THE TRANSPORT OF SALINE WATER IN THE POLDERED REGION OF BANGLADESH

S.C. Worland[1,2], G.M. Hornberger[1,2,3], S.L. Goodbred[1,2]
[1] Earth and Environmental Science Department, Vanderbilt University
[2] Vanderbilt Institute for Energy and Environment
[3] Civil and Environmental Engineering, Vanderbilt University

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Fig. 1


Fig. 2


Fig. 3


Fig. 4

Figs. **(1)** Embankment **(2)** Inside embankment at well site **(3)** household on polder **(4)** electromagnetic induction in rice field

Introduction

MOTIVATION

Bangladesh hosts 160 million inhabitants, giving it one of the highest population densities in the world. Much of the usable groundwater is saline or contaminated with arsenic, generating health issues that further exacerbate social tensions. This project is part of a larger attempt to generate an integrated social, environmental and engineering model to investigate the critical interactions between natural and human systems. The poldered areas in southwest Bangladesh offer a lens to explore these interactions.

STUDY SITE

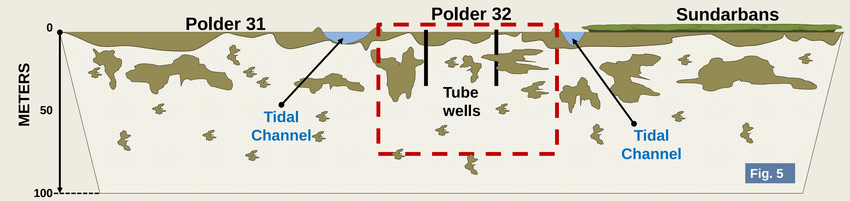


Fig. 5

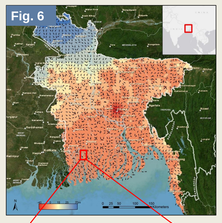


Fig. 6

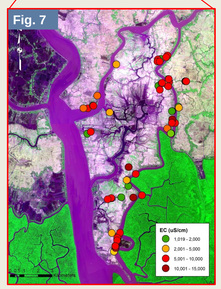


Fig. 7

Figs. **(5)** Cross section of study site, **(6)** map of Bangladesh with regional flow vectors and water table elevations, **(7)** groundwater salinity values on Polder 32

- Polder number 32, located 100 km from the coast (Fig. 1-3)
- Regional groundwater flow towards Bay of Bengal (Fig. 4)
- Preliminary sampling revealed sporadic lateral distribution of salinity
- Previous work demonstrates the unlikely exchange of tidal channel water into groundwater
- Inundated with fresh water during the monsoon season

RESEARCH QUESTIONS

1. What is the ***origin*** of the saline water in the shallow (75 meters) aquifer beneath Polder 32?
2. What mechanisms generate the salinity ***distribution*** found during sampling (fig. 5)?
3. How is the saline water ***transported*** in the shallow aquifer?

METHODS

1. Radiogenic isotopes (^{14}C and ^{3}H)
2. Electromagnetic induction and stratigraphic cores
3. Two dimensional finite element model

MATLAB Model parameters

- Two dimensional finite element method
- Implicitly solved
- Fixed head boundary conditions
- Galerkin weighted residual method
- Variable hydraulic transmissivity

1. Groundwater Flow Equation

$$\frac{\partial}{\partial x}\left(T_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_y \frac{\partial h}{\partial y}\right) = 0$$

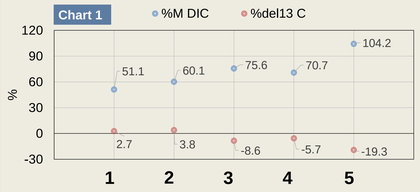
2. Advection Diffusion Equation

$$\frac{\partial c}{\partial t} = -u_x \frac{\partial c}{\partial x} - u_y \frac{\partial c}{\partial y} + D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + \gamma$$

Results

1. ISOTOPES

- carbon isotopes: connate water
- Tritium results are pending
- Sample five was taken from an artificial recharge site and was not used to plot the age contours



