SUBMARINE GROUNDWATER DISCHARGE (SGD) EXTRAPOLATION FOR PORT JEFFERSON HARBOR, NY.

Tsvi Pick[1],

[1]Stony Brook University, Department of Geosciences, Stony Brook, NY, 11794.

Email: tpick@ic.sunysb.edu

ABSTRACT
Groundwater typology is a method which is intended to address the relative lack of submarine groundwater discharge (SGD) data on a global basis. On the local scale, a typology was developed for Port Jefferson Harbor with the ultimate goal of scaling nitrates additions to the Long Island Sound.

SGD measurements at one location in the south-east side of the Harbor were extrapolated around the shore in 100-m intervals of the harbor using a typology based on calculations of freshwater underflow. The highest SGD rates were forecast to be found in the east side of the Harbor (Belle Terre community), and in the west side of the Harbor (Poquott community). Lower SGD rates are estimated to be found in the south and south-east end of the Harbor, in the area of Port Jefferson community.

INTRODUCTION
Submarine groundwater discharge (SGD) is a composited flux of groundwater underflow and diffused sea-water that occurs in the coastal zone (Bokuniewicz, 2001; Bokuniewicz et al., 2003; Moore, 2009). Classically, SGD flux is much greater than underflow (Cartwright et al., 2004; Mulligan and Charette, 2009), confined to a distance of up to 100m from the water's edge and modified by tidal fluctuations, with larger SGD rates linked to low tides (Burnett et al., 2006). When underflow absorbs elevated concentrations of dissolved, SGD lifts fluxes of dissolved constitutes to the coastal environment (Wachnicka et al., 2011). When considering implications of SGD, Nitrate (N) is a bio-geochemical of importance. Naturally, or artificially disproportionate N discharge is called eutrophication. Artificially eutrophication is often linked to phosphates (P) and N infiltration into groundwater underflow (Lee et al., 2009; Mutchler et al., 2007; Tapia González et al., 2008). When discharged, SGD may cause an intense increase of organisms (e.g. phytoplankton) (Troccoli-Ghinaglia et al., 2010), leading to oxygen depletion, or hypoxia (Kodama and Horiguchi, 2011). Thus, some habitats may not survive in the hypoxic environment.
Measurement of SGD is a daunting task. Therefore, data are usually obtained at only few sites along the shore (Taniguchi et al., 2002). In order to assess the regional supply of SGD, point measurements need to be extrapolated over wider areas from characteristics measured at one or a few sites. One strategy for accomplishing this

extrapolation is the use of groundwater typology (Bokuniewicz, 2001; Bokuniewicz et al., 2003; Buddemeier et al., 2008; Dahl et al., 2007; Dulaiova et al., 2006).
SGD data extrapolation over the surroundings of Port Jefferson Harbor, NY; as a part of a study purposed to assess N additions into the Long Island Sound, through groundwater underflow; is described.

PREVIOUS WORK

Local typologies had been constructed for Manhasset Bay and Northport Harbor (Pick, 2012). Sparse, direct measurements of SGD were correlated with calculations of freshwater underflow using modeling relationships from Destouni and Prieto (2003). Port Jefferson Harbor, located in the town of Brookhaven, NY, is a natural deep water harbor. At its opening, the Harbor is connected to Setauket Harbor, and Conscience Bay, and is also at its widest with an almost 1800m width. The Port Jefferson Harbor is about 2.2 km long (measured on Google Earth™), and its deepest water depth is around 7.6m (Google Earth™ elevation data). The surroundings of the Harbor are divided between three communities. From Belle Terre community, in the east coast side, to Port Jefferson community in the south, and south-west coastal zone, and Poquott community in the western coast of the Harbor. Belle Terre community has a population density of 369.2 people/ km^2 for a 2.3 km^2 area. Population density of Port Jefferson community is 998.6 people/ km^2 for a 7.8 km^2 area. Poquott community has a population density of 855.6 people/ km^2, for a 1 km^2 area (US 2000 Census, www.census.gov). Average precipitation in this area as was measured using rain gauge data in the location of Brookhaven National Laboratory (BNL) is 90 cm/ year (Zhou and Hanson, 2008). Port Jefferson Harbor was recognized as a critical area for wading birds, and includes designated areas as New York State Significant Coastal Fish and Wildlife Habitat (www.brookhaven.org). Nevertheless, the Port Jefferson Harbor area is highly developed. Surroundings of the Harbor include an electric power plant, and a sewage treatment plant (Buck et al., 2005; Freudenberg, 2008), all communities around the Port Jefferson Harbor are connected to a sewer system (http://www.co.suffolk.ny.us/Home/departments/planning/Cartography%20and%20GIS/Cartography/Online%20Maps.aspx). Dominant sources of groundwater nitrate are expected to be due to leakage in the sewer system, fertilizer applications and road runoff.

