Environmental Concepts

Water quality protection requires an understanding of basic environmental concepts, such as:

- concepts related to climate and microclimates
- concepts related to water, such as the hydrologic cycle and watersheds
- concepts related to soils, such as soil texture and soil moisture
- concepts related to geology, such as karst topography

Water, soils, and geology all play a role in environmental fate and transport mechanisms (such as runoff and leaching) that can contribute to water quality impacts. BMPs act on these fate and transport mechanisms to prevent water quality contamination.

Climate and Microclimates

Golf course superintendent must develop management programs that address nutrient and pest management needs while understanding the effect of a changing climate and microclimates might have on the need for irrigation and the fate of applied materials.

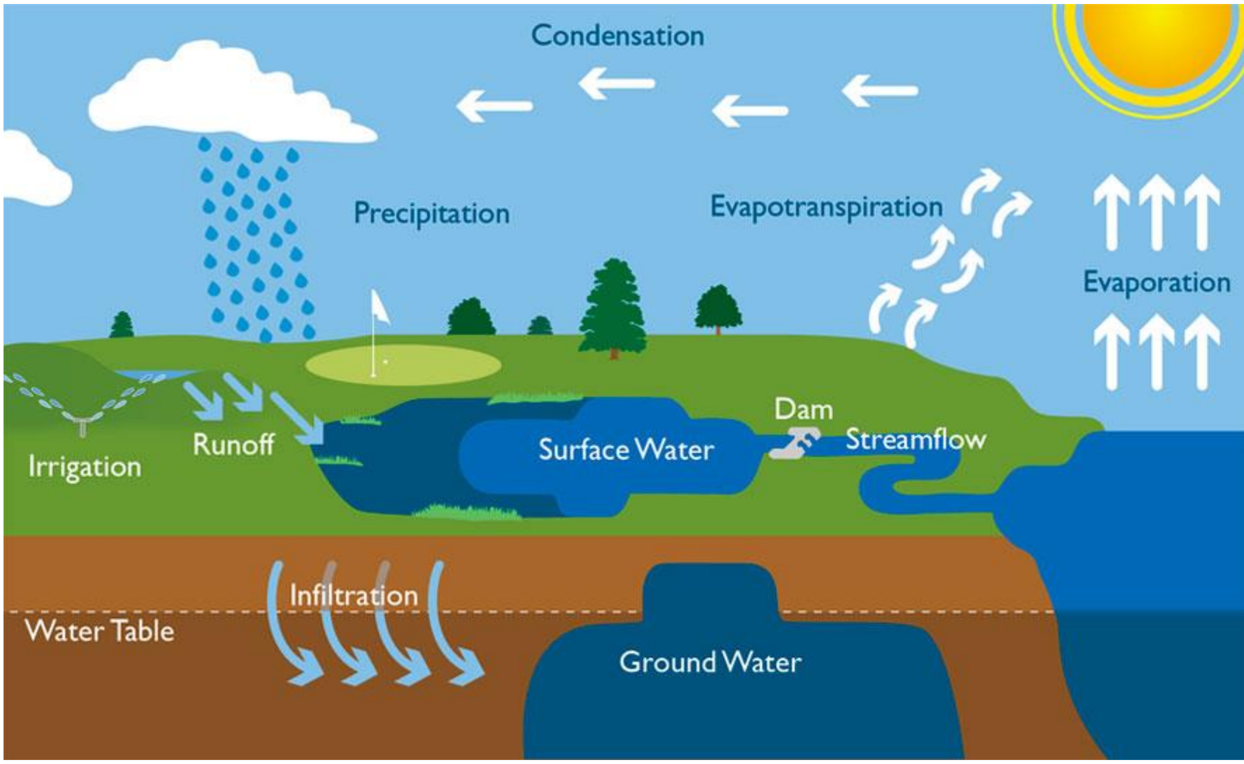
Projections of a changing climate suggest that rainfall events will become less frequent, but more intense. As a result, a greater volume of the precipitation is expected to run off instead of infiltrating into the soil and replenishing groundwater. Consequently, the need for supplemental irrigation may increase, and superintendents will need to take greater care in the applying fertilizer and pesticides to reduce the risk of runoff. Structural BMPs are also valuable in managing increased runoff. For more information on available climate data for New York, see the Northeast Regional Climate Center (http://www.nrcc.cornell.edu/).

Golf courses are diverse landscapes with a variety of microclimates that require site-specific management to maintain uniform playing conditions. Microclimates are created by landforms as well as by vegetation and water bodies. In each case, the golf course superintendent must adapt management programs that address nutrient and pest management needs while understanding the effect these microclimates might have on the fate of applied materials.

