Testing and comparing two models for watershed planning

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Introduction

Planning at the watershed level provides a link between the understanding of the environmental function of a watershed system and the political, cultural, and economic systems of that area. Watershed planning, from the federal and state perspective, focuses primarily on water quality. In order to receive federal or State of New Hampshire funding for the development of a watershed plan, the watershed planning process must address the nine elements required by the U.S. Environmental Protection Agency (EPA). In the United States, phosphorus (P) and nitrogen are the most common cause of impaired surface waters (Carpenter et al., 1998), and P is the limiting nutrient in freshwater ecosystems (Schindler, 1977). As the limiting nutrient, it is P that controls primary productivity in freshwater systems such as lakes. EPA and New Hampshire Department of Environmental Services (DES) guide watershed planners to use water quality models to estimate P loading into watersheds. Two such models were examined for this study: SWAT (Soil and Water Assessment Tool) and STEPL (Spreadsheet Tool for Estimating Pollutant Load) (Table 1).

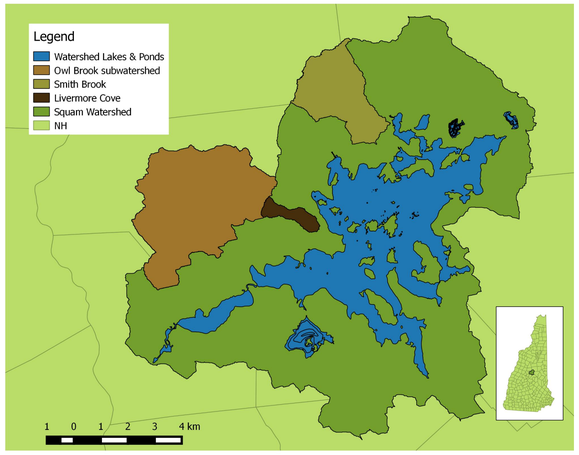
Purpose

This study assesses and analyzes two pollutant loading models, SWAT and STEPL, to see which model is most suitable for meeting EPA and DES watershed plan requirements for determining the relationship between land cover and water quality in the Squam Watershed. It supports the Squam Watershed Plan by providing the framework and technical aspects of the EPA's Nine Elements of a Watershed Plan (EPA, 2008).

Research Questions

- How is land use related to P loading in tributaries in the Squam Watershed?
- How do STEPL and SWAT compare when applied in the Squam Watershed?
- What is the most appropriate application for each of these models when considering watershed management within the state of New Hampshire?

Figure 1: The Squam Watershed



Methods

Study Area

Three tributaries in the Squam Watershed were selected for this analysis (Figure 1). These sites are spread geographically across the watershed, have a range in subwatershed area, exhibit different land cover characteristics, and had an adequate water quality data gathered during the 1999-2000 Squam Tributary Monitoring Study.

SWAT

SWAT is an open-sourced spatially based model accessed through QGIS. SWAT uses slope, land cover and soils to estimate water flow and nutrients loading into watershed basins. The following data was inputted into the model:

- Slope (National Elevation Database):
  - Based on NH planning guidelines, slopes categorized by suitability for development (<15%, 15-25%, >25%)
- Land cover (National Land Cover Database-NLCD): 14 different land cover classes
- Soils (Soil Survey Geographic Database)
- Weather
  - Precipitation (NOAA, Plymouth weather station)
  - Temperature (NOAA, Plymouth weather station)
  - Relative humidity (Hubbard Brook)
  - Solar radiation (Hubbard Brook)
  - Wind speed (Hubbard Brook)

STEPL

STEPL is spreadsheet based model. The only input required to run STEPL is land cover. STEPL has four different land cover classes (urban, forest, pastureland, and cropland) that were generated using the NLCD. The soil hydrologic group was changed to the predominant soil in the Squam Watershed.

Model results were compared with observed results from the 1999-2000 Squam tributary monitoring study (SLA, 2002) and with P studies from Hubbard Brook, a nearby experimental forest that has served as a location for many watershed dynamic studies.