METHODS

The typology was based on calculation of the underflow, that is, the volume of groundwater flowing under the shoreline. The coastal zones of the specific areas were divided into 100m cells, specified by their central, Slate-Plane coordinates. There are 45 coastal cells for Port Jefferson Harbor (Figure 1, below).

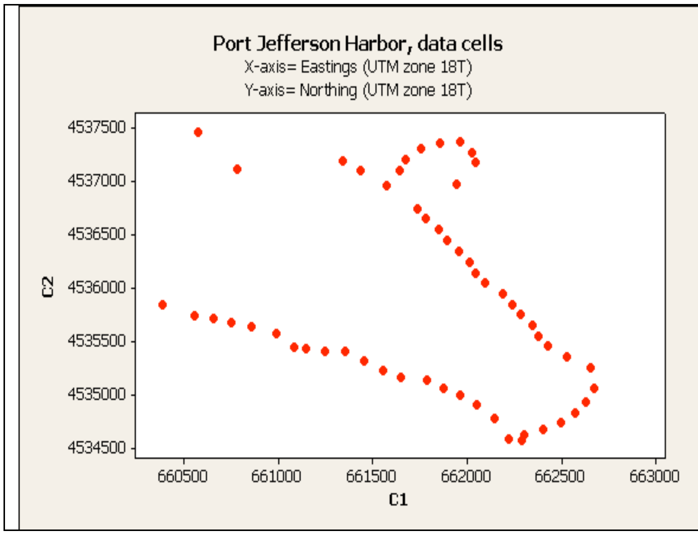

Figure 1 (Left). Coastal data cells for Port Jefferson Harbor.

Groundwater contours are not available for this area, excluding a small portion of the area south to the Harbor. These data are insignificant when building a typology. Available data from USGS wells (whttp://nwis.waterdata.usgs.gov/usa/nwis/gwlevels) are not significant to build groundwater typology as well (Figure 2, below).

Figure 2 (Left). USGS wells data, represented by the pins images, for surroundings of Port Jefferson Harbor.

The conventional wisdom is groundwater elevation mimics land elevation (Toth, 1963). To overcome the lack of groundwater data in the surroundings of Port Jefferson Harbor, a linear regression that describes water table elevation, as was observed from the USGS wells data, as a function of land elevation. Land elevations were measured at a fixed distance from the shore using Google Earth™ (Figure 3, below).

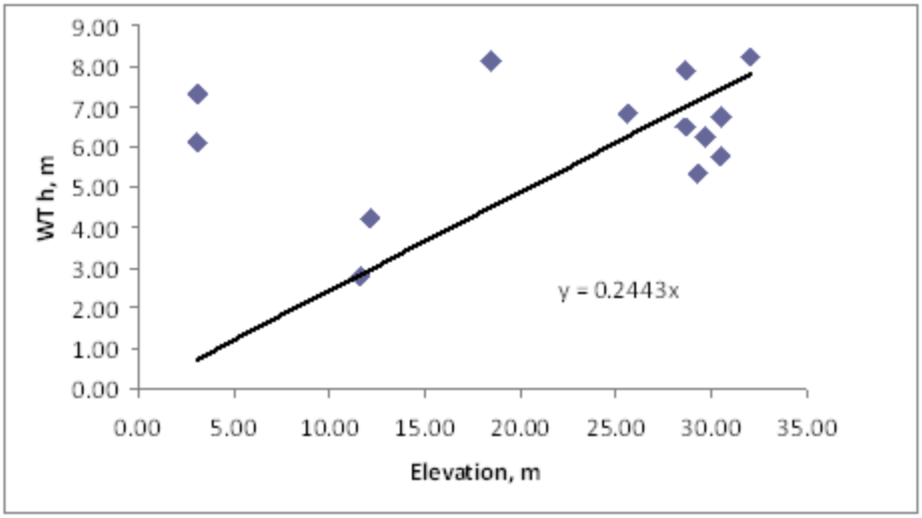

Figure 3 (Left). Relationship between land (Google Earth™ data), and water table elevations (USGS wells data)

