ASSESSMENT OF THE EFFECTS OF ACIDIC DEPOSITION ON AQUATIC RESOURCES IN THE SOUTHERN APPALACHIAN MOUNTAINS

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DEFINITIONS

Acid anion - negatively charged ion that does not react with hydrogen ion in the pH range of most natural waters.

Acid-base chemistry - the reaction of acids (proton donors) with bases (proton acceptors). In the context of this report, this means the reactions of natural and anthropogenic acids and bases, the result of which is described in terms of **pH** and **acid neutralizing capacity** of the system.

Acid mine drainage - runoff with high concentrations of metals and sulfate and high levels of acidity resulting from the oxidation of sulfide minerals that have been exposed to air and water by mining activities.

Acid neutralizing capacity (ANC) - the equivalent capacity of a solution to neutralize strong acids. The components of ANC include weak bases (carbonate species, dissociated organic acids, alumino-hydroxides, borates, and silicates) and strong bases (primarily, OH^-). In the National Surface Water Survey, as well as in most other recent studies of acid-base chemistry of surface waters, ANC was measured by the Gran titration procedure.

Acidic deposition - transfer of acids and acidifying compounds from the atmosphere to terrestrial and aquatic environments via rain, snow, sleet, hail, cloud droplets, particles, and gas exchange.

Acidic episode - an **episode** in a water body in which **acidification** of surface water to an **acid neutralizing capacity** less than or equal to 0 occurs.

Acidic stream - a stream in which the **acid neutralizing capacity** is less than or equal to 0.

Acidification - the decrease of **acid neutralizing capacity** in water or **base saturation** in soil caused by natural or anthropogenic processes.

Acidified - pertaining to a natural water that has experienced a decrease in **acid neutralizing capacity** or a soil that has experienced a reduction in **base saturation.**

Anion - a negatively charged ion.

Anion-cation balance - a method of assessing whether all ions have been accounted for and measured accurately; in an electrically neutral solution, such as water, the total charge of positive ions (**cations**) equals the total charge of negative ions (**anions**).

Anion exchange/adsorption - a reversible process occurring in soil by which anions are adsorbed and released.

Anthropogenic - of, relating to, derived from, or caused by humans or related to human activities or actions.

Base cation - an alkali or alkaline earth metal cation (Ca^{2+}, Mg^{2+}, K^+, Na^+).

Base cation buffering - the capacity of a watershed soil or a sediment to supply base cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) to receiving surface waters in exchange for acid cations (H^+, Al^{3+}); may occur through cation exchange in soils or weathering of soil or bedrock minerals.

Base cation supply - The rate at which base cations can be supplied to buffer incoming acid cations; this rate is determined by the relative rate of mineral weathering, the availability of base cations on exchange sites, and the rate of mobile anion leaching.

Base saturation - the proportion of total soil **cation exchange capacity** that is occupied by exchangeable **base cations**, i.e., by Ca^{2+}, Mg^{2+}, K^+, and Na^+.

Bedrock - solid rock exposed at the surface of the earth or overlain by saprolites or unconsolidated material.

Benthic - referring to bottom zones or bottom-dwelling organisms in water bodies.

Beyond Bold - most aggressive of the three Emissions Control Strategies specified by SAMI for evaluating future conditions.

Bias - a systematic difference (error) between a measured (or predicted) value and its true value.

Biological effects - changes in biological (organismal, populational, community-level) structure and/or function in response to some causal agent; also referred to as biological response.

Biological significance - the quality of being important in maintaining the structure and/or function of biological populations or communities.

Bold-with-Constraints - Emissions Control Strategy specified by SAMI which incorporates additional local-state controls on emissions of sulfur and nitrogen beyond those already implemented or scheduled by be implemented.

Calibration - process of checking, adjusting, or standardizing operating characteristics of instruments or coefficients in a mathematical model with empirical data of known quality. The process of evaluating the scale readings of an instrument with a known standard in terms of the physical quantity to be measured.

Catchment - see **watershed**.

Cation - a positively charged ion.

Cation exchange - the interchange between a cation in solution and another cation on the surface of any surface-active material such as clay or organic matter.

Cation exchange capacity - the sum total of exchangeable cations that a soil can adsorb.

Cation leaching - movement of cations out of soil, in conjunction with mobile anions in soil solution.

Conductance - (See **specific conductance**.)

Decomposition - the microbially mediated reaction that converts solid or dissolved organic matter into its constituents (also called decay or mineralization).

Denitrification - biologically mediated conversion of nitrate to gaseous forms of nitrogen (N_2, NO, N_2O); denitrification occurs during decomposition of organic matter.

Diatom - Alga in the class Bacillariophyceae, which are characterized by cell walls composed of two siliceous halves, known as valves (2 valves = a frustule). These siliceous valves are taxonomically diagnostic and well preserved in lake sediments, so past diatom assemblages can be interpreted from their fossil remains.

Dry deposition - transfer of substances from the atmosphere to terrestrial and aquatic environments via gravitational settling of large particles and turbulent transfer of trace gases and small particles.

Dynamic model - a mathematical model in which time is included as an independent variable.

Empirical model - representation of a real system by a mathematical description based on experimental or observational data.

Episodes - a subset of hydrological phenomena known as events. Episodes, driven by rainfall or snowmelt, occur when **acidification** takes place during a **hydrologic event**. Changes in other chemical **parameters**, such as aluminum and calcium, are frequently associated with episodes.

Episodic acidification - the short-term decrease of **acid neutralizing capacity** from a lake or stream. This process has a time scale of hours to weeks and is usually associated with **hydrological events**.

Equivalent - unit of ionic concentration, a mole of charge; the quantity of a substance that either gains or loses one mole of protons or electrons.

Evapotranspiration - the process by which water is returned to the air through direct evaporation or transpiration by vegetation.

Forecast - to estimate the probability of some future event or condition as a result of rational study and analysis of available data.

Frame - a structural representation of a population providing a sampling capability.

Gran analysis - a mathematical procedure used to determine the equivalence points of a titration curve for **acid neutralizing capacity**.

Ground water - water in a saturated zone within soil or rock.

Hindcast - to estimate the probability of some past event or condition as a result of rational study and analysis of available data.

Hydrologic(al) event - pertaining to increased water flow or discharge resulting from rainfall or snowmelt.

Hydrologic(al) flow paths - surface and subsurface routes by which water travels from where it is deposited by precipitation to where it drains from a **watershed**.

Hydrology - the science that treats the waters of the earth--their occurrence, circulation, and distribution; their chemical and physical properties; and their reaction with their environment, including their relationship to living things.

Index sample - as defined in the NSWS, a sample or group of samples taken from a certain place at each sampling unit (lake or stream reach) at a particular time of the year. For the National Stream Survey, the index sample was the average of 2 or 3 samples collected during the spring baseflow period within a stream reach.

Inorganic aluminum - the sum of free aluminum ions (Al^{3+}) and dissolved aluminum bound to inorganic ligands.

Mineral acids - inorganic acids, e.g., H_2SO_4, HNO_3, HCl, H_2CO_3.

Mineralization - process of converting organic nitrogen in the soil into ammonium, which is then available for biological uptake.

Mineral weathering - dissolution of rocks and minerals by chemical and physical processes.

Mobile anions - anions that flow in solutions through watershed soils, wetlands, streams, or lakes without being adsorbed or retained through physical, biological, or geochemical processes.

Model - an abstraction or representation of a system, generally on a smaller scale.

Natural acids - acids produced within terrestrial or aquatic systems through natural, biological, and geochemical processes; i.e., not a result of acidic deposition or deposition of acid precursors.

Nitrification - oxidation of ammonium to nitrite or nitrate by microorganisms. A by-product of this reaction is H^+.

Nitrogen fixation - biological conversion of elemental nitrogen (N_2) to organic N.

Nitrogen saturation - condition whereby nitrogen inputs to an alpine or forested ecosystem exceed biological retention.

Node - sampling location for the National Stream Survey. Each selected stream segment was sampled at two locations, the upper and lower nodes.

Nutrient cycling - the movement or transfer of chemicals required for biological maintenance or growth among components of the ecosystem by physical, chemical, or biological processes.

Occult deposition - transfer of substances from the atmosphere to terrestrial and aquatic environments via fog or cloudwater. Within the SAMI region, clouds are most important in this regard, especially at high elevation.

On-the-Way - Emissions Control Strategy specified by SAMI. This was the most conservative of the three strategies proposed by SAMI for evaluating future conditions, It is based on assumptions regarding emissions control that are already promulgated by existing laws.

Organic acids - heterogeneous group of acids generally possessing a carboxyl (-COOH) group or phenolic (C-OH) group; includes fulvic and humic acids.

Organic aluminum - aluminum bound to organic matter, operationally defined as that fraction of aluminum determined by colorimetry after sample is passed through a strong cation exchange column.

Parameter - (1) a characteristic factor that remains at a constant value during the analysis, or (2) a quantity that describes a statistical population attribute.

pH - the negative logarithm of the hydrogen ion activity. The **pH** scale is generally presented from 1 (most acidic) to 14 (most alkaline); a difference of one **pH** unit indicates a tenfold change in hydrogen ion activity.

Physiography - the study of the genesis and evolution of land forms; a description of the elevation, slope, and aspect of a study area.

Pool - in ecological systems, the supply of an element or compound, such as exchangeable or weatherable cations or adsorbed sulfate, in a defined component of the ecosystem.

Population - for the purpose of this report, (1) the total number of streams within a given geographical region or the total number of streams with a given set of defined chemical, physical, or biological characteristics; or (2) an assemblage of organisms of the same species inhabiting a given ecosystem.

Probability sample - a sample in which each unit has a known probability of being selected.

Project - to estimate future possibilities based on rational study and current conditions or trends.

Quality assurance - a system of activities for which the purpose is to provide assurance that a product (e.g., data base) meets a defined standard of quality with a stated level of confidence.

Quality control - steps taken during sample collection and analysis to ensure that data quality meets the minimum standards established in a **quality assurance** plan.

Regionalization - describing or estimating a characteristic of interest on a regional basis.

Scenario - one possible deposition sequence, assuming continued constant or some proportional change in future deposition and the subsequent effects associated with this deposition sequence.

Simulation - description of a system response to different conditions or inputs using a **model** rather than actually observing the response to the conditions or inputs.

Simulation model - mathematical model that is used with actual or synthetic input data, or both, to produce long-term time series or predictions.

Species richness - the number of species occurring in a given aquatic ecosystem, generally estimated by the number of species caught using a standard sampling regime.

Specific conductance - the conductivity between two plates with an area of 1 cm^2 across a distance of 1 cm at 25°C.

Steady state - the condition that occurs when the sources and sinks of a property (e.g., mass, volume, concentration) of a system are in balance (e.g., inputs equal outputs; production equals consumption).

Strategy - as defined by SAMI, a suite of possible controls on the atmospheric emissions of S and N, and the deposition patterns and levels that are estimated to result from these controls, should they be implemented.

Stratified design - a statistical design in which the population is divided into strata, and a sample selected from each stratum.

Stream order - a method of categorizing streams based on their position in the drainage network. First-order streams are permanent streams with no permanent tributaries. Higher-order streams are formed by the confluence of two or more streams of the next lower stream order.

Subpopulation - any defined subset of the target **population**.

Sulfate adsorption - the process by which sulfate is chemically exchanged (e.g., for OH^-) or adsorbed onto positively charged sites on the soil matrix; under some conditions this process is reversible, and the sulfate may be desorbed.

Sulfate retention - the physical, biological, and geochemical processes by which sulfate in **watersheds** is held, retained, or prevented from reaching receiving surface waters.

Sum of base cations (SBC or C_B) - refers to the equivalent sum of Ca^{2+}, Mg^{2+}, Na^+, and K^+. The term specifically excludes cationic Al^{n+} and Mn^{2+}.

Sum of strong acid anions (SAA or C_A) - refers to the equivalent sum of SO_4^{2-}, NO_3^-, Cl^-, and F^-. The term specifically excludes organic acid anions.

Surficial geology - characteristics of the earth's surface, especially consisting of unconsolidated residual, colluvial, alluvial, or glacial deposits lying on the bedrock.

Synoptic - relating to or displaying conditions as they exist at a point in time over a broad area.

Target population - a subset of a **population** explicitly defined by a given set of exclusion criteria to which inferences are to be drawn from the sample attributes.

Validation - comparison of **model** results with a set of prototype data not used for verification. Comparison includes the following: (1) using a data set very similar to the verification data to determine the validity of the model under conditions for which it was designed; (2) using a data set quite different from the verification data to determine the validity of the model under conditions for which it was not designed but could possibly be used; and (3) using post-construction prototype data to determine the validity of the predictions based on model results.

Variable - a quantity that may assume any one of a set of values during analysis.

Watershed - the geographic area from which surface water drains into a particular lake or point along a stream.

Wet deposition - transfer of substances from the atmosphere to terrestrial and aquatic environments via precipitation, e.g., rain, snow, sleet, hail, and cloud droplets. Droplet deposition is sometimes referred to as occult deposition.

ACRONYMS

ANC	Acid neutralizing capacity
BWC	Bold-with-Constraints Emissions Control Strategy
BYB	Beyond Bold Emissions Control Strategy
CALK	Calculated ANC
CEC	Cation exchange capacity
DDF	Dry and occult deposition enhancement factor
DDRP	Direct Delayed Response Project
DOC	Dissolved organic carbon
EMAP	Environmental Monitoring and Assessment Project
EPA	U.S. Environmental Protection Agency
FISH	Fish in Sensitive Habitats Project
MAGIC	Model of Acidification of Groundwater in Catchments
NADP	National Atmospheric Deposition Program
NAPAP	National Acid Precipitation Assessment Program
NSS	National Stream Survey
NSWS	National Surface Water Survey
NuCM	Nutrient Cycling Model
OTW	On-the-Way Emissions Control Strategy
QA/QC	Quality assurance/quality control
SAA	Sum of mineral acid anions
SAMAB	Southern Appalachian Man and the Biosphere program
SAMI	Southern Appalachian Mountains Initiative
SBC	Sum of base cations
SIP	State Implementation Plans
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VTSSS	Virginia Trout Stream Sensitivity Study

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EXECUTIVE SUMMARY

Background

The Southern Appalachian Mountains Initiative (SAMI) is a voluntary partnership that includes state and federal agencies, industry, academia, environmental groups, and the interested public. Its goal is to identify and recommend strategies to remedy existing air pollution impacts to natural resources in the eight state Southern Appalachian Mountains (SA) region and to prevent future adverse impacts. Particular emphasis is placed on resource protection within the ten Class I national parks and wilderness areas that occur within the SAMI domain (Figure ES-1).

SAMI is conducting an Integrated Assessment of air pollution sensitivities and effects that focuses on acidic deposition, ozone, and visibility. The assessment links emissions, atmospheric transport, environmental effects, and socioeconomic models to derive projections of future impacts under varying levels of emissions. This report presents the results of aquatic effects modeling within the acidic deposition assessment for SAMI.

Biological resources within the SAMI domain that are sensitive to adverse impacts from acidic deposition include aquatic biota and forests. Aquatic impacts can affect invertebrate as well as vertebrate communities, but have been most thoroughly studied for fish. Fish communities of high-gradient SA streams may contain a variety of species, but are often dominated by trout, especially native brook trout. Acidification damage to brook trout populations in the SAMI region is an important environmental concern. It is hoped that emissions reductions in the future may reverse some of that damage and/or prevent additional damage from occurring.

Acidic deposition has contributed to a decline in the availability of calcium and other base cations in the soils of acid-sensitive forest ecosystems by the leaching of base cations from foliage and from the primary rooting zone and by the mobilization of aluminum from soils to soil solution and drainage water. Both nitrogen and sulfur deposition have contributed to these mechanisms. As a consequence, foliar calcium levels and soil and root calcium to aluminum ratios are considered low to deficient over much of the southern spruce-fir region, and this will have adverse impacts on forest growth and health.

The primary objective of this assessment was to provide a model-based qualitative and quantitative evaluation of the effects of atmospheric sulfur and nitrogen deposition on aquatic

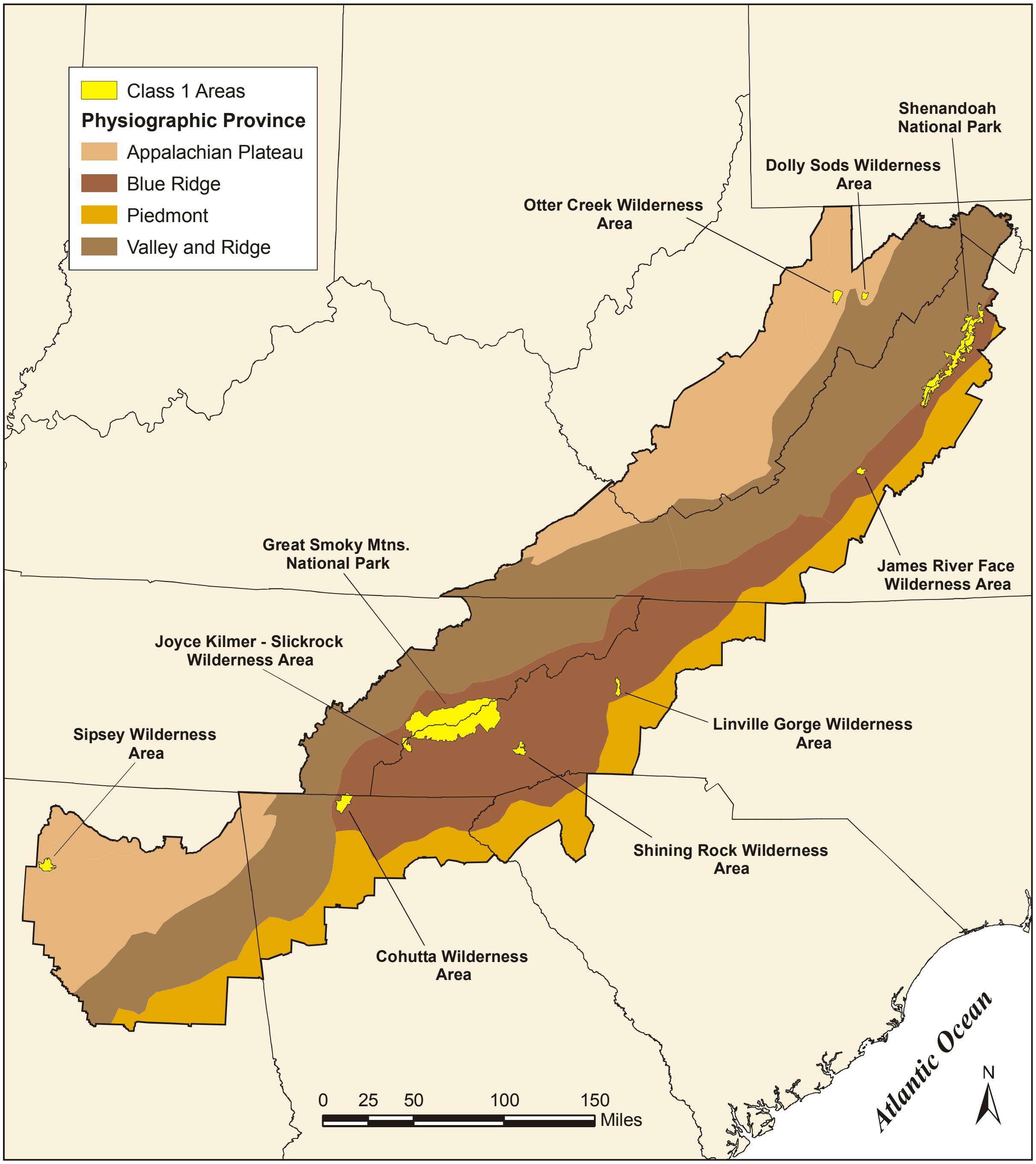


Figure ES-1. Map showing SAMI domain, physiographic provinces, and location of Class I areas.

resources in the SA. Particular emphasis was placed on characterizing the responses of resources in ten Class I areas that occur within the SAMI domain.

Approach

Aquatic resources were classified for regional modeling according to their potential sensitivity to acidic deposition using acid neutralizing capacity (ANC) and physiographic province as the primary indicator variables. Four ANC sensitivity classes were employed (Table ES-1).

Table ES-1. ANC ranges defined for acidification modeling

ANC ≤ 0 µeq/L	acidic; unsuitable for brook trout
ANC > 0 to ≤ 20 µeq/L	highly sensitive to chronic and episodic acidification; marginal for brook trout
ANC > 20 to ≤ 50 µeq/L	potentially sensitive to chronic and episodic acidification; brook trout status indeterminate
ANC > 50 to ≤ 150 µeq/L	may be sensitive to episodic acidification to low ANC values under possible future deposition levels; suitable for brook trout

There are three physiographic provinces within the SAMI domain that contain acid-sensitive stream resources and have been included in surveys of streamwater chemistry. The provinces are Blue Ridge, Ridge and Valley, and Appalachian Plateau. A portion of the SAMI domain also occurs within the Piedmont province, which, based on National Stream Survey (NSS) data, does not have streams with ANC less than 50 µeq/L, and so would not be expected to be very sensitive to acidification.

Databases were acquired for use in this assessment from a variety of sources. Water quality data were derived from a number of national and regional databases and many more localized studies. These included the NSS, Environmental Monitoring and Assessment Project (EMAP), Virginia Trout Stream Sensitivity Study (VTSSS), and a variety of studies coordinated by the National Park Service, U.S. Forest Service, Tennessee Valley Authority, and U.S. Geological Survey. Soils data were largely derived from the Direct Delayed Response Project (DDRP) database, intensive watershed studies at Coweeta and Fernow experimental forests, and soil studies conducted within several of the national parks and national forests located within the SAMI domain. In cases where data were unavailable for important areas, data were collected explicitly for the SAMI effort. The list of potential modeling sites was screened to remove from consideration sites for which the water chemistry data were not internally consistent or for which available data suggested the possibility of significant influence on streamwater chemistry from road salt, geological sulfur, land use, or insect defoliation.

Regional aquatic modeling was conducted with the Model of Acidification of Groundwater in Catchments (MAGIC) model for 40 to 50 sites within each physiographic province, stratified by ANC class. A total of 12 modeling groups (designated modeling bins) was selected, based on three physiographic provinces and four ANC classes within each. MAGIC was successfully calibrated to 130 watersheds throughout the SAMI geographic domain for the regional assessment and an additional 34 Special Interest watersheds, mostly located in Class I areas.

For the regional modeling, an effort was made to not select too many watersheds for modeling that occurred in the same general area. This was done to avoid skewing the results too heavily to one portion of the region. A secondary objective of the aquatic assessment was, however, to evaluate acidification issues within each of the Class I areas within the SAMI domain that contain acid-sensitive aquatic resources. Therefore, in addition to the MAGIC modeling that was conducted for the regional assessment, modeling was also conducted for any watershed that occurred within a Class I area that had not already been modeled for the regional assessment. The results of these analyses were used for the site-specific assessments that were conducted for each of the Class I areas.

Wet deposition estimates were derived for each site using the spatial extrapolation model of Grimm and Lynch (1997), based on observed wet deposition at NADP monitoring stations. This model provided a spatially interpolated value of wet deposition for the reference period (1990 to 1995) at each site, correcting for changes in precipitation volume with elevation.

The ASTRAP model was used to provide estimates of wet, dry, and occult (cloud) deposition of sulfur and nitrogen oxide at 33 sites in and around the SAMI region. The ASTRAP results were assigned to each of the effects modeling sites using a nearest-neighbor approach that included correction for elevation. ASTRAP produced wet, dry, and occult deposition estimates of sulfur and nitrogen oxide every ten years starting in 1900 and ending in 1990. The model outputs are smoothed estimates of deposition roughly equivalent to a ten-year moving average centered on each of the output years.

The wet, dry, and occult deposition estimates provided by ASTRAP for each year were used to calculate the dry plus occult deposition enhancement factors (DDF) for each year and each site, with which to estimate total deposition from wet deposition. This provided time series of DDF for sulfur and nitrogen oxide for each ASTRAP site extending from 1900 to 1990. The value of DDF for 1990 was used as the absolute value of DDF for the SAMI reference period (1990-1995) and was assumed to remain constant in the future.

Changes in future atmospheric deposition were specified for the simulations in two ways. An initial analysis was conducted by assuming that future deposition of all ions would stay constant at 1995 levels. Results of this constant deposition scenario were used as a base case against which the results of emissions control strategies could be evaluated. In addition, a suite of simulations was based on three regional strategies of emissions controls provided by SAMI.

The strategies represent air regulatory requirements being implemented at the time of SAMI's formation, expected reductions under recent federal regulatory actions, and additional strategies that SAMI might recommend for regional, state, or community-based actions. The spatial patterns of these emissions control options resulted in varying estimated future changes in sulfur and nitrogen deposition at different locations within the SAMI domain. The strategies that were implemented for this assessment were designated On-the-Way (OTW), Bold-with-Constraints (BWC), and Beyond Bold (BYB). OTW is the reference strategy that represents SAMI's best estimates for acidic deposition controls that have been promulgated and are relatively certain. These include the 1990 Clean Air Act Amendments and several mobile source reductions, including EPA's call for revised State Implementation Plans (SIP). OTW was applied to all eastern states, focused on utility and highway vehicle sectors. BWC and BYB strategies assume progressively larger emissions reductions. For emissions reductions beyond those of OTW, they are targeted only to the eight SAMI states, but cover all emissions sectors.

Two aspects of regional extrapolation were conducted for this assessment: quantitative and spatial. The quantitative extrapolation focused on numbers and percentages of stream reaches and length of streams that the model predicts might respond in a certain way. Spatial extrapolation tried to show where those streams were located and what features of the landscape were commonly associated with that response.

For the SAMI-wide regional assessment, the only statistically rigorous spatial frame available that covered most of the geographical extent of the SAMI domain was that of the NSS. By applying the future modeling results from modeled watersheds to the NSS sites, we were able to estimate future changes in streamwater acid-base chemistry throughout the SAMI region for all of the watersheds in the region that were represented by the NSS statistical design.

The quantitative regional analysis was based on a design that consisted of 12 landscape units and MAGIC model projections of streamwater response for a suite (in most cases $n \geq 7$) of watersheds selected within each landscape unit. The median model response for each unit was applied to all similar (within the same unit), statistically-selected NSS sites in the SAMI domain. The NSS statistical frame was then used to estimate the number and percentage of stream reaches in the SAMI region that were projected to behave in certain ways or to change their chemistry according to various chemical criteria.

Deposition Results

Estimated values for sulfur and nitrogen deposition in the 1995 base year varied by about a factor of five across the SAMI domain. Highest values were found at the high elevation sites of Great Smoky Mountains National Park and in the northern and southern sections of the Appalachian Plateau physiographic province in West Virginia and Tennessee.

Sulfur deposition was predicted to decrease at all sites under all strategies, but the decreases were smallest for the OTW Strategy (mean -57%), intermediate for the BWC Strategy (mean −67%), and largest for the BYB Strategy (mean -73%). Projected changes in sulfur deposition were largest in those areas that showed the highest 1995 deposition.

The projected percent change in total nitrogen deposition from 1995 to 2040 differed dramatically among the three strategies. Total nitrogen deposition was projected to increase at the majority of the sites under the OTW Strategy (mean +10%), but to decrease at all of the sites under the BYB Strategy (mean -34%). Results for nitrogen deposition for the BWC Strategy were intermediate (mean -14%). The projections were substantially different for the two components of total nitrogen, oxidized nitrogen (nitrate), and reduced nitrogen (ammonia and ammonium). Nitrate deposition was projected to decrease under all strategies, from a mean of -20% in the OTW Strategy to -26% in BWC and -31% in BYB. In contrast, reduced nitrogen was projected to increase in OTW and BWC (mean +29% and +11%, respectively), but to decrease slightly (mean -4%) in BYB. Percent changes in base cation deposition were small (typically <10%) at all sites for all strategies.

Stream Chemistry Results

Base cation concentration and ANC of streams vary spatially, as do several other factors that influence the sensitivity of streams to acidification. Within the SAMI region, these variations appear to be partly related to geology, partly related to patterns in atmospheric deposition and partly related to physiography. All site simulations showed reduced soil base saturation and most sites showed reduced base cation leaching to streamwater. Thus, the model output suggested continued soil acidification, but a decreased rate of soil acidification, under all strategies.

In response to the OTW strategy, streamwater sulfate concentrations were projected to decrease substantially (> 20 μeq/L) at about one-fourth of the sites, mostly in West Virginia. These are the sites that are currently closest to sulfur steady state, where the amount of sulfur entering the watershed in deposition approximately equals the amount leaving the watershed in streamwater. Because much of the incoming sulfur currently leaches out of these watersheds as streamwater sulfate, a substantial decrease in sulfate output was projected by the model in response to a substantial decrease in simulated sulfur input. Most sites outside West Virginia showed modest (< 10 μeq/L) increases in streamwater sulfate concentration in response to the OTW Strategy even though sulfur deposition was projected to decline substantially. These sites are currently retaining a high percentage of the sulfur input and are expected to exhibit gradual decreases in sulfur adsorption on soils over time, thereby leading to higher concentrations of sulfate in streamwater. This simulated increase in streamwater sulfate concentration has the potential to contribute to further acidification. The BWC and BYB strategies resulted in progressively larger and more widespread declines in streamwater sulfate concentrations. Although some sites continued to show projected increases in streamwater sulfate concentration for both of these strategies, these increases became progressively smaller in magnitude and more confined geographically to the southern portion of the SAMI region.

Some watersheds currently leach significant amounts of nitrate from soils to streamwater and were therefore projected by the model to be responsive to future changes in nitrogen deposition. These watersheds were scattered throughout the SAMI domain, but were mostly found in West Virginia and near the North Carolina-Tennessee border.

In response to the OTW strategy, streamwater nitrate concentrations increased at some sites and decreased at others. Projected changes in streamwater nitrate concentration were largest for those sites that exhibited the highest nitrate concentrations in 1995. These largest changes were primarily decreases in concentration, and they were mostly located in West Virginia.

Streamwater nitrate concentrations decreased at nearly all sites under the BWC Strategy and at all sites under the BYB Strategy. Again, the largest and geographically most consistent decreases in projected streamwater nitrate concentration were in West Virginia, and to a lesser extent near the North Carolina-Tennessee border.

The changes in streamwater sulfate and nitrate concentrations in response to the Emissions Control Strategies, discussed above, coupled with projected changes in base cation concentrations and soil base saturation, resulted in varying projected changes in streamwater ANC. Streamwater ANC is largely determined by the balance between sulfate, nitrate, and base cation concentrations in solution. Each of the strategies resulted in projections of increased ANC in some streams and decreased ANC in others. Progressively more of the sites were projected to show increased ANC as emissions and deposition were reduced in the sequence of larger emissions reductions from the OTW to BYB Strategies.

There were rather pronounced differences in projected streamwater responses to the various strategies in the south versus the north. In the south, projected streamwater sulfate concentrations increased at most sites under most strategies. In addition, projected nitrate concentrations either increased very slightly (e.g., many sites in OTW) or decreased by a small to modest amount (generally < 5 μeq/L). Virtually all southern sites under the OTW and BWC Strategies, and almost all southern sites under the BYB Strategy, were projected to continue to acidify. This projected acidification was substantial (> 10 μeq/L) at many sites in the OTW, and to a lesser extent BWC, Strategy; under the BYB Strategy, however, the projected continued acidification was generally < 10 μeq/L. It was much more strongly associated with projected change in streamwater sulfate concentration than with change in nitrate concentration. At a few sites, including those where sulfate concentration decreased, base cation concentrations were projected to decrease by more than 5 to 10 μeq/L, especially in the BYB Strategy.

The picture of projected changes in streamwater chemistry was very different in the northern (Virginia and West Virginia) part of the SAMI region. There, projected streamwater sulfate concentrations decreased substantially at most sites in the OTW Strategy to almost all sites in the BYB Strategy. The observed gradient from south to north in projected streamwater sulfate concentrations was further complicated by observed east-west gradients in sulfate and other parameters from the Blue Ridge to the Appalachian Plateau physiographic provinces. Projected streamwater nitrate concentrations in the north showed moderate decreases (> 5 μeq/L) at many of the sites in the Appalachian Plateau physiographic province, especially in the BYB Strategy.

The majority of the northern sites showed projections of continued acidification (decreased ANC) in the OTW strategy. The number of sites projected to continue to acidify and the magnitudes of projected acidification were less for the BWC, and especially the BYB Strategy. Thus, ANC was projected to decrease at many northern sites and strategies, in spite of rather large decreases in sulfate, and to a lesser extent, nitrate concentrations in streamwater. This was because projected decreases in sum of base cation concentrations were substantial at many of those sites. The larger emissions reductions of the BYB Strategy were sufficient to offset this base cation depletion and result in projected increases in ANC at many northern sites.

The overall response of the modeled watersheds to the OTW Emissions Control Strategy suggested relatively modest future changes in streamwater chemistry at most sites. Most sites showed change of ANC (either up or down) from 1995 to 2040 of 20 μeq/L or less. These model projections of change in ANC were small in comparison with the projections of continued future acidification if sulfur and nitrogen deposition were held constant into the future at 1995 levels. The model results suggest that current efforts to reduce emissions from 1995 levels, as represented by the OTW Emissions Control Strategy, will prevent substantial future deterioration in streamwater acid-base chemistry. However, additional reductions in emissions, as represented by the BWC and BYB Emissions Control Strategies, will probably not have a large impact on streamwater chemistry to the year 2040.

In general, the model simulations for the OTW strategy suggested that streamwater quality would decline at most sites, although these projected declines were generally small. ANC projections showed a steady increase in the percent of the modeled group that was acidic, from 18% in 1995 to 25% in 2040. Concurrently, the percent of the modeled group that had ANC > 50 μeq/L was projected to decrease from 37% to 28%. The percent of modeled streams in the intermediate classes (0 to 20 and 20 to 50 μeq/L) showed little change (< 1%), mainly because each class was projected to lose some streams to the next lowest class.

About 13% of the modeled group was projected to increase in ANC in response to the OTW strategy. These were primarily acidic and very low-ANC (≤ 20 μeq/L) streams in the Ridge and Valley and the Appalachian Plateau Physiographic provinces. They were mostly high in sulfate concentration (> 50 μeq/L) in 1995 and responded to the simulated large decreases in sulfur deposition with rather large projected decreases in streamwater sulfate concentration and increased ANC. However, most sites, including almost all of the higher-ANC sites, showed projected continued acidification.

Although the BWC Strategy resulted in a large number of sites that were projected to show some increase in ANC, the majority of sites were projected to continue to acidify, and the resulting percentages of modeled streams in various ANC classes suggested a general deterioration of water quality, which in most cases was small in magnitude. This deterioration occurred largely in the first 15 years of the simulations, with some subsequent improvement.

The BYB Strategy resulted in the lowest level of both sulfur and nitrogen deposition of the three Emissions Control Strategies. Most sites showed a reduction in sulfur deposition of more than 70%, and a reduction of total nitrogen deposition of more than 30%. In response to these simulated decreases in deposition, the majority of the acidic and very low-ANC ($\leq$ 20 µeq/L) sites showed some ANC recovery by 2040. The majority of the higher-ANC sites showed continued acidification, which was mainly attributable to decreased sulfur adsorption on soils over time.

Modeled changes in streamwater ANC in the SAMI strategies were driven primarily by changes in sulfur deposition, rather than changes in nitrogen deposition. This was because simulated changes in nitrogen deposition were smaller than simulated changes in sulfur deposition and because simulated changes in nitrogen deposition were projected to have substantial impacts on streamwater nitrate concentration only in a limited geographical area.

Watersheds found to be most sensitive to modeled changes in nitrogen deposition were located primarily in the northern section of the Appalachian Plateau province in West Virginia and at high elevation in the Blue Ridge Province in North Carolina and Tennessee.

SAMI policy is based on consideration of model projections that extend to the year 2040. However, the dynamics of watershed acidification and recovery operate over much longer time periods. At sites such as the acid-sensitive streams within the SAMI domain, the temporal aspects of sulfur adsorption and desorption may contribute further to changes in streamwater sulfate concentration (which in large part drive changes in ANC) that occur over many decades or longer. In addition, at the most acid-sensitive watersheds, base cations may have been depleted by more than five decades of high atmospheric sulfur and nitrogen loading and intensive human land use. It is expected that it will take many decades or longer of low atmospheric sulfur and perhaps nitrogen loading for weathering reactions to restore the soil base cation pools to levels that approximate pre-acidification conditions.

The MAGIC model forecast results suggested that the recovery of many streams from acidification would continue well beyond 2040 under reduced atmospheric deposition. Sites that showed improvement by 2040 in streamwater ANC, and also many sites that showed slight additional acidification (< about 10 μeq/L) between 1995 and 2040, showed continued improvement beyond 2040. Many of these sites showed projections of further improvement between 2040 and 2100 of an additional 10 to 20 μeq/L or more of ANC. Some sites that showed projected acidification between 1995 and 2040 exhibited further projected acidification after 2040. Under the BYB strategy, the percent of the modeled group that was projected to be acidic declined to an estimated 8% in 2100. Thus, the projected improvement from 1995 (18% acidic) to 2040 (15% acidic) was only about one-third of the projected improvement from 2040 to 2100, even though deposition was held constant from 2040 to 2100 in the simulations.

Projected Biological Response of Streams

Sites projected to show increased ANC would be expected to become more hospitable for brook trout and for other species of aquatic biota. These projected improvements in biological conditions are attributable to decreased chronic toxicity and/or decreased likelihood of episodic toxicity of streamwater to sensitive species. Such an interpretation assumes that habitat characteristics other than acid-base chemistry (e.g., food, shelter, temperature, dissolved oxygen) are not limiting the particular species occurrence, growth, or health. Sites projected to show decreased ANC would generally be expected to become more inhospitable for aquatic biota.

Some sites might change appreciably in future chemistry, and yet show little or no biological response. For example, a stream that is currently highly acidic might exhibit a large increase or decrease in ANC and remain essentially equally inhospitable. Conversely, a stream that currently exhibits biologically-favorable chemistry might experience a large ANC change with little change in biological status as long as the ANC remains above response thresholds. Nevertheless, in most cases, a decrease in ANC would generally be expected to have an adverse impact on some species, especially if the ANC is in the critical range from near zero to near or below 50 μeq/L. Similarly, an increase in ANC would generally be expected to have a beneficial impact on some species, especially if the ANC is in the critical range.

Model results in response to the various Emissions Control Strategies did not indicate that large numbers of streams would be likely to shift in biological response categories. For example, the percent of the modeled group projected to be chronically acidic in 2040 ranged from an increase of 7.7% of the modeled streams in OTW to a decrease of 3.1% in BYB, compared with the 1995 reference value. Similarly, the percent of the modeled group projected in OTW to be either chronically or episodically acidic was 7.7% higher in 2040, as compared with 1995 reference values. The percent of the modeled group projected to be either chronically or episodically acidic was 45.5% both in 1995 and in the 2040 projection for the BYB Strategy. That projected percentage increased from 45.5% in 1995 to 51.5% and 53.1% in the BWC and OTW Strategies, respectively.

These results suggest that there would be only rather small differences among the strategies in the projected percent of streams in the various biological response categories. However, biological conditions were projected to be worse at most sites in 2040 under the OTW and BWC Strategies, as compared with 1995 reference conditions. Biological conditions were projected to improve slightly under the BYB Strategy, based on the projected percent of acidic and low-ANC streams. Under all of the strategies, biological conditions were projected to be dramatically better in 2040 than they would be under a scenario of constant deposition at 1995 levels. For example, the percentage of the modeled group that was projected to be chronically acidic (unsuitable for brook trout) in 2040 was almost three times higher under the scenario of constant deposition at 1995 levels as compared with the BYB Strategy.

Extrapolation to NSS Population

The projected differences in streamwater chemistry were small among the three strategies. When these estimates were extrapolated to the population of streams within the SAMI domain, based on the NSS statistical frame, the differences became even smaller. This was because a large number of acidic and low-ANC streams were intentionally selected for modeling, even though such streams are relatively rare within the SAMI region. NSS population estimates suggested little difference among strategies in the population of streams within the SAMI region that are represented by the NSS statistical frame. The NSS sampled most streams at two locations, an upstream site (upper node) and a downstream site (lower node). In general upper nodes had lower ANC than lower nodes. An estimated 7% of the NSS upper node stream population was acidic in 1995. Model projections suggested that this percentage would increase to 10% in 2040 under OTW, but remain at 7% under BWC and BYB. Population projections for lower node streams also showed small changes. Only 3% were acidic in 1995. Model projections suggested that the percent acidic would remain constant under OTW, and decrease to 2% under BWC and 1% under BYB.

Population estimates for the upper and lower nodes were combined to generate estimates of stream length within the various ANC classes. There was a small decline in the estimated length of projected acidic streams in 2040 from the OTW to the BYB Strategies. Otherwise, there was little difference in projected stream length in the different ANC classes as a consequence of adopting one or another Emissions Control Strategy.

These extrapolations to the NSS statistical frame help to put the modeling results into the context of the universe of streams that exist within the region. This is important because about 60% of the streams in the SAMI region have ANC > 150 μeq/L. These high-ANC streams are not expected to be acid-sensitive and were not modeled for this assessment. Nevertheless, they constitute the majority of the streams within the region.

Marked geographic differences were observed, with almost all of the projected acidic and low-ANC lower node streams in 2040 occurring in the northern Appalachian Plateau, regardless of strategy. The projected percentages of acidic and low-ANC upstream reach ends (upper nodes) were somewhat more evenly distributed than the lower nodes, but still mostly confined to the northern section of the SAMI region. Again, the northern Appalachian Plateau was the predominant location of projected acidic and low-ANC upper node streams in 2040. Over 25% of the estimated 4,890 upper node Northern Appalachian Plateau stream reaches were projected under the OTW Strategy to be acidic and about 43% were projected to have ANC ≤ 20 μeq/L in 2040.

Under the OTW Strategy, many of the low-ANC streams in the northern Appalachian Plateau subpopulation were simulated to decline by about 10 μeq/L in ANC from 1995 to 2040. These projected decreases in streamwater ANC were sufficiently large as to result in quite a large increase in the percent of streams in the northern Appalachian Plateau that were projected to be acidic in 2040 as compared with 1985 NSS measurements. The estimated percent of streams that was acidic in 1985 ranged from 3% (lower node) to 6% (upper node) in the northern Appalachian Plateau. Under the OTW Strategy, the percent of acidic lower node streams in that subregion was projected to increase to 12%, and acidic upper node streams to increase to 25%, by 2040, with most of the increases occurring between 1985 and 1995. These are very large increases and this subregion represents most of the additional acidification associated with the OTW Strategy. Even under the BYB Strategy, the percent of acidic northern Appalachian Plateau upper node streams was very high (19%). Such changes in ANC would be expected to have significant adverse impacts on brook trout and other aquatic biota within this subpopulation. Over 40% of the streams in this subregion are expected to be either episodically or chronically unsuitable for brook trout in 2040 as a consequence of the projected low ANC values.

It is interesting to note that despite the rather large projected declines in streamwater sulfate and nitrate concentrations in the northern Appalachian Plateau, median projected streamwater ANC declined in two of the strategies. This was because the projected changes in base cation concentrations in streamwater were larger than the projected changes in sulfate plus nitrate concentrations.

Spatial Extrapolation

A regional spatial analysis was conducted to determine the extent to which streamwater ANC for 926 streams in and near the SAMI region correlated with landscape features that were available spatially for the entire study region and known or suspected to be important contributors to surface water acidification sensitivity. Such features included lithology, elevation, watershed area, watershed relief, forest vegetation type, soil type, and ecoregion.

Compared to other regions that have been glaciated and/or have deeper soils, the unglaciated shallow soils of the mid-Appalachian region appear to be rather closely associated with underlying bedrock with respect to their acid-base characteristics. A geologic classification scheme was therefore developed for the SAMI region. The geologic map coverage that served as the basis for the landscape classification was provided by the Eastern Mineral Resources Team of the U.S. Geological Survey (USGS), which has aggregated map units from available state geologic maps (1:500,000 scale or better) to develop uniform multistate lithologic maps. This coverage has been developed for all of the SAMI states except South Carolina, for which work is in progress. The 59 lithologic units represented in this regional coverage for the SAMI study area were aggregated into a five-unit landscape classification scheme, generally based on composition and weathering properties of the primary rock type associated with each lithologic map unit. A geographic information system (GIS) was used to calculate the percentage distribution of each of the USGS lithologic map units and the derivative landscape classes in each of the study watersheds.

Almost all of the acidic streams and most of the highly sensitive streams (ANC 0 to <20 μeq/L) were associated with the siliceous landscape class, the most acid-sensitive of the five classes. For this analysis, only those sites for which the entire watershed occupied a single geologic class were included (n = 487). All of the streams in the other sensitive classes (ANC 0 to 20 µeq/L and 20 to <50 µeq/L) were associated with the siliceous, felsic, and argillaceous classes. All of the streams associated with the mafic and carbonate classes were relatively insensitive (ANC $\geq$ 50 µeq/L). Because there was considerable overlap in ANC values among the classes, the classification scheme does not provide a good basis for predicting the ANC of individual streams. However, the classification scheme indicates areas with high percentages of low-ANC streams, as well as areas without low-ANC streams. The relationships identified between streamwater ANC and geologic sensitivity class were used as the foundation for a watershed sensitivity classification scheme, which is described below.

Several landscape variables were found to correlate well with the percentage of sampled streams (n=926) in various ANC classes within and in proximity to the SAMI region. In particular, certain landscape types were found to contain high percentages of either acidic and low-ANC streams or to contain high percentages of high-ANC streams. Many of the landscape variables are to some extent intercorrelated. For example, sampling sites that occur at higher elevation generally have smaller watershed areas, and are more likely to be underlain by resistant bedrock and to be occupied by particular forest types, such as spruce-fir or maple-beech-birch. In contrast, lower-elevation sites tend to have larger watershed areas, to be underlain by less resistant bedrock and to be covered by oak forest types or non-forest vegetation, including agricultural cover types.

A classification scheme was developed for the SAMI region, based on geologic sensitivity class and elevation. The objective in developing this scheme was to define an area, based on landscape variables, that was spatially limited, and yet contained the vast majority of the acidic and low-ANC streams known to occur within the SAMI domain. These are the streams that have been most adversely impacted by acidic deposition to date and to a large extent are also the streams for which biological recovery may be possible under significantly reduced future deposition.

The siliceous geologic sensitivity class was fairly restricted in area, covering 23% of the SAMI domain, and yet included the vast majority of the acidic (69%) and ANC $\leq$ 20 (59%) sampled streams. Examination of the locations of the acidic and low-ANC stream sampling sites relative to the location of lithologic coverages classified as siliceous revealed that many additional acidic and low-ANC stream sites were located outside, but in proximity to, the siliceous class. A 750 m buffer was therefore added in the GIS to the siliceous class coverage. Addition of this buffer substantially increased the extent to which acidic and low-ANC streams were now included (97 and 87%, respectively), with only moderate increase in the size of the defined area (to 35% of the SAMI region).

We identified two issues which likely contributed significantly to the finding that many acidic and low-ANC stream sampling points were located just outside the most acid-sensitive geologic class. First, many watersheds are partly or largely occupied by lithologic coverages of the siliceous type, and yet the stream sampling location was actually somewhat downstream of the boundary between the siliceous class and another class. If the distance between the sampling point and the sensitivity class boundary was short, one would expect streamwater chemistry in most cases to be generally reflective of the upstream siliceous geologic material. Second, geologic sensitivity classes were designated using lithologic coverages of rather coarse and variable scale. There is therefore some uncertainty regarding the exact location of lithologic boundaries. Thus, it is not surprising that the extent to which the siliceous class included acidic and low-ANC sites improved considerably upon addition of a buffer zone.

Deletion of low-elevation areas (< 400 m) dramatically reduced the size of the area of interest, to 22% of the SAMI domain, with little loss of acidic and/or low-ANC sites. It was also found that there were still a number of low-ANC stream sites excluded from the area of interest, and most of these were found at high elevation (> 1,000 m). All areas above 1,000 m elevation that were not already included within the siliceous class and associated buffer were therefore added to the area of interest. The final classification scheme only covered 26% of the SAMI region, and yet contained 95% of the acidic sampled stream sites and 88% of the ANC $\leq$ 20 μeq/L sites. This is the final scheme recommended for evaluation of acidic deposition sensitivities and effects. The area encompassed by this region is shown in Figure ES-2. As shown on the map, all acidic and low-ANC streams are either within or in proximity to the final mapped area.

Relationships were also found to occur between landscape features and the extent to which watersheds were projected to respond to future reductions in acidic deposition. For example, there were 28 modeled streams that were acidic in 1995, but projected to have ANC > 0 in 2040 in the BYB Strategy. Of those, 86% occurred within the sensitive area shown in Figure ES-2.

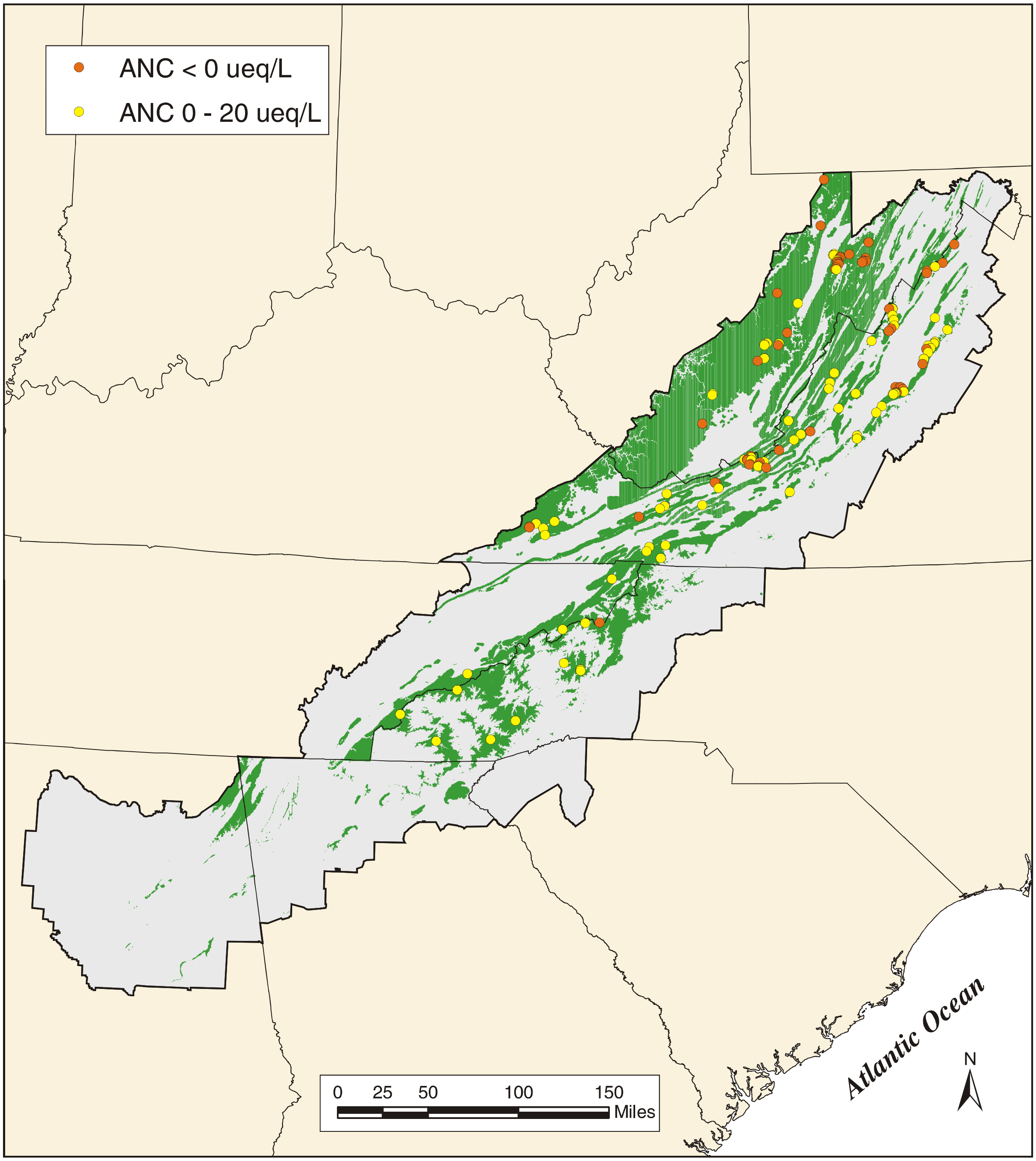


Figure ES-2. Final area delimited by the acidification sensitivity classification scheme. The area shaded in green includes the siliceous geologic sensitivity class, surrounded by a 750 m buffer. In addition, all areas less than 400 m elevation have been deleted and areas greater than 1,000 m elevation have been added. The area thus circumscribed includes 95% of the known acidic (ANC ≤0) streams and 88% of the known streams having ANC ≤ 20 μeq/L. Furthermore, all known streams having ANC ≤ 20 μeq/L are in proximity to the final mapped area.

Class I Assessment

In addition to the regional modeling that was conducted for the SAMI region as a whole, available water chemistry data and model output for all modeled watersheds (regional and special interest) were examined for each of the individual Class I areas within the SAMI domain. There were distinct differences in acid-base chemistry among the Class I areas and among the various subregions of the SAMI domain. For example, acidic streams appear to be especially prevalent in the Dolly Sods and Otter Creek Wilderness areas on the West Virginia Plateau. The lower quartile of available measured streamwater ANC values was also below 25 µeq/L in Shenandoah and Great Smoky Mountains National Parks and James River Face Wilderness. The wilderness areas with higher ANC are all located in the southern half of the SAMI region, in the Southern Blue Ridge and Alabama Plateau.

A total of 55 watersheds was modeled with MAGIC (including both Regional and Special Interest sites) and 8 watersheds with NuCM within Class I areas. Under the OTW Strategy, the median ANC in each of the Class I areas except Otter Creek Wilderness was projected to decrease, in several cases by about 10 µeq/L, from 1995 to 2040. Under the BYB Strategy, only Sipsey Wilderness had substantial projected ANC decreases (> 5 µeq/L), and these could be attributed to decreased sulfur adsorption in soils. Effects were most pronounced for the scenario of constant deposition at 1995 levels. Under this scenario, the number of modeled Class I sites that were acidic was projected to increase by 60% by 2040, with corresponding decreases in the number of sites in other ANC classes, especially ANC 0 to 20 µeq/L.

Nine streams in the Otter Creek Wilderness Area were modeled with MAGIC, seven of which were acidic at the time of sampling, with simulated 1995 ANC ranging from +15 to -111 µeq/L. Streamwater sulfate concentrations in the modeled streams of the Otter Creek Wilderness Area tended to be higher than in the other Class I areas (i.e., generally about 120 to 150 µeq/L). For seven of the modeled sites, projected ANC in 2040 was below -40 µeq/L, regardless of strategy. Biological recovery would likely not occur by 2040 at any of these sites. For the other two sites, ANC in 2040 differed among strategies, but ranged from -1 to 13 µeq/L, regardless of strategy. Each of the strategies prevented projected 2040 streamwater chemistry of these two streams from becoming strongly acidic (compared with -16 and -27 µeq/L under the scenario of constant deposition at 1995 levels). There was little indication, however, that the BYB Strategy would yield significantly improved biological conditions in these streams as compared with the other strategies.

Because half of the modeled streams in Shenandoah National Park had ANC between about -5 and 40 µeq/L in 1995, rather small future changes in ANC could have pronounced impacts on biological status. Large differences were projected for streamwater chemistry in this park between the scenario of constant deposition at 1995 levels and the 3 strategies. For example, under constant 1995 deposition, almost half of the modeled sites were projected to have ANC < 20 µeq/L in 2040. In contrast, modeling of the BYB Strategy indicated that all except two of those streams would likely increase to above 20 µeq/L by 2040.

<u>Uncertainties</u>

There are numerous uncertainties associated with conducting as assessment of this type, only some of which are quantifiable. The major uncertainties include the quality of the model input data, temporal variability (especially seasonal and episodic) in water chemistry, variability in biological response to water chemistry, model validity and accuracy, model calibration uncertainty, errors associated with missing model input data, and errors associated with regional extrapolation of modeling results from individual watersheds to the region. It is anticipated that such errors and uncertainties are not additive, but rather would be expected to some extent to cancel each other out. Although it is not possible to rigorously quantify the overall uncertainty in the assessment results, analyses were conducted to evaluate and put into perspective many of these major uncertainties.

Rigorous screening criteria were adopted for regional modeling site selection, to ensure that the data for the modeling sites were internally consistent and that sites were not included if they showed indication of significant impacts on acid-base chemistry other than acidic deposition (geological sulfur, acid mine drainage, road salt, land use). The resulting database appeared to be internally consistent, displaying good agreement between theoretical (calculated from the charge balance) and analytical (titrated) ANC values and reasonable relationships between pH and ANC. The majority of the selected modeling sites had been sampled within large synoptic water chemistry surveys that had been developed employing rigorous Quality Assurance/Quality Control (QA/QC) programs. The model input data appears to generally be of very high quality. Nevertheless, based on previous analyses of National Surface Water Survey data, laboratory analytical error for calculated ANC is likely on the order of about ±13 µeq/L,.

Streamwater and soil solution chemistry are temporally variable, mainly in response to changing hydrological conditions and seasonal patterns in plant and microbial activities. This uncertainty was considered in the selection of ANC classes used for stratifying modeling sites and for presentation of the results. In other words, the interpretation of the model projections of chronic chemistry allows for the likelihood of additional episodic acidification. Although the extent and magnitude of episodic acidification varies from site to site and with meteorological conditions, some generalities are possible. For example, minimum measured episodic ANC values published for Virginia streams were generally about 20% lower than the median spring ANC.

Data were available from the VTSSS with which to evaluate the agreement between MAGIC simulated and observed values over the ten-year period of record. MAGIC was calibrated to 33 VTSSS sites. The average root mean squared error (RMSE) for the difference between simulated and observed ANC ranged from 3 to 13 μeq/L, with a mean of 7 μeq/L.

There were errors introduced into the modeling effort as a consequence of not having soils analytical data available for all of the MAGIC modeling sites. For Tier II sites, soils data were borrowed from a nearby Tier I site located within the same geological setting. For Tier III sites, soils data were borrowed from the Tier I site judged to be most comparable with respect to streamwater ANC (an indicator of watershed soils conditions), geologic sensitivity class, location, elevation and streamwater sulfate concentration (an indicator of sulfur adsorption on soils). The error associated with needing to borrow soils data for Tier II and Tier III sites was quantified by calibrating selected Tier I watersheds twice, once using the appropriate site-specific soils data, and a second time using borrowed soils data from an alternate site, using either Tier II or Tier III protocols. Multiple Emissions Controls Strategies were then simulated for each of the two calibrations at each site. The results showed generally good agreement between model projections of streamwater ANC using measured versus borrowed soils data. Errors were generally less than about 10 μeq/L. The error range calculated by the RMSE of the observed differences between model projections based on site-specific versus borrowed soils data was less than 4 μeq/L.

There is uncertainty associated with extrapolating the results of site-specific modeling at 130 regional locations to the population of streams within the SAMI domain. Substantial effort was devoted to selection of regional modeling sites that spanned the range of available data with respect to all variables thought to be important in discriminating among the likely response functions within the study area. Thus, sites were selected to maximize diversity of model sites with respect to physiographic province, water chemistry (ANC, sulfate, nitrate concentrations), geographic location, and elevation. Because the sites were not selected from a statistical frame, it may not be reasonable to use the modeled responses of these 130 watersheds to directly describe changes to the population of streams in the SAMI domain.

Using the Horvitz-Thompson variance algorithm, and given the NSS sample size and sites used to estimate the SAMI domain, the exact standard error of any population estimate can be made. As a general guideline, estimates of around 50% of the SAMI population have a standard error of plus or minus 7 to 9 percentage points. For the tails of the SAMI regional distribution (e.g. 10% of the sites are low in ANC), the standard error of the NSS estimates are plus or minus 2 to 5 percentage points. Standard errors are given as ranges because exact estimates depend on which sites are affected and from which sample strata they were selected.

The difference between the best and worst case regional estimate was (based on the maximum and minimum estimates of ANC change among sites within a given modeling bin) about plus or minus 1 to 7 percentage points from the median within-bin result among the various ANC classes. Thus, as a worst case, the bin extrapolation process had an error about equivalent to the error in the statistical extrapolation of the regional population from the NSS sample sites. In actuality, it was probably a fair amount smaller than that.

Major Conclusions

Atmospheric modeling of the three Emissions Control Strategies specified by SAMI resulted in large estimated reductions in sulfur deposition at the effects modeling sites. Mean percent changes in sulfur deposition from 1995 to 2040 ranged from -57% (OTW Strategy) to -73% (BYB Strategy). Estimated changes in total nitrogen deposition were smaller, ranging from mean values of +10% to -34% for the three strategies. Reference year deposition values and estimates of change in deposition were highest at high-elevation locations in western North Carolina and eastern Tennessee and in the Appalachian Plateau of West Virginia.

MAGIC model projections of streamwater chemistry suggested a general deterioration in future streamwater acid-base chemistry under the OTW and BWC strategies. These model projections of change were small at most sites, however, and relatively few sites were simulated to change ANC class. The latter were selected to be reflective of biological suitability of streamwater. Projected changes in streamwater chemistry were more strongly driven by changes in sulfur than nitrogen deposition. This was because nitrogen deposition changes estimated for the Emissions Control Strategies were much smaller than sulfur deposition changes, and because only a small subset of the modeled streams were projected to be sensitive to modest changes in nitrogen deposition. These nitrogen-sensitive streams were mainly located at high-elevation near the North Carolina/Tennessee border and in the Appalachian Plateau of West Virginia.

When model results were extrapolated to the population of streams in the SAMI region, it was found that differences among strategies in projected percentages of streams in various ANC classes were on the order of a few percent of the total stream population or less. Low-ANC streams ($\leq$ 20 µeq/L) are relatively rare within the SAMI region, and only a small percent of those were projected to change in ANC in the future by a large enough amount to cause them to change ANC class.

Although the model projections of future change in streamwater ANC in response to the Emissions Control Strategies suggested little change, as compared with reference year conditions, these projections represented pronounced improvements as compared with model projections based on continued deposition at 1995 levels. Results of the continued constant deposition scenario suggested substantial future deterioration in streamwater acid-base chemistry, with likely associated biological impacts.

Model projections beyond 2040 suggested that the sites projected to increase in ANC from 1995 to 2040, and also many of the sites that showed projected small additional acidification from 1995 to 2020, would show considerable additional improvement in ANC beyond 2040, even if future deposition was held constant at 2040 levels. This was because the full effects of deposition reductions in the SAMI region develop over periods of many decades or longer. Ecosystems exhibited delayed responses because of modeled changes in sulfur adsorption on soils and depletion of watershed base cation reserves.

Streamwater sensitivity to acidification varies spatially throughout the region, especially as influenced by geology and elevation. A regional classification system was developed, based on those elements, to indicate the location of acid-sensitive streams within the SAMI domain. A high-interest area was delineated, which covered 26% of the region and yet included 95% of all known acidic streams and 88% of those known to have ANC $\leq$ 20 µeq/L. This high interest area, which included extensive portions of the Appalachian Plateau physiographic province in West Virginia, also indicated the location of streams projected to show the greatest improvements in chemistry in response to emissions controls. Almost all streams projected to have ANC below 20 µeq/L in 2040, regardless of strategy, were located in the northern Appalachian Plateau subregion.

1.0 INTRODUCTION

1.1 Background

The Southern Appalachian Mountains Initiative (SAMI) is a voluntary partnership that includes state and federal agencies, industry, academia, environmental groups, and the interested public. Its goal is to identify and recommend strategies to remedy existing air pollution impacts to natural resources in the eight state Southern Appalachian Mountains region and to prevent future adverse impacts. Particular emphasis is placed on resource protection within the ten Class I national parks and wilderness areas[1] that occur within the SAMI domain (Figure 1-1).

SAMI is conducting an Integrated Assessment of air pollution sensitivities and effects that focuses on acidic deposition, ozone, and visibility. The assessment links emissions, atmospheric transport, environmental effects, and socioeconomic models to derive projections of future impacts under varying levels of emissions. Emissions management strategies represent air regulatory requirements that were being implemented at the time of SAMI's formation, expected emissions reductions under recent Federal regulatory actions, and alternative strategies that SAMI might recommend for regional, state, or community-based actions (Brewer et al. 2000).

The acidic deposition assessment has been conducted for SAMI in two phases. During Phase I, aquatic and forest responses to hypothesized changes in future sulfur and nitrogen deposition were evaluated for three watersheds located in Great Smoky Mountains National Park (Noland Divide) and Shenandoah National Park (White Oak Run and North Fork Dry Run). The former two watersheds are highly sensitive to streamwater acidification and have annual average streamwater acid neutralizing capacity (ANC) between 0 and 20 µeq/L. The latter watershed is only slightly sensitive, with annual average ANC at about 90 µeq/L. Aquatic and terrestrial responses were simulated with the MAGIC (Cosby et al. 1985) and NuCM (Liu et al. 1991, Johnson and Lindberg 1991) models, respectively. Results of the Phase I analyses, reported by Cosby and Sullivan (1999), Munson (1999), and Brewer et al. (2000), provided guidance to SAMI on assessment design and a preliminary indication of model results. Phase I results are summarized in Appendix A. Phase II, the results of which are reported here for aquatic effects, provides a regional characterization across the SAMI region, based on the same two

[1] Class I areas are national parks over 6,000 ac and wilderness areas over 5,000 ac that were in existence prior to August, 1977. The Clean Air Act and its amendments provide the highest level of protection to Class I Areas, and indicate that federal land managers have "an affirmative responsibility to protect air quality related values (AQRV).... within a Class I area."

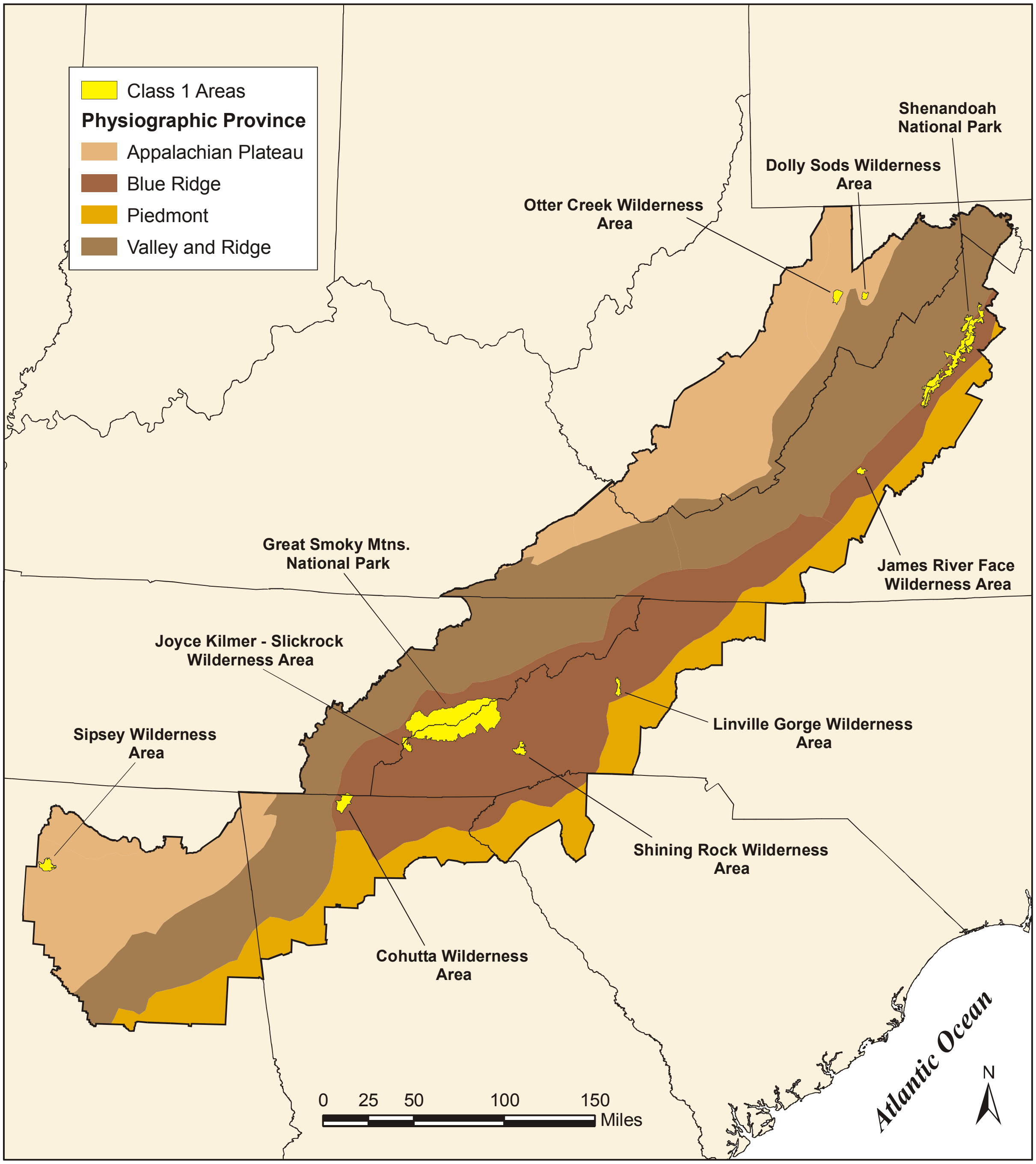


Figure 1-1. Map showing SAMI domain, physiographic provinces, and location of Class I areas.

models utilized in Phase I. Phase II results for terrestrial ecosystems are reported by Sullivan et al. (in review).

1.2 SAMI Region

Forests cover most of the ridges throughout the SAMI region. It is largely on these forested ridges that most of the acid-sensitive aquatic and terrestrial resources are located. The forests are dominated by deciduous trees in most places, although coniferous trees are dominant in some of the higher elevation areas. Most of the forests are regenerating subsequent to nearly total harvest by the early part of the 20th century.

The Appalachian Mountain region constitutes an important region of concern with respect to the effects of acidic deposition. Many streams at higher elevation, particularly in the mid-Appalachian portion of the region (northern portion of the SAMI domain), have chronically low ANC values and the region receives one of the highest rates of acidic deposition in the United States (Herlihy et al. 1993). The acid-base status of streamwaters in forested upland watersheds in the southern and mid-Appalachian Mountains has been extensively investigated in recent years (e.g., Cosby et al. 1991, Church et al. 1992, Herlihy et al. 1993, Webb et al. 1994, van Sickle and Church 1995). Small first to third order streams dominate the mid-Appalachian Highlands; about 63% are first order streams and an additional 15% are second order (U.S. EPA 1998, Herlihy et al. 2000).

Wet sulfur deposition varies throughout the SAMI region from about 5.5 to 10 kg/ha/yr, and wet nitrogen deposition varies from about 4 to 8 kg/ha/yr, based on NADP data. Dry and occult (cloud) deposition are also highly variable, with highest known values at high elevations in the Great Smoky Mountains (Webb et al. 1999).

Sulfur-adsorption by soils is an important aspect of watershed acid-neutralization in the southeastern United States. Where S-adsorption is high, even relatively high levels of sulfur deposition have little or no impact on surface water chemistry, at least in the short-term. Over long periods of time, however, this sulfur adsorption in soils can be reduced under continued high levels of sulfur deposition, causing a delayed acidification response. Streamwater sulfate concentrations and stream discharge estimates suggest that sulfur outputs approximate inputs in some of the watersheds of the Appalachian Plateau, and therefore these watersheds are near steady-state with respect to sulfur. Sulfur-adsorption in soils is highest in the Southern Blue Ridge, where about half of the incoming sulfur is retained, and is somewhat lower in the Valley and Ridge watersheds (Herlihy et al. 1993). Thus, there is a general pattern of increasing sulfur adsorption as you move from the north to the south and from the Appalachian Plateau to the Blue Ridge physiographic provinces in the mid- and southern Appalachian Mountains.

The Environmental Protection Agency's (EPA) Direct Delayed Response Project (DDRP) (Church et al. 1989) addressed questions regarding the extent to which watershed acidification responses are immediate (directly proportional to changes in deposition input) or lag in time due to soil processes. Such processes were described in detail by Turner et al. (1990). The principal mechanisms whereby acidification and/or recovery responses may be substantially delayed subsequent to a change in sulfur deposition include sulfur retention in soils and the supply and leaching of base cations. Where an appreciable percentage of sulfur deposition input is retained in watershed soils, acidification response will be delayed as the sulfur adsorption in the soil declines over time. Similarly, where base cation supply from weathering is low, continued leaching of base cations over time by acidic deposition can further deplete the soil base cation supply, causing acidification of both soils and drainage water. Within the SAMI domain, many watersheds exhibit strong sulfur retention. In addition, some watersheds have become depleted of their base cation reserves by some combination of: 1) low weathering rates and therefore low initial base cation stocks in soils, 2) accelerated leaching of base cations by acidic deposition, and 3) loss of base cations in response to land use (e.g., timber harvesting, agriculture). For these reasons, many watersheds within the SAMI domain exhibit delayed acidification. Thus, the soils and surface waters of the SAMI region have not yet realized the full effects of the elevated sulfur deposition received to date (Herlihy et al. 1993). This delayed response creates a situation whereby many streams will continue to acidify even if acidic deposition is not increased. In fact, some streams will continue to acidify even if acidic deposition levels in the future are decreased substantially. Whereas such delays occur to some extent elsewhere, they are far more pronounced in the SAMI region than in other areas of North America (Church et al. 1989, Baker et all 1990, Charles 1991, Sullivan 2000).

