November 1999

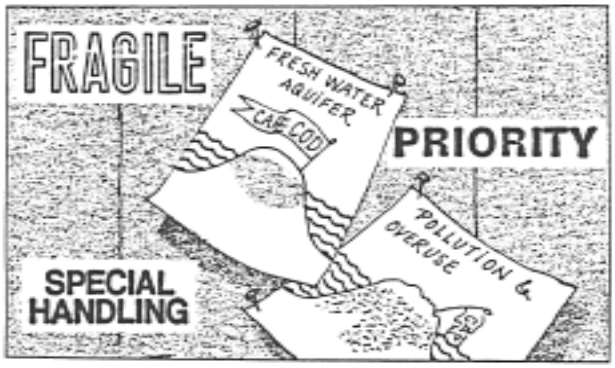
CAPE COD—
A Community Connected By Water

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

WATER FUNDAMENTALS

Imagine what life would be like if your local drinking water source was unsafe to drink, or there wasn't enough available for daily needs—if you had to rely only on bottled water brought from outside. To prevent this from becoming reality, Cape Codders must learn to protect and conserve their water supply—a limited and valuable resource.

Humans can truly be called water creatures: 65% of our body weight is water. We live on a planet made largely of water: 70% of the surface is water, with a volume of 330 million cubic miles, representing 10% of the planet's mass. Next to air, water is the most important constituent for the survival of all living things. Some forms of life can function without air, but none without water. It might be reassuring and sobering to know that the amount of water at present on our globe is roughly the same that existed three billion years ago, according to the best evidence (H.L. Goodwin, 1977).



This material was orginally created in 1990 by the
Cape Cod Environmental Resource Center by Marsh Alibrandi, Brenda Boleyn, Patricia Davis, Adrienne Latimer, Susanne Lear, Gilbery Newton, Susan Nickerson, Susan Peters and Barbara Waters.

Illustrations by Louise Russell. Text Edited by Van Morrill and Gabrielle Belfit.

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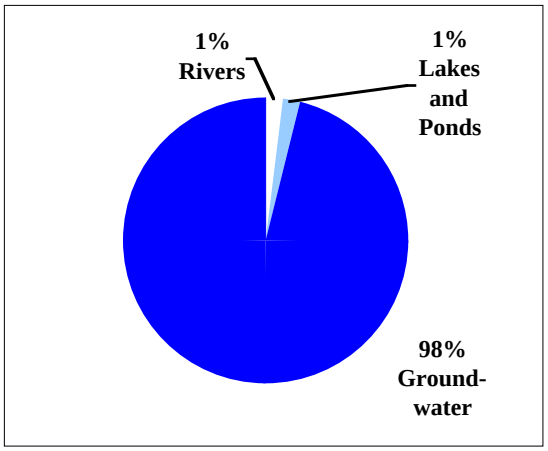
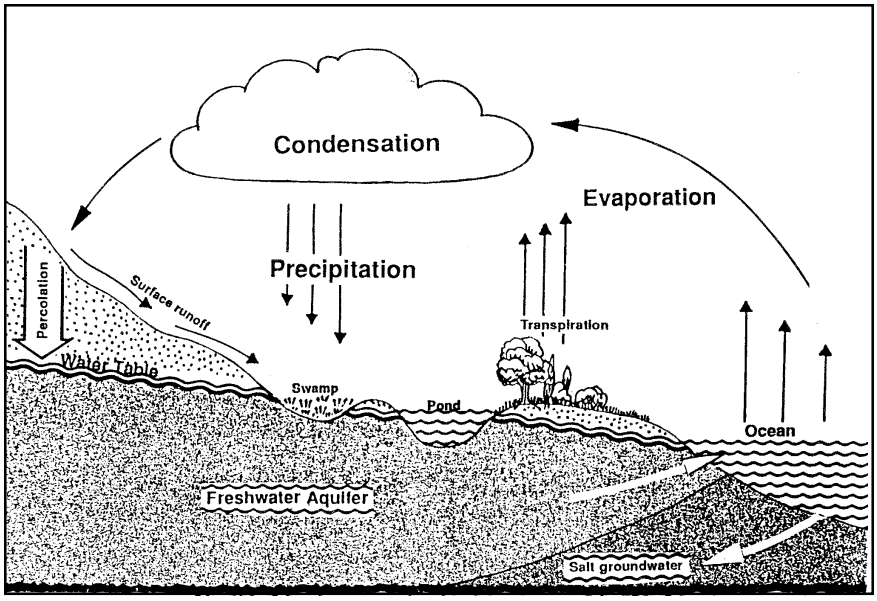
The Water Cycle

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, driven by the water or **hydrologic cycle**. This cycle is made of four basic processes: **Precipitation**, **Percolation/Surface Runoff**, **Evaporation/Transpiration**, and **Condensation**.