Hydrologic Cycle

The sun is the powerhouse for the hydrologic cycle, providing the energy for phase changes of water (evaporation and condensation) and for the storage and release of latent heat. Because water is an efficient solvent, all water-soluble elements follow this cycle at least partially. Thus, the hydrologic cycle is the integrating process for the fluxes of water, energy, and the chemical elements throughout the environment.

Water enters the hydrologic system as precipitation, primarily in the form of rainfall or snowmelt. It is then delivered to surface waters from runoff or infiltrates into the subsurface. Water can leave the system via stream flow or runoff, evaporation from open bodies of water, or evapotranspiration (evaporation from soil surfaces and transpiration from the soil by plants).



The hydrologic cycle is the cyclic movement of water in its various phases through the atmosphere, to the Earth, over and through the land, to the ocean, and back to the atmosphere.

Groundwater Recharge

Water moves through the surface of the earth, eventually through the soil horizons to natural storage areas below the ground. Depending on subsurface rock formations and overall permeability, the filling of these storage areas or "recharge" can collect water from a few hundred square feet to a few square miles. Groundwater often provides the source of water for perennial stream flow at base flow conditions when there is no precipitation. It is critical to understand the basics of groundwater recharge, both in size and scope, to mitigate potential contamination.

Infiltration and Runoff

The amount of water that infiltrates into the ground from the total run off depends on a number of variables, including the intensity of precipitation or irrigation, soil infiltration capacity, site characteristics, antecedent soil moisture, and season.

Water that infiltrates into the soil either is stored within the soil profile or percolates downward toward groundwater, depending on the soil moisture conditions and soil structure. This soil water is then available for evapotranspiration. If the moisture-holding capacity of the soil is exceeded, the excess water percolates downward through the soil profile to groundwater. If the soils are at saturation, any additional precipitation does not infiltrate into the soil and becomes surface runoff instead. It is in this runoff that more soluble compounds applied to turf have the greatest potential to move off site.

Site characteristics including land use, land cover, soils, and topography also influence the amount of infiltration versus amount of runoff. Turf, forests, fields, and other vegetated areas slow down the flow of runoff, filter out sediments, and trap pollutants or break them down biologically. Conversely, hard impermeable surfaces such as buildings, roads, parking areas, and exposed bedrock prevent water from infiltrating into the ground. These hard impermeable surfaces, as well as bare soils, offer little resistance to reduce the velocity of runoff. Similarly, compacted soils and saturated soils retard the infiltration of water and therefore promote runoff. Lastly, steep slopes can increase the rate and amount of runoff.

The amount of runoff versus infiltration at any location also varies seasonally. During the winter, soils in New York are likely to be frozen and impermeable to water. Snowmelt, rain, and low evapotranspiration rates in the spring generate wet soil conditions and downward movement of water to groundwater. The potential for runoff is high because the near-saturated or partially frozen soils have low water infiltration capacities. During the summer, high rates of evaporation and plant water uptake may reduce soil water storage, leaving none to percolate downward. Summer rains only partially recharge the soil profile, and the soil's moisture holding capacity is typically not exceeded. Except for high-intensity thunderstorms, runoff and erosion potentials are generally low during the summer. In the late fall, evapotranspiration rates decrease, and groundwater recharge occurs when the moisture-holding capacity of the soil is exceeded. Runoff and erosion potentials also increase during this period. However, in New York, runoff from turf most often occurs from wet soils and not from high rainfall intensity.

Watersheds

A watershed is generally defined as an area of land that drains into a body of water, such as a river, lake, estuary, reservoir, sea, or ocean. Thus, all golf courses are in some watershed.

A watershed includes the network of rivers, streams, and lakes that convey the water, as well as the land surfaces from which water runs off. Watershed boundaries follow the highest ridgeline around the stream channels and meet at the bottom or lowest point of the land where water flows out of the watershed. The boundary between watersheds is defined as the topographic dividing line from which water flows in two different directions.

Identifying and defining watersheds depends on the scale at which the landscape is examined. A watershed may be small and represent a single tributary within a larger system (such as a subwatershed), or be large and cover thousands of miles and cross numerous state boundaries, such as the Chesapeake Bay watershed. New York State is divided into 17 watersheds.

Watersheds in New York State.

At a larger scale, the U.S. Geological Survey (USGS) has divided and subdivided the United States into units classified into four levels: regions, subregions, accounting units, and cataloging units. A fifth field of classification (watershed) and sixth field (sub-watershed) are currently under development by USGS. The hydrologic units are arranged or nested within each other, from the smallest (cataloging units) to the largest (regions). Note that watersheds cut across typical regulatory boundaries such as counties and states, which can complicate regulation.

