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/ km² for a 2.3 km² area. Population density of Port Jefferson community is 998.6 people/ km² for a 7.8 km² area. Poquott community has a population density of 855.6 people/ km², for a 1 km² 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).
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 (wht://nwis.waterdata.usgs.gov/usa/nwis/gwlevels) are not significant to build groundwater typology as well (Figure 2, below).

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).
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.

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 m³/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 m³/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).
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:


