APPENDIX D METRIC MODELING

D1 Introduction

Seven watershed health metrics are quantified for NHDPlus catchments from Boosted Regression Tree (BRT) models. BRTs are a relatively recent approach to modeling ecological relationships that combine two methods: 1) regression tree modeling; and 2) boosting (Elith, Leathwick, & Hastie, 2008).

A regression tree is comprised of a group of leaves that represent possible response variable outcomes and a group of branches connected to each leaf. Each split in the branch network denotes a relationship between a predictor value and a response outcome evident in the training dataset (i.e., a certain predictor value leads to one known outcome or group of outcomes while another predictor value leads to a different known outcome or group of outcomes). Regression trees are constructed to minimize the error between observed and predicted values.

Boosting is a method for improving model predictions by creating multiple submodels for a response variable rather than one single model. Submodels are developed iteratively, with the first submodel fit to minimize prediction errors in the entire dataset, and subsequent submodels focusing on improving predictions for observations that are poorly predicted by existing submodels. A BRT model therefore consists of several regression trees for any one response variable.

BRT models are well suited for modeling complex ecological relationships and have several advantages over traditional statistical methods (e.g., multiple linear regression or generalized linear modeling). Specifically, BRT models:

- Can be used to predict several data types (e.g., numeric, categorical, or binary);
- Are insensitive to outliers in response and predictor datasets. A pre-processing step to evaluate data distributions and remove outliers is therefore not required;
- Capture interactions between individual predictors in the regression tree structure and do not require the use of "interaction terms" as possible predictor variables (e.g., the product of two predictors that together have an interaction effect);
- Have no assumption of a linear relationship between predictor and response variables and nonlinear relationships are accounted for; and
- Address overfitting without subjective determinations of "significant" predictors.

This Appendix details the methods applied to develop regression models of watershed health metrics and model results.

D2 Methods

Preparation of Response Data

BRT modeling was undertaken to produce a group of statistical models to predict values of watershed health metrics for any NHDPlus catchment in Alabama and the Mobile Bay Basin. Seven metrics were selected for modeling (hereafter referred to as *response variables*):

- Stream habitat condition rating;
- Stream nitrate-nitrite (NO_3-NO_2) concentration;

- Stream total phosphorus (TP) concentration;
- Stream total suspended solids (TSS) concentration;
- Stream conductivity;
- Stream fish Index of Biotic Integrity (IBI) rating; and
- Stream macroinvertebrate IBI rating.

Habitat and biological response variables (habitat rating, fish IBI rating, and macroinvertebrate IBI rating) are multimetric indices used by ADEM and GSA to assess the overall condition of stream habitat, fish communities, and macroinvertebrate communities in wadeable streams throughout the state. Each was selected as a potential watershed health metric because it integrates multiple characteristics of stream habitat or biology. Water quality response variables (NO_3-NO_2, TP, TSS, and conductivity) were selected on the basis of data availability and relevance to aquatic ecosystem health.

Model development was initiated by acquiring and preparing stream monitoring data for input as observed response variable outcomes. The following paragraphs detail sources of data and processing steps for each response variable.

Stream Habitat Rating - ADEM monitors several habitat characteristics in streams across Alabama as part of reach-scale habitat assessments, including the extent of pools, riffles, and runs; channel dimensions; and substrate properties. These characteristics are combined into an overall stream habitat score and rating (Optimal, Sub-optimal, Marginal, or Poor). Separate scoring systems are used to rate riffle/run and glide/pool habitat types, and separate ratings thresholds are used for streams in the Southeastern Plains ecoregion.

Stream habitat scores and ratings compiled for modeling were acquired from ADEM (Lisa Huff, personal communication). Habitat data were processed to produce a single representative rating for each monitored catchment. Processing steps included:

- Filter data to remove ratings for assessments conducted before January 1, 2000;
- Determine the NHDPlus catchment of each monitoring site using reported latitude/longitude coordinates, site names, and catchment names;
- Calculate the median of scores reported for all sites within catchment boundaries. This provided a single score per monitored catchment;
- Convert median habitat scores to categorical ratings (Optimal, Sub-optimal, Marginal, or Poor) using thresholds displayed in Table D-1.

Note that categorical habitat *ratings* were modeled rather than numeric habitat *scores*. This is because scores are not directly comparable across the state. For example, a score of 55 corresponds to habitat in "sub-optimal" condition for streams in the Southeastern Plains ecoregion while the same score corresponds to habitat in "marginal" condition for streams throughout the remainder of the state. An attempt to model relationships between landscape predictors and stream habitat condition using habitat scores would be hindered by the lack of comparability between scoring systems.

TABLE D-1. THRESHOLDS FOR CONVERTING NUMERIC STREAM HABITAT SCORES TO CATEGORICAL RATINGS.

Ecoregion	Stream Habitat Rating			
	Optimal	Sub-Optimal	Marginal	Poor
Southeastern Plains	66-100	53-65	40-52	<40
All Others	71-100	59-70	41-58	<41

Nitrate-Nitrite, Total Phosphorus, Total Suspended Solids, and Conductivity – Water quality data for stream monitoring locations in Alabama, Georgia, Mississippi, and Tennessee were acquired from the EPA and USGS Water Quality Portal (http://www.waterqualitydata.us/). Data were processed to produce representative growing season concentrations of NO_3-NO_2, TP, TSS, and conductivity for each monitored catchment in Alabama and the Mobile Bay Basin. Processing steps included:

- Filter data to retain –
  - Samples for total phosphorus, dissolved nitrate-nitrite nitrogen, total suspended solids, and conductivity;
  - Samples collected on or after January 1, 2000;
  - Samples collected during growing season months (March through October);
  - Samples collected in Alabama or the Mobile Bay Basin;
  - Samples with no noted lab failure; and
  - Samples that are not primarily influenced by point source discharges.
- Determine the catchment of each monitoring site using reported latitude/longitude coordinates, site names, and catchment names.
- Perform an additional filter to retain data for catchments with at least five samples.
- For samples with concentrations reported as "non-detect", substitute the catchment minimum.
- Calculate the median of samples reported for sites within catchment boundaries.

Note that an effort was made to remove stream sample data that are primarily driven by point source discharges. Because detailed information on point source loading was not available for modeling, an attempt to quantify relationships between water quality and landscape predictors would be hindered with the inclusion of point source driven data points.

