# Sports Field Best Management Practices Manual: Florida Edition

*Guidelines for the Sustainable Management of Natural and Synthetic Sports Turf Systems*

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# SECTION 1:  ENVIRONMENTAL CONCEPTS

This section establishes the foundation for environmental stewardship in sports field management. It outlines key environmental factors such as air, soil, and water quality, and water use efficiency. These concepts are critical in ensuring that sports turf management practices align with sustainable and responsible environmental practices.

Steps should be taken to preserve wildlife and native plant habitats surrounding athletic fields.  It is important to consider how field management practices impact the surrounding natural ecosystems. These natural systems support, maintain and provide various ecosystem services such as filtering pollutants from runoff, sequestering carbon, regulating temperatures, and providing habitat for native biodiversity.  All these services contribute to supporting good air and water quality conditions for humans, plants, and animals.

Turfgrass landscapes can specifically provide a range of ecosystem services according to a review of the scientific literature:

**Turfgrass landscapes can:**

- Moderate urban temperature extremes
- Produce oxygen via photosynthesis
- Sequester carbon
- Improve air, water, and soil quality
- Reduce water runoff and increase infiltration
- Decrease soil erosion

- Reduce noise pollution
- Provide wildlife habitat
- Prevent risk of wildfire
- Provide various economic, social, and recreational benefits

Due to the differing management required for athletic fields compared to other turfgrass landscapes, some of these services may be reduced or absent in athletic fields. For example, carbon sequestration via accumulation of organic matter in the soil has been found to be minimal in athletic fields compared to ornamental turfgrass[2].

## Air Quality

Athletic fields and the surrounding landscape can have a positive impact on air quality, compared to other urban greenspaces. The air-purifying actions of healthy turf and other plant life can be offset by impacts such as air pollution from maintenance machinery, increased traffic, and the energy used to heat and cool the buildings and run the irrigation system. Similarly, nitrous oxide emission resulting from fertilizer applications to turf contribute to greenhouse gases, but management strategies such as irrigating after fertilization and using controlled-release fertilizers may reduce these emissions.

Good design and proper maintenance practices can do much to minimize these effects; energy-efficient facilities can be designed, and petroleum engine-driven equipment can be kept properly tuned and running at peak efficiency. Replacing gas-powered with electric equipment can reduce the emissions from these activities. Minimizing pesticide spray drift and solvent use can also reduce air pollution.

## Soil and Water Quality

There are several significant environmental concerns related to soil and water quality for athletic fields. These concerns primarily relate to plant nutrients, pesticides, erosion, sediment (turbidity), and the handling and disposal of waste materials.

### ***<u>Nutrients</u>***

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 groundwater and surface water, potassium, unlike nitrogen and phosphorus, is not an element of impairment causing environmental concerns.

Liebig's Law of the Minimum states that growth is limited by whatever is in shortest supply. The environmental effect of contributing excess nutrients depends on the ecosystem. Freshwater systems are commonly presumed to be limited by phosphorus whereas marine systems are presumed to be limited by nitrogen. In contrast to much of the USA and the rest of the world, in many parts of Florida phosphate is naturally abundant in the rock and soil. Due to this prevalence of phosphate, algae and plant life in waterbodies in these P-rich areas are typically limited by the amount of nitrogen available. Too much nitrogen can lead to algal blooms. When the algae eventually die and decompose, oxygen is stripped from the water, which can result in fish kills due to 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. In the same way that nutrients are applied to athletic fields to enhance growth, a limiting nutrient unintentionally added to surface waters will increase plant growth.

Nitrate is a form of nitrogen of special concern to groundwater. The federal standard for nitrate-nitrogen ($NO_3$-N) in drinking water is 10 parts per million (ppm) or milligrams per liter (mg/l). This 10 ppm standard is intended to prevent methemeglobinemia (also known as blue baby syndrome) that emerges when excess nitrate is present in drinking water, affecting the ability of our blood to transport oxygen throughout our body. In Florida, the law considers most groundwater to be potential drinking water, and therefore this standard applies to almost all groundwater. Nitrate can be leached into groundwater from animal wastes, septic tanks, sewage treatment plants, or the overapplication of fertilizers. Other forms of N (such as ammonium or urea) can also be transformed into nitrate by various microbial transformations.

For athletic fields, excess nutrient problems can be reduced through the development of proper nutrient management plans and the careful execution of those plans.

## ***Pesticides***

Pesticide use on athletic fields may be the most publicly controversial topic of all when it comes to environmental issues. Pesticides include both herbicides and insecticides. 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 bees, a beneficial pollinator, or affect plants, birds, wildlife, fish, or other aquatic life in rivers, streams, and lakes. Some participants, spectators, or people living nearby may also be sensitive to certain chemicals.

Pest control on sports fields should not begin with pesticides. The fundamental basis of an environmentally sound pest control program is a process called Integrated Pest Management (IPM). IPM focuses on the basics of identifying the pests, monitoring pest-thresholds, 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 biorationals and other less toxic 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 the 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 groundwater 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 remain in the soil and groundwater.

The professional pesticide applicators on athletic fields 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 athletic fields are aware of the least toxic and most environmentally sound methods of pest control.

## ***Wastes***

Wastes from athletic fields include grass clippings, plant material, and chemical by-products. Whenever possible, waste production should be avoided. The disposal of waste products on athletic fields presents the same sort of problems as it does throughout 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 should be collected and subsequently composted for use in gardens and other landscaped areas around the athletic fields or provided to homeowners. Proper composting procedures should be followed allowing sufficient time for pesticide residues to degrade. As at any office or home, paper, cans, glass, and many other materials should be recycled.

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

Equipment wash areas can also generate waste such as grass clippings and traces of fuel, oil, and metals that are washed off the engines and moving parts.

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 sports field manager 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 athletic fields.

## Water Conservation

Potable water supplies in Florida are limited and demand continues to grow. The challenge is to find solutions to maintain the quality of athletic fields while using less water. BMPs and educational programs are necessary to change the public's mindset toward the inevitable changes in water-related issues.

There are many ways to conserve water on athletic fields. Ideally, only the play and practice areas should be irrigated under normal conditions. Selecting drought-tolerant varieties of turfgrasses can help maintain attractive and high-quality playing surfaces while minimizing water use. Surrounding 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 for providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation.

A well-designed irrigation system that is maintained at peak efficiency helps to ensure that the water used is applied efficiently and 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 flushing salts from the rootzone. Modern irrigation systems that are computer-controlled with weather stations, automatic rain- and soil moisture–sensing controls, and multiple zones can water different areas to meet their varying needs.  This allows specific areas in an athletic complex that was 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.  If properly designed, rain and runoff captured in stormwater ponds and cisterns may provide most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during extended drought periods.  Other sports fields may be located where nonpotable reuse water from a wastewater treatment plant is available.  Such water is highly treated for pathogens and safe for human contact. However, it is also a source of nutrients and should be monitored and evaluated as a source of nutrient load to the sports field. Fertilization should be adjusted to account for nutrient loads from reclaimed irrigation. In some coastal areas, nonpotable, brackish water is being successfully used for sports field irrigation.  Both brackish water and reuse water have high salt concentrations, though. Therefore, using either of these sources for irrigation requires specific attention be paid to salt tolerance of plants and soil salinity. For example, landscapes with brackish water sources for irrigation may select salt-tolerant grasses such as seashore paspalum *(Paspalum vaginatum)* and the use of drought- and salt-tolerant plants in surrounding areas.  Horizontal wells are another potential alternative water source.  They are very site-specific but can tap into surficial groundwater sources, avoiding the use of traditionally deeper aquifers and wells.

# SECTION 2: ENVIRONMENTAL MONITORING

Environmental monitoring is essential for assessing the impact of sports field management on surrounding ecosystems. This section covers quality assurance measures and monitoring strategies at different stages—before, during, and after construction—to ensure compliance with environmental regulations and the effectiveness of BMPs in maintaining ecological integrity.

Every athletic complex should have a plan to monitor the state of the environment and the effects that athletic fields may be having on the environment. Monitoring is the method used to establish if outside events are changing the water quality or other environmental conditions entering the athletic complex/field, or if the athletic complex/field is having a positive, neutral, or negative effect on surrounding environmental conditions (e.g., water quality, biodiversity). It also provides a body of evidence to substantiate these changes should allegations be made that the athletic field/complex is responsible for environmental changes. It should be noted that a single sample is rarely meaningful in isolation and that most sampling should be conducted over time, and results should be reviewed as trends over time. Ideally, this monitoring would also be designed with a natural reference location also being monitored to establish whether changes are due to the athletic field or if changes are a broader pattern.

## 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 DEP'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 DEP, and that involve the measurement, use, or submission of environmental data or reports to DEP.

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 is used, and all QA/QC procedures followed. Athletic field management must have good data to make good decisions, and if an athletic field 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 searchable portal of NELAP certified labs can be found at: https://floridadep.gov/dear/florida-dep-laboratory/content/nelap-certified-laboratory-search. Sample specific standard operating procedures (SOPs) are available at https://floridadep.gov/dear/quality-assurance/content/dep-sops.

## Predevelopment Monitoring

The development process and preconstruction monitoring should begin as soon as possible, 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 athletic complex development on adjacent major rivers, streams, or lakes, if present,*
- *Flowing tributaries, wetlands, and water features draining the athletic complex development, if present,*
- *Any additional sites selected prior to development, and*
- *At upgradient and downgradient wells, as suggested by the hydrogeologist or regulatory agency.*

Water quality is typically assessed based on concentration of compounds measured in the water, but the volume of water is also a factor that can affect the concentration as well as assist in interpretation of results. Therefore, an assessment of the relative quantity of water at the time of sampling is also useful. This can be done by measuring the “stage” or water level at the time of sampling or the presence or absence of flow. This also helps to define whether a measured concentration is moving onto or off of the athletic field area.

Four rounds of samples should be taken about three months apart, 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. Surface waterbodies are typically more dynamic than groundwater systems and therefore should be monitored more frequently.

Sampling parameters are determined based on sports field operation and basin-specific parameters of concern (these may be identified by DEP's Total Maximum Daily Load [TMDL] Program). Water samples should be analyzed for nitrogen and phosphorus (including both total and dissolved forms), pH and alkalinity, total suspended solids, and any pesticides expected to be used on the sports field. Additional monitoring parameters such as dissolved oxygen or heavy metals may be included if site conditions warrant (e.g., use of reclaimed water, nearby surface waters, or historical contamination). For new developments adjacent to water bodies, a one-time ecological assessment may be conducted during planning to document baseline aquatic conditions.

## Monitoring During Construction

Construction site monitoring should focus on erosion and the discharge of sediments offsite. Turbidity and suspended solids are the primary parameters at this stage. The most important monitoring component during construction is to carry out frequent visual inspections of erosion and sedimentation control BMPs on the construction site and ensure that the contractor makes prompt and correct repairs, should control measures be damaged (i.e., silt fence becomes damaged). The *Florida Stormwater Erosion and Sedimentation Control Inspector's* Manual is an excellent resource (http://publicfiles.dep.state.fl.us/DEAR/Stormwater_Training_Docs/erosion-inspectors-manual.pdf).

## Postconstruction Operational Monitoring

A water quality monitoring plan should be prepared to ensure the ongoing protection of groundwater and surface water quality after construction is completed. The same sites should be monitored 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 athletic field turf and surrounding landscaping. Samples should be collected four times per year, approximately three months apart to capture seasonal variability. Should there be no discharge or flow 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 seasonally every third year thereafter, provided that all required water quality monitoring has been completed and the athletic complex continues to implement all current management plans. It may also be wise to sample if a significant change has been made in field operation or design that could affect nearby water quality.*
- *Sampling parameters should be determined based on field operations and any basin-specific parameters of concern (identified by the TMDL Program or local regulators).*

# SECTION 3: PLANNING, DESIGN AND CONSTRUCTION OF SPORTS FIELDS IN FLORIDA

## Introduction

The construction phase of sports fields and their ancillary support facilities poses the greatest risk of ecosystem alteration. With proper planning and design, sports field facilities can be constructed and maintained with minimal impact to existing wildlife and their habitat.

## Regulatory Considerations

Local, state, and federal regulations are in place impacting planning, design, and construction of sports fields in Florida. Early engagement among developers, designers, local community groups, and permitting agencies is essential to designing and constructing a sports field facility that minimizes environmental impact and meets the needs for the approval process. Proper planning will minimize expenses due to unforeseen construction requirements.

## 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 siting of sports field amenities are essential during the planning process. Developers, designers, and others involved in sports field development are encouraged to work closely with local community groups and regulatory/permitting agencies during planning and siting, and throughout the development process. 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 sports field facility:

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 including invasive species. Determine areas that merit special protection or restoration.
3. Identify those management practices that will protect environmental resources during the construction phase and later during sports field 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, if problems should occur, by demonstrating the intended environmental stewardship provided by the sports field.

The design of a sports field facility should be based on the information gathered in the first three steps listed above. A good design flows in harmony with the natural landscape. The facility should be designed and sited 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. 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 resource standpoint, this involves protecting both ground water and surface water, and limiting the use of potable water supplies for irrigation. . https://floridadep.gov/dear/water-quality-restoration/content/basin-management-action-plans-bmaps

Although many operational and maintenance BMPs do not come into play until a sports field 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.

**Design and Construction Best Management Practices:**

1. Retain a qualified sports field manager/project manager at the beginning of the design and construction process to integrate sustainable maintenance practices in the development, maintenance, and operation of the facility.
2. Design the facility to minimize the need to alter or remove existing native landscapes. The field layout should identify the areas that provide opportunities for restoration.
3. Design the facility to retain as much natural vegetation as possible. Where appropriate, consider enhancing existing vegetation through the supplemental planting of native vegetation/materials in out-of-play areas.

4. Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance, invasive, and exotic plants should be removed and replaced with native species that are adapted to that site.
5. Locate the facility so that critical wildlife habitat is conserved, and the development does not adversely affect viable, occupied native wildlife habitat on the site.
6. Identify regional wildlife corridors and configure the facility layout to maintain and/or enhance native habitat to facilitate the use of these corridors. Any existing or proposed crossings of wildlife corridors associated with field maintenance and use should be minimized, and unavoidable crossings should be designed to accommodate wildlife movement.
7. Use only qualified contractors who are experienced in the special requirements of sports field construction.
8. 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.
9. Schedule construction and turf establishment to allow for the most efficient progress of the work, while optimizing environmental conservation and resource management.

## Site Selection

The site selection for a sports field facility and subsequent site plan largely determines the facility's environmental compatibility within the community. The involvement of land use specialists, water resource managers, and geotechnical professionals is critical in selecting a site that provides environmental benefits.

Identifying the resources at a site is necessary to understand how to design the facility and surrounding development, to understand the long-term maintenance procedures and associated operational costs to be incurred, and to know how best to protect the site's environmental resources.

*Important Steps in Site Selection*

- Topographical land maps are essential before beginning any type of design activity for a sports field or facility. 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, may perform poorly under heavy use, and may create runoff into nearby waters. The types of soils present significantly affect the expense of sports field 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 facility’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 including invasive plants.  Wildlife habitat conservation and restoration should play a crucial role in site analysis and selection.  The site design should include the preservation of these areas.

## Watershed

Florida has 29 major watersheds, also known as a drainage basins, that funnel surface and ground water and drains it into a single stream, lake, ocean, or other reservoir. Sports fields are situated within and are connected to these watersheds. Consequently, this connectivity can present both opportunities and challenges for managing sports fields. Care must be taken to ensure that pollutants that originate on the sports field remain on the facility and are not conveyed beyond the area of desired effect/application to areas of unintended impact.

## 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 wetlands 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 Florida's ecosystem.

While wetlands do pose a special concern, their mere presence is not incompatible with sports fields. With care, many sports field facilities have been threaded through sensitive areas, and with proper design and management can coincide. When incorporated into a sports field 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 jurisdictions of federal, state, and local agencies.  At the federal level alone, the U.S. Army Corps of Engineers (USACOE), EPA, FWS, National Oceanic and Atmospheric Administration (NOAA), and maritime agencies may all be involved.  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 construction along wetlands is being considered, contact the local government and/or local FDEPDEP or water management district office before developing 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.

**Best Management Practices for Wetlands:**

1. Ensure that proper permitting has been obtained before working on any wetlands.

2. Ensure that wetlands have been properly delineated before working in and around any wetlands.

## Drainage

Adequate drainage is necessary for growing healthy turfgrass. In Florida, where high rainfall events are common in the summer and fall, installation of an effective drainage system is critical. A qualified sports field architect, working in conjunction with a stormwater engineer, should review soils and site conditions to develop a stormwater management system that complies with regulatory requirements.

Proper surface drainage is essential in the design of sports fields. Each field should be an individual drainage unit, avoiding runoff from adjacent fields or surrounding terrain. Interceptor drains should be installed if natural contours direct runoff toward the field. Surface drainage designs usually fall into two categories: crowned fields and flat fields sloped to one side or to the ends. The typical slope for sports fields ranges from 1% to 1.75%. Soccer fields often require additional drainage systems due to their lower slope requirements.

Crowned fields, commonly used for football fields, efficiently shed water. However, fields used for both football and soccer may face issues with sideline areas, which require consistent slopes to prevent waterlogging and damage from foot traffic. Flat fields may need an installed drainage system, especially in the lower areas. Ensure records indicate the field's flat design to prevent future recrowning attempts. Catch basins, placed outside the play area with a small grid on top, aid surface drainage and monitor the drain system's effectiveness. Avoid creating hills and valleys along the field edge by using swales.

When reconstructing a field, survey water movement and set new grades before regrading. Ensure consistent soil depth to avoid areas with poor drainage. For small spot drainage issues, apply topdressing and use a solid field leveler to smooth the surface, improving surface drainage. Deep-tine aeration can help improve infiltration and percolation by opening the soil. Follow up with sand topdressing to maintain open aeration holes, enhancing internal drainage and promoting turf health.

Internal drainage is also critical. Infiltration and percolation are vital processes, allowing rainwater to move downward through the soil. Compaction is a common problem that hinders water movement. Aeration can alleviate compaction and improve internal drainage. Healthy soil structure, formed by soil aggregates, is crucial for water movement. Compaction from heavy equipment or foot traffic can destroy soil structure, leading to poor drainage. Adding amendments like coarse sand can enhance permeability and improve drainage. The sand content should be at least 70% to ensure effective water movement through the soil.

Installed drain systems are essential for effective water management. Pipe drains, using perforated pipes laid in gravel-filled trenches, remove water from the subsoil. Proper placement and installation are critical to prevent clogging and ensure long-term effectiveness. Interceptor drains, designed to intercept and channel away water from surrounding areas, help manage surface and subsoil water, preventing it from affecting the field. Modern vertical drains, installed in narrower, shallower trenches and filled with coarse sand, efficiently remove surface water and are especially useful in problem areas.

Routine inspection and maintenance of drainage systems are essential. Remove debris and unwanted plant growth to ensure the system functions as designed. Implement buffer zones and filtration techniques in the design and construction process to maintain water quality. Ensure internal drainage systems discharge through pretreatment zones and vegetative buffers.

By integrating these advanced drainage practices, sports fields can maintain optimal conditions, reducing the risk of waterlogging and ensuring healthy turfgrass growth.

**Best Management Practices for Drainage:**

1. Ensure Proper Planning and Design:
    - Engage qualified professionals early in the process to design an effective drainage system.
    - Design each field as an individual drainage unit to prevent runoff from adjacent fields.
2. Implement Effective Surface Drainage:
    - Utilize crowned or flat fields with appropriate slopes (1% to 1.75%) to facilitate drainage.
    - Install interceptor drains if natural contours direct runoff toward the field.
    - Use catch basins outside the play area to aid surface drainage and monitor effectiveness.
3. Maintain and Reconstruct Field Contours:
    - Regularly survey water movement and regrade fields as necessary to ensure consistent soil depth and proper drainage.
    - Apply topdressing and use solid field levelers to address small spot drainage issues.
4. Enhance Internal Drainage:
    - Use deep-tine aeration and sand topdressing to improve infiltration and percolation.
    - Maintain healthy soil structure by preventing compaction from heavy equipment or foot traffic.

- Add soil amendments like coarse sand to enhance permeability.

5. Install and Maintain Drain Systems:
    - Use perforated pipe drains, interceptor drains, and vertical drains for effective water management.
    - Ensure proper placement and installation to prevent clogging and maintain long-term effectiveness.
    - Regularly inspect and maintain drainage systems to remove debris and unwanted plant growth.
6. Protect Water Quality:
    - Implement buffer zones and filtration techniques to maintain water quality.
    - Ensure drainage systems discharge through pretreatment zones and vegetative buffers.

## Erosion and Sediment 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 ready for construction, and then plant, sod, or otherwise cover it as soon as possible to prevent erosion.

Sports field 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 FDEPDEP 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.

**Best Management Practices for Erosion and Sediment Control**

1. Develop a working knowledge of erosion and sediment control management. Each state has its own specifications including types of acceptable structures, materials, and design features.
2. 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.
3. Hydro-seeding or hydro-mulching offer soil stabilization.

## Water Quality Buffers

Buffers around the shore of a waterbody or other sensitive areas filter and purify runoff as it passes across the buffer. 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.

## Springs, Spring Runs, and Wet Sinks

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

## Sports Fields

Sports fields typically occupy a significant portion of the total facility area and account for most of the play. Sports fields in Florida typically receive heavy use throughout the year. Careful design and intensive turf management are required to maintain a good playing surface under these conditions. The nature of the games calls for short mowing compared to other turfgrass systems, which also limits the size of the root system. As a result, frequent watering and fertilizing may be necessary, particularly when fields are receiving high levels of use. This high-stress environment also makes the turf more susceptible to pests.

No procedure or method of field 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.

## Profile of the Field

There are many construction techniques for sports fields. Again, a qualified sports field architect working with experienced agronomic professionals should determine the appropriate technique and methods for field construction. No matter what method is used, developing a consistent profile throughout all the fields is important for a facility's maintenance practices.

A sports field with a constructed sand-based rootzone features a layered design that typically includes a 12-inch layer of sand-based rootzone mix over a 4-inch layer of drainage gravel with underground drainage pipes. An intermediate layer is required if the gravel and rootzone materials do not meet the proper particle size distribution of the rootzone mixture relative to the gravel. Other construction methods used throughout Florida provide acceptable playing conditions when built properly. The materials used to build a sports field should be carefully selected to withstand play and maintenance traffic, promote rapid drainage, and provide an excellent growing environment for the turf.

A BMP plan must address both surficial and internal field 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

The playing surfaces of the fields are the most intensely managed areas in a sports facility. Because the most frequent mowing, cultivation, fertilization, and pest management practices are performed on fields, the irrigation system should be designed and installed so that the playing surfaces can be watered independently. With standard single-head coverage, parts of the field or surrounds are often watered unnecessarily, wasting water and promoting poor root structure and fungal growth. The use of part-circle heads can conserve water. See Section 4 for more details.

## 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 fields, 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. Fields are typically planted using 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.

### ***Plant Selection: Sunlight, Shade, and Air Circulation***

Selecting the appropriate turfgrass species for a given site is fundamental to maintaining a healthy and functional sports field. The principle of "Right Plant, Right Place" underpins environmentally responsible landscape management and applies directly to turfgrass systems. While native plants are often ideal due to their adaptation to local soils, climates, pests, and nutrient conditions, sports fields require a more targeted approach to meet performance demands. In these managed environments, choosing turfgrass species that are best suited to the site's specific light, air circulation, and soil characteristics is essential. The overarching BMP goal is to maintain field conditions that closely mimic a natural ecosystem while still meeting the functional requirements of a sports facility.