The SAMI region includes three physiographic provinces in which acid-sensitive streams are found. These are oriented as southwest to northeastern bands: Blue Ridge Mountains, Valley and Ridge, and Appalachian Plateau (Figure 1-1). There are no historical data available on streamwater chemistry in the region. However, the National Stream Survey (NSS; Kaufmann et al. 1988) sampled streams throughout the region. In the Valley and Ridge Province, low ANC streams are generally absent from the valleys, many of which contain limestone bedrock. Ridge streams are often acid-sensitive, however, and about one fourth are low in ANC (≤ 50 μeq/L) in their upper reaches. The highest proportion of acidic (5%) and low ANC (31%) streams are found in the Appalachian Plateau Province (Herlihy et al. 1996), even after excluding those affected by acid mine drainage (Herlihy et al. 1990). Acidic and low ANC streams are more prevalent in the northern part of the region, in Virginia and West Virginia, than in the south. This gradient is due, at least in part, to the generally higher rates of sulfur and nitrogen deposition (high-elevation portions of the southern SAMI region are an exception) and the lower S-adsorption of soils in the northern part of the region. Throughout the region, acidic and low-ANC streams are generally confined to small (< 20 km^2) upland, forested watersheds in areas of base-poor, weathering-resistant bedrock (Herlihy et al. 1993).

Water bodies are regarded by residents of the SA region as extremely important. Multiple uses include drinking water, fishing, other aquatic recreation, transportation, livestock watering, irrigation, flood control, hydroelectric power, wildlife observation, and waterfront human habitation.

A 1977 NC survey of resource mangers demonstrated that the most important management priority is maintenance of high quality streams; the survey concluded that both the general public and municipal leaders view stream degradation as their greatest resource problem. A more-recent and broadbased survey (SAMAB 1996) concluded that trout populations in particular are regarded by residents as one of the region's most valuable aquatic natural resources, and trout populations and trout habitat are major concerns to the public in the SA. Sources of concern generally fall into three categories: 1) fisheries for native brook trout (*Salvelinus fontinalis*) and introduced rainbow (*Oncorhynchus mykiss*) and brown (*Salmo trutto*) trout; 2) "existence value" for brook trout, regarded as a beautiful and intrinsically valuable native species; and 3) the presence of trout as indicators of high water quality. Acidification is a conspicuous threat to all three trout species in the region. Of the three, native brook trout is the most acid tolerant, brown trout introduced from Europe is intermediate in acid tolerance, and rainbow trout introduced from the western US is most sensitive.

1.3 Biological Resources at Risk

The lack of recent glaciation in the Southeast versus the Northeast has contributed to high species richness in aquatic environments, but also to acid-sensitive, base-poor soils. The Southeast was not glaciated during the last glacial period (about 100,000 to 10,000 years ago).

As a result, the soils of the Southeast are largely residual, relatively deep, and highly structured vertically, versus those in glaciated areas to the north. The lower horizons of southeastern soils are also rich in iron and aluminum, which can strongly affect stream chemistry via efficient retention of many negatively charged solutes (e.g. sulfate, phosphate, organic anions associated with dissolved organic carbon [DOC]), of which sulfate is of major interest in the context of acidification. Ultisols represent one of the dominant soil groups in the Southeast; these are characterized by sandy or loamy surface horizons and subsurface horizons that are loamy or clayey in texture. They are typically acidic soils that are low in base saturation (Adams and Hackney 1992).

The lack of glacial activity has had a greater impact on aquatic than terrestrial biodiversity; most northeastern terrestrial communities "migrated" south, then north again with onset and ending of the glacial period. Aquatic forms, especially fish and mollusks, had less opportunity for southward movement, and either adapted to colder conditions or became extinct in the northeast, resulting in substantially lower aquatic biodiversity in glaciated versus unglaciated areas (Adams and Hackney 1992).

The Southeast contains some of the most evolutionarily significant areas on the continent, with the greatest known diversity for several aquatic groups, notably fish, salamanders and macroinvertebrates (Adams and Hackney 1992, Jenkins and Burkhead 1993, Walsh et al. 1995). The Nature Conservancy (1998) identified about 325 watersheds of about 2200 in the contiguous 48 states that were considered critical to conserve aquatic biodiversity; more than half of these are in the Southeast. With respect to mountain streams specifically, more than 60 high-gradient streams and rivers of the Southern Appalachians (SA) were recognized as outstanding for their high scenic, recreational, geologic and wildlife values (National Park Service 1981, Wallace et al. 1992). A large percentage of regional streams are dilute, low-ANC waters (Elwood 1991), including the most dilute water bodies in the eastern United States (Elwood et al. 1991). Dilute surface waters, with their low concentrations of buffering materials, are sensitive to acidification.

Of the 37.4 million acres in the SA region (as defined by SAMAB 1996), 14.6 million acres (39%) are in the range of wild trout, with up to 33,000 miles of potential wild trout streams. The distribution of trout stream mileage percentage by state is 39% in Virginia, 32% in North Carolina, 10% in Georgia, 10% in Tennessee, 7% in West Virginia, 2% in South Carolina, and 0% in Alabama (SAMAB 1996).

Southern Appalachian streams contain a rich diversity of invertebrate, fish and salamander species. Local species richness depends on thermal regime, water chemistry, patterns of discharge, plus substrate type and geomorphology (Wallace et al. 1992).

Invertebrate Communities

Aquatic invertebrate species richness in the region is probably the greatest in North America, with many endemic species. Indeed, the regional invertebrate fauna includes many as yet undescribed species. The invertebrate fauna in the cool high mountain streams in the region contain species that are elsewhere only found further north. Many regional taxa have evolved rather elaborate morphological and behavioral adaptations for maintaining their positions in high-gradient streams with high current velocity (Wallace et al. 1992).

Macroinvertebrates are defined as animals without backbones, which can be seen with the unaided eye, usually larger than 0.01 inches in at least one dimension. Aquatic benthic macroinvertebrates occur on the bottoms of streams or lakes, in or among substrates such as stones, plants, or wood. In the SA, immature aquatic insects represent most of the macroinvertebrates, together with mollusks and crustaceans. The community contains many species of known sensitivity to stresses such as acidification or sedimentation. As with other groups, counts of taxa (such as families, genera or species) at impacted versus unimpacted sites are often lower, due to loss of sensitive taxa, so lower species richness or absence of specific taxa is often taken to indicate impacts (SAMAB 1996).

Benthic invertebrates play important roles in the breakdown of terrestrial and detrital material in streams, as well as nutrient regeneration. Many fish, waterfowl and other bird species rely on benthic invertebrates as their primary food source. Acidification could therefore affect structure, function and trophic relations in stream ecosystems. Because benthic invertebrates are diverse, relatively easy to collect (though time-consuming to identify), and have short generation times, they are used as indicator species for a number of potential pollutants. This is true in the case of acidification and recovery from acidification, because communities typically contain some species with known acid sensitivities (Baker et. al. 1990).

Fish Communities

The SA area is widely regarded as one of the most diverse landscapes in the Temperate Zone (SAMAB 1996). Fish diversity in the Southeast region is quite high. There are about 950 freshwater fish species in North America (Jenkins and Burkhead 1993), of which about 485 species can be found in the Southeast, and about 350 species can be found in the SA south of the Roanoke and New Rivers (Walsh et al. 1995). The total numbers of fish species by state in the region is very large: 107 in Maryland, 164 in West Virginia 199 in North Carolina, 210 in Virginia, plus the richest state freshwater fish fauna in the country, 307 in Tennessee (Jenkins and Burkhead 1993). Regional habitat and intraspecific genetic diversity are also regarded as high. Thus, the Southeast is a unique national biodiversity resource for fish. Unfortunately, the Southern Appalachian Assessment concluded that 70% of sampled stream locations show moderate to severe fish community degradation, and that about 50% of the stream miles in WVA and VA regions show habitat impairment (SAMAB 1996).

Fish communities of high-gradient southeastern streams may contain a variety of species, but are often dominated by trout, especially brook trout (Table 1-1). There has been little regional ecological research on other species except in biogeographic and systematic studies. However, Jenkins and Burkhead (1993) provided much ecological information on the fish species of Virginia, many of which are found elsewhere in the Southeast. There are clear patterns in species distribution from headwater streams to rivers, which can also be seen in community comparisons among reaches at different elevations; the clearest pattern is that species richness (total number of species present) increases in a downstream direction. This is thought to result from the rather small number of upstream species, which must tolerate simultaneously highest current velocities and lowest pH. Fish are absent from the highest headwaters, where they are replaced by salamanders. The highest-elevation fish species is usually brook trout, typically joined downstream by dace (e.g., blacknose dace [*Rhinichthys atratulus*]), a sculpin (e.g. mottled sculpin [*Cottus bairdi*]) and a darter (e.g. fantail darter [*Etheostoma flabellare*]), and perhaps by introduced brown or rainbow trout (Wallace et al.

Table 1-1. Fish standing stock biomass and trout contribution to total fish biomass at various elevations in western NC streams (after Wallace et al. 1992).

	Elevation (m)						
Parameter	>1219	1067-1219	914-1067	762-914	610-762	457-610	<457
Total fish biomass (g/m^2)	1	1.55	1.74	2.1	2.1	2.15	1.66
Trout contribution (% total biomass)	99.9	86.8	63.5	26.6	33	36.3	25.7
Brook trout (as % total trout numbers)	93.1	30.7	29.7	30.7	7.8	5.8	9.1

1992). In the context of acidification, the introduced trout are both more acid-sensitive than brook trout, and will not be present in acidified waters.

Proceeding downstream, other dace, darters, chubs, shiners, suckers and others are added (Table 1-2). In larger downstream reaches, still regarded as high-gradient, the important gamefish smallmouth bass (*Salmoides dolomieu*) is most abundant in riffles over substrate which is about 40% clean gravel, boulder or bedrock, and at gradients of 0.8-4.8 m/km and depth at least 1.2 m (Wallace et al. 1992).

Table 1-2. Percent contribution by fish species to annual production in three sections of Guys Run, VA.

Species	Stream Section		
	Upper	Middle	Lower
Brook trout	60	61	14
Mottled sculpin	29	18	27
Blacknose dace	10	9	9
Torrent sucker	1	5	4
Bluehead chub	<1	5	37
Fantail darter	<1	<1	
Longnose dace		1	4
Rosyside dace		<1	3
Mountain redbelly dace			<1
Rock bass			<1
Smallmouth bass			<1
Total fish production (g/m2/yr)	2.84	3.16	3.96
Total fish biomass	2.14	2.56	4.74

In the study of stream fish, four factors, in addition to stream chemistry, are related to patterns of distribution and abundance: temperature regime, gradient, stream order, and flow regime. Streams are divided into cold versus warm water; cold water streams have temperatures that rarely exceed 24-26 ºC for extended periods, and are characterized by trout and sculpin. Even at low temperatures, trout have relatively high metabolic rates, and are more active than most fish. They can thus use food resources more effectively than other fish at cold or cool temperatures (Moyle and Cech 2000).

Whereas temperature is of importance in determining broad distributional patterns, gradient (number of meters drop per km of stream) is often of greater importance locally. This is because gradient has great influence on water velocity, substrate size, number and size of pools, and oxygen content. High-gradient streams may have little slow water, with bottoms of bedrock, boulders and cobbles (Moyle and Cech 2000).

Stream order is a classification of streams based on branching patterns. In most river systems, first order streams are the highest, smallest, coldest, highest-gradient streams, with fewest species of fish. As stream order increases, species richness also increases, usually regarded as a consequence of increase in habitat diversity; turbidity, temperature, and stream size increase as well. As stream order increases, usually new species of fish are added at a higher rate than upstream fish are subtracted from the community (Moyle and Cech 2000).

The trophic structure (food web) of the fish community changes with stream order. In first order streams, the dominant fish (e.g. trout) usually feed on insects that drop into the water from the overhanging vegetation or on detritus. In higher order streams, predators of aquatic insects are added, then piscivores. However most stream fish are opportunistic feeders and may feed on a wide variety of foods (Moyle and Cech 2000).

There is a general pattern of increasing fish species richness and abundance from lower order to higher order streams, probably resulting from a greater variety of habitat types (including spawning and nursery areas) and food sources in higher-order reaches. Perhaps because of the greater possibility of isolation, low-order streams are likely to host species unique to each drainage (Adams and Hackney 1992).

Streams change continuously in physical and chemical characteristics from headwaters to river mouth. Changes include shift from primarily terrestrial (in the headwaters) to in-stream organic matter contributions and changes in nutrient and water retention times, water volume and velocity, oxygen content, substrate size, gradient, and temperature regime. These shifts play important roles in determining the biological communities in different stream and river sections. For example, localized differences in gradient have great effects on fish and invertebrate occurrences, and may result in markedly discontinuous distributions of individual species (Adams and Hackney 1992).

These factors that affect the distribution and abundance of aquatic biota are also important from an acidification standpoint because the effects of acidification interact with other habitat characteristics to determine the species and biological communities that will occur in a given stream reach. Suitable streamwater acid-base chemistry is a necessary, but not necessarily sufficient, prerequisite for supporting brook trout, or any other species or biological community.

1.4 Recent Studies

There are a number of locations within the SAMI domain where watersheds have been the subject of intensive hydrogeochemical study. These include:

Fernow Experimental Forest - West Virginia (c.f., Adams et al. 1997, Peterjohn et al. 1996)

Shenandoah National Park - Virginia (c.f., Ryan et al. 1989, Cosby et al. 1991)

Great Smoky Mountains National Park - North Carolina and Tennessee (c.f., Johnson and Lindberg 1991, Nodvin et al. 1995, Flum et al. 1997)

Coweeta Hydrologic Laboratory - North Carolina (c.f., Swank and Vose 1997)

Oak Ridge Reservation - Tennessee (c.f., Mulholland 1992)

Each of these locations includes multiple study watersheds, some with rather lengthy periods of record for streamwater chemistry, extending back to the early 1970s (Fernow and Coweeta) to early 1990s (Walker Branch at Oak Ridge Reservation). Some watersheds have been the subject of experimental watershed acidification and nutrient cycling experiments.

As part of the National Acid Precipitation Assessment Program (NAPAP), the U.S. EPA conducted the National Stream Survey (NSS), which sampled streams throughout most of the SAMI domain, except for the western part of the Appalachian Plateau. The NSS was conducted during spring baseflow in 1985 and 1986 and represents chronic, rather than episodic, chemistry. Because the NSS used a statistical (probability) design, it provides the best available picture of the regional status and extent of chronic acid-base chemistry in the region (Baker et al. 1990).

The NSS sampled streams represented on 1:250,000-scale USGS topographic maps and having watersheds smaller than 155 km^2. Stream segments were selected for sampling using a randomized systematic approach, and were sampled at both the upstream and downstream ends (nodes) of each segment (Kaufmann et al. 1991).

In 1993 and 1994, the U.S. EPA, through the Environmental Monitoring and Assessment Project (EMAP), sampled approximately 400 streams across the Mid-Atlantic Highlands, which includes the northern portion of the SAMI domain (western VA and WV) and also portions of MD, PA, and NY. A statistical selection process was adopted in order to allow for unbiased population estimates of stream chemistry, habitat characteristics, and biology.

The Virginia Trout Stream Sensitivity Study (VTSSS) conducted a synoptic survey of streamwater chemistry for 344 (~80%) of the native brook trout streams in western Virginia.

Subsequently, a geographically-distributed subset of the surveyed streams were selected for long-term monitoring and research (Webb et al. 1994). About half of the streams included in the VTSSS had ANC < 50 μeq/L, suggesting widespread sensitivity to acidic deposition impacts. In contrast, the ANC distribution obtained by the NSS (Kaufmann et al. 1988) for western Virginia suggested that only about 15% of the streams in the NSS target population had ANC < 50 μeq/L. Webb et al. (1994) attributed these chemical differences to the smaller watershed size, more mountainous topography, and generally more inert bedrock of the VTSSS watersheds. Thus, the VTSSS focused on a subset of watersheds that were somewhat more acid-sensitive than the population of watersheds represented by the NSS.

Webb et al. (1994) devised a watershed classification scheme for western Virginia based on ecoregion maps, geologic maps, and streamwater chemistry data. Watershed response classes were designated, in decreasing order of acid-sensitivity, as siliclastic, minor carbonate, granitic, basaltic, and carbonate classes. Median streamwater ANC in the siliclastic class was only 3 to 4 μeq/L in the Blue Ridge Mountains and Allegheny Ridges subregions. The minor carbonate and granitic classes were somewhat less acid-sensitive, with median ANC values of 20 and 61 μeq/L, respectively.

Streamwater chemistry within the SAMI region varies seasonally. Results of chemical analyses of water samples collected between October 1987 and April, 1993 in VTSSS headwater streams (n=78) showed that ANC values tend to be lower by about 10 μeq/L (in acidic and near-acidic streams) to 40 μeq/L (in intermediate ANC streams) during winter and spring than they are during summer and fall.

Studies at a few stream sites in the mid-Appalachian Mountains have documented toxic stream water chemistry conditions during hydrological episodes, fish kills, and loss of fish populations, as a result of increased acidity. An estimated 18% of potential brook trout streams in the mid-Appalachian Mountains are too acidic for brook trout survival (Herlihy et al. 1996).

An effort to assess the effects of acid-base chemistry on fish communities in upland streams of Virginia was initiated in 1992 (Bulger et al. 1995). The study streams experienced both chronic and episodic acidification. A number of differences in fish communities were apparent between the low and high-ANC streams in this study. These included differences in such factors as age, size, and condition of individual fish, survival, number of fish species, and population size. Young brook trout exposed to chronic and episodic acidity experienced increased mortality

(MacAvoy and Bulger 1995); the condition of blacknose dace was poor in the low-ANC streams compared to the high ANC streams (Dennis and Bulger 1995).

Recent analyses (Bulger et al. 1998, 2000) divided VA's streams into four categories of acid-base status, to compare the number of streams currently in each category, versus estimated numbers in pre-industrial times and in the future.

- Chronically Acidic: ANC values less than or equal to 0 µeq/L indicate streams that are no longer able to neutralize acidity and cannot host populations of brook trout or any other fish species.

- Episodically Acidic: Streams with an ANC between 0 and 20 µeq/L experience regular episodic acidification at levels harmful to brook trout and other aquatic species and host, at best, reduced fish communities.

- Indeterminate: Streams whose ANC values fall between 20 and 50 µeq/L are extremely sensitive to further acidification; they may or may not host brook trout populations, depending on the frequency and magnitude of acid events and other habitat characteristics. They certainly host fewer fish species than streams with higher ANC values.

- Not Acidic: Streams with ANC greater than 50 µeq/L, a level which is unlikely to immediately threaten the survival of brook trout populations (although levels as low as 50 µeq/L are too acidic for many other fish species).

Streams in the SAMI domain are affected by a host of environmental factors, including but not limited to acidic deposition. Meteorology, geology, land use, and forest health can also have important influence on streamwater chemistry. Water chemistry data collected as part of the VTSSS between 1987 and 1993, and presented by Webb et al. (1994), provide an excellent example of complex interactions between terrestrial biota and drainage water chemistry. Since its introduction to North America during the last century, the gypsy moth has expanded its range to include most of the northeastern United States. Since about 1984, the area of forest defoliation by the gypsy moth has expanded southward about 30 km/yr along the mountain ridges of western Virginia. Infestation and accompanying forest defoliation occurs at a given site over a period of several years.

Webb et al. (1994) compared quarterly pre- and post-defoliation streamwater chemistry for 23 VTSSS watersheds. Nitrate concentrations increased dramatically with defoliation in most of the streams, typically to 10 to 20 µeq/L or higher. The most probable source of the increased streamwater nitrate concentration was the nitrogen content of the forest foliage consumed by the gypsy moth larvae (Webb et al. 1994). Additional observed changes in streamwater chemistry included decreased sulfate concentrations and ANC, which were also hypothesized to be attributable to the gypsy moth defoliation. Increased nitrification in response to the increased soil nitrogen pool may have caused soil acidification, which in turn would be expected to increase sulfur adsorption in soils (c.f., Johnson and Cole 1980). In addition, declines in sulfur deposition during the comparison period may have played a role in the observed sulfate response.

Streamwater chemistry in two headwater catchments in Shenandoah National Park (White Oak Run and Deep Run) showed trends of increasing sulfate concentrations in the 1980s (Ryan et al. 1989). In the 1990s, however, the sulfate concentrations were altered as a consequence of gypsy moth defoliation. These changes induced by insect damage masked any continued change in sulfate concentration that may have been occurring in response to changes in atmospheric inputs of sulfur and progressive decline in the sulfur adsorption of watershed soils (Webb et al. 1995).

Eshleman et al. (1998) examined nitrate fluxes from five small (< 15 km^2) forested watersheds in the Chesapeake Bay Basin during the period 1988 to 1995. Four of the watersheds were located in Shenandoah National Park, within the Blue Ridge Province, and the fifth in Savage River State Forest in western Maryland, within the Appalachian Plateau Province. The five watersheds varied in geology and acid sensitivity, with baseflow ANC typically in the range of 0 to 10 μeq/L in Paine Run to the range of 150 to 350 μeq/L in Piney River. Forest vegetation was also variable. The composition of oak species (*Quercus* spp.), which are a preferred food source of gypsy moth larvae, ranged from 100% in Paine Run to about 60% in three of the other watersheds. Nitrate concentrations increased markedly in at least three of the watersheds during the late 1980s to early 1990s, with peak annual average nitrate concentrations of about 30 to 55 μeq/L. The increased leakage of nitrate occurred contemporaneously with a period of intense defoliation by the gypsy moth larva. Nitrate leaching was shown to occur primarily during storm flow conditions.

2.0 OBJECTIVES

The primary objective of this assessment is to build on the SAMI Phase I Assessment results in order to provide a model-based qualitative and quantitative evaluation of the effects of atmospheric sulfur and nitrogen deposition on aquatic resources in the southern Appalachian Mountains. There are a number of components of this assessment, and therefore a number of secondary objectives. The area of interest has been restricted to the boundary of the SAMI domain. Particular emphasis was placed on characterizing the responses of aquatic resources in ten Class I areas that occur within the SAMI domain:

- Great Smoky Mountains National Park - Tennessee-North Carolina border
- Shenandoah National Park -Virginia
- Sipsey Wilderness Area - US Forest Service, northwestern Alabama
- Cohutta Wilderness Area - US Forest Service, northern Georgia
- Shining Rock Wilderness Area - US Forest Service, western North Carolina
- Joyce Kilmer - Slickrock Wilderness Area - US Forest Service, western North Carolina
- Linville Gorge Wilderness Area - US Forest Service, western North Carolina
- James River Face Wilderness Area - US Forest Service, Virginia
- Dolly Sods Wilderness Area - US Forest Service, West Virginia
- Otter Creek Wilderness Area - US Forest Service, West Virginia

The aquatic component of the assessment was conducted with the MAGIC model. The principal objectives of the aquatic assessment were to:

1. provide estimates of future changes in streamwater chemistry of potentially acid-sensitive streams in the SAMI region, including population-based estimates, in response to multiple sulfur and nitrogen Emissions Control Strategies provided by SAMI;

2. provide quantitative estimates of future changes in streamwater chemistry of potentially acid-sensitive streams within the Class I areas in the SAMI domain for which there are adequate model-input data; provide these estimates of change in response to multiple sulfur and nitrogen Emissions Control Strategies provided by SAMI;

3. evaluate the relationships between the sensitivity of streams to future changes in acid-base chemistry and features of the landscape that can be expressed regionally with existing data throughout the SAMI domain; to the extent possible, classify the aquatic resources within the SAMI domain in terms of their sensitivity to change in acid-base chemistry and map the results of this classification.

Thus, this assessment for aquatic systems contains a regional component for the entire SAMI domain (objectives 1 and 3) and a component specific to the Class I areas that occur within the SAMI region (objective 2).

3.0 METHODS

3.1 Assessment Design

There were essentially three primary components to the Phase II SAMI assessment: 1) a regional aquatic assessment for the SAMI domain, 2) a preliminary aquatic assessment for each of the Class I areas in the SAMI domain that contain acid-sensitive aquatic resources, and 3) a site-specific forest assessment. The latter is reported by Munson et al. (in review).

The two models (NuCM, which was used in the terrestrial assessment, and MAGIC) require many of the same data for implementation (soil chemistry, catchment characteristics, hydrology, deposition, etc.). However, the two models operate at different scales of spatial and temporal aggregation. One advantage of implementing both models under a common program is that we have been able to ensure that the common data used in the two modeling approaches (for simulating effects of both aquatic and terrestrial resources) are compatible with each other and where possible derive from the same sources.

There were multiple tasks involved in the Aquatics Assessment, ranging from selection of modeling sites to assessment of the projected impacts of future acidic deposition on fish (Table 3-1). Aquatic resources were classified for regional modeling according to their potential sensitivity to acidic deposition using ANC and physiographic province as the primary indicator variables. Four ANC sensitivity classes were employed. These classes are similar to previous classification schemes used in assessment of aquatic resources (e.g., VTSSS, NAPAP) for science, policy and decision making. The classes also are biologically relevant in that they

Table 3-1. Major components of the aquatic assessment.
1. Select and model watersheds throughout the region
2. Select and model additional Class I sites
3. Consider three strategies of emissions controls and a constant 1995 deposition scenario
4. Extrapolate regional results (link to NSS) to the population of streams within the SAMI region.
5. Express Class I results on "found site" basis
6. Evaluate relationships between modeled response/sensitivity and landscape features that are regionally known
7. Data permitting, map regions of greatest sensitivity/response
8. Assess impacts on brook trout

provide a mechanistic link between water quality and the status of a number of important fish species, allowing us to extrapolate water quality projections to biological effects. The four ANC classes selected for stratification of aquatic resources were: ≤ 0 µeq/L, > 0 to ≤ 20 µeq/L, > 20 to ≤ 50 µeq/L; and > 50 to ≤ 150 µeq/L (Table 3-2). Streams that have ANC > 150 µeq/L are not considered sensitive to adverse impacts of acidification.

Table 3-2. ANC ranges defined for acidification modeling.

ANC ≤ 0 µeq/L	acidic
ANC > 0 to ≤ 20 µeq/L	highly sensitive to chronic and episodic acidification
ANC > 20 to ≤ 50 µeq/L	potentially sensitive to chronic and episodic acidification
ANC > 50 to ≤ 150 µeq/L	may be sensitive to episodic acidification to low ANC values under possible future deposition levels.

There are three physiographic provinces within the SAMI domain that contain acid-sensitive stream resources and have been included in synoptic surveys of streamwater chemistry. The provinces are Blue Ridge, Ridge and Valley, and Appalachian Plateau. A portion of the SAMI domain also occurs within the Piedmont province, which, based on NSS data, does not have streams with ANC less than 50 µeq/L.

Databases were acquired for use in this assessment from a variety of sources. Water quality data were derived from a number of national and regional databases and many more localized studies. These included the NSS, EMAP, VTSSS, and a variety of studies coordinated by the National Park Service, U.S. Forest Service, Tennessee Valley Authority, and U.S. Geological Survey. Soils data were largely derived from the Direct Delayed Response Project (DDRP) database, intensive watershed studies at Coweeta and Fernow experimental forests, and soil studies conducted within several of the national parks and national forests located within the SAMI domain.

Data of a variety of types and from a variety of sources were utilized within the resource classification and model calibration/simulation components of the study. Resource classification was based on such factors as water chemistry, vegetation type, soil physical and chemical characteristics, land use, topography and bedrock geology. The resource classification resulted in the designation of discretely defined landscape units with similar ecological or response characteristics. Landscape units, defined in different ways, provided the framework for model calibration/simulation and were used for the regional extrapolation of modeling results. Landscape units based on physiographic province and streamwater ANC also provided the structure for the assembly, collation, integration and management of the diverse data needed for the project.

Regional aquatic modeling was conducted for 40 to 50 sites within each of the three physiographic provinces, stratified by ANC class. A total of 12 modeling bins was therefore selected, based on three physiographic provinces and four ANC classes within each (Table 3-3).

Table 3-3. Numbering of modeling bins for the SAMI regional modeling effort.

	Physiographic Province		
ANC Class (µeq/L)[1]	Blue Ridge	Ridge and Valley	Appalachian Plateau
≤ 0	1	5	9
> 0 to ≤ 20	2	6	10
> 20 to ≤ 50	3	7	11
> 50 to 150	4	8	12

[1] ANC is calculated as sum of base cations minus sum of mineral acid anions

3.2 Data Compilation

Candidate sites for MAGIC modeling were identified throughout the SAMI region. Most had been sampled in conjunction with various synoptic surveys of stream chemistry. Sites were classified into physiographic province based on Fenneman (1938). A discrepancy was noted, however, regarding location of the Fenneman boundary between the Blue Ridge and Ridge and Valley physiographic provinces in the vicinity of Shenandoah National Park. Several sites in the eastern portion of the park were erroneously classified as being in the Ridge and Valley province, when they should have been included within the Blue Ridge. This error was apparently associated with changing scale from the coarse national scale of the original Fenneman boundary delineation to the finer scale of the SAMI assessment. The problem was rectified by manually moving the province boundary to correspond with local knowledge in the vicinity of the park.

Two stream chemistry databases were assembled for this project. The first was a compilation of data from all available stream sampling sites located in and around the SAMI domain. The only prerequisite for including sites was the availability of measured ANC. There were 999 sites included in this database (Figure 3-1). It was used to evaluate landscape classification and relationships between acidification sensitivity, as reflected by ANC, and spatially available data layers that might correlate with acidification sensitivity, including geology, vegetation type, soils type, ecoregion, watershed area, and landscape topography and position. The watershed boundaries for each of these sites were obtained digitally or in hard copy format, or were manually digitized or determined electronically from available Digital Elevation Models (DEMs). Candidate sites were grouped into three tiers to reflect different levels of data availability. Tier I sites were those for which soils data were available from a soil pit within the watershed (although other soils data from outside the watershed may have also been used [c.f., EPA's DDRP study]). Tier II sites were those for which soils data were not available from the watershed, but were available from a nearby watershed on the same geology. Tier III sites were those for which no soils data were available; for these sites an objective routine was developed for borrowing soils data from a watershed having generally similar characteristics. The error associated with the use of surrogate soils data for Tier II and III watersheds was quantified. Water quality data for at least one sample occasion during the 1980s or 1990s was required for all candidate sites.

The second dataset constructed for this project included those sites selected as candidate MAGIC modeling sites. The watershed data required for acidification modeling and regional characterization were obtained from a number of national and regional databases, including the NSS, DDRP, VTSSS, EMAP, and a number of localized studies coordinated by the National Park Service, the USDA Forest Service, the USDA Natural Resources Conservation Service, and the Tennessee Valley Authority. In several cases where data were unavailable for important areas, data were collected explicitly for the SAMI effort.

The objective of the data assembly effort was to acquire streamwater and soil composition data for watersheds in Class 1 areas and other forested watersheds in the SAMI region. The minimum required streamwater and soil composition data included the following measurements:

- stream water composition: pH, ANC, Ca^{2+}, Mg^{2+}, K^+, Na^+, SO_4^{2-}, NO_3^-, and Cl^-
- soil properties: thickness and total cation exchange capacity, exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+), and pH

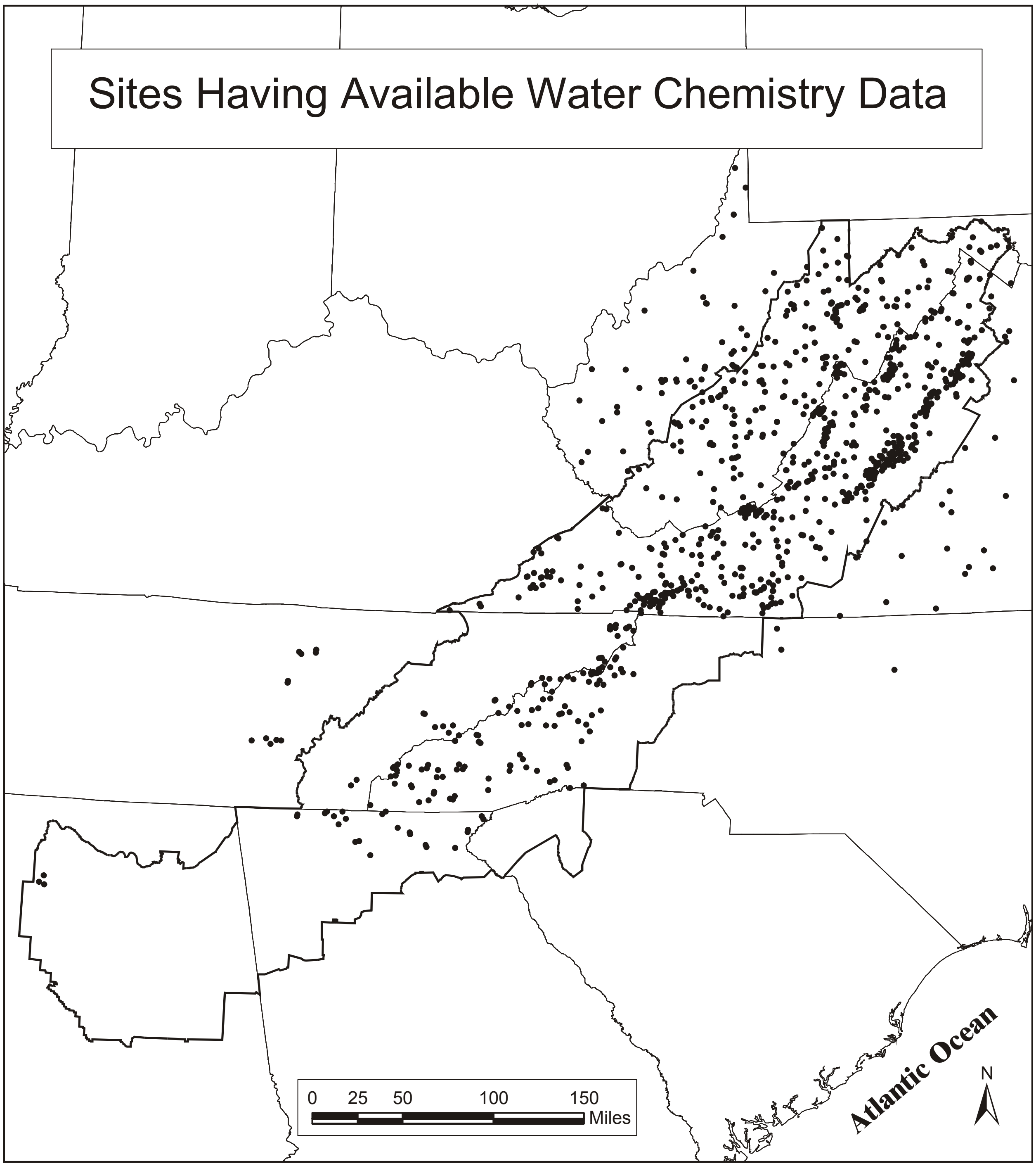


Figure 3-1. Water chemistry sampling sites used for evaluation of landscape classification.

Streamwater composition data for at least one sample occasion during the 1980s or 1990s was required for all candidate sites for either MAGIC application or regional characterization. In cases where multiple streamwater composition records were available for individual sites, the record nearest in time to the spring of 1995 was selected. For MAGIC application in cases where data from multiple soil sites were available for an individual watershed, the data were aggregated on an area-weighted basis to reflect the distribution of mapped soil types within the watershed.

3.3 Site Selection

3.3.1 Regional Stream Sites

Sites were selected for modeling on the basis of multiple criteria. Of particular importance in this regard was the availability of model input data. Appendix B describes data acquisition activities. Potential sites were identified from four primary sources: NSS (including stream sites modeled in the DDRP), EMAP, VTSSS, and a database of miscellaneous sites (Table 3-4). Site locations for the three primary stream surveys are shown in Figure 3-2. The latter source consisted of potential sites identified by members of our project team as a result of contacting researchers and federal agency personnel who work in the SAMI region. The list of potential sites was then screened to remove from consideration sites for which the water chemistry data were not internally consistent or for which available data suggested the possibility of significant influence from road salt, geological sulfur, or land use/insect defoliation.

Table 3-4. Source of water chemistry data for the 130 regional modeling sites.

Data Source	Number of Modeled Streams Included
NSS	43
EMAP	15
VTSSS	31
Other Studies	41

Candidate sites for regional modeling were screened for data quality on the basis of database internal consistency. Sites were deleted from consideration if the available data suggested an error in one or more measurements, as reflected in large deviation between calculated (using the charge balance) and titrated ANC. In addition, sites that exhibited characteristics indicative of road salt contamination, significant land use or insect impacts, or geological sulfur were deleted. A few sites were also deleted for which the calculated and

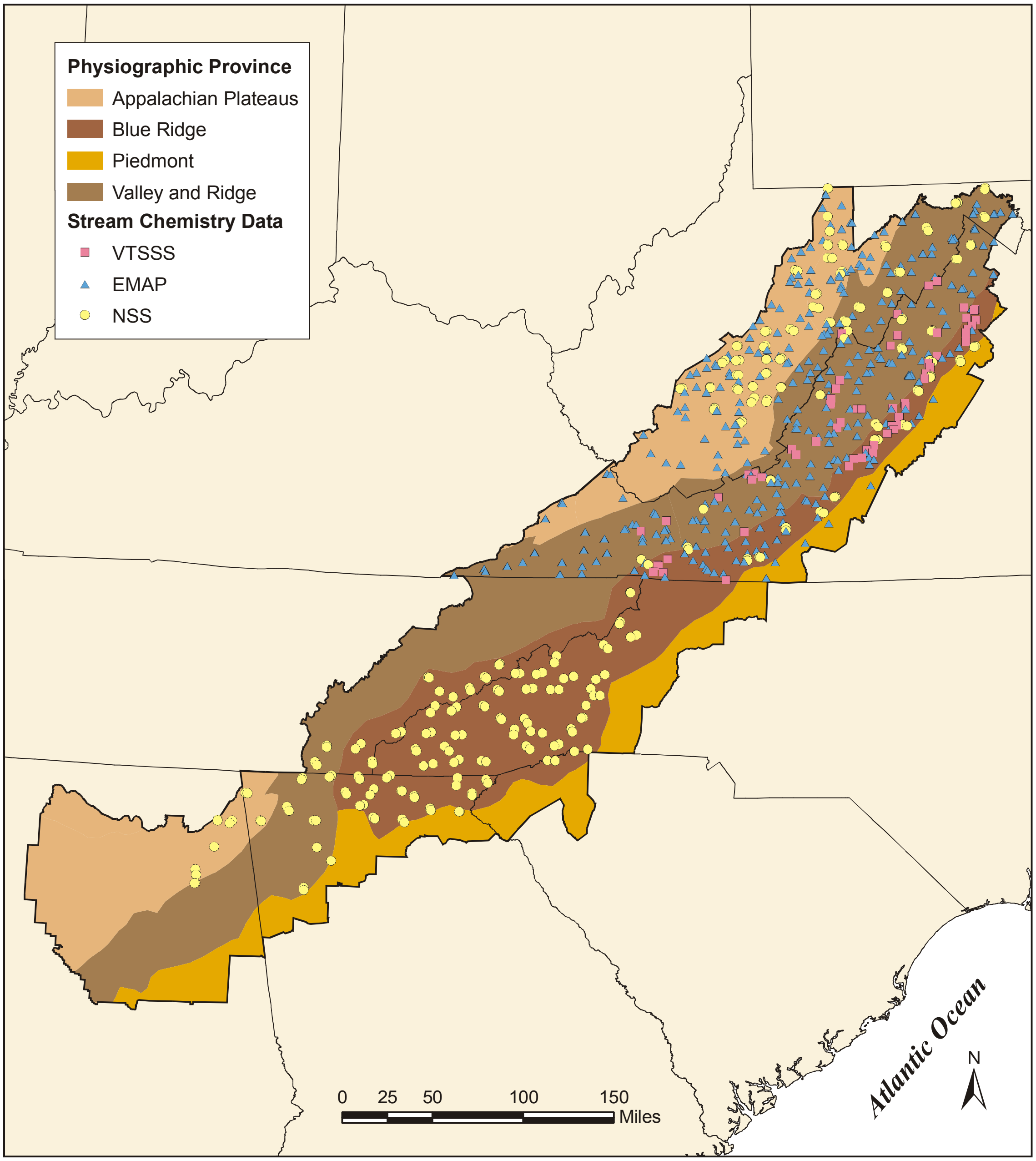


Figure 3-2. Location of NSS, EMAP, and VTSSS sites within the SAMI domain.

titrated ANC differed by a moderate amount (7 to 20 μeq/L), but where that difference would cause them to be classified into two different ANC classes (different modeling bins) and there were other good candidate modeling sites for that bin. The sites that were deleted and the justifications for deletion are listed in Appendix C.

The major factors controlling stream ANC and future changes in ANC are soils characteristics, bedrock geology, base cation availability, hydrology, nitrogen retention, and soil sulfate adsorption capacity. These factors can be segregated to some extent using streamwater ANC and physiographic province as the primary classification variables. Thus, we adopted a landscape design with four classes defined by stream ANC to reflect soils, geology, hydrology, and base cation availability (Tables 3-2, 3-3) and three physiographic classes related to geology and sulfate adsorption (Blue Ridge, Ridge & Valley, and Appalachian Plateau). Herlihy et al. (1993) found that the degree of sulfate adsorption was strongly related to physiographic province in the NSS. Streams in the Blue Ridge retained the most sulfate, whereas those in the Appalachian Plateau had the least sulfate retention and were often near steady-state with respect to sulfur deposition.

Watershed selection for MAGIC modeling followed a structured approach that was based on the following criteria:

- aquatic sensitivity class - a target was established of 30 watersheds to be selected for modeling from each of the ANC sensitivity classes (≤ 0 μeq/L, > 0 to ≤ 20 μeq/L, > 20 to ≤50 μeq/L, and > 50 to 150 μeq/L). Within each ANC class, the selected watersheds were divided approximately equally among the three acid-sensitive physiographic provinces that occur within the SAMI domain: Blue Ridge, Valley and Ridge, and Appalachian Plateau. Thus, there are 12 modeling bins, stratified by 4 ANC classes and 3 physiographic provinces. Approximately ten or more watersheds were modeled within each of the modeling bins, data permitting.

- available data - high priority was placed on selection of watersheds for which MAGIC input data for watershed soils were available from the watershed or from a nearby watershed that occurred on similar geology. Where some, but not all, input data were available, missing data were generated using a surrogate approach.

- watershed location - high priority was placed on selection of watersheds that were well distributed geographically within the SAMI region, and within the Class I areas.

- ANC distribution - within a given ANC class, an attempt was made to select streams that had ANC values that spanned the range of ANC for that class.

- site diversity - an effort was made to select sites that exhibited a range of values for sulfate concentration, nitrate concentration, and site elevation.

After completion of the data screening, the final list of sites for inclusion in the modeling effort was developed from the remaining candidates on the basis of data availability plus several additional considerations. All Tier I sites were modeled. All sites located in Class I areas were modeled, although all of these were not necessarily used in the regional analysis; some were used only for the specific Class I area assessment(s). Tier II sites were chosen preferentially over Tier III sites. Both nodes (upper and lower) of an NSS stream were only selected for modeling if the two nodes fell into two different ANC classes. For each of the 12 modeling bins, a total of 11 or more watersheds were targeted for regional modeling, assuming that at least 10 of those would be successfully calibrated. However, in a few cases, fewer than 10 potential candidates were available. More than 11 watersheds were selected for a given bin when: 1) more than 11 Tier I sites occurred in that bin, and/or 2) additional (non-Tier I) sites were needed to achieve a reasonable distribution within the bin across geographical area, streamwater ANC, sulfate and nitrate concentrations, and elevation. One site was deleted after calibration because it contained high sulfate concentration (396 μeq/L) and large amounts of internal watershed weathering of sulfur and chloride were required to calibrate MAGIC to that site.

After selecting all of the Tier I sites in a modeling bin, we examined the distribution of several key variables across the remaining candidate sites (Tiers II and III) in relation to those same distributions across Tier I sites (all of which were selected for modeling). Additional sites were then selected from among the Tier II and Tier III candidates in order to maximize within-bin diversity in terms of the key parameters. Those parameters were, in descending order of importance: geographic location along the longitudinal axis of the SAMI domain (which runs approximately from the southwest to the northeast), calculated ANC, sulfate concentration, nitrate concentration, and elevation. For each bin, candidate sites were selected that maximized within-bin distribution across the range of geographic location and ANC. Where there were options in terms of which sites could be selected that would maximize the location and ANC distributions, the effort was made to also maximize the distributions across sulfate and nitrate concentrations and elevation. Wherever possible, Tier II sites were selected preferentially over Tier III sites. In general, the site selection was very successful in maximizing within-bin diversity across the distributions of the identified key parameters (Appendix D). This is important in view of the regional nature of this assessment. In particular, we wanted to be sure that the process of site selection did not inadvertently result in greater within-bin homogeneity than was actually represented by the available water quality data.

The bins are labeled according to the appropriate province (BR, Blue Ridge; RV, Ridge and Valley; AP, Appalachian Plateau), followed by the calculated ANC class (≤ 0, 0-20, 20-50, or 50-150). The distributions of candidate sites across the 12 modeling bins are depicted in Figure 3-3. Two of the bins contained only a few candidate sites, and so all of those were selected for modeling. These were Bins BR ≤ 0 and RV ≤ 0, which represent acidic (ANC # 0) streams in the Blue Ridge and Ridge and Valley physiographic provinces, respectively. Only three sites were found for Bin BR ≤ 0, which was not surprising given that the NSS did not sample any acidic streams in the Blue Ridge province. We can therefore conclude that acidic streams, as represented by the NSS frame population, are rare in this province. Similarly, Bin RV≤0 included only six sites, only one of which was included in the NSS. Each of the remaining 10 bins contained a sufficient number of sites to allow selection of 7 or more streams for regional modeling. For two of these (Bins AP 0-20 and AP 20-50), the number of candidate sites was sufficiently small that all were selected for regional modeling. In order to obtain 10 sites for Bin AP 20-50, three NSS sites that were slightly outside the SAMI boundary but within the Appalachian Plateau physiographic province were included within Bin AP 20-50. Similarly, one site was selected for each of two other bins in the Appalachian Plateau (≤ 0 and 50-150) that were outside the SAMI boundary. This was done in order to obtain sites for these bins in the southern portion of the province.

The final site selection process resulted in the selection and successful calibration of 130 watersheds for MAGIC modeling within the regional assessment. The sites and selected primary attributes are listed in Appendix E. Site locations are depicted in Figures 3-4 and 3-5.

3.3.2 Special Interest Stream Sites

For the regional modeling described previously, an effort was made to not select too many watersheds for modeling that occurred in the same general area. This was done to avoid skewing the results too heavily to one portion of the region. A secondary objective of the aquatic assessment was, however, to evaluate acidification issues within each of the nine Class I areas (excluding Linville Gorge) within the SAMI domain that contain acid-sensitive aquatic resources. In order to satisfy this assessment objective, we wanted to model all Class I area

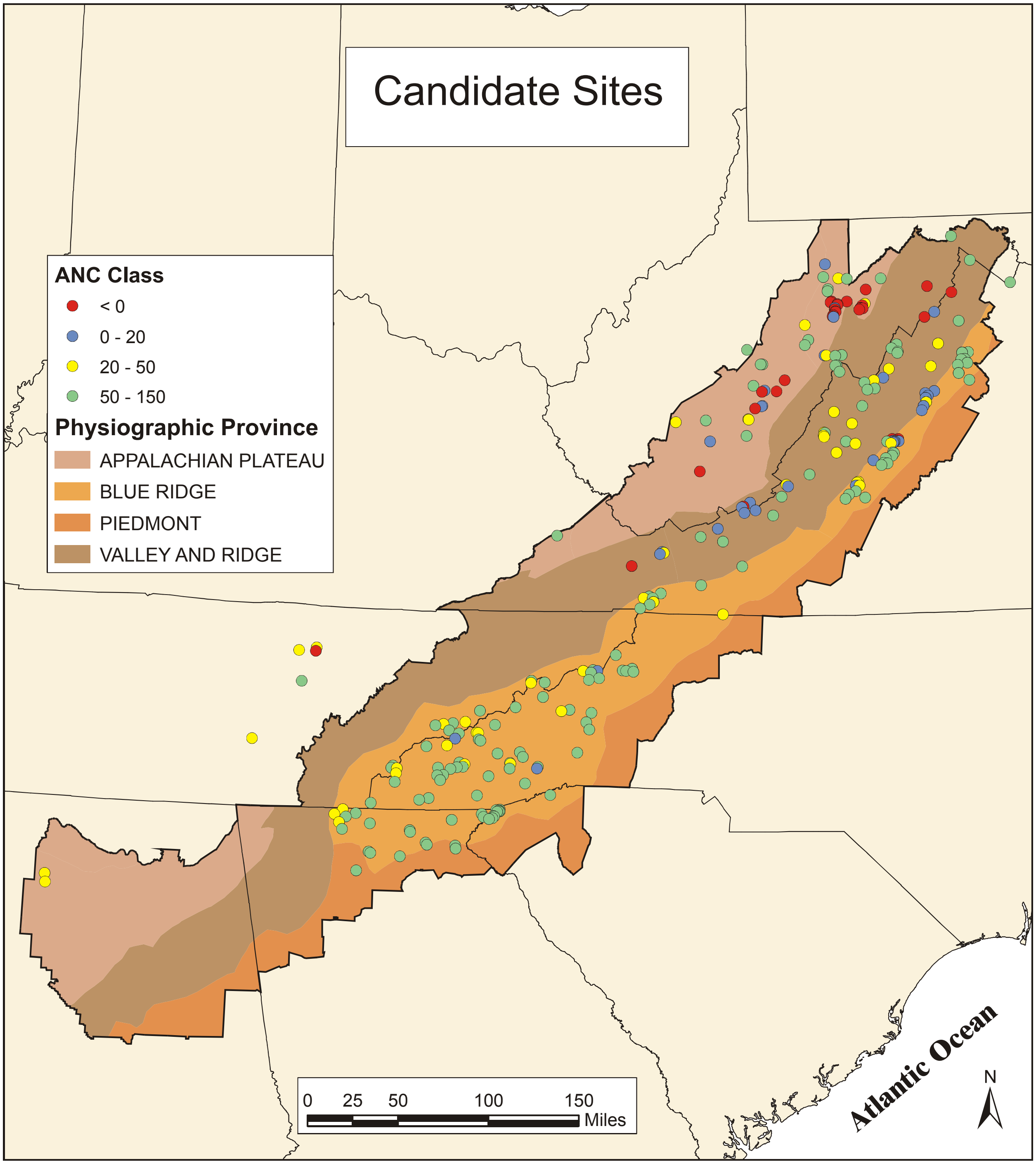


Figure 3-3. Candidate MAGIC modeling sites, after completion of the data quality screening. Only sites having ANC ≤ 150 μeq/L are included.

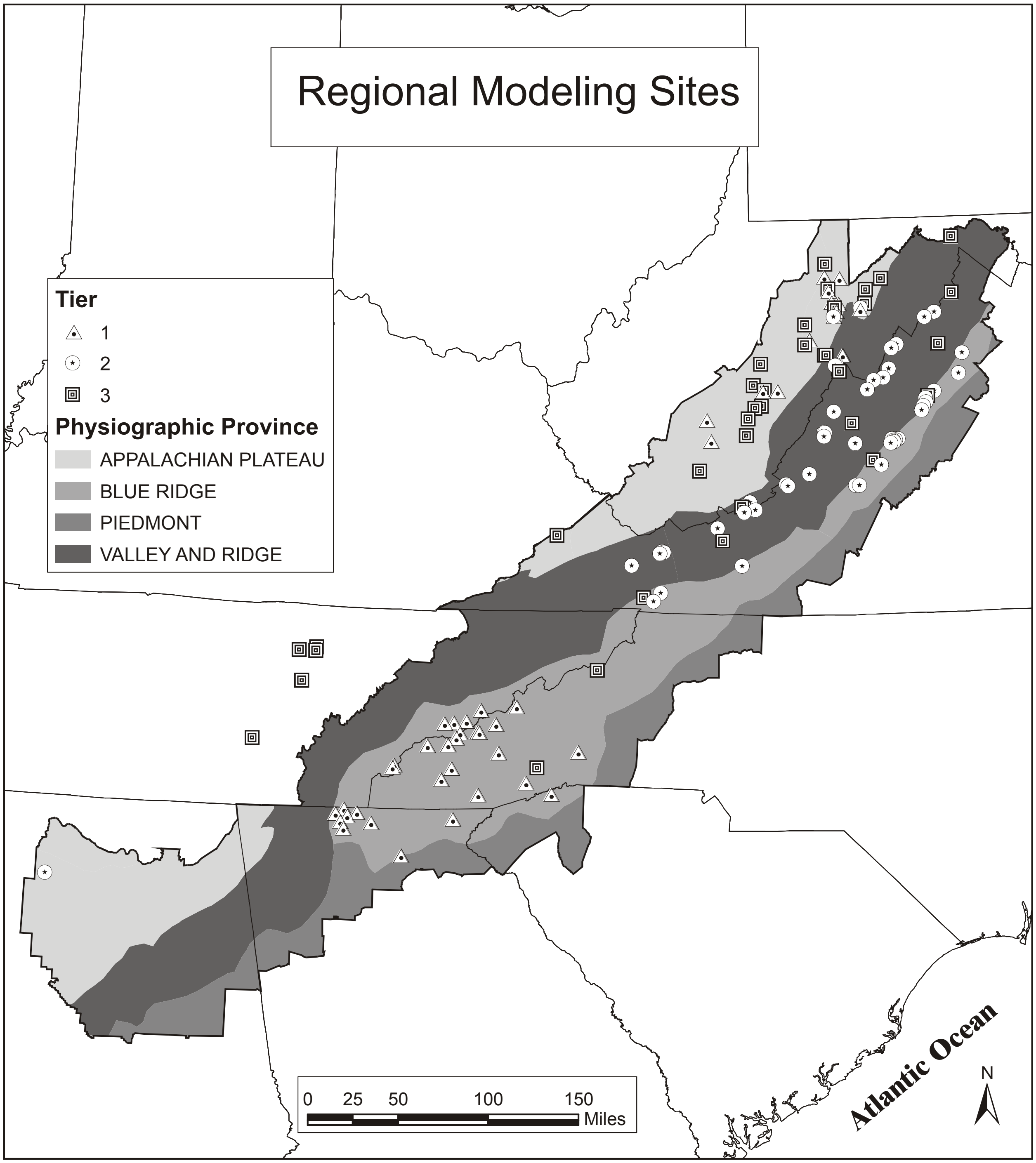


Figure 3-4. Selected regional MAGIC modeling sites, coded by tier to reflect the availability of soils data. Also shown are the boundaries of the physiographic provinces.

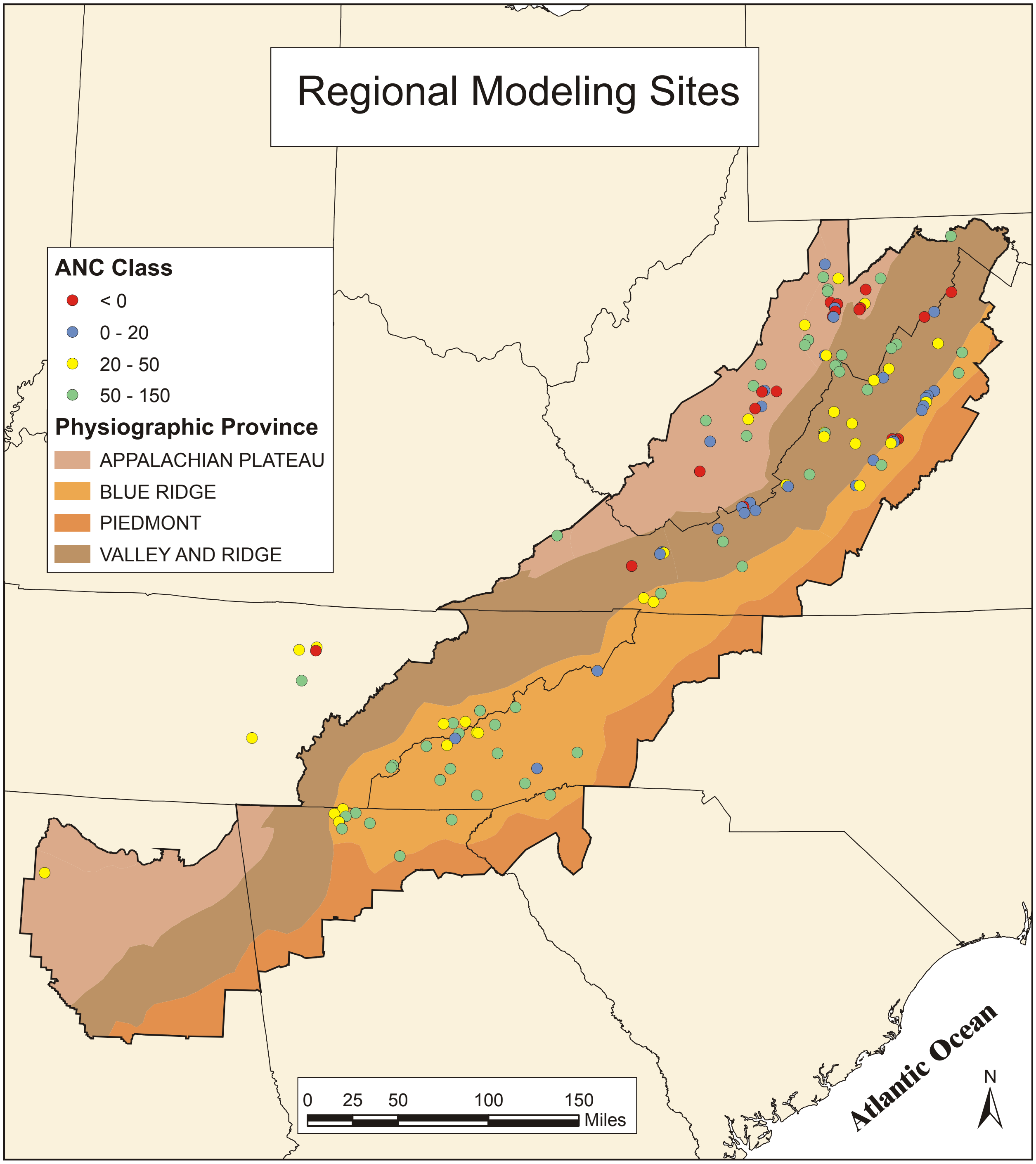


Figure 3-5. Selected regional MAGIC modeling sites, coded by ANC class. Also shown are the boundaries of the physiographic provinces.

treams for which adequate data had been compiled. Therefore, in addition to the MAGIC modeling that was conducted for the regional assessment, modeling was also conducted for any watershed that occurred within a Class I area that had not already been modeled for the regional assessment. The results of these analyses were used for the site-specific assessments that were conducted for each of the Class I areas.

Watersheds that were selected for modeling to contribute to the Class I assessments, but that had not been included within the regional modeling effort, were designated as Special Interest Watersheds. They totaled 34 watersheds, 7 of which were recalibrations of regional watersheds for QA purposes, and 27 of which were new modeling. They are listed in Appendix F. Also included as Special Interest were a limited number of watersheds that were deemed to be important because of their proximity to a Class I area or because they had been the subject of intensive research and/or extensive monitoring. Special interest watersheds were not subjected to the same rigorous screening procedures applied to candidate regional modeling sites. As a consequence, the group of special interest watersheds includes some watersheds that were deleted from consideration as regional candidates.

We extended the modeling results to the spatial base of the Class I areas to the extent possible with the available data. We modeled a suite of watersheds for which sufficient model input data were available within each of the Class I areas except Joyce Kilmer/Slickrock Wilderness Area and Linville Gorge. The modeled watersheds were not necessarily representative of all watersheds within the Class I areas, but rather represent "found" samples.

3.4 Resource Response Modeling

Watershed modeling was conducted using MAGIC and NuCM for projecting streamwater and forest/soil response, respectively. The assessment of aquatic effects is based on the MAGIC model output, and the assessment of terrestrial effects (Munson et al. in review) is based on the NuCM model output. MAGIC has been used extensively in regional assessments in North America and Europe and can be applied to a relatively large number of watersheds in a regional framework. NuCM can be used for regional assessment purposes, but has extensive input data requirements and requires considerable calibration effort. NuCM is therefore more commonly used for site-specific applications.

3.4.1 Application of MAGIC for Aquatic Assessment

MAGIC was successfully calibrated to 130 watersheds throughout the SAMI geographic domain for the regional assessment and an additional 34 Special Interest watersheds. The input data required for aquatic resource modeling with the MAGIC model (stream water, catchment, soils, and deposition data) were assembled and maintained in data bases (electronic spreadsheets) for each landscape unit. These input data bases were accessed by programs that generate the initial parameter files and optimization files for each site within the different modeling bins. The initial parameter files contain observed (or estimated) soils, deposition and catchment data for each site. The optimization files contain the observed soil and streamwater data that were the targets for the calibration at each site, and the ranges of uncertainty in each of the observed values. The spreadsheets and input files constitute the primary data used in the applications of MAGIC for each site, and they have been archived.

Missing MAGIC model input data were generated for Tier III sites using a surrogate approach, whereby a watershed that lacked one or more input parameters was paired with a watershed for which all input data were available. This pairing was accomplished by comparing watershed similarity on the basis of streamwater characteristics (ANC, sulfate, and base cation concentrations), physical characterization (location, elevation), and bedrock geology data. The missing data were then "borrowed" from the data-rich paired watershed judged to be most similar. The error associated with this surrogate data assignment step was quantified by applying the same approach to a suite of data-rich watersheds (i.e., borrowing data from a different data-rich watershed) and quantifying the average deviation between the projected streamwater ANC values obtained using measured data versus surrogate data.

3.4.2 Representation of Deposition and Meteorology Data for MAGIC

MAGIC requires, as atmospheric inputs for each SAMI site, estimates of the total annual deposition (eq/ha/yr) of eight ions, and the annual precipitation volume (m/yr). The eight ions are: Ca, Mg, Na, K, NH_4, SO_4, Cl, and NO_3. These total deposition data are required at each site for each year of the calibration period (the years for which observed streamwater data are used for calibrating the model to each site). Estimated total deposition data are also required for the 140 years preceding the calibration period as part of the calibration protocol for MAGIC, and for each year of any future scenario or strategy that will be run using MAGIC. This section discusses the procedures used for generating these required long-term sequences of total ionic deposition for each SAMI site.

Total deposition of an ion at a particular SAMI site for any year can be represented as combined wet, dry, and occult (cloud and fog) deposition:

$$\text{TotDep} = \text{WetDep} + \text{DryDep} + \text{OccDep}.$$

Inputs to the model are specified as wet deposition (the annual flux in meq/m^2/yr) and a dry and occult deposition factor (DDF, unitless) used to multiply the wet deposition in order to get total deposition:

$$\text{TotDep} = \text{WetDep} * \text{DDF},$$

where

$$\text{DDF} = 1 + \text{DryDep} / \text{WetDep} + \text{OccDep} / \text{WetDep}.$$

Thus, given an annual wet deposition flux (WetDep), the ratio of dry deposition to wet deposition (DryDep / WetDep), and the ratio of occult deposition to wet deposition (OccDep / WetDep) for a given year at a site, the total deposition for that site and year is uniquely determined.

In order to calibrate MAGIC and run future scenarios or strategies, time-series of the total deposition at each site are needed for each year of: a) the calibration period; b) the historical reconstructions; and c) the future scenarios or strategies. Such long-term observations do not exist and these sequences must be estimated. The procedure used to provide these input data was as follows. The absolute values of wet deposition and DDF (calculated from the DryDep/WetDep and OccDep/WetDep ratios) for each ion were averaged over the period 1991-1995. The averages at a site were used as Reference Year deposition values for the site (the Reference Year was designated as 1995). These absolute values for the Reference Year were derived from observed data as described below.

Given the Reference Year deposition values, the deposition data for historical and calibration periods can be calculated using the Reference Year absolute values and scaled time series of wet deposition and DDF that give the values for a given year as a fraction of the

Reference Year value. For instance, to calculate the total deposition of a particular ion in some historical year j:

TotDep(j) = [WetDep(0) * WetDepScale(j)] * [DDF(0) * DDF Scale(j)] ,

where WetDep(0) is the Reference Year wet deposition ($meq/m^2/yr$) of the ion, WetDepScale(j) is the scaled value of wet deposition in year j (expressed as a fraction of the wet deposition in the Reference Year), DDF(0) is the dry and occult deposition factor for the ion for the Reference Year, and DDFScale(j) is the scaled value of the dry and occult deposition factor in year j (expressed as a fraction of the DDF in the Reference Year). In constructing the the historical deposition data, the scaled sequences of wet deposition and DDF are derived from simulations using the ASTRAP model as described in Appendix N.

Given the same Reference Year deposition values, the deposition data for the future deposition scenarios and strategies can be calculated using the Reference Year absolute values and a scaled time series of changes in total deposition to give the total deposition values for a given future year as a fraction of the Reference Year value. For instance, to calculate the total deposition of a particular ion in some future year j:

TotDep(j) = [WetDep(0) * DDF(0)] * TotDep Scale(j) ,

where WetDep(0) is the Reference Year wet deposition ($meq/m^2/yr$) of the ion, DDF(0) is the dry and occult deposition factor for the ion for the Reference Year, and TotDepScale(j) is the scaled value of the total deposition factor in year j (expressed as a fraction of the total deposition in the Reference Year).

Therefore, four inputs are required for each of the eight deposition ions in MAGIC in order to set the total deposition for all years required in the calibrations and future simulations:

1) the absolute value of wet deposition at the site for the Reference Year ($meq/m^2/yr$);

2) the absolute value of DDF (calculated from DryDep/WetDep and OccDep/WetDep ratios) for the site for the Reference Year, (unitless);

3) time series of scaled values of wet deposition and scaled values of DDF covering all historical years necessary to calibrate the model (scaled to the Reference Year);

4) time series of scaled values of future total deposition covering all future years of interest to the SAMI strategy runs (scaled to the Reference Year).

The *absolute* value of wet deposition is highly time and space specific - varying geographically within the SAMI region, varying locally with elevation, and varying from year to year. It is desirable to have the estimates of wet deposition take into account the geographic location and elevation of the site as well as the year for which calibration data are available. Therefore estimates of wet deposition used for the SAMI Reference Year should be derived from a procedure (model) that has a high spatial resolution and considers elevation effects.

The *absolute* value of the DDF specifies the ratio between the absolute amounts of wet and total deposition. This ratio is less variable in time and space than is the estimate of total deposition. That is, if in a given year the wet deposition goes up, then the total deposition usually goes up also (and conversely); and if the elevation or aspect of a given site results in lower wet deposition, the total deposition will be lower also (and conversely). Estimates of DDF used for MAGIC calibrations may, therefore, be derived from a procedure (model) that has a lower spatial resolution and/or temporally smoothes the data.

Similarly, the *long-term sequences* used for MAGIC simulations do not require detailed spatial or temporal resolution. That is, if for any given year the deposition goes up at one site, it also goes up at neighboring sites. Thus, *scaled sequences* of deposition (normalized to the same year) at neighboring sites will be very similar, even if the absolute deposition at the sites is very different due to local aspect, elevation, etc. MAGIC requires scaled long-term sequences of wet deposition, DDF, and total deposition. Therefore, if the scaled long-term patterns of any of these do not vary much from place to place or year to year, estimates of the *scaled sequences* may be derived from a procedure (model) that has a relatively low spatial resolution and/or temporally smoothes the data.

With these thoughts in mind, we turn to a discussion of the sources of deposition data used for the calibration of MAGIC for the SAMI sites and the specification of deposition inputs to MAGIC for the future projections.

3.4.2.1 Wet Deposition Data (Reference Year and Calibration values).

The absolute values of wet deposition used for defining the SAMI Reference Year and for the MAGIC calibrations must be highly site specific. We used estimated wet deposition data for each site derived from the spatial extrapolation model of Grimm and Lynch (1997) referred to here as the Lynch model. The Lynch model is based on observed wet deposition at NADP monitoring stations, and provides a spatially interpolated value of wet deposition of each of the eight ions needed for MAGIC. The model also makes a correction for changes in precipitation volume (and thus wet deposition) based on the altitude at a given site. This correction arises from a model of orographic effects on precipitation volumes derived from regional climatological data.

The latitude, longitude, and elevation of the MAGIC modeling sites were provided as inputs to the Lynch model. The model outputs were quarterly and annual wet deposition estimates for each modeling site. The annual data were used for definition of the SAMI Reference Year and for MAGIC calibration and simulation. The NADP data (and thus the estimates provided by Lynch's model) cover the period 1983 to 1998. This period includes the SAMI reference period and the calibration periods for MAGIC sites. Details of the wet deposition data for the SAMI Reference Year are provided in Appendix L.

3.4.2.2 Dry and Occult Deposition Data and Historical Deposition Sequences

The ASTRAP model was used to provide estimates of wet, dry, and occult deposition of sulfur and oxidized nitrogen at 33 sites in and around the SAMI region (Shannon 1998). The ASTRAP sites included 21 existing NADP deposition monitoring stations, 7 sites in Class I areas, and 5 sites that were neither NADP nor Class I. A number of these sites were outside the boundaries of SAMI and at a much lower elevation than the sites being modeled by MAGIC. A subset of the ASTRAP sites was used to set deposition input ratios for MAGIC (see Appendix L). For each of the sites, ASTRAP produced wet, dry, and occult deposition estimates of sulfur and oxidized nitrogen every ten years starting in 1900 and ending in 1990. The model outputs are smoothed estimates of deposition roughly equivalent to a ten-year moving average centered on each of the output years.

Given the limited spatial and temporal resolution of the outputs from ASTRAP, these data were not sufficient for specification of the absolute wet deposition values needed for calibration of MAGIC. The outputs of ASTRAP were used, however, to estimate the absolute DDF for each site (using the DryDep/WetDep and OccDep/WetDep ratios from the ASTRAP output), and to set up the scaled sequences of past wet deposition and DDF for the calibration of each site.

The wet, dry, and occult deposition estimates provided by ASTRAP for each year (for both sulfur and oxidized nitrogen) at each ASTRAP site were used to calculate the DDF for each year and each site. This provided time series of DDF for sulfur and oxidized nitrogen for each ASTRAP site extending from 1900 to 1990. The value of DDF for 1990 was used as the absolute value of DDF for the SAMI Reference Year. MAGIC sites were assigned the DDF value of the nearest ASTRAP site, considering both distance and elevation. The time series of DDF values from 1900 to 1990 for each ASTRAP site was normalized to the 1990 value at each site to provide scaled sequences of DDF. The scaled sequence of past DDF used for each MAGIC site was taken from the nearest ASTRAP site. Details of the dry/wet, occ/wet, and DDF data for each ASTRAP site, the historical scaled sequences for DDF for each ASTRAP site, and the assigned values for each MAGIC site are provided in Appendix L.

At each of Shannon's sites, the time series of wet deposition were converted to scaled sequences by normalizing the values in any year to the value in 1990 at each site. The scaled sequence of past wet deposition used for each MAGIC site was taken from the nearest ASTRAP site. Details of the historical scaled sequences for wet deposition for each ASTRAP site, and the assigned values for each MAGIC site are provided in Appendix L.

3.4.2.3 Specification of Deposition for Future Projections

SAMI characterized atmospheric emissions of 12 emission precursors to ozone, acid deposition, and atmospheric aerosols, including SO_2, NO_x, and NH_3. These emissions were examined for five source sectors:

- utilities
- industry
- highway vehicles
- non-road engines, and
- area sources.

It was assumed for the reference strategy that current land use patterns and lifestyle behaviors would continue into the future. For the bold strategies, however, it was assumed that highway vehicle use would decline. Emissions projections for nitrogen and sulfur are shown in Figure 3-6 for the eight SAMI states (Odman et al. 2002a).

