# Design of Permeable Reactive Barriers to Reduce Nitrogen Flux

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**Background.** Septic systems are used to manage more than 80% of wastewater on Cape Cod and Martha's Vineyard, Massachusetts. Bacterial reactions transform organic nitrogen to ammonia and then to nitrate which is stable under aerobic conditions that discharges to coastal waters. In 2013, USEPA announced a framework for implementing the Clean Water Act with states to implement a water-quality based approach using a process to determine pollutant reduction requirements and develop total maximum daily load (TMDLs), which are load based versus a target concentration standard to achieve water quality goals. The cost to bring Cape Cod communities in compliance with the Clean Water Act entirely through traditional wastewater treatment and sewers is estimated to be $4 to $8 billion. To reduce overall costs, the Cape Cod 208 Water Quality Management Plan includes traditional wastewater treatment with non-traditional technologies for reducing nitrate mass flux to coastal waters.

**Approach.** Denitrification permeable reactive barriers (PRBs) are one of the primary non-traditional technologies. Future installation of PRBs with thousands of linear feet are being considered in Cape Cod communities. Four communities have performed evaluations of denitrification PRBs, including site selection assessments, column studies, and in situ demonstration tests injecting emulsified vegetable oil (EVO).

**Results.** The pilot PRBs ranged from 50 to 200 feet long perpendicular to groundwater flow and between 18 to 43 feet thick with estimated groundwater flowrates of 0.1 to 0.6 ft/day and influent nitrate-N concentrations of 2 to 10 mg/L. EVO loadings ranged between 0.040 to 0.102 gallons (average 0.72 gallons) per cubic foot of PRB were employed. All four PRBs received buffers (sodium bicarbonate and/or calcium carbonate) at loadings of 0.0053 to 0.050 pounds per cubic foot of PRB to raise the pH by 0.9 to 2.2 SU. Dissolved oxygen and nitrate-N were reduced to very low concentrations up to 125 feet downgradient of the PRBs for up to 6 years after injection. PRBs were as close as 80 feet from a water body. Maximum ferrous iron concentrations ranged between 1 to 263 mg/L, maximum manganese from 8 to 29.7 mg/L, and methane from 7 to 17 mg/L (where collected). Understanding the groundwater flow rate and direction and flux of nitrate are critical to the design.