To identify point source driven monitoring sites, the locations of facilities discharging to US waters in the EPA Integrated Compliance Information System - National Pollutant Discharge Elimination System (ICIS-NPDES) database were acquired from the EPA Reach Address Database website (http://epamap32.epa.gov/radims/). Sample data for stream water quality monitoring sites that met the following criteria were removed prior to calculating catchment medians:

- Within 1 mile upstream or downstream of any facility designated as a "major" discharger.
- Within 1 mile upstream or downstream of any facility designated as a "minor" discharger *AND* with permit type listed as "NPDES Individual" *AND* whose name indicates it is a wastewater treatment facility.

- Within 1 mile upstream or downstream of any facility designated as a “minor” discharger *AND* with permit type listed as “NPDES Individual” *AND* whose discharge monitoring records indicate that it discharges nitrogen, phosphorus, suspended solids, or dissolved solids.

Fish IBI and Macroinvertebrate IBI – ADEM and GSA monitor the number and proportion of several taxonomic and functional fish and macroinvertebrate groups in streams throughout the state. For each monitored site, fish community variables are combined into an overall fish IBI score and rating (Excellent, Good, Fair, Poor, or Very Poor). Similarly, macroinvertebrate community variables are combined into an overall macroinvertebrate IBI score and rating.

Fish IBI data compiled for the assessment were derived from 2002-2011 ADEM/GSA field assessments and were acquired from GSA (Pat O’Neil, personal communication). Data for five fish IBI rating types were available:

- Fish IBI scores and ratings for streams in the Tennessee Valley ichthyoregion;
- Fish IBI scores and ratings for streams in the Ridge and Valley/Piedmont ichthyoregion;
- Fish IBI scores and ratings for streams in the Plateau ichthyoregion;
- Fish IBI scores and ratings for streams in the Hills and Coastal Terraces ichthyoregion; and
- Fish IBI scores and ratings for streams in the Southern Plains ichthyoregion.

Macroinvertebrate IBI data were derived from 2000-2012 field assessments and were acquired from ADEM (Lisa Huff, personal communication). Macroinvertebrate IBI data included IBI ratings only.

IBI data were processed to produce a representative macroinvertebrate IBI rating and a representative fish IBI rating for each monitored catchment. Processing steps included:

- Macroinvertebrate IBI rating
    - Determine the catchment of each monitoring site using reported latitude/longitude coordinates, site names, and catchment names; and
    - Verify that a single macroinvertebrate IBI rating was reported for each monitored catchment. Catchments with multiple, conflicting ratings were not used for modeling. This step differs from fish IBI data processing (in which the median of fish IBI scores for a catchment were calculated) because categorical macroinvertebrate IBI ratings were supplied by ADEM rather than numeric macroinvertebrate IBI scores.
- Fish IBI rating
    - Determine the catchment of each monitoring site using reported latitude/longitude coordinates, site names, and catchment names;
    - For each monitored catchment, calculate the median of fish IBI scores for sites within catchment boundaries. This step produced a single fish IBI score per catchment; and
    - Convert median fish IBI scores to ratings using thresholds displayed in Table D-2.

Note that categorical IBI *ratings* were modeled rather than numeric IBI *scores*. Like stream habitat scores, fish and macroinvertebrate IBI scores are not directly comparable across the state. For example, a fish IBI score of 29 corresponds to fish communities in “fair” condition for Tennessee Valley streams while the same score corresponds to fish communities in “poor” condition for streams in other ecoregions. An attempt to model relationships between landscape predictors and biological community condition using IBI scores would be hindered by the lack of comparability between IBI types.

TABLE D-2. THRESHOLDS FOR CONVERTING NUMERIC FISH IBI SCORES TO CATEGORICAL RATINGS.

Fish IBI Type	Rating				
	Excellent	Good	Fair	Poor	Very Poor
Tennessee Valley	>50	41-50	29-40	21-28	<21
Ridge and Valley/Piedmont	>50	43-50	35-42	27-34	<27
Plateau	≥50	41-49	33-40	26-32	<26
Hills and Coastal Terraces	≥50	43-49	35-42	27-34	<27
Southern Plains	≥50	44-49	36-43	26-35	<26

Summary statistics for each response variable are provided in Table D-3 through Table D-6 and maps of catchments with monitoring data are displayed in Figure D-1 and Figure D-2. After processing response variable datasets to generate catchment values, the histogram of each continuous response variable (NO_3-NO_2, TP, TSS, and conductivity) was reviewed. Logarithmic and reciprocal root transformations were applied as needed so that all variables were approximately normally distributed. Categorical response variables (habitat rating, fish IBI rating, and macroinvertebrate IBI rating) were assumed to follow a multinomial distribution for BRT modeling.

TABLE D-3. SUMMARY STATISTICS FOR WATER QUALITY RESPONSE VARIABLES.

Response Variable	No. of Catchments	Minimum	Maximum	Mean	Median
NO_3-NO_2 Concentration (mg/L)	824	0.002	14.24	0.48	0.20
TP Concentration (mg/L)	776	0.01	10.57	0.09	0.04
TSS Concentration (mg/L)	819	1.0	75.0	8.9	7.0
Conductivity (µS/cm)	938	11	28850	289	117

TABLE D-4. DISTRIBUTION OF OBSERVED MACROINVERTEBRATE IBI RATINGS.

Macroinvertebrate IBI Rating	No. of Catchments	% of Total
Excellent	9	2%
Good	87	19%
Fair	166	37%
Poor	153	34%
Very Poor	35	8%
Total	450	-

TABLE D-5. DISTRIBUTION OF OBSERVED FISH IBI RATINGS.

Fish IBI Rating	No. of Catchments	% of Total
Excellent	11	2%
Good	125	27%
Fair	195	42%
Poor	98	21%
Very Poor	31	7%
Total	460	-

TABLE D-6. DISTRIBUTION OF OBSERVED STREAM HABITAT CONDITION RATINGS.

