified from the risk assessment. All pesticides whose risk ratio is greater than one-twentieth the point at which risk is presumed to be more than negligible must be analyzed.

Field Methods

Provide variables, container type, preservation and holding times for water samples; methods for collection of samples; examples of field data sheets, showing that they are suitable for recording the required information.

Laboratory

Identify the laboratory to be used for sample analysis. {The laboratory must have and retain NELAP certification by the State of Florida Department of Health to conduct chemical analyses on surface water and drinking water. (See Rule 62-160, F.A.C. – Quality Assurance Rules at <http://www.dep.state.fl.us/labs/qa/index.htm>)}

Data Storage and Reporting

Provide the details of specific data storage, analysis, and reporting plan that will be implemented.

Data Analysis

Describe specific methods of data analysis, with data compared to appropriate background concentrations.

Criteria for Management Response

Describe in detail: management response criteria for both non-pesticide analytes and pesticides; concentrations that will elicit responses; measures to be taken if concentrations are exceeded.

Field Quality Control and General Water and Sediment Sampling Considerations

Provide a detailed description of the field quality assurance program; the program must be sufficient to ensure prevention of contamination and must include a field quality control plan.

Drawings and Tables

Drawings and tables for the Water Quality Monitoring section of the Plan must include at least:

- A map or drawing showing locations of all surface water and sediment sample stations
- A table of variables to be analyzed (x) in surface waters and sediments
- A table of variables, container types, preservation, and holding times for water samples
- A table of variables, container type, preservation, and holding times for sediment samples
- A table of response thresholds for each sampling variable
- A table of quality control samples for the golf course.

WATER CONSERVATION

To minimize waste and maximize efficiency in use of water for irrigation, a system that provides the correct amount of water at the proper time and only in the proper places is important. Use of the proper turfgrass is also critical for this purpose, as covered in Integrated Pest Management.

Irrigation Water Management Information

Calculations: calculate the amount of irrigation required for the golf course. Calculations must show that irrigation will not result in runoff.

Weather Station: a weather station must be on site. Provide a detailed description of its instrumentation

Irrigation System: Describe in detail the computer-controlled system that will be used to manage irrigation. Map the irrigation _heads_ to show the areas that each head will cover with its spray pattern. Irrigation heads must not put water in natural areas, lakes, or other natural resources or on paved surfaces.

Drawings and tables

Drawings and tables for the Water Conservation section of the Plan must include at least:

- A map or drawing showing the location of all irrigation heads and the water distribution pattern of each head.
- A table of calculated putting green and tee irrigation requirements based on long-term climatic records.
- A table of calculated fairway irrigation requirements based on long-term climatic records.

INTEGRATED PEST MANAGEMENT

The objective of the Integrated Pest Management (IPM) program is to use information about turfgrass pest problems and environmental conditions that may precipitate

those problems to establish a management system that integrates turfgrass cultural practices and pest control measures to prevent or control unacceptable levels of pest damage and minimize application of pesticides. A high quality IPM program is essential to minimize the potential risk of contamination of water resources and to conserve water resources.

Agronomic Considerations and Requirements

Soil Mixes and Modifications:

Putting Greens. Provide detailed drawings of putting greens, including showing drainage system. Greens should be constructed based on a modification of the United States Golf Association method as detailed in _USGA Recommendations for a Method of Putting Green Construction_ (USGA Green Section Record, 1993); or at www.usga.org/green. Include detailed information on soil mixes and amendments to be used.

Tees. Provide detailed drawings of tees, including showing any drainage system. Tees should be constructed in a manner similar to the putting greens, but need not include subsurface drains. Include detailed information on soil mixes and amendments to be used.

Fairways, Roughs, and Driving Range. Identify locations and numbers of soil samples that will be obtained. Obtain soil samples from as many locations as necessary and have them analyzed to provide a proper analytical basis for pre-planting fertilization decisions that will minimize fertilization requirements. Include detailed information on soil mixes and amendments to be used.

Turfgrass Selection. Turfgrasses used must be demonstrated to be scientifically selected to be proper for the eco-region of the golf course, to minimize irrigation requirements, fertilization needs, and pesticide use:

Greens. Identify turfgrass to be used on greens and provide a detailed explanation of suitability in light of the requirements above.