For a given scenario or strategy, the deposition in future years was specified as a fraction of the total deposition in the reference year 1995. For the scenario of continued constant deposition

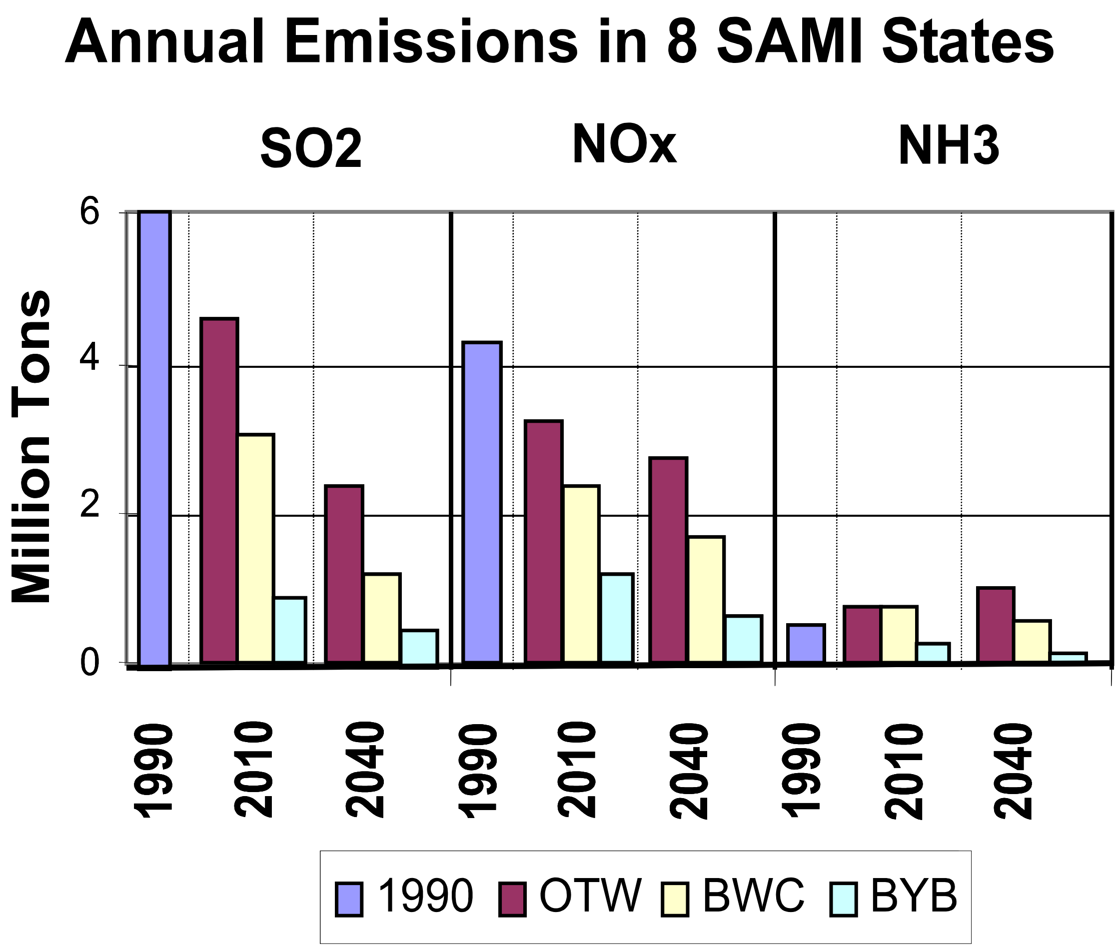


Figure 3-6. Annual emissions estimates for the eight SAMI states (Odman et al. 2002a)

at 1995 levels, a single future deposition sequence was used for all MAGIC sites. For the strategy runs, the deposition changes had a spatial component, and different sequences of future changes were used for different MAGIC sites. The relative changes specified for the strategies were provided by the SAMI atmospheric modeling contractor as changes in total deposition (Odman et al. 2002). In that the future deposition changes were specified only as changes in total deposition, these were implemented in MAGIC by assuming that wet, dry and occult deposition all change by the same relative amount. Details of the calculation of future deposition are given in Appendix G.

For each site, it was necessary to couple the past scaled sequences (used for the MAGIC calibration at the site) to the future scaled sequences (used for the scenario or strategy simulations). The past scaled sequences were tied to ASTRAP's past deposition estimates which end in 1990. The future scaled sequences were based on the SAMI Reference Year, 1995. For each MAGIC site, it was necessary to provide estimates of the changes in deposition that occurred between 1990 and 1995. These changes were derived from the site specific deposition data provided by the Lynch model.

3.4.3 Protocol for MAGIC Calibration and Simulation at Individual Sites

The aggregated nature of the MAGIC model requires that it be calibrated to observed data from a system before it could be used to examine potential system response. Calibration is achieved by setting the values of certain parameters within the model that can be directly measured or observed in the system of interest (called fixed parameters). The model is then run (using observed and/or assumed atmospheric and hydrologic inputs) and the outputs (streamwater and soil chemical variables - called criterion variables) are compared to observed values of these variables. If the observed and simulated values differ, the values of another set of parameters in the model (called optimized parameters) are adjusted to improve the fit. After a number of iterations, the simulated-minus-observed values of the criterion variables usually converge to zero (within some specified tolerance). The model is then considered calibrated. If new assumptions (or values) for any of the fixed variables or inputs to the model are subsequently adopted, the model must be re-calibrated by re-adjusting the optimized parameters until the simulated-minus-observed values of the criterion variables again fall within the specified tolerance. The model and its application methods for this assessment are further described in Appendix H.

3.4.3.1 Calibration Data

The calibration procedure requires that streamwater quality, soil chemical and physical characteristics, and atmospheric deposition data be available for each stream. The water quality data needed for calibration are the concentrations of the individual base cations (Ca, Mg, Na, and K) and acid anions (Cl, SO_4, and NO_3) and the stream pH. The soil data used in the model include soil depth and bulk density, soil pH, soil cation-exchange capacity, and exchangeable bases on the soil (Ca, Mg, Na, and K). The atmospheric deposition inputs to the model must be estimates of total deposition, not just wet deposition.

Streamwater quality data used for calibration were derived from a number of sampling programs in the SAMI region. Some data were from survey sites that were sampled only once, while some data were from monitoring sites with variable sampling frequency. In the case of survey data, the single observed value was used for model calibration. For monitoring data, the annual average values of the streamwater quality variables were calculated, using a volume weighting procedure if possible. If more than one year of monitoring data were available, up to three years were used to define the average water chemistry for calibration. Details of the water quality data used for calibration at each site are given in Appendix I.

Soil data for model calibration were derived as areally averaged values of soil parameters within a watershed. If soils data for a soil pit were vertically stratified, the soils data for the individual soil horizons at that sampling site were averaged based on horizon, depth, and bulk density to obtain single vertically aggregated values for the soil pit. If multiple pits were available for a site, the data were spatially averaged using a weighting scheme based on geologic patterns within the watershed (if possible). Details of the soils data used for calibration at each site are given in Appendix I.

Total atmospheric deposition consists of three components: wet deposition, the flux of ions occurring in precipitation; dry deposition, resulting from gaseous and particulate fluxes; and cloud/fog deposition which can be particularly important in mountainous areas. The methods used to derive estimates of these deposition inputs to the model were discussed in the previous section. The deposition values used for calibration are summarized in Appendices H and J.

3.4.3.2 Calibration and Simulation Procedures

The procedures for calibrating and applying MAGIC to an individual site involve a number of steps, use a number of programs, and produce several discrete outputs. Please refer to Figure 3-7 for this general discussion of the calibration and simulation protocols.

The input data required by the model (streamwater, watershed, soils, and deposition data) were assembled and maintained in data bases (electronic spreadsheets) for each landscape unit. When complete, these data bases were accessed by a program (MAGIC-IN) that generated the initial parameter files (xxx.PR) and optimization (xxx.OPT) files for each SAMI site. The initial parameter files contain observed (or estimated) soils, deposition, and watershed data for each site. The optimization files contain the observed soil and streamwater data that are the targets for the calibration at each site, and the ranges of uncertainty in each of the observed values.

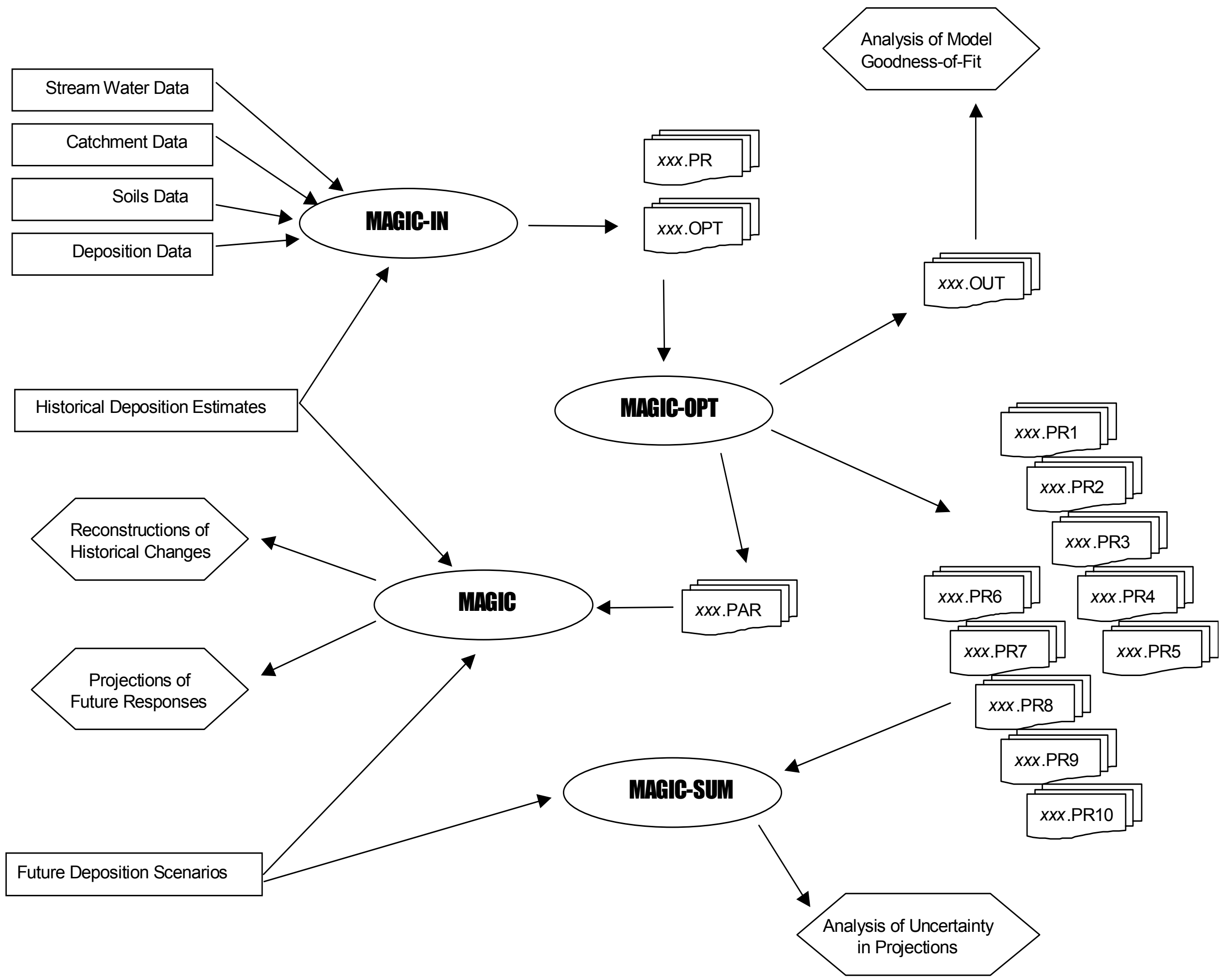


Figure 3-7. Flow chart for calibration and application of MAGIC in SAMI.

The initial parameter and optimization files for each site were sequentially passed to the optimization program (MAGIC-OPT). This program produced three outputs as each site was calibrated. The first (xxx.OUT) is an ASCII file of results that was passed to statistical routines for analysis and summary of model goodness-of-fit for the site. The second (xxx.PR1 ... xxx.PR10) was the multiple calibrated parameter set used in the fuzzy calibration procedure to assess model uncertainty (see below). The third (xxx.PAR) was the average parameter set for each site (average of the multiple calibration parameter sets) which represents the most likely responses of the site.

The multiple calibrated parameter set (xxx.PR1…xxx.pr10) for each site was used by the program MAGIC-RUN with estimates of historical or future deposition to produce two outputs: 1) reconstructions of historical change at the site; or 2) forecasts of most likely future responses for the applied future deposition scenario. Both of these outputs are in the form of electronic spreadsheets giving simulated values for all modeled variables for each year of each scenario at the site. The multiple calibrated parameter sets were also used with the same estimates of future deposition and the program MAGIC-RUN to produce an analysis of the uncertainty in model projections for that scenario. The results of the uncertainty analysis is in the form of an electronic spreadsheet giving simulated ranges (upper and lower values) for all modeled variables for each year of each scenario at the site.

The implementation of this protocol for calibration and simulation provides a structure for quality control and serves to document the calibration procedure, providing a degree of objectivity in the calibration process. The input data files and programs have been archived along with the MAGIC program. The assumptions involved in the calibration of MAGIC have thus become "fixed and documented". That is, anyone given the input files and programs will generate the same intermediate and final products. There are no subjective decisions made during the calibration of any site that may be forgotten, obscured or confused. We hope, thus, to keep any subjective bias in calibration from affecting scenario or strategy simulations. A similar objective protocol was used for MAGIC applications in NAPAP and has been used in a number of regional studies in the US and Europe.

3.4.3.3 Performance Analysis

The multiple calibration procedure for each site produced summary statistics (mean, standard deviation, maximum and minimum) for the observed values, the simulated values and the differences (simulated-observed values) of each of the 15 stream variables and each of the 7 soil variables simulated for each of the sites. In addition, plots of simulated versus observed values for stream variables were constructed (see Section 4.1). These analyses allowed us to determine that the model calibration results were not biased and did not contain unacceptably large residual errors.

3.4.3.4 Analysis of Uncertainty

The estimates of the fixed parameters, the deposition inputs, and the target variable values to which the model is calibrated all contain uncertainties. The multiple optimization procedure that was implemented for calibrating the model allows estimation of the effects of these uncertainties on simulated values from the calibrated model.

The procedure consists of multiple calibrations of each site using random values of the fixed parameters drawn from the observed range of values, and random values of deposition from the range of atmospheric model estimates. Each of the multiple calibrations begin with (1) a random selection of values of fixed parameters and deposition, and (2) a random selection of the starting values of the adjustable parameters. The adjustable parameters are then optimized to achieve a minimum error fit to the target variables. This procedure is repeated ten times for each site. The final calibrated model is represented by the ensemble of parameter values of all of the successful calibrations. To provide an estimate of the uncertainty (or reliability) of a simulated response to a given scenario, all of the ensemble parameter sets are run using the scenario. For any year in the scenario, the largest and smallest values of a simulated variable define the upper and lower confidence bounds for that site's response for the scenario under consideration. Applied for all variables and all years of the scenario (program MAGIC-RUN in Figure 3-7), this procedure results in a band of simulated values through time that encompasses the likely response of the site for any point in the scenario. The distributions of these uncertainty estimates for each landscape unit can be regionalized to provide overall estimates of uncertainty for a scenario. The results of the uncertainty analysis are presented in Section 4.1.

3.4.4 Classification of Biological Status

We used a classification system for biological status of fish defined by the average annual stream ANC. A four-category scheme was employed in which the ANC ranges of the four classes presented were chosen to represent thresholds for responses of brook trout to acidic conditions (Table 3-5 and below). This classification scheme was a principal result of the Fish In Sensitive Habitats (FISH) Study, a three year field experiment that studied the responses of fish (individuals, populations, and communities) to changes in acid-base status in streams in Shenandoah National Park, VA (Bulger et al. 1995).

Streams that have annual average ANC greater than 50 μeq/L are generally suitable for brook trout because they have a large enough buffering capacity that persistent acidification poses no threat to brook trout and there is little likelihood of storm-induced acidic episodes lethal to brook trout. The ANC in these streams typically remains above zero in all seasons and flow regimes. As a result, reproducing brook trout populations are expected if the habitat is otherwise suitable.

Table 3-5. Brook trout categories, ANC classes, and ANC thresholds for brook trout responses to acidification in forested, headwater catchments in western VA.

Brook Trout Category	ANC Class	ANC Range (µeq/L)	Brook Trout Response
Suitable	Not acidic	> 50	Reproducing brook trout populations expected where habitat suitable
Indeterminate	Indeterminate	20-50	Extremely sensitive to acidification; brook trout response variable
Marginal	Episodically acidic	0-20	Sub-lethal and/or lethal effects on brook trout possible
Unsuitable	Chronically acidic	< 0	Lethal effects on brook trout probable

ANC values below 200 µeq/L have been regarded elsewhere as "sensitive" to acidification for general ecological purposes (Altshuller and Linthurst 1984, Winger et al. 1987, Knapp et al. 1988). Bulger et al. (1998), examining brook trout response only, set the threshold for unaffected streams much lower because brook trout are a relatively acid tolerant species. For this project, we have specified an upper ANC category of 50 to 150 µeq/L. Streams in this category may experience episodic chemistry that affects species more sensitive than brook trout. In addition, possible future increases in chronic acidification due to decreased sulfur adsorption could lead to episodic chemistry that inhibits brook trout survival at some time in the future.

Streams that we term *indeterminate* (annual average ANC from 20 to 50 µeq/L) comprise a problematic category for prediction of both acidic deposition effects and brook trout status. Streams in this category have been designated elsewhere as "extremely sensitive" to acidification (Gibson et al. 1983, Schindler 1988), because any further reduction in ANC can produce deleterious biological effects. In this range of average annual ANC, streams may or may not experience lethal episodic acidification during storms. The occurrence of episodic acidity depends on a number of hydrologic, physical, and chemical characteristics that cannot be readily predicted, such as the ratio of stormflow to baseflow (a function of the geomorphology of the catchment and storm severity), and the occurrence of springs or minor alkaline tributaries (that can buffer storm events at these levels of ANC). The status of brook trout populations is also difficult to predict in these streams. Brook trout populations can be healthy if other habitat characteristics are favorable or poor if the habitat quality declines.

Streams that are *episodically acidic* (annual average ANC from 0 to 20 μeq/L) are *marginal* for brook trout because they have so little buffering capacity that acid episodes are likely (Hyer et al. 1995). Although the frequency and magnitude of episodes varies, streams in this category have already lost sensitive fish species, and display a reduced species richness. Examples of species lost might include longnose dace, mottled sculpin, northern hog sucker, central stoneroller, river chub, and rosyside dace (Heard et al. 1997; Bulger et al. 1995, 1998). There are measurable sub-lethal stresses on individuals in these streams, including low body weight and condition factor in blacknose dace and brook trout (Dennis et al. 1995, Dennis and Bulger 1995, Bulger et al. 1998), and lower population density in brook trout and other more acid-tolerant species (Bulger et al. 1995). Missing year classes of brook trout also become more likely. Streams in this category can have baseflow chemistry tolerable to brook trout fry but acidic episodes lethal to fry (MacAvoy and Bulger 1995).

Streams that are *chronically acidic* (annual average ANC less than 0 μeq/L) are *unsuitable* for brook trout. Forested, headwater streams in the mountains of Virginia with annual average ANC less than zero have negative ANC for much of the year, not just during storm events. As a result, the biological communities of streams in this category are severely affected. Loss of even acid-tolerant species occurs in these streams, and species richness is very low. Such streams cannot support healthy brook trout populations. Additional information regarding the sensitivity of aquatic biota to acidification is provided in Appendix J.

3.5 Model Projections

Model forecasts of future stream chemistry were developed for each of the watersheds to which MAGIC was calibrated. The dynamics of future atmospheric deposition were specified for these simulations in two ways. An initial analysis was conducted by assuming that future deposition of all ions would stay constant at 1995 levels. Results of this constant deposition scenario were used to classify resources according to sensitivity to acidic deposition and as a base case against which the results of emissions control strategies could be evaluated. In addition, a suite of simulations was based on three regional strategies of emissions controls provided by SAMI.

The strategies represent air regulatory requirements being implemented at the time of SAMI's formation, expected reductions under recent federal regulatory actions, and additional strategies that SAMI might recommend for regional, state, or community-based actions (Ogburn et al. 2001). Emissions inventories were developed for precursors of acidic deposition and ozone for the major source categories throughout the eastern U.S. Nine, week-long episodes of air quality were selected to represent air quality and meteorological conditions over the five-year period, 1990-1995. Air quality modeling results for these episodes were combined to represent seasonal and annual air quality metrics, which were projected to the years 2010 and 2040. Future growths of emissions source subcategories were estimated based on projections of population, industrial growth, electricity generation, non-utility point sources, vehicles, and area sources, using projections from the Bureau of Economic Analysis, U.S. EPA, U.S. Department of Transportation, U.S. Department of Energy, and Power Systems Research (Ogburn et al. 2001).

The spatial dynamics of these emissions control options resulted in varying estimated future changes in sulfur and nitrogen deposition at different locations within the SAMI domain. The strategies that were implemented for this assessment were designated On-the-Way (OTW), Bold-with-Constraints (BWC), and Beyond Bold (BYB). OTW is the reference strategy that represents SAMI's best estimates for acidic deposition controls that have been promulgated and are relatively certain. These include the 1990 Clean Air Act Amendments and several mobile source reductions, including EPA's call for revised State Implementation Plans (SIP). OTW was applied to all eastern states, focused on utility and highway vehicle sectors. BWC and BYB strategies assume progressively larger emissions reductions. They are targeted only to the eight SAMI states, but cover all emissions sectors. All strategies assume: current land use patterns and lifestyle behaviors continue, existing or anticipated new technology, and replacement of utility units at age 65 years with cleaner technology.

Under the OTW strategy, sulfur dioxide emissions are projected to decline substantially, especially by 2040. Nitrogen oxide emissions are also projected to decrease, but they are offset by projected emissions increases in ammonia-nitrogen. Under the BWC and BYB strategies, nitrogen emissions are projected to decrease.

Streamwater ANC at a future date was computed for a given stream and model projection by adding the model projection of change in ANC (difference between model estimate of ANC in Year X and calibrated ANC in the reference year) to the value measured in the reference year (or adjusted to the reference year, if measured during some other year). This was done, in keeping with protocols developed for DDRP (Church et al. 1989, 1992), because all calibrated models, including MAGIC and NuCM, have some bias in the calibration of ANC (and other parameters) at most sites.

3.5.1 Analysis of Constant 1995 Deposition Scenario

A scenario was implemented that involved maintaining constant deposition into the future at 1995 levels for all major ions. One purpose of this scenario analysis was to aid in the development of a classification system to illustrate watershed responsiveness to acidic deposition. Scenario results provide a metric for judging which watersheds would be most responsive to continued constant and/or future changes in sulfur and nitrogen deposition. Results of the model simulations that assumed constant deposition at 1995 levels also provided a baseline against which the results of emissions control strategy simulations could be compared.

3.5.2 Strategy Runs

In conjunction with the atmospheric modeling contractor, an approach was developed for supplying future deposition inputs sufficient for the MAGIC and NuCM input requirements (Odman et al. 2002). The approach utilized specified emissions levels for the years 1995, 2010, and 2040, under baseline assumptions, and several alternative emissions control strategies, and interpolation (ramping) procedures for specifying deposition for the intervening years. These estimates of deposition were then used in our modeling to represent deposition to each modeled watershed. For each year of the simulation and each strategy, MAGIC estimated the responses of the following streamwater chemistry output variables: sulfate, nitrate, ANC, sum of base cations (SBC), calcium, magnesium, pH, aluminum, base saturation of soils, and stream discharge. This report focuses primarily on ANC output, and secondarily on the responses of sulfate, nitrate, and base cations. Outputs were saved of the responses for the years 1995, 2010, 2020, 2030, and 2040. Summarized NuCM output included soil base saturation, Ca:Al molar ratio in soil solution, and the same streamwater variables (where appropriate) as were simulated by MAGIC.

3.6 Regional Extrapolation of Modeling Results

3.6.1 Quantitative Extrapolation

Extrapolating model results, at individual sites, of future changes in streamwater chemistry to broad regional landscapes is complicated. Model results are specific to the characteristics of the modeled sites. Streamwater ANC, sulfate/nitrate retention processes, and watershed soil and geological conditions all greatly influence model projections and vary widely across the SAMI domain. Thus, any regional extrapolation requires knowledge of conditions across the entire region. The simplest way to make an extrapolation would be to have a census of conditions in all streams in the region. Due to the size of the SAMI region, this is totally impractical for even measuring simple things like stream ANC, much less applying process models to predict future changes in condition. In the absence of census data, a statistical survey of randomly selected stream sites can be used to infer condition across the region with known confidence bounds.

There are two aspects of regional extrapolation that are of interest to SAMI: the quantitative and the spatial components. Quantitative extrapolation focuses on numbers or percentages of stream reaches and length of streams that the model predicts might respond in a certain way. Spatial extrapolation tries to show where those streams are located and what features of the landscape (soils, geology, vegetation, elevation) are commonly associated with that response (Table 3-6). Our approach to each for this assessment is described below.

For the SAMI-wide regional assessment, the only statistically rigorous spatial frame available that covered most of the geographical extent of the SAMI domain was that of the NSS (see description in Appendix K). Results from the 153 stream segments sampled in the SAMI region in the NSS were earlier used to infer acid-base status for all 62,000 km of stream in the SAMI region (Herlihy et al. 1996). By applying the future modeling results from our modeled watersheds to the NSS sites, we were able to make a rigorous estimation of future changes in streamwater acid-base chemistry throughout the SAMI region for all of the watersheds in the region that were represented by the NSS statistical design and that have ANC $\leq$ 150 μeq/L. Results of the modeling were also put into the perspective of all streams within the region, including those that were represented by the NSS statistical design and that have ANC > 150 μeq/L. It was assumed that these higher-ANC streams would be insensitive to changes in acidic deposition or would not change their ANC in the future by an amount that would be biologically meaningful.

Table 3-6. Principal aspects of regional extrapolation.

	Quantitative Extrapolation	Spatial Extrapolation
Basis	Statistically-selected or regionally-representative watersheds	Region-wide mapped landscape features
Objective	To quantify the number, percent, or length of streams within a defined region that respond in a particular way	To show the location of streams within a defined region that respond in a particular way.
Kinds of Questions that can be Addressed	1. How many stream reaches will become acidic by 2040 if deposition remains constant? 2. How many miles of stream will improve from ANC < 0 to ANC > 0 in 2040 under a particular strategy? 3. Will streams in the Blue Ridge or the Appalachian Plateau benefit more from implementation of a particular strategy? 4. How will the percentages of streams that are acidic or very low in ANC change in the future in response to a particular strategy?	1. Where are the majority of the acidic streams located? 2. Which state will see the largest improvement in streamwater acid-base chemistry under a particular strategy? 3. Using ANC ≤ 20 μeq/L as an indicator of adverse fish response, where will most of the fisheries improvements occur if a particular strategy is implemented? 4. What features of the landscape are associated with acid sensitivity?

Almost all of the SAMI domain is within areas sampled and assessed by the NSS (Figure 3-2). SAMI areas outside the NSS study area boundary were expected to have high ANC (> 400 μeq/L) based on available alkalinity maps (Omernik and Powers 1983). For the statistical extrapolation, we clipped out the NSS sites that fell within the SAMI domain using a GIS. Only "target" NSS sites were selected, which removed streams in urban areas, dry streams, those with gross perturbations, and those acidic due to mine drainage. There were 149 NSS reaches in the SAMI area, represented by 147 upstream reach end sample sites and 145 downstream reach end sample sites. There were slightly different numbers of reach ends sampled because some reach ends could not be sampled due to "non-target" conditions at that site, although the other reach end may have been sampleable. A total of 143 reaches were sampled at both ends and were used in the stream length estimates, which interpolated conditions between the reach ends as described in Appendix K. Using the NSS population expansion algorithm, these sites were judged to represent an estimated 19,026 (standard error=1,648) upstream reach ends and 19,185 (standard error=1,659) downstream reach ends or 63,295 (standard error=6,293) km of stream.

The stream population in the SAMI domain was divided for the statistical extrapolation into 12 classes or "bins" based on physiography and streamwater defined ANC (Table 3-7). The purpose of the bins was to group sites that would be expected to behave similarly with respect to acidic deposition effects on streamwater chemistry. To extend the modeling results to the NSS spatial base, we used the 12 different landscape units (modeling bins) throughout the SAMI area that we expected would have generally similar within-bin responses to the differing future acidic deposition strategies. Out of the 130 different watersheds that were modeled in the regional modeling effort, there were 7 or more modeled sites in 10 of the 12 landscape units. All modeled sites and all NSS sites were assigned to a bin based on physiographic province and defined ANC. For each of the modeled sites, MAGIC projected changes in streamwater chemistry for each strategy and ending year based on a 1995 start point. We added the modeled change from 1985 to 1995 for each site (same for all strategies) to these predicted changes,

Table 3-7. Breakdown of the NSS sites within the SAMI domain by model projection bins showing the number of NSS sample sites and estimated population size in each bin.

Bin #	Province / ANC class (μeq/L)	Upstream End Sample Size (Estimated Number of Reaches)	Downstream End Sample Size (Estimated Number of Reaches)
1	Blue Ridge / < 0	0	0
2	Blue Ridge / 0-20	1 (318)	0
3	Blue Ridge / 20-50	5 (100)	2 (39)
4	Blue Ridge / 50-150	38 (2,513)	34 (1,754)
5	Ridge&Valley / < 0	1 (318)	0
6	Ridge&Valley / 0-20	1 (47)	1 (47)
7	Ridge&Valley / 20-50	1 (121)	0
8	Ridge&Valley / 50-150	4 (1,271)	4 (1,271)
9	Plateau / < 0	4 (756)	3 (610)
10	Plateau / 0-20	3 (672)	3 (656)
11	Plateau / 20-50	6 (1,206)	2 (465)
12	Plateau / 50-150	6 (848)	8 (1,313)
	Total NSS in SAMI	147 (19,026))	145 (19,185)

corresponding to the time of NSS data collection (1985 or 1986) to get a total 1985 to ending year change in concentration for each strategy. For each bin, we calculated a median, minimum and maximum value of change in streamwater ANC, nitrate, sulfate, and base cations based on all the modeled sites in that bin. Within any given bin, the median modeled concentration change for that bin was added to the observed streamwater concentration at each NSS site that occurred in that bin. This was done for each bin. Thus, the median change in model-projected stream chemistry (e.g., ANC, sulfate, SBC, etc.) for each deposition strategy within each modeling bin was applied to each individual NSS site that occurred in that landscape unit (Table 3-7). For example, if the forecasted median change in ANC was a decrease in ANC of 10 μeq/L in modeling bin X for a particular strategy, we subtracted 10 μeq/L from each NSS site that occurred in modeling bin X for making future predictions under that strategy. After integrating this information within each landscape unit, the NSS population expansion algorithm (Kaufmann et al. 1988) was used to infer regional condition for each strategy at each NSS site in that bin. We then made regional population estimates using the NSS statistical design algorithms and the predicted future streamwater concentrations at all the NSS sites. For the high ANC (> 150 μeq/L) sites, which were not modeled, we assumed that there was no change in streamwater chemistry in any of the strategies. Even if there would indeed have been small modeled changes for these high-ANC streams, such changes would not be biologically important. For an error analysis illustrating best/worst case estimates, the minimum/maximum modeled change in each bin was added to the NSS observed chemistry in each bin.

The quantitative regional analysis was thus based on a design that consisted of 12 landscape units and MAGIC model projections of streamwater response for a suite (in most cases $n \geq 7$) of watersheds selected within each landscape unit. The median model response for each unit was applied to all similar (within the same unit), statistically-selected NSS sites in the SAMI domain. The NSS statistical frame was then used to estimate the number and percentage of stream reaches in the SAMI region that were projected to behave in certain ways or to change their chemistry according to various chemical criteria (i.e., become acidic, change from one ANC class to another, recover more than 10 μeq/L of ANC, etc.).

For the small number of NSS sites that occur within the Piedmont Province section of the SAMI region, it was assumed that they would respond in a similar fashion to watersheds of comparable ANC in the Blue Ridge Province This assumption is inconsequential for this assessment because all NSS sites in the Piedmont Province had ANC > 50 μeq/L.

3.6.2 Spatial Extrapolation

The spatial extrapolation was based on an analysis of streams and landscape features that:

1. were digitally available or could readily be digitized or calculated in the GIS,
2. covered all or most of the SAMI domain in a similar or comparable fashion, and
3. are known to correlate with streamwater acid-base chemistry or acidification response.

The objective was to identify mapped features that could be shown (at the scale of available data) to be associated with streamwater chemistry. Based upon the location of such mapped features, the locations of streams of various response types were identified and mapped.

There are several issues that make this kind of analysis difficult and the results uncertain. These issues must be considered in interpreting the mapped output of the spatial component of this assessment. The principal complicating factors are as follows:

1. watersheds respond to acidic deposition in a complex fashion, and that response is governed by the INTERACTION of processes controlled by meteorology, geology, soils, vegetation, and hydrology. There is no way to map the interaction, although we can map pieces of it.

2. The scale of available mapped data is of much lower resolution than the scale of important watershed processes that control water chemistry. Coarse lumping of what is actually detailed diversity can limit the utility of any regional-scale map.

3. Within any regionally mapable landscape unit, there is almost always a range of streamwater chemistry that may or may not include acid-sensitive streams. There are many landscape units that contain no acid-sensitive streams but few landscape units that contain only acid-sensitive streams.

Because of these limitations, the best that can be accomplished in a spatial assessment of this type is an identification (and mapping) of those areas where the majority of the most responsive, or most acid-sensitive, streams are likely to be found. Mixed in with them, there will almost always also be streams that are not responsive or not acid-sensitive.

Appropriate spatial data were compiled, or in some cases generated, for this assessment from a variety of sources. A database of approximately 1,000 watersheds was assembled for which we had measured streamwater ANC. These watersheds were located throughout the SAMI domain (Figure 3-1). Watershed area was acquired, developed, or digitized for each. The majority of the ANC data were collected by the NSS, EMAP, VTSSS, or various Forest Service stream surveys. Additional coverages included lithology, soils, vegetation types, ecoregions, and elevation.

Results of these analyses help to clarify the extent to which aquatic resources throughout the SAMI region are at risk from acidic deposition and provide a general indication of the spatial distribution of the at-risk aquatic resources. Also provided are quantitative estimates of the extent to which those risks will change in response to various levels of future acidic deposition. The percentage of the total resource represented by the various at-risk classes of aquatic resources was estimated for multiple future emissions strategies. Sustainability of aquatic ecosystems was assessed for differing levels of acid deposition by relating model outputs of surface water and soil water chemistry to generally accepted thresholds for biological damage. Biological diversity of aquatic resources was addressed primarily from the standpoint of fish diversity and the response of brook trout.

We explored the extent to which the sensitivity to aquatic acidification was related to watershed features that could be quantitatively expressed regionally throughout the SAMI domain. Acidification sensitivity relative to five primary potential predictor variables was examined: bedrock geology, regional soils coverage, forest cover, ecoregion (c.f., Omernik and Bailey 1997, Bryce et al. 1999), and watershed position (elevation, local relief). The extent to which sensitivity to acidification correlated with such broad-scale landscape indicator variables determined the degree to which modeling results could be mapped spatially. This provided an indication of where the most acid-sensitive streams are likely to occur within the region. It did not, however, indicate areas where we would expect all streams to respond in a particular way. This is because streams that are highly acid-sensitive are often located in close proximity to streams of considerably less sensitivity due to differences in such characteristics as hydrology, slope, and fine-scale differences in geology and soils. In particular, scattered pockets of highly weatherable bedrock, and their interaction with drainage water, in areas dominated by slow-weathering geology often causes a mixture of streamwater sensitivity within an area generally classified as highly acid-sensitive.

4.0 RESULTS

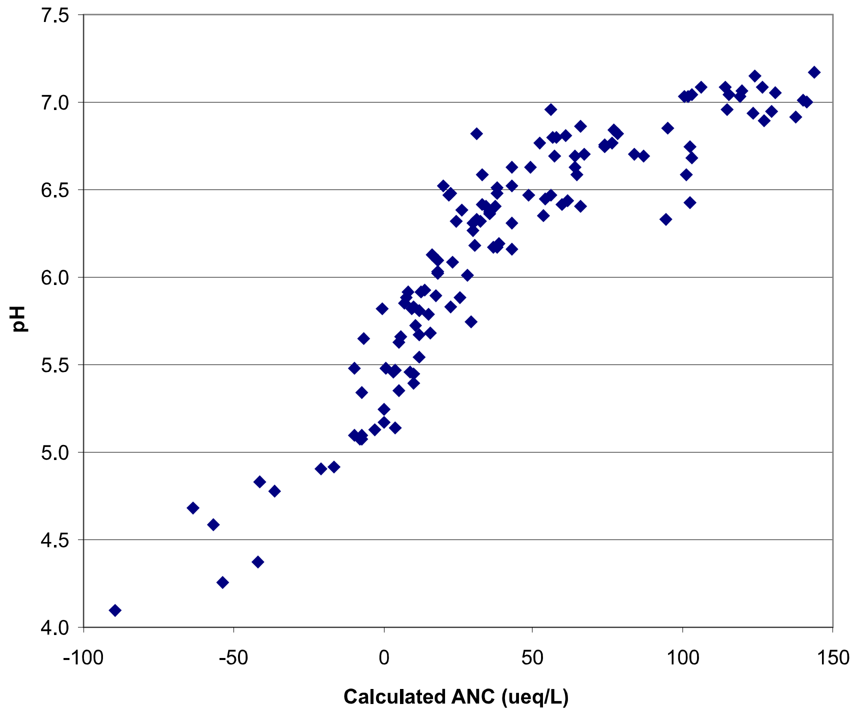
4.1 Calibration Results

The final regional streamwater database was internally consistent. There was a rather uniform pattern to the distribution of pH versus ANC (Figure 4-1a), as would be expected for dilute, low-DOC streams (c.f., Charles 1991). In addition, the plot of ANC calculated, using the charge balance, versus titrated ANC showed close agreement (Figure 4-1b). As expected, some titrated ANC values were slightly higher than calculated ANC values for acidic and low-ANC streams (points below the 1:1 line on left side of plot). This pattern can be attributed to the likely presence of relatively high concentrations of inorganic Al in some acidic streams (c.f., Sullivan et al. 1989). Also as expected, titrated ANC values for the majority of the sites were slightly lower than calculated ANC values at the upper end of the ANC distribution (points above the 1:1 line on right side of plot). This was likely due to low concentrations of DOC in these samples, which slightly lowers titrated ANC.

MAGIC was successfully calibrated to 164 watersheds, including 130 regional sites and 34 special interest sites (mainly additional sites within Class I areas). Results of predicted versus observed chemistry in the calibration year are shown for all modeled sites in Figure 4-2. Agreement was very good for all variables, with the exception of pH. The MAGIC model calculates pH using a number of constituents, including the charge-balance ANC and the concentrations of dissolved organic carbon (DOC) and Al. Values for DOC and/or Al were missing from many of the model site databases. This introduced additional uncertainty into the estimates of pH for the calibration year. For this reason, model outputs of pH are not used in this assessment; rather, estimates of biological response are based on model estimates of changes in ANC.

For a group of model sites that had been surveyed in the VTSSS, long-term monitoring data (~10 years) were available and were used in the evaluation of model performance. For each of the 12 modeling bins that contained one or more VTSSS monitoring sites, a representative site was selected to examine predicted versus observed chemistry for the full period of record. Results showed close agreement at all sites (Figure 4-3). Results of these calibration uncertainty analyses are further discussed in Section 4.4.

For some of the sites included in the MAGIC modeling effort, site-specific soils data were not available as input for the model calibration. Rather, soils data were obtained for these calibration sites from surrogate sites. For Tier II sites, soils data were obtained in each case from



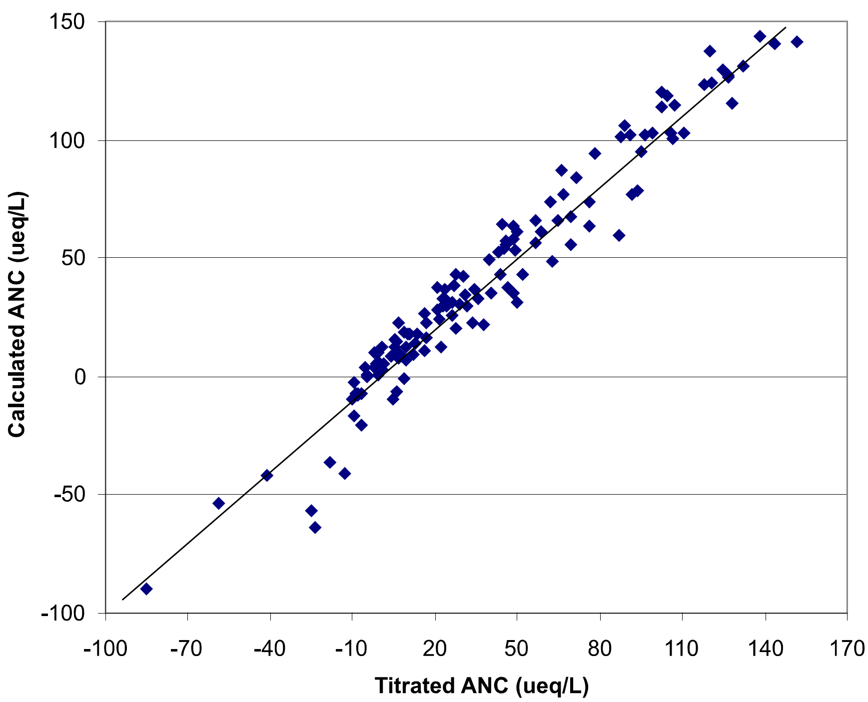


Figure 4-1. Plot of a) pH versus calculated ANC and b) calculated versus titrated ANC for the regional aquatic modeling sites.

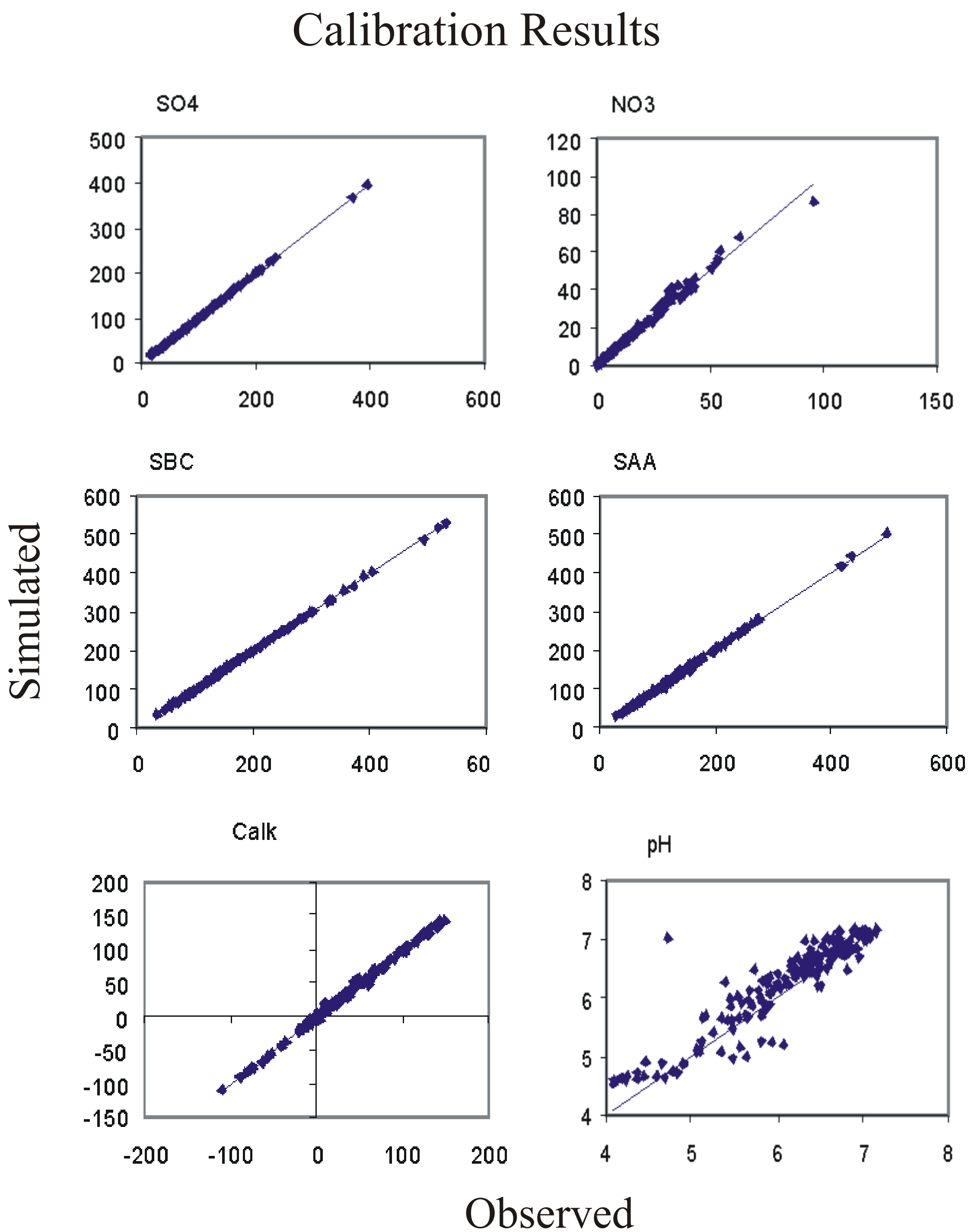


Figure 4-2. Calibration results for the MAGIC model, expressed as predicted versus observed values in the calibration year, for sulfate, nitrate, sum of base cations (SBC), sum of mineral acid anions (SAA), calculated ANC (Calk), and pH.

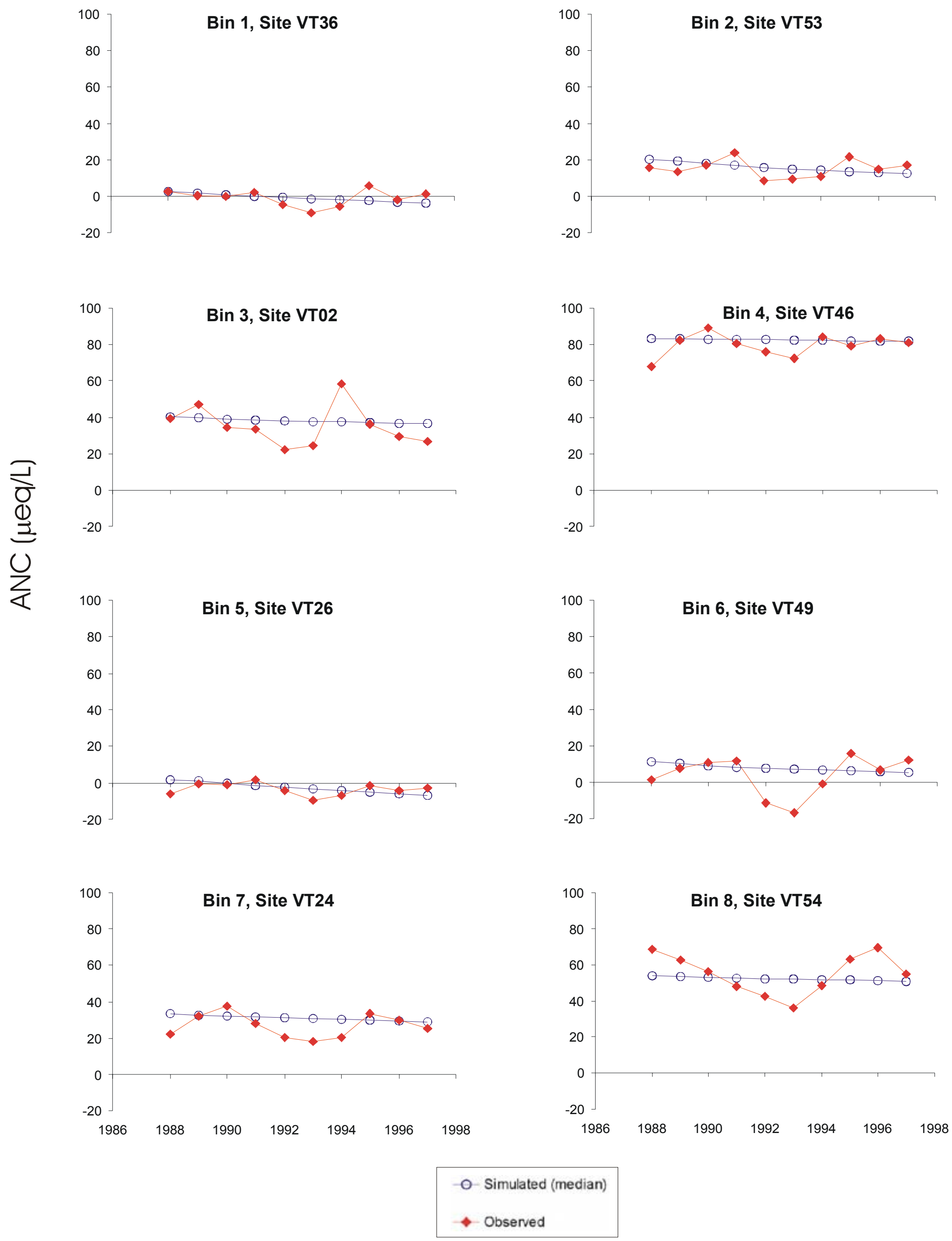


Figure 4-3. Predicted versus observed ANC over a ten-year period for a representative VTSSS site in each of the 8 modeling bins in which one or more long term monitoring VTSSS sites occurred. The calibration period for these sites was 1989-1991 (3 year average). No VTSSS sites occurred within the Appalachian Plateau Physiographic province (Bins 9-12).

a nearby soils data site known to occur on similar geology. For Tier III sites, soils data were obtained from a surrogate Tier I site (a modeling site for which site-specific soils data were available), selected to be similar in geologic sensitivity class, location, streamwater ANC, and streamwater sulfate concentration.

Use of surrogate soils data for Tier II and III modeling sites introduced additional uncertainty into the calibration process, and potentially the model projections. The magnitude of this uncertainty was evaluated by calibrating selected Tier I sites twice, once using the appropriate site-specific soils data and a second time using the surrogate soils protocols of either the Tier II or Tier III sites. Model projections of ANC, in the reference year and in 2010 and 2040, are shown for these sites in Figure 4-4. Results based on the Tier I calibration (shown on the x-axis) are compared with results based on the surrogate soils calibration (Tier II or III, shown on the y-axis of the plots in panels A and B, respectively). In all cases, there was close agreement between model projections based on site-specific (Tier I) data and model projections based on borrowed (Tier II or III) data. See further discussion in Section 4.4.

4.2 Regional Aquatic Assessment

4.2.1 Deposition Estimates

Estimates of total atmospheric deposition of sulfur and total nitrogen (oxidized nitrogen plus reduced nitrogen) for the reference year (1995) are shown for the 130 regional modeling sites in Figure 4-5. These estimates include wet, dry, and occult (cloud) deposition. Deposition of both sulfur and nitrogen was highest in the high-elevation areas of western North Carolina and eastern Tennessee and in the Appalachian Plateau of West Virginia. Additional details regarding deposition values used for model calibration and projections, including dry and occult deposition factors and scaled sequences, are given in Appendix L.

Predicted changes in the values of total sulfur and nitrogen deposition for the period 1995 to 2040 are shown for the regional modeling sites in Figures 4-6 to 4-9 under each of the three Emissions Control Strategies. Sulfur deposition was predicted to decrease at all sites under all strategies, but the decreases were smallest for the OTW Strategy (mean -57%), intermediate for the BWC Strategy (mean -67%), and largest for the BYB Strategy (mean -73%). Projected changes in sulfur deposition were largest in those areas that showed the highest 1995 deposition.

For nitrogen deposition, the projected changes were largest in West Virginia. The projected percent change in total nitrogen deposition from 1995 to 2040 differed dramatically among the

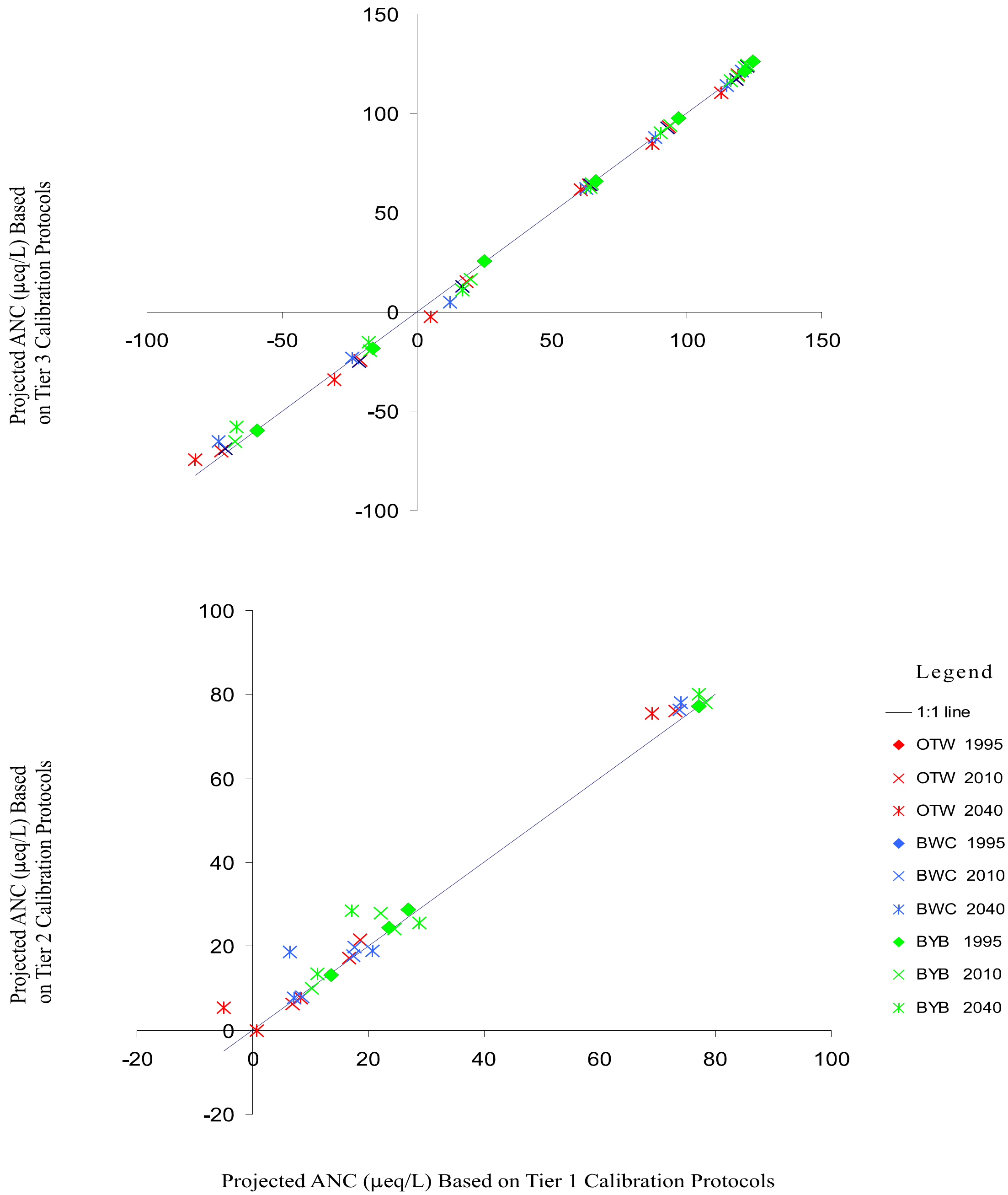


Figure 4-4. Results of sensitivity analysis to examine uncertainty associated with borrowing soils data for 4 Tier I sites recalibrated using Tier II protocols and 7 Tier I sites recalibrated using Tier III protocols. MAGIC model projections of ANC are presented in the years 1995, 2010, and 2040 under different Emissions Control Strategies. Results presented on the x-axis are based on model calibrations utilizing existing site-specific soils data. On the y-axis is presented results obtained using an alternative calibration that ignored existing site-specific soils data, and instead borrowed soils data from an alternate site using Tier II or Tier III protocols.

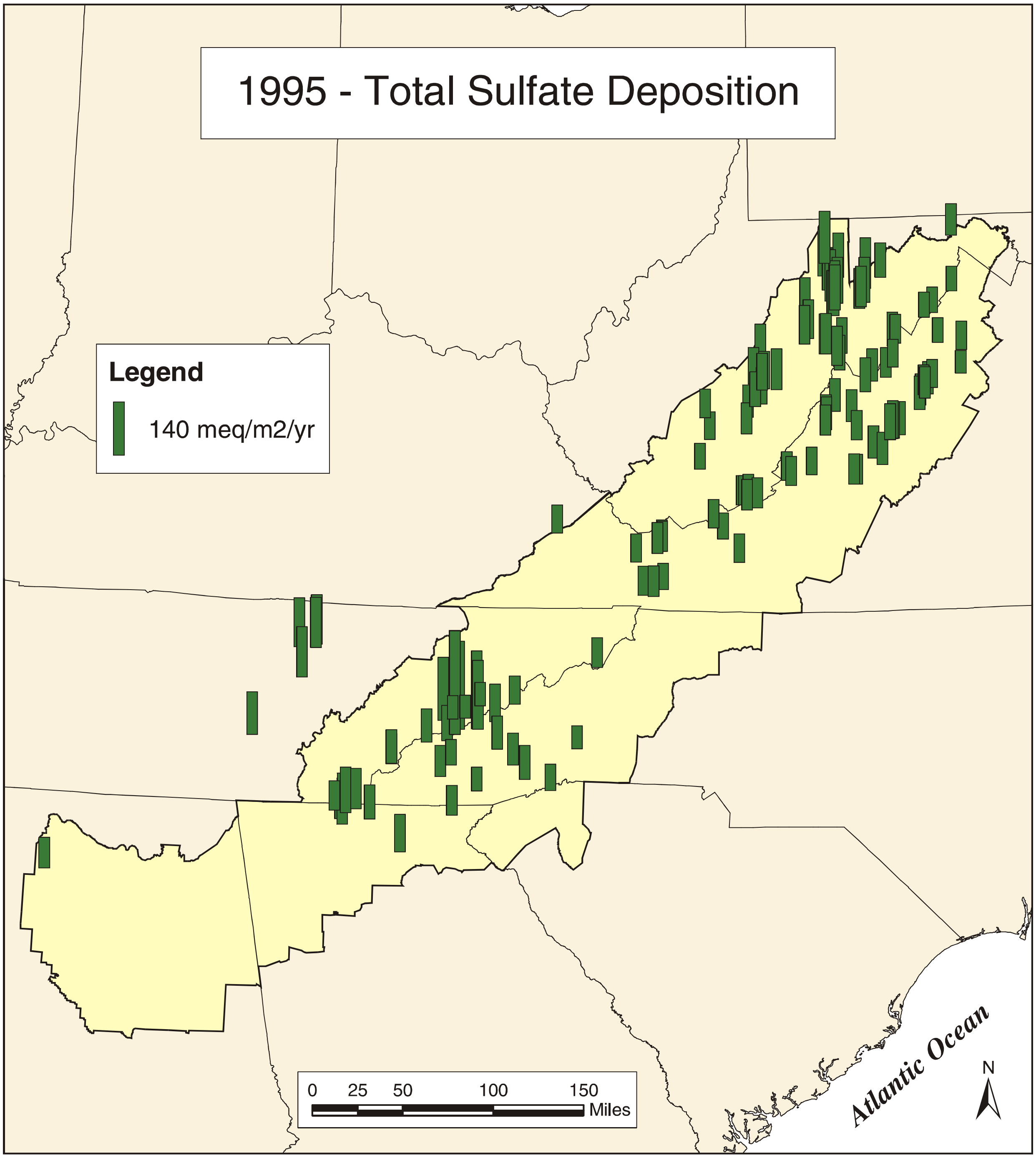


Figure 4-5. Maps showing estimated total deposition of A) sulfur and B) nitrogen in the 1995 reference year, interpolated to each of the regional modeling sites. These estimates include wet, dry, and cloud deposition and both oxidized and reduced forms of nitrogen. The heights of the bars on this, and subsequent similar maps, are proportional to the concentration of the constituents depicted.

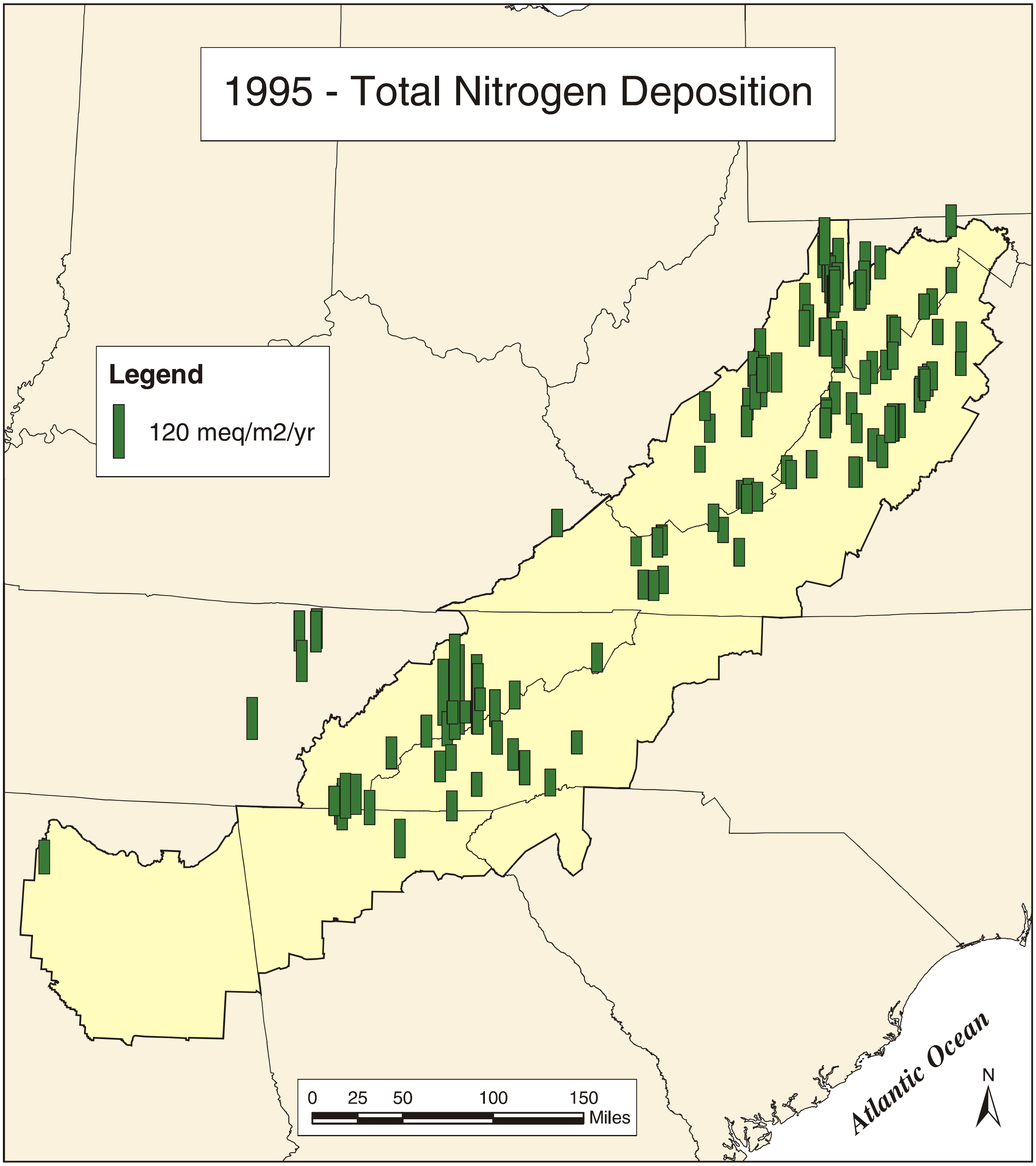


Figure 4-5. Continued.

three strategies. Total nitrogen deposition was projected to increase at the majority of the sites under the On-the-Way Strategy (mean +10%), but to decrease at all of the sites under the Beyond-Bold Strategy (mean -34%). Results for nitrogen deposition for the Bold-with-Constraints Strategy were intermediate (mean -14%; Figure 4-6). The projections were substantially different for the two components of total nitrogen, oxidized nitrogen (nitrate), and reduced nitrogen (ammonia and ammonium). Nitrate deposition was projected to decrease under all strategies, from a mean of -20% in the OTW Strategy to -26% in BWC and -31% in BYB. In contrast, reduced nitrogen was projected to increase in OTW and BWC (mean +29% and +11%, respectively), but to decrease slightly (mean -4%) in BYB.

Percent changes in base cation deposition were small (typically <10%) at all sites for all strategies. Values at the regional modeling sites for the resulting total deposition estimates for both sulfate and total nitrogen are mapped in Appendix M for each of the Emissions Control Strategies.

The spatial patterns in predicted change in sulfur and nitrogen deposition for the three strategies, depicted in Figures 4-7 to 4-9, show that the projected increases in nitrogen deposition, while small compared with projected changes in sulfur deposition, tended to be greatest in western North Carolina, Tennessee, and Georgia. The largest projected decreases in nitrogen deposition were in West Virginia. The largest decreases in sulfur deposition tended to be in the Appalachian Plateau Physiographic Province and also in the area of western North Carolina and eastern Tennessee (Figures 4-7 to 4-9).

4.2.2 Future Changes in Streamwater Chemistry in Response to Emissions Control Strategies

4.2.2.1 Response to 2040

In response to continued sulfur and nitrogen deposition loading to the regional modeling sites, on-going soil processes in the modeled watersheds, and simulated changes in the future deposition levels of sulfur, nitrogen, and base cations, the MAGIC model projected future changes in the concentration of sulfate and nitrate in streamwater (Figures 4-10 and 4-11).

The median (50th percentile) simulated change in streamwater concentrations of major ionic constituents from 1995 to 2040, along with the 25^{th} and 75^{th} percentiles of simulated change, are given in Table 4-1 for the three Emissions Control Strategies. In general, changes were largest for sulfate and base cations, with smaller simulated changes in ANC and nitrate concentrations. Across strategies, the simulated changes in streamwater chemistry were generally largest for the

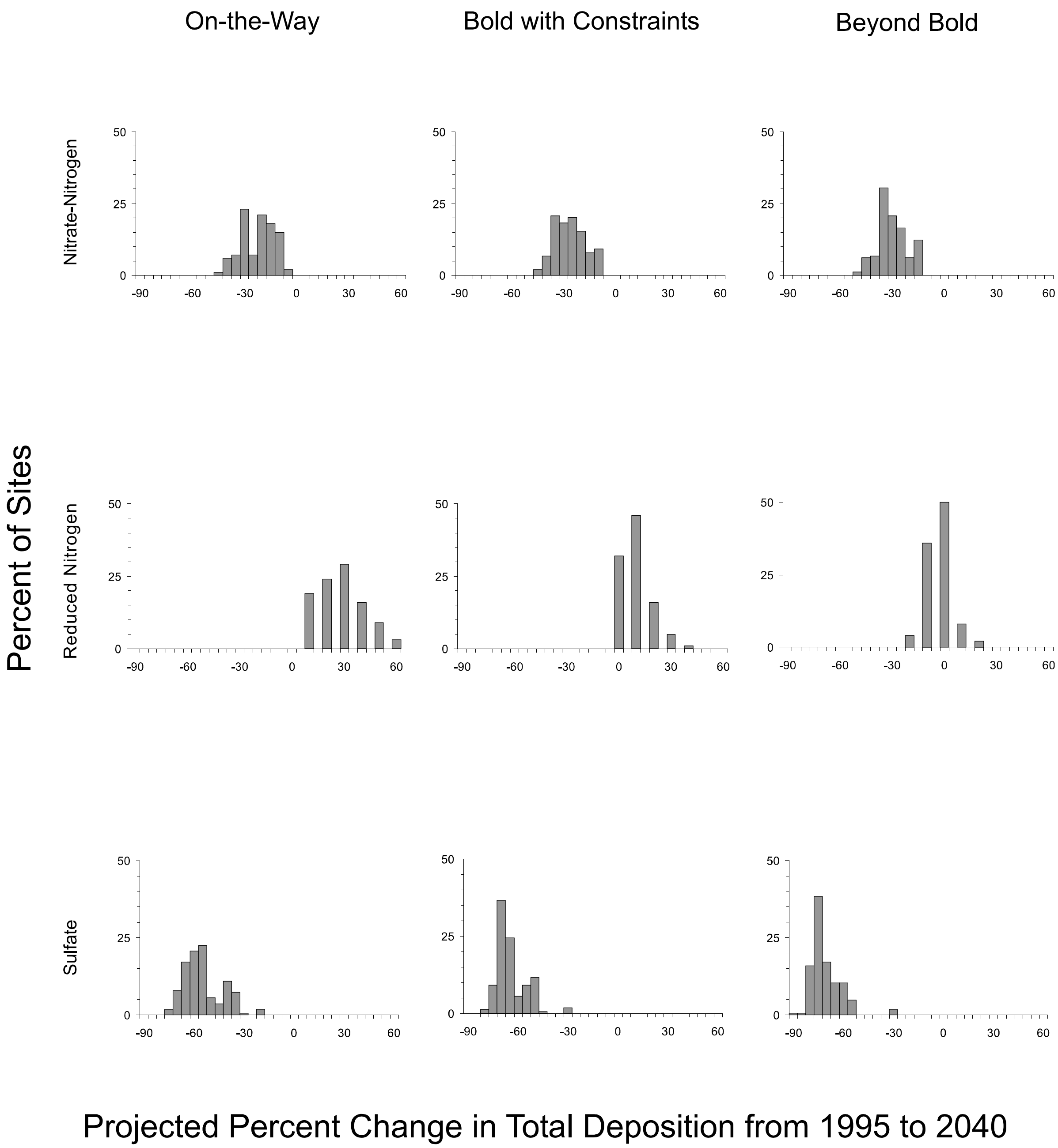


Figure 4-6. Estimated percent changes in the total deposition of sulfur, reduced nitrogen, and nitrate-nitrogen at MAGIC modeling sites from 1995 to 2040 under each of the Emissions Control Strategies.

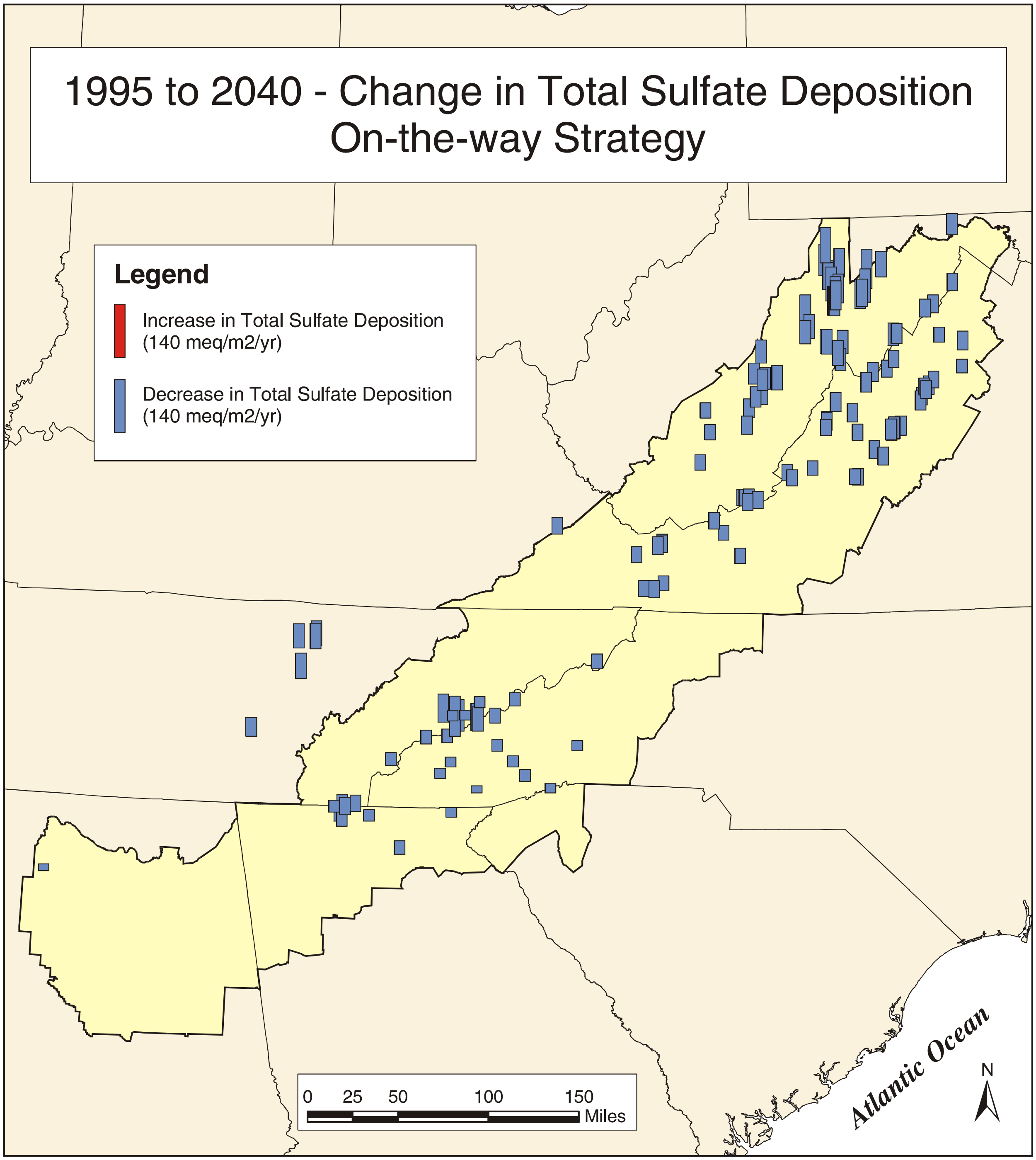


Figure 4-7. Maps showing estimated change in the total deposition of A) sulfur and B) nitrogen at regional MAGIC modeling sites in response to the OTW Emissions Control Strategy.

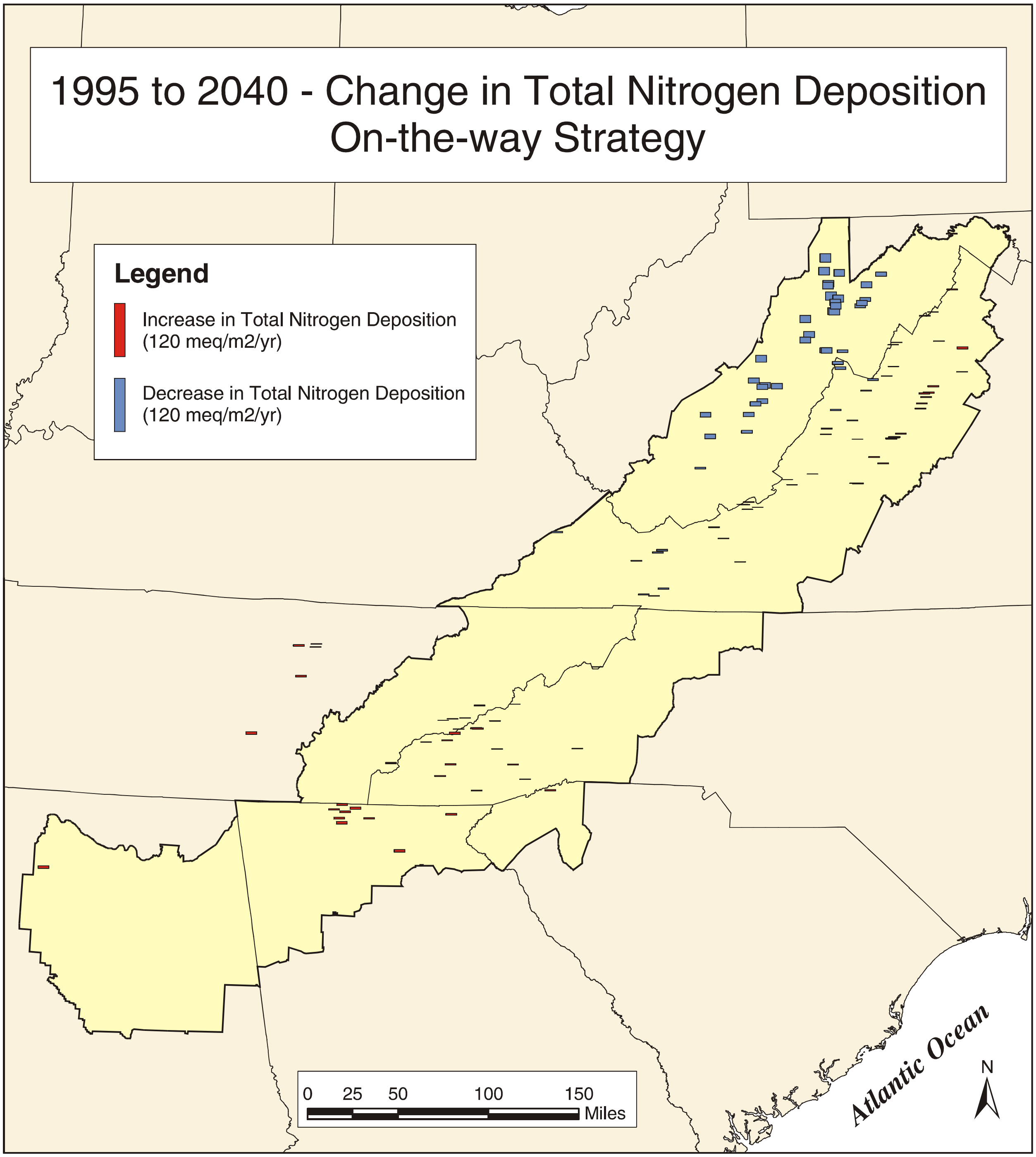


Figure 4-7. Continued.

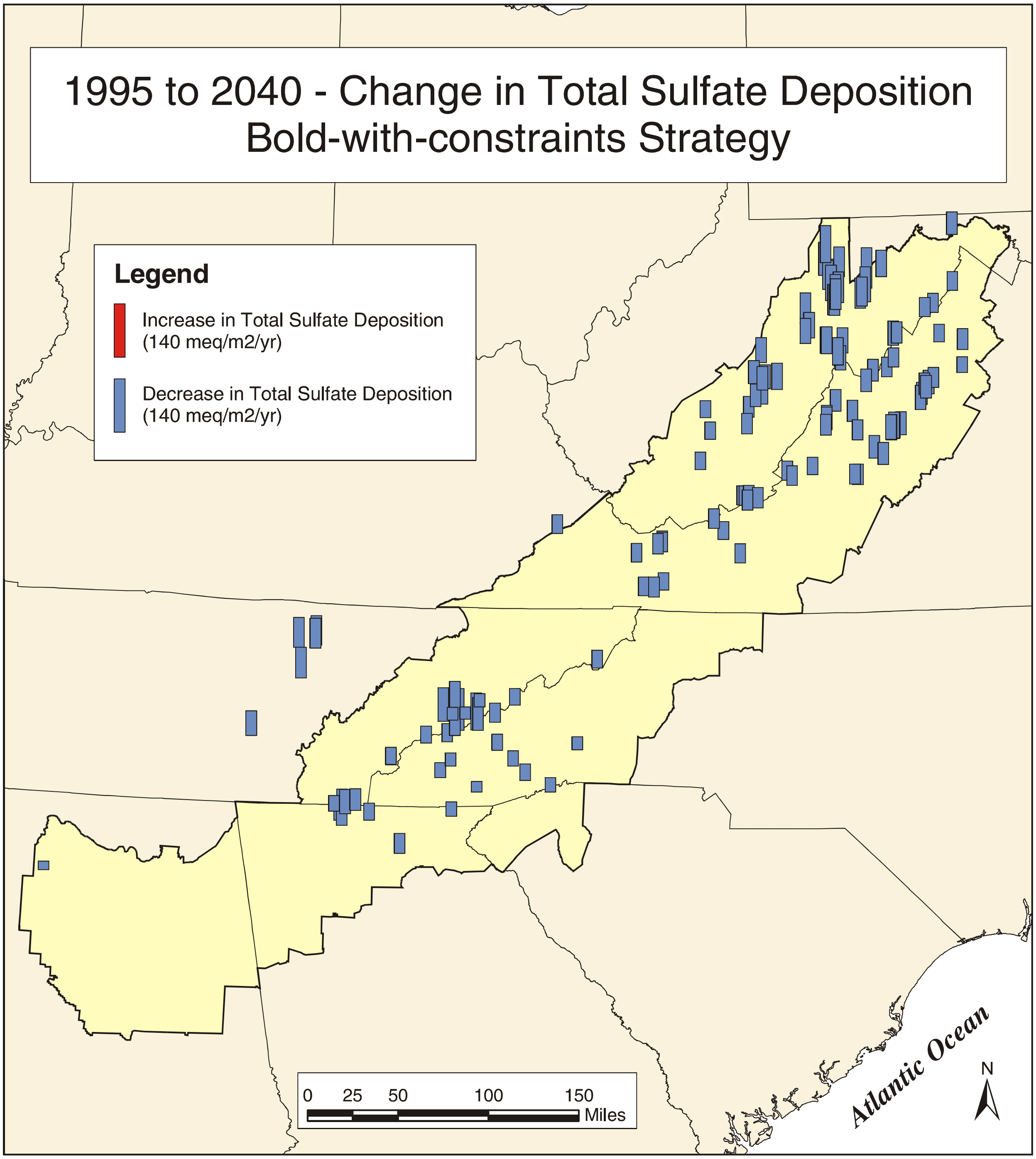
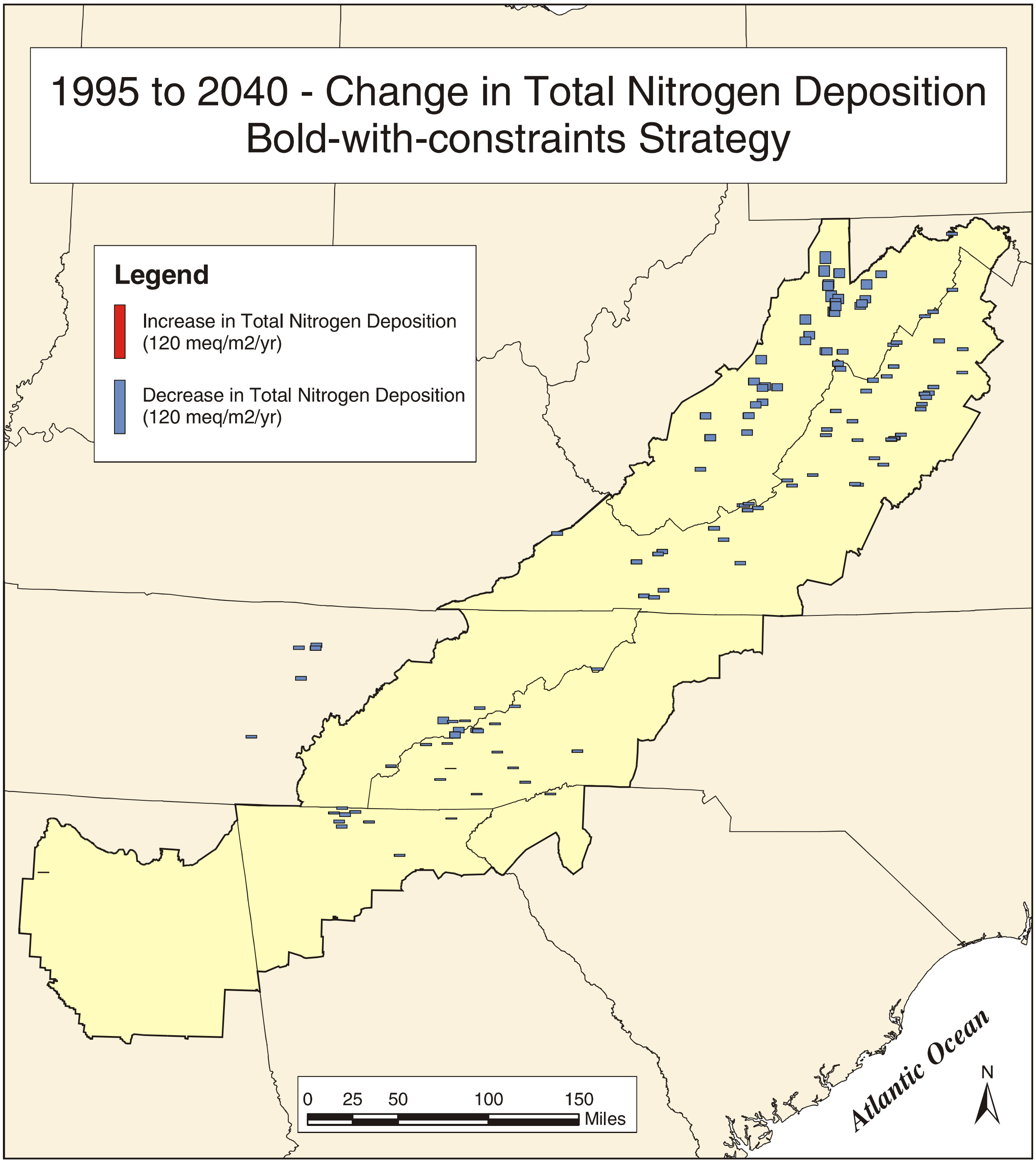


Figure 4-8. Maps showing estimated change in the total deposition of A) sulfur and B) nitrogen at regional MAGIC modeling sites in response to the BWC Emissions Control Strategy.



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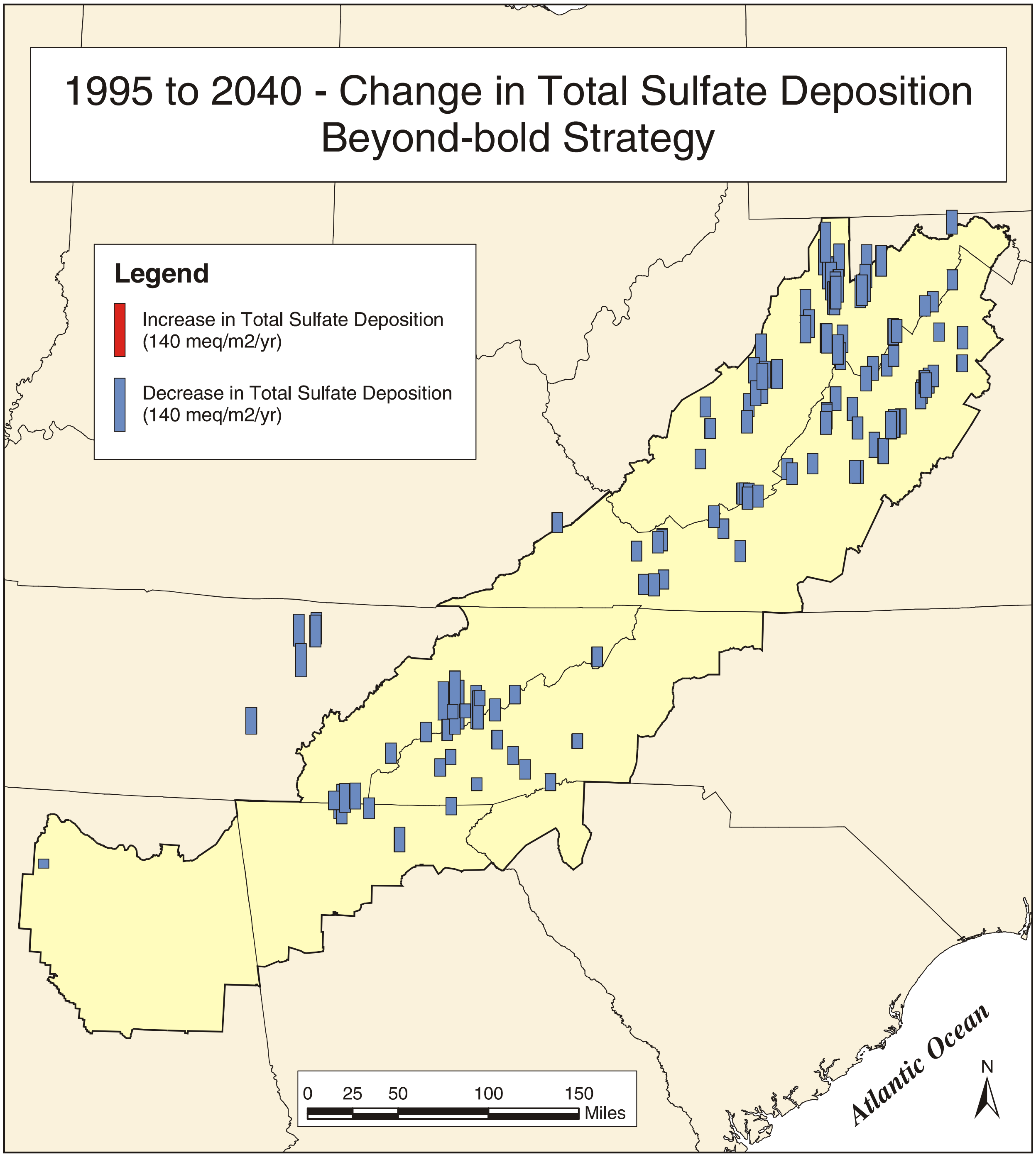
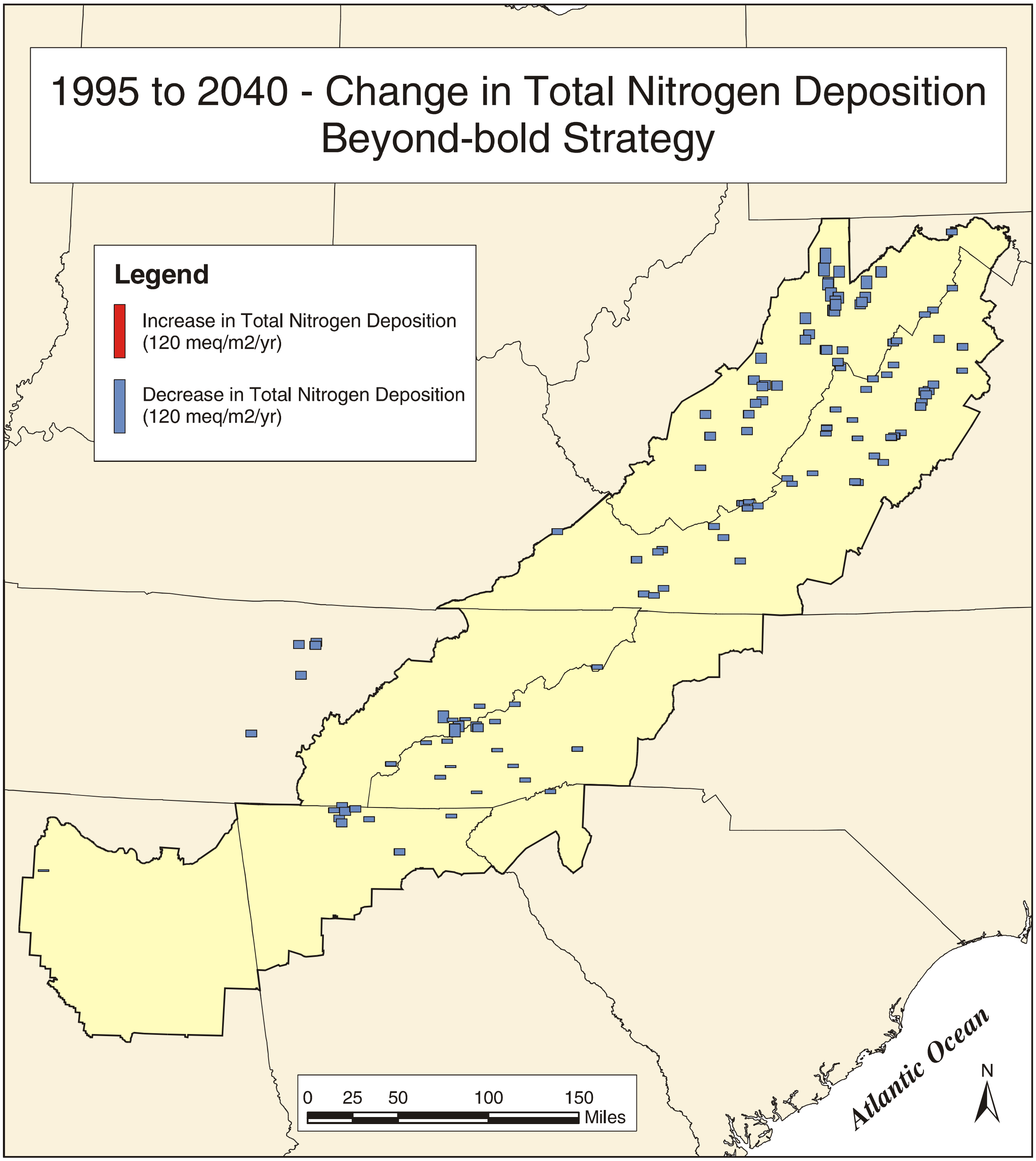


Figure 4-9. Maps showing estimated change in the total deposition of A) sulfur and B) nitrogen at regional MAGIC modeling sites in response to the BYB Emissions Control Strategy.



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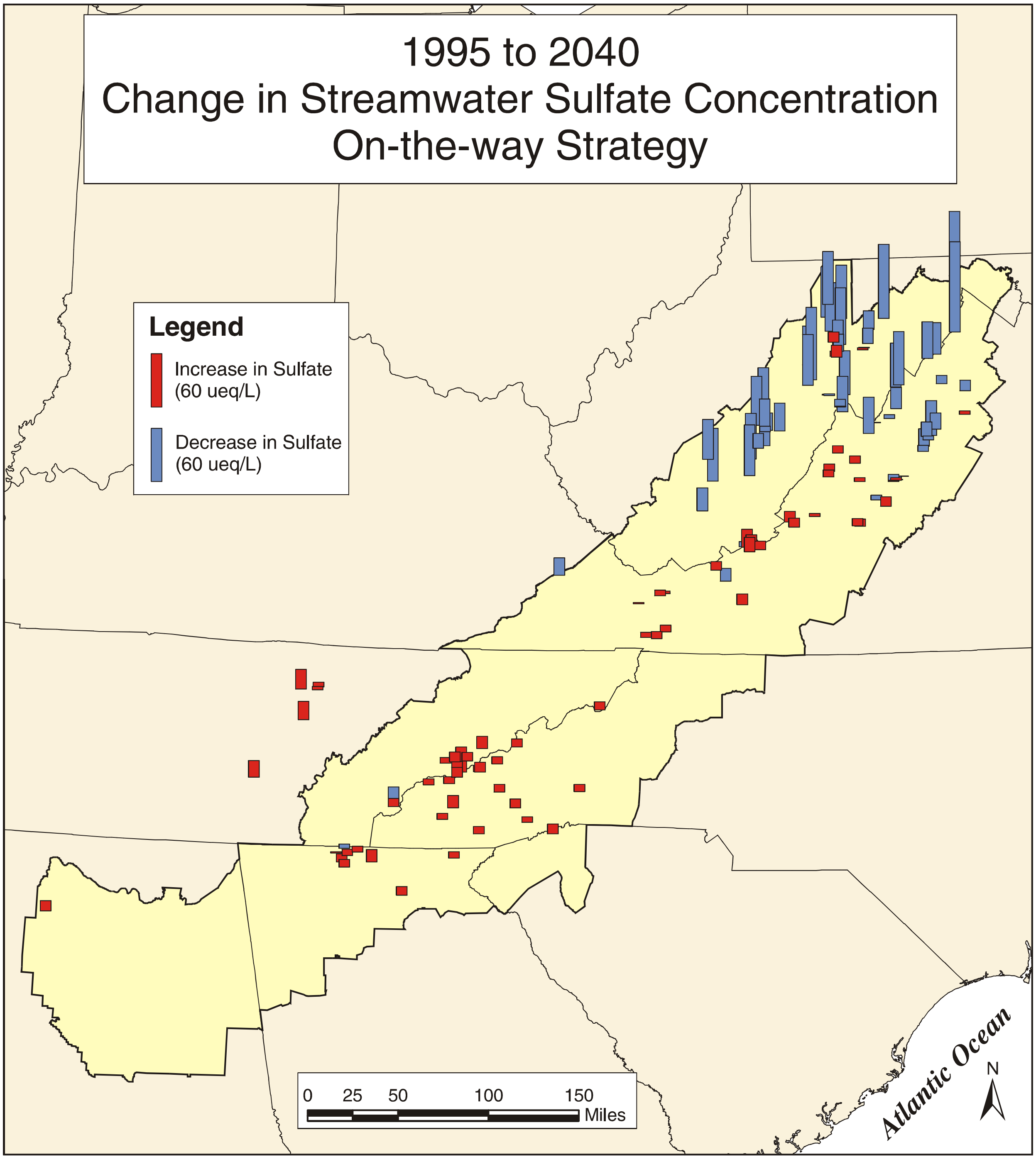
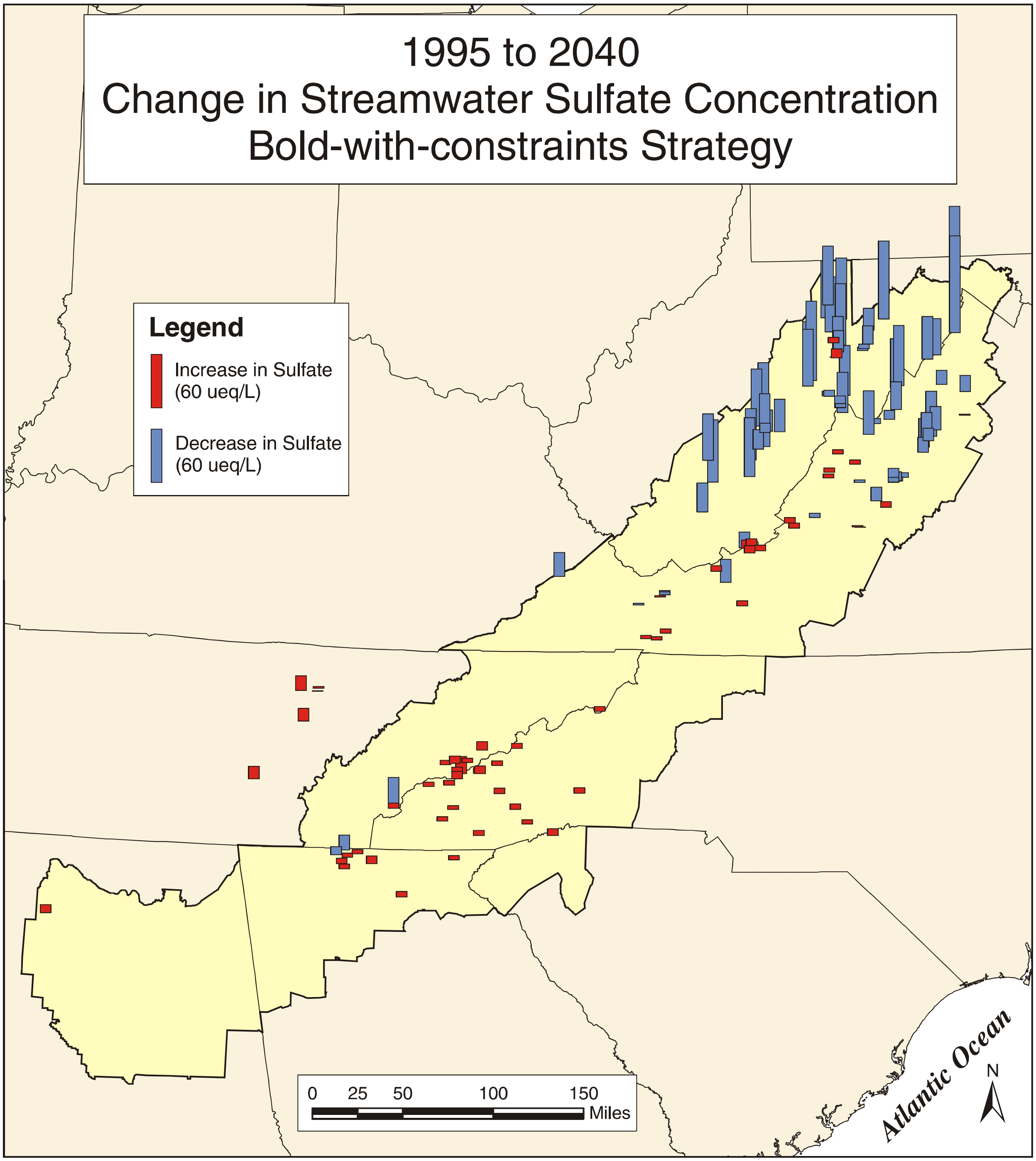


Figure 4-10. Maps showing simulated changes in streamwater sulfate concentration from 1995 to 2040 in response to each of the three Emissions Control Strategies.



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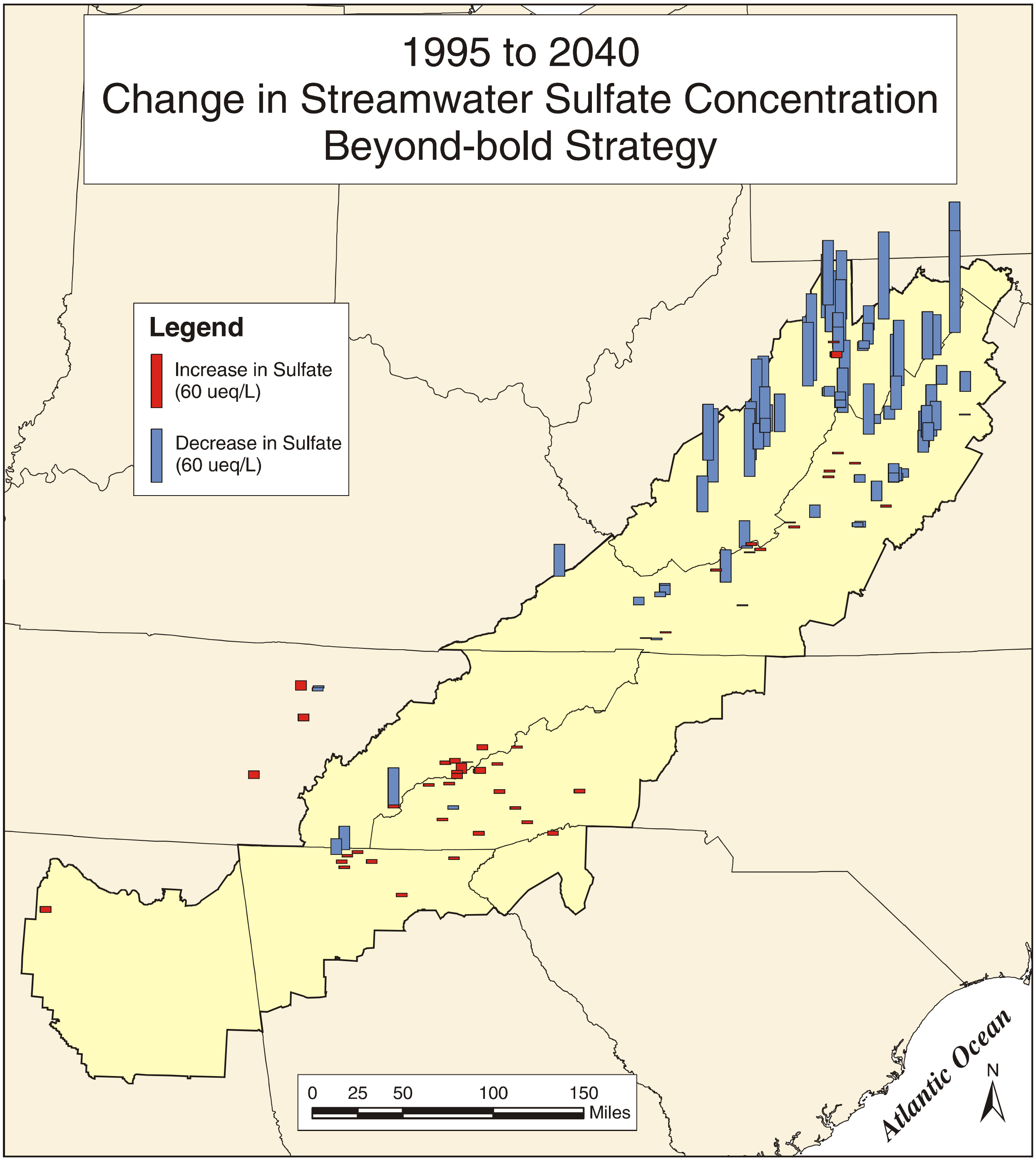

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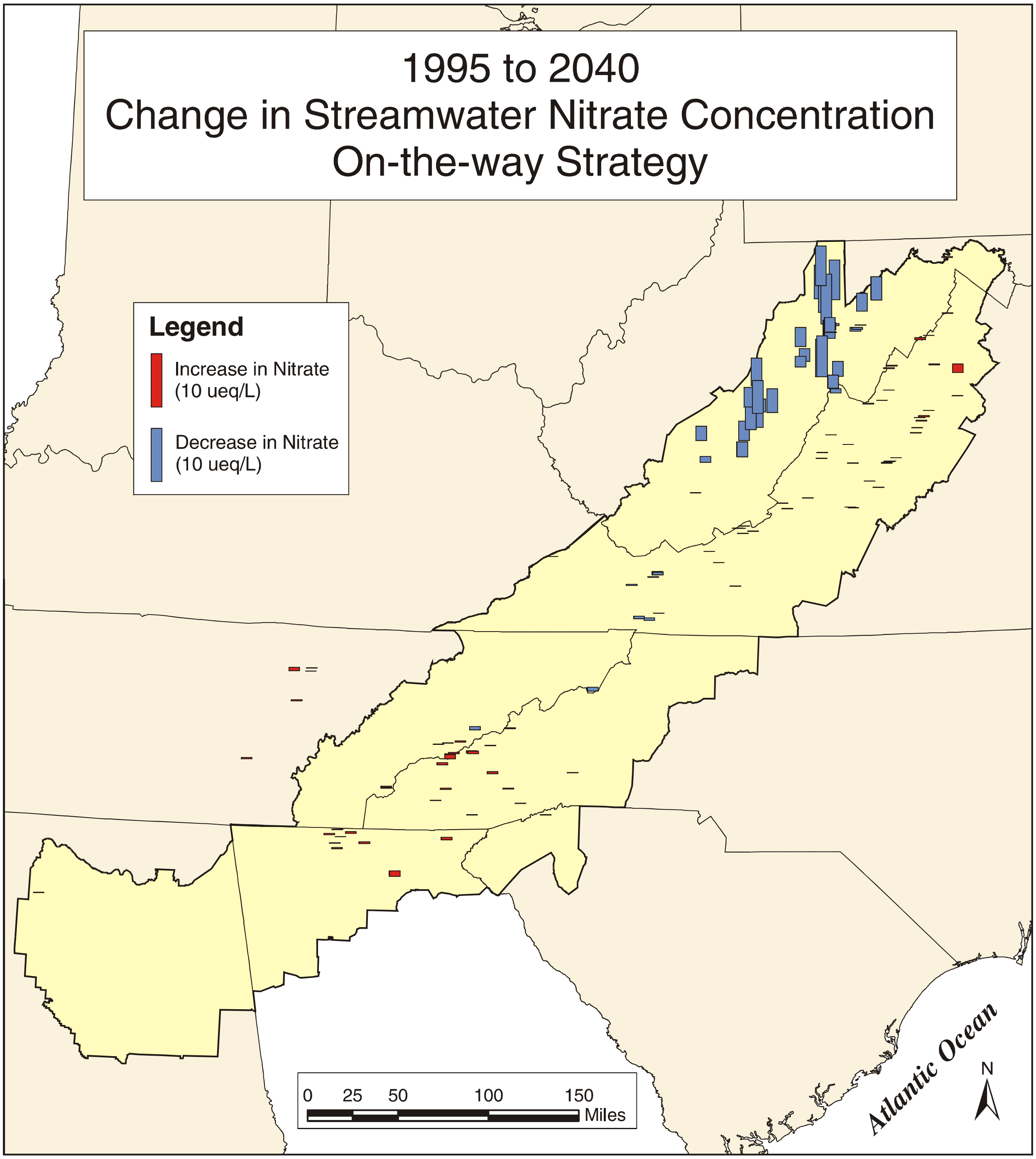
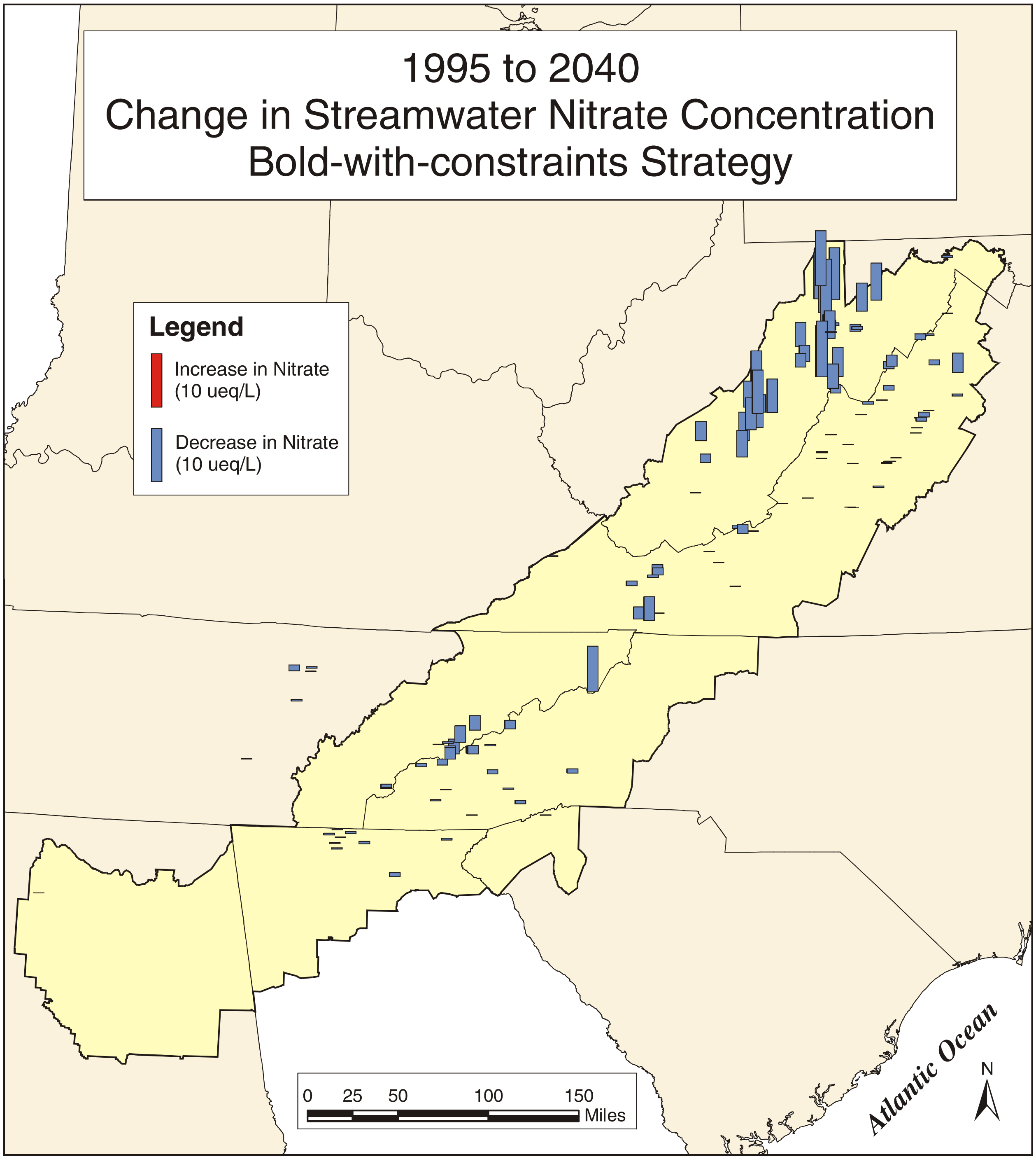


Figure 4-11. Maps showing simulated changes in streamwater nitrate concentration from 1995 to 2040 in response to each of the three Emissions Control Strategies.



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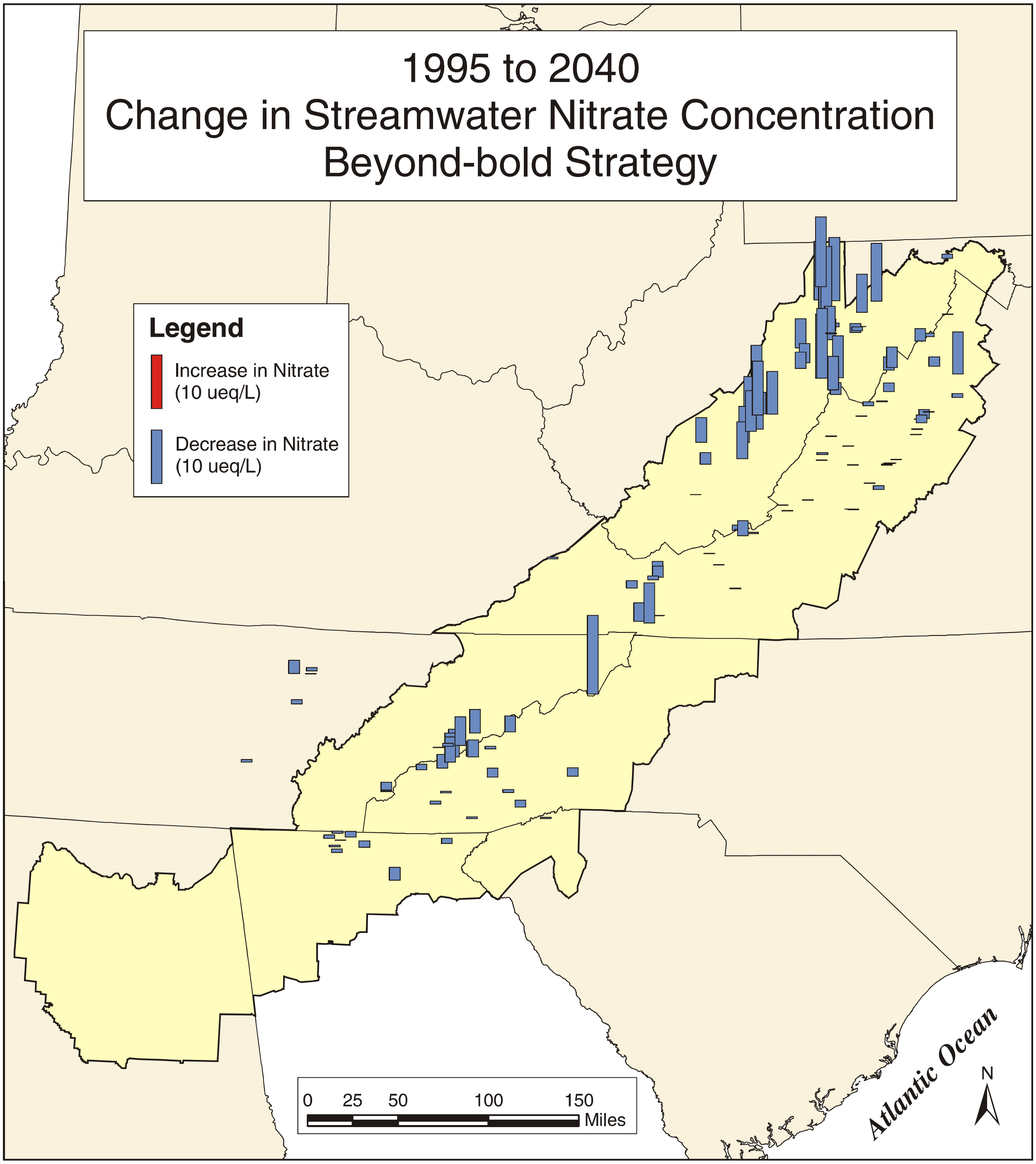


Figure 4-11. Continued.

Table 4-1. MAGIC model projections of changes in streamwater chemistry (25th, 50th, and 75th percentiles) at regional modeling sites from 1995 to 2040 under the Emissions Control Strategies and the scenario of constant future deposition at 1995 levels. Units are in μeq/L.

	OTW			BWC			BYB			Constant 1995 Deposition		
Parameter	25	50	75	25	50	75	25	50	75	25	50	75
Sulfate	-19.8	1.9	8.3	-27.4	-4.0	5.5	-36.3	-8.7	2.6	9.4	15.1	21.4
Nitrate	-0.70	0.03	0.10	-2.52	-0.58	-0.07	-3.92	-1.00	-0.15	-0.02	0.00	0.00
Sum of Base Cations	-24.7	-4.6	0.2	-28.8	-6.5	-1.4	-32.5	-7.6	-2.6	-7.4	-0.6	2.9
ANC	-10.3	-6.7	-3.6	-6.9	-4.2	0.2	-3.9	-1.3	4.3	-25.3	-19.3	-12.2

BYB strategy, which called for the largest reductions in emissions and deposition of sulfur and nitrogen.

In response to the OTW strategy, streamwater sulfate concentrations were simulated to decrease substantially (> 20 μeq/L) at about one-fourth of the sites, mostly in West Virginia (Figure 4-10). These are the sites that are currently closest to sulfur steady state. Because much of the incoming sulfur currently leaches out of these watersheds as streamwater sulfate, a substantial decrease in sulfur input would be expected to cause a substantial decrease in sulfate output, and this is what was projected by the model. Most sites outside West Virginia showed modest (< 10 μeq/L) increases in streamwater sulfate concentration in response to the OTW Strategy even though sulfur deposition was simulated to decline substantially. These sites are currently retaining a high percentage of the sulfur input and are expected to exhibit gradual decreases in sulfur adsorption on soils over time, thereby leading to higher concentrations of sulfate in streamwater. This simulated increase in streamwater sulfate concentration has the potential to contribute to further acidification. The BWC and BYB strategies resulted in progressively larger and more widespread declines in streamwater sulfate concentrations (Table 4-1, Figure 4-10). Although some sites continued to show simulated increases in streamwater sulfate concentration for both of these strategies, these increases became progressively smaller in magnitude and more confined geographically to the southern portion of the SAMI region (Figure 4-10).

In response to the OTW strategy, streamwater nitrate concentrations increased at some sites and decreased at others. Simulated changes in streamwater nitrate concentration were largest for those sites that exhibited the highest nitrate concentrations in 1995. These largest changes were primarily decreases in concentration, and they were mostly located in West Virginia. Streamwater nitrate concentrations decreased at nearly all sites under the BWC Strategy and at all sites under the BYB Strategy (Figure 4-11). Again, the largest and geographically most consistent decreases in projected streamwater nitrate concentration were in West Virginia, and to a lesser extent near the North Carolina-Tennessee border.

The changes in streamwater sulfate and nitrate concentrations in response to the Emissions Control Strategies, discussed above, coupled with simulated changes in base cation concentrations and soil base saturation resulted in varying simulated changes in streamwater ANC (Figure 4-12). Each of the strategies resulted in projections of increased ANC in some streams and decreased ANC in others. Progressively more of the sites were projected to show increased ANC as emissions and deposition were reduced in the sequence of larger emissions reductions from the OTW to BYB Strategies. Sites projected to increase in ANC were all in the north (West Virginia and northern Virginia) in OTW and mostly in the north in BWC and BYB. The vast majority of sites showed projections of some continued acidification under the OTW and BWC Strategies, suggesting a general deterioration of future streamwater acid-base chemistry. With the larger emissions controls of the BYB Strategy, the majority of the northern sites showed projected increases in ANC, although most sites in the South still showed projected continued acidification (Figure 4-12).

There were rather pronounced differences in projected streamwater responses to the various strategies in the south versus the north. In the south, projected streamwater sulfate concentrations increased at most sites under most strategies. In addition, projected nitrate concentrations either increased very slightly (e.g., many sites in OTW) or decreased by a small to modest amount (< 5 μeq/L at most sites). Virtually all southern sites under the OTW and BWC Strategies, and almost all southern sites under the BYB Strategy, were projected to continue to acidify. This projected acidification was substantial (> 10 μeq/L) at many sites in the OTW, and to a lesser extent BWC, Strategy; under the BYB Strategy, however, the projected continued acidification was generally < 10 μeq/L. It was much more strongly associated with change in streamwater sulfate concentration than with change in nitrate concentration. At a few sites, including those where sulfate concentration decreased, base cation concentrations were projected to decrease by more than 5 to 10 μeq/L, especially in the BYB Strategy (Figure 4-13).

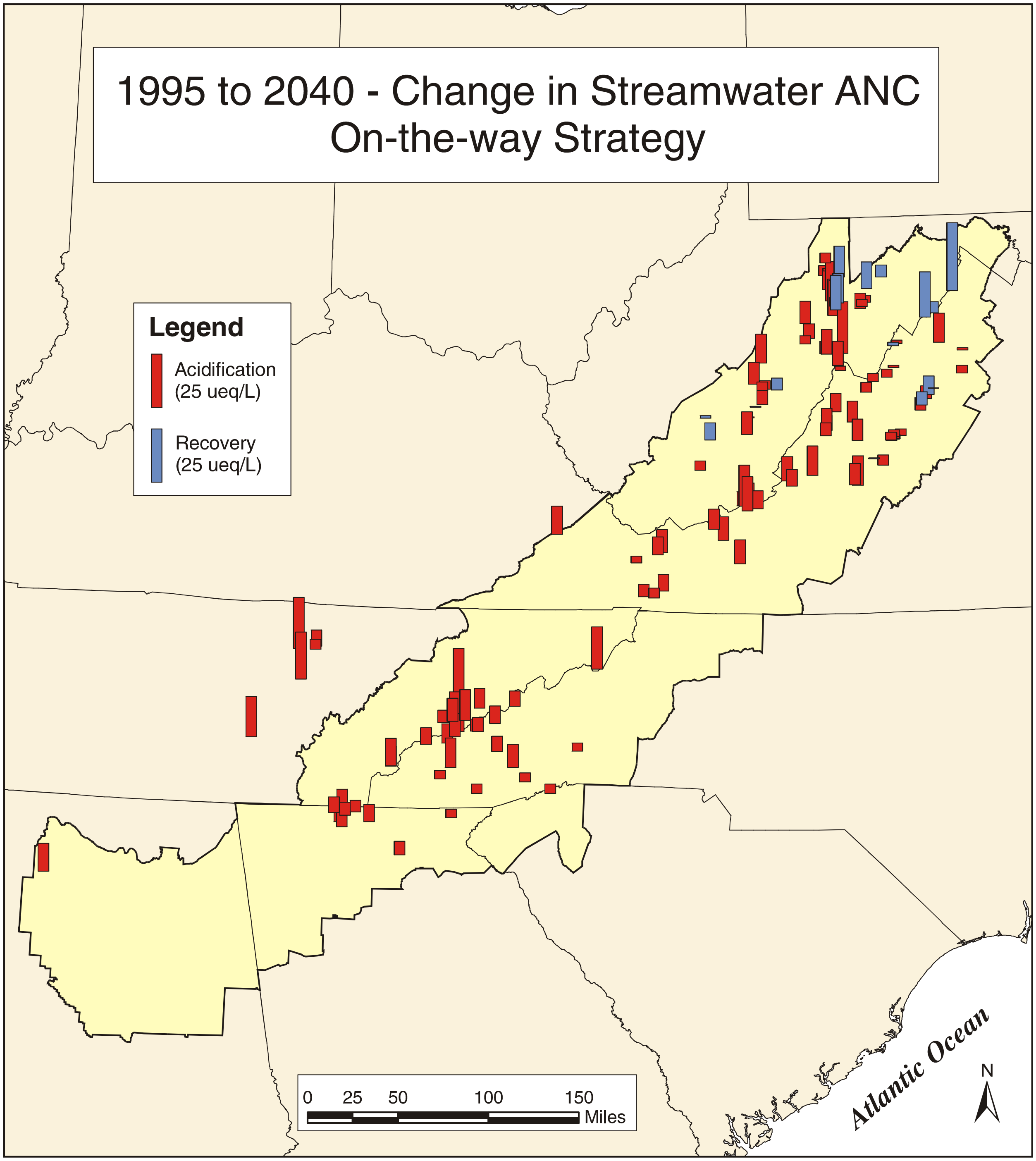
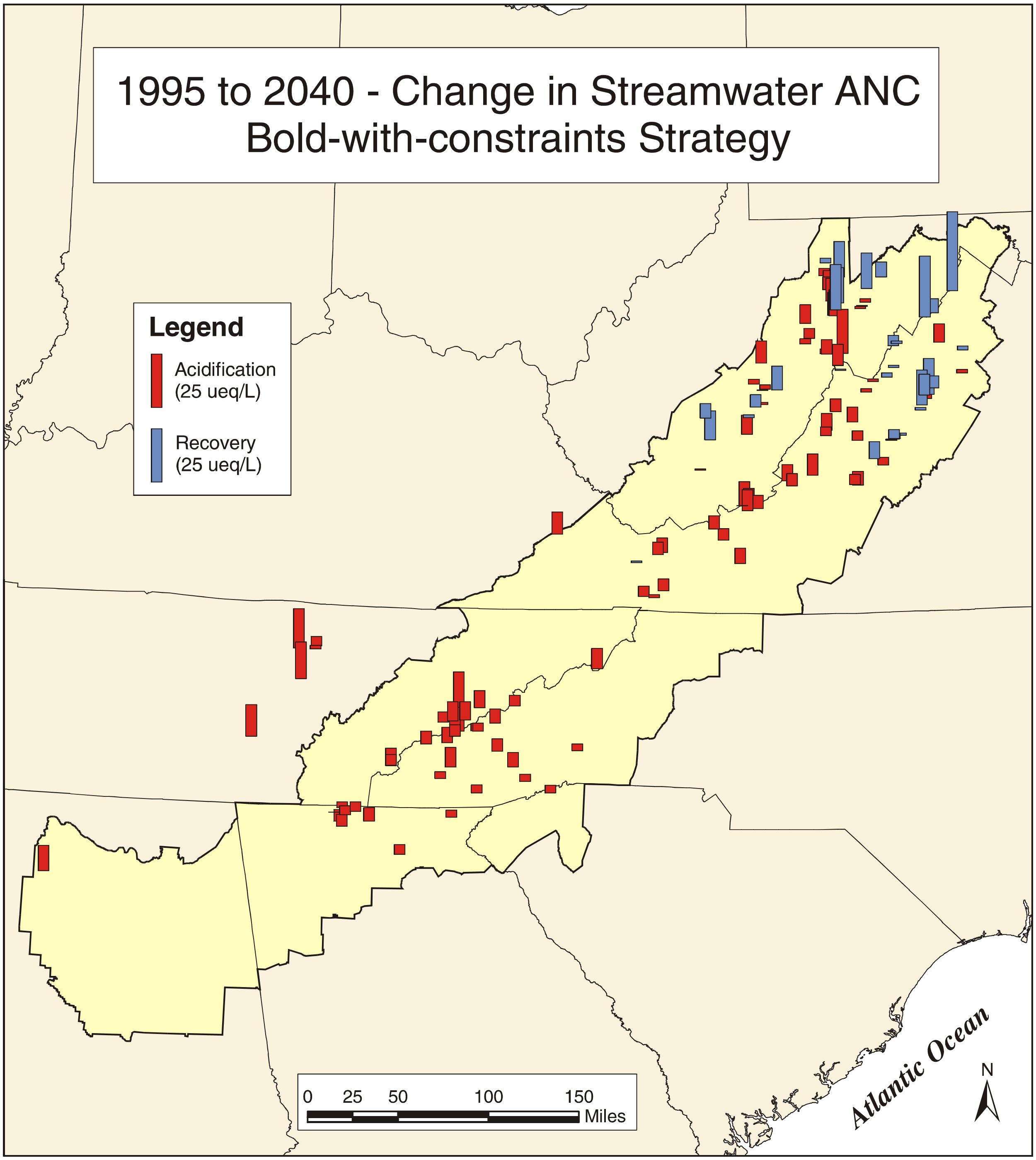


Figure 4-12. Maps showing simulated changes in streamwater ANC from 1995 to 2040 in response to each of the three Emissions Control Strategies.



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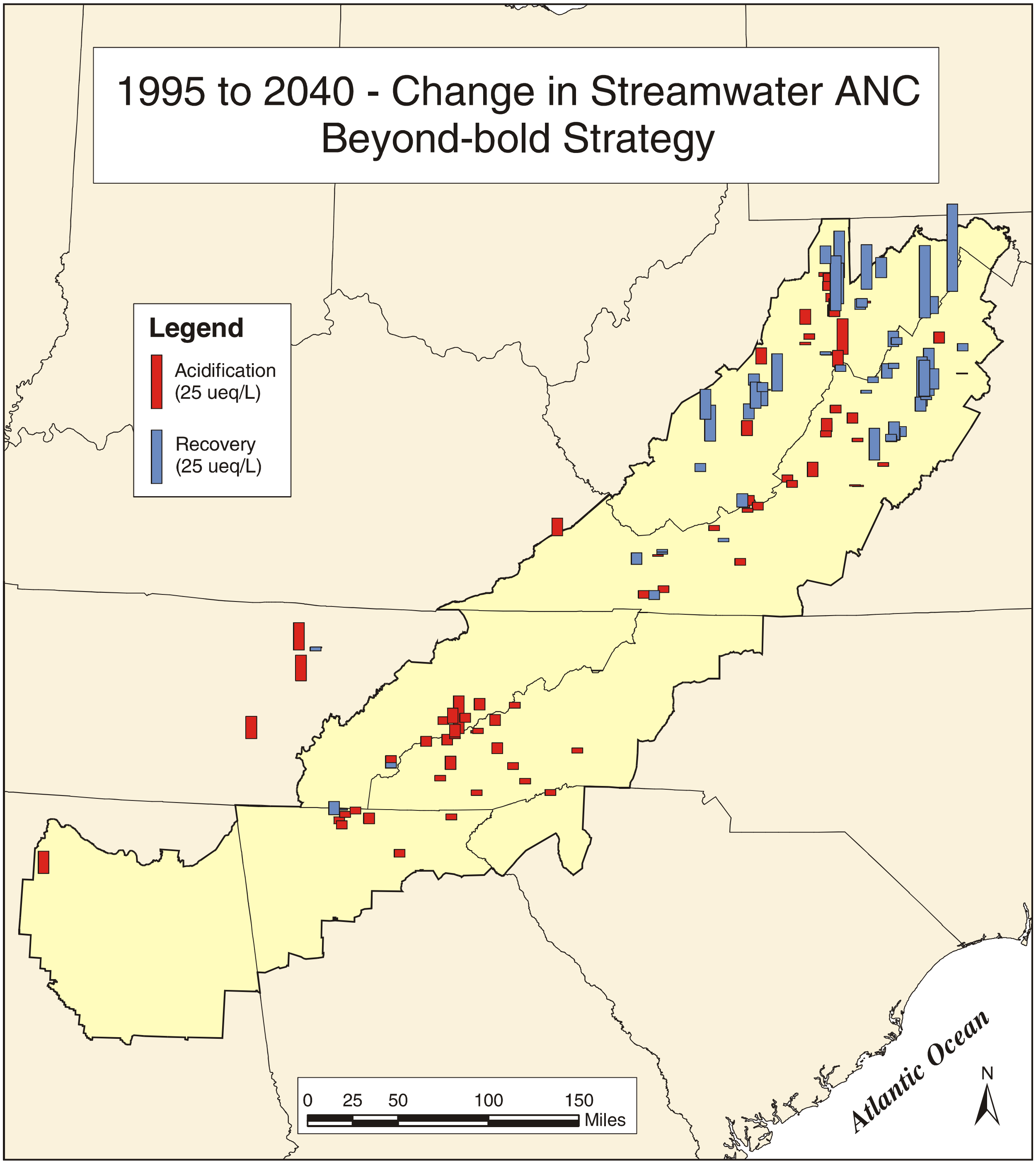

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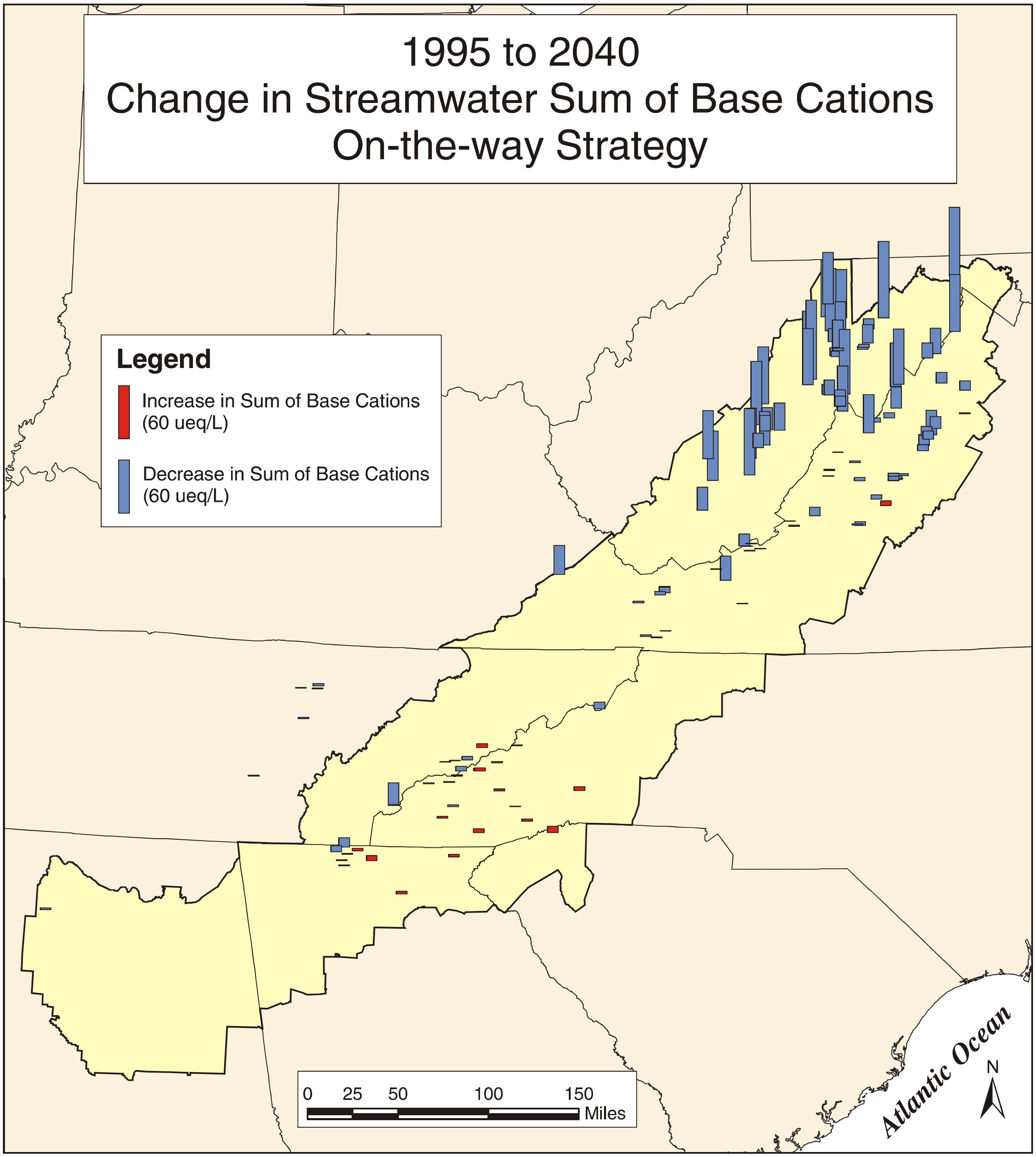
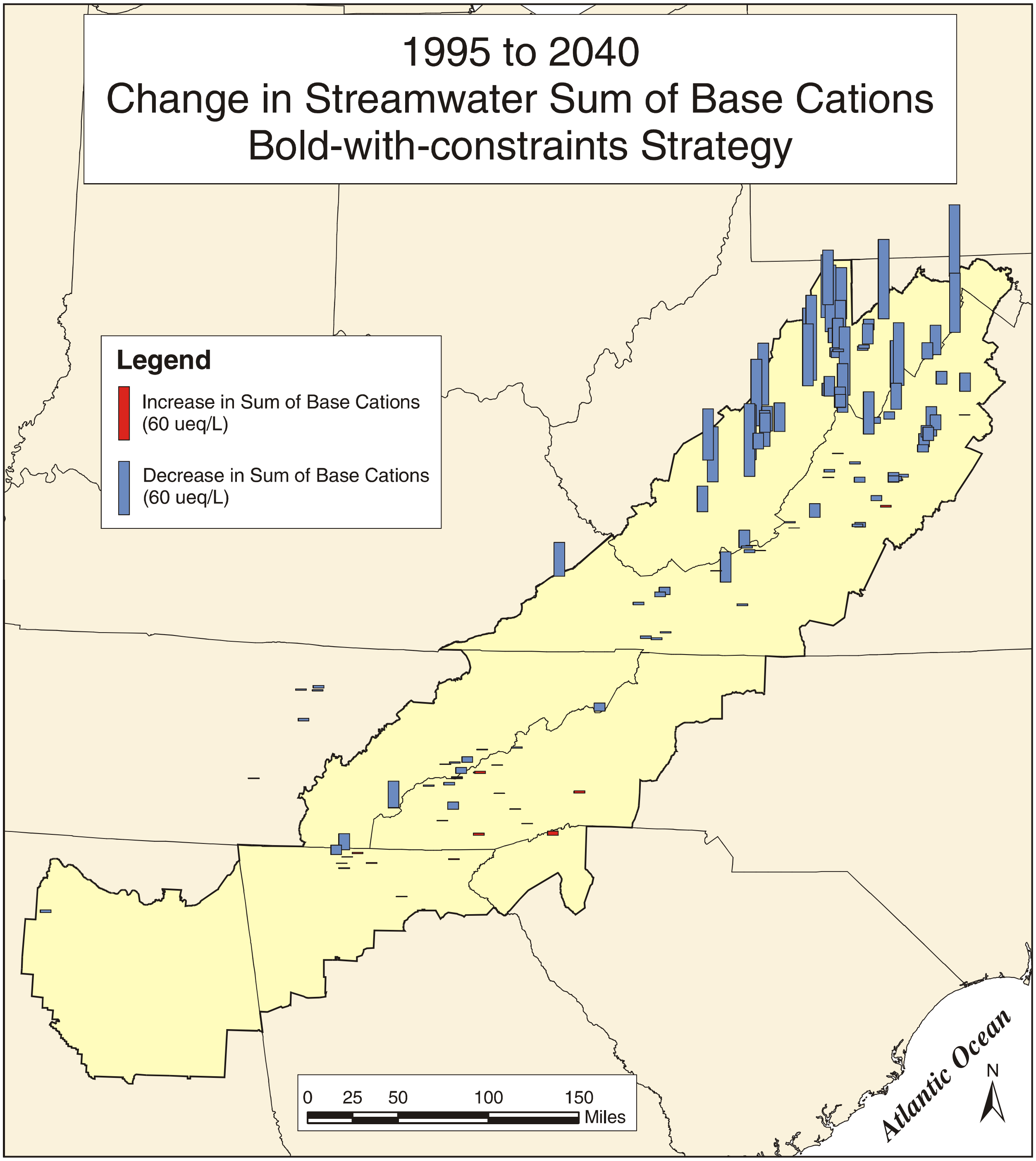


Figure 4-13. Maps showing simulated changes in streamwater sum of base cations from 1995 to 2040 in response to each of the three Emissions Control Strategies.



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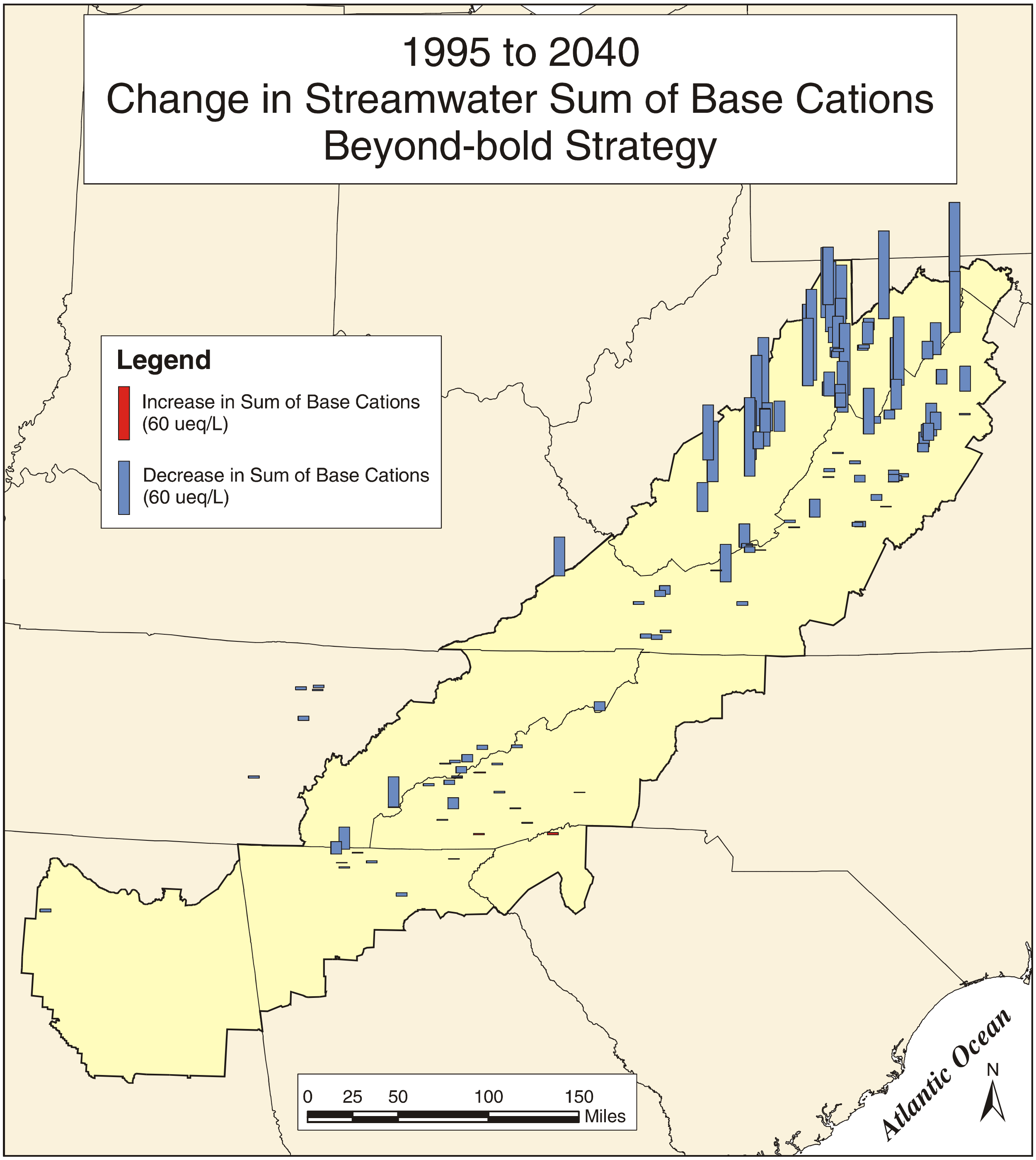


Figure 4-13. Continued.

The picture of projected changes in streamwater chemistry was very different in the northern part of the SAMI region. There, projected streamwater sulfate concentrations decreased substantially at most sites in the OTW Strategy to almost all sites in the BYB Strategy. The observed gradient from south to north in projected streamwater sulfate concentrations was further complicated by observed gradients in sulfate and other parameters from the Blue Ridge to the Appalachian Plateau physiographic provinces (from southeast to northwest in the northern half of the SAMI domain). These gradients are illustrated in Table 4-2, in which median values are given for key chemical variables, stratified by physiographic province, in the northeastern (Virginia and West Virginia) and also in the southwestern (other SAMI states) portions of the SAMI domain. Projected streamwater nitrate concentrations in the north showed moderate decreases (> 5 μeq/L) at many of the sites in the Appalachian Plateau physiographic province, especially in the BYB Strategy. The majority of the northern sites showed projections of continued acidification (decreased ANC) in the OTW strategy. The number of sites projected to continue to acidify and the magnitudes of projected acidification were less for the BWC, and especially the BYB Strategy. Thus, ANC was projected to decrease at many northern sites and strategies, in spite of rather large decreases in sulfate, and to a lesser extent, nitrate concentrations. This was because projected decreases in sum of base cation concentrations (Figure 4-13) were substantial at many of those sites (c.f., Table 4-2). The larger emissions reductions of the BYB Strategy were sufficient to offset this base cation depletion and result in projected increases in ANC at many northern sites.

Results of the MAGIC simulations in response to the three Emissions Control Strategies are presented graphically in Figure 4-14 for the period 1995 to 2040 for all regional modeling sites in each of the 12 modeling bins. Within a given physiographic province and strategy, the magnitude of acidification, projected for the period 1995 to 2040, generally increased with increasing ANC class. Note that some sites were simulated to have acidified between the time of sampling and 1995, and therefore showed starting points below the lower cutoff of the respective ANC class. Most sites showed rather small simulated changes in streamwater ANC. Some sites showed continued acidification early in the simulation followed by ANC improvements later in the simulation. This pattern was most pronounced for the BYB Strategy.

The overall response of the modeled watersheds to the OTW Emissions Control Strategy suggested relatively modest future changes in streamwater chemistry at most sites. Most sites showed change of ANC (either up or down) from 1995 to 2040 of 20 μeq/L or less. This was in

Table 4-2. Projected changes in median values of streamwater chemistry at the regional modeling sites from 1995 to 2040 in each of the three Emissions Control Strategies, stratified into two segments of the SAMI region (northeast and southwest) and by physiographic province.

