USING GEOGRAPHICAL INFORMATION SYSTEM (GIS)-BASED WATERSHED CHARACTERISTICS TO PREDICT STREAM VISUAL ASSESSMENT SCORES

By

ELLEN L. FYOCK

A thesis submitted to the

Graduate School-New Brunswick

Rutgers, The State University of New Jersey

in partial fulfillment of the requirements

for the degree of

Master of Science

Graduate Program in

Environmental Science

written under the direction of

Dr. Christopher Obropta

and approved by

____

____

____

New Brunswick, New Jersey

May, 2008

ABSTRACT OF THE THESIS

Using Geographical Information System (GIS)-based Watershed Characteristics to Predict Stream Visual Assessment Scores

by ELLEN FYOCK

Thesis Director:
Dr. Christopher C. Obropta

The Stream Visual Assessment Protocol (SVAP) was designed as a cost-effective measurement of stream condition that can be used by non-scientific individuals with minimal training. It is intended as a preliminary assessment to determine problem areas where further study is needed. Although the SVAP is a simple assessment, resources are still required to train staff and volunteers on the protocol and to spend days in the field collecting data. However, if existing data can be used to obtain comparable stream health information without requiring field work, the cost associated with these resources can be reduced. This research investigated whether models can be created using previously collected SVAP data and GIS-based watershed characteristics to evaluate stream conditions to eliminate field work.

Using GIS, characteristics such as basin area and stream size were calculated for the areas draining into SVAP assessment locations. Digital data was used to determine characteristics based on land use/cover and soils. Statistical models were created using SVAP data from the Ramapo watershed in northeastern New Jersey. Models significant at $\alpha = 0.10$ or lower were applied to the Wanaque watershed to determine whether the SVAP scores can be predicted in another location. While the regression models generally explained a high amount of variance in the Ramapo SVAP scores, the SVAP scores for Wanaque could not be accurately predicted from the test models.

ACKNOWLEDGMENTS

I would like to thank my advisor, Christopher Obropta, for his continued support. I am grateful to all the members of my committee, Christopher Obropta, John Reinfelder, and Christopher Uchrin, for their time and assistance. A special thank you goes to Rob Miskewitz for his professional guidance throughout the entire process. I would also like to thank Steve Yergeau, Mehran Niazi, Sean Walsh, and Katie Giacalone for their technical knowledge and counsel and all of my other colleagues from the Water Resources Program, including Greg Rusciano, Sandra Goodrow, Cheryl Burdick, Josef Kardos, Elaine Rossi, and Lisa Evrard for their support. I would also like to extend my appreciation to Martha Rajaei for her procedural guidance and support. And finally I would like to thank my friends and family for their encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Rapid assessment protocols are often used as a precursor to in-depth sampling and analysis. These procedures generally provide preliminary information on stream conditions in order to target problem areas that demand more intensive study. The advantages to these assessments are that they are not time-intensive and expend fewer resources than more comprehensive analyses. However they still require work in the field collecting information, as well as subsequent evaluation, and can not replace the in-depth study that follows.

A variety of assessment protocols have been developed that take into account the biological, chemical and physical aspects of stream health. Biological indices focus on aquatic macroinvertebrate and fish communities, which are easily affected by stream contamination or alteration, as indicators of riparian health (Sawyer et al., 2004). Two commonly used methods are the Index of Biotic Integrity (IBI) and the River Invertebrate Prediction and Classification System (RIVPACS) (Gergel et al., 2002). Chemical indices reflect water quality attributes, which are often indicators of point source and non-point source pollution from stormwater runoff. They may include measurements of pH, temperature, turbidity, concentration of metals, or the presence of other polluting chemicals (Ibid). Water quality sampling is more costly and time consuming than rapid assessments (Peterson, 2006).

Physical habitat assessments have become more prevalent over the past 20 years and have become well accepted by state and federal agencies in the United States (Bjorkland et al., 1999). These methods take into account the physical condition of the stream channel and extend into the riparian area (Gergel et. al, 2002). Studies have also begun to expand beyond the immediate riparian zone to include the influence of the surrounding watershed. These studies use aerial imagery, field results and data from geographical information systems (GIS) to measure the effects of land use and other landscape indicators (Gergel et al., 2002).

Regional factors, such as land use, topography and climate, must also be considered, so assessments need to be adapted to local conditions. Unfortunately, this also leads to a variety of assessment methods and collected data (Somerville and Pruitt, 2004). Often, different assessments are measured against each other to evaluate their effectiveness and to determine the most effective set of stream health indicators. Biological assessments are frequently used to determine physical and chemical stressors, as well as the influence from the broader landscape, as macroinvertebrate and fish assemblages are easily influenced by physical habitat conditions, water chemistry and broader watershed characteristics. (Gergel et al., 2002).

LITERATURE REVIEW

Biological Assessments

Sawyer et al. (2004) compared macroinvertebrate habitat to physical habitat, water chemistry and land use in a watershed in Alabama. Physical habitat data was collected using the US EPA's Rapid Bioassessment Protocol and Ohio's Qualitative Habitat Evaluation Index and a comparison of these methods found them to be highly correlated at r = 0.80. Land use percentages were calculated for the catchment area surrounding each sampling point using GIS to delineate the areas. Sawyer et al., (2004) used principal component analysis (PCA) to group variables, and then correlated them with biological data to determine which factors relate to community structure. Macroinvertebrate and fish assemblages were found to correlate the most strongly with physical habitat factors, with stream width and catchment area correlating to EPT richness (r = 0.588). The chemical factors of ammonia and turbidity negatively correlated with macroinvertebrate diversity (r = -0.358). Percent agriculture was the only land use factor that correlated with biological indices, correlating with sensitive EPT taxa (r = 0.452). While Sawyer et al. obtained the physical habitat factors through field study, this research will show how these measurements can also be calculated using hydrologic modeling in GIS.

Kennen (1999) compared macroinvertebrate community to watershed characteristics in order to evaluate relationships with impairment levels. GIS was used to calculate catchment areas and land use was determined from aerial photography. Regression analysis showed that impairment most significantly related to amount of urban land, amount of forested land, and total flow of municipal effluent. The resulting regression equation showed a rank correlation of 0.684. Although the study did not include physical habitat characteristics, it does show that land use data can be use to evaluate stream health.

Kokes et al. (2006) evaluated modeling software that uses reference data from the Czech Republic to predict macroinvertebrate assemblages from watershed characteristics. To use this software, physical stream data were collected from sample sites in the field or obtained using GIS data layers, and forward selection analysis determined the best set of predictors from the data. The predictors selected were: distance from source, stream order, altitude, longitude, latitude, slope and catchment area with a total variance of 85%. These variables would be entered into the system to predict macroinvertebrate assemblages and the results are used to assess stream conditions for water management projects. Again, many of the predictor variables that Kokes et al. collected in the field can also be determined using GIS software.

Conversely, Norton et al. (2002) tested a model that uses biological data to predict physical and chemical stream conditions to simplify how biological indices can be used to support water management initiatives. Principal component analysis narrowed a set of 18 measured physical and chemical variables to 6 factors, and multiple linear regression models were created for each factor. The models for all of the variables were significant at $\alpha = 0.05$ but explained little variance in the data, though the stream chemistry models were stronger than the physical models. The model for the chemical variables TSS, Fe and BOD explained the most variability at $r^2 = 0.34$ and the model for the physical variables riffle quality, substrate quality and embeddedness explained the least, at $r^2 = 0.10$.

Rogers et al. (2002) used macroinvertebrate data to evaluate impacts from chemical and physical factors such as metal contamination and habitat conditions, and to measure the importance of studying these factors together. They found that biological conditions were significantly dependent on physical habitat at a 95% confidence level, with the regression model accounting for 30% of the variability of biological conditions. By adding in the metal contaminant variables the model was able to explain 49% of the variability of macroinvertebrate assemblages. The authors also note that some sites that exhibited high physical habitat scores scored low for biological condition due to metal contamination. This suggests that one kind of data alone may not be sufficient to provide accurate stream conditions, and multiple factors combined may be better indicators of biological stress.

The characteristics that impact stream health are complex and often interrelated (Gergel et al., 2002). These studies have shown that relationships can be found between biological data and physical and chemical stream conditions, in addition to conditions in the broader watershed. These results can be used to streamline how information is collected for preliminary evaluation by focusing on the indicators that require the fewest resources. For instance, in Sawyer et al. (2004) and Kokes et al. (2006), some of the physical habitat factors that correlated most strongly were physical parameters, such as catchment area and stream length or width, which can also be determined using GIS applications. Land use composition, which can also be determined using GIS, was also found to be significant (Sawyer et al., 2004 and Kennan, 1999). Establishing a set of indicators that can be generated in the office would help to simplify the preliminary evaluation.

Predicting Physical and Chemical Habitat Information

Research on whether stream health information can be predicted from broad watershed characteristics such as land use has varied by data type and analytical methods. In an early study using GIS, Richards and Host (1994) compared macroinvertebrate assemblages and physical habitat information with land use data from the U.S. Geological Survey. GIS was used to overlay the land use information with manually delineated watershed boundaries and stream habitat was assessed for the reach above a sample point for each area. Pearson correlations were used to compare stream habitat variables to macroinvertebrate data collected from the sample points to determine which stream characteristics influence the macroinvertebrate structure. The physical habitat variables that had significant correlations ($\alpha <= 0.10$) were embeddedness, substrate size, amount of woody debris, algal abundance, stream width, percent run, percent shade and sinuosity. These habitat variables were then compared to the land use data, and significant correlations were found between embeddedness and percent agriculture ($r = 0.63$, $\alpha = 0.05$), as well as substrate size and urban development ($r = 0.55$, $\alpha = 0.10$). These results support that it is possible to determine relationships between land use data and stream assessment information.

Amis et al. (2007) compared a combination of physical, chemical and biological parameters to land use and land cover variables to create a GIS-based model for predicting stream integrity. Physical characteristics were measured and weighted by the author's determination of relative impact, and include: bank erosion, channel modification, vegetation decrease, flooding, flow modification and bed modification. The study area was delineated based on variations in geology, natural vegetation and altitude, and therefore varied in how many assessment sites were found in each study area. This information was layered with land use and population density data and these parameters were assigned weights based on their perceived impacts. Linear statistical models were created at different spatial scales to determine relationships between the data sets. The models predicted stream integrity from the land use/land cover variables with 77% accuracy. The extent of cover by natural vegetation was found to be a strong predictor at all scales although its contribution to variability was not noted by the authors. One interesting aspect of this study was that the spatial differences were taken into consideration. The land use/land cover data were calculated for various distances from the stream to determine if spatial scale would affect the ability for land use to predict stream health. The results showed that the larger catchment areas were more effective at predicting stream health, supporting that the collective influences of a watershed are representative of stream health.

Snyder et al. (2005) used linear regression to determine whether stream health rankings could be predicted using land use and land cover information. Stream health was determined by a combination of biological data and physical stream data ranked from poor to excellent. Land use and land cover data were calculated using satellite imagery to determine percent tree cover, percent impervious surface area and percent crop. Slope and flow path were also calculated by delineating the watershed in GIS. Logistic regression models showed impervious surface area to be the most important predictive variable, contributing 33% of the variance in stream health conditions. Percent tree cover was also significant at $\alpha = 0.05$ but contributed very little to the variance (2%).

Some studies have focused only on impervious surface data to explore its effects on stream health. Cianfrani et al. (2006) evaluated total impervious area to determine relationships with stream width, depth, pools, sediment size, large woody debris, embeddedness and sinuosity. Impervious area was calculated using aerial photography and categorized based on the percent of impervious area. Stream characteristics were measured in the field. Statistical analysis showed that total impervious area was significantly correlated with the amount of large woody debris ($\alpha = 0.05$), sinuosity ($\alpha = 0.10$) and, at higher levels of impervious area, pool depth ($\alpha = 0.05$).

In another study focusing on impervious surface, Ourso & Frenzel (2003) investigated percent impervious surface as an indicator of urbanization effects on stream health. Impervious area was calculated using satellite imagery and compared to stream habitat, macroinvertebrate, and water chemistry data collected in the field, as well as land use data from satellite imagery and aerial photography. Physical characteristics that correlated with percent impervious area at $\alpha = 0.05$ were sinuosity ($r = -0.844$), percent bank erosion ($r = -0.681$) and percent reach > 20% embedded ($r = 0.587$). Although the specific stream characteristics differed between this study and that of Cianfrani et al., both reflect the effects of runoff from impervious surfaces and reinforce its effectiveness as a predictor of stream health. Ourso & Frenzel question the accuracy of their results due to their low coefficients of determination, attributing them to the subjectivity of erosion and embeddedness assessments and the unreliability of sinuosity measurements for shorter stream segments. However, if the subjectivity of field assessments is questionable, then further study on using GIS-based data to assess streams would be useful.

Some research on GIS as a predictor of stream health focuses only on chemical conditions. Peterson & Urquhart (2005) used GIS to develop a statistical model to predict dissolved organic carbon (DOC) from watershed characteristics that were calculated in GIS or accessed from GIS-based datasets. DOC was related to percent open water, percent wetlands, percent rock type and mean minimum temperature, with 72% of the variability explained by the model. A lack of consistency of the model across study regions indicates that different models may be needed in different geographical areas. The authors were also concerned that the model does not account for changes in water quality due to local factors, such as point sources of organic inputs, which would not be represented in overall land use information. However, the authors were confident in the model's general accuracy when predicting DOC from watershed characteristics.

Zampella et al. (2007) found relationships between GIS-based land use data obtained from the New Jersey Department of Environmental Protection (NJDEP) and chemical data using both graphical analysis and statistical modeling. Using regression analysis at $\alpha = 0.05$, urban land was found to be a significant predictor of pH ($r^2 = 0.75$), specific conductance ($r^2 = 0.68$) and chloride ($r^2 = 0.83$). Upland agriculture was found to be a significant predictor of calcium ($r^2 = 0.65$) and magnesium ($r^2 = 0.67$). The study also stressed the importance of including both urban land and upland agriculture variables to analyze water quality, as each was a major predictor variable for different models.

Santos-Roman et al. (2003) used GIS and remote sensing data to derive variables such as channel length, drainage area, slope, shape, change in land cover, climate and geology in order to develop statistical models that predict water quality conditions in 15 basins in Puerto Rico. Using multivariate analysis and stepwise regression at $\alpha = 0.15$, they found that water quality can be predicted consistently, with the most significant predictor as forest rate of change ($p = 0.0004$). Other significant parameters were percent of limestone ($p = 0.0408$), annual rainfall ($p = 0.0407$) and watershed shape ($p = 0.0208$).

Both of these studies found that using GIS information such as land use, climate and rock type is accurate enough to predict water quality information. However the ability of GIS to predict chemical water quality does not demonstrate its ability to predict other aspects of stream health, such as physical conditions. However, it does provide a foundation that can help target further area of research.

GIS and Statistical Analysis

As these studies have shown, using GIS to analyze data can be an effective way to predict stream assessment results. GIS data is often available from state or other local agencies and is becoming increasingly easier to obtain through free Internet downloads. Additional watershed information can also be generated using hydrological modeling applications in GIS software. GIS-based applications allow the overlay of different categories of data to compare within the same geographical area. For instance, Boggs et al. (2001) were able to use GIS-derived data and data linked in GIS from soil and land use maps to generate the variables needed for a modification of the revised universal soil loss equation (RUSLE) to determine erosion risk on a watershed scale.

Using statistical analysis, relationships between GIS-based data and field-collected data can be investigated. Many studies use correlation analysis to find relationships between datasets, which may suggest a cause and effect, such as a change in water chemistry causing a change in fish population. Another commonly used statistical method is regression analysis, which provides a statistical model that can be used to predict results based on a fixed set of variables. The use of GIS to predict stream conditions should not be considered as an absolute replacement for field work, but it could become an effective way to provide the information used in the early planning stages of restoration projects. If field assessment data can be predicted from GIS-based data, it can reduce the amount of preliminary field work needed.

With the availability of numerous means of assessing stream conditions, it is difficult to determine the most effective method. Dale and Beyeler (2001) examined characteristics that would make effective ecological indicators. Their criteria included that indicators should be easily measured, responsive to stress in a predictable manner, and should integrate key gradients across ecological systems. In 2004 the US Environmental Protection Agency (EPA) and the US Army Corps of Engineers (USACE) co-funded a review of physical stream assessments used across the country (Somerville and Pruitt, 2004). The methods were studied to identify the assessment types most suitable to evaluate stream health based on the conditions set forth by the Clean Water Act. Forty-five methods were reviewed based on a survey that was sent to a combination of regulatory and non-regulatory agencies, and results varied based on complexity of the protocol and relevance to the Clean Water Act. The objectives for the different assessments also varied, and no single variable was commonly cited by the respondents. Some of the qualities suggested by the study as important for a thorough assessment are objectivity, data management and appropriate training.

To use an assessment method for statistical analysis, it would need to be based on quantitative rankings that can be easily compared to other numeric watershed characteristics. The flexibility to measure stream health elements either individually or as part of a total score would be useful in determining the most effective model. As a result this research will examine the Stream Assessment Visual Protocol and its ability to be predicted by watershed characteristics.

Stream Assessment Visual Protocol

The Stream Assessment Visual Protocol (SVAP) was developed by the Natural Resources Conservation Service (NRCS) and the U.S. Department of Agriculture as a rapid visual assessment of stream physical habitat (USDA, 1998). It is intended for non-scientists, such as riparian landowners and local volunteers, and requires minimal training (Bjorkland et al., 1999). Physical stream elements are qualitatively rated from 1-10, and the scores of each element are averaged for an overall score for the site. The assessment scores can be used to find the location of impaired streams to target for further study in the development of conservation and restoration programs.

The effectiveness of the SVAP has been measured in a few studies. During its development, the SVAP was tested at 182 sites and compared to a variety of assessment procedures, including the Index of Biotic Integrity (IBI) and state-specific protocols (USDA, 1998). Most of the procedures compared well with the SVAP, and those that were considered poor were attributed to the level of experience, draft of the protocol in use or regional differences in stream types (Bjorkland et al., 1999). Precision was also tested during development by comparing SVAP results from trained individuals who independently assessed the same reach, and the coefficient of variation was 8.8 percent for the overall stream score (USDA, 1998). In the study by the EPA and USACE, the SVAP was among the assessments reviewed. Although the overall suitability score was low, this was in reference to the Clean Water Act guidelines which are not the intended use for the SVAP evaluations (Gerger et al., 2002). The SVAP scored well in the level of effort and level of expertise categories, which is important in a method designed to be cost-effective and user-friendly.

A study by Ward et al. (2003) evaluated the SVAP in comparison with two other visual assessments: The US EPA's Habitat Assessment Field Data Sheet (HAFDS) and the US Department of Interior Bureau of Land Management's Proper Functioning Condition (PFC) assessment. Data on channel width, depth, slope, substrate and vegetation, was collected on site as the other assessments were conducted. This information was compared to each assessment type using regression analysis to determine how these stream characteristics affect assessment scores, and SVAP scores were found to be affected by entrenchment, slope, substrate size, percent run and canopy. The SVAP correlated well with the HAFDS (r = 0.81), as the elements measured by the two procedures are very similar. The SVAP and PFC had a weaker correlation (r = 0.54), but the scoring method and type of information assessed for the PFC differed more. Rosgen Stream Morphological Classifications were also determined for each reach and compared to the assessments to determine if stream class affects the outcome of the assessment. Results showed that there is a difference in average SVAP score for different stream class, and care should be taken when comparing SVAP scores from different stream environments.

One study by Teels et al. (2006) used the SVAP and IBI to measure the response to riparian buffer establishment. Drainage areas were delineated for each sample site and overlaid with GIS land use. Both methods were successful in showing an improvement in stream health following the buffer establishment. As part of the study, IBI scores were compared to the SVAP, which was considered to represent "local" stream conditions, and to land use, which was considered to reflect broader stream conditions. SVAP scores were shown to correlate strongly with IBI scores (r = 0.70) while land use showed weaker negative correlations with IBI scores (r = -0.38). The results indicate that GIS-generated land use data may lack the detail needed to evaluate biological stream conditions as effectively as stream assessments. But as some correlation was found, this does not eliminate GIS as a means to collect preliminary assessment data in order to target locations for more detailed assessments.

Studies that compare stream assessments based on numerical ranking have shown that their results correlate strongly and the SVAP is no exception (Bjorkland et al., 1999 Ward et al., 2003, Teels et al., 2006). Physical stream assessment and GIS-based data have also been effective in predicting other stream health conditions (Sawyer et al., 2004, Kennen, 1999, Kokes et al., 2006). Few studies have used GIS data to predict physical stream assessment information. Amis et al. (2007) developed a statistical model to predict stream health characteristics from land use data, however the variables used were not part of any particular assessment valuation so the reusability for specific management initiatives would be limited. It should also be noted that this study took place in South Africa, so the available data, as well as regional conditions, would be very different from those studied in the US. Snyder et al. (2005) predicted a specific set of stream health rankings which were restricted to classifications of excellent, good, fair, poor and unknown, and which may be to vague to be effective in aiding decisions when targeting restoration.

This research will test the hypothesis that statistical models can be developed to predict specific stream assessment rankings from GIS-based data that can be reused on a regular basis to support management strategies for stream health restoration. This study will evaluate a set of variables found in GIS-based data sets or that can be generated in GIS using hydrological modeling applications. Because landscape metrics have been correlated to stream habitat conditions at both the catchment and riparian levels (Gergel et al., 2002), variables will include land use characteristics for the immediate drainage area as well as the collective upstream areas for each assessment location. This data will be compared to SVAP data that was collected in the field, and regression analysis will be used to create statistical models that will be tested to predict SVAP scores from another watershed. If the SVAP data can be reasonably predicted by the models, this research will demonstrate that preliminary stream conditions can be assessed using GIS analysis of watershed characteristics and can streamline the preliminary stream assessment process.

METHODS

Study Area

The area selected for this study was the 238 square mile Watershed Management Area 3 (WMA3) in New Jersey. WMA3 is part of the Passaic River Basin, which spans northern New Jersey and parts of New York. Approximately 80 percent of WMA3 is in the Highlands Physiographic Province. The watershed consists of 58% forest, 25% urban and 17% water and wetlands based on 2002 NJDEP Land Use/Land Cover data. The population of WMA3 is over 244,000 residents, according to 2000 Census data.

WMA3 consists of four watersheds: Pequannock, Pompton, Ramapo and Wanaque (Figure 1). For this study, the 48 square mile Ramapo watershed was evaluated to obtain the data to build the statistical models. The Wanaque watershed, which is 79 square miles, was used for the data to validate the models. The Ramapo watershed is 44% forest which makes up most of the land to the west of the Ramapo River, 40% urban, generally found to the east of the river, and 11% water and wetlands. The Wanaque watershed is mostly undeveloped with 70% forest land, 14% urban and 15% water and wetlands. Both rivers feed into the Pompton River with drainage areas extending into New York.

Assessment Data Collection

Assessment data were collected by the Rutgers Cooperative Research & Extension Water Resources Program and TRC Omni Environmental Corporation as part of an overall restoration plan for WMA3. Streams were assessed using the SVAP between March 2002 and September 2002. These assessments are performed by visually studying segments of the stream and rating up to 15 riparian separate elements by assigning them a numerical rating. The number of elements evaluated may vary as not all are applicable at each assessment site. The individual elements are averaged for a total assessment score to prioritize further action. Low scores indicate impacted conditions and high scores generally represent a healthy stream; the numerical definition of low and high may vary based on location and study goals (NRCS 1998).

SVAP scores were determined for 69 reaches in the Ramapo watershed and 81 reaches in the Wanaque watershed. Physical stream elements were rated from 1-10, and the scores of each element were averaged for an overall score for the site. GPS coordinates were taken for each SVAP location which allowed the data to be imported into ArcGIS as point locations in a shape file for spatial GIS analysis.

Individual elements that were assessed were bank stability, barriers to fish movement, canopy cover, channel condition, hydrologic alteration, instream fish cover, invertebrate habitat, nutrient enrichment, presence of pools, riffle embeddedness, riparian zone and water appearance. Manure presence was not evaluated as the watershed is less than 1% agricultural and no known livestock use occurs near the streams. Salinity was also not applicable as the streams in WMA3 are freshwater. Macroinveterbrate data were not collected as part of this study. Some of the sites did not assess all of the elements based on applicability at each site. For instance, riffle embeddedness is only measured if riffles are present, and canopy cover is not evaluated if the active reach width is greater than 50 feet. Table 1 shows the number of reaches evaluated for each element.

Digital Data Collection

The Ramapo watershed was delineated using the EPA's Better Assessment Science Integrating point and Nonpoint Sources (BASINS) software system, with ESRI's

ArcView 3.3, in order to determine the subbasin area that drains to each SVAP point. Digital elevation models (DEMs) and stream network data were obtained from the NJDEP for the NJ portion (NJDEP Web site, 2007) and from the New York State Department of Conservation (NYSDC) for the NY portion (CUGIR Web site, 2007). The Ramapo SVAP points were used as the outlets to generate 69 separate drainage basins (Figure 2). The following data were generated for each basin: area, cumulative area (sum of upstream basin area), reach length, reach width, reach depth and basin slope. Because assessments are limited by access to the stream, the SVAP data points were not evenly dispersed throughout the watershed and drainage areas ranged from 0.1 hectares to 831 hectares.

The drainage basins were overlain with land use and land cover information (NJDEP 2002 Land Use/Land Cover for NJ, NJDEP Web site, 2007; and USGS 1990 Land Use/Land Cover for NY, CUGIR Web site, 2007) to determine land use type using Anderson Level I classifications (NJDEP, 2007), as well as impervious surface areas, for each drainage basin. Calculated land use variables include forest area, urban area, wetland/water area, percent forest, percent urban, percent wetland/water, impervious surface area, and percent impervious surface. Agriculture and barren land data were not used in the analysis as they make up less than 1% of the study area. A STATSGO soils data layer included in BASINS was used to obtain the drainage basin hydrologic soil group and erodibility factor. In order to use them in statistical analysis, hydrologic soil group letters were converted to numbers, where A = 1, B = 2, C = 3 and D = 4. The land use and soils data were spatially intersected, and SCS curve numbers were calculated for each basin based on Anderson Level II classifications and the dominant hydrologic soil group for each basin. Composite variables for the entire drainage area for each basin were also included by calculating the total upstream area in the watershed that drains into each lower basin. A total of 26 basin characteristics were determined. Table 2 shows the variables with their sources.

Statistical Analysis

Principal Component Analysis

Principal component analysis (PCA) was used to determine if any similarities exist between the basins that would affect the ability to predict stream conditions. PCA is a statistical method that transforms variables into a new set of components, the first of which explains the most variance in the data with each successive component explaining a smaller portion of the remaining variability (Kim et al., 2006). A scatter plot of the first two components can visually show groupings between the data (Burns et al., 1997). These clusters can indicate similar traits between variables that can be useful in data analysis.

The Ramapo data for each subbasin were imported into the SAS statistical software application for PCA analysis. The results showed that the first component accounted for 66.25% of the variance and the second component accounted for 26.03%. The first two components were graphed on a scatter plot, with the first component on the x axis and the second component on the y axis. The plotted results showed two clear groupings, with 7 points scattered outside of these clusters. Analysis of the clusters revealed that one set of points consisted of basins that were primarily comprised of urban land use (% urban > 28) and the second cluster consisted of basins primarily comprised of forest land use (% forest > 50). Points not found within either cluster were either comprised of a greater water/wetland area (%water/wetland > 20) or were significantly small (less than 0.01% of watershed area). Figure 3 shows the results of the PCA plot. The groupings indicated that similar traits may exist between basins with the same predominant land use. As a result, the basins were also split into two data sets to create separate regression models based on predominant land use type: basins with greater than 50% forest (n = 31) and the basins with greater than 28% urban (n = 31). The seven outliers from the PCA analysis were excluded from these models.

Regression Analysis

Multiple linear regression analysis was used to develop models to predict SVAP scores from watershed characteristics. The models have the general form:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{p-1} X_{p-1} + \varepsilon_i \qquad (1)$$

where Y_i are the SVAP scores, β_0 is the y-intercept, $\beta_{1, \ldots\ldots,} \beta_{p-1}$ are the regression coefficients of the p explanatory variables, $X_{1, \ldots\ldots,} X_{p-1}$ are the values of the p explanatory variables, and ε_i is the error that is unexplained by the model (SAS Institute, 2003; Norton et al., 2002). Using SAS, the SVAP score was entered as the dependant variable, and the watershed characteristics were entered as independent variables. Because the number of independent variables cannot exceed the number of observations, or basins with SVAP data, some of the models were built without including all of the watershed characteristics. For those models, different combinations of basin characteristics were tried until the best fit was found. Backward elimination determined the best set of predictor variables, including only variables that were significant at $\alpha = 0.05$. If no predictor variables were found to be significant at $\alpha = 0.05$, a significance level of $\alpha = 0.10$ was used instead.

Initial model runs using the Wanaque data resulted in predictions of abnormally large positive and negative SVAP scores, far outside the range of 1 to 10. This could be a result of the fact that some of the predictor variables were in units with a broad range of areas and lengths. For instance, the Ramapo drainage areas ranged from 2 to 831 hectares, and the cumulative drainage areas ranged from 31 to 12234 hectares. The Wanaque drainage areas ranged from 0.05 to 6363 hectares, with cumulative drainage areas ranging from 18 to 19984 hectares. To normalize the disparity in variables the units were converted to percentages.

The drainage basin area and cumulative area variables were converted to percentages of the watershed area, and the reach length and cumulative length variables were converted to percentages of the total stream length in the watershed. Other area-based variables (impervious surface area, composite surface area, forest area, urban area and water/wetland area) were removed because percentage variables already existed for these factors. The data were recalculated for both the Ramapo and Wanaque watersheds.

Principal component analysis was conducted on the new Ramapo variable calculations to see if any changes occurred. While the groupings were less distinct in the new analysis, there was still a separation between the more forested drainage areas and those with more urban area (Figure 4). The new data were divided based on this new analysis, with one set for % Forest > 41 (n = 37) and one set for % Urban > 43 (n = 35). Because the area data were normalized, there were no outliers due to drainage area size. In addition, because the results were not clearly clustered the new analysis did not isolate the basins with higher wetland area. As a result, all drainage basins are included in the new analysis. Since there was less of a distinction between the forested and urbanized basins, four basins were included in both the Forest and Urban analyses.