Tees, Fairways, and Roughs. Identify turfgrass to be used on tees, fairways, and roughs and provide a detailed explanation of suitability in light of the requirements above.

Construction Erosion Control and Water

Conservation. Identify techniques to reduce soil erosion, and discuss these practices in detail. Identify techniques to reduce water use, and discuss these practices in detail.

Basic Growing-in Program:

Watering: identify techniques to reduce water use, and discuss these practices in detail.

Fertilizing: Identify techniques to reduce fertilizer loss, and discuss these practices in detail.

Mowing: identify mowing heights separately for putting greens, tees, and fairways.

Rolling: provide a description of the rolling program.

Tee and putting surfaces development: provide a description of the cultural practices to be used.

Pest control: provide a description of the program for pest inspections during the growing-in period.

Golf Course Cultural Practices (Post-Grow-in)

Mowing. Identify mowing practices and heights separately for putting greens, tees, and fairways.

Nutrient Management:

General Provisions. Describe in detail the step-by-step approach to nutrient management to be used, including management measures to minimize or eliminate any threat to ground or surface water from fertilizers. Identify types of fertilizers to be used.

Basic Fertilizer Program. Identify in tables for greens, tees, fairways, and roughs: (1) each type of fertilizer to be used, (2) the recommended amounts for fertilizers; and (3) the timings of fertilizer applications. Show information for nitrogen, phosphorus, and potassium.

Cultivation. Describe in detail the management programs for turf. Include spiking, vertical mowing, aerifying, topdressing, and rolling.

Basic Annual Maintenance Guide for the Golf Course

Provide tables identifying basic annual maintenance guides for the golf course. Include separate tables for greens, tees, fairways and roughs. Include activity and when it would routinely be completed. Include the following at a minimum:

- Soil Analysis.
- Calibration of Equipment.
- Mowing.
- Fertilizing.
- Irrigation Program.

- Spiking.
- Vertical Mowing.
- Aerifying.
- Topdressing.
- Liming.
- Wetting Agent Applications.
- Raking and Edging Bunkers.
- Weed Control.
- Insect Control.
- Disease Control.
- Nematode Control.

Pesticide Selection and Risk Assessment

Select pesticides for use at the golf course using U.S. Environmental Protection Agency (EPA) established procedures for assessing the risk of pesticide use to human health and the environment. Use the US EPA approved screening models for pesticides (GEENEC and SCI-GROW). Provide a spreadsheet of all of the input data. Provide a spreadsheet of all the output data. Evaluate the results based on Acute Aquatic Toxicity, Chronic Aquatic Toxicity, and Human Health. Use Environmental Impact Quotients (EIQ) to rank pesticides for use and show the EIQs in a table. Identify in a table, all of the restrictions for use.

Specific Local Problems

Disease Management. Identify and discuss in detail anticipated diseases in terms of conditions in the region of the site which favor their development, what measures can be taken to reduce the potential, and management and control measures, whether cultural, biological, or chemical. List each disease and describe and prioritize management strategies to prevent or control the disease, including any pesticides and references to results of the risk assessment. Provide thresholds for all control measures.

Insect and Nematode Control. Identify and discuss in detail anticipated insects in terms of conditions in the region of the site which favor development, what measures can be taken to reduce the potential, and management and control measures, whether cultural, biological, or chemical. List each insect and describe and prioritize management strategies to prevent or control the insect, including any pesticides and references to results of the risk assessment. Provide thresholds for all control measures.

Turf Weed Control. Identify and discuss in detail anticipated weeds in terms of conditions in the region of the site which favor their development, what measures can be taken to reduce the potential, and management and control measures, whether cultural, biological, or chemical.. List each weed and describe and prioritize management strategies to prevent or control the weed, including any pesticides and references to the results of the risk assessment. Provide thresholds for all control measures.

Lake and Pond Weed Management. Identify and discuss in detail anticipated lake and pond weeds in terms of conditions in the region of the site which favor their development, what measures can be taken to reduce the potential and management and control measures, whether cultural, biological, or chemical. List each weed and describe and prioritize management strategies that can prevent or control the weed, with emphasis on particular problems that can arise with use in water bodies. Include the potential aquatic herbicides and the effective concentrations for control, the LC50 for use, and calculations to assess potential damage to the water body. Provide thresholds for all control measures.