The first level of classification divides the United States into 21 major regions. Regions contain either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region, which includes a number of rivers draining into the Gulf of Mexico. New York State is situated within the boundaries of three regions: Ohio, Mid-Atlantic, and Great Lakes.

For more information on watersheds, see:

- NYS Department of Environmental Conservation (NYSDEC) web site on New York watersheds (http://www.dec.ny.gov/lands/60135.html)
- USGS watershed classification (http://water.usgs.gov/GIS/huc.html)

- U.S. Environmental Protection Agency (EPA) Surf Your Watershed (http://cfpub.epa.gov/surf/locate/index.cfm)

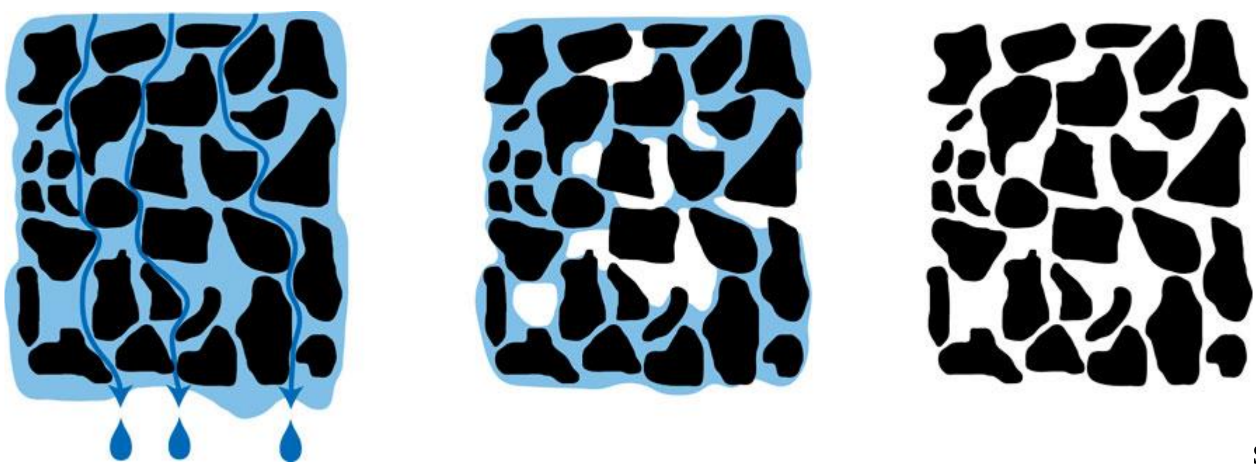
Soils

Soil is the growing medium for turf on golf courses. Golf course superintendents must understand the behavior and function of water in the soil, as it assists with determining the potential off-site movement of fertilizers and pesticides.

Water can infiltrate into the soil and then can be held in pores or adhere to soil particles. The infiltration and water holding capacity of a soil involves different forms of energy. Three forces determine the water storage capacity of soil:

- gravitational potential, which draws water down and through the soil profile.
- matrix potential, which is defined by the adsorption of water to the soil particle surfaces. Smaller soil particles, like clay or silt, as well as organic matter, have a greater total surface area than a coarser material such as sand.
- osmotic potential, which is the attraction of water to solutes. The plant root system uses osmotic potential to draw water from the soil across the root membrane.

