Quantifying the impact of shallow wastewater injection on groundwater nutrient fluxes to surface waters in the Florida Keys National Marine Sanctuary: a pilot study

Project Plan

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Meet our chief analytical chemists

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Incoming PSU PhD student

What do we know about the problem?

Despite stricter regulations on wastewater management in FL, the surface waters in the FKNMS still bear elevated nutrient loads (FDEP RAD, 2018; Briceño & Boyer, 2020)

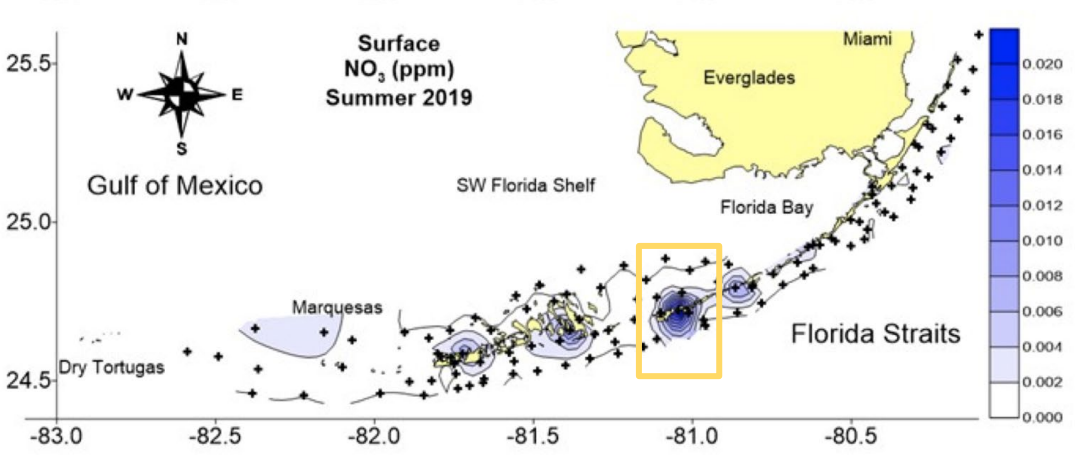
23 WBIDs are impaired for nutrients within the halo zone (<500 m from shore)

Table 1. WBIDs with impairments in the Florida Keys

Note: Gray shading denotes WBIDs impaired for DO, in addition to nutrient impairment.

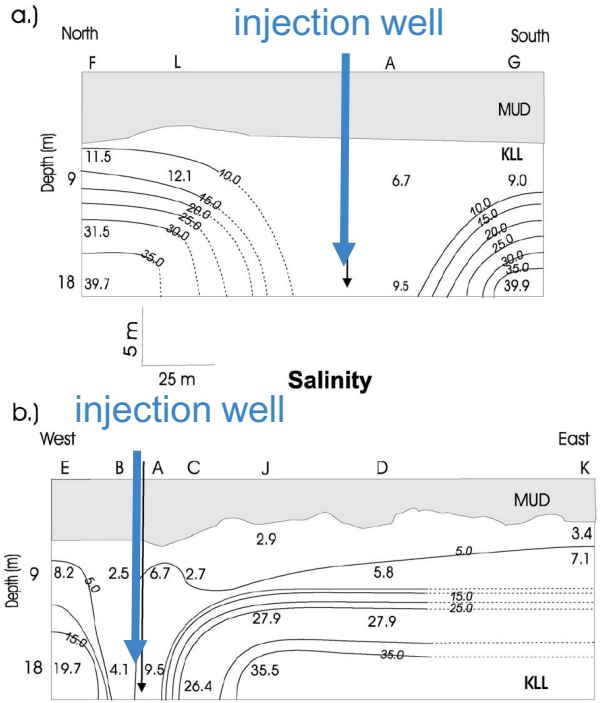
WBID	Waterbody Name	Location	Stakeholders in WBID
6006A	South Key Largo	Northern Keys	Key Largo Wastewater Treatment District (KLWTD) Florida Department of Transportation (FDOT)
6006B	Middle Key Largo	Northern Keys	KLWTD Monroe County FDOT
6006C	Upper Key Largo	Northern Keys	Monroe County FDOT
6009	Plantation Keys	Northern Keys	Village of Islamorada FDOT
6010	Long Key	Central Keys	City of Layton Monroe County FDOT
6011A	Vaca Key	Central Keys	City of Marathon FDOT
6011B	Key Colony	Central Keys	City of Key Colony Beach FDOT
6011C	Grassy Key	Central Keys	City of Marathon FDOT

Nitrate impairment of halo zone around Marathon



What do we know about the problem?