Scouting and Monitoring Program

Describe in detail a scouting and monitoring program for identifying developing problems with diseases, insects and nematodes, turf weeds, and pond weeds. The scouting and monitoring program should be detailed by day, week, month, and year and by greens, tees, fairways, roughs, water bodies, wetlands, and other out of play areas. Identify the specific information that will be collected. Include record keeping requirements and copies of forms to be used for record-keeping purposes.

Pesticide Safety Plan

Provide a detailed plan explaining the storage, handling, disposal, and record-keeping practices for pesticides to be used at the golf course. Include forms to be used and a detailed spill prevention and response plan that includes prevention measures, containment measures, and training programs and activities.

Personnel Managing the Program

Provide descriptions of the duties and responsibilities of positions at the golf course of personnel who will be responsible for activities that affect IPM activities. Include minimum qualifications for each position. Include at least superintendent, assistant superintendent, irrigation technician, pesticide technician, and mechanic.

Drawings and Tables

To the extent not otherwise provided in response to items above for the IPM portion of the Plan, include the following figures and tables:

Figures:

- Integrated Pest Management decision flow chart.
- Drawings showing locations of particular areas with anticipated pest problems and identifying the related environmental conditions and particular anticipated problems.

Tables:

- Mowing heights for greens, tees, fairways, roughs by season
- Fertilizer applications on greens and tees
- Fertilizer schedule for greens and tees
- Fertilizer applications on fairways and roughs
- Fertilizer schedule for fairways and roughs
- Basic annual maintenance guide
- Results of the modeling exercises for pesticide selection
- Restrictions for use of pesticides
- Thresholds for instituting management for turfgrass diseases
- Fungicides for control of specific turfgrass diseases
- Thresholds for instituting management for insect control
- Insecticides for control of specific turfgrass insects
- Thresholds for instituting management for nematicide control
- Herbicides for control of specific turfgrass weeds
- Thresholds for instituting management for turfgrass weed control
- Standard aquatic nuisance plant control methods

MAINTENANCE FACILITIES

The maintenance facilities (MF) must incorporate Best Management Practices to minimize the potential for contamination of water resources. The pesticide mixing and storage facility, the wash pad, and the fuel center are focal points.

Pesticide Mixing and Storage Facility

Provide a description, with plans and drawings, for a pesticide mixing and storage facility that will protect nearby water resources from pesticides. The facility must be self-contained and designed and built so that no free liquid leaves the facility but is contained and collected for treat-

ment. Mixing and loading should be done in the pesticide storage building near the center area with downward-sloping concrete to provide containment for any inadvertent spills. A sump should be located at the base of the sloped area, thus facilitating clean-up of spills or overflow. A similar containment area should be included for washing down pesticide application equipment (or the mixing and loading area should be designed to accommodate that use, also.) A system of rinse water tanks should be included to store excess water from the filling or rinsing of sprayers. Storage areas should be arranged so that liquid pesticides are stored separately from or below dry pesticides and have berms or “lips” around areas where liquid pesticides are stored.

Wash Pad

Provide a description, with plans and drawings, for a wash pad where washing of equipment other than pesticide application equipment will take place. The wash pad must be constructed of concrete, have a roof over it, be sealed, and slope downward to a central collection point, where grass clippings and sediments are can be collected and separated out. Include plans for treating and cleaning used water for recycling or explain where it will be discharged and how it will be cleaned and treated prior to discharge.

Fuel Island

Provide a description, with plans and drawings, for the fuel island. The fuel island should include the following protective features:

- Double walled, above ground tanks and pumps.
- A roof to minimize chances for contamination from rainwater and evaporative effects of higher temperatures caused by sunlight on fuel tanks.
- A sealed concrete pad with a berm or other measures for containment and collection of fuel spills for treatment. Include plans for collecting and treating spills.
- Lighting around and beneath the roof to allow for operation during periods of darkness or low light.
- Lightning protection on the fuel island roof.

