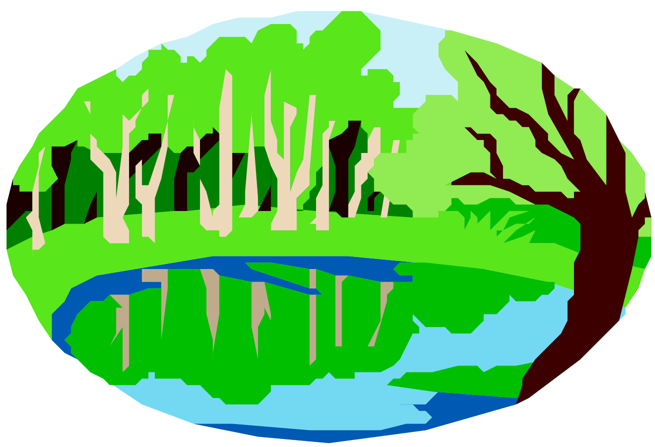
May 2000

CAPE COD—
A Community Connected By Water

This brochure is Part Three in a series on Water Resource Education Information, presented as part of the "Communities Connected by Water" Program

Kettle Hole Ponds: Windows on the Aquifer

Henry David Thoreau once wrote, "A lake is the landscape's most beautiful and expressive feature. It is the earth's eye looking into which the beholder measures the depth of his own nature.

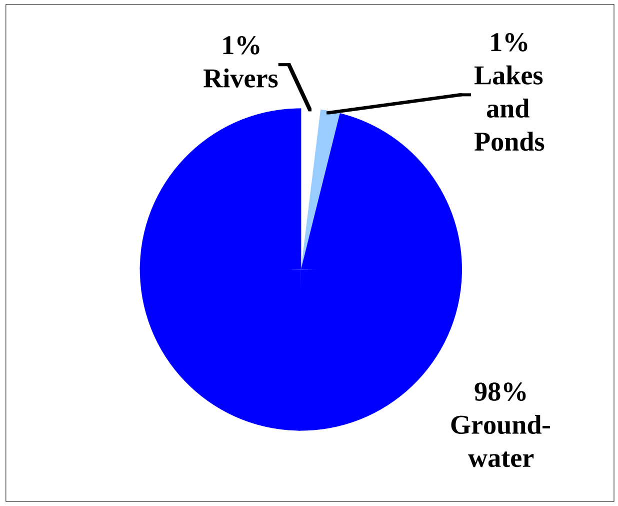


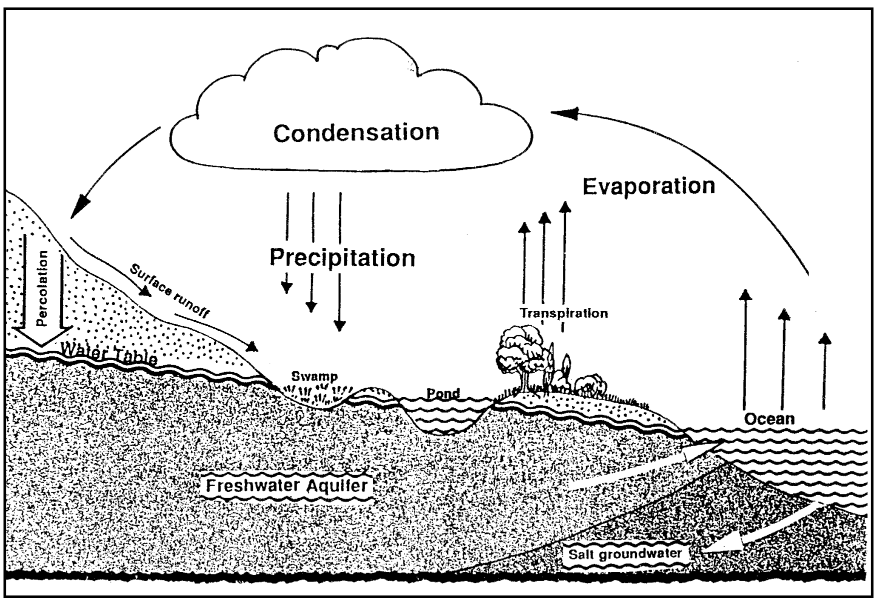
About 12,000 years ago, the glaciers retreated from Cape Cod leaving large chunks of ice behind. As these chunks of ice melted, the landscape above them collapsed forming large depressions called "kettle holes". When these depressions dip below the groundwater table, they are filled with water and create the hundreds of ponds we see on Cape Cod today. Typically, the ponds lack a surface water inlet or outlet. Instead, the sandy sides of these ponds allow a steady inflow and outflow of water to and from the adjacent aquifer. The pond surfaces generally fluctuate up and down in response to the seasonal rise and fall of the water table, giving us a "window" into the aquifer.

