DRAINAGE, DRAINAGE, DRAINAGE

Paul E. Rieke and Rafael Carrascosa-Gonzalez
Crop and Soil Sciences, M.S.U.

The summer of 1995 was one which will be remembered for variable weather patterns. Periods of heavy rainfall, cloudy days, high temperatures, and very high relative humidities resulted in serious stress on our cool season grasses. Toss in alternating periods of high temperatures, bright and sunny days, and low relative humidities. The result was a lot of turf stress and stress for turf managers as well. We have not experienced this kind of environmental stress and turf loss, at least in recent years. If we go back to the days without good irrigation control and before we learned how to maintain annual bluegrass, there were times when more turf loss occurred than in 1995.

Extended wet, humid periods in 1995 kept the surface of the soil wet for many successive days. The grass grew rapidly, requiring frequent mowing. Meanwhile, golfing pressure continued. The combination of traffic and wet soil conditions resulted in significant compaction of the surface soil. Any place which had a drainage problem was susceptible to turf loss due to increased disease pressure, high soil temperatures, lack of soil oxygen, and compaction. More realistically, a combination of these problems caused turf loss. Unfortunately, poor drainage is not always evident until the damage is done.

This paper will address the effects of drainage problems on turf, how to identify some of the problems and general drainage strategies. The specifics of drainage systems and their design will be left to the engineers.

IMPACT OF POOR DRAINAGE

Effects of poor drainage can contribute to a long list of turf problems. If the soil is near field capacity (upper limit of available water), it becomes susceptible to 1) compaction from traffic. Compaction is probably the most common soil problem and often goes unrecognized. It results in a lack of adequate oxygen in the soil because of poor exchange of gases. Roots and microorganisms utilize oxygen for respiration, releasing carbon dioxide and other gases. Aeration is the process by which these gases move by diffusion to the air above the soil and oxygen moves into the soil. When the soil is saturated and/or compacted, this process of gas exchange does not readily occur, resulting in a lack of oxygen. The combination of compaction and lack of oxygen results in 2) shallow, restricted rooting, particularly reducing deep roots.

Other problems associated with poor drainage and lack of oxygen are 3) denitrification and development of 4) black layer. Denitrification occurs when certain soil microorganisms convert nitrate nitrogen into gaseous forms which escape into the atmosphere. Saturated soil conditions are ideal for denitrification. This condition is readily observable where field corn is growing in wet spots. As you travel along corn fields, you often see low spots where the corn is very short and yellow, exhibiting a lack of nitrogen due to loss by denitrification. This process can occur under turf conditions as well, but the symptoms are not as evident. Still, one can often identify low places where the grass is yellow due to low nitrogen.

Black layer occurs when there is a lack of oxygen in the soil. Under conditions of adequate oxygen, sulfur compounds in the soil are converted (oxidized) to sulfate. When oxygen is limiting, sulfur compounds are reduced to sulfides which form hydrogen sulfide gas causing the "black layer" smell and are toxic to grass at fairly low concentrations. The sulfide portion can precipitate with iron and manganese found in all soils, causing the black color. Unfortunately, this turf problem occurs most commonly in sands which would be expected to drain well. There are various theories as to why the black layer forms where it does, but a lack of oxygen is always a factor. This is obvious from the effects of cultivation and topdressing a green that has a black layer. Subsequent to treatment, a narrow band of soil around the cultivation holes that have been filled with sand loses the black layer color because of the improved oxygen status around the hole. Among the management practices recommended for control of a black layer condition are: 1) reducing sulfur inputs from fertilizers and irrigations sources; 2) careful irrigation control with hand syringing as necessary; 3) cultivation (with removal of the cores) and topdressing if the turf is strong enough to withstand these treatments; and 4) improving drainage.

When turf is regularly subjected to wet soil conditions the plant tends to become very succulent, having large cells and thin cell walls. In this situation, water molecules in the plant are free rather than being bound to the cytoplasm, making them susceptible to several environmental stresses. Among these are 5) moisture stress, 6) high temperature stress, 7) poor wear tolerance, and 8) crown hydration damage. Environmental stresses played a major role in much of the turf loss in the summer of 1995. Because of the weather conditions the turf had very poor hardiness.

_______Other problems, such as 9) excess growth, requiring more frequent mowing, and 10) scalping may occur when the turf is kept too wet by excessive rainfall and high humidity. Perhaps more importantly, the turf is susceptible to environmental stresses. In 1995, there were two periods when the turf was particularly susceptible to wilting conditions. During May the weather was cloudy, damp and cool. In early June the weather turned sunny, dry and hot for about 3 weeks. Because the turf had not hardened off during the spring, it did not tolerate well the high moisture loss conditions in early June. From late June through mid-August, the weather was characterized by frequent rainfall, high temperatures, and very high relative humidities. Turf became very succulent. After mid-August, sunny, dry weather returned with higher than normal temperatures. Again, turf suffered because it was not very hardy. In this condition, turf has poor wear tolerance which was widely evident last summer.