Table 1: Model comparison

	SWAT	STEPL
Weather	Daily weather data from nearby stations	Uses 30-year meteorological average for only precipitation
Land Cover	14 classes	4 classes
Soils	Soil Survey Geographic Database	Soil hydrologic group
Slope	User defined: <15%, 15-25%, >25%	Not included
Created by	US Department of Agriculture	Environmental Protection Agency
Number of publications	470	2
Ease of Use	Complex	Simple
How it works	Spatially based	Spreadsheet based
Output	Daily time step	Long-term annual average P loading

Results

Table 2: Model results

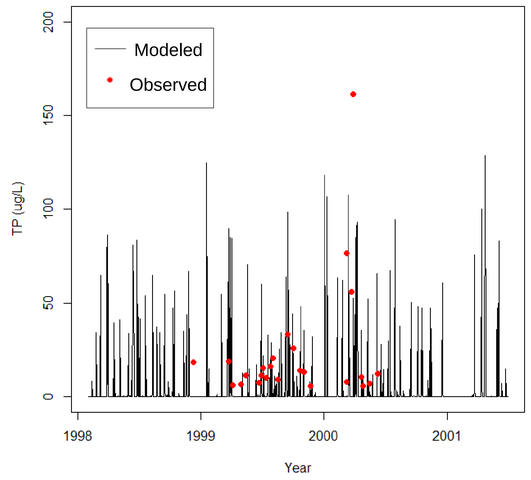
Subwatershed	Model	Annual P loading estimate (kg P/ha/year)
Livermore Cove	SWAT	0.13-0.20
Livermore Cove	STEPL	0.21
Owl Brook	SWAT	0.21-0.36
Owl Brook	STEPL	0.14
Smith Brook	SWAT	0.23-0.37
Smith Brook	STEPL	0.13

Model results were compared with observed results from the 1999-2000 Squam tributary monitoring study (SLA, 2002) and with P studies from Hubbard Brook, a nearby experimental forest that has served as a location for many watershed dynamic studies. Table 2 displays the results of both SWAT and STEPL in the three subbasins of the Squam Watershed. Figure 2 shows the results of the SWAT model compared to observed values in 1999-2000 in the Livermore Cove subwatershed.

Table 3: P studies from Hubbard Brook

Study	Kg P/ha/year
Yanai, 1992	0.02
Dillon & Molot, 1997	0.02-.26
Meyer & Likens, 2016	13
Hobbie & Likens, 1973	0.02-0.04

Figure 2: Livermore Brook P loading



Conclusions

- SWAT and STEPL provide estimates of phosphorus fluxes from Squam's subbasins into the Lakes. STEPL is simple whereas SWAT involves more data for estimating nutrient loading.
- STEPL generates an annual estimate of P loading based on the 30-year meteorological average of precipitation. This ignores the dynamics of any system. STEPL cannot account for variability that comes with storm dynamics.
- SWAT provides a daily estimate of phosphorus flux. Model estimates are created using soil type, slope, land cover, and daily weather data. With this more extensive parameterization, SWAT should be able to better account for phosphorus dynamics and the variability associated with a watershed system.
- Results from running both an uncalibrated SWAT and STEPL generated annual P loading in the Squam watershed that was higher than loading studies from Hubbard Brook (Tables 2 & 3). This observation raises concern about the validity of either model without extensive calibration.
- Phosphorus dynamics are closely tied with storm flow. Hourly flux during storm events could provide more information about how much P moves through the watershed, based on the assumption that most P is entering the system from overland flow.
- We cannot conclude that SWAT is an appropriate model for understanding phosphorus fluxes in the Squam Watershed. To understand phosphorus in the Squam Watershed ***more water quality samples are necessary***. Sampling of tributaries during storm events would be the best approach for providing the necessary data to better determine P load in the watershed.
- Models provide estimates of nutrient fluxes, and provide a framework for understanding how we can reduce nutrient loading into surface water through management. However, at the watershed planning and management level, we are not confirming the accuracy of the fluxes generated by the models because they are not going through rigorous scientific study to calibrate parameters and validate that the models represent a known reality. ***Careful monitoring of tributaries is necessary to both validate and calibrate models and to further understand the watershed system***.

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