This project is a Massachusetts Watershed Initiative
funded by an EOEA grant to APCC and the Cape Cod Commission.

The Water Cycle

Water exists in three forms: solid (ice), liquid, and gas (vapor), and is found in all these forms throughout the globe. While the earth has an abundant supply of water, the amount of usable freshwater actually comprises less than 1% of the earth's water. Of this 1%, 98% is groundwater and the remaining 2% is fresh surface water. All waters on the earth are continually in motion from the earth to the sky, and back again. This water or **hydrologic cycle** is made of four basic processes: Precipitation, Percolation/Surface Runoff, Evaporation/Transpiration, and Condensation.



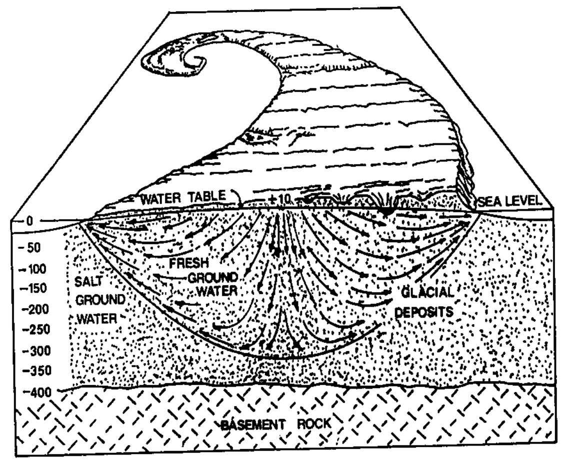


Rain and snow are the most frequent forms of **precipitation**. After reaching the earth's surface, some portion of the water will be absorbed into the soil. On Cape Cod, over half of the rain and snow that falls each year will infiltrate into the ground and recharge the aquifer or **groundwater** supply.

Evaporation is the process of water being converted to gas through wind and sun energy. During the growing season, plants take up precipitation passing by their roots and return it to the atmosphere through their leaves in a process known as transpiration. These two paths of water returning to the air are often lumped together under the term **evapotranspiration**. Vapor water in the air rises up and forms clouds, which at some point will **condense** from gas to liquid, and fall back to earth as **precipitation**, thus completing the hydrologic cycle.

