GROUND WATER DISCHARGE TO PLEASANT BAY
Gregory S. Horne
December 8, 2008

When septic effluent has filtered through the vadose zone to the water table, it is entrained and diluted with ground water flowing within the aquifer. In the Monomoy single source aquifer the ground water is flowing seawards at a rate of about 1 cm/hr under the impetus of the hydrostatic head produced by the differential elevation of the water table. The density of the septic effluent is only a few milligrams per liter (parts per million) greater than the density of the surrounding ground water. Therefore, there is no appreciable physical inertia for the effluent to fall through the ground water. The rate of ground water flow seawards is several orders of magnitude greater than any significant factor promoting downward mixing, such as convection, advection or diffusion, so most of the effluent remains within the upper portion of the seaward flowing ground water. Thus, the effluent approaches the ground surface level as it flows towards the shoreline at grade, ultimately discharging at or very near the shoreline.

In a simple relatively homogeneous and isotropic aquifer, devoid of continuous permeability barriers, such as we have in this portion of Cape Cod, the vast majority of the ground water discharges directly into the marine environment near the shoreline. Additionally, due to the significant density difference between fresh water in the aquifer and the underlying seawater that surrounds the Cape, and without special and continuous permeability barriers, and piezometric field reversals, there is no reason for significant amounts of fresh water to flow under the salt water upon which it floats, and emerge from under Pleasant Bay. Therefore, the fresh water aquifer sits atop the underlying salt water as a floating lens. The weight of the fresh water does depress the underlying salt water, and some fresh water may discharge into the Bay at some distance seaward of the shoreline. So when the ground water containing septic effluent emerges at a flow rate of 1 cm/hr at or near the shoreline, it is immediately entrained within and diluted by Bay waters which are discharging out of the Bay for half the day at a rate of about 50,000 cm/hr (0.5 km/hr). This is an increase in velocity and dilution by more than four magnitudes.

Simple cursory examination of the perimeter of the Pleasant Bay system (e.g.: Google Earth combined with a brief field trip) shows that most of it is bordered by relatively mature mixed hardwood and evergreen forest, with extensive fringing salt marshes along the shoreline. Nitrogen is a critical nutrient element required for primary productivity, and it is actively attenuated from ground water by growing vegetation. There has been no apparent attempt in the SMAST-MEP analysis to consider the probable assimilation of nitrogen in discharging ground water by coastal vegetation. Since coastal trees are rooted directly into the fresh ground water lens near the shoreline, and since marsh grasses have been shown to be efficient effluent scrubbers in numerous studies, nitrogen loss to plant uptake along the coast would have a significant effect on reducing nitrogen levels in the ground water <u>before</u> discharge to the Bay.

An even more glaring and serious omission in the SMAST-MEP analysis is the complete failure to even attempt to sample and analyze the discharging ground water for relative nitrogen concentrations. The loading calculations for Pleasant Bay are all hypothetical, with no attempt to calibrate with real analytical data from the ground water. This significant omission can be easily and inexpensively ameliorated by a simple testing program. I propose to conduct such a testing program in March of 2009, in order to find out how much nitrogen really is discharging through the ground water into Pleasant Bay.