USGA®

BUILDING THE USGA PUTTING GREEN: Tips for Success

2018 REVISION

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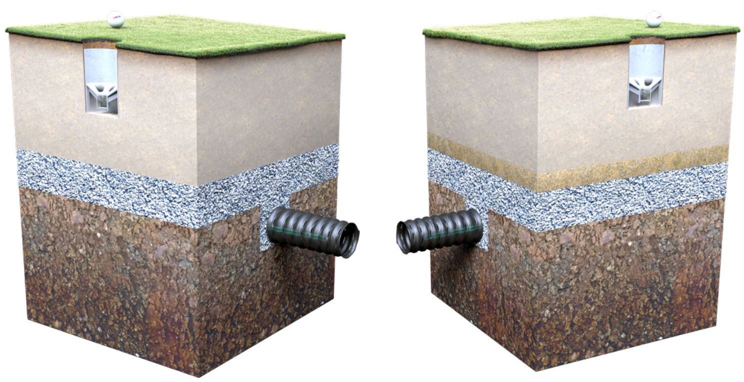
BUILDING THE USGA PUTTING GREEN:

Tips for Success

The USGA first published the USGA Recommendations for a Method of Putting Green Construction in 1960. It has been successfully used throughout the world in a wide variety of environments. The method is periodically updated to reflect the knowledge gained through scientific research, new technologies in golf course construction and field experiences.

The *USGA Recommendations for a Method of Putting Green Construction* (hereafter referred to as the Recommendations) include specific details and parameters regarding putting green construction and are not intended to be a "how to" document. For example, the Recommendations include scientifically derived parameters for the rootzone mixture, organic matter selection and gravel size. However, the Recommendations do not describe exact procedures for how best to excavate the cavity, lay out the drainage design or install the gravel and rootzone mixture. This document addresses the practical side of putting green construction. It also includes suggestions for planting and grow in.

When it comes to building a putting green, there is almost always more than one construction technique that can be used to complete the job. Equipment, soil conditions, contractor experience, crew size, architectural style, budget considerations and the weather all influence how the work is accomplished. Years of industry experience with the construction of USGA putting greens have yielded many good ideas; some make the construction process easier while others prove more helpful later in the life of a putting green. The tips for success included in this document are from the combined input of experienced agronomists, architects, builders and golf course superintendents. The tips are organized by the various stages of putting green construction.



THE USGA RECOMMENDS DIFFERENT PROFILES – ONE WITH AN INTERMEDIATE LAYER AND ONE WITHOUT – DEPENDING ON THE MATERIALS USED DURING CONSTRUCTION.

The Planning Stage

TIP 1: Evaluate the growing conditions of the proposed putting green site

Prior to beginning the actual construction of a new putting green, or renovation of an existing putting green, there are very important steps that should be taken to help ensure the success of the construction project. One of the most important steps is the evaluation of the site on which the putting green is to be constructed.

It is of utmost importance to select a site that provides favorable growing conditions. Factors that are of high priority include sunlight, air movement across the putting green, traffic patterns onto and off the putting green and drainage patterns. The USGA Green Section Collection, "Troubleshooting Problem Greens," provides additional insight into the comprehensive assessment of these and many other factors. While this document should be

VISITING THE SAND AND GRAVEL SUPPLIER HELPS ESTABLISH QUALITY CONTROL PROCEDURES AND PROVIDES EVERYONE WITH A BETTER UNDERSTANDING OF THE PROJECT REQUIREMENTS.

reviewed prior to the construction of any putting green, it also can prove invaluable when trying to identify why an existing putting green is performing poorly.

There are many examples of poorly performing putting greens that were completely rebuilt only to fail again despite the efforts of a highly skilled turfgrass manager. Even the best of construction techniques cannot compensate for poor growing conditions. Conversely, it is not uncommon to find putting greens that are poorly built by today's standards but located in such ideal growing environments that turf thrives despite the construction limitations.

TIP 2: Valuable construction information can be found at www.usga.org

A plethora of information about putting green construction can be found on the USGA Website including articles about the history of the Recommendations and selecting the proper rootzone sand, a quality control checklist for putting green construction and numerous case studies that describe various types of construction projects.

TIP 3: Select an accredited soil physical testing laboratory to evaluate potential construction materials

There is a common misconception that the rootzone mixture in a USGA putting green is always composed of 80 percent sand and 20 percent peat moss. In fact, sands, organic materials and other amendments vary so widely in their composition that the proper percentages can be determined only through scientific analysis. Thus, a critical step prior to construction is the collection and testing of potential construction materials. An accredited, physical soil testing laboratory should perform this testing. A current list of accredited labs is available on the A2LA Website. The USGA recommends that one of these labs be used throughout all aspects of the project.

TIP 4: Visit the sand and gravel supplier

When searching for gravel and sand options, make personal visits to suppliers. Visiting the site where materials are processed and stockpiled provides a good opportunity to get to know the supplier and discuss various issues important to the project. Sand and gravel suppliers may not have much experience with golf course construction, so they may be unaware of the stringent parameters in the Recommendations that might exceed those of their typical customers. Provide potential suppliers with a copy of the Recommendations and information about the accredited laboratory you have

IT IS EXTREMELY IMPORTANT THAT A SOUND, CONSISTENT SAMPLING PROCEDURE BE FOLLOWED THROUGHOUT THE PROJECT.

chosen. If the rootzone components will be blended on the supplier's site, be sure to select a location where the rootzone mixture can be stored without becoming contaminated with other materials.

TIP 5: Collect samples in the proper manner

It is very important to follow proper procedures when collecting samples from a stockpile for laboratory analysis. Improper sample collection can result in significant variability in test reports, even though the samples may have come from the exact same pile. The USGA article, "Quality Control Sampling of Sand and Rootzone Mixture Stockpiles," details the correct sampling method.

TIP 6: Know how to interpret and use test results

Testing potential construction materials is a critical process that can result in a great deal of controversy if the testing is improperly performed or the results incorrectly interpreted. Accredited soil testing laboratories follow very specific protocols to test and evaluate construction materials. Like all testing procedures, the results of these protocols have scientific limits in terms of their accuracy. Unfortunately, some golf course construction contracts have been written in a manner that demands greater accuracy of test results than can be delivered by the laboratory testing protocols. This has resulted in confusion, disruption of the construction project, lost revenue and even civil action.

The USGA, working closely with university scientists and accredited labs, has identified the maximum amount of variation for key test parameters measured during quality control testing. Table 1 details the variability percentage for each parameter. This variability percentage is more accurately defined as the confidence interval and is used to establish a range of acceptable values for each measured parameter. The USGA article, "Guidelines for Establishing Quality Control Tolerances," goes into greater detail regarding this subject.

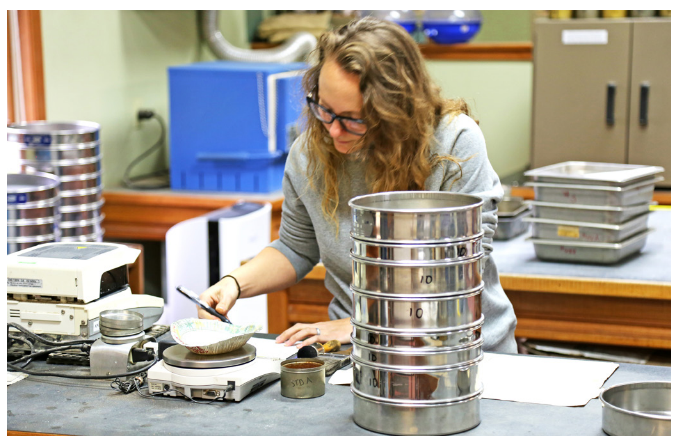
For example, assume a laboratory test indicates that the approved rootzone is 10 percent fine sand. Using the confidence interval percentage for fine sand, 15 percent, the acceptable fine sand value is 10 plus or minus 1.5 for an acceptable range for quality control testing of 8.5 to 11.5 percent.

It is important to correctly interpret and utilize the results of physical soil testing, so discuss the results with lab personnel and contact your regional USGA Agronomist.

TIP 7: Select one accredited laboratory and stick with them throughout the project

There are several key points to keep in mind during the testing process:

The first is to select one accredited laboratory and utilize only that lab throughout the entire project. Attempts to compare one lab's results against another's will likely result in confusion. There is enough variability in current laboratory protocols to result in significantly different results between labs, despite their best efforts, and it would be impossible to determine which lab is right. It is very important for everyone to realize that although the results do vary from lab to lab, all accredited labs are achieving and reporting



SELECT AN ACCREDITED LABORATORY AND UTILIZE THEM THROUGHOUT THE PROJECT TO ENSURE CONSISTENCY.

TABLE 1. USGA Confidence Intervals for Quality Control Testing

TEST PARAMETER	USGA CONFIDENCE INTERVAL(%)
Fine gravel	50
Very coarse sand	50
Coarse sand	15
Medium sand	15
Fine sand	15
Very fine sand	30
Total porosity	10
Air-filled porosity	15
Capillary porosity	15
Saturated hydraulic conductivity	25
[1] Percent organic matter	± 0.2 for mixes with > 1% OM ± 0.15 for mixes with ≤ 1% OM

[1] The confidence interval for organic matter is an absolute value, not a percentage of the target organic matter content. For example, a rootzone mixture with a target organic matter content of 0.7 percent would have an acceptable range of 0.55 to 0.85 percent.

agronomically sound information. In other words, if one accredited lab finds that a rootzone mixture drains at 14 inches per hour and another accredited lab determines the rate to be 20 inches per hour, the variance will not result in failure of the putting green due to drainage problems. However, if a contract calls for the rootzone mixture to drain at 14 inches per hour within plus or minus 1 inch per hour, legal problems are likely to arise due to the inherent variance of lab results.

The variability in laboratory test reports is not solely due to weaknesses in the testing protocols or differences in how labs perform the tests; it also stems from improper sampling and the mishandling of samples, different blending techniques and, most importantly, from the fact that materials can change as they are loaded, installed and worked with heavy equipment. If test results indicate that the materials fall within the parameters outlined in the Recommendations, moderate changes in lab reports do not signify poor workmanship or quality.

TIP 8: Don't overemphasize infiltration rate results

Soil physical testing labs test and report on numerous physical aspects of the rootzone mixture including the particle size gradation of the sand, percentage organic matter in the mixture, moisture retention, bulk density, infiltration rate – i.e., saturated hydraulic conductivity, or Ksat – and both air- and water-filled porosity percentages.

These numbers provide insights into how the rootzone mixture will perform. Often, unfortunately, too much emphasis is placed on infiltration rate. This may be because it is easier to visualize water moving into a putting green at a certain rate than it is to understand porosity values. The test for infiltration rate is one of the most variable rootzone tests. Even with the best efforts of a lab, infiltration rate test results may vary by 10 or more percent. When field variability is considered, infiltration rate has a variability range, or confidence interval, of 25 percent.