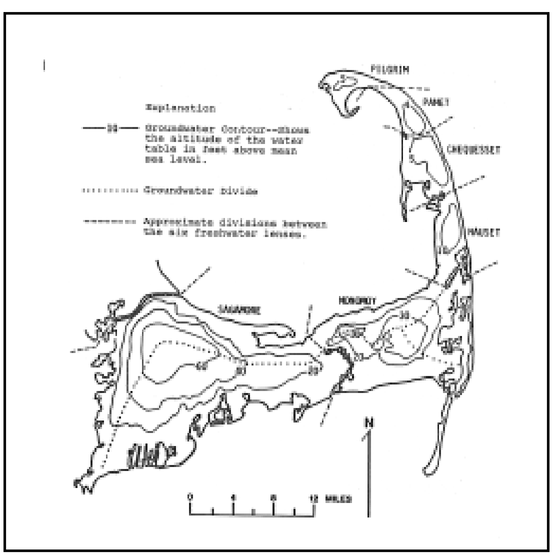
The Underlying Hydrogeology

verticle scale greatly exaggerated



Cape Cod is a mound of sediments pushed into place by glacial action over a period of several thousand years during the last ice age and distributed as **outwash plain** by the melting of the glaciers. Beneath our feet, in the sand, lies our groundwater/drinking water. The water-saturated soil, known as the **aquifer**, extends in some places to a depth of approximately 400 feet (130 meters), then grows more shallow toward the edges of the land as seen in the cross-section to the left. When drawn true to scale the aquifer appears as a thin film of water, which because of its convex shape resembles a lens. On Cape Cod, water moves about one foot (30 cm) per day through the soil. It is pushed by gravity toward the shore or tidal river where it is gradually discharged and lost from the aquifer.

The aquifer on the upper Cape extends down to bedrock. This bedrock is much deeper under the lower Cape where the freshwater sits on top of salt groundwater. The separation of the fresh and salt water is assured by the greater **density** (weight) of the seawater.



The Cape gets approximately 42 inches of rain and snow each year to recharge our aquifer. Because this aquifer represents our only source of drinking water, the Cape system has been designated a "sole-source aquifer" by the federal government, which means that extra protection should be taken to ensure that it is maintained as a safe water supply.

Within this aquifer are found six separate areas of groundwater, called **lenses**. They are named by their location: Sagamore, Monomoy, Nauset, Chequesset, Pamet, and Pilgrim. The lenses are separated by tidal rivers which prevent the groundwater from passing between them.

Great Ponds

According to Massachusetts General Laws, all standing natural bodies of water in excess of ten acres are classified as **great ponds** and are open to general public use unless restricted by special acts of the legislature. In 1933, the legislature designated 164 Great Ponds on Cape Cod. One of these ponds, Long Pond in Falmouth, is used as a public water supply. This list is out of date and requires updating.

In 1969, an inventory of ponds, lakes, and reservoirs in Barnstable County reported 208 great ponds. It included information on the physical, biological, and land-water use characteristics of the ponds.

Great ponds have generally received enhanced study opportunities through grant programs and state agencies. Many ponds were sampled during the 1970's and 80's and selected lakes and ponds were studied under the Clean Lakes program. The Department of Fisheries and Wildlife provides regular stocking of trout in a number of healthy ponds across the region.

Presently, Department of Environmental Management lake and pond grants have allowed concerned citizens to gather data for use towards better management. Citizen monitoring groups have collected important water quality data on a handful of ponds. These include Shawme Pond in Sandwich, Long Pond in Brewster and Harwich, Lake Wequaquet in Barnstable, Gull Pond in Wellfleet, and Crystal Pond in Orleans. A coalition of groups interested in protecting ponds have received a $30,000 grant to develop a Cape Cod Pond stewardship strategy from the Massachusetts Watershed Initiative.

GREAT PONDS ON CAPE COD

LENS	TOWNS	# OF GREAT PONDS	AREA (acres)
SAGAMORE	Bourne, Sandwich Falmouth, Mashpee Barnstable, Yarmouth	111	6318
MONOMOY	Dennis, Brewster, Harwich, Chatham, Orleans	74	3881
NAUSET	Eastham, South Wellfleet	7	239
CHEQUESSET	Wellfleet, South Truro	12	354
PAMET	Truro	1	351
PILGRIM	Provincetown	3	65