Model Prediction Ability

Drainage basins were delineated for 81 SVAP data points in the Wanaque watershed (Figure 5), and watershed characteristics were determined using the same methods as with the Ramapo data. These results were used to run the regression models to determine whether they can predict the data for another watershed.

The Nash-Sutcliffe model efficiency coefficient was used to assess the ability of the model to predict SVAP scores. The model predictions and SVAP scores from the Wanaque watershed were compared using the Nash-Sutcliff equation:

$$E = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} \left(O_i - \bar{O}\right)^2} \qquad (2)$$

where O_i is the observed SVAP score, P_i is the score predicted by the model, and $\bar{O}$ is the mean observed SVAP score (Krause et al., 2005). Efficiencies can range from 1 to -∞. An efficiency of E = 1 represents a prediction that perfectly matches the observed data. An efficiency of E = 0 signifies that the predictions are as accurate as the mean of the SVAP scores. Efficiencies less than zero indicate that the mean of the observations would be a better predictor than the model. Observed versus predicted results were plotted for each model and a 1:1 line was applied to represent an efficiency of E = 1.

RESULTS

Ramapo Regression Analysis

Regression models were created for each SVAP element as well as the score averaged from the categories, and all models were significant at $\alpha = 0.05$. The coefficient of determination (R^2) for these models ranged from 0.16 to 0.93. Regression models were also created for the data that were split into two sets based on the PCA results. The R-squared results for these 39 regression models are shown in Table 3, where **n** is the number of observations based on the number of assessments conducted. Statistical models were created using the coefficients derived from the regression analysis. A list of the regression model equations is found in Table 4.

Model Prediction Ability

Data from the Wanaque watershed were inserted into the regression models to determine whether they can predict SVAP scores in another watershed. As with the Ramapo data, these were arranged into three sets: all basins, greater than 50% forest, and greater than 28% urban. Because the Wanaque watershed is more forested than the Ramapo watershed (70% vs. 44% respectively), there were more than double the number of basins used in the Forest equations (maximum of n = 62) than in the Urban equations (maximum of n = 23), however some of the basins are included in both sets of models because they have large percentages of both forest and urban land.

Due to the abnormally large values predicted from the original regression models, new regression analysis was conducted using the normalized Ramapo variables to generate a new set of prediction models. All but five of the models were significant at $\alpha = 0.05$. Three of those were significant at $\alpha = 0.10$ and the regression analysis did not result in any significant coefficients for the Riffle Embeddedness scores for all basins and basins > 28% urban. The new R-squared values are shown in Table 5 and the model equations are shown in Table 6.

The revised Wanaque data were inserted into the new regression models. While these results were less erratic than the models that were run before the data were normalized, there were still some models that resulted in predictions outside the range of SVAP scores from 1 to 10. A Nash-Sutcliffe model efficiency coefficient (E) was calculated for the predicted and observed SVAP scores. The results are shown in Table 7. All E values are less than zero, indicating that the models were unable to predict the SVAP scores more accurately than the mean of the observed SVAP scores. The observed versus predicted plots can be found in Figure 6. Models with E values less than -3 were not included in the graphical analysis, eliminating most of the models with results that predicted results outside of the scoring range of 1 to 10.

DISCUSSION

The negative efficiency results show that the regression models were not successful in predicting the SVAP scores. Two of the regression models did not have any significant predictor variables and 22 models predicted results outside of the SVAP score range of 1-10. The models that included all basins were better at predicting the scores, with most *E* values between 0 and -2, two at about -7 and one low efficiency value of -127. The forest and urban datasets on the other hand each had several *E* values that were lower than -100.

The scatter plots for most of the models indicate that they tend to under-predict the high SVAP scores and over-predict the low scores. For instance, if we look at the model with the highest *E* value and use it to target for assessment only the areas with predicted scores of 6.0 or lower, our assessment would neglect four locations with lower actual scores of 4.5, 5.5 and 6.0 (see Figure 7). Increasing the predicted score to 8.0 to account for over-estimated predictions would result in the assessments of all locations, even those with scores up to 10.0. When predicting stream health conditions from a model, some under-prediction is acceptable because the main drawback would be that some sites might be assessed with favorable conditions. Although resources would be expended unnecessarily, there would still be fewer resources spent than if all sites were investigated as if there was no model used. However, the drawback from over-prediction is much more substantial, because the result would be that sites that are impacted would not be studied. If impaired sites are neglected, not only would potential sources of impairment be ignored, but resources could also be wasted in areas that may not be the primary source of stress. To avoid these consequences, more accurate predictions would be needed before these models could be useful in reducing SVAP assessments.

Several factors were considered in an effort to determine why the models were not effective in predicting accurate SVAP scores. In a study by Peterson & Urquhart (2006), regression model testing indicated that data from some geographical areas fit the model better than others, suggesting that regional differences could affect the reusability. However their model was tested across the entire state of Maryland. The Wanaque watershed is adjacent to the Ramapo watershed and similar in physical characteristics, so there should be limited geographical differences that would influence the ability to predict assessment scores.

In general, the models that were created using more observations predicted better than those that were derived using a smaller sample size. For instance, the models created using all of the basins (n = 69) were more accurate at predicting SVAP scores than those using only forest basins (n = 37) or those using only urban basins (n = 35). The SVAP elements that had data for every basin (Average Score, Bank Stability, Channel Condition, Riparian Zone) also predicted better than those with fewer observations (Instream Fish Cover, Invertebrate Habitat, Nutrient Enrichment, Riffle Embeddedness), which in most cases was contrary to the high R^2 results in the regression models (see Tables 3 & 5). This could be the result of overfitting the model, where the sample size is too small in relation to the amount of predictor variables, resulting in a model that gives overly optimistic model results yet fails to replicate results with other datasets (Babyack, 2004). According to Babyack, an accurate model requires a minimum of 10 observations per predictor variables, which in this study would require 210 observations. However, the Ramapo dataset only contained a maximum of 69 observations and in some cases the input variables had to be reduced so as to not exceed the number of observations. This inverse relationship between numbers of observations and model R-squared values is shown in Figure 8. This overfitting could explain why some of the model R^2 results were so high, especially for the smaller datasets, and why these models were much less successful in predicting the SVAP scores with the test data.

The optimistically high regression model R^2 results could also be due to the intercorrelation between some of the variables (Richards, 1931). According to Richards, if the intercorrelation between independent variables is high, for instance if they consist of factors that add up to greater than 95 percent, they will result in unusually high coefficients. As a result, the outputs of the model could vary much more than if only one of the intercorrelated variables were used. The Ramapo and Wanaque land use data calculated for the analysis includes percentages forest, urban and water/wetland that in most subbasins add up to 100 percent. The redundant inclusion of all three of these variables in the analysis may be a cause of the inability to generate models that can successfully predict new data.

To establish whether the models represented a reliable relationship between the SVAP data and the predicted variables, regression analysis was also performed on the Wanaque dataset (n = 81), as well as a combination of the Ramapo and Wanaque data (n = 150) for the Average SVAP Score data. If the Ramapo data is representative of the larger watershed, the same predictor variables should consistently appear in the other models. In Norton et al. (2002), regression models were created to predict physical and chemical conditions from macroinvertebrate habitat. Regression models were built from a complete data set (n = 179) but in order to test the data a separate set of regression models were created out of a random subset of the data (n = 143) with the remaining data used to test the models (n = 36). These models were not published, however the authors state that the results between the two sets of models were similar. For the Ramapo model the predictor variables were: composite width, composite depth, and percent forest. The Wanaque model also included percent forest as a predictor, but no others were selected. The model for the combined Ramapo and Wanaque dataset selected percent area and percent urban as significant predictor variables. Because each model produced different sets of predictor variables, the validity of these models as accurate predictors is questionable.

Few studies that attempt to create statistical models to predict stream conditions provide any validation that the model is able to successfully predict other data samples. Amis et al. (2007) developed a statistical model that predicted 79% of the variance in stream health conditions based on watershed characteristics from only 22 basins. Their test model also compared the predictions with the same observations used to create the data models, so it is difficult to know whether their model would be successful with another set of data. Snyder et al. (2005) also created a regression model to predict stream health rankings but did not test the model on another dataset. However, they explained the model variance using an adjusted R^2 value, which estimates how well the model would predict a new set of data (Babyak, 2004). Their model explained the variation in the predicted rankings 35% of the time, with impervious surface area accounting for 33% of the variation.

Although Kokes et al. (2006) developed modeling software with variables that explain 85% of the variation in macroinvertebrate assemblages, they do not produce any test results, although they do state that the model has been in use since 2001. Other studies using regression analysis to predict macroinvertebrate populations from other stream and watershed characteristics have generally not attempted to develop a reusable equation to predict other populations. Kennen (1999) also created regression equations to predict macroinvertebrate community impairment from land use and water quality data, but only to establish relationships between the data and not to reproduce results on other data sets. Rogers et al. (2002) created a regression model that explained 49% of the variance in biological conditions but only with the goal of showing the combined effects of physical and chemical data, and not to reproduce the prediction results.

Studies focusing on predicting water quality data using regression analysis tend to include more support for reusability, but with varying results. Zampella et al. (2007) developed a model from 25 sample sites using data for "altered" land use, or % urban and % agriculture, and the model explained 80% of the variability of water quality data. They tested the model using sample data from 18 other sites, and found no significant change ($\alpha = 0.05$) between the observed and predicted data except for the pH values, which were generally predicted higher than the observed values. Peterson & Urquhart (2006) created a regression model that explained 72% of the variation in DOC concentrations from percent water, wetland vegetation, rock type and temperature. They tested the model by generating 3083 predictions for the entire state of Maryland and analyzing the distribution of the results. They found that the model seemed to under-predict the DOC, as 90% of the predictions were low according to Maryland Department of Natural Resources standards, and it should be used as a conservative estimate rather than a predictor of absolute results. Santos-Roman et al. (2003) analyzed water quality data using regression analysis, however the model equations only calculate scores that classify the watersheds into land-use based water quality categories from the cluster analysis, and do not actually predict any specific conditions.

Despite the fact that several studies have attempted to create statistical models to predict stream health conditions, few have been able to accomplish more than establishing relationships between different types of characteristics. Although the Ramapo regression models did not successfully predict the Wanaque SVAP scores, the models were evaluated to see which variables contributed the most variance in SVAP score by reviewing the partial R^2 generated in SAS. For instance, the Average Score model for all basins explained 39% of the variation in SVAP scores, and 25% was explained by the composite reach width parameter. Composite reach depth and percent forest, the other significant variables in the model, explained only 6% and 8% of the variance respectively. Other variables that contributed to more than half of the variance of scores for all basins were cumulative area for Barriers to Fish Movement (34%), erodability for both Instream Fish Cover (33.5%) and Pools (20.4%), and cumulative reach length for Water Appearance (39.2%). For the models where Forest > 41%, composite percent impervious surface contributed to more than half of the variation in the Average Score (32.2%) and Water Appearance (36.6%) models. In the regression models with Urban > 43%, cumulative reach length contributed to most of the variation in the Water Appearance model (42%).

Other studies have identified similar parameters that can be used as indicators of stream health. Sawyer et al. (2004) also found reach width and subbasin area to be related to stream health in their study of macroinvertebrate composition. Snyder et al. (2005) established percent impervious surface as a significant variable in predicting stream health rankings, and in studies by Cianfrani et al. (2006) and Ourso & Frenzel (2003), impervious surface was correlated strongly with stream habitat conditions.

Although the models were not able to predict specific SVAP scores, the variables that were selected in the regression analysis reflect a logical relationship with the stream conditions that were assessed. Considering the models with the two highest efficiencies, bank stability and riparian zone, we can determine a relationship between the parameters included in the model and the SVAP element (Table 6a). The predicted bank stability score would be negatively influenced by an increase in percent urban area, supporting the fact that an increase in urban land can cause an increase in runoff entering the stream which can lead to bank erosion (Corbett, 1997). The predicted riparian zone score is positively related to percent forest, which considers that the reduction of forest land can include the area adjacent to the stream. This demonstrates that the relationship of the variables in the models can be used as general indicators of stream conditions which could aid in the prioritization of assessment locations.

CONCLUSION

Although the regression models appeared to explain a high amount of the variability in the SVAP scores, they were not successful in predicting scores from another data set. Some SVAP elements were predicted more accurately than others, but the high R-squared results could be a result of overfitting the models due to small dataset sizes. Few studies have been able to create models that can successfully predict stream health conditions on new sets of data, however many use model results as general indicators of stream health. While this would not allow the elimination stream health assessments, it can help in setting priorities of which sites to evaluate first.

Recommendations for Future Study

Future study should include increasing the data set size to prevent overfitting of the model. The goal of maintaining a 10 to 1 ratio between observations and predictor variables was recommended by Babyak (2004) so evaluating the predictive strength of 21 watershed characteristics would require at least 210 sample sites for regression analysis, plus additional sites to test whether the model can predict other datasets. However, breaking up the sites into smaller categories, such as high percent forest and high percent urban, would require an even greater initial sample size.

Further analysis should also be conducted in geographically different areas, such as a region with dominant agriculture use, to determine if the results would improve based on those conditions. Since no significant agricultural areas were in the study area for this research, the effect of agricultural land use on stream assessments could not be determined. The presence of agriculture can dramatically affect several of the SVAP scores, such as nutrient enrichment due to the presence of excess phosphorus, riffle embeddedness due to an increase in sediment from erosion and runoff, and riparian zone due to a lack of riparian vegetation around the stream banks. The SVAP was originally intended to be used in agricultural areas (USDA, 1998) so additional study can determine whether better predictions can be produced under these conditions.

REFERENCES

Amis, M.A., Rouget, M. Balmford, A., Thuiller, W., Kleynhans, C.J., Day, J., Nel, J., 2007. Predicting Freshwater habitat integrity using land-use surrogates. *Water SA*. 22(2): 215-221.

Babyak, M.A., 2004. What you see may not be what you get: A brief, nontechnical introduction to overfitting in regression-type models. *Psychosomatic Medicine.* 66: 411-421.

Bjorkland, R., Pringle, C.M., Newton, B., 2001. A Stream Visual Assessment Protocol (SVAP) for riparian landowners. *Environ. Monit. Assess.* 68: 99-125.

Boggs, G., Devonport, C., Evans, K., Puit, P., 2001. GIS-based rapid assessment of erosion risk in a small catchment in the wet/dry tropics of Australia. *Land Degrad. Develop.* 12: 417-434.

Burns, W.A., Mankiewicz, P.J., Bence, A.E., Page, D.S., Parker, K.R., 1997. A principal-component and least-squares method for allocating polycyclic aromatic hydrocarbons in sediment to multiple sources. *Environ. Toxicol. Chem.* 16(6): 1119-1131.

Cianfrani, C.M., Hession, W.C., Rizzo, D.M., 2006. Water imperviousness impacts on stream channel condition in southeastern Pennsylvania. *J. of the American Water Resources Association.* 42(4): 941-956.

Corbett, C.W., Wahl, M., Porter, D.E., Edwards, D., Moise, C., 1997. Nonpoint source runoff modeling: A comparison of a forested watershed and an urban watershed on the South Carolina coast. *J. of Experimental Marine Biology and Ecology.* 213(1): 133-149.

Cornell University Geospatial Information Repository (CUGIR), 2007, http://cugir.mannlib.cornell.edu.

Dale, V.H., Beyeler, S.C., 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators.* 1: 3-10.

Gergel, S.E., Turner, M.G., Miller, J.R., Melack, J.M., Stanley, E.H., 2002. Landscape indicators of human impacts to riverine systems. *Aquat. Sci.,* 64: 118-128.

Kennen, J.G., 1999. Relation of Macroinvertebrate Community Impairment to Catchment Characteristics in New Jersey Streams. *J. of the American Water Resources Association.* 35(4): 939-955.

Kim, M., Kennicutt II, M.C., Qian, Y., 2006. Molecular and stable carbon isotopic characterization of PAH contaminants at McMurdo Station, Antarctica. *Marine Pollution Bulletin.* 52: 1585-1590.

Kokes, J., Zahradkova, S., Nemejcova, D., Hodovsky, J., Jarkovsky, J., Soldan, T., 2006. The PERLA system in the Czech Republic: a multivariate approach for assessing the ecological status of running waters. *Hydrobiologia.* 566: 343-354.

Krause, P., Boyle, D.P., Base, F., 2005. Comparison of different efficiency criteria for hydrological model assessment. *Advances in Geosciences*. 4: 89-97.

New Jersey Department of Environmental Protection (NJDEP), 2007, http://www.nj.gov/dep/gis.

Norton, S.B., Cormier, S.M., Smith, M., Jones, R.C., Schubauer-Berigan, M., 2002. Predicting levels of stress from biological assessment data: Empirical models from the eastern Corn Belt plains, Ohio, USA. *Environ. Toxicol. Chem.* 21: 1168-1175.

Ourso, R.T., and Frenzel, S.A., 2003. Identification of linear and threshold responses in streams along a gradient of urbanization in Anchorage, Alaska. *Hydrobiologia*. 501: 117-131.

Peterson, E.E., and Urquhart, N.S., 2006. Predicting water quality impaired stream segments using landscape-scale data and a regional geostatistical model: A case study in Maryland. *Environ. Monit. Asses.* 121: 615-638.

Richards, C., and Host, G., 1994. Examining land use influences on stream habitats and macroinvertebrates: A GIS approach. *Water Resources Bulletin*. 30(4): 729-738.

Richards, H. I., 1931. Analysis of the spurious effect of high intercorrelation of independent variables on regression and correlation coefficients. *J. of the American Statistical Association.* 26(173): 21-29.

Rogers, C.E., Brabander, D.J., Barbour, M.T., Hemond, H.F., 2002. Use of physical, chemical, and biological indices to assess impacts of contaminants and physical habitat alteration in urban streams. *Environ. Toxicol. Chem.* 21(6): 1156-1167.

Santos-Roman, D.M., Warner, G.S., Scatena, F., 2003. Multivariate analysis of water quality and physical characteristics of selected watersheds in Puerto Rico. *J. of the American Water Resources Association.* 39(4): 829-839.

SAS Institute, 2003. Regression Analysis. *SAS/STAT User's Guide.* Cary, NC.

Sawyer, J.A., Stewart, P.M., Mullen, M.M., Simon, T.P., Bennett, H.H., 2004. Influence of habitat, water quality, and land use on macro-invertebrate and fish assemblages of a southeastern coastal plain watershed, USA. *Aquatic Ecosystem Health & Management*, 7(1): 85-99.

Snyder, M.N., Goetz, S.J., Wright, R.K., 2005. Stream health rankings predicted by satellite derived land cover metrics. *J. of the American Water Resources Association.* 41(3): 659-677.

Somerville, D.E. and B.A. Pruitt. 2004. Physical Stream Assessment: A Review of Selected Protocols for Use in the Clean Water Act Section 404 Program. September 2004, Prepared for the U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division (Order No. 3W-0503-NATX). Washington, D.C. 213 pp.

Teels, B.M., Rewa, C.A., Myers, J., Aquatic condition response to riparian buffer establishment. 2006. *Wildlife Society Bulletin.* 34(4): 927-935.

Ward, T.A., Tate, K.W., Atwill, E.R., Lile, D.F., Lancaster, D.L., McDougald, N., Barry, S., Ingram, R.S., George, H.A., Jensen, W., Frost, W.E., Phillips, G.G., Markegard, Larson, S., 2003. A comparison of three visual assessments for riparian and stream health. *J. of Soil and Water Conservation.* 58(2): 83-88.

U.S. Department of Agriculture's Natural Resources Conservation Service, 1998. Stream Visual Assessment Protocol. NWCC-TN-99-1. National Water and Climate Center, Portland, OR.

U.S. Department of Agriculture's Natural Resources Conservation Service, 1986. Urban Hydrology for Small Watersheds. 210-VI-TR-55, Second Ed., Conservation Engineering Division, Washington, DC.

Zampella, R.A., Procopio, N.A., Lathrop, R.G., Dow, C.L., 2007. Relationship of land-use/ land-cover patterns and surface-water quality in the Mullica River basin. *J. of the American Water Resources Association.* 43(3): 594-603.

SVAP Element	Number of Sites Evaluated
Bank Stability	69
Barriers to Fish Movement	43
Canopy Cover	45
Channel Condition	69
Hydrologic Alteration	62
Instream Fish Cover	39
Invertebrate Habitat	24
Nutrient Enrichment	41
Pools	52
Riffle Embeddedness	25
Riparian Zone	69
Water Appearance	68

Table 1. SVAP elements measured in the Ramapo watershed.

Variable	Source
Drainage basin Area	BASINS delineation results
Cumulative Area	BASINS delineation results
Reach Length	BASINS delineation results
Cumulative Reach Length	Sum of upstream reach lengths
Reach Width	BASINS delineation results
Composite Reach Width	Length-weighted average of upstream reach widths
Reach Depth	BASINS delineation results
Composite Reach Depth	Length-weighted average of reach upstream depths
Curve Number	SCS Curve Number table (from USDA TR-55) using hydrologic soil group from soils layer and Anderson Level II classifications from NJDEP and NYSDC land use/land cover data. Results were area-weighted and summed for each drainage basin.
Composite Curve Number	Area-weighted sum of upstream curve numbers
Erodibility Factor	EPA STATSGO soils layer data
Composite Erodibility	Area-weighted sum of erodibility factor
% Impervious Surface	NJDEP and NYSDC land use/land cover data
Composite % Impervious Surface	Composite impervious surface area divided by total cumulative area
Impervious Surface Area	NJDEP and NYSDC land use/land cover data
Composite Impervious Surface Area	EPA
Hydrologic soil group	From STATSGO soils component layer data, converted to numbers 1-4 and area weighted for each drainage basin
Composite Hydrogroup	Sum of area-weighted hydrologic soil group numbers
Slope	BASINS delineation results
Composite Slope	Area weighted average of slope
Forest Area	NJDEP and NYSDC land use/land cover data
Urban Area	NJDEP and NYSDC land use/land cover data
Water/Wetland Area	NJDEP and NYSDC land use/land cover data
% Forest	Forest Area divided by Basin Area
% Urban	Urban Area divided by Basin Area
% Water/Wetland	Water/Wetland Area divided by Basin Area

Table 2. Predictor variables measured in the regression models and how they were obtained for analysis.

	All Basins		% Forest > 50		% Urban > 28	
	n	R^2	n	R^2	n	R^2
SVAP Average Score	69	0.5847	31	0.9513	31	0.6877
SVAP Bank Stability	69	0.1612	31	0.8434	31	0.6569
SVAP Barriers to Fish	43	0.6144	20	0.9957	17	0.9155
SVAP Canopy Cover	45	0.3138	19	0.9999	20	0.9999
SVAP Channel Condition	69	0.2851	31	0.9350	31	0.9293
SVAP Hydrologic Alteration	62	0.4692	29	0.9973	15	0.9940
SVAP Instream Fish Cover	39	0.9282	19	0.9977	28	0.9999
SVAP Invertebrate Habitat	24	0.8715	11	0.9999	9	0.9802
SVAP Nutrient Enrichment	25	0.6944	15	0.9723	19	0.9781
SVAP Pools	52	0.8847	27	0.8199	19	0.9999
SVAP Riffle Embeddedness	25	0.8871	13	0.8933	10	0.9999
SVAP Riparian Zone	69	0.2969	31	0.2503	31	0.7012
SVAP Water Appearance	68	0.5362	30	0.9736	31	0.3307
All models are significant at $\alpha = 0.05$.						

Table 3. R-squared values for the regression models developed using the Ramapo data before it was normalized.

Parameter Coefficients	Regression equations by SVAP element												
	Average Score	Bank Stability	Barriers to Fish Mvmnt	Canopy Cover	Channel Condition	Instream Fish Cover	Hydro-logic Alteration	Inverte-brate Habitat	Nutrient Enrich-ment	Pools	Riffle Embedd-edness	Riparian Zone	Water Appear-ance
Intercept	4.95524	7.25993	14.6782	7.96321	2.02079	-75.8857	5.60959	4.63892	-6.3917	14.02	6.84361	5.43578	6.31817
Subbasin Area							0.00215						
Cumulative Area			-0.00557	-0.0003							-0.0059		
Reach Length						-0.00074					-0.00119		
Cumulative Reach Length	-0.0003							-0.00157		0.0001	0.000659		-0.0001
Reach Width	2.40139		8.29189			4.98154		19.56541			0.52274		0.33283
Composite Reach Width	-2.7445				-0.26704	-5.61412	-1.56266	-19.66561		-4.8081			
Reach Depth	-32.269		-130.564			-110.85		-368.87608	-1.9298				
Composite Reach Depth	36.5106					125.443	20.2845	402.85084		75.596			
Curve Number							0.0362				-0.06036		
Composite CN							-0.04715			-0.0241			
Erodability	6.2047					-12.5885		68.72414					
Composite Erodability					12.84472			-58.17884		-15.12	8.61885		
Impervious Surface (%)		-0.034						-0.09154		-0.055	0.09624		
Composite IS (%)						0.22091			0.10126		-0.18806		
Impervious Surface (acres)	0.01352		0.04768			0.0175				0.0293	0.01564		
Composite IS (acres)			-0.00543			-0.00723							
Hydrologic soil group						-2.12331	-2.92662		-2.8785	1.4185	2.09028		
Composite Hydrogroup							3.10094		6.89564	-1.9562			
Slope							0.02111			-0.0226	-0.03511		-0.032
Composite Slope													
Forest Area	4.1E-07										7.55E-07		
Urban Area	-1E-06		-3.4E-06			-2.8E-06		-0.00000255		-3E-06			
Water/ Wetland Area						8.7E-06		0.00000926	2.1E-06				
% Forest	1.15045				2.4676	93.1611			2.82301			2.64521	3.96198
% Urban						91.0955					-5.02449		
% Water/ Wetland						91.367	4.01133	-15.39449					

Table 4a. Regression model equations for all basins using the Ramapo data before the unit-based variables were normalized percentages.

Parameter Coefficients	Regression equations by SVAP element		
		Forest Average Score	Urban Average Score
	Intercept	141.39693	10.95588
	Subbasin Area	0.01263	
	Cumulative Area	-0.0155	-2.9E-04
	Reach Length		
	Cumulative Reach Length		
	Reach Width	20.6634	
	Composite Reach Width	-20.40127	
	Reach Depth	-268.56013	
	Composite Reach Depth	275.27165	-6.0324
	Curve Number	0.09983	
	Composite CN	-0.17956	
	Erodability		30.03071
	Composite Erodability	19.15028	-20.04969
	Impervious Surface (%)	-1.02234	
	Composite Impervious Surface (%)		
	Impervious Surface (acres)	0.1921	0.01296
	Composite Impervious Surface (acres)	-0.0095	
	Hydrogroup		
	Composite Hydrogroup	6.50186	-2.82065
	Slope	0.03177	0.06352
	Composite Slope		
	Forest Area		0.00000178
	Urban Area	-0.00002253	-1.7E-06
	Water/ Wetland Area		
	% Forest	-153.02805	
	% Urban	-122.45869	
	% Water/ Wetland	-155.85964	

Table 4b. Regression model equations for basins with % Forest > 50 and % Urban > 28 using the Ramapo data before the unit-based variables were normalized as percentages.

Parameter Coefficients	Regression equations by SVAP element												
	Average Score	Bank Stability	Barriers to Fish Mvmnt	Canopy Cover	Channel Condition	Instream Fish Cover	Hydro-logic Alteration	Inverte-brate Habitat	Nutrient Enrich-ment	Pools	Riffle Embedd-edness	Riparian Zone	Water Appear-ance
Intercept	5.89429	7.4062	12.78903	7.95808	2.66916	0.33666	7.46588	-79.4118	-1.30615	8.46918	N/A	5.57943	6.02236
Subbasin Area (%)									31.73733				
Cumulative Area (%)			-3.14184	-3.18857					12.80145				
Reach Length (%)										-33.4462			
Cumulative Reach Length (%)								-117.394		46.00714			-12.35
Reach Width								20.68503		-4.25242			0.45333
Composite Reach Width	-0.8753				-0.30895		-0.34869	-31.0525					
Reach Depth								-410.952	-24.5436	66.37307			
Composite Reach Depth	13.8625							626.9561	18.52966				
Curve Number									0.0659				
Composite CN									-0.08838				
Erodability Factor			-16.7097			-12.306				-13.7449			
Composite Erodability					9.4107								
Impervious Surface (%)													
Composite Impervious Surface (%)						0.14316		0.19682	0.23028				
Hydrologic soil group						-3.57722			-5.7936				
Composite Hydrogroup						6.12116			7.74154				
Slope (%)									0.03146				-0.0308
Composite Slope (%)									-0.03839				
% Forest	1.39776				2.54068	3.54477		77.34496	7.04071			2.36902	3.90849
% Urban		-1.5665						68.07802					
% Water/Wetland					5.13		4.9685	68.55001					

Table 6a. Regression model equations for all basins using the Ramapo data after the unit-based variables were normalized as percentages.

	All Basins		% Forest > 41		% Urban > 43	
	n	R^2	n	R^2	n	R^2
SVAP Average Score	69	0.3926	37	0.4219	35	0.5219
SVAP Bank Stability	69	0.1704	37	0.6194	25	0.3707
SVAP Barriers to Fish	43	0.4883	26	0.9712	21	0.9999
SVAP Canopy Cover	45	0.3213	24	0.9273 (α = 0.10)	23	0.9320
SVAP Channel Condition	69	0.3390	37	0.5019	35	0.3718
SVAP Hydrologic Alteration	62	0.2293	34	0.6463 (α = 0.10)	30	0.6114
SVAP Instream Fish Cover	39	0.6423	21	0.9998	19	0.9999
SVAP Invertebrate Habitat	24	0.8490	13	0.9999	21	0.9427
SVAP Nutrient Enrichment	25	0.8201	20	0.9992	23	0.9751
SVAP Pools	52	0.4133	32	0.1811	22	0.9991
SVAP Riffle Embeddedness	25	N/A	16	0.9982	10	N/A
SVAP Riparian Zone	69	0.2382	37	0.1916 (α = 0.10)	35	0.5894
SVAP Water Appearance	68	0.5557	36	0.5316	35	0.5540
All models are significant at α = 0.05 unless indicated otherwise. Items marked N/A did not have any significant coefficients remaining in the model.						

Table 5. R-squared values for the regression models developed using the Ramapo data after the unit-based variables were normalized as percentages.

