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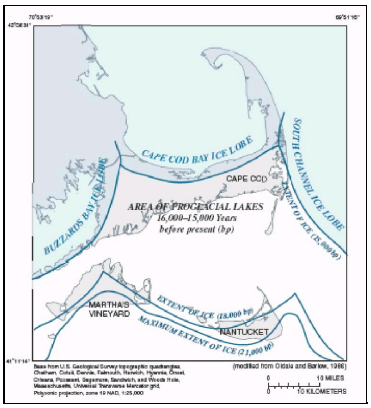
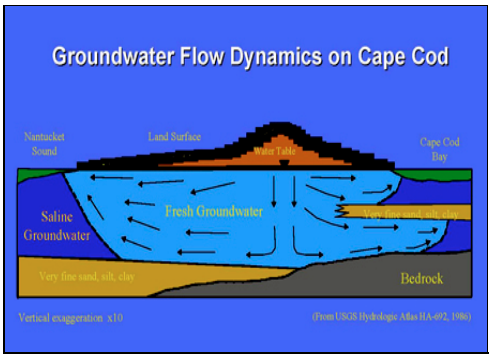
..CAPE COD'S SOLE SOURCE AQUIFER..

Physical Setting



Cape Cod is a sand and gravel remnant of the last continental deglaciation that occurred from 15,000 to 20,000 years ago. As shown in Figure 1 to the left, the Cape is a series of broad gently sloping outwash plains that are truncated by long linear moraine deposits found along the present day Route 6 Mid -Cape Highway and Route 28 MacArthur Boulevard. The glacial deposits are approximately 150 to 900 feet thick from Buzzards Bay to Provincetown. The glacial deposits are generally coarse to medium sand but grade to finer materials at depth. The coarse sands are extremely permeable making for a high yielding groundwater system.

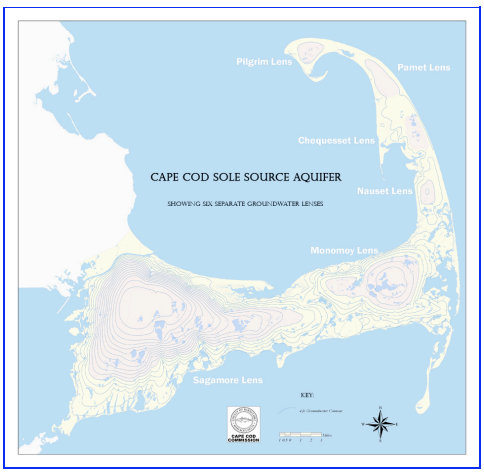
Figure 1



The groundwater of Cape Cod is bounded at the top by the water table, which is ubiquitous across the Cape, a sharp transition zone between fresh and marine water at the shore and bedrock below (Figure 2). The groundwater system is recharged solely from precipitation, at a rate of 27 inches per year (approximately 60% of precipitation). The groundwater system is in dynamic equilibrium between recharge and discharge to the surrounding marine waters and flows at approximately 1 foot per day due to gravity. Because groundwater located further inland has greater distances to travel to get to the shore, the accumulation of recharge over the ages mounds up.

Figure 2

The mounds of groundwater are relatively thin and convex and therefore are referred to as lenses of groundwater. The Cape Cod aquifer system is comprised of six separate lenses as shown in Figure 3.



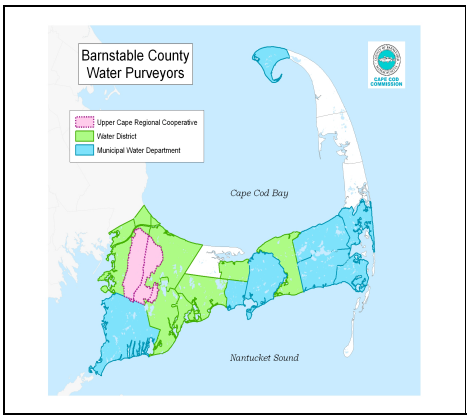
The topographic lines of the aquifer are referred to as water table contours which are used by hydrogeologists to plot the exact flow of groundwater. Over the years this effort has lead to the use of complex groundwater models to predict and answer many questions about how the aquifer responds to new stresses such as pumping and the discharge of wastewater.