Stream Habitat Rating	No. of Catchments	% of Total
Optimal	252	37%
Sub-Optimal	256	38%
Marginal	148	22%
Poor	22	3%
Total	678	-

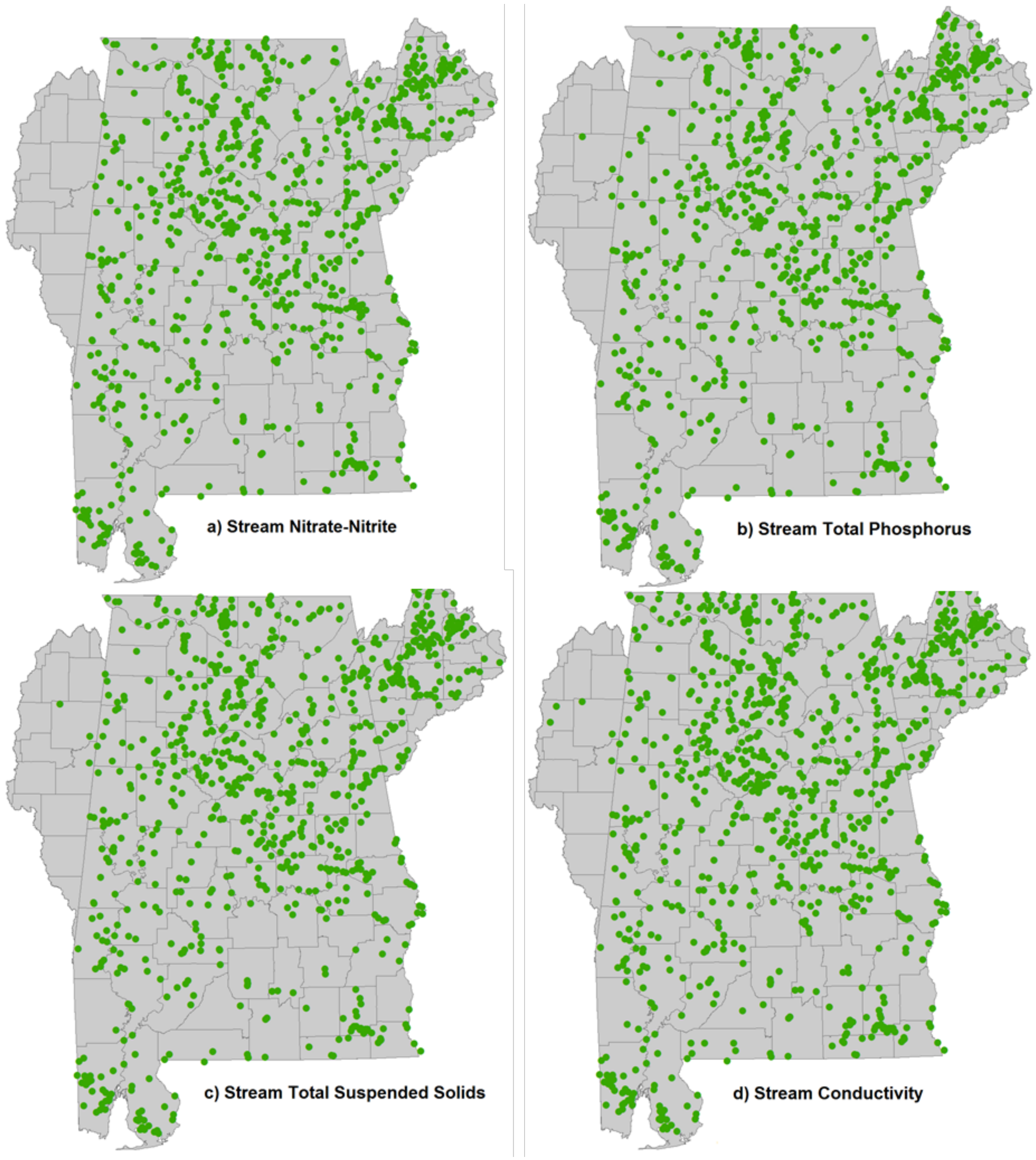

Figure D-1. Maps showing location of NHDPlus catchments with water quality monitoring data. Points are drawn at catchment centers.

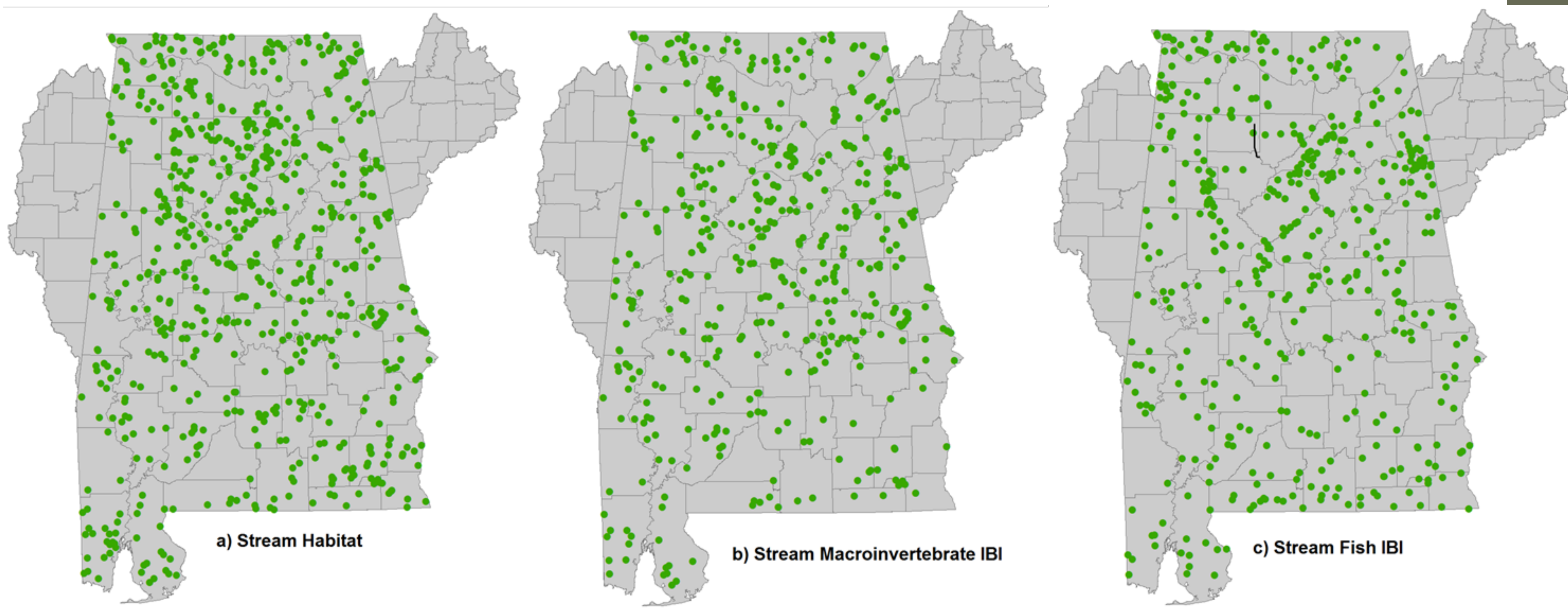

FIGURE D-2. MAPS SHOWING LOCATION OF NHDPLUS CATCHMENTS WITH STREAM HABITAT AND BIOLOGICAL MONITORING DATA. POINTS ARE DRAWN AT CATCHMENT CEN

Preparation of Predictor Data

Predictors of stream health included in BRT modeling are landscape variables that describe land cover, soils, topography, climate, and anthropogenic features of NHDPlus catchments (Table D-7). Predictors were selected on the basis of data availability and relevance to stream health. A predictor database was prepared by compiling predictor values for all catchments in Alabama and the Mobile Bay Basin at both incremental and cumulative scales. Incremental values reflect within-catchment conditions only. Cumulative values reflect conditions throughout all upstream catchments.