Sunlight availability is a primary consideration in turfgrass selection. Bermudagrass and seashore paspalum, commonly used on sports fields, require full or nearly full sunlight. These species are typically maintained at low mowing heights, which limits leaf area and makes adequate sunlight vital for sustaining photosynthesis and turf recovery. In contrast, turfgrasses growing in shaded conditions tend to produce elongated leaves and stems as they compete for limited light. This growth response often leads to reduced vigor, lower stand density, and increased vulnerability to weed encroachment. Although heavy shade is uncommon on most community fields, it may occur in stadiums or areas adjacent to buildings or large tree canopies.

Air circulation is another critical environmental factor that influences turf health. Adequate airflow helps dry leaf surfaces and reduces the likelihood of disease development. In areas where airflow is restricted—particularly when combined with shade—persistent surface moisture can create favorable conditions for fungal pathogens. Poorly designed field areas that limit air movement may experience chronic turf health issues if not addressed.

To mitigate these challenges, it is important to identify areas with limited light and airflow during the planning and design phases of field development. Where practical, tree pruning and removal of understory vegetation can improve both light penetration and air movement. Additionally, irrigation practices should be adjusted in locations where moisture tends to accumulate to help prevent turf decline and minimize disease pressure.

## ***Soil Amendments***

Sports field rootzones have traditionally 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 sports field construction. These include clinoptilolite zeolites, polyacrylamides (PAMs), diatomaceous earths, calcined clays, porous ceramics, and iron humates. Field tests suggest that amendments with moderate levels of CEC and moderate levels of moisture retention (calcined clays and porous ceramics) produce 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 in the root-zone mix for a sand-based field is that phosphorus leaching is almost eliminated.

## Athletic Field Lighting

Proper lighting is crucial for synthetic turf fields, especially in Florida where evening use is common due to daytime heat. Well-designed lighting systems enhance player safety, improve visibility for spectators, and extend the usable hours of the facility. When designing or upgrading field lighting, several factors must be considered. Light levels should meet or exceed standards set by governing bodies, with a minimum of 50 foot-candles recommended for most high school and collegiate sports, and higher levels (75-100 foot-candles) for televised events. Uniformity is equally important, aiming for consistent lighting across the entire field to prevent dark spots or overly bright areas. A uniformity ratio (average to minimum illumination) of 1.5:1 or better is ideal. Glare control strategies should be implemented to minimize discomfort for players, officials, and spectators, which may include precise aiming of fixtures and the use of glare shields. Choosing lamps with a high color rendering index (CRI) ensures accurate color perception, crucial for player and ball visibility.

LED lighting systems have become the standard for new installations and upgrades due to their energy efficiency, long lifespan, and superior control capabilities. A comprehensive lighting management plan should be implemented, including regular maintenance and cleaning of fixtures, periodic light level testing, a re-lamping schedule based on manufacturer recommendations and usage patterns, protocols for adjusting lighting levels based on the type of activity, and integration with the facility's overall energy management strategy. Advanced lighting control systems offer additional benefits, such as zonal control for partial field use, dimming capabilities for energy savings during non-critical use, automated scheduling to prevent unnecessary use, remote control and monitoring capabilities, and integration with emergency systems for instant full illumination if needed.

Environmental considerations should also factor into lighting design. Use fixtures designed to minimize light pollution and sky glow, implement automatic shutoff systems to ensure lights aren't left on unnecessarily, consider the impact on local wildlife, especially in areas near natural habitats, and explore options for renewable energy sources, such as solar-powered lighting for ancillary areas. The lighting system should be included in the field's emergency action plan, with protocols for sudden lighting failures during events and the use of lighting in emergency evacuation scenarios.

By implementing a well-designed and properly maintained lighting system, facility managers can significantly enhance the safety, usability, and overall experience of sports fields in Florida's unique environment. Regular assessment and updating of the lighting system will ensure it continues to meet the evolving needs of the facility and its users while adhering to the latest standards and technologies in the field.

## Maintenance and Storage Facilities

Maintenance facilities include areas for equipment fueling, washing, storage and repair; the sports field manager'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 sports field facility. Few other functional spaces offer the potential for such expensive liability, either for chemical contamination of the environment or for exposure to facility 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.

**Best Management Practices for Pesticide Storage:**

1. Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment.
2. Store pesticides in a roofed concrete or metal structure with a lockable door.
3. Construct floors of seamless metal or concrete sealed with a chemical-resistant paint.
4. Equip the floor with a continuous curb to retain spilled materials.
5. Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.
6. Provide storage for PPE where it is easily accessible in the event of an emergency, but not in the pesticide storage area.
7. Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides.
8. Use shelving made of plastic or reinforced metal. Keep metal shelving painted.
9. Provide appropriate exhaust ventilation and an emergency wash area.
10. Always place dry materials above liquids, never liquids above dry materials.
11. Never place liquids above eye level.

***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 local government officials to determine if special restrictions apply.

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

**Best Management Practices for Mixing and Loading:**

1. Locate operations well away from ground water wells and areas where runoff may carry spilled pesticides into surface waterbodies.
2. Do not build new facilities on potentially contaminated sites.
3. An open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides
4. 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.
5. The sump should be small and easily accessible for cleaning.

6. Ensure that workers always use all PPEs required by the pesticide label.
7. Assess the level of training and supervision required by staff.
8. Any material that collects on the pad must be applied as a pesticide or disposed of as a (potentially hazardous) waste.
9. Clean up spills immediately!

***Chemical Mixing Center Design***

To minimize the risk of pesticides accumulating in the environment from repetitive spills, most sports field 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 publications 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 30º from vertical, 45º 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.

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 sports field facility. 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 facility. 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.

**Best Management Practices for Fertilizer Storage and Handling:**

1. Store nitrogen-based fertilizers separately from fuels, solvents, and pesticides to reduce fire risk. Use a concrete building with a flame-resistant roof when possible.
2. Keep fertilizer dry by storing it under cover. Dry bulk materials may be stored on a concrete or asphalt pad if protected from rain and runoff. Rule 62-762, F.A.C., requires secondary containment for liquid fertilizer tanks over 550 gallons—this is recommended even when not mandated.
3. Immediately sweep up any spilled fertilizer.

## ***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. Some local governments require such a system. The FDEPDEP 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/GuideBMPClosed-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).

**Best Management Practices for Equipment Wash Area:**

1. Do not wash equipment unnecessarily.
2. Clean equipment over an impervious area, and keep it swept clean.
3. Brush or blow equipment with compressed air before, or instead of, washing.

4. Use spring shutoff nozzles.
5. Use a closed-loop recycling system for washwater and follow the FDEPDEP BMPs.
6. Recycle system filters and sludge should be treated and disposed of as hazardous waste.

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.

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 FDEPDEP district sends a letter saying so. Such a letter can save a lot of expense and grief in the future, if FDEPDEP or another agency receives a complaint because someone thinks you are operating illegally. Before designing and constructing the wash system, check with the local FDEPDEP 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 follow FDEPDEP storage tank regulations (Rule 62-761, F.A.C.). Call the nearest FDEPDEP 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 springloaded 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 FDEPDEP publication, *A Guide on Hazardous Waste Management for Florida's Auto Repair and Paint and Body Shops* (https://depedms.dep.state.fl.us/Oculus/servlet/shell?command=getEntity&[guid=2.403128.1]&[profile=DWM%20Historical%20Repository]).

**Best Management Practices for Repair Facility:**

1. 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.
2. Use solvent-recycling machines or water-based cleaning machines to cut down on the use of flammable and/or toxic solvents.
3. 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 FDEPDEP Web site for current information.

## Parking Lots and Traffic Paths

Roadways associated with a sports field facility 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 facility 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.

## Conclusion

The planning, design and construction phase is a critical time to address environmental issues and incorporate Best Management Practices into the sports field facility. Engaging all stakeholders including developers, designers, local community groups, and permitting agencies early in the process is key to creating an environmentally sound facility while meeting the needs of the sporting community.

The thoughtful design of drainage, stormwater management, wetland areas, and non-play areas can greatly minimize a facility's impact on the environment. Retaining natural vegetation, utilizing native plant species, preserving wildlife habitat and corridors, and maintaining riparian buffers are important strategies.

The maintenance facility should be carefully planned with well-designed pesticide storage and mixing areas, equipment wash stations, fueling areas, and repair shops to avoid soil and water contamination.

By applying the Best Management Practices detailed in this chapter during the planning, design and construction phases, sports field managers can create an athletic complex that is an asset to the community and the environment. The extra effort put in during these initial stages will be repaid many times in the efficient operation of the facility and the wellbeing of the surrounding ecosystem.

# SECTION 4: IRRIGATION

Efficient water use is a major component of BMPs, making irrigation a critical aspect of sports field management. This section covers water sources, system design, installation, scheduling, and maintenance, ensuring fields receive adequate hydration while minimizing water waste and adhering to water-use regulations.

Florida receives abundant rainfall averaging between 40 and 60 inches a year. However, there are significant seasonal variations in rainfall. Therefore, at certain times of the year, rainfall is not sufficient to sustain turf health and withstand the rigors of sports play in Florida's temperate weather and sandy soils.

Although sports fields use natural rainfall as the greater part of their annual water budget, irrigation is an important part of maintenance. To ensure efficient watering, fields 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 field performance.

## Understanding Plant-Water Relationships

Soil contains 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 essential functions including water and nutrient transport. The evaporation of water from the leaf surface results in evaporative cooling, thus reducing 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 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. Evapotranspiration 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***

Florida's water management districts issue consumptive use permits (CUPs) or water use permits (WUPs) allowing sports facilities 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.

Developers of new sports fields should understand the reliability of water sources before construction to ensure that sufficient supplies are available for establishment and maintenance.

All alternative water sources should be considered including but not limited to:

- Wells
- Existing surface water
- Stormwater runoff detention ponds

- Reclaimed water
- Brackish water
- Reverse osmosis
- Aquifer storage and recovery (ASR)
- Horizontal wells

The water management districts require that the lowest quality water appropriate be considered first for water use permits.

Facilities located along the state's coastal margins may need to use reverse osmosis to remove chlorides (salts) from saline water sources or use brackish aquifers in conjunction with salt-tolerant turfgrass varieties.

***Brackish Water***

Brackish water is too salty for human consumption but not as salty as seawater. It may be found in/near:

- Near-coastal surface waters, often tidally influenced
- Shallow ground water affected by saltwater intrusion
- Very deep aquifers overlain by other freshwater aquifers

When using brackish water, special care must be taken if there are landscaped ornamental areas as they may be damaged by the saline content. The use of brackish water may also require the periodic flushing of salts that built up at or near the surface of the soil.

**Best Management Practices for Brackish Water Supplies:**

1. Select salt-tolerant turfgrass varieties when using brackish or highly saline water.
2. Regularly flush soils with fresh water to prevent salt buildup in the root zone, especially before fertilization to avoid nutrient leaching.
3. Avoid using brackish water in areas with a shallow freshwater aquifer, as it may increase groundwater salinity. Consult your water management district before use.

***Reclaimed Water***

The use of reclaimed, or recycled, water from wastewater treatment plants for sports field irrigation is common in many areas of Florida. Water reuse is governed under Rule 62-610, Part III, F.A.C., and administered by DEP'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.

Sports fields are efficient and effective users of reclaimed water, and the use of reclaimed water for sports field irrigation is encouraged.

DEP, 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:

- DEP 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, sports field 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 sports facility 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 sports facility 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. Sports facilities 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 facility does not need it. This often occurs during rainy periods, when fields need it least and treatment plants need to get rid of excess water the most. This can lead to very soggy conditions that can damage turf and result in runoff that increases nonpoint source pollution. When using reclaimed water, any nearby potable wells that could be affected by reclaimed water moving into the water table must be identified. Setbacks from such wells are mandated by law and must be observed.

**Best Management Practices for Reclaimed Water:**

1. 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 computes 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.

2. 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.)
3. 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.
4. Any facility 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.
5. Obtain information at the time of contracting, and at least annually, about the quality of the reclaimed water to be delivered.
6. 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.

## 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 *DEP Standards for Landscape Irrigation in Florida*, as well as manufacturers' recommendations, to design the most appropriate system for a location. 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
    1. Water source
    2. Pump
    3. Filters
    4. Valves (including backflow valves)
2. Water conveyance
    1. Mainline
    2. Manifold
    3. Lateral lines
    4. Isolation valves

3. Distribution devices
    1. Impact, oscillating, and rotary sprinklers
    2. Sprayheads
    3. Microirrigation emitters
4. 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, which are always color-coded purple for reclaimed water systems, should provide the appropriate pressure required for maximum irrigation uniformity, and distribution devices should be designed for optimum uniform coverage. Isolation valves should be installed in key locations, so that a leak can be repaired while the rest of the system is still operational. It may seem obvious, but a distribution system should not be designed to irrigate nonplanted areas (such as driveways, parking lots, roads, sidewalks, roof overhangs, and natural buffer zones). An irrigation system should also be designed differently for play and non-play areas.

## ***Irrigation for Play Areas***

Irrigation for play areas should contain the following elements:

- **Computerized control systems** should be installed on all new sports field irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments for every zone. By adjusting the watering times based on actual site conditions for each zone, water can be conserved and used most efficiently. Appropriate cutoff devices should be installed so that line breaks do not cause a system to run excessively.
- **Weather stations** help turf managers 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 field 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**, when used, 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 spikes and surges) are infrequent, and if the turf manager has access to qualified technical support.
- **Heads and nozzles** should be selected to maximize the uniformity of coverage. The proper spacing of heads during field 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.

- The irrigation of **field edges and surrounds** should be designed to provide inward and outward sprinkler coverage for maximum efficiency and turf maintenance. With single-head coverage around the edges, the slopes are often watered unnecessarily, which wastes water.
- Additionally, **operational control of each head** around the field is preferred over systems that provide total 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 fields**. Irrigation heads need to be strategically placed to minimize the amount of water applied to surrounding areas. The soils used for these areas may be heavier and poorly drained, compared with the modified soils in playing surfaces. Surrounds may hold water better and may not need to be irrigated as frequently as a well-drained field.

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. For variable wind directions, triangular spacing is more uniform than square spacing. Practical experience may suggest closer spacing than the guidelines. After the system is constructed and operating, periodic "catch can" uniformity tests should be performed (see the section on Irrigation Management).

## ***Irrigation for Non-play Areas and Landscape Plantings***

Non-play areas include aesthetic turf around facilities, 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* (Available: https://ffl.ifas.ufl.edu/professionals/BMP_manual.htm). 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 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.

**Best Management Practices for Irrigation System Design:**

1. Application Rate Management
   - Must not exceed soil absorption and retention capacity
   - Consider soil type and infiltration rates
   - Account for slope and runoff potential
2. Operating Pressure Considerations
   - Design pressure must not exceed source pressure
   - Account for peak use times
   - Consider supply line pressures at final buildout

- Include pressure regulation where needed

3. Distribution System Design

    - Design for optimum uniform coverage
    - Limit flow rate difference to 10% between first and last distribution device
    - Maintain pressure difference within 20%
    - Zone turf and landscape areas separately
    - Space heads for head-to-head coverage in turf areas

4. System Flexibility

    - Design to meet peak water requirements
    - Allow for seasonal irrigation changes
    - Accommodate local restrictions
    - Include manual quick coupler valves near playing surfaces

5. Technical Specifications

    - Flow velocity must be 5 feet per second or less
    - Include thrust blocks and air-release valves
    - Use check valves in low areas
    - Install isolation valves in key locations
    - Avoid irrigating nonplanted areas
    - Use part-circle heads along edges

## 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 DEP *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.

**Best Management Practices for Irrigation System Installation:**

1. Only qualified specialists should install the irrigation system.
2. Construction must be consistent with the design.
3. The designer must approve any design changes before construction.
4. Construction and materials must meet existing standards and criteria.
5. Acceptable safety practices must be followed during construction.
6. Prior to construction, identify and flag all underground cables, pipes, and other obstacles
7. Spare hydraulic tubing and electrical wiring should be installed during construction for rapid repairs in case of leaks, breaks, and short circuits.

8. Remote field controllers should be grounded according to code.
9. Provide owner with as-built plans, operating manuals, and warranties, as well as written instructions on how to change the irrigation system's timers, clocks, and controllers.
10. 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 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, turf managers 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. Sports facility owners are legally bound to abide by any and all restrictions placed on irrigation. Failure to comply can result in punitive action by the districts.

It is also important to abide by the CUP/WUP granted to the facility. 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.

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, facility users, and the public should be maintained to explain what you are doing and why.

## ***Irrigation Scheduling***

Before a turf manager 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 facility. The use of soil moisture probes, inspections for visual symptoms such as wilting turf, computer models, and tensiometers may supplement these measurements. Computerized displays are available to help visualize the system.

Water loss rates decrease with reduced solar radiation, minimal wind, high relative humidity, and low air temperatures. A turf manager 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 most sports turf, the majority of roots are in the top 6 inches of soil. Irrigate to wet this depth unless the root zone extends deeper. 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 good practice used for low-maintenance areas, such as practice fields or out-of-bound areas. Managers of competition fields 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 programs. 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.

***Soil Moisture Probes***

Soil moisture probes are now commonly used by sports turf managers to measure soil moisture across a range of soil conditions. Newer versions of these instruments can also measure electrical conductivity

(EC) indicating the level of salt in the soil and canopy temperature. Coupled with GPS technology and mapping software, turf managers can easily identify areas of concern.

***Irrigation Control with Feedback***

Irrigation control with feedback simply means that the control system receives feedback from a single sensor, or multiple sensors dispersed across the facility. 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 sports field irrigation systems.

Many types of soil moisture sensors have become commercially available. 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 aerification 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.

***Evapotranspiration-based Control Systems***

ET-based control systems have been available for many years. The oldest type, consisting of a full weather station that interfaces with a controller for a large, irrigated area. 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 (https://onerain.com/) high-resolution, gage-adjusted Doppler radar rainfall data may be used to provide spatially distributed irrigation scheduling.

## ***Operating Older Systems***

Not all sports facilities are so fortunate as to have a modern irrigation system or smart controllers.

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 important. These principles may be applied to any facility 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.

**Best Management Practices for Irrigation Operation:**

1. **Irrigation Scheduling Based on Water Needs**
    - Operate the system based on the moisture requirements of the turfgrass (or other plants), ensuring that irrigation aligns with actual water needs.

- When applicable, coordinate irrigation with fertilizer or chemical applications per label directions to optimize resource use and minimize runoff.

2. **System Calibration and Auditing**
    - Regularly calibrate the system by conducting irrigation audits. This ensures water delivery meets design specifications and helps verify nozzle performance and uniformity.
3. **Utilization of Sensors and Automation**
    - Install rain sensors that automatically shut off the system when a specified amount of rainfall (typically ¼ to ½ inch) is received.
    - Integrate pressure sensors (both high and low) to detect malfunctions or breaks and automatically halt operations, minimizing water waste and system damage.
    - Where possible, use computerized systems that allow remote cancellation of programs when weather conditions provide adequate moisture.
4. **Daily Monitoring and Record Keeping**
    - Perform daily inspections to identify any malfunctions, breaks, or inefficiencies in the system.
    - Log water usage and system performance data daily. These records are valuable for adjusting irrigation schedules during droughts and for long-term system evaluation.
5. **Optimizing Irrigation Application**
    - Apply irrigation quantities that do not exceed the soil's moisture storage capacity in the root zone, and ensure the rate of application does not surpass the soil's absorption capacity.

    - For granular fertilizer applications, apply enough water (typically about ¼ inch) to wash particles off foliage while minimizing runoff.

6. **Integration with Cultural Practices**
    - Whenever possible, align irrigation with other cultural practices (e.g., mowing, nutrient, or herbicide applications) to promote healthy turfgrass development and encourage deep rooting, which can reduce overall water requirements.

## System Maintenance

Irrigation system maintenance on a sports field 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 must 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 sports field 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.

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

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

   AAR = (Average can volume [mL] x 4.66) / (Can area [in2] x Time [min])

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 = Average of low quarter / Average of all cans

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

Effective Application Rate = AAR x Distribution Uniformity

Adjust the schedule based on the effective application rate, and implement all repairs needed to improve distribution uniformity.

The Irrigation Association website provides a webtool for identifying a certified professional irrigation auditor (Available: https://www.irrigation.org/IA/Certification/Hire-Certified/Find-a-Certified-Professional/IA/Certification/Find-a-Certified-Pro.aspx?hkey=d5c9649e-1170-4d09-8a78-401808ed0ccb). Additionally, the IA provides useful irrigation audit policies, procedures, and worksheets on their website (Available: https://www.irrigation.org/IA/Certification/Landscape-Certifications/CGIA/IA/Certification/CGIA.aspx).

## Irrigation System Maintenance

Effective maintenance of an irrigation system is critical for ensuring optimal performance, extending equipment life, and preventing costly repairs or renovations. A comprehensive maintenance program combines proactive, preventive practices with prompt corrective actions, supported by detailed recordkeeping.

**Best Management Practices for Irrigation System Maintenance and Management:**

1. **Daily and Weekly Inspections:**
    - Conduct daily visual inspections and review computer logs to ensure proper operation of pumps, valves, controllers, and sprinkler heads.

- Observe system operations weekly—either during scheduled maintenance activities or through brief operational tests—to detect issues such as misaligned or inoperable heads, leaks, and chronic wet or dry spots.

2. **Scheduled Maintenance Procedures:**
   - Follow manufacturer recommendations for routine maintenance of pumps, valves, fittings, and sprinkler components.
   - Perform annual checks on application/distribution efficiencies and replace worn components before they lead to resource waste.
3. **System Calibration and Auditing:**
   - Regularly calibrate the system and conduct periodic professional irrigation audits (at least once every few years) to ensure proper water delivery and system performance.
4. **Infrastructure and Component Documentation:**
   - Keep detailed records of equipment run-time hours, lubrication, overhauls, and all maintenance activities.
   - Document the condition of infrastructure elements such as pipes, wires, and fittings, and investigate recurring issues that might indicate larger problems (e.g., pump station issues, corrosion, rodent damage, or electrical surges).
5. **Monitoring Water Usage:**
   - Log the amount of water applied (including system usage and rainfall) to identify opportunities for improvement and to support cost analysis for potential future renovations.
6. **Timely Corrective Maintenance:**

- Address day-to-day failures promptly by cleaning clogged nozzles, realigning heads, or performing minor repairs before the next scheduled irrigation cycle.
- Replace or repair broken or worn components with parts that match the original specifications to maintain system integrity.

7. **Recordkeeping for Continuous Improvement:**
    - Document all corrective actions taken. These records help identify patterns of recurring issues and inform future maintenance or upgrade decisions.

## System Renovation

As maintenance costs increase, the question of whether to renovate arises. Renovating an irrigation system 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 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 facility with other personnel gives you a starting point.
- 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 does not 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:

1. Updating control systems,
2. Improving field coverage,
3. Improving coverage on surrounds and other areas,
4. Repairing/replacing elements of the system infrastructure,
5. Repairing/replacing the pump station, and
6. All the above.

As you begin to identify areas or reasons for upgrading, you will need to find appropriate professionals (such as irrigation designers 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 facility 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.

# SECTION 5:  NUTRIENT MANAGEMENT

Fertilization programs for sports field grasses require ample nutrients for optimum growth and performance quality but must also protect Florida's fragile environment.  Proper nutrient management plays a key role in the reduction of environmental risk and increases can significantly impact facility finances. Trying to improvise one fertilization schedule that encompasses all facilities within the state is unrealistic.  Field performance, 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 coaches, athletes, and program supporters.