Effluent plumes are **buoyant**, and rapidly return to the surface after injection



Griggs et al., 2003

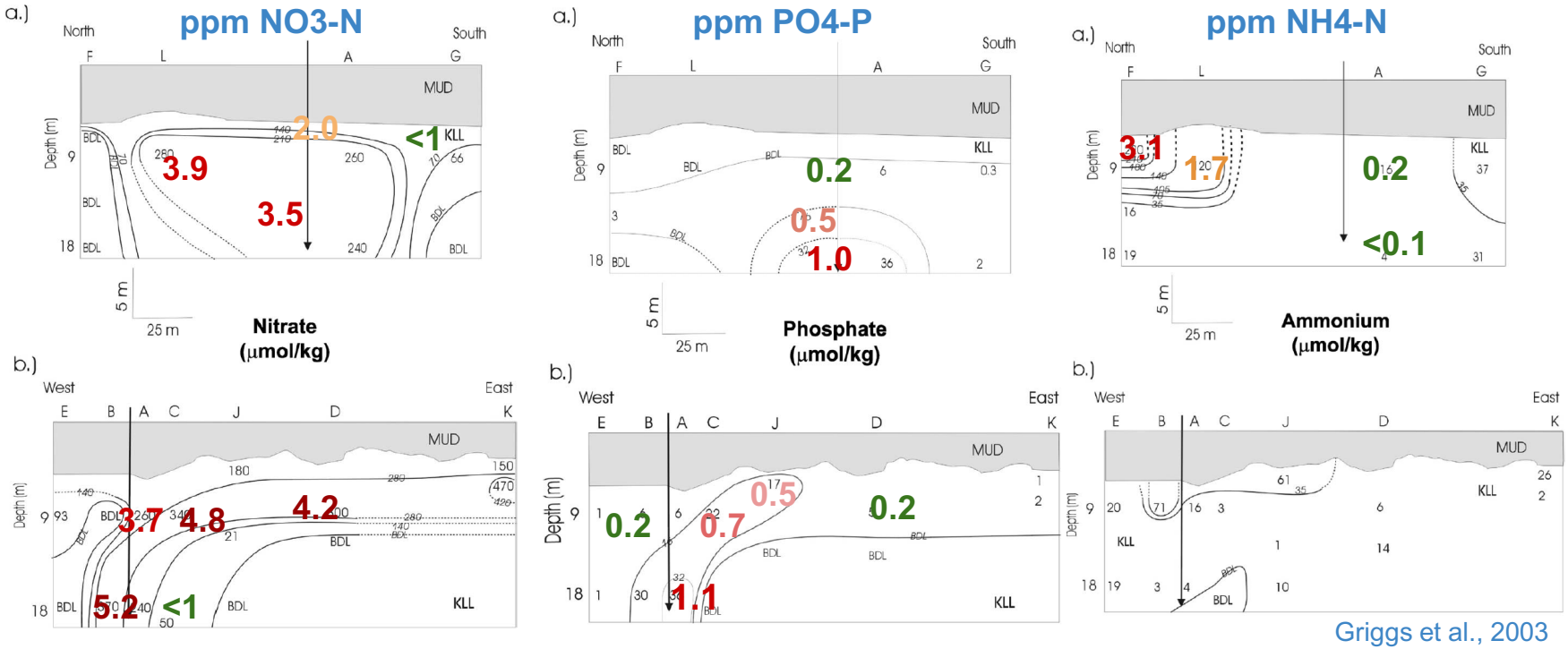
Key Largo Limestone

No Holocene mud cap at Marathon + ~45% porosity, high permeability = **rapid groundwater migration**

Images: http://www.uwosh.edu/faculty_staff/hiatt/Teaching/360_Florida/2005_Ancient.html

What do we know about the problem?

