Good morning. My name is Nickitas Georgas and I am a Research Engineer and Ph.D. candidate at Stevens Institute of Technology. Before joining Stevens I worked for HydroQual as a project scientist, and my last project with the company is the work I will be presenting today, called “Estimation of Non-Point Source Nitrogen Loads to Long Island Sound Using a Simple Model for BMP Screening.” Mark Tedesco, from the Long Island Sound Office of the EPA was this project’s director. Drs. Kevin Farley from Manhattan College and Sri Rangarajan from HydroQual where the PIs.
Here is the outline of the presentation. I will first define the study area, along with the project goals and the GIS modeling methodology we followed. Then I will present the model, its calibration, and application to the study area, which were my responsibilities in this project. Finally, I will walk you through a Demo of the BMP-selection tool called “Poll-Track” that was created for this study.
The study area was defined by EPA, and covered the NY and CT watersheds that contribute Nitrogen loads to Long Island Sound. We mainly focused on in-basin watersheds, described as such in the 1999 LIS Nitrogen TMDL document that was adopted in 2001 and came after 15 year long studies and negotiations in response to the eutrophication problem the Sound experienced. The TMDL set reduction goals for Nitrogen loads contributed by in-basin sources. The nominal goal for in-basin combined Point and Non-Point Sources was set to 58.5%.
The TMDL assumes an in-basin non-point source Nitrogen load reduction by 10%. This 10% load allocation guidance has been taken seriously by the states. For example CT has set a Phase III TMDL goal to include nutrient management BMP in all dairy operations by 2014. http://www.epa.gov/ne/eco/tmdl/assets/pdfs/ct/longislandsound.pdf

LIS EPA, after discussion with the States’ DEP/DEC and other stakeholders, funded this project with the goal to create a simple decision support tool that would provide a practical means for analysis of and selection from a list of Best Management Practices based on a breakdown of nitrogen loads on a watershed by watershed level. In summary, the project goal was to create a user-friendly, science based tool, that would allow a watershed manager to select a series of BMPs to achieve the 10% load allocation goal based on an inventory of loading sources, local knowledge, and cost considerations.
This slide describes the general methodology followed. We relied on three “models.”

The first, the ArcView Generalized Watershed Loading functions called AVGWLF, is an EPA-Basins-like GIS interface developed by Penn State that allows the import and manipulation of GIS themes for hydrologic modeling. Meteorological databases for rain and air temperature stations are linked to provide the driving mechanism for runoff generation. Global GIS coverages for land use, soil types, digital elevation models, census demographics, groundwater and soil nitrogen concentrations, etc. are input to AVGWLF, and processed on a watershed basis. AVGWLF’s output are three distinct files that cover the meteorological drivers (weather), the hydrologic transport parameters per land use type (transport) and the associated nutrient (in this case Nitrogen) concentrations. These three files are then input to the GWLF mid-level hydrologic model developed by Dr. Haith of Cornell University. GWLF runs hydrologic simulations to calculate runoff and loads from different land classes, point sources, septic systems, and groundwater baseflow. The resulting monthly loads and contributing areas are tabulated, and averaged on an annual basis. The tabulated annualized total nitrogen loads are then input as a lookup table to an Excel based tool created for this study by adopting a visual basic approach to a precursor software called Predict developed by Penn State for Pennsylvania. This tool, called Pollution Tracking, or Poll-Track, can be used by the watershed manager to easily run different BMP scenarios on the existing loads, calculating load reduction and associated cost.
Maps here show some of the GIS coverage themes converted to AVGWLF input for this study: Top Left: Available water-holding capacity in surface soils, in centimeters, computed based on NRCS STATSGO soil coverages. This map also shows the location of selected weather stations for this study. Top Right: Digital Elevation Map of the area; Elevation in meters. Bottom Left: An AVGWLF-compatible representation of major land uses in the area, based on University of Connecticut and EPA Basins publicly available information, circa 1995. Bottom Right: Percent of population using septic tanks instead of public sewerage as defined in AVGWLF, based on available US CENSUS data, circa 1995.
This schematic explains the hydrologic processes simulated by GWLF. Rainfall has three distinct pathways: it is lost as evapotranspiration, becomes runoff, or infiltrates in a watershed-wide groundwater zone that manifests itself as in-stream base-flow, with possible losses to deep storage aquifers. Runoff from individual land uses carries urban washoff, eroded sediments, and dissolved nitrogen. The base-flow part of the streamflow also carries dissolved nitrogen, including septic system outflows. To these nitrogen loads, known point source loads can be added, to create total water yield and load contributed by each watershed.
This simplified schematic shows the treatment of nutrients within GWLF. There are two distinct phases, dissolved and solid. Dissolved runoff loads are contributed by storm water times a specified concentration by land use type. Groundwater loads are contributed by the calculated baseflow times a groundwater concentration. Solid phase loads are contributed by rural runoff as soil erodes based on the Universal Soil Loss Equation and by urban runoff of accumulated solids based on an exponential accumulation – washoff function.
AVGWLF Model Calibration