Among other benefits, applied nutrients inflate the available pool of nutrients and allow turfgrass to recover from damage, increase its resistance to stress, and increase its playability. However, the increase in available nutrients also increases the potential risk of environmental impact. 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 sports facilities.  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 goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant uptake.

## Regulatory Considerations

The state of Florida has unique and delicate ecosystems consisting of waterways flowing above and below ground. Florida's sports fields with healthy turf can serve as nature's best water filter for these systems. Florida Sports Turf Managers, through the proper use of nutrients, can ensure a positive impact. Planning, practicing and recording applications, following the 4Rs (Right Place, Right Time, Right Source, and Right Rate) and teaching others are key to the successful harmony. Rules and regulations have been put in place around the state regarding fertilizer use and applications. The goal of a sports field manager is to not only comply but to go above and beyond regulations with the Florida Sports Turf BMPs.

It is the personal responsibility of Florida Sports Field Managers to know, understand, and follow state and local laws pertaining to fertilizer and fertilizer applications. Understand fertilizer. Know the laws. Follow the rules.

## Soil Testing

Although it may not be an essential practice for the everyday maintenance of a healthy sports fields, testing to determine the soil's chemical properties before installing turfgrass is recommended. For Florida turfgrasses, soil testing can be used to diagnosis or manage issues associated with pH, salinity, sodicity, phosphorus (P), potassium (K), or magnesium (Mg). After initial soil testing, additional testing may be required only when fertility problems arise and the responses to fertilization are poor. 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 turfgrass response. The amount of nutrients extracted by a particular extractant is only an index relative to turfgrass response, but because correlation response studies have not been conducted on Florida turfgrasses, the value of soil test recommendations is limited.

## ***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 5-1). 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.

**Figure 5-1. 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 soil testing laboratory for chemical analysis. You should use the same laboratory on a continued basis to establish a historical log of your soil properties. Laboratories across Florida may not use the same extractant, so if you change labs often you may be comparing results obtained by different methods.

## ***Soil Test Interpretation***

A soil analysis supplies valuable information on a soil's nutritional status and can detect potential problems that limit plant growth. As noted, a routine soil analysis supplies information on the soil pH, salinity, sodicity, P, K, and Mg status of the soil. Soil testing labs may analyze and provide fertilizer recommendations for other variables such as nitrogen (N), Calcium (Ca), sulfur (S), boron (B), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). However, these fertilizer recommendations are not based upon current evidence and therefore following soil test recommendations for these elements is not a best management practice. Additionally, soil test recommendations based upon the basic cation saturation ratio (BCSR) method have been proven to be inaccurate and, therefore applying nutrients based upon the BCSR method is also not a best management practice. Many turfgrass managers have chosen to utilize the sufficiency level of available nutrients (SLAN) or the minimum level of sustainable nutrition (MLSN). These soil test interpretations are supported by evidence, but it is important to realize that the fertilizer recommendations are based upon soil samples collected across a wide range of locations and soils. Thus, SLAN and MLSN recommendations are not specific to Florida and may greatly differ from University of Florida recommendations. Therefore, following the UF/IFAS soil test recommendations is the best management practice for Florida turfgrasses.

### ***Soil Acidity***

Soil reaction, or pH, is important because it influences several soil factors that affect plant growth. Soil bacteria that transform and release N from organic matter function best in the pH range of 5.5 to 7.0; certain fertilizer materials also supply nutrients more efficiently in this range.

Plant nutrients, particularly P, K, Ca, Mg, B, Cu, Fe, Mn, and Zn, are generally more available to plants in the pH range of 5.5 to 6.5. Often, these plant nutrients are more available to plants at pH values below 5.5 than in soils with pH values above 6.5. However, in certain soils, when the soil pH drops below 5.0, aluminum (Al) may become toxic to plant growth.

Turfgrasses differ in their adaptability to soil acidity. For example, centipedegrass and bahiagrass grow better in an acid environment (pH 5.0 to 6.0) than St. Augustinegrass or zoysiagrass, which grow best in near neutral or alkaline soils (pH 6.5 to 7.5) (Figure 5-2).

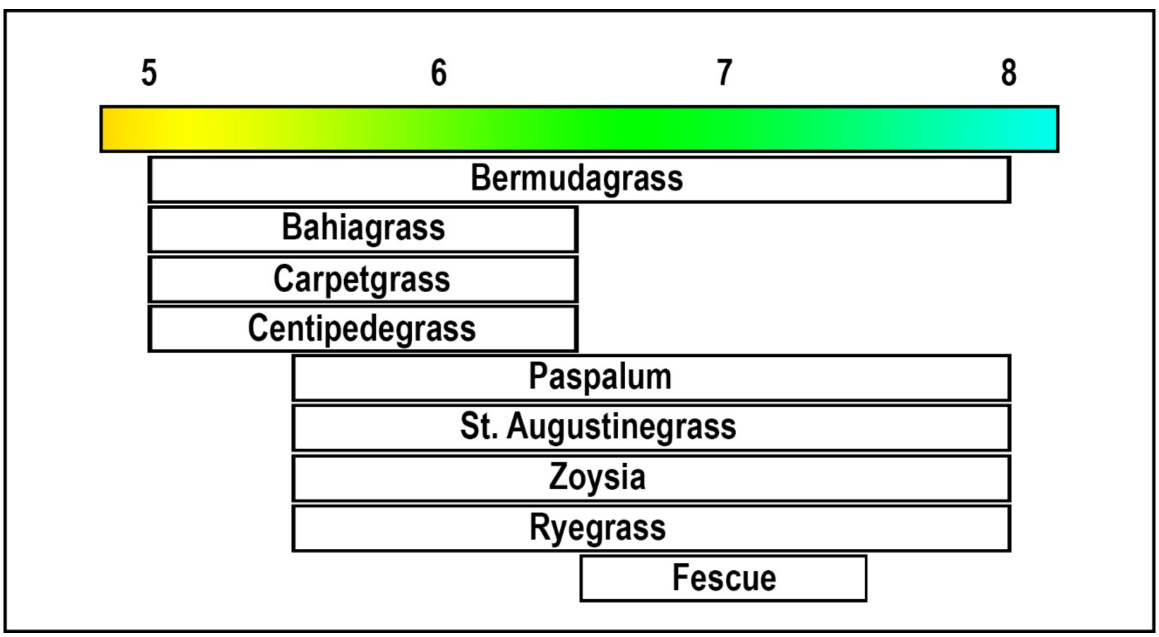



**Figure 5-2. Soil pH ranges for Florida turfgrasses.**

### *P, K, and Mg*

For Florida turfgrasses, the Mehlich III extracted P, K, and Mg are categorized as 'sufficient' if the values are equal to or greater than 20, 30, and 20 ppm, respectively. Thus, in Florida, a soil test can tell you when *not* to apply P, K, and Mg, but a soil test cannot tell you how much to apply when the soil test value is below the critical soil level. This is due to the previously mentioned lack of calibration data between soil test nutrient levels and a measured response to the application of a given element. Some soil tests may recommend P, K, and Mg application rates based upon the conversion of parts per million to pounds per acre. Theoretically, this method would increase the existing soil level to the recommended minimum. Unfortunately, this method also has not been correlated with a measured turfgrass response and, thus this method is not a best management practice. Rather than relying upon non-evidence-based soil test recommendations to apply P, K, and Mg, UF/IFAS utilizes the soil test minimum values in combination with known turfgrass responses (Table 5-1).

Table 5-1. UF/IFAS soil test recommendations for P, K, and Mg based upon the Mehlich III soil test extractant and documented turfgrass responses.

| Nutrient | Critical Concentration | < Critical Concentration | > Critical Concentration |
|---|---|---|---|
| P | 20 | Apply 0.5 lb of $P_2O_5$/1,000 sq. ft. once. | No response to P expected |
| K | 30 | Apply K at a N:K ratio of 2:1 to 1:1 for most sports fields. | No response to K expected |
| Mg | 20 | Rate unknown | No response to Mg expected |

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 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).

**Best Management Practices for Soil Testing:**

1. Collect soil samples accurately and consistently to provide useful soil test information over time.
2. Divide the facility into logical components such as each baseball or softball field, football field, or soccer pitch, etc.
3. Collect 10 to 15 soil samples randomly from each section and blend together to provide a representative soil sample.
4. Collect soil samples from the same depth (4 inches).
5. Use the same extractant for each test to compare soil test results over time.
6. Only use soil test results to manage pH, salinity, sodicity, P, K, and Mg.
7. In most case, you can reduce or eliminate the application of P, K, and Mg when Mehlich III soil test critical values are equal to or greater than 20, 30, and 20 ppm, respectively.
8. Keep soil tests from prior years to allow you to observe changes over time.

## Tissue Testing

Because of the mobility of most essential nutrients for turfgrass growth in Florida soils, one of the best indicators of appropriate fertilization and plant 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 nutrient analysis provides an estimation of what will be available for plants throughout the upcoming growing season, whereas, tissue analysis offers a precise measurement of nutrients in the turfgrass leaf tissue at the time of sampling. 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 (Figure 5-3). 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.

**Figure 5-3. Turfgrass leaf tissue can be collected during normal mowing.**

If facilities exist at your location, dry the collected clippings at approximately $70^{o}$ C ($158^{o}$ F) for 24 hours, and then mail them to your preferred 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 nutritional purposes or fungicides 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***

Multiple methods are used to interpret turfgrass tissue nutrient values. However, UF/IFAS turfgrass faculty prefer to use a method referred to as 'reference ranges.' Reference ranges provide the range of nutrients that exist in healthy turfgrass . Reference ranges are applicable to turfgrasses because they utilize turf quality as the primary metric rather than yield. UF/IFAS turfgrass faculty have developed reference ranges for St. Augustinegrass and short cut (~0.5") bermudagrass (Table 5-2). When a turfgrass nutrient concentration is outside of the reference range, that nutrient becomes of greater concern of limiting turf quality. Once a nutrient level drops below the reference range, an application of that nutrient may be warranted. When nutrient concentrations exceed the reference range, the turfgrass may be receiving excessive or toxic levels of that nutrient and a reduction in that nutrient may be recommended. 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 reference range. This nutrient management strategy leads to proper fertilization and a reduction in possible adverse environmental and economic impacts.

| Table 5-2. Nutrient ranges for warm-season turfgrass species. | | | | | |
|---|---|---|---|---|---|
| | Bermudagrass* | St. Augustinegrass* | Seashore Paspalum** | Centipedegrass** | Zoysiagrass** |
| | ---------- % ---------- | | | | |
| N | 1.95-4.63 | 1.53-2.41 | 2.80-3.50 | 1.5-2.9 | 2.04-2.36 |
| P | 0.15-0.43 | 0.30-0.55 | 0.30-0.60 | 0.18-0.26 | 0.19-0.22 |
| K | 0.43-1.28 | 1.1-2.25 | 2.00-4.00 | 1.12-2.50 | 1.05-1.27 |
| Ca | 0.15-0.63 | 0.24-0.54 | 0.25-1.50 | 0.50-1.15 | 0.44-0.56 |
| Mg | 0.04-0.10 | 0.20-0.46 | 0.25-0.60 | 0.12-0.21 | 0.13-0.15 |
| S | 0.07-0.20 | 0.15-0.48 | 0.20-0.60 | 0.20-0.38 | 0.32-0.37 |
| Na | 0.05-0.17 | 0.00-0.17 | - | - | - |
| | ---------- ppm ---------- | | | | |
| Fe | 29.99-131.23 | 8.32-137.16 | 50-500 | 102-221 | 188-318 |
| Mn | 6.82-29.78 | 47.53-183.17 | 50-300 | 35-75 | 25-34 |
| Zn | 15.60-44.96 | 30.93-73.73 | 20-250 | 17-40 | 36-55 |
| Cu | 0.00-15.17 | 0.0-15.79 | 5-50 | 2-7 | 2-4 |
| B | 0.00-16.32 | 0.69-9.05 | 5-60 | 5-10 | 6-11 |
| Mo | - | - | 0.5-1.0 | 0.14-0.30 | 0.12-0.30 |
| Al | 5.01-26.37 | 0.00-206.08 | - | - | - |
| * Reference ranges – nutrient ranges of 95% of acceptable turfgrass in Florida. | | | | | |
| ** Sufficiency ranges (Bryson et al., 2014) | | | | | |

For more information, see your county Cooperative Extension Service agent or the publication, *Tissue Testing and Interpretation for Florida Turfgrasses* (available: http://edis.ifas.ufl.edu/ep539).

**Best Management Practices for Tissue Testing:**

1. Collect tissue samples during regular mowing.
2. Collect tissue prior to any potential contamination event including fertilization, topdressing, pesticide applications, etc.
3. Place tissue in paper bags, not plastic.
4. Allow tissue samples to air-dry at your facility before mailing them, if possible.
5. Sample poor-quality turfgrass separately from higher-quality turfgrass.
6. Collect a tissue sample at the first sign of nutrient stress.
7. Sample tissue frequently to allow a more accurate assessment of your turfgrass nutrient status changes over time.
8. Tissue sampling one to two times per year will suffice for most sports fields.
9. Keep tissue tests from prior years to allow you to observe changes over time.

Efficient nutrient management programs are created with a fundamental understanding of the Florida fertilizer label, fertilizers, and the role of each nutrient in the plant. Some nutrients are sufficient in nature and do not require additional applications to achieve acceptable playing conditions, whereas other nutrients are limited in nature and may require regular applications to sustain acceptable turfgrass. Additionally, many elements are not elements of environmental impairment, whereas other elements can alter our ecosystem, if improperly managed. This section provides the basic information necessary to make informed decisions regarding nutrient applications to Florida sports fields.

## The Florida Fertilizer Label

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 N, P, and K guaranteed by the manufacturer to be in the fertilizer. Nitrogen is expressed as N, available phosphate as $P_2O_5$, and soluble potash as $K_2O$. The percent sign is not used, but instead the numbers are separated by dashes, and the order is always N, $P_2O_5$, and $K_2O$ (for example, 15-0-15).

Florida law requires that the manufacturer purchase and affix a label to each bag, package, container, or lot of fertilizer offered for sale in the state. The law requires that each label shows specific information about the analysis and composition of the mixture or material. More detailed information on this topic can be found at https://edis.ifas.ufl.edu/publication/SS170.

Once the value of soil testing, tissue testing, and the fertilizer label is understood, a basic knowledge of the role and fate of applied nutrients in the turfgrass system is essential to efficient nutrient management. The primary macronutrients—nitrogen, phosphorus, and potassium (N, P, and K, respectively)—receive the greatest attention because they are needed in the greatest quantities in plants and can be deficient in the soil and often require regular applications to sustain acceptable turfgrass. Golf and athletic turfgrass is responsible for only 5% of the total amount of N applied in Florida. Despite having a low N footprint, sports field managers must handle N with care to minimize any environmental risk. Excessive nutrients can lead to algal blooms and stimulate the growth of noxious plants in lakes and streams leading to reduced oxygen available for game fish such as bass and sunfish.

**The Role of Plant Nutrients**

Plants require 17 essential nutrients for healthy growth, which are divided into macronutrients and micronutrients. The macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Micronutrients needed in smaller amounts include iron, manganese, zinc, copper, boron, molybdenum, chlorine, and nickel. Each nutrient plays a specific role in plant functions such as photosynthesis, enzyme activity, and cell structure.

## ***Nitrogen***

### *The Role of Nitrogen*

Nitrogen is one of the most important elements turf managers apply to turfgrasses. Turfgrass almost always responds to N applications by increasing growth and green color. The soil supply of N is low and the turfgrass demand is high because N is required to create amino acids and proteins, is part of the plant's DNA and RNA, and plant hormones.

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 field performance. Turf managers often measure N needs based on turf color, density, clipping amount, and recovery from injury. However, it is the effect of N on other aspects of turf management that often influences a turf manager's success or failure.

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 energy produced through 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 general, N has a direct impact on turf growth and recovery from injuries such as divots and traffic injury. 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.

***Fate and transformation of N***

Turfgrass Uptake

Nitrogen in Florida turfgrass systems is very dynamic meaning that there are many processes that influence its availability to plants and fate in the environment (Figure 5-4). The objective of all N applications to turfgrass is to maximize turfgrass uptake and the resulting increase in turfgrass growth, quality, and performance while limiting its losses to the environment. More information on the fate of nitrogen can be found at https://edis.ifas.ufl.edu/publication/EP546.

Numerous factors may influence turfgrass uptake of N including but not limited to: turfgrass species, season, N type, N rate, and moisture management.

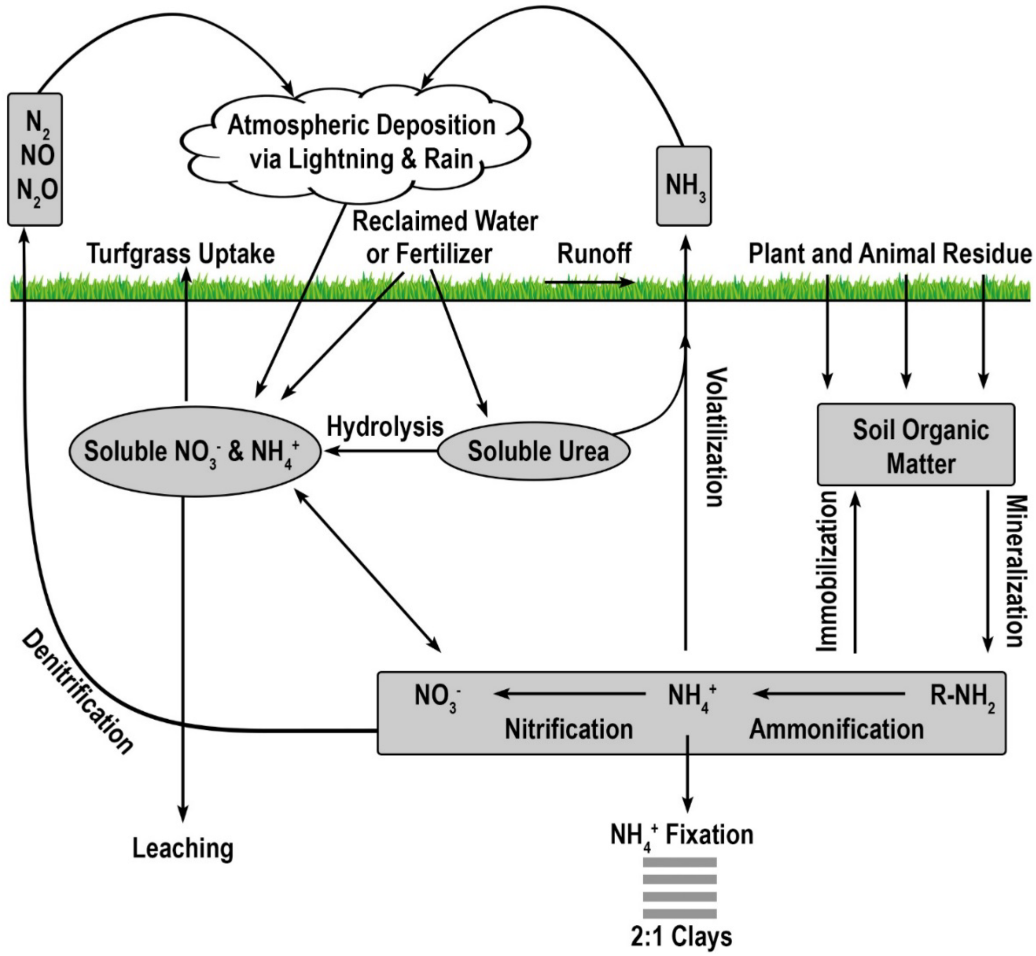



**Figure 5-4. The nitrogen cycle in Florida turfgrass systems.**

Like most plants, the change in climatic seasons can have a dramatic influence on plant growth and nutrient uptake. During the winter in northern Florida, most warm-season turfgrasses will exhibit a decrease in growth and may enter dormancy. Even in southern Florida, reduced turfgrass growth will occur during the winter but true dormancy has not been reported. As turfgrass growth declines, the amount of N needed by the turfgrass also declines. Thus, uptake of applied N can be lower in the winter than in the summer. Therefore, the agronomic advantages to applying N to dormant turfgrasses are low relative to the environmental risk.  Thus, N applications to dormant or semi-dormant turfgrasses in Florida is not recommended.

A driving factor behind UF/IFAS nutrient recommendations to turfgrass is to apply the amount of N necessary to achieve a desired turfgrass response without applying more N than the turfgrass can consume at any given time.  When UF/IFAS recommended N rates are followed, turfgrass uptake of applied N ranges from 40-68%. When small quantities of N are applied, very little N has an opportunity to escape turfgrass assimilation.  As rates of soluble N increase, the amount of N recovered in turfgrass tissues decreases.  However, slow-release N sources often require higher application rates compared with soluble N sources to achieve the same desired turfgrass response because only a small portion of the slow-release N will become soluble daily.  Consequently, higher rates of slow-release N sources may result in greater percent uptake of applied N than lower rates.  Additionally, a single application of slow-release N at a high rate may result in the same N uptake as soluble N applied as a split application. Therefore, slow-release N sources may be applied at higher rates than soluble N sources so long as the single application rate and total annual N applied do not exceed UF/IFAS recommendations.

Moisture management greatly influences plant uptake of applied N.  Most N is taken up by the plant via the soil solution.  Thus, when the soil water content exceeds the soil water holding capacity, N in the soil solution may be moved below the rootzone, which results in reduced plant uptake.  Conversely, when insufficient water is applied, the turfgrass may enter a state of drought-induced dormancy in which the turfgrass reduces water and N uptake to survive.  Thus, careful consideration should be given to applying sufficient water to maintain acceptable turfgrass, but not applying more water than can be retained by the soil. Generally, rain sensors, soil water sensors, and evapotranspiration-based irrigation controllers apply water more effectively than automatically timed controllers.

Runoff

Another potential loss comes from runoff. Runoff is defined as the lateral movement of N beyond the target location. Runoff may occur above or below the soil surface but always occurs above the deepest root. Nitrogen lost via runoff may be influenced by topography, soil type, soil compaction, soil moisture, rainfall, and fertilizer type. Because Florida soils are predominantly sand-based and have a high water infiltration capacity, the movement of water across the soil surface (runoff) is far less common than the movement of water down into the soil (leaching).

Leaching

Nutrient leaching is of particular concern because it moves soluble N below the turfgrass root zone and into ground water resources. Factors such as turfgrass species, N source and rate, irrigation practices, and turf stress influence the extent of N leaching. Deeper-rooted turfgrasses and practices like deep, infrequent irrigation help reduce leaching by encouraging root development. UF/IFAS recommends delaying N applications until 60 days after sod planting to allow root establishment and minimize N loss. Excessive irrigation or seasonal rainfall can increase leaching, but sensor- or ET-based irrigation significantly reduces this risk. To further prevent leaching, UF/IFAS recommends refraining from applying any N when the National Weather Service has issued a flood, tropical storm, or hurricane watch or warning, or if heavy rains are likely. These recommendations reduce the risk of exceeding the soils water retention capacity and, in turn, reduce N leaching. Increasing the rate of applied N beyond the rate recommended by UF/IFAS can increase the risk of N leaching losses. UF/IFAS turfgrass nutrient recommendations consider the turfgrass need for N and the potential impact on the environment. UF/IFAS nutrient recommendations are often 50-75% less than the amount of N necessary to increase N leaching losses above the natural environment. Thus, current rates are considered conservative and exceeding these rates is unnecessary because any further increase in turfgrass growth or quality is minimal and could come at a cost to the environment.

