Tracking Trace Metal Cycling in Stony Brook Harbor, NY by using GIS Applications

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1. Introduction

In coastal aquifers, the mixing of fresh groundwater with seawater occurs in a nearshore area termed the subterranean estuary (STE)(Moore, 1999). In the STE, rapid changes in porewater dissolved oxygen and salinity at the saltwater/freshwater boundary generates a unique set of redox conditions that can control the speciation of trace metals and in turn, the overall flux to the overlying surface waters. GIS is an interactive medium that can incorporate datasets from water quality measurements, landuse descriptions, and hydrologic properties all into one functioning geodatabase (DiLuzio et al., 2004). The goal of this project is to exhaust multiple applications in ArcMap in order to display areas within a local embayment of the Long Island Sound, NY that are more prone to receiving nonpoint source pollution as well as evaluate the water quality being discharged at these select areas.

2. Methods

Study Site and Motivation

- Stony Brook Harbor, which connects to the Long Island Sound, NY via a narrow inlet (Fig.1)
- Submarine groundwater is discharged (SGD) through the Upper Glacial Aquifer
- Stony Brook Harbor has been subjected to **harmful algal blooms** occurring during the summer months

Figure 1.

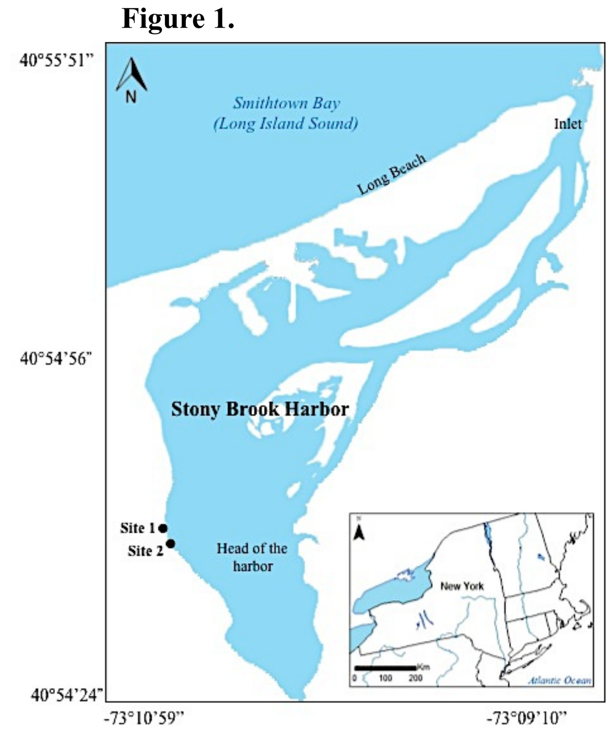
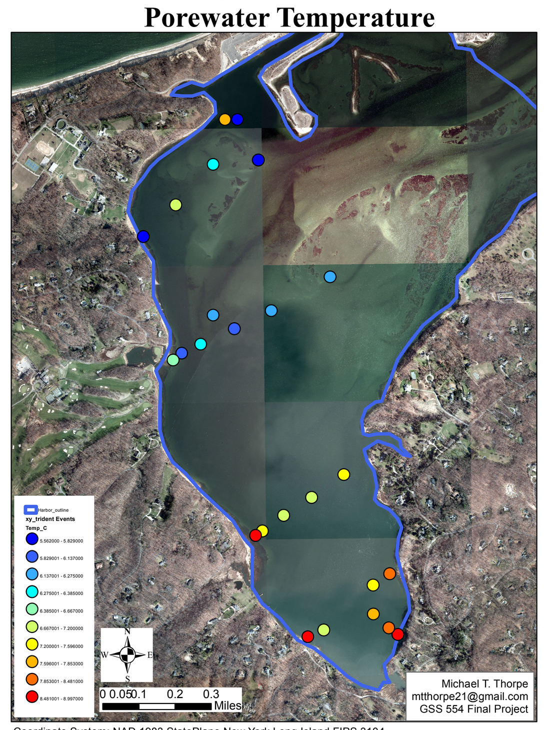


Figure 2. Stony Brook Harbor Porewater Temperature



Geochemical Geophysical Tracers

- Trident probe collected pore water samples at depth of 60 cm along various locations of the harbor (Fig. 2)
- Trident probe samples measured for temperature, salinity, and conductivity.
- Piezometer wells were drilled to a maximum depth of 10 m and were screened at various depths along the well
- Piezometer wells were sampled for trace metal concentration

Figure 3.