The Cape Cod Aquifer is extremely susceptible to contamination from various land uses and acti vities. The aquifer has been seriously impacted from military activities, gas stations, landfills and a host of other activities. These examples have lead to multiple strategies to protect the aquifer at all levels of government and spawned a vigorous industry for the assessment and clean-up of contaminated groundwater. The groundwater of Cape Cod is fairly well protected except for impacts due to the prevalence

of residential septic systems.

Figure 3 (click to download larger image)

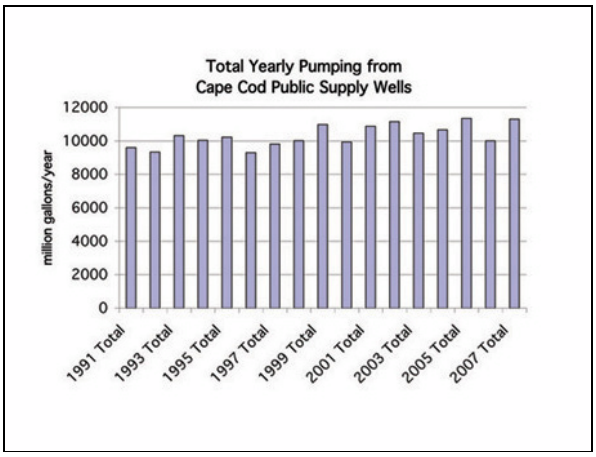
Drinking Water Supplies



Municipal Suppliers

The Cape Cod Aquifer provides 100% of the Cape's drinking water. There are 18 separate water districts or departments across Cape Cod (figure 4). Altogether there are 158 gravel pack water supply wells and one surface reservoir. Approximately 85% of Cape Cod is serviced with public water. The Outer Cape communities of Truro, Wellfleet and Eastham are serviced almost entirely with private or small volume wells.

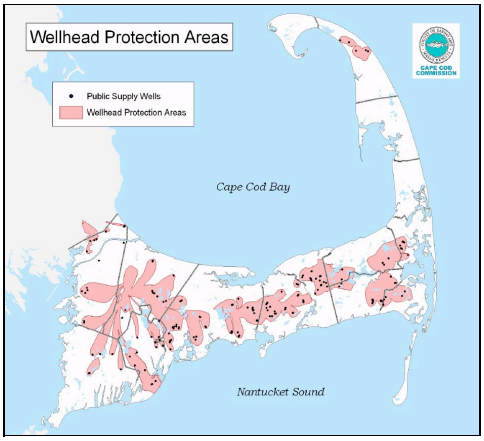
Figure 4



Water Quantity

Since 2000, public community drinking water suppliers have pumped on average about 10.7 billion gallons of groundwater per year from Cape Cod's Sole Source Aquifer. The graph at left (Figure 5) shows the pumping over the last decade has been up and down due to seasonal climatic variations, such as rainy summers but, for the most part is fairly consistent. Study by the U.S. Geological Survey indicates that groundwater pumping accounts for approximately 10% of the annual recharge from precipitation.

Figure 5



Wellhead Protection

Over 30 years ago water planners combined their knowledge of groundwater with policy mechanisms to protect Cape Cod drinking water. Adoption of Wellhead Protection Areas was a major strategy to protect the land area that receives precipitation to recharge the pumping wells. Today each town has zoning and Board of Health bylaws to protect their wellhead protection areas, which are collectively shown on Figure 6. In addition, the public embraced acquisition of land for protection for wellhead areas through local, regional and state actions like the Cape Cod Land Bank. The Wellhead Protection Areas are also referred to as DEP Zone IIs where state regulations (310 CMR 22) and Cape Cod Commission RPP minimum performance standards prohibit or limit land uses that are potentially detrimental to water quality.

DEP regulations do not specifically prohibit large publicly owned wastewater treatment works in Zone 11's, but the RPP limits their use in Zone IIs for the restoration of water quality.