***Nitrogen Sources***

High quality turfgrasses can be produced using virtually any N fertilizer. The primary difference between N sources is their cost, their release characteristics, and their influence on environmental risk. Understanding how certain N sources should be blended and applied is an essential component in an efficient nutrient management plan. In many cases, N sources are applied without regard to their release characteristics. This is an improper practice and increases the risk of negative environmental impact. Each N source (particularly slow-release forms) is unique and therefore should be managed accordingly. Applying a polymer-coated urea in the same manner one would apply a sulfur-coated urea greatly reduces the value of the polymer-coated urea. Similarly, applying 2 pounds of N from ammonium sulfate may cause burning, while applying 2 pounds of N from certain polymer-coated ureas may not provide the desired turfgrass response. Rate, application date, location, and turfgrass species all should be included in your nutrient application decision.

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.

### 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.*
- *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 turfgrass response may be observed.*
- *Greater potential for N loss from volatility, leaching, and runoff.*

To overcome some of the disadvantages of soluble N sources, fertilizer manufacturers have developed an array of slow- or controlled-release products (Table 5-3). 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 potential is 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. For more information on N fertilizer sources for turfgrasses, see the publication: *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: http://edis.ifas.ufl.edu/LH014).

Table 5-3. Guaranteed analysis, salt index, and acidifying effect of common raw materials used in granular and liquid fertilizer blends for turfgrasses.

| | | | N-P-K | Other Nutrients | Salt Index | Relative Acidifying Effect |
|---|---|---|---|---|---|---|
| N | Soluble | Ammonium Nitrate | 34-0-0 | | 105 | 59 |
| | | Ammonium Sulfate | 21-0-0 | | 69 | 110 |
| | | Diammonium Phosphate | 18-46-0 | | 34 | 64 |
| | | Monoammonium Phosphate | 10-50-0 | | 30 | 56 |
| | | Calcium Nitrate | 15-0-0 | | | -20 |
| | | Potassium Nitrate | 13-0-44 | | 74 | -26 |
| | | Sodium Nitrate | 16-0-0 | | 100 | -29 |
| | | Urea | 46-0-0 | | 75 | 84 |
| | Slow-Release | Urea Formaldehyde | 38-0-0 | | | |
| | | Methylene Urea | 40-0-0 | | | |
| | | Isobutylidene Diurea | 31-0-0 | | | 57 |
| | | Polymer-coated Urea | Variable | | | 80 |
| | | Sulfur-coated Urea | Variable | | | 110, variable |
| | | Biosolids | Variable | | 3.5 | 10 |
| | | Natural Organics | Variable | | 3.5 | 10 |
| | Liquids | Methylene Urea | 28-0-0 | | | |
| | | Triazone | 28-0-0 | | | |
| | | Ammonium Polyphosphate | 10-34-0 | | | |
| | | Ammonium Thiosulfate | 12-0-0 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sprayable<br>Powders | Methylene Urea | 41-0-0 | | | |
| | | Urea Formaldehyde | 38-0-0 | | | |
| P | Soluble | Ordinary Superphosphate | 0-20-0 | | 8 | 0 |
| | | Concentrated Superphosphate | 0-46-0 | | 10 | 0 |
| | | Phosphoric Acid | 0-55-0 | | | |
| | | Superphosphoric Acid | 0-72-0 | | | |
| | | Monoammonium Phosphate | 11-48-0 | | 30 | 56 |
| | | Diammonium Phosphate | 18-46-0 | | 34 | 64 |
| | Slow-Release | Natural Organics | Variable | | | |
| | | Polymer-Coated | Variable | | | |
| K | Soluble | Potassium Chloride | 0-0-62 | | 116 | 0 |
| | | Potassium Sulfate | 0-0-52 | | 46 | 0 |
| | | Potassium Magnesium Sulfate | 0-0-022 | | 43 | 0 |
| | | Potassium Nitrate | 13-0-44 | | 74 | -26 |
| | Slow-Release | Polymer-Coated | Variable | | | 0 |
| Ca | Soluble | Limestone (calcitic) | 0-0-0 | Ca = 40 | | |
| | | Limestone (dolomitic) | 0-0-0 | Ca = 21; Mg = 13 | | |
| | | Hydrated Lime | 0-0-0 | Ca = 54 | | |
| | | Gypsum | 0-0-0 | Ca = 23 | | |
| | | Calcium Nitrate | 15-0-0 | Ca = 24 | | |
| | | Ordinary Superphosphate | 0-20-0 | Ca = 20 | | |
| | | Concentrated Superphosphate | 0-46-0 | Ca = 13 | | |
| Mg | Soluble | Limestone (dolomitic) | 0-0-0 | Ca = 21; Mg = 13 | | |
| | | Magnesium Oxide | 0-0-0 | Mg = 55 | | |
| | | Magnesium Sucrate | 0-0-0 | Mg = 45 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Magnesium Sulfate | 0-0-0 | Mg = 10 | | |
| | Slow-Release | Kieserite | 0-0-0 | Mg = 18 | | |
| | | Polymer-Coated | Variable | Mg = Variable | | |
| Fe | Soluble | Iron Sulfate | 0-0-0 | Fe = 20 | | |
| | | Iron EDTA | 0-0-0 | Fe = 10 | | |
| | | Iron DTPA | 0-0-0 | Fe = 10 | | |
| | | Iron EDDHA | 0-0-0 | Fe = 5 | | |
| | Insoluble | Iron Sucrate | 0-0-0 | Fe = 55 | | |
| | | Iron Oxide | 0-0-0 | Fe = 75 | | |
| | Liquid | Iron Gluconate | 0-0-0 | Fe = Variable | | |
| | | Iron Glucoheptonate | 0-0-0 | Fe = Variable | | |
| | | Iron Citrate | 0-0-0 | Fe = Variable | | |
| | | Iron Polysaccharide | 0-0-0 | Fe = Variable | | |
| Mn | Soluble | Manganese Sulfate | 0-0-0 | Mn = 27 | | |
| | | Manganese EDTA | 0-0-0 | Mn = 12 | | |
| | Insoluble | Manganese Sucrate | 0-0-0 | Mn = 35 | | |
| | | Manganese Oxide | 0-0-0 | Mn = 68 | | |

## ***Phosphorus***

Phosphorus (P) is a common component of many turfgrass nutrition programs. P has many functions within the plant including energy transfer. Most Florida soils contain large quantities of total P and, although total P has little to no relationship with plant available P, most Florida soils also contain an adequate supply of plant available P.

### ***Role of P***

Phosphorus has many functions, but the most essential function is energy transfer. Energy obtained during photosynthesis is stored in compounds and transferred to other parts of the plant. When these high-energy molecules are split, a relatively large quantity of energy is given off and used for various metabolic processes. Essentially every metabolic process in turfgrass development requires P.

P is absorbed by the plant as either $H_2PO_4^-$ or $HPO_4^{2-}$ (often referred to as orthophosphate or ortho-P) with the former more prevalent at low soil pH and the latter more prevalent at high soil pH.

P deficient turfgrass can appear different from other nutrient deficiencies. P deficient turfgrass may actually appear darker green, particularly on the older leaves. When darker green leaves are observed in conjunction with reduced growth, P deficiency may be the causeIf P deficiency progresses, older leaves may appear purple.

P is associated with increased root growth, particularly during the early stages of development. During these early stages, the turfgrass has a high demand for energy and very little ability to supply P due to insufficient root growth. Thus, applications of P during turfgrass establishment increase root production and turfgrass establishment. Special care should be given to the N:P ratio during establishment. Research on golf course putting greens suggests that a ratio of 5:2 increased establishment compared to a 1:0 N:P, whereas further increases of P above a 5:2 N:P may decrease establishment. The increase in turfgrass establishment through the application of P is also a function of the initial soil P value. Soil test P levels are used to indicate when P should <u>not</u> be applied. This holds true even during establishment. Although the exact soil P level required to establish turfgrasses on Florida soils remains unknown, P fertilizer applied during turfgrass establishment on soils with medium or high P levels (≥ 50 ppm) have resulted in no increase in turfgrass establishment.

***Soil Phosphorus***

Most Florida soils contain an adequate supply of available P to sustain acceptable turfgrass quality with some exceptions. Turfgrasses maintained at very low heights-of-cut grown on sand-based systems often encounter stresses that are atypical of grasses maintained at higher heights-of-cut. These stresses are often alleviated with the application of P and, thus, the use of P is often higher than other turfgrasses under these scenarios.

Available P is highest in soil solution when the pH is between 5.0 and 7.2 with maximum turfgrass uptake occurring at a soil pH of 6.5 (Figure 25). Below 5.0, P precipitates with Fe or Al and falls out of solution. Above 7.2, P may bind with Ca and become unavailable for plant uptakePlant available P is one reason why soil pH is a critical part of soil testing for turfgrasses.

Soil organic matter contains between 1% and 3% P but only a small fraction is already in the ortho-P (plant available) form and must be mineralized to become plant available. P mineralization rates have been documented to increase during the warmer summer months compared to the cooler winter months. Thus, for turfgrasses growing on soils with appreciable organic matter, less P fertilizer may be necessary during the summer months than the winter months. This dynamic is more magnified in the northern part of Florida where temperature fluctuations between winter and summer are greater than that of south Florida.

<u>Soil Testing for Phosphorus</u>

P soil tests for Florida turfgrasses has limited use. Soil test P values are often not calibrated to a turfgrass response, thus, applying specific amounts of P based upon a soil P test has been proven unreliable. However, soil test values may be used to indicate when P should not be applied. A Mehlich III soil test value ≥ 20 ppm indicates a turfgrass response to P is unlikely and, therefore, P may be omitted from nutrient applications without concern for a reduction in turfgrass quality or growth. When Mehlich III soil test values are below 20 ppm, P may be warranted, but the exact amount of P one should apply is questionable because soil test P values and a response to applied P have not been calibrated, as previously mentioned.

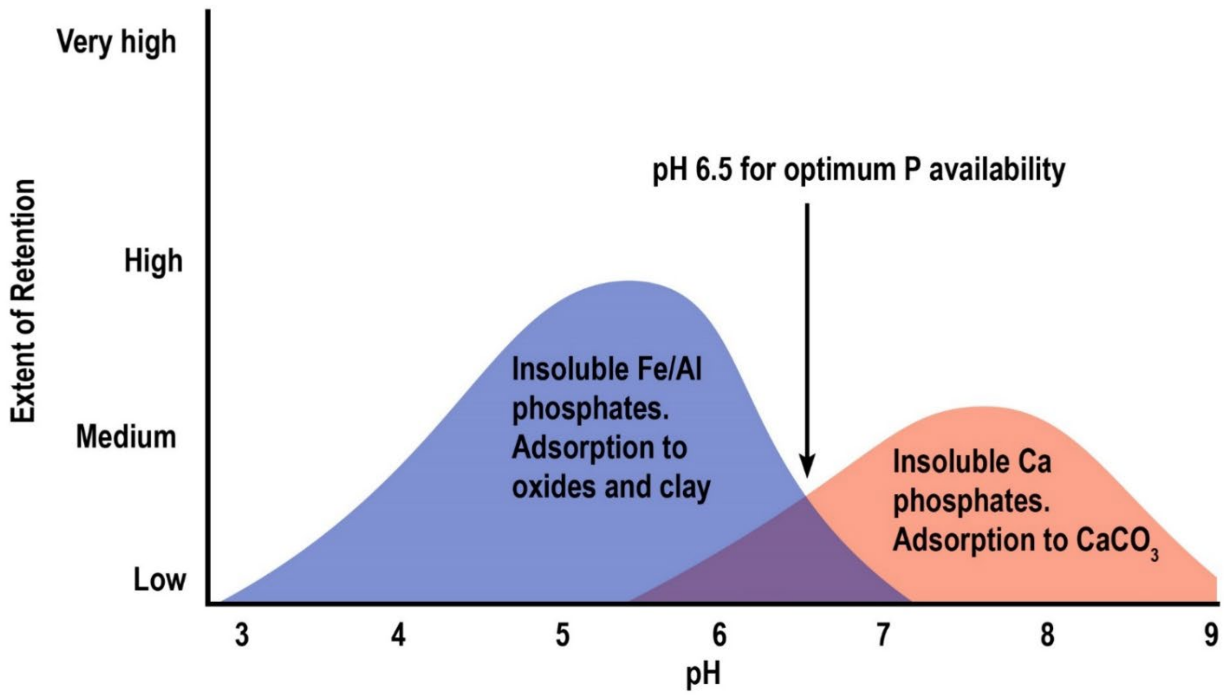



**Figure 5-5. Soil pH influences P solubility. (Stevenson, Cycles of Soil, p. 250, 1986)**

Sandy soils, such as those under many sports fields, 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-based systems.
In alkaline soils (pH > 7.5), calcium binds with P to render it unavailable. Applied P becomes less soluble over time and thus unavailable to the turf.

Fate of P

Soil reactions with P are very different than soil reactions with N (Figure 5-6). In the case of N, the primary source and sink of N is the atmosphere, whereas the source and sink of P is the soil itself. P may dissolve from primary and secondary minerals or enter the soil solution via mineralization from organic matter. Many Florida soils are rich with P and, in fact, Florida is one of the world's largest sources of phosphate rock. Once P has entered the soil solution, P may again become unavailable for plant uptake by precipitating into a secondary mineral or through immobilization by soil microbes.

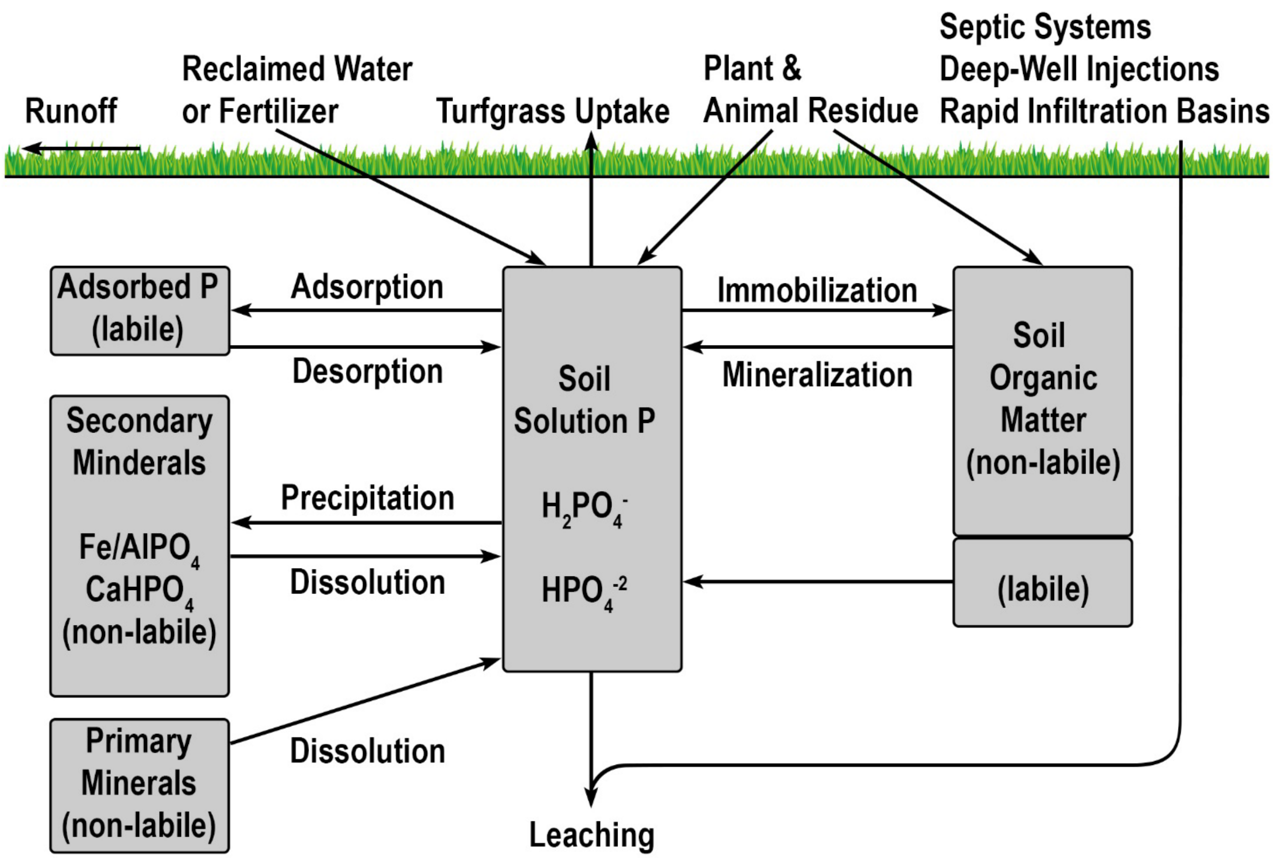



**Figure 5-6. The P cycle in Florida soils.**

When surface applied, P readily binds with Fe and Al at low pH and Ca at high pH. Thus, pH management highly influences the availability of P for turfgrass uptake. As one may expect, pH management also influences off-site movement of P. However, leaching and runoff of P do not readily occur except under specific conditions. Such conditions include soluble P applications to uncoated sands, soluble P applications immediately prior to a significant rain event, or natural organic fertilizer that is applied based upon the rate of N rather than P. P runoff is very rare but occurs when excessive rainfall results in soil erosion. The soil itself will have some P bound as secondary or primary minerals and can move off-site. Because healthy turfgrass is a deterrent to erosion, maintaining healthy turfgrass or other ground cover on slopes that lead to waterbodies can significantly reduce P runoff.

### *Tissue Testing for Phosphorus*

Tissue testing is a valid method to determine whether P is limiting turfgrass quality. Phosphorus concentrations in turfgrasses will vary depending upon the species and cultivar (Table 5-2). As previously mentioned, UF/IFAS utilizes reference ranges to determine the nutrient concentrations within 95% of acceptable turfgrass. When P concentrations fall below or exceed 95% of the acceptable population, P applications should be adjusted up or down, accordingly.

The true value of turfgrass tissue analysis for P is to indicate when P should *not* be applied. The lower P reference range for bermudagrass and St. Augustinegrass in Florida is 0.15% and 0.3%, respectively. When turfgrass P concentrations are greater than these values, P applications should be limited. When tissue P concentrations are below these values, an application of P may be warranted and the amount of P to apply should follow current UF/IFAS recommendations for establishing turfgrasses, which is no more than 1 pound of P per 1,000 sq. ft.

### *P Nutrient Sources*

When naturally available soil P is too low to meet the turfgrass needs, P may be applied as one of numerous P fertilizers. Nearly all P sources used in turfgrass management originated from mined P, usually apatite (a form of calcium phosphate). Once applied to the soil, P sources will have vastly different reactions in the soil. In most soils, P is immobile, and the solution concentration of P is highly dependent upon pH and P source, thus, an understanding of P source reactions is essential to maximize the efficient use of applied P.

<u>Ordinary and Triple Superphosphate</u>

Mined apatite is reacted with either sulfuric or phosphoric acid to form ordinary or triple superphosphate (OSP and TSP, respectively). OSP and TSP have a guaranteed analysis of 0-20-0 and 0-46-0, respectively. Both are highly water soluble and reduce the soil pH around the fertilizer particle to approximately 1.5. Thus, OSP and TSP are good sources of P on the high pH and calcareous soils of Florida. Conversely, if the soil pH is already near 5.0, OSP and TSP would be poor choices because the soil pH would be reduced below 5.0 resulting in a larger percentage of applied P becoming bound by Al or Fe.

<u>Monoammonium and Diammonium Phosphates</u>

Both monoammonium (MAP) and diammonium phosphate (DAP) are manufactured by reacting ammonia with phosphoric acid. MAP and DAP have guaranteed analyses of 11-48-0 and 18-46-0, respectively. MAP is less acidifying than OSP and TSP, but the soil pH directly around the fertilizer particle will still be around 3.5. Thus, MAP is a good choice for high pH soils.

DAP is the most used fertilizer on earth and is a good choice for acidic soils because the application of DAP results in a pH of 8.5 immediately around the fertilizer granule. When DAP is applied to high pH, calcareous soils, the P is immediately bound by Ca to form dicalcium phosphate and the N will volatilize because ammonium is highly soluble and easily converted to ammonia gas. Overtime, the soil pH will return to the initial soil pH due to the conversion of ammonium to nitrate (nitrification). However, in the time required to reduce the soil pH back to its initial level, much of the P and N will have been lost to precipitation and volatilization, respectively. When soil pH exceeds 6.5, volatilization of N from DAP can exceed 30% of applied N and can be 5x greater than that of MAP and 2x greater than that of urea and ammonium sulfate. Thus, DAP should not be used on high pH, calcareous soils. Unfortunately, DAP is regularly applied to Florida turfgrasses without consideration of soil pH because the cost of N and P in DAP results in a less expensive fertilizer blend than other combinations of N and P. This perceived savings is invalid due to the quantity of N and P that is lost after application on high pH soils.

Liquid Phosphorus

P may be applied as a liquid or as a foliar spray. Liquids are applied in water at 80 gallons per acre or higher, whereas foliar sprays are designed to remain on the leaf surface and are applied at lower rates near 40 gallons per acre. In either case, P in liquid form is usually as phosphoric acid. The ammoniated P sources previously mentioned may also be used as a liquid, but phosphoric acid is more common because it only contains P and it tends to be the least expensive liquid source. The P concentration of liquid P fertilizers vary greatly because the phosphoric acid must be diluted in water and may be blended with other components, particularly N and K.

Organic Phosphorus

Most, if not all, natural organic fertilizers are manufactured from plant, animal, or municipal wastes and contain a component of P. Typical P concentrations of organic fertilizers range between 1% and 7%. Organic P fertilizers contain both inorganic and organic P with the ratio of inorganic P:organic P varying widely depending upon the source.  However, on average, P in organic fertilizers is roughly 50% organic and 50% inorganic.  Thus, half of the total applied P would immediately contribute to soil solution P whereas, the remaining organic P requires mineralization to be converted to a plant-available form.

Natural organic fertilizers are often viewed more favorably than synthetic fertilizers due to a perceived reduction in environmental risk.  However, evidence indicates that natural organic fertilizers may increase environmental risk compared to synthetic fertilizers with respect to P.  Caution should be taken when using natural organic fertilizers to minimize the risk of P leaching and/or runoff.  When natural organic fertilizers are applied at rates sufficient to meet N needs, more P is applied than the turfgrass can utilize leading to excess P lost to the environment.  Thus, natural organic fertilizers should be applied as a supplemental N source or applied based upon the rate of P, without exceeding UF/IFAS recommendations.

For more information on P sources for turfgrasses, see the publication: *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: http://edis.ifas.ufl.edu/LH014).

## ***Potassium***

Potassium is an essential element not usually associated with a prominent, easily seen response in a plant's shoot color or density. K is often called the "health" element, since an ample supply of K increases a plant's tolerance to cold, heat, drought, diseases, and wear stresses, but only in cases where the turfgrass was K deficient. When turfgrass is regularly supplied with K, additional K has not been shown to further enhance the turfgrass stress resistance.

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 K concentration increases in a plant, the tissue water content increases and the plant becomes 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.

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.

### ***K Tissue Testing***

Measuring the K concentration of turfgrass leaf tissue may help indicate when K is limiting turfgrass performance. Turfgrass leaf K concentrations will vary according to species. The current reference ranges for bermudagrass and St. Augustinegrass are 0.43-1.28 and 1.10-2.25%. Reference ranges for each bermudagrass cultivar have not yet been developed. As K concentrations approach the lower ranges, K is more likely to limit turfgrass quality and, thus, a K application may be warranted.