WASTE MANAGEMENT

Provide a waste management plan that:

1. Describes measures to be taken to reduce, reuse, and recycle materials in the planning, construction, and management of the golf course. Include product use considerations, product manufacturing considerations, raw materials considerations, and disposal and reuse considerations.
2. Describes measures to be taken to minimize waste of

energy and energy resources. Include steps to conserve energy and maximize efficient use of energy in lighting, buildings, HVAC, equipment and machinery, motors and vehicles.

WILDLIFE HABITAT MANAGEMENT

Site Overview

Provide a detailed description, with maps and drawings, of the site and its vicinity, placing the site in a regional context, including its eco-region and watersheds.

- Identify the natural vegetation “zone” for the site [the latter is available from the Landscape Restoration Handbook, Harker, et al., published by Lewis Publishers, or other similar reference materials]. Identify all habitats and existing vegetation communities on the site. Of those habitats and species (wetlands, stream corridors, listed species, etc.), identify all that are endangered, threatened, or otherwise mandated by any local, state, or federal agency for protection (including critical habitat for protected wildlife). Identify all other existing habitat patches, terrestrial and aquatic flora, exotic and invasive plants, and plants native to the site’s eco-region.
- Identify existing wildlife (avian, terrestrial, and aquatic) on the site. Identify all of those that are endangered, threatened, or otherwise mandated by any local, state, or federal agency for protection. Identify any exotic, non-native species of wildlife on site.
- Identify all habitat centers, as well as corridors that connect the habitat centers, including those on land adjacent to the site. Identify all water sources for wildlife and particularly significant sources of food or shelter for particular species of wildlife.

Exotic and Invasive Species Removal and Replacement

Provide a plan for removal or control of exotic and invasive species of plants and animals; and for use of native species in plantings on the golf course, including both naturalized areas and actively managed portions.

Habitat Protection and Restoration Measures

Provide a habitat protection and restoration plan for the site using government mandated protection areas, coupled with identified conservation/restoration zones and the creation of connections or wildlife corridors to maximize habitat that is naturally occurring and native to the eco-region of the site. As part of this plan, identify key habitat and species that will be protected through design measures and in construction and management of the golf course. Explain in detail the measures that will be taken to protect those habitats and species and to minimize or mitigate impacts on them. Include explanations of how habitat corridors will be maintained or created to ensure access of these wildlife species to water, food, and

shelter. In preparing this plan, address both aquatic habitat (e.g., ponds, streams, wetlands) and terrestrial habitat. Pay special attention to areas where the managed golf course meets the aquatic environment. In those areas, provide for both vertical and horizontal habitat and design course water features both to maximize wildlife value and also to assure that chemical products used on the course do not cause environmental impact to water and wildlife. Include maps and drawings to illustrate the actions described in this part of the wildlife habitat management plan.

Wildlife and Habitat Management Plan

Provide a wildlife and habitat management plan to maximize biological diversity for species of wildlife during various times of the year. (e.g., provide nesting opportunities for breeding birds, but also provide food, water, and shelter for birds that may be found on site only in non-breeding seasons or just during migration). In preparing this plan, address both aquatic habitat and terrestrial habitat. Wildlife planning should include not only birds, but also mammals, reptiles and amphibians, native pollinators, fish, and so forth. Include maps and drawings to illustrate the actions described in this part of the wildlife habitat management plan.

Monitoring Program

Describe in detail a wildlife and habitat monitoring program for the site. Identify the locations, types of habitat and species, number of sample transects, and data analysis methods. Include maps and drawings to illustrate the actions described in this part of the wildlife habitat management plan.

CONSTRUCTION MANAGEMENT

Prepare a Construction Management Plan to guide managers, contractors, and other personnel during clearing and construction of the golf course. The plan should make sure that the following matters are identified and discussed and that written protocols are in place prior to construction. Names and phone numbers for responsible contact persons must be identified on the plans. This plan must be provided to developer and contractor staff before work begins and be compared to post-construction as-built plans to determine that it was followed.

1. Clearly identify all jurisdictional limits (shown on a plan with details).
2. Define protocols and locations for clearing vegetation on a site plan (shown on a plan with details).
3. Clearing should be iterative (shown on a plan with details).
4. Identify clearing lines with uniform color coding (shown on a plan with details).