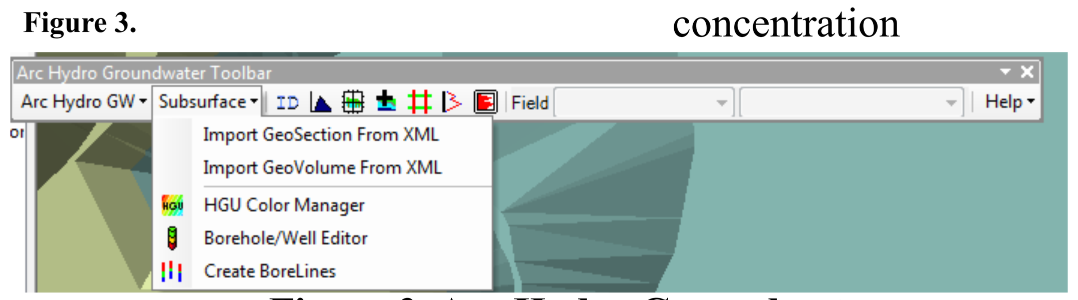


Figure 3. Arc Hydro Groundwater

- Screenshot of what the toolset looks like
- Borehole/Well Editor main function used

GIS Analysis

- Collection of all necessary data sets
  - 1m resolution digital elevation model (DEM)
  - 3m resolution orthographic photographs
- Projected using the NAD 1983 State Plane New York Long Island FIPS 3104 coordinate system

GIS Analysis Continued…

- 3D analyst toolbox was used at which point a raster file was converted to a TIN file (Fig. 4).
- Kriging was used to interpolate the temperature points obtained across the harbor
- Inverse Distance Weight (IDW) was used to interpolate conductivity measurements
- Arc Hydro Groundwater Toolbar that was utilized for the secondary analysis of this project (Fig 3.)
- Borehole/Well Editor main toolset employed

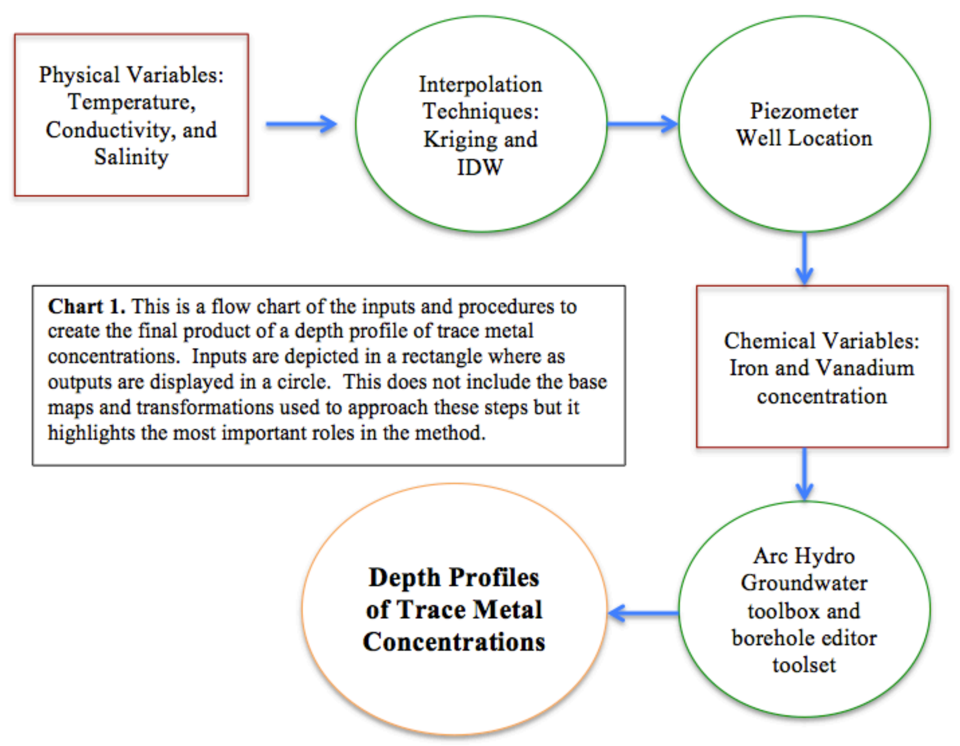


Chart 1. This is a flow chart of the inputs and procedures to create the final product of a depth profile of trace metal concentrations. Inputs are depicted in a rectangle where as outputs are displayed in a circle. This does not include the base maps and transformations used to approach these steps but it highlights the most important roles in the method.