This method, which allows usage of land elevation as a surrogate to water table elevation, was used to overcome the lack of data. Water table elevation (m) was computed to be equal to 0.2443 multiplied by land elevation (m) for this area.
SGD was measured using manual seepage meters (Lee, 1977), and extrapolated by computing of available hydrological parameters which are available by the USGS, physical data available by Google Earth™. The underflow was calculated using an hydraulic conductivity of 76.2 m/day (Busciolano, 2002). The underflow was converted to SGD using the relationships of Destouni and Prieto (2003) and calibrated with the direct measurements. An aquifer thickness of 5 m was assumed, to explain SGD rates in the measurement site. SGD measurements were made with a vented benthic chamber (Lee, 1977). The sediment layer was penetrated by the top of a 55 gallon drum with 2 holes. One hole was sealed with a rubber stopper during collection periods, and the other was a small nozzle covered with a 3.79-liter collection bag connected with a piece of Tygon tubing. The bag was zip-tied to the Tygon tubing to prevent leaks. A Schlumberger “CTD-Diver” pressure sensor (model DI261: 10m/80 mS/cm) was attached to at least one of the drums at the nozzle to record tide levels and water temperature.

RESULTS

SGD in Port Jefferson was measured in one location, northern to Setauket Yacht Club, the Port Jefferson community. Coordinated of the measurements site location are 40.95167; -73.06750. Three seepage meters were installed, July 13th, 2010, 13 meters away from the coast, parallel to the shore line. Data, with relationship to tides, were collected from 12:00 PM to 4:00 PM. Results show variation in SGD measurements. Figure 4, below, illustrates the variations in SGD measurements which were recorded.

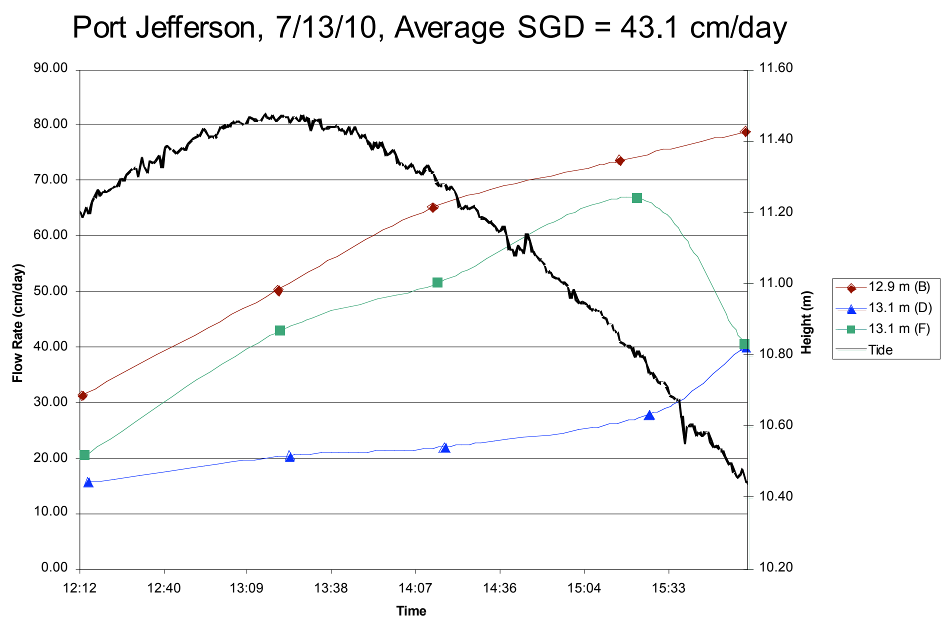

Figure 4 (Left). SGD measured variations, Port Jefferson Harbor, July 13th, 2010.