Pre-calculated values of some predictors were available as part of the NHDPlus dataset (McKay, Bondelid, & Dewald, 2012). Other predictors were quantified as part of this effort from existing geospatial datasets. Sources of predictor values are listed in Table D-7.

TABLE D-7. LANDSCAPE VARIABLES CONSIDERED FOR STREAM HEALTH MODELING. PREDICTORS INCLUDED IN FINAL MODELS ARE DENOTED WITH AN "I" IF INCREMENTAL VALUES WERE USED AND A "C" IF CUMULATIVE VALUES WERE USED.

Predictor Variable Name	Source(s)[a]	Scale
Stream Order	NHDPlus	I
Stream Slope	NHDPlus	I
Stream Density	NHDPlus	I, C
Mean Watershed Elevation	NED	-
Mean Watershed Slope	NED	I, C
Mean Wetness Index	EPA R4(a)	C
Mean Annual Precipitation	NHDPlus	C
Mean Annual Temperature	NHDPlus	C
Mean Annual Potential Evapotranspiration	NHDPlus	-
Mean Soil Erodibility	STATSGO	C
Percent Hydrologic Soil Group A Soils	STATSGO	C
Percent Hydrologic Soil Group B Soils	STATSGO	C
Percent Hydrologic Soil Group C Soils	STATSGO	C
Percent Hydrologic Soil Group D Soils	STATSGO	C
Percent Natural Land Cover (Riparian)	NLCD	-
Percent Agricultural Land Cover (Riparian)	NLCD	-
Percent Urban Land Cover (Riparian)	NLCD	-
Percent Impervious Cover (Riparian)	NLCD	-
Percent Wetland Cover (Riparian)	NLCD	-
Percent Natural Land Cover (Hydrologically Active Zone)	NLCD	C
Percent Agricultural Land Cover (Hydrologically Active Zone)	NLCD	C
Percent Urban Land Cover (Hydrologically Active Zone)	NLCD	C
Percent Impervious Cover (Hydrologically Active Zone)	NLCD	C
Percent Wetland Cover (Hydrologically Active Zone)	NLCD	C
Percent Natural Land Cover (Watershed)	NLCD	I
Percent Agricultural Land Cover (Watershed)	NLCD	I
Percent Urban Land Cover (Watershed)	NLCD	I
Percent Impervious Cover (Watershed)	NLCD	I

Predictor Variable Name	Source(s)[a]	Scale
Percent Wetland Cover (Watershed)	NLCD	I
Dam Density	NABD	C
Road Density	TIGER	C
Mean Empower Density	EPA R4(b)	I, C

[a] Data sources: NHDPlus – Supplied as part of NHDPlus Version 2 dataset or calculated from NHDPlus data; NLCD – Calculated from 2006 National Land Cover Dataset; STATSGO – Calculated from State Soil Geographic Database; NED – Calculated from National Elevation Dataset digital elevation model; TIGER – Calculated from Topologically Integrated Geographic Encoding and Referencing road centerline geodatabase; EPA R4(a) – Calculated from wetness index dataset acquired from EPA Region 4; EPA R4(b) – Calculated from empower density grid acquired from EPA Region 4. Empower density is a measure of the annual non-renewable energy use per unit time within a given area (Brown & Vivas, 2005). Higher values correspond to higher intensity of human activity.

Model Development

BRT models were developed using R software, the *gbm* package (Ridgeway, 2013), and the *dismo* package (Hijmans, Phillips, Leathwick, & Elith, 2013). Key parameters for BRT modeling are the learning rate and tree complexity, which determine the number of regression trees in the full (boosted) model. With too few trees, the model is underfit and does not adequately describe relationships in the data. Too many trees create an overfit model that provides poor predictions for the sites not used to train the model.

The optimal number of trees for each BRT model was determined using the k-fold cross-validation (CV) methodology described in Elith et al. (2008). This method randomly divides the full dataset into 10 subsets. Each subset is further divided into a training dataset, used for developing a BRT model, and a validation dataset, used for assessing predictive error. The optimal number of trees is the number that minimizes mean prediction error in the validation portion of the 10 CV subsets, and a final model is developed using the optimal number of trees and the full dataset. Here, the CV method was modified slightly by first setting aside a randomly selected portion (25%) of the full dataset for independent validation of final model predictions.

Response variable outcomes can be weighted for model fitting so that more emphasis is placed on minimizing predictive error for certain observations relative to others. Weighting was applied for development of the stream habitat rating, fish IBI rating, and macroinvertebrate IBI rating models due to the uneven distribution of observations (see Table D-3 through Table D-6). Observed ratings were initially weighted in inverse proportion to their frequency of occurrence. Weights were then adjusted until the accuracy rate of predictions for the training dataset was similar for all ratings.

An initial set of BRT models was developed for stream health variables using all available predictor variables. Following initial model development, predictors were refined to simplify final models and remove unimportant/redundant predictors. First, predictor correlation was examined by reviewing Pearson correlation coefficients for each predictor pair. For pairs with strong correlation (correlation coefficient greater than 0.9), one predictor was selected for removal to reduce redundancy in the predictor dataset. A second group of models was then generated using trimmed predictor data. Performance statistics for the initial and revised models were compared and the revised models pointed to reduced over-fitting. Next, relative influence scores were examined for predictors in the revised models. Relative influence scores describe the importance of an individual predictor on model predictions. Scores range from 0 to 100, with 100 corresponding to the highest possible influence, and are determined from the number of times a predictor appears in a regression tree and the average improvement in model performance resulting from its presence. Relative influence scores were evaluated to identify predictors with negligible influence (<1%) across all models that could be removed to further refine the predictor dataset. However, no predictors fit this criterion and the revised models developed from trimmed (non-redundant) predictor dataset were used for subsequent analysis.