3. Results

Figure 4.

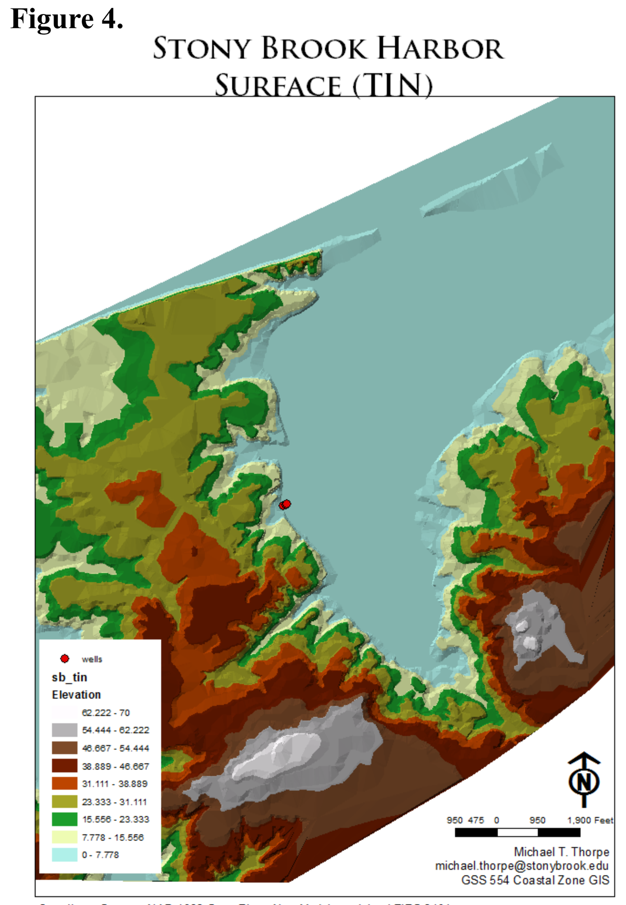


Figure 4. Triangulate Irregular Network Surface

- Surface Representation of Stony Brook Harbor using a triangulated irregular network (TIN) surface.
- Lower elevations represented in blues and higher elevations in red and the highest in gray.
- TIN is used to exemplify shoreline features as well as area contributing to SGD