Parameter Coefficients	Regression equations by SVAP element												
	Average Score	Bank Stability	Barriers to Fish Mvmnt	Canopy Cover	Channel Condition	Instream Fish Cover	Hydro-logic Alteration	Inverte-brate Habitat	Nutrient Enrich-ment	Pools	Riffle Embedd-edness	Riparian Zone	Water Appear-ance
Intercept	6.23897	7.05069	-1050.85	26.30672	0.91809	673.2326	-5.94129	14.3311	4725.008	3.5101	142.17299	3.74294	5.56054
Subbasin Area (%)			575.1923	626.5963		274.5605		561.149					
Cumulative Area (%)	4.67408		-400.797	-447.207	3.30143	-827.538	12.15878	-920.48					
Reach Length (%)	-41.578	-51.7478	-548.566	-515.213	-47.9222	-175.252	-33.73953	-322.13	-57.132				-49.8345
Cumulative Reach Length (%)			455.9337	499.5897		215.4604		-25.107	26.78854				
Reach Width						41.33974	-0.36051	90.8253	-4.58947	0.4988	-18.20166		
Composite Reach Width						-32.2155		-75.108	6.54316	-6.5356	36.07591		
Reach Depth		10.3363	-107.04	-105.898		-497.848		-1442.5	67.94868		305.78713		5.444
Composite Reach Depth		-12.2801	105.7353	95.67352		438.0379		1360.65	-91.0907	96.668	-571.5264		
Curve Number	0.02715		-0.38647	-0.41913		0.1466	-0.02817		-0.02506		-0.16156		0.03347
Composite CN	-0.0451		0.28983	0.33287	-0.03936	-0.28647		-0.2523			-0.13171		-0.04747
Erodability Factor			61.77823	26.23682		-23.5152	-14.14882				109.51155		
Composite Erodability	13.9725	21.223	-116.285	-52.7075	15.26764	40.19623	34.46405	30.1752			-254.0744	14.7696	15.2379
Impervious Surface (%)			0.78355			-0.85059	-0.17489		-0.33936			-0.107	
Composite Impervious Surface (%)	-0.2242	-0.25493		0.68183		0.63275			0.19185		1.87901		-0.2709
Hydrologic soil group		3.98442	27.21121	28.65412	2.18807		2.87471		3.51189		12.98311		
Composite Hydrogroup		-5.2738	-49.3364	-40.2543				2.3125	-3.99753		-37.12271		
Slope (%)			-0.11286	-0.14191		0.18654			0.05594		0.07293		
Composite Slope (%)				0.07848			0.05597		-0.01065		0.07906		
% Forest			1156.869	38.40574		-668.899			-4716.03				
% Urban			1147.439	33.8033	-6.05868	-641.812			-4707.98				
% Water/Wetland			1121.288			-652.219	5.35971		-4711.55				

Table 6b. Regression model equations for basins with % Forest >41 using the Ramapo data after the unit-based variables were normalized as percentages.

Parameter Coefficients	Average Score	Bank Stability	Barriers to Fish Mvmnt	Canopy Cover	Channel Condition	Instream Fish Cover	Hydro-logic Alteration	Inverte-brate Habitat	Nutrient Enrich-ment	Pools	Riffle Embedd-edness	Riparian Zone	Water Appear-ance
	Regression equations by SVAP element												
Intercept	10.0867	5.24474	115.729	57.3509	8.57382	60.29012	9.45614	-250.386	0.25653	142.436	N/A	2.36289	5.11709
Subbasin Area (%)			-114.462	483.856				72.1553					
Cumulative Area (%)		-42.629	-459.228				-26.82529		69.0501	-137.904			
Reach Length (%)				-423.83		120.7586			42.4364	-139.265			
Cumulative Reach Length (%)		43.3347	-221.948	68.2544		-4.59846	24.82281	-230.032		612.299			-13.525
Reach Width			124.9293	-147.28				37.13054	-3.51019	-62.0031			0.48964
Composite Reach Width	-0.9437		-139.996	178.283	-0.54891	3.07999		-51.138		57.9469			
Reach Depth			-2722.14					-704.948		1152.17			
Composite Reach Depth	13.3903		3427.672			-39.0671		995.7501		-1250.33			
Curve Number			-0.18691			0.04555			0.19561	-0.09878			
Composite CN			-0.49753			-0.36033			0.18833	-0.4544			
Erodability Factor			-49.7565	-125.34	17.46455	-8.62767			-44.2594	-176.181		19.5871	
Composite Erodability		13.2689	33.16464	48.2279					42.7677	307.019		-16.823	
Impervious Surface (%)				0.30433		0.11519				0.59448			
Composite Impervious Surface (%)			0.33765	-0.4882		-0.23415		0.41067	1.10498	-0.76906			
Hydrologic soil group	-1.676	-1.2436	3.70777	-2.8107	-3.00689	-6.00748	-4.41304		-7.64183	-6.6788		-3.5058	
Composite Hydrogroup			33.14834			17.87922	2.84882	13.75237				4.72796	
Slope (%)			0.05804	0.08718						-0.45055			
Composite Slope (%)			0.83712	0.20836		-0.34851		0.08757	0.32787	0.16627		-0.0885	
% Forest	4.08357		-297.869	-20.71	5.17851	-48.1201	5.28778	199.0632		-70.3549		6.81111	4.38368
% Urban			-261.062	-34.495		-58.4227		196.69	-15.5974	-108.624			
% Water/Wetland			-271.896			-57.4853		182.8803	-13.5364	-167.755			

Table 6c. Regression model equations for basins with % Urban >43 using the Ramapo data after the unit-based variables were normalized as percentages.

	All Basins *E*	% Forest > 41 *E*	% Urban > 43 *E*
SVAP Average Score	-0.309	-1.707	-0.601
SVAP Bank Stability	-0.206	-2.566	-0.931
SVAP Barriers to Fish	-0.208	-77.499	-90.841
SVAP Canopy Cover	-0.270	-116.296	-76874.606
SVAP Channel Condition	-0.458	-0.791	-0.457
SVAP Hydrologic Alteration	-0.388	-1.984	-1.114
SVAP Instream Fish Cover	-0.704	-935.117	-12.865
SVAP Invertebrate Habitat	-127.213	-6102.408	-18.889
SVAP Nutrient Enrichment	-6.995	-17766.772	-74.913
SVAP Pools	-6.955	-4.173	-163.967
SVAP Riffle Embeddedness	N/A	-718.303	NA
SVAP Riparian Zone	-0.081	-1.391	-1.616
SVAP Water Appearance	-1.467	-1.879	-1.403
Items with N/A did not have models.			

Table 7. Nash-Sutcliffe model efficiency coefficient (*E*) for observed vs. predicted SVAP scores. A negative *E* value signifies that the mean SVAP score is better at predicting SVAP scores than the model.

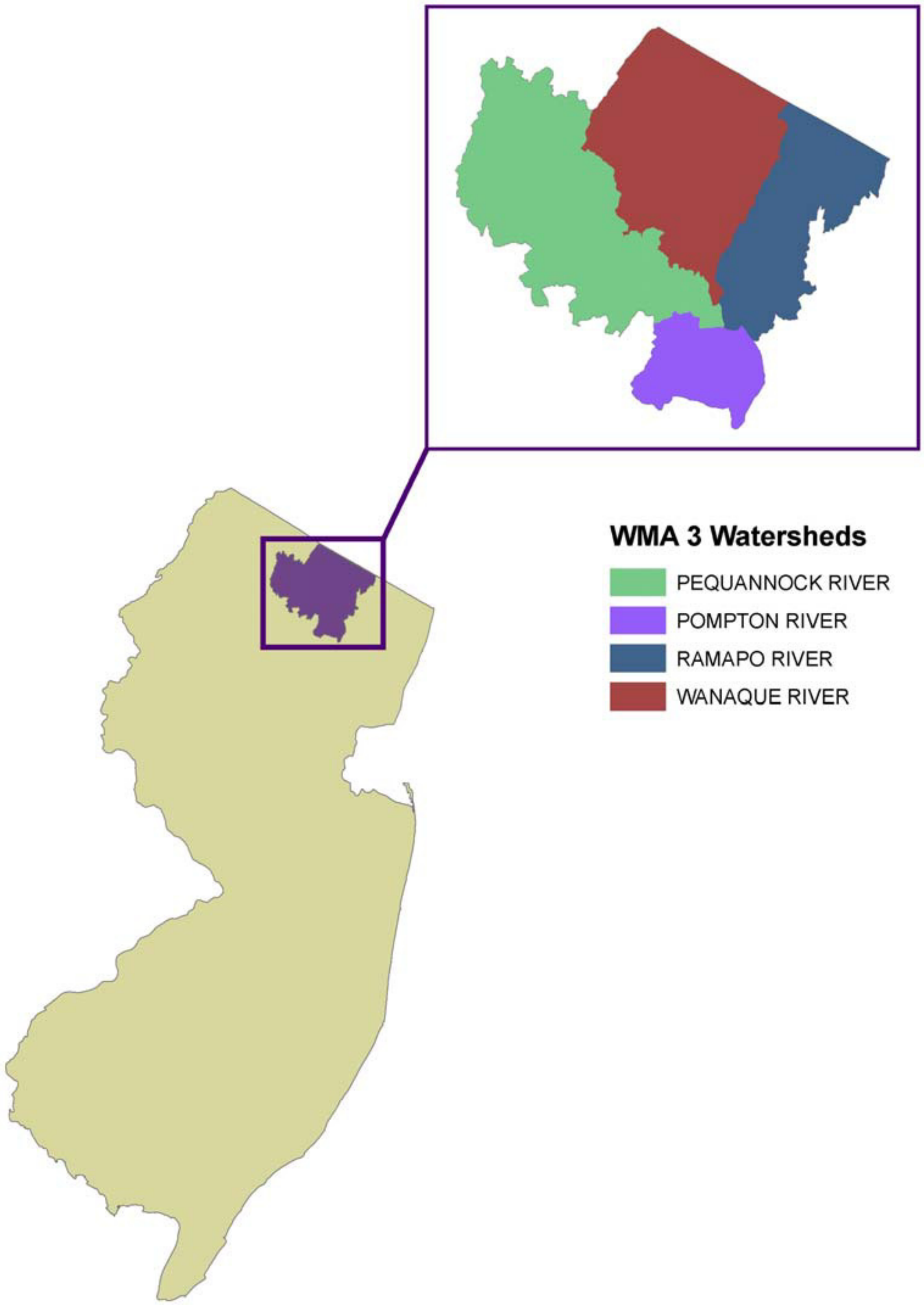


Figure 1. Location of Watershed Management Area (WMA) 3

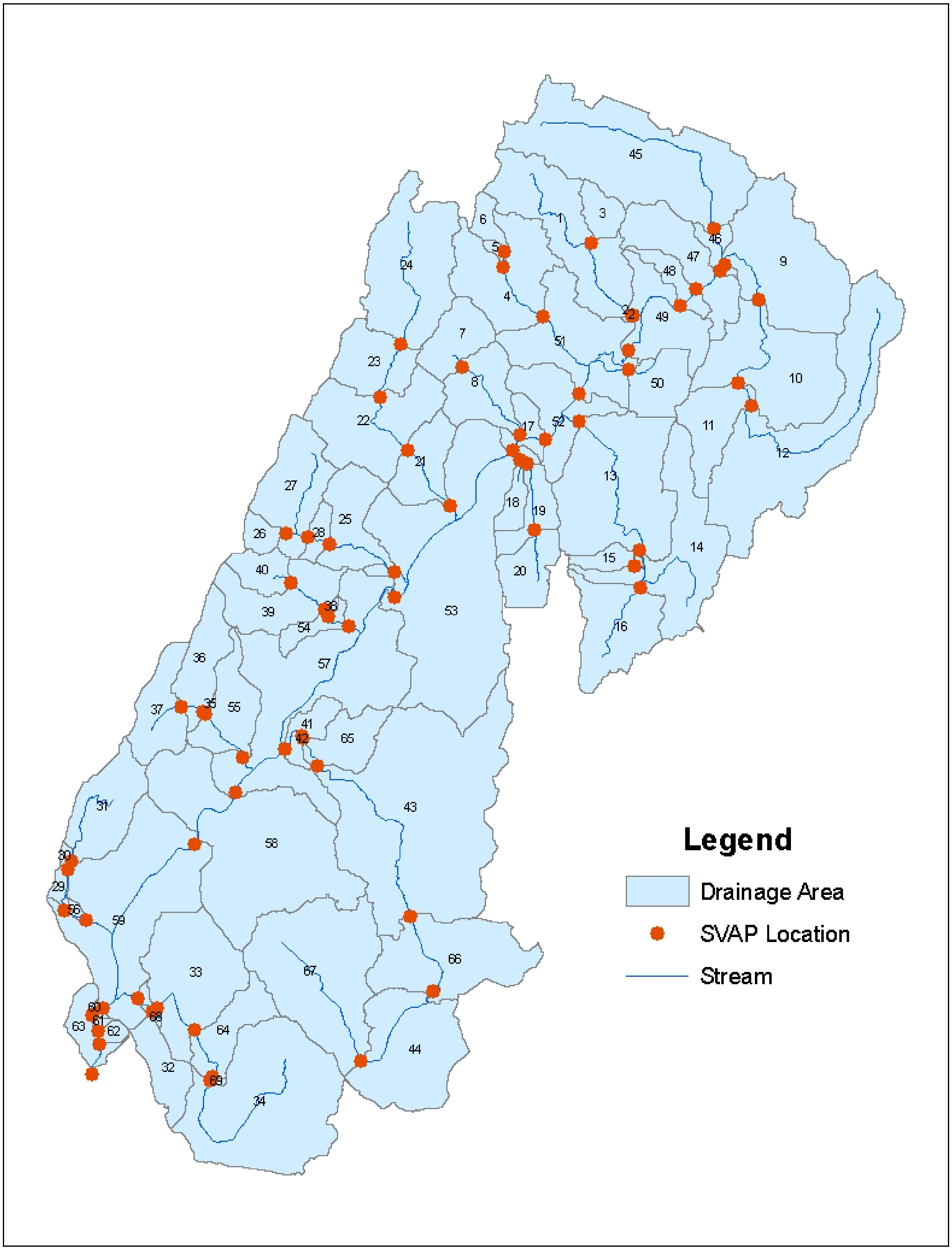


Figure 2. Map of Ramapo watershed and drainage area for each SVAP location.

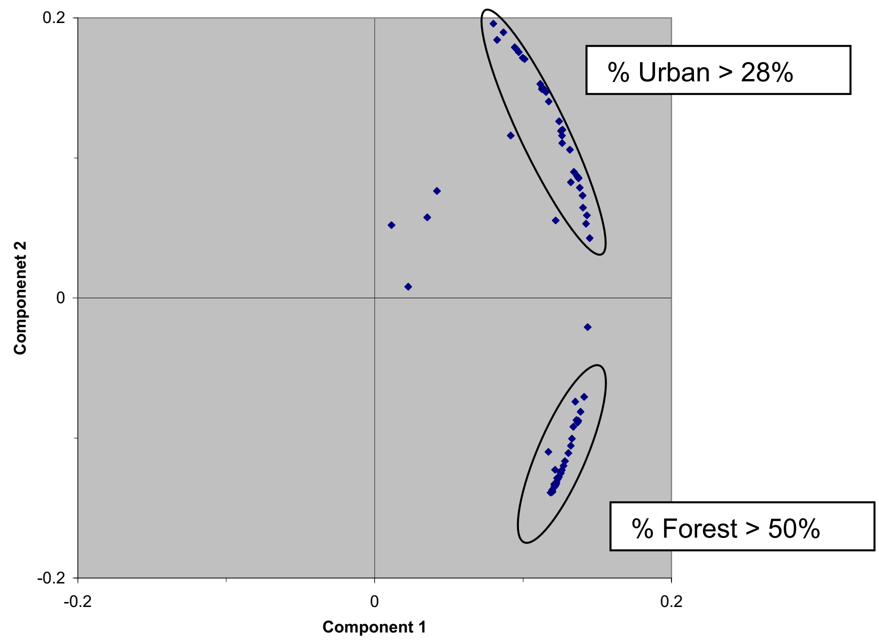


Figure 3. Principal Component Analysis: Ramapo subbasins before unit-based data were normalized as percentages. Results revealed subbasin clusters based on percentage of land use.

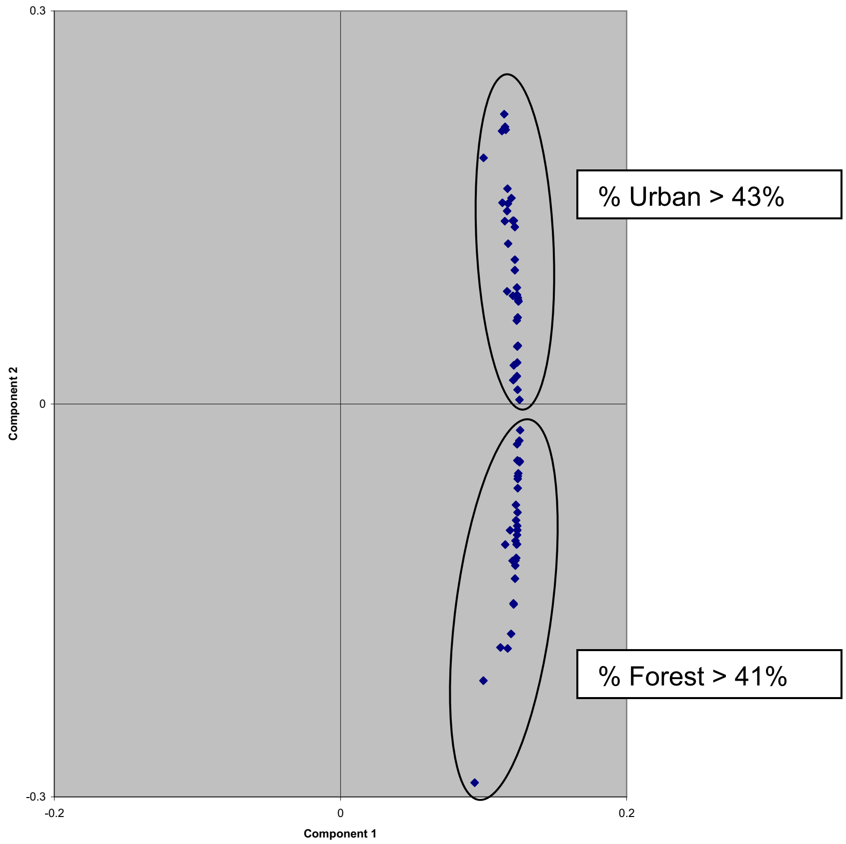


Figure 4. Principal Component Analysis: Ramapo subbasins after unit-based data were normalized as percentages. Subbasin clusters based on percentage of land use were still apparent.

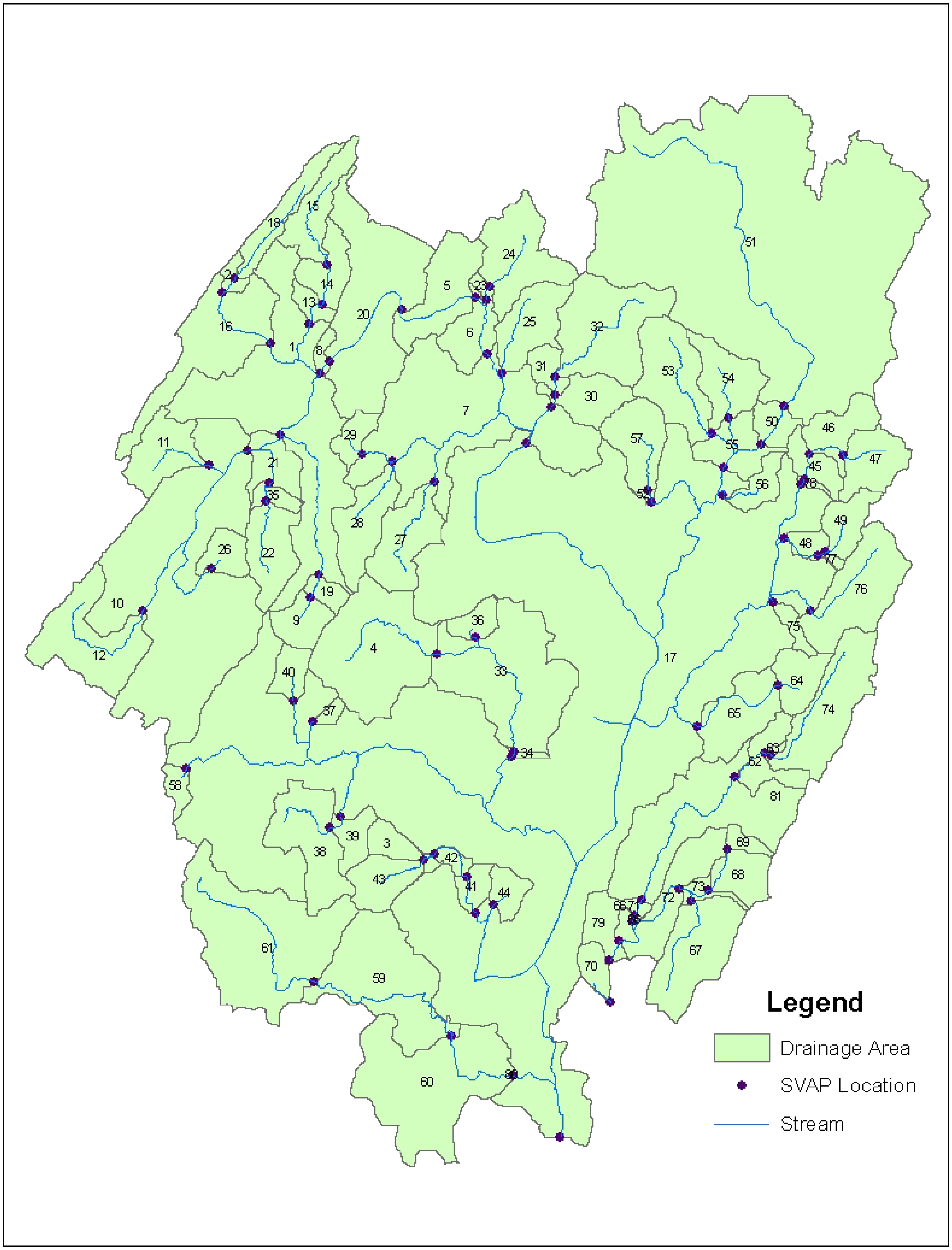


Figure 5. Map of Wanaque watershed and drainage area to each SVAP location.

Figure 6a. Plot of predicted versus observed Average SVAP scores for Wanaque watershed.

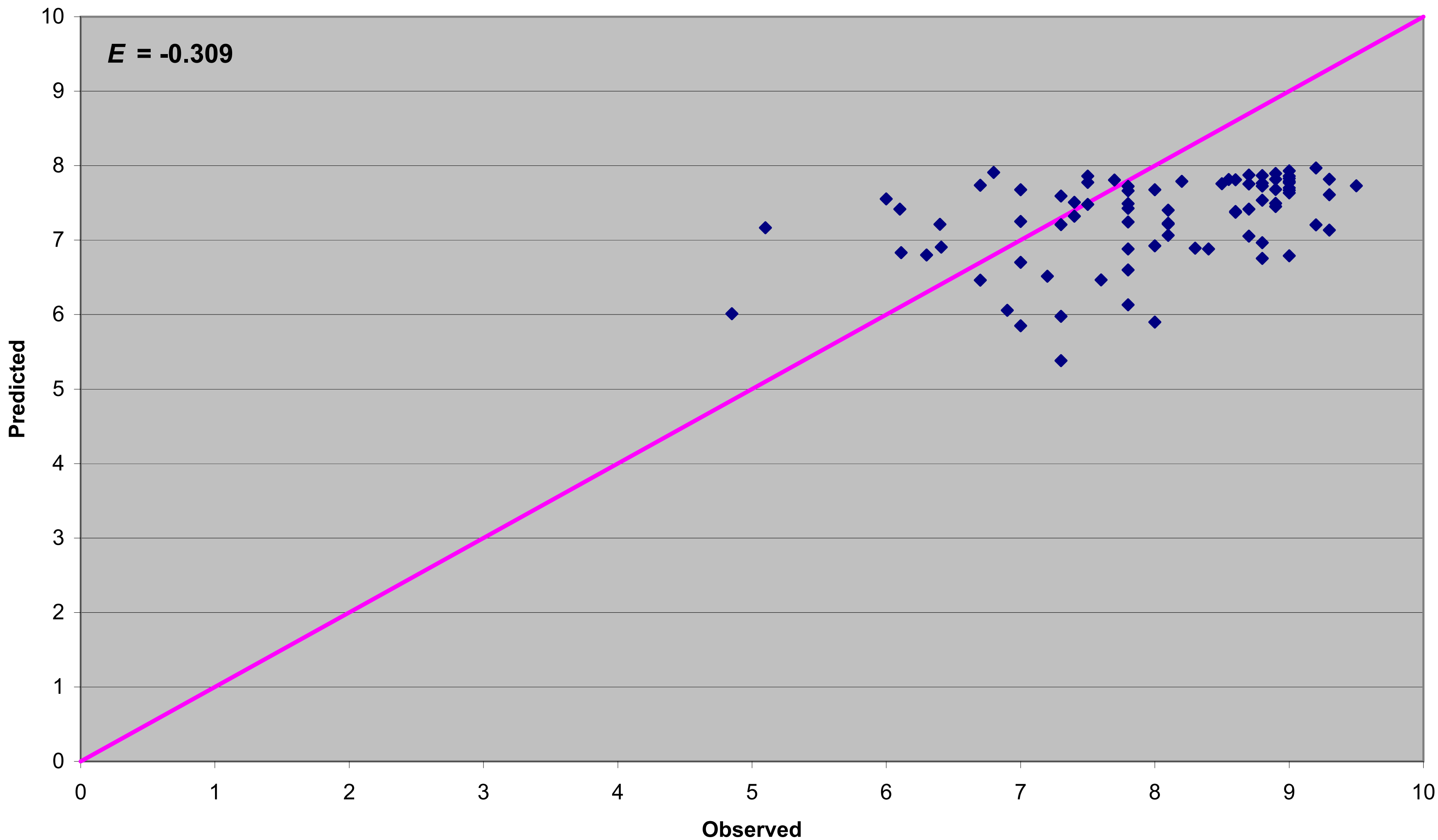


Figure 6u. Plot of predicted versus observed Water Appearance SVAP scores for Wanaque basins > 43% urban.

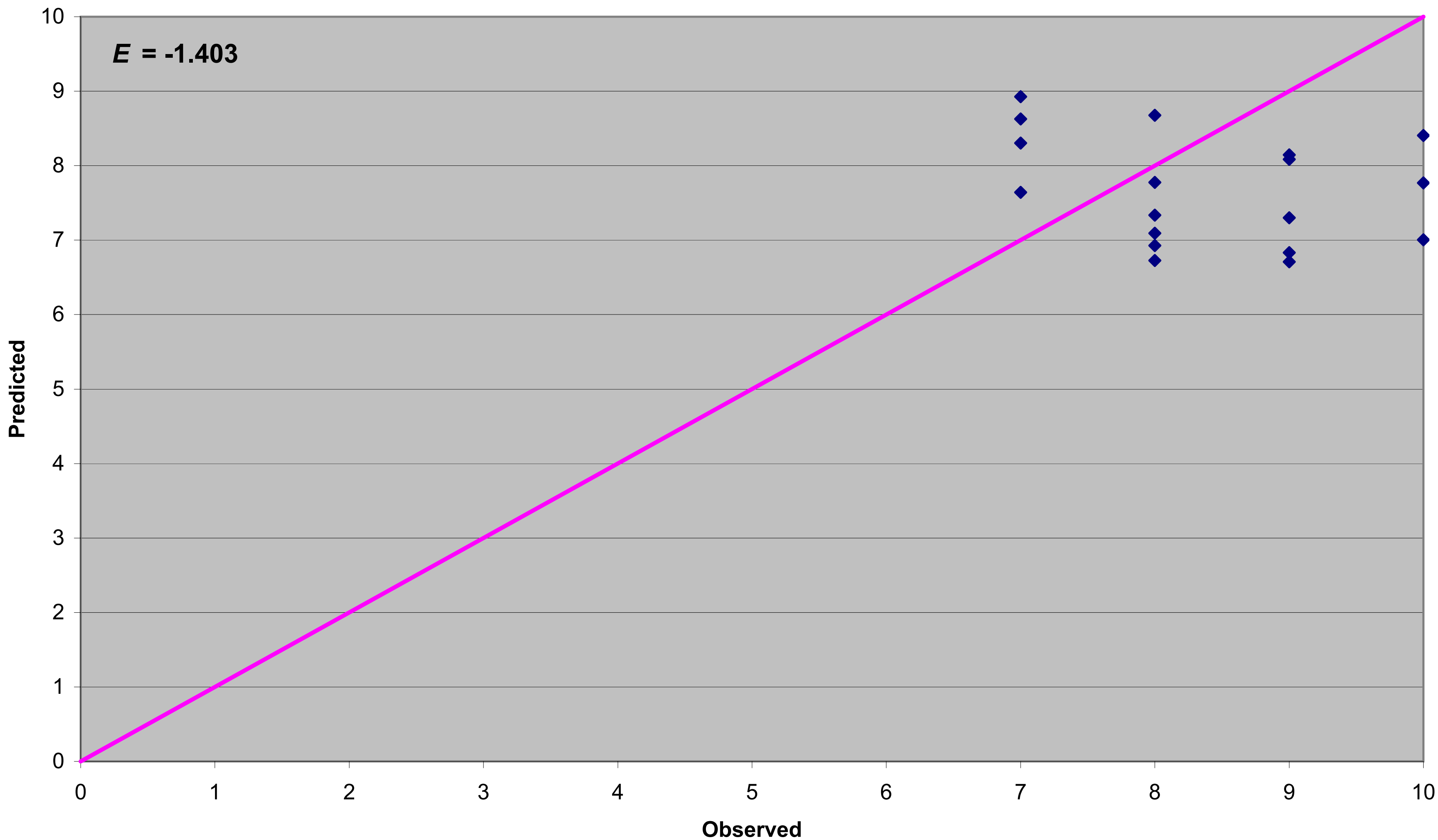


Figure 6b. Plot of predicted versus observed Bank Stability SVAP scores for Wanaque watershed.