Physiographic Province	Number of Sites	Δ Sulfate	Δ Nitrate	Δ SBC	ΔANC
OTW STRATEGY					
Virginia and West Virginia					
Blue Ridge	16	1.8	0.03	-2.2	-4.0
Valley and Ridge	41	-0.45	0.02	-6.8	-6.6
Appalachian Plateau	34	-31.2	-3.5	-33.8	-4.4
North Carolina, Tennessee, South Carolina, Georgia, and Alabama					
Blue Ridge	33	8.8	0.15	1.0	-8.0
Appalachian Plateau	6	15.3	0.15	-1.2	-15.9
BWC STRATEGY					
Virginia and West Virginia					
Blue Ridge	16	-2.7	-0.04	-3.0	-1.0
Valley and Ridge	41	-5.6	-0.37	-8.2	-4.7
Appalachian Plateau	34	-36.3	-4.9	-38.4	-1.4
North Carolina, Tennessee, South Carolina, Georgia, and Alabama					
Blue Ridge	33	5.6	-0.48	-0.60	-5.4
Appalachian Plateau	6	11.6	-0.23	-1.9	-13.3
BYB STRATEGY					
Virginia and West Virginia					
Blue Ridge	16	-7.4	-0.09	-5.1	2.9
Valley and Ridge	41	-13.8	-0.36	-10.3	-0.83
Appalachian Plateau	34	-40.4	-5.8	-39.3	2.6
North Carolina, Tennessee, South Carolina, Georgia, and Alabama					
Blue Ridge	33	3.2	-1.0	-2.3	-3.2
Appalachian Plateau	6	7.2	-0.53	-3.1	-10.4

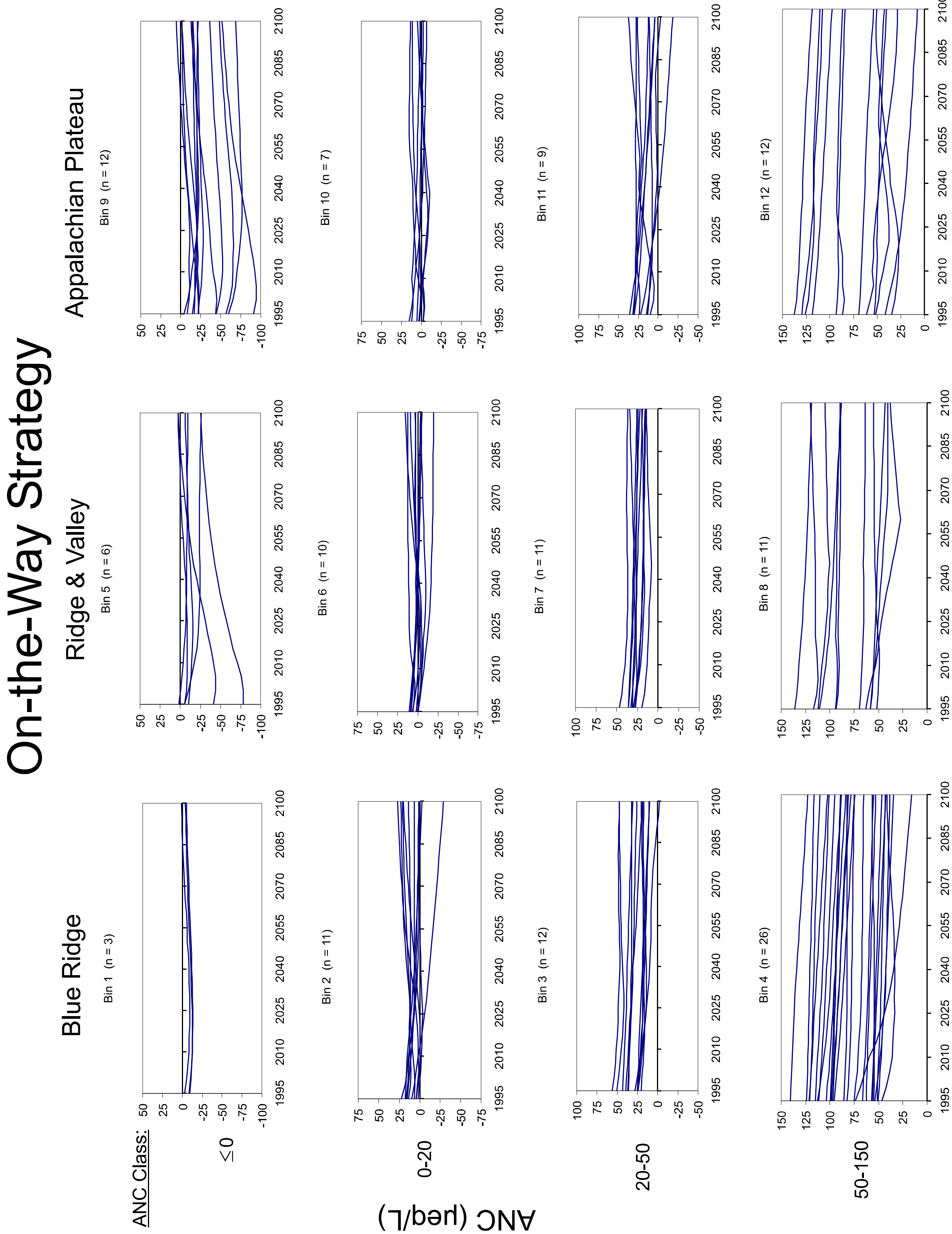
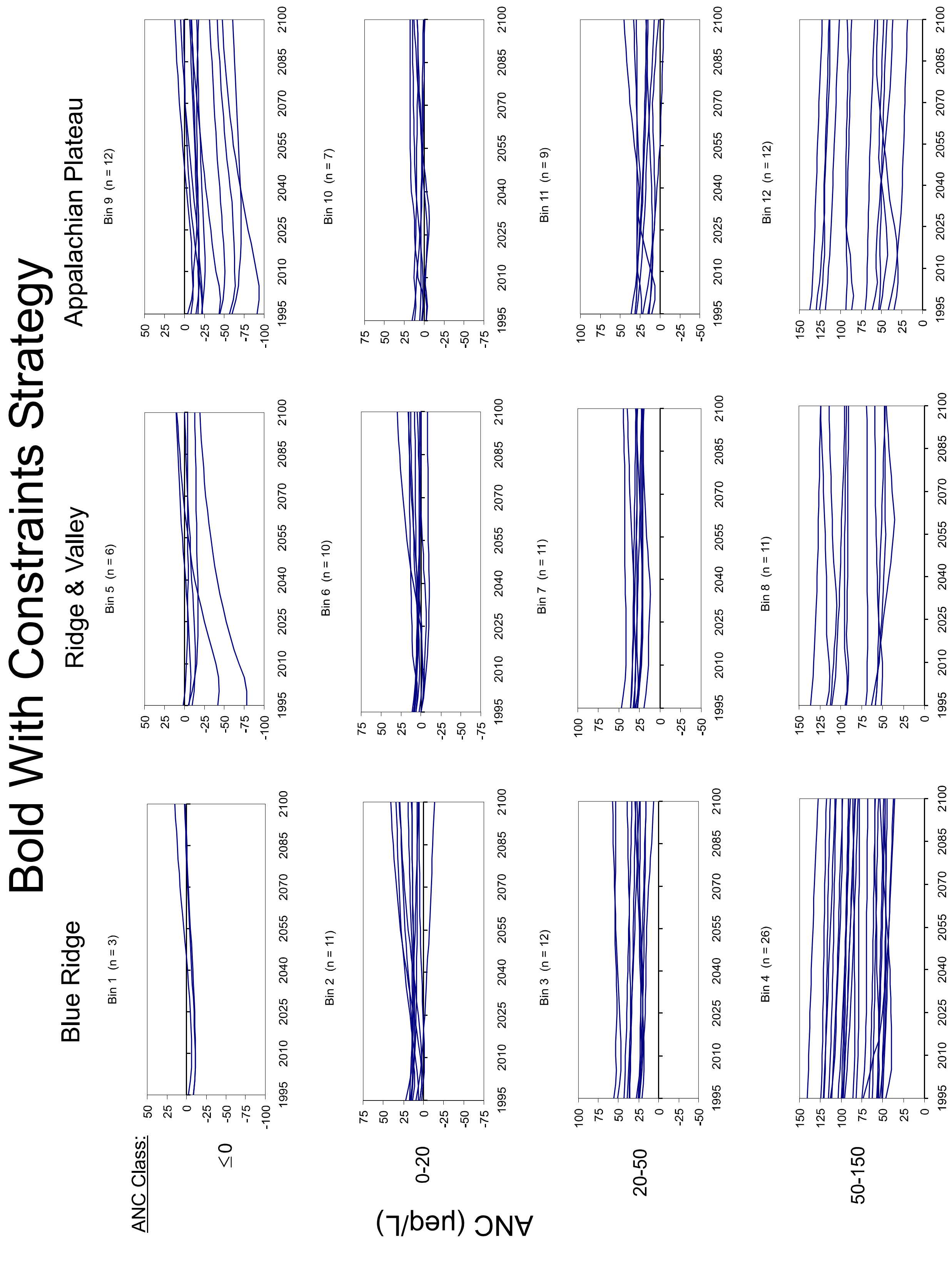


Figure 4-14. Simulated ANC response from 1995 to 2100 of all modeling sites within each of the 12 regional modeling bins in response to each of the three Emissions Control Strategies.



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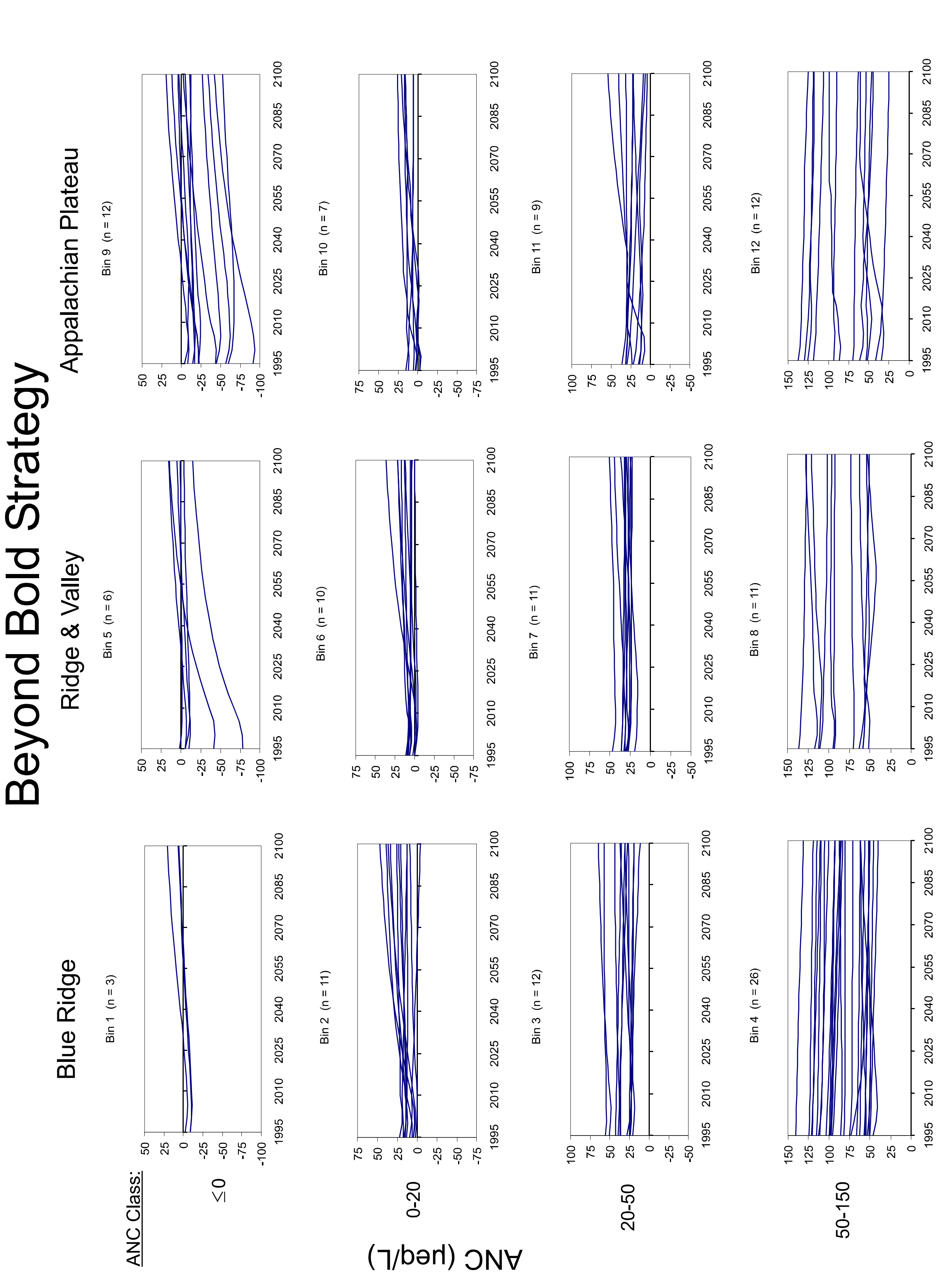


Figure 4-14. Continued.

spite of the large decreases in sulfur, and variable changes in nitrogen, deposition represented, on average across the region, by the strategies. Although individual modeled watersheds exhibited varying projections of future change, the typical response suggested either modest ANC increase or modest additional acidification of about 1 to 20 μeq/L over the course of the simulation. These model projections of change in ANC were small in comparison with the projections of continued future acidification if sulfur and nitrogen deposition were held constant into the future at 1995 levels (Table 4-1).

In general, the model simulations for the OTW strategy suggested that streamwater quality would decline at most sites. ANC projections showed a steady increase in the percent of the modeled group that was acidic, from 18% in 1995 to 25% in 2040. Concurrently, the percent of the modeled group that had ANC > 50 μeq/L was projected to decrease from 37% to 28%. The percent in the intermediate classes (0 to 20 and 20 to 50 μeq/L) showed little change (< 1%; Figure 4-15).

About 13% of the modeled group was projected to increase in ANC in response to the OTW strategy. These were primarily acidic and very low-ANC (≤ 20 μeq/L) streams in the Ridge and Valley and the Appalachian Plateau Physiographic provinces. They were mostly high in sulfate concentration (> 50 μeq/L) in 1995 and responded to the simulated large decreases in sulfur deposition with rather large decreases in streamwater sulfate concentration and increased ANC (Figures 4-12 and 4-16). However, almost all of the higher-ANC sites showed projected continued acidification (Figure 4-16).

The BWC strategy resulted in larger reductions in sulfur and nitrogen deposition, as compared with the OTW strategy. More sites showed improvement (increased ANC) in 2040, especially from among the acidic and very low-ANC classes (≤ 20 μeq/L, Figure 4-12). By 2010, the percent of the group that was simulated to be acidic increased from 18% in 1995 to 22%; this percentage decreased to 19% by 2040. Concurrently, the percent of the group represented by higher-ANC sites (> 50 μeq/L) decreased from 37% in 1995 to 33% in 2020, and then decreased to 31% by 2040. Thus, although the BWC Strategy resulted in a large number of sites that were simulated to show some increase in ANC, the majority of sites were simulated to continue to acidify, and the resulting percentages of modeled streams in various ANC classes suggested a general deterioration of water quality. This deterioration occurred largely in the first 15 years of the simulations, with some subsequent improvement.

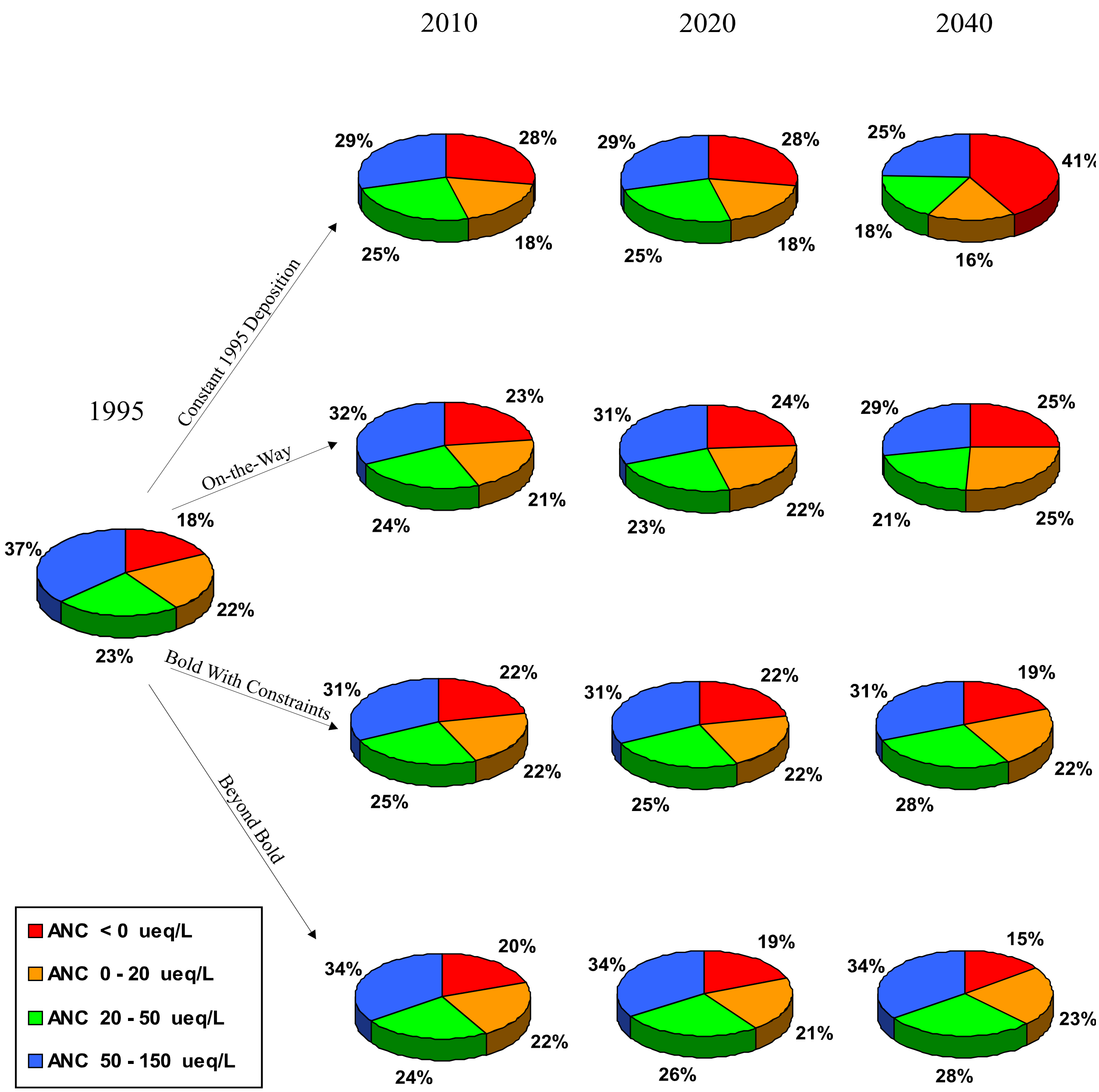


Figure 4-15. Pie charts of MAGIC model estimates of streamwater ANC in the reference year and in 2010, 2020, and 2040 in response to a scenario of constant deposition at 1995 levels and three Emissions Control Strategies. These percentages relate only to the group of 130 modeled streams, not to the population of streams within the region.

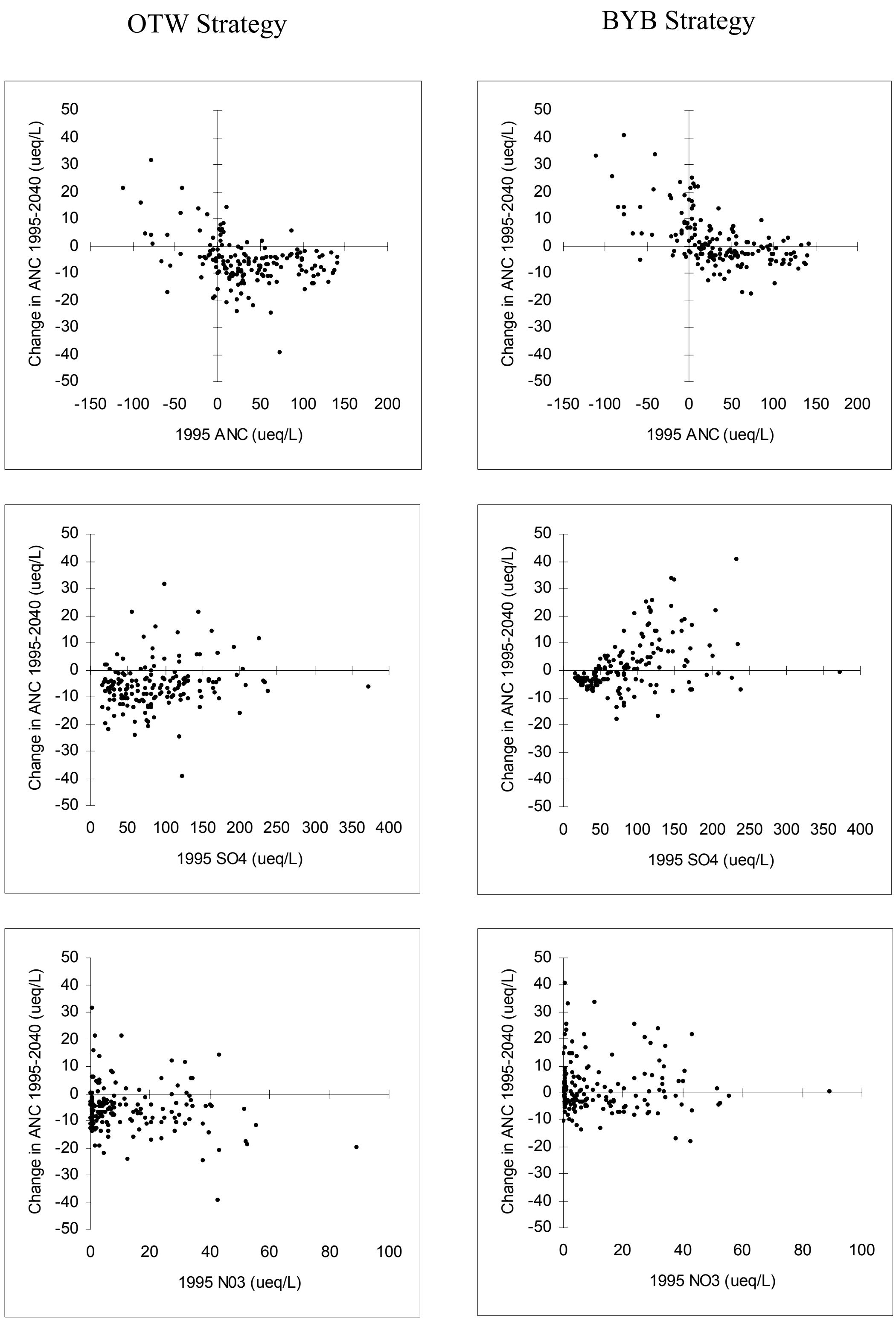


Figure 4-16. Scatter diagrams showing selected relationships between modeled responses and 1995 streamwater chemistry for the OTW and BYB strategies.

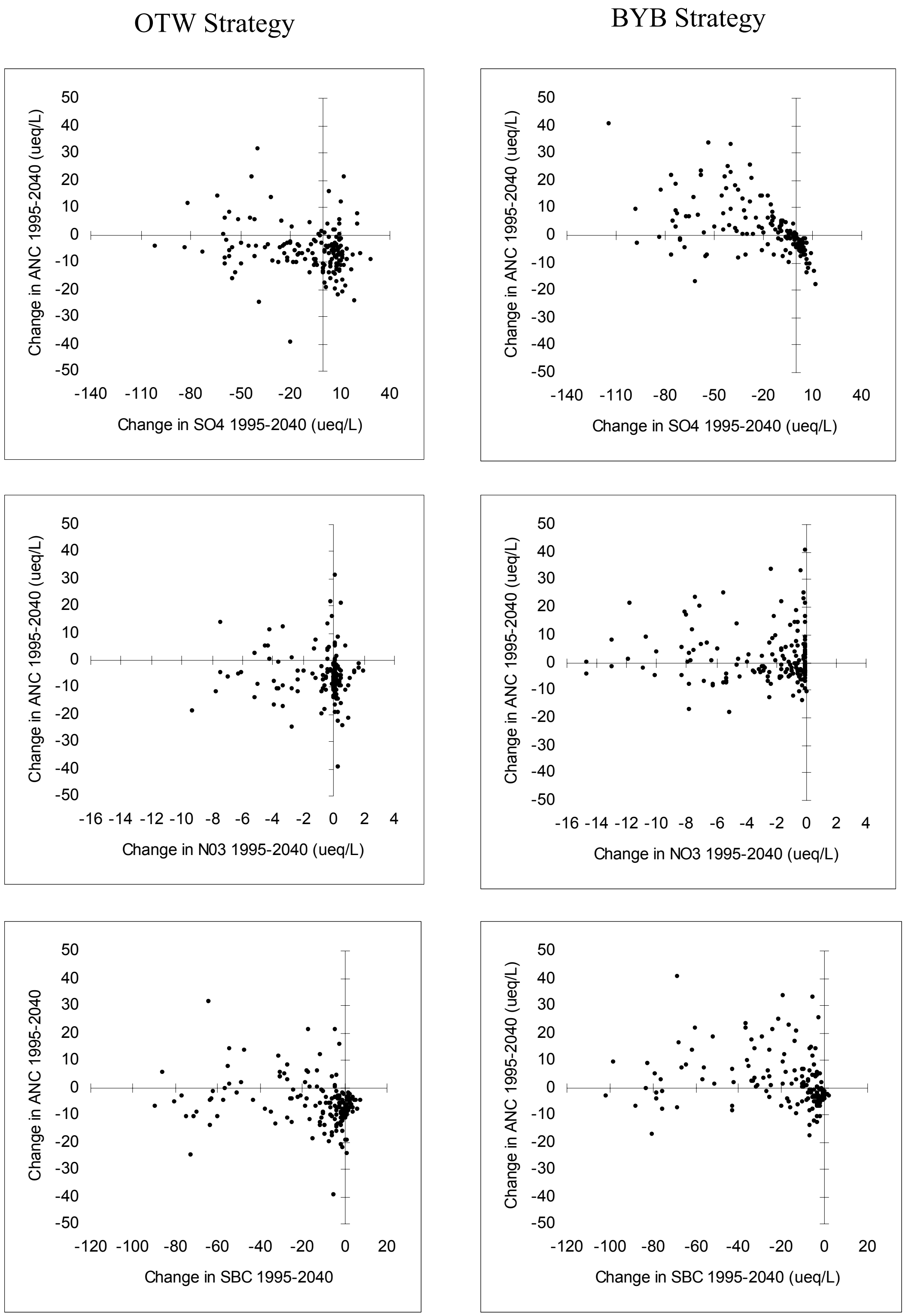


Figure 4-16. Continued.

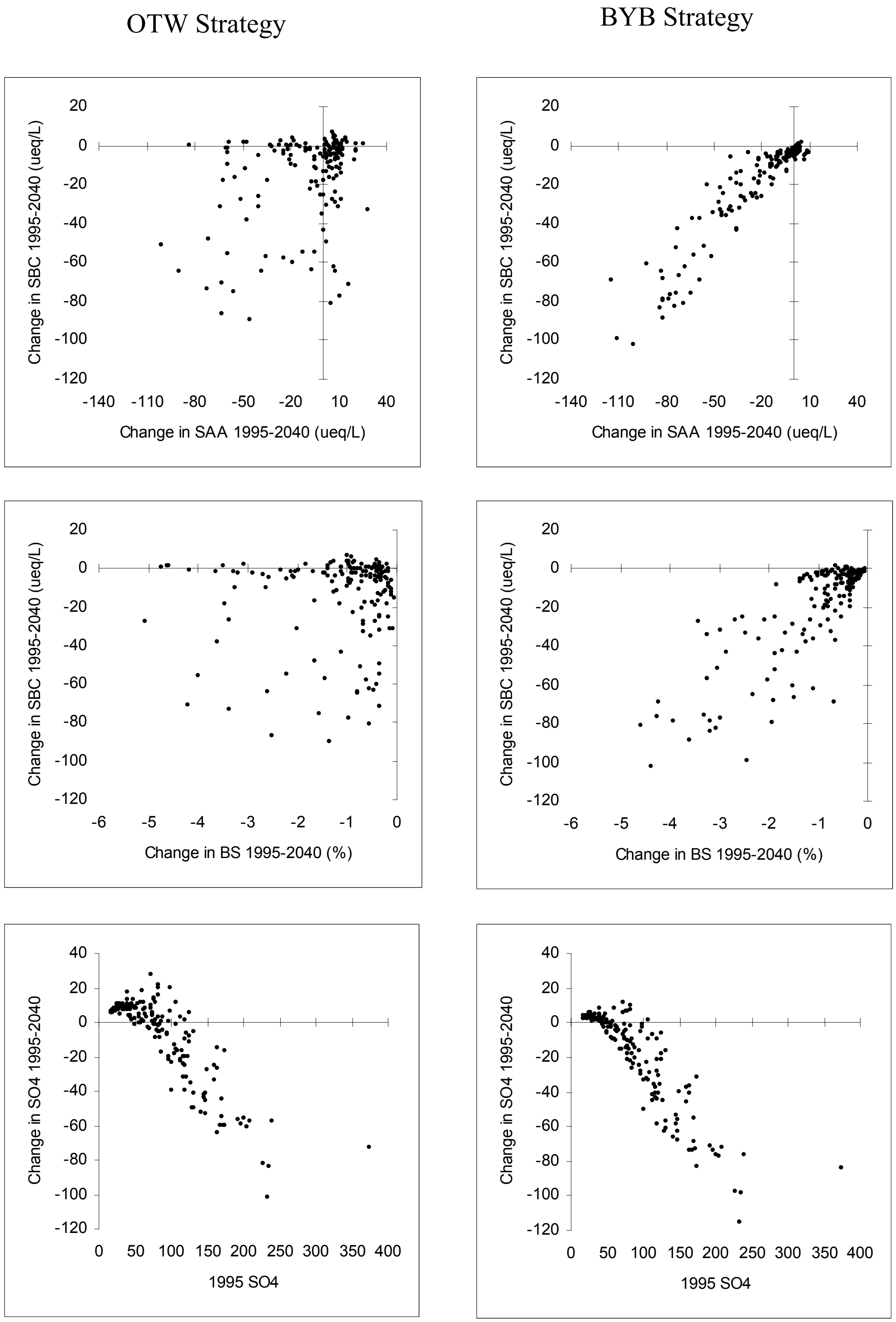


Figure 4-16. Continued.

The BYB Strategy resulted in the lowest level of both sulfur and nitrogen deposition of the three Emissions Control Strategies. Most sites showed a reduction in sulfur deposition of more than 70%, and a reduction of total nitrogen deposition of more than 30%. In response to these simulated decreases in deposition, the majority of the acidic and very low-ANC ($\leq$ 20 μeq/L) sites showed some ANC recovery by 2040 (Figure 4-16). The majority of the higher-ANC sites showed continued acidification.

The projected percentage of the group of modeled sites projected to be acidic or to have very low ANC ($\leq$ 20 μeq/L) was the same in 2040 as in 1995 under the BYB Strategy (45%), although there was an interim increase to 49% in 2010. In addition, the model projected that some of the sites that were acidic in 1995 shifted to the ANC class 0 to 20 μeq/L by 2040. Thus, the percent of the group projected to be acidic decreased from 18% in 1995 to 15% by 2040. The model also projected that some of the sites that were initially in the ANC class 50 - 150 μeq/L would shift to the 20 - 50 μeq/L class (Figure 4-15).

The model results suggested, in general, rather modest future changes and very little improvement in streamwater acid-base chemistry in response to the Emissions Control Strategies. However, these future changes in fact represent a pronounced improvement in acid-base chemistry as compared with what the model estimated would occur if emissions and deposition were maintained at 1995 levels into the future. Table 4-1 provides quantitative estimates of change in ANC, expressed as the median and quartile increases or decreases in streamwater ANC in the year 2040 for each of the SAMI emissions control strategies and the scenario of constant 1995 deposition. The various model bins showed a median decline in ANC that ranged from about 19 (constant 1995 deposition scenario) to 1 μeq/L (BYB Strategy; Table 4-1). The difference in projected median change in ANC from 1995 to 2040 among the three Emissions Control Strategies was small (range of median projected change in ANC was -7 μeq/L in the OTW Strategy to -1 μeq/L in the BYB Strategy) in comparison with the difference in projected median ANC between the scenario of constant deposition at 1995 levels and any of the strategies (difference in median projected ANC between constant deposition scenario and strategies ranged from -13 [OTW] to -18 [BYB]).

Thus, the model estimates of future change in streamwater ANC should be interpreted in light of the model estimates of likely future change in streamwater ANC in the absence of emissions reductions. Although the model suggested little or no improvement from the 1995 baseline in overall acid-base chemistry in response to the three strategies, these are actually quite substantial improvements in comparison with the estimated continued acidification that would be expected to occur without these emissions reductions.

There were observed patterns of projected ANC change related to the starting point (1995) ANC, the starting point sulfate concentration, and the simulated changes in sulfate concentration (Figure 4-16). However, projected acidification, or lack thereof, was not consistently associated with particular patterns in starting point nitrate concentration, change in nitrate concentration, or change in base cation concentration (Figure 4-16). Projected changes in the sum of base cations were negatively correlated with the projected changes in the sum of strong acid anions (mostly sulfate plus nitrate) and with the projected changes in soil base saturation for the BYB Strategy. Such correlations were much weaker for the OTW Strategy, which entailed smaller and more variable changes in deposition.

4.2.2.2 Long-term Responses

There is an additional factor that contributes to the observation of only small to modest changes in future streamwater ANC in response to implementation of the various Emissions Control Strategies. This has to do with the length of the time period of the model simulations. SAMI policy is based on consideration of model projections that extend to the year 2040. However, the dynamics of watershed acidification and recovery operate over much longer time periods (c.f., Warfvinge et al. 1992). At sites such as the acid-sensitive streams within the SAMI domain, the temporal aspects of sulfur adsorption and desorption may contribute further to changes in streamwater sulfate concentration (which in large part drive changes in ANC) that occur over many decades or longer. In addition, at the most acid-sensitive watersheds, base cations may have been depleted by more than five decades of high atmospheric sulfur loading and intensive human land use, including timber harvest and agriculture (c.f., Kirchner and Lydersen 1995, Lawrence et al. 1995, Sullivan et al. 1996, Likens et al. 1996, Lawrence and Huntington 1999). It is expected that it will take many decades or longer of low atmospheric sulfur loading for weathering reactions to restore the soil base cation pools to levels that approximate pre-acidification conditions.

The MAGIC model forecast results suggested that the recovery of many streams from acidification would continue well beyond 2040 under reduced atmospheric sulfur loading. Sites that showed improvement by 2040 in streamwater ANC, and also many sites that showed slight additional acidification (< about 10 μeq/L) between 1995 and 2040, showed continued improvement beyond 2040 (Figure 4-17). This effect is shown in the figure as sites below the 1:1 line on the right side of the graphs. Many of these sites showed further improvement between 2040 and 2100 of an additional 10 to 20 μeq/L or more of ANC. Some sites that showed projected acidification between 1995 and 2040 (sites on left side of graphs) exhibited further projected acidification after 2040. These sites are represented by points above the 1:1 line on the left side of the graph. Under the BYB strategy, the percent of modeled streams that were projected to be acidic declined to an estimated 8% acidic in 2100. Thus, the projected improvement from 1995 (18% acidic) to 2040 (15% acidic) was only about one-third of the projected improvement from 2040 to 2100, even though deposition was held constant from 2040 to 2100 in the simulations.

4.2.3 Future Changes in Biology

Streams within the SAMI domain showed varying modeled responses to the Emissions Control Strategies, with some streams simulated in some strategies to improve and some to deteriorate in their acid-base chemistry. Sites projected to show increased ANC would be expected to become more hospitable for brook trout and for other species of aquatic biota. These projected improvements in biological conditions are attributable to decreased chronic toxicity and/or decreased likelihood of episodic toxicity of streamwater to sensitive species. Such an interpretation assumes that habitat characteristics other than acid-base chemistry (e.g., food, shelter, temperature, dissolved oxygen) are not limiting the particular species occurrence, growth, or health. Sites projected to show decreased ANC would be expected to become more inhospitable for aquatic biota.

It must recognized that some sites might change appreciably in future chemistry, and yet show little or no biological response. For example, a stream that is highly acidic currently might exhibit a large increase or decrease in ANC and remain essentially equally inhospitable. Conversely, a stream that currently exhibits biologically-favorable chemistry might experience a large ANC change with little change in biological status as long as the ANC remains above response thresholds. Nevertheless, in most cases, a decrease in ANC would generally be expected to have an adverse impact on some species, especially if the ANC is in the critical range from near zero to near or below 50 μeq/L. Similarly, an increase in ANC would generally be expected to have a beneficial impact on some species, especially if the ANC is in the critical range.

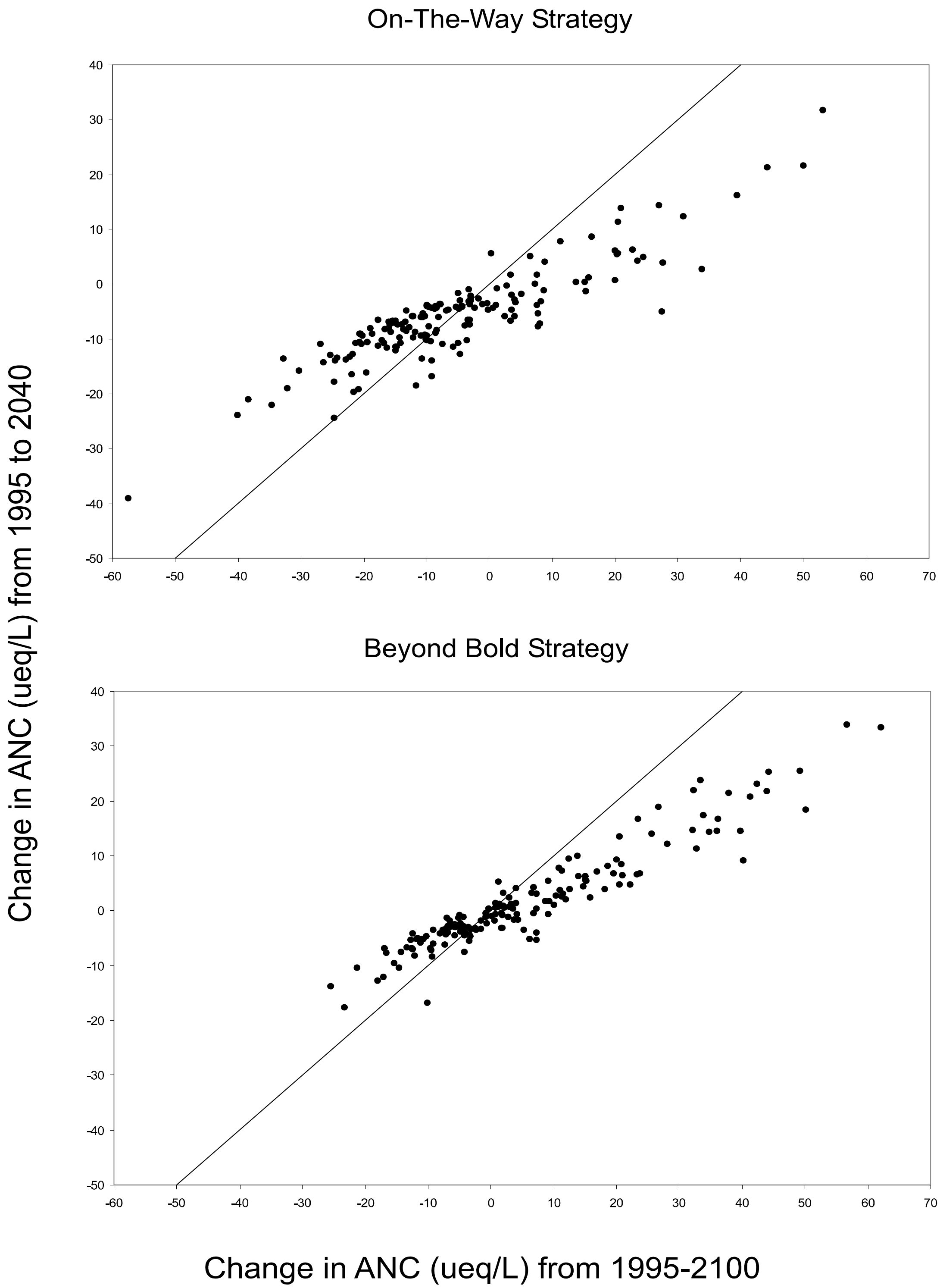


Figure 4-17. MAGIC model estimates of change in ANC from 1995 to 2040 as compared with change in ANC from 1995 to 2100. For this analysis, MAGIC projections were based on Emissions Control Strategies to 2040 and constant deposition thereafter. Points below the 1:1 line indicate improved water quality after 2040, whereas points above the 1:1 line indicate continued acidification after 2040.

Model results in response to the various Emissions Control Strategies did not indicate that large numbers of streams would be likely to shift in biological response categories (Figure 4-18). For example, the percent of modeled group of streams projected to be chronically acidic in 2040 ranged from an increase of 7.7% of the modeled group of streams in OTW to a decrease of 3.1% in BYB, compared with the 1995 reference value (Table 4-3). Similarly, the percent of the modeled group projected in OTW to be either chronically or episodically acidic was 7.7% higher in 2040, as compared with 1995 reference values. The percent projected to be either chronically or episodically acidic was 45.5% both in 1995 and in the 2040 projection for the BYB Strategy. That projected percentage increased to 51.5% and 53.1% in the BWC and OTW Strategies, respectively (Table 4-3).

Table 4-3. Percent of the 130 regional streams modeled with MAGIC* that were projected to be chronically acidic, episodically acidic, or transitional in 2040, as compared with 1995 values.

Strategy or Scenario	Projected Percent of Modeled Streams		
	Chronically Acidic	Episodically Acidic	Transitional
1995 Reference	18	28	18
Projections in 2040			
Scenario of constant deposition at 1995 levels	42	16	14
OTW Strategy	25	27	18
BWC Strategy	19	32	18
BYB Strategy	15	31	20

* These percentages only apply to the group of modeled streams. Percent changes for acidic and low-ANC streams in the population of streams that occur within the SAMI region are generally expected to be much smaller. Ths is because the acidic and low-ANC streams selected for modeling are not very common within the region (see Figure 4-20).

These results suggest that there would be only rather small differences among the strategies in the projected percent of streams in the various biological response categories. However, biological conditions were projected to be worse at most sites in 2040 under the OTW and BWC Strategies, as compared with 1995 reference conditions (Table 4-1, Figure 4-18). Biological conditions were projected to improve slightly under the BYB Strategy, based on the projected number of acidic and low-ANC streams. Under all of the strategies, biological conditions were projected to be dramatically better in 2040 than they would be under a scenario of constant deposition at 1995 levels. For example, the percent of the group projected to be acidic in 2040 was almost three times higher (42% of modeled streams) under the scenario of constant

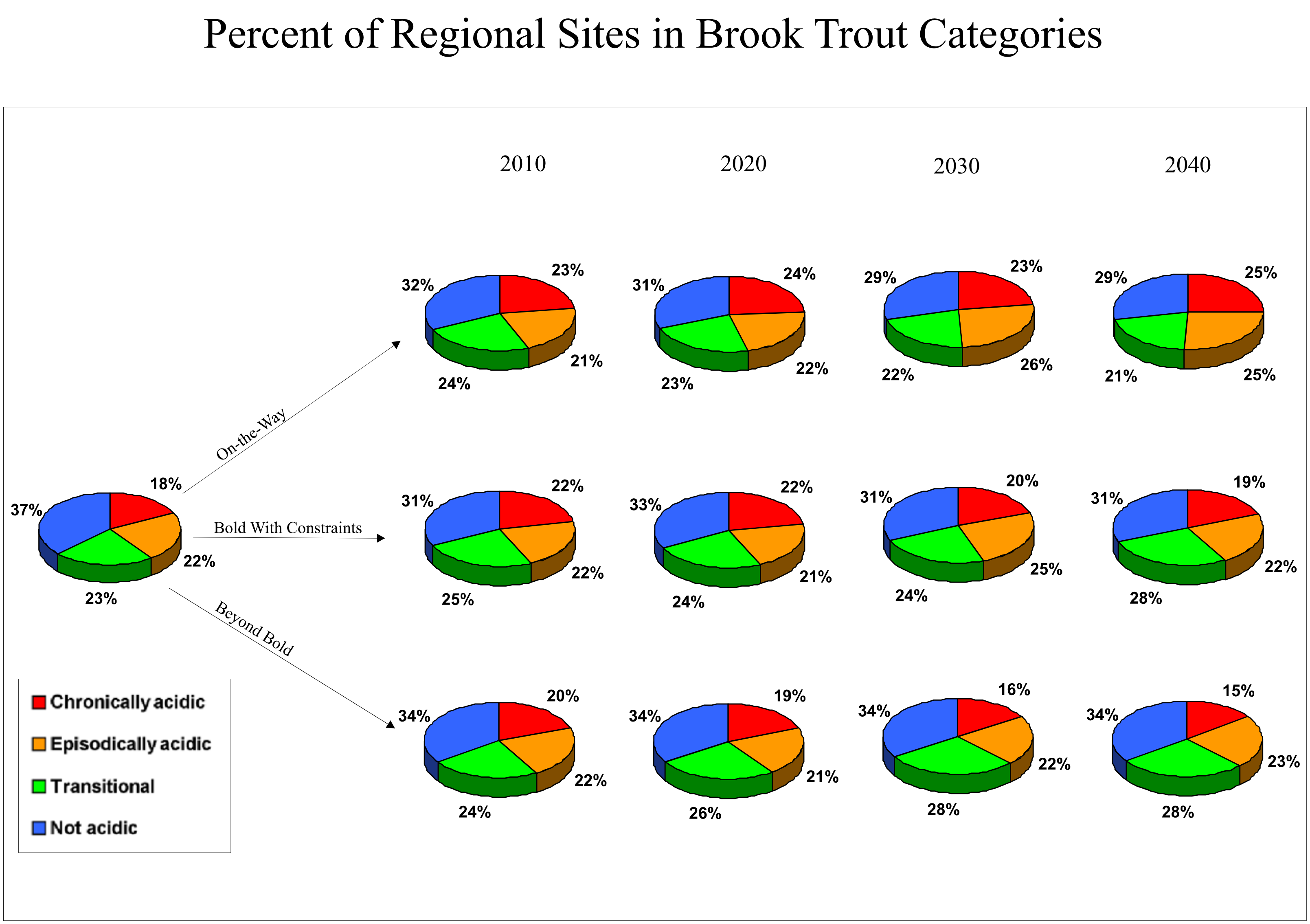


Figure 4-18. Pie charts of MAGIC model estimates of streamwater biological response classes in the 1995 reference year and in 2010, 2020, 2030, and 2040 in response to a scenario of constant deposition at 1995 levels and three Emissions Control Strategies. Results apply to the 130 modeled regional streams, not to the population of streams within the SAMI region.

deposition at 1995 levels as compared with the BYB Strategy (15% of modeled streams acidic in 2040).

4.2.4 Population Estimates

The regional extrapolation of modeling results to the population of streams in the SAMI region represented by the NSS statistical frame was based on the median value of the MAGIC simulation of the projected change in ANC of all streams within each of the modeling bins. This median change was calculated for the years 2010, 2020, 2030, and 2040 for each Emissions Control Strategy. As an example, the estimated change in ANC for each regional modeling site is given in Figure 4-19, grouped by modeling bin, for the period between 1995 and 2040. The median value for each bin was used to estimate the change in ANC from 1995 to a future year, under each of the strategies, that would occur at all NSS sites within the ANC class and physiographic province represented by that bin.

The median value of the ANC change simulated for each of the three strategies from 1995 to 2040 for sites within each bin is given in Table 4-4. These median values were used in the population estimation procedures.

There was not a clear indication that streams having high nitrate concentration responded differently than did streams having low nitrate concentration. This result suggests that the

Table 4-4. Model projections of median change in ANC from 1995 to 2040 under the three Emissions Control Strategies and under assumed constant 1995 deposition of all ions for each of the 12 modeling bins.

Physiographic Province	ANC Class	Median Simulated Change in ANC			
		OTW	BWC	BYB	Constant 1995 Deposition
Blue Ridge	≤ 0	-2.9	1.6	4.9	-14.7
	0-20	-10.4	-5.4	-0.6	-17.7
	20-50	-7.4	-4.7	-2.6	-16.1
	50-150	-5.1	-3.6	-2.7	-8.5
Ridge and Valley	≤ 0	-7.2	-2.0	1.9	-22.8
	0-20	-7.2	0.1	4.2	-18.2
	20-50	-8.5	-4.5	1.2	-19.0
	50-150	-4.7	-1.6	-0.4	-20.9
Appalachian Plateau	≤ 0	-4.1	1.6	4.8	-23.2
	0-20	-6.7	-2.1	7.4	-18.1
	20-50	-4.8	-2.8	-4.0	-26.2
	50-150	-9.0	-8.0	-4.3	-22.0

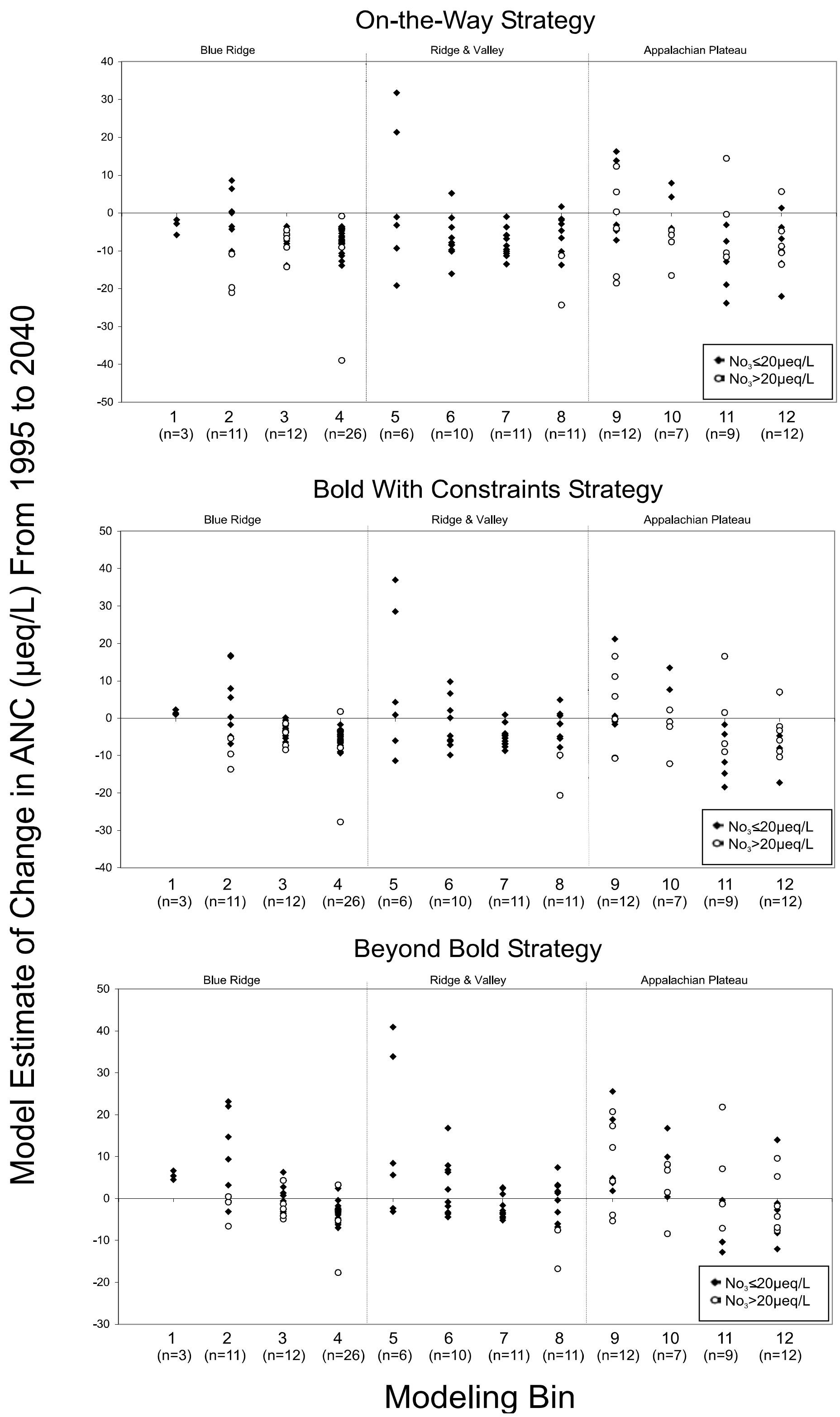


Figure 4-19. Model estimate of change in ANC from 1995 to 2040 for each of the Emissions Control Strategies, grouped by modeling bin. Points are coded (open or filled) by 1995 nitrate concentration.

modeled responses to changes in nitrogen deposition were not an appreciable component of the overall ANC response in most cases. Therefore, no attempt was made to stratify streams according to simulated nitrogen response.

The resulting population estimates for the years 1995, 2010, 2020, 2030, and 2040 are shown in Figure 4-20 for NSS upper node streams. Sixty percent of these streams had 1995 ANC > 150 μeq/L and were assumed to not change in ANC in the future by biologically meaningful amounts under any strategy (none of these high-ANC streams were modeled for this assessment). An estimated 7% of the upper node stream population was acidic in 1995. Model projections suggested that this percentage would increase to 10% in 2040 under OTW, but remain at 7% under BWC and BYB (Figure 4-20). Population projections for lower node streams also showed small changes. Only 3% were acidic in 1995. Model projections suggested that the percent acidic would remain constant under OTW, and decrease to 2% under BWC and 1% under BYB (data not shown). The among-strategy differences for both the upper and lower nodes are illustrated in Figure 4-21 for the year 2040.

Population estimates for the upper and lower nodes were combined to generate estimates of stream length within the various ANC classes (Figure 4-22). There was a small decline in the estimated length of projected acidic streams in 2040 from the OTW to the BYB Strategies. Otherwise, there was little difference in projected stream length in the different ANC classes as a consequence of adopting one or another Emissions Control Strategy.

4.2.5 Aquatic Resource Classification

The results of the regional analyses presented and discussed thus far pertain to numbers, percentages, and extent of affected streams within the SAMI domain. This assessment is quantitative in the sense that it estimates the percent of the resource assigned to different effects categories or how many kilometers of streams are likely to be affected in various ways by future emissions and deposition of sulfur and nitrogen. The population estimates are grounded in the NSS; in other words, numeric quantities presented in the population estimates relate only to the statistical frame of the survey. This frame population includes all streams that are depicted on USGS maps of a certain scale. This quantitative assessment provides little in the way of spatial information, however, other than to discriminate between streams that occur within the different physiographic provinces or between streams that occur in the north versus the south.

Figure 4-20. Population estimates of the percent of upper node streams, based on the NSS population of streams within the SAMI region, in the various ANC classes for the years 1995, 2010, 2020, 2030, and 2040. Results are presented for each of the three Emissions Control Strategies.

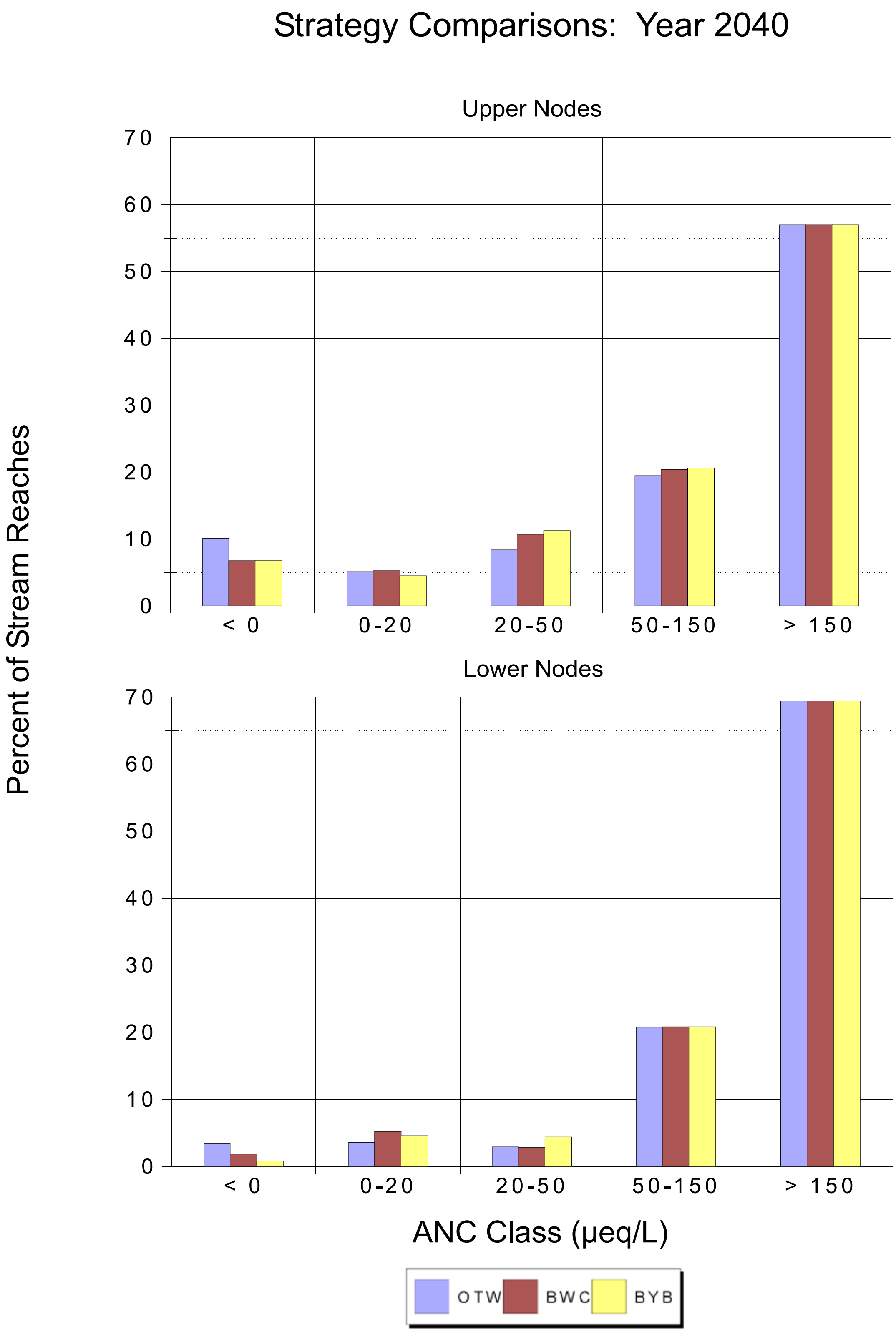


Figure 4-21. Among-strategy differences in population projections at both the upper and lower stream nodes, based on the NSS statistical frame within the SAMI region.

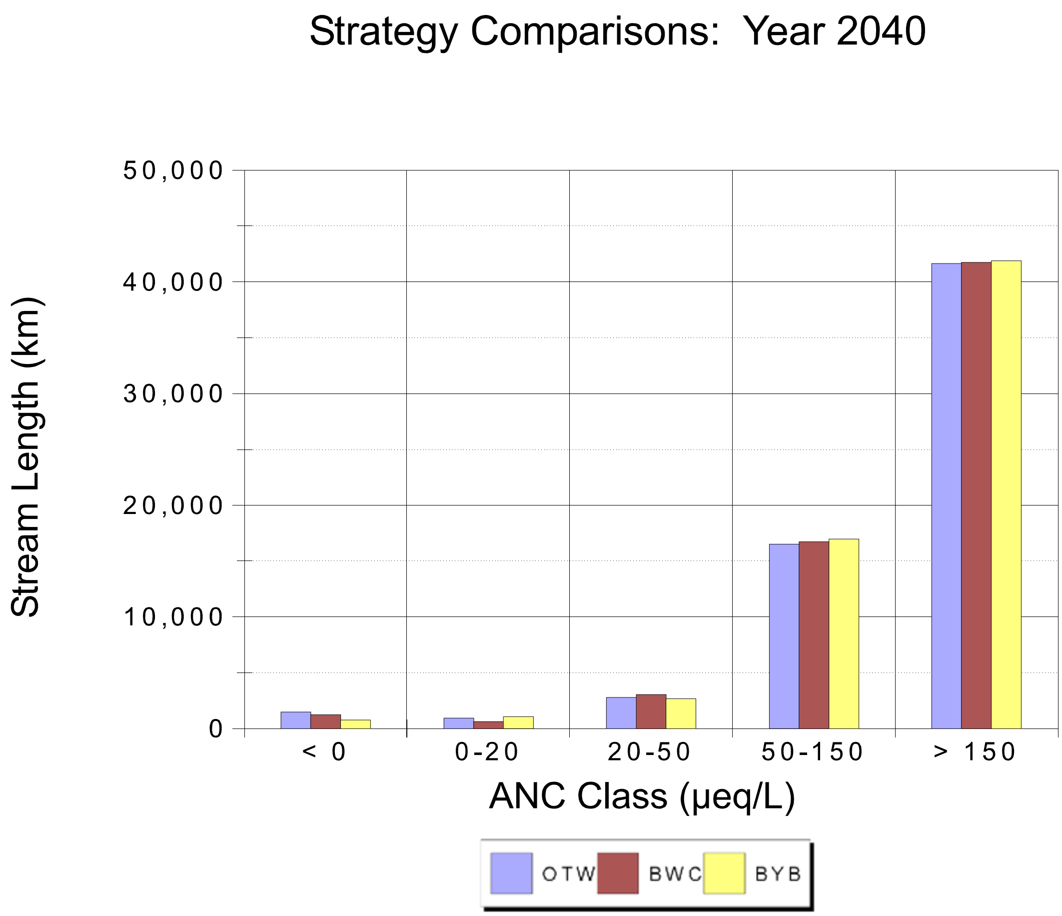


Figure 4-22. Estimated stream length in the SAMI region within various ANC classes in the year 2040 for each of the Emissions Control Strategies.

Additional questions that might be deemed to be important, but that cannot be addressed using the population-based data summarized above, could include the following:

- Where within the SAMI domain are the most acid-sensitive streams located?
- What portions of the region will see the greatest improvements in streamwater chemistry and biology in response to future emissions reductions strategies?
- Are there features of the landscape that correlate with current streamwater acid-base chemistry and/or sensitivity to change in streamwater acid-base chemistry in response to atmospheric deposition? If so, what are those features and how are they distributed across the landscape?

A regional aquatic resource classification scheme was developed to help us to address questions such as these, and it is described below.

4.2.5.1 Relationships Between Streamwater Chemistry and Watershed Features

A regional spatial analysis was conducted to determine the extent to which streamwater ANC in the SAMI region correlated with landscape features that were 1) known or suspected to be important contributors to surface water acidification sensitivity, and 2) available spatially for the entire study region. Such features included lithology, elevation, watershed area, watershed relief, forest vegetation type, soil type, and ecoregion. For example, relative to nonacidic streams in the mid-Atlantic Highlands region of the NSS, acidic streams tended to be located in smaller watersheds at higher elevation with steeper gradients. Acidic streams in the NSS were found almost exclusively at elevations > 300 m and in watersheds less than 20 km^2 (Herlihy et al. 1993).

The relationship between bedrock geology and the ANC of streams in the mid-Appalachian region has been well-recognized (Lynch and Dise 1985, DeWalle et al. 1987, Cosby et al. 1991, Puckett and Bricker 1992, Herlihy et al. 1993). Compared to other regions that have been glaciated and/or have deeper soils, the unglaciated shallow soils of the mid-Appalachian region appear to be rather closely associated with underlying bedrock with respect to their acid-base characteristics.

Lynch and Dise (1985) found that watersheds in Shenandoah National Park that had a larger proportion of their area above 2400 ft (732 m) had lower streamwater ANC. Such a gradient may have been due to the general observation that well-developed soils are less common at higher elevation, where slopes are often steeper and temperatures lower. Furthermore, slower weathering, and greater precipitation, acidic deposition, and base cation leaching at higher elevation likely all play significant roles in such observed relationships. Similar results have been found for Great Smoky Mountains National Park (Silsbee and Larson 1982).

The forest *per se* is not a major controlling variable for streamwater ANC. It can be, however, a useful indicator of the watersheds most likely to be sensitive to, and/or impacted by, acidic deposition in the SAMI region (Herlihy et al. 1993). Most acidic streams within the SAMI region are found in forested watersheds in the northen portion of the region, and streams with ANC < 50 μeq/L are also more common in forested watersheds. In particular, there is a clear distinction in the Valley and Ridge Province between the more acid-sensitive streams of the forested ridges and the less acid-sensitive streams of the valleys, which contain mixed land use (Herlihy et al. 1993).

Ecoregions were designed to provide a spatial framework for ecological assessments, research, inventory, monitoring, and management. They delimit large areas within which local ecosystems reoccur more or less throughout the region in a predictable pattern. Within a given ecoregion, the aggregate of all terrestrial and aquatic ecosystem components is different from, or less variant than, other areas (Omernik and Bailey 1997).

The effective extrapolation of watershed data regarding sensitivity to acidification requires a knowledge of the larger regions in which similar characteristics exist. Watersheds provide the study units and ecological regions are intended to provide the mechanism for extrapolation (Omernik and Bailey 1997). Watersheds within a given ecoregion will tend to be somewhat more similar to one another and different from those in other ecoregions (Omernik and Griffith 1991).

Ecoregions are depictions of ecosystem patterns that are created through a classification process that captures the spatial pattern of relatively homogeneous landscape areas at a specific scale (Bailey 1995, Omernik 1995, Bryce et al. 1999). Ecoregions can be redefined in different ways at different scales. The scale of application is important because the influence of specific landscape features (e.g., geologic class, vegetation type) on resource integrity (e.g., forest health, streamwater acid-base chemistry) is highly scale-dependent. For example, a stream located in a watershed that contains limestone, but that occurs in a region of largely granitic bedrock, will have high ANC even though the region as a whole may be best represented by low-ANC streams.

4.2.5.1.1 Lithology-based landscape classification

Previous work showed that watershed bedrock is a primary determinant of streamwater ANC and response to acidic deposition in the SA region (Lynch and Dise 1985, Bricker and Rice 1989, Webb et al. 1994, Webb 1999, and Webb et al. 2001). Bulger et al. (2000) demonstrated that classification of landscape by bedrock type can provide a basis for regionalizing the results of watershed acidification modeling in western Virginia. These observations, plus the availability of recently developed geologic map coverages for most of the SAMI region, suggested that a useful landscape classification scheme could be developed based in part on the relationship between lithology and streamwater ANC.

A first step toward development of a lithology-based landscape classification system involved extending the three-unit classification scheme developed by Peper et al. (1995) for use in the Southern Appalachian Assessment (SAA; SAMAB 1996). Based on evaluation of the utility of this initial work, a decision was made to proceed with development of a more-detailed, five-unit classification scheme for the SAMI region.

The streamwater composition data available for development and evaluation of a landscape classification scheme for the SAMI region were compiled in support of the SAMI aquatic effects assessment. Available water quality data were assembled for streamwaters associated with watersheds in both the SAMI region and in adjacent areas within physiographic provinces represented in the SAMI region. These data were obtained from a number of national and regional databases, including the NSS, EMAP, VTSSS, and a number of localized studies coordinated by the National Park Service, the USDA Forest Service, and the Tennessee Valley Authority. For this analysis, the available streamwater data were screened to only include sampling sites for which complete geologic map coverage was available for the watershed. The total number of sampling sites used in the analysis was 999. Figure 3-1 shows the location of the available sites in relation to the SAMI region.

Streamwater ANC served as the primary criterion variable for evaluation of the geologic classification scheme. A single ANC value was associated with each stream. In cases where multiple sample values were available, samples most nearly representing the spring of 1995 were selected.

The geologic map coverage that served as the basis for the landscape classification was provided by the Eastern Mineral Resources Team of the USGS, which has aggregated map units from available state geologic maps (1:500,000 scale or better) to develop uniform multistate lithologic maps (Bruce Johnson, USGS, Reston, VA, pers. comm. 2000). This coverage has been developed for all of the SAMI states except South Carolina, for which work is in progress (Figure 4-23). As described below, the 59 lithologic units represented in this regional coverage for the SAMI study area were further aggregated into a five-unit landscape classification scheme. A geographic information system (GIS) was used to calculate the percentage distribution of each of the USGS lithologic map units and the derivative landscape classes in each of the study watersheds.

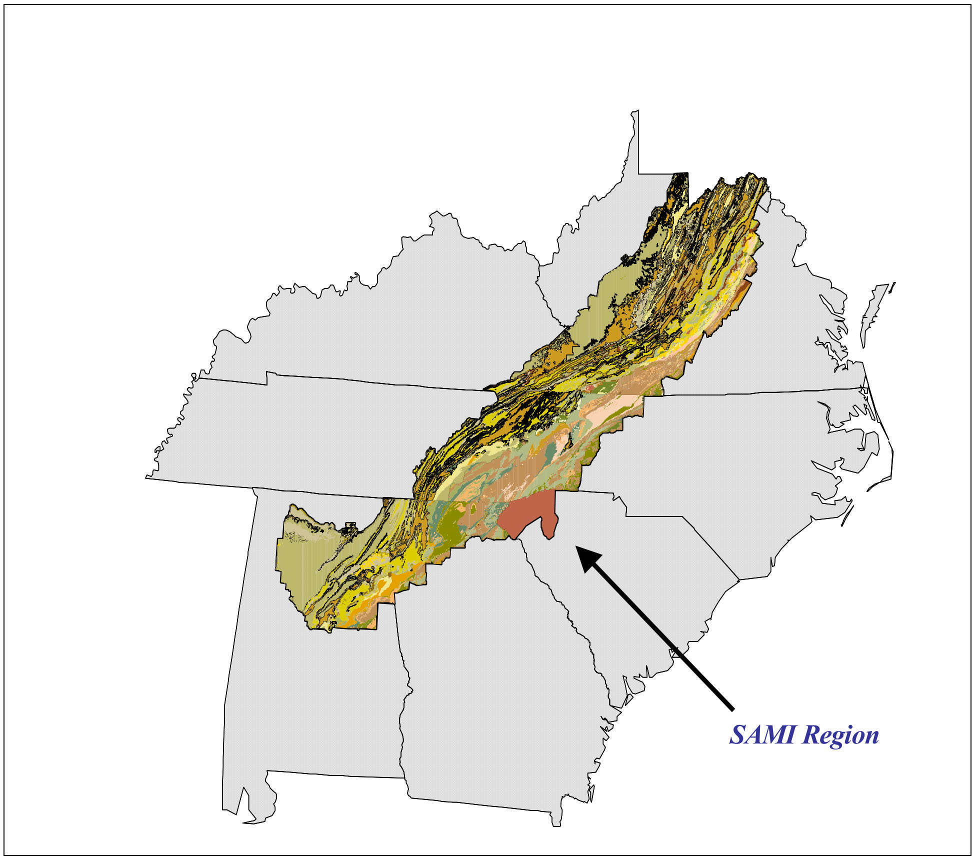


Figure 4-23. USGS lithologic map units for SAMI region. This map includes 59 lithologic units aggregated from state geologic maps (minimum map scale: 1:500,000). Data were not available for North Carolina.

The USGS lithologic map units were combined to create the five-unit landscape classification, generally based on composition and weathering properties of the primary rock type associated with each lithologic map unit. These units and examples of included rock types are:

Siliceous:	sandstone, quartzite
Argillaceous:	shale, siltstone
Felsic:	granite, gneiss
Mafic:	basalt, anorthosite
Carbonate:	limestone, dolomite

Figure 4-24 presents the general scheme used to classify the non-carbonate lithologic units according to the properties expected to influence the ANC of associated streamwaters. Note that

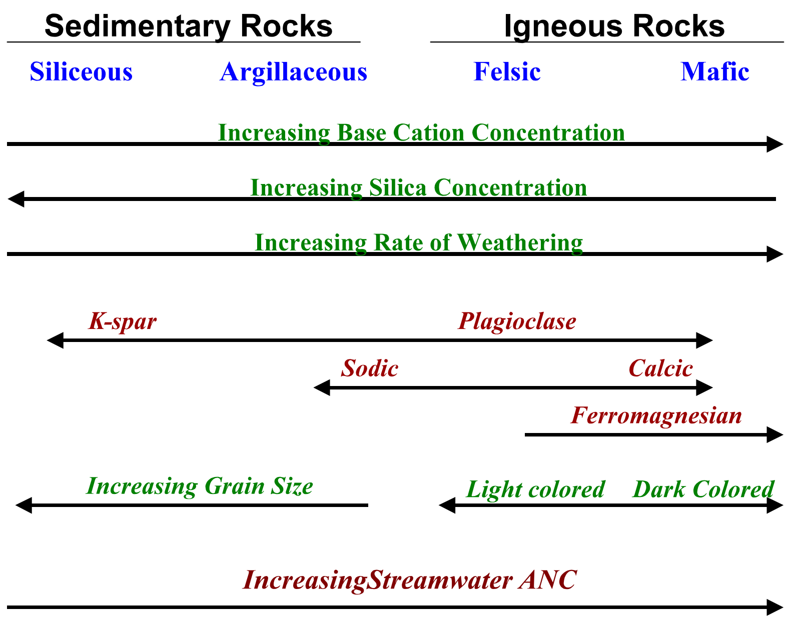


Figure 4-24. Conceptual scheme for lithologic classification.

lithologic map units with primary rock types defined by structure rather than composition were classified based on secondary rock type or state-by-state formation descriptions. Examples of lithologic map units in this category include: conglomerate, metasedimentary rock, breccias, and schist.