Figure 5. Stony Brook Harbor Porewater Temperature

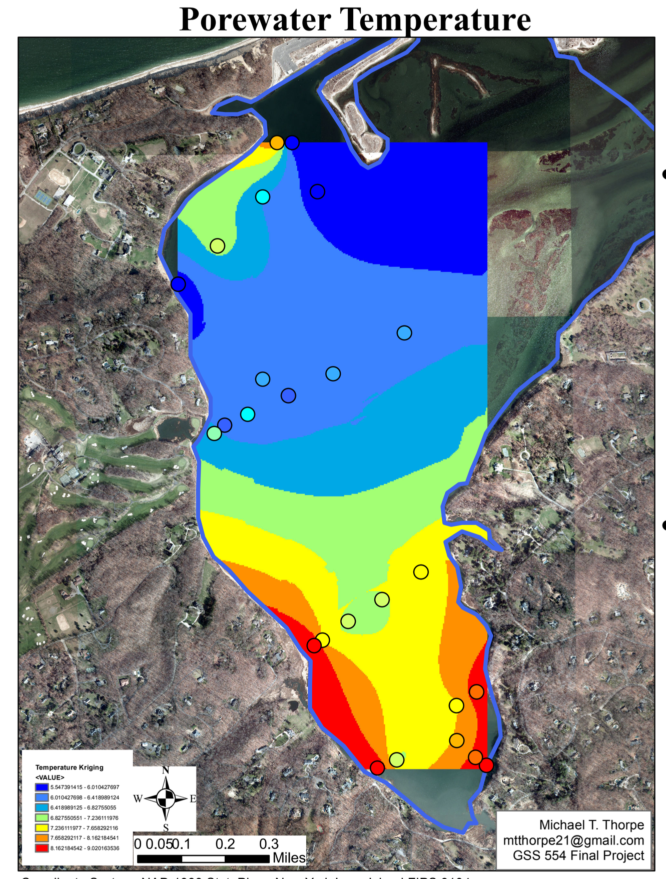


Figure 5. Temperature Interpolation

- Using the temperature reading from the porewater, a Kriging interpolation method was conducted in order to highlight areas of cooler water.
- Areas where we see cooler porewater (blue) we would expect to have a higher SGD. Areas in red indicate recirculated seawater

Figure 6. Stony Brook Harbor Porewater Conductivity

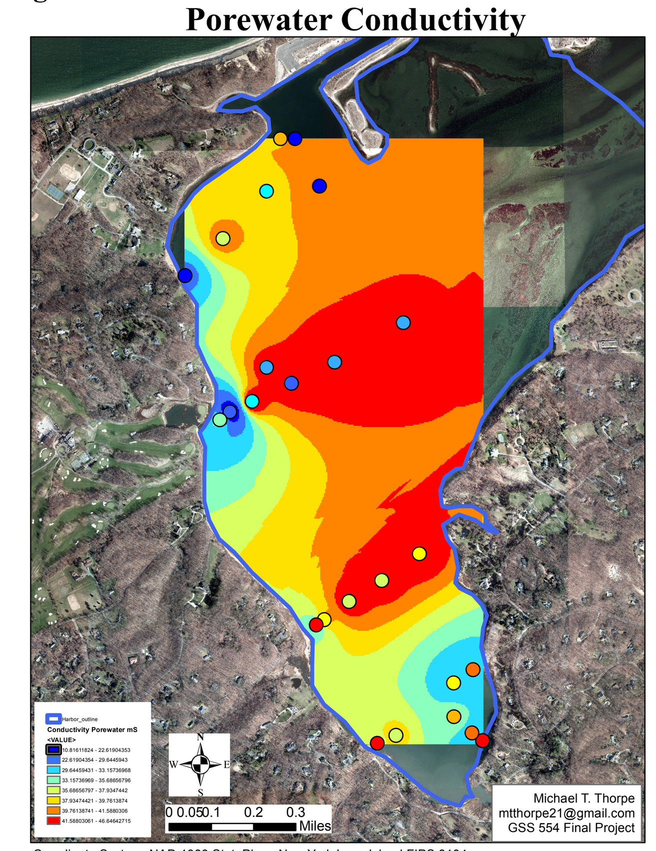


Figure 6. Conductivity Interpolation

- This figure uses an inverse distance weight interpolation for porewater conductivity
- The premise for using porewater conductivity is that terrestrial derived groundwater is more "fresh" and therefore will react less with the material it is permeating through

Figure 7.

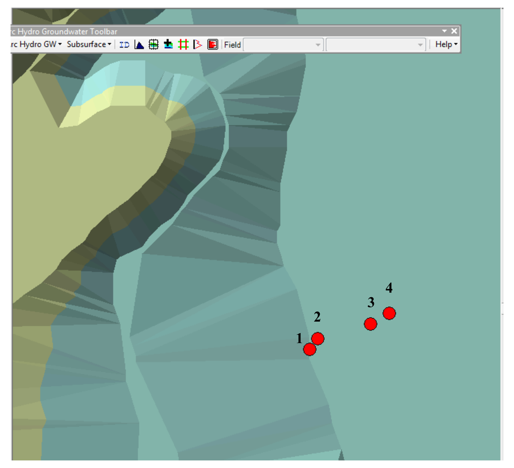


Figure 7. Piezometer Well Location

- Determined from interpolations where most SGD would be expected to occur
- See Fig 4 for spatial reference

Figure 8 a.