Nitrate and phosphate were effectively removed from the slower velocity flow path margins by ***microbial N cycling*** and ***phosphate adsorption*** onto karst at Key Colony Beach, but nitrogen loads remained high in the central, faster flow paths.

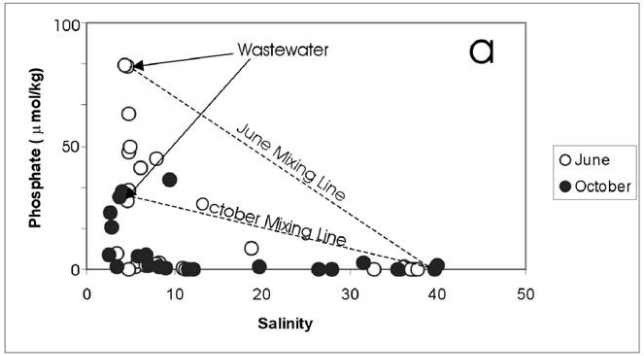


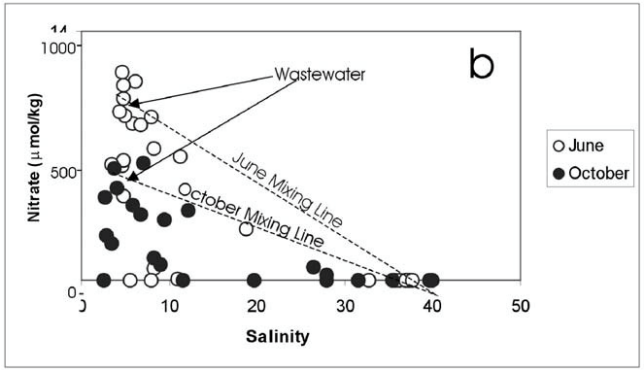
Griggs et al., 2003

EPA wastewater effluent standards @ Marathon Area 3 WWTF: 3 ppm N03-N; 1 ppm PO4-P

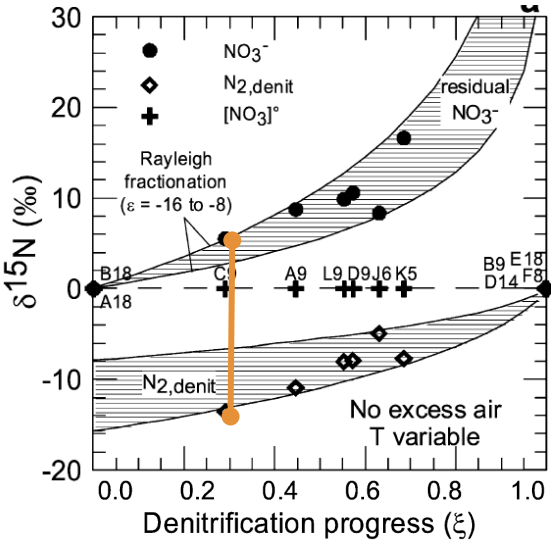
Uptake and adsorption effectively remove N + P in slow flow margins

Non-conservative behavior = effective uptake; not just mixing with saline groundwater