5. Preserve specimen trees (shown on a plan with details).
6. Protect specimen trees (shown on a plan with details).
7. Maintain or restore edge conditions of preservation areas within and adjacent to cleared areas (shown on a plan with details).
8. Preserve key wildlife habitat within the ecosystem (shown on a plan with details).
9. Identify and follow haul routes at all times (shown on a plan with details).
10. Prepare and implement an erosion control plan (shown on a plan with details).
11. Identify areas for soil storage, burn and rubbish piles, and other types of waste or recycling and reuse materials management areas (shown on a plan with details).
12. Prohibit littering and require disposal of garbage and trash only in identified areas.
13. Prevent littering by requiring deposit of wastes for (shown on a plan with details).
14. Do not wash out concrete equipment in drainage ditches or storm drains (identify where washing will occur).
15. Report and clean up any hazardous material spills (shown on a plan with details as to how this will be handled).
16. Develop and conduct an education program for construction workers to communicate the requirements (prepare handouts and provide evidence that this has been accomplished—stickers on hardhats, for example).
17. Direct surface and subsurface drainage from greens over vegetative buffers, through vegetative swales, or into sumps and filtering devices before discharging to water (shown on a plan with details).
18. Route drainage from fairways away from direct input to surface waters (shown on a plan with details).
19. Clearing for cart paths should follow the guidelines for clearing of the golf course (shown on a plan with details).
20. Establish a nursery on the site for plantings (shown on a plan with details).

APPENDICIES

Analysis of Pesticides for Use at the Golf Course

Provide an appendix with the analysis of pesticides for use on the golf course. The analysis must include the following tables:

- The Input Variables for the Tier 1 Modeling Used to Select Pesticides
- Results of the Tier 1 Modeling to Evaluate Pesticides for Use

- Environmental Impact Quotients for Pesticides That Were Evaluated

Hazardous Materials Communication Program

Provide a detailed program for communication of information to staff on proper handling, storage, use, and disposal of hazardous materials.

Summary of Studies on Water Quality and Nutrients and Pesticides

Identify and summarize scientific water quality studies for the site water bodies.

APPENDIX E: GOLF COURSE BEST MANAGEMENT PRACTICE CHECKLIST

This checklist is intended to help the superintendent review operations at the course, determine where improvements can be made, and show the progress being made. It should be updated annually and then reviewed with the management team and greens committee.

No governmental agency or municipality can, without major changes to Florida law, require adherence to this checklist as written. It is meant to be comprehensive, and as such to help the golf course achieve a level of environmental stewardship and management greater than the minimums required by law. Conversely, any BMP checklist to be adopted by rule or ordinance must be nar-

rowly written and limited to the scope of the regulating agency's authority under the enabling statute, as well as being publicly noticed per Chapter 120, F.S. For example, while FDEP could, through the rule adoption process, adopt a BMP checklist addressing water pollution, it does not have the legal authority to address pesticide use or fire safety. Still, the practices listed are good ideas. (FDEP can, however, take action after pollution has occurred due to a spill or a fire, for instance.)

Please use the checklist on the following pages in the spirit in which it was written, and may your golf course always be green.