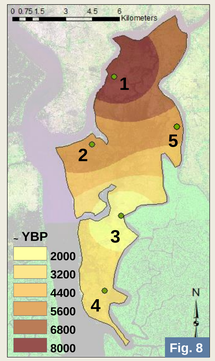
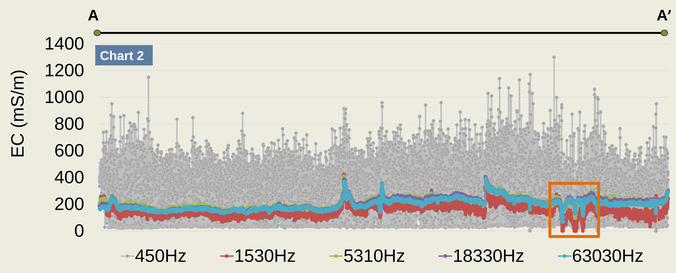


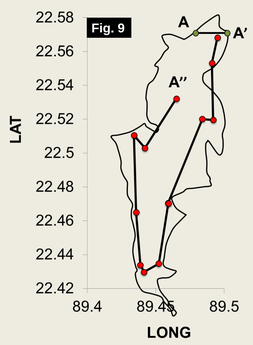
Chart **(1)** carbon isotope results

Fig. **(8)** Contoured map of groundwater ages using non-corrected values of %modern DIC

2. ELECTROMAGNETIC INDUCTION AND STRATIGRAPHIC CORES

- Cores reveal 5-20 meter clay confining unit with relatively open aquifer architecture with variable clay units throughout
- EM induction returned electrical conductivity values that mostly correspond with clay
- Both cores and EM induction suggest variable direct recharge depending on thickness of clay cap (orange boxes)





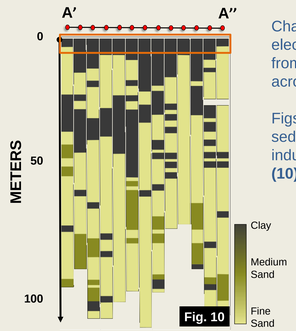
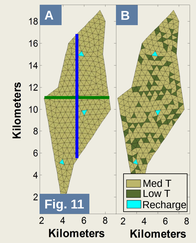


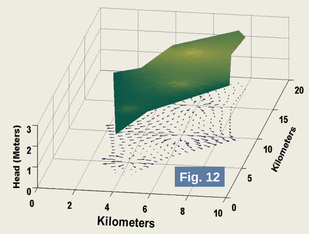
Chart **(2)** electromagnetic data from a ~1km transect across the polder

Figs. **(9)** Polder with sediment core EM induction transects, **(10)** Sediment cores

3. TWO DIMENSIONAL FINITE ELEMENT MODEL

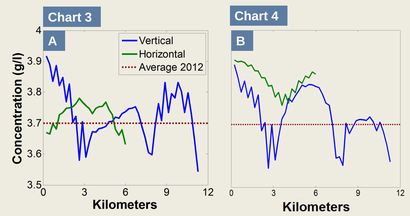
- Flow vectors primarily move northwest to southeast
- Salinity best explained by homogenous, isotropic aquifer with direct recharge
- Variability not well demonstrated in model

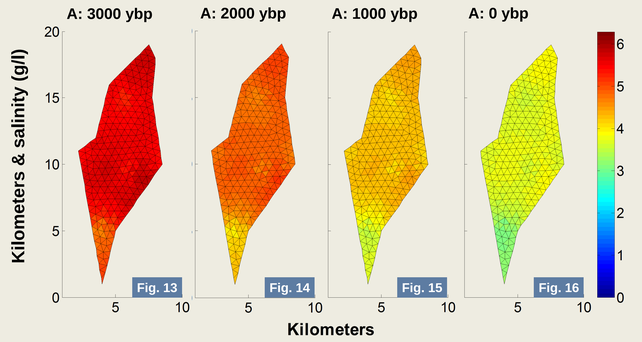




Figs. **(11:A,B)** Isotropic T and anisotropic T scenarios, **(12)** solution to flow equation with fixed head boundaries and direct recharge **(13-16)** evolution of groundwater salinity for 4000 years

Chart **(3)** model salinity output for 4000 yrs and scenario A, **(4)** and scenario B





Discussion

The shallow groundwater beneath the poldered region of Bangladesh is ancient estuarine water that was deposited along with the sediments that compose the aquifer. Isolated direct recharge freshens the water in the aquifer and generates spatial variability in water salinity. The clay cap prevents large amounts of meteoric water from entering the aquifer, suggesting that the flushing rates for the connate water are on the order of tens of thousands of years.

ACKNOWLEDGEMENTS

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- John Ayers, Gregory George, Chris Tasich, Laura Bennyworth and David Fry
- Per-Olof Persson and Gilbert Strang, "A Simple Mesh Generator in MATLAB," SIAM Review Vol. 46 (2) 2004.