Other problems associated with these conditions are 11) scald and 12) wet wilt. When the soil is wet and the turf is weak, 13) mowing and other maintenance activities are restricted. This was evident on many golf courses. Any low spot which lost grass then was susceptible to rut formation from mowing equipment, further damaging the turf. Attempts to aerify these wet spots either were not successful or could not be done because the soil was too wet.

Some diseases (14) are more prevalent under wet soil conditions which could be caused by poor drainage. Depending on the source of the information, diseases enhanced under high moisture situations are brown patch, pythium, Fusarium patch, Typhula blight, yellow tuft, red thread, and Geaumannomyces. How significantly these are enhanced on poorly drained sites will vary with conditions and grass.

Wet soils will often have more weeds (15), particularly annual bluegrass, knotweed, and crabgrass. There may be more algae (16) and moss (17) present and a very common problem on wet sites is 18) excessive thatch. For one thing, wet soil conditions can be conducive to excess grass growth. And, the lack of oxygen reduces the natural decomposition of dead plant parts. When the soil is too wet roots tend to grow in the thatch layer rather than into the soil. As a result, thatch tends to build up. We have seen this on golf courses, lawns, and other grounds sites. Often, when a turf is over-watered, thatch is a serious problem.

While most of the attention given to drainage problems is focused on the growing season, there are a couple of problems which occur during other seasons. The most important is crown hydration damage. This normally occurs during late winter and early spring when the turf in low areas begins to take up water, hydrating the plant. If this occurs, followed by a hard freeze, ice crystals form in the plant disrupting the cells and causing death of the turf. Annual bluegrass is the most susceptible species, particularly the root crown portion of the plant. This problem can occur any place water stands, and can develop in only a few days. Usually the ground is frozen, restricting internal drainage. One solution is to improve surface drainage to encourage water runoff from susceptible sites.

Turfgrass seedlings will be more susceptible to 19) frost heaving on wet sites, particularly when exposed to sunlight. Wet soils 20) warm up slowly in the spring, delaying growth resumption. This can delay use of the site. On the other hand, this can be beneficial on wet sites like fairways or sod farms located on organic soils. These sites will be lowest in the landscape where frost occurs in cool weather. Since the soil stays cold longer, growth does not start as soon and mowing does not have to begin as early. This can permit more time for drainage to occur before growth starts when regular mowing is required.

Considering this long list of problems which can be associated with poor drainage, it is clear that the importance of having adequate drainage on heavily utilized turfs is a necessary part of the management program.

HOW WATER MOVES THROUGH THE SOIL

There are two major factors which influence water moment in soil. One is the attraction of water to soil particles. The second is gravity. Water molecules are strongly attracted to the surface of soil particles (sometimes referred to as adhesion). Water is also attracted to other water molecules by surface tension (also called cohesion). This water occurs in layers around the soil particles. The first layer is held very strongly, the second less strongly, etc.

The other major factor is gravity which pulls the water downward. Since water is attracted to water by surface tension, water molecules deeper in the soil are attracted to the water molecules just above. This process continues to the surface of the soil through continuous water films. The competition between the attraction to the soil and the influence of gravity determine how much water a soil holds to plants versus how much drains out of the root zone so deep soil drains more thoroughly than a shallow soil.

Anything that breaks the water films reduces drainage. The typical example is the perched water table concept utilized in construction of U.S.G.A. specification and similar greens. By placing coarse soil particles (gravel or very coarse sand) under the smaller diameter sandy media (fine to coarse sands), the continuous water films are broken at the interface between these soil materials. The result is water is held in the sandy layer above the coarser material below because the continuous water films are interrupted and gravity cannot exert as much influence on the water in the top mix. This results is the "perched water table" which is built into these greens. It provides a water conserving system, giving better water use efficiency and reducing the potential for leaching compared to a sandy green which has no perched water table. A sand which is 20 inches deep will be drier at the surface than the same sand which is only 8 inches deep to a perched water table.

However, when shallow layers of varying soil materials are present as a result of construction or topdressing errors, the result can be a perched water table at that point. In the U.S.G.A. type construction the top mix is supposed to be deep enough to permit gravity to have influence and adequate drainage should occur. But when there are shallow layers near the surface a perched water table can occur at the interface between the alternating layers. One common example is alternating layers of sand and thatch when sand topdressing is done at improper frequency or rates. Use of a finer-textured soil-based topdressing mix on a sand green can also cause a perched water table. With a perched water table at the surface, more water is held there than desired. This can contribute to some of the drainage problems outlined above. Wet spots may develop in some low areas of perched water table greens while localized dry spots often occur on the high spots. When 2-3 inches of topdressing have accumulated, in subsequent years rooting may eventually stop at the interface of the two divergent materials. Once such a mistake has occurred, it is not possible to remove the layer. However, if the layer interface is not too deep, one can utilize an aggressive cultivation and topdressing program to alleviate the effects of such a layer.