- Available Observations
  - Tributary TN Data from CTDEP

- Model Calibration
  - Annual Loads/Flow Duration Curves
  - Monthly Correlograms and $R^2$
  - Time-series Comparisons

We proceed with the presentation of the AVGWLF model calibration procedure and results.

Available observations for model-data comparisons were available for three river basins in CT by CTDEP. The model was compared to annual loads calculated from these observations. Flow duration curves were compared. Monthly flow and load correlograms were created and quantified by $R^2$. Also, time series for flows and loads were qualitatively compared.
This is an image of the three calibration watersheds used in this study. Namely, Quinnipiac, Norwalk, and Salmon. They were selected due to data availability and because they spanned a size range and had varying land use distributions.
Here are some general assumptions and simplifications used in this study. The study followed generalized guidelines from the GWLF manual and GIS-manipulation guidelines from the AVGWLF manual. An underlying assumption to GWLF is that regional watershed basins provide enough resolution. We took the conservative approach of not allowing groundwater losses to deep storage reservoirs. As the AVGWLF developers assumed in their simulation for Pennsylvania watersheds, septic tanks with out a specified normal operation specification in the Census data were assumed short-circuited. AVGWLF did not allow for in-stream nitrogen attenuation dynamics, which according to other studies can be as high as 10% of the in-stream load. Already existing BMPs before the 10-year calibration period of 1985-1995, were not included in the baseline. And, finally, water diversions to nearby watersheds were not included. Watershed managers could include such a posteriori.
This slide shows AVGWLF performance for the three calibration watersheds. Correlograms (X-Y plots) on the left. Cumulative flow curves over the 10 year period on the middle. Monthly flow R² ranged from 0.78 to 0.88. Total 10-year water yield compared well, within 4%. These results were compared to a rating by CTDEP used to qualify an earlier HSPF study for the same three watersheds. Interestingly, as far as seasonal to annual loads were concerned AVGWLF performed better or equally as good to HSPF in most cases. This is not to say that AVGWLF is better than HSPF, as HSPF is a much more complex hydraulic model that has the ability to capture day to day dynamics while the hydrologic AVGWLF does not. However, on an annual basis, this is not relevant, and the use of a simpler model such as AVGWLF allows for a much quicker yet substantive application, preferred when time and money are limited.
This is an example hydrograph comparing AVGWLF simulation results and streamflow data for the Norwalk River. As you can see, although the correspondence is substantial, big events are big, recession is reasonable, and the cumulative yield was within 1%, individual events may not be captured perfectly by the model.
This slide shows similar plots for AVGWLF performance for total nitrogen: Correlograms (left) and cumulative TN load analyses (right); 10-year calibration period. R² here is lower than for flow, and comparable to an independent application of AVGWLF conducted for the New England Interstate Commission. The cumulative load curves also show weaker correspondence to observed data, especially after the first five years. Although this may be partly due to BMPs put in place before 1995, one other major reason is that the data were much more sparse in the last 5 years of the calibration period compromising our ability to quantify long-period comparisons.
After the LIS EPA and the stakeholders were satisfied with the degree of calibration, the model was applied to the remaining CT and NY watersheds to provide inputs for the BMP selection tool.
These maps show the spatial variation of the contribution of the eight non-point source categories to the total nitrogen loads to Long Island Sound, normalized by the total area of each contributing subwatershed, as estimated by AVGWLF during this study. The spatial variation reflects physiographical differences, differences in land-use and soils, urbanization, and rainfall patterns. The following contributors are shown in this slide: Groundwater; Septic Systems; High Density Urban areas; Low Density Urban areas; Forested areas, including inland waters and other non-urban and non-agricultural land uses; Hay and Pasture; Row Crops; Streambank erosion.
This is a breakup of the calculated loads for the whole domain. Baseflow-carried loads are the biggest contributor, a very important finding, with implications for BMP selection. Septic systems follow, by a substantial 17% of the load, another significant finding. Runoff categories contribute the most of the remaining 28%, with a small contribution from streambank erosion.
The importance of nitrogen-reach groundwater in Long Island is also seen in this chart depicting total NPS nitrogen loads in kg/year. Because of that, 25% of the NPS load comes from NY basins, which account for only 15% of the area. The NY basins tend to be smaller in acreage than the ones in CT, thus, the highest total load components by individual watersheds are all estimated to originate in CT watersheds. Namely, Housatonic, Naugatuck, and Tenmile have the highest total component loads, all three situated in the western part of Connecticut within the Housatonic River Basin.
The tabulated GWLF results are now part of the POLL-TRACK tool developed for this project. I wanted to give you an example application, but be cautioned that this is a made up example, not a real-life one. I am not a BMP person, and as such perhaps suitable for trying this as a lay person would. I chose the main stem of the Housatonic river watershed as my example. Most of the river’s length cuts through agricultural fields, then high-density urban areas, then low-density ones. In terms of area, most of the watershed falls under the hay/pasture category with 25% urban areas too. High-density urban areas contribute the most nitrogen-laden runoff, even though the major mode of nitrogen transport to the Sound is again through groundwater baseflow.