A map of the resulting five-unit landscape classification scheme for the SAMI region is provided in Figure 4-25. Appendix N includes a list indicating the assignment of individual lithologic units to the five sensitivity classes.

Although important information is provided by other streamwater solutes, ANC concentration provides the best single criterion for evaluation of the geologic classification scheme. ANC is both a measure of current acid-base status and a product of watershed processes that determine the presence of acidic and basic constituents in solution. We can expect future response to acidic deposition to differ among streams with different ANC levels. ANC has thus served as a primary variable for stratifying streams to be modeled for the SAMI aquatic effects assessment.

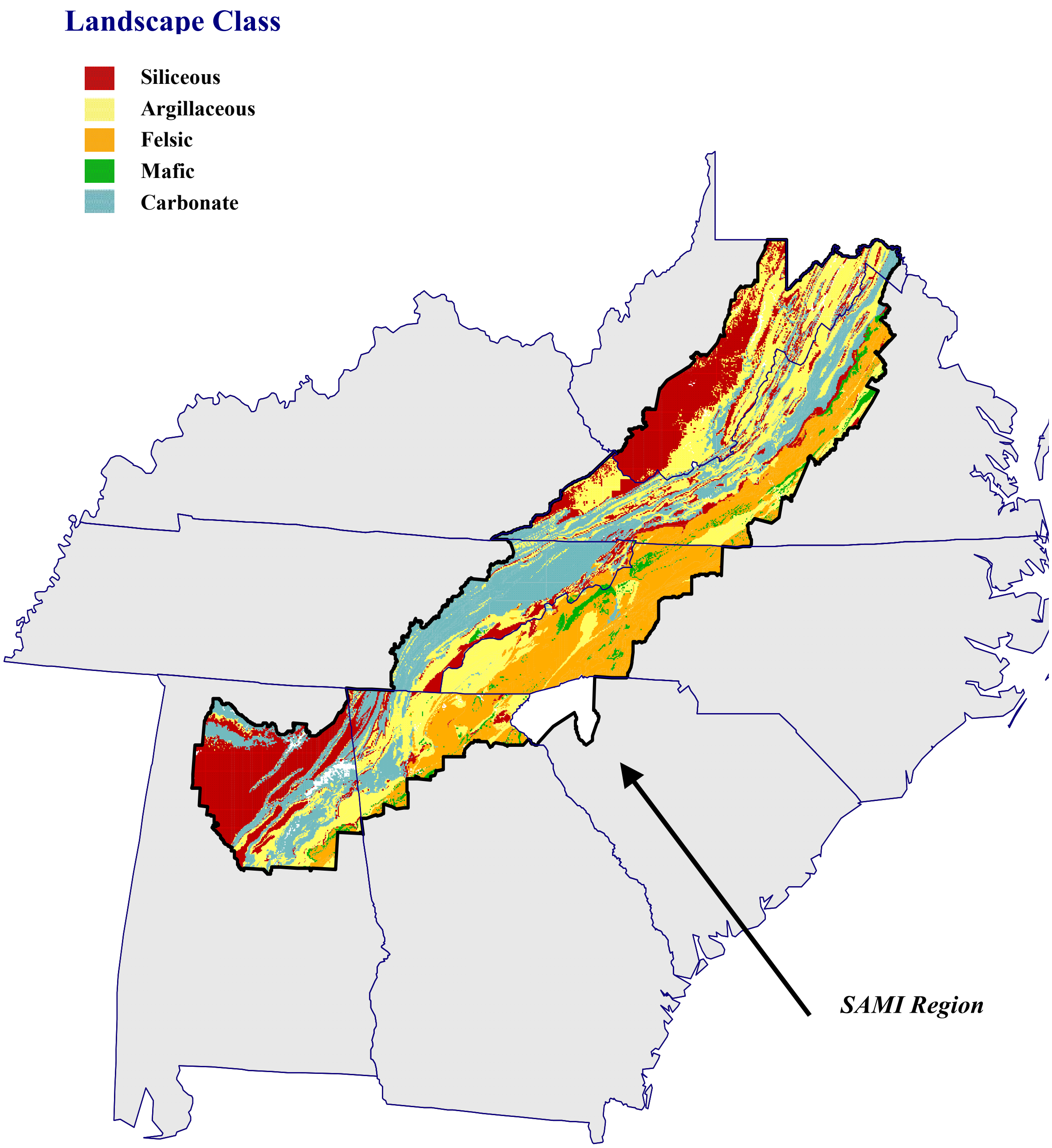


Figure 4-25. Geologic response classification for SAMI region. Data were not available for South Carolina.

As indicated in Table 4-5 and Figure 4-26, almost all of the acidic streams (ANC <0 μeq/L) and most of the highly sensitive streams (ANC 0 to <20 μeq/L) were associated with the siliceous landscape class. For this analysis, only those sites for which the entire watershed occupied a single geologic class were included (n = 487). All of the streams in the sensitive classes (ANC 0 to 20 μeq/L and 20 to <50 μeq/L) were associated with the siliceous, felsic, and argillaceous classes. All of the streams associated with the mafic and carbonate classes were relatively insensitive (ANC ≥ 50 μeq/L). This information can be used to indicate the geographic distribution of acidic and sensitive streams throughout the SAMI region.

Because there was considerable overlap in ANC values among the classes, the classification scheme does not provide a good basis for predicting the ANC of individual streams. However, given the general separation in ANC distributions among the classes, it is evident that the classification scheme will serve to indicate areas with high percentages of low-ANC streams, as well as areas without low-ANC streams.

An additional issue concerns the discrimination between the felsic and argillaceous classes. Given that the ANC distributions are similar, it might seem reasonable to represent these as a single class. However, these classes are different with respect to important acid-base properties that determine differences in response to acidic deposition. Examination of detailed data for a number of Virginia watersheds associated with these classes indicated differences in both base-cation availability and sulfur retention between these landscape types (Webb 1999). Streams associated with felsic geology have low base-cation concentrations and low sulfate

Table 4-5. Distribution of SAMI region sites grouped by lithology-based landscape class in relation to ANC criteria (n=487).*

ANC (μeq/L)	Siliceous	Argillaceous	Felsic	Mafic	Carbonate
<0	15	1	0	0	0
0 to <20	14	6	4	0	0
20 to <50	18	11	17	0	0
50 to <150	17	36	38	58	9
>150	36	46	42	42	91

* The distributions include only streams associated with single landscape classes

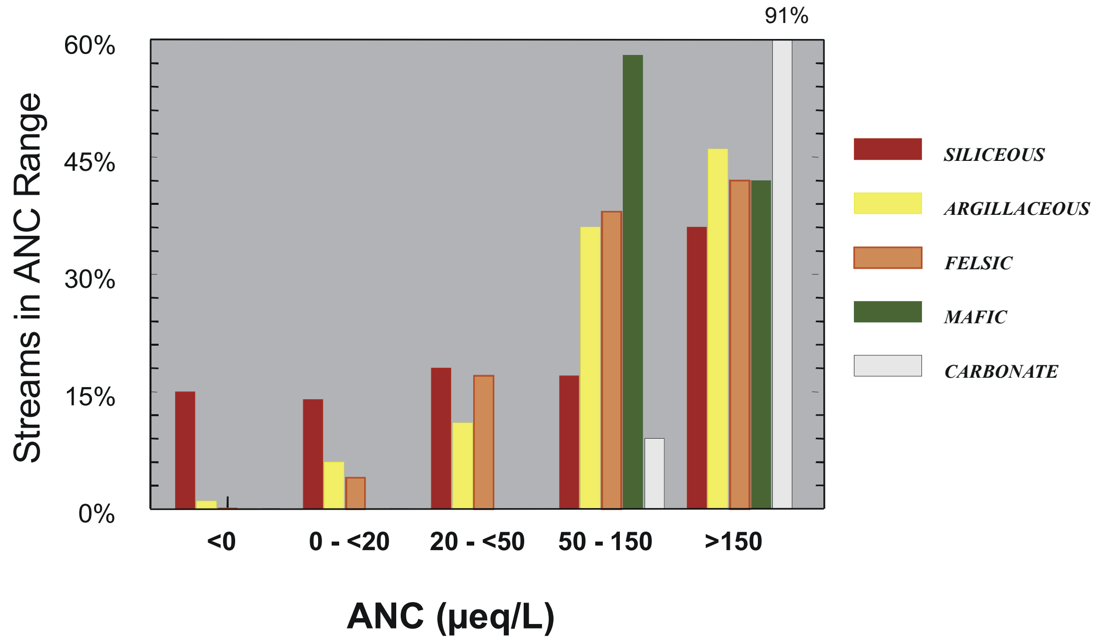


Figure 4-26. Distribution of SAMI region sites grouped by acid-base response class in relation to ANC criteria. All sites represent single landscape classes (n=487).

concentrations. In contrast, streams associated with argillaceous geology have both relatively higher base cation concentrations and relatively higher sulfate concentrations. Although ANC, which is determined by the difference in base cations and acid anions (including sulfate), is similar for streams associated with these two geologic classes, this observation may not extend to future responses to changes in acidic deposition.

Several sources of uncertainty affected the effort to correlate ANC with regional lithology. These included uncertainties associated with the water quality data, the delineation of watershed boundaries, past and present land use, and geologic mapping. The latter may be the most problematic.

A major problem with the presently available geologic mapping is unreliable identification of carbonate rock distribution. A percentage of the streams associated with even the siliceous (most-acidic) class have very high ANC. This suggests the presence of unmapped, but chemically significant, carbonate rock inclusions in geologic formations that are primarily noncarbonate. In many cases carbonate rock types are indicated as secondary lithologies in descriptions of non-carbonate formations. The presence of these secondary lithologies is geographically variable and efforts to account for their influence on the landscape classification schemes were not successful. This problem, and perhaps other mapping problems, limits the use of the lithology-based classification schemes for prediction of ANC for particular streams. However, the described lithology-based landscape classification scheme does indicate the geographic distribution of acidic and sensitive streams throughout the SAMI region. This will be useful for characterizing both the current and projected future acid-base status of streams within the SAMI region. The relationships identified between streamwater ANC and geologic sensitivity class were used as the foundation for a watershed sensitivity classification scheme, which is described below.

4.2.5.1.2 Final classification scheme for evaluation of watershed sensitivity to acidic deposition

The relationships between streamwater ANC and landscape characteristics other than lithology were also examined using the database of 999 streams located in and around the SAMI domain for which streamwater ANC data were available. The results of these analyses, coupled with the geologic sensitivity classes, were then used as the basis for development of an acidic deposition sensitivity classification scheme, which was further evaluated using data from the 926 streams that had been sampled within the SAMI domain. Several landscape variables were found to correlate well with the percentage of sampled streams in various ANC classes (Table 4-6). In particular, certain landscape types were found to contain high percentages of either acidic and low-ANC streams or to contain high percentages of high-ANC streams. The data summarized in this table are based on analyses of landscape units that corresponded spatially with the sampling point locations. It must be recognized, however, that each sampling point location is, by definition, the lowest elevational point within its respective watershed. The remainder of the watershed may, in some cases, lie within one or more other landscape units located at higher elevation. Water chemistry at the sampling point integrates the characteristics that occur throughout the watershed, not just the characteristics present at the sampling point.

The Appalachian Plateau physiographic province contained the highest percentage (16%) of acidic sampled streams, followed by the Valley and Ridge Province (8%) and Blue Ridge Province (1%). No acidic streams were sampled in the Piedmont province. The highest percentage of streams having ANC between 0 and 20 μeq/L was found in the Valley and Ridge

Table 4-6. Relationships between selected landscape variables and streamwater ANC for 926 stream sampling locations with the SAMI domain.

Category	Percent SAMI Region covered by Landscape Unit	Number of Sampling Sites Within Unit	Percent of Sampled Streams in ANC Class				
			Class 1 (<0)	Class 2 (0-20)	Class 3 (20-50)	Class 4 (50-150)	Class 5 (>150)
Physiographic Province							
Appalachian Plateau	23.59	151	15.89	9.93	8.61	17.22	48.34
Valley and Ridge	38.17	337	8.31	10.98	16.91	25.22	38.58
Blue Ridge	23.97	422	1.42	6.87	16.82	45.50	29.38
Piedmont	14.27	16	0	0	6.25	31.25	62.50
Geologic Sensitivity Class							
Siliceous	23.35	274	14.96	15.69	20.07	21.17	28.10
Argillaceous	32.64	326	3.07	8.59	15.34	36.50	36.50
Felsic	19.86	195	0.00	3.08	14.87	46.67	35.38
Mafic	2.62	46	2.17	0.00	13.04	47.83	36.96
Carbonate	17.72	66	9.09	6.06	1.52	10.61	42.73
Unclassified	0.97	8	0.00	0.00	0.00	12.50	87.50
Elevation (m)							
<400	44.3	154	1.3	3.9	10.4	31.2	53.2
400-600	19.9	279	5.7	7.5	13.3	36.6	36.9
600-800	19.0	260	6.9	8.8	12.3	30.8	41.2
800-1000	10.1	146	8.2	13.0	20.5	35.6	22.6
>1000	6.5	87	11.5	13.8	31.0	29.9	13.8
Forest Type							
Spruce-Fir	0.29	9	11.11	33.33	0.00	55.56	0.00
Maple-Beech-Birch	3.29	47	17.02	19.15	23.40	19.15	21.28
White-Red-Jack Pine	1.59	46	26.09	8.70	26.09	30.43	8.70
Loblolly-Shortleaf Pine	6.48	15	6.67	0.00	0.00	46.67	46.67
Oak-Pine	17.15	149	6.04	5.37	16.78	53.02	18.79
Oak-Hickory	42.45	509	4.52	11.00	17.29	33.01	34.18
Non-Forest	27.74	149	2.68	0.67	4.03	17.45	75.17
Watershed Area (km^2)							
0-5	N/A	470	8.1	11.1	16.2	33.4	31.3
5-10	N/A	165	9.1	9.1	20.6	31.7	26.7
10-20	N/A	126	4.8	6.3	14.3	32.1	42.9
20-40	N/A	78	0.0	9.0	11.5	32.1	47.4
>40	N/A	87	0.0	1.1	5.7	29.9	63.2

Table 4-6. Continued

Category	Percent SAMI Region covered by Landscape Unit	Number of Sampling Sites Within Unit	Percent of Sampled Streams in ANC Class				
			Class 1 (<0)	Class 2 (0-20)	Class 3 (20-50)	Class 4 (50-150)	Class 5 (>150)
Soils Type*							
Moomaw-Jefferson-Alonzville	0.96	29	13.79	17.24	13.79	17.24	37.93
Shottower-Laidig-Weikert	1.13	53	16.98	9.43	24.53	22.64	26.42
Edneyville-Tusquitee-Ashe	1.21	27	3.70	3.70	22.22	33.33	37.04
Catoctin-Myersville-Rock Outcrop	1.31	95	0.00	0.00	15.79	63.16	21.05
Gilpin-Dekalb-Ernest	2.17	26	7.69	11.54	11.54	30.77	38.46
Hayesville-Parker-Peaks	3.20	54	0.00	5.56	11.11	27.78	55.56
Frederick-Carbo-Timberville	4.01	28	0.00	0.00	3.57	10.71	85.71
Wallen-Dekalb-Drypond	4.17	146	10.27	19.86	21.92	30.82	17.12
Berks-Weikert-Laidig	1.31	81	3.70	7.41	16.05	45.68	27.16
Ecoregion*							
66a - Northern Igneous Ridges	1.53	118	0.00	0.85	15.25	66.95	16.95
66b - Trap Rock and Conglomerate Uplands	0.47	45	17.78	35.56	24.44	11.11	11.11
66c - Piedmont Uplands	2.26	27	0.00	0.00	11.11	7.41	81.48
66d - Southern Igneous Ridges and Mountains	6.49	87	1.15	4.60	17.24	37.93	39.08
66e - Southern Sedimentary Ridges	1.79	55	0.00	10.91	25.45	47.27	16.36
66g - Southern Metasedimentary Mountains	4.08	48	0.00	6.25	27.08	47.92	18.75
67a - Northern Limestone/Dolomite Valleys	2.84	27	3.70	7.41	0.00	11.11	77.78
67b - Northern Shale Valleys	2.91	48	2.08	6.25	12.50	29.17	50.00
67c - Northern Sandstone Ridges	3.21	40	7.50	12.50	20.00	27.50	32.50
67d - Northern Dissected Ridges and Knobs	4.63	110	2.73	7.27	26.36	36.36	27.27
67h - Southern Sandstone Ridges	4.21	52	26.92	23.08	13.46	23.08	13.46
69a - Forested Hills and Mountains	5.85	84	27.38	13.10	7.14	13.10	39.29
69d - Cumberland Mountains	5.08	38	5.26	10.53	10.53	23.68	50.00
Watershed Relief (m)							
0-200	N/A	176	5.7	7.4	9.1	25.0	52.8
200-400	N/A	309	7.1	10.4	14.6	30.1	37.9
400-600	N/A	279	9.3	12.5	20.4	27.6	30.1
600-800	N/A	113	0.9	1.8	16.8	52.2	28.3
>800	N/A	49	0.0	2.0	10.2	65.3	22.4

* Includes only soil types and ecoregions for which there were 25 or more sampling sites.

Province (11%) and the highest percentage of streams having ANC between 20 and 50 μeq/L was found in the Valley and Ridge and the Blue Ridge Provinces (17%). The combined percentages, including all streams having ANC ≤ 50 μeq/L, were fairly similar among the three most acid-sensitive physiographic provinces within the SAMI region, ranging from 25% in the Blue Ridge to 36% in the Ridge and Valley.

The five designated geologic sensitivity classes showed good ANC discrimination, with highest percentage of acidic and low-ANC stream sampling points being located in the siliceous class. The acidic, ANC 0 to 20 μeq/L, and ANC 20 to 50 μeq/L streams were all most prevalent in the siliceous class. The vast majority of the carbonate and unclassified sampling sites had high ANC (>150 μeq/L). A total of 1% of the region was not classified and this was mainly in South Carolina, where lithologic coverages had not been completed by USGS at the time of this analysis. Only eight sampling sites occurred in unclassified areas, and none of them had ANC ≤ 50 μeq/L.

Note that the correspondence between acidic streams and the siliceous geologic sensitivity class was higher for the analysis restricted to streams for which the entire watershed was included within a single sensitivity class (Figure 4-26) than it was for the analysis based only on sampling point locations (Table 4-6). In the latter case, many sampling points were included for which the watershed was occupied by multiple geologic sensitivity classes.

There was a clear pattern of increasing percentages of stream sampling sites having low ANC as site elevation increased (Table 4-6). This pattern was very apparent for acidic streams and streams having ANC between 0 and 20 μeq/L, both of which showed values <4% for sites located at elevations below 400 m, and values >11% for elevations > 1,000 m. These relationships are shown graphically in Figure 4-27. Over 53% of the low-elevation sites (< 400 m) had high ANC (> 150 μeq/L), compared with only 14% of the high-elevation sites (> 1,000 m, Table 4-6).

Certain forest types were commonly associated with acidic streams: white-red-jack pine, maple-beech-birch, and spruce-fir. In each of these types, >11% of sampled streams were acidic. In contrast, only 3% of the non-forested sites were acidic and 75% had high ANC (> 150 μeq/L, Table 4-6). Only nine sites were sampled within the spruce-fir vegetation type, in part because spruce-fir covers only 0.3% of the SAMI region and in part because, for many watersheds that were partly covered by spruce-fir forests, the stream sampling location actually occurred below the elevational limit of this forest type. A pattern was observed, however, of

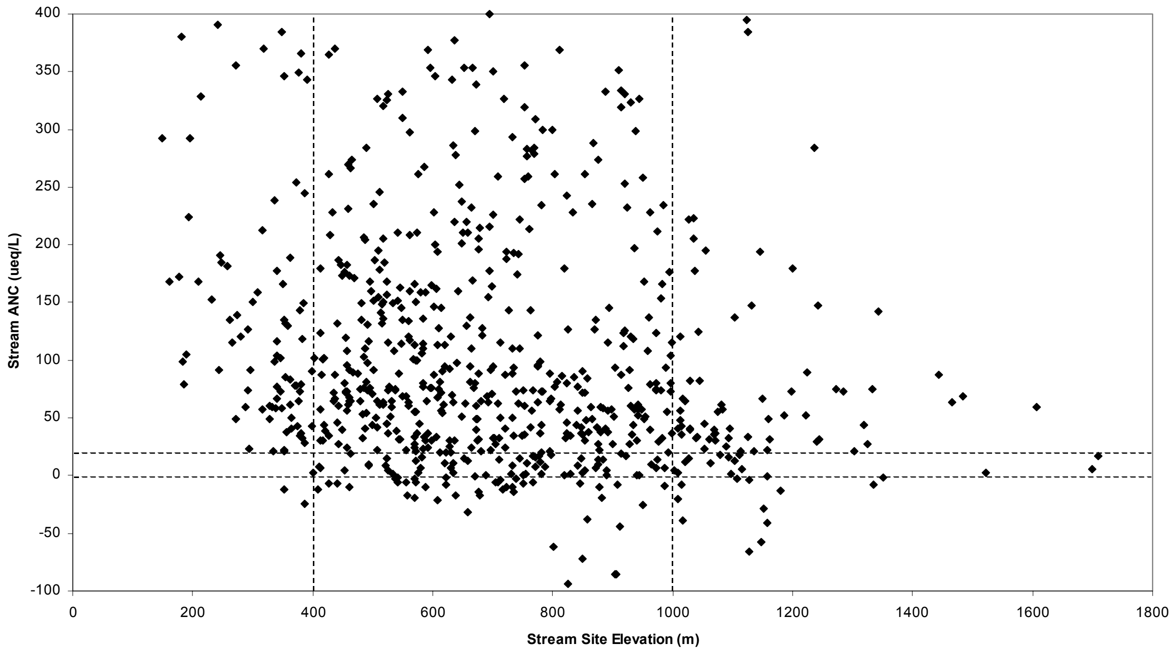


Figure 4-27. Scatter plot showing the relationship between streamwater ANC and sample site elevation for the 926 streamwater sample site locations within the SAMI region for which ANC data were available. Sites having ANC > 400 µeq/L or < -100 µeq/L were deleted from this figure. Reference lines have been added to show the locations of the primary ANC reference values that correspond with probable impacts on brook trout (0 and 20 µeq/L) and to show the locations of the elevational references of 400 m and 1000 m. A very low percentage of the sites located below 400 m show ANC ≤ 20 µeq/L. At higher elevations, larger numbers and higher-percentages of streams having ANC ≤ 0 and ≤ 20 µeq/L are found.

low and acidic ANC often occurring in watersheds exhibiting higher spruce-fir coverage (Figure 4-28). Similar results were found for the maple-beech-birch and white-red-jack pine forest types. Oak hickory and oak pine forests, by far the most prevalent forest types within the SAMI region (42 and 17% coverage, respectively), did not show clear patterns in stream ANC versus the percent forest coverage (shown for oak hickory in Figure 4-28).

Acidic and low-ANC streams were more prevalent in small watersheds. There was a rather consistent increase in the percent of sampled streams in the acidic and ANC 0 to 20 µeq/L categories, and a decrease in the percent of sampled streams in the high ANC (> 150 µeq/L) category, as watershed area increased. About 8% of the streams that had watersheds smaller than 20 km^2 were acidic, compared with 0% of the streams with watersheds > 20 km^2 (Table 4-6).

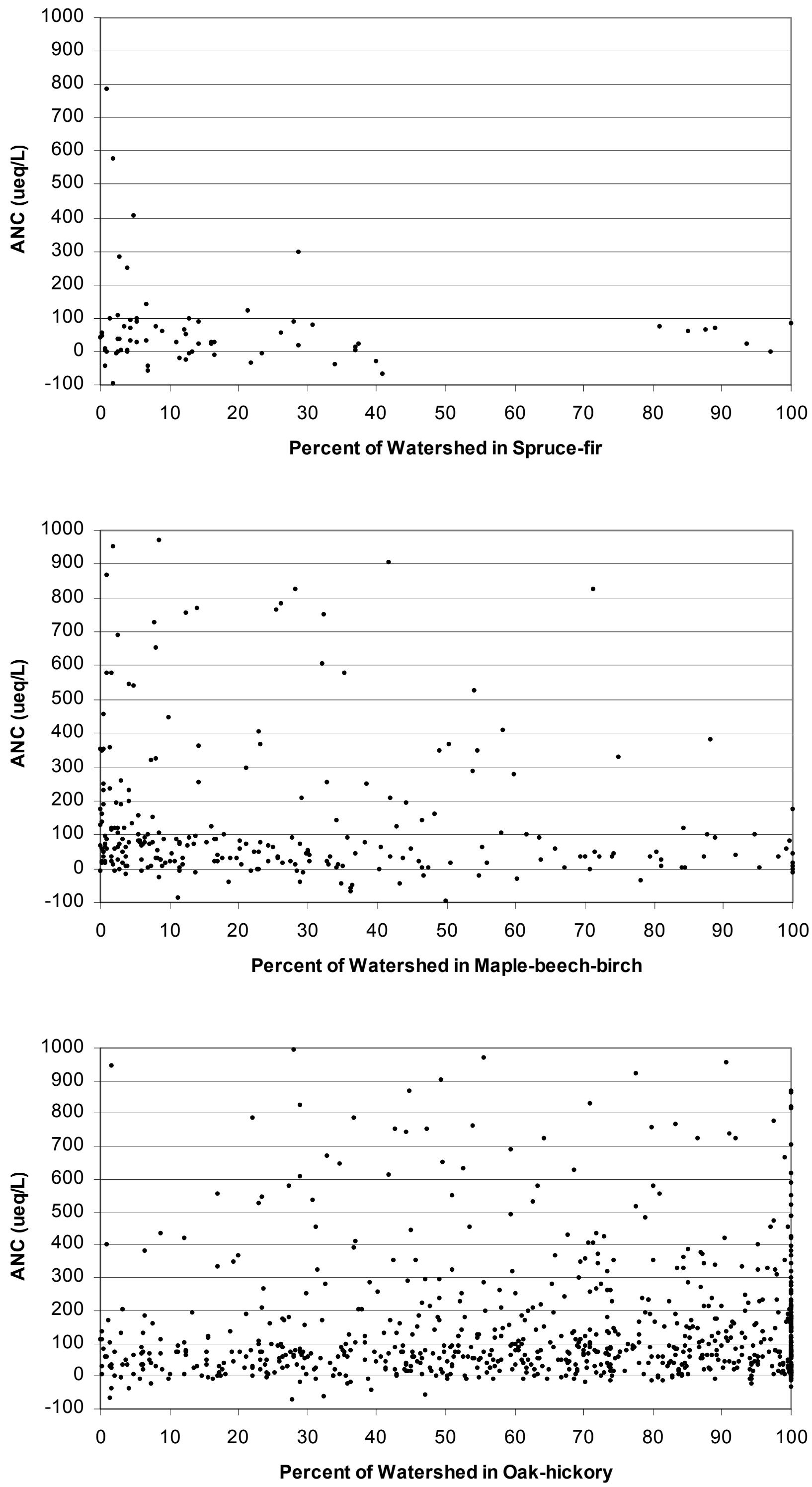


Figure 4-28. Streamwater ANC versus percent of the watershed covered by a certain vegetation type. Watersheds that have appreciable percentages of spruce-fir forest coverage tend to exhibit low or negative ANC. Similar results were found for maple-beech-birch and white-red-jack pine forests, but not for other vegetation types such as oak-hickory forests.

There were several STATSGO soils types that were associated with high percentages of acidic and low-ANC sampled streams, notably the Wallen-DeKalb-Drypond, Moomaw-Jefferson-Alonzville, and Shottower-Laidig-Weikert. Each of these was characterized by over 25% of the sampled streams having ANC $\leq$ 20 μeq/L. Each occupied a very small component of the SAMI domain, however (4.2, 1.0, and 1.1%, respectively). Their utility for classification purposes was therefore somewhat limited. In general, the soils data that were available regionally were not sufficient to discriminate their acid-base properties. A more detailed soils coverage might be more useful for classification purposes.

There were 13 ecoregions within the SAMI region that were represented by more than 25 sample locations. Most of those contained acidic (9 of 13) and ANC 0 to 20 μeq/L (12 of 13) streams and each occupied less than 7% of the SAMI domain. The ecoregion designation was therefore of limited utility as a classification parameter to be added to geologic sensitivity and elevation. Nevertheless, only four ecoregions (Forested Hills and Mountains, 69a; Southern Sandstone Ridges, 67h; Trap Rock and Conglomerate Uplands, 66b; and Northern Sandstone Ridges, 67c) contained 81% of the known acidic streams and 66% of the known streams having ANC $\leq$ 20 μeq/L in the SAMI domain, and these four ecoregions only occupied 13% of the region.

There was a general tendency for watersheds having less than 600 m of vertical relief to have higher percentages of acidic and low-ANC streams than watersheds of greater relief. There was not a consistent pattern observed, however, between relief and streamwater ANC (Table 4-6).

Many of these variables are to some extent intercorrelated. For example, sampling sites that occur at higher elevation generally have smaller watershed areas, and are more likely to be underlain by resistant bedrock and to be occupied by particular forest types, such as spruce-fir or maple-beech-birch. In contrast, lower-elevation sites tend to have larger watershed areas, to be underlain by less resistant bedrock and to be covered by oak forest types or non-forest vegetation, including agricultural cover types.

A classification scheme was developed for the SAMI region, based on geologic sensitivity class and elevation. The objective in developing this scheme was to define an area, based on landscape variables, that was spatially limited, and yet contained the vast majority of the acidic and low-ANC streams known to occur within the SAMI domain. These are the streams that have been most adversely impacted by acidic deposition to date and to a large extent are also the streams for which biological recovery may be possible under significantly reduced future deposition.

The siliceous geologic sensitivity class was fairly restricted in area, covering 23% of the SAMI domain, and yet included the vast majority of the acidic (69%) and ANC ≤ 20 (59%) sampled streams. Examination of the locations of the acidic and low-ANC stream sampling sites relative to the location of lithologic coverages classified as siliceous revealed that many additional acidic and low-ANC stream sites were located outside, but in close proximity to, the siliceous class. A 750 m buffer was therefore added in the GIS to the siliceous class coverage. Addition of this buffer substantially increased the extent to which acidic and low-ANC streams were now included (97 and 87%, respectively), with only moderate increase in the size of the defined area (to 35% of the SAMI region, Table 4-7).

Table 4-7. Inclusion of acidic and low-ANC streams* within landscape classification schemes defined on the basis of geologic sensitivity and elevation.

Class Number	Basis for Classification	Percent of SAMI Region Included	Percent of Acidic and Low-ANC Streams Included	
			ANC ≤ 0 µeq/L	ANC ≤ 20 µeq/L
1	Siliceous class	23	69	59
2	Siliceous class w/750 m buffer	35	97	87
3	Siliceous class w/750 m buffer minus elevation < 400 m	22	93	82
4	Siliceous class w/750 m buffer minus elevation < 400 m plus elevation > 1000 m	26	95	88

* based on existing data for 926 stream sampling points within the SAMI domain

We identified two issues which likely contributed significantly to the finding that many acidic and low-ANC stream sampling points were located just outside the most acid-sensitive geologic class. First, many watersheds are partly or largely occupied by lithologic coverages of the siliceous type, and yet the sampling location is actually somewhat downstream of the boundary between the siliceous class and another class. If the distance between the sampling point and the sensitivity class boundary is short, one would expect streamwater chemistry in most cases to be generally reflective of the upstream siliceous geologic material. Second, geologic sensitivity classes were designated using lithologic coverages of rather coarse and variable scale. There is therefore some uncertainty regarding the exact location of lithologic boundaries. Thus, it is not surprising that the extent to which the siliceous class included acidic and low-ANC sites improved considerably upon addition of a buffer zone.

Deletion of low-elevation areas (< 400 m) dramatically reduced the size of the area of interest, to 22% of the SAMI domain, with little loss of acidic and/or low-ANC sites. It was also found that there were still a number of low-ANC stream sites excluded from the area of interest, and most of these were found at high elevation (> 1,000 m). All areas above 1,000 m elevation that were not already included within the siliceous class and associated buffer were therefore added to the area of interest. The resulting classification scheme only covered 26% of the SAMI region, and yet contained 95% of the acidic sampled stream sites and 88% of the ANC ≤ 20 μeq/L sites. This is the final scheme recommended for evaluation of acidic deposition sensitivities and effects. The area encompassed by this region is shown in Figure 4-29. As shown on the map, all acidic and low-ANC streams are either within or in close proximity to the final mapped area.

The four ecoregions indicated as 66b (Trap Rock and Conglomerate Uplands), 67c (Northern Sandstone Ridges), 67h (Southern Sandstone Ridges), and 69a (Forested Hills and Mountains) can be used as an alternate classification system, which includes the majority of the most acid-sensitive streams within the SAMI region, and yet only encompasses 13% of the region. Within these four ecoregions were found 81% of the known acidic streams and 66% of the known streams having ANC ≤ 20 μeq/L. Addition of ecoregions 66i (High Mountains), 66e (Southern Sedimentary Ridges), and 67d (Northern Dissected Ridges and Knobs) increased the area covered to 20% of the SAMI region. This area represented by seven ecoregions included 88% of the acidic streams and 82% of the streams having ANC ≤ 20 μeq/L. Thus, this area represented by seven ecoregions constitutes an alternative basis for focusing on the region of greatest interest.

4.2.5.1.3 Landscape features associated with watershed responses to changes in acidic deposition

The previous Section presented results of analyses that focused on the observed relationship between landscape features and current or recent streamwater chemistry. It was found that the

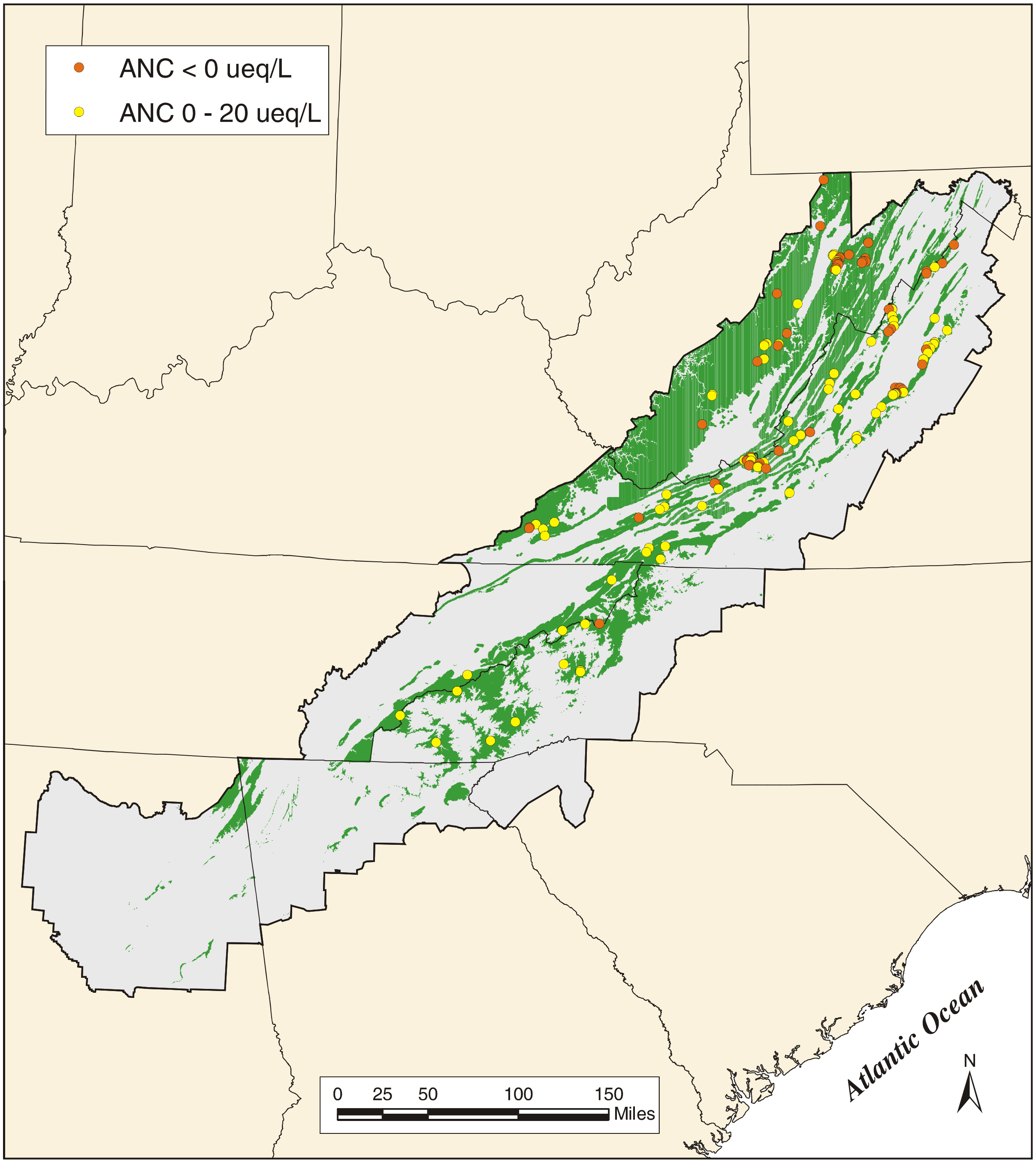


Figure 4-29. Final area delimited by the acidification sensitivity classification scheme. The shaded area includes the siliceous geologic sensitivity class, surrounded by a 750 m buffer. In addition all areas less than 400 m elevation have been deleted and areas greater than 1,000 m elevation have been added. The area thus circumscribed includes 95% of the known acidic streams and 88% of the known streams having ANC ≤ 20 μeq/L. Furthermore, all known streams having ANC ≤ 20 μeq/L are in close proximity to the final mapped area.

location of acidic and low-ANC streams was predictable, based on lithology (as reflected by geologic sensitivity class), elevation, and ecoregion. Relationships were also found to occur between landscape features and the extent to which watersheds were projected to respond to future reductions in acidic deposition. For example, there were 28 modeled streams that were acidic in 1995, but projected to have ANC > 0 in 2040 in the BYB Strategy. Of those, 86% occurred within the sensitive area shown in Figure 4-29.

4.3 Class I Area Assessment

In addition to the regional modeling that was conducted for the SAMI region as a whole, and presented in the previous Section, available water chemistry data and model output for all modeled watersheds (regional and special interest) were examined for each of the individual Class I areas within the SAMI domain. An earlier report to SAMI by Herlihy et al. (1996) compiled available water chemistry data. There were distinct differences in acid-base chemistry among the Class I areas and among the various subregions of the SAMI domain (Table 4-8).

Based on measurements of visibility impairment, acid deposition, and ground level ozone, the National Park Service has determined that air quality problems in the Great Smoky Mountains and Shenandoah National Parks are among the most serious in the national parks system. These two parks have been more intensively studied with respect to acidic deposition effects than other parts of the Southern Appalachian Mountain region, and also contain some of the watersheds that are the most sensitive and have been adversely impacted by stream acidification, effects on fisheries, ozone damage to foliage, and visibility impairment.

Acidic streams appear to be especially prevalent in Dolly Sods and Otter Creek Wilderness areas on the West Virginia Plateau. The lower quartile of measured streamwater ANC values was also below 25 μeq/L in Shenandoah and Great Smoky Mountains National Parks and James River Face Wilderness. The wilderness areas with higher ANC (Table 4-8) are all located in the southern half of the SAMI region, in the Southern Blue Ridge and Alabama Plateau.

The Class I areas in the West Virginia Appalachian Plateau Subregion (Dolly Sods and Otter Creek Wilderness Areas) contained acidic streams, with median ANC of -28 and -18 μeq/L, respectively. In the Northern Blue Ridge Subregion (Shenandoah National Park and James River Face Wilderness Area), many streams had ANC ≤ 50 μeq/L, and median ANC

Table 4-8. Median values (with first and third quartiles in parentheses) for major ion chemistry in streams in Class I wilderness areas and in the entire Southern Appalachians. Year(s) of data collection and number of observations (n) are given below the wilderness area name. (Source: Herlihy et al. 1996)

Wilderness Area	ANC (µeq/L)	pH	Sulfate (µeq/L)	Nitrate (µeq/L)	Chloride (µeq/L)	DOC (mg/L)
Dolly Sods (1994) (n=34)	-18 (-53 - -3)	4.7 (4.3-5.1)	105 (91-115)	4 (2-6)	11 (9-12)	2.2 (1.7-3.1)
Otter Creek 1994 (n=63)	-28 (-82 - 11)	4-6 (4.1-6.0)	129 (111-153)	6 (1-14)	9 (8-10)	2.0 (0.9-3.1)
Shenandoah NP 1981-1982 (n=47)	82 (21-120)	6.7 (6.0-6.9)	85 (66-103)	7 (3-23)	28 (25-32)	--
James River Face 1991-1994 (n=8)	25 (22-44)	6.3 (6.1-6.5)	68 (54.74)	0 (0-0)	19 (18-20)	--
Great Smoky Mt. NP 1994-1995 (n=337)	44 (24-64)	6.4 (6.2-6.6)	31 (18-46)	15 (6-29)	14 (12-16)	--
Joyce Kilmer/Slickrock 1992-1994 (n=9)	70 (53-80)	--	--	7 (6-11)	--	--
Shining Rock 1992-1995 (n=9)	70 (65-80)	6.8 (6.7-7.0)	--	7 (6-7)	--	--
Cohutta 1992-1994 (n=16)	41 (26-56)	6.5 (6.2-6.6)	35 (25-53)	14 (9-21)	24 (21-28)	1.8 (1.4-2.5)
Sipsey 1991-1993 (n=30)	245 (120-699)	7.3 (6.8-7.6)	94 (83-106)	2 (1-3)	33 (32-34)	2.2 (1.6-2.7)
SAMI Region Streams[a] 1986 NSS (N=19,940)	172 (65-491)	7.1 (6.5-7.5)	135 (62-229)	16 (4-34)	36 (18-68)	1.0 (0.7-1.7)
Acidic SAMI Streams[a] 1986 NSS (N=730)	-24 (-35 - -24)	4.7 (4.5-4.7)	142 (117-229)	0.3 (0.2-3.5)	16 (12-25)	1.4 (1.0-1.7)
S. Blue Ridge Lakes[a] 1984 ELS (N=71)	152 (87-246)	6.8 (6.7-7.0)	29 (23-36)	1 (0-6)	25 (18-42)	1.0 (1.2-1.5)

[a] Regional estimate for SAMI region streams is calculated using National Stream Survey (NSS) data for the upstream segment end population (extrapolated from 154 sample streams). The Southern Blue Ridge lake estimate is extrapolated from 45 lakes sampled in the Eastern Lake Survey (L. Baker et al. 1990).
-- Not measured, no data found

values were 82 and 25 µeq/L, respectively. The Southern Blue Ridge Subregion included five Class I areas (Great Smoky Mountains National Park, and the Joyce Kilmer/Slickrock, Shining Rock, Linville Gorge and Cohutta Wilderness Areas). Although Linville Gorge Wilderness is not known to include any acid-sensitive streams, median ANC in the other areas ranged from 41 to 70 µeq/L. In general, streams in this subregion exhibit lower sulfate and higher nitrate than streams in the other subregions. The Sipsey Wilderness Area in the Alabama Appalachian Plateau Subregion is drained by streams that tend to have high ANC (median, 245 µeq/L).

In general, streams within the Class I areas have considerably lower ANC than does the overall population of streams in the SAMI region. The median ANC for the region, as represented by the National Stream Survey (Kaufman et al. 1988) was 172 µeq/L (Table 4-8). In contrast, of the nine acid-sensitive Class I areas (excluding Linville Gorge), only Sipsey Wilderness had median ANC above 82 μeq/L.

A breakdown of watersheds modeled in each of the Class I areas, including both regional and special interest sites, is shown in Table 4-9.

Table 4-9. Class I watersheds, including both regional and special interest modeling sites, with selected water chemistry variables (at the time of sampling) and elevation.

Class I Area	Site ID	Site Name	ANC		Sulfate (μeq/L)	Nitrate (μeq/L)	Elevation (m)
			Titrated	Calculated			
Cohutta WA	CO06	Bear Brook	56.6	65.6	20	0.7	427
	CO10	Beech Creek	62.4	48.8	83	3.1	472
	CO05	Hickory Creek	43.6	42.8	77	4.0	390
	CO01	Un-named eastern Trib	37.7	22.2	24	1.9	707
Dolly Sods WA	DS19	Fisher Spring Run	-20.8	-17.9	97	5.5	1011
	DS04	Little Stonecoal Run	-58.9	-53.8	117	6.7	932
	DS06	Stonecoal Run (left branch)	-66.2	-63.0	112	6.6	1127
	DS09	Stonecoal Run (right branch)	-41.5	-41.9	105	2.8	1115
	DS50	Unnamed	-29.9	-14.6	73	3.6	1097
Great Smoky Mtns. NP	2A07812	Correll Branch	102.7	114.1	23	3.7	884
	2A07805	Cosby Creek	98.8	103.0	41	24.8	436
	2A07816	Eagle Creek	56.5	56.4	20	7.6	579
	2A07811	False Gap Prong	16.2	26.2	44	39.4	549
	2A07817	Forney Creek	30.4	42.7	24	20.8	732
	GS04	GSMNP Deep Creek	69.4	67.2	76	41.9	1600
	GS08	GSMNP Enloe Creek	31.2	34.2	17	24.1	1500
	GS05	GSMNP Jay Bird Branch	27.9	42.8	20	0.3	1248
	GS06	GSMNP LeConte Creek	77.9	94.5	40	3.9	570
	GS01	GSMNP Noland Creek - NE fork	6.4	7.5	41	42.6	1740
	GS02	GSMNP Noland Creek - NW fork	17.1	16.4	28	37.2	1800
	GS07	GSMNP Raven Fork	21.2	24.5	25	26.6	1800
	2A07810L	Little River	68.0	73.0	36	16.9	433
James River Face WA	VT76	Belfast Creek	8.7	14.1	51	0.3	317
	M038	Big Hellgate Creek	23.7	30.7	76	0.3	317
	M039	Little Hellgate Creek	19.4	23.8	42	0.3	317
	VT77	Matts Creek	44.3	51.4	57	0.0	412
	M037	Sulphur Spring Creek	26.1	31.1	69	0.3	427
Otter Creek WA	OC35	Coal Run	-38.8	-55.7	158	2.1	688
	OC02	Condon Run	-25.2	-57.0	123	19.2	923
	OC08	Unnamed	-44.8	-74.1	129	2.1	871
	OC09	Devils Gulch	-85.4	-89.7	118	0.7	853
	OC32	Moores Run	-62.3	-75.6	124	2.7	798

Table 4-9. Continued.							
Class I Area	Site ID	Site Name	ANC		Sulfate (µeq/L)	Nitrate (µeq/L)	Elevation (m)
			Titrated	Calculated			
Otter Creek WA	WV531S	Otter Cr	0.3	3.2	120	8.0	847
	OC79	Otter Creek (Upper)	10.7	17.9	74	23.2	950
	OC31	Possession Camp Run	-94.7	-109.6	148	1.4	798
	OC05	Yellow Creek	-85.3	-82.8	123	1.8	911
Shining Rock WA	BJ77	BEFPR	31.1	42.7	23	3.2	971
	BJ76	CDB	37.4	48.5	26	6.9	971
Shenandoah NP	VT58	Brokenback Run	76.3	90.0	40	6.8	329
	DR01	Deep Run	0.7	3.4	106	3.9	415
	VT62	Hazel Run	84.1	105.5	39	4.3	329
	2B047076L	Lower Lewis Run	5.0	9.5	109	0.2	354
	VT36	Meadow Run	-1.0	0.8	89	0.1	451
	NFDR	North Fork of Dry Run	67.1	77.1	99	28.6	488
	VT35	Paine Run	2.2	5.3	111	22.4	424
	VA531S	Ragged Run	65.5	67.8	48	20.3	505
	VT66	Rose River	131.7	148.3	53	31.8	341
	VT59	Staunton River	79.6	96.2	44	5.0	308
	VT53	Two Mile Run	9.97	18.12	98.59	0.25	372
	VT75	White Oak Canyon R	122.00	140.66	53.08	33.15	354
	WOR	White Oak Run	16.50	25.02	74.78	32.04	451
Sipsey WA	SP41	Quillan Creek	99.9	102.1	70	6.0	183
	SP39	Un-named Trib above 38	49.96	31.34	74.85	0.00	250
	SP10	Un-named Trib between 8 and 9	79.94	49.30	93.69	1.79	186

A total of 54 watersheds was modeled with MAGIC within Class I areas. Results of the MAGIC modeling for the various Class I sites are shown in Figure 4-30, expressed as the number of sites within the various ANC classes in 1995, 2010, 2020, and 2040 under the scenario of continuing constant deposition at 1995 levels and under the three Emissions Control Strategies. Median projected changes in streamwater ANC within each Class I area are given in Table 4-10. Under the OTW Strategy, the median ANC in each of the Class I areas except Otter Creek Wilderness was projected to decrease, in several cases by about 10 µeq/L, from 1995 to 2040. Under the BYB Strategy, only Sipsey Wilderness had substantial projected ANC decreases (> 5 µeq/L, Table 4-10).

Effects were most pronounced for the scenario of constant deposition at 1995 levels. Under this scenario, the number of modeled Class I sites that were acidic was projected to increase by 60% by 2040, with corresponding decreases in the number of sites in other ANC classes, especially ANC 0 to 20 µeq/L (Figure 4-30).

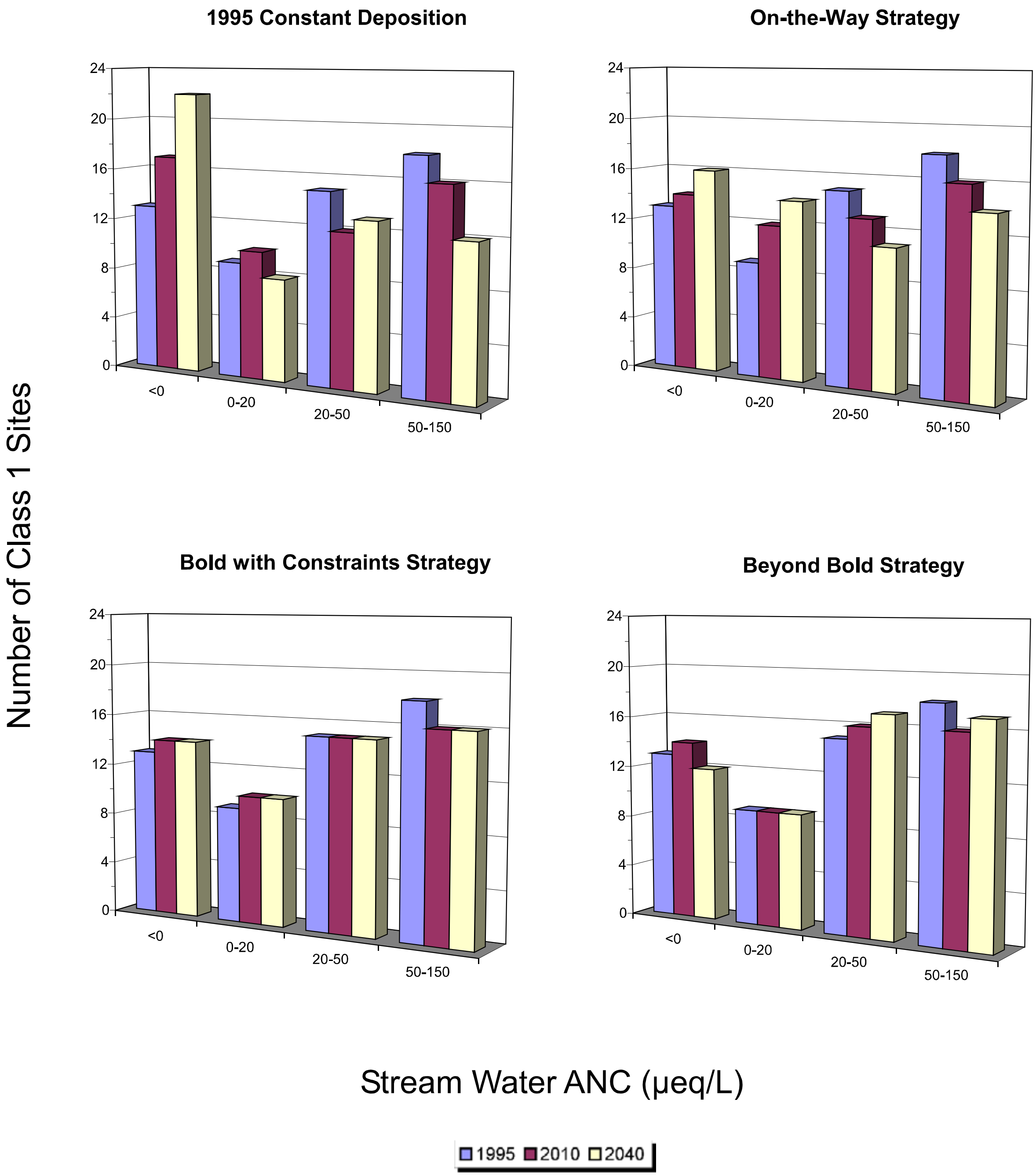


Figure 4-30. Projected number of modeled Class I area watersheds in each of the ANC classes in three simulation years (1995, 2010, 2040) under the scenario of constant deposition of all ions at 1995 levels and under the three Emissions Control Strategies.

Table 4-10. Median projected change in ANC from the 1995 baseline to 2040 within each of the Class I areas, under the three Emissions Control Strategies and the scenario of constant deposition at 1995 levels.

Class I Area	Number of Modeled Sites	OTW	BWC	BYB	Constant 1995 Deposition
Cohutta WA	4	-7.8	-3.5	-1.0	-12.8
Dolly Sods WA	5	-6.5	-1.0	4.0	-43.4
Great Smoky Mtns. NP	14	-9.9	-7.6	-5.0	-11.9
James River Face WA	5	-10.1	-4.9	-0.6	-22.5
Otter Creek WA	9	4.2	9.6	14.5	-38.7
Shenandoah NP	13	-2.7	-0.6	1.4	-10.1
Shining Rock WA	2	-5.9	-4.4	-3.4	-7.2
Sipsey WA	3	-12.9	-11.8	-10.4	-19.3

Results for Class I area watersheds under the three Emissions Control Strategies were considerably less dramatic than results for the scenario of constant deposition at 1995 levels. For both the OTW and the BWC Strategies, the number of acidic Class I sites was projected to increase from 24% in 1995 to 29% (OTW) and 25% (BWC) in 2040; the projected number of acidic Class I sites decreased to 22% the BYB Strategy.

4.3.1 West Virginia Appalachian Plateau Subregion

4.3.1.1 Dolly Sods Wilderness

The Dolly Sods Wilderness is located in the northeastern portion of West Virginia in the Appalachian Plateau. Elevations range from 2,600 to 3,900 ft (790 to 1890 m). The 43 km^2 wilderness is drained by Red Creek, the headwaters of which are located outside the wilderness area. Bedrock geology includes numerous formations (Allegheny, Pottsville, Conemaugh, Mauch Chunk) dominated by sandstone and shale, associated with coal deposits. Greenbrier limestone is found at the downstream end of the major creeks (Herlihy et al. 1996).

A survey was conducted of streamwater chemistry at 43 sites in Dolly Sods in May, 1994 (Webb 1995). All sampled streams in the wilderness had ANC $\leq$ 50 µeq/L and 82% of the stream length was acidic. Sulfate concentrations averaged 105 µeq/L, which suggested about 40% sulfur retention in the watersheds, on average (Herlihy et al. 1996). Herlihy et al. (1996)

found no evidence of substantial geological sources of sulfur in any of the study watersheds and dissolved organic carbon concentrations were not high (median, 2.2 mg/L; maximum. 4.7 mg/L).

A total of five streams in Dolly Sods were modeled with MAGIC, of which three were selected as special interest sites. All were acidic at the time of sampling, with projected ANC in 1995 ranging from -17 to -67 μeq/L. Model results of the three Emission Control Strategies for all of these sites are shown in Figure 4-31. Sulfate and nitrate concentrations in the modeled streams were generally near 100 and 5 μeq/L, respectively.

All strategies resulted in projected continued acidification of all of the modeled streams, at least to 2005. Some increase in ANC was simulated thereafter at most sites, especially in the BYB Strategy. None of the strategies resulted in projected ANC in 2040 being higher than -19 μeq/L in any of the streams, however. It is therefore unlikely that any of the strategies would contribute to any meaningful biological recovery at any of the modeled streams in Dolly Sods Wilderness Area.

4.3.1.2 Otter Creek Wilderness

The Otter Creek Wilderness is located 25 km from Dolly Sods Wilderness, on the Appalachian Plateau in the northeastern part of West Virginia. It covers 81 km^2, ranging in elevation from 1,800 to 3,900 ft (550 to 1,190 m), and includes most of the Otter Creek watershed. Bedrock geology is similar to that of Dolly Sods.

The majority of the stream length in Otter Creek Wilderness that was surveyed by Webb (1995) was acidic (53%), 17% had ANC between 0 and 50 μeq/L, and 18% had ANC > 50 μeq/L. An additional 13% of the stream length was heavily influenced by organic acidity (DOC > 5 mg/L; Herlihy et al. 1996).

A total of nine streams in Otter Creek were modeled with MAGIC, of which five were selected as special interest sites. All except two were acidic at the time of sampling, with simulated 1995 ANC ranging from +15 to -111 μeq/L. Model results of the Emissions Control Strategies for all of these sites are shown in Figure 4-32. Streamwater sulfate concentrations in the modeled streams of Otter Creek tended to be higher than in the other Class I areas, generally about 120 to 150 μeq/L (Table 4-8). Nitrate concentrations were variable, ranging from 1 to 23 μeq/L.

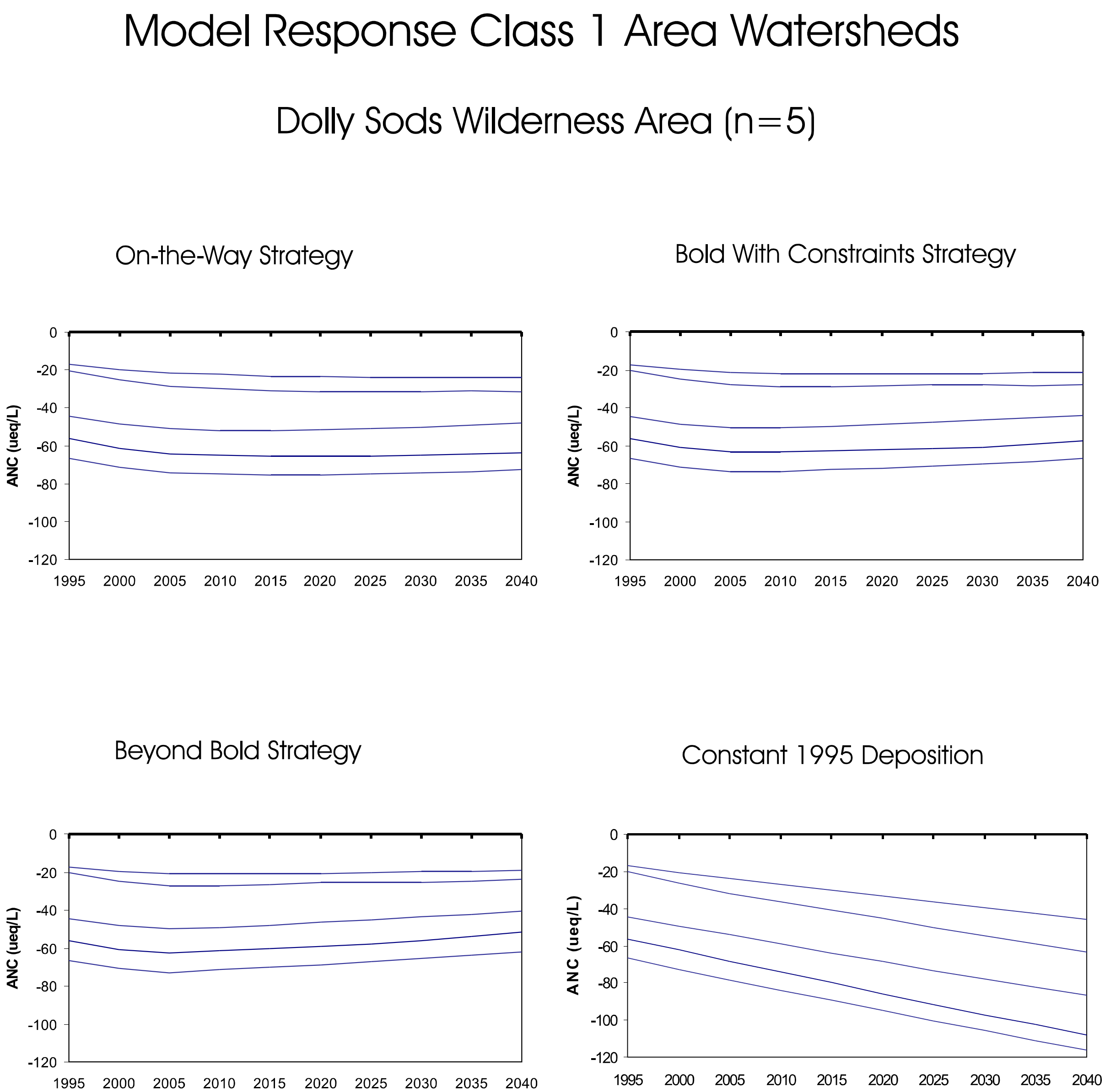


Figure 4-31. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Dolly Sods Wilderness that were selected for regional or special interest modeling.

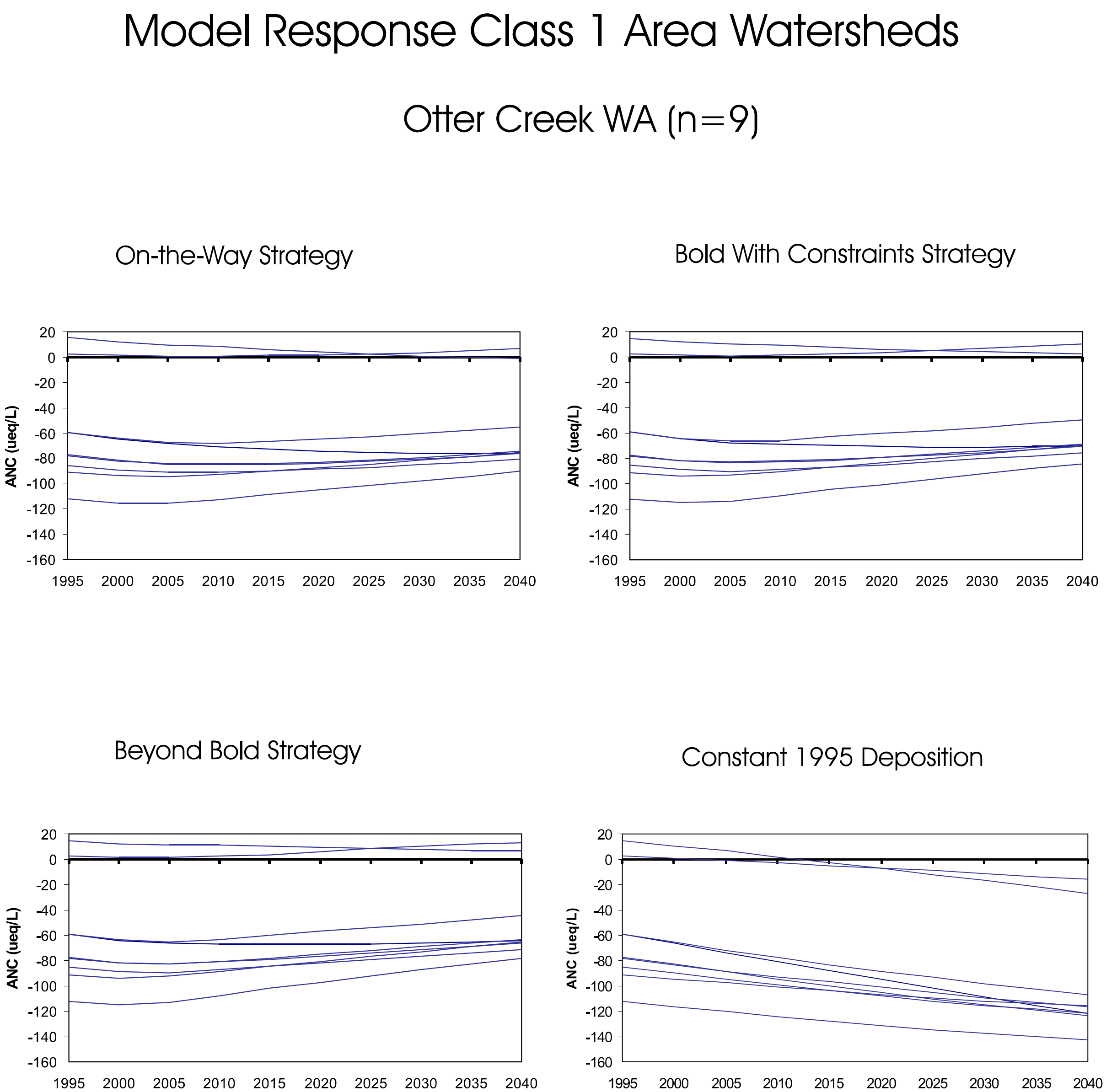


Figure 4-32. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Otter Creek Wilderness that were selected for regional or special interest modeling.

For seven of the modeled sites, projected ANC in 2040 was below -40 µeq/L, regardless of strategy. Biological recovery would not occur by 2040 at any of these sites. For the other two sites, ANC in 2040 differed among strategies, but was confined to the range of -1 to 13 µeq/L, regardless of strategy. Each of the strategies prevented projected 2040 streamwater chemistry of these two streams from becoming strongly acidic (compared with -16 and -27 µeq/L under the scenario of constant deposition at 1995 levels). But there was little indication that the BYB Strategy would yield significantly improved biological conditions in these streams as compared with the other strategies.

Most streams draining the Dolly Sods and Otter Creek Wilderness Areas have concentrations of H^+ and Al_i that are high enough to be toxic to many species of aquatic biota. Model simulations suggested that none of the strategies would appreciably alter that condition.

A limestone doser operates on the main stem of Otter Creek, which ameliorates the acidic conditions. Sulfate concentrations are high (median, 129 µeq/L), but Herlihy et al. (1996) concluded that there was no evidence of significant watershed sources of S.

4.3.2 Northern Blue Ridge Subregion

4.3.2.1 Shenandoah National Park

Shenandoah National Park is located in the northern portion of Virginia in the northern Blue Ridge Mountains. The park straddles a 110 km Section of the crest of the Blue Ridge. Elevation ranges from 600 to 4,050 ft (180 to 1,230 m) in this 788 km^2 park.

There is a strong relationship between streamwater ANC and geology in Shenandoah National Park (Cosby et al. 1991). The geologic formations in the southwestern part of the park are most resistant to weathering and have the streams with lowest ANC. About one fourth of the streams in the park have ANC ≤50 µeq/L (Cosby et al. 1991, Webb et al. 1996).

Thirteen streams were modeled with MAGIC in Shenandoah National Park, eight streams within the regional modeling effort and an additional five streams as special interest sites. ANC values of the modeled streams were highly variable, ranging from near zero to nearly 150 µeq/L. Streamwater sulfate and nitrate concentrations in the modeled streams were similarly variable; sulfate concentrations differed by nearly a factor of 3 (39 to 111 µeq/L) and nitrate concentrations ranged from near zero to over 30 µeq/L.

Because half of the modeled streams in Shenandoah National Park had ANC between about -5 and 40 µeq/L in 1995, rather small future changes in ANC can have pronounced impacts on biological status. Large differences were projected for streamwater chemistry in this park between the scenario of constant deposition at 1995 levels and the 3 strategies. For example, under constant 1995 deposition, almost half of the modeled sites were projected to have ANC < 20 μeq/L in 2040. In contrast, the BYB Strategy allowed all except two of those streams to increase to above 20 μeq/L (Figure 4-33).

4.3.2.2 James River Face Wilderness

The James River Face Wilderness comprises 35 km^2 in the mid-Section of Virginia. Elevation varies from 650 to 2,950 ft (200 to 900 m). Bedrock geology is mainly sandstone and quartzite from the Chilhowee Group, and Pedlar Formation (Virginia 1963, Herlihy et al. 1996). Streams in the wilderness are first order and drain outwards from the higher elevations in the center of the wilderness.

Herlihy et al. (1996) compiled available streamwater chemistry data, which included eight sites. Median sulfate concentration was 68 μeq/L and median ANC was 25 μeq/L. Seven of the eight streams had ANC between 0 and 50 μeq/L.

MAGIC modeling was conducted for five sites in James River Face (Figure 4-34), of which three were special interest sites. ANC values of the modeled sites fell within 3 ANC classes (0 to ≤20, >20 to ≤50, and >50 to 150 μeq/L) at the time of sampling, but the calculated ANC values ranged from 14 μeq/L to just above 50 μeq/L. Sulfate concentrations were generally intermediate (~60 μeq/L ± 20) and nitrate concentrations were uniformly low (Table 4-9).

All sites were projected to continue to acidify under all strategies through at least 2005, followed by lessened continued acidification or increased ANC thereafter. The scenario of continued future deposition at 1995 levels resulted in four sites having ANC in 2040 near or below zero. In contrast, under the BYB Strategy, all sites were projected to have ANC above 16 μeq/L. Under the OTW Strategy, four of five sites were projected to have ANC in 2040 less than 20 μeq/L. Thus, these strategy results suggest that many streams in this wilderness area would respond to the various strategies with streamwater chemistry that would have different levels of biological impacts.