On the other hand, particle size gradation and percentage organic matter tests are much more accurate. The improved accuracy makes these results better suited for use in quality control programs. Measurable quality control standards should be established to ensure that the rootzone mixture remains as consistent as possible throughout the blending and installation processes.

TIP 9: Institute a quality control testing program

Quality control testing is the best means to ensure that the materials used during the construction of a new putting green remain reasonably consistent throughout the project. Quality control of the rootzone mixture is one of the most critical aspects. A typical quality control program involves the following steps:

1. Visit sand and gravel suppliers and collect 1-gallon samples of the sand, gravel and other amendments that will be used. Follow the procedure for sampling rootzone stockpiles referenced in Tip 4 of this section. Submit these samples to the accredited laboratory chosen for the project.

2. Based on test results, the lab will offer their advice on the best combination of materials by developing a particular mixing ratio. Identifying the best materials and mixing ratio before contracting with sand and gravel suppliers will help the suppliers develop more accurate bids.

3. The selected materials should be blended when the actual putting green construction begins. Collect a sample from the first 200-ton pile of blended rootzone mixture. Submit this sample for analysis to the same laboratory that did the preliminary testing. Keep in mind that it is very unlikely that the test results from the first 200-ton pile will exactly match the preliminary results. Several months may have elapsed between the two sets of tests, during which time the makeup of the sand or amendments may have slightly changed. The goal of the 200-ton test should not be to exactly match the preliminary test results, but rather to ensure that the current materials and blending processes yield a rootzone mixture that is agronomically suitable for the project and within the Recommendations.

4. After the laboratory verifies that the blending operation is producing an acceptable rootzone mixture, remove samples from each 1,000-ton pile and submit them to the laboratory for testing. Typically, the lab will measure particle size distribution and organic matter percentage by weight to ensure the blending process has remained consistent. The blending of additional rootzone mix can continue while these tests are performed. However, the 1,000-ton pile that is being analyzed should be isolated until testing indicates that it meets the quality control parameters identified in Table 1. Each 1,000-ton pile can be tested in this manner and, after meeting the quality control parameters, combined into a larger pile for hauling to the construction site. It may be necessary to reduce the sampling interval to every 500 tons if test results indicate borderline numbers or wide fluctuations in the nature of the materials.

Many of the accredited laboratories offer quality control testing services and can advise their consumers on how best to design an entire quality control program.

TIP 10: Allow plenty of time for testing and blending

Allow plenty of time for preparing construction materials. Sand and gravel suppliers vary widely in the quantity of materials they can harvest and clean per day. The nature of the sand and gravel may also vary within the material source, requiring the recalibration of equipment. Additionally, laboratory analysis of quality control samples takes time, as does shipping materials to the lab. Contact the lab to determine how much time will be required to perform quality control tests and what quantities of the materials should be shipped for analysis. Should the lab tests indicate problems with the mixing process, time will be needed for reblending. Equipment breakdowns and uncooperative weather also may cause delays.

TIP 11: Perform the blending operation at the sand plant

If possible, blending the rootzone mixture often is best accomplished at the sand plant. Key advantages of this arrangement include reduced trucking costs and, in most cases, adequate room to store stockpiles of sand, organic matter and other amendments if necessary. While it is certainly possible to stockpile and mix materials at a golf course, great care must be taken to keep the materials free of contamination. Many courses have tried to prevent contamination by stockpiling rootzone materials in a parking lot. Although this can be effective at preventing contamination from soil, weed seeds and vegetation; it also presents the possibility that large equipment utilized for hauling, blending and loading rootzone materials could damage the parking lot itself. Regardless of where the blending takes place, a clean storage area must be identified for stockpiling the final rootzone mixture.

Another advantage to blending at the sand plant is reduced waste. When transferring stockpiles of rootzone mixture to trucks for hauling, it is important to load only the mixture and not any of the material upon which the mix is stored. This is particularly important if the mix is stored on soil or turf. To avoid contamination, loader operators should keep their buckets at least a couple of inches above the base of the pile to leave some clean rootzone mixture as a buffer. Maintaining this buffer creates a certain amount of waste. Some mix will also be lost as it is dumped into trucks and transferred to the construction site. Most blenders and golf course contractors estimate a waste factor of 10 to 20 percent during the blending and hauling process. If rootzone blending is accomplished at the construction site, that waste becomes part of the project cost. However, when the blending is accomplished at the sand plant, the consumer is normally charged only for the material that crosses the scales as trucks exit the plant. Although some rootzone mixture is lost during trucking and installation, most of the waste occurs within the confines of the plant, resulting in greater value for the consumer.

TIP 12: Save a sample of the final rootzone mixture for visual comparison

Although certainly not a scientific test, a sample of the approved rootzone mixture can be used to visually assess deliveries of rootzone mixture as they arrive at the site. The project superintendent can compare the color and texture of the mix in a truck with that of a sample collected from the approved mix. If there is a significant difference in appearance, the material in the truck can be temporarily stockpiled until further testing is performed. Be aware that differences in moisture levels can change the color of the rootzone mixture, so care must be taken not to overemphasize this simple test.

TIP 13: Collect and store a 5-gallon sample of the final rootzone mixture

As a putting green ages, periodically remove rootzone mixture samples for physical analysis. This type of testing

BLENDING THE ROOTZONE MATERIALS AT THE SAND PLANT PROVIDES NUMEROUS ADVANTAGES OVER BLENDING AT THE CONSTRUCTION SITE.

EXTRA TIME SPENT PREPARING THE SUBGRADE WILL RESULT IN A SMOOTH, WELL-COMPACTED BASE THAT WILL SERVE AS A STRONG FOUNDATION UPON WHICH TO BUILD A PUTTING GREEN.

will determine if undesirable changes are occurring to the rootzone mixture, particularly regarding its ability to drain. For example, if the percentage of clay in the rootzone mixture is rapidly increasing, the source of the clay must be identified and reduced or eliminated. By saving some of the original rootzone mixture, it will be easy to compare rootzone samples collected from putting greens as they age to the original material. The soil physical testing laboratory also can use the original mixture to calibrate their testing procedures to more closely match the original test results. This allows for a more accurate assessment of how the rootzone mixture has changed over time.

TIP 14: Utilize the expertise of USGA Agronomists

There are many aspects of putting green maintenance and construction planning that should be addressed prior to beginning the actual construction process. USGA Agronomists have dealt with these issues many times and are an excellent source of information. Anyone considering a project as large as the construction or reconstruction of a putting green is urged to contact your regional USGA Agronomist.

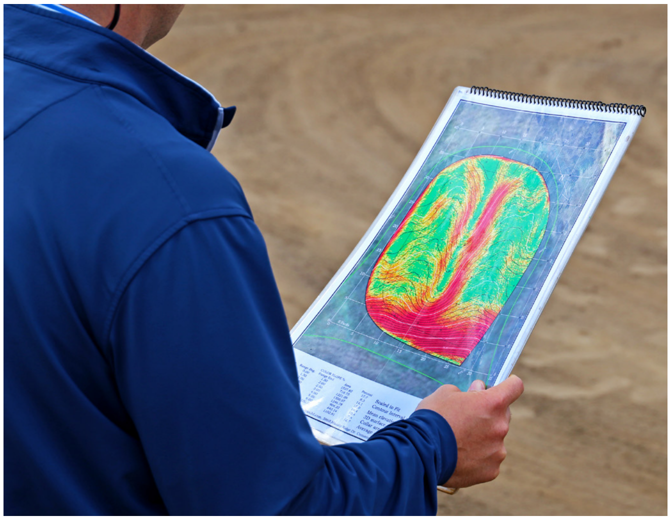
Subgrade

Like the foundation of any structure, proper construction of the subgrade is critical to the success of a putting green. Extra care and effort during this stage helps improve the efficiency of subsequent construction steps. In many cases, construction of the subgrade is the most difficult aspect of putting green construction. Often, the soils utilized during subgrade construction are of poor quality and difficult to grade smoothly, making the task of achieving a firm and smooth subgrade challenging.

Preparing the subgrade differs depending on the type of construction. When building an entirely new putting green, the subgrade usually is prepared during rough shaping of the putting green complex. When renovating an existing putting green, the putting green site may be excavated while the surrounding areas are left undisturbed. In either case large, tracked equipment is typically used during subgrade construction.

TIP 1: The subgrade does not have to exactly mirror the finished putting green contours

The Recommendations state that, “the slope of the subgrade should conform to the general slope of the finished grade.” Prior to the 1993 revision, the Recommendations stated that the subgrade must conform to the final grade of the putting green, plus or minus 0.5 inch. During the process of reviewing the Recommendations, it was realized that varying the depth of the gravel layer would not adversely impact putting green performance as long as a minimum of 4 inches of gravel is maintained. Using additional gravel to shape the final contours of the putting green often is easier than



SPECIALIZED SURVEYING EQUIPMENT MAKES IT POSSIBLE TO DIGITALLY MAP PUTTING SURFACES PRIOR TO RENOVATION SO THE CONTOURS CAN BE REPLICATED EXACTLY.

working with the heavy soil typically used to construct the subgrade, so the USGA adjusted the subgrade contouring recommendation.

TIP 2: Provide equipment operators with enough information to achieve the desired subgrade

A variety of methods can be used to ensure the subgrade is built according to the golf course architect's design. Grade stakes are commonly used to help equipment operators create the general contours of a finished putting green. The density of staking depends on the complexity of putting green contours and the experience of the equipment operators. As a general rule, grade stakes installed in 20-foot intervals provide sufficient guidance while allowing enough maneuvering room.

Some putting green renovation projects require new putting greens to conform to the exact contours of existing putting greens. A variety of methods can be used to successfully replicate the contours of an existing putting green; including intensive staking and GPS mapping. When replicating a putting green, the subgrade should be frequently surveyed to ensure that the shaping is as precise as possible.

TIP 3: Coring out an existing putting green requires precision and thoroughness

When existing putting greens are rebuilt, typically they are excavated to the appropriate depth while leaving surrounding areas undisturbed. This process, commonly referred to as coring out, often is conducted using an excavator with an articulating bucket that allows for precise excavation. The existing rootzone mixture, gravel layer and any subsurface drainage pipes must be removed during the excavation process. The subgrade floor can then be graded according to the golf course architect's design. Invariably, some hand shoveling is necessary to achieve a sharp, well-defined wall on the putting green cavity.

TIP 4: Work the subgrade to achieve smoothness and compaction

After the subgrade has been roughly shaped, small equipment is typically used to develop a smooth, well-compacted floor. The operator repeatedly works the entire subgrade surface, eliminating clods greater than 1 inch in diameter and filling low areas where water might accumulate. Any stones or roots that come to the surface during this process should be removed.

