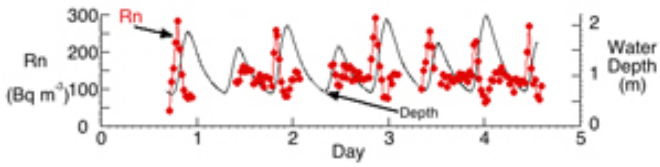
Atlantic Coastal Groundwater Systems

SUMMARY:

This project seeks to identify sites and rates of submarine groundwater discharge (SGD) to the coastal ocean. Additional goals are to relate the locations of groundwater discharge to the local and regional geologic framework and the flux of groundwater-derived nutrients to nutrient fluxes from other sources.



Data from Salt Pond, Cape Cod National Seashore (MA), showing the correlation between low tidal stage and maximum activity of radon, a natural tracer of groundwater discharge.

INVESTIGATORS:

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DESCRIPTION:

Quantification of groundwater fluxes to the coastal ocean is important for assessing sustainable groundwater use and for determining the impact of groundwater-derived nutrient fluxes on coastal ecosystems. The discharge of groundwater to the ocean, however, is often diffuse and heterogeneous rendering such measurements difficult.

These investigations use a variety of complementary approaches to quantify the role of ground water in the delivery of fresh water and nutrients to several geologically distinct coastal areas. In particular, they attempt to determine natural flow paths and discharge rates to permit optimization of human use of coastal aquifers, while minimizing negative impacts to coastal ecosystems, including impacts such as excessive algal blooms and decline of seagrass beds and salt marshes.

START DATE OF PROJECT:

1 October, 2004

END DATE OF PROJECT:

1 October, 2005

LOCATION:

North Carolina (Neuse River Estuary and Outer Banks), Cape Cod (Cape Cod National Seashore and Waquoit Bay), and Florida (multiple locations)

APPROACH:

This research depends critically upon techniques that define locations of groundwater flow and discharge (primarily geophysical), together with approaches that quantify fluxes of ground water beneath and into coastal waters (primarily geochemical).

The methods for identifiying locations of groundwater discharge include geophysical approaches such as streaming resistivity measurements that infer freshwater-saltwater relationships in the subsurface and groundwater discharge locations based on the higher electrical resistance of fresh water contained in sediments, compared to saltwater (Manheim et al., 2004). Such data can be compared to acoustic or seismic records of subsurface geology, as well as data obtained by onshore and offshore drilling, in order to relate locations of discharge to subsurface geology.

A variety of methods exist for quantifying rates of discharge. A direct approach involves use of seepage meters, which are enclosures placed on the seafloor that measure flow over a small area. When flow is heterogeneous, as it typically is, it becomes difficult to extrapolate seepage meter results to a larger area. Essential tools for quantifying ground water fluxes include geochemical approaches that integrate over much larger areas. Two primary geochemical tracers, radon and radium isotopes, that are strongly enriched in groundwater compared to surface water. Radon is an excellent tracer of groundwater discharge to the coastal ocean because it: is enriched in ground water by 1-3 orders of magnitude over activities in surface waters; behaves conservatively upon mixing between freshwater and seawater; is produced continuously from naturally occurring, long-lived U-series parent isotopes in sediments, soils and rocks; decays with a 4-day half life, ensuring that excess Rn is only found near a site of groundwater discharge; and reflects discharge over a wide area. The flux of ground water to coastal waters can be determined from an estimate of the radon flux to surface waters and the mean activity of radon in groundwater, using corrections for radon loss due to gas exchange and mixing (following the approach of Burnett and Dulaiova (2003)). A similar approach can be used with a suite of radium isotopes (Moore, 1996; Moore, 2003), although interpretation of such fluxes based on radium isotopes is complicated by the strong dependence of radium activity in groundwater on salinity (Charette, personal communication, 2004). These groundwater fluxes thus measured can be

translated into fluxes of nutrients or other contaminants simply by multiplying the water flux by the nutrient (or contaminant) concentration. Furthermore, the groundwater flux estimates can be compared to predictions based on groundwater flow models. A website outlining this research is being planned for completion early in 2005.

RESULTS:

Surface water radon mapping system developed

Radon is an excellent tracer of groundwater discharge to the coastal ocean, yet measurements have traditionally been difficult and time-consuming. New technology is now allowing much more rapid measurements. A system was recently developed to allow mapping surface water radon activities in real time (~10 minutes/sample) while steaming in a ship. Scientists and engineers from both the USGS and the Woods Hole Oceanographic Institution were involved in the development and testing. Parameters measured include GPS position (lat, long), water depth, salinity, temperature, and radon activity; the system also logs data to a single file.