Source: An Inventory of the Ponds, Lakes, and Reservoirs of Massachusetts, 1969

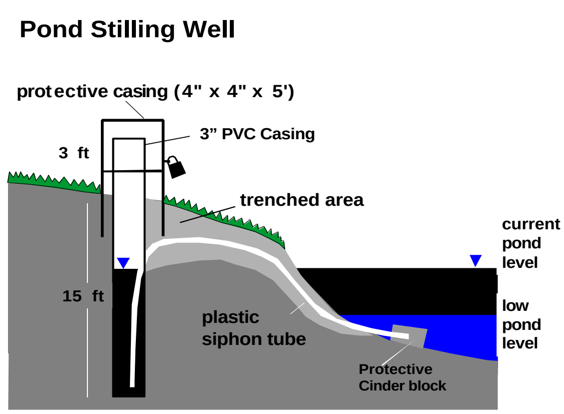
The Water Budget

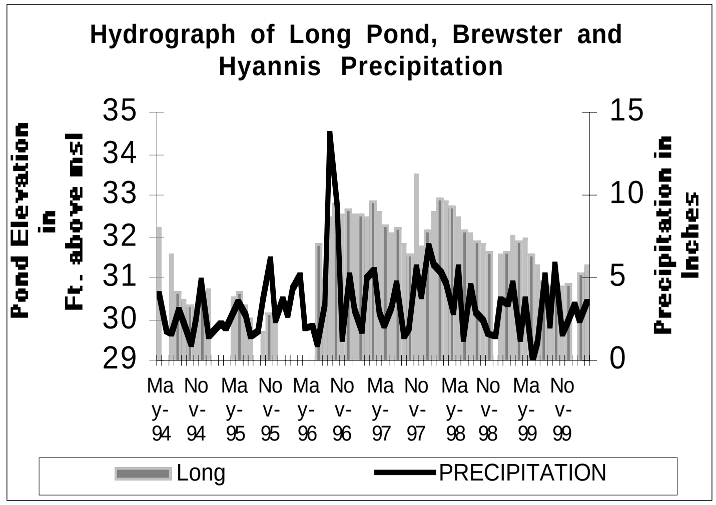
Like many natural resources, water is an exhaustible and limited resource. Using the finite water supply wisely means that we must understand how much water we have and how our use affects the supply.

Groundwater levels rise and fall throughout the years, based on seasonal trends. In the winter and spring, there is little evaporation, plants are dormant, and the water table level rises. From May to November, water is drawn out of the aquifer in greater amounts for water supplies and the water table falls due to evaporation and uptake by plants.

In general, water levels in kettle ponds are similar to levels in the surrounding groundwater. Changes in the water table level can be seen directly by looking at a kettle pond. Generally, this is most noticeable by looking at the size of the shoreline beaches. The beaches become larger during times of low water and become smaller and sometimes disappear altogether during years with above average precipitation.

A more accurate and dependable way to measure the height of a kettle pond has been developed by the U. S. Geological Survey. This method consists of an onshore stilling well that is directly connected to the pond by a stretch of buried tubing. The height of the pond surface is equal to the water table height measured in the well.





Presently, there are 17 stilling wells installed on Cape pond shorelines and measured monthly. These can be locked and measured year round giving a consistent record of fluctuating pond levels.

Maintaining long term information on the elevation of a pond is helpful in determining if there are water table trends, the susceptibility of endangered shoreline plant species, and assisting in evaluating groundwater flow direction and the impact of surrounding land use.