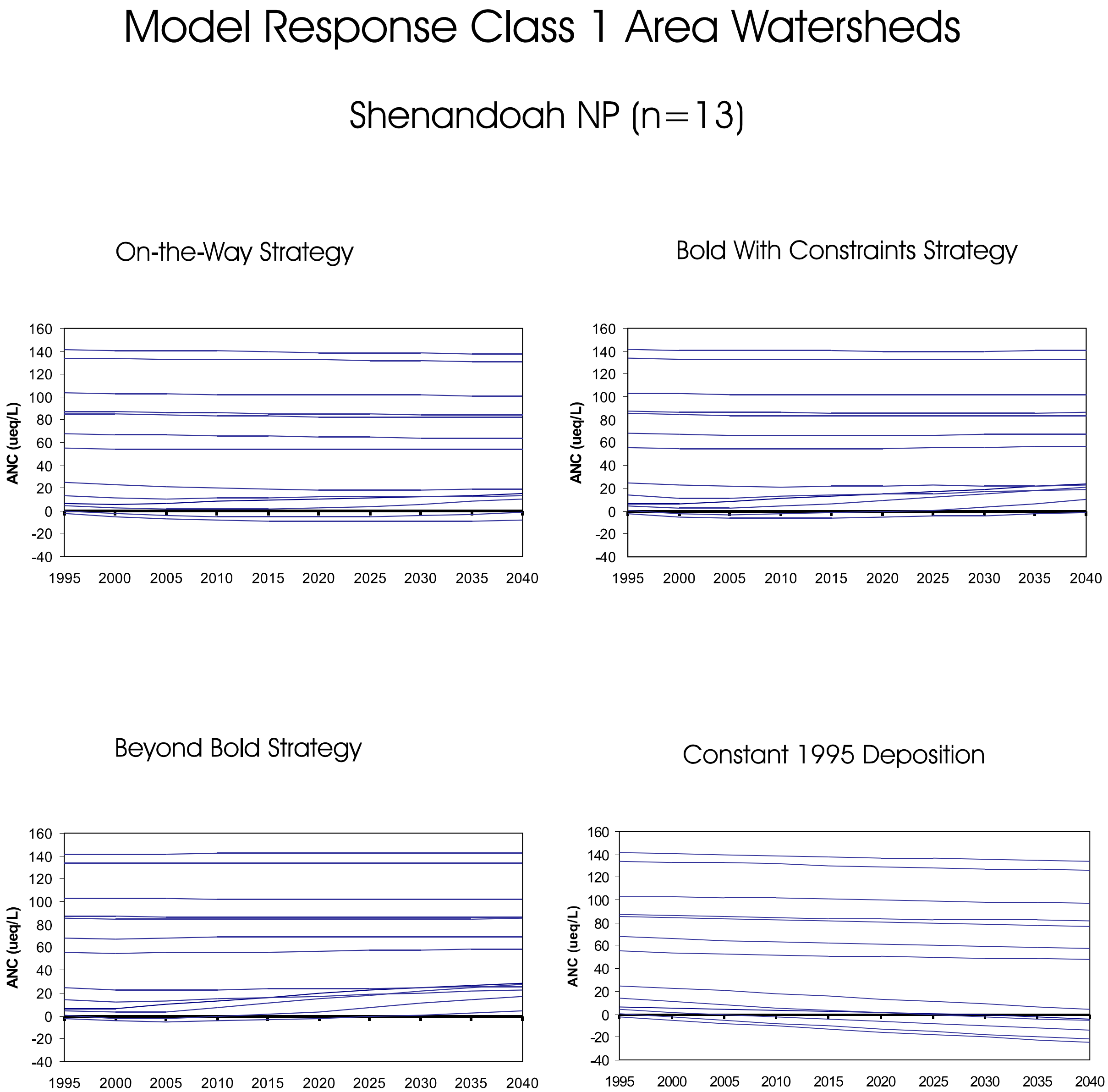


Figure 4-33. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Shenandoah National Park that were selected for regional or special interest

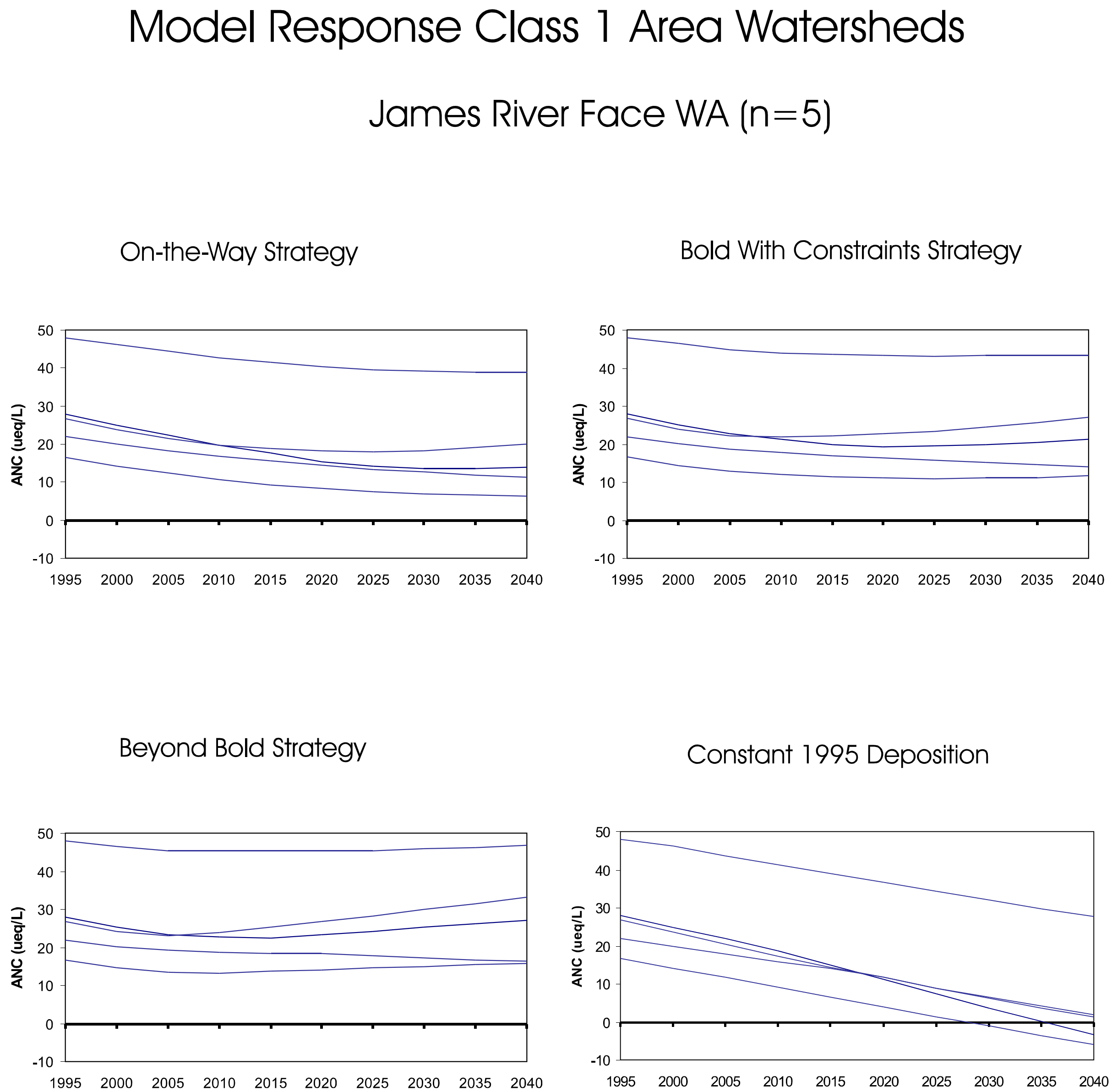


Figure 4-34. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within James River Face Wilderness that were selected for regional or special interest modeling.

4.3.3 Southern Blue Ridge Subregion

4.3.3.1 Great Smoky Mountains National Park (GSMNP)

There are nearly 200,000 km of streams in the SAMI region, based on EPA River Reach File-Version 3 at a 1:100,000 scale. Of those, about 2,750 km of streams are located in the 10 Class I areas that occur within the SAMI region. Herlihy et al. (1996) estimated that 74% of the total Class I stream length occurs within Great Smoky Mountains National Park (GSMNP). Thus, this park contains the vast majority of the Class I aquatic resources within the SAMI domain that are potentially sensitive to air quality degradation.

The GSMNP is located in Tennessee and North Carolina. Bedrock is uplifted sedimentary rock, primarily sandstone and some limestone (Elwood et al. 1991). Some watersheds are underlain in part by the Anakeesta Formation, which contains pyrite and contributes geological sulfur to drainage water, especially in disturbed areas such as along road cuts.

Results of stream chemistry studies in GSMNP have been reported by Silsbee and Larson (1982), Kaufman et al. (1988), Elwood et al. (1991), Cook et al. (1994), Flum and Nodvin (1995), and Herlihy et al. (1996). Results of these studies indicate that low-ANC streams are common throughout the park, and acidic streams are found at the higher elevations. On average, about 70% of atmospherically-deposited sulfur and 65% of deposited nitrogen are retained in watershed soils (Herlihy et al. 1996). At higher elevation sites, streamwater nitrate concentrations are frequently greater than sulfate concentrations and contribute significantly to the observed acidity of these streams. Forest dynamics, as influenced by logging and land use history, are important regulators of streamwater chemistry because of their influence on N-uptake. Bedrock geology is a good predictor of streamwater acid-base status within the park. The higher ANC systems are generally associated with limestone and most are located in the western portion of the park.

Elevation ranges from 900 to 6,640 ft (274 to 2,024 m) in the park. The upper portions of GSMNP are higher than elevations in any of the other Class I areas, and this contributes to both the acid-sensitivity of many of the first order streams in the park and to higher deposition levels of sulfur and N.

The acid base chemistry of five forested watershed streams in Great Smoky Mountains National Park was investigated by Cook et al. (1994). The study watersheds ranged in elevation from 1100 to 2000 m and included steep, unlogged coniferous (*Picea rubens, Abies fraseri*) and deciduous (*Betula alleghaniensis*) forests. Bedrock at higher elevations in the Walker Camp

Prong and Trout Branch watersheds is a pyritic carbonaceous phillite (Anakeesta Formation), and at lower elevations is a graded, quartz and potassium feldspar sandstone (Thunderhead Formation; Cook et al. 1994). Soils overlying the Anakeesta Formation are subject to landslides and have lower pH and higher sulfate concentration due to oxidation of pyrite (Huckabee et al. 1975).

Three of the streams studied by Cook et al. (1994) had low ANC (-30 to -15 μeq/L): WP-3, WP-4, and Trout Branch. This was attributed to the presence of sulfate derived from both atmospheric deposition and bedrock sources of S, a small capacity of the thin soils to retain sulfate, and a large export of nitrate. Mean nitrate concentrations were high at all of the sites, ranging from 49 to 75 μeq/L. This was attributed by Cook et al. (1994) to several possible mechanisms that could cause enhanced nitrate leaching in these old-growth forests:

1) lower nitrogen demand of the old-growth forest vegetation,
2) greater net nitrogen mineralization of organic nitrogen in old-growth systems,
3) greater nitrification in old growth systems, and
4) higher rates of dry deposition and cloud inputs.

Nitrate concentrations in upland streams of Great Smoky Mountain National Park are very high in some locations (~ 100 μeq/L) and are correlated with elevation and forest stand age (Cook et al. 1994). The old growth sites at higher elevation showed the highest nitrate concentrations, likely due to the higher rates of nitrogen deposition and flashier hydrology at high elevation, as well as decreased vegetative N-demand in the more mature forest stands. High nitrogen deposition at these sites has likely contributed to both chronic and episodic acidification (Flum and Nodvin 1995, Nodvin et al. 1995).

Adverse effects on aquatic biota have also been found in Great Smoky Mountains National Park. A steady decline in brook trout range has been reported since the 1930s (Herlihy et al. 1996). In addition, invertebrate density and number of species were higher in high-pH streams (Rosemond et al. 1992).

A total of 14 sites were modeled with MAGIC in Great Smoky Mountains National Park (Figure 4-35), only one of which was a special interest site. ANC concentrations were variable, ranging from 8 to 114 μeq/L at the time of sampling. Streamwater sulfate concentrations were low, ranging from 17 to 76 μeq/L, with only one site above 44 μeq/L, but nitrate concentrations were rather high at the majority of the sites, ranging up to 43 μeq/L and commonly above 20

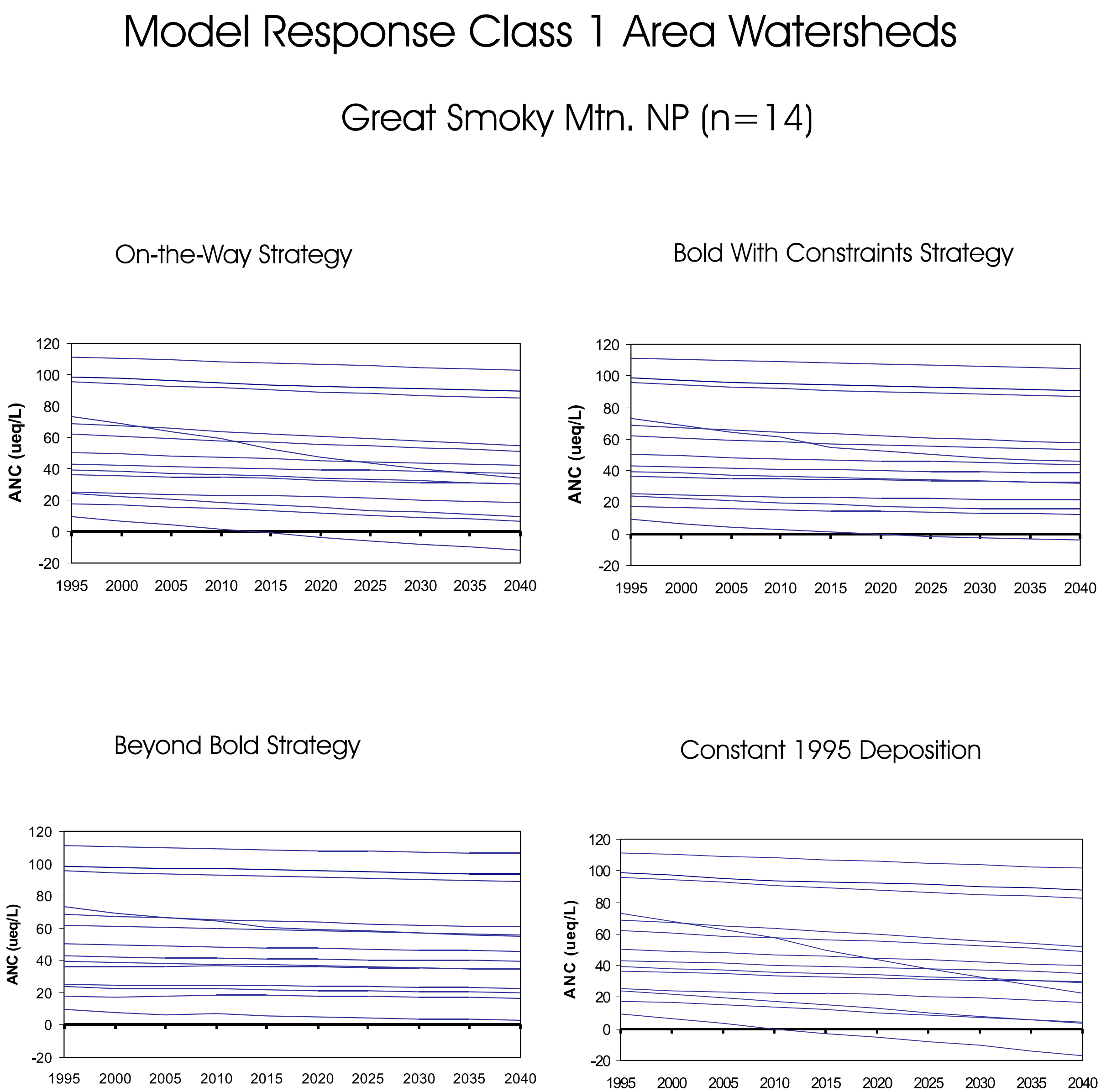


Figure 4-35. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Great Smoky Mountains National Park that were selected for regional or special interest modeling.

μeq/L. More than half of the modeled sites had simulated ANC between 0 and 50 μeq/L in 1995. Therefore, small differences among strategy results might be expected to have appreciable effects on biological conditions. Under the OTW Strategy, one site was projected to be acidic in 2040 and three other sites to have ANC between 0 and 20 μeq/L. Under the BYB Strategy, no sites were projected to be acidic in 2040 and three sites still had projected ANC ≤ 20 μeq/L. Thus, the differences among strategies were rather small. This was, in part, because the simulated changes in streamwater sulfate and nitrate concentrations in this park were rather small and tended to cancel each other out (Figures 4-9 to 4-11).

4.3.3.2 Joyce Kilmer/Slickrock Wilderness

The Joyce Kilmer/Slickrock Wilderness area comprises 69 km^2 of forested terrain that includes the headwaters of two stream systems (Slickrock Creek and Little Santeetlah Creek). Elevations range between 2,000 and 5,300 ft (610 to 1,615 m). This wilderness is adjacent to GSMNP and has similar geology and topography. Available streamwater chemistry data were summarized by Herlihy et al. (1996), and indicated that about one-third of the assessed stream length in the area had ANC between 0 and 50 μeq/L; the rest had ANC > 50 μeq/L. This earlier assessment was based on data for about 30% of the stream length in the wilderness, represented on 1:100,000-scale maps.

No sites were modeled in this Class I area for the SAMI Assessment.

4.3.3.3 Linnville Gorge Wilderness

There are few stream resources within the Linnville Gorge Wilderness other than a 20 km stretch of the Linnville River, which flows through the gorge. Because the Linnville River is not a low-order stream, it is highly unlikely that it is acid-sensitive (Herlihy et al. 1996). Surface water resources in this wilderness therefore were not modeled for this SAMI modeling effort.

4.3.3.4 Shining Rock Wilderness

The Shining Rock Wilderness comprises 75 km^2 of wilderness, drained by the headwaters of the East Fork of the Pigeon River in the southern portion of North Carolina. Elevations range from 3,300 to 6,000 ft (1,000 to 1,830 m). Herlihy et al. (1996) reported streamwater ANC for nine sites, located on two stream systems. All sites had ANC between 50 and 100 μeq/L.

Two sites were modeled in this wilderness. Both had simulated 1995 ANC near 50 μeq/L. Both were projected to continue to acidify, but the amount of future acidification (through 2040) was not strongly dependent on assumptions regarding future deposition. Results for the scenario of constant deposition at 1995 levels and the BYB Strategy were similar (Figure 4-36).

4.3.3.5 Cohutta Wilderness

The Cohutta Wilderness is located in northern Georgia, and ranges in elevation from 1,000 to 3,900 ft (300 to 1,190 m). It includes 121 km^2, drained by the headwaters of the Conasauga and Jacks Rivers. Herlihy et al. (1996) summarized streamwater chemistry for 15 sites, representing about three-fourths of the 145 km of stream length that are depicted on 1:100,000-scale maps. Almost all of the sampled sites had ANC $\leq$ 50 μeq/L, but none were acidic. Streamwater nitrate concentrations were relatively high, with a median of 14 μeq/L.

Four sites were modeled with MAGIC in Cohutta, all of which were included in the regional modeling set. ANC values were generally similar, with calculated ANC ranging from 22 to 66 μeq/L at the time of sampling. Sulfate concentrations were rather high at two sites (~ 80 μeq/L) and low (~ 20 μeq/L) at the other two sites. Nitrate concentrations were uniformly low (<5 μeq/L). Strategy results were generally similar; the modeled sites showed little change in ANC, regardless of strategy (Figure 4-37).

4.3.4 Alabama Appalachian Plateau Subregion

4.3.4.1 Sipsey Wilderness

The Sipsey Wilderness is located in northern Alabama, is 52 km^2 in area, and ranges from 500 to 1,000 ft (150 to 300 m) elevation. The wilderness area is drained by Sipsey Fork, which is formed by the confluence of Thompson Creek and Hubbard Creek, the headwaters of which are located outside the wilderness area. Herlihy et al. (1996) summarized available water chemistry data, which covered about half of the stream length in the area that is represented on 1:100,000-scale maps.

Some parts of the wilderness are underlain by the Bangor limestone formation, which imparts high ANC (> 200 μeq/L) to the streams that drain it. Other parts are drained by streams that are underlain by bedrock of the Pottsville (pebbly quartzose sandstone) and Parkwood (shale, sandstone) formations (Osbourne et al. 1989, Herlihy et al. 1996). Many of these streams have ANC near 50 μeq/L.

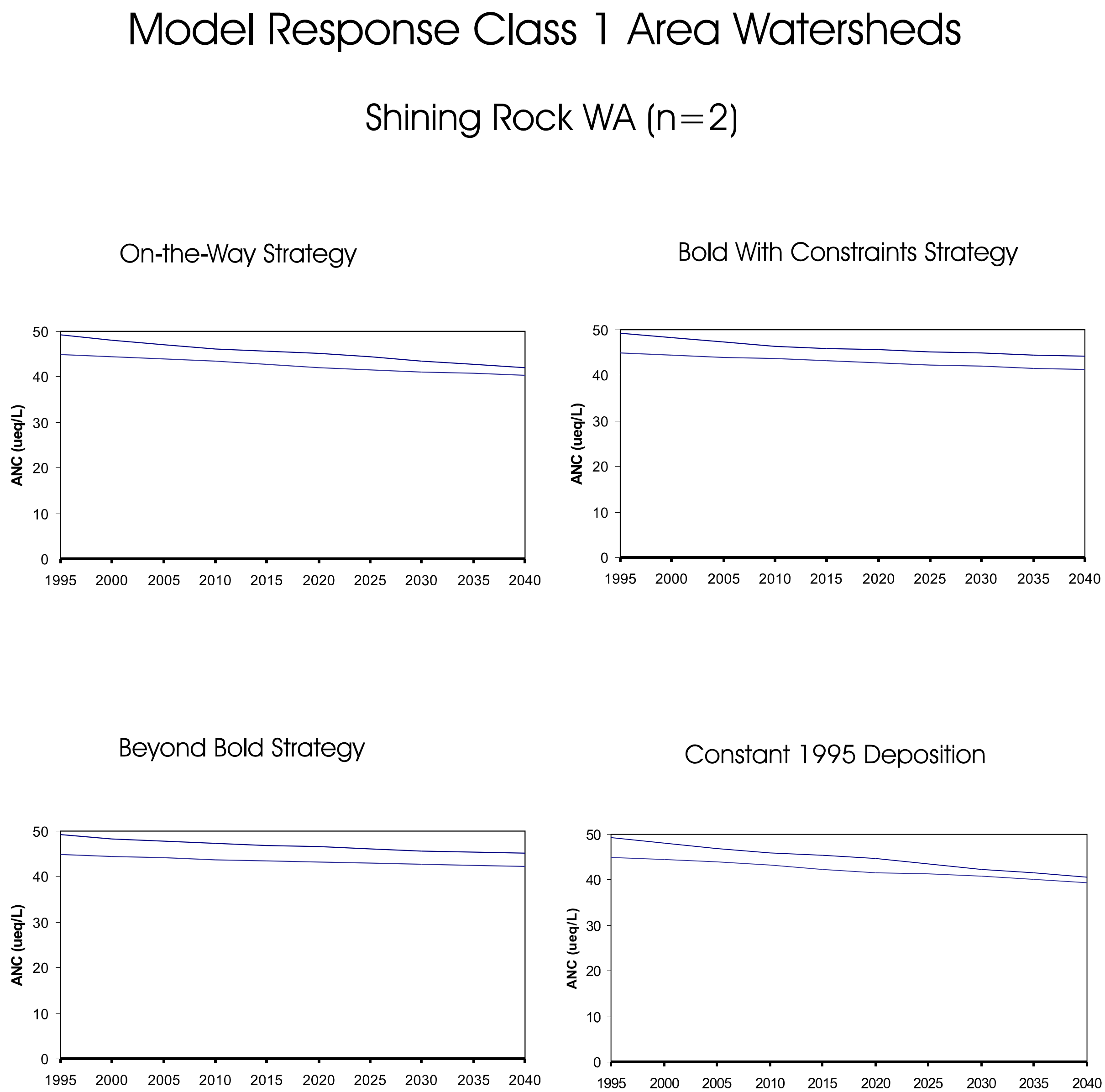


Figure 4-36. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Shining Rock Wilderness that were selected for regional or special interest modeling.

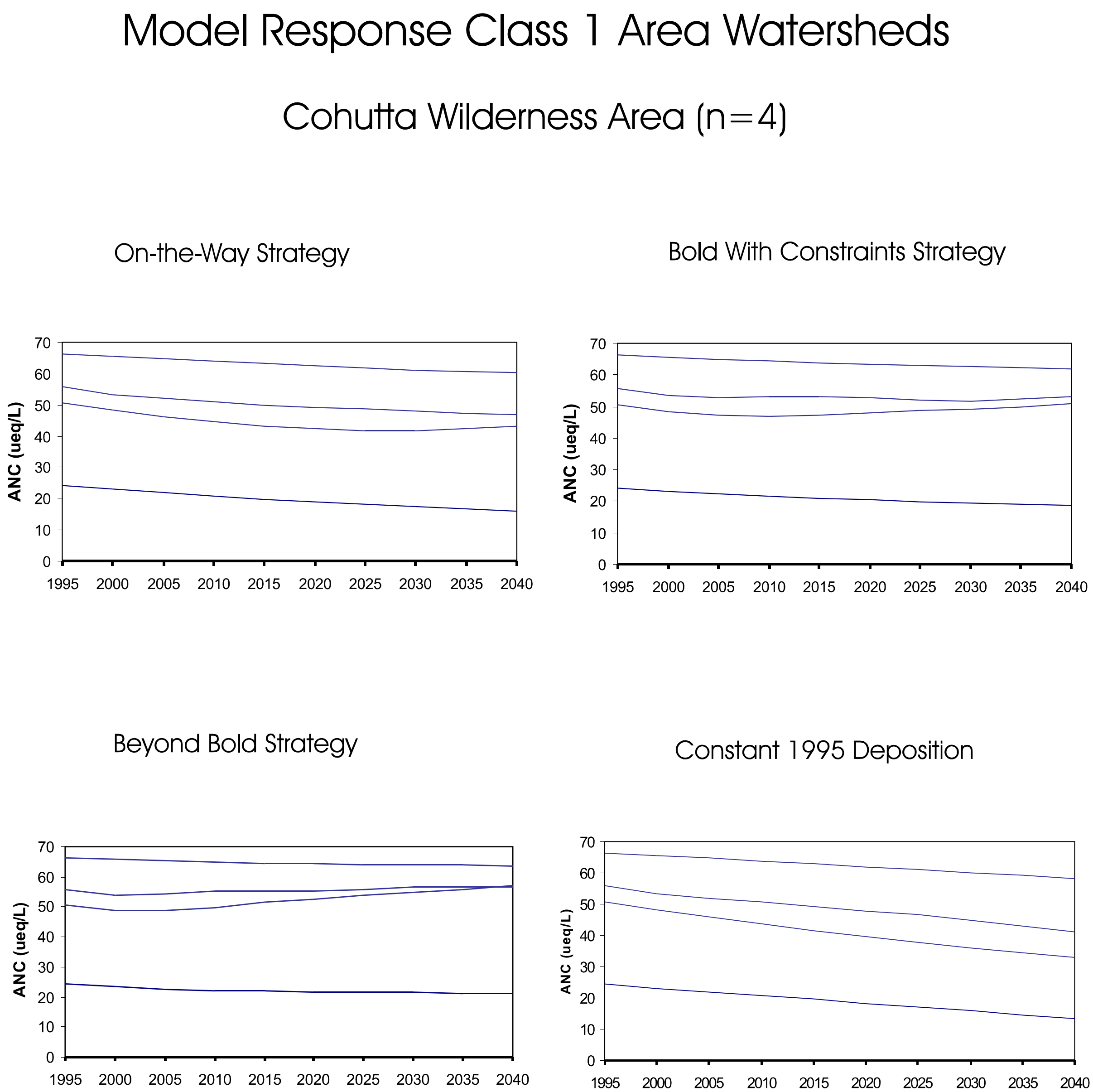


Figure 4-37. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Cohutta Wilderness that were selected for regional or special interest modeling.

Three watersheds were modeled in Sipsey, one in the regional data set and two as special interest sites. Calculated ANC values ranged from 31 to 102 μeq/L in the three modeled streams at the time of sampling. Sulfate concentrations were fairly high, relative to depositional inputs, ranging from 70 to 94 μeq/L. Nitrate concentrations were low (≤ 6 μeq/L). All of the modeled sites occurred at elevation ≤ 250 m.

There was little difference in the model projections among strategies. In each case, one stream was projected to have ANC in 2040 slightly below 20 μeq/L (Figure 4-38).

4.4 Sensitivity of Model Output to Major Uncertainties

There are numerous uncertainties associated with conducting as assessment of this type, some of which are quantifiable, some not. The major uncertainties relate to model input data quality, temporal variability (especially seasonal and episodic) in water chemistry, variability in biological response to water chemistry, model validity and accuracy, model calibration uncertainty, errors associated with missing model input data, and errors associated with regional extrapolation of modeling results from individual watersheds to the region. Such errors and uncertainties are not additive, but rather would be expected to some extent to cancel each other out. Although it is not possible to rigorously quantify the overall uncertainty in the assessment results, analyses were conducted to evaluate and put into perspective many of these major uncertainties.

4.4.1 Quality of Input Data

Rigorous screening criteria were adopted for regional modeling site selection, to ensure that the data for the modeling sites were internally consistent and that sites were not included if they showed indication of significant impacts on acid-base chemistry other than acidic deposition (geological sulfur, acid mine drainage, road salt, land use). The resulting database appeared to be internally consistent, showing good agreement between calculated (from the charge balance) and titrated ANC and reasonable relationships between pH and ANC (Figure 4-1). The majority of the selected modeling sites had been sampled within large synoptic water chemistry surveys that had substantial Quality Assurance/Quality Control (QA/QC) programs. We believe that the model input data are generally of very high quality. Nevertheless, we expect that the laboratory analytical error for calculated ANC is on the order of 13 μeq/L, based on previous analyses of National Surface Water Survey data (T. Sullivan, unpublished data).

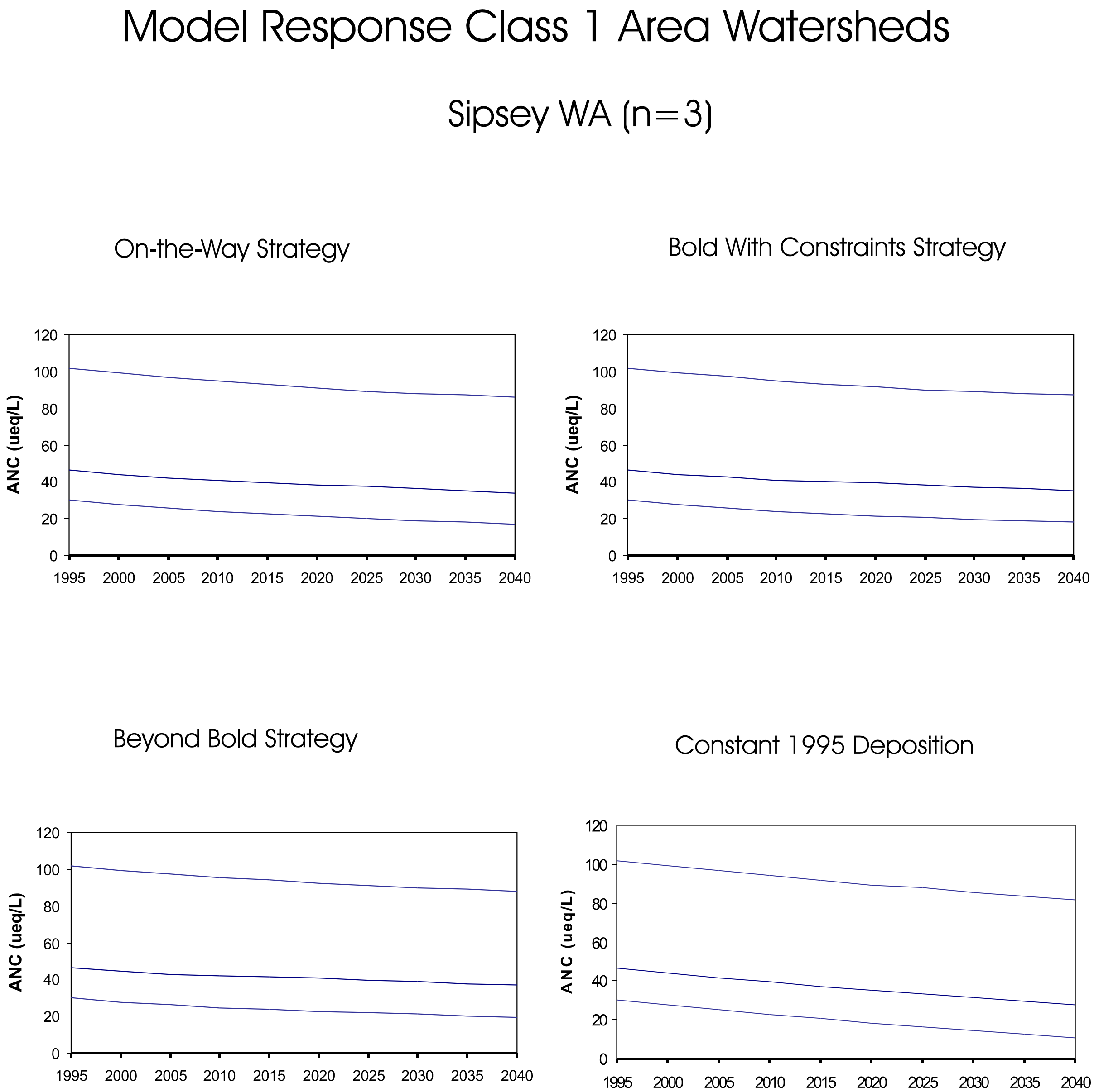


Figure 4-38. MAGIC model output for each of the Emissions Control Strategies and the scenario of constant 1995 deposition for all streams within Sipsey Wilderness that were selected for regional or special interest modeling.

4.4.2 Temporal Variability of Input Data

Streamwater and soil solution chemistry are temporally variable, mainly in response to changing hydrological conditions and seasonal patterns in plant and microbial activities. As a consequence, water chemistry varies over time. Most streamwater chemistry data used in this assessment represented spring baseflow periods, thereby minimizing this variability to some degree. It is expected that streamwater chemistry at most sites varies substantially from the chemistry recorded at the time of sampling. As a consequence, most streams would be expected to show lower ANC during some periods (i.e., rainfall events) as compared with measured values used here. This uncertainty was considered in the selection of ANC classes used for stratifying modeling sites and for presentation of the results. In other words, the interpretation of the model projections of chronic chemistry allows for the likelihood of additional episodic acidification. Although the extent and magnitude of episodic acidification varies from site to site and with meteorological conditions, some generalities are possible. For example, Webb et al. (1994) developed an empirical approach to quantify streamwater ANC of extreme events in VTSSS long-term monitoring streams in western Virginia, based on the model of Eshleman (1988). Minimum measured episodic ANC values were about 20% lower than the median spring ANC.

4.4.3 Biological Responses

For the biological component of this assessment, streams were classified into response classes expected to correspond in a general way with brook trout responses to change in streamwater ANC. These results must be interpreted in light of the known variability in brook trout response due to differential life stage sensitivities to streamwater chemistry, the existence in the stream system of refugia of higher ANC, and variable episodic toxicity. In addition, it must be recognized that aquatic biota other than brook trout exhibit different levels of sensitivity to changes in acid-base chemistry.

In general, inferences regarding potential future change in biological systems in response to changing levels of acidic deposition are subject to greater uncertainty than are inferences regarding chemical change. This is largely because of the considerable variability that exists with respect to:

- intraspecific and interspecific differences in sensitivity to low ANC, low pH, and high aluminum concentrations in streamwater,

- chronic versus episodic toxicity response functions, and
- importance of factors other than acid-base chemistry in determining habitat suitability (i.e., water temperature, food sources, dissolved oxygen content, stream morphology, etc.).

4.4.4 Model Validity and Accuracy

The MAGIC model, like any process-based model of acid-base chemistry, is a simplification of an array of physical, chemical, and biological processes. Such simplification invariably results in uncertainty with respect to model structure and performance. Unfortunately, models of ecosystem behavior can never truly be validated because environmental systems are not closed and because some processes might assume importance only under particular circumstances. Furthermore, with any model, it is possible to get the right answer for the wrong reason (c.f., Oreskes et al. 1994 for a discussion of model validation). Nevertheless, the MAGIC model has been extensively tested against independent measurements of chemical acidification and recovery. These tests have included many comparisons between model projections of ANC or pH and the results of whole-watershed manipulation experiments and comparisons between model hindcasts of pH and diatom-inferred pH. In general, the MAGIC model has shown good agreement with these independent measurements or estimates of chemical change. See the review of Sullivan (2000) for additional information.

For this study, data were available from the VTSSS with which to evaluate the agreement between MAGIC simulated and observed values over a ten-year period of record. MAGIC was calibrated to 33 VTSSS sites, representing all eight of the modeling bins within the Blue Ridge and Ridge and Valley provinces, but none of the Appalachian Plateau modeling bins. The root mean squared error (RMSE) was selected as the statistic for comparing the goodness of fit between simulated and observed values. It is equal to the square root of the average squared difference between the 10 pairs of simulated and observed values (one for each of the 10 years of record). One site was selected to represent each modeling bin and the simulated and observed results are shown in Figure 4-3. The RMSE for the eight sites shown in the figure ranged from 4 to 11 μeq/L, with a mean of 7.6 μeq/L. The range and mean of the 25 sites not selected for display were similar (3 to 13 and 7.1 μeq/L, respectively).

4.4.5 Model Calibration and Simulation Uncertainty

The aggregated nature of the MAGIC model requires that it be calibrated to observed data from a system before it can be used to examine potential system response. Calibration is achieved by setting the values of certain parameters within the model that can be directly measured or observed in the system of interest (called "fixed" parameters). The model is then run (using observed and/or assumed atmospheric and hydrologic inputs) and the outputs (stream water and soil chemical variables, called "criterion" variables) are compared to observed values of these variables. If the observed and simulated values differ, the values of another set of parameters in the model (called "optimized" parameters) are adjusted to improve the fit. After a number of iterations, the simulated-minus-observed values of the criterion variables usually converge to zero (within some specified tolerance). The model is then considered calibrated. If new assumptions (or values) for any of the fixed variables or inputs to the model are subsequently adopted, the model must be re-calibrated by re-adjusting the optimized parameters until the simulated-minus-observed values of the criterion variables again fall within the specified tolerance.

The estimates of the fixed parameters and deposition inputs used for calibration are subject to uncertainties so a multiple optimization procedure was implemented for calibrating the model at each SAMI site. The multiple optimization procedure consisted of repeated calibrations of each site using random values of the fixed parameters drawn from the observed possible range of values for each site, and random values of deposition from a range including uncertainty about the interpolated values for each site. Each of the calibrations began with (1) a random selection of values of fixed parameters and deposition, and (2) a random selection of the starting values of the optimized parameters. The optimized parameters were then adjusted using a steepest-descent algorithm to achieve a minimum error fit to the "criterion" or target variables. This procedure was undertaken ten times for each SAMI site. The final calibrated model for a site is represented by the ensemble of parameter values and variable values of all of the successful calibrations.

The effects of the uncertainty in the assumptions made in calibrating the model (and the inherent uncertainties in the data available) can be assessed by using all successful calibrations for a site when simulating the response to different scenarios of future deposition. The model then produces an ensemble of simulated values for each site. The median of all simulated values is considered the most likely response of the site. The projections from MAGIC reported throughout this document are the median values from the ensemble of calibrations for each of the SAMI sites. The simulated values in the ensemble can also be used to estimate the magnitude of the uncertainty in the projection. Specifically, the difference in any year between the maximum and minimum simulated values from the ensemble of calibrated parameter sets can be used to define an "uncertainty" (or "confidence") width for the simulation at any point in time. All ten of the successful model calibrations will lie within this range of values.

The uncertainty widths for simulated charge balance ANC for the SAMI reference year (Table 4-11) are of the same order as the uncertainties in the observed values (as discussed above). As expected, the uncertainties grow somewhat as the model is used to project the future response of ANC for each of the three SAMI strategies (Table 4-11), but the increase is not severe. The uncertainty widths reported in Table 4-11 are the average uncertainty widths calculated across the 164 calibrated sites. The widths at any individual site may be lower or higher, but the average gives a robust indication of the size of calibration uncertainty in general.

Table 4-11. Average uncertainty widths for simulated charge balance ANC for two different years in each of the three SAMI strategies. The uncertainty width is the difference in projected ANC between the two calibrations (of 10 constructed) that resulted in the highest and the lowest values in a given year. Units are μeq/L. There are 164 sites for each average value. The average uncertainty width for simulated ANC for the SAMI Reference Year, 1995, is 11.3 μeq/L.

Strategy	Year 2010	Year 2040
OTW	15.1	23.2
BWC	15.0	23.0
BYB	14.9	23.3

4.4.6 Missing Model Input Data

There were errors introduced into the modeling effort as a consequence of not having soils data available for all of the MAGIC modeling sites. For Tier II sites, soils data were borrowed from a nearby Tier I site located on the same geology. For Tier III sites, soils data were borrowed from the Tier I site judged to be most comparable with respect to streamwater ANC (an integrator of watershed soils conditions), geologic sensitivity class, location, elevation and streamwater sulfate concentration (an integrator of sulfur adsorption on soils). The error associated with needing to borrow soils data for Tier II and Tier III sites was quantified by calibrating selected Tier I watersheds twice, once using the appropriate site-specific soils data, and a second time using borrowed soils data from an alternate site, using either Tier II or Tier III protocols. Multiple Emissions Controls Strategies were then simulated for each of the two calibrations at each site. The results showed generally good agreement between model projections of streamwater ANC using measured versus borrowed soils data (Figure 4-4). Errors were generally less than about 10 μeq/L. The RMSE of the observed differences between model projections based on site-specific versus borrowed soils data was 3.9 μeq/L for Tier II protocol applications, based on four sites and seven simulated ANC values at each site. Similarly, the RMSE was 2.9 for Tier III protocol applications, based on seven sites and seven simulated ANC values at each site (c.f., Figure 4-4).

4.4.7 Uncertainty and Regional Extrapolation of Results

There is uncertainty associated with extrapolating the results of site-specific modeling at 130 regional locations to the population of streams within the SAMI domain. Substantial effort was devoted to selection of regional modeling sites that spanned the range of available data with respect to all variables thought to be important in discriminating among the likely response functions within the study area. Thus, sites were selected to maximize diversity of model sites with respect to physiographic province, water chemistry (ANC, sulfate, nitrate concentrations), geographic location, and elevation. Because the sites were not selected from a statistical frame, it is not possible to use the modeled responses of these 130 watersheds to describe changes to the population of streams in the SAMI domain. We expect that the sites are representative, but we cannot demonstrate that they are representative.

Regional extrapolation error, which is the error involved in predicting condition for the whole SAMI region, can be broken into two components: estimating population conditions from statistical survey data, and extrapolating future site changes in regional subpopulations based on the median change from the model subpopulation bins. The NSS employed a statistical survey design to estimate the condition of the more than 19,000 stream reaches in the SAMI domain based on a sample of almost 150 stream reaches. Similar to a Gallup poll where phone interviews of ~400 random people can be used to predict national and state election results within a defined margin of error, the NSS statistical design also has quantifiable error bounds for regional population estimates. Using the Horvitz-Thompson variance algorithm (Appendix K), and given the NSS sample size and sites used to estimate the SAMI domain, the exact standard error of any population estimate can be made. As a general guideline, estimates of around 50% of the SAMI population have a standard error of plus or minus 7 to 9 percentage points. For the tails of the SAMI regional distribution (e.g. 10% of the sites are low in ANC), the standard error of the NSS estimates are plus or minus 2 to 5 percentage points. Standard errors are given as ranges because exact estimates depend on which sites are affected and from which sample strata they were selected.

To make worst case estimates of the effects of using the "bin" approach for applying future MAGIC model results to the NSS sites (Section 3.6.1), we performed a min/max estimation by adding the bin minimum and maximum projected chemical change to each NSS site instead of the median chemical change. This is a worst case in that we are taking the most extreme model results from the bin instead of the central tendency. An illustration of the effect of this uncertainty analysis is shown for the OTW strategy in year 2040 for the regional estimate of ANC in Upper and Lower stream reach ends in Figure 4-39. The difference in the best and worst case regional estimate is about plus or minus 1 to 7 percentage points from the median result among the various ANC classes. Thus, as a worst case, the bin extrapolation process has an error about equivalent to the error in the statistical extrapolation of the regional population from the sample sites described above. In actuality, it is probably a fair amount smaller than that.

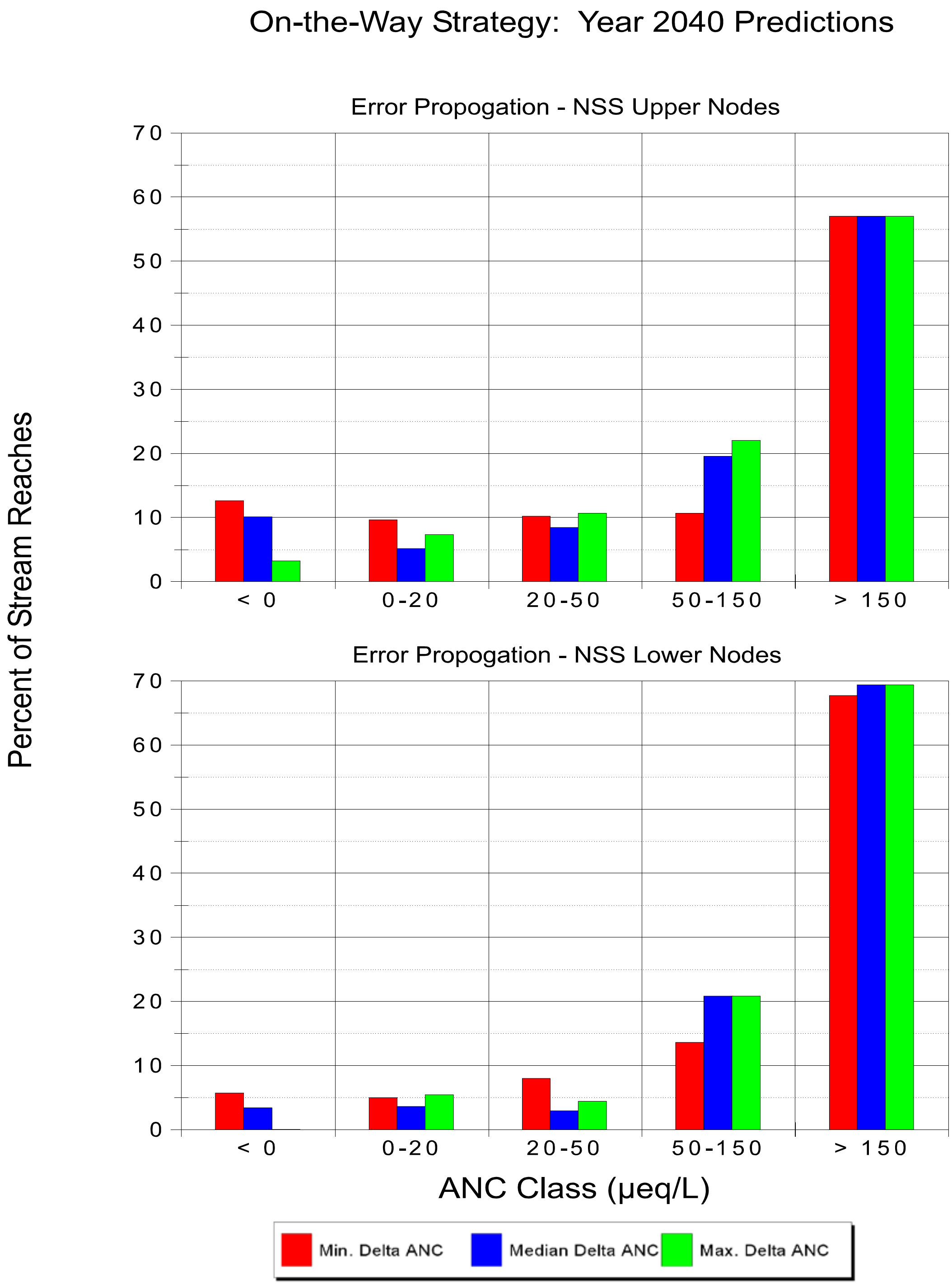


Figure 4-39. Illustration of worst case error analysis for the bin extrapolation process used for making regional projections. Maximum and minimum values were obtained by taking the maximum or minimum within-bin estimate of projected future change in ANC, rather than the median value. Note that the median estimate within a given ANC class is not necessarily intermediate in magnitude between the maximum and minimum values because value selection can cause some streams to change ANC class.

5.0 DISCUSSION

5.1 Watershed Sensitivity to Acidification

Surface waters that are sensitive to acidification from acidic deposition of sulfur or nitrogen typically exhibit a number of characteristics. Such characteristics either predispose the waters to acidification and/or correlate with other parameters that predispose the waters to acidification. Although precise guidelines are not widely accepted, general ranges of parameter values that reflect sensitivity are as follows (Peterson and Sullivan 1998, Sullivan 2000):

<u>Dilute</u> - Waters have low concentrations of all major ions, and therefore specific conductance is low (< 25 µS/cm).

<u>Acid neutralizing capacity</u> - ANC is low. Acidification sensitivity has long been defined as ANC<200 µeq/L, although more recent research has shown this criterion to be too inclusive (Sullivan 1990). Waters sensitive to chronic acidification generally have ANC<50 µeq/L, and waters sensitive to episodic acidification generally have ANC<100 µeq/L.

<u>Base cations</u> - Concentrations are low in non-acidified waters, but increase (often substantially) in response to acidic deposition. The amount of increase is dependent on the acid-sensitivity of the watershed. In relatively pristine areas, the concentration of ($Ca^{2+} + Mg^{2+} + K^+ + Na^+$) in sensitive waters will generally be less than about 50 to 100 µeq/L.

<u>Organic acids</u> - Concentrations are low in waters sensitive to the effects of acidic deposition. Dissolved organic carbon (DOC) imparts substantial pH buffering and causes water to be naturally low in pH and ANC, or even to be acidic (ANC<0).

<u>pH</u> - pH is low, generally less than 6.0 to 6.5 in acid-sensitive waters. In areas that have received substantial acidic deposition, acidified lakes (as quantified by analyses of diatom remains in lake sediments) are generally those that had pre-industrial pH between 5 and 6.

<u>Acid anions</u> - Sensitive waters generally do not have large contributions of mineral acid anions (e.g., sulfate, nitrate, F^-, Cl^-) from geological or geothermal sources. In particular, the concentration of sulfate in drainage waters would usually not be substantially higher than could reasonably be attributed to atmospheric inputs, after accounting for probable dry deposition and evapotranspiration.

Physical characteristics - Sensitive waters are usually found at moderate to high elevation, in areas of high relief, with flashy hydrology and minimal contact between drainage waters and soils or geologic material that may contribute weathering products to solution. Sensitive streams are generally low order.

It was recognized relatively early in acidification research that most of the major concentrations of low-ANC surface waters were probably located in areas underlain by bedrock resistant to weathering. Subsequent compilations of available water chemistry data (e.g., Omernik and Powers 1983, Eilers and Selle 1991) refined and expanded this image of sensitive areas in North America. The extensive research programs conducted in Europe, in Canada, and through NAPAP provided additional insight into factors contributing to the sensitivity of surface waters to acidic deposition by revealing the importance of soil composition and hydrologic flowpath, in addition to geology, in delineating sensitive regions.

The geologic composition of a region plays a dominant role in influencing the chemistry and therefore sensitivity of surface waters to the effects of acidic deposition. Bedrock geology formed the basis for a national map of surface water sensitivity (Norton et al. 1982) and has been used in numerous acidification studies of more limited extent (e.g. Bricker and Rice 1989, Dise 1984, Gibson et al. 1983). Analysis of bedrock composition continues to be an important element for assessing sensitivity of surface waters in mountainous regions (e.g. Stauffer 1990, Stauffer and Whittchen 1991, Vertucci and Eilers 1993).

The presence of large populations of acidic and low-ANC lakes and streams in regions such as northern Florida that are underlain by calcareous bedrock illustrate that if the surface waters are isolated from highly weatherable bedrock minerals, acid-base status is not controlled by bedrock geology (Sullivan and Eilers 1994). Thus, both soil and bedrock composition may exert strong influence on surface water acid-base chemistry, and therefore are important factors to be considered in defining acid-sensitive regions.

The third principal factor now recognized as critical in contributing to the sensitivity of aquatic resources is watershed hydrology. The movement of water through the soils, into a stream, and the interchange between drainage water and the soils and sediments regulate the type and degree of watershed response to acidic inputs. Streams in the same physiographic setting can have radically different sensitivities to acidic deposition depending on the relative contributions of near-surface drainage water and deeper, more highly buffered groundwater (Eilers et al. 1983, Chen et al. 1984, Driscoll et al. 1991). Natural hydrologic events also radically alter sensitivity to acidification by bypassing normal neutralization processes during high flow periods or changing flowpaths during extended droughts (Webster et al. 1990). The importance of hydrologic factors in influencing the acid-base chemistry of surface waters across the United States was reinforced by Newell (1993), who identified hydrology as a key component associated with changes in the acid-base chemistry of lakes included in EPA's Long Term Monitoring Program.

Watersheds differ in their sensitivity to continued atmospheric loading of sulfur or nitrogen and also to changes in those loading rates. Watersheds that exhibit substantial sulfur adsorption on soils will often show reduced sensitivity to future changes in sulfur deposition. In addition, such watersheds may show continued acidification under dramatically reduced sulfur deposition, in part because of a gradual decrease in sulfur adsorption over time. Watersheds also differ with respect to the extent to which nitrogen deposition is retained within soils and biota versus leached to streamwater as nitrate. Watersheds that currently leach significant amounts of nitrogen are expected to be most responsive to future changes in nitrogen deposition.

Nitrogen dynamics in the SAMI region are also strongly influenced by watershed disturbance. For example, forest defoliation by the gypsy moth in Shenandoah National Park and surrounding areas dramatically increased NO_3^- export in some watersheds. In addition, wind damage and forest defoliation by the fall cankerworm resulted in small transient increases in NO_3^- export at Coweeta Hydrological Laboratory (Webb et al. 1999).

Gosz and Murdoch (1999) concluded that studies in deciduous forests suggest a threshold for nitrogen saturation (the point at which N inputs exceed biological demand and an appreciable percent of the nitrogen input is exported from the watershed as nitrate in streamwater) at nitrogen deposition rates of about 9-12 kg/ha/yr. Based on a review of recent research and monitoring studies in the southern Appalachian region, Gosz and Murdoch concluded that:

- some areas receiving high levels of nitrogen deposition have been subject to nitrogen saturation, whereas other have not;
- nitrogen saturation is not strictly a function of forest maturation;
- natural disturbance can be associated with elevated nitrogen export; and
- there are relationships between climate and nitrogen cycling.

Nitrogen retention in southern Appalachian watersheds is highly variable, ranging from about 1% to 98% (Webb et al. 1999). At five intensively studied watersheds within the region, nitrogen export was near zero (< 0.2 kg/ha/yr) for the three sites that receive less than about 9 kg/ha/yr of total nitrogen deposition: Coweeta, Walker Branch and White Oak Run (pre-insect defoliation). In contrast, the two sites having higher total nitrogen deposition (each greater than about 13 kg/ha/yr at Fernow and Noland Divide) exhibited elevated nitrogen export, about 4 and 16 kg/ha/yr, respectively (Webb et al. 1999).

Forest soils that are sensitive to acidification typically show low base saturation (< 15%). Such soils, especially those that exhibit very low base saturation (< 10%), have low levels of exchangeable base cations in the soil and tend to have low concentrations of calcium and high concentrations of aluminum in soil solution.

5.2 Atmospheric Deposition

Estimated values for sulfur and nitrogen deposition in the 1995 base year varied by about a factor of five across the SAMI domain. Highest values were found at the high elevation sites of Great Smoky Mountains National Park and in the northern and southern section of the Appalachian Plateau physiographic province in West Virginia and Tennessee (Figure 4-5). There were also large spatial variations in the projected changes in both sulfur and nitrogen deposition within the three Emissions Control Strategies (Figures 4-7 to 4-9). Simulated changes in atmospheric deposition, generated by the Atmospheric Deposition Modeling component of SAMI, in response to the three Emissions Control Strategies, varied spatially across the region and among strategies. In some cases, sulfur deposition was simulated to decrease while nitrogen deposition increased. In most cases, both sulfur and nitrogen deposition were simulated to decline in the future. Sulfur deposition was projected to decline at all sites under all strategies. Nitrogen deposition was projected to increase at some sites, especially under the OTW Strategy, although it was projected to decrease at other sites under all strategies.

These spatial differences in starting point deposition, and in projections of change in deposition both across space and across strategies, contributed to the observed heterogeneity in modeled streamwater response. When coupled with the spatial gradients and variability in watershed sensitivity to acidification with either sulfur or nitrogen, the various Emissions Control Strategies resulted in a wide range of projected streamwater responses.

5.3 Aquatic Assessment

Results of the MAGIC modeling effort were complex, with substantial variation in simulated watershed response within and among Emissions Control Strategies. There were multiple reasons for this complexity, reflecting regional differences in current deposition, future changes in deposition, and watershed sensitivity to acidification. Some of the major complicating factors are discussed below.

Base cation concentration and ANC of streams vary spatially, as do several factors that influence sensitivity to acidification. Within the SAMI region, these variations appear to be partly related to geology, partly related to atmospheric deposition and partly related to physiography. All sites were simulated to exhibit reduced soil base saturation and most sites showed reduced base cation leaching. Thus, the model output suggested continued soil acidification, but a decreased rate of soil acidification, under all strategies.

Some watersheds currently leach significant amounts of nitrate from soils to streamwater and were therefore simulated to be responsive to future changes in nitrogen deposition. These watersheds were scattered throughout the SAMI domain, but were mostly found in West Virginia and near the North Carolina-Tennessee border. The sites most responsive to future changes in nitrogen deposition can be seen as those sites that exhibited the largest decreases in streamwater nitrate concentration in the BYB Strategy (Figure 4-11). Although precise cutoff values are subjective, the sites that showed decreases in streamwater nitrate concentrations that were greater than about 5 μeq/L in the BYB Strategy can be considered sensitive, in general terms, to modest changes in nitrogen deposition. Other watersheds currently retain essentially all nitrogen deposition and would not be expected to respond to modest changes in future nitrogen deposition.

Some watersheds currently leach high concentrations of sulfate, and were simulated to exhibit decreased streamwater sulfate concentration and increased future ANC under reduced sulfur deposition. Other watersheds currently adsorb most deposited sulfur and are expected to be less responsive to reduced sulfur deposition. To further complicate the story, the amount of sulfur adsorbed at many of the modeling sites was projected to decrease in the future under virtually any continued sulfur deposition loading. This caused a situation whereby many sites were projected to continue to acidify in response to the increased streamwater sulfate concentration even while sulfur deposition is being reduced. Such streams were located mainly in the southern portion of the SAMI region and in the Blue Ridge physiographic province in the north. In some cases, the model projected continued acidification of streamwater while both sulfur deposition and sulfate and nitrate concentrations in streamwater declined. Such a situation was caused by projected large declines in base cation concentrations at these sites. The model output suggested that base cation depletion at these sites was so great as to counteract the benefits that might otherwise accrue from decreased streamwater concentrations of sulfate and nitrate. Because changes in base cation deposition in the Emissions Control Strategies were small, this response can largely be attributed to base cation depletion from soils.

These complications interact spatially and temporally within the SAMI domain to yield significant variability in model responses to the Emissions Control Strategies. Such variations must be considered in order to understand the results of this modeling exercise.

The average projected change in ANC from 1995 to 2040 is given in Table 5-1 for each of the ANC classes in each of the Emissions Control Strategies. Under most strategies, the average ANC of most ANC classes decreased from 1995 to 2040, especially for streams that had ANC > 20 in 1995. The exceptions to this pattern were the acidic streams under the BWC and BYB strategies and the streams in the ANC 0 to 20 μeq/L class in the BYB strategy. Other than the more acidic streams under the more aggressive Emissions Control Strategies, most streams showed projected continued acidification to 2040.

Table 5-1. Projected change in class-average ANC for upper stream reaches between the 1995 reference year and 2040.

ANC Class	Average Projected Change in ANC (μeq/L)		
	OTW	BWC	BYB
≤ 0	-5.0	0.5	3.9
0-20	-7.9	-3.1	4.8
20-50	-5.3	-3.1	-3.5
50-150	-5.7	-3.9	-2.4

The largest differences in projected change in the percentage of modeled streams in the various ANC classes from 1995 to 2040 occurred for the acidic class (Figure 5-1). The scenario of continued deposition at 1995 levels resulted in more than a doubling of the percent of acidic modeled streams, from 18% in 1995 to 41% in 2040. Each of the Emissions Control Strategies resulted in smaller estimates of percent of modeled streams projected to be acidic in 2040, from 25% in OTW to 15% in BYB. These results suggested that acid-base chemistry would generally deteriorate from 1995 conditions under OTW, but to improve slightly under BYB. Continued improvement was projected to occur beyond 2040, even if deposition was held constant

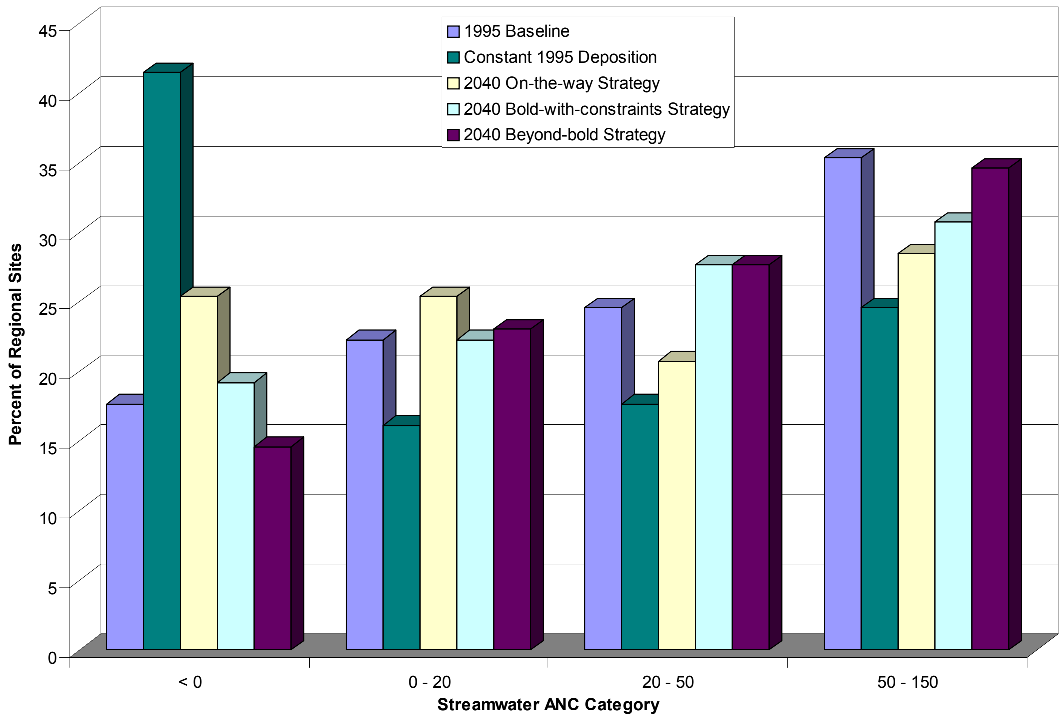


Figure 5-1. Projected percent of regional modeling sites in each ANC class in 2040, based on the scenario of constant 1995 deposition and each of the strategies. Also shown are baseline values for streamwater ANC in 1995.

thereafter. Thus, the model projected that benefits would continue to accrue beyond 2040 from emissions reductions enacted prior to 2040.

The projected differences in streamwater chemistry were small among the three strategies. When these estimates were extrapolated to the population of streams within the SAMI domain, based on the NSS statistical frame, the differences became even smaller. For example, an estimated 7% of the NSS upper node stream population within the SAMI region was acidic in 1995, and this percentage increased to 10% in OTW, but remained constant at 7% in BWC and BYB (Figure 4-20). The lower node streams changed from an estimated 3% acidic in 1995 to 3, 2, and 1% acidic in 2040 in the OTW, BWC, and BYB Strategies, respectively. These extrapolations to the NSS statistical frame help to put the modeling results into the context of the universe of streams that exist within the region. This is important because about 60% of the streams in the SAMI region have ANC > 150 μeq/L. These high-ANC streams are not expected to be acid-sensitive and were not modeled for this assessment. Nevertheless, they constitute the majority of the streams within the region.

5.3.1 Intraregional Variability

The SAMI region is highly diverse with respect to its geologic and edaphic (soils) characteristics. Elevation, climate, and vegetation are similarly variable in response to both north-south and elevational gradients in temperature, precipitation, and atmospheric deposition. Some of these differences are reflected in the separation into physiographic provinces (Fenneman 1938).

The geology of the southern Blue Ridge is diverse and complex. To the east, the province is dominated by early Precambrian metamorphic and granitic rocks (Hatcher 1988) and in the west by metamorphosed sedimentary rock, primarily sandstone, with some limestone (King et al. 1968, Elwood et al. 1991). The sandstones cover about 60% of Great Smoky Mountains National Park, and are characterized as massive and of low porosity, with quartz and potassium feldspars as the dominant minerals (Elwood et al. 1991).

In the northern portion of the region, the Blue Ridge Province comprises a narrow (10 to 25 km wide) band of steep-sided mountains that consist of a single major ridgeline, with smaller discontinuous ridges that extend to the east and west. In southern Virginia, the province expands to include a mountainous plateau area that ranges up to 40 km in width. To the southwest, the mountains become closely spaced ridges of greater height and width that end in a complex ridge system that covers portions of North and South Carolina, Tennessee, and Georgia (Harris and Tuttle 1983).

The steep, forested slopes of the Blue Ridge are not highly suitable for agriculture, although soils in the hollows and on gentler slopes were sufficiently deep and fertile to support farms (Gathright 1976). The number of farms has declined in recent decades and much of the Blue Ridge is now covered by second-growth forest (Bryce et al. 1999).

The Ridge and Valley Province represents the eastern margin of the Paleozoic interior sea. Selective erosion is conspicuous throughout this region. Limestones and shales were easily eroded, and siliceous sandstone and conglomerate were more resistant. The combination of folding and selective erosion resulted in a great number of ridges separated by valleys filled with erosional material (Fenneman 1938). The lateral compression that formed the folds also caused thrust faults, especially along the eastern boundary. Since uplift, the entire surface has been eroded, resulting in a marked evenness of crest height.

The limestones, shales, and sandstones that form the Ridge and Valley have been folded and eroded to form steep, parallel ridges of resistant sandstone and rounded shale knobs alternating with limestone and shale valleys. The ridges are covered with thin, infertile soils and are forested. The valleys experience intensive agriculture and also expanding urban and industrial land use (Bryce et al. 1999).

The geology of the Appalachian Plateau is similar to that of the Valley and Ridge, although the strata are generally flat and undeformed in most places, rather than folded. The plateau is highly dissected, however. Arable limestone areas are not widely distributed, but layers of soft bituminous coal are common. Coal mining and silviculture are the major land uses (Bryce et al. 1999).

The Appalachian Plateau has experienced repeated uplift, but the mountains have been removed by erosion. The province is heavily dissected, and the extent and style of dissection provide the basis for classification into different sections (Fenneman 1938). The edges of the plateau are formed by relatively strong rock strata, but the central syncline also contains a large proportion of shale along with the more resistant sandstone. To the southwest of West Virginia, the rocks are mainly sandstones and conglomerates of the Pottsville series. The beds thicken toward the south until, in Tennessee, a single stratum (Walden sandstone) constitutes most of the mass of the plateau (Fenneman 1938).

The plateau is called Allegheny in the north and Cumberland in the south, although the boundary is somewhat arbitrary. In a general way, however, the rocks to the south are more resistant and less dissected (Fenneman 1938).

Differences in ANC among streams in the southeastern United States appear to be related primarily to differences in the capacity of watersheds to mobilize base cations through weathering and cation exchange and to retain sulfate by adsorption on soil particles (Elwood 1991). Nitrogen retention within the watershed is also important because it is substantially less than 100% in some areas. To a significant extent, these processes vary between physiographic provinces.

The NSS did not sample any acidic streams in the southern Blue Ridge, and estimated that less than 1% of the stream reaches in the southern Blue Ridge were acidic. The results of a study by Winger et al. (1987), however, demonstrated that acidic first-order streams did exist in the region (3% of sampled streams were acidic), although the study was not statistically-based. In addition, the two acidic streams sampled by Winger et al. (1987) drained watersheds that contain the Anakeesta formation, a pyritic phyllite which is a potential geologic source of sulfate in streamwater (Huckabee et al. 1975, Elwood et al. 1991).

Sulfur retention in watersheds in the SAMI region is highly variable, ranging from near zero to well over 75% (Rochelle and Church 1987; Kaufmann et al. 1988; Church et al. 1989, 1992). Similarly, MAGIC model projections suggested considerable variability in the extent to which sulfur retention will change under continued sulfur deposition. Some watersheds were projected to come into steady state (sulfur input ≈ sulfur output) only after more than 150 yr of sulfur deposition at 1984 levels (Church et al. 1992). Soils of the mid-Appalachian Region of the DDRP, which includes the northern portion of the SAMI region, were projected to reach sulfur steady state faster than soils of the southern Blue Ridge Region (35 yrs vs 61 yrs) and also to reach much higher sulfate concentrations in streams (214 μeq/L vs 120 μeq/L) once steady state is attained (Church et al. 1992).

In the mid-Atlantic Highlands, the net annual retention of atmospherically-deposited sulfur varies among physiographic provinces, and these differences are probably due in part to differences in soils and geology, and in part due to different histories of sulfur deposition loading. Median net annual sulfur retention was estimated to be 11% in the Appalachian Plateau, 35% in the combined Blue Ridge and Valley and Ridge Provinces, and 60% in the Piedmont Province (Herlihy et al. 1993).

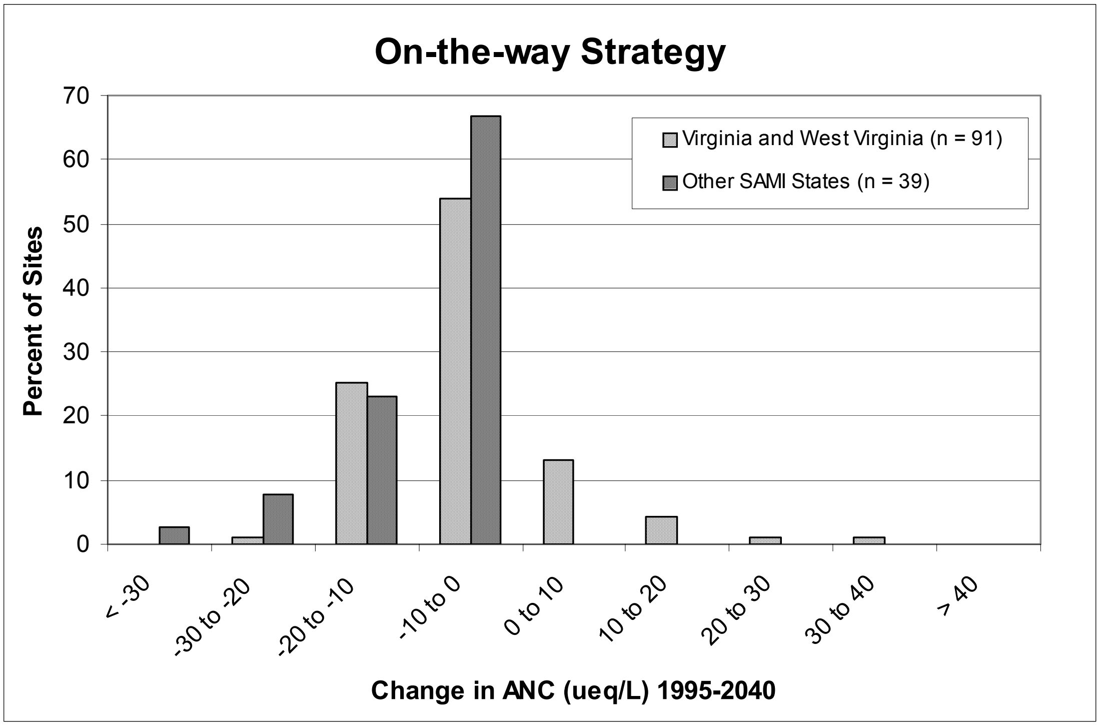
Cosby et al. (1991) estimated that the expected average steady state sulfate concentration in VTSSS streams would be about 200 μeq/L. This estimate was based on wet sulfur deposition approximately equal to 8 kg/ha/yr, assumed dry deposition equal to 50% of wet deposition, and an estimated annual runoff of 36 cm/yr. Cosby et al. (1991) concluded that VTSSS streams were retaining, on average, two-thirds of the total deposited sulfur. The sulfate concentrations in VTSSS streams tended to be somewhat higher in the Ridge and Valley (median 92 μeq/L) than in the Blue Ridge (median 61 μeq/L). These differences were attributed to the higher sulfur retention capacity of Ultisol soils, which are common in the Blue Ridge, as compared with the Inceptisols that are more common in the Ridge and Valley Province. Potentially higher sulfur deposition in the Ridge and Valley, due to its close proximity to deposition sources to the west, was also suggested as being an important contributor to the observed spatial patterns in streamwater sulfate concentration (Cosby et al. 1991).

Watersheds in the southern Blue Ridge retain a significant fraction (~ 70% to 80%) of atmospherically-deposited sulfur (Rochelle et al. 1987, Rochelle and Church 1987). The mobility of sulfate in some southern Blue Ridge watersheds has increased, however (c.f., Eshleman and Kaufmann 1988, Elwood et al. 1991). Median sulfate concentration in streamwater is about twice as high in the northern portion of the Blue Ridge Province, as compared with the southern portion (Elwood 1991).

MAGIC modeling results illustrated large variations in projected change in water chemistry related to site location. These were most strongly related to north-south gradients and differences among physiographic provinces. For example, modeling sites in the northern portion of the SAMI region (Virginia and West Virginia) showed a broad range of projected change in ANC at the 91 modeling sites in this area (Figure 5-2). Some sites showed projected ANC increases of more than 20 μeq/L in response to the OTW strategy. Other sites showed projected decreases in ANC of comparable magnitude. In contrast, the 39 sites in the southern portion of the SAMI region all showed projected decreases in streamwater ANC in response to the OTW Strategy. Differences between north and south were less pronounced for the BYB Strategy, but projected changes in ANC tended to be more commonly positive and of larger magnitude in the north (Figure 5-2).