The water moves downward by gravity and **percolates** or infiltrates through the pores and **recharges** the **water table** which indicates the level of water in the ground.

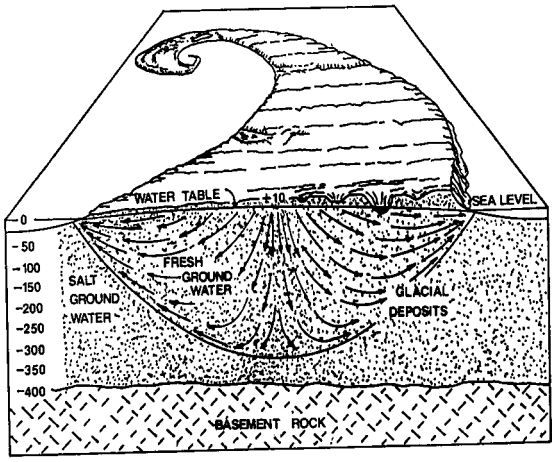
Water taken in by the roots of plants will be returned back to the atmosphere through the process of **transpiration**, along with water **evaporated** from the surface of the earth.

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.

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.

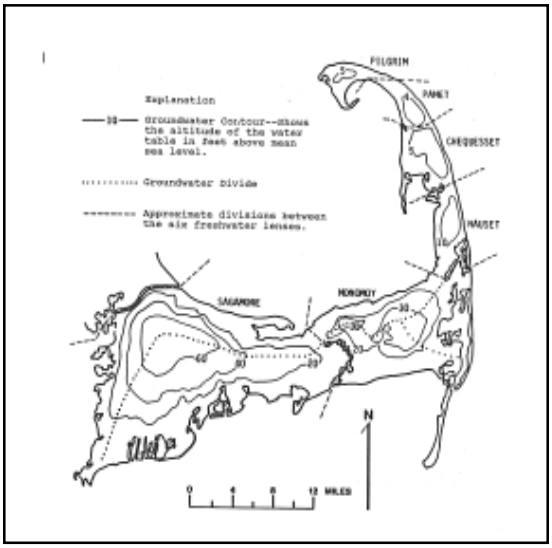
The Underlying Hydrogeology

verticle scale greatly exaggerated



Cape Cod is a mound of sediments pushed into place by glacial action over a period of several thousand years and distributed as **outwash plain** by the melting of that glacier. 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. 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 pulled by gravity toward the shore or tidal river where it is gradually discharged (lost) from the aquifer.

The aquifer on the upper Cape extends toward bedrock. This bedrock tapers off toward the lower Cape where the freshwater sits on top of salt groundwater. Their separation is assured by the greater **density** (weight) of the seawater.



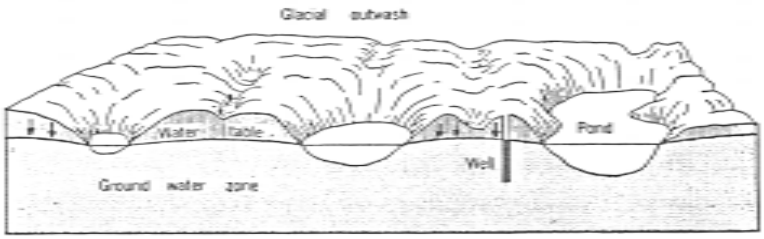
The Cape gets approximately 42 inches of rain and snow each year to recharge our freshwater supply. Because this supply represents our only source of drinking water, the Cape system has been designated a "sole-source aquifer" by the federal government, which means that extra protective measures may be required.

Within this single aquifer are found six areas of elevated groundwater, called **lenses**. They are named by their location: Sagamore, Monomoy, Nauset, Chequesset, Pamet, and Pilgrim. Their elevations and tidal rivers prevent the groundwater from passing between lenses.

Surface and Groundwater Interactions

The kettle ponds of the Cape are actually indentations left by melting ice chunks from the glacier. They are now filled with groundwater, with their surface marking the level of groundwater around them (the water table). The fluctuation of water levels in a pond is governed by the groundwater levels surrounding them.

When water is drawn through a well, the water moves through the aquifer from the area around it. The size of this area, called the **zone of contribution**, varies according to the rate of pumping and the direction of groundwater flow. It is very important to protect the zone of contribution from pollutant sources, especially true for the 145 public supply wells. Good planning and management are needed in order to maintain high water quality into the future. The Communities Connected By Water grant program seeks to have every town adopt appropriate bylaws and regulations.



