Submarine Groundwater Discharge at an Open Ocean Marine Beach in California

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ABSTRACT

Experiments were conducted in July 2006 to investigate the role of the neap-spring tidal cycle on variability of submarine groundwater discharge at Stinson Beach, California. Submarine groundwater discharge is the flow of water, regardless of fluid composition or driving force, from the seabed to the sea. Stinson Beach is a Central California community of approximately 650 residences where onsite wastewater treatment systems (septic systems) are used exclusively for wastewater disposal. Shallow groundwater at the site has high concentrations of dissolved inorganic nitrogen, soluble reactive phosphate, and human fecal bacteria. Monitoring across a fortnight showed a groundwater-derived freshening and nutrification of the surf zone at neap tide. Saline and fresh groundwater discharge to the surf zone was estimated using a combination of analytical models and a surf zone mass balance using a single rip cell, or the zone of circulation between two adjacent rip currents, as a control volume. Total discharge, the sum of the fresh and saline components, was maximal at spring tide, and was approximately 140% of total discharge at neap tide. However, discharge of the fresh component was maximal at neap tide, approximately an order of magnitude above the spring tide counterpart. Changes to discharge estimates across the fortnight were closely linked to changes in seaward hydraulic gradient across the fresh part of the aquifer. Gradients in this region appear to be controlled to a large degree by aquifer overheight, or hydraulic mounding, near the beach face. Dupuit estimates of seaward fresh groundwater flow in the fresh part of the aquifer agreed well with the results of the mass balance, i.e. fresh seaward flow was markedly increased at neap tide. Interestingly, the nutrification and freshening of the surf zone was not associated with a similar increase in fecal indicator bacteria concentrations in the surf zone, indicating that the surficial aquifer may be attenuating these septic effluent constituents to a high degree. However, the freshening and nutrification of the surf zone at neap tide was followed by a 4-day increase in chlorophyll *a* concentrations in the surf zone. The role of nutrient-enrichment by SGD in causing increases of chlorophyll *a* in the coastal ocean at the site was explored using a controlled mesocosm experiment. A full year of dense hydraulic head monitoring at the field site helped elucidate the importance not only of fortnightly tides but also swell events and seasonal precipitation in driving water table fluctuations at the site.

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