IDENTIFYING POOR DRAINAGE

There are several obvious clues for identification of poor drainage including standing water, low areas with dead grass, excessive thatch, loss of turf due to crown hydration, poor stress tolerance, poor wear tolerance, shallow rooting, patches of weeds, ruts, and compaction, among others. The lowest spots in the landscape are usually where the wet spots occur. Occasionally, springs will cause water to come to the surface in areas with higher elevation. While the obvious problem areas are easy to identify, there are other aspects of poor drainage which require more than casual observation. These are associated with soil conditions.

The presence of a high water table can cause drainage problems. Standing water at the surface is one indication of a water table problem. This may be present throughout the year or appear only during seasons of excess rainfall. However, standing water may not be present on flat landscapes, yet can lead to many of the problems cited above. Regular checking the soil profile is perhaps the easiest means of locating a water table problem. This can be done with a soil auger, a soil probe, or a shovel and should be checked during both wet and dry seasons. Soil Survey Reports, available from your Resource Conservation District (the old Soil Conservation Service) or Cooperative Extension Service offices are also very valuable sources of information on soil types and general drainage conditions. While the soil maps may not be highly precise, they still can be helpful in evaluating soil conditions. These reports give typical soil profile descriptions and drainage conditions that can be useful. An example is a soil that has a sandy surface, but a clayey layer exists below, a result of the manner in which soil was laid in place by nature. Understanding this is necessary to determine the best approach to improving drainage.

A more subtle example of drainage limitations is the existence of a soil layer caused by man. These may occur as a result of construction or as a result of a layer of relatively impermeable, clayey soil. Compaction, as a result of traffic during construction, maintenance operations, or topdressing layers commonly cause limitations in drainage. Problems with topdressing are described in the previous section. A cultivation pan which restricts water movement that is caused by aerifying to the same depth with a vertical operating aerifier over a period of years can cause drainage limitations. Careful examination of the soil profile can reveal such problems. The cause of poor drainage must first be identified before a practical solution can be recommended.

An approach we have used to determine the drainage limitations near the surface of putting greens utilizes a technique I first observed in New Zealand. At the New Zealand Turf Culture Institute, Keith McAuliffe and his staff use common aluminum irrigation pipe (1). Four-inch pipe is cut to lengths of 4, 6, 8, and 10 inches. The upper end is smoothed. The bottom end is carefully sharpened (with the bevel on the outside edge) with a grinding wheel. The 4-inch tube is driven into the green to the 2-inch depth to sample the 0-2 inch layer of soil. The 6-inch tube is then used to extract the 2-4 inch depth. The 4-6 and 6-8 inch depths are sampled with the 8 and 10-inch tubes, respectively. The tubes are then placed on a metal grid. Water is added to the tubes to maintain a 1/2-inch head. Water which passes through each tube is collected and measured periodically, often on a 5-minute interval. The amount of water collected is converted to an infiltration rate.

Using this technique one can determine which soil layer is most limiting for water movement through the soil. One can then decide what course of action is most appropriate to alleviate the condition. To illustrate this point, consider the data in the tables that follow. The data from New Zealand point out the effect of waiting too long to begin topdressing a new sand green. The original soil (4-6 inch depth) had an infiltration rate of over 7 inches per hour. Once a good topdressing program was begun the infiltration rate was equally high at over 7 inches. However, the 2-4 inch depth revealed that use of a poor topdressing material and/or an accumulation of roots and thatch caused water movement to be severely restricted. Even though that layer was buried by acceptable topdressing it was still seriously limiting in water movement. This infiltration technique verified the limiting layer which may not have been evident visually. In this case, an aggressive aerification program was recommended with tines that would penetrate through the limiting layer. Topdressing with the appropriate sand would then provide open channels through which water, air, and roots could move.

Infiltration rate of soil layers in putting greens

Soil depth inches	Infiltration rate inches/hour
New Zealand green, sand topdressed	
0-2	7.7
2-4	0.4
4-6	7.1
Detroit area green, sand topdressed over native soil	
0-2	19.8
2-4	1.2
4-6	0.6
6-8	1.8

In the second case, the topdressing program was giving good results with a very high infiltration rate in the surface 2 inches. The greatest limitation to water movement was in the 4-6 inch depth, probably a cultivation pan that developed before topdressing was started. Here, a deep aerifier would be suggested which could penetrate through the 4-6 inch depth. Observation of the soil deeper in the profile indicated the soil did not change below the 6-inch depth.