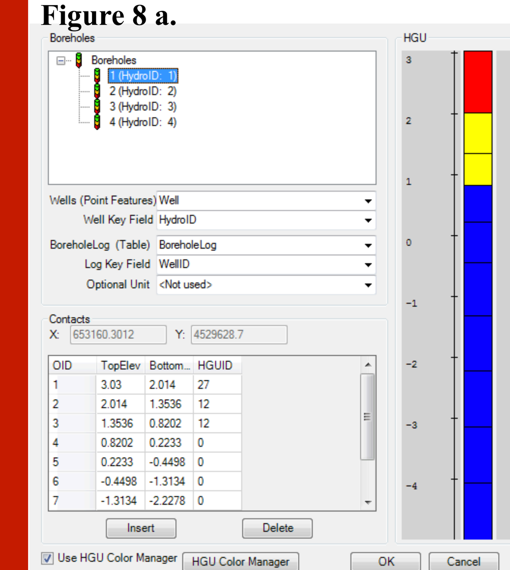


Figure 8a. Borehole Toolset

- Result of the Borehole tool set after inputting x, y, and z coordinates along with concentration
- HGUID is the ID code for concentration (mg/L)
- Top elevation for ID #1 represents surface water

Figure 8 b.

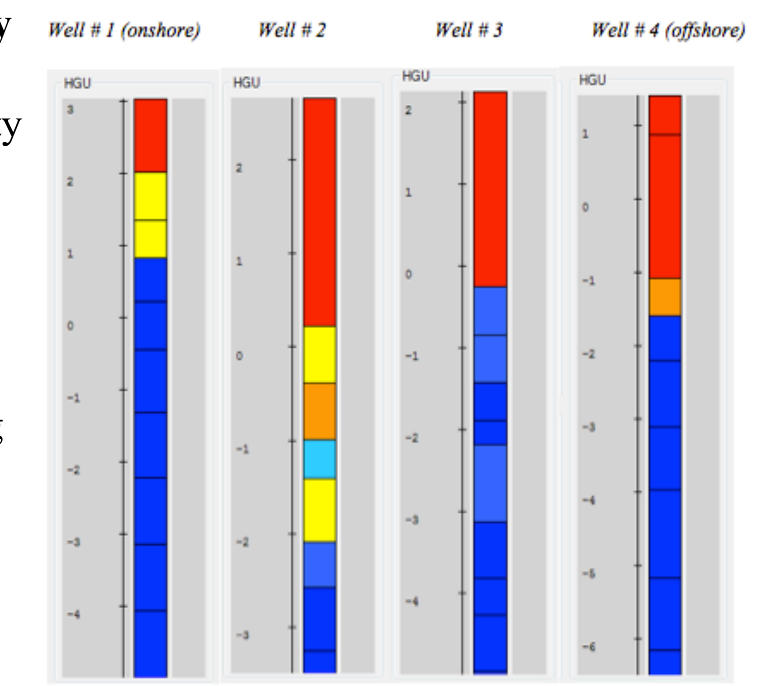


Figure 8b. Salinity Profiles

- Results of Salinity measurements taken from Piezometer wells
- Well numbers coincide with placement on Fig 7.
- Blue represents freshwater endmember
- Red signifies salinity plume

Figure 9 a.