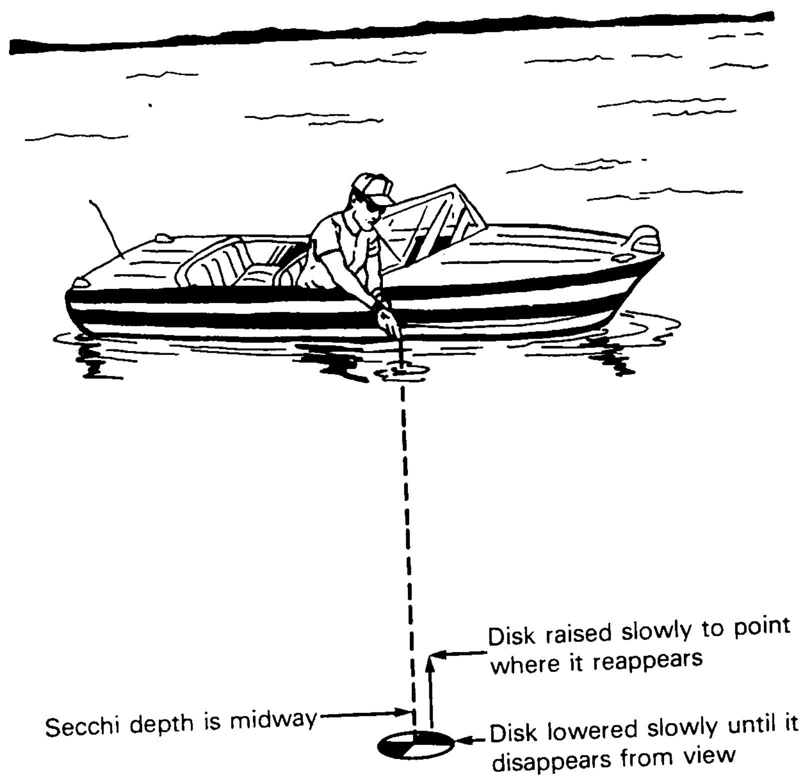
Pond levels that are too high can cause shoreline erosion, flooded basements, and stormwater and wastewater disposal problems for homeowners.

In years of very little precipitation, the water table can fall sharply, causing a drying of some wetlands, lowering of pond levels, and lead to a water budget deficit. This effect can be exacerbated by the increased seasonal demand for drinking water and irrigation. On Cape Cod over 23 million gallons of water are pumped daily from 145 public supply wells and thousand of private wells. In the summer this amount exceeds 45 million gallons. A number of shallow ponds in the Hyannis area went dry in 1991 when a record low water table was further reduced by increased water supply pumping nearby. Pumping impacts are site specific and can be reduced by locating public supply wells away from surface waters.

Characterizing Our Ponds

If there is a problem in a pond, a fish kill or algal bloom for example, people often want to "do something about it." In order to figure out what the best thing to do is, scientists and managers usually need to have a better understanding of how the ecosystem of the pond functions and what conditions may have led to the problem in the first place. Often getting a better understanding of the conditions in the pond will require some sort of study, which can be enhanced through the participation of citizen water quality monitors.

One of the best indicators of pond ecosystem function is regular measuring of pond water clarity. This measurement is taken by lowering a **Secchi disk** into the water and noting when it cannot be seen anymore. This is an indication of how deep into the pond sunlight can penetrate and is usually considerably shallower in ponds with extensive algal populations and nutrient inputs.



Other measures which are easily collected and very informative are temperature and dissolved oxygen. Water temperature within a lake changes over the course of a year and sets up layers of water that have different water quality characteristics. Dissolved oxygen is affected by temperature, but can also be impacted by extensive plant populations that can increase concentrations during sunny days or by thick organic sediments that consume oxygen as they are digested. Regular collection of temperature and dissolved oxygen during the summer can reveal important information about the overall health of a lake ecosystem.

Other measures that can be collected by well trained citizen volunteers are phosphorus, chlorophyll, and nitrogen water quality samples. Phosphorus is generally the key nutrient in pond ecosystems; as more phosphorus is added the plant population increases, which causes increases in species that eat the plants and other species that eat them. However, too much phosphorus can create conditions that favor one plant and cause the species that depend on other plants to disappear from a pond.