Model Evaluation

A weight-of-evidence approach was used to evaluate model performance and select a final group of stream health metrics. Models for continuous response variables (NO_3-NO_2, TP, TSS, and conductivity) were evaluated from the correlation between observations and predictions. Three correlation statistics were examined:

- Training Correlation – Pearson correlation coefficient for observations in the training dataset and predictions generated by the final model. This is a *goodness-of-fit statistic* for the final model.
- Cross Validation (CV) Correlation – Mean Pearson correlation coefficient for observations in the 10 CV validation subsets and predictions generated by CV models with the optimal number of regression trees. This is a *predictive performance statistic* for CV models.
- Independent Correlation – Pearson correlation coefficient for observations in the independent validation dataset and predictions generated by the final model. This is a *predictive performance statistic* for the final model.

Models for categorical response variables (stream habitat rating and fish IBI rating) were evaluated from their classification success rates. Classification success rates describe the percentage of catchments that are correctly classified as "Excellent", "Good", "Fair", "Poor", or "Very Poor" (for fish IBI and macroinvertebrate IBI) or "Optimal", "Sub-optimal", "Marginal" or "Poor" (for stream habitat condition). Two groups of classification success rates were examined:

- Training Success Rate – Classification success rate for observations in the training dataset based on predictions generated by the final model. This is a *goodness-of-fit statistic* for the final model.
- Validation Success Rate – Classification success rate for observations in the independent validation dataset based on predictions generated by the final model. This is a *predictive performance statistic* for the final model.

D3 Results & Discussion

Model performance statistics for continuous response variables are displayed in Table D-8. Training correlation is highest for conductivity (0.91) and lowest for TP (0.82). For all models, training correlation is greater than CV correlation, indicating that performance suffers from some overfitting. CV and independent correlations are in line with one another, supporting the use of the CV methodology to optimize model parameters.

TABLE D-8. CORRELATION COEFFICIENTS FOR CONTINUOUS RESPONSE VARIABLES.

Response Variable	Correlation		
	Training	Cross Validation	Independent Validation
NO_3-NO_2 Concentration	0.88	0.72	0.71
TP Concentration	0.82	0.48	0.53
TSS Concentration	0.81	0.51	0.56
Conductivity	0.91	0.63	0.72

Model performance statistics for categorical response variables are displayed in Table D-9. Training classification success rate is highest for macroinvertebrate IBI rating (79% of sites correctly classified) and lowest for fish IBI rating (65% of sites correctly classified). For reference, the "by-chance" success rate is also shown in Table D-9, calculated from the distribution of observed ratings as the expected success rate if catchments were randomly assigned a rating. Training success rates are over two times greater than by-chance rates for all variables.

Similar to models for continuous response variables, overfitting is evident in models of stream habitat rating, macroinvertebrate IBI rating, and fish IBI rating. Validation success rates are lower than training values by several percentage points, with macroinvertebrate IBI and stream habitat showing the largest discrepancy between training and validation performance.

TABLE D-9. CLASSIFICATION SUCCESS RATES FOR CATEGORICAL RESPONSE VARIABLES.

Response Variable	Model Success Rate		By-Chance Success Rate
	Training	Validation	
Stream Habitat Rating	73%	46%	33%
Fish IBI Rating	65%	47%	30%
Macroinvertebrate IBI Rating	79%	50%	30%

Contingency tables for observed and predicted ratings for validation catchments are shown in Table D-10 through Table D-12. Contingency tables allow for a review of model performance by rating category. For stream habitat rating (Table D-10), classification success rates are similar for "optimal" (48%), "sub-optimal" (49%), and "marginal" (42%) catchments. Only 5 sites were rated "poor" in the validation dataset. Although none were correctly classified by the model, the small sample size hinders any conclusions of how well the model predicts the occurrence of "poor" stream habitat. The same is true for "excellent" and "very poor" ratings for both macroinvertebrate IBI and fish IBI, as the validation dataset contains few catchments (≤10) with these ratings.

Table D-10. Stream habitat rating contingency table for validation catchments.

		Predicted				
		Optimal	Sub-Optimal	Marginal	Poor	Success Rate
Observed	Optimal (56 sites)	27	19	10	0	48%
	Sub-Optimal (71 sites)	15	35	21	0	49%
	Marginal(38 sites)	6	14	16	2	42%
	Poor (5 sites)	0	4	1	0	0%
	Error Rate	44%	51%	67%	100%	

Table D-11. Fish IBI rating contingency table for validation catchments.

		Predicted					
		Excellent	Good	Fair	Poor	Very Poor	Success Rate
Observed	Excellent (1 site)	0	1	0	0	0	0%
	Good (50 sites)	0	16	11	3	0	53%
	Fair (30 sites)	0	10	28	12	0	56%
	Poor (24 sites)	0	2	11	9	2	38%
	Very Poor (10 sites)	0	2	3	4	1	10%
	Error Rate	0%	48%	47%	68%	67%	

Table D-12. Macroinvertebrate IBI rating contingency table for validation catchments.

		Predicted					
		Excellent	Good	Fair	Poor	Very Poor	Success Rate
Observed	Excellent (2 sites)	1	0	1	0	0	50%
	Good (43 sites)	1	17	8	1	0	63%
	Fair (27 sites)	1	5	19	14	4	44%
	Poor (33 sites)	0	1	9	14	9	42%
	Very Poor (8 sites)	0	0	1	2	5	63%
	Error Rate	67%	26%	50%	55%	72%	

Relative influence plots for stream response variables are shown in Figure D-3 through Figure D-9. Each plot displays relative influence scores for the 10 most influential predictors. Influential predictors characterize a combination of natural watershed characteristics and anthropogenic features. Although relative influence plots provide some insight into cause-effect relationships between watershed condition and stream health, BRT models were not explicitly developed to uncover cause-effect relationships. Rather, the goal of BRT modeling was to extrapolate patterns between observations of stream health and landscape variables for the purpose of predicting stream health metrics for any NHDPlus catchment. Nevertheless, influential predictors can serve as a starting point for discussion of management approaches to maintain or improve stream health, and predictors with the highest relevance to management efforts are highlighted in red in relative influence plots.

Model performance statistics and relative influence plots together indicate that BRT models are adequate for supporting a statewide or regional screening-level assessment of watershed protection and restoration priorities. Predictions generated by these models for all NHDPlus catchments in Alabama and the Mobile Bay Basin are used to develop the indices of watershed health presented in Section 3 of this report. The application of model predictions for uses requiring highly accurate estimates of catchment- or reach-scale conditions is not recommended.