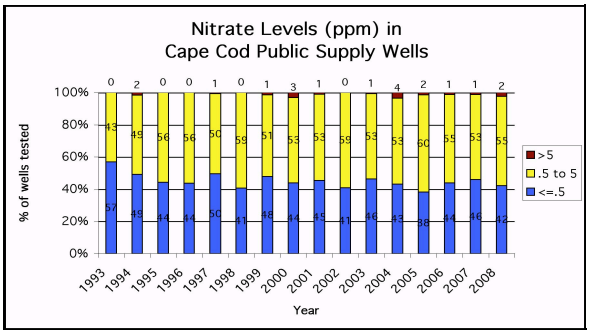
Figure 6

Drinking Water Quality

Nitrogen in Drinking Water Supplies

Nitrate-nitrogen, is a major component of human wastewater. Nitrogen passes through septic systems virtually untreated and is introduced to the underlying groundwater. Nitrate, is often used as an indicator of drinking water quality. A maximum contaminant limit (MCL) of 10 ppm of nitrate as nitrogen for drinking water supplies has been established by the USEPA and adopted by MA state regulation. The limit was established to protect infants from methemoglobinemia or "blue-baby" syndrome, a potentially fatal blood disorder which can occur when too much nitrate limits the amount of oxygen in the blood. Although inconclusive, some health studies have also linked high nitrate levels to certain types of cancer. The Barnstable County Regional Policy Plan established a nitrogen loading concentration of 5 ppm to ensure that nitrate levels in drinking water will not approach the federal standard. This protection standard had been adopted both locally and at the state level. The quality of Cape Cod's community public drinking water supply is generally very good, but over the past 15 years there has

been a trend toward some degradation (Figure 7).



Between 1993 and 2008, the percentage of public supply wells tested that had nitrate levels at or below .5 ppm (considered very clean) fell from 57%-42%. During the same time period the percentage of public drinking water levels with nitrate levels between .5 and 5 ppm (the RPP limit) increased from 43%-55%. The percentage of wells testing above the 5ppm standard has varied between 0% and 4% during the past 15 years and no community public supply wells have tested over 10ppm.

Figure 7

The 2008 nitrate concentrations in the Cape's community supply wells are shown on Figure 8. In general, the wells with higher concentrations are the older ones that are located downgradient of high density residential areas. However, even well protected water supply wells have somewhat elevated concentrations of nitrate that is derived from septic systems and other non-point sources.

Small volume non-community drinking water wells, which are generally shallower, pump less water and are often closer to septic systems, have shown a greater degradation than the larger and deeper community wells. Since 2000, the number of very clean non-community public wells with nitrate levels below .5 ppm has stayed around 35% compared to 42-44% of the deeper community public supply wells. The non-community wells with levels greater than 5 mg/l ranged from 7-15% compared to 3% of the community wells. The number of non-community wells with nitrate levels greater than the MCL of 10 mg/l has ranged from 2-6. All of the wells exceeding the drinking water limit are located on the Outer Cape where wastewater disposal and private water supply often occur on the same lot. In response to poor water quality, Wellfleet invested in a public waters supply system to serve its Central downtown district and Eastham has begun water supply site investigations as a first step to provide a public water system.