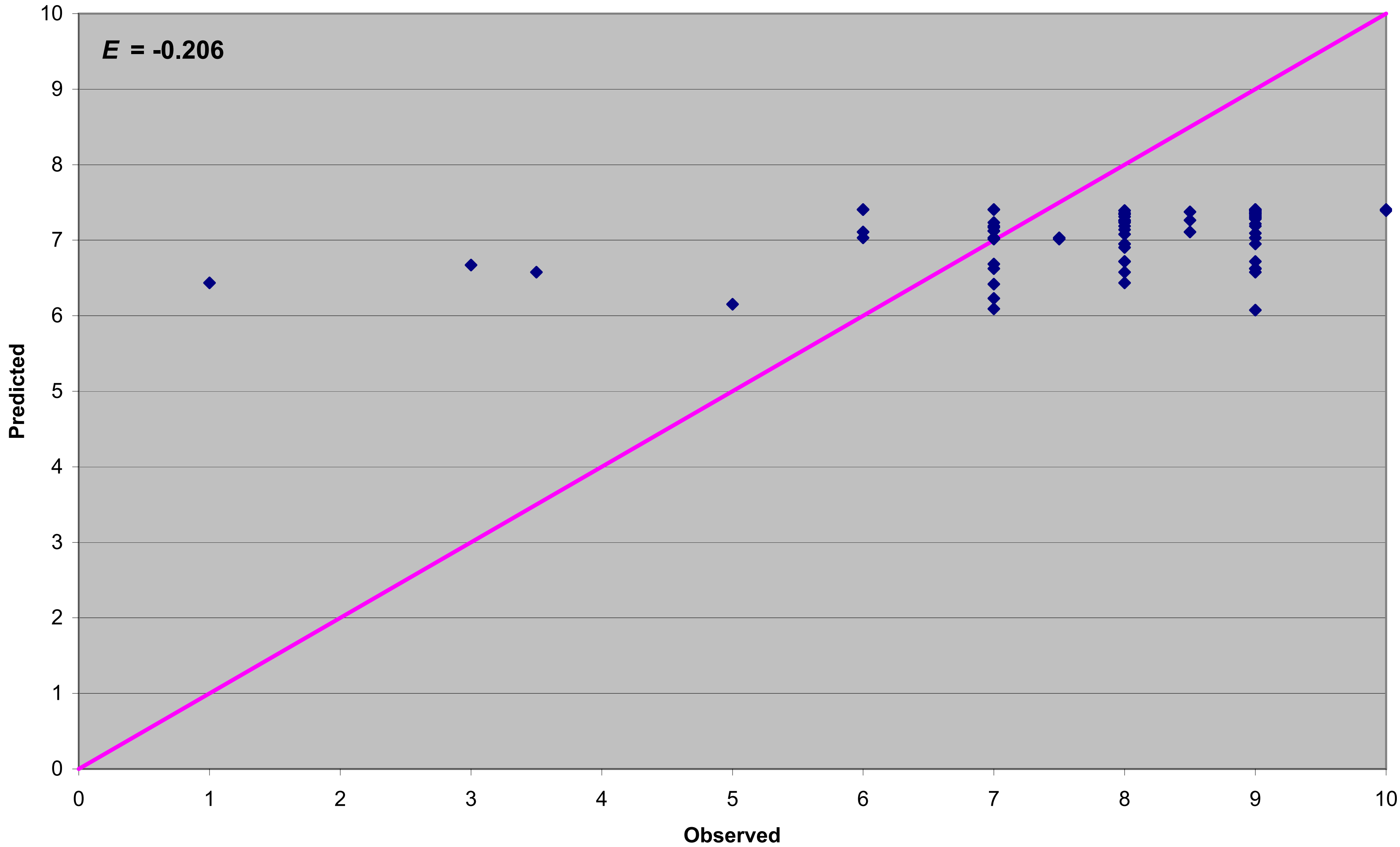


Figure 6c. Plot of predicted versus observed Barriers to Fish Movement SVAP scores for Wanaque watershed.

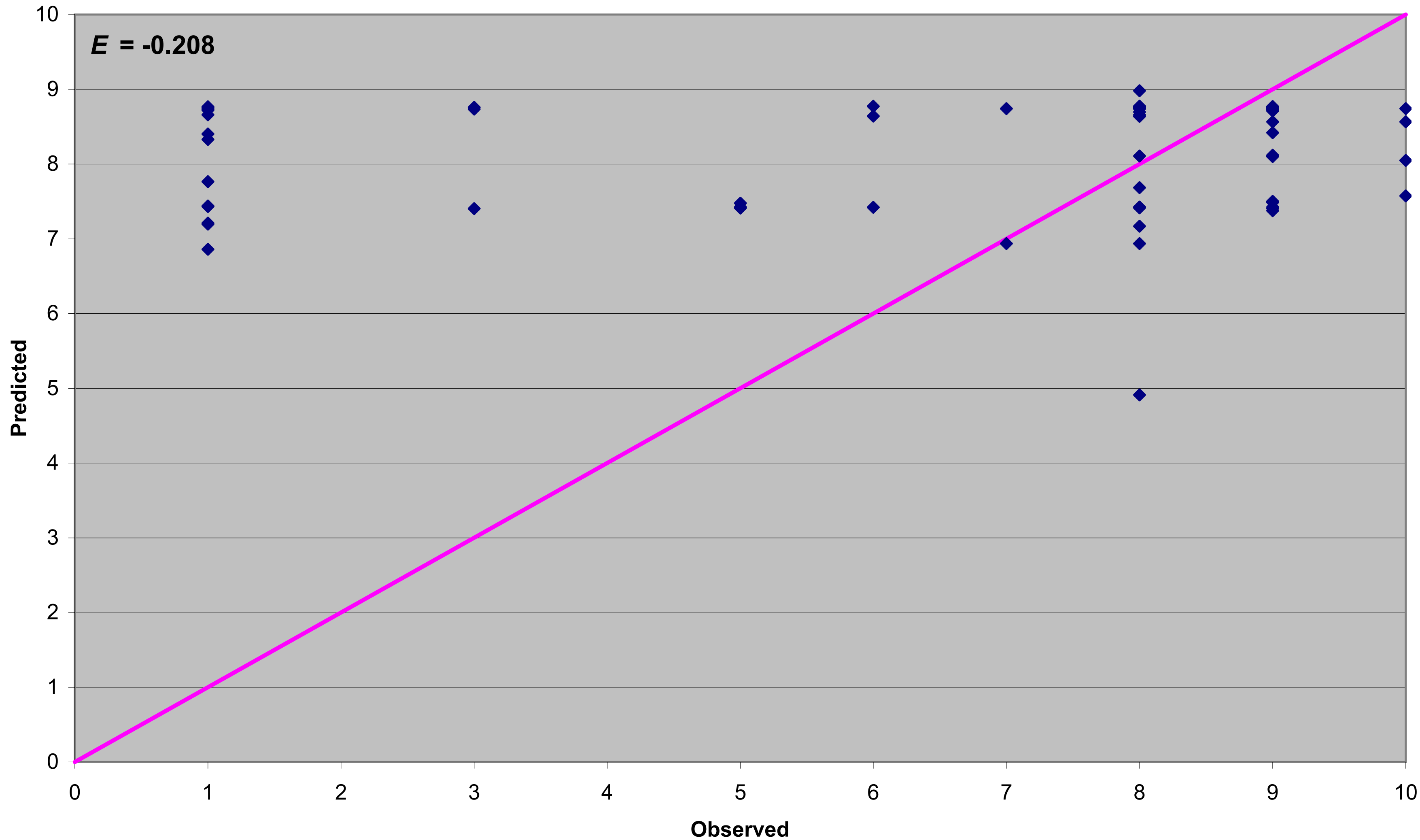


Figure 6d. Plot of predicted versus observed Canopy Cover SVAP scores for Wanaque watershed.

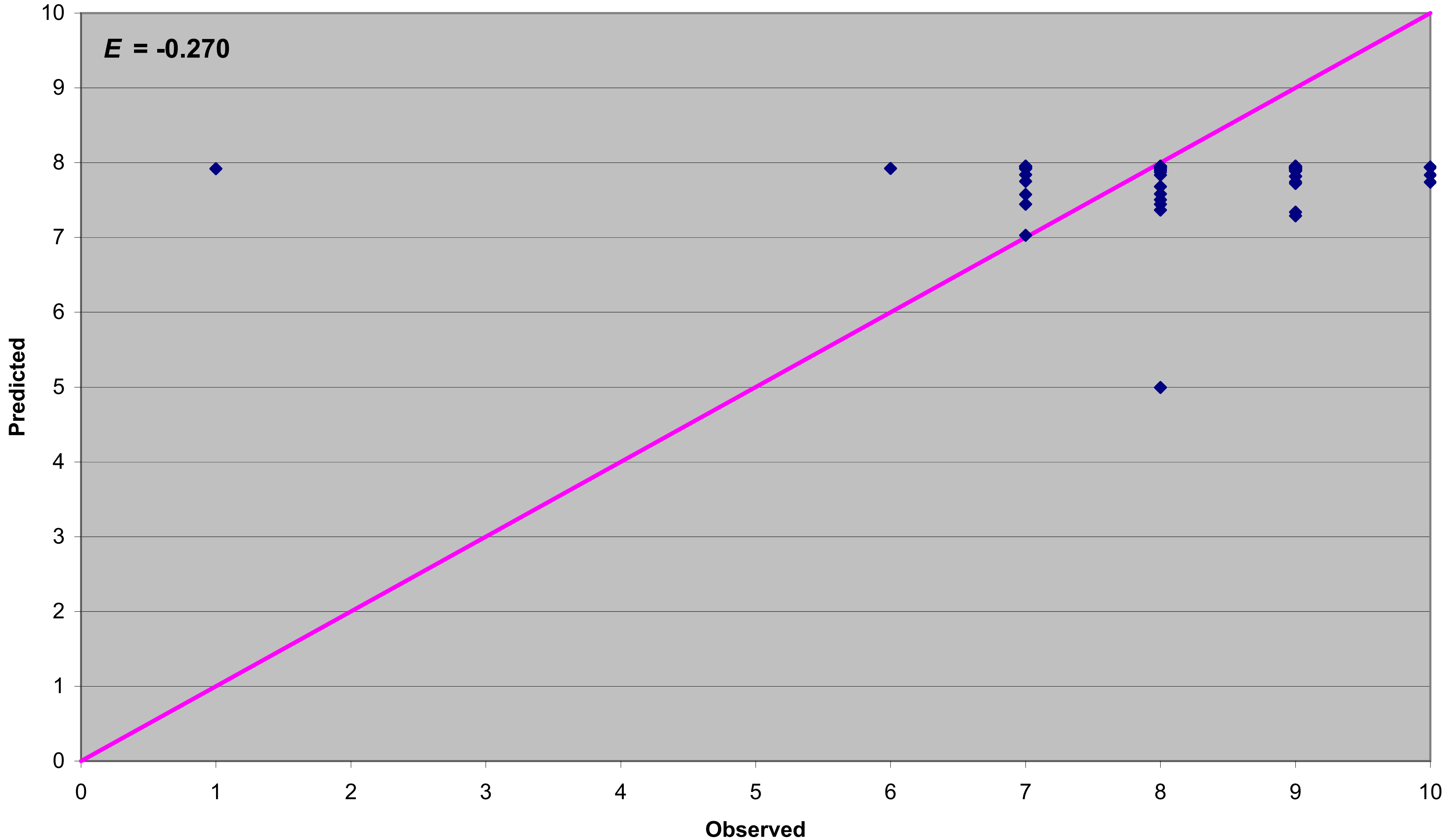


Figure 6e. Plot of predicted versus observed Channel Condition SVAP scores for Wanaque watershed.

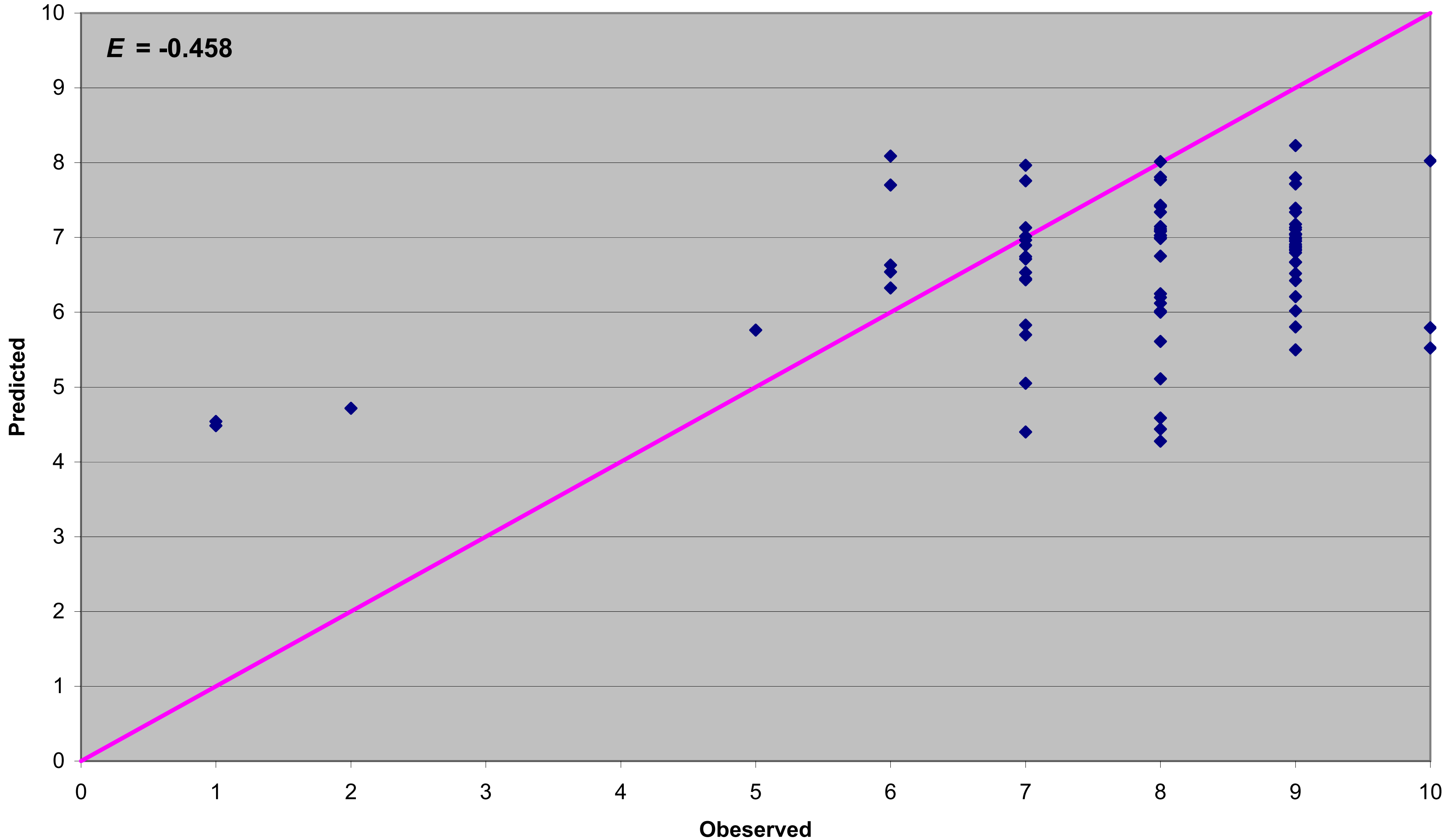


Figure 6f. Plot of predicted versus observed Hydrologic Alteration SVAP scores for Wanaque watershed.

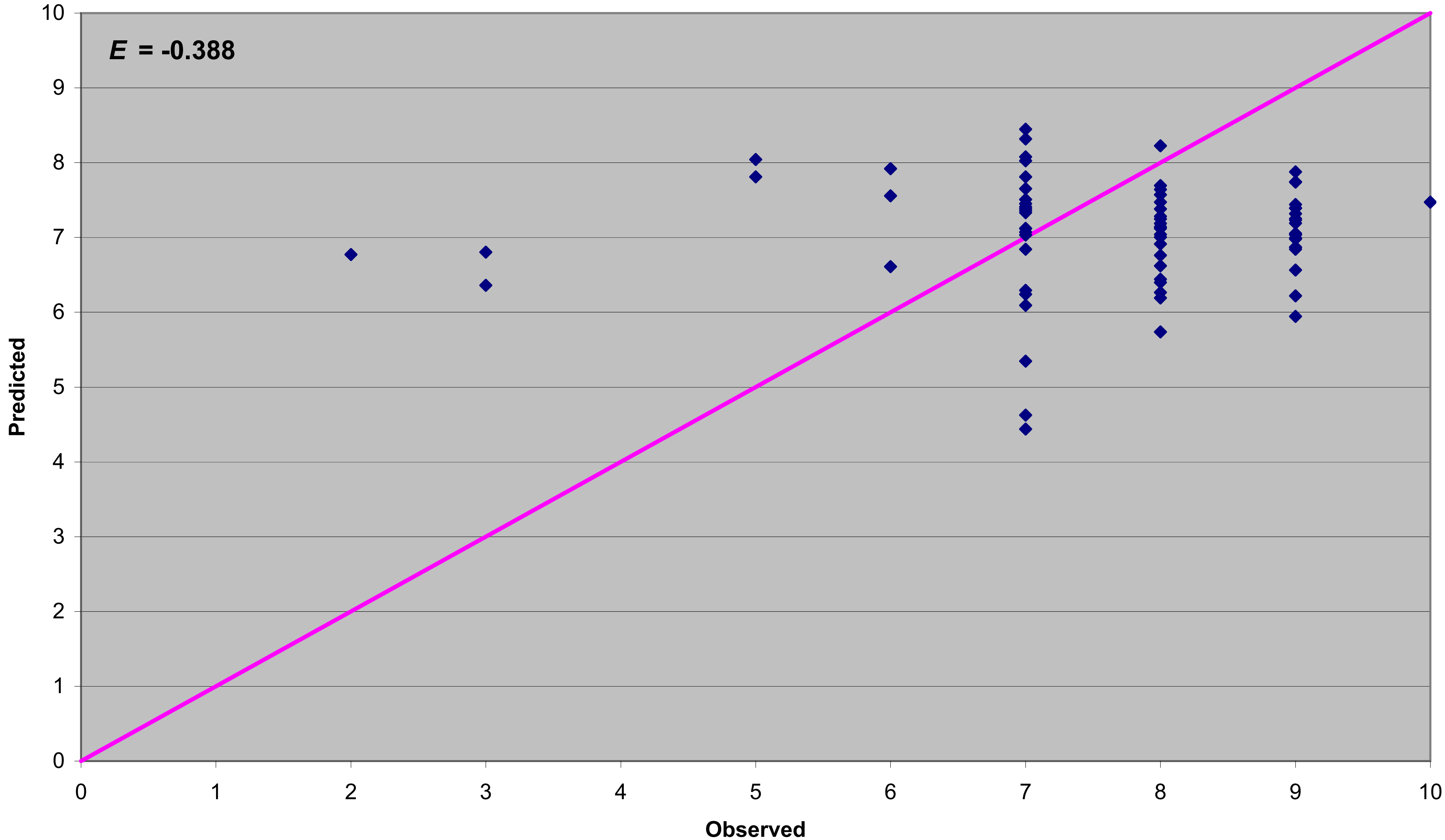


Figure 6g. Plot of predicted versus observed Instream Fish Cover SVAP scores for Wanaque watershed.

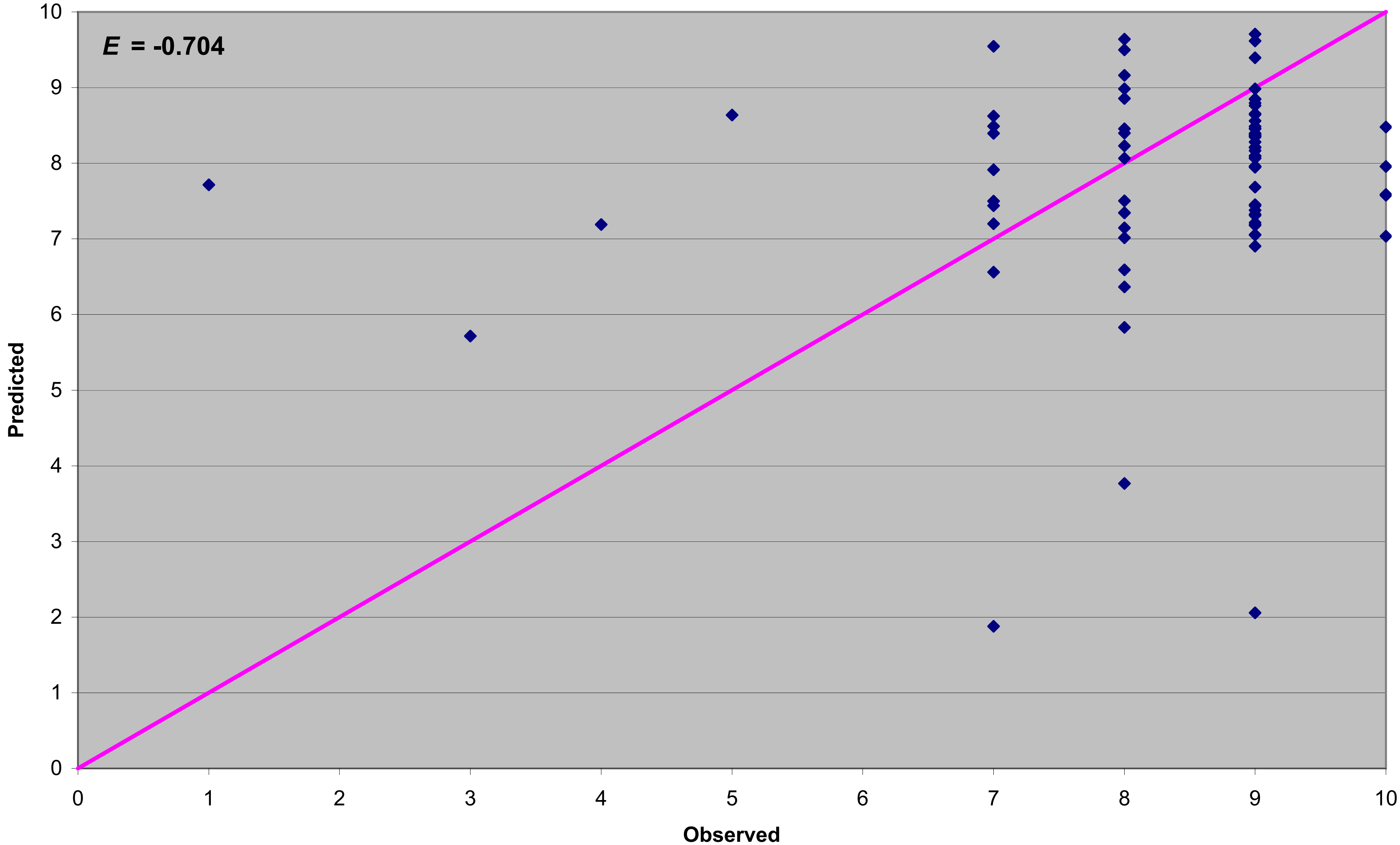


Figure 6h. Plot of predicted versus observed Riparian Zone SVAP scores for Wanaque watershed.

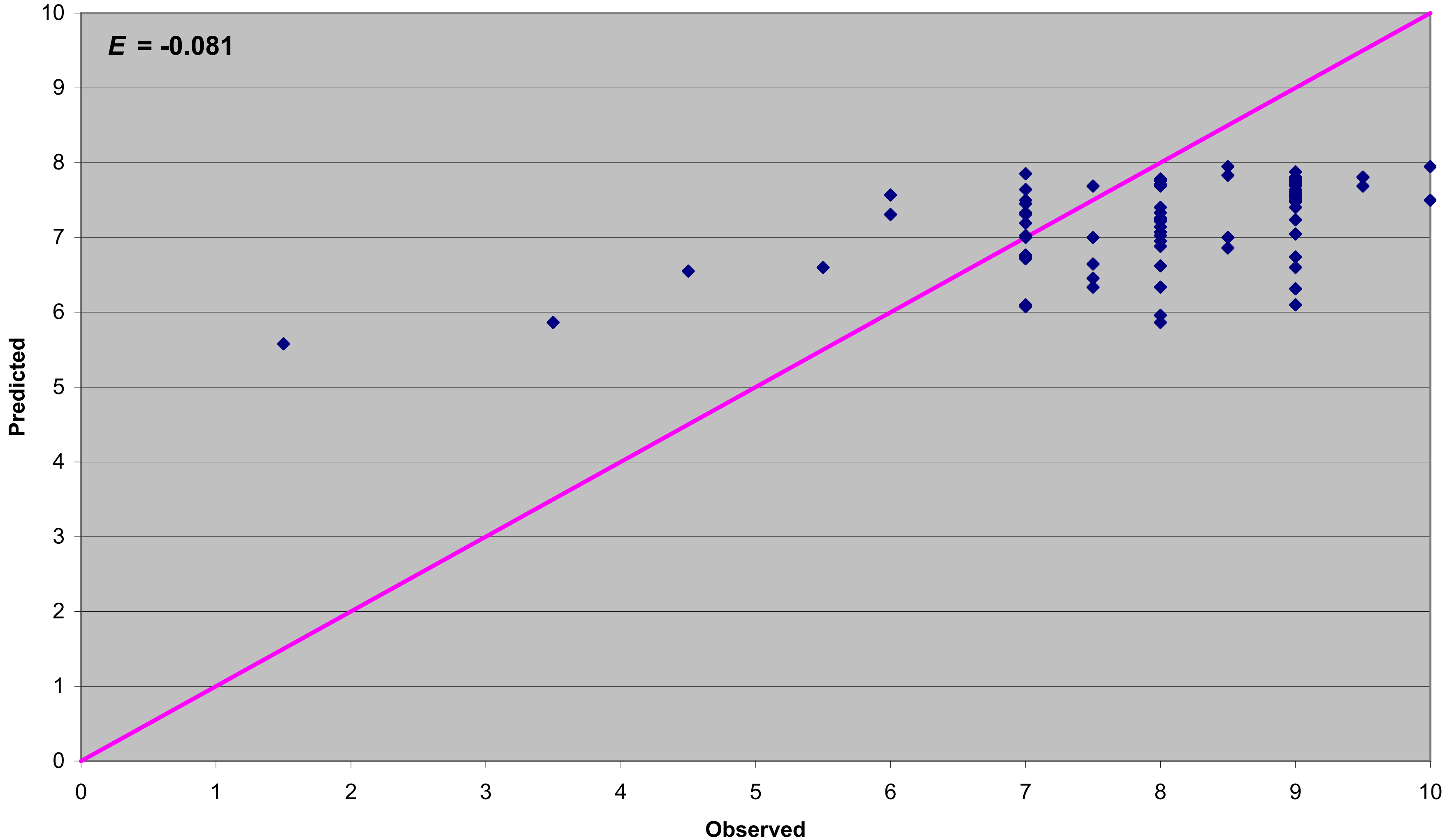


Figure 6i. Plot of predicted versus observed Water Appearance SVAP scores for Wanaque watershed.

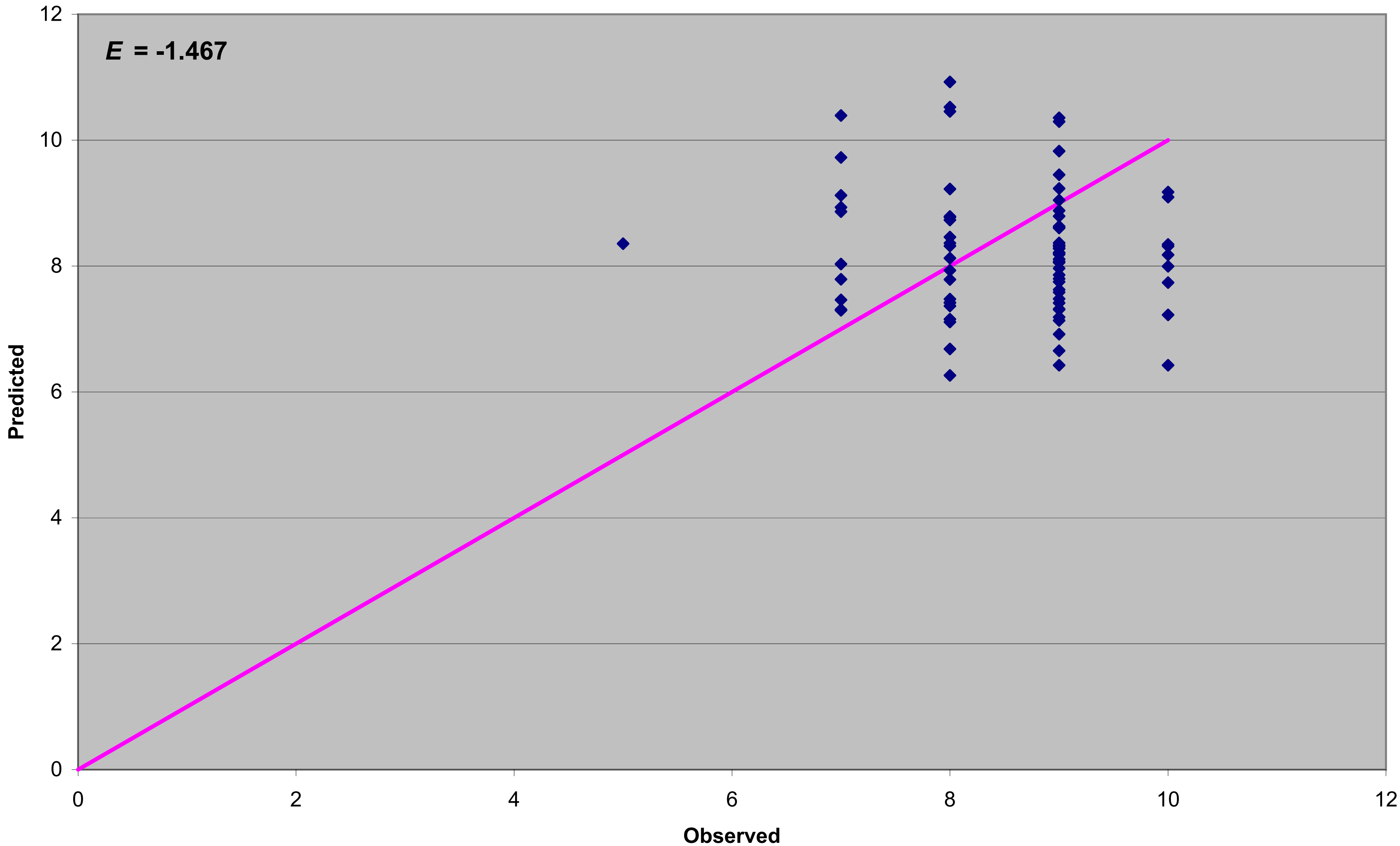


Figure 6j. Plot of predicted versus observed Average SVAP scores for Wanaque basins > 41% forest.

