Monitoring

Coastal Contamination

New Methods to Determine Groundwater Discharges Into Surface Waters

Landfills and hazardous waste sites located in coastal environments pose a potential threat to surface water bodies through the exchange of groundwater-borne contaminants. It is estimated that one out of five Navy landfills are subject to groundwater exchange through tidal influence. Therefore, the ability to determine where groundwater is discharging, at what rate, and what contaminant concentrations are entering the surface water body is important to understanding these sites and determining the need for remediation.

Groundwater discharge (or "seepage") into coastal environments has been studied extensively using a variety of methods. The primary driver for seepage in near-shore environments is probably discharge from land to surface water induced by the hydraulic gradient in the terrestrial aquifer. (Note: The hydraulic gradient in the terrestrial aquifer is the difference in water level that drives the flow of the groundwater.) However, significant contributions to seepage may also be caused by groundwater circulation and oscillating flow induced by tidal stages. In coastal areas with strong tides, the movement of seawater into the aquifer may create tidal mixing zones. This tidally mixed zone may be important in controlling the exchange of groundwater due to a process referred to as "tidal pumping." Tidal pumping occurs when seawater mixes with groundwater at high tide and then, as the tide recedes, the seawater and groundwater is drawn out into the coastal waters. Because this process repeats every tidal cycle, appreciable volumes of groundwater can be extracted over time. The conceptual model for migration of contaminants from groundwater to coastal surface water is shown in Figure 1.

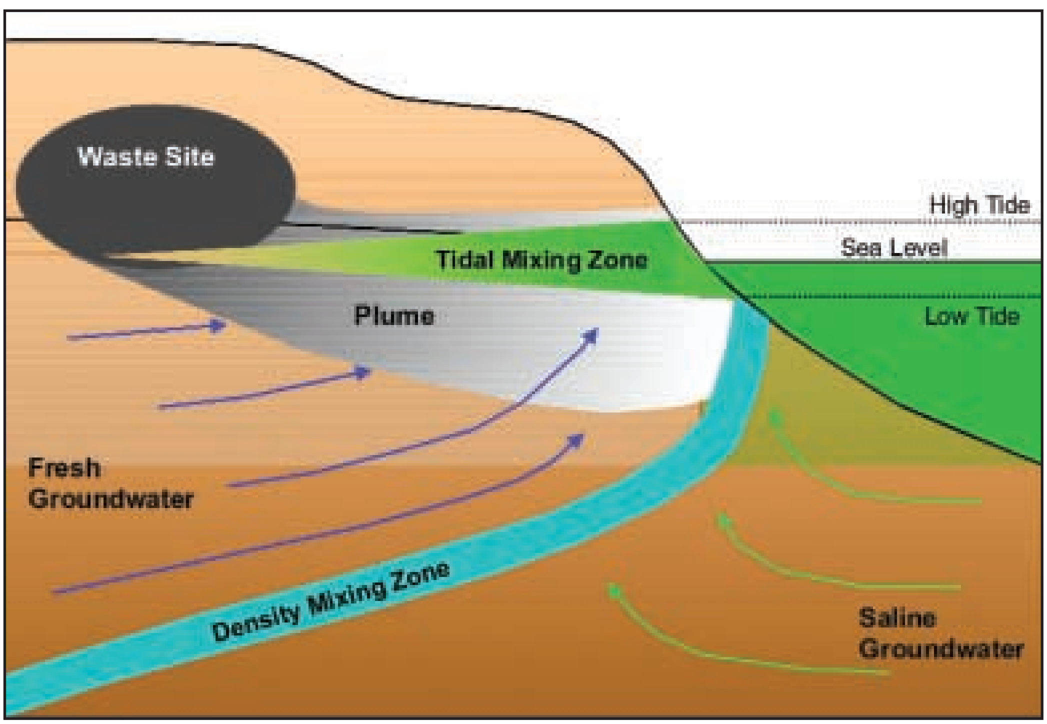


FIGURE 1: Conceptual model of Coastal Contaminant Migration Process.

Groundwater discharge can contribute significant quantities of water to an overlying surface water body. The impact, both chemical and physical, may be heightened in smaller bodies of water such as embayments and lagoons due to their limited volume and restricted fluid exchange with the open ocean.

New Monitoring Methods

Two major obstacles in studying groundwater exchange have been:

1. Identifying the spatial location where exchange is likely to take place, and
2. Accurately measuring the groundwater seepage across the sediment-water interface.

Two new techniques exist for identifying potential areas of groundwater impingement into surface water as well as quantifying flow rates and contaminant levels. These two monitoring techniques, the Trident® Probe and the UltraSeep® Meter, were developed by Navy engineers in conjunction with scientists from Cornell University.