Florida Golf Course Best Management Practice Checklist					
ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
	<i>General Management Practices</i>				
1	Do you have a site-specific golf course natural resource management plan?				
2	Has a site characterization been completed for the following: location, topography, soils, geology, surface waters, ground water, vegetation, and wildlife habitat and populations?				
3	Have all environmentally sensitive areas been identified and mapped?				
4	Have all special management zone (SMZ) areas been identified and mapped?				
5	Have all SMZs been implemented?				
6	Have all drainage patterns and features been mapped along with associated buffers and SMZs?				
7	Are maps displayed in areas where all maintenance employees will be familiar with them and the BMP/SMZ procedures to be followed?				
8	Do all maintenance workers receive BMP training on a regular basis, in addition to or alternating with safety training?				
9	Are the individuals responsible for environmental management, safety and training, and emergency response clearly identified?				
10	Have you assigned a designated spokesperson for media inquiries in the event of an emergency?				
11	Are regular emergency response drills scheduled with employees?				
12	Is a list of emergency response agencies and contacts displayed in visible areas throughout the facility?				
13	Is the most current response plan on file with all the appropriate agencies (fire department, local emergency planning agencies, etc.)?				
14	Have you provided a tour of golf course facilities to the local emergency response team?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
	<i>General Management Practices</i>				
15	Have you formed a resource advisory group, including nongolf community representatives, to assist with planning and implementing environmental projects and educational efforts?				
16	Do you have written materials such as brochures, signs, and newsletters, to promote environmental awareness among the golfing and nongolfing community?				
17	Do you invite patrons and community members to participate in environmental projects?				
	<i>General BMPs for Maintenance and Chemical Facilities</i>				
1	Are detailed maps of the facility provided in heavily traveled areas? Maps should include the location of fire extinguishers, showers, eye-wash stations, and evacuation routes.				
2	Is the proper emergency spill equipment on hand?				
3	Is portable fire equipment located throughout the facility?				
4	Are employees trained on the purpose and proper use of PPE to limit the potential of exposure to skin and eyes?				
5	Is the proper emergency response equipment and protective equipment available to respond to chemical spills or fires?				
6	Are first-aid and eye-wash stations maintained in critical areas in the facility?				
7	Do you maintain a detailed product inventory?				
8	Is a label and MSDS maintained for each chemical stored at the facility, including ammonia, certain fertilizer products, pesticides, solvents, and other hazardous waste materials?				
9	Are inspections and maintenance of environmental installations—including barriers, slopes, retention areas, and tank containment—performed regularly?				
10	Is there proper security throughout the facility (e.g., security fences/gates, lighting, surveillance, lockouts on secondary containment)?				
11	Is the property properly secured to control access in and out of the facility?				
12	Are visible safety reminders and warnings placed in storage areas?				
13	Are areas used for storage kept clean and clear of dust and damaged materials?				
	<i>Pesticide Storage and Handling</i>				
1	Do the design and construction of maintenance and chemical facilities prevent stormwater contamination and prevent potential contaminants from leaving the plant area? The facility should be carefully observed to ensure that no contaminated discharges occur either to existing on-site stormwater systems or to municipal storm sewer systems, or off-site by any other means.				
2	Are all pesticide containers stored in an impervious, curbed area?				
3	Do all mixing tanks, pumps, hoses, and other pesticide storage, mixing, and loading equipment have some type of containment to prevent contamination in the event of a spill or rupture?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
4	Is a check valve or air gap separation ALWAYS used to prevent backflow into the water source?				
5	Are appropriate PPEs as indicated on the label or MSDS ALWAYS used when handling pesticides?				
6	Is adequate headspace left when filling the tank?				
7	Is adequate ventilation provided to prevent vapor accumulation?				
8	Are all dry pesticides stored above or away from liquids?				
9	Are all pesticides stored at or below eye level?				
10	Are all pesticide labels legible and containers in good condition?				
11	Are valves in the mixing and loading area properly labeled?				
12	Are valves locked during off hours to prevent tampering?				
13	Are all secondary containment walls and floors covered with an impervious coating?				
14	Are seams and cracks in secondary containment walls and floors sealed in a timely manner?				
15	Are all pesticides mixed and loaded into application equipment within a protected containment area?				
16	Are all spills cleaned up immediately?				
17	Is the sump drained and cleaned each day, or any time incompatible pesticides are handled?				
18	Is excess pesticide mix applied as a pesticide to a label-authorized site or saved for later use?				
19	Is tank or container rinse water applied as a pesticide to a label-authorized site or saved for later use as makeup water for compatible applications?				
	Fertilizer Storage and Handling				
1	Are pesticides and fertilizer stored in separate buildings, or with a concrete firewall maintaining separation?				
2	Is bagged ammonium nitrate stored at least 3 feet away from any building wall?				
3	Are ammonium nitrate and other strongly oxidizing materials stored away from sludge products or organic materials?				
4	Are all unloading and loading points for fertilizer/raw material designed to minimize accidental release and allow for easy cleanup?				
5	Are dry fertilizer and raw materials covered from the elements?				
6	Are unloading, loading, and other critical control points swept after use to further control dust and spills?				
7	Are all fertilizers loaded over impervious areas or over a tarp or other temporary barrier to contain spills?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
	Fueling				