General Pond Ecology

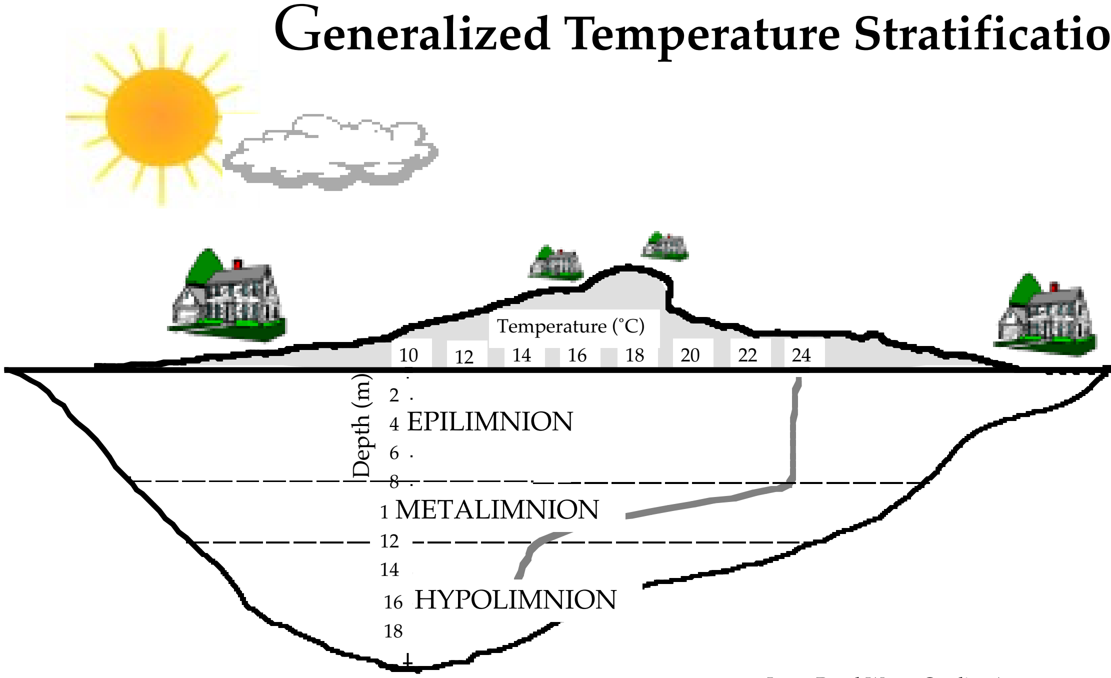
Lake ecosystems are controlled by interactions among the physical features of the lake, such as its shape, strength and direction of wind, air and water temperature, groundwater and surface water inflows and outflows and by chemical interactions between and among the plants and animals in the lake and the sediments, water, and constituents in the water.

The ecosystems of Cape Cod kettle ponds change through the seasons of the year and from year to year depending on all of the factors above, but temperature changes are a key factor for every pond. Beginning in early spring, air and water temperatures begin to rise as the days become longer. If the winds are strong enough, the warming of the water is consistent and even temperatures are maintained throughout the water column. But usually, at some point, the warming is too rapid, the winds are not strong enough, and cooler bottom waters are separated from warmer upper waters. This process is called **stratification**.

The upper, warmer waters continue to warm as the year moves into the summer. This layer of water is called the **epilimnion**. The cooler, bottom waters generally maintain a temperature close to the overall temperature of the lake just prior to the onset of stratification. This lower layer is called the **hypolimnion**. The transition zone between these two layers is called the metalimnion.

A variety of species utilize the temperature and water quality differences between the layers. The cooler waters can hold more **dissolved oxygen**, so fish such as trout generally spend more of their time in the hypolimnion. The sediments at the bottom of the hypolimnion are rich in nutrients and usually support catfish and other bottom feeding fish, as well as worms and other creatures living in the sediments. Since rooted aquatic plants and floating algae need light for photosynthesis, they are generally found only in the epilimnion.

As temperatures cool in the fall, the stratification begins to weaken because the temperature differences between the upper and lower layers become smaller. Wind energy eventually disrupts the stratification, making the water in the lake well mixed again.