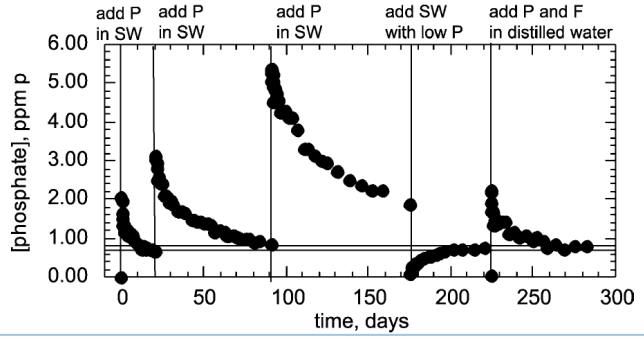
Griggs et al., 2003



Expected: ^{15}N enrichment during denitrification

Observed: N_2-NO_3 fractionation associated with denitrification

Phosphate adsorbs onto carbonate in flow through experiments



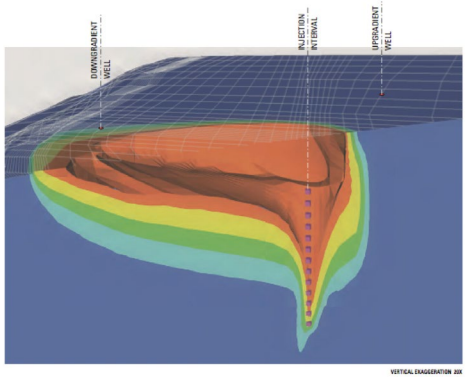
Objectives

(1) to characterize wastewater **plume geometry, composition and migration** at a single disposal facility in the FKNMS,

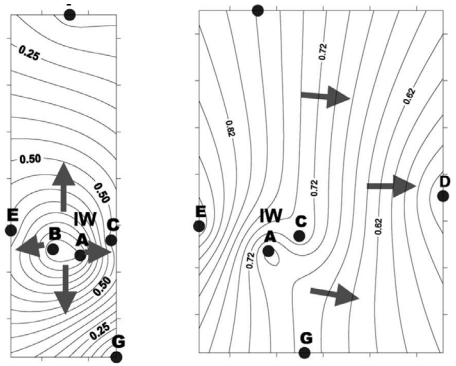
(2) to quantify the impact of shallow well effluent injections on **nitrogen and phosphorus contents** of groundwater in the halo zone

(3) to evaluate **generalizability** of our findings to sites with different geology, effluent chemistry and volume, and plume migration, with the goal of informing FDEP regulatory decisions.

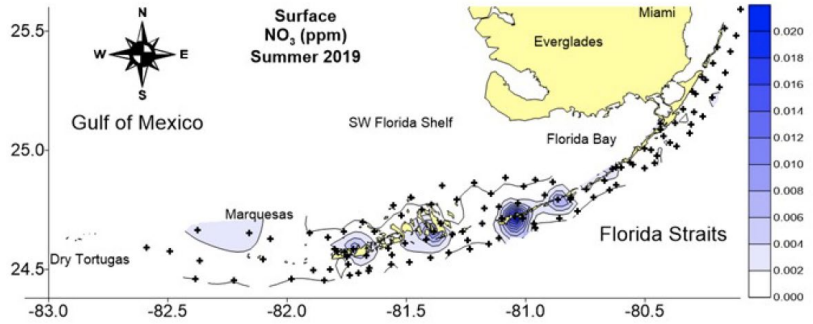
geometry, density



migration



composition



Broad overview of work plan

(1) Characterize the **geometry, travel time, and surface emergence** of wastewater plume nutrient loads

(2) Report the **N and P nutrient content** of groundwater and nearshore surface waters

(3) Calculate the stability of dissolved phases within the wastewater effluent and groundwaters as an **assessment of water quality, mineral reactivity and nutrient removal efficiency**

(4) Assimilate geochemical data with **SEAWAT reactive transport model** to evaluate the transferability of knowledge to wastewater management in FKNMS and other carbonate aquifers