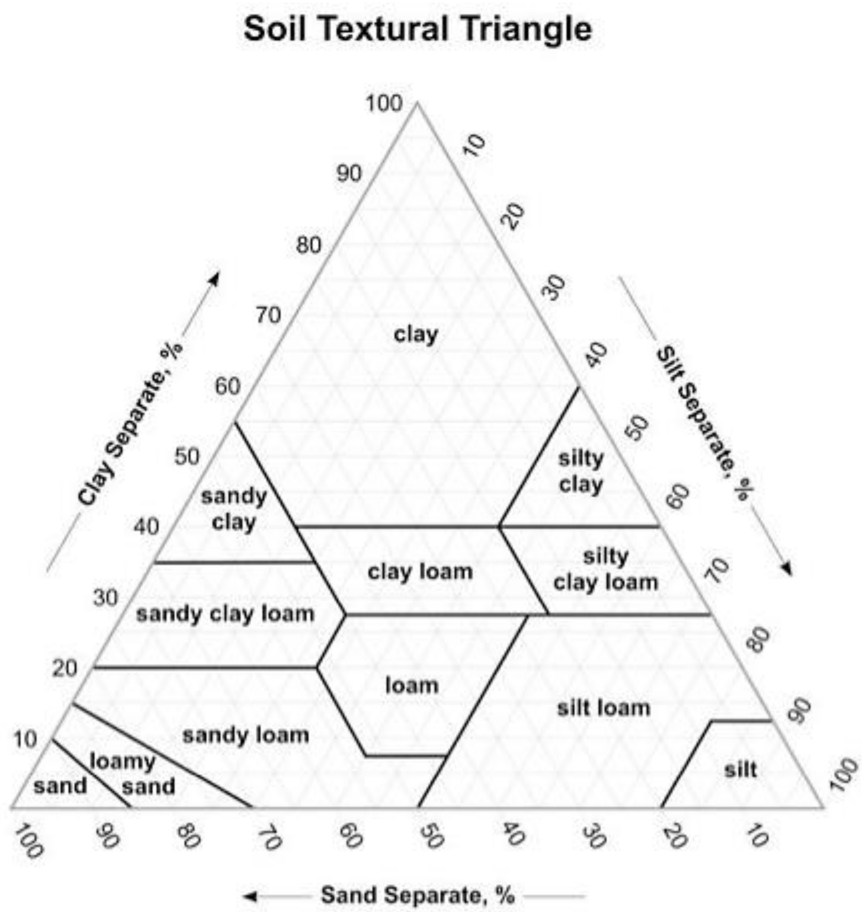
Downward movement of water through large soil pores or when soil is fully saturated is driven by gravity, hence the term gravitational water. When the soil is saturated, some of this water will become groundwater recharge or can enter drainage tiles, if present. The amount of water that remains after gravity has exerted its influence is referred to as the "field capacity" of the soil.



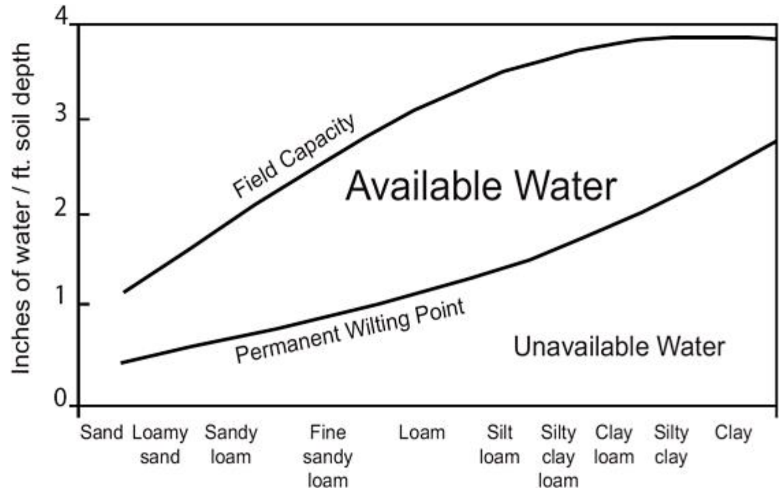
Soil water field conditions: saturation (left); field capacity (middle), and wilting point (right).

The water content of the soil determines whether plants thrive or wilt. Evapotranspiration from the turf surface draws water from the soil. If this process continues unabated and no irrigation or rainfall occurs, the soil will dry to a point known as the wilting point. The difference between soil moisture content at field capacity and the point at which plants wilt due to lack of moisture is referred to as "plant available water". Often little plant-available water is present in the soil when it reaches the wilting point, which is the point at which the soil holds the water with greater energy force than the plant can exert to extract it.

The amount of plant-available water depends upon the soil structure, texture, and organic matter. The classification of soil structure and textural analysis is shown in the soil texture triangle. Lab analysis can determine the percent distribution of sand, silt, and clay. The amount of plant-available water held by different soils is presented in the figure below. Commercially available moisture meters are able to read soil moisture percentage.



Soil textural triangle depicting soil particle distribution for different soils. Soil size definitions are as follows: Clay <0.002mm, Silt = 0.002-0.05 mm, Sand = 0.05 -2.0 mm. *Source:* USDA.



Available water by soil type. *Source:* Ohio Agronomy Guide, 14th edition, Bulletin 472-05.

Adding amendments to sand can dramatically increase the plant-available water capacity (PAWC), as shown in the table. While peat only slightly increases the PAWC of a 12-inch sand root zone, adding calcine diatomite and a natural zeolite can double or even triple the PAWC of sand.