TIP 5: If the subgrade is unstable, lime stabilization or a geotextile fabric liner may be necessary

Some sites have native subsoil that is inherently unstable due to high water tables, highly expansive clays and other

EXCAVATING A PUTTING GREEN CAVITY TO THE APPROPRIATE DEPTH WHILE LEAVING THE SURROUNDING AREAS MOSTLY UNDISTURBED IS A PROCESS COMMONLY REFERRED TO AS CORING OUT.

geologic conditions. In these cases, a geotextile fabric may be necessary to prevent the gravel layer and rootzone layer from sinking into unstable subgrade soils. However, every effort should be made to stabilize unstable soils prior to taking this step. For example, when completely rebuilding an existing putting green, it is not uncommon to find the soil at the base of an excavated green cavity to be quite wet. One potential solution is to remove the base soil and spread it out in an adjacent area to encourage rapid drying. Turning the soil every day or two can speed the drying process. As the subsoil is drying, other work can be done to avoid construction delays. Once the soil is dry, it can be replaced in 6-inch lifts and recompacted to 90 to 95 percent Proctor density to provide a firm, stable base for the putting green.

Lime stabilization is arguably the most common method of stabilizing subsoil. This method requires adding hydrated lime – approximately 2 to 6 percent by weight – to an unstable subsoil. The hydrated lime is added either as a wet slurry or dry granular material then mixed with the soil using a large tilling machine commonly known as a pulvimixer. Water is added as necessary. Once mixed, the soil is stirred or rolled using a grader or similar device then remixed with a pulvimixer. Once the lime-treated soil is thoroughly mixed and spread to the desired thickness, it can be compacted and brought to grade. This entire process typically requires several days to accomplish.

Treating unstable, high-clay soils with lime has the net result of increasing soil strength, durability, compressibility and workability while decreasing swelling potential and soil plasticity. The advice of a geotechnical engineer should be sought for guidance as to the effectiveness of soil stabilization techniques. Geotechnical engineers also can provide recommendations on the amount of lime and the thickness of the stabilized layer required when using lime to stabilize soils.

If soil stabilization is not feasible, it may be necessary to separate the subgrade from the gravel layer by covering the subgrade with a geotextile fabric. By laying geotextile fabric over the subgrade, the gravel layer is prevented from sinking into the underlying soil. If this option is chosen, the geotextile should cover the entire floor of the subgrade and extend down the sides and along the bottom of the drainage trenches as well. Do not cover the drainage pipes with the geotextile fabric. Placing the fabric under the drainage pipes will help ensure the long-term success and proper functioning of the drainage system.

TIP 6: If the subgrade is comprised of fill material, build in lifts to reduce settling

To prevent the settling of a putting green constructed on fill material, it is imperative that the subgrade be constructed in stages. This is often referred to as building in lifts. In this method, the fill material is installed gradually, typically 6 inches at a time. Placing the fill material in lifts allows the shaper to repeatedly track over the subgrade at each level, eliminating air pockets and compacting the soil as lifts are

CAVITY WALLS SHOULD BE AS CLOSE TO 90 DEGREES TO THE CAVITY FLOOR AS POSSIBLE. COLLAR AREAS SHOULD ALSO BE INCLUDED WITHIN THE PUTTING GREEN CAVITY.

installed. Although this may appear inefficient, this compacting process is extremely important to long-term putting green stability.

TIP 7: The cavity walls should be as close to 90 degrees to the cavity floor as possible

USGA Agronomists are often asked whether the walls of a putting green cavity should be vertical or constructed with a slope. The walls should be as close to 90 degrees to the cavity floor as possible. A 90-degree angle is usually easier to create when coring out a putting green considering the equipment used and the compacted nature of the surrounding soil. It can be more difficult to achieve a perfect, 90-degree angle between the floor and cavity wall during new construction or with certain soil types. Building the cavity walls as close to 90 degrees to the cavity floor as possible prevents large differences in rootzone depth along the putting green perimeter. More gradual slopes will lead to a greater range of rootzone mix depths, which could cause water management problems. Collar areas should be included in the putting green cavity and constructed to the same standards as the putting green.

INSTALLING A WICKING BARRIER ALONG THE PUTTING GREEN CAVITY WALL IS OPTIONAL BUT MAY IMPROVE MOISTURE MANAGEMENT IN CERTAIN CIRCUMSTANCES.

Wicking Barrier

Installing a wicking barrier along the putting green cavity walls is optional. A wicking barrier is a plastic membrane that is impervious to water. Its purpose is to prevent water from being drawn out of the relatively porous rootzone mixture and into a more finely graded native soils that surround some putting greens. In certain circumstances, the native soil can draw enough water from the rootzone mixture that drought stress may occur along the perimeter of the putting green cavity.

Wicking to the point of drought stress does not occur on all putting greens. Rootzone mixes that are on the coarse end of the USGA-recommended particle size distribution usually retain less water than a more finely graded mix and are more prone to drought stress, particularly if surrounded by a native soil that is high in clay. This problem is exacerbated when a cool-season turf such as bentgrass is maintained on the putting green and a warm-season turf such as bermudagrass is maintained adjacent to the putting green.

Installing a wicking barrier is a straightforward process. Most often, grade stakes are driven into the subgrade along the cavity wall. Polyethylene plastic sheeting that is 6 to 8 mil and usually 18 to 36 inches wide is stapled to the grade stakes. The wicking barrier is allowed to extend 4 to 6 inches above the cavity wall. Soil is carefully added along the outside of the barrier while gravel is added along the inside to ensure that the barrier doesn't shift as the cavity is filled. After the putting green cavity has been filled with rootzone mixture, the wicking barrier should be cut so that it is slightly below the surface of the putting green. Extra hand tamping of the material on both sides of the barrier will help prevent the barrier from becoming exposed in the future.

TIP 1: Keep the wicking barrier upright during sodding

Many projects require that sod be laid around the perimeter of the putting green, often extending outward to include the surrounds. This excellent practice prevents sloped areas from eroding during the frequent irrigation utilized when growing in a new putting green. When laying sod immediately adjacent

LEAVING APPROXIMATELY 4 INCHES OF THE BARRIER ABOVE THE SURROUNDING GRADE WILL HELP PREVENT SOIL FROM WASHING ONTO THE PUTTING GREEN. IT IS REMOVED LATER WITH A CARPET KNIFE OR SIMILAR TOOL.

to a putting green cavity, care must be taken to ensure the wicking barrier is not trapped under the sod. Should this occur, the turf will not be able to properly root.

TIP 2: Use an 18-inch wicking barrier and install it so that approximately 4 inches of the barrier extends above the surface to help control erosion

While plastic sheeting is inexpensive and readily available in hardware and paint stores, it is possible to purchase a much heavier plastic material made especially for use as a wicking barrier. A popular choice among golf course builders is an 18-inch-wide, 30-mil-thick material. The additional thickness makes the material easier to install than 6 to 8 mil plastic sheeting because it is more rigid and stands up better while staking. The additional thickness is also believed to provide longer-term protection against subsurface encroachment of bermudagrass rhizomes. Also, by leaving 4 to 6 inches of the thicker barrier extending above the surrounding grade during establishment of seed or sprigs, the rootzone mix is much better protected against washouts or contamination from runoff from surrounding areas. The extra material is left in place until the putting green is ready for the first mowing. Then, a carpet knife or similar tool can be used to cut the barrier to a level slightly below the surrounding grade.

TIP 3: Contact a regional USGA Agronomist to determine if a wicking barrier is recommended for your project

The wicking barrier is optional and not necessary in all areas. Check with your regional USGA Agronomist for advice on whether the barrier may be needed.

Drainage

The subsurface drainage system serves an extremely important function – it removes excess water from the putting green cavity. A USGA putting green rootzone mixture has a minimum infiltration rate of 6 inches per hour, meaning excess water quickly moves downward into the gravel layer. The water then moves laterally through the gravel layer and across the surface of the subgrade until it reaches a drain line. Without a functioning drainage system, water would accumulate in the putting green cavity and the rootzone mixture quickly would become saturated. It is important to be aware that putting green drainage systems are most vulnerable to damage during installation. Taking extra time and effort to ensure drainage systems are correctly installed will be rewarded with many years of well-draining putting greens.

TIP 1: Design drainage systems specific to the needs of each putting green

The layout and installation of an effective drainage system is accomplished with a combination of drainage engineering and feel. Years ago, many putting greens were designed with limited contouring and a fairly uniform grade from back to front. These designs lent themselves to the classic herringbone drainage pattern. The main drain line exited the front of the putting green and was extended away from the green site to an out-of-play area. Many modern putting greens, however, are designed with contours that cause water to move in multiple directions. As a result, it may be necessary to have two or more outfall points in a single putting green. Regardless of complexity, it is important to remember that the main drain lines should follow along the lines of maximum fall, and the lateral lines should extend across subgrade slopes to intercept water.

TIP 2: Use marking paint to lay out the entire drainage system before trenching

Once the subgrade has been thoroughly compacted, the drainage lines can be laid out. Use marking paint to indicate where drainage trenches are to be excavated. Given the flexibility of today's pipe materials, it is not necessary to have perfectly straight lines. However, keep in mind the limited ability of equipment to trench on a curve. In most cases, it

SPRAY PAINT AND A MARKING GUN MAKE IT EASY TO LAY OUT DRAINAGE LINES.

is easier to install an extra few feet of pipe along a straight line to ensure complete drainage than to attempt installing a curved drain line.

TIP 3: Use the right trenching equipment

A variety of trenching equipment can be used to excavate drain lines. Typically, a trenching machine or a mini-excavator is used to dig trenches for putting green drainage systems. Although larger equipment can be used, excavating a larger volume of soil greatly increases the amount of labor and gravel required to complete the work. Although a 4-inch-wide trenching implement usually creates a trench that is at least 5 inches wide, avoid using anything less than a 6-inch-wide trenching implement because it can be difficult to properly install drainage pipe in narrow trenches. During the installation of any putting green drainage system, it likely will be necessary to dig some sections by hand; especially trenches for perimeter drains – i.e., smile drains – that should be installed immediately against the cavity wall.

TIP 4: There are many ways to manage trench spoils

Removing spoils from drainage trenches can be a labor-intensive process, but it is essential for ensuring the proper functioning of the drainage system. A mini-excavator can directly load spoils into waiting utility vehicles while excavating drainage trenches, but removing spoils generated by other trenching methods may require a significant amount of hand work. It may be possible to facilitate the removal of spoils from large putting green cavities by using a small tractor equipped with a box blade and a front-end loader. The box blade can carefully be used to pull spoils away from drainage trenches, creating neat piles that can easily be loaded into utility vehicles using the front-end loader.