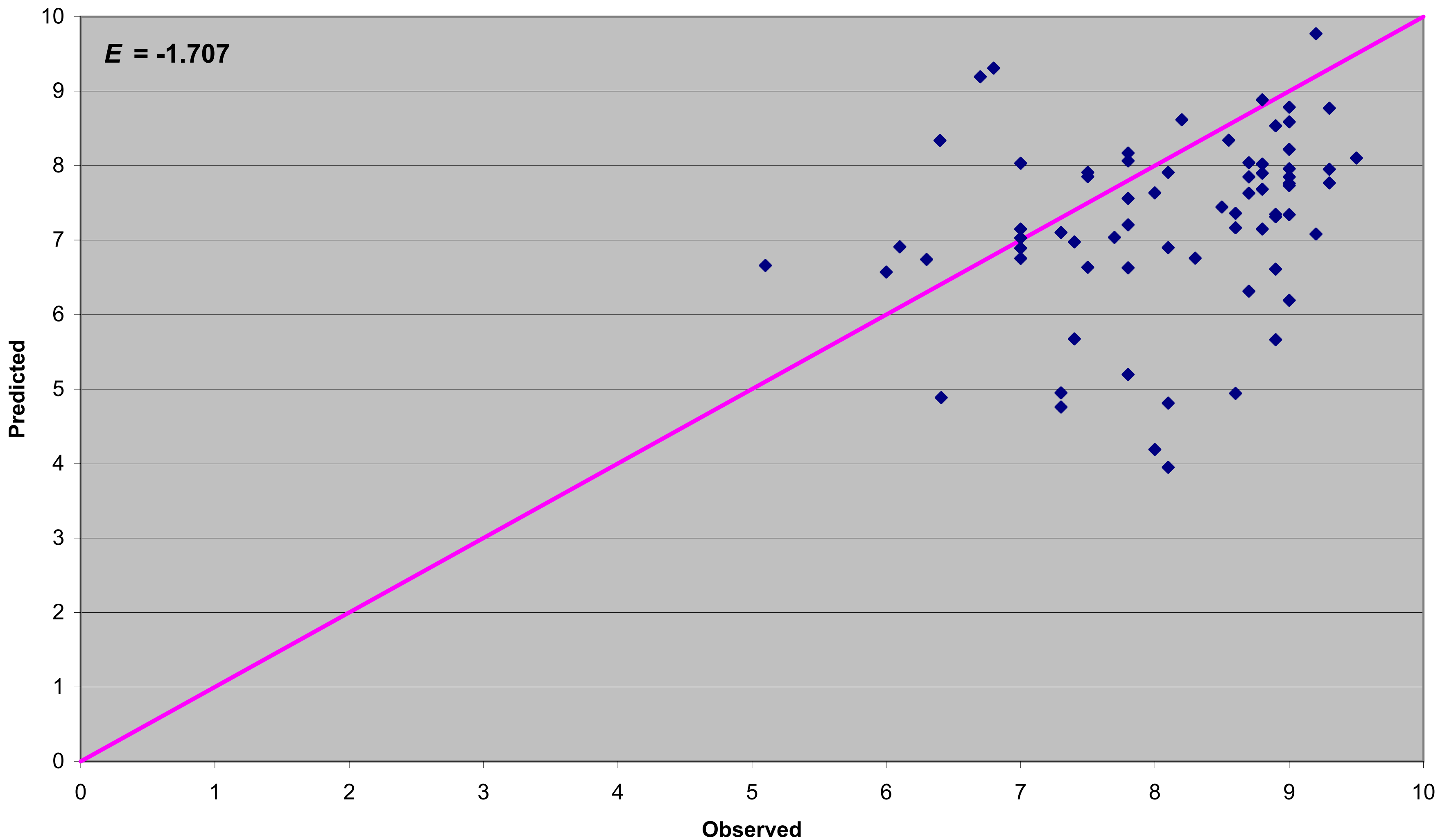


Figure 6k. Plot of predicted versus observed Bank Stability SVAP scores for Wanaque basins > 41% forest.

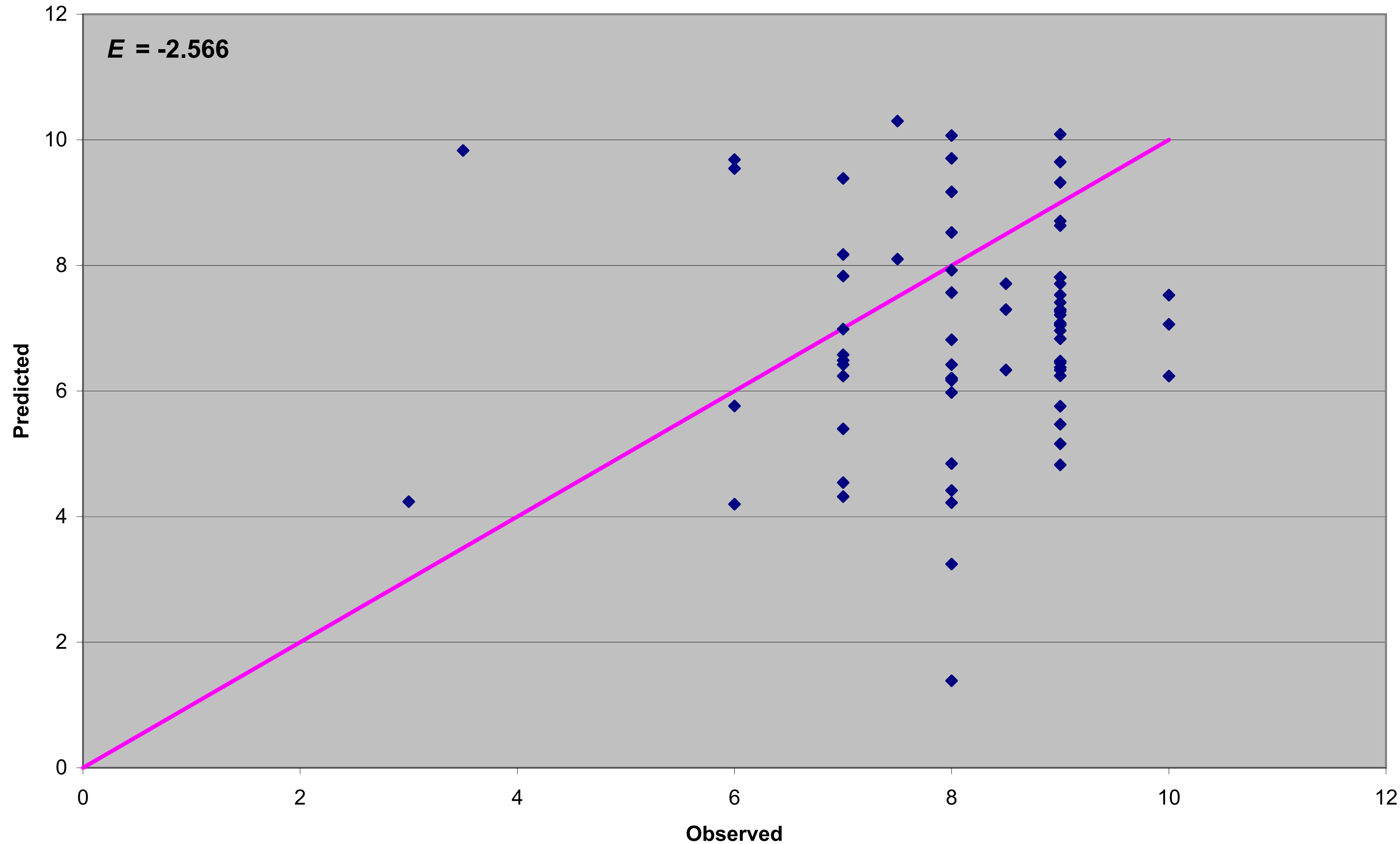


Figure 6l. Plot of predicted versus observed Channel Condition SVAP scores for Wanaque basins > 41% forest.

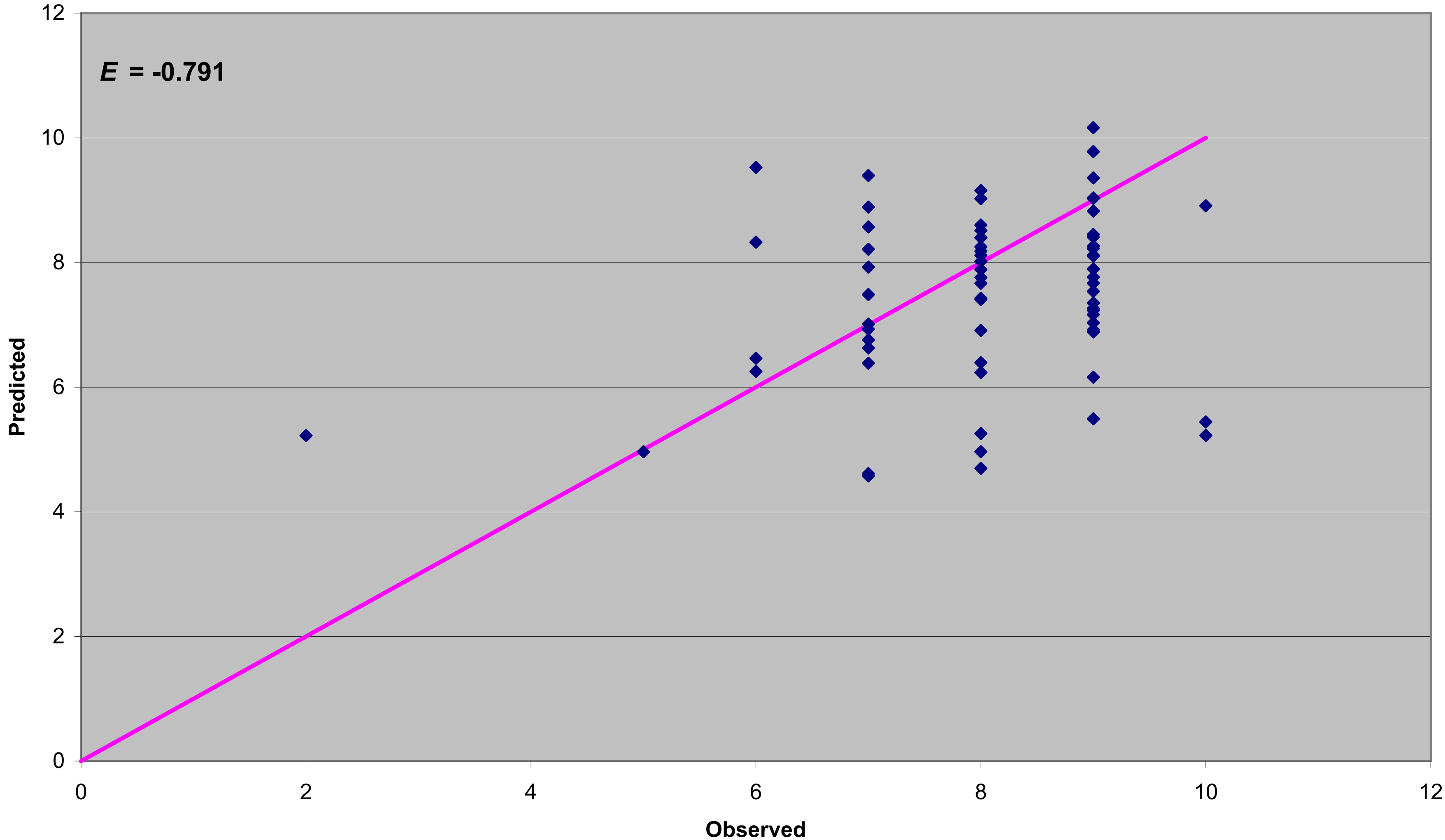


Figure 6m. Plot of predicted versus observed Hydrologic Alteration SVAP scores for Wanaque basins > 41% forest.

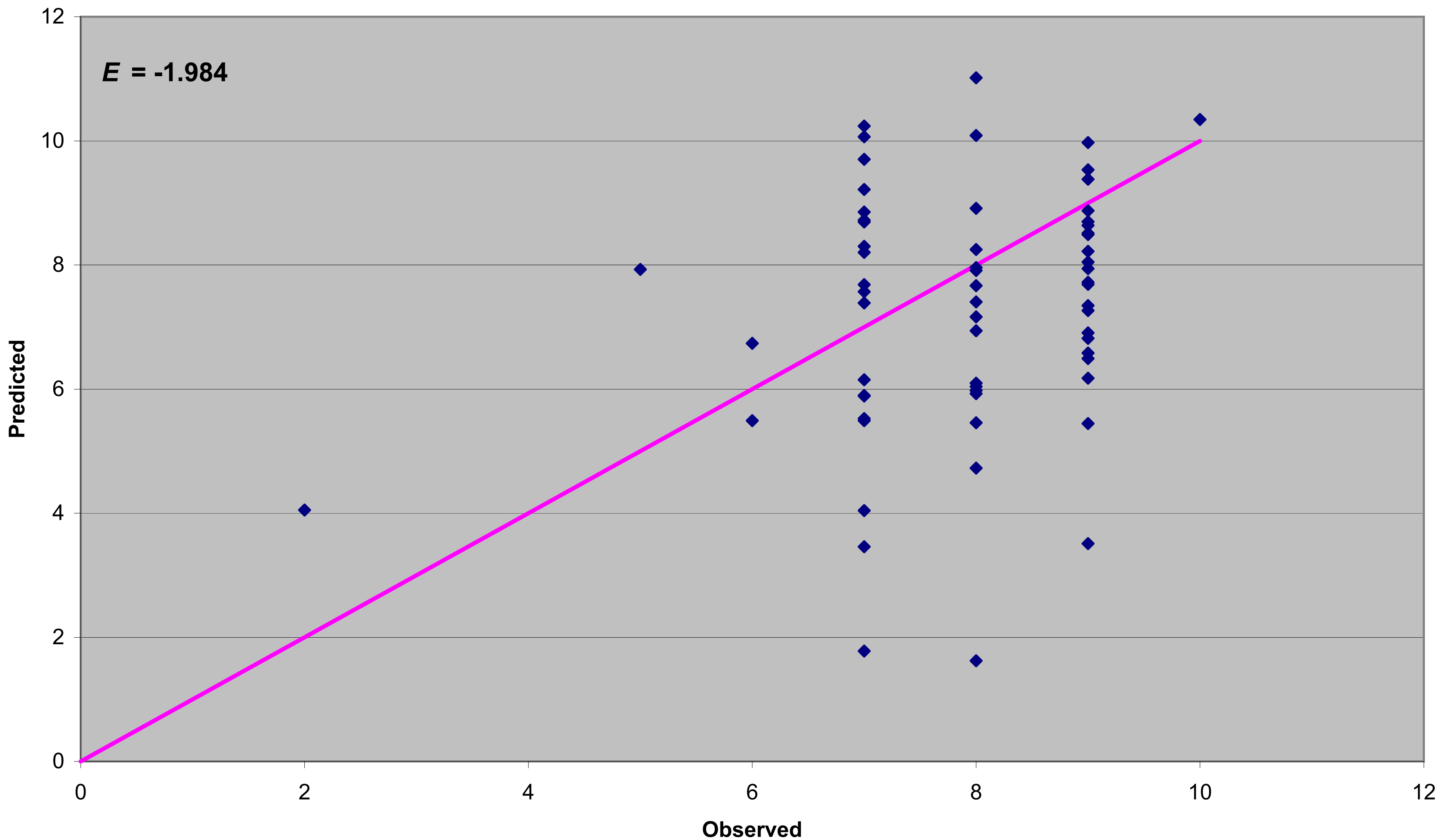


Figure 6n. Plot of predicted versus observed Riparian Zone SVAP scores for Wanaque basins > 41% forest.

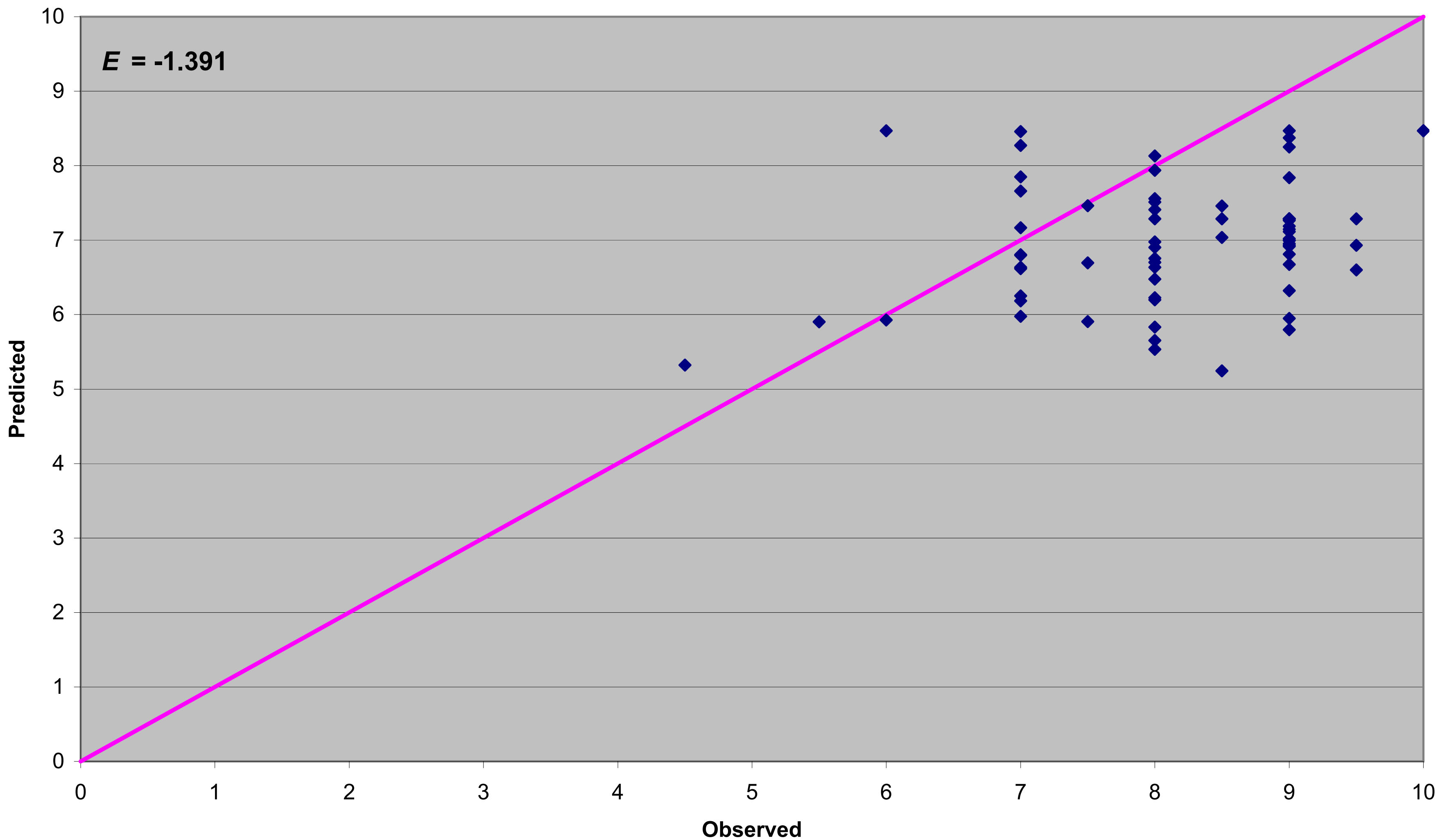


Figure 6o. Plot of predicted versus observed Water Appearance SVAP scores for Wanaque basins > 41% forest.

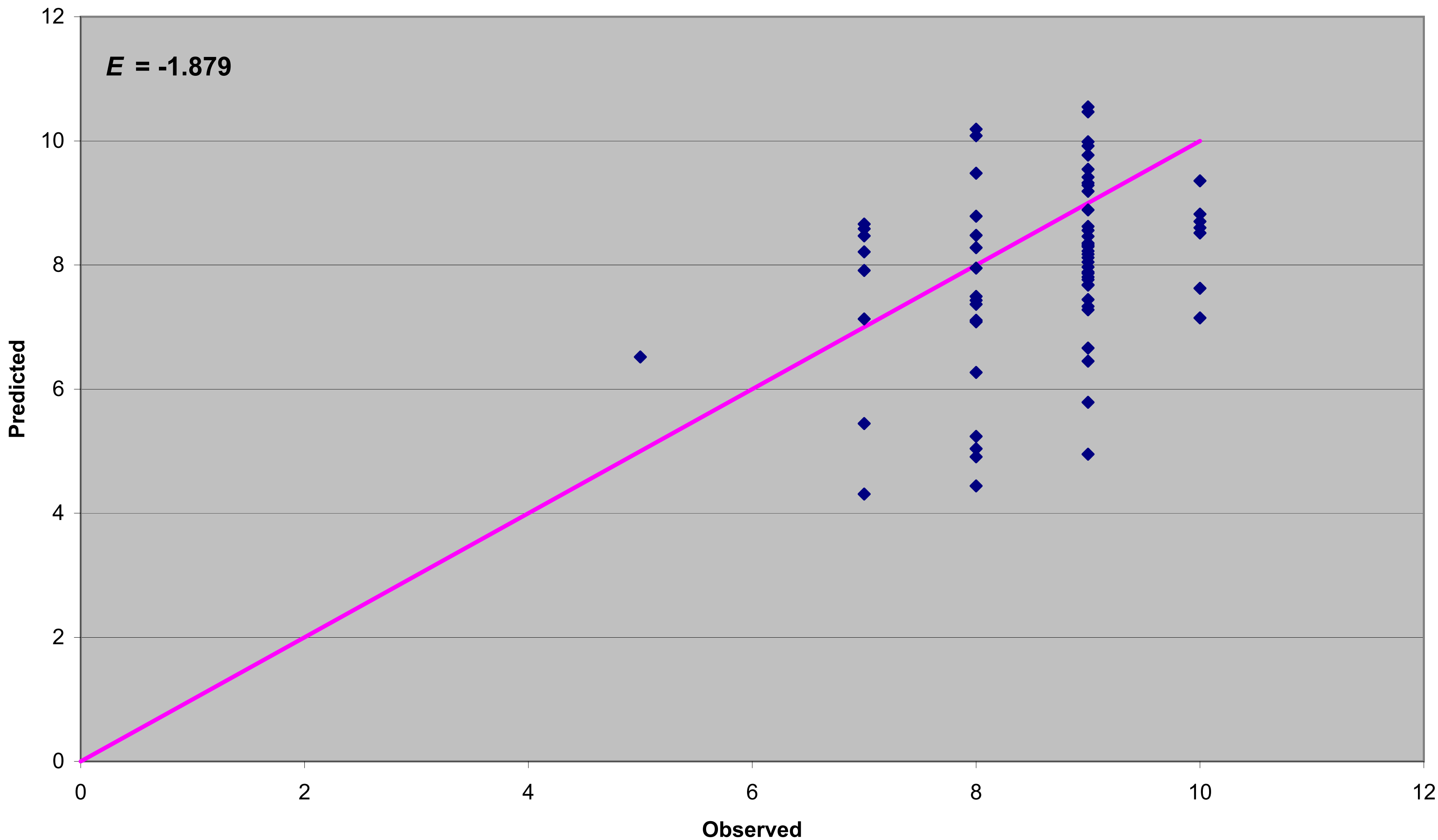


Figure 6p. Plot of predicted versus observed Average SVAP scores for Wanaque basins > 43% urban.

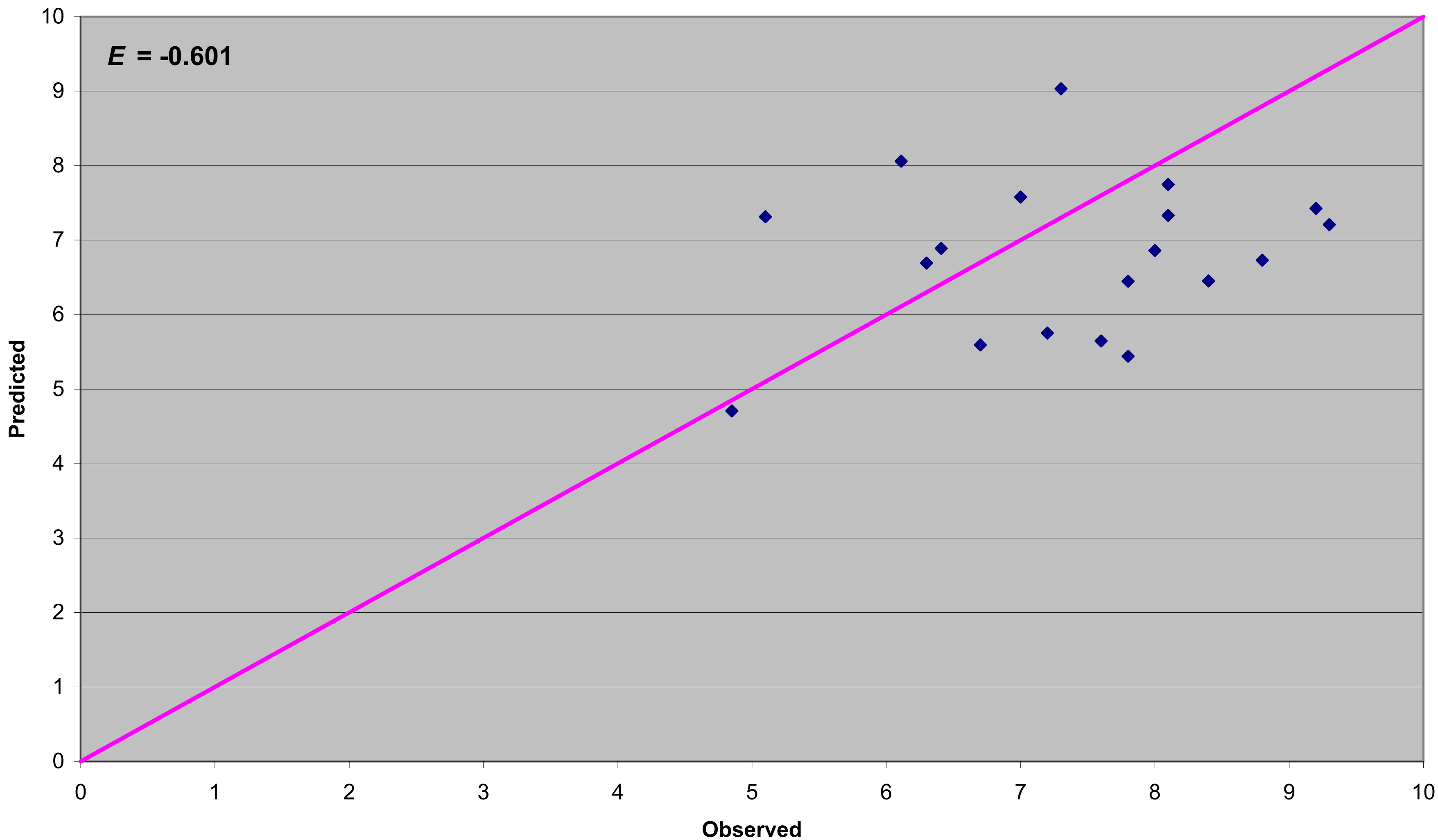


Figure 6q. Plot of predicted versus observed Bank Stability SVAP scores for Wanaque basins > 43% urban.

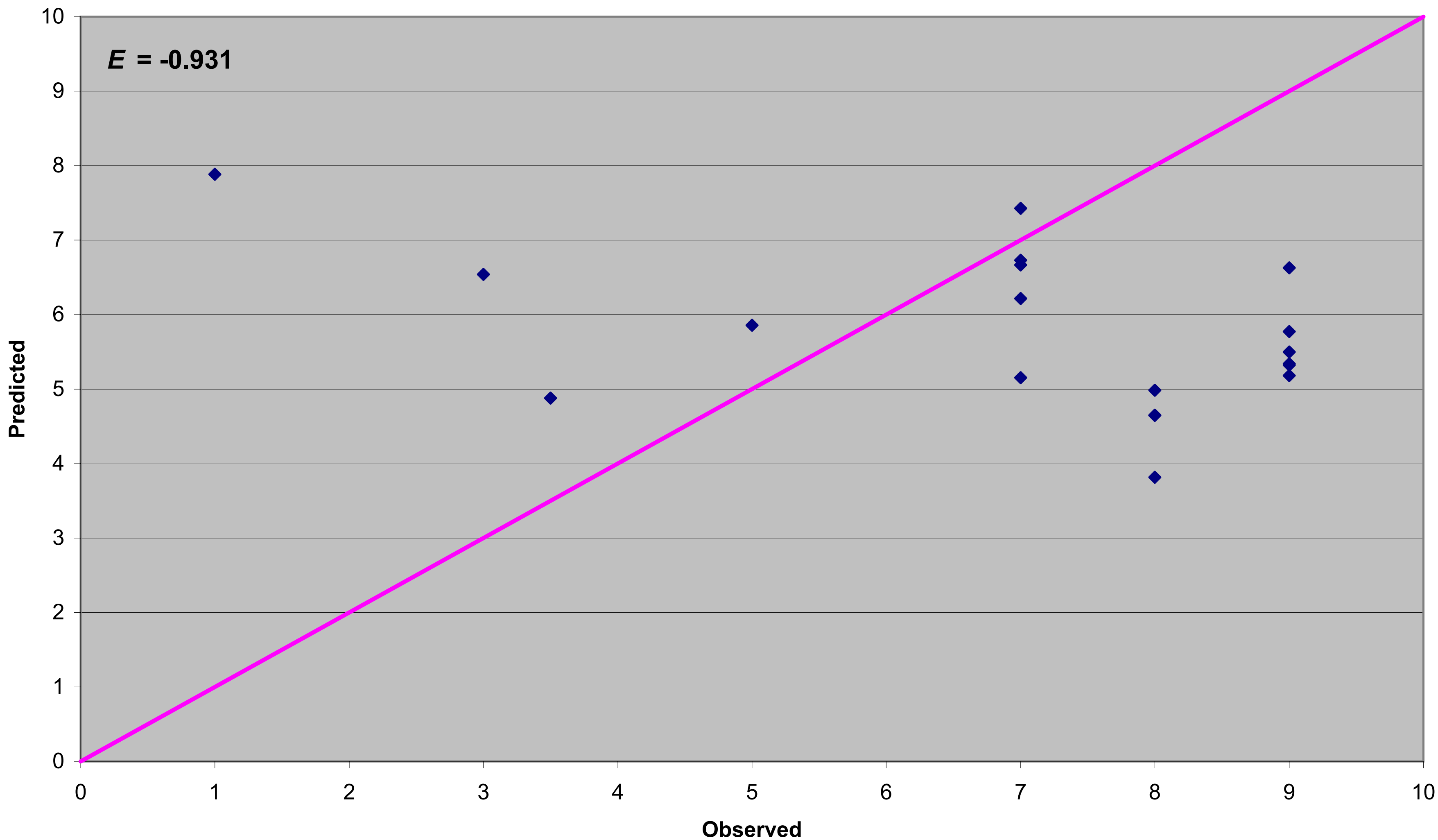


Figure 6r. Plot of predicted versus observed Channel Condition SVAP scores for Wanaque basins > 43% urban.