Plant-available water holding capacity for sand and sand with amendments

Material	**Plant available water holding capacity (% by volume)**
Sand	4
Sand/Calcine clay (90:10)	6
Sand/Calcine diatomite (90:10)	8
Sand/Natural zeolite (90:10)	11
Sand/peat (80:20)	5

For more information on soils in New York, see http://websoilsurvey.nrcs.usda.gov.

Geology

Golf courses can cover large expanses of land that may vary in geological properties. Understanding these geological properties is critical because these properties can pose risks for ground or surface water contamination.

Surficial Geology

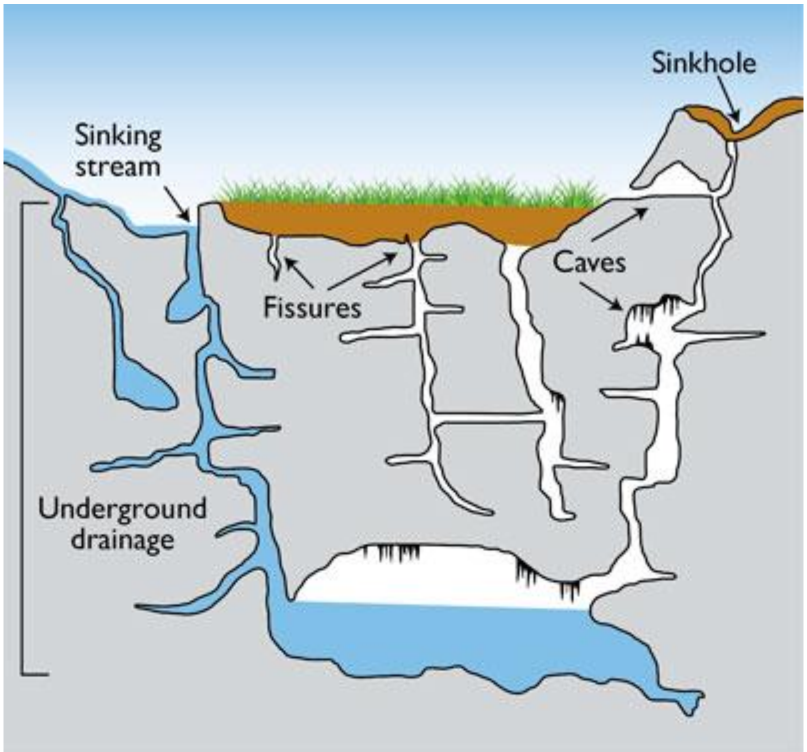
Surficial geology is the study of landforms and the unconsolidated sediments that lie beneath these landforms. The type of surficial geology, along with the type of subsoil and depth to groundwater, can influence the surface water and groundwater interactions that allow contaminants to move from one medium to the other.

Soils with hard pans or finer textured horizons in the subsoil may have a greater ability to adsorb contaminants as they leach through the surface horizons. The greatest potential for groundwater contamination occurs where sandy soil overlies porous materials (such as limestone or coarse gravel) with a shallow water table.

For New York State maps of surficial geology, see http://www.nysm.nysed.gov/gis/#surf.

Karst Geology

Karst geology (also called karst topography) is a type of surficial geology associated with carbonate bedrock (limestone, dolomite, or marble) and characterized by sinkholes, depressions in the land surface, caves, and underground drainage systems.



Karst geology is characterized by such features as sinkholes, fissures, and caves.

In New York State, continental glaciation and local stratigraphic and structural conditions have produced karst features, which may affect the quality and quantity of groundwater in the state.

Karst features are created over time by rainwater, which dissolves the carbonate bedrock as it drains into fractures, creating channels and openings in bedrock. These channels and openings to the ground surface provide a direct connection between surface water and groundwater; these enhanced connections are known as “focused” or ‘direct’ recharge. Direct recharge quickly replenishes the water supply; however, it also leaves the aquifer particularly vulnerable to contamination, especially where the topsoil layer is thin and does not filter out potential contaminants.

Available bedrock geology maps of NYS identify carbonate bedrock areas that indicate the potential presence of karst features. However, higher resolution maps of the boundaries as well as karst features in these bedrock units would be better suited for site-specific management, but may not be available from other sources.

For more information on karst geology, see:

- Bedrock geology map of NYS: http://www.agiweb.org/environment/karstmap.pdf
- "Living with Karst", American Geological Institute: http://www.agiweb.org/environment/publications/karst.pdf
- Fickies, R.H. and Fallis, E., 1996, Rock Type Map of New York State: New York State Geological Survey, Open file Report 1g1222, scale 1:1,000,000.