Since removing trench spoils is often labor-intensive, some contractors opt instead to spread the spoils over the subgrade floor. This practice is perfectly acceptable

PERIMETER DRAINS – i.e., SMILE DRAINS – SHOULD BE INSTALLED IMMEDIATELY AGAINST THE CAVITY WALL.

provided the spoils are evenly spread, well compacted, and do not distort the subgrade or result in areas that prevent water from freely flowing to drainage lines. Large aggregates – i.e., greater than 1 inch in diameter – should be broken up to maintain a smooth cavity floor. Techniques that help trenching machines process spoils into smaller, spreadable particles include trenching on straight lines, running the trenching chain at a high rpm and operating at a slow ground speed.

All debris must be removed from the bottom of every drainage trench. Narrow shovels are effective tools for this task. Although the floor of each trench does not need to be perfectly smooth, it is vital to remove all large aggregates, stones and roots that could compromise the drainage system. Large obstructions can cause drainage pipes to buckle and may disrupt the 0.5-percent minimum slope necessary to ensure proper drainage. They also can stress joints where drainage pipes meet and cause them to separate, particularly as the trenches are backfilled with gravel. As a general rule, break up or remove aggregates or stones in excess of 1 inch in diameter.

TIP 5: Maintain a minimum 0.5-percent slope on drainage trenches by checking with a level or surveying tools

A bed of gravel should be laid in the bottom of all drainage trenches. This layer of gravel should be a

USE A SURVEYING INSTRUMENT TO ENSURE THAT DRAINAGE TRENCHES MAINTAIN AT LEAST A 0.5-PERCENT SLOPE TO THE EXIT POINTS OF THE DRAINAGE SYSTEM.

minimum of 1 inch deep to prevent the drainage pipe from laying directly on the soil. If necessary, the gravel can be deeper to maintain proper slope. In addition to protecting the drainage pipe from the underlying soil, the gravel serves another purpose: it facilitates preparing a smooth base for the drainage pipe. After the gravel is added to the trench floor, use a level or surveying instrument to ensure that all drainage trenches maintain a minimum 0.5-percent slope as outlined in the Recommendations.

THERE ARE NUMEROUS DRAINAGE PIPE OPTIONS THAT ARE SUITABLE FOR PUTTING GREEN CONSTRUCTION.

TIP 6: Select the style of drainage pipe best suited to your project

There are numerous drainage pipe materials on the market, but the vast majority of projects use one of three types of pipe. Semi-rigid, double-walled, perforated plastic pipe that has a smooth interior surface and a corrugated exterior has become increasingly popular. This type of pipe is not easily crushed, and its smooth interior facilitates future cleaning, if necessary. Its rigidity makes it easy to work with, assuming the drainage trenches are reasonably straight, and the perforations cut along the pipe's circumference allow water to enter. Cost is the most significant drawback when comparing this type of drainage pipe with others, although this type of pipe is not tremendously more expensive than the alternatives.

Flexible, single-walled, corrugated plastic pipe also is commonly used. This style of pipe is corrugated internally and externally, unlike the previously mentioned style of pipe. It is the most flexible of the recommended materials, but its flexibility comes at the cost of strength. This type of pipe is more easily crushed than other options, so care must be taken when backfilling and crossing drainage trenches with equipment. This type of pipe also is the least expensive of the three most common styles of drainage pipe and the easiest to install because its flexibility can reduce the need for joints. It can readily be purchased in large rolls, but the curled nature of the rolls may cause the pipe to bow in the drainage trenches prior to being covered with gravel. Extra care must be taken to ensure that this style of pipe is lying flat on the gravel that lines the bottom of the drainage trenches and that it does not bend against the trench walls during backfilling. It may be necessary to hold the pipe down as the drainage trenches are backfilled with gravel to avoid any issues. Like the double-walled pipe, perforations along the circumference of this pipe allow water to enter.

The third commonly used style of drainage pipe is rigid, PVC sewer pipe. This type of pipe is commonly used in septic line installations and often is readily available at local plumbing supply outlets. This type of pipe has large holes – usually 0.50 to 0.75 inch in diameter – along its entire length. Given the size of the holes, it is quite possible for gravel to fall through and into the pipe. Therefore, it is critical that the pipe be installed with the holes facing downward – i.e., toward the bottom of the drainage trench.

Flat pipe placed directly on a prepared subgrade may be used as an alternative to traditional pipes provided that the flat pipe conforms to ASTM D7001, is a minimum of 12 inches wide and is not covered with a geotextile sleeve. The flat pipe should be stapled to the subgrade or otherwise held in place to prevent it from shifting during construction. Rational combinations of round and flat pipe may be employed within a drainage system. All other guidelines for drainage system installation apply to this alternative construction method.

DRAINAGE PIPES SHOULD BE JOINED USING SPECIALIZED CONNECTION FITTINGS. MANY CONTRACTORS WILL SECURE EACH CONNECTION WITH TAPE TO PREVENT SEPARATION.

Lengths of pipe should be joined using specialized connection fittings. Care should be taken when using connection fittings to ensure that the pipes do not pull apart from the joints when backfilling the drainage trenches with gravel. Many contractors secure each drainage system joint with duct tape to prevent separation.

TIP 7: Use heavy plywood to avoid damaging the drainage system

During the process of preparing the drainage trenches and installing drainage pipe, equipment will have to navigate within the confines of the putting green cavity. Such traffic can help compact and smooth the subgrade; however, as equipment traverses a putting green cavity it may need to cross over drainage trenches. To prevent damage to the trenches and drainage pipe, use 0.75- to 1-inch-thick plywood sheets – or other sufficiently rigid materials – to create small bridges over the trenches that must be crossed. The protective material should be removed prior to installing the gravel layer.

TIP 8: Protect the terminal point of the drainage pipe

Route all drainage lines to an area where the terminal end of the pipe can be protected from crushing and blockage. Many otherwise properly constructed putting greens have failed to deliver adequate drainage because the terminal point of the drainage system was unprotected. When the terminal point is left unprotected sediment, leaves and animals can block or otherwise compromise the flow of water from the drainage system. The simplest way to protect the terminal point of a drainage pipe is to cap the end with a screen or grate. Another option is to terminate the drainage system in a valve or meter box. This is a particularly useful approach when the pipe terminates into a gravel sump. In this case, the box should extend into the sump, allowing visual inspection of the drainage pipe's functionality. Even a large-diameter – i.e., at least 10 inches – irrigation or drainage pipe can be used create a protective encasement for drainage pipes that terminate into a gravel sump. Place a grate on the surface of a protective valve box or pipe to allow visual inspection and prevent contamination.

TIP 9: Avoid extending drainage lines into bodies of water

If possible, do not allow drainage water to exit directly into any body of water. Although nutrient leaching from a properly built putting green can be kept to a minimum through sensible fertilization practices, bodies of water into which drainage systems terminate may be susceptible to contamination when high amounts of nitrogen and phosphorus are utilized during establishment. Ideally, drainage lines should extend to the surface in an out-of-play area and allow drainage water to be distributed over a large area.

TIP 10: Bury a locator wire with the drainage pipe, or map the drainage system with GPS, to allow easy location in the future

Despite the best efforts to protect drainage lines, sometimes they can become damaged or blocked. Unfortunately, once the pipes are buried they are very difficult to find. Placing a metal locator wire or metal tape along with the pipes in each drainage trench is a relatively inexpensive solution to this problem. Fourteen-gauge irrigation wire works well for this purpose and often is readily available since irrigation work frequently accompanies putting green construction projects.

IF A LOCATOR WIRE IS INSTALLED IN EACH DRAINAGE TRENCH, A WIRE-TRACKING DEVICE CAN BE USED TO QUICKLY LOCATE THE DRAINAGE SYSTEM AFTER IT HAS BEEN BURIED.

Locator wire should be installed in each drainage trench and properly spliced together at any joints to maintain electrical conductivity along the entire wire path. It also is a good idea to place a wire along the cavity wall and connect it to the wires installed with the drainage system. This allows easy location of the original putting green perimeter which can help prevent the loss of valuable putting surface and hole locations.

After the locator wires or tape have been installed and connected, they should be terminated in a small junction box. Often, terminal junction boxes for locator wire are installed near an irrigation head or cleanout port to facilitate future location. A wire-tracking device can be connected to the locator wires if the location of a drainage pipe or putting green perimeter needs to be pinpointed in the future.

A GPS receiver also can be used to map the location of the drainage system and original putting green perimeter. However, the accuracy of GPS mapping is variable and dependent upon myriad factors such as satellite geometry, obstructions, atmospheric conditions and the complexity of the mapping receivers.

TIP 11: Install a cleanout port on the high side of the putting green to allow for easy access and cleaning

A cleanout port extending from the main drainage pipe should be installed along with the drainage system. Inserting a hose into the cleanout port allows for the flushing of silt and other debris from the main drainage lines. A small camera also can be inserted into the cleanout port to visually inspect the integrity of the drainage system. Simply extending the main drainage pipe out from the high side of the cavity and turning it up to the surface establishes an effective cleanout port. Cap the cleanout port and cover it with a grate or irrigation valve box to prevent contamination.

TIP 12: Install an inspection port on the low side of the putting green

Installing an inspection port near the terminal point of the drainage system allows for quick inspection of the drainage system and can give valuable insight into watering practices. Establishing this inspection port is as simple as installing a riser to the surface from the low side of the main drainage pipe. Like the cleanout port, the riser should be capped and covered with a drainage grate or irrigation valve box. This port also can serve as an access point for drain cleaning and inspection tools. If a bunker drain is to be connected to the putting green drainage system, be sure it is connected downstream from the inspection port so that the port reveals only putting green drainage flow rather than aggregate flow from the putting green and bunker.

TIP 13: Use the right type of pipe for the job

It may seem obvious, but it is important to use the right type of drainage pipe for each area. Within putting green cavities, slotted or perforated drainage pipes should be used to collect drainage water. When drainage pipe exits a putting green, however, solid or non-perforated pipe should be employed. Clearly, solid pipe used within a putting green cavity can't collect drainage water and perforated pipe laid in a soil trench may become clogged or result in a constantly wet area along the drainage line.

TIP 14: Putting green and bunker drains should be separate systems

The best practice is to keep putting green and bunker drainage systems separate from one another. Bunker drains are far more vulnerable to blockage because of washouts. Bunker washouts can cause silt and clay to migrate into drainage pipes where it can disrupt the flow of drainage water. Therefore, a putting green drain line should never run through a bunker cavity or tie into a bunker drainage system. Occasionally, it is necessary to tie a bunker drain into a putting green drain line. However, a bunker drain should only be connected to a putting green drainage system downstream of the inspection port on the low side of the main putting green drainage pipe.

TIP 15: No matter how good the subsurface drainage system is, positive surface drainage is still critical

Draining excess water is critical to successful putting green management. Some believe that the combination of drainage pipes and a gravel layer provides so much subsurface drainage that surface drainage is no longer necessary. As a result, putting greens have been constructed with low, water-collecting areas. If the rootzone mixture drains rapidly and the gravel and drainage pipes are functional, even low-lying areas that collect water will drain quite well. However, the internal drainage capacity of rootzone mixtures inevitably decreases as putting greens age. Also, low-lying areas leave the turf susceptible to winter injury from ice accumulation when the soils are frozen. Therefore, every putting green should have excellent surface drainage in addition to a subsurface drainage system.