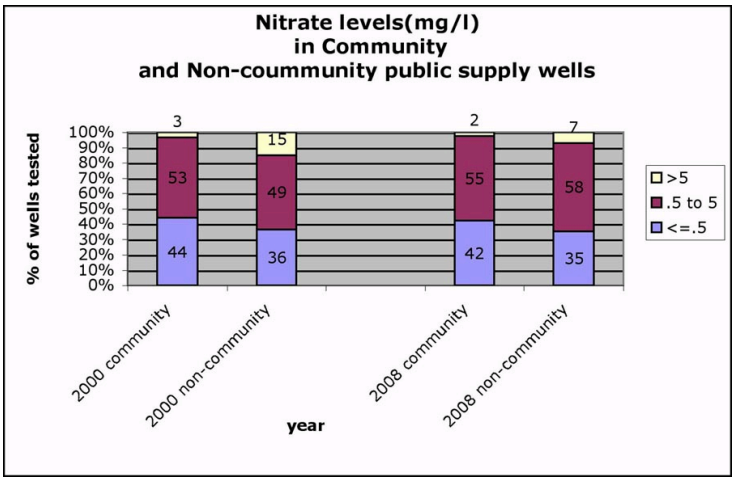


Figure 8

Emerging Compounds – Pharmaceuticals and Personal Care Products

Nitrate-nitrogen, besides being a contaminant itself, can also indicate the possible presence of other wastewater contaminants such as disease causing organisms, solvents, cleaners, petroleum compounds, PPCP's (pharmaceuticals and personal care products) and other emerging contaminants. "Emerging contaminants" are chemicals or microorganisms that are not commonly monitored or regulated in the environment, but are suspected of having potentially adverse ecological and (or) human health effects. They can include hormones, human and veterinary pharmaceuticals, and household products like soaps and lotions, insect repellents, perfumes and other fragrances, sunscreens, and hand sanitizers.

There have been numerous national studies done to investigate and document the occurrence of these emerging compounds in wastewater, surface and groundwater. In 1999 and 2000, the U.S. Geological Survey conducted a national stream reconnaissance testing 139 streams in 30 states for 95 organic wastewater compounds (OWC). Eighty-two of the 95 compounds were detected in at least one sample and 80% of the streams had at least one OWC detected. (Barnes, et al 2002). In 2000, USGS sampled 47 groundwater sites across 18 states. Ninety-eight % of the sites sampled had detections of emerging contaminants, with 46 of the 83 contaminants being found at least once. (Barnes et al.2008)

During 2001, USGS analyzed 25 ground and 49 surface-water untreated public drinking water supply sources in 25 states and Puerto Rico. Ninety-six % of the samples showed at least one emerging contaminant. The emerging contaminants were more frequently detected in surface-water than ground-water sources. (Focazio et al. 2008) Generally, all of these studies have detected the presence of a variety of organic wastewater contaminants and PCPP's. The detections were more common in the stream samples (86%)and surface water samples than in groundwater (35%). Mixtures of chemicals were common and the concentrations measured were generally at low levels (often less than 1microgram /liter) just slightly above detection levels.

In June 2004 the U.S. Geological Survey and the Barnstable County Health Department (Zimmerman 2005), sampled wastewater sources and public, semipublic, and private drinking water supplies on Cape Cod that were thought to be affected by wastewater because of previously high nitrate-nitrogen concentrations. Forty-three of the eighty-five PPCP and organic wastewater contaminant compounds that were analyzed for were detected in the wastewater samples. Thirteen were detected in low concentrations (less than 1 microgram/liter) in the private and semipublic drinking water supplies and three, an antibiotic, an antidepressant, and a solvent, were detected in the public water supply.

Although the ability to detect these emerging compounds at extremely low levels in drinking water has been greatly improved, the human health effects from these low level concentrations are not well documented.

In the absence of better information about the actual occurrence of these compounds and need to provide a level of protection, DEP recently incorporated very stringent performance standards for proposed wastewater discharges in Zone IIs. DEP has adopted a Total Organic Carbon Concentration of 3 mg/l. TOC is a surrogate for PPCP. Some studies have documented that PPCP will be absorbed on to particulates of carbon. Therefore removing this carbon will provide a level of protection to the underlying aquifer and public supply wells. However removing TOC to this level will require an extremely high level of treatment with 20-30% higher capital treatment costs and higher annual operation and maintenance. Investigations into the transport of PPCP have found that the majority of these compounds do not travel very far in the groundwater. In fact monitoring wells downgradient of existing wastewater disposal sites on Cape Cod have found concentrations of TOC below the 3 ppm concentration. The Massachusetts Environmental Trust has recently funded a study by Silent Spring Institute to sample and test public supplies for these emerging compounds. The RWMP recommends a regional review of the findings of the SSI study and further review of the DEP regulations for cost-effectiveness.

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