1	Are fuel and product tanks protected from potential damage caused from vehicle collisions if they are close to heavy traffic areas?				
2	Are all tanks registered, if required by Rules 62-761 or 62-762, F.A.C.?				
3	Do all tanks and hoses have shutoff valves?				
4	Are spill buckets located at all liquid transfer points?				
5	Are the correct line and couplers provided at each transfer point?				
6	Are all tanks and secondary containment inspected monthly for problems such as deterioration, defects, and leaking, and is the inspection documented?				
7	Are all storage tanks properly labeled?				
8	Does containment volume equal at least 110% of the largest tank capacity?				
	Equipment Washing				
1	Is all equipment blown with compressed air before washing to remove dry material and minimize wastewater generation?				
2	Are all washing hoses equipped with automatic shutoff nozzles?				
3	Are grass clippings composted and used elsewhere on the grounds?				
4	Are all exotic or diseased materials safely disposed of?				
5	Is all washwater for nonpesticide equipment filtered and recycled, or otherwise properly disposed of in accordance with an industrial wastewater permit or exemption letter?				
6	Is pesticide spray equipment washed separately at the chemical mixing center?				
	Equipment Repair and Maintenance				
1	Does each piece of equipment have a designated storage/parking space to allow the tracking of leaks?				
2	Are batteries properly stored and disposed of?				
3	Are drums containing used oil or oil filters properly labeled and stored in contained areas?				
4	Are washwater recycling system filters properly labeled and stored in contained areas?				
5	Are chemical materials, solvents, paints, lubricants, and other substances clearly and accurately labeled?				
6	Are solvents and other flammable materials properly stored, handled, and recycled or disposed of?				
7	Have you informed employees of materials classified as hazardous?				
8	Have you ensured proper training in the handling of hazardous materials?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
	Stormwater				
1	Is stormwater diverted away from areas where it may become contaminated, such as loading/unloading areas, storage areas, and truck traffic areas?				
2	Is all stormwater that has contacted process areas, including parking lots and driveways that handle truck traffic, contained in an impervious containment structure and used for pasture irrigation or similar uses?				
3	Are equipment rinse pads curbed to prevent rinsate from being washed off the pad?				
4	Are all stormwater conveyances and holding facilities inspected frequently for cracks or leakage, and repaired immediately?				
5	Do all stormwater discharges from impervious areas flow through swales, rain gardens, bioretention areas, or other stormwater treatment train components before discharge to a waterbody or storm sewer?				
6	Do you maximize the use of pervious pavements or other pervious materials for overflow parking, walking paths, etc.?				
	Water Supply and Irrigation				
1	If the water supply is from a municipal source, is required protection from back-siphoning installed?				
2	For on-site wells, is the wellhead elevated or curbed to protect leaks and spills from entering the well?				
3	Is the wellhead protected from back-siphoning?				
4	Has the irrigation system been audited within the last year?				
5	Have all repairs and adjustments recommended by the last audit been completed?				
6	Is the system inspected frequently (at least weekly, if operating) as a part of regular course operation, and are all employees trained to report damaged heads, leaks, and other problems?				
7	Are preventive and corrective maintenance records kept in a manner to allow convenient review and identification of trends?				
8	Does the system allow for the selective irrigation of greens, tees, and fairways as needed (double heads, etc.)?				
9	Is irrigation control based on on-site weather information, soil moisture, and localized plant needs, rather than a fixed schedule?				
10	Are all defects in the irrigation system noted and repaired promptly and properly?				
	Nutrient Management				
1	Are individual applications of soluble nitrogen limited to 1/2 lb./1,000 ft ² on sandy soils, including greens?				
2	Where existing distribution equipment cannot maintain even distribution of lower application rates of soluble nitrogen, are applications limited to 1 lb./1,000 ft ² ?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
3	Are soil tests performed before phosphorus is applied, and then only if test results show that phosphorus is needed?				
4	Are proper cultural practices employed to prevent stress to the turf, so that excess fertilizer is not required for recovery?				
5	Are records kept of all nutrient applications?				
6	In addition to plant needs, is the timing of fertilizer application adjusted to account for impending weather, to minimize loss to the environment?				
7	Are personnel trained and precautions taken to ensure that fertilizer is not applied to impervious areas or directly to waterbodies?				
	Cultural Practices				
1	Is turf mowed at the high end of the recommended range unless conditions dictate otherwise?				
2	Are mowing practices adjusted for shade or drought conditions?				
3	Are fertilizer and irrigation levels adjusted for shaded areas?				
4	Are clippings returned to the soil on roughs and fairways?				
5	Are collected clippings composted or otherwise recycled?				
6	Are aeration and verticutting practiced to avoid compaction and excessive thatch?				
	Lake and Aquatic Plant Management				
1	Are native plant or unfertilized grass buffers of 25 feet used around waterbodies wherever practicable?				
2	Are grass buffers mowed at 2 inches or higher to slow and filter overland flow to waterbodies?				
3	Are swales and berms used to avoid direct runoff whenever practicable?				
4	Is IPM practiced in lake management so that chemical controls are minimized?				
	Pest Management				
1	Is IPM used at all times?				
2	Are cultural controls, irrigation, and nutrient applications managed to minimize stress and minimize susceptibility to pest damage?				
3	Are records kept of all pesticide applications?				
4	Are employees trained in scouting and monitoring for pest damage?				
5	Are records of pest scouting maintained to assist in detecting trends?				
	Environmental Monitoring				
1	Do you visually inspect natural areas and waterbodies for erosion damage, sediment, exotic species, algae, fish kills, pollutant plumes, and other problems as a regular part of IPM scouting and course observation?				