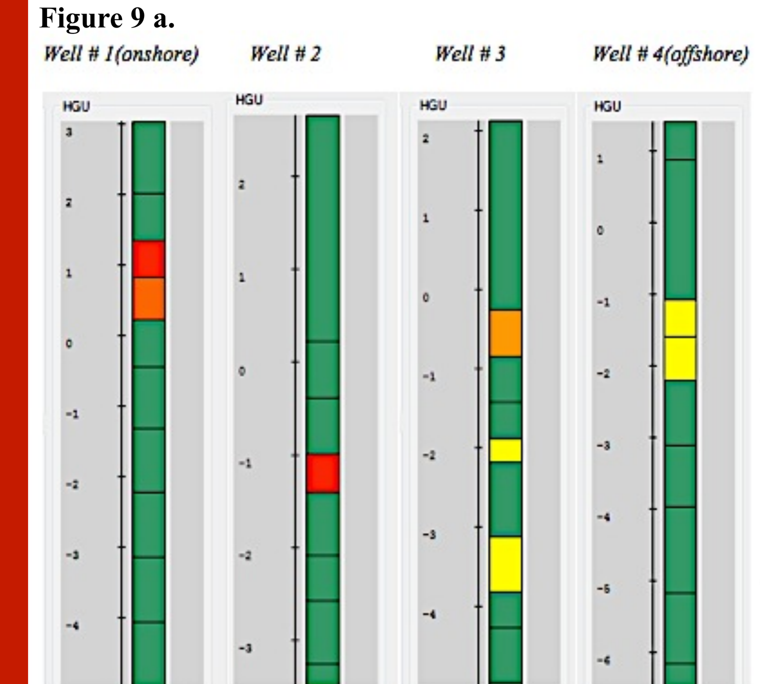


Figure 9 b.

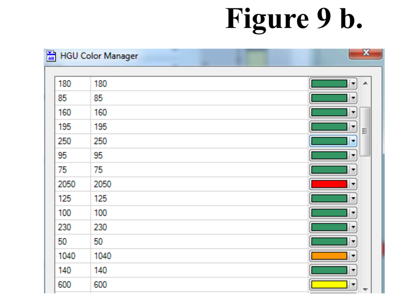


Figure 9. Iron Profile

- Iron has a maximum concentration (ppb) in salinity transition zone (a)
- Green represents depletion and red is maximum (b)

Figure 10 a.

Figure 10 b.

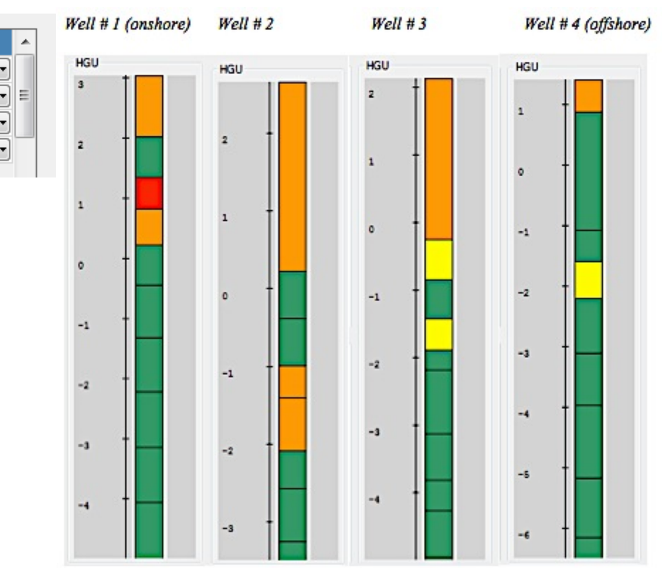


Figure 10. Vanadium Profile

- color scheme follows that of iron with the lowest concentration in green and highest concentration (ppb) in red (a)
- Something to note with the vanadium distribution is an elevated concentration at the surface
- This could potentially be the result of a groundwater input
- Vanadium can be produced from fossil fuel combustion and with the concentration levels at the surface surpassing the typical levels found in nature, this source may be anthropogenic

4. Conclusions

- The use of geographic information systems in investigating nonpoint source pollution in coastal environments provides a systematic way to evaluate these very sensitive environments
- By using the easily obtained physical variables of temperature, salinity, and conductivity an environmental assessment can be conducted in a cost efficient manner
- This can then translate into examining the influence that that anthropogenic actions have on the groundwater discharging into coastal waters
- Vanadium is of particular interest as previous investigations suggest it may be sourced from the freshwater end-member (Beck et al., 2010)
- The results of this project can be used in future coastal zone protection projects aimed at water quality control and environmental feedback from nonpoint source pollution

5. Recommendations

- Future recommendations would be to consider a larger study area and see if the same principals are consistent
- This type of GIS work highlights the capability of the Arc Hydro groundwater toolset by displaying the valuable information that can be translated from a surface to subsurface interface
- The next step in carrying out this project would be to obtain the full subsurface analyst extension in order to create a 3D outcrop view of the piezometer well transect

8. References

Beck, A. J., Cochran, J. K., & Sañudo-Wilhelmy, S. A. (2010). The distribution and speciation of dissolved trace metals in a shallow subterranean estuary. *Marine Chemistry*, *121*(1), 145-156.

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