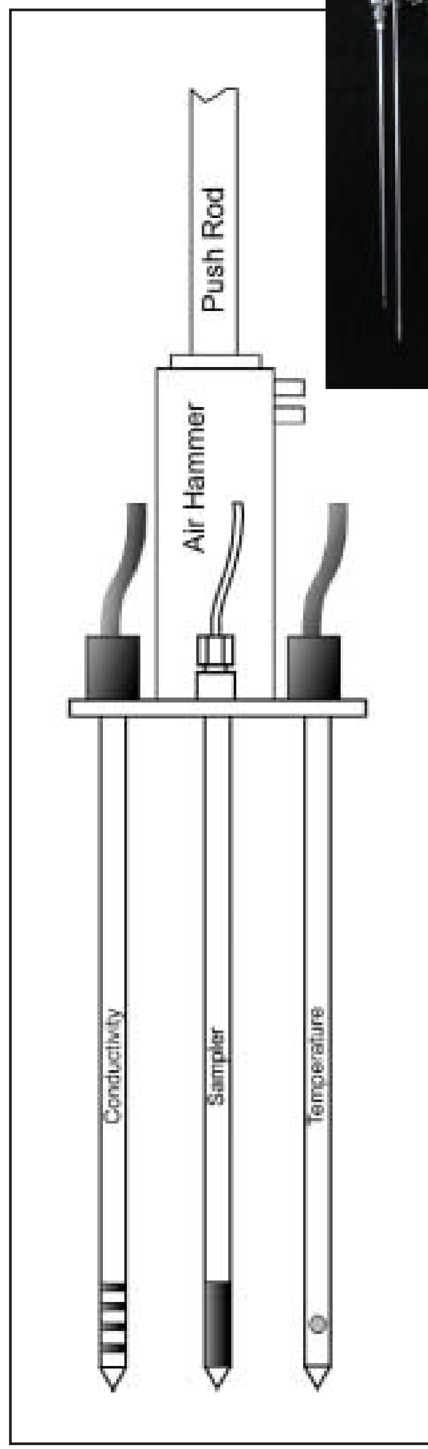
Trident® Probe

The Trident® Probe is a flexible, multi-sensor sampling probe for screening and mapping groundwater plumes at the surface water interface. It consists of a simple direct-push system equipped with temperature, conductivity, and porewater sampling probes. (A schematic and photo of the Trident® Probe are shown in Figure 2.) Contrast in temperature and conductivity between surface water and groundwater are used to determine likely areas of groundwater impingement. The water sampler is then used to collect samples for subsequent chemical analysis.

Measurements with the temperature probe can be used to identify areas of groundwater seepage which may appear either warmer or colder than the surface water depending on seasonal and site characteristics. The conductivity measurements can be used to detect contrast in salinity and/or clay content in unconsolidated sediments. The conductivity signal varies primarily as a function of clay content and porosity. Areas of likely groundwater seepage are generally associated with low conductivity, either as a result of low salinity, low clay content (high permeability), or both. The water sampling probe then allows interstitial water to be extracted from the sediment at selected depths up to about 60 centimeters (cm) below the sediment-water interface. Porewater is collected by syringe or vacuum pump extraction through a small-diameter stainless steel probe.

Recent trials show that the Trident® Probe provided rapid spatial assessment of coastal contamination migration. The Trident® Probe was tested at the North Island Site 9 in San Diego, CA and the potential area of groundwater discharge was successfully identified based on the areas having the greatest contrast in temperature and conductivity measurements.

FIGURE 2: Photo and schematic diagram of Trident® Probe.



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UltraSeep® Meter

The UltraSeep® Meter is a modular, state-of-the-art seepage meter for direct measurement of groundwater and contaminant discharges at the surface and groundwater interface. It features an ultrasonic flowmeter that provides continuous, direct measurement of groundwater flow. The water sampler employs a low-flow peristaltic pump with sample selector valve and sample bag array. The on-board sensors measure temperature and conductivity and the controller stores data and controls sampling events. The feedback control system regulates water sampling to maximize sampling volume without restricting flow. The flowmeter provides accurate detection of a specific discharge or recharge in the range of 0.1 to 150 cubic meters per day.

The ability to collect a continuous seepage record is critical to understanding the dynamics of the exchange process, especially in areas with strong tidal influence. In addition, the flow sensing capability allows water samples to be collected in proportion to the seepage rate, enabling the direct quantification of the chemical loading associated with the groundwater discharge. At coastal sites, a typical deployment runs over a 12 to 18 hour period to capture an entire semi-diurnal tidal cycle (two tidal cycles per day). During this time, the seepage rate is continuously monitored and up to six water samples can be collected for chemical analysis. At the end of deployment, the meter is recovered using either a lift line to the recovery boat or by diver assistance.

Conclusions

Cost savings from employing these new monitoring methods is potentially significant over conventional terrestrial investigations and fate and transport modeling. Improved site knowledge also leads to the selection of more appropriate, less expensive remedial alternatives. These technologies should be considered if one or more of the following conditions exist at a site:

- There is a clear identification of a terrestrial contaminant plume migrating to the shoreward boundary of the surface water body,
- Applicable regulations or other compliance/cleanup drivers require identification of contaminant exposure levels in the surface water or at the interface,
- Hydrogeologic modeling results are ambiguous or require field validation,
- The area where the plume is impinging needs to be clearly delineated to address risk and/or remedial options (Trident®), and/or
- The rate of discharge and associated contaminant loading requires delineation to address risk and/or remedial options (UltraSeep®).

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