***K Soil Testing***

Soil test K levels ≥ 30 ppm indicate a turfgrass response to applied K is unlikely. When soil test K levels are < 30 ppm, K should be applied at the rates described below. Keep in mind, because K easily leaches, K should be applied with each N application to minimize any opportunity for K deficiency. To that end, soil testing for K is usually not necessary so long as you are following the K recommendations described in the following section.

***K Application Rates***

K should be applied regularly to reduce the chances of K deficiency that can occur due to K leaching in Florida's sandy soils. Because of the additional stresses typically encountered on low height-of-cut turfgrasses, K should be applied at a rate equal to the rate of N and be applied on the same application interval as N. For other areas of the facility, K should also be applied at the same time as N but the rate of K should be one-half the rate of N. Exceeding a 2:1 N:K ratio on most sports fields will not increase turfgrass quality or turfgrass tissue K (Figure 5-7).

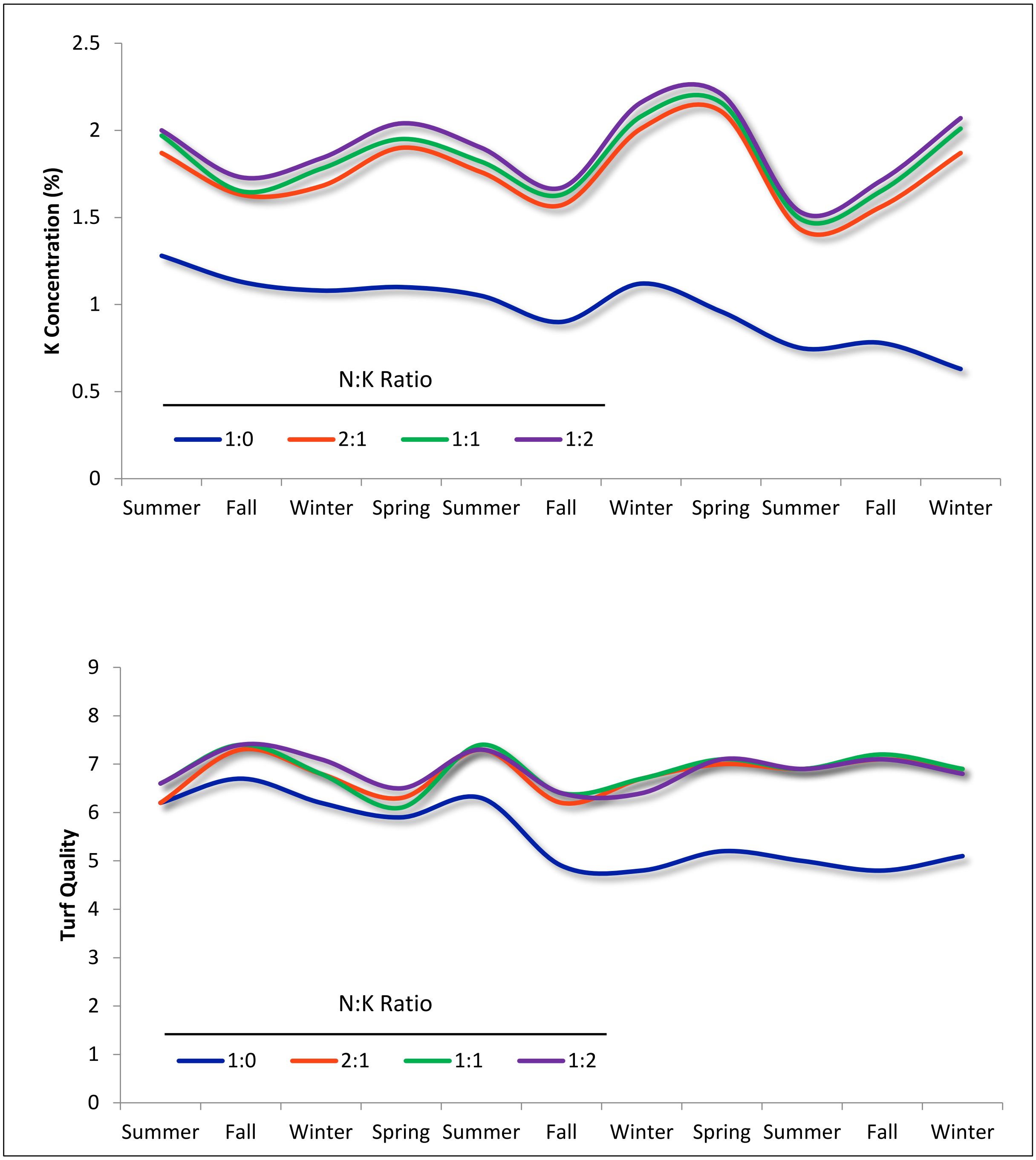



**Figure 5-7. For maximum K-use efficiency, K should be applied to sports fields with normal N applications at one-half the rate of N.**

***K Fertilizer Sources***

Potassium fertilizer often is referred to as "potash." The soluble K content of a fertilizer is expressed as $K_2O$. Turfgrass response or (in most cases) lack of response to K is the same regardless of the type of K source applied. Therefore, the choice of which K source to use is based upon your needs and budget.

Potassium Chloride

Potassium chloride is sometimes referred to as muriate of potash or KCl. In Florida, KCl is the most common K fertilizer because it is usually the least expensive K source. Care should be taken to water-in KCl after applications because KCl also has the highest burn potential of any K source fertilizer (per pound of fertilizer) (Table 5-2).

Potassium Sulfate

When burn potential is a concern, potassium sulfate should be used in lieu of KCl because the burn potential of potassium sulfate is less than one-half that of KCl.

Potassium Magnesium Sulfate

Potassium magnesium sulfate may be referred to as SPM, Sul-Po-Mag, or sulfate of potash magnesia. As the name suggests, SPM is both a source of K and Mg. Although SPM has a low burn potential per pound of fertilizer, SPM has the highest burn potential per pound of K.

Potassium Nitrate

Potassium nitrate is often referred to as Pot-Nit. Like SPM, potassium nitrate is a multi-nutrient product supplying both K and N.

Slow-Release Potassium

Sulfur and polymer-coated K sources are the only available sources of slow-release K. K never enters into a molecular compound in plants or animals, thus, slow-release, organic K sources do not exist. The K substrate may be any soluble K source, but the substrate is normally KCl because KCl is the least expensive granular K fertilizer. The burn potential of coated K is much lower than their uncoated, soluble K counterparts because only small amounts of K are released into the soil/turfgrass system at any one time. Sulfur and polymer-coated K fertilizers release their K in the same manner as coated N sources. However, unlike coated N sources, an enhanced turfgrass response to slow-release K sources relative to soluble K sources has not been documented.

## ***Secondary Plant Nutrients***

### ***Calcium***

Florida soils are naturally high in Ca because much of the parent material that formed Florida soils is comprised of limestone. Consequently, Ca deficiency in Florida turfgrasses is extremely rare, and the probability of observing a direct Ca response is very low. Applying Ca fertilizers to artificially increase soil Ca above the level necessary for proper plant growth normally does not result in an increase in plant uptake because Ca uptake is genetically controlled. Function of Calcium in Turfgrasses

Calcium is absorbed by the turfgrass as $Ca^{2+}$ and, under normal conditions, turfgrass receives sufficient quantities of $Ca^{2+}$ from the soil without the need to apply Ca-fertilizers. Calcium is required for cell membranes to function properly. Most Ca in turfgrasses is found in cell vacuoles or serves as a structural component of cell walls. Calcium activates some enzymes but inhibits others. Deficiency symptoms, although exceedingly rare, will appear on newer leaves/tissues first. Deficiency may appear as twisted or deformed tissue in roots, stems, or leaves where cell division occurs. Leaf blades may appear rose to brown in color and the lead tips and/or margins may wither.

<u>Soil Testing for Calcium</u>

Soil testing for Ca is of little value because the extractant dissolves Ca compounds, which would not otherwise be plant available. As importantly, soil test correlations between Ca soil test values and a turfgrass response to applied Ca do not exist for Florida soils. The use of base saturation (BCSR) to interpret soil Ca is not supported by evidence, has been widely rejected by land grant universities, and is not a best management practice. Additionally, the application of Ca has been shown to provide no beneficial effect on turfgrass grown on calcareous sand-based systems.

Soil pH and Bicarbonates

Soil acidity and bicarbonate management are the primary purposes of Ca applications to Florida turfgrasses. The application of gypsum does not increase pH as does limestone despite both materials containing Ca. It is limestone's counterion ($CO_3^-$) that reduces pH and because gypsum contains $SO_4^{-2}$ rather than $CO_3^-$, no increase in pH will occur.

The application of gypsum may lower pH if the soil pH is initially high due to the presence of Na. The turfgrass response, if any, would likely be due to the increased biological activity that typically accompanies a reduction in pH i.e., increased microbial activity and increased micronutrient availability. However, a turfgrass response to such a scenario has not been documented in Florida.

Direct toxicity to bicarbonates has been documented but tolerance limits for most turfgrasses remains unknown. In most cases, bicarbonates are a concern due to their ability to bind with Ca and Mg and leave behind soluble Na. Additionally, water low in Na and dissolved salts but high in bicarbonates may result in unacceptable pH levels (>8.0). The application of gypsum will reduce the presence of bicarbonates.

Salt Remediation

Gypsum *is* a salt and, therefore, the application of gypsum does not remediate salt-affected turfgrass and, in fact, may exacerbate salt-related problems.

Calcium Sources

- *Irrigation Water*

One of the most common Ca sources for irrigated turfgrass is the irrigation water itself. Because much of our water is sourced from the aquifer, ponds, and lakes, Ca content of irrigation water is commonly in excess of 40 ppm. Therefore, for every 1 million gallons applied, you would also be applying 40 gallons of Ca.

- *Lime*

Limestone is the most common source of lime because limestone is inexpensive and readily available. Limestone is comprised of Ca carbonate and it is one of the least expensive Ca sources available for turfgrass use. However, lime may also be burned lime, hydrated lime, or dolomitic lime. Each lime source has a different capacity to neutralize acidity and increase pH. Lime should be used as a Ca source when soil pH falls below the suggested pH range for the turfgrass being grown. If soil pH is already greater than the suggested range, gypsum should be the preferred Ca source in place of lime.

- *Gypsum*

The application of gypsum may enhance soil permeability in clay-textured saline soils. High sodium levels cause dispersion of clays and often results in poor drainage. Gypsum can alleviate sodic soils by replacing Na with Ca on the soil's exchange sites which enhances soil structure and increases soil permeability. However, Florida soils naturally have little to no structure due to their high sand content. Florida's sandy soils and high rainfall also enables Na to be easily leached without the application of gypsum. Thus, the application of gypsum to turfgrasses grown on Florida soils has little to no influence on soil structure.

- *Calcium Chelates*

Some lime and gypsum sources may contain a chelating or complexing agent such as lignosulfates, citrates, gluconates, or plant extracts. These additives are designed to increase the solubility and availability of Ca for plant uptake. When the soil pH is low (< 5.5), the use of calcium chelates on Florida soils may increase pH more effectively than non-chelated Ca sources. However, very few Ca chelates have been tested and confirmed to increase pH more efficiently than non-chelated Ca. Under normal Florida conditions, Ca is naturally solubilized from the soil and remains soluble in the soil for extended periods. Therefore, fertilizer additives intended to increase Ca solubility are normally not necessary. The release of Ca from a fertilizer source may vary depending upon the particle size, density, and structure.

- *Calcium Nitrate*

Calcium nitrate has a guaranteed N and Ca analysis of 15% and 19%, respectively. The product is normally applied based upon the nitrogen component and consequently, any turfgrass response is likely due to nitrogen. However, if the soil pH is below a suggested turfgrass range, calcium nitrate will increase pH and supply nitrogen in a single application.

***Magnesium***

Magnesium (Mg) exists in soils primarily as $Mg^{2+}$ and is an essential element for all plants. The primary function of Mg in turfgrass is to serve as the central atom in the chlorophyll molecule. Other functions of Mg in turfgrasses include enzyme activation, stabilization of ribosomes during protein synthesis, and maximization of energy during phosphate transfer. Mg is mobile within the plant; thus, deficiency symptoms typically appear as a chlorosis on older leaves first.

<u>Soil Magnesium</u>

Mehlich III extractable Mg in unfertilized Florida soils typically ranges from 20-40 ppm. Because it is positively charged, Mg can be retained on the soils cation exchange sites (CEC). However, the benefit of this retention may be quite low in Florida soils because many Florida soils are predominantly sand and have a low CEC. Unlike Fe and Mn, Mg remains soluble in Florida soils for extended periods. Thus, the use of Mg chelates to enhance Mg solubility has limited value. Additionally, the application of other cations, such as Ca in fertilizers or Na in reclaimed water, has a tendency to replace Mg on exchange sites, which can exacerbate Mg leaching and lead to Mg deficiency in turfgrasses.

Soil testing can only be used to indicate when Mg applications are *unnecessary*. A Mehlich III Mg value of 20 ppm or greater indicates that a turfgrass response to Mg is unlikely. Under normal Florida conditions, many Florida soils already contain > 20 ppm Mg. Therefore, Mg applications are generally unnecessary. Below 20 ppm Mehlich III Mg, a turfgrass response to Mg may occur but the amount of Mg to apply is unknown because Mg calibration responses have not been determined. Other methods of interpreting soil test Mg values are commonly used, such as the BCSR. However, as previously mentioned, the BCSR has been determined to be inaccurate and should not be used in turfgrass management.

<u>Magnesium Sources</u>

- *Magnesium Sulfate*

Also known as Epsom's salt, Mg sulfate has an analysis of 10% Mg and appears as a white, angular particle or prill, and it is 100% water soluble. It is a common Mg fertilizer because it can be spread or sprayed and it is normally less expensive than other Mg fertilizers on a pound of Mg basis.

- *Sulfate of Potash Magnesia*

Sulfate of potash magnesia (often referred to as SPM) provides both K and Mg in a single fertilizer. SPM can be more expensive than Mg sulfate per pound of Mg but, because it also contains K, the cost of the fertilizer is offset because the applicator does not need to pay for additional K. SPM is manufactured in numerous forms including brown prills and pink crystals and the variety of particle sizes allows SPM to be applied to nearly any turfgrass at differing heights-of-cut. Typical analysis is 22% K and 10% Mg.

- *Dolomite*

Dolomite is calcium-magnesium carbonate and is usually used as a liming source rather than a Mg source. Dolomite analyses can vary but a typical analysis is 18% Ca and 10% Mg. The use of dolomite as a Mg source on soils with a pH > 6.5 is not recommended for turfgrasses due to the further increase in pH. In contrast, turfgrass grown on low pH soils that are documented as Mg deficient may respond more favorably to dolomite than to calcium carbonate.

- *Keiserite*

Keiserite ($MgSO_4 \cdot H_2O$) is a natural occurring mineral possessing 17% Mg and is obtained during the mining of potash ore. Few, if any, turfgrass fertilizers contain kieserite, but kieserite is included in some landscape fertilizers that may be inadvertently applied to turfgrass. As with most minerals, kieserite must weather in order to release Mg. To this end, kieserite has been documented to provide extended release of Mg compared to soluble Mg sources. The influence of kieserite on Florida turfgrasses has not been investigated, thus, its value relative to other Mg fertilizers is unknown.

- *Magnesium Oxide*

Mg oxide (MgO) contains 56% Mg and is applied to Florida turfgrasses in the form of frits (homogenous granules of metal oxides). Because Mg is in the oxide form, the solubility of Mg in MgO is extremely low. Studies have shown that MgO does not increase Mehlich III Mg levels in soils. The use of MgO and all forms of MgO (hydroxides, frits, sucrates, etc.) to supply Mg to turfgrass is not a best management practice.

- *Magnesium Sucrate*

Mg sucrate is manufactured by pelletizing MgO powder into a black or dark-red granule. Although the granules rapidly disperse in water, this dispersion only forms a suspension of undissolved particles and, thus, Mg remains mostly insoluble. Mg sucrate has been studied on turfgrass in central and north Florida and does not increase turfgrass quality or color relative to untreated turfgrass.

- *Magnesium Chelates*

Mg may be chelated for use on soils or as a foliar spray. Limited information exists on chelated Mg for turfgrasses, however, evidence indicates that chelated Mg may result in the same turf response and soil solubility as non-chelated Mg. Under normal Florida conditions, non-chelated Mg will remain soluble in soils for many weeks after application, which implies the addition of a chelating agent is unnecessary.

- *Organic Magnesium*

Some natural organic fertilizers such as municipal biosolids may contain small amounts of Mg. The value of this Mg in turfgrass management is difficult to determine because most organic Mg sources also contain nitrogen and/or phosphorus, which also increases turfgrass greening and can obscure the influence of Mg. Organic Mg may become plant available through mineralization and be taken up by the turfgrass. However, this dynamic has not been adequately investigate in Florida turfgrasses and, therefore, the value of using organic Mg remains unknown.

Turfgrass Response to Magnesium

A turfgrass response to Mg in Florida has been documented but responses are uncommon. When a response occurs, the turfgrass usually appears darker green with little to no increase in growth. UF/IFAS research on Mg is limited but recent findings indicate that the soil may provide adequate Mg to sustain acceptable turfgrass and further addition of Mg via fertilizers may be of little value. When Mg is desired, current evidence indicates foliar Mg may be a more effective Mg source than granular, although both granular and liquid soluble Mg sources will remain soluble and, therefore, plant available in Florida soils for many weeks after application.

***Sulfur***

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. Sulfur deficiency in Florida turfgrasses is exceedingly rare because many common fertilizers contain sulfate as the counterion to the element of interest, such as Fe sulfate, Mg sulfate, ammonium sulfate, etc. When deficiencies occur, they are more likely to 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.

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 situations where excessive irrigation is practiced, or drainage is poor. 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 soils receiving excessive irrigation. The black layer can usually be controlled by proper water management.

## ***Micronutrients***

Micronutrients are just as essential as macronutrients but are required in relatively smaller amounts. Many soils in the United States supply sufficient levels of micronutrients for turfgrass growth and development. 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, micronutrient deficiencies may occur but are rarely confirmed for any micronutrient other than Fe and Mn.

Fe and Mn are the only micronutrients that have been documented to provide a turfgrass response in Florida. Fe should be applied only as a foliar spray at between 1-5 lbs. of Fe per acre. Granular Fe chelates may result in a turfgrass response but often require multiple applications of ≥ 20 lbs. per acre. Mn may be applied as either a foliar or granular application but a response to Mn is uncommon from either source. The lack of turfgrass response typical from either granular Fe or Mn is due to the rapid soil oxidation (within hours) of Fe and Mn. Foliar applications avoid soil contact and therefore result in a more consistent response.

Managing micronutrient applications based upon soil testing is not a best management practice. As previously stated, for Florida turfgrasses, soil testing is useful in managing pH, salinity, and provides critical minimum values for P, K, and Mg.

***Iron***

Iron is commonly applied using granular or foliar sources to enhance turfgrass color. Iron applications can result in darker green turfgrass but may result in no turfgrass response at all.
Role of Iron in Turfgrasses

Turfgrass can appear darker green after an Fe application because the supply of Fe from the soil is low and the demand for Fe in the plant is high. Iron is needed in numerous photosynthetic functions, including activation of enzymes that catalyze chlorophyll synthesis, maintenance of thylakoid membrane (the site of the light-dependent photosynthesis reaction) structural integrity, and the transfer of electrons during photosynthesis. Be aware that although several nutritional elements may result in darker green turfgrass, the roles of most elements within the plant are not interchangeable with one another. Thus, the application of Fe will not cure N deficiency.

Iron is immobile in the plant (i.e., does not move from one plant tissue to another) and, thus, deficiency appears on younger leaves first. Iron deficiency is commonly observed in Florida in the spring following N fertilizer applications.  This phenomenon can occur on any turfgrass but usually is occurs only on bahiagrass, centipedegrass, and St. Augustinegrass. This can be frustrating because the N application should have resulted in a greener turfgrass but, in fact, the turfgrass may appear chlorotic in places. The most likely explanation is that during the winter months, the rate of turfgrass shoot and root growth declines. In north Florida, growth may cease altogether whereas in south Florida, growth may slow down. Nitrogen applied during the spring encourages turfgrass growth and, in turn, increases the demand for Fe. This demand for Fe cannot be met because turfgrass root growth is still limited in the spring and, thus, the ability to take up Fe is low resulting in chlorotic leaf blades. Cool, wet soils tend to exacerbate this chlorosis. As soil temperatures increase, the quantity of turfgrass roots increases resulting in greater uptake of Fe and a decrease in Fe deficiency symptoms. Springtime occurrences of Fe deficiency are more common in central and north Florida than in south Florida and normally dissipate within a few weeks. Otherwise, turfgrass Fe chlorosis can be minimized by applying foliar Fe at a rate between 1-5 lbs. of Fe per acre (Figure 5-8).

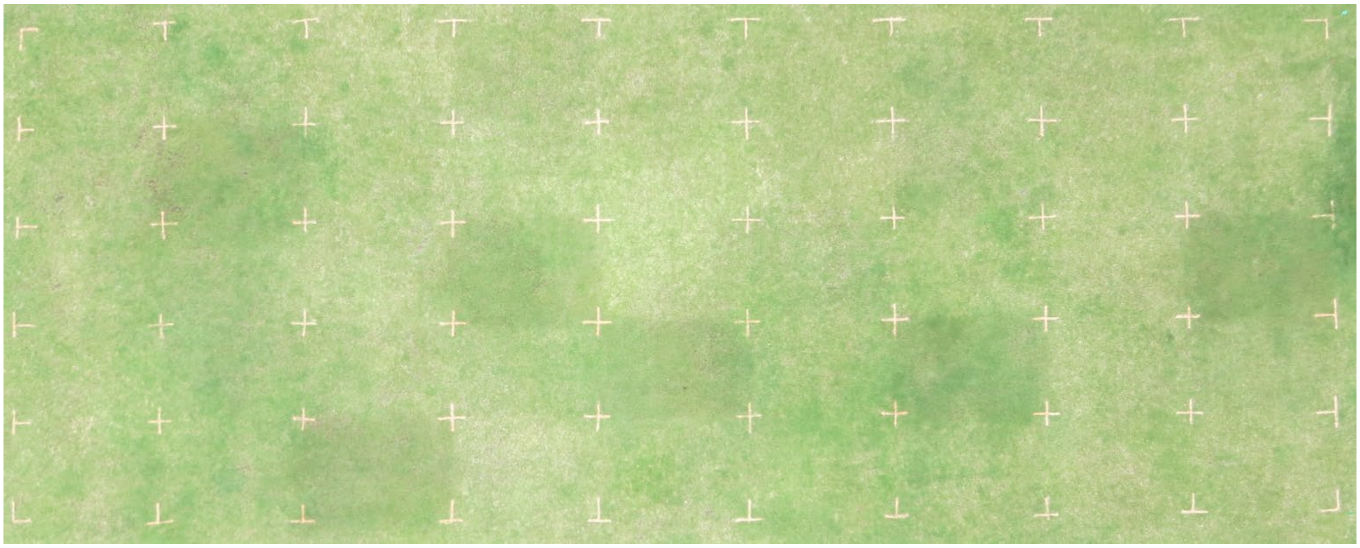


Figure 5-8. Bermudagrass showing response to foliar iron (each dark green rectangle) compared to granular Fe or no Fe (all remaining rectangles).

Soil Iron

Iron makes up about 5% of the earth's crust but most of this Fe is bound in primary or secondary minerals and is unavailable for plant uptake.