GROUNDWATER LENSES OF THE CAPE COD AQUIFER

LENS	TOWNS	WATER VOLUME WITHDRAWN (MGD)	AREA (SQ MI)	MAXIMUM ELEVATION (FT)
SAGAMORE	Bourne, Sandwich Falmouth, Mashpee Barnstable, Yarmouth	25 (summer) 13 (off-season)	165	70
MONOMOY	Dennis, Brewster, Harwich, Chatham, Orleans	12 (summer) 5 (off-season)	66	30
NAUSET	Eastham, South Wellfleet	2.0/.8 Estimate	15	15
CHEQUESSET	Wellfleet, South Truro	1.5/.5	17	8
PAMET	Truro	1.3/.6	11	6
PILGRIM	Provincetown	N/A	4	5

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, when there is little evaporation and plants are dormant, the water table levels rise. From May to November, water is drawn out of the aquifer in greater amounts and the water table falls due to evaporation uptake by plants and water supply withdrawal.

To maintain a balance, the water "expenses" lost must be offset by "income" from rainfall, the only source of new water. Water is lost from the aquifer as groundwater discharges to the oceans through streams and subsurface flow, by pumping from wells, and evapotranspiration.

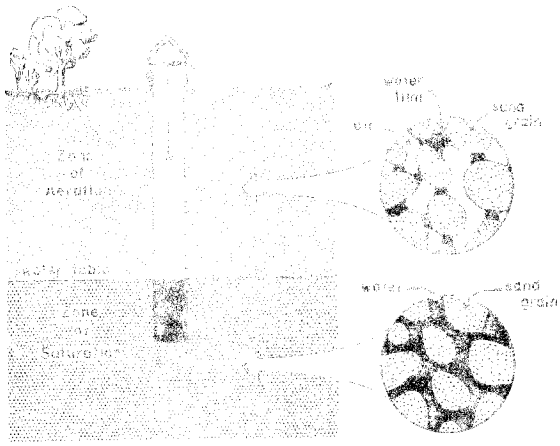
In years of very little precipitation, the water table could fall sharply, causing a drying of some wetlands, and lead to a water budget deficit.

Conversely, some years have great amounts of rainfall, giving a budget surplus. In order to keep the budget as a surplus, it would be wise to maximize the recharge from inflow and minimize the losses.

Over 23 million gallons of water is pumped daily from 145 public supply wells and thousands of private wells. In the summer this amount exceeds 45 million gallons per day. 90 percent of it is returned to the aquifer through wastewater disposal, which recharges the aquifer. Water is lost from runnoff and evaporation on paved surfaces and excessive irrigation.

Few of us practice thrift in our daily water use. Historically, the cost of water has been low or not linked to actual consumption, and there were few incentives for conservation. Today, more and more towns are using a rate structure based on use, the more you use, the more you pay.

Zones of Aeration and Saturation



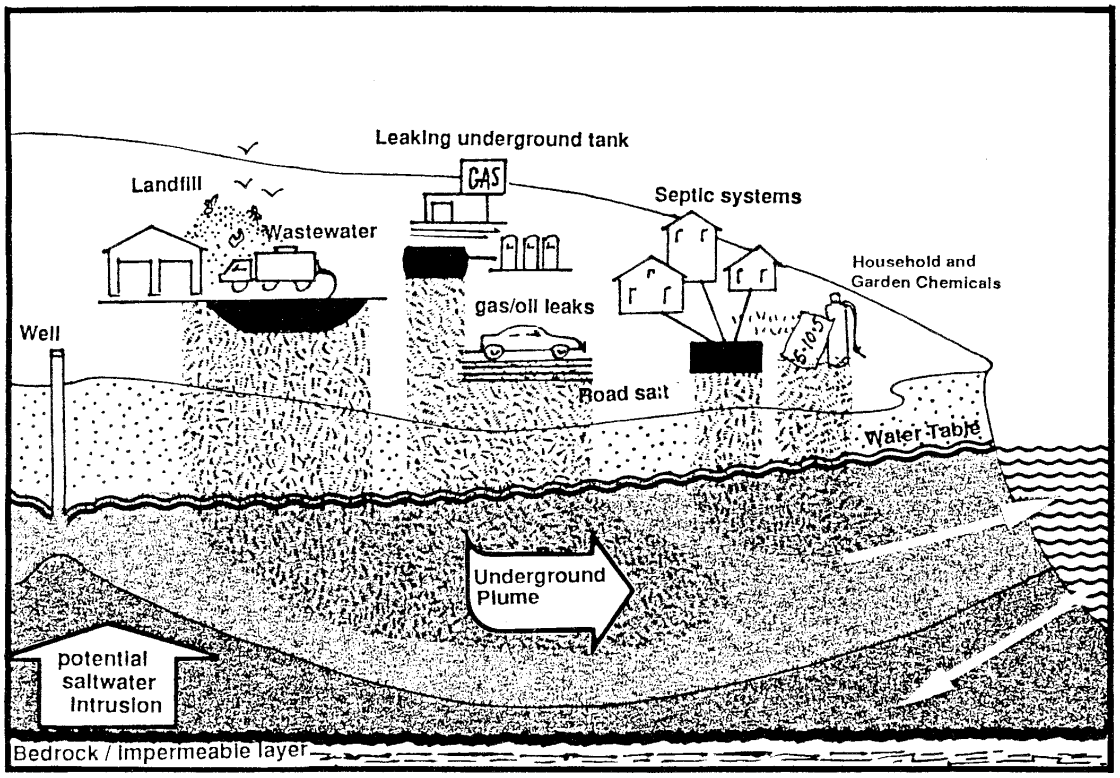
Soils have zones of aeration and saturation. The **zone of aeration** is above the water table, where the openings in the soil are filled with air. In the **zone of saturation**, all the open spaces in the soil are filled with water. Plant roots must have aeration as well as moisture.