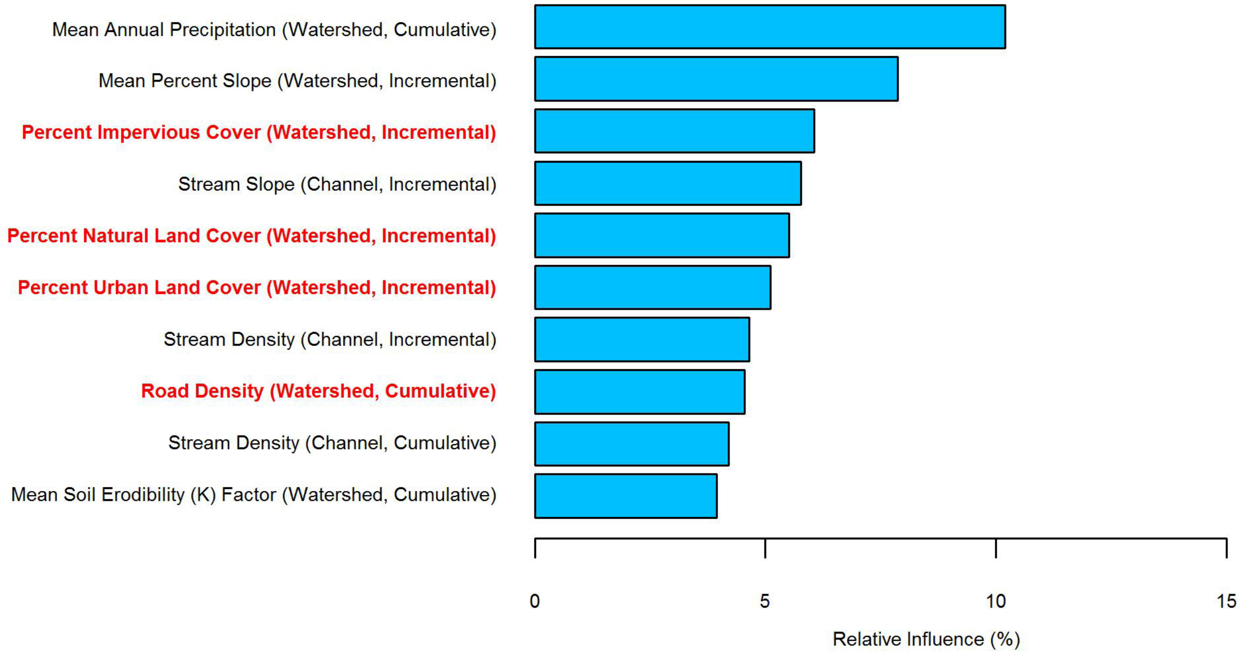

FIGURE D-3. RELATIVE INFLUENCE PLOT FOR STREAM HABITAT RATING.

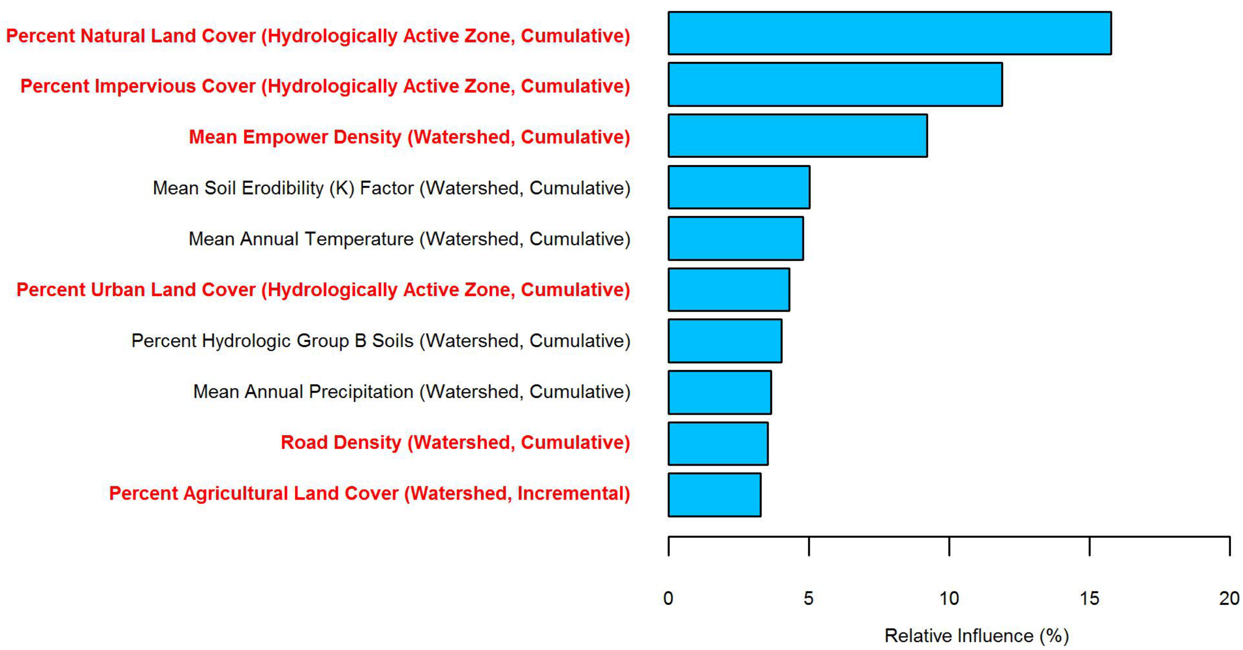

FIGURE D-4. RELATIVE INFLUENCE PLOT FOR STREAM NITRATE-NITRITE CONCENTRATION (GROWING SEASON MEDIAN).