The availability of Fe in soils is dependent upon soil moisture, soil pH, soil temperature, and organic matter content. As soil moisture increases, the quantity of Fe available for plant uptake also increases. However, excessive soil moisture limits oxygen and negatively influences turfgrass root growth. Thus, a moist soil that is not too dry or too wet is ideal.

- *Soil Testing for Iron*

Iron applications should not be based upon soil test Fe levels. Most soil testing labs will test for Fe, but do not provide a fertilizer recommendation. This is because the concentration of Fe changes rapidly in most aerated soils and thus, by the time the applicator receives the recommendation, the soil Fe levels would likely be different from the initial soil concentration. In addition, soil test calibrations used to predict a response to the application of Fe have not been established on Florida soils.

<u>Iron Sources</u>

- *Iron Sulfate*

Iron sulfate is perhaps the most common soluble granular Fe source for turfgrasses. Iron sulfate typically has an analysis of 20% Fe and appears as a white or light greenish blue, angular particle or prill, and it is 100% water soluble. Both granular and foliar forms of Fe sulfate are used in turfgrass management, but only foliar Fe sulfate has resulted in a positive turfgrass response in Florida. Granular Fe sulfate must dissolve into the soil solution and be taken up by the roots. During this process, Fe sulfate reacts with water to form an Fe hydroxide which is often as a reddish brown stain on surfaces such as concrete sidewalks or roads (Figure 5-9). Because these stains are formed chemically, they are difficult to remove. Therefore, Fe sulfate should be applied as a liquid to the turfgrass foliage rather than applied to the soil.

If applied as a foliar spray at 1-5 pounds of Fe per acre, Fe sulfate generally improves turfgrass color for up to 4 weeks. The longevity of response is a function of the amount of Fe applied, the amount of N applied, and the time of year. Exceeding 5 pounds of Fe per acre increases the probability of leaf burn and may temporarily turn the turfgrass leaves black. Foliar Fe cannot be used to cure chlorosis resulting from N deficiency. Iron cures Fe deficiency and N cures N deficiency.

Figure 5-9. Fe sulfate fertilizer particles will rapidly dissolve and stain wet surfaces such as concrete roads and sidewalks.

- *Iron Humate*

Iron humate is the bi-product of water treatment facilities that produce potable water from humate-rich river water. The material is normally a dark brown to black granule and has a guaranteed Fe analysis of 14%. Iron humate is approximately 30% water soluble with the remaining Fe being in a slowly available form. Over a two-year period in two Florida locations, a single applications of 20 pounds of Fe (as Fe humate) per acre resulted in no improvement in bermudagrass color or quality.

- *Iron Oxide*

Iron oxide is the end product of Fe weathering and more than 99.5% of Fe within Fe oxide is water insoluble. The product is normally a black, angular, very hard granule and guarantees 50% or more Fe. No turfgrass response to Fe oxide has been observed in research studies. Iron oxide and all forms or Fe oxide should not be used as a turfgrass fertilizer.

- *Iron Sucrate*

Iron sucrate is manufactured by pelletizing powdered Fe oxide using a sugar, usually molasses. The product is normally a spherical, black prill and guarantees 50% or more Fe. Although the prills readily disperse in water, Fe sucrate is not water soluble. The dispersion forms a suspension in water but the fine particles remain insoluble. Turfgrass research using Fe sucrate clearly shows that Fe sucrate does not improve turf quality, growth, or color.

- *Iron Chelates*

Many Fe chelates exist for use on turfgrasses but only ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), and ethylenediaminedi-o-hydroxyphenlyacetic acid (EDDHA) are documented to result in turfgrass responses when applied to the soil. Other Fe chelates such as gluconate, glucoheptonate, and citrate applied as foliar sprays commonly improve turf color, but they do not increase the availability of Fe in the soil. Keep in mind that high application rates of Fe chelates, especially Fe EDTA, can be phytotoxic to some landscape plants.

- *Powder-Coated Iron*

Some fertilizers may be blended with a component of very fine Fe powder added when the fertilizer is being blended. This powder attaches to each fertilizer particle, which greatly increases the uniformity of Fe distributed across the turfgrass. The Fe powder may be derived from Fe sulfate, Fe oxide, or Fe chelate. Each of these powder-coated Fe sources have been tested on Florida turfgrass and none have increased turfgrass color or quality compared to untreated turfgrass.

- *Organic Iron*

The value of organic Fe in fertilizers such as Milorganite® or municipal biosolids is difficult to evaluate because most organic Fe sources also contain N and/or P. Separating the influence of Fe from the influence of the N and P is very difficult and, thus, a real response to organic Fe has not yet been documented on Florida turfgrasses.

***Manganese***

Manganese influences the rate of photosynthesis and is a cofactor for ~35 enzymes. Lignin biosynthesis requires Mn and in the absence of Mn, thylakoid membranes begin to degrade resulting in a loss of chlorophyll.

<u>Soil Manganese</u>

The majority of Mn in Florida soils is unavailable for plant uptake and exists in various minerals or in organic matter. Similar to Fe, Mn quickly oxides when it comes into contact with soil.

Soil Testing for Manganese

Soil testing for Mn in Florida turfgrass systems is unreliable because the concentration of Mn changes rapidly between sampling and analysis.

Turfgrass Response to Manganese

Bermudagrass at varying mowing heights has shown responses to applied Mn in Florida. In each case, the response was described as enhanced greening with no increase in growth. Both foliar and granular forms of Mn can alleviate Mn-deficiency symptoms although foliar Mn may be more effective than granular because granular Mn may be rendered unavailable through soil oxidation.

***Other essential elements***

The other plant essential elements – boron, copper, zinc, molybdenum, and chlorine – are required in very low amounts. Soil test values for these elements are unknown and turfgrass responses to these elements have not been observed in Florida.

## Soil pH

Soil pH has many effects on plants but probably influences them most by affecting the availability of important nutrients. For example, when soil pH values are < 5.0, aluminum, iron, and manganese are highly soluble. High levels of aluminum can reduce plant uptake of phosphorus, calcium, magnesium, and iron. At 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 > 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.

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, quality, and performance.

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
- Better soil structure and tilth.

Soil pH should be monitored by annual soil testing. Intensively managed and artificially constructed areas such as sand-based sports fields 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 buffering capacity, such as those in Florida, is to apply 1 ton of lime per acre to raise the pH 1 unit (Figure 5-10). 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.

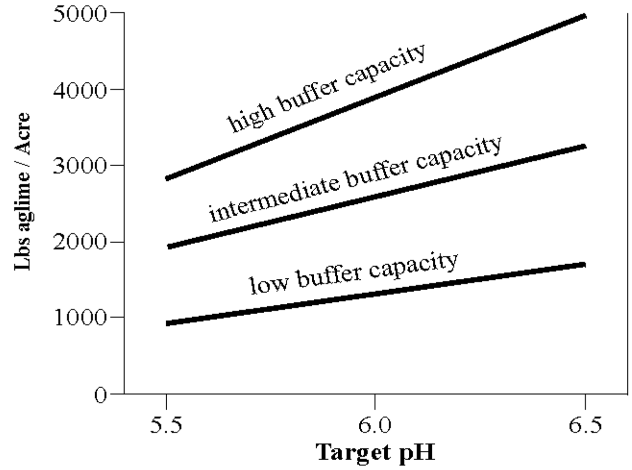



**Figure 5-10. Effects of buffering capacity on lime requirements**

Pulverized calcitic or dolomitic limestone with a calcium carbonate equivalent (CCE), or neutralizing power, of 90 or greater is recommended for liming sports 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.

**Best Management Practices for Soil pH:**

1. To increase soil pH, apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca2+ and neutralizes acidity.
2. To lower soil pH, use products containing elemental sulfur, such as sulfur or sulfur-coated urea; or use ammonium sulfate.

3. In some cases, utilizing injection pumps into irrigation water to address pH can be beneficial.

## Establishment

Grow-in, or the establishment of turfgrass, is one of the most intensive phases in turfgrass management. Typically, to promote rapid establishment, 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 nutrients when the turfgrass coverage is low and gradually increasing the rate of nutrients as the turfgrass establishes—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 be reduced. For installation of fresh-cut sod which has been fertilized within 45 days of harvest, N or P 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.

Some sports field construction firms have used sand only as a root-zone mix. Sand-only fields 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 facilities.

P is 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 Mehlich III soil test values fall below 20 ppm.

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. Generally, turfgrasses do not respond to K when Mehlich III soil test values are greater than 30 ppm. 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.

## Fertilizer Application

### *Calibration*

The only way to accurately know how much fertilizer is actually being applied is to calibrate the 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 non-target 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 sidewalks, 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 feeding 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 $ft^2$) at low spray volumes (e.g., 1/2 gal. per 1,000 $ft^2$). Low nutrient and spray volumes minimize costs and supplement the normal fertilization program with nutrients absorbed directly by turfgrass leaves.

At higher spray volumes, (e.g., 3 to 5 gals. per 1,000 $ft^2$), 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.

Foliar fertilization offers several advantages that make it a valuable tool in turfgrass management. Because nutrients are applied in liquid form directly to the leaf surface, issues such as particle segregation, which is common with granular products, are avoided. This method allows for efficient uptake of micronutrients by bypassing soil interactions and provides improved uniformity of application, particularly with low-rate products. Nutrients are delivered in water-soluble forms, and foliar applications can often be combined with pesticides, increasing operational efficiency. However, there are also disadvantages to consider. Applying sufficient nutrients without causing leaf burn can be difficult, and foliar products are generally more expensive than granular options. They may require more frequent applications at low rates, which increases labor needs. Additionally, some formulations may crystallize or salt out at lower temperatures, and because turf response is typically short-lived, repeated applications are often necessary to maintain results.

The application of micronutrients, Fe 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. 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 may be 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.

***Precision Application***

Precision application refers to the use of automated application equipment using global positioning system (GPS) data and detailed mapping to apply precise amounts of a product 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 $ft^2$ 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 often require higher N rates than areas receiving less play. Various methods can be devised to increase the rate of fertilizer applied by irrigation systems on these areas.

**Best Management Practices for Fertilizer Application:**

1. The objective of all nutrient applications is plant uptake and the corresponding desirable response.
2. Apply nutrients when turfgrass is actively growing.
3. Apply slow-release N fertilizers at the appropriate time of year to maximize the products' release characteristics. For example, an application of slow-release N to

warm-season turfgrasses in fall may not be as effective as the same application applied in early summer because of the prolonged release time in fall.

4. Follow UF/IFAS N application rates.
5. N application rates from slow-release materials should take into consideration the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.
6. Low height-of-cut sports fields require more nutrition than other areas due to the extra stresses imposed by mowing heights, traffic, etc.
7. Higher height-of-cut fields often require fewer nutrients than other locations because of their increased height of cut, less damage, and clipping return.
8. Exercise caution when applying nutrients during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff.
9. During establishment, use appropriate rates and products to minimize N loss due to increased water applications, increased nutrients rates, and reduced root mass.
10. Be aware of the different types of spreaders and understand the advantages and disadvantages of each.
11. Use the appropriate spreader for the chosen fertilizer.
12. Calibration reduces environmental risk and increases profitability.
13. Proper fertilizer storage, loading, and clean-up reduce environmental risk.
14. Avoid applying fertilizer to soils that are at, or near, saturation or following rain events that leave the soils wet.

15. Do not apply fertilizer when the National Weather Service has issued a flood, tropical storm, or hurricane warning, or if heavy rains are likely.

# SECTION 6: CULTURAL PRACTICES FOR SPORTS 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

Mowing is the most basic yet most important cultural practice a sports field manager can use to maintain 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 sports fields can be mowed close to the ground, since their terminal growing points (crowns) are located at or just below the soil surface. 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, resulting from food reserves being used for new shoot tissue development at the expense of root and rhizome growth after mowing. Improper mowing exacerbates this problem. If the correct mowing height and frequency are used, the turfgrass 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 and the further depletion of food reserves. Remember, stressed turf means a weaker plant that is more vulnerable to drought, insects, and disease, requiring 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 sports turf are governed by the grass variety and its intended use. For example, high-profile bermudagrass fields may be mowed below 1 inch to provide a smooth, fast playing surface, while practice fields and multi-purpose community fields may be maintained at 1-1.5 inches for better durability and ease of maintenance. Argentine bahiagrass should be mowed at 2.5 to 3 inches. Understanding genetic limitations of your particular turfgrass can help reduce turf stress and the need to apply plant protectants. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and stress.

## ***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 closely mowed sports turf, such as baseball infields, may need to be watered and fertilized more frequently than other playing surfaces. Roots (plus lateral stems) are where carbohydrate reserves are stored.

Therefore, shallow roots on a baseball infield 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 shaded areas be mowed as high as the sport and field use will allow. Also, research suggests that applying the plant growth regulator trinexapac-ethyl (Primo™) to shaded turf improves 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 on practice fields and less formal areas. Conversely, reel mowers cut best at heights below 1 inch and are used on most high-quality sports fields, especially those requiring low mowing heights.

## ***Season***

The season of the year may also influence mowing height. In early spring, turfgrasses have a more prostrate (horizontal) 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 when bermudagrass is dormant.

## ***Environmental Stresses***

Mowing height should be increased during more stressful periods, particularly during prolonged cloudy weather or drought. Increase mowing height as high as the sport and field use will allow. Even an increase of 0.25 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 1 inch, the calculation is as follows:

1" X 1.5 = 1.5"

The grass should be allowed to reach 1.5 inches and then mowed. Thus, 0.5 inch of clippings is removed (one-third) and 1 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 the potential for 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 bermudagrass fields. 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 approximately 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, tough weeds and seed stalks, while reel mowers cannot. Rotary mowers may also decrease herbicide use on practice fields and other low input fields 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 repeatedly mowed 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 practice fields 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. 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 riding mowers.

Mowing directions should not be repeated over the long term, even though this may produce alternating color 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". Grain results in an uneven cut, a streaked appearance, and a poor-quality playing surface.

Varying the pattern of successive mowings easily prevents grain, encourages the upright growth of the shoots, and improves the overall turf quality. The mowing patterns or directions of sports fields should be changed regularly and cleanup laps routinely reversed or skipped. Often a rotating clock pattern is followed for mowing directions and is changed weekly.

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.

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 sports fields 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 landscape beds or inaccessible mowing areas. If not composted, the clippings should be dispersed so that piles do not form.

**Best Management Practices for Mowing Sports Fields:**

1. Mowing Height
    - Match height to the turf variety and intended field use (e.g., bermudagrass <1 inch for high-profile fields, 1–1.5 inches for practice fields, bahiagrass 2.5–3 inches).
    - Keep in mind that the “bench setting” on a flat surface may not match the actual cutting height when operating on soft ground or over thick thatch
    - Adjust mowing height seasonally (lower in early spring, higher in summer/fall), and increase it by at least 30% in shaded areas.

2. Mowing Frequency
    - Follow the one-third rule: remove no more than 30–40% of the leaf blade at each mowing.
    - Base mowing intervals on the turf's growth rate, which is influenced by temperature, fertilization, and rainfall.
    - If turf becomes too tall, reduce the height gradually over multiple mowings to avoid scalping.
3. Root and Shoot Health
    - Minimize excessive defoliation to maintain a balanced root-to-shoot ratio and to conserve carbohydrate reserves.
    - Recognize that low-cut turf (for example, baseball infields) requires more frequent irrigation and fertilization because shallower roots store fewer resources.
    - Raise the mowing height during stress periods (drought or high temperatures) to maintain deeper roots and adequate leaf area.
4. Mowing Patterns
    - Change mowing directions regularly (e.g., follow a rotating "clock" pattern) to prevent grass from leaning in one direction (grain).
    - Vary cleanup laps and turning areas to limit compaction and repeated scalping of high spots.
5. Mowing Equipment

- Reel mowers: best for low-cut, high-quality turf (below 1–1.5 inches) but require frequent adjustments and more skill to operate.
- Rotary mowers: versatile for mid-range heights; keep blades sharp to prevent tearing leaf blades.
- Flail mowers: well-suited for tall, infrequently mowed areas; they finely shred clippings without creating large projectiles.

6. Equipment Care and Maintenance
    - Keep blades sharp and balanced for a clean cut; lubricate and adjust parts regularly according to manufacturer guidelines.
    - Store equipment in a clean, dry, secure area; maintain detailed service logs to help schedule preventive maintenance and track costs.
7. Clipping Management
    - Return clippings to the turf to recycle nutrients (2–4% nitrogen, plus phosphorus and potassium).
    - Remove clippings only if they clump or smother the grass, or if they interfere with field usage.
    - If collected, compost or dispose of clippings properly to prevent odors and fire hazards.
8. Environmental and Seasonal Considerations
    - Raise mowing heights during stressful conditions (drought, extreme heat, prolonged cloudiness) to maintain photosynthesis and reduce water needs.

- Lower the cutting height slightly in early spring to remove thatch and encourage faster green-up; raise it again in summer/fall to reduce stress and protect turf crowns.
- Balance a smooth, playable surface with overall turf health to minimize pest pressures and maintain quality.

## Turfgrass Cultivation Practices

Cultivation practices are an important part of turf management. Heavily used areas such as sports fields 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 is the practice of inserting "tines" into the playing surface to create an opening for increased air and water movement. Aerification can be done using solid or "coring" tines that remove small soil cores or plugs from the turf surface, leaving a hole in the sod. 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 aerating 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.

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

***Soil Compaction***

One of the primary goals of core aerification 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%.

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 aerification 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 sports fields depends on the manager's control of soil moisture content.

The best method for preventing compaction is to build fields 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 high-traffic sports field construction. All soils should be tested by an accredited soil laboratory before use. Proper surface contouring and subsurface drainage in the form of perforated drainage pipes also hasten the removal of excessive surface water.

Traffic and play on fields 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 and play after heavy rains, and avoid mowing 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 aerification 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***

Sports fields can accumulate thatch and organic matter quite aggressively in Florida's warm climate. 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. High-traffic areas of sports fields must be core aerified several times each year during the summer. Various aerifier tine diameters and spacings affect the percentage of surface affected.

***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 fields 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 playing 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. 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.

Two newer approaches to aerification include air injection and linear decompaction. Equipment like the Air2G2 utilized compressed air injected into the soil profile at depths up to 12 inches, fracturing compacted layers and creating vertical and horizontal fissures that improve soil health with minimal surface disruption. Linear decompaction similar to the Imants ShockWave utilize vertically oriented blades that oscillate as they penetrate the soil profile. This oscillation creates lateral fractures in the soil with minimal surface disruption.

## ***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. For most sports fields, 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 acceptable and the underlying soil is adequate.

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.

***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 soccer goal mouths, between hash marks on football fields, and baseball infields—require a minimum of 4 to 6 core aerifications annually. Additional aerifications may be needed on exceptionally small fields 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 may result in poorly drained soils, thin grass stands, and continued problems with algae.

Less-intense traffic areas should be aerified as needed. Most sports field areas 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 field with a minimal disruption of the playing 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.

## ***Deep Aeration***

Sports field managers have several options available to them that for managing compaction deep in the soil profile. 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 manager 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 sand-based fields, an undesirable soil profile can be improved by topdressing with desirable soil following deep aerification.

Deep aerification creates more surface damage than shallow depth models. The initial expense also prevents many facilities 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 facilities may choose to share the cost of purchasing a unit.

Another option 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.

Two more recent approaches to reducing compaction deep in the profile include high-pressure air injection (Air2G2) and linear decompaction (Inmants ShockWave). Both of these tools allow for improvement of soil conditions through disrupting compacted layers in the soil profile while causing minimal damage to the playing surface.

Some facilities still possess a Toro Hydroject™, a machine that uses 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 field'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 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 high-traffic areas. 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 aerification (e.g., every 4 to 8 weeks).

## ***Vertical Mowing (Verticutting)***

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 closely mowed turf when the knives are set just to nick the surface of the turf. Shallow vertical mowing breaks up cores following aerification, 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. 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 sports fields exceeds .25 to .5 inch**.** Shallow vertical mowing should be completed at least once per month for non-overseeded bermudagrass fields. Some of the newer bermudagrass cultivars 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 available for many of today's large area mowers. This equipment allows for frequent vertical mowing and simultaneous debris collection. For light surface grooming, the vertical blades 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 mowers to lightly groom sports turf. Likewise, brush attachments can be used in conjunction with daily mowing.

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.

## ***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 sports field managers have reduced the number of coring and topdressing procedures in recent years due to budget and time/scheduling constraints. These are sound, fundamental agronomic practices that are necessary to maintain an optimal sports turf surface. If eliminated, the quality of the field 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 $ft^2$) 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. A thatch layer of 0.25 to 0.5 inch on sports fields is desirable, but it is necessary to dilute this layer with sand. The relatively thin thatch layer cushions the turf and helps to protect bermudagrass crowns from traffic. When thatch is not excessive (≤ 0.5 inch), approximately 1 cubic yard per 5,000 $ft^2$ 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 field 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 $ft^2$ of field 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 events to increase turf density and provide a smoother playing surface. In addition, frequent, light topdressing should be applied to new fields 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 manager'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 field.

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 silos, or polyethylene covers provide good storage conditions until the material is used.

When the underlying soil of the play surface 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 can improve poorly draining fields. Between these corings, conventional aerification 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 manager attempts to slowly change the root zone of a field by this method.

The most commonly observed problem is the formation of various alternating layers of soil when different topdressing 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, microperched 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 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***

Rolling has become a more common practice in sports turf management. Some routinely roll (i.e., weekly) while others roll prior to major events to provide a smoother, faster playing surface. Various types of rollers are used, from stand-alone units to those that can be towed behind a utility vehicle.

### ***Benefits***

Limited research provides some guidelines on the expected benefits of rolling. Rolling can help smooth out minor surface irregularities, potentially improving ball roll and footing for athletes. It may also help press divots back into place after events. On newly sodded areas, rolling can help improve sod-to-soil contact for better rooting.

### ***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 available that still achieves the desired effect. Rollers also should be used only on fields 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 before major events 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 if rolling is done frequently.

**Best Management Practices for Turfgrass Cultivation:**

1. Aerify regularly using hollow tines during active growth to relieve compaction, improve water infiltration, and promote root development.
2. Use deep cultivation tools (e.g., deep-tine, air injection, linear decompaction) annually to disrupt compacted soil layers and enhance rooting depth.
3. Manage thatch through core aerification, vertical mowing, and sand topdressing to maintain a thatch layer ≤ 0.5 inch.
4. Topdress frequently with clean, weed-free sand compatible with the existing rootzone to smooth surfaces and dilute thatch.
5. Avoid traffic and mowing on wet soils; use wide turf tires to minimize compaction.
6. Verticut monthly during the growing season to manage grain and reduce surface organic matter buildup.
7. Use slicing and spiking between core aerifications for minor compaction relief with minimal surface disruption.

8. Roll fields only as needed before major events or after sodding—never when soil is saturated.

## Overseeding

Overseeding is the practice of establishing a temporary cool-season grass into the base bermudagrass for improved winter 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 sports facility should evaluate whether overseeding is worth the increased requirements for natural resources and labor. Some facilities choose to apply pigments to certain playing surfaces, instead of overseeding them, as it requires fewer resources than overseeding and is a more environmentally responsible alternative. This section discusses BMPs for facilities 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.

## ***Seedbed 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. 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 grass used for overseeding sports fields in Florida is perennial ryegrass. Annual ryegrass and intermediate ryegrass are used to a lesser extent. Care should be taken to select cultivars and mixtures characterized by improved disease resistance, improved wear tolerance, and ease of spring transition.

