Investigating Groundwater Discharge into Coastal Bays

Overview, Past Research, and Potential Applications in the Delaware Inland Bays

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This talk...

• Overview of coastal groundwater dynamics

• Brief look at work on Cape Cod

• Background on previous Indian River Bay work and ideas for future research in the Inland Bays
Coastal Groundwater:
Fresh Groundwater Flow to the Coast:
Fresh Groundwater Flow to the Coast:

Implications for ecosystems
Submarine Groundwater Discharge (SGD):
Driving Mechanisms of SGD

- Fresh Discharge
- Mixing Zone
- Saline Circulation
Driving Mechanisms of SGD

**Steady Forcing**

1 – Freshwater discharge

2 – Density-driven circulation
Driving Mechanisms of SGD

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1 – Freshwater discharge

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Driving Mechanisms of SGD

**Transient Forcing**

1 – Nearshore: tides and waves
2 – Offshore: waves and tides
3 – Seasonal forcing
Sodium Bromide Tracer Test: Initial Salinity Profile
Elapsed Time 2:20
Elapsed Time 21:00
Elapsed Time 33:00
Elapsed Time 47:46
Elapsed Time 76:00
Elapsed Time 80:00
Driving Mechanisms of SGD

Transient Forcing

1 – Nearshore: tides and waves

2 – Offshore: waves and tides

3 – Seasonal forcing
Offshore: tides
Offshore: tides, waves

Time
Driving Mechanisms of SGD

Transient Forcing

1 – Nearshore: tides and waves
2 – Offshore: waves and tides
3 – Seasonal forcing
\[ z = \frac{\rho_f}{\rho_s - \rho_f} x \approx 40x \]
Tools for Measuring/Estimating SGD

In the field:
- Seepage Meters (direct)
- Hydraulic Gradients (indirect)
- Tracers (very indirect)

Modeling:
- 2D, 3D numerical models
- Variable-density
Seepage Meters
Seepage Meters
Hydraulic Head Gradients (Piezometers)
Tools for Measuring/Estimating SGD

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Modeling

- **Simulate** groundwater flow and solute transport
  - Based on governing equations (physics)

A TOOL for understanding systems

- Different features/conceptual models → *controls*
  (what determines groundwater discharge rates?)

- Simulation → *answers to questions*
  (what are estimated groundwater discharge rates?)

- Variation of parameters → *sensitivity*
  (how sure are we of the estimates?)
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Seepage Meter Transect Results:

Discharge [m/d]

Salinity [ppt]

Distance from Shore [m]

2002 & 2003

1.5 m

50 m

1 m
Fresh Outflow

Distance from Shore [m]

Discharge [m/d]

Fresh Discharge

Saline Circulation
Nearshore: Tides and Waves

Distance from Shore [m]

Discharge [m/d]

Fresh Discharge

Saline Circulation
Seasonal in and out
**Numerical Model**

- 2D
- Simulates groundwater flow and salt transport
Seafloor Groundwater Discharge (Modeled)
From Waquoit Bay…

- Different forcing mechanisms move water of different origins (terrestrial, marine) and at different flow rates
- We are able to quantify flow rates and zones using field measurements and modeling

We also Know…

- Different types of discharging water may have different levels and types of dissolved nutrients (high vs. low, bioavailable vs. non-bioavailable)

Identifying types and rates of SGD could help estimate nutrient loads

Potential application to Inland Bays
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Prior Related Work in Indian River Bay:
(DGS, DNREC, USGS, UD, etc…)

Onshore and Offshore…

**Geology**
- Characterization of Columbia Aquifer
- Identification of paleovalleys

**Hydrogeology**
- Characterization of hydraulic properties
- Estimation of fresh groundwater flow

**Geochemistry**
- Salinity distribution
- Nutrients
- Ages
Prior Related Work in Indian River Bay:  
(DGS, DNREC, USGS, UD, etc…) 

Onshore and Offshore…

• Valuable *basis* for understanding the system

• Reveals *complexities* previously not understood

• Essential *framework* for future research on hydrogeology and nutrient loading to the bays
Mckenna, Andres, and Lepp, 2007
Krantz et al., 2004
Classical Conceptualization:
Indian River Bay Conceptualization:
Discharge Modes:

- Focused, Shoreline
- Focused and Diffuse, Shore Parallel (Shallow low-K-Controlled)
- Focused and Diffuse, Irregular (Paleochannel-Controlled)

Legend:
- Blue: Focused Fresh Discharge
- Light Blue: Diffuse Fresh Discharge
- Green: Saline or Zero Discharge/Inflow
Böhlke and Krantz, 2003

Diagram showing groundwater flow and chemical composition in an aquifer system. The diagram includes labeled sections for Upland, Bay, and Incised Valley, with arrows indicating movement of fresh and saline ground water, as well as the presence of NO₃⁻, NH₄⁺, and N₂ (denit.) concentrations. The confining layer is indicated as the base of the surficial aquifer.
Indian River Bay Conceptualization:
To Investigate these Ideas:

Field Work:
- Further hydrogeologic investigation
- SGD measurements on the bayfloor
- Geochemical sampling and analyses

Modeling:
- Large 3D model of watershed and bays
- Smaller models of individual mechanisms

- Estimate fluxes of fresh and saline groundwater, and associated nutrient species
Results May:

- Improve understanding of coastal groundwater systems
- Aid in development of more effective management schemes
- Help to identify practices that may exacerbate nutrient loading
- Improve the health of bay ecosystems!
Thank You!

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