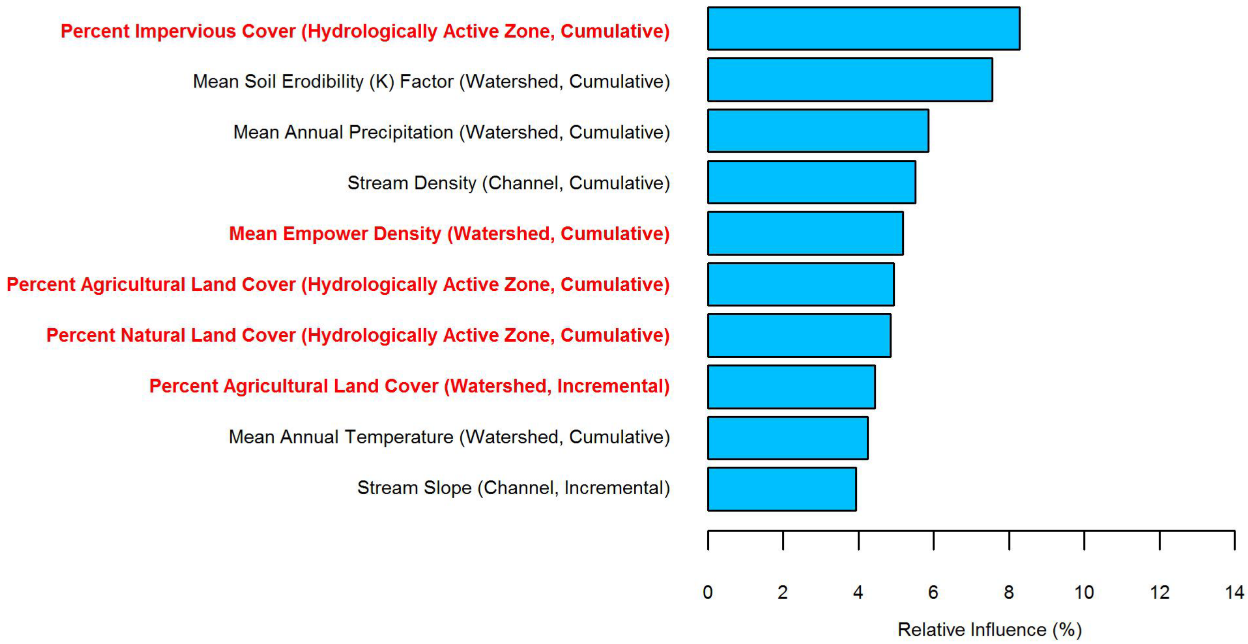

FIGURE D-5. RELATIVE INFLUENCE PLOT FOR STREAM TOTAL PHOSPHORUS CONCENTRATION (GROWING SEASON MEDIAN).

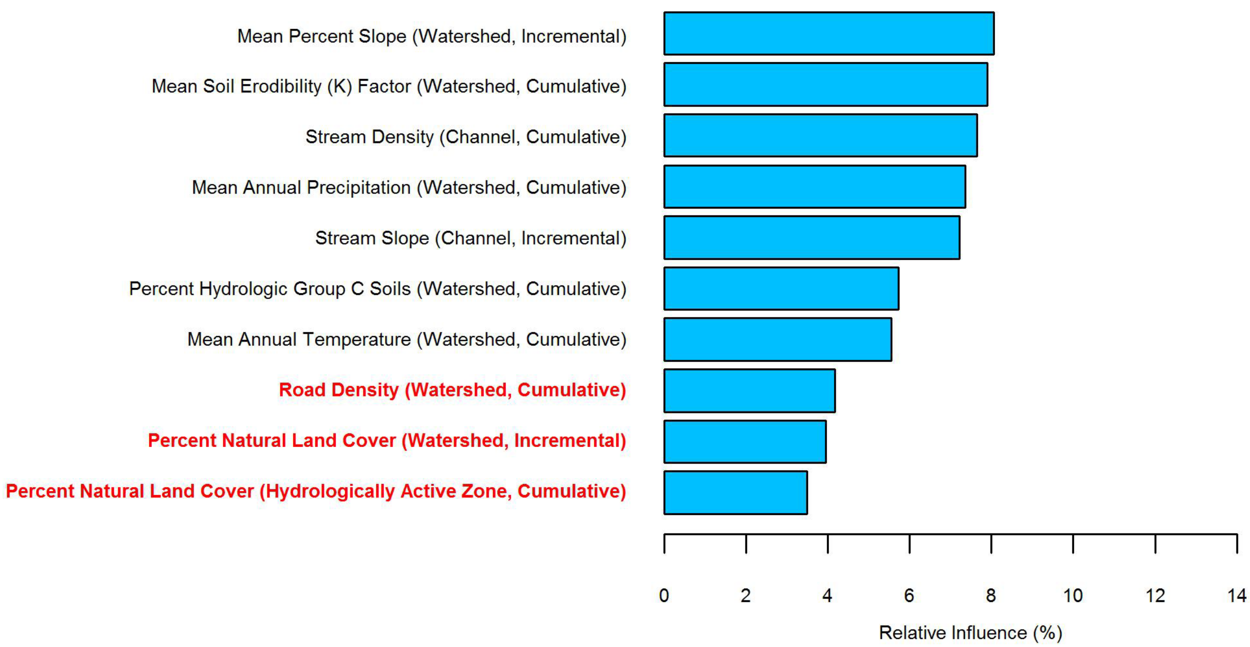

FIGURE D-6. RELATIVE INFLUENCE PLOT FOR STREAM TOTAL SUSPENDED SOLIDS CONCENTRATION (GROWING SEASON MEDIAN).