As expected, the sites that exhibited the highest concentrations of streamwater nitrate in 1995 showed the largest projected changes in streamwater nitrate in response to the strategies (Figure 5-3). Projected changes were generally largest for a given baseline nitrate concentration in the Appalachian Plateau province, and generally smallest in the Blue Ridge. Sizeable (e.g., > 5 μeq/L) changes in projected streamwater nitrate concentration were generally restricted to the Appalachian Plateau in the OTW Strategy, but to a lesser extent in the BYB Strategy. These are the sites that are most responsive to changes in nitrogen deposition.

The projected percentages of NSS downstream reach ends (lower nodes) having ANC in the year 2040 that was acidic or below 20 μeq/L are listed in Table 5-2, stratified by north and south and by physiographic province. Marked geographic differences were observed, with almost all of the projected acidic and low-ANC lower node streams in 2040 occurring in the northern Appalachian Plateau, regardless of strategy. The projected percentages of acidic and low-ANC upstream reach ends (upper nodes) were somewhat more evenly distributed than the lower nodes, but still mostly confined to the northern section of the SAMI region. Again, the northern Appalachian Plateau was the predominant location of projected acidic and low-ANC streams in 2040. Over 25% of the estimated 4,890 upper node northern Appalachian Plateau stream reaches were projected under the OTW Strategy to be acidic and about 43% were projected to have ANC ≤ 20 μeq/L in 2040 (Table 5-3).



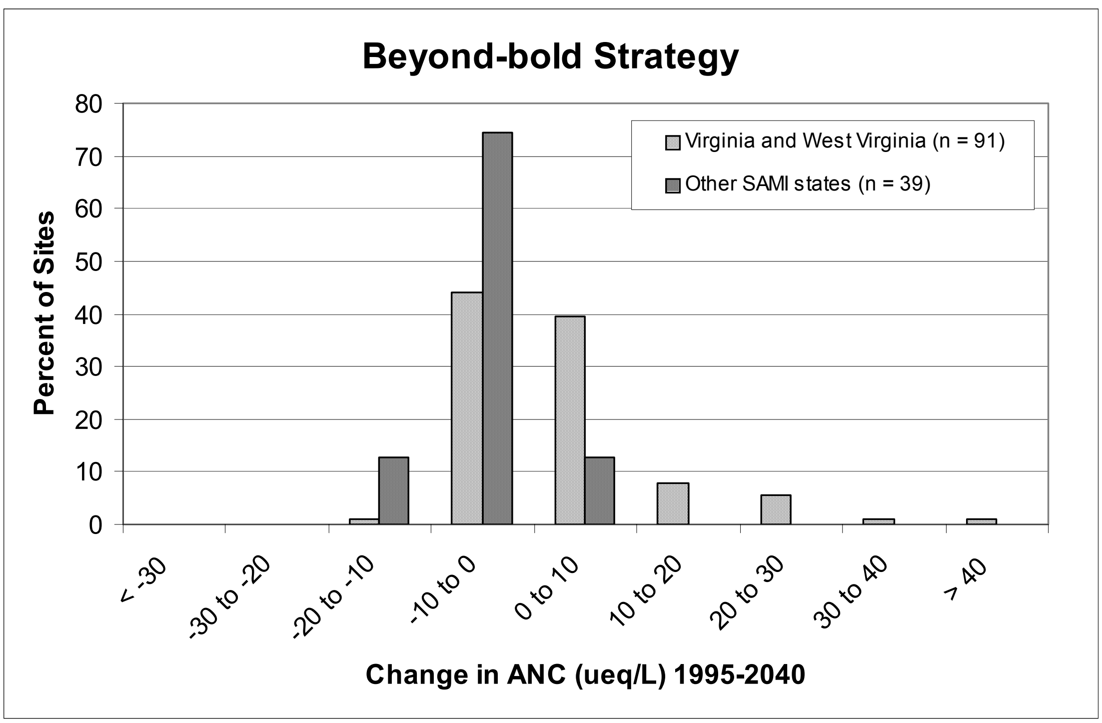


Figure 5-2. Model projection of change in streamwater ANC from 1995 to 2040 under the OTW and BYB Emissions Control Strategies in the northern section of the SAMI region (Virginia and West Virginia) versus the southern portion (all other SAMI states).

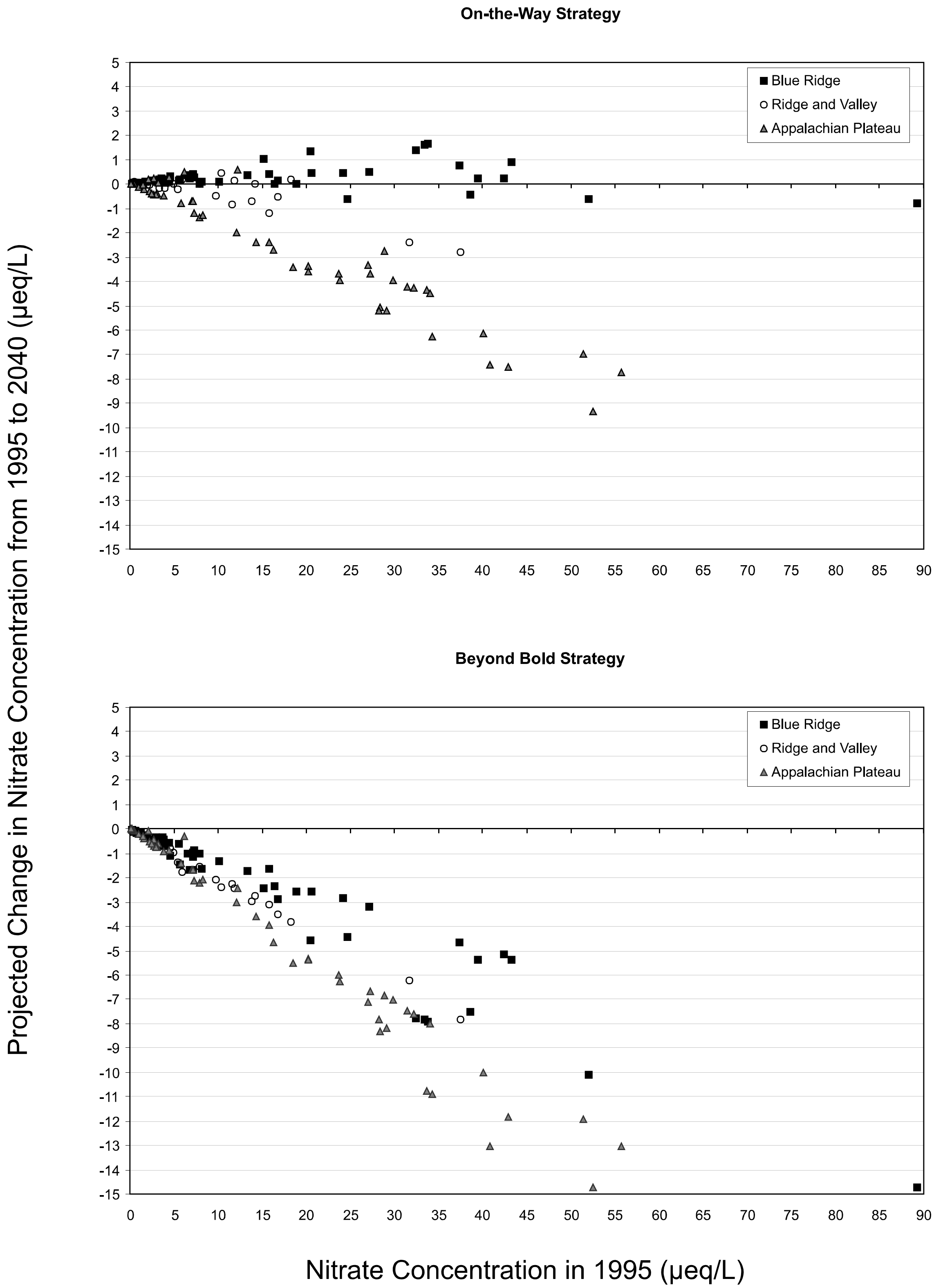


Figure 5-3. Projected change in streamwater nitrate concentrations from 1995 to 2040 for the OTW and BYB strategies versus the nitrate concentrations in streamwater in 1995. Sites are coded by physiographic province.

Table 5-2. Predicted percent of reach ends with ANC below 0 and 20 μeq/L in the year 1995.

Class*	Downstream Reach Ends N	Downstream ANC ≤ 0	Downstream ANC ≤ 20	Upstream Reach Ends N	Upstream ANC ≤ 0	Upstream ANC ≤ 20
Northern Blue Ridge	2,033	0	0	2,510	0	12.7
Northern Ridge & Valley	6,022	0.8	0.8	5,068	6.3	7.2
Northern Appalachian Plateau	4,890	12.5	25.9	5,050	19.1	28.3
Southern Blue Ridge	4,289	0	0.6	4,289	0	0.6
Southern Ridge & Valley	1,142	0	0	1,566	0	0
All SAMI	19,185	3.4	7.0	19,026	6.7	11.2

N is the estimated total number of stream reaches in the population.
* NSS sample size in the southern Appalachian Plateau is too small to make reliable population estimates so they are not presented.

Table 5-3. Predicted percent of downstream and upstream stream reach ends with ANC ≤ 0 μeq/L and ANC ≤ 20 μeq/L in the three SAMI future deposition strategies in the year 2040.

Class*	N	ANC ≤ 0 OTW	ANC ≤ 0 BWC	ANC ≤ 0 BYB	ANC ≤20 OTW	ANC ≤20 BWC	ANC ≤20 BYB
Downstream							
Northern Blue Ridge	2,034	0	0	0	0	0	0
Northern Ridge & Valley	6,022	0.8	0.8	0	0.8	0.8	0.8
Northern Appalachian Plateau	4,890	12.5	5.9	3.0	25.9	25.9	19.7
Southern Blue Ridge	4,289	0	0	0	0.6	0.6	0.6
Southern Ridge & Valley	1,142	0	0	0	0	0	0
All SAMI	19,185	3.4	1.8	1.8	7.0	7.0	5.4
Upstream							
Northern Blue Ridge	2,034	12.7	0	0	12.7	12.7	12.7
Northern Ridge & Valley	6,022	6.3	6.3	6.3	7.2	7.2	7.2
Northern Appalachian Plateau	4,890	25.4	19.1	19.1	42.9	31.1	28.3
Southern Blue Ridge	4,289	0	0	0	0.9	0.6	0.6
Southern Ridge & Valley	1,142	0	0	0	0	0	0
All SAMI	19,026	10.1	6.7	6.7	15.2	12.0	11.2

N is the estimated total number of stream reaches in the population.
* NSS sample size in the southern Appalachian Plateau is too small to make reliable population estimates so they are not presented.

Under the OTW Strategy, many of the low-ANC streams in the northern Appalachian Plateau subpopulation were simulated to decline by about 10 μeq/L in ANC from 1995 to 2040. These projected decreases in streamwater ANC were sufficiently large as to result in quite a large increase in the percent of streams in the northern Appalachian Plateau that were projected to be acidic in 2040 as compared with 1995 estimates. The estimated percent of streams that was acidic in 1985 ranged from 3% (lower node) to 6% (upper node) in the northern Appalachian Plateau. Under the OTW Strategy, the percent of acidic lower node streams was projected to increase by 2040 to 12% and acidic upper node streams to increase to 25%, with most of the increases occurring between 1985 and 1995. These are very large increases and this subregion represents most of the additional acidification associated with the OTW Strategy. This acidification can largely be attributed to base cation depletion in watershed soils. Even under the BYB Strategy, the percent of acidic northern Appalachian Plateau upper node streams was very high (19%; Table 5-3). Such changes in ANC would be expected to have significant adverse impacts on brook trout and other aquatic biota within this subpopulation. Over 40% are expected to be either episodically or chronically unsuitable for brook trout in 2040 as a consequence of the projected low ANC values.

Projected changes in ANC values (as opposed to endpoint ANC values) for the NSS subregional populations in response to the three strategies did not show such large geographical variations (Table 5-4). All subpopulations showed a median decline in projected ANC from 1995 to 2040 for the OTW and BWC strategies. Under the BYB Strategy, the northern Blue

Table 5-4. Median change in ANC (ueq/L) from 1995 to 2040 in 130 regional model sites in the three SAMI future deposition strategies. Negative numbers indicate a decline in ANC over time.

Physiographic Province*	Sample Size	Strategy		
		OTW	BWC	BYB
Northern Blue Ridge	16	-4.0	-1.0	+2.9
Northern Ridge & Valley	41	-6.6	-4.7	-0.4
Northern Appalachian Plateau	34	-4.4	-1.4	+3.9
Southern Blue Ridge	33	-8.0	-5.4	-3.2
Southern Appalachian Plateau	6	-15.9	-13.3	-10.4
ALL	130	-6.7	-4.2	-1.3

* There were no model sites in the southern Ridge & Valley

Ridge and northern Appalachian Plateau showed small (< 4 μeq/L) positive median changes in projected ANC, whereas other subpopulations also showed projected declines under the BYB Strategy. Projected future acidification was generally about twice as high or higher in the southern Appalachian Plateau as compared with other subpopulations, but the sample size of modeled streams was small (n=6). Projected acidification was consistently greater in the south, however, than in the north (Table 5-4). This observation can largely be attributed to the consistent projections of positive median changes in streamwater sulfate concentration in southern streams (Table 5-5). Whereas sulfate concentrations in streams of the northern Appalachian Plateau typically decreased by median values of -31 to -42 μeq/L in the strategies, median changes in streamwater sulfate concentration in the south ranged from +3 (southern Blue Ridge in BYB) to +15 μeq/L (southern Appalachian Plateau in OTW). These differences in streamwater chemistry reflect differences in sulfur adsorption on soils.

Median projected changes in streamwater nitrate concentration were generally near 0, except in the northern Appalachian Plateau. Changes were most pronounced under the BYB Strategy (-5.8 μeq/L; Table 5-6).

It is interesting to note that despite the rather large projected declines in streamwater sulfate and nitrate concentrations in the northern Appalachian Plateau, median projected streamwater ANC declined in two of the strategies. This was because the projected changes in base cation concentrations in streamwater in this subregion were generally larger than the projected changes in sulfate plus nitrate concentrations (Tables 5-5 to 5-7).

Table 5-5. Median change in sulfate (ueq/L) from 1995 to 2040 in 130 regional model sites in the three SAMI future deposition strategies. Negative numbers indicate a decline in sulfate over time.

Physiographic Province*	Sample Size	Strategy		
		OTW	BWC	BYB
Northern Blue Ridge	16	+1.8	-2.7	-7.4
Northern Ridge & Valley	41	-0.5	-5.6	-13.8
Northern Appalachian Plateau	34	-31.2	-36.3	-41.6
Southern Blue Ridge	33	+8.8	+5.6	+3.2
Southern Appalachian Plateau	6	+15.2	+11.6	+7.2
ALL	130	+1.9	-4.0	-8.7

* There were no model sites in the southern Ridge & Valley

Table 5-6. Median change in nitrate (ueq/L) from 1995 to 2040 in 130 regional model sites in the three SAMI future deposition strategies. Negative numbers indicate a decline in nitrate over time.

Physiographic Province*	Sample Size	Strategy		
		OTW	BWC	BYB
Northern Blue Ridge	16	0	0	-0.1
Northern Ridge & Valley	41	0	-0.4	-0.4
Northern Appalachian Plateau	34	-3.5	-4.9	-5.8
Southern Blue Ridge	33	0.2	-0.5	-1.0
Southern Appalachian Plateau	6	0.1	-0.2	-0.5
ALL	130	0	-0.6	-1.0

* There were no model sites in the southern Ridge & Valley

Table 5-7. Median change in base cations (ueq/L) from 1995 to 2040 in 130 regional model sites in the three SAMI future deposition strategies. Negative numbers indicate a decline in base cations over time.

Physiographic Province*	Sample Size	Strategy		
		OTW	BWC	BYB
Northern Blue Ridge	16	-2.2	-3.0	-5.1
Northern Ridge & Valley	41	-6.8	-8.2	-10.3
Northern Appalachian Plateau	34	-33.8	-38.4	-42.8
Southern Blue Ridge	33	+1.0	-0.6	-2.3
Southern Appalachian Plateau	6	-1.2	-1.9	-3.1
ALL	130	-4.6	-6.5	-7.6

* There were no model sites in the southern Ridge & Valley

5.3.2 Biological Effects

Model results in response to the Emissions Control Strategies did not indicate that large numbers of streams would be likely to shift in biological response categories in the future. For example, the population of upper node streams projected to be chronically acidic (ANC $\leq$ 0) only increased from 7% in 1995 to 10% in 2040 in the OTW Strategy, and did not change in the other two strategies. In addition, for the lower ANC classes ($\leq$ 0 and 0-20 µeq/L), the projected average changes in ANC shown in Table 5-1 were generally small (< 8 µeq/L). Nevertheless, projected small decreases in streamwater ANC suggest an increased likelihood of adverse effects on some species of aquatic biota due to chronic and/or episodic acidification. For some streams in the transitional class (ANC 20-50 μeq/L), the model results suggest increased possibility of episodic acidification to ANC values that could adversely impact some species. For higher ANC streams (> 50 μeq/L), it is not clear to what extent the projected small changes in ANC might impact aquatic biota. Such impacts, if they would occur, would probably be small.

Species loss is a highly predictable result of aquatic acidification. Aquatic species (fish and macroinvertebrates) differ in tolerance of acidic conditions. Acidification lowers species counts by eliminating sensitive species first, followed by species of intermediate tolerance, and finally by the loss of even the most acid-tolerant species as acidification progresses. Regionally, this results in a unambiguous relationship between acid-base status of water bodies and the number of aquatic species they host, such that unacidified lakes and streams host more species than acidified lakes and streams.

Bulger et al. (1999) reported an observed linear relationship between fish species richness and minimum streamwater ANC in streams within Shenandoah National Park. In general, there was one fewer fish species with every decrease in minimum recorded ANC of 21 μeq/L. Other factors besides acid-base chemistry may influence this observed relationship. However, the data reported by Bulger et al. (1999) suggest that the small projected decreases in ANC in response to the SAMI strategies would probably not have an appreciable effect on fish species richness for the majority of streams in the region. For the streams projected to change the most in the future, however, fish species richness may very well be affected. For example, one-fourth of the modeling sites showed projected decreases in ANC of more than 10 μeq/L in the OTW strategy and more than 25 μeq/L under continued constant deposition at 1995 levels. Many of these most responsive streams are located in Class I areas. Over half of the modeled streams in all Class I areas except Shining Rock Wilderness were projected to decline in ANC by more than 10 μeq/L by 2040 under continued constant deposition.

5.3.3 Nitrogen Saturation

Nitrogen is an essential nutrient for both aquatic and terrestrial organisms, and is a growth-limiting nutrient in most ecosystems. Thus, nitrogen inputs to natural systems are not necessarily harmful. For each ecosystem, there is an optimum nitrogen level which will maximize ecosystem productivity without causing significant changes in species distribution or abundance. Above the optimum level, harmful effects can occur in both aquatic and terrestrial ecosystem compartments (Gunderson 1992).

The nitrogen cycle is extremely complex and controlled by many factors besides atmospheric emissions and deposition. Also, nitrogen inputs that may be beneficial to some species or ecosystems may be harmful to others. Increased atmospheric deposition of nitrogen does not necessarily cause adverse environmental impacts. In most areas, added nitrogen is taken up by terrestrial biota and the most significant effect seems to be an increase in forest productivity (Kauppi et al. 1992). However, under certain circumstances, atmospherically-deposited nitrogen can exceed the capacity of forest ecosystems to take up nitrogen. In some areas, especially at high elevation, terrestrial ecosystems have become nitrogen-saturated[1] and high levels of deposition have caused elevated levels of nitrate in drainage waters (Aber et al. 1989, 1991; Stoddard 1994). This enhanced leaching of nitrate causes depletion of calcium and other base cations from forest soils and can cause acidification of soils and drainage waters in areas of base-poor soils.

Analyses have been conducted in the northeastern United States and Europe to examine the relationships between nitrogen deposition and nitrate leaching to surface waters. The relationship between measured wet deposition of nitrogen and streamwater output of nitrate was evaluated by Driscoll et al. (1989a) for sites in North America (mostly eastern areas), and augmented by Stoddard (1994). The resulting data showed a pattern of nitrogen leaching at wet-inputs greater than approximately 400 eq/ha/yr (5.6 kg N/ha/yr). Stoddard (1994) presented a geographical analysis of patterns of watershed loss of nitrogen throughout the northeastern United States. He identified approximately 100 surface water sites in the region with sufficiently intensive data to determine their nitrogen status. Sites were coded according to their presumed stage of nitrogen retention, and sites ranged from Stage 0 (background condition) through Stage 2 (chronic impacts). The geographic pattern in watershed nitrogen retention depicted by Stoddard (1994) followed the geographic pattern of nitrogen deposition. Sites in the Adirondack and Catskill Mountains in New York, where nitrogen deposition is about 11 to 13 kg N/ha/yr, were typically identified as Stage 1 (episodic impacts) or Stage 2. Sites in Maine, where

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[1] The term nitrogen-saturation has been defined in a variety of ways, all reflecting a condition whereby the input of nitrogen (e.g., as nitrate, ammonium) to the ecosystem exceeds the requirements of terrestrial biota and a substantial fraction of the incoming nitrogen leaches out of the ecosystem as nitrate in groundwater and surface water.

nitrogen deposition is about half as high, were nearly all Stage 0. Sites in New Hampshire and Vermont, which receive intermediate levels of nitrogen deposition, were identified as primarily Stage 0, with some Stage 1 sites. Based on this analysis, a reasonable threshold of nitrogen deposition for transforming a northeastern site from the "natural" Stage 0 condition to Stage 1 would correspond to the deposition levels found throughout New Hampshire and Vermont, approximately 8 kg N/ha/yr. This agreed with Driscoll et al.'s (1989a) interpretation, which suggested nitrogen leaching at wet inputs above about 5.6 kg N/ha/yr, which would likely correspond to total nitrogen inputs near 10 kg N/ha/yr. This is likely the approximate level at which episodic aquatic effects of nitrogen deposition would become apparent in many watersheds of the eastern United States.

A survey of nitrogen outputs from 65 forested plots and catchments throughout Europe was conducted by Dise and Wright (1995). Below throughfall inputs of about 10 kg N/ha/yr, there was very little nitrogen leaching at any of the study sites. At throughfall inputs greater than 25 kg N/ha/yr, the study catchments consistently leached high concentrations of inorganic nitrogen. At intermediate deposition values (10-25 kg N/ha/yr), Dise and Wright (1995) observed a broad range of watershed responses. Nitrogen output was most highly correlated with input nitrogen (r^2=0.69), but also significantly correlated with input sulfur, soil pH, percent slope, bedrock type, and latitude. A combination of input nitrogen (positive correlation) and soil pH (negative correlation) explained 87% of the variation in output nitrogen at 20 sites (Dise and Wright 1995).

Similarly, a threshold of nitrate leaching at deposition levels above about 10 kg N/ha/yr was found at experimental sites throughout Europe by Tietema and Beier (1995); no significant leaching was observed at deposition levels below this threshold.

Nitrate leaching losses from soils to drainage waters are governed by a complex suite of ecosystem processes in addition to nitrogen inputs from atmospheric deposition. In particular, mineralization and nitrification processes play important roles in regulating the quantity of, and temporal variability in, the concentration of nitrate in soil solution, and consequently leaching losses from the rooting zone (Johnson et al. 1991, Joslin et al. 1987). Thus, nitrate leaching is partly under biological control and typically shows pronounced seasonal variability.

High leaching of nitrate in soil water and streamwater draining high-elevation spruce-fir forests has been documented in numerous studies in the SA region (c.f., Joslin and Wolfe 1992; Joslin et al. 1992; Van Miegroet et al. 1991a,b; Nodvin et al. 1995). This high nitrate leaching has been attributed to a combination of high nitrogen deposition, low nitrogen uptake by forest vegetation, and inherently high nitrogen release from soils. The latter feature is associated with low carbon to nitrogen ratios in mineral soil, high nitrogen mineralization potential, and high nitrification (Joslin et al. 1992, Eagar et al. 1996).

In general, deciduous forest stands do not progress toward nitrogen-saturation as rapidly or as far as coniferous stands because they tend to have higher rates of nitrogen uptake and requirement. Decreased growth and increased mortality associated with excess nitrogen have more commonly been observed in coniferous stands (Aber et al. 1998). Indeed, most of the lower elevation deciduous stands, including >90% of all forests in the U.S., are nitrogen-deficient and are therefore likely to benefit (i.e., grow faster) with increased inputs of nitrogen.

There are examples of nitrogen saturation in lower-elevation forests of the SA, especially in West Virginia. For example, progressive increases in streamwater nitrate and calcium concentrations were measured at the Fernow Experimental Forest in the 1970s and 1980s (Edwards and Helvey 1991, Adams et al. 1997, 2000). This watershed has received higher nitrogen deposition (average throughfall input of 22 kg/ha/yr of nitrogen deposition in the 1980s) than is typical for low-elevation areas of the SA, however (Eagar et al. 1996), and this may explain the observed nitrogen saturation.

The MAGIC model does not currently contain a mechanism to determine at what point forested ecosystems that receive elevated nitrogen deposition will begin to leach nitrate to streamwaters, although this is a topic of current research. Available evidence suggests that nitrate leaching is mainly limited to forested ecosystems that receive more than about 10 kg N/ha/yr deposition. This is approximately equal to the average nitrogen deposition estimated for the MAGIC modeling sites for 1995 and under the OTW Emissions Control Strategy for the year 2040 (Appendix G, Table G-5). This may account for the observation that about half of the modeled streams had nitrate concentration > 2 μeq/L in 1995. Under the BYB Strategy, the average nitrogen deposition was estimated to decrease to 8.8 kg N/ha/yr by 2040 (Appendix G, Table G-7). It is not likely that the relatively small nitrogen deposition changes estimated for these Emissions Control Strategies will have an appreciable effect on the proportion of the nitrogen input to forested watersheds in the SA that will leach as nitrate to streamwaters. Although the MAGIC model estimated that streamwater nitrate concentrations might decrease from 1995 to 2040 by up to 15 μeq/L (Figure 5-3), there is no evidence to suggest that the percent of incoming nitrogen that is leached to streamwaters will change appreciably.

5.3.4 Intra-annual Variability

Model projections prepared for this assessment were based on chronic, annual average streamwater chemistry. Superimposed upon that chemistry are seasonal and episodic variability with both natural and anthropogenic (human-caused) components (c.f., Wigington et al. 1993). The magnitude and principal causes of episodic acidification are variable from watershed to watershed within the SAMI domain. For example, O'Brien et al. (1993) compared episodic variability of acid-base chemistry among five mid-Atlantic watersheds and examined the relationships to bedrock type and physiography. The study watersheds were located in three physiographic provinces: Coastal Plain, Valley and Ridge, and Blue Ridge. In general, greater losses of streamwater ANC during episodes were observed in watersheds underlain by reactive bedrock (carbonate, metabasalt), and smaller losses of ANC were observed in watersheds underlain by quartzites and unconsolidated quartz sands and cobbles. Little change in sulfate concentration and ANC was found during episodes at the site that was chronically acidic (Mill Run, VA). At the other four sites, ANC decreased in concert with episodic increases in sulfate concentration, but the slope of the relationship was variable. Nitrate was not the primary acidic anion during stormflow in any of the streams, in contrast to observations commonly found in the Northeast. This finding was attributed by O'Brien et al. (1993) to the fact that mid-Atlantic watersheds do not experience a long dormant period under snowpack and so nitrate is taken up by terrestrial biota, and therefore is retained in the study watersheds year-round.

Published episodic stream chemistry data are available from a number of streams in the northern portion of, and just to the north of, the SAMI region (Wigington et al. 1990). Streams in this area that become episodically acidic have tended to be those that had pre-episode spring baseflow ANC less than about 30 μeq/L (c.f., Figure 3 in Herlihy et al. 1993).

6.0 CONCLUSIONS

This report summarizes recent efforts to quantitatively project the environmental effects of acidic deposition on aquatic resources within the Southern Appalachian Mountains. A number of conclusions can be drawn from this assessment. These conclusions relate to an array of issues and potential environmental effects ranging from atmospheric deposition to streamwater chemistry, forest health, and effects on fisheries. Model projections, in response to the three Emissions Control Strategies developed for this study, yielded a range of responses. These modeled responses varied within and among strategies and showed distinct geographical patterns, especially with respect to north-south gradients and across physiographic provinces. The primary conclusions of this study are summarized below.

Deposition

There is high spatial variability within the SAMI study area in the current atmospheric deposition of sulfur and nitrogen. Highest levels of deposition of both elements have been observed in the high elevation portions of the Great Smoky Mountains, where cloud deposition contributes heavily to the total deposition loads, and in West Virginia.

Atmospheric modeling of the three Emissions Control Strategies developed for this study by SAMI resulted in estimated large reductions in projected sulfur deposition for all three strategies. The mean percent changes in sulfur deposition at the modeled sites from 1995 to 2040 were -57%, -67%, and -73% for the OTW, BWC, and BYB strategies, respectively. Estimated changes in total (oxidized plus reduced) nitrogen deposition for these strategies were much smaller. Mean percent changes in nitrogen deposition indicated an increase of 10% for OTW and decreases of 14% and 34% for BWC and BYB. Estimated future changes in sulfur and nitrogen deposition were not uniformly distributed across the SAMI region. Changes were in many cases estimated to be largest in West Virginia.

The principal conclusions with respect to deposition are as follows:

- High spatial variability was observed in current deposition of sulfur and nitrogen, with highest quantities observed at high-elevation sites in western North Carolina and eastern Tennessee and in the Appalachian Plateau physiographic province of West Virginia.

- High spatial variability was observed in modeled changes in sulfur and nitrogen deposition in response to the three Emissions Control Strategies

- Generalized strategy results for deposition were as follows:

- All strategies showed decreased sulfur and oxidized nitrogen deposition at all sites, with largest decreases in the BYB Strategy.

- Reduced nitrogen deposition increased at all sites under the OTW Strategy, at most sites under the BWC Strategy, and at about half of the sites under the BYB Strategy.

- Projected changes in total (oxidized plus reduced) nitrogen were variable across sites and strategies, with largest decreases in West Virginia,

Watershed Sensitivity to Acidification

Watersheds within the SAMI study area are highly variable spatially with respect to their sensitivity to acidification. This sensitivity is reflected in variations in base cation concentration and ANC of streamwaters, soil base saturation, sulfur adsorption on soils, and watershed retention of atmospheric nitrogen inputs. To some extent, elements of watershed sensitivity are predictable, based on such features as geology, elevation, and physiographic province.

Lithologic coverages developed by the USGS were classified into five geologic sensitivity classes, ranging from primarily siliceous rock types (most acid-sensitive) to carbonate types (least acid-sensitive). Although lithology proved to be the best single predictor of acid sensitivity, as reflected by negative or low values of ANC, lithology was an inconsistent predictor of site-specific ANC. Acidic and low-ANC streams were almost always found in areas covered by lithologies classified in the most sensitive geologic classes. However, other less acid-sensitive watersheds were also found within areas covered by these classes. This finding is a logical reflection of the coarse scale of available lithologic maps used as the basis for geologic sensitivity classification and the common presence of pockets of highly weatherable geologic materials within areas generally classified as acid sensitive.

The extent to which watersheds currently retain sulfur and nitrogen inputs has an important effect on simulated responses to changing levels of sulfur and nitrogen deposition. Sulfur retention was noted to vary spatially and this variation was related to location, both relative to physiographic province and latitude.

Sulfur retention was projected to decline at many sites, especially in the southern portion of the Ridge and Valley Province and throughout the Blue Ridge Province. This projected decline in sulfur adsorption on soils contributes to model projections of delayed acidification at many of these sites.

Model results suggested that nitrogen retention may be influenced by latitude, elevation, and physiographic province. In general, the areas with the lowest nitrogen retention, as indicated by high nitrogen leaching as streamwater nitrate, were located mostly at high elevation in the Blue Ridge Province and in northern portions of the Appalachian Plateau Province.

Conclusions regarding watershed sensitivity to acidification and the observed relationships between acid-base chemistry of streams and watershed characteristics include the following:

- Base cation concentration and ANC of streamwaters vary spatially.

- Lithology, by itself, is not an entirely reliable predictor of streamwater ANC. However, lithology can be grouped into generalized sensitivity classes, and the most acid-sensitive watersheds are almost always found within areas covered by lithologies classified as most sensitive. In addition, other less acid-sensitive watersheds are also located within areas covered by the most sensitive geologic classes.

- The ability of watersheds to retain (versus leach to streamwaters) incoming sulfur and nitrogen varies spatially, and this retention ability has a large impact on modeled responses of streamwater chemistry to changes in deposition of sulfur or nitrogen.

- Some watersheds currently retain a high percentage of sulfur deposition through sulfur adsorption on soils, but that adsorption was projected to decrease with continued sulfur deposition loading.

- A classification scheme was developed for the SAMI region based on lithologic sensitivity class and stream site elevation. The acid-sensitive area delimited in this manner only covered 26% of the SAMI domain, but included 95% of the stream sites presently known to be acidic and 88% of the sites exhibiting an ANC $\leq$ 20 μeq/L. It also included 86% of the stream sites that were projected to be both acidic in 1995 and to increase to positive ANC by 2040 in the BYB Strategy.

<u>Streamwater Chemistry</u>

Streams exhibited a broad range of response to the cumulative sulfur deposition loadings received to date and the large simulated decreases in sulfur deposition in the future. Some streams showed modeled streamwater sulfate concentrations increasing in the future, even while sulfur deposition in two strategies was reduced by more than two-thirds. These were mostly sites that had relatively low sulfate concentrations ($\leq$ about 50 μeq/L) in 1995. They generally showed simulated future acidification, which was most pronounced for the OTW strategy. Other streams were simulated to show relatively large decreases in future streamwater sulfate concentrations and concurrent increases in ANC in response to the strategies, with progressively larger changes from the OTW to the BYB strategies. These tended to be streams that had relatively high concentrations of sulfate (> 50 µeq/L) in 1995, suggesting that these watersheds were likely closer to equilibrium with respect to inputs and outputs of sulfur. Some streams were projected to decrease in both sulfate and nitrate concentrations but nevertheless to continue to acidify. This response can be attributed to large simulated decreases in base cation concentrations at these sites.

Most simulated changes in streamwater ANC from years 1995 to 2040 were relatively small compared to the very large estimates of decreased sulfur deposition represented by the strategies. Few modeled streams showed projected change in ANC more than about 20 µeq/L. Some of the largest changes were simulated for some of the streams that were most acidic in 1995. For such streams, however, even relatively large increases in ANC would still result in negative ANC streamwater, and therefore little biological benefit would be expected from the simulated improvement in chemistry. The model suggested, however, that benefits would continue to accrue well beyond 2040 for all strategies, even if deposition was held constant at 2040 levels into the future.

None of the strategies resulted in projections of large improvements in the percent of modeled streams within the various ANC classes. Although the BWC strategy and more substantially the BYB strategy resulted in fewer acidic and low-ANC streams than did the OTW strategy, these differences were relatively small (< 10% of the modeled streams). In all cases, however, strategy projections of improvement, based on changes in the percent of the modeled group estimated to be acidic in 2040, were pronounced (16% to 26% lower) in comparison with results of the scenario that was based on continued future deposition at 1995 levels. The model results suggest that current efforts to reduce emissions from 1995 levels, as represented by the OTW Emissions Control Strategy, will prevent substantial future deterioration in streamwater acid-base chemistry. However, additional reductions in emissions, as represented by the BWC and BYB Emissions Control Strategies, will probably not have a large additional impact on streamwater chemistry to the year 2040.

Watersheds that had relatively high nitrate concentrations in 1995 (> about 20 µeq/L) were most sensitive to estimated changes in future nitrogen deposition. However, projected acidification was not consistently associated with particular patterns in starting point nitrate concentrations or projected changes in nitrate concentrations. Sizeable (e.g., > 5 µeq/L) projected changes in streamwater nitrate concentration were mostly restricted to the Appalachian Plateau.

Modeled changes in streamwater ANC in the SAMI strategies were driven primarily by changes in sulfur deposition, rather than changes in nitrogen deposition. This was because simulated changes in nitrogen deposition were smaller than simulated changes in sulfur deposition and because simulated changes in nitrogen deposition were projected to have substantial impacts on streamwater nitrate concentration only in a limited geographical area.

Watersheds found to be most sensitive to modeled changes in nitrogen deposition were located primarily in the northern section of the Appalachian Plateau province in West Virginia and at high elevation in the Blue Ridge Province in North Carolina and Tennessee.

Of the 130 watersheds included in the regional modeling effort, 18% were acidic in 1995. Model results suggested that this percentage should be expected to increase by the year 2040 to 25%, 19%, and 15% under the OTW, BWC, and BYB strategies, respectively. Estimates of change in the number of streams within this group having low ANC ($\leq$ 20 μeq/L) under the three strategies were 50%, 41%, and 38%, respectively, as compared with 40% in 1995. The model estimated that more streams would likely shift downward from the "0 to 20 μeq/L" class to the "less than 0 μeq/L" class than would shift between the classes < 20 μeq/L and those > 20 μeq/L. These changes that were simulated for the group of 130 regional watersheds are expected to be generally representative of the types of potentially acid-sensitive streams (defined as those having ANC $\leq$ 150 μeq/L) found within the SAMI region.

Modeling results were extended to the statistical frame of the NSS by applying the median model output from among all modeling sites within a given modeling bin to all NSS sites within the ANC class and physiographic province represented by that bin. There were 12 bins, stratified by 3 physiographic provinces and 4 ANC classes. Based on the NSS statistical design, approximately 3% of the lower node streams within the study area were acidic and chronically unsuitable for supporting brook trout in 1995. That percentage was projected to decline by 2040 to 2% (BWC) and 1% (BYB), but to remain at 3% under the OTW strategy. Similarly, an estimated 7% of the upper node streams were acidic in 1995, and that percentage was projected to increase to 10% under OTW but to remain at 7% under the other two strategies.

The percent of streams represented by the NSS statistical design within the SAMI domain that were projected to be suitable for brook trout (ANC > 50 μeq/L) in 2040 was estimated to range from 77% (OTW Strategy) to 78% (BYB Strategy) for upper node streams (compared with 78% in 1995) and would remain stable at 90% for lower node streams in 1995 and under the three strategies. The percent of chronically and/or episodically acidic lower node streams within the study area was projected to be similar in 2040, regardless of strategy (7% for all strategies). For upper node streams, those projected percentages would vary from 15% (OTW) to 12% (BWC) and 11% (BYB). The latter strategy yielded an estimated percent of chronically and/or episodically acidic upper node streams in 2040 equal to the estimated percent in 1995.

Important conclusions regarding streamwater chemistry include the following:

- Many watersheds showed modeled streamwater sulfate concentration increasing, even while sulfur deposition was projected to decline.

- Some watersheds that currently show low sulfur retention and high streamwater sulfate concentration were projected to decrease in sulfate concentration and increase in ANC in response to lower sulfur deposition.

- Watersheds that currently show relatively low nitrogen retention and high streamwater nitrate concentration are projected to further acidify in response to the increased nitrogen deposition of some strategies.

- The median projected changes in streamwater ANC from 1995 to 2040 for the 130 regional modeling sites ranged from -1.3 (BYB Strategy) to -6.7 (OTW Strategy). All strategies indicated continued acidification of the median stream site, despite large decreases in sulfur, and in some cases nitrogen, deposition. These projected changes were highly variable across the study area, however.

- Streamwater acid-base chemistry was generally projected to deteriorate under the OTW and to a lesser extent the BWC Strategy from 1995 to 2040. Under the BYB Strategy, streamwater chemistry in 2040 was projected to be similar to chemistry in 1995. These projected differences among strategies were small ($\leq$ 4% of the SAMI stream population).

- Projected continued acidification was largest for sites in the southern portion of the SAMI region, mainly due to model projections of future decreases in sulfur adsorption on soils. Projected future increases in streamwater ANC, where they occurred, were largest in the north, especially in the BYB Strategy.

- Modeled changes in streamwater ANC in the SAMI strategies were driven primarily by changes in sulfur deposition, rather than changes in nitrogen deposition. This was because simulated changes in nitrogen deposition were smaller than simulated changes in sulfur deposition and because simulated changes in nitrogen deposition were projected to have substantial impacts on streamwater nitrate concentration only in a limited geographical area.

- Watersheds found to be most sensitive to modeled changes in nitrogen deposition were located primarily in the northern section of the Appalachian Plateau province in West Virginia and at high elevation in the Blue Ridge Province in North Carolina and Tennessee.

- Base cation depletion caused some streams to be projected to continue to acidify in the future despite projected decreases in streamwater sulfate and nitrate concentrations.

- The Emissions Control Strategies resulted in very small projected differences in the percentages of streams or length of stream segments within the various ANC classes.

- Although the model projections of future change in streamwater ANC in response to the Emissions Control Strategies suggested only modest changes and little improvement as compared with baseline conditions, the projections represent pronounced improvements in acid-base chemistry as compared with projections based on continued deposition at 1995 levels.

- Model projections beyond 2040 suggested that the sites that were projected to increase in ANC from 1995 to 2040, and also many of the sites that showed projected slight additional acidification from 1995 to 2040, would show considerable additional improvement in ANC beyond 2040, even if future deposition was held constant at 2040 levels.

- Almost all streams that were projected to have ANC below 20 μeq/L in 2040, in all of the strategies, were located in the northern Appalachian Plateau subregion.

Biological Effects

Conclusions regarding biological effects have greater uncertainty than conclusions regarding changes in the chemistry of streamwater. This is because of the complexity of the factors that govern biological systems response. For example, fish habitat suitability is determined by a host of variables, of which acid-base status is only one. For that reason, biological inferences derived from the modeling results presented in this report should be treated with caution.

There is no doubt that acidification of surface waters lowers species diversity for both fish and invertebrates. Since species differ in acid sensitivity, there is a predictable sequence of species loss as acidification progresses. The elevated concentrations of hydrogen ion and aluminum, which occur as pH and ANC falls, act as poisons which attack the gill structures responsible for body salt and water balance. This produces a cascade of negative physiological effects culminating in death of the organism.

These processes are well understood and appear to occur wherever fish and invertebrates are affected by the acidification of aquatic habitats. Adequate habitat structure is a necessary, but not sufficient, requirement for healthy fish populations; water acid-base chemistry must be suitable as well.

Results from the modeled group of regional watersheds suggested that the percent of the potentially acid-sensitive streams having chemistry unsuitable for brook trout would increase slightly during the period 1995 to 2040 under the OTW, but not the BYB strategy. Other species of fish, and also other species of aquatic biota other than fish, would also be expected to respond to the simulated changes in streamwater ANC. Fish species richness and aquatic species diversity, both within and among taxonomic groups, would be expected to decline with simulated acidification and increase with simulated chemical improvement.

Important conclusions regarding biological effects include the following:

- The number of acid-sensitive streams having chemistry either chronically or episodically unsuitable for brook trout was projected to increase under the OTW and BWC Strategies, but decrease slightly under the BYB Strategy.

- Forest soil conditions were projected to deteriorate at most of the modeled forest sites under all strategies. The calcium to aluminum molar ratio in soil solution was projected to decline well below the generally accepted threshold for protection of forest health and growth at many sites, especially spruce-fir sites.

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APPENDIX A

SUMMARY OF THE PHASE I SAMI AQUATIC AND TERRESTRIAL ASSESSMENT

Summary of Phase I Results

Results of Phase I of the SAMI aquatic and forest assessment were presented by Cosby and Sullivan (1999), Munson et al. (1999), and Brewer et al. (2000). Three watersheds were calibrated to each of the two models and ten deposition scenarios were conducted. The scenarios included various levels of future changes in SO_4^{2-} and NO_3^- deposition, and in two cases also base cation deposition. Major findings are summarized below.

The scenarios were based on percentage changes in SO_4^{2-}, NO_3^-, and (in some cases) base cation deposition relative to deposition of these ions in a reference year (1995). All other ions in deposition were assumed to remain constant into the future at the reference year levels. The reference year deposition for each site was based on the volume weighted annual average total deposition of each ion. For each scenario, simulations were run for forty-five years into the future (1996-2040). For the scenarios assuming either increased or decreased deposition of an ion, the deposition increases or decreases were implemented as a step change in 1996 and the deposition of the changed ions was maintained constant at the new level until the year 2040. Deposition was the only input or parameter changed in the scenarios. Soil characteristics, hydrological responses and biological dynamics were all assumed to be constant into the future (at reference year values) for each scenario.

The ten future atmospheric deposition scenarios used for the MAGIC and NuCM simulations for each site in SAMI Phase I were:

Scenario 1	No changes
Scenario 2	30% reduction in sulfate, 20% decrease in nitrate
Scenario 3	30% reduction in sulfate, 20% increase in nitrate
Scenario 4	50% reduction in sulfate, 40% decrease in nitrate
Scenario 5	50% reduction in sulfate, 20% increase in nitrate
Scenario 6	30% reduction in sulfate, 20% increase in nitrate, 20% decrease in calcium, magnesium, sodium, and potassium
Scenario 7	70% reduction in sulfate, 20% decrease in nitrate
Scenario 8	70% reduction in sulfate, 20% increase in nitrate
Scenario 9	70% reduction in sulfate, 40% decrease in nitrate
Scenario 10	70% reduction in sulfate, 20% decrease in nitrate, 20% decrease in calcium, magnesium, sodium, and potassium

MAGIC

Comparisons of simulated and observed monthly average stream ANC (an integrated measure of overall model goodness-of-fit) for each Phase I site indicated that the model could successfully reproduce observed streamwater quality at all three SAMI Phase I sites. Results at each site are summarized below.

Noland Divide

MAGIC simulations with 0% or 30% reductions in SO_4^{2-} deposition resulted in increases in annual average stream SO_4^{2-} concentrations at Noland Divide. MAGIC simulations with 50% reductions in SO_4^{2-} deposition resulted in only slight increases (approximately 3 μeq/L) in annual average stream SO_4^{2-} concentrations (relative to the reference year) whereas 70% reductions in SO_4^{2-} deposition resulted in slight decreases (approximately 3 μeq/L). These simulation results suggested that reductions of SO_4^{2-} deposition of 50% to 70% (relative to the reference year) would be necessary to prevent further increases in annual average stream SO_4^{2-} concentrations at Noland Divide.

MAGIC simulations of changes in annual average stream NO_3^- concentrations in response to changes in NO_3^- deposition suggested that Noland Divide water quality is responsive to NO_3^- deposition, with responses to changed NO_3^- deposition being relatively rapid. The magnitude of changes in annual average stream NO_3^- concentrations were proportional to the changes in atmospheric NO_3^- deposition.

Of the ten scenarios considered for Noland Divide, one scenario resulted in increased simulated annual average ANC (scenario 9), two scenarios resulted in essentially no change in simulated annual average ANC (± 10% of reference year alkalinity; scenarios 4 and 7). The remaining seven scenarios resulted in declines in simulated annual average ANC (scenarios 1,2, 3, 5, 6, 8, and 10). Four scenarios resulted in simulated annual average ANC that was less than zero (scenarios 1, 3, 5, and 6). These results suggested that, for Noland Divide, reductions in the total acidity of deposition of at least 55% (relative to the reference year), would be necessary to prevent annual average stream ANC from becoming negative.

North Fork Dry Run

MAGIC simulations with 0% change in SO_4^{2-} deposition resulted in slight increases in annual average stream SO_4^{2-} concentrations at North Fork Dry Run. MAGIC simulations with 30%, 50%, and 70% reductions in SO_4^{2-} deposition all resulted in declines in annual average stream SO_4^{2-} concentrations. These simulation results suggested that the catchment at North Fork Dry Run is nearly at steady state with respect to SO_4^{2-} deposition (i.e., SO_4^{2-} output flux equals SO_4^{2-} input flux). Reductions in SO_4^{2-} deposition will likely result in declines in annual average stream SO_4^{2-} concentrations and the declines will be proportional to the magnitude of the deposition reduction.

MAGIC simulations of changes in annual average stream NO_3^- concentrations in response to changes in NO_3^- deposition suggested that North Fork Dry Run water quality was somewhat responsive to NO_3^- deposition, with responses to changed deposition being relatively rapid. However, the simulated changes in annual average stream NO_3^- concentrations were relatively small, and there was not a large difference in response across the scenarios.

Of the ten scenarios considered for North Fork Dry Run, one scenario resulted in slightly increased simulated annual average ANC (scenario 9). Three scenarios resulted in declines in simulated annual average ANC of greater than 10% of the reference value (scenarios 1, 3, and 6). The remaining six scenarios resulted in essentially no change in simulated annual average ANC (± 10% in reference year ANC; scenarios 2, 4, 5, 7, 8, and 10). No scenarios resulted in simulated annual average ANC that was less than zero. Despite relatively large declines in simulated acid anion concentrations resulting from the deposition reductions in nine of the ten scenarios, the simulated ANC of the stream did not change significantly. These results suggested that North Fork Dry Run was not particularly sensitive to acidification and that no reductions in the total acidity of deposition (relative to the reference year) would be necessary to prevent annual average stream ANC from becoming negative.

White Oak Run

MAGIC simulations with 0% or 30% reductions in SO_4^{2-} deposition resulted in increases in annual average stream SO_4^{2-} concentrations at White Oak Run. MAGIC simulations with 50% reductions in SO_4^{2-} deposition resulted in approximately constant annual average stream SO_4^{2-} concentrations (relative to the reference year). Reductions of 70% in SO_4^{2-} deposition resulted in decreases in annual average stream SO_4^{2-} concentrations. These simulation results suggested that reductions of SO_4^{2-} deposition of 50% (relative to the reference year) would be necessary to prevent further increases in annual average stream SO_4^{2-} concentrations at White Oak Run.

The calibrated nitrogen dynamics at White Oak Run did not allow leakage of NO_3^- from the soils (in agreement with observed behavior in the calibration period). Plant and soil uptake in the catchment of White Oak Run apparently remove all deposited (and nitrified) N. This uptake capacity was not exceeded in any of the future deposition scenarios. The White Oak Run simulations were therefore unresponsive to simulated changes in atmospheric deposition of NO_3^-.

Of the 10 scenarios considered for White Oak Run, none resulted in increased simulated annual average stream ANC. All 10 scenarios produced declines in simulated annual average stream ANC that were greater than 10% of the reference value. Only four scenarios resulted in simulated annual average stream ANC that was significantly greater than zero (scenarios 7, 8, 9, and 10). Four scenarios resulted in simulated annual average ANC that was significantly below zero (scenarios 1, 2, 3, and 6). These results suggested that, for White Oak Run, reductions in the deposition of SO_4^{2-} of at least 50% (relative to the reference year) would be needed to prevent annual average stream ANC from becoming negative.

Differences in Simulated Responses Across the Three Phase I Watersheds

At Noland Divide, between 50% and 70% reductions in SO_4^{2-} deposition were needed in the simulations to prevent increases in stream SO_4^{2-}. At White Oak Run, at least 50% reductions in SO_4^{2-} deposition were needed for the same effect. At Shaver Hollow, however, any future reduction of SO_4^{2-} deposition in the simulations resulted in decreases in stream SO_4^{2-} concentrations. The simulations suggested the need for relatively large reductions in SO_4^{2-} deposition at Noland Divide and White Oak Run, and this resulted from the fact that the deposition input of SO_4^{2-} was greater than the output through stream discharge in 1995. The North Fork Dry Run catchment, however, had apparently reached an approximate steady state with deposition in 1995, and therefore any change in SO_4^{2-} deposition would lead to a corresponding change in streamwater SO_4^{2-} concentration.

These results suggested that the amount of SO_4^{2-} adsorption occurring in soils at Noland Divide and White Oak Run was greater than at North Fork Dry Run. Considering that the deposition of SO_4^{2-} is more than twice as great at Noland Divide than at either of the VA sites, we can rank the catchments in terms of SO_4^{2-} adsorption capacity (from greatest to least) as Noland Divide, White Oak Run, and then North Fork Dry Run.

All catchments were simulated to nitrify essentially all of the NH_4^+ deposited from the atmosphere, resulting in an increase in available NO_3^- in the soil. Both deposited NO_3^- and NO_3^- derived from nitrified NH_4^+ were then available for biological uptake and/or NO_3^- leaching in streamwater . Loss of atmospherically deposited NO_3^- through runoff was variable among the sites. The Noland Divide catchment had the highest proportional loss of NO_3^- (relative to deposition) of the three catchments (Noland Divide = 86% loss in runoff of deposited NO_3^-, North Fork Dry Run = 37%, White Oak Run = 1%). As with SO_4^{2-} retention, there was a ranking for NO_3^- retention (but it was different from that for SO_4^{2-}). The NO_3^- retention ranking indicated that White Oak Run was greater than North Fork Dry Run, which was greater than Noland Divide. MAGIC did not simulate any changes in the retention properties of the soils of the three catchments for any of the future scenarios. Therefore, the catchment with the strongest retention (White Oak Run) responded very little to the scenarios. Regardless of the change in NO_3^- deposition, whether up or down, the soils in the White Oak Run simulation still retained 99% of NO_3^- and there was no response in the stream. In that the NO_3^- was removed from solution in the soil, there was therefore no effect of changes in NO_3^- deposition on any other ion in the soil. The Noland Divide catchment had the lowest NO_3^- retention and therefore was the most sensitive to changes in NO_3^- deposition.

The relatively high retention of NO_3^- in the Virginia catchments relative to Noland Divide probably resulted from differences in vegetation dynamics at the sites. The high elevation spruce in Noland Divide are declining, reducing the overall vegetative demand for N in Noland Divide. The Virginia sites, on the other hand, are second growth forests, growing on relatively N-poor soils with a concomitant greater demand for atmospherically deposited N. The moderate leakage of NO_3^- from North Fork Dry Run was probably a 5 to 10 year transient response to the gypsy moth outbreak that occurred in the catchment. In the absence of gypsy moth infestation, nearly all the sites we have studied in the mountains of Virginia show complete retention of N.

The ANC responses of the streams varied in yet another pattern from that of SO_4^{2-} or NO_3^-. A 55% reduction in total deposition acidity was needed in the simulations to prevent loss of ANC in Noland Divide (i.e., to prevent ANC from declining to values less than zero). A 70%

reduction in total deposition acidity was needed for the same effect in White Oak Run. At North Fork Dry Run, however, none of the scenarios that were considered resulted in complete loss of ANC from the stream. Based on these results, we can classify White Oak Run as very sensitive to acidification Noland Divide as sensitive to acidification, and North Fork Dry Run as not sensitive.

The net production of ANC was approximately equal for North Fork Dry Run and Noland Divide. Even though Noland Divide produced more base cations than North Fork Dry Run, it also exported more acid anions, with the result that net buffering of acidity at Noland Divide was roughly equal to that at North Fork Dry Run. The net buffering of acidity at White Oak Run was about 25% lower than at the other two sites. The reason that simulations for North Fork Dry Run did not produce negative ANC for any scenario was that the starting values (in 1995) of ANC in North Fork Dry Run were higher. During the simulations, ANC values declined at all three sites. In Noland Divide, however, none of the scenarios drove the ANC to negative values.

Noland Divide was deemed to be moderately responsive to changes in SO_4^{2-} deposition, very responsive to changes in NO_3^- deposition, relatively sensitive to loss of ANC, and would require substantial decreases in total deposition acidity to maintain positive ANC in the stream.

North Fork Dry Run was very responsive to changes in SO_4^{2-} deposition, somewhat responsive to changes in NO_3^- deposition, relatively insensitive to loss of ANC, and would require only moderate decreases in total deposition acidity to maintain positive ANC in the stream.

White Oak Run was somewhat responsive to changes in SO_4^{2-} deposition, not responsive to changes in NO_3^- deposition, very sensitive to loss of ANC, and would require substantial decreases in SO_4^{2-} deposition to maintain positive ANC in the stream.

The responses to deposition represented by these three sites covered a range of behaviors that reflect variations in real catchment processes in the southern Appalachian Mountains. By applying the models to these three sites, we exercised the models across a range of responses that represent the qualitative and quantitative variations that would likely be encountered in the Phase II regional modeling assessment.

NuCM

The forest Nutrient Cycling Model (NuCM) is a PC-based model which simulates the processes that alter the acid-base properties of precipitation as it moves through the forest canopy, into and through watershed soils, and into surface waters. These processes include vegetation growth, litter fall and decay, soil biogeochemical processes, and water routing. The model can be used to simulate a forest plot or a forested watershed with a stream. Model output includes nutrient pool sizes in the soil and vegetation and fluxes between them. Nutrient concentrations in soil solution, throughfall, and streamflow, as well as sorbed concentrations, can be plotted versus time. Detailed cycle charts for key solutes are also produced.

NuCM was calibrated using existing data sets from the three selected watersheds. Noland Divide and Shaver Hollow were calibrated using observed inputs for the period 1991-1995. White Oak Run was calibrated using inputs for the period 1980-1985 to avoid the effects of a later gypsy moth infestation. Following calibration, deposition scenarios were run to determine how the systems respond to changes in deposition. These scenarios were based upon the average of observed deposition levels from 1991-1995 for all three watersheds.

Noland Divide

Streamwater concentrations of SO_4^{2-} at Noland Divide showed small responses to changes in atmospheric deposition of S. The range in streamwater SO_4^{2-} concentrations at the end of the simulations is 10-15 µeq/L even though input SO_4^{2-} concentrations were altered by up to 70 percent. Changes in NO_3^- deposition, however, did produce discernible changes in simulated streamwater NO_3^- concentrations, with final concentrations ranging from 20 to near 50 µeq/L. These changes in strong acid anion concentrations appeared to be largely compensated-for by changes in base cation concentrations, as reflected by relatively small changes in streamwater ANC for all scenarios simulated. The range of final ANC values is approximately 10-15 µeq/l.

Whereas the response of streamwaters to changes in S deposition were small, there were changes in the simulated concentrations of Ca^{2+} and Al^{n+} in the soil solution in the rooting zone at Noland Divide in response to 50 and 70 percent reductions in S deposition. These large deposition reductions resulted in Ca/Al ratios greater than 1 in 2040, indicating decreases in forest stress.

North Fork Dry Run

The simulated response to changing SO_4^{2-} deposition at North Fork Dry Run was generally similar to that observed at White Oak Run. Reductions in SO_4^{2-} deposition resulted in lower stream SO_4^{2-} concentrations, but changes in ANC were dampened as a result of changes in base cation concentrations. Changes in NO_3^- deposition resulted in changes in streamwater NO_3^- concentrations that were intermediate between those of White Oak Run and Noland Divide, but they appear to have little impact on ANC.

The soil solution response in the rooting zone at North Fork Dry Run was similar to that at White Oak Run in that Ca^{2+} concentrations decreased and Al^{n+} concentrations increased over time for all scenarios. Unlike White Oak Run, however, there were discernible differences among the various scenarios, with soil acidification being most severe for Scenario 1 (no change in deposition) and least severe for the 70 percent SO_4^{2-} deposition reduction scenarios. In addition, although soil acidification was taking place in the simulations, Ca/Al ratios below 1 were not observed for any of the scenarios by the year 2040.

White Oak Run

The response of White Oak Run streamwater was significantly different compared to that of Noland Divide. Simulated SO_4^{2-} concentrations increased to around 100 μeq/L for the reference year scenario (Scenario 1 - maintain 1995 deposition levels). These increased SO_4^{2-} concentrations were partially offset by cation exchange and weathering releases of base cations. The net result was a decrease in flow-weighted average annual ANC over the simulation period from just over 15 μeq/ L to around -5 μeq/L. Fifty and thirty percent reductions in S deposition resulted in smaller decreases in ANC, whereas seventy percent decreases in S deposition resulted in ANC concentrations in 2040 similar to those observed in the reference year. The response to changes in NO_3^- deposition are considerably dampened compared to the responses at Noland Divide and appear to have little impact on streamwater ANC values.

Soil solution concentrations in the rooting zone at White Oak Run showed steady declines in Ca^{2+} concentrations and increases in Al^{n+} concentrations for all scenarios over the simulation period. This is indicative of soil acidification. By 2040, the simulated Ca/Al ratio declined to values lower than 1 for all scenarios, which suggests that forest stress may increase over time.

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APPENDIX B

WATERSHED DATA ACQUISITION

The compilation of watershed information for SAMI's aquatic and terrestrial effects assessments involved identification and acquisition of data collected over a range of spatial and temporal scales. Regionally extensive information was mainly limited to stream water composition data obtained for one or only a few points in time. More comprehensive information, including stream water composition data obtained for multiple points in time, as well as soil and vegetation data, was available for a number of intensively studied watersheds and geographically limited research areas.

1. Regionally Extensive Data Sources

The National Stream Survey

- *Stream water composition*

A one-time synoptic sampling survey to obtain acid-base chemistry data for regional surface waters was conducted in 1986 as part of the National Acid Precipitation Assessment Program (Kaufmann et al., 1988). Data obtained for the SAMI region included: 69 sites in WV, 36 sites in VA, 40 sites in NC, 21 sites in TN, and 19 sites in GA. Contact: Alan Herlihy, U.S. EPA, Corvallis, Oregon.

Environmental Monitoring and Assessment Program

- *Stream water composition*

Acid-base chemistry data were obtained for regional surface waters through aquatic monitoring components of the U.S. EPA Environmental Monitoring and Assessment Program. Data obtained for the SAMI region included: 154 sites in WV, 180 sites in VA, and 3 sites in NC. Contact: Alan Herlihy, U.S. EPA, Corvallis, Oregon.

Virginia Trout Stream Sensitivity Survey

- *Stream water composition*

Acid-base chemistry data were obtained for 304 streams sampled in a 1987 synoptic survey of native brook trout streams in western Virginia mountain watersheds associated with non-carbonate bedrock. Additional time-series data (quarterly samples beginning in 1988) were obtained for a subset of 60 streams representing a lithologic stratification of the streams in the larger population. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

U.S.D.A. Forest Service TN/NC/SC Stream Surveys

- *Stream water composition*

Acid-base chemistry data were obtained for streams sampled in a 1999-2000 synoptic survey of National Forest streams in North Carolina and Tennessee. Data were obtained for 36 sites in NC and 29 sites in TN. Contact: Bill Jackson, U.S.D.A. Forest Service, Asheville, North Carolina.

Direct-Delayed Response Project

- *Soils information*

Chemical analyses of soils were obtained for a subset of watersheds associated with the National Stream Survey as part of the National Acid Precipitation Assessment Program (Church et al., 1992). Contact: Robbins Church, U.S.EPA, Corvallis, Oregon.

2. Geographically Intensive Data Sources

Otter Creek and Dolly Sods Wildernesses (WV)

- *Stream water composition*

A one-time synoptic sampling survey was conducted in May 1994 providing acid-base chemistry for surface water sites in Otter Creek Wilderness (OCW) and Dolly Sods Wilderness (DSW) (Webb et al., 1997). Data for the SAMI assessment were obtained for 8 major tributaries in OCW and 5 major tributaries in DSW. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Soils information*

Chemical analyses were obtained for recent samples from represented soil series in OCW and DSW. Contact: Anthony Jenkins, U.S.D.A. Natural Resource Conservation Service, Fayetteville, West Virginia.

- *Mineralogical information*

Bedrock maps and general lithology were summarized by Webb et al., (1997) based on earlier geologic maps and reports. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Vegetation information*

Descriptions of vegetation characteristics were provided with soil sampling site descriptions. Contact: Anthony Jenkins, U.S.D.A. Natural Resource Conservation Service, Fayetteville, West Virginia.

<u>Fernow Experimental Forest (WV)</u>

- *Stream water composition*

Acid-base chemistry data were obtained for 3 control (undisturbed) watersheds sampled weekly beginning in 1987. Daily discharge data were also obtained. Contact: Mary Beth Adams, U.S.D.A. Forest Service, Timber and Watershed Laboratory, Parsons, West Virginia.

- *Soils information*

Chemical analyses were obtained for soil samples collected in 1988 from one of the watersheds and considered representative of the other watersheds. Soil water chemistry was obtained during 1989-1995 from one of the watersheds. Contact: Mary Beth Adams, U.S.D.A. Forest Service, Timber and Watershed Laboratory, Parsons, West Virginia.

Sulfate adsorption data were obtained for an adjacent Fernow watershed, providing a reasonable surrogate (Lusk, 1988).

- *Mineralogical information*

Soil mineralogy data were obtained for an adjacent Fernow watershed, providing a reasonable surrogate (Lusk, 1988).

- *Vegetation information*

Descriptions of vegetation characteristics were obtained for one of the watersheds and considered representative of the other watersheds. Contact: Mary Beth Adams, U.S.D.A. Forest Service, Timber and Watershed Laboratory, Parsons, West Virginia.

Total above ground biomass data for Fernow forests was obtained from Adams (1999).

<u>James River Face Wilderness (VA)</u>

- *Stream water composition*

A one-time synoptic sampling survey was conducted in January 1991 providing acid-base chemistry for 4 watersheds. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia. (Note: additional data were obtained for 2 sites sampled quarterly beginning in 1991. The data for these sites are included in the VTSSS regional-scale data set.)

- *Soils information*

Chemical analyses were obtained one watershed considered representative of the other watersheds were obtained for samples collected in 2000. Contact: Cindy Huber, U.S.D.A. Forest Service, Roanoke, Virginia.

- *Mineralogical information*

Bedrock maps and general lithology obtained from Spencer (1968).

- *Vegetation information*

Descriptions of vegetation characteristics were provided with soil sampling site descriptions and Rawinski et al. (1996).

<u>Shenandoah National Park (VA)</u>

- *Stream water composition*

Weekly stream water sampling beginning 1979-1992 provided acid-base chemistry for 6 watersheds. Continuous discharge gaging provided for 5 of the watersheds. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Soils information*

Chemical analyses were obtained for samples collected in 2 of the watersheds (White Oak Run and North Fork of Dry Run). Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Mineralogical information*

Bedrock maps and general lithology obtained from Gathright (1976).

- *Vegetation information*

Descriptions of vegetation characteristics were provided by parkwide vegetation mapping. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

<u>Lewis Fork Wilderness (VA)</u>

- *Stream water composition*

Quarterly stream water sampling data were obtained for Lewis Fork through the regional-scale VTSSS sampling program. Contact: Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Soils information*

Chemical analyses were obtained for samples collected in 2000. Contact: Cindy Huber, U.S.D.A. Forest Service, Roanoke, Virginia.

- *Mineralogical information*

Bedrock maps and general lithology obtained from U.S.D.A. geologic map coverage. Contact: Cindy Huber, U.S.D.A. Forest Service, Roanoke, Virginia.

- *Vegetation information*

Descriptions of vegetation characteristics were provided with soil sampling site descriptions.

White Top Mountain (VA)

- *Soils information*

Chemical analyses were obtained for 2 samples collected near the summit. Soil solution chemistry data were obtained for samples collected from 25 sites in the summit area. Contact: Alan Mays, Tennessee Valley Authority, Norris, Tennessee.

- *Mineralogical information*

Provided in site descriptions of Joslin and Wolfe (1992).

- *Vegetation information*

Descriptions of vegetation characteristics were provided by Joslin and Wolfe (1992).

Clinch Ranger District (VA)

- *Stream water composition*

Acid-base chemistry data for stream water samples collected 4 times during the period 1996-2000 were obtained for 5 streams in the Clinch Ranger District of the Jefferson National Forest. Contact: Cindy Huber, U.S.D.A. Forest Service, Roanoke, Virginia.

Great Smoky Mountains National Park (NC)

- *Stream water composition*

Acid-base chemistry data were obtained for samples collected at 7 sites in 2000 for association with available soil data. Contacts: Jim Renfro, Great Smoky Mountains National Park, Gatlinburg, TN; Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Soils information*

Chemical analyses of soil samples, as well as soil solution chemistry data, were provided for Noland Divide, Becking, and Beech sites in Johnson and Lindberg (1992).

Chemical analyses of soil samples, as well as soil solution chemistry data, were provided for sites in the Raven Fork-Enloe Creek basin in Jones et al. (1983). Additional detailed records of sampling and analyses were also obtained. Contact: Alan Mays, Tennessee Valley Authority, Norris, Tennessee.

Chemical analyses of soil samples, as well as soil solution chemistry data, were obtained for Cove Mountain and Twin Creek sites. Contact: Alan Mays, Tennessee Valley Authority, Norris, Tennessee.

- *Mineralogical information*

Soil mineralogical information for the Noland Divide, Becking, and Beech sites was provided in site descriptions in Johnson and Lindberg (1992).

- *Vegetation information*

Descriptions of vegetation characteristics were provided with soil sampling site descriptions in Johnson and Lindberg (1992) and Johnson and Lindberg (1992), as well as with soil sampling site descriptions for Cove Mountain and Twin Creek sites.

<u>Black Mountain (NC)</u>

- *Stream water composition*

A single site on the South Fork of Upper Creek was sampled for analysis of acid-base chemistry in 2000. Contacts: Pat Brewer, SAMI, Asheville, North Carolina; Rick Webb, Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.

- *Soils information*

Chemical analyses were provided for one site sampled in the South Fork of Upper Creek watershed in 1985. Contact: Pat Brewer, SAMI, Asheville, North Carolina.

<u>Joyce Kilmer/Shining Rock Wilderness (NC)</u>

- *Stream water composition*

Acid-base chemistry data were obtained for samples collected weekly in 1999 at one site in Joyce Kilmer. Contact: Jim Vose, Coweeta Hydrologic Laboratory, Otto, North Carolina. (Note: additional stream water composition data were obtained for Joyce Kilmer/Shining Rock Wilderness through regional synoptic sampling conducted by the U.S.D.A. Forest Service. These data are included in the U.S.D.A. Forest Service TN/NC/SC Stream Surveys data set.)

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- *Soils information*

Chemical analyses were provided for one site sampled in Joyce Kilmer. Contact: Jim Vose, Coweeta Hydrologic Laboratory, Otto, North Carolina.

- *Mineralogical information*

Soil mineralogy data were provided with soil sampling site descriptions. Contact: Jim Vose, Coweeta Hydrologic Laboratory, Otto, North Carolina.

- *Vegetation information*

Descriptions of vegetation characteristics were provided with soil sampling site descriptions. Contact: Jim Vose, Coweeta Hydrologic Laboratory, Otto, North Carolina.

Laurel Branch (TN)

- *Stream water composition*

Acid-base chemistry data were obtained for samples collected monthly on Laurel Branch in 1986-1987 (Olem et al., 1988).

- *Soils information*

Chemical analyses were provided for multiple sites sampled in 1987. Contact: Alan Mays, Tennessee Valley Authority, Norris, Tennessee.

- *Mineralogical information*

Soil mineralogy data were provided with soil sampling site descriptions. Contact: Alan Mays, Tennessee Valley Authority, Norris, Tennessee.

- *Vegetation information*

Descriptions of vegetation characteristics were provided in Olem et al. 1988).

Cohutta Wilderness (GA)

- *Stream water composition*

Acid-base chemistry data were obtained for samples collected on 4 streams in 1992-1994. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

- *Soils information*

  Chemical analyses were provided for sites sampled in 2000. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

- *Mineralogical information*

  Soil mineralogy data were provided with soil series descriptions. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

Sipsey Wilderness (GA)

- *Stream water composition*

  Acid-base chemistry data were obtained for samples collected on 3 streams in 1991-1994. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

- *Soils information*

  Chemical analyses were provided for sites sampled in 2000. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

- *Mineralogical information*

  Soil mineralogy data were provided with soil series descriptions. Contact: Dave Wergowske, U.S.D.A. Forest Service, Montgomery, Alabama.

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APPENDIX C

CRITERIA FOR EXCLUDING CANDIDATE SITES FROM CONSIDERATION AS REGIONAL MODELING SITES

Candidate sites for regional modeling were screened in an effort to exclude sites that showed evidence of error in one or more chemical parameter values or that showed evidence of large influence from geologic sources of SO_4^{2-} and/or Cl^- or terrestrial sources of NO_3^-. If the difference between titrated and calculated ANC exceeded 15 μeq/L (low ANC sites) to 20 μeq/L (higher ANC sites) and that difference could not reasonably be attributed to Al (c.f., Sullivan et al. 1989), then we assumed that there was a high probability of an error in one or more of the input parameters (used to calculate ANC: CALK = sum of base cations plus NH_4^+ minus sum of mineral acid anions) and the site was deleted from consideration. Smaller differences between titrated and calculated ANC were used as the justification for deletion if those differences would result in different bin assignment, but only where there was an adequate number of alternative candidates. This was done to avoid confusion in interpretation in situations where alternative bin assignments were possible.

Sites that had Cl concentrations ≥ 100 μeq/L were presumed to be contaminated with road salt and were deleted. Four sites had high NO_3 concentration (> 100 μeq/L) and were presumed impacted by land use or insect defoliation; two of those also had high Cl. Several sites showed evidence of geological sulfur (acid mine drainage), with streamwater SO_4^{2-} concentrations > 400 μeq/L.

Table C-1. Deleted candidate sites for regional MAGIC modeling.

Site	Criteria for Deletion[a]	Data Used as Basis for Deletion
BJ51	1,3	CALK = -28; ANC = 125; Cl = 783
BJ15	1,