Gravel Layer

The gravel layer provides an extremely critical function, it allows the rapid movement of excess water from the rootzone mixture into the drainage pipe. Since the gravel layer covers the entire subgrade, drainage from the rootzone mixture into the gravel layer is quite uniform. This results in much more uniform moisture levels in the rootzone mixture itself. Research has shown that, without the gravel layer, the moisture levels in the rootzone mixture can vary widely and are strongly influenced by the location of underlying drainage lines. The gravel also creates a perched or suspended water table, increasing the rootzone's ability to retain nutrients and moisture. This occurs because of the significant change in texture between the gravel and the much finer rootzone materials. In addition, the gravel provides a barrier to salts that might otherwise be drawn from the subsoil into the rootzone mixture via capillary action. Finally, the gravel layer prevents the migration of fine particles into the drainage pipes, which could adversely affect their functioning.

TIP 1: Finding the right gravel can save money and work

To accomplish these goals it is imperative that the gravel be properly sized in relation to the rootzone mixture. Soil physical testing laboratories perform the testing necessary to ensure that the rootzone mixture and the gravel are compatible.

TIP 2: Crushed stone can make an excellent gravel layer

Earlier versions of the Recommendations called for the use of pea gravel. Although this material is still suitable for use in the gravel layer, the current Recommendations also allow the use of crushed stone. This permits a greater range of materials to be used which may reduce costs. Crushed stone also has the advantage of being more stable beneath construction equipment. In contrast, rounded pea gravel shifts easily beneath tires and tracks, resulting in rutting that must be smoothed prior to installing the rootzone mixture. However, it is important to note that crushed stone materials vary widely – ranging from limestone to granite – and must be tested to be sure they are suitable not only in size but in physical and chemical stability as well. Soil physical testing laboratories can run tests to ensure that an appropriate material is used.

TIP 3: If possible, select a gravel that is pH-neutral

There is evidence that placing low-pH rootzone mixtures over high-pH gravel materials such as limestone and dolomite contributes to the formation of iron oxide layers at the interface between the rootzone mix and the gravel. These layers have been shown to impede drainage from the rootzone mix into the gravel layer. If there is an available option, it would be prudent to select a gravel that is pH-neutral.

TIP 4: Use 0.75- to 1-inch-thick plywood sheets to cover drainage lines if they must be crossed with equipment

Installing the gravel layer is fairly simple. Assuming the subgrade is well-compacted, the gravel can be hauled into the putting green cavity with a front-end loader

THE GRAVEL LAYER SHOULD BE SPREAD TO A MINIMUM DEPTH OF 4 INCHES. THE SURFACE OF THE GRAVEL LAYER SHOULD MIRROR THE FINISHED SURFACE OF THE PUTTING GREEN.

or a small dump truck. However, great care must be taken to avoid collapsing drainage trenches or crushing the drainage pipe when crossing drainage lines with gravel-hauling equipment. Such damage can be almost completely avoided by using 0.75- to 1-inch-thick plywood sheets to cover drainage lines whenever they must be crossed. Also, crossing drainage trenches in a direction perpendicular to their orientation will help prevent undue damage.

TIP 5: Varying the depth of the gravel can facilitate the establishment of final contours

Once the gravel is installed, it should be carefully smoothed to eliminate tracks and establish the proper depth. A layer of gravel at least 4 inches thick is required by the Recommendations. However, greater depths can be utilized without adversely affecting putting green performance. The option to make the gravel deeper often can simplify putting green construction. In many areas, subgrade soils are very difficult to work with due to their high clay content. The Recommendations require only that the subgrade conform to the general slope of the finished grade, be firmly compacted, and have no water-collecting hollows or low areas. So, instead of having to match the final grade with heavy subgrade soil, the depth of the gravel can be varied to achieve the final putting green contours. It is much easier to smooth gravel into precise contours than it is to work with heavy soil. Keep in mind that once the gravel layer has been fully installed, the contours of the gravel surface should mirror the proposed finished grade of the putting surface. The depth of the intermediate layer, if necessary, and the rootzone mixture should not be varied to alter putting green contours.

TIP 6: Use a probe marked at 4 inches to check the depth of the gravel layer

The Recommendations call for the depth of the gravel layer to be a minimum of 4 inches. A metal probe that is marked at 4 inches can be used to easily probe the gravel and ensure the proper depth.

TIP 7: You might find it easier to lay “tile” rather than “carpet”

Gravel – as well as the intermediate layer and rootzone mixture – is usually spread in one of two ways. The most common option is to spread the gravel over the entire subgrade before starting on the next layer. An analogy can be made to how carpet is normally laid. First, the floor of the room is completely covered with carpet padding. Carpet is then laid over the padding to complete the job. The main advantage to this technique is that once the subgrade has been completely covered, it is easy to see what the final putting green contours will look like when finished. This method also allows gravel to be moved about – as long as the 4-inch minimum depth is maintained – to create minor changes in contouring. Low areas can be easily spotted and filled with additional gravel. Since the intermediate layer and rootzone mixture should be installed to consistent depths, filling low areas in the gravel layer helps ensure good surface drainage on the final putting surface.

The second method occasionally used to fill putting green cavities is to add all the layers as the crew works its way across the putting green. For example, gravel is spread over a small portion of the subgrade, usually an area of about 10 feet by 10 feet. If an intermediate layer is to be used, it is next spread over the same area. Finally, the rootzone mixture is spread over the same area. In this case, an appropriate analogy can be made to laying tile rather than carpet. When a floor or wall is covered with tile, adhesive is first applied to a fairly small section of the total area and then tiles are applied to the same section. The process is repeated until the floor or wall is completely covered. Building a putting green in this manner normally begins by finding the point of easiest access in and out of the cavity and starting the spreading process on the opposite side of the putting green. Thus, the putting green cavity is filled, section by section, back to the access point.

The main advantage to this method is that the hauling equipment travels over the subgrade, eliminating rutting and reducing the risk of damaging drainage lines. A disadvantage of this method is the need to have all construction materials on-site for the construction of each putting green.

Intermediate Layer

Installing the intermediate layer has always been one of the most difficult aspects of building a USGA putting green. The concept of the intermediate layer is simple – it serves as a barrier between the rootzone mixture and the gravel layer. It is necessary to use the intermediate layer when the gravel and rootzone components are sized such that there could be migration or movement of the finer rootzone mixture into the much more coarsely graded gravel. To better understand why the intermediate layer is needed in certain situations, imagine a layer of basketballs 4 feet deep. If you poured marbles over the layer of basketballs, they would quickly move into and fill all the large gaps between the basketballs. You could prevent this migration by first placing a layer of tennis balls between the basketballs and the marbles. Although a few marbles might move into the gaps between the tennis balls, they would not move very far into the tennis ball layer before becoming trapped. These trapped marbles would then prevent other marbles from moving downward. This process is referred to as bridging.

TIP 1: Source gravel that is compatible with the rootzone mixture so that the intermediate layer can be eliminated – it is almost always worth the extra expense

Laboratory analysis of the gravel and rootzone mixture can determine if bridging will occur without the intermediate layer. If bridging will not occur, the intermediate layer should be included or a different gravel that is compatible with the rootzone mixture must be sourced. This may or may not involve greater transportation costs, but any added expense should be weighed against the savings achieved by not having to use an intermediate layer. After the Recommendations were modified in 1993 to allow the elimination of the intermediate layer if all laboratory tests determine it to be unnecessary, the intermediate layer seldom has been used.

If an intermediate layer is necessary, it will take additional time and effort to install. Since the intermediate layer usually is installed to a depth of approximately 2 inches, it is difficult to spread with machinery and extra hand work is required. Keep in mind that the depth of the intermediate layer must be consistent and that the final contours should mirror the finished grade of the putting green.

Rootzone Mixture Selection

Selecting a rootzone mixture is a critical aspect of the USGA Recommendations. A rootzone mix that meets the parameters in the Recommendations will provide the ability to maintain firm and smooth putting greens. Selecting a rootzone mix on the finer or coarser end of the recommended particle size distribution may yield benefits for golf facilities looking for firmer putting greens, or where rapid infiltration is imperative due to saline irrigation water. A close review of the Recommendations and the tips included herein will help decision-makers select a rootzone mixture that is most appropriate for their facility.

TIP 1: Closely examine the particle size distribution of the sand used in the rootzone mixture

The Recommendations allow for a wide particle size range when selecting a sand for the rootzone mixture. Such a broad range enables successful construction and management of putting greens around the world. Sand with a high percentage of fine particles will yield greater capillary porosity – i.e., moisture retention – than a coarse sand and may benefit from inorganic amendments to improve air-filled porosity. On the other hand, sand with a high percentage of coarse particles will yield greater infiltration rates than a fine sand and will benefit from organic amendments to improve moisture retention.

TIP 2: Emphasize moisture retention over infiltration rate

An ideal rootzone mixture will drain adequately and retain enough moisture to avoid frequent irrigation and droughty conditions. As stated in Tip 7 from The Planning Stage section, focus on the rootzone mixture's performance parameters including total porosity, air-filled porosity, capillary porosity and infiltration rate. A rootzone mix can offer rapid infiltration and still retain adequate moisture.

A rootzone mix with an infiltration rate of 6 or more inches per hour will yield desirable drainage characteristics and the ability to flush salts. It is a misconception that a rootzone mix must drain at 25 or more inches per hour to adequately leach salts. Such rootzone mixes are often droughty and difficult and costly to maintain.

TIP 3: A water release study can provide valuable information about moisture retention in a rootzone mixture

Capillary porosity describes the amount of water a mix holds at a single soil water potential or soil suction, it doesn't provide a full picture of the water release characteristics of the mix or explain how much water is available to turf. Another test to consider is a water release study. These studies subject rootzone mixtures to suction or pressure that removes water from the rootzone pores in increments. At each incremental increase in suction or pressure, water is extracted from increasingly smaller pores. A water release curve may be especially helpful when constructing variable-depth putting greens. Typically, pure-sand rootzone mixes show greater differences in water content with changing depth than mixes with high organic matter content.

TIP 4: It is important to understand how different factors influence water retention and drainage

The sand particle sizes and amendments used in a rootzone mixture influence both infiltration rate and water retention. Fine sands may or may not have lower infiltration rate values, but they are likely to have higher capillary porosities than coarse sands. Coarse-textured peats – e.g., sphagnum peat –have higher water retention with less impact on Ksat than finer-textured reed sedge peats.

Adding small amounts of soil to a rootzone mix will likely reduce the infiltration rate without a significant increase in water retention. This is because soil, in and of itself, does not have very high water retention. The high water retention observed in sand and soil mixtures is primarily the result of fine soil particles plugging the large pores between the sand particles. Incorporating inorganic amendments like porous ceramics often increases water retention without decreasing infiltration rate.