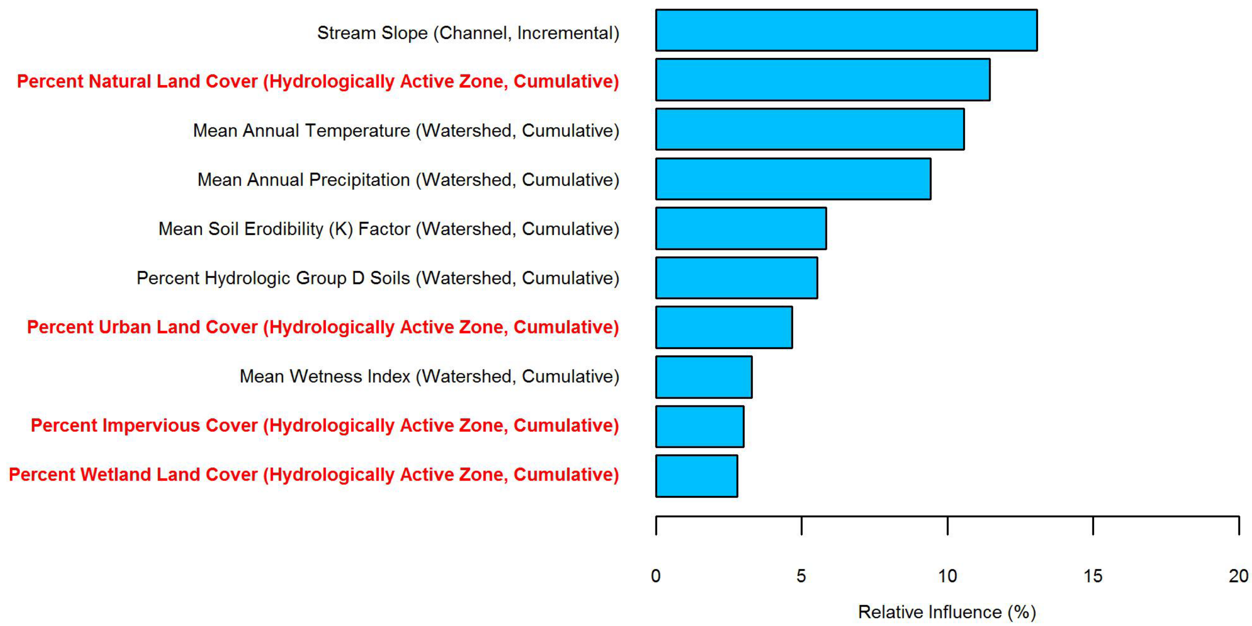

FIGURE D-7. RELATIVE INFLUENCE PLOT FOR STREAM CONDUCTIVITY (GROWING SEASON MEDIAN).

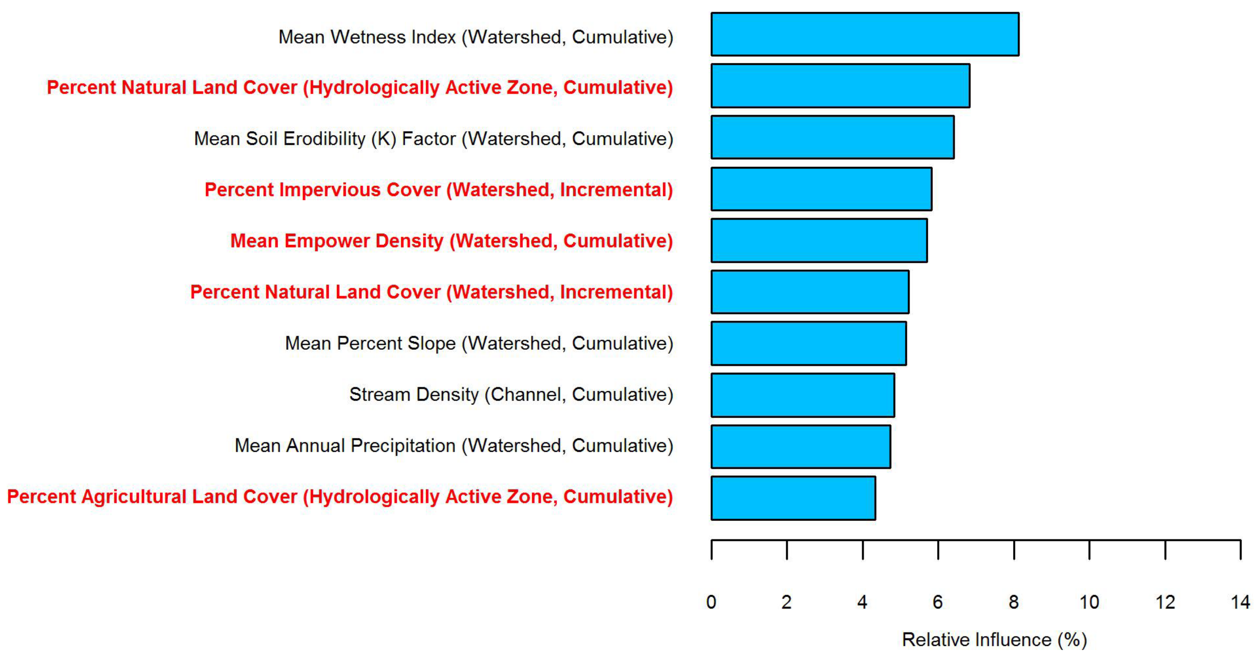

FIGURE D-8. RELATIVE INFLUENCE PLOT FOR FISH INDEX OF BIOTIC INTEGRITY RATING.

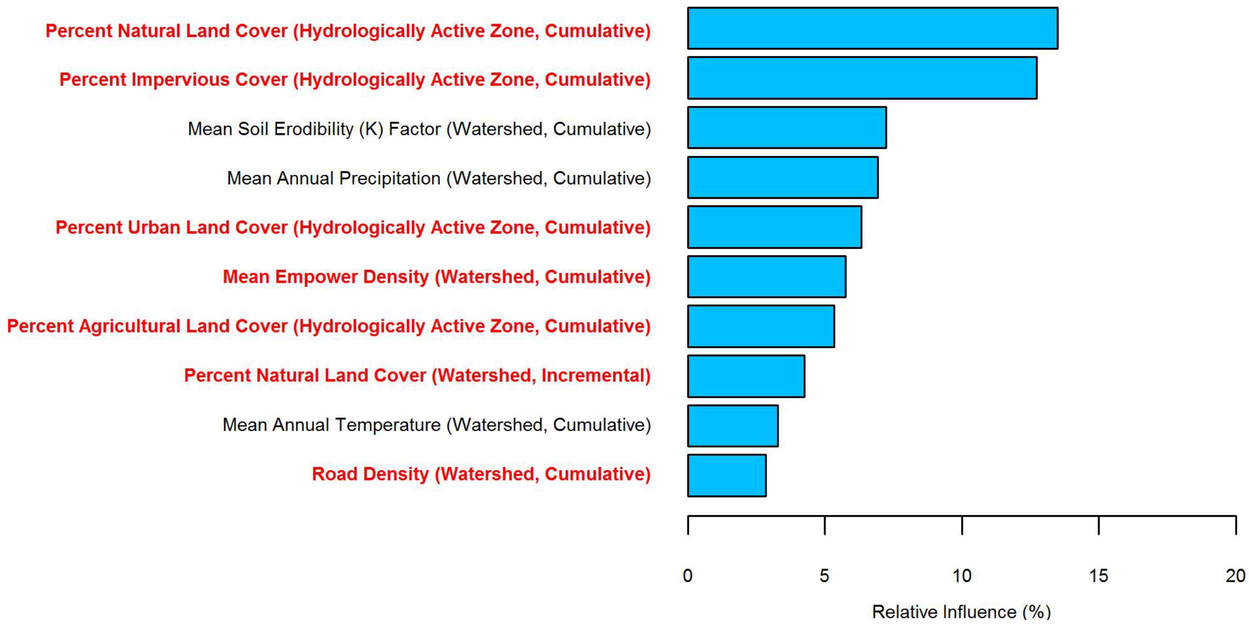

FIGURE D-9. RELATIVE INFLUENCE PLOT FOR MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY RATING.