## ***Post-planting 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. The use of preemergence herbicides helps reduce the emergence of overseed in unwanted areas. Once grass is established, gradually reduce watering frequency to decrease disease potential.

Mow overseeded areas when the new stand reaches about 1/3 higher than the desired mowing height. Use a sharp mower that does not pull up seedlings. Once the grass is well established, mowing heights gradually can be reduced to the desired height.

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 $ft^2$ every 2 to 3 weeks with a soluble N source (e.g., urea, ammonium sulfate), or 1 lb. N per 1,000 $ft^2$ per month with a slow-release N source (e.g., PCU, SCU, reacted products, biosolids) is adequate to promote desired growth without overstimulating growth and encouraging disease. More frequent applications using lower rates may be needed if the recovery time from traffic or weather damage is slow. Whenever possible, traffic should be minimized during grass establishment.

Applications of phosphorus, potassium, manganese, and iron should be considered during winter. These nutrients provide desirable color without stimulating excessive shoot growth. Soil phosphorus levels and rates should be determined by soil testing. Potassium should be applied at one-half the rate of N. Iron generally is applied every 3 to 4 weeks as ferrous sulfate at 2 oz. per 1,000 $ft^2$. Manganese can be applied as manganese sulfate at 0.5 to 1 oz. per 1,000 $ft^2$ 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 reduced by applying a small amount (0.125 to 0.25 lb. N per 1,000 $ft^2$ ) of a quick-release N source. Brown patch and Pythium blight may occur on fields that drain poorly, or during continuous wet periods. Excessive 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 monitor 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 vigor. When the warm-season, base grass regrowth is observed, restore fertilizer applications. Many herbicides are available that can be used as transition aids that can selectively kill the overseed grass. Some have achieved overseed removal by withholding irrigation for a period of time. This is not advisable as it can lead to warm-season turfgrass desiccation leading to injury.

## Turfgrass Colorants

Maintaining aesthetically pleasing and functional sports fields during late fall and winter poses a significant challenge, particularly in regions where warm-season turfgrasses enter dormancy. Traditionally, overseeding with cool-season grasses has been employed to ensure green cover and playability. However, the use of turfgrass colorants has emerged as a viable alternative, offering several benefits over overseeding. This section will explore the application of turfgrass colorants to enhance in-season color and serve as an alternative to overseeding during the late fall and winter months.

### ***Benefits of Turfgrass Colorants***

Turfgrass colorants provide an effective and efficient solution to maintaining green, visually appealing sports fields during the dormancy period of warm-season grasses. One of the primary benefits of using turfgrass colorants is cost efficiency. Colorants reduce the expenses associated with overseeding, such as the cost of seed, labor, and the additional maintenance practices required for cool-season grasses. This can lead to significant savings for sports field managers.

Resource conservation is another notable advantage of turfgrass colorants. Overseeding requires substantial water and fertilizer inputs to establish and maintain cool-season grasses. By eliminating the need for these resources, colorants align with sustainable management practices and water conservation goals. This is particularly important in regions where water availability is limited.

Enhanced playability is a crucial factor for sports fields, and turfgrass colorants can provide a consistent green color that improves the visual appeal and functionality of the field. Unlike overseeding, which can result in uneven growth and transition issues, colorants offer a uniform playing surface throughout the dormant season. This ensures a high-quality experience for athletes and spectators alike.

The environmental impact of using turfgrass colorants is also significant. By reducing soil erosion and the risk of nutrient runoff associated with overseeding, colorants help maintain field integrity and minimize environmental disruption. This makes colorants a more environmentally friendly option for sports field management.

## ***Application of Turfgrass Colorants***

Selecting the right colorant is essential for achieving the desired visual effect. High-quality, UV-stable colorants are recommended to ensure long-lasting color. It is crucial to choose products that are safe for both the turf and the environment. Timing and frequency of application are important factors to consider. The optimal timing for initial application is typically in late fall, just before the turf enters full dormancy. Subsequent applications may be necessary to maintain color throughout the winter, depending on weather conditions, field use, and the specific product used.

Proper application techniques are critical for achieving uniform coverage and avoiding streaking. Specialized sprayers with consistent pressure and nozzle calibration are recommended. Applying colorants in multiple directions can help ensure even distribution. Before application, fields should be mowed and debris removed to provide a clean surface for the colorant to adhere to. Moisture levels should be monitored, as overly dry or wet conditions can affect colorant performance.

Safety considerations are paramount when applying turfgrass colorants. Ensure that all personnel involved in the application process are trained and equipped with appropriate protective gear. It is important to follow the manufacturer's guidelines and safety data sheets (SDS) for handling and applying colorants.

High-profile fields, such as those used for professional sports or significant events, often require impeccable aesthetics. Turfgrass colorants can play a crucial role in enhancing the visual appeal of these fields, ensuring a vibrant green color that meets the high standards expected for such venues. The use of colorants can provide a consistent and attractive field appearance, which is essential for televised events and large audiences. Additionally, colorants can be applied strategically to highlight specific areas, such as logos and field markings, further enhancing the field's overall presentation.

While specific research studies on the use of turfgrass colorants are limited, practical experiences from sports field managers across various regions have demonstrated the efficacy of turfgrass colorants in maintaining green color and playability during the dormant season. High-profile fields, such as professional stadiums and tournament venues, have successfully used colorants to maintain an immaculate appearance, showcasing the versatility and effectiveness of this practice. It is recommended to consult with local extension services or turfgrass research programs for detailed studies and data on the use of colorants in your specific region.

## Shade and Tree Management

In general, most turfgrasses grow 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 sidelines and goal areas 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.

**Best Management Practices for Turfgrass Growth in Shade:**

1. 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.

2. 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 ft^2^, 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 ft^2^ at any one time.
3. 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.
4. 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.
5. Increase air circulation: Very few fungi can infect dry leaves. Where a field 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 field, fans are sometimes used to dry out the soil and increase ET by providing a 3- to 4-mile-per-hour breeze at the surface.

6. Consider shade-tolerant grass species: In areas with persistent shade issues, consider using more shade-tolerant turfgrass cultivars.

# SECTION 7: INTEGRATED PEST MANAGEMENT

Integrated Pest Management (IPM) is a year-round activity on Florida's sports fields. 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 sports field managers 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.

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 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.

## ***Cultural Controls***

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, weeds, and insects, thus reducing the need for chemical treatment.

**Best Management Practices for Cultural Controls:**

1. Prevent pest introduction by using certified plant material and proper sanitization practices
2. When possible, increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed seed germination.
3. Stimulate or increase root growth if root-feeding pests are detected (e.g., through aeration, fertilization).

1. Time irrigation to avoid excess moisture or drought stress and minimize the duration of leaf wetness.

2. Wash mowers to avoid spreading pathogens and weeds.
3. Allow turf to dry before mowing.
4. Manage thatch by adjusting fertility levels, mechanical removal, topdressing, or other means.
5. Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
6. Avoid outdoor lighting or use sodium-vapor lightbulbs during peak mole cricket flight periods, from dusk to 2 hours after dusk. If unavoidable, anticipate increased mole cricket pressure in turf below lights.

## ***Biological Controls***

Biological control involves 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 sports field environment can also be modified to attract natural enemies, provide habitat for them, and protect them from pesticide applications. For example, in out-of-play areas, flowering plants provide insect parasitoids and predators with habitat and food resources, who then forage for turfgrass insect pests on nearby playing surfaces.

**Best Management Practices for Biological Controls:**

1. Maintain peripheral areas as refuges for beneficial organisms

2. When possible, use insecticides that are selective for the target pest and safer for beneficial arthropods (e.g., reduced-risk insecticides)
3. Avoid widespread applications of broad-spectrum, contact-toxic insecticides when possible
4. Install diverse flowering plants in out-of-play areas adjacent to managed turf to attract predatory and parasitic insects and promote biological control of turfgrass insect pests.

## ***Genetic Controls***

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, weaken or kill the pests. Selecting resistant cultivars or plant species when designing sports fields is a very important part of IPM. Although managers often work with established plant material, they can still recommend changes during renovation or replacement phases.

## ***Chemical Controls***

Chemical controls include a wide assortment of conventional, broad-spectrum pesticides and more selective chemicals, such as microbial insecticides and insect growth regulators. IPM does not preclude the use of pesticides, but it does promote the use of the least toxic and most selective alternatives when chemicals are necessary. Pesticides are only one tool used against pests and should be used responsibly and in combination with other, less-toxic control tactics.

**Best Management Practices for Chemical Controls:**

1. 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.
2. Follow pesticide label instructions for irrigation requirements.
3. Avoid broad-spectrum pesticides when possible to conserve beneficial insects.
4. Manage pesticide resistance by rotating pesticides with different modes of action, as appropriate.
5. Preventively apply pesticides only in areas where severe damage previously occurred, was documented, and can be reasonably expected again.

When determining which products are available for use by turfgrass managers, and when and how to use them, refer to the following UF/IFAS Extension Publications:

- Insect Pest Management on Turfgrass (available: https://edis.ifas.ufl.edu/ig001) - ARCHIVED
- Turfgrass Disease Management (available: https://edis.ifas.ufl.edu/lh040)
- Nematode Management for Golf Courses in Florida (available: https://edis.ifas.ufl.edu/in124)
- Weed Biology and Management in Turf Series (available: https://edis.ifas.ufl.edu/topic_series_weed_biology_and_management_in_turf)
- Pesticide Formulations (available: https://edis.ifas.ufl.edu/pi231) Online searches for University of Florida extension publications can be made at http://edis.ifas.ufl.edu/advsearch.html.

Consult with UF/IFAS extension agents or faculty, chemical distributors, product manufacturers, or independent turf or sports field maintenance consultants.

The basic steps of an IPM program are as follows:

- *Identify key pests and key plants. Know which pests are associated with the turf species and cultivars being used.*
- *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" reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.*

## ***Written Plans and Record Keeping***

It is essential to develop a written IPM plan and to record the results of scouting to develop historical information, document patterns of pest activity, and document successes and failures. Record keeping is required to comply with the federal Superfund Amendments and Reauthorization Act (SARA, Title III), which contains emergency planning and community right-to-know legislation. If restricted-use pesticides (RUPs) are used on sports fields, certain record-keeping requirements apply.

**Best Management Practices for Written Plans:**

1. Document, identify, and record key pest activities on key plants and locations.
2. 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).
3. Determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.
4. Observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so intelligent decisions can be made regarding how damaging they are and what control strategies are necessary.

## ***Monitoring and Scouting***

Monitoring, or scouting, is the most important element of a successful IPM program. It enables you to monitor 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 to develop historical information, document patterns of pest activity, and document successes and failures.

Look for the following when monitoring:

- ***What are the signs of the pest?*** *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.*

**Best Management Practices for Monitoring and Scouting:**

1. Observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so intelligent decisions can be made regarding how damaging they are and what control strategies are necessary.
2. Recognize different pests, 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).
3. Determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.
4. Document, identify, and record key pest activities on key plants.
5. Look for signs of the pest. These may include mushrooms, animal damage, insect frass, or webbing.
6. Identify the symptoms of the pest. Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.
7. Determine the damage. Problem areas might include the edges of fields, shady areas, or poorly drained areas.
8. Document when the damage occurred. Note the time of day, year, and flowering stages of nearby plants.

9. Map pest outbreak locations to identify patterns and susceptible areas for future target applications and ultimate pesticide reductions.

## ***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 site for direction on which resources to use: https://plantpath.ifas.ufl.edu/extension/plant-diagnostic-services/. These include the 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://entnemdept.ufl.edu/nematology-assay-lab/). The Rapid Turfgrass Diagnostic Service was designed and implemented for managers of high quality turfgrass in Florida for very fast turn-around (available: https://turf.ifas.ufl.edu/rapid-turf-diagnostics-service/).

# SECTION 8 – PESTICIDE MANAGEMENT

## Pesticide Regulation and Legal Issues

Before any pesticide product is sold or distributed in Florida, it must be registered by the U.S. Environmental Protection Agency (EPA) and Florida Department of Agriculture and Consumers Services (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***

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.

Pesticides registered for use in Florida carry a label that provides, among other information, the maximum allowed application rates; approved application methods and times, sites, and pests;

and directions for safe and effective use. State and federal laws require the use and disposal of pesticides according to the label.

**Best Management Practices for Pesticide Management:**

1. Only apply pesticides that are legally registered at all levels of jurisdiction.
2. Only apply pesticides that are legally registered for use on sports fields and athletic facilities (for example, do not apply pesticides labeled for agricultural uses even though they may have the same active ingredient).
3. Apply according to manufacturer recommendations as seen on label.

## ***Licensing Requirements for Pesticide Use in Sports Field Maintenance***

Laws regarding pesticide use (Chapter 487, F.S.) require that sports field managers using restricted use pesticides (RUPs) obtain a RUP applicator license from FDACS. Information found here (https://pested.ifas.ufl.edu/media/pestedifasufledu/docs/PI292.pdf) can guide you to find out which pesticide license you may need. This link provides helpful information on how to obtain your pesticide license - https://pested.ifas.ufl.edu/applicators/. For more information contact the FDACS Bureau of Licensing and Enforcement at (850) 617–7870.

## ***Continuing Education and Applicator Training***

Once a pesticide applicator has successfully passed the examinations, continuing education units (CEUs) or retesting are necessary for renewal. UF/IFAS and industry associations such as the Sports Field Managers Association (SFMA) 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.

***Record Keeping***

The Florida pesticide law requires certified applicators to keep records of applications 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.

Florida law requires that you record the following items to comply with the RUP recordkeeping requirement:

- *Brand or product name*
- *EPA registration number*
- *Total amount applied*
- *Location of application site*
- *Size of area treated*
- *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*
- *Name of the person authorizing the application, if the licensed applicator does not own or lease the property*

Florida law also requires 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 five cumulative acres within a 24-hour period. For a land or surface area less than five 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://forms.freshfromflorida.com/13328.pdf.

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.

**Best Management Practices for Record Keeping:**

1. Keep and maintain records of all pesticides used to meet legal (federal, state, and local) reporting requirements.

2. Use records to monitor pest control efforts and to plan future management actions.
3. Use electronic or hard-copy forms and software tools to properly track pesticide inventory and use.
4. Develop and implement a pesticide drift management plan.
5. Keep a backup set of records in a safe, but separate storage area.

## Pesticides and Water Quality

Because Florida's climate favors the growth of many harmful insects, nematodes, weeds, and plant diseases, sports fields often need 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 sports field management and is desired by both facility managers 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.

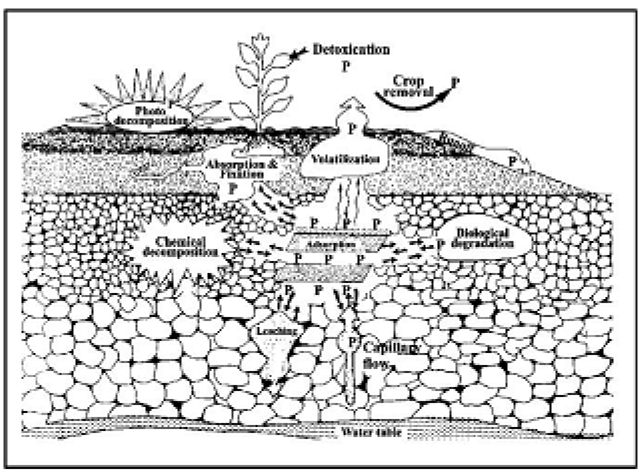
### ***Surface Water and Ground Water Resources***

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.

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. This recharge water can pick up pesticide and carry them into the ground water. 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.

## ***Behavior of Pesticides in Soil and Water***

**Figure x. Pathways of pesticide loss (Rao and Hornsby, 1993; adapted from Skrotch and Sheet, 1981)**




Once a pesticide is applied to turfgrass, several environmental fate processes may occur (**Figure x**). 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.

***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 been attributed to exposure to pesticides—usually because 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, fungi, or other microorganisms that might degrade thatch or control pathogens or are important to nutrient dynamics and overall soil health.

This is particularly important for sports fields, which are often located near schools, residential areas, or other sensitive sites. 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 turf or neighboring properties, pets, or people. It may also contaminate surface water if the pesticide settles on a waterbody.

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 modern pesticides are designed to break down or "degrade" relatively rapidly over time as a result of chemical and microbiological reactions in soils. Sunlight breaks down some pesticides, and soil microorganisms can break down others. 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. In the soil, a pesticide's half-life may be affected by soil type, soil horizons, sediments, temperature, and pH.

As a pesticide moves through soil, some of it binds 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.

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).

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.

## ***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.

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 surfaces 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., honeybees). A “bee hazard” warning may be required in the environmental hazard section of the product labels for pesticide active ingredients or formulations that are acutely toxic to honeybees.
- 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:

*Managing Pesticide Drift*

(Available: https://edis.ifas.ufl.edu/pi232)

- *Pesticide Formulations*

(Available: https://edis.ifas.ufl.edu/pi231)

**Best Management Practices for Pesticide Selection:**

1. Select pesticides that have a low runoff and leaching potential.
2. Before applying a pesticide, evaluate the impact of site-specific characteristics (for example, proximity to surface water, water table, and well-heads; soil type; prevailing wind; etc.) and pesticide-specific characteristics (for example, half-lives and $K_{oc}$ values).
3. Select pesticides with reduced impact on pollinators.
4. Select pesticides that, when applied according to the label, have no known effect on endangered species present on the facility.

## ***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 $LD_{50}$ value, which is the dose that is lethal to 50% of the test animal population. Therefore, the lower the $LD_{50}$ value, the more toxic the pesticide.

This is particularly important in sports field management where there may be multiple exposure routes to consider:

- Applicator exposure during mixing and application
- Player contact with treated surfaces
- Spectator exposure from drift or vapor
- Maintenance staff exposure during post-application field work

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/pdffiles/PI/PI00800.pdf).

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:

- National Pesticide Telecommunications Network fact sheet, *Signal Words* (available: http://npic.orst.edu/factsheets/signalwords.pdf).

**Best Management Practices for Pesticide Risk and Applicator Safety:**

1. Select the least toxic pesticide with the lowest exposure potential.
2. Know the emergency response procedure in case excessive exposure occurs. Schedule applications during periods of lowest field use.
3. Post appropriate signage and observe all re-entry intervals.
4. Maintain detailed records of applications and any reported exposure incidents.
5. Consider wind conditions and proximity to occupied areas when applying pesticides.

## ***Pesticide Handling and Storage***

The proper handling and storage of pesticides is important for sports field facilities, particularly those located at schools or public parks where security and safety are paramount concerns. Failure to properly handle and store pesticides may lead to:

- Serious injury or death of an operator or bystander
- Fires
- Environmental contamination resulting in large fines and cleanup costs
- Civil lawsuits
- Destruction of the turf you are trying to protect
- Wasted pesticide product
- Facility closure or restricted access
- Adverse public relations

## ***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 Safety Data Sheet (SDS) for each pesticide for the safety equipment requirements.

Additional sources of information on PPE include the following:

- *Personal Protective Equipment for Handling Pesticides* (Available: http://edis.ifas.ufl.edu/pi061)
- *Laundering Pesticide-Contaminated Clothing* (Available: http://nasdonline.org/1912/d001868/laundering-pesticide-contaminated-clothing.html)

**Best Management Practices for Personal Protection Equipment:**

1. Provide adequate PPE for all employees who work with pesticides (including equipment technicians who service pesticide application equipment).
2. Ensure that PPE is sized appropriately for each person using it.
3. Make certain that PPE is appropriate for the chemicals used.
4. Ensure that PPE meets rigorous testing standards and is not just the least expensive.
5. Store PPE where it is easily accessible but not in the pesticide storage area.
6. Forbid employees who apply pesticides from wearing facility uniforms home where they may come into contact with children.
7. Provide laundering facilities or uniform service for employee uniforms.
8. The federal Occupational Safety and Health Administration (OSHA) requires employers to fit test workers who must wear tight-fitting respirators.

9. Meet requirements for OSHA 1910.134 Respiratory Protection Program.

## ***Pesticide Storage***

For sports field facilities, especially those at schools or public venues, proper pesticide storage is critical. The storage and handling of pesticides in their concentrated forms pose the highest potential risk to ground water or surface water. 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 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 Florida Department of Community Affairs (FDCA) and your local emergency response agency. Check with your dealer about community right-to-know laws for the materials that you purchase.

### ***Storage Facilities***

Pesticides should be stored in a lockable concrete or metal building. For sports facilities, especially those on school grounds or public parks, secure storage is essential. It protects both Florida's environment and reduces the risk of pesticide theft, vandalism, or unauthorized access. This is particularly important given that sports fields are often located in high-traffic areas with regular public access.

The pesticide storage area should be separated from other buildings or at least separated from areas used to store other materials, especially fertilizers. For sports facilities, these storage areas should also be:

- Located away from high-traffic areas and spectator zones
- Clearly marked with appropriate warning signs in multiple languages if needed
- Secured with high-quality locks and security systems if warranted
- Positioned to allow emergency service access
- At least 50 feet from other structures to allow fire department access

Storage Facility Requirements:

- Floors should be impervious and sealed with a chemical-resistant paint
- Continuous sill to retain spilled materials and no drains, although a sump may be included
- Sloped ramps at the entrance for safe material movement
- Sturdy plastic or reinforced metal shelving (metal shelving should be kept painted to avoid corrosion)
- Never use wooden shelving, as it may absorb spilled pesticides
- Automatic exhaust fans and emergency wash area
- Explosion-proof lighting may be required
- Light and fan switches located outside 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 SDSs 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).

**Best Management Practices for Pesticide Storage Facilities:**

1. Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
2. Store pesticides in a lockable concrete or metal building separate from other buildings.
3. Locate storage facilities away from other structures to allow emergency access.
4. Storage facility floors should be impervious and sealed with chemical-resistant paint.
5. Floors should have a continuous sill to retain spilled materials and no drains, although a sump may be included.
6. 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.
7. Shelving should be made of sturdy plastic or reinforced metal.
8. Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides.
9. 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.

10. Avoid temperature extremes inside the pesticide storage facility.
11. Personal protective equipment (PPE) should be easily accessible and stored immediately outside the pesticide storage area.
12. Do not transport pesticides in the passenger section of a vehicle.
13. Never leave pesticides unattended during transport.
14. Ensure labels are on every package and container.
15. Ensure proper ventilation and lighting systems are maintained.
16. Post clear warning signs and emergency contact information.
17. Maintain an up-to-date inventory system with current SDSs.
18. Ensure that labels remain properly affixed to their containers.
19. Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.

***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 Extension Bookstore, and the USDA–NRCS.

Operation Cleansweep is a mobile collection program that provides agricultural producers, nursery and golf course operators, and pest control services a safe and economical method of disposing of cancelled, suspended and unusable pesticides. Contact FDEP at https://floridadep.gov/waste/permitting-compliance-assistance/content/operation-cleansweep-pesticides.

**Best Management Practices for Pesticide Inventory:**

1. An inventory of the pesticides kept in the storage building and the Safety Data Sheets (SDS) for the chemicals used in the operation should be accessible on the premises but not kept in the pesticide storage room itself.
2. Adopt the “first in–first out” principle, using the oldest products first to ensure that the product shelf life does not expire.
3. Participate in “Operation Cleansweep” to assist with free disposal of cancelled, suspended, and unusable pesticides that are being stored.

## ***Chemical Mixing and Loading***

For sports field facilities, the proper location and design of chemical mixing areas is crucial. 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. This is especially important when mixing and loading areas may be near athletic fields, spectator areas, or parking lots.

