# Testing an eddy correlation method of quantifying fresh submarine groundwater discharge

## SUMMARY:

Submarine groundwater discharge (SGD) delivers a significant flux of nutrients to coastal waters and contributes to eutrophication in many locations in the U.S. Yet, quantifying and characterizing SGD remains difficult, despite our awareness of its importance, because discharge is diffuse and heterogeneous and occurs below the water surface, where direct observation and measurement are difficult. SGD fluxes have been quantified using a variety of methods, including: 1) hydrologic models; 2) seepage meters and 3) radioisotopic tracers. Each of these approaches has some limitations, however. In some locations, groundwater flow models are sufficiently well developed that they can be used to predict the delivery of fresh groundwater to the coast. While in these settings the hydrologic budget may be well constrained such that total discharge over a large coastal area is well known, the precise location of discharge of that freshwater in the coastal zone is hard to model accurately because available data on the submarine geology are rarely adequate. This is a limitation of most models. Furthermore, measured fluxes sometimes disagree with model predictions by an order of magnitude or more (e.g. Smith and Zawadzki, 2003). SGD has also been quantified for many years using seepage meters (e.g. Lee, 1977). However, at their best, seepage meters only yield an average discharge rate spanning the small area of deployment (typically less than 1m2). Because discharge is often heterogeneous, many seepage meters are needed to yield discharge estimates representative of a large area. Furthermore, the presence of an enclosure on the sediment surface alters water flow and can alter the advective flux through the sediment. SGD fluxes integrated over a large area have been quantified using radon and radium isotope measurements (Moore, 1996; Burnett and Dulaiova, 2003; Crusius et al., 2005) and have compared favorably to estimates based on seepage meters. Yet, in some locations it is possible that flux estimates based on radioisotopes may reflect the combined flux of recirculated seawater and fresh groundwater (e.g. Smith and Zawadzki W., 2003). Therefore, there is a need for new, non-invasive methods to quantify the submarine discharge of fresh groundwater integrated over a large area. In this work, we propose to test a method to quantify this flux using a novel #eddy flux correlation# method in water, patterned after recent work using this approach to quantify oxygen fluxes across the sediment-water interface (Berg et al., 2003). Fluxes measured in this manner will be compared to fluxes estimated using seepage meters and radon. It is worth noting that we have prepared this proposal as a #proof of concept# proposal, rather than an #environmental technologies# proposal, due to some inherent uncertainties in the application of the technique, for reasons that will be discussed in the methods section. Dr. Chris Weidman, Director of Research at the Waquoit Bay National Estuarine Research Reserve (WBNERR), has been contacted about this research plan. Dr. Weidman agreed that would be a valuable tool for quantifying submarine groundwater discharge at Waquoit Bay and at other NERR sites in the country.

## INVESTIGATORS:

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## DESCRIPTION:

The main objective of this study is to develop and test a new method for quantifying fresh groundwater flux into a marine system. As such, this methodology could prove important for quantifying the flux of any contaminant from groundwater to coastal waters. The project would achieve one of CICEET#s main objectives of making sure new and innovative technologies and methods are available to solve anthropogenic contamination problems. The primary contaminant flux of concern from groundwater to the coastal ocean is nutrients. Most importantly, this work addresses CICEET Focus Area 3e: to develop new and cost-effective technologies and methods to identify sources of nutrients. If other contaminants are a concern in a certain location, this method might also address focus areas 1d and 2b, as well (identifying sources of toxic and microbial contaminants).

## START DATE OF PROJECT:

June 1, 2005

## END DATE OF PROJECT:

September 30, 2006

## TOPIC:

Coastal and Marine Geology

## APPROACH:

The fresh groundwater flux would be quantified using a non-invasive eddy correlation approach that integrates over a wide area. Turbulent advection is the dominant vertical transport mechanism in the water column in almost all natural aquatic environments. The new technique relies on measuring the turbulent fluctuations of: 1) the vertical velocity and 2) the corresponding salinity (S) and/or temperature (T) simultaneously and at the same point in the water column but close to the sediment surface. If such measurements are done with an adequate temporal resolution to capture these fluctuations and for a period long enough to obtain a statistically sound representation of their variations, then the vertical flux of salt and heat can be derived. Note that the S measurements should yield information on the freshwater flux. However, the T measurements can yield an estimate of groundwater flow as well, as we will also measure the temperature of the advecting groundwater, which is much lower than surface water during the summer. Such measurements obviously do not suffer from the same shortcomings as seepage meter measurements because fluxes are determined under true in situ conditions, i.e., without any disturbance of the sediment and under the natural hydrodynamic conditions. This technique is limited, however to solutes that can be measured rapidly and accurately in situ, which rules out using this approach for quantifying fluxes of most solutes. Although use of this approach for quantifying fluxes has only recently been carried out within the water column (Berg et al., 2003), it has been used for several decades to determine fluxes by eddy correlation in the atmospheric boundary layer (e.g., Wyngaard 1989). This approach requires simultaneous measurements from two instruments, the Acoustic Doppler Velocimeter (ADV) and a small, fast, accurate conductivity and temperature sensor. The ADV belongs to and is routinely used by one of the PIs (Berg). The ADV measures the 3D velocity field in a small cylindrical volume, approximately 1.5 cm long and 0.6 cm in diameter, located on the ADV#s center line, 10 cm from the base of the three sensors, as marked on Fig. 1. The conductivity/temperature (CT) data will be correlated with the velocity measurements to permit quantification of the flux. Any drift in the conductivity and temperature sensor can effectively be filtered out using known techniques when the data are processed (Berg et al., 2003). Both the ADV and the CT sensor will be mounted on a rack for initial tests of the technique, as was done when quantifying O2 fluxes (Fig. 1). The tip of the CT sensor will be located immediately next to the border of the ADV's measuring volume. The rack is designed so that the position of the measuring volume and the tip of the microelectrode can be adjusted in the range of 10-55 cm above the sediment surface. Data acquisition will be controlled above the water surface by a PC. The PC and supporting electronics will be powered by batteries and will be isolated galvanically from all other electronic devices.

## IMPACT/RESULTS:

This technique for quantifying fresh SGD has never been attempted before, to our knowledge. Indeed, the only fluxes across the sediment-water interface that have been quantified using the eddy correlation approach are O2 fluxes, and this approach has only been documented in a single publication (Berg et al., 2003). Hence, this approach for quantifying fresh groundwater flux is unprecedented and novel.