The bottom line is: If the capillary porosity – i.e., water retention – of a rootzone mix is within the recommended range of 15 to 25 percent, the mix should not be excessively droughty even if the infiltration rate is high.

TIP 5: For a stable surface, pay attention to particle size, shape and gradation

The particle size distribution and particle shape of rootzone sands influences putting green stability and firmness. A widely graded sand comprised of fine, medium, and coarse particles will tend to compact and yield firmer surfaces than a uniform sand comprised of narrowly graded material with a large percentage of particles within a particular size range. The uniformity of a rootzone mix can be expressed as the coefficient of uniformity (Cu). The Cu should fall within the recommended range of 1.8 to 3.5 for mixes with peat, and 2 to 3.5 for mixes with inorganic amendments or sand only. Mixtures with low Cu values may result in unstable surfaces and soft putting greens. Soil – preferably sandy loam with a minimum sand content of 60-percent and no more than 5- to 20-percent clay content – can be added to the rootzone mixture to increase the Cu. However, the final rootzone mixture must meet the performance criteria established in the Recommendations.

Golf courses that desire very firm putting greens may choose a rootzone mixture with a high Cu, possibly even one higher than what is outlined in the Recommendations. Be aware that a rootzone mix with an excessively high Cu may become overly compacted, impairing putting green performance. A rootzone mix with a high Cu must be thoroughly tested by an accredited lab to ensure adequate total porosity and air-filled porosity.

THE SIZE AND SHAPE OF ROOTZONE SAND PARTICLES WILL HAVE A SIGNIFICANT IMPACT ON PUTTING GREEN PERFORMANCE.

Sand shape also influences putting green stability and firmness. A low-Cu rootzone mixture that has highly angular sands will likely provide adequate stability whereas a rounded sand with a moderate Cu may be unstable.

Organic Matter Selection

The most common organic amendment in putting green rootzone mixtures is peat. It is used to increase the water and nutrient retention of a mix. The USGA Recommendations state that any peat selected for use in a rootzone mixture must have an organic matter content of at least 85 percent by weight. It is important to know that there are a variety of peat options that meet this standard, but each will affect rootzone performance in different ways. Selecting the peat that is best suited to your goals requires careful planning and laboratory analysis.

TIP 1: Not all peats are the same

Peats are mined from bogs and vary considerably in botanical origin, quality and performance. When dried and screened specifically for putting green rootzones, peats can make an excellent rootzone amendment.

TABLE 2. Common Peat Characteristics

PEAT	pH	ORGANIC MATTER (%)	WATER HOLDING[1] (%)	DENSITY[2] (LBS./CU. FT.)	ORGANIC YIELD (LBS. OM/CU.FT.)
Sphagnum	4-4.5	90-98	700-1,400	7-9	3-5
Reed sedge	4.5-7	85-90	400-500	14-16	6-10

[1] As shown, sphagnum peat holds seven to 14 times its weight in water.
[2] Density is determined from peat in a loose state; it will vary from the compressed bales delivered.

Sphagnum peats are derived from sphagnum mosses. The peat is dried and screened to produce a peat product specifically for putting green rootzones. Reed sedge peats are peats whose botanical origin is reeds and sedges. These peats are generally more mature than sphagnum peats. They have a finer texture than sphagnum peats due to their more decomposed state. Peat humus is a term for well-decomposed peats of which the botanical origin is unknown. These peats rarely meet USGA Recommendations for organic matter content and therefore are seldom used in putting green rootzone mixtures.

TIP 2: Evaluate peats on several characteristics to ensure their desired performance

Several characteristics of a peat can be used to define its quality and suitability for a putting green rootzone:

Percent organic matter: Not all peats are created equal in this regard. The type and age of a peat will influence its organic matter content. The USGA recommends that a peat have an organic matter content of at least 85 percent by weight to be used as a rootzone amendment. Sometimes there is reference to the ash content of a peat. The ash is what remains after the organic carbon is burned off during testing. Subtracting the ash content percentage from 100 percent yields the organic matter content of the peat.

Fiber content: Peats are fibrous by nature. In a putting green rootzone mix, these fibers act like sponges that hold water. Younger peats – e.g., sphagnum moss peats – are more fibrous than older, finer-textured reed sedge peats and therefore have a much higher water holding capacity. Since they have a coarser texture, fibrous peats will not reduce the infiltration rate of rootzone mixes as much as a finer-textured peat. The USGA does not recommend any specific fiber content, but it is helpful for the end user to understand the influence fiber content has on drainage and water retention before selecting a peat for a putting green rootzone mixture.

Density: Density is expressed as weight per unit volume – typically pounds per cubic foot. The density of a peat influences the amount of organic matter by weight that a peat will contribute to a rootzone mix. Peat density is influenced by age, texture and moisture content. Some reed sedge peats are nearly twice as dense as sphagnum moss peats. Table 2 lists densities of common sphagnum and reed sedge peats. Also listed is the organic yield – i.e., the amount of actual organic matter in one cubic foot of peat. This is calculated from the density, organic matter content and moisture content of the peat. Based on these data, you can see that you may need only half as much reed sedge peat to produce a rootzone mix with the same amount of organic matter by weight as a sphagnum peat mix. This is just one reason why you shouldn't specify a volume to mix ratio for peat content.

Table 2 lists characteristics of brand-name sphagnum and reed sedge peats. These data are based on repeated testing of peat samples routinely sent to one lab. Realize that some variability is common within each peat source and from year to year.

High-organic-content or muck soils should never be used in putting green rootzone mixtures. These are often labeled local peats in many areas. While they may look like peat, they are often fine-textured soils harvested from swamplands.

SPREADING EQUIPMENT SHOULD REMAIN ON THE ROOTZONE MIX AT ALL TIMES TO AVOID DISRUPTING THE GRAVEL LAYER OR DAMAGING THE DRAINAGE SYSTEM.

Rootzone Mixture Installation

The rootzone mixture should be installed to a compacted depth of 12 inches, plus or minus 1 inch. Like the gravel layer, the rootzone mixture can be spread over the entire putting green at once or in stages. The most important considerations are achieving a consistent depth and not disturbing the underlying layers during installation.

Tracked equipment is better suited for spreading the rootzone mixture. Tracks have a large surface area that reduces rutting and aids in the uniform compaction of the rootzone mix. Rubber-tired loaders can be used to install rootzone mix, but they often cause severe rutting and present a higher risk of disturbing the gravel layer or becoming stuck while the mix is loose.

TIP 1: Spread the rootzone mixture into the cavity over already-installed mix rather than over the gravel layer

While spreading the rootzone mixture, equipment should work on top of the mix and never on top of the gravel. In other words, the rootzone mix should be spread from areas where mix has already been installed until the entire cavity is filled to the proper depth. In addition to protecting the gravel and drainage layers, this process of traversing over the rootzone mixture many times as it is installed will minimize the need for further compaction. Be sure to clean equipment tracks or tires prior to traversing the mix to avoid any contamination.

TIP 2: Test the rootzone mixture to predict how much it will compress or settle

Rootzone mixes vary in the degree to which they will compact or compress. Sands that are very angular or widely graded will compress the most. Rounded sands and sands with a narrow gradation compress the least.

The likely amount of compression is important information when determining how much rootzone mix is needed for a project and or to fill each putting green cavity. Some laboratories will test for compression and offer advice regarding how much extra material to purchase. If the selected lab does not perform such testing, a rough estimate can be made in the field. Fill a 5-gallon bucket with dry rootzone mix and place a weight on top of the mix – e.g., a 12-inch diameter concrete paving stone works well. Set the bucket on a running piece of heavy machinery that will apply strong vibration to the bucket. After a few minutes of intense vibration, measure the amount of settling. This will provide a rough estimate of how much extra mix must be placed in the putting green cavity so that after compacting the surface grade will be at the correct elevation.

TIP 3: Tracking with heavy equipment and repeated watering will help settle and compact the rootzone mixture

Throughout the installation process, water should be applied to the rootzone mixture to help settle and compact it. Once the mixture has been installed to its final depth of 12 inches, plus or minus 1 inch, tracking over the entire surface in at least two directions with heavy equipment will help achieve uniform compaction. During the tracking process, get as close to the putting green edges as possible without touching the surrounding soil. This will help compact areas of mixture along the perimeter of the putting green that may not have received much traffic during installation. Working the perimeter of a putting green with a vibratory plate compactor will also help settle the rootzone mix.

A MECHANICAL BUNKER RAKE CAN BE VERY HELPFUL FOR SMOOTHING THE PUTTING SURFACE AND FINE TUNING THE FINISHED CONTOURS.

TIP 4: Use a mechanical bunker rake to help finalize the surface of the rootzone mixture

After the rootzone mixture has been installed and compacted, a mechanical bunker rake can be used to smooth the surface and fine tune the finished contours. Working in a continuous, circular motion the rake should pass over the entire putting green many times to smooth and compact the rootzone. Pulling a metal drag mat behind the bunker rake will help eliminate small imperfections.

TIP 5: If the putting green is not to be planted immediately, use a cover to prevent erosion or contamination

Typically, a putting green is planted shortly after the rootzone mixture has been installed. However, in some cases it may be days or even weeks before planting takes place. If planting must be delayed, it is a good idea to cover the finished rootzone surface with clean straw, plastic sheeting or a geotextile fabric. This limits erosion due to heavy rains. If surface water from surrounding areas is channeled onto the putting surface, straw bales or an erosion fence should be used to prevent the washing of soil from the surrounds onto the putting green surface.

TIP 6: Use a probe to check the depth of the rootzone mixture

The Recommendations call for the compacted depth of the rootzone mixture to be 12 inches, plus or minus 1 inch. This is a tight tolerance, so rootzone depth must be constantly monitored to ensure uniform compliance throughout the entire putting green cavity. A metal probe that is marked at 12 inches can be used to easily check rootzone depth.

Variable Depth

Some superintendents have expressed interest in using a variable-depth rootzone when building putting greens according to USGA Recommendations. A variable-depth rootzone deviates from USGA Recommendations by decreasing the rootzone depth to 8 to 10 inches in elevated areas of a putting green – e.g., mounds – and increasing the rootzone depth to 14 to 16 inches in low-lying areas of a putting green.

TIP 1: Why consider a variable-depth rootzone?

Not all the water in a putting green rootzone flows vertically into the gravel and out the drain lines. Some of the water moves laterally to low-lying areas of the putting green. Consequently, high-elevation areas – e.g., mounds – may dry rapidly while soil moisture increases in low-lying areas – e.g., often areas near the putting green perimeter.