One of the best containment methods is the use of a properly designed and constructed chemical mixing center (CMC). 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.

For sports facilities, consider these additional factors when designing mixing areas:

- Distance from high-traffic areas and spectator zones

- Accessibility for delivery vehicles
- Security from unauthorized access
- Proper drainage and containment
- Emergency equipment accessibility
- Proper lighting for early morning or evening mixing operations

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 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, oil spill material, or sand may be used to clean up small spills and then applied as topdressing in accordance with the label rates or disposed of as a waste. Solid materials, of course, can be swept up and reused.

Wastewater 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 wastewater 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).

**Best Management Practices for Chemical Mixing and Loading:**

1. Ensure mixing and loading areas are properly sited away from sensitive areas
2. Use impermeable surfaces for all mixing and loading operations
3. Clean mixing areas daily and immediately after any spill
4. Maintain spill containment and cleanup equipment at mixing sites
5. Keep detailed records of all mixing and loading operations
6. Train all staff in proper mixing and loading procedures
7. Ensure proper security measures are in place
8. Post clear signage and emergency contact information

***Pesticide Container Management***

The containers of some commonly used pesticides are classified as hazardous waste if not properly rinsed, and as such, are subject to the many rules and regulations governing hazardous waste. The improper disposal of a hazardous waste can result in 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.

For sports field facilities, proper container management is particularly important due to:

- Public visibility and scrutiny of operations
- Proximity to sensitive areas or populations
- Need to maintain positive public relations
- Risk of unauthorized access to empty containers
- Local regulations regarding waste disposal

Both federal law (FIFRA) and the Florida Pesticide Law (Chapter 487, F.S.) 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.

Immediate and proper rinsing removes more than 99% of the container residues typically left by most liquid pesticide formulations. Properly rinsed pesticide containers pose minimal risk for contamination of soil and water resources. For sports field facilities, proper rinsing is especially important as containers may be temporarily stored in areas with higher foot traffic or near maintenance facilities.

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

- Formulation residues have not had time to dry and cake
- Rinsing during mixing/loading allows rinse water to be added to the spray mix
- Reduces risk of exposure to maintenance staff or facility users
- Minimizes storage of contaminated containers

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.*

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.

**Best Management Practices for Pesticide Container Management:**

1. Rinse pesticide containers immediately to remove the most residue.

2. Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.
3. Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.
4. Puncture empty and rinsed pesticide containers and dispose of according to the label.
5. Store rinsed containers securely until disposal.
6. Maintain detailed records of container disposal.
7. Follow all local regulations for container disposal.

## ***Emergency Preparedness and Spill Management***

Sports field facilities must be particularly well-prepared for pesticide emergencies due to:

- Proximity to public areas
- Potential impact on scheduled activities
- Media attention during incidents
- Need for rapid response to protect public safety
- Multiple stakeholders involved in emergency response

Every sports field facility should have an emergency response plan that includes:

- Clear chain of command
- Communication protocols with facility users
- Evacuation procedures if needed
- Media response procedures
- Coordination with local emergency services
- Specific procedures for different types of incidents

- Contact information for all relevant authorities

Accidents happen. Advance preparation on what to do when an accident occurs is essential to mitigate human health effects and environmental impact. The size and scope of the accident dictates the necessary response.

Sports field managers and facility owners must comply with all applicable federal, state, and local regulations on:

- Spill response training for employees
- Spill-reporting requirements
- Spill containment procedures
- Cleanup protocols
- Public notification requirements
- Documentation procedures

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. 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 turf as a pesticide in accordance with the label instructions. Large spills or uncontained spills involving hazardous materials may best be remediated by hazardous material cleanup professionals.

***Emergency Response Steps***

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 SDS and the label. Follow these 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*
4. ***STORE*** *the containers of spilled material until they can be applied as a pesticide or appropriately disposed of*

**Best Management Practices for Emergency Response:**

1. Develop a facility-specific emergency response plan that includes procedures to control, contain, collect, and store spilled materials.
2. Prominently post "Important Telephone Numbers" including CHEMTREC, for emergency information on hazards or actions to take in the event of a spill.
3. Ensure an adequately sized spill containment kit is readily available.
4. Designate a spokesperson who will speak on behalf of the facility should an emergency occur.
5. Host a tour for local emergency response teams to show them the facilities and discuss the emergency response plan.

6. Maintain good relationships with local emergency responders.
7. Conduct regular emergency response drills.
8. Keep detailed records of all incidents and responses.
9. Review and update emergency procedures annually.

For emergency (only) information on hazards or actions to take in the event of a spill, call CHEMTREC, at (800) 424-9300. For information on whether a spilled chemical requires reporting, call the CERCLA/RCRA help line at (800) 424-9346.

Remember: The safety of people—including facility users, spectators, and emergency responders—always takes precedence over environmental concerns during an emergency response. However, once people are safe, take all necessary steps to contain the spill and prevent environmental contamination.

# SECTION 9: MAINTENANCE OPERATIONS FOR SPORTS FIELDS

Good housekeeping within and outside the maintenance facility is critical to protecting Florida's natural resources. Managers responsible for the operation, training, and supervising of employees should audit routinely to measure BMP effectiveness, repair needs, and future improvements.

Routine inspections should evaluate employee performance in properly maintaining and applying the necessary BMPs. Timely inspection meetings allow for questions and follow-up, which supports positive morale, accident prevention, and identifying inappropriate practices that may negatively impact the environment.

There are five important areas of concern that require constant attention: Fueling Areas, Equipment Washing Facilities, Chemical Mixing Centers, Equipment Storage Areas, and Waste Handling Sites. Each area requires a separate BMP checklist to ensure employee safety, minimize environmental risks, and support reliable equipment operation and longevity.

Recordkeeping is essential for reporting incidences, supporting renovation needs, and meeting federal, state, and local government compliance requirements.

## Fueling Areas

Storage Tank Compliance is part of the Permitting and Compliance Assistance Program in the Florida Department of Environmental Protection's Division of Waste Management (Storage Tank Compliance). Stationary aboveground tanks with a capacity greater than 550 gallons and underground storage tanks with a capacity greater than 110 gallons are regulated by DEP. This guide provides helpful information when considering storage tanks: Getting Started for New Storage Tank Owners.

The first line of managing the maintenance of fueling areas is to minimize the possibility of discharge and the need for disposal. With 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 allow any water that is contaminated to be discharged to the environment.

Treat contaminated water on-site by using commercially available treatment systems, discharging it to an DEP-permitted off-site industrial wastewater treatment system, or transporting it by tanker truck to a treatment facility. Never discharge contaminated water 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 DEP 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.

**Best Management Practices for Fueling Areas:**

1. Above-ground storage tanks (ASTs) are preferred as they are more easily monitored for leaks.
2. Fueling stations should be located under roofed areas with concrete pavement, not asphalt.
3. Fueling areas should also have spill containment and recovery facilities located nearby.
4. Develop a record-keeping process to monitor and detect leakage from storage tanks.
5. Visually inspect any AST for leakage and structural integrity.
6. Secure fuel storage facilities and allow access only to authorized and properly trained staff.

## Equipment Washing Facility

An equipment-washing facility can be a source of both surface and groundwater pollution if the wastewater generated is not properly handled. All equipment used in the maintenance of sports fields should be designed, used, maintained, and stored in a way that eliminates or minimizes the potential for pollution. Wastewater 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 wastewater (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 wastewater to flow to a grassed retention area or swale. Do not allow any wastewater 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.

Grass clippings-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. 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 wastewater to flow directly into surface waters or storm drains.

While there are no state requirements to have a closed recycling system for wastewater, 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 DEP publication Guide to Best Management Practices for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment

Wash Facilities provides additional information on the design and operation of these facilities and the BMPs that may help you avoid the need for a permit. 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 DEP 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 separators since the pesticide residues will contaminate the oil that is salvaged. Be aware that the oil collected in these systems may be classified as 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.

**Best Management Practices for Equipment Washing:**

1. Use compressed air to blow off equipment because it is less harmful to the equipment's hydraulic seals, eliminates wastewater, and produces dry material that is easier to handle.
2. 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.
3. Handle clippings and dust separately. After the residue dries on the pad, it can be collected and composted or spread in the field.
4. Minimize the use of detergents. Use only biodegradable non-phosphate detergents.
5. Solvents and degreasers should be used over a collection basin or pad that collects all used material.
6. 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.
7. Do not discharge wastewater to surface water or groundwater either directly or indirectly through ditches, storm drains, or canals.
8. 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.
9. Never discharge to a sanitary sewer system without written approval from the proper entity.
10. Never discharge to a septic tank.

Other options include the following:

- Use a closed-loop wastewater recycling system and follow DEP BMPs.
- Discharge to a treatment system that is permitted under DEP industrial wastewater rules.
- Use the wastewater for field irrigation.

## Pesticide Application Equipment Washing

Wastewater 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 wastewater 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 chemical mixing center (CMC). The pad should be flushed with clean water after the equipment is washed, and the captured wastewater 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 DEP-permitted treatment facility.

**Pesticide Application Equipment Washing Best Management Practices**

- Use compressed air to blow off equipment before washing.
- Wash equipment on a concrete or asphalt pad that allows the water to be collected and treated or disposed of properly.
- Minimize the use of detergents when washing pesticide application equipment. Use only biodegradable, non-phosphate detergents if necessary.
- Ensure washwater is collected and reused or disposed of in accordance with pesticide label instructions.
- Do not discharge pesticide-contaminated washwater to surface water or groundwater.

## Equipment Storage and Maintenance

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.

**Best Management Practices for Equipment Storage and Maintenance:**

1. Store and maintain equipment in a covered area complete with a sealed impervious surface to limit the risk of fluid leaks contaminating the environment and to facilitate the early detection of small leaks that may require repair before causing significant damage to the turf or the environment.
2. Seal floor drains unless they are connected to a holding tank or sanitary sewer with permission from the local wastewater treatment plant.
3. Store pesticide and fertilizer application equipment in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment and possibly contaminate soil or water.
4. Store solvents and degreasers in lockable metal cabinets away from ignition sources in a well-ventilated area. These products are generally toxic and highly flammable. Never store them with fertilizers or in areas where smoking is permitted.
5. Keep an inventory of solvents and Safety Data Sheets (SDS) for those materials on-site but in a different location where they will be easily accessible in case of an emergency.
6. Keep basins of solvent baths covered to reduce emissions of volatile organic compounds (VOC).
7. When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
8. Always use appropriate PPE when working with solvents.
9. Never allow solvents or degreasers to drain onto pavement or soil or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.

10. Collect used solvents and degreasers in containers clearly marked with contents and date; schedule collection by a commercial service.
11. Blow off all equipment with compressed air to reduce damage to hydraulic seals.

## Waste Handling

### ***Hazardous Materials***

- Ensure that all containers are sealed, secured, and properly labeled. Use only DEP-approved licensed contractors for disposal.

### ***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.
- Antifreeze must be recycled or disposed of as 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. Make sure that all caps are in place to contain the acid. Store batteries on an impervious surface and preferably under roof. 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 groundwater.
- 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 products. 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 SDSs 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 DEP-approved licensed contractors.

## Composting

- Ideally, composting sites should be located on a contained impervious surface pad to prevent translocation of nutrient-enriched leachate to runoff or leaching and allow the periodic turning of materials. 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 (Continued)***

- Office paper, recyclable plastics, glass, and aluminum should be recycled in accordance with local recycling ordinances. Place containers for recycling aluminum cans and glass or plastic soft drink bottles at convenient locations on the sports field. Check with your local collection provider to ensure proper collection and disposal of other recyclable materials. This can include electronics, computer equipment, light bulbs, and used tires.

**Best Management Practices for Waste Handling:**

1. Pesticides that have been mixed for application must be disposed of as waste and may be classified as hazardous waste depending on the materials involved. Contact local authorities for guidance regarding proper disposal.
2. Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them as directed by local and state authorities.
3. Antifreeze may be considered hazardous waste by state or local laws and should be handled accordingly. Commercial services are available to collect and recycle antifreeze.
4. Lead-acid batteries are classified as hazardous waste unless they are properly recycled.
5. Store old batteries on impervious surfaces where they are protected from rainfall and recycle as soon as possible.

6. Recycle used tires.
7. Recycle or dispose of fluorescent tubes and other lights according to state requirements.

**Additional Considerations for Sports Field Management**

- **Local Regulations**: Be aware of any specific local regulations that may apply to sports field facilities, particularly those near schools or public parks.
- **Recycling Programs**: Consider implementing a recycling program for sports equipment and uniforms that are no longer usable.
- **Artificial Turf Maintenance**: For artificial turf fields, follow manufacturer guidelines for proper maintenance and disposal of worn-out turf materials.
- **Natural Turf Renovation**: When renovating natural turf fields, consider options for reusing or recycling removed turf and soil.
- **Noise Pollution**: Be mindful of noise pollution when operating maintenance equipment, especially in residential areas or during early morning or late evening hours.
- **Integrated Pest Management (IPM)**: Implement an Integrated Pest Management (IPM) program to reduce reliance on chemical pesticides and minimize waste.
- **Regulation Updates**: Stay informed about updates to Florida's environmental regulations that may affect sports field management practices. The Florida Department of Environmental Protection website (Florida DEP) is a good resource for current information.

Remember, these best practices are designed to protect Florida's natural resources while maintaining high-quality sports fields. Regular training of staff and clear communication of these practices are essential for their successful implementation.

# SECTION 10: SYNTHETIC SPORTS FIELDS

While natural grass remains the preferred playing surface for most sports fields in Florida, some facilities have installed synthetic turf fields in recent years. Synthetic turf can provide a consistent, durable surface that allows for increased field usage, especially in high-traffic areas or multi-use facilities. The Sunshine State's unique environmental factors—including high temperatures, humidity, frequent rainfall, and occasional extreme weather events—create a set of challenges that demand specialized management approaches. This chapter outlines comprehensive best management practices (BMPs) for synthetic turf fields in Florida with the goal of maximizing field performance, ensuring user safety, extending field longevity, and addressing environmental concerns.

## Field Construction and Installation

The foundation of a high-performing synthetic turf field lies in proper construction and installation, which is particularly crucial in Florida's demanding climate. Given Florida's propensity for heavy rainfall and potential flooding, exceptional drainage is paramount. A minimum slope of 0.5% is recommended, but in areas prone to more intense precipitation, a slope of up to 1% may be advisable. The subsurface drainage system should be designed to handle not just average rainfall but also intense storm events. This typically involves a network of perforated pipes within a gravel layer beneath the turf.

Key components of a well-designed base include:

- Geotextile fabric layer to separate subgrade from aggregate
- 4-6 inches of larger stone (1-1.5 inch diameter)
- 2-3 inches of smaller stone (0.5-0.75 inch diameter)
- Final layer of fine aggregate or stabilized stone dust

In Florida, it's crucial to consider the potential for sinkholes, particularly in karst topography areas. Geotechnical surveys and appropriate substrate stabilization measures may be necessary in vulnerable locations. This might involve additional reinforcement layers or specialized geotextiles designed to bridge potential voids.

The choice of turf and infill materials should be specifically suited to Florida's hot and humid conditions. Turf fibers with advanced heat-reflective properties and UV stabilizers can help mitigate extreme surface temperatures and resist degradation from intense sunlight.

Factors to consider when selecting infill include:

- Heat absorption and retention properties
- Drainage capabilities
- Durability in high-UV environments
- Resistance to microbial growth in humid conditions
- Potential for migration during heavy rain events
- Player safety characteristics
- Environmental impact and end-of-life recyclability

Some newer infill options specifically designed for hot climates include coated silica sand with cooling properties, cork and coconut fiber blends, treated olive cores, and engineered geoinfills. It's crucial to test multiple infill options under simulated Florida conditions before making a final selection.

The installation of a shock pad beneath the turf is strongly recommended for Florida fields. When selecting a shock pad, consider pads with excellent drainage properties to handle heavy rainfall, materials resistant to moisture-related degradation, pads that contribute to heat reduction (some newer products incorporate phase-change materials for this purpose), and thickness and density appropriate for the intended sports and level of play.

**Best Management Practices for Synthetic Field Construction:**

1. Conduct geotechnical surveys to assess sinkhole risk.
2. Design drainage for heavy rainfall (0.5–1% slope; subsurface pipes in layered stone).
3. Use a base with geotextile, large and small stone, and fine aggregate.
4. Select UV- and heat-resistant turf and infill materials.
5. Test infill options under simulated Florida conditions.
6. Install shock pads with drainage, thermal reduction, and sport-specific cushioning.

## Temperature Management

Temperature management is perhaps the most critical concern for synthetic fields in Florida. Surface temperatures on these fields can exceed 150°F on hot days, posing significant health risks to athletes**.** Establish a temperature monitoring protocol that includes multiple daily readings during peak heat periods, measurements at various locations across the field, recording of ambient air temperature and humidity alongside surface readings, and documentation of weather conditions. This data should be logged and analyzed over time to identify patterns and inform management decisions.

Several cooling strategies can be employed to manage field temperatures:

- Automated irrigation systems for cooling
- Misting systems (with proper water quality management)
- Reflective field covers for periods of non-use
- Infill products with cooling properties
- Subsurface cooling systems (e.g., cooling pipes or glycol circulation)

Develop a comprehensive heat management policy that includes a tiered system of activity modifications based on WBGT (Wet Bulb Globe Temperature) readings, mandatory cool-down periods during extreme heat, alteration of practice times to avoid the hottest parts of the day, and gradual acclimatization protocols for athletes, especially at the start of fall sports seasons.

Additionally, develop comprehensive educational materials covering:

- Signs and symptoms of heat-related illnesses
- Proper hydration practices
- Appropriate clothing and equipment for synthetic turf use in hot conditions
- Importance of acclimatization and gradual intensity increases
- Emergency protocols for heat-related incidents

## Maintenance Practices

Regular, diligent maintenance is key to ensuring field safety, performance, and longevity, particularly in Florida's challenging climate. Implement a comprehensive grooming program that includes daily inspection and light grooming of high-wear areas, weekly full-field grooming using a combination of techniques (brushing to stand fibers upright, raking to redistribute infill, light dragging to level the surface), and monthly deep grooming to decompact infill and restore field resilience.

While synthetic fields do not need to be mowed, regular cleaning is important. Develop a cleaning protocol that addresses removal of organic debris, management of spills and stains, removal of chewing gum and other adhesive materials, cleaning of perimeter areas to prevent tracking of contaminants onto the field, and application of approved cleaning agents for disinfection and odor control.

As synthetic fields are used and begin to age, it will be necessary to repair damaged sections. Develop a repair kit and protocol for addressing common issues such as seam repairs, inlay touchups, fiber replacement in worn areas, and perimeter re-attachment.

**Best Management Practices for Synthetic Field Maintenance:**

1. Inspect daily; groom high-wear areas lightly.
2. Perform weekly full-field grooming and monthly deep grooming.
3. Track infill depth and replenish as needed.
4. Clean regularly: debris, stains, adhesives, and perimeter areas.

5. Conduct routine inspections (daily to post-storm).
6. Maintain repair kits and document repairs.
7. Test bi-annually (Gmax), annually (HIC), and quarterly (infill, fibers, ball response, infiltration).

## Stormwater Management

Florida's high rainfall and potential for intense storm events necessitate robust stormwater management strategies for synthetic turf fields**.** Develop a drainage maintenance plan that includes a map of the entire drainage system, a schedule for routine inspections and cleaning, protocols for addressing common drainage issues, and procedures for testing infiltration rates across the field surface.

When designing these systems, consider local rainfall patterns and intensity, soil types and infiltration rates, potential pollutants from field runoff, and integration with existing municipal stormwater systems.

When implementing a water reuse system, size storage tanks based on local rainfall patterns and anticipated usage, implement appropriate filtration and treatment systems, regularly test water quality to ensure safety for intended uses, and develop clear protocols for system maintenance and water distribution.

## Pest Management

While synthetic fields generally reduce many pest issues common to natural turf, Florida's climate can still present unique challenges. Implement a vegetation management plan that includes regular perimeter inspections, hand removal of small weeds before they establish, careful spot treatment with approved herbicides when necessary, and installation of root barriers or additional weed-suppressing materials at field edges.

Develop an integrated pest management (IPM) plan that includes:

- Regular monitoring protocols
- Identification guides for common pests
- Treatment thresholds and response plans
- List of approved, low-impact treatment options

Consider deterrence methods for animals such as buried fencing or other physical barriers, motion-activated sprinklers or lighting, ultrasonic repellent devices, and planting of repellent vegetation in surrounding landscaped areas.

Develop a microbial management plan that includes regular inspections (especially in shaded or poorly draining areas), prompt cleaning and drying of affected areas, application of approved antimicrobial treatments as needed, and addressing underlying moisture issues (e.g., improving drainage, increasing air flow).

## Environmental Considerations

Responsible environmental stewardship should be a priority in synthetic turf management, especially given Florida's diverse and sensitive ecosystems. Implement a monitoring program for infill containment that includes quarterly inspections of nearby waterways and drainage systems, documentation of any observed infill accumulation, and protocols for cleanup and containment improvement if issues are found.

When implementing heat island mitigation strategies, consider:

- Impact on field visibility and playability
- Maintenance requirements for added vegetation
- Potential for increased debris on the field from nearby plantings
- Integration with overall facility aesthetics and function

For end-of-life planning, start the process at least 1-2 years before expected field replacement, explore options for partial recycling or reuse, consider the environmental impact of transportation to recycling facilities, and investigate local regulations regarding synthetic turf disposal and recycling.

Implement water conservation measures such as:

- Using high-efficiency, low-flow nozzles for cooling systems
- Capturing and reusing runoff water for field maintenance
- Implementing smart controls on cooling systems to minimize water waste

- Regular maintenance of irrigation systems to prevent leaks and ensure optimal performance

To manage chemical runoff, use biodegradable cleaning agents when possible, implement containment measures during cleaning operations, train staff on proper chemical application and disposal procedures, and monitor and treat runoff water before it enters local water systems.

## Safety and Risk Management

Prioritizing user safety requires a comprehensive approach that goes beyond just field maintenance. Develop a standardized inspection form that covers field surface condition, perimeter and boundary conditions, goal post and equipment safety, signage and field markings, and surrounding areas. Develop and regularly review an emergency action plan that addresses various scenarios, and conduct regular drills to test the effectiveness of emergency response plans.

Implement comprehensive lightning safety measures, including:

- Installing a reliable lightning detection system
- Establishing clear policies for field clearance and sheltering during thunderstorms
- Designating and clearly marking safe shelter areas
- Training staff and educating users on lightning safety procedures
- Considering installing lightning protection systems on tall structures near the field

Regularly update educational materials for users based on feedback and any incidents that occur. Implement a system for tracking and analyzing injuries that occur on the field, including developing a standardized injury reporting form, regular review of injury data by facility management and safety committee, and collaboration with local sports medicine professionals for data analysis and recommendations.

Effective management of synthetic turf fields in Florida requires a comprehensive, proactive approach that addresses the unique challenges posed by the state's climate and environment. By implementing these best management practices, facility managers can help ensure their synthetic fields remain safe, high-performing, and long-lasting while minimizing environmental impact.

As research in this field continues to evolve and new technologies emerge, staying informed about the latest developments will be crucial. Facility managers should maintain connections with industry associations, academic researchers, and experienced peers to keep abreast of emerging best practices and innovations in synthetic turf management.

Ultimately, successful synthetic turf management in Florida's challenging conditions requires a commitment to ongoing learning, adaptation, and careful stewardship. By embracing these principles, managers can provide high-quality athletic surfaces that serve their communities while respecting the unique natural environment of the Sunshine State.