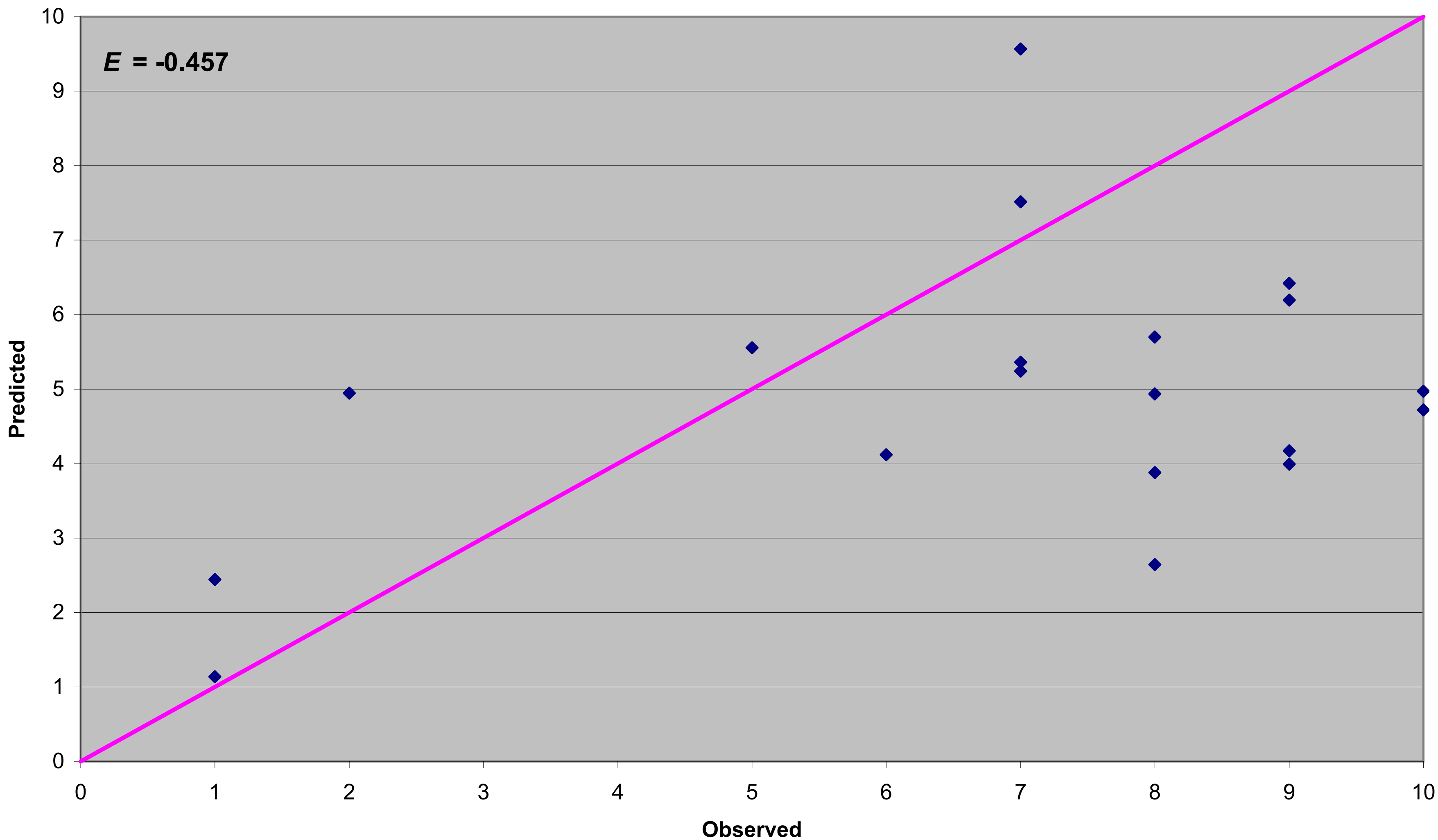


Figure 6s. Plot of predicted versus observed Hydrologic Alteration SVAP scores for Wanaque basins > 43% urban.

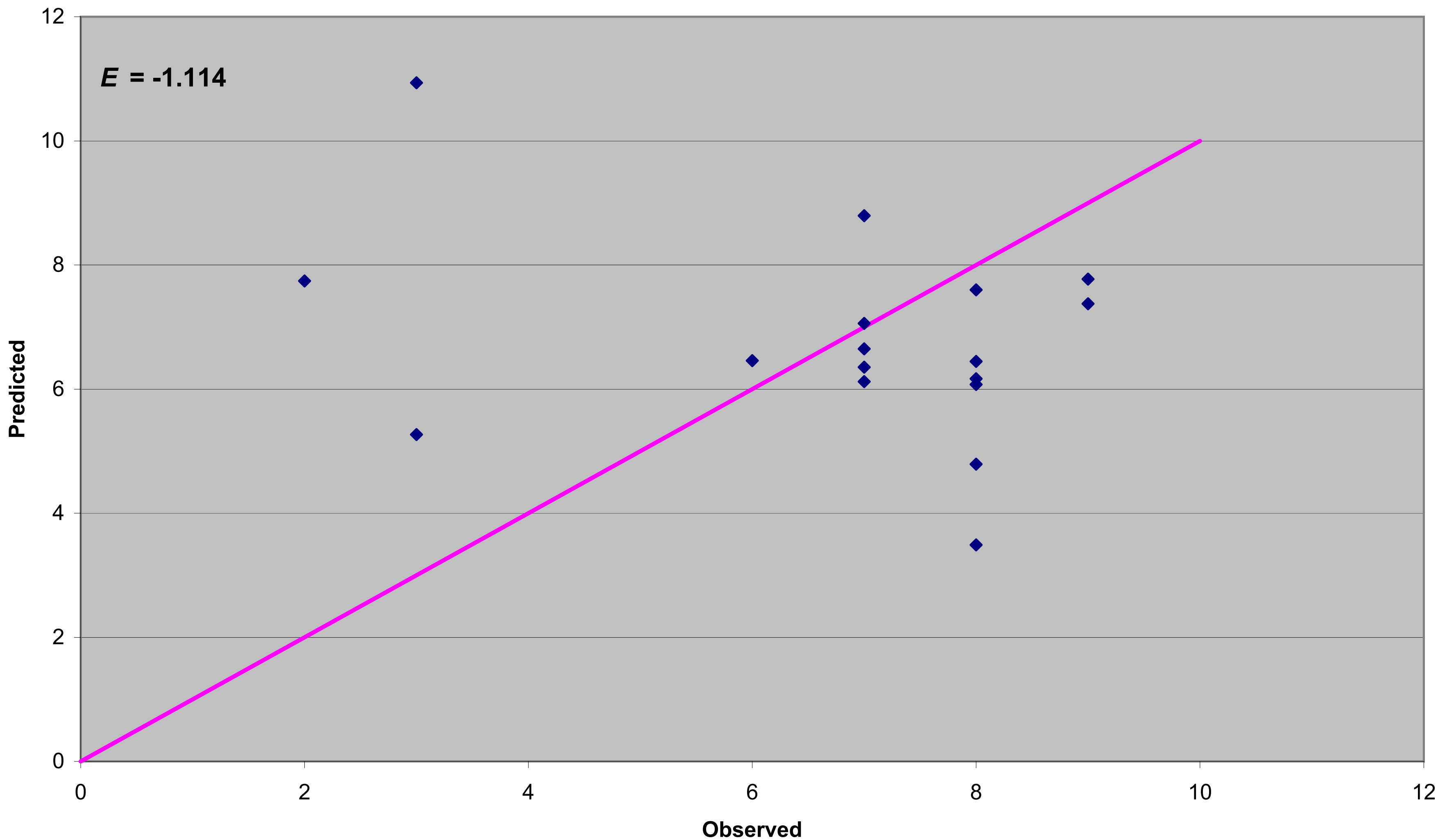
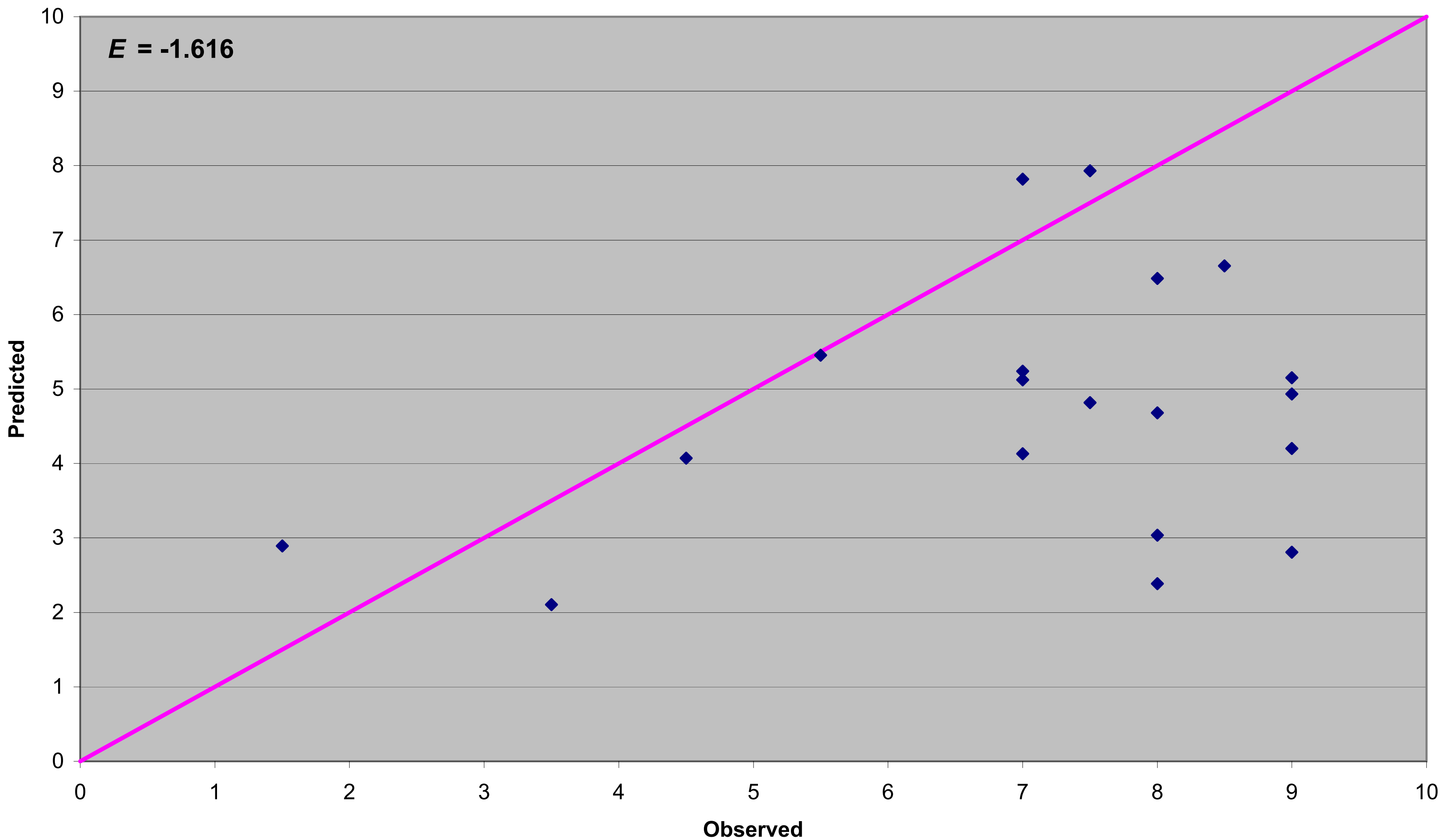


Figure 6t. Plot of predicted versus observed Riparian Zone SVAP scores for Wanaque basins > 43% urban.



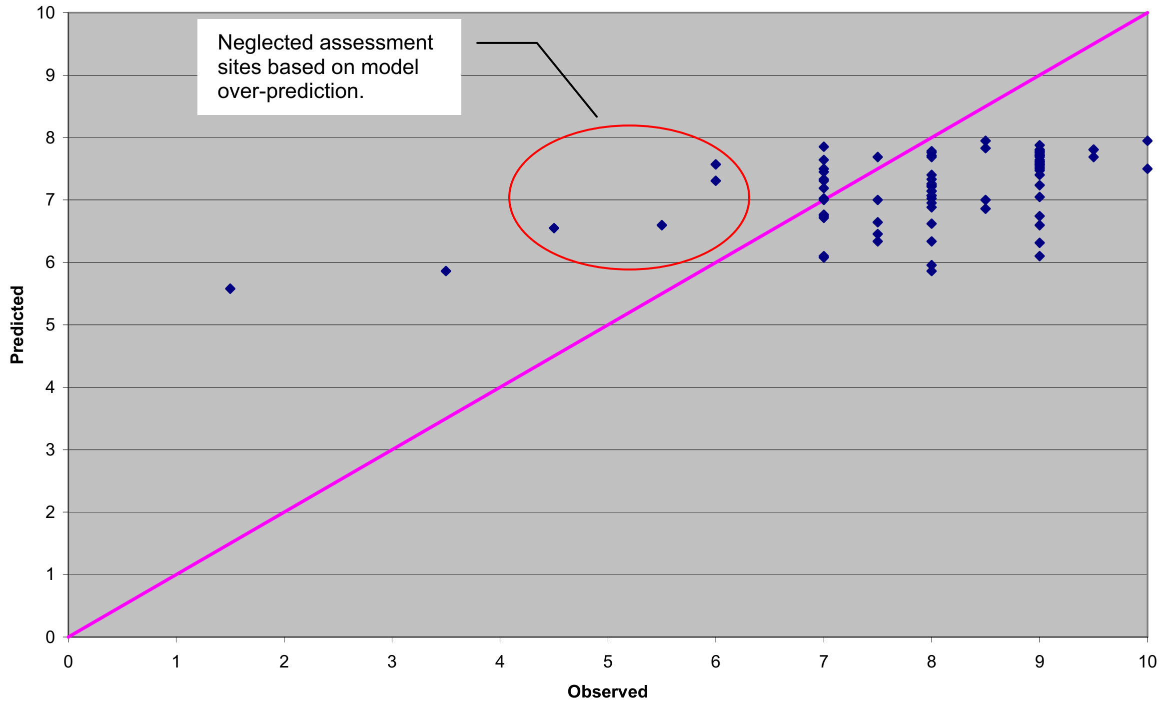
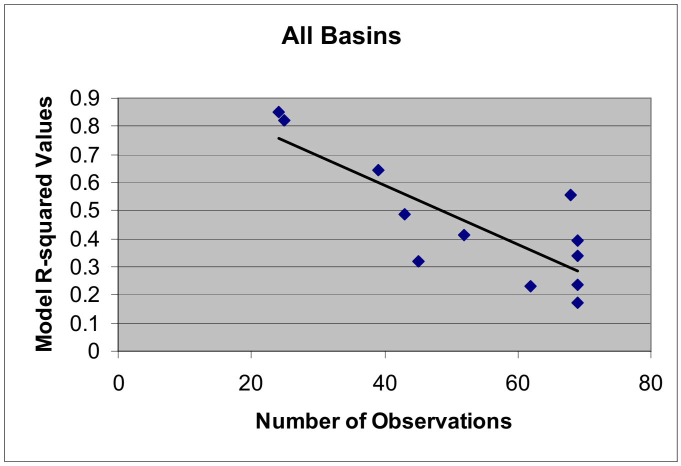
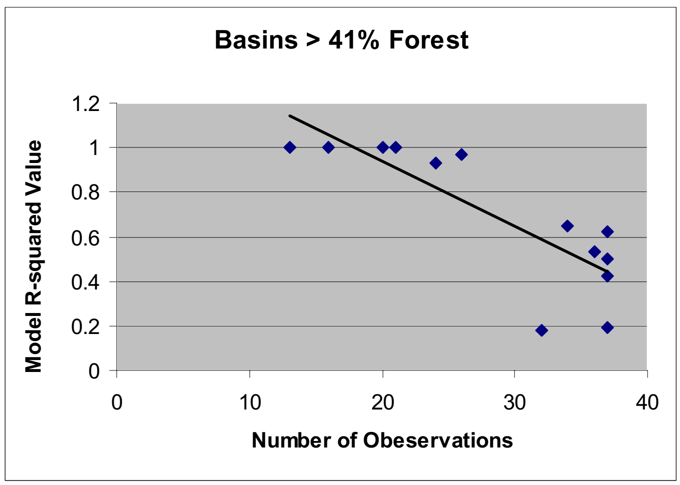


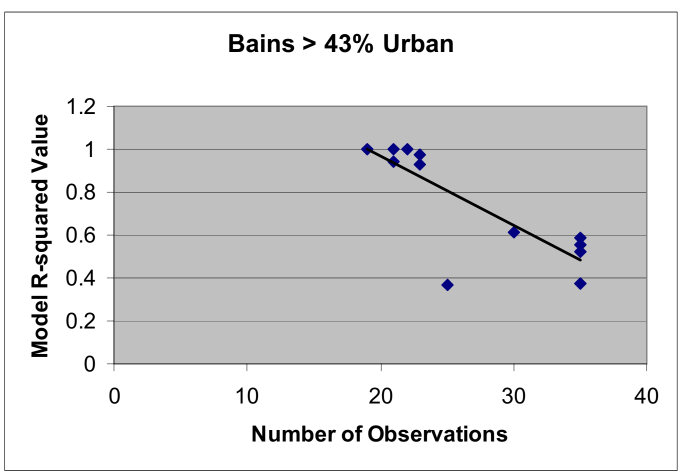
Figure 7. Regression model over-prediction. If only sites with predicted scores less than 6 are targeted, four sites with actual scores of 6 or below would be neglected.



a)



b)



c)

Figure 8. Inverse relationship between numbers of observations and model R-squared values for a) All basin data, b) basins greater than 41 percent forest, and c) basins greater than 43 percent urban.

APPENDIX

Sub-basin	Average SVAP Score	SVAP Channel Condition	SVAP Hydrologic Alteration	SVAP Riparian Zone	SVAP Bank Stability	SVAP Water Appear-ance	SVAP Nutrient Enrich-ment	SVAP Barriers to Fish Movement	SVAP Instream Fish Cover	SVAP Pools	SVAP Inverte-brate Habitat	SVAP Canopy Cover	SVAP Riffle Embedded ness
1	7.50	6	6	8	7	8	8	8	8	8	0	8	0
2	7.60	5	7	8	4.5	9	8	8	8	8	8	9	8
3	8.60	7	8	8	9.0	9	8	9	9	9	9	8	8
4	7.90	6	7	9	8.0	9	8	8	8	8	0	8	8
5	7.50	7	7	9	8.0	8	8	8	8	8	0	7	7
6	7.00	8	0	4	7.0	7	7	10	5	4	7	10	0
7	8.10	7	8	8	8.0	8	8	8	9	9	0	9	7
8	7.90	8	8	8	8.0	8	8	8	7	7	0	8	8
9	6.70	6	7	7	6.5	8	7	8	8	8	8	8	8
10	6.50	6	7	6	6.0	7	0	0	0	7	0	7	0
11	7.40	6	7	7	6.5	7	0	8	8	8	7	8	8
12	6.60	6	7	6	5.5	7	0	0	0	7	0	7	7
13	7.00	5	0	8	6.0	8	8	0	0	0	0	7	0
14	6.80	6	7	6	7.0	7	0	0	0	7	0	0	0
15	7.20	7	7	7	6.0	7	7	0	8	8	0	8	0
16	6.90	6	7	7	6.0	7	7	0	0	7	0	7	0
17	7.90	8	8	8	8.0	8	8	7	8	8	8	8	8
18	7.40	6	7	8	6.0	8	0	0	0	8	0	8	8
19	7.10	6	7	7	6.0	7	8	6	0	8	0	8	8
20	7.60	8	8	7	7.0	8	0	0	8	8	0	7	0
21	6.60	5	6	7	6.0	8	0	0	0	8	0	0	0
22	9.10	9	9	10	9.0	9	0	9	9	9	9	9	9
23	6.80	6	7	7	6.8	8	0	8	8	8	0	7	8
24	7.30	6	7	7	6.5	8	8	7	0	8	0	8	0
25	8.05	7	8	8	8.0	9	9	0	0	8	0	0	0
26	8.30	7	8	8	7.0	9	8	9	9	9	9	9	8
27	7.25	7	7	7	6.8	8	0	8	8	8	0	8	8
28	8.30	8	8	8	8.0	9	0	0	0	8	0	9	8
29	4.80	4	5	4	5.0	6	0	0	0	0	0	0	0
30	5.00	5	5	4	5.0	6	0	0	0	0	0	0	0
31	5.20	5	5	5	5.0	6	0	0	0	0	0	0	0
32	6.70	6	7	7	6.5	7	7	7	7	7	0	0	6
33	6.90	6	7	7	6.0	8	0	0	0	0	0	0	0
34	7.40	6	7	8	6.0	8	8	0	0	8	8	8	7
35	8.00	8	7	8	8.5	0	0	0	0	9	0	0	0

Appendix A: SVAP data collected for the Ramapo Watershed. A zero indicates no score was recorded.
Page 1 of 2

Sub-basin	Average SVAP Score	SVAP Channel Condition	SVAP Hydrologic Alteration	SVAP Riparian Zone	SVAP Bank Stability	SVAP Water Appear-ance	SVAP Nutrient Enrich-ment	SVAP Barriers to Fish Movement	SVAP Instream Fish Cover	SVAP Pools	SVAP Inverte-brate Habitat	SVAP Canopy Cover	SVAP Riffle Embedded ness
36	8.10	8	8	8	8.0	9	8	5	9	9	9	0	0
37	7.30	7	8	7	7.0	9	0	6	0	0	0	0	0
38	7.00	6	7	7	6.0	8	0	0	0	7	0	8	0
39	9.10	9	9	9	9.0	10	0	0	0	9	9	0	0
40	9.10	9	9	9	9.0	10	8	9	9	10	9	0	0
41	6.50	7	7	6	6.0	7	7	5	7	0	0	0	0
42	7.10	6	7	6	7.0	8	8	8	7	0	0	0	0
43	5.55	4	5	6	4.5	7	7	0	0	0	0	0	0
44	6.70	6	7	7	6.5	7	0	0	0	0	0	0	0
45	7.40	7	7	8	7.0	8	0	0	0	0	0	0	0
46	7.00	7	7	7	6.0	8	0	0	0	0	0	0	0
47	7.35	6	8	7	7.0	9	9	0	0	0	0	8	0
48	7.00	6	6	6	6.0	7	7	8	8	8	7	8	7
49	6.90	7	8	5	8.0	8	5	0	8	8	0	5	0
50	6.60	5	6	7	6.0	7	0	7	7	7	7	7	7
51	7.00	8	7	7	6.0	7	0	0	0	7	0	0	0
52	6.50	6	6	7	6.0	7	7	7	0	8	0	8	0
53	7.75	7	7	8	8.0	8	0	8	8	8	8	0	0
54	7.45	7	8	7	7.0	7	0	8	8	8	7	7	7
55	7.05	6	6	6	7.0	8	8	9	6	8	0	6	0
56	6.97	6	7	7	6.5	7	0	8	0	8	0	7	7
57	7.00	6	7	7	7.0	7	7	8	0	8	0	6	0
58	6.50	5	6	6	7.0	7	7	8	6	0	0	0	0
59	6.25	7	6	7	6.5	7	7	3	7	0	0	0	0
60	4.80	7	0	5	4.5	5	3	1	3	9	7	4	0
61	4.60	5	0	6	6.0	3	3	1	3	9	2	8	0
62	3.60	1	3	5	6.5	1	5	1	2	9	0	3	0
63	3.40	1	0	5	9.0	1	5	1	4	0	2	3	0
64	6.90	6	7	8	7.5	8	0	5	0	0	0	0	0
65	5.00	3	2	3	5.0	9	4	10	3	3	3	10	0
66	3.32	5	3	3	6.5	4	2	1	3	2	4	3	0
67	7.10	8	8	4	8.0	9	8	6	5	2	7	10	0
68	8.40	10	0	9	8.5	10	10	1	8	7	10	9	10
69	8.90	10	0	10	8.5	9	10	10	8	6	10	7	9

Appendix A: SVAP data collected for the Ramapo Watershed. A zero indicates no score was recorded.
Page 2 of 2

Sub-basin	Subbasin Drainage Area (ha)	% Drainage Area	% Cumulative Length	Cumulative Area (ha)	% Cumulative Area	Reach Length (m)	% Reach Length	Cumulative Reach Length (m)	Reach Width (m)	Composite Reach Width (m)	Reach Depth (m)
1	290.0595	0.0237	0.0447	339.9440	0.0278	3955.0872	0.0442	4000.4128	2.6880	2.4183	0.2121
2	0.0999	0.0000	0.0448	340.0439	0.0278	9.9934	0.0001	4010.4062	2.6885	2.4184	0.2121
3	49.8846	0.0041	0.0005	49.8846	0.0041	45.3256	0.0005	45.3256	0.8499	0.8499	0.0984
4	235.7707	0.0193	0.0181	275.8481	0.0225	1238.0107	0.0138	1624.5339	2.3713	2.1234	0.1951
5	8.8184	0.0007	0.0043	40.0774	0.0033	297.0844	0.0033	386.5232	0.7453	0.6648	0.0902
6	31.2590	0.0026	0.0010	31.2590	0.0026	89.4388	0.0010	89.4388	0.6421	0.6421	0.0816
7	100.7978	0.0082	0.0033	100.7978	0.0082	298.6520	0.0033	298.6520	1.2962	1.2962	0.1304
8	126.9734	0.0104	0.0238	227.7712	0.0186	1835.3146	0.0205	2133.9666	2.1139	1.7520	0.1807
9	349.8011	0.0286	0.1009	1304.4187	0.1066	1396.1913	0.0156	9032.1342	6.0234	4.5536	0.3632
10	317.8430	0.0260	0.0853	954.6176	0.0780	2088.5799	0.0233	7635.9429	4.9944	4.0151	0.3205
11	126.6439	0.0104	0.0620	636.7746	0.0520	494.2343	0.0055	5547.3630	3.9172	3.5263	0.2726
12	510.1307	0.0417	0.0565	510.1307	0.0417	5053.1287	0.0565	5053.1287	3.4292	3.4292	0.2495
13	404.4194	0.0331	0.0837	900.7983	0.0736	3233.9306	0.0361	7487.8168	4.8235	3.6144	0.3132
14	275.7882	0.0225	0.0475	496.3788	0.0406	2497.1597	0.0279	4253.8862	3.3735	2.6293	0.2468
15	33.0466	0.0027	0.0017	33.0466	0.0027	151.4692	0.0017	151.4692	0.6638	0.6638	0.0835
16	187.5440	0.0153	0.0179	187.5440	0.0153	1605.2573	0.0179	1605.2573	1.8813	1.8813	0.1672
17	44.9211	0.0037	0.4012	4533.2429	0.3705	691.6784	0.0077	35909.3913	12.7185	4.7242	0.5977
18	35.3636	0.0029	0.0041	35.3636	0.0029	367.8958	0.0041	367.8958	0.6914	0.6914	0.0858
19	71.9656	0.0059	0.0241	167.7300	0.0137	1214.4727	0.0136	2155.8403	1.7594	1.4725	0.1599
20	95.7644	0.0078	0.0105	95.7644	0.0078	941.3676	0.0105	941.3676	1.2569	1.2569	0.1278
21	110.8945	0.0091	0.0712	808.6591	0.0661	1315.2393	0.0147	6369.7886	4.5212	3.4271	0.3000
22	250.3915	0.0205	0.0565	697.7646	0.0570	1400.0365	0.0156	5054.5493	4.1382	3.2532	0.2828
23	126.7837	0.0104	0.0408	447.3731	0.0366	1090.8280	0.0122	3654.5128	3.1695	2.7579	0.2367
24	320.5894	0.0262	0.0286	320.5894	0.0262	2563.6848	0.0286	2563.6848	2.5951	2.5951	0.2072
25	137.6494	0.0113	0.0420	381.7991	0.0312	1421.0278	0.0159	3756.7249	2.8820	2.2362	0.2222
26	32.6871	0.0027	0.0002	32.6871	0.0027	21.1993	0.0002	21.1993	0.6595	0.6595	0.0831
27	181.1823	0.0148	0.0214	213.8694	0.0175	1890.9278	0.0211	1912.1271	2.0355	1.8252	0.1762
28	30.2803	0.0025	0.0261	244.1497	0.0200	423.5700	0.0047	2335.6971	2.2039	1.8722	0.1858
29	15.8292	0.0013	0.0329	184.0186	0.0150	780.6151	0.0087	2941.3660	1.8600	1.7289	0.1659
30	7.5501	0.0006	0.0241	168.1894	0.0137	160.6054	0.0018	2160.7509	1.7623	1.7166	0.1601
31	160.6393	0.0131	0.0223	160.6393	0.0131	2000.1455	0.0223	2000.1455	1.7144	1.7144	0.1571
32	95.9441	0.0078	0.0740	994.5852	0.0813	376.0276	0.0042	6626.8992	5.1189	4.0145	0.3258
33	278.8242	0.0228	0.0660	895.3354	0.0732	1174.6209	0.0131	5908.9638	4.8060	3.8932	0.3124
34	503.1799	0.0411	0.0399	503.1799	0.0411	3574.5651	0.0399	3574.5651	3.4011	3.4011	0.2481
35	2.1971	0.0002	0.0134	244.8388	0.0200	64.1001	0.0007	1196.4695	2.2076	1.8267	0.1860

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.