Research conducted at Michigan State University from 1998 through 2002 revealed that when using a sand-based rootzone mixture with low capillary porosity – i.e., low moisture retention – varying the rootzone depth improved soil moisture uniformity on an undulating putting green. However, when the sand was amended with soil or peat, the differences between the variable depth and uniform 12-inch

FUMIGATION SHOULD ONLY BE PERFORMED BY LICENSED PROFESSIONALS.

depth recommended by the USGA were not as evident. Amending the sand rootzone with soil or peat improved soil moisture uniformity when compared to the sand-only rootzone mixture regardless of construction type.

This research confirms the importance of selecting rootzone materials with adequate moisture retention and air-filled porosity to provide consistent soil moisture conditions on undulating putting greens. It is important to conduct full performance testing of the rootzone mixture, especially when considering variable-depth construction.

A rootzone layer constructed with varying depths may help to improve soil moisture uniformity across a moderately undulating putting green when compared to a uniform 12-inch rootzone. However, the cost implications and construction challenges of the variable-depth method may offset any benefits observed in the field.

TIP 2: Variable-Depth Construction Methods

At present, constructing a variable-depth putting green rootzone is more of an art than a science. Researchers from Michigan State University have developed information discussing the subject.

Fumigation

Fumigating the rootzone mixture is not always necessary but can be beneficial in certain circumstances. Fumigation is most often needed in areas where nutsedge, nematodes and other difficult-to-control pests and weeds are prevalent. It also is used frequently in the replanting of bermudagrass putting greens to achieve the most complete control possible of the previous turf variety. To determine if fumigation is recommended for your project, contact your regional USGA Agronomist.

TIP 1: Soil fumigation should only be performed by licensed professionals using specialized equipment

Handled properly, soil fumigants can safely and effectively control weed seeds and pests in a rootzone mixture, ensuring the cleanest stand of turf possible. Eliminating competition from weeds also can result in more rapid establishment of new putting green turf. However, the chemicals utilized for fumigation are dangerous and need to be applied extremely carefully. It is highly recommended to hire experienced, licensed fumigation contractors to perform this task.

Planting

With the construction completed, the new putting green is ready to be planted. Seeding and sprigging techniques vary widely, often depending largely on the type of planting equipment available. Regardless of the method used, a key to success is good seed or sprig contact with the rootzone mixture. Research has proven that extremely high seeding or sprigging rates do not result in earlier opening dates and can actually lead to weaker plants. Ideal rates depend on the species and variety of turfgrass being planted. Check

SPREAD BENTGRASS SEED IN MULTIPLE DIRECTIONS TO ACHIEVE A MORE EVEN DISTRIBUTION.

with your regional USGA Agronomist for the rates and procedures that have proven most successful in your area.

TIP 1: Don't underestimate the importance of favorable planting dates

Planting dates have a tremendous impact on the success of newly established putting greens. Although bentgrass and bermudagrass varieties used on putting greens have a fairly wide range of dates over which they can be successfully established, both species perform much better when planted in favorable climatic conditions. This improved performance includes more rapid establishment and reduced susceptibility to stresses such as insects and diseases.

Ideal planting dates for each turf species and variety depend on the local climatic conditions. To obtain the best date range for your area, contact your regional USGA Agronomist or university extension specialist.

TIP 2: Mix seed with a low salt index, organic fertilizer to ease spreading

The very small size of bentgrass seed makes it difficult to spread in windy conditions. The small size also makes it difficult to see where the seed has fallen, which can result in skips and overlaps during seeding. Mixing the seed with a darkly colored, organic fertilizer with a low salt index can significantly reduce both problems. Mixing percentages should be based on the desired seeding rate and the fertilizer analysis. For example, if the desired fertilizer rate is 1.5 pounds of nitrogen per 1,000 square feet using a fertilizer with an analysis of 6-2-0, 25 pounds of fertilizer is required to treat every 1,000 square feet. If the desired seeding rate is 1.5 pounds per 1,000 square feet, 1.5 pounds of bentgrass seed should be mixed with every 25 pounds of fertilizer. Since it is best to apply the mixture over the putting green in two directions to ensure more even coverage, the spreader should be calibrated to apply 12.5 pounds of the seed/fertilizer mixture to every 1,000 square feet.

TIP 3: Plant seed in two directions to ensure better coverage

It is best to apply seed in two directions using a drop spreader, usually in a perpendicular pattern. This is the most reliable method to ensure even coverage.

TIP 4: If you are uncertain about the seed or sprig purity, have it analyzed by a seed testing laboratory

Only certified seed or sprigs should be used to establish a new putting green. However, even certification cannot guarantee that all contaminants – particularly weed seeds and other turfgrass seeds – have been screened from the seed. Even very small percentages of *Poa annua* and *Poa trivialis* in stands of creeping bentgrass can result in a significant reduction in the quality of the stand. In the case of bermudagrass sprigs, the most frequent contaminants include common bermudagrass and weeds such as goosegrass and sedges.

There are laboratories that specialize in examining the purity of bentgrass seed. Your regional USGA Agronomist can assist in finding a lab capable of such testing. Unfortunately, no such testing process is available for bermudagrass sprigs. The best option to ensure a pure stand of bermudagrass is to use a combination of these efforts:

- Purchase only certified sprigs.
- Make a personal visit to the supplier to visually inspect the quality control protocols of their operation.
- Ask about the age of the source fields. Fields that have recently been fumigated and re-established are less likely to be contaminated with undesirable types of bermudagrass.
- Contact other courses that have purchased sprigs from the supplier to determine the success of their plantings.

A MECHANICAL BUNKER RAKE WITH KNOBBY TIRES CAN IMPROVE SEED-TO-SOIL CONTACT.

TIP 5: Improve seed-to-soil or sprig-to-soil contact by tracking-in the sprigs or seed with knobby tires

The knobby tires utilized on most mechanical bunker rakes do an excellent job of pushing newly planted seed or sprigs into the upper portion of the rootzone mixture. This same equipment often is used to compact and smooth the rootzone surface. When tracking-in seeds or sprigs, drive in large circles or in overlapping straight lines; the key is to cover the entire surface at least three or four times. In the case of bentgrass seed, germination frequently first occurs in the small depressions left by the knobby tires, giving the putting green a checkered appearance. Although these depressions gradually disappear, the initial lack of uniformity is distracting to some. This can be greatly reduced by following the mechanical bunker rake with a roller to smooth out any depressions.

TIP 6: After seeding, use leaf rakes to work the seed into the upper 0.5 inch of the rootzone mixture

Some individuals do not like the tracks left when driving over the seed with knobby tires as suggested in Planting Tip 5. The smoothest finish can be achieved by using a leaf rake to incorporate seeds into the rootzone mixture. Typically, this is done by walking across the putting green while dragging a leaf rake behind to smooth footprints and work the seed into the mix. This process creates small furrows that quickly settle out as the putting green is irrigated.

TIP 7: If a new putting green is to be sodded, take great care not to seal off the rootzone

Ideally, putting greens should be established from seed or sprigs. However, when time constraints demand that sod be used, great care must be taken to avoid sealing off the new rootzone. The best choice is to use sod grown on the same sand used in the rootzone mix. Sod that is grown on a soil or sand that is finer in texture than the rootzone mix will almost certainly cause severe drainage problems. The finer materials will result in excess water being retained near the surface of the putting green. This can lead to increased disease susceptibility, reduced rooting and black layer. Although sod grown on a more coarsely textured rootzone will be less likely to cause problems, the best option is to use a sod that has been washed free of all soil and sand. Washed sod is available from many growers. Another option is to purchase sod that is grown over plastic sheeting, often referred to as soilless sod.

Grow In

Sometimes, growing in a new putting green can be as challenging as building it. This is particularly true for turf managers whose previous experience has been limited to dealing with mature putting greens or soil-based putting greens. More than a few skilled superintendents have found themselves struggling to keep a new putting green on an even keel during the first three to six months following planting.

The most common difficulties encountered during the grow-in process involve fertilization and irrigation. Since the rootzone mixture of a USGA putting green invariably is composed of a high percentage of sand, nutrient- and water-retention characteristics are much lower than that of a soil-based rootzone. As a result, a putting green that appears to be adequately fertilized one day may appear to be underfertilized just a couple of days later. Irrigation is even more demanding, since sand-based rootzones are prone to drying out at the surface – particularly during windy conditions.

TIP 1: Use a combination of slow-release and rapidly available nutrients

During a grow in, both types of fertilizer have advantages and disadvantages. Therefore, a combination of the two results in the best fertilization regime. Slow-release organic fertilizers provide a constant source of nitrogen that is less prone to leaching and can be applied in larger amounts without fear of burning young turf. Products with readily available sources of nitrogen provide the quick burst of nitrogen necessary to encourage rapid growth and achieve complete turf coverage.

The key is to fertilize the immature putting greens often, but in small amounts. It is not uncommon for a new putting green to require 1.5 to 2 pounds of nitrogen, 1 to 2 pounds of phosphorus and 1 to 2 pounds of potassium per 1,000 square feet every month until complete coverage is achieved – usually within 6 to 12 weeks. Although the exact amounts of fertilizers to apply must be adjusted to every grow-in situation, many superintendents have had success using a program similar to that depicted in Table 3.

There is no universal grow-in regime that fits all putting

TABLE 3. Sample Grow In Fertilization Schedule

During blending	If pH adjustments need to be made, it is best to do so during the blending process. This allows lime, sulfur or gypsum to be incorporated throughout the entire rootzone mixture. The amount of amendments necessary can be determined only through laboratory testing. When adding lime to a rootzone mix for bentgrass putting greens, keep in mind that take-all patch is more severe in high-pH soils. If pH values do not need to be raised but calcium levels are low, gypsum is a better choice than lime.
Prior to planting – usually one to three days before seeding or sprigging	Apply a starter fertilizer – typically in a 1:2:1 ratio of N:P:K – at a rate to provide 1 to 1.5 pounds of P_2O_5 per 1,000 square feet. This also is a good time to apply micronutrients in order to ensure the sufficient availability of all plant-essential nutrients. Also apply a slow-release, composted organic product at a rate to provide 1 pound of nitrogen per 1,000 square feet. Ideally, these materials should be lightly incorporated into the upper 1 to 2 inches of the rootzone. This can easily be done with a mechanical bunker rake or even by hand using a garden rake. Further incorporation will occur as the new putting green is smoothed to the finished surface and readied for planting.
1st week following planting (week 1)	Apply a complete fertilizer – typically a 12-12-12 or equivalent – to provide 0.3 to 0.5 pound of nitrogen, phosphorus and potassium per 1,000 square feet. This provides a readily available source of nutrients for the emerging plants.
2nd week following planting (week 2)	It is likely that new turf leaves are surfacing. To apply a light feeding of nitrogen and phosphorus without burning the turf, a slow-release organic fertilizer should be applied at a rate to provide 0.3 to 0.5 pound of nitrogen per 1,000 square feet.
3rd week following planting (week 3)	By now, the turfgrass should be rooted enough to withstand its first mowing. This is a good time to apply another 0.3 to 0.5 pound of nitrogen per 1,000 square feet. A fertilizer with a 3:1:2 ratio – e.g., 15-5-10 – will provide enough of each element but in small enough amounts to avoid burning new leaves.
Each week thereafter until complete coverage is achieved	Continue this rotation of applications beginning with week 1 and continuing through week 3.

greens. There are simply too many variables. For example, a sprigged bermudagrass putting green must be managed differently than a seeded bentgrass putting green. A new putting green located in a climate that includes heavy rains will require more frequent fertilization to help compensate for nutrient leaching. Even microclimates can result in different grow-in regimes. A putting green exposed to strong winds will be more prone to drying than a putting green on the same course that is tucked into a grove of trees. Putting greens whose architecture includes steep mounding will be more difficult to manage from an irrigation standpoint than a putting green with more subtle contours.