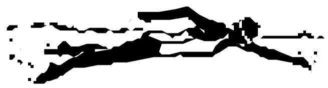


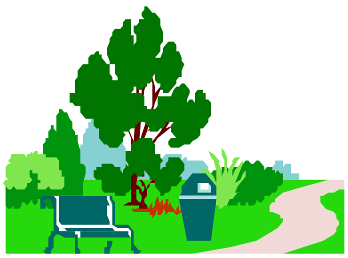
Generalized Temperature Stratification

Example temperature data from Station 1 on August 15, 1997

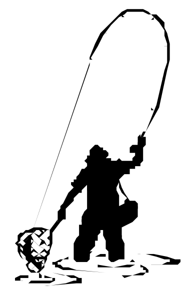
Long Pond Water Quality Assessment
Cape Cod Commission, 1999

Protection and Management





Many of our ponds are experiencing water quality degradation caused by increased nutrient loads associated with shoreline development. Management strategies that have been identified to lessen future impacts from development include: pond restoration, establishing minimum setbacks for septic systems, road, and lawns, providing natural buffer strips between lawns and ponds, treatment of direct and nearshore stormwater runoff and continued public education. Any management plan must include continued sampling and monitoring of conditions within the pond. As competiton for use of the ponds from various recreational groups including swimmers, fishermen, waterskiers and jetskiers continues to increase, a comprehensive effort to characterize and assess the water quality of our freshwater ponds is needed. Only when we know that status of our ponds, will we be able to develop effective management plans that can provide the public with the best possible recreational experience, while still protecting and preserving these important natural resources.



For Additional Information:

Association for the Preservation of Cape Cod	(508)255-4142
Barnstable County Department of Health and the Environment	(508)362-2511 X 320
Cape Cod Commission	(508)362-3828
Cape Cod Cooperative Extension	(508)362-2511
Division of Fisheries and Wildlife	(508)759-3406
Massachusetts Department of Environmental Protection (Southeast Regional office in Lakeville)	(508)946-2760
Your Local Health Department	________________
Your Local Water Supplier	________________
EOEA Basin Team Leader	(508) 946-2812

Glossary of Pond Terms

Aquifer: underground sediments saturated with water
Benthic: sediment or near sediment submerged environment
Condensation: vapor water changing to liquid, due to cooling
Dissolved oxygen: the concentration of oxygen in the water
Epilimnion: the upper layer of a stratified lake
Eutrophication: the process of increasing plant productivity while also reducing diversity and ecosystem stability
Evaporation: liquid water changing to vapor (gas), due to warming
Groundwater: water held in the pores of underground soil and sediments
Water (hydrologic) cycle: process in which water moves from atmosphere to earth to oceans and back to atmosphere, through actions of precipitation, infiltration, evapotranspiration, and condensation.
Hypolimnion: the lower layer of a stratified lake
Kettle hole: a natural depression in a glacial outwash plain
Lens: a convex mound of groundwater within an aquifer; separated from other lens by surface streams.
Outwash plain: broad and generally flat land surface created by the sediments (sand, gravel, till) from meltwater streams that flowed out of glaciers.
Percolation: water trickling downward through the cracks and pores in soil and sub-surface material
Phosphorus: an essential element for biological growth, usually limited in freshwater systems
Recharge: replenishment of water to an aquifer — from rainfall/precipitation, rein-jection of wastewater, or percolation from surface water bodies
Sole-source aquifer: an aquifer body that is the only source of water supply to a region
Surface runoff: the portion of precipitation that flows over the land surface rather than infiltrating into the ground
Transpiration: water evaporated from plants and trees, through the leaves
Water table: upper boundary of groundwater, separating zone of aeration from zone of saturation
Zone of contribution: the area of an aquifer that yields water to a pumping well or pond

Communities Connected By Water Series

Winter 1999 - Fall 2000

- Protecting Drinking Water -Outer Cape
  Coastal Resources-Mid Cape
  Surface Water-Lower Cape

Upcoming Forums:

- Protecting Open Space and Natural Habitats
- Linking Resource Protection and Growth Management
- Building a Watershed Advocacy Network