The concept of aeration vs. saturation may be simulated by a damp vs. soaked kitchen sponge. The saturated sponge will accept no more water, and any air had been replaced by water. The circles in the figure on the left show how water occupies the pore spaces between the sand grains.

Pollution

One of the greatest threats to public health for Cape Cod is groundwater pollution. Some contaminants are toxic, colorless, and odorless. When deposited on land, these substances may find their way to Cape Cod's sole-source aquifer by dissolving and/or moving with the water. Pollution can originate from a distinct point source, such as a gasoline spill, or from a broad range of non-point sources. The most common sources are waste disposal (sewage/septic and household), road runoff, spills, household cleaners and solvents, commercial/industrial process chemicals, mining operations, and agriculture (herbicides/pesticides, fertilizers). The highly permeable soil that promotes good rainfall infiltration also lets contaminants infiltrate easily, making it vulnerable to surface spills and contaminants. When pollutants leach into the groundwater, it becomes a plume of contaminated groundwater, which migrates with groundwater flow.

Human and animal waste is high in nitrogen, which becomes primarily nitrate when discharged into water. In surface water, the nitrates interact with plants and algae, stimulating growth sharply. The algae grow rapidly, and after their short life cycle, they die and decay, which consumes oxygen in the water, drawing it away from the native plants and animals, a process called eutrophication. In groundwater, the nitrates can cause health problems serious to infants. Whether an on-site septic system, or a sewage treatment plant, wastewater released to our groundwater will have detrimental impacts wherever it goes.



Summary: A Bountiful But Vulnerable Resource

Using groundwater as the community water supply brings the benefit of a generally reliable and abundant source, but also carries extra responsibility to closely monitor its health. An aquifer provides good quality water as long as the supplier and town maintain diligent testing for contaminants, and measure its properties on a frequent basis. Pollution can occur far from the wellhead, in place or time, and require the skills of a detective to find the causes of contamination.

This susceptibility to unseen pollution makes it very important to proactively prevent it whenever possible. It might seem more difficult to establish acceptable bylaws and regulations for groundwater protection, given the highly charged political environment in many towns. However, the financial and intangible costs are much lower in the long run when groundwater is protected from contamination. Besides the cost of treatment systems and remediation studies, groundwater contamination can undermine property values, municipal tax revenues, and possibly even threaten human lives. Since so many people rely on groundwater in their daily lives, everyone should understand it's fundamentals, so it can be protected and used wisely.

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
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 Groundwater Terms

Aquifer: underground sediments saturated with water
Condensation: vapor water changing to liquid, due to cooling
Density: mass per-unit-of-volume (weight concentration)
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, evapo-transpiration, and condensation.
Leachate: pollutant chemicals that have infiltrated groundwater from a pollution source (e.g. landfill)
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 subsurface material
Recharge: replenishment of water to an aquifer — from rainfall/precipitation, reinjection 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
Zone of aeration: ground subsurface lying above the water table in which some water is present, but most of pore space is without water
Zone of saturation: subsurface lying below water table where pores are filled with water

Communities Connected By Water Series

Winter 1999 - Fall 2000

- Protecting Drinking Water and Coastal Resources Program (Groundwater supply, surface water impacts, wastewater management) presented on the Outer, Upper, Mid and Lower Cape

Upcoming Forums:

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