Florida Golf Course Best Management Practice Checklist

ID#	Practice	Yes (or N/A)	Partial per Plan (Year to Finish)	No	Planned (Year Start/ Finish)
2	Do you have a mechanism for immediate employee reporting of water quality or other environmental problems to supervisors for corrective action or and/or reporting to regulatory agencies, if appropriate?				
3	Do you keep written records of monitoring and inspections, results, and corrective or preventive measures?				
4	Have you conducted at least 4 quarters of baseline water quality testing?				
5	Do you conduct routine follow-up water quality testing (at least every 3 to 5 years) and after significant modifications that might affect water quality?				

EMERGENCY REPORTING

For Ambulance, Fire, or Police,
DIAL 911

State Warning Point

(Florida Department of Community Affairs, Division of Emergency Management)
24 hrs. toll-free • 1-800-320-0519
or (850) 413-9911

National Response Center

24 hrs. toll-free • 1-800-424-8802

(Federal law requires that anyone who releases into the environment a reportable quantity of a hazardous substance [including oil when water is or may be affected] or a material identified as a marine pollutant, must immediately notify the NRC).

HELP LINE NUMBERS

(for chemical hazard information and regulatory questions)

CHEMTREC HOT LINE (Emergency only)

24 hrs. toll-free • 1-800-424-9300

CERCLA / RCRA help line

Toll-free • 1-800-424-9346

NON-EMERGENCY NUMBERS

State Emergency Response Commission

(NOT a 24-hr. number) 1-800-635-7179

(This is for follow-up reporting for state spill-reporting requirements. In an emergency, call the State Warning Point. If federal reporting is required, also call the National Response Center.)

Florida Department of Agriculture and Consumer Services

Bureau of Compliance Monitoring (850) 488-3314
Bureau of Pesticides (850) 487-0532

Florida Department of Environmental Protection

FDEP Nonpoint Source Management Section (Tallahassee) (850) 245-7508

FDEP Stormwater/NPDES Section (Tallahassee) (850) 245-7522

FDEP Hazardous Waste Management Section (Tallahassee) (850) 245-8707

FDEP District offices:
Northwest (Pensacola) (850) 595-8300

Northeast (Jacksonville) (904) 448-4300

Central (Orlando) (407) 894-7555

Southeast (West Palm Beach) (561) 681-6800

Southwest (Tampa) (813) 744-6100

South (Ft. Myers) (941) 332-6975

Water Management Districts

Local phone Toll-free

Northwest Florida (Tallahassee) (850) 539-5999

Suwannee River (Live Oak) (904) 362-1001 1-800-226-1066

St. John's River (Palatka) (904) 329-4500 1-800-451-7106

Southwest Florida (Brooksville) (352) 796-7211 1-800-423-1476

South Florida (West Palm Beach) (561) 686-8800 1-800-432-2045