The average SGD value, 43.1 cm/day, is the value that was used to scale the Typology. Typology was used to divide SGD around the Harbor into 5 groups, based on discharge rates of m^3/m/year. The smallest discharge group, up to 3500 m3/m/year can be found mostly in the south side of the Harbor (Port Jefferson community). Other discharge rates were 3500 to 8000, 8000 to 11500, and 11500 to 15000. The highest discharge rate, 15000 to 27000 m^3/m/year, was computed to be mainly in the Belle Terre community in the east side of the Harbor, and also in the Poquott community, in the west side of the Harbor (Figure 5, below).

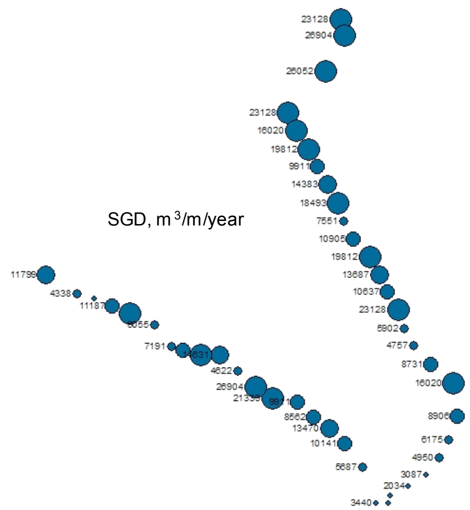

Figure5. Computed SGD rates for Port Jefferson Harbor.

It must be empathized that the typology is not a model, but a method to extrapolate data, and direct measurements would be required to test the results. The typology, however, is an efficient and cost-effective method to identify which sites at which measurements would be most useful. Future studies are planned to be carried out for the surrounding of Port Jefferson Harbor, and for the entire north shore of Long Island, NY.

CONCLUSION:
My study suggests that a typology which is formulated on the basis of underflow seems to give consistent patterns and reasonable results for SGD fluxes. As the typology is formulated here and calibrated against the few, available measurements, areas of high SGD correspond to areas of high underflow. In this case, because the typology is based on available measurements, they obviously reproduced the measured values. However, they also suggest the sites at which new, site-specific measurements would be most efficient and cost effective.

References:

Bokuniewicz, H., 2001, Toward a coastal ground-water typology: Journal of Sea Research, v. 46, p. 99-108.

Bokuniewicz, H., Buddemeier, R., Maxwell, B., and Smith, C., 2003, The typological approach to submarine groundwater discharge (SGD): Biogeochemistry, v. 66, p. 145- 158.

Buck, N.J., Gobler, C.J., and Sanudo-Wilhelmy, S.A., 2005, Dissolved trace element concentrations in the east River-long Island Sound System: Relative importance of autochthonous versus allochthonous sources: Environmental Science & Technology, v. 39, p. 3528-3537.

Buddemeier, R.W., Smith, S.V., Swaney, D.P., Crossland, C.J., and Maxwell, B.A., 2008, Coastal typology: An integrative "neutral" technique for coastal zone characterization and analysis: Estuarine, Coastal and Shelf Science, v. 77, p. 197-205.

Burnett, W.C., Aggarwal, P.K., Aureli, A., Bokuniewicz, H., Cable, J.E., Charette, M.A., Kontar, E., Krupa, S., Kulkarni, K.M., Loveless, A., Moore, W.S., Oberdorfer, J.A., Oliveira, J., Ozyurt, N., Povinec, P., Privitera, A.M.G., Rajar, R., Ramessur, R.T., Scholten, J., Stieglitz, T., Taniguchi, M., and Turner, J.V., 2006, Quantifying submarine groundwater discharge in the coastal zone via multiple methods: Science of The Total Environment, v. 367, p. 498-543.

Busciolano, R., 2002, Water-Table and Potentiometric-Surface Altitudes of the Upper Glacial, Magothy, and Lloyd Aquifers on Long Island, New York, in Marhc-April 2000, with a Summary of Hydrogeologic Conditions, Water-Resources Investigations Report 01-4165: Coram, New York, USGS.

