# Material flux to the ocean through coastal aquifers

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Unlike the direct input of fresh groundwater to the ocean, this study focuses on chemical reactions that occur as groundwater and seawater mix in coastal aquifers. In many ways this system is similar to an estuary with the river component replaced with fresh groundwater. In coastal aquifers there is a mixing of seawater and freshwater and a significant number of chemical reactions are occurring. Coastal aquifers have relatively high total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) and carbon concentrations (Table 1) and therefore any significant flux of water from these aquifers to the ocean will strongly affect coastal water nutrient, trace metal, and carbon budgets. This study attempts to quantify the chemical effect of subterranean groundwater discharge (SGWD) to the open ocean and focuses on a section of the South Atlantic Bight between Cape Fear and the Savannah River and may not be representative of all coastal areas.

Table 1. Composition of water from coastal aquifers

| | Location | Salinity | TDN | TDP | DOC | $^{226}$Ra | $^{228}$Ra |
|---|---|---|---|---|---|---|---|
| | | | μM | μM | μM | dpm/L | dpm/L |
| Surficial Aquifers | | | | | | | |
| | N. Inlet | 34 | 110 | 30 | 830 | 6 | 12 |
| | Port Royal Sound | 26 | 230 | 17 | | 2 | 7 |
| Limestone aquifer | | | | | | | |
| | U. Floridian Hilton | 21 | 150 | 3 | | | |
| | U. Floridian Port Royal | 27 | 150 | 20 | 420 | | |
| Offshore Wells | | | | | | | |
| | 1 | 35.4 | 55 | 4.8 | 195 | 3.4 | 2.9 |
| | A | 35.2 | 136 | 6.6 | 300 | 5.4 | 8.7 |
| | 2 | 35.9 | 22 | 2.1 | 1130 | 1.9 | 1 |
| | K | 35 | 112 | 8 | 133 | 1.7 | 3.4 |
| SAB bottom water | | | | | | | |
| | | 36 | <0.1 | <0.1 | 30 | 0.2 | 0.4 |

Radium isotopes, both short lived ($^{223}$Ra, $t_{1/2}$ = 11.4 days and $^{224}$Ra, $t_{1/2}$ = 3.6 days) and relatively long lived ($^{226}$Ra, $t_{1/2}$ = 1600 years) were used to quantify the exchange rate of coastal waters with the open ocean ($^{226}$Ra and $^{223}$Ra) and the offshore flux of material from the subterranean system ($^{226}$Ra). These tracers are useful as the [Ra] in subterranean waters is high relative to ocean surface waters and they do no react strongly in the coastal oceans.

Shore-perpendicular profiles of the short lived Ra isotopes are consistent with eddy-diffusion rather than advection. Using these profiles one can estimate eddy diffusion coefficients (exchange rates) of ca. 400 $m^2$/s from coastal oceans to the surface open oceans. This exchange rate can be combined with offshore concentration gradients (using $^{226}$Ra) to determine the tracer flux to the open ocean. Five $^{226}$Ra shore-perpendicular profiles were measured off Charleston and Winyah Bay (South Carolina) (Figure 1) and show a steady decrease in concentration from ~25 dpm on the inner shelf to the open ocean value around 8 dpm at about 45 km off shore. This translates to a $^{226}$Ra gradient = 2.6 dpm/m$^3$/km. If we then multiply by the eddy-diffusion coefficient we obtain a value of 1x 10$^5$ dpm/m$^2$/d. Therefore the $\Sigma^{226}$Ra flux from coastal to open oceans for the 320 km stretch of coast × 10 m water depth = 3 × 10$^{11}$ dpm/d.

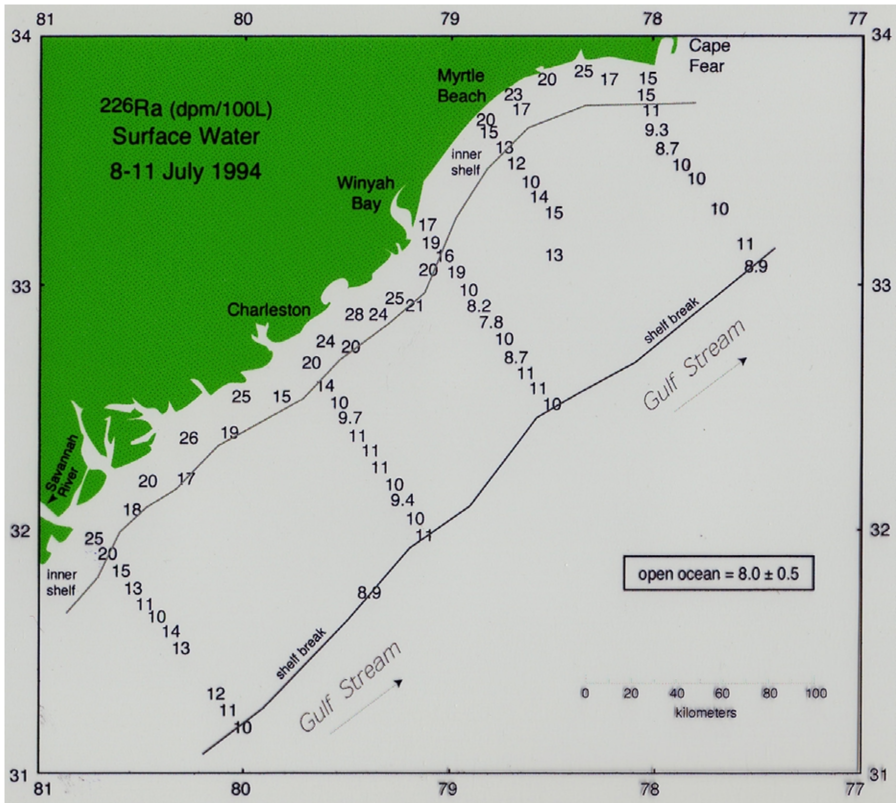


Figure 1. Shore-perpendicular profiles of $^{226}$Ra

The crux to the technique lies in the assumption that the system is in steady state and therefore this flux from coastal to open ocean must be balanced by input from the subterranean fluids, rivers, sewers, or other sources. The riverine source is only 3% of the flux required by the offshore flux estimate (1×10$^{10}$ dpm/d). If other sources are as small, the subterranean estuary flux must be approximately 3 × 10$^{11}$ dpm/d. If subterranean estuary waters contain 7 dpm $^{226}$Ra/L (100 × ocean water), the discharge must be 500m$^3$/s or around half of the river flow for the area.

Now by measuring other components of interest (i.e. TDN, TDP) in the subterranean fluids, the fluxes of reactive species (nutrients, metals) to the coastal ocean due to the subterranean estuary can be calculated. These are summarized below (Table 2) and show that SGWD is a significant source of nutrients to the open ocean.

| Table 2. Fluxes of Nutrients to the SAB (Savannah-Cape Fear) | | | |
|---|---|---|---|
| Source | N flux $10^6$ mol/day | P flux $10^6$ mol/day | Reference |
| Rivers | 1.6 | 0.07 | Krest et al., 2000 |
| Atmosphere | 3.5 | | Prospero et al., 1996 |
| Upwelling | 5.7 | | Atkinson et al., 1984 |
| SGD | 6.3 | 0.2 | $^{226}$Ra balance |