TIP 2: A physical soil analysis can provide insight into the grow-in requirements of a new putting green

Major differences in water and nutrient requirements can exist depending on the composition of the rootzone mixture. For example, a putting green that drains at 18 inches per hour almost certainly will have significantly higher fertilizer and irrigation requirements than a putting green that drains at 6 inches per hour. These factors make the very-fast-draining putting green more difficult to manage during the first year or so.

Learning to manage the various characteristics of a rootzone mixture makes the grow-in process one in which a high level of feel is required of the turf manager. Constant inspection of a new putting green is an absolute necessity. As is the case with many skills, experience is often the best teacher.

TIP 3: Monitor pad development to help determine when a new putting green is ready to be opened for play

Putting greens vary in the amount of time they need to reach a level of maturity that is capable of withstanding play. In other words, how long must golfers wait before they can play golf on a new putting green? One of the best ways to evaluate when a new putting green is ready for play is to measure the layer of organic matter – often called the pad or mat – that accumulates between the crown of the plant and the rootzone mixture. This pad is crucial to the new turf's ability to withstand traffic. Without a thick enough pad, new turf wears severely in areas of concentrated traffic. Wear injury on new putting greens is frequently seen around the perimeter and at access points.

The necessary thickness of the pad depends on the amount of play the putting green will receive, the ability to disperse entrance and exit traffic over numerous points and the time of year when the putting green is opened. For example, a new putting green on a course that is very heavily played will need a more fully developed pad – approximately 0.25 inch thick – than a new putting green on a course that receives limited play. Keep in mind, however, almost any new putting green is likely to get unusually heavy play when it first opens.

As a general rule, 0.25 inch of organic pad is sufficient to withstand a moderate traffic load – i.e., approximately 30,000 rounds of golf per year. A cup cutter, pocketknife or soil profile tool can be used to evaluate pad development and the stability of the putting surface.

Putting greens with numerous entrance and exit points often fare better after opening because traffic can be dispersed over a wider area. Similarly, putting greens with an abundance of hole locations can withstand play much better than a putting green that has only a few hole locations. Of course, a putting green located in a favorable growing environment and opened for play during a time of the year that supports active turf growth will tolerate much heavier play without experiencing severe wear and tear. These factors must be kept in mind to determine when a putting green is ready to be opened.

TIP 4: Institute sectional maintenance for the entire grow-in process. Ideally, individuals should be assigned not more than six putting greens each

The individuals assigned to each section should be held responsible for hand watering the newly planted putting greens. They also should be trained to watch for pest outbreaks and wear injury. By providing this level of management, problems can be identified much earlier and controlled much easier. Another benefit to sectional maintenance is the feeling of ownership each of the section managers quickly develops. Within a matter of a few weeks, each section manager knows his or her putting greens better than anyone else.

TIP 5: Keep in mind that putting greens do not mature at the same pace

Although planted at the same time, the rate of turfgrass establishment will vary from putting green to putting green. This is largely due to variances in the microclimate of individual putting greens. Variations in turf establishment can be a source of frustration for everyone. Some courses choose not to reopen until every new putting green is fully ready to receive play. Others choose to open individual putting greens for play as soon as they are ready; relying on temporary greens on holes where the grow in is progressing more slowly.

TIP 6: Limit the use of overhead sprinklers and hand water the newly planted putting greens as much as possible

Overhead sprinklers apply large amounts of water in a short period of time and are more likely to cause erosion than hand watering. Proper hand watering applies water much more gently and reduces the risk of disrupting the surface. Overhead irrigation also has the disadvantage of applying water to areas other than the putting green. Since the surrounds of putting greens are often sodded and typically need water less often than a putting green, frequent overhead irrigation can result in extremely wet putting green surrounds. This can cause turf health issues and make mowing difficult, if not impossible.

TIP 7: After reopening the putting green(s), play is likely to be unusually heavy since golfers are understandably anxious to try out the new putting greens

Since newly established turfgrass is highly vulnerable to wear and tear, steps should be taken to keep play at reasonable levels. One way of doing this is to expand the tee time interval to 10 or even 15 minutes or enact a limit on the number of tee times per day. Traffic control around a new putting green must be especially diligent. Use ropes, signs and barriers to direct golfers to as many different entrance and exit points as possible.

TIP 8: Prior to opening a new putting green, inform golfers that some wear and tear on a new putting surface is often unavoidable

New putting greens go from not having to endure golfer traffic at all to receiving what will likely be heavier-than-usual play. It is not uncommon for new putting greens to show excessive wear in areas where traffic is concentrated, and it may be necessary to temporarily close damaged putting greens to give them a few more weeks to mature. If temporary greens were utilized during the construction and grow-in process, it is a good idea to continue maintaining them for a period of time after the new putting greens open just in case they are needed.

TIP 9: Institute a spikeless shoe policy for at least the first eight to 10 weeks after a new putting green is opened

Aggressive golf shoes can quickly damage young turf plants, especially when the surface is wet from rain or heavy irrigation. Many courses have found that wear issues around hole locations dissipate when golfers wear spikeless golf shoes instead of aggressive golf shoes.

TIP 10: Mow with walk-behind equipment for at least the first full season following planting

Walk-behind mowers are far less likely to cause wear injury or create ruts. If necessary, triplex mowers can be used once complete turf coverage has been achieved and the rootzone mixture has become compacted enough to support them. However, use caution when mowing new putting green perimeters with a triplex because the tires and reels may cause concentrated wear and turf decline.

TIP 11: Begin mowing as soon as turf is well rooted

Initial mowing heights on new bentgrass putting greens should be no higher than 0.25 inch. Bermudagrass mowing heights should also be 0.25 inch or less. The mowing height for the first cutting depends largely on the smoothness of the surface. For both bentgrass and bermudagrass, low and frequent mowing encourages the rapid lateral spreading that is critical to obtain complete turf coverage. Since it is almost impossible to keep new putting surfaces perfectly smooth due to the frequent irrigation necessary during establishment, some scalping is inevitable. However, it is better to scalp new turfgrass plants early to allow time for recovery rather than waiting to lower the height of cut and risk scalping just prior to opening.

TIP 12: Aeration should be unnecessary on newly seeded or sprigged putting greens since the rootzone is composed of a high percentage of sand and, therefore, is highly resistant to compaction

However, a combination of aeration and rolling can be very effective in smoothing a rough putting green surface. A common practice on new putting greens that have been established to the point that turf covers the entire putting surface is to aerate with solid tines, irrigate and then roll with a small asphalt roller – typically one that weighs less than 1,000 pounds. The roller compresses the rootzone mix into the voids created by the aerator. Irrigation provides a lubricant that allows the rootzone mix to compress. The result is a smoother surface.

Also, keep in mind that some putting green turfgrass cultivars can produce large quantities of organic matter in a relatively short period of time. Aeration and topdressing are the most effective tools to prevent excess organic matter from accumulating and should be employed based on examination of the soil profile, regardless of the age of a putting green.

TIP 13: Cultivation will be necessary for sodded putting greens

Virtually all sod projects result in layering near the surface. Sodding a putting green provides a playable surface much faster than seeding or sprigging, but the sod layer must be removed through cultivation within a couple of years following installation. The organic layer that accompanies sod, even if it is less than 0.5 inch thick, is concerning because it will hold moisture and limit root development. Detrimental sod layers will also diminish the desirable physical properties of a sand-based rootzone and create soft playing conditions. Core aeration, aggressive verticutting, and topdressing are the most reliable programs to remove and dilute sod layers in putting greens.

TOPDRESSING IS AN IMPORTANT PART OF ESTABLISHING A NEW PUTTING GREEN REGARDLESS OF WHETHER IT WAS PLANTED FROM SEED, SPRIGS OR SOD.

TIP 14: Aeration and rolling can make transition areas less severe and reduce mower scalping

Occasionally, the transition area from one level of a putting green to another may end up more severe than planned, resulting in scalping. The steepness of these transitions can be softened through a combination of aeration and rolling.

Core aeration – typically with 0.500- to 0.625-inch diameter tines – should be performed on the crest of the transition area. Then, remove the cores and irrigate the area. Roll the area with a 500- to 1,000-pound roller to compress the area, making the transition less steep. Finally, allow the aerated area to completely recover. Repeat this process as often as necessary to create a more gradual slope that is less prone to scalping.

TIP 15: Topdressing is a critical procedure for smoothing a newly established putting green

In the past, USGA Agronomists encouraged topdressing with the exact same material that comprised the rootzone mixture – typically a mixture of sand and organic matter. However, today's turfgrass varieties tend to be quite aggressive in terms of organic matter production. Therefore, it is most often recommended that the topdressing material solely be composed of the same sand used to create the rootzone mixture.

TIP 16: Begin topdressing once a new putting green has 75-percent turf coverage

Using a fertilizer spreader to perform light, frequent topdressing applications will avoid creating ruts in unstable putting greens. A conventional topdresser can be used once the surface firms up, but avoid filling the machine with too much material because the extra weight could cause ruts.

Conclusion

Successful putting green construction is much more than a series of steps from subgrade shaping to grow in. For example, this document does not address the wide variety of architectural considerations that have a definite impact on the agronomics of a putting green. In addition, golf course builders and superintendents will need to adjust to the constantly changing conditions and unexpected challenges that are part of almost every major construction project. For existing courses that are rebuilding their putting greens, one of the most difficult aspects of the project is educating golfers about the benefits they can expect after giving up all or part of their course for the duration of the construction and grow in.

Fortunately, there are many excellent resources available to anyone interested in the subject of putting green construction. Contact your regional USGA Agronomist for more information about building and establishing putting greens in your area or visit usga.org for a variety of online resources.

References and Additional Reading

1. The USGA Recommendations For a Method of Putting Green Construction
2. Troubleshooting Problem Greens
3. Directory of A2LA accredited laboratories
4. Quality Control Sampling of Sand and Rootzone Mixture Stockpiles
5. Guidelines for Establishing Quality Control Tolerances
6. A Quality Control Checklist for Successful Greens Reconstruction