Sub-basin	Subbasin Drainage Area (ha)	% Drainage Area	% Cumulative Length	Cumulative Area (ha)	% Cumulative Area	Reach Length (m)	% Reach Length	Cumulative Reach Length (m)	Reach Width (m)	Composite Reach Width (m)	Reach Depth (m)
36	119.4233	0.0098	0.0127	242.6417	0.0198	409.4372	0.0046	1132.3694	2.1957	1.8232	0.1853
37	123.2184	0.0101	0.0081	123.2184	0.0101	722.9322	0.0081	722.9322	1.4622	1.4622	0.1413
38	3.3356	0.0003	0.0165	222.2684	0.0182	170.5988	0.0019	1473.5669	2.0831	1.7624	0.1789
39	158.4122	0.0129	0.0146	218.9328	0.0179	886.1094	0.0099	1302.9681	2.0643	1.7575	0.1779
40	60.5206	0.0049	0.0047	60.5206	0.0049	416.8587	0.0047	416.8587	0.9544	0.9544	0.1063
41	54.1689	0.0044	0.1283	1980.6616	0.1619	582.4608	0.0065	11486.5150	7.7388	5.6895	0.4292
42	0.2197	0.0000	0.1218	1926.4926	0.1575	52.3921	0.0006	10904.0542	7.6111	5.6318	0.4245
43	831.7788	0.0680	0.1147	1830.7882	0.1496	3931.0470	0.0439	10270.9159	7.3820	5.5284	0.4159
44	293.2852	0.0240	0.0223	717.2091	0.0586	1995.2096	0.0223	1995.2096	4.2070	3.5342	0.2859
45	527.5280	0.0431	0.0493	527.5280	0.0431	4412.8884	0.0493	4412.8884	3.4989	3.4989	0.2528
46	31.9980	0.0026	0.1517	1863.9447	0.1524	134.7645	0.0015	13579.7871	7.4619	4.3051	0.4189
47	166.8611	0.0136	0.1581	2030.8058	0.1660	573.1775	0.0064	14152.9646	7.8558	4.5968	0.4335
48	47.8472	0.0039	0.1626	2078.6530	0.1699	399.1495	0.0045	14552.1141	7.9663	4.6744	0.4376
49	157.7231	0.0129	0.2274	2576.4200	0.2106	1791.4955	0.0200	20354.0158	9.0615	4.6452	0.4768
50	99.0700	0.0081	0.0072	99.0700	0.0081	640.5597	0.0072	640.5597	1.2828	1.2828	0.1295
51	259.1300	0.0212	0.2745	3210.4682	0.2624	1947.9615	0.0218	24567.0709	10.3402	4.7844	0.5207
52	149.2842	0.0122	0.3696	4260.5506	0.3482	1028.8586	0.0115	33083.7463	12.2538	4.7988	0.5831
53	783.3424	0.0640	0.5823	6710.1370	0.5485	3560.4071	0.0398	52120.0480	16.0927	5.6509	0.6993
54	37.8903	0.0031	0.0216	260.1587	0.0213	464.2540	0.0052	1937.8209	2.2895	1.8391	0.1906
55	127.4428	0.0104	0.0255	372.2816	0.0304	1083.9695	0.0121	2280.4390	2.8387	2.1731	0.2199
56	7.2006	0.0006	0.0381	191.2191	0.0156	465.9686	0.0052	3407.3346	1.9033	1.7355	0.1685
57	565.5281	0.0462	0.8154	9888.7670	0.8083	5165.4562	0.0577	72990.2791	20.3084	6.2657	0.8166
58	586.9899	0.0480	0.8312	10475.7569	0.8563	1411.3285	0.0158	74401.6076	21.0233	7.0926	0.8356
59	488.6190	0.0399	0.9844	12150.1802	0.9931	3679.9123	0.0411	88115.7537	22.9794	7.3952	0.8867
60	4.8137	0.0004	0.9875	12154.9939	0.9935	274.6727	0.0031	88390.4264	22.9849	7.4014	0.8868
61	6.1120	0.0005	0.9909	12161.1059	0.9940	305.3633	0.0034	88695.7897	22.9918	7.4092	0.8870
62	14.4011	0.0012	0.9933	12175.5070	0.9952	218.1412	0.0024	88913.9309	23.0082	7.4277	0.8874
63	58.7529	0.0048	1.0000	12234.2599	1.0000	597.4509	0.0067	89511.3818	23.0747	7.5028	0.8891
64	110.7148	0.0090	0.0529	616.5112	0.0504	1107.3857	0.0124	4734.3429	3.8420	3.4803	0.2691
65	95.4847	0.0078	0.1212	1926.2729	0.1574	580.7462	0.0065	10851.6621	7.6106	5.6316	0.4245
66	281.8003	0.0230	0.0708	999.0094	0.0817	1659.1558	0.0185	6339.8689	5.1325	3.9851	0.3264
67	423.9239	0.0347	0.0300	423.9239	0.0347	2685.5035	0.0300	2685.5035	3.0688	3.0688	0.2317
68	3.3057	0.0003	0.0698	898.6411	0.0735	341.9078	0.0038	6250.8716	4.8166	3.8966	0.3129
69	2.6166	0.0002	0.0405	505.7965	0.0413	52.3921	0.0006	3626.9572	3.4117	3.4012	0.2486

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.
Page 2 of 6

Sub-basin	Composite Reach Depth (m)	CN (Area Wt.)	Composite CN (Area Wt.)	Erodability (tons/acre)	Composite Erodability (tons/acre)	Impervious Surface (%)	Composite Impervious Surface (%)	Impervious Surface (acres)	Composite Impervious Surface (acres)	Hydrogroup (Area Wt.)
1	0.1954	76	79	0.31	0.26	0.45	0.65	3.2462	5.4311	2.8310
2	0.1954	66	79	0.37	0.00	0.00	0.65	0.0000	5.4311	1.9990
3	0.0984	92	92	0.24	0.24	1.78	1.78	2.1849	2.1849	2.9930
4	0.1789	92	92	0.24	0.21	0.02	0.02	0.1257	0.1257	3.0000
5	0.0835	92	93	0.24	0.05	0.00	0.00	0.0000	0.0000	2.9490
6	0.0816	94	94	0.24	0.24	0.00	0.00	0.0000	0.0000	2.9960
7	0.1304	93	93	0.24	0.24	0.00	0.00	0.0000	0.0000	3.0000
8	0.1584	79	86	0.37	0.21	0.00	0.00	0.0000	0.0000	2.8430
9	0.2995	25	47	0.33	0.09	38.72	34.91	188.3394	937.6745	2.3240
10	0.2762	53	55	0.31	0.10	37.95	33.52	297.9234	749.3352	2.1530
11	0.2541	69	57	0.33	0.06	34.47	31.30	107.8799	451.4117	2.7020
12	0.2495	54	54	0.30	0.30	30.52	30.52	343.5318	343.5318	2.6210
13	0.2540	72	70	0.33	0.15	17.76	16.94	177.3040	368.4002	2.9100
14	0.2059	71	67	0.30	0.17	19.87	16.26	132.7998	191.0961	2.6040
15	0.0835	71	71	0.28	0.28	7.12	7.12	5.5493	5.5493	2.9170
16	0.1672	61	61	0.33	0.33	12.57	12.57	52.7471	52.7471	2.5990
17	0.2974	29	57	0.37	0.00	0.76	16.77	0.8488	1630.8367	2.0000
18	0.0858	63	63	0.33	0.33	9.02	9.02	7.7832	7.7832	3.0070
19	0.1416	66	68	0.33	0.14	12.72	10.31	22.6069	31.2607	3.2700
20	0.1278	69	69	0.28	0.28	8.50	8.50	8.6538	8.6538	3.5000
21	0.2480	74	88	0.31	0.04	0.21	0.07	0.5862	1.4576	2.7700
22	0.2397	90	90	0.24	0.09	0.02	0.05	0.1061	0.8714	2.9970
23	0.2156	93	90	0.24	0.07	0.24	0.07	0.7653	0.7653	2.9940
24	0.2072	89	89	0.24	0.24	0.00	0.00	0.0000	0.0000	3.0000
25	0.1856	81	86	0.31	0.11	0.36	0.21	1.2253	1.9654	2.8960
26	0.0831	87	87	0.24	0.24	0.00	0.00	0.0000	0.0000	3.0000
27	0.1620	89	89	0.24	0.20	0.12	0.10	0.5526	0.5526	2.9950
28	0.1649	94	89	0.24	0.03	0.25	0.12	0.1875	0.7401	2.9940
29	0.1580	66	84	0.24	0.02	26.12	7.90	10.1649	35.8247	2.9850
30	0.1572	90	86	0.24	0.01	7.36	6.18	1.3723	25.6598	3.0000
31	0.1571	86	86	0.24	0.24	6.13	6.13	24.2875	24.2875	2.9950
32	0.2762	87	68	0.43	0.04	19.33	15.02	45.8059	368.4289	2.9990
33	0.2707	50	66	0.42	0.13	16.77	14.59	115.5120	322.2024	2.9670
34	0.2481	73	73	0.43	0.43	13.22	13.22	164.0730	164.0730	3.0010
35	0.1632	94	84	0.24	0.00	0.24	0.38	0.0133	2.2810	3.0000

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.

Sub-basin	Composite Reach Depth (m)	CN (Area Wt.)	Composite CN (Area Wt.)	Erodability (tons/acre)	Composite Erodability (tons/acre)	Impervious Surface (%)	Composite Impervious Surface (%)	Impervious Surface (acres)	Composite Impervious Surface (acres)	Hydrogroup (Area Wt.)
36	0.1630	86	84	0.24	0.12	0.77	0.38	2.2678	2.2678	2.9960
37	0.1413	82	82	0.24	0.24	0.00	0.00	0.0000	0.0000	3.0000
38	0.1584	10	84	0.37	0.01	0.26	0.24	0.0214	1.3305	2.0000
39	0.1581	84	86	0.31	0.22	0.26	0.24	1.0057	1.3092	2.9640
40	0.1063	89	89	0.24	0.24	0.20	0.20	0.3035	0.3035	2.9880
41	0.3453	59	62	0.37	0.01	24.33	17.63	32.4500	859.0717	1.9930
42	0.3429	73	63	0.37	0.00	34.99	17.44	0.1899	826.6217	2.0000
43	0.3386	58	62	0.36	0.16	21.59	16.73	442.0915	753.0728	2.4500
44	0.2539	66	63	0.41	0.17	9.23	12.22	65.8422	65.8422	2.7140
45	0.2528	27	27	0.29	0.29	5.83	5.83	26.1546	26.1546	2.4750
46	0.2884	35	41	0.37	0.01	26.17	26.53	20.6209	984.4501	1.9960
47	0.3003	56	42	0.30	0.02	20.47	26.04	84.4070	1068.8571	2.4100
48	0.3034	48	43	0.30	0.01	34.69	26.23	40.9685	1109.8256	2.2880
49	0.2998	48	48	0.30	0.02	11.17	21.94	43.5203	1158.7769	2.4160
50	0.1295	71	71	0.33	0.33	26.66	26.66	64.3763	64.3763	2.9420
51	0.3020	55	53	0.30	0.02	2.08	18.60	13.3331	1236.6120	2.4280
52	0.3017	46	56	0.29	0.01	6.78	17.83	24.9757	1629.9879	2.1250
53	0.3270	54	63	0.30	0.03	4.64	12.19	89.7909	1763.0946	2.7130
54	0.1631	45	79	0.31	0.04	1.39	0.41	1.3046	2.6351	2.4210
55	0.1826	72	80	0.31	0.10	1.73	0.84	5.4367	7.7177	2.7890
56	0.1584	59	83	0.31	0.01	34.83	8.91	6.1973	42.0220	2.8250
57	0.3489	42	62	0.30	0.02	16.19	12.77	226.2951	2858.8142	2.2950
58	0.3762	62	62	0.33	0.02	21.78	13.28	315.9032	3174.7175	2.4250
59	0.3851	59	63	0.38	0.02	18.30	13.55	220.8588	3806.0271	2.5000
60	0.3853	86	63	0.43	0.00	46.46	13.57	5.5257	3811.5528	3.0000
61	0.3856	85	63	0.43	0.00	51.16	13.59	7.7268	3819.2795	3.0000
62	0.3861	84	63	0.40	0.00	32.64	13.61	11.5839	3830.8634	2.9910
63	0.3886	77	63	0.40	0.00	35.64	13.72	51.7458	3882.6093	2.4080
64	0.2519	72	73	0.43	0.08	15.23	13.61	41.4042	206.6904	2.9820
65	0.3429	72	63	0.33	0.02	31.16	17.44	73.3590	826.4318	2.9590
66	0.2743	70	65	0.40	0.11	13.85	12.68	95.5897	310.9813	2.7710
67	0.2317	61	61	0.40	0.40	14.28	14.28	149.5495	149.5495	2.4890
68	0.2709	82	66	0.43	0.00	5.15	14.56	0.4205	322.6229	3.0000
69	0.2481	81	73	0.43	0.00	18.76	13.25	1.2132	165.2862	3.0000

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.

Sub-basin	Composite Hydrogroup	Velocity (m/s)	Composite Velocity (m/s)	Slope (%)	Composite Slope (%)	Forest Area (ha)	Urban Area (ha)	Water/Wetland Area (ha)	%Forest	%Urban	%Water/ wetland
1	2.85	2.490083	2.39463	57.1047	55.7632	254.6878275	6.835226857	28.53641483	0.8781	0.0236	0.0984
2	2.85	1.70581	2.3944676	26.8008	55.7546	0.065150463	0.034718518	0	0.6524	0.3476	0.0000
3	2.99	1.692535	1.6925346	47.9625	47.9625	37.67301452	5.956768385	6.144917354	0.7569	0.1197	0.1235
4	3.00	2.493376	2.398393	60.0133	59.1257	213.0176716	4.617894318	18.12513817	0.9035	0.0196	0.0769
5	2.99	2.009975	1.6501827	73.7979	53.9039	8.6686	0	0	1.0000	0.0000	0.0000
6	3.00	1.543203	1.5432035	48.2916	48.2916	29.0302	0	2.188873226	0.9299	0.0000	0.0701
7	3.00	2.347788	2.3477877	71.2543	71.2543	95.73403964	0.056648417	5.007074721	0.9498	0.0006	0.0497
8	2.91	2.575122	2.4898156	67.1283	68.9542	118.492966	0	8.320666388	0.9344	0.0000	0.0656
9	2.44	1.670411	1.5794031	21.4581	20.0948	23.19350877	165.6903034	7.945499724	0.1178	0.8416	0.0404
10	2.48	1.710258	1.5426881	23.0171	19.5953	32.1424383	274.8393631	10.69144111	0.1012	0.8652	0.0337
11	2.64	1.617975	1.4535694	21.5820	17.8873	31.51488137	89.4518408	4.703830058	0.2488	0.7063	0.0371
12	2.62	1.410783	1.4107834	16.9701	16.9701	92.10064676	329.0743375	27.08883777	0.2022	0.7224	0.0595
13	2.75	1.508704	1.4296229	18.0062	17.5711	140.046278	207.5205161	56.48923406	0.3466	0.5136	0.1398
14	2.62	1.312674	1.3483417	14.7585	17.2166	70.5543518	163.2829577	36.25469171	0.2609	0.6038	0.1341
15	2.92	0.940923	0.9409229	17.5184	17.5184	12.6509983	17.48175181	1.396668449	0.4012	0.5545	0.0443
16	2.60	1.395855	1.3958549	20.7781	20.7781	50.1227948	106.574324	13.1505145	0.2951	0.6275	0.0774
17	2.58	2.625428	2.0665586	53.8283	35.6297	28.13380629	1.473971158	15.31329032	0.6263	0.0328	0.3409
18	3.01	1.345512	1.3455122	34.8195	34.8195	11.46829329	20.67102295	2.784866507	0.3284	0.5919	0.0797
19	3.40	1.978773	1.8438882	43.1023	41.1341	33.46273433	37.05701817	1.395900908	0.4653	0.5153	0.0194
20	3.50	1.736663	1.736663	39.6551	39.6551	71.02902939	17.74714405	6.947419028	0.7420	0.1854	0.0726
21	2.97	3.180051	2.6839456	80.8956	61.8993	108.1788613	0.948941355	1.547002367	0.9774	0.0086	0.0140
22	3.00	2.859265	2.599656	66.5659	58.8802	232.983197	4.483287087	12.70531398	0.9313	0.0179	0.0508
23	3.00	2.612944	2.4439011	59.5685	54.5786	109.755946	8.718090461	8.049975937	0.8675	0.0689	0.0636
24	3.00	2.374949	2.374949	52.6052	52.6052	258.8285019	2.708102795	59.05281202	0.8074	0.0084	0.1842
25	2.96	2.852677	2.5246087	73.1623	63.9152	125.699475	4.589902489	7.270157254	0.9138	0.0334	0.0529
26	3.00	1.715112	1.7151116	58.5083	58.5083	29.01704326	1.584868479	2.085205823	0.8877	0.0485	0.0638
27	3.00	2.340009	2.2718043	56.3523	56.6818	154.4909915	10.08005454	16.32163972	0.8540	0.0557	0.0902
28	3.00	2.708704	2.3275098	72.9686	58.7018	28.65585768	1.517862553	0.046633495	0.9482	0.0502	0.0015
29	2.99	1.648428	1.9554498	29.1402	42.4749	5.197636058	10.55170229	0	0.3300	0.6700	0.0000
30	3.00	2.204227	1.9807123	53.4304	43.7299	6.020571533	1.529523449	0	0.7974	0.2026	0.0000
31	3.00	1.969727	1.9697266	43.2740	43.2740	132.3041269	25.35635625	2.699140019	0.8250	0.1581	0.0168
32	2.99	1.84078	1.7359187	26.5679	24.8125	21.54581103	71.78178379	2.576587874	0.2247	0.7485	0.0269
33	2.99	1.930639	1.7260618	29.5088	24.6881	72.8985977	144.2822884	61.53346675	0.2616	0.5177	0.2208
34	3.00	1.545416	1.5454159	20.4140	20.4140	144.6912076	174.6551737	180.5786564	0.2882	0.3479	0.3597
35	3.00	2.009643	1.971845	45.8122	42.3260	1.962009801	0.035788858	0.199318929	0.8930	0.0163	0.0907

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.
Page 5 of 6

Sub-basin	Composite Hydrogroup	Velocity (m/s)	Composite Velocity (m/s)	Slope (%)	Composite Slope (%)	Forest Area (ha)	Urban Area (ha)	Water/Wetland Area (ha)	%Forest	%Urban	%Water/wetland
36	3.00	2.144301	1.9714098	38.9471	38.9471	95.40002673	8.378010954	15.48549973	0.7999	0.0702	0.1298
37	3.00	1.794087	1.7940874	43.9519	52.6988	88.27069148	3.507607888	31.4400497	0.7164	0.0285	0.2552
38	2.96	2.076784	2.1739468	54.7648	52.8321	2.744148188	0.173085236	0.418390549	0.8227	0.0519	0.1254
39	2.97	2.314302	2.1750608	47.7731	47.7731	143.1471998	6.925047244	7.960428886	0.9058	0.0438	0.0504
40	2.99	1.753473	1.7534726	31.0510	27.4399	48.61820775	6.702807812	4.959901524	0.8065	0.1112	0.0823
41	2.56	2.022383	1.86799	5.1242	27.3384	5.916399995	38.06305592	9.999728458	0.1096	0.7051	0.1853
42	2.57	0.821494	1.8633888	28.6199	27.3754	0	0.219711759	0	0.0000	1.0000	0.0000
43	2.55	1.940645	1.8624573	36.1525	28.6420	175.4170621	596.1192023	52.10200119	0.2117	0.7193	0.0629
44	2.58	2.110711	1.8369874	58.4162	58.4162	91.27786597	142.0669782	55.21620952	0.3163	0.4923	0.1914
45	2.48	2.624218	2.6242179	11.5773	30.7942	130.6805423	36.55992556	14.22571666	0.7204	0.2016	0.0784
46	2.44	1.234467	1.9439077	38.5743	31.4335	0.330219972	22.03579326	9.519808226	0.0104	0.6911	0.2986
47	2.44	2.254246	1.9721207	35.7153	31.5320	64.17930402	95.90969279	6.772097076	0.3846	0.5748	0.0406
48	2.43	2.169348	1.9772396	26.0470	34.3932	10.50264673	33.01524286	4.279404843	0.2197	0.6907	0.0895
49	2.49	1.850819	2.053157	25.0943	25.0943	46.40900346	68.40301053	37.93812297	0.2943	0.4338	0.2406
50	2.94	1.389202	1.3892019	53.4965	37.7732	36.85150141	48.29236168	6.943835119	0.3771	0.4941	0.0710
51	2.54	2.643663	2.1395442	42.1790	33.6563	170.5980901	35.13947053	53.22270777	0.6588	0.1357	0.2055
52	2.57	2.329261	2.0161787	47.4318	41.9161	74.17963223	41.89999366	33.09467141	0.4973	0.2809	0.2219
53	2.69	2.421648	2.2333343	59.6856	53.7164	514.9976026	168.9122548	78.18853451	0.6577	0.2157	0.0998
54	2.88	2.469249	2.2183376	54.5126	46.4849	28.58783548	7.00066523	2.271830086	0.7551	0.1849	0.0600
55	2.93	2.455638	2.1441966	4.8440	41.0579	109.6940152	12.3745992	5.374192553	0.8607	0.0971	0.0422
56	2.99	0.675781	1.9243054	51.2997	40.0357	0	7.197889554	0.002663995	0.0000	0.9996	0.0004
57	2.65	2.460487	2.1875884	32.7674	39.6284	237.2842187	273.9134115	53.16126032	0.4196	0.4843	0.0940
58	2.64	1.958712	2.1737442	32.2056	38.1396	218.6479644	319.8641625	43.92309524	0.3725	0.5449	0.0748
59	2.67	1.921562	2.1277577	27.8655	38.1355	125.6202104	269.8617785	92.83738181	0.2573	0.5526	0.1901
60	2.67	1.787294	2.1276107	33.3321	38.1331	1.014505986	2.752681057	1.046497854	0.2108	0.5718	0.2174
61	2.67	1.954723	2.127501	58.9824	38.1578	0.94805335	3.703914064	1.460014239	0.1551	0.6060	0.2389
62	2.67	2.599981	2.1280885	13.4874	38.0393	3.771640207	9.952933592	0.636585706	0.2626	0.6930	0.0443
63	2.67	1.242844	2.12437	31.6104	22.5079	2.408974523	48.54461267	7.799334484	0.0410	0.8263	0.1327
64	3.00	1.953661	1.6276183	26.6803	27.3409	50.91302477	51.4700423	7.151741033	0.4627	0.4677	0.0650
65	2.57	1.874559	1.8634704	20.4785	26.3392	10.34446931	81.55574059	3.364811319	0.1086	0.8561	0.0353
66	2.63	1.616498	1.7849028	23.4459	23.4459	38.27518396	221.9046008	19.21256127	0.1370	0.7942	0.0688
67	2.49	1.631354	1.631354	7.5581	24.6251	86.52725062	287.9118173	48.66466551	0.2042	0.6794	0.1148
68	2.99	0.977344	1.7240241	40.0189	20.5154	2.545958908	0.759704372	0	0.7702	0.2298	0.0000
69	3.00	2.164635	1.5492532	12.3400	20.4500	1.08201941	1.284577075	0.249970824	0.4135	0.4909	0.0955

Appendix B: Ramapo Watershed variables for the 69 subbasins determined using GIS.
Page 6 of 6

Subbasin	Average SVAP Score	Channel Condition	Hydrologic Alteration	Riparian Zone	Bank Stability	Water Appear-ance	Nutrient Enrich-ment	Barriers to Fish Move-ment	Instream Fish Cover	Pools	Inverte-brate Habitat	Canopy Cover	Riffle Embedd-edness
1	7.00	8	8	8.0	8.0	9	9	9	9	9	7	9	6
2	9.20	10	10	9.0	9.0	10	10	9	9	9	9	9	9
3	9.00	9	9	9.0	9.0	9	9	9	9	9	9	9	9
4	9.30	8	7	7.0	7.0	8	7	5	7	7	7	7	7
5	8.80	8	8	8.0	7.0	9	9	9	9	9	9	9	8
6	9.00	8	7	8.0	8.0	8	8	1	9	9	9	9	9
7	7.80	9	9	8.0	7.5	9	9	9	9	9	9	9	9
9	7.50	8	7	8.0	8.0	9	9	1	9	9	9	9	8
10	7.80	7	7	7.0	7.0	7	7	8	8	7	7	8	7
11	8.20	7	7	7.0	7.0	7	7	8	8	7	7	8	7
12	8.90	7	5	7.0	7.0	7	6	1	9	0	0	0	0
13	6.70	9	9	9.0	9.0	9	9	9	9	9	9	9	9
14	6.80	6	8	6.0	6.0	8	8	3	8	8	6	7	6
15	9.30	9	8	8.0	8.0	9	9	9	9	9	9	9	9
16	8.80	8	7	8.5	8.5	8	9	5	9	9	8	9	8
17	7.30	8	7	8.0	8.0	8	8	8	9	9	8	8	7
18	9.00	7	6	7.5	7.5	7	7	7	7	8	7	7	7
19	8.10	9	9	8.0	9.0	9	9	9	9	9	9	9	0
22	8.60	9	0	9.0	10.0	10	7	10	7	0	0	1	0
23	8.70	9	9	9.0	9.0	10	9	10	10	10	9	9	9
24	8.80	8	7	7.0	8.0	9	8	6	9	9	9	9	9
25	9.00	7	7	7.0	6.0	8	8	5	7	8	7	6	6
27	9.00	8	8	9.0	8.5	9	9	9	9	9	9	9	0
28	7.00	7	7	7.5	8.0	8	8	1	7	8	7	7	8
29	6.00	9	9	9.0	9.0	9	9	9	9	9	9	9	0
30	8.55	8	8	9.0	7.0	9	9	9	9	9	9	9	9
31	8.90	9	7	9.0	9.0	9	9	9	9	9	9	9	9
32	8.50	9	9	9.0	9.0	9	9	9	9	9	9	9	9
33	8.10	9	9	9.0	9.0	9	8	8	9	8	8	9	8
34	8.70	8	8	9.0	9.0	9	9	8	9	9	8	9	9
36	7.40	9	8	9.0	9.0	10	9	8	10	9	9	9	0
37	8.60	9	9	8.0	9.0	9	9	9	9	9	9	9	9
38	8.80	9	8	9.0	9.0	9	8	9	9	9	9	9	9

Appendix C: SVAP data collected for the Wanaque Watershed. A score of zero indicates no score recorded.
Page 1 of 2

Subbasin	Average SVAP Score	Channel Condition	Hydrologic Alteration	Riparian Zone	Bank Stability	Water Appear-ance	Nutrient Enrich-ment	Barriers to Fish Move-ment	Instream Fish Cover	Pools	Inverte-brate Habitat	Canopy Cover	Riffle Embedd-edness
39	8.00	8	8	9.0	9.0	9	9	8	9	9	9	9	8
40	8.90	9	0	8.5	8.0	0	0	8	0	0	0	7	0
41	9.00	8	7	8.0	8.0	9	8	1	9	8	8	8	8
42	8.80	7	7	6.0	6.0	8	8	8	8	7	8	8	7
43	9.50	9	9	10.0	9.0	9	9	8	10	9	9	10	9
44	9.00	7	7	8.0	8.0	8	7	6	8	8	7	8	7
45	7.80	9	9	9.0	9.0	9	9	9	9	9	9	9	9
46	8.90	7	7	9.0	9.0	9	9	1	9	9	9	9	9
47	7.80	9	9	9.0	9.0	9	9	9	9	9	9	9	9
49	9.00	9	9	9.0	9.0	9	9	9	9	9	9	9	9
50	7.00	8	8	9.0	8.5	8	9	8	9	9	8	9	0
51	8.00	9	9	8.5	9.0	9	9	9	9	9	9	9	8
53	8.60	8	8	8.5	8.0	9	9	9	9	9	8	9	8
54	9.00	8	9	9.0	9.0	9	9	9	9	9	9	9	9
55	7.30	9	0	9.5	9.0	10	7	7	5	1	0	7	10
56	7.80	8	7	8.0	8.0	8	8	1	7	8	8	8	8
57	8.90	6	6	7.0	7.0	5	6	1	7	7	7	7	6
59	8.70	9	9	8.0	8.0	9	9	1	8	8	9	7	8
60	8.30	9	9	9.0	10.0	10	10	9	10	10	9	10	9
61	7.40	8	7	9.0	8.0	9	8	1	9	9	8	8	8
64	6.10	6	7	7.0	7.0	8	8	8	8	8	7	8	7
67	7.80	7	8	7.0	7.0	8	8	8	8	8	8	8	8
68	7.30	6	8	7.0	6.0	8	8	9	8	8	9	8	8
70	7.30	7	0	9.5	10.0	7	7	3	8	0	0	9	0
74	7.50	9	9	10.0	9.0	9	8	8	9	9	9	10	9
75	8.10	9	0	9.5	9.0	0	0	8	8	0	0	9	0
76	7.70	8	9	8.0	8.0	9	8	8	9	9	9	9	9
77	8.70	8	8	8.0	8.0	8	8	6	9	9	8	9	8
78	7.50	9	9	8.0	9.0	9	9	9	9	9	9	9	9

Appendix C: SVAP data collected for the Wanaque Watershed. A score of zero indicates no score recorded.
Page 2 of 2