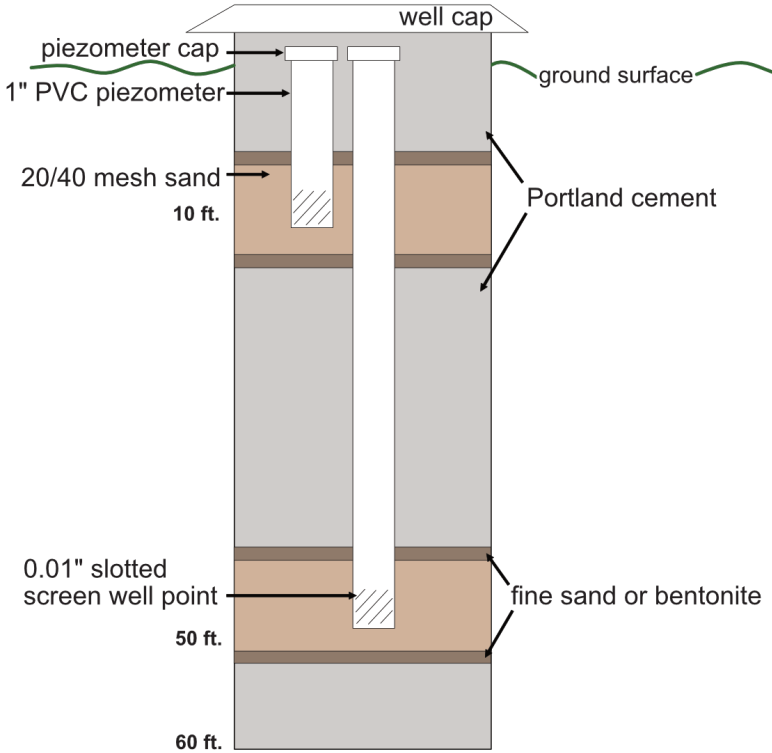
(5) Assess the **causative relationship** between shallow injection well effluent and high nutrient loads and other anthropogenic contaminants to nearshore surface waters

Study site: Marathon Area 3 Wastewater Treatment Facility

5 sampling wells will be drilled in early summer by J & C Drilling

An **additional 5 wells** will be drilled early 2022; locations selected based on preliminary characterization of plume geometry

Well design


well cap
piezometer cap
1" PVC piezometer
ground surface
20/40 mesh sand
10 ft.
Portland cement
0.01" slotted
screen well point
50 ft.
fine sand or bentonite
60 ft.


Wastewater Treatment Facility
Preliminary Monitoring Wells
Study Area
Gulf of Mexico
Crane Point
(location of sucralose chemical tracer studies by FOLKs)
Area 3 Wastewater Treatment Facility
Area 4 Wastewater Treatment Facility
Boot Key Harbor
N
600m
mainland FL
Marathon
80 km

Analytical overview - all in NELAC-certified labs

Nutrient concentrations (Total Nitrogen, Phosphate, Ammonium) within the main flow path and slower velocity margins of plume

Dissolved N_2 gas concentrations to quantify magnitude of denitrification along flow path

´ ^{15}N of dissolved N_2, NO_3^- and **NO_2^-** to quantify the contribution of denitrification versus other nitrate reduction processes

Tracer studies: pharmaceuticals + fluorescence (rhodamine and fluorescein dye injections)

Dissolved ion concentrations: calculate N and P speciation from dissolved ions, temperature, and salinity to evaluate chemical reactivity and sequestration potential