Neuse River Estuary survey

A field survey in the Neuse River Estuary involving electrical resistivity and radiochemical measurements was carried out during April 2004. One site of discharge, inferred from elevated activities of radon, was consistent with the location of a paleochannel based on existing seismic information. Further seismic surveying was carried out during the summer of 2004. A summary of field activities is described at http://soundwaves.usgs.gov/2004/06/fieldwork.html. Sites of significant discharge inferred from the resistivity survey will be targeted for more extensive radon mapping during the spring of 2005. An abstract was prepared based on the electrical resistivity data for a presentation at the American Geophysical Union meeting in San Francisco in December 2004.

Cape Cod National Seashore surveys and experiments

Field surveys conducted during the spring and summer of 2004 included electrical resistivity surveying of Nauset Marsh and Pleasant Bay, as well as regions outside the barrier islands, and a multi-faceted investigation of submarine groundwater discharge (SGD) rates to Salt Pond, a kettle pond breached by rising sea level. A radon-based SGD estimate was derived using a mass balance approach based on radon outflow from the pond, corrected for inputs from the adjacent Nauset Marsh and losses due to gas exchange and decay. This approach yielded a pond-integrated upper limit of roughly 5 cm/d, a figure that is very similar to a multi-year average flow estimate from a hydrologic model. SGD estimates using seepage meters deployed in shallow waters were more than a factor of two higher than the radon and model estimates, which may indicate that discharge occurred only in the shallow regions of the pond and not through the deeper, fine-grained sediments. An abstract was prepared based on these data for a presentation at the American Geophysical Union meeting in San Francisco in December 2004.

Florida

A variety of studies of SGD are underway in the carbonate-dominated systems of the Florida platform. Sites include Tampa Bay, Indian River Lagoon, the Everglades, Biscayne Bay, Crescent Beach Spring and the Loxahatchee River Estuary.

PUBLICATIONS:

- Crusius, J, D Koopmans, JF Bratton, L Ryckman, M Charette, K Halloran, K Kroeger, P Henderson, J Colman, J Masterson; Submarine groundwater discharge to Salt Pond (MA) estimated from continuous 222Rn measurements; Eos, Transactions American Geophysical Union, in press.
- Bratton, John F.; Bohlke, John Karl; Manheim, Frank T. and Krantz, David E.Ground Water Beneath Coastal Bays of the Delmarva Peninisula: Ages and Nutrients,Special issue on discharge to estuaries/oceans, December 2004
- Krantz, David E.; Manheim, Frank T.; Bratton, John F. and Phelan, Daniel T.Hydrogeologic Setting and Ground Water Flow Beneath a Section of Indian River bay, Delaware,Special issue on discharge to estuaries/oceans, December 2004
- Manheim, Frank T.; Krantz, David E. and Bratton, John F.Studying Ground Water Under Delmarva Coastal Bays Using Electrical Resistivity ,Special issue on discharge to estuaries/oceans, December 2004
- Swarzenski, PW, Reich, C, Burnett, B, Dulaiova, H, Martin R and Meunier, J (2004) Using novel geophysical and geochemical techniques to study submarine groundwater discharge in Biscayne Bay, Fl. USGS OFR xxxx
- Swarzenski, PW, Charette, M and Langevin, C (2004) Using an autonomous, electromagnetic seepage meter to study coastal groundwater/surface water exchange. USGS OFR xxxx
- Swarzenski PW, Bratton, J and Crusius, J (2004) Submarine groundwater discharge and its role in coastal processes and ecosystems. USGS OFR 2004-1226
- Swarzenski, PW and JL Kindinger. (2003) Leaky Coastal Margins: Examples of Enhanced Coastal Groundwater/Surface Water Exchange from Tampa Bay and Crescent Beach Submarine Spring, Florida, USA. In Coastal Aquifer Management, Monitoring and Modeling and Case Studies Eds A. Cheng and D. Ouazar. CRC/Lewis Press, pp 93-112. INVITED CONTRIBUTION
- Porcelli, D and Swarzenski, PW (2003) The behaviour of U- and Th series nuclides in groundwater and the tracing of groundwater. Reviews in Mineralogy and Geochemistry. 52: 317-361. INVITED CONTRIBUTION
- Martin, JM, Hartl, KM, Corbett, RD, Swarzenski, PW and Cable, JE (2003) A multi-level pore-water sampler for permeable sediments. J. Sedimentary Research. 73 (1): 128-132.

RELATED:

- Soundwaves article on CMGP submarine groundwater research.
- Soundwaves article on Neuse River integrated science project.
- Neuse River marine resisitivity maps.
- Bratton et al., Northeast Coastal Ecosystems and Resources Framework for Science.
- Masterson, J.P., Simulated Interaction Between Freshwater and Saltwater and Effects of Ground-Water Pumping and Sea-Level Change, Lower Cape Cod Aquifer System, Massachusetts
- Barlow, P.M., Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast.
- Submarine Ground-Water Discharge