Sub-basin	Subbasin Drainage Area (ha)	% Drainage Area	Cumulative Area	% Cumulative Area	Reach Length	% Reach Length	Cumulative Reach Length	% Cumulative Reach Length	Reach Width	Composite Reach Width	Reach Depth	Compostie Reach Depth
1	764.792	0.035553	3454.2921	0.160580	5199.99	0.044881	22576.0896	0.194854	10.8045	4.190671032	0.5362	0.262460493
2	24.9568	0.001160	131.7946	0.006127	378.449	0.003266	2800.9644	0.024175	1.5224	1.366547498	0.1452	0.135080831
3	60.9788	0.002835	167.4471	0.007784	277.095	0.002392	1372.554	0.011847	1.7576	1.423827343	0.1598	0.138649891
4	422.248	0.019629	422.248	0.019629	2955.24	0.025507	2955.2373	0.025507	3.0615	3.0615	0.2313	0.2313
5	194.4212	0.009038	4184.4602	0.194524	1813.18	0.015650	27116.9372	0.234046	12.122	5.47363005	0.5789	0.313999659
6	100.9756	0.004694	4520.0934	0.210126	354.825	0.003062	29184.8612	0.251895	12.6963	5.362941697	0.597	0.309541834
7	746.077	0.034683	6260.7665	0.291045	2445.31	0.021105	41449.7435	0.357753	15.4371	5.163799573	0.6801	0.299208326
8	21.2617	0.000988	3475.5538	0.161569	314.349	0.002713	22890.4389	0.197567	10.8444	4.28204521	0.5375	0.266237549
9	83.8684	0.003899	83.8684	0.003899	630.56	0.005442	630.5603	0.005442	1.1608	1.1608	0.1212	0.1212
10	1121.3374	0.052128	1597.0542	0.074242	297.939	0.002572	5015.4456	0.043288	6.8011	2.300084038	0.3938	0.187193989
11	141.9011	0.006597	141.9011	0.006597	1549.42	0.013373	1549.4212	0.013373	1.5914	1.5914	0.1495	0.1495
12	267.7136	0.012445	267.7136	0.012445	2914.91	0.025159	2914.9088	0.025159	2.3291	2.3291	0.1928	0.1928
13	34.3842	0.001598	258.4859	0.012016	624.853	0.005393	3700.0109	0.031935	2.2806	1.772527499	0.1901	0.160048773
14	94.9137	0.004412	224.1017	0.010418	861.265	0.007434	3075.1575	0.026542	2.0934	1.669290241	0.1795	0.153942545
15	129.188	0.006006	129.188	0.006006	2213.89	0.019108	2213.8929	0.019108	1.5043	1.5043	0.144	0.144
16	310.8562	0.014451	442.6508	0.020578	1776.34	0.015332	4577.3057	0.039507	3.1494	2.058429303	0.2357	0.174128689
17	6363.48	0.295820	19984.5195	0.929023	10027.7	0.086549	99482.2075	0.858631	30.9746	7.375828627	1.082	0.368235024
18	106.8378	0.004967	106.8378	0.004967	2422.52	0.020909	2422.5156	0.020909	1.3422	1.3422	0.1335	0.1335
19	35.5826	0.001654	119.451	0.005553	499.373	0.004310	1129.9337	0.009752	1.4352	1.282070886	0.1396	0.129331867
20	514.4852	0.023917	3990.039	0.185485	2413.32	0.020829	25303.7575	0.218397	11.7808	4.997230866	0.568	0.295017818
21	92.1873	0.004286	1868.9123	0.086880	778.893	0.006723	5794.3386	0.050011	7.4738	2.995551015	0.4194	0.218407843
22	147.264	0.006846	147.264	0.006846	1685.13	0.014544	1685.1278	0.014544	1.6272	1.6272	0.1518	0.1518
23	13.1125	0.000610	234.6576	0.010909	301.221	0.002600	1713.0991	0.014786	2.152	2.091918296	0.1829	0.179438503
24	221.5451	0.010299	221.5451	0.010299	1411.88	0.012186	1411.8781	0.012186	2.0791	2.0791	0.1787	0.1787
25	150.4098	0.006992	150.4098	0.006992	1715.11	0.014803	1715.1078	0.014803	1.648	1.648	0.1531	0.1531
26	66.102	0.003073	66.102	0.003073	253.177	0.002185	253.1768	0.002185	1.0063	1.0063	0.1102	0.1102
27	172.3506	0.008012	172.3506	0.008012	2414.47	0.020839	2414.4701	0.020839	1.7883	1.7883	0.1616	0.1616
28	153.9051	0.007155	153.9051	0.007155	1703.82	0.014706	1703.816	0.014706	1.6709	1.6709	0.1545	0.1545
29	52.3803	0.002435	52.3803	0.002435	417.21	0.003601	417.2098	0.003601	0.8752	0.8752	0.1004	0.1004
30	106.7479	0.004962	465.5503	0.021642	293.652	0.002535	3568.9712	0.030804	3.2462	2.638480569	0.2405	0.209368614
31	45.4695	0.002114	358.8024	0.016680	367.035	0.003168	3275.3188	0.028269	2.7765	2.583994798	0.2167	0.206577494
32	313.3329	0.014566	313.3329	0.014566	2908.28	0.025101	2908.2837	0.025101	2.5597	2.5597	0.2053	0.2053
33	467.6775	0.021741	940.1386	0.043704	3657.05	0.031564	6890.5943	0.059473	4.9489	3.974013079	0.3186	0.272277146

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	Subbasin Drainage Area (ha)	% Drainage Area	Cumulative Area	% Cumulative Area	Reach Length	% Reach Length	Cumulative Reach Length	% Cumulative Reach Length	Reach Width	Composite Reach Width	Reach Depth	Compostie Reach Depth
34	10.1765	0.000473	950.3151	0.044177	130.624	0.001127	7021.2181	0.060600	4.9809	3.992745356	0.32	0.273164989
35	32.4069	0.001507	179.6709	0.008352	489.38	0.004224	2174.5078	0.018768	1.8335	1.673628481	0.1643	0.154613165
36	50.2132	0.002334	50.2132	0.002334	278.307	0.002402	278.3073	0.002402	0.8533	0.8533	0.0987	0.0987
37	17.8962	0.000832	17.8962	0.000832	14.99	0.000129	14.99	0.000129	0.4595	0.4595	0.0653	0.0653
38	223.7022	0.010399	223.7022	0.010399	1599.68	0.013807	1599.6822	0.013807	2.0912	2.0912	0.1794	0.1794
39	62.6566	0.002913	286.3589	0.013312	397.015	0.003427	1996.6973	0.017233	2.4251	2.157591306	0.198	0.183098348
40	57.6932	0.002682	57.6932	0.002682	594.31	0.005129	594.3102	0.005129	0.9274	0.9274	0.1043	0.1043
41	46.9175	0.002181	240.6097	0.011185	856.415	0.007392	3399.7335	0.029343	2.1846	1.785648923	0.1847	0.160839613
42	26.2451	0.001220	193.6922	0.009004	1170.76	0.010105	2304.2744	0.019888	1.918	1.997797026	0.1694	0.17393203
43	106.4683	0.004949	106.4683	0.004949	1095.46	0.009455	1095.4591	0.009455	1.3394	1.3394	0.1333	0.1333
44	54.6772	0.002542	54.6772	0.002542	331.409	0.002860	331.409	0.002860	0.898	0.898	0.1021	0.1021
45	67.3703	0.003132	296.4953	0.013783	618.289	0.005336	2387.5032	0.020607	2.4763	1.959434658	0.2008	0.170880984
46	104.3211	0.004850	229.125	0.010651	833.709	0.007196	1769.214	0.015270	2.1215	1.778805147	0.1811	0.160425152
47	124.8039	0.005802	124.8039	0.005802	935.505	0.008074	935.5046	0.008074	1.4734	1.4734	0.142	0.142
48	34.8936	0.001622	128.1195	0.005956	862.685	0.007446	1892.3301	0.016333	1.4968	1.326266595	0.1435	0.132220018
49	85.0568	0.003954	85.0568	0.003954	830.782	0.007170	830.7824	0.007170	1.1706	1.1706	0.1219	0.1219
50	58.3623	0.002713	2587.1663	0.120270	945.057	0.008157	9450.5312	0.081568	9.0842	8.972960047	0.4776	0.473730002
51	2528.804	0.117557	2528.804	0.117557	8505.47	0.073411	8505.4745	0.073411	8.9606	8.9606	0.4733	0.4733
52	6.002	0.000279	151.9577	0.007064	267.102	0.002305	1571.0615	0.013560	1.6581	1.62523253	0.1537	0.151625033
53	221.8547	0.010313	221.8547	0.010313	2496.84	0.021550	2496.8417	0.021550	2.0808	2.0808	0.1788	0.1788
54	143.9384	0.006691	143.9384	0.006691	1281.61	0.011062	1281.6094	0.011062	1.6051	1.6051	0.1504	0.1504
55	112.9397	0.005250	3065.8991	0.142525	972.612	0.008395	14201.5943	0.122574	10.0583	7.170645736	0.5112	0.39526469
56	59.4808	0.002765	59.4808	0.002765	908.66	0.007843	908.6595	0.007843	0.9445	0.9445	0.1056	0.1056
57	145.9557	0.006785	145.9557	0.006785	1303.96	0.011254	1303.96	0.011254	1.6185	1.6185	0.1512	0.1512
58	35.1232	0.001633	35.1232	0.001633	224.201	0.001935	224.2011	0.001935	0.6886	0.6886	0.0855	0.0855
59	386.5854	0.017971	957.8351	0.044527	4330.87	0.037380	8661.1676	0.074755	5.0045	4.337393382	0.321	0.291001951
60	496.4392	0.023078	1454.2743	0.067605	2135.39	0.018431	10796.5593	0.093185	6.4295	4.751179569	0.3793	0.308465933
61	571.2496	0.026556	571.2496	0.026556	4330.3	0.037375	4330.3022	0.037375	3.6702	3.6702	0.261	0.261
62	90.9489	0.004228	354.7778	0.016493	904.373	0.007806	4019.8591	0.034695	2.7578	2.387090995	0.2157	0.195775809
63	5.8822	0.000273	263.8288	0.012265	168.883	0.001458	3115.4861	0.026890	2.3088	2.279480431	0.1916	0.189992153
64	93.3457	0.004339	93.3457	0.004339	452.334	0.003904	452.3336	0.003904	1.2378	1.2378	0.1265	0.1265
65	174.4878	0.008111	267.8335	0.012451	2261.29	0.019517	2713.6213	0.023421	2.3297	2.147691163	0.1928	0.181748451
66	2.0473	0.000095	833.3008	0.038738	116.491	0.001005	8396.9679	0.072474	4.6033	3.51633444	0.3036	0.250808365

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	Subbasin Drainage Area (ha)	% Drainage Area	Cumulative Area	% Cumulative Area	Reach Length	% Reach Length	Cumulative Reach Length	% Cumulative Reach Length	Reach Width	Composite Reach Width	Reach Depth	Compostie Reach Depth
67	244.2948	0.011357	244.2948	0.011357	2275.21	0.019637	2275.2125	0.019637	2.2046	2.2046	0.1858	0.1858
68	91.1786	0.004239	118.5922	0.005513	996.028	0.008597	1011.0178	0.008726	1.429	1.416610857	0.1392	0.138285196
69	27.4135	0.001274	27.4135	0.001274	14.99	0.000129	14.99	0.000129	0.5934	0.5934	0.0775	0.0775
70	46.598	0.002166	46.598	0.002166	561.464	0.004846	561.4641	0.004846	0.8158	0.8158	0.0958	0.0958
71	14.6006	0.000679	831.2535	0.038643	363.606	0.003138	8280.4769	0.071469	4.5965	3.501042844	0.3033	0.250065684
72	184.7441	0.008588	1408.9945	0.065500	841.278	0.007261	9238.2458	0.079735	6.3086	3.77061121	0.3745	0.262072304
73	28.0626	0.001305	390.9496	0.018174	450.117	0.003885	3736.3471	0.032248	2.9232	2.077947656	0.2243	0.177581059
74	257.9466	0.011991	257.9466	0.011991	2946.6	0.025432	2946.6035	0.025432	2.2778	2.2778	0.1899	0.1899
75	30.07	0.001398	30.07	0.001398	14.99	0.000129	14.99	0.000129	0.6273	0.6273	0.0804	0.0804
76	256.8182	0.011939	256.8182	0.011939	2212.95	0.019100	2212.9494	0.019100	2.2718	2.2718	0.1896	0.1896
77	8.1691	0.000380	93.2259	0.004334	198.863	0.001716	1029.645	0.008887	1.2368	1.183385673	0.1264	0.122769117
78	6.6012	0.000307	303.0966	0.014090	124.77	0.001077	2512.273	0.021683	2.5092	1.986738264	0.2026	0.172456281
79	71.2152	0.003311	1480.2097	0.068811	431.343	0.003723	12974.5929	0.111984	6.4981	3.283167896	0.382	0.237741011
80	0.0499	0.000002	1454.3242	0.067607	9.9934	0.000086	10806.5527	0.093271	6.4296	4.752731695	0.3793	0.308531437
81	461.8752	0.021471	816.653	0.037964	3897.01	0.033635	7916.871	0.068331	4.5479	3.450730709	0.3011	0.247620739

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	CN	Composite CN calc	Erodibility (tons/acre)	Comp Erodability (tons/acre)	Impervious Surface %	Composite Impervious Surface %	Impervious Surface Acres	Composite Impervious Surface Acres	Hydrogroup #	Composite Hydrogroup	Slope (%)
1	68.13	67.56073	0.31999999	0.319514394	9.3418	7.28598038	176.4376987	621.8989194	3	2.99999991	36.7083
2	73	62.380633	0.31999999	0.319999993	0	0	0	0	3	3	64.5331
3	68.15	64.35408	0.23999999	0.239999995	3.125	1.137278706	4.705624663	4.705624663	3	3	64.4135
4	64.09	64.09	0.27999999	0.279999994	0.3571	0.357032402	3.725186138	3.725186138	3	3	40.2541
5	70.7	66.733448	0.27999999	0.317740622	2.8462	8.132586697	13.66935243	840.8932932	3	2.99999993	63.8417
6	67.88	66.806277	0.23999999	0.311968101	0.9375	7.549655938	2.339162781	843.232456	3	2.99999993	63.182
7	66.97	67.146958	0.27999999	0.299912065	7.1402	6.827251876	131.6335918	1056.200035	3	2.99999995	57.8683
8	79.56	67.634136	0.31999999	0.319517365	20.7576	7.367975491	10.86970047	632.7686198	3	2.99999991	19.0593
9	60.16	60.16	0.29999999	0.299999993	5.7692	5.752710333	11.9218488	11.9218488	3	3	40.9983
10	66.02	66.57292	0.31999999	0.319999973	8.9521	7.474654656	246.673106	294.973861	3	2.99999981	48.5887
11	64.4	64.4	0.31999999	0.319999993	1.8333	1.832655156	6.425978386	6.425978386	3	3	62.4161
12	72.75	72.75	0.31999999	0.319999993	4.9627	4.903936025	32.44053258	32.44053258	3	3	55.6323
13	61.36	66.622968	0.31999999	0.319999993	0	0.038188825	0	0.24391915	3	3	58.9954
14	70.48	67.430472	0.31999999	0.319999993	0.1042	0.044048183	0.24391915	0.24391915	3	3	65.9038
15	65.19	65.19	0.31999999	0.319999993	0	0	0	0	3	3	63.2574
16	67.85	66.221554	0.31999999	0.319999993	0.8871	0.616675421	6.745134868	6.745134868	3	3	69.7695
17	64.85	65.627827	0.29666666	0.270429409	8.7999	6.812998753	1383.579226	3364.377854	2.948197205	2.95760671	45.8976
18	59.9	59.9	0.31999999	0.319999993	0	0	0	0	3	3	47.4878
19	62.86	60.964288	0.31999999	0.305957683	7.5	6.273203171	6.59435228	18.51620108	3	3	31.2885
20	59.15	66.540171	0.31999999	0.319579596	15.303	8.390217299	194.4553209	827.2239407	3	2.99999992	25.6795
21	62.1	59.952194	0.31999999	0.289236277	23.0667	7.52455503	52.51628251	347.4901435	3	2.71159016	12.9104
22	89.39	89.39	0.31999999	0.319999993	16.0313	16.00520625	58.24124003	58.24124003	3	3	39.6246
23	50.29	67.642939	0.23999999	0.239999995	0	0	0	0	3	3	98.6197
24	68.67	68.67	0.23999999	0.239999995	0	0	0	0	3	3	71.5153
25	70.95	70.95	0.23999999	0.239999995	0	0	0	0	3	3	70.151
26	55.6	55.6	0.31999999	0.319999993	5.7759	5.775901253	9.434244015	9.434244015	3	3	28.0227
27	68.78	68.78	0.25999999	0.259999994	7.2059	7.205899634	30.68836521	30.68836521	3	3	53.8499
28	71.68	71.68	0.31999999	0.319999993	7.5694	7.558105244	28.74343661	28.74343661	3	3	44.3611
29	70.77	70.77	0.31999999	0.319999993	12.1698	12.16979507	15.75157524	15.75157524	3	3	29.5296
30	69.84	66.998815	0.23999999	0.239999995	2.3333	0.534661431	6.150610326	6.150610326	3	3	51.7152
31	73	66.15353	0.23999999	0.239999995	0	0	0	0	3	3	72.5266
32	65.16	65.16	0.23999999	0.239999995	0	0	0	0	3	3	57.8726
33	69.49	66.840895	0.23999999	0.257965371	5.3779	3.15822574	62.14603002	73.36818886	3	3.00000032	53.074

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	CN	Composite CN calc	Erodibility (tons/acre)	Comp Erodability (tons/acre)	Impervious Surface %	Composite Impervious Surface %	Impervious Surface Acres	Composite Impervious Surface Acres	Hydrogroup #	Composite Hydrogroup	Slope (%)
34	65.99	66.831783	0.23999999	0.257772988	16.3636	3.286910194	3.815976767	77.18416563	3	3.00000032	89.7524
35	69.23	85.753779	0.31999999	0.319999993	17.8571	16.32235183	14.22458206	72.46582209	3	3	25.9335
36	65.3	65.3	0.23999999	0.239999995	6.087	6.042202628	7.49697271	7.49697271	3	3	66.2339
37	72.25	72.25	0.27999999	0.279999994	7.1429	6.644643091	2.938361522	2.938361522	3	3	50.1223
38	63.79	63.79	0.23999999	0.239999995	3.4524	3.443923729	19.03691301	19.03691301	3	3	38.9422
39	64.11	63.859995	0.23999999	0.239999911	2.7273	3.287122073	4.222527486	23.25944049	3	2.99999895	41.6621
40	72.23	72.23	0.27999999	0.279999994	9.1026	9.102601098	12.97665877	12.97665877	3	3	50.1371
41	68.82	66.199616	0.23999999	0.239999995	0	1.156528119	0	6.876098249	3	3	38.6305
42	73.29	48.055993	0.23999999	0.166211831	3.4091	1.436670572	2.170473586	6.876098249	3	2.07764794	41.2712
43	62.18	62.18	0.23999999	0.239999995	0	0	0	0	3	3	65.4851
44	64.82	64.82	0.23999999	0.239999995	2.5	2.494521525	3.370282207	3.370282207	3	3	53.0758
45	63.21	56.985789	0.23999999	0.239999995	0.9375	4.549273179	1.560675711	33.32978985	3	3	50.1195
46	64.47	55.155666	0.23999999	0.239999995	5.75	5.6112534	14.88265612	31.76911413	3	3	50.368
47	47.37	47.37	0.23999999	0.239999995	5.4762	5.475674987	16.88645801	16.88645801	3	3	48.5304
48	78.08	71.619416	0.23999999	0.239999995	9.6875	5.213908612	8.338410087	16.50636314	3	3	33.9735
49	68.75	68.75	0.23999999	0.239999995	3.3333	3.278645474	6.890904691	6.890904691	3	3	61.3741
50	68.81	70.911499	0.23999999	0.206487712	0.9091	5.01544783	1.311042962	320.6319588	3	3.10722115	67.612
51	70.96	70.96	0.20571428	0.205714281	5.1724	5.110218279	319.3209159	319.3209159	3.109695711	3.10969571	59.9566
52	72.42	68.405101	0.23999999	0.239999995	25	10.69377785	3.707742277	40.15379663	3	3	33.8204
53	71.24	71.24	0.23999999	0.239999995	1.3158	1.321050525	7.242038127	7.242038127	3	3	61.6571
54	73.18	73.18	0.23999999	0.239999995	0	0	0	0	3	3	69.8713
55	68.67	70.959201	0.23999999	0.211720574	12.5	4.7868115	34.7670243	362.6410213	3	3.09047883	34.869
56	74.45	74.45	0.23999999	0.239999995	12.25	12.25000567	18.00469779	18.00469779	3	3	34.3961
57	68.24	68.24	0.23999999	0.239999995	10.1786	10.10547456	36.44605435	36.44605435	3	3	61.9358
58	70.19	70.19	0.31999999	0.319999993	15	14.31818716	12.42667262	12.42667262	3	3	29.474
59	68.37	65.877055	0.23999999	0.23999997	0.2174	3.633371995	2.052204285	85.99503106	3	2.99999969	49.1155
60	57.22	62.921834	0.23999999	0.239999978	7.5874	4.890951134	89.76187485	175.7569059	3	2.99999979	38.9707
61	64.19	64.19	0.23999999	0.239999995	6.1022	5.946821948	83.94282677	83.94282677	3	3	42.2013
62	71.96	69.105579	0.23999999	0.239999927	9.0323	4.894661905	20.28089316	42.90934452	3	2.99999915	46.9755
63	74.77	68.12161	0.23999999	0.239999995	12.5	3.471042132	1.804516833	22.62845135	3	3	38.7355
64	63.71	63.71	0.23999999	0.239999995	6.25	6.231280842	14.37289945	14.37289945	3	3	52.618
65	64.43	64.179065	0.23999999	0.239999995	25.9756	19.07781215	111.8872242	126.2601236	3	3	35.1774
66	80.5	69.897408	0.23999999	0.27602767	44.5238	12.53152065	2.252377308	258.034822	3	2.9945606	11.8083

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	CN	Composite CN calc	Erodibility (tons/acre)	Comp Erodability (tons/acre)	Impervious Surface %	Composite Impervious Surface %	Impervious Surface Acres	Composite Impervious Surface Acres	Hydrogroup #	Composite Hydrogroup	Slope (%)
67	66.8	66.8	0.23999999	0.239999995	4.5062	4.456374398	26.90101327	26.90101327	3	3	53.6047
68	73.61	74.049138	0.23999999	0.239999792	12.7143	13.23586001	28.4375435	38.7865397	3	2.99999747	64.787
69	75.51	75.51	0.23999999	0.239999995	15.2778	15.27780614	10.3489962	10.3489962	3	3	56.6258
70	68.57	68.57	0.305	0.305	19.2647	19.26468981	22.18206855	22.18206855	2.153383237	2.15338324	16.0889
71	83.14	69.871295	0.23999999	0.276116402	21.087	12.45272799	7.425638956	255.7824447	3	2.9945472	17.4315
72	74.13	51.058145	0.305	0.203237861	13.2979	9.154450688	60.68885927	318.7236813	2.995381876	2.16377627	47.6165
73	74.1	69.522981	0.23999999	0.239999933	12.8947	7.723311675	8.922453849	74.61000682	3	2.99999923	45.1735
74	67.97	67.97	0.23999999	0.239999995	3.3333	3.267083515	20.82393452	20.82393452	3	3	61.7718
75	75.87	75.87	0.23999999	0.239999995	19.0909	19.09088419	14.18509395	14.18509395	3	3	42.0047
76	67.98	67.98	0.23999999	0.239999995	2.7143	2.662564678	16.89657613	16.89657613	3	3	65.8835
77	73.9	69.201279	0.23999999	0.239999995	6.4286	3.545715636	1.277048357	8.167953048	3	3	64.8639
78	69.18	57.251351	0.23999999	0.239999915	0	4.45019217	0	33.32978985	3	2.99999901	52.9626
79	70.67	66.963909	0.305	0.256848004	18.1731	10.75387918	31.97970927	393.3336881	2.161216767	2.85202655	27.7042
80	69.91	62.922074	0.23999999	0.239999978	5	4.890954991	0.006169289	175.7630752	3	2.99999979	44.1732
81	70.04	69.63406	0.305	0.276762079	18.0056	12.3073842	205.4474612	248.3568057	2.9901864	2.99444935	52.2591

Sub-basin	Composite % Slope	Forest area (ha)	Urban Area (ha)	Wetland/ Water Area (ha)	Forest %	Urban %	Wetland/ Water %
1	47.884512	461.56	186.91	93.48	0.6	0.24	0.122229
2	50.7155206	24.86	0	0	1	0	0
3	65.0948581	54.69	1.45	4.33	0.9	0.02	0.07
4	40.2541	356.84	11.13	54.28	0.85	0.03	0.12855
5	45.7493245	180.2	7.15	7.05	0.93	0.04	0.036261
6	47.5550091	93.91	0	7.07	0.93	0	0.070017
7	50.0394874	573.88	64.66	83.28	0.77	0.09	0.111624
8	47.7081738	4.37	15.9	0.93	0.21	0.75	0.043741
9	40.9983	55.73	11.59	16.28	0.66	0.14	0.194114
10	50.1467762	618.16	328.09	157.48	0.55	0.29	0.140439
11	62.4161	123.23	0.76	17.01	0.87	0.01	0.119872
12	55.6323	186	65.21	10.2	0.69	0.24	0.0381
13	63.6621964	28.74	0	5.45	0.84	0	0.16
14	64.3782287	91.47	0	3.27	0.96	0	0.03
15	63.2574	115.36	0	13.79	0.89	0	0.106744
16	64.0963789	279.12	2.92	23.3	0.9	0.01	0.074954
17	48.7869185	3820.89	938.63	1535.7	0.6	0.15	0.24133
18	47.4878	86.27	0	18.89	0.81	0	0.17681
19	38.1059012	21.36	3.37	7.59	0.6	0.09	0.213307
20	44.8677438	164.69	109.48	240.07	0.32	0.21	0.466622
21	43.4890896	11.2	40.75	33.46	0.12	0.44	0.362957
22	39.6246	85.99	46.47	9.9	0.58	0.32	0.067226
23	73.0298746	11.32	0	1.38	0.86	0	0.11
24	71.5153	208.89	0	12.59	0.94	0	0.06
25	70.151	146.08	0	4.21	0.97	0	0.03
26	28.0227	31.62	16.72	17.75	0.48	0.25	0.268524
27	53.8499	148.81	11.68	11.84	0.86	0.07	0.07
28	44.3611	121.06	21.81	7.38	0.79	0.14	0.047952
29	29.5296	38.56	9.33	4.3	0.74	0.18	0.08
30	57.8919761	101.43	0.57	4.67	0.95	0.01	0.043748
31	59.729639	45.31	0	0	1	0	0
32	57.8726	280.59	0	33.82	0.9	0	0.11
33	48.0190314	346.06	79.82	33.93	0.74	0.17	0.07255

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	Composite % Slope	Forest area (ha)	Urban Area (ha)	Wetland/ Water Area (ha)	Forest %	Urban %	Wetland/ Water %
34	48.4659354	6.26	2.01	1.15	0.62	0.2	0.11
35	37.1551622	7.22	20.48	4.5	0.22	0.63	0.138859
36	66.2339	35.59	4.52	6.49	0.71	0.09	0.129249
37	50.1223	12.59	3.46	0.6	0.7	0.19	0.033527
38	38.9422	188.18	4.1	29.09	0.84	0.02	0.13
39	39.5373126	50.85	3.33	8.48	0.81	0.05	0.135341
40	50.1371	38.02	16.6	3.1	0.66	0.29	0.05
41	57.3358367	43.86	0	2.67	0.93	0	0.06
42	35.2284252	18.48	6.68	0.6	0.7	0.25	0.02
43	65.4851	88.53	0	16.12	0.83	0	0.15
44	53.0758	44.74	3.36	6.46	0.82	0.06	0.118148
45	49.5380335	56.61	1.72	9.05	0.84	0.03	0.134332
46	49.3670632	83.51	8.48	12.78	0.8	0.08	0.12
47	48.5304	76.54	13.97	34.26	0.61	0.11	0.274511
48	54.1340073	17.2	17.35	0.06	0.49	0.5	0
49	61.3741	65.68	12.24	5.73	0.77	0.14	0.067367
50	60.1292935	51.68	3.3	3.39	0.89	0.06	0.058085
51	59.9566	2323.98	110.03	49.84	0.92	0.04	0.019709
52	60.8253026	1.34	3.72	0.95	0.22	0.62	0.16
53	61.6571	200.03	6.85	11.3	0.9	0.03	0.05
54	69.8713	125.69	16.92	4.7	0.87	0.12	0.03
55	59.7666951	71.04	32.77	8.65	0.63	0.29	0.07659
56	34.3961	48.38	10.42	0.55	0.81	0.18	0.01
57	61.9358	130.01	4.11	10.79	0.89	0.03	0.07
58	29.474	11.19	17.41	4.9	0.32	0.5	0.139509
59	44.9918895	357.09	0.1	24.32	0.92	0	0.06291
60	42.9364626	314.91	50.96	110.29	0.63	0.1	0.222162
61	42.2013	415.47	62.3	75.53	0.73	0.11	0.132219
62	57.5967431	44.33	39.96	6.59	0.49	0.44	0.07
63	61.2581937	2.51	3.09	0.24	0.43	0.53	0.04
64	52.618	56.55	21.95	14.56	0.61	0.24	0.155979
65	41.2558219	53.99	87.45	32.89	0.31	0.5	0.188495
66	53.8219975	0.33	1.72	0	0.16	0.84	0

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .

Sub-basin	Composite % Slope	Forest area (ha)	Urban Area (ha)	Wetland/ Water Area (ha)	Forest %	Urban %	Wetland/ Water %
67	53.6047	165.65	45.31	26.99	0.68	0.19	0.110481
68	62.9004212	66.17	22.3	2.08	0.73	0.24	0.02
69	56.6258	12.04	14.57	0.8	0.44	0.53	0.03
70	16.0889	23.51	21.66	1.42	0.5	0.46	0.030473
71	53.9254733	1.7	12.41	0.16	0.12	0.85	0.01
72	38.0745141	75.56	98.04	9.15	0.41	0.53	0.05
73	55.8193042	12.5	14.04	1	0.45	0.5	0.035635
74	61.7718	229.77	3.65	17.98	0.89	0.01	0.069704
75	42.0047	16.33	13.19	0.56	0.54	0.44	0.02
76	65.8835	232.76	1.69	17.46	0.91	0.01	0.067986
77	61.6799005	7.68	0.36	0	0.94	0.04	0
78	49.6126015	6.2	0	0.34	0.94	0	0.051506
79	50.9855567	26.35	44.33	0.54	0.37	0.62	0.007583
80	42.936505	0	0.04	0.01	0	0.8	0.2
81	54.5779273	197.06	214.84	47.51	0.43	0.47	0.102863

Appendix D: Wanaque Watershed variables for the 81 subbasins determined using GIS .