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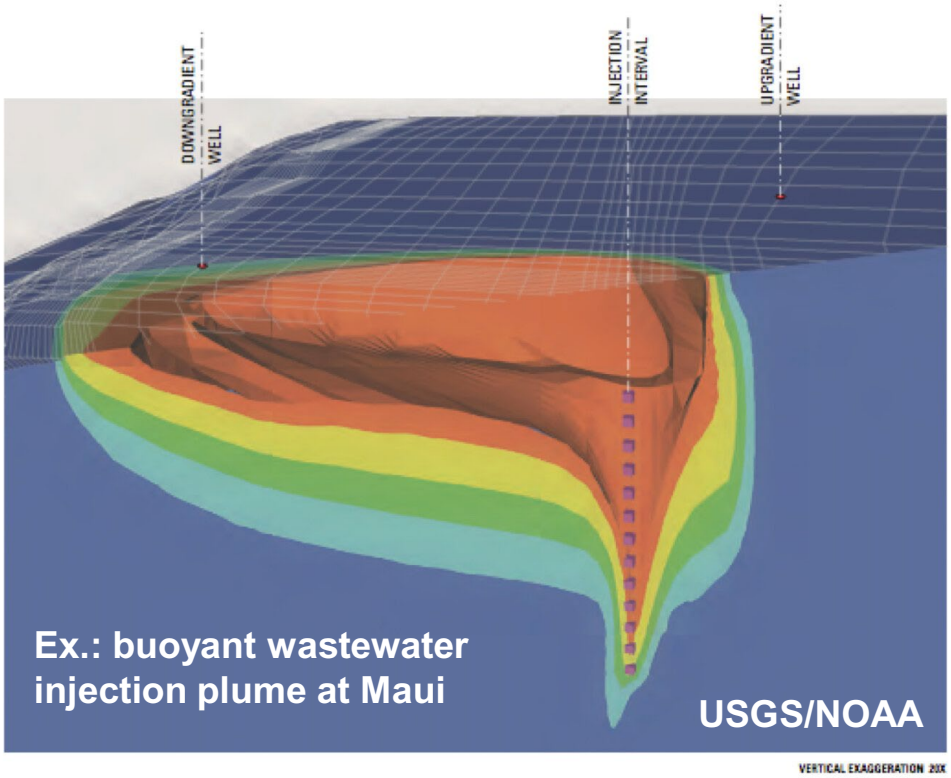
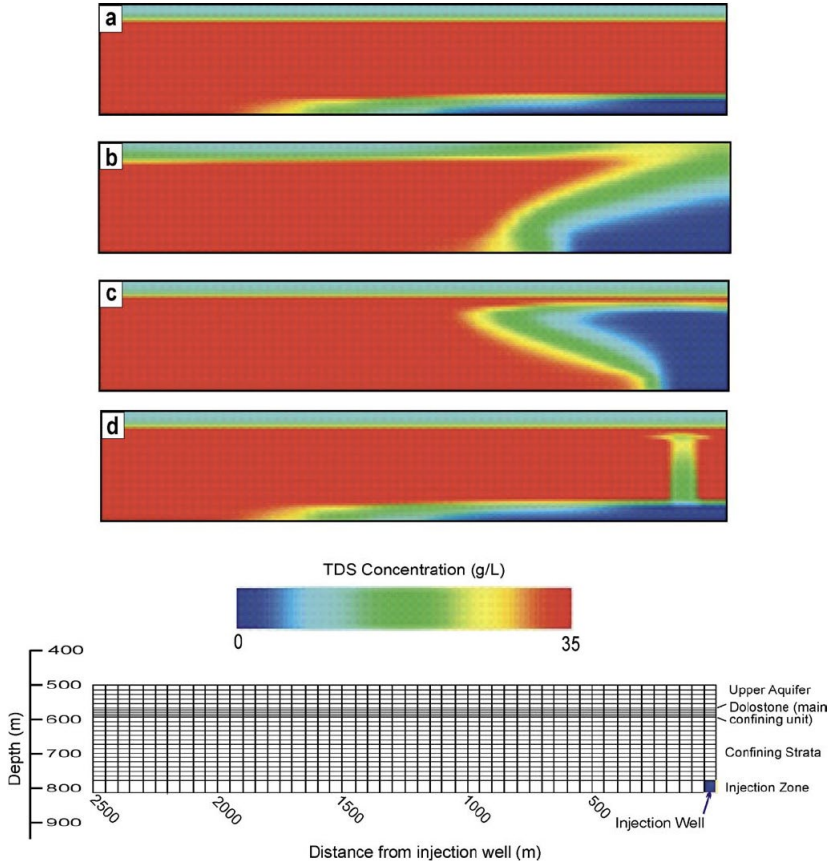
SEAWAT modeling





Hunt, 2006, Ground-Water Nutrient Flux to Coastal Waters and Numerical Simulation of Wastewater Injection at Kihei, Maui, Hawaii, USGS, Scientific Investigations Report 20065283

Maliva et al., 2007, *Hydrogeology* (wastewater injection in SE FL, 10 year effluent migration)

Hypothesis testing

Hypothesis: Short residence times of shallow wastewater effluent injections in the aquifer reduces the efficiency and permanence of nutrient removal.

Experiment: Inject mixed seawater + effluent to reduce density contrast between the plume and surrounding saline groundwater

Predicted outcome: Increased residence time in subsurface karst will increase denitrification efficiency and phosphate adsorption onto KLL

Current work schedule