At another site this technique revealed greater compaction (lower infiltration) on the front of the green where traffic was concentrated than at the low traffic area at the back of the green. Thus, it may be necessary to treat the front of the green differently from the less trafficked area. One relatively young sand green had the lowest infiltration rate in the 0-2 inch depth, likely caused by an inadequate topdressing program similar to that suggested for the New Zealand green. In northern U.S. our climate encourages extensive bentgrass root growth. Because temperatures are cooler, there is a tendency for this root material to accumulate which then could plug the pores in sand greens. This reduces infiltration and may limit oxygen in the surface layer. During grow-in on many greens, intensive fertilization and irrigation programs contribute to very rapid growth. The grass is mowed high until the turf achieves good density and a good root system. This combination often results in development of a significant thatch layer. Such a thatch layer can limit water movement, particularly when buried by subsequent topdressing. For these reasons, it is essential that an integrated turf management program be followed which balances fertilization, irrigation, grooming, cultivation, and topdressing so that this condition does not develop.

DRAINAGE MANAGEMENT

Before determining what drainage is needed one must decide whether poor drainage exists and why. Only then can an appropriate course of action be taken.

1. The first approach to improving drainage should always be to provide as much surface drainage as is consistent with the site and use of turf. This is especially crucial for high traffic areas such as greens, tees, and areas where traffic concentrates.
2. Check out the internal drainage. Where necessary, install tile drains. For simple drainage problems, these can often be designed by the turf manager. On more complicated sites, it is wise to consult a drainage engineer to be sure the system is adequately designed and proper outlets exist. Unfortunately, when drainage has been installed in the worst areas adjacent wet spots then become more evident. A practical drainage engineer can help plan the system well.
3. Usually a combination of surface and internal drainage will be needed.
4. Check with local authorities to determine whether you can legally drain the water off your site to an existing body of water.
5. Use the irrigation carefully. A useful adage is "Drainage begins at the pump house." Some turf may have been lost during 1995 because irrigation was applied during hot weather although evapotranspiration rates were low. Be careful to consider an estimate of evapotranspiration in your irrigation program. When the weather was so hot during July and early August, the relative humidity was exceedingly high and the weather was often cloudy. The result was low evapotranspiration rates. Very little water was needed by the turf even though the temperatures were high. Unfortunately, many areas of the state also had frequent, heavy rainfall. If irrigation was applied previous to those thunderstorms, the turf sat in saturated soils while very hot. The lack of oxygen, high soil temperature, traffic, and disease pressure caused a significant amount of turf loss. Some courses lost turf in spite of very careful irrigation management.
6. When irrigating perched water table greens, remember that this is a water conserving system. In contrast, the surrounds will either have unrestricted drainage so the water moves out of the root zone or it runs off sloping areas. Often, the surrounds will wilt before the perched water table greens. To prevent turf loss on the surrounds, irrigation is applied. This means the greens may be receiving too much water. Possible solutions are to syringe the surrounds only or installation of 2-speed heads or a separate system to irrigate the surrounds.
7. An alternative for construction of new perched water table greens, one might utilize only 8 inches or so of top mix on the high spots and gradually increase the depth to 16-18 inches in the low areas. It seems logical this would help alleviate water related problems found on some perched water table greens. Localized dry spots are found on the high, dry areas of these greens while if black layer is present it is normally restricted to the lower areas of the green. Water held in the perched water table moves down the slope from the higher elevations to lower elevations. By constructing greens in this manner, the problems of localized dry spots on high spots and soil wetness in the low areas of some greens should be reduced. To my knowledge this concept has not been previously suggested and it has <u>not been tested</u>.
8. Follow an integrated turf management program. Because conditions vary from one spot to another, it is best to plan a program which is best suited for that site. Environmental conditions, traffic, and irrigation systems differ, so it makes sense that some <u>site specific management</u> is appropriate. To do this requires careful evaluation of site and soil conditions. Then one can determine what irrigation or topdressing program is most appropriate, for example.

9. If all else fails, it may be necessary to reconstruct a given site. In the long run, this may be the most efficient approach to attaining a quality turf. However, with careful analysis of the situation, including good drainage, it may be possible to improve conditions with reasonable cost.

Drainage is only one part of a good turf management program. Poor drainage just makes the job a lot harder. There is real wisdom in the often quoted statement "For a good golf course, one needs good drainage and common sense. If there is a shortage of the latter, use more of the former." It is almost impossible to have too much drainage!

LITERATURE CITED

1. McAuliffe, K.W., P.E. Rieke, and D.J. Horne. Int. Turfgrass Soc. Res. J., Vol. 7:444-450.