I hope I have two minutes to just show you how POLL-TRACK looks like.
So here are some results from POLL-TRACK I generated. I first assumed that by 1999, the year of the LIS TMDL, some BMPs were actually installed in the watershed, allocated by 10% to each applicable BMP. This is the year 1999 start, different than the baseline run due to the already installed BMP by 4% less nitrogen load. How do we get to a 10% NPS load reduction from 1999 levels?

For the first load scenario I assumed that 100% of the river miles in agricultural and low-density urban areas have adjacent land available for creating vegetated buffer strips. I also assumed that no such land was available along high-density urban river miles. Those buffer strips alone brought the NPS load down by 6.1% for only $25,000 (estimated based on Pennsylvania data, that can change from the user). Then, two more additional BMP were considered. First an expensive detention basin project that would service 70% of the high-density urban areas, and, second, a much less expensive nutrient management program for all agricultural areas. The additional BMPs, separately, had largely the same effect, and met the 10% NPS load allocation guideline. However, nutrient management is estimated to cost substantially less. Maybe CTDEP was thinking along these lines when they made a goal of installing nutrient management in all dairy farms by 2014.
Finally, I would like to acknowledge a few people with significant contributions to the overall effort. Thank you very much. I would be glad to answer any questions.
One thing that I should note here is that by conservatively assuming no groundwater losses to deeper aquifers, possible dilution with historic groundwater with residence times from 100-400 years is not accounted for. Thus, groundwater concentrations in baseflow might be slightly smaller than the ones seen here that came from shallow wells. Deep groundwater seepage to the Sound may account for up to 50% of the total groundwater contribution in places with deep recharge basins and lack of streams as in the North Fork area of Long Island.
Estimated NPS TN loads generated by individual WS.

This graph shows the AVGWLF loading factors, calculated for each watershed per unit area type. Overall, groundwater loads per unit area are the highest, especially in NY, and the Long Island North Shore, which is a highly agricultural area known for “blue baby” disease. The underlying groundwater concentrations assigned in GWLF came from a review of historical data from USGS as well as the National Groundwater Clearinghouse Database.