Cartwright, N., Li, L., and Nielsen, P., 2004, Response of the salt-freshwater interface in a coastal aquifer to a wave-induced groundwater pulse: field observations and modelling: Advances in Water Resources, v. 27, p. 297-303.

Dahl, M., Nilsson, B., Langhoff, J.H., and Refsgaard, J.C., 2007, Review of classification systems and new multi-scale typology of groundwater-surface water interaction: Journal of Hydrology, v. 344, p. 1-16.

Dulaiova, H., Burnett, W.C., Chantona, J.P., Moore, W.S., Bokuniewiczc, H.J., Charette, M.A., and Sholkovitz, E., 2006, Assessment of groundwater dischargesnext term into West Neck Bay, New York, via natural tracers Continental Shelf Research, v. 26, p. 1971-1983.

Freudenberg, R., 2008, Long Island Sound Environmental Threat Assessment, Long Island Sound Stewardship Initiative.

Kodama, K., and Horiguchi, T., 2011, Effects of hypoxia on benthic organisms in Tokyo Bay, Japan: A review: Marine Pollution Bulletin, v. In Press, Corrected Proof.

Lee, D.R., 1977, A device for measuring seepage flux in lakes and estuaries: Limnology and Oceanography, v. 22, p. 140-147.

Lee, Y.-W., Hwang, D.-W., Kim, G., Lee, W.-C., and Oh, H.-T., 2009, Nutrient inputs from submarine groundwater discharge (SGD) in Masan Bay, an embayment surrounded by heavily industrialized cities, Korea: Science of The Total Environment, v. 407, p. 3181-3188.

Moore, W.S., 2009, Submarine Groundwater Discharge, *in* John, H.S., Karl, K.T., and Steve, A.T., eds., Encyclopedia of Ocean Sciences: Oxford, Academic Press, p. 551-558.

Mulligan, A.E., and Charette, M.A., 2009, Groundwater Flow to the Coastal Ocean, *in* John, H.S., Karl, K.T., and Steve, A.T., eds., Encyclopedia of Ocean Sciences: Oxford, Academic Press, p. 88-97.

Mutchler, T., Dunton, K.H., Townsend-Small, A., Fredriksen, S., and Rasser, M.K., 2007, Isotopic and elemental indicators of nutrient sources and status of coastal habitats in the Caribbean Sea, Yucatan Peninsula, Mexico: Estuarine, Coastal and Shelf Science, v. 74, p. 449-457.

Pick, T., 2012 Submarine Groundwater Discharge (SGD) extrapolation for Small Bays and Estuaries in Long Island, NY: Manhasset Bay, Northport Harbor, and Port Jefferson Harbor: (In preparation for submission).

Taniguchi, M., Burnett, W.C., Cable, J.E., and Turner, J.V., 2002, Investigation of submarine groundwater discharge: Hydrological Processes, v. 16, p. 2115- 2129.

Tapia González, F.U., Herrera-Silveira, J.A., and Aguirre-Macedo, M.L., 2008, Water quality variability and eutrophic trends in karstic tropical coastal lagoons of the Yucatán Peninsula: Estuarine, Coastal and Shelf Science, v. 76, p. 418-430.

Toth, J., 1963, A Theoretical Analysis of Groundwater Flow in Small Drainage Basins: Journal of Geophysical Research, v. 68, p. 4785–4812.

Troccoli-Ghinaglia, L., Herrera-Silveira, J.A., Comín, F.A., and Díaz-Ramos, J.R., 2010, Phytoplankton community variations in tropical coastal area affected where submarine groundwater occurs: Continental Shelf Research, v. 30, p. 2082-2091.

Wachnicka, A., Gaiser, E., and Boyer, J., 2011, Ecology and distribution of diatoms in Biscayne Bay, Florida (USA): Implications for bioassessment and paleoenvironmental studies: Ecological Indicators, v. 11, p. 622-632.

Zhou, L., and Hanson, G.N., 2008, Annual Precipitation Pattern over Long Isalnd Based on Radar Data: Proceedings of The Fifteenth Conference on Geology of Long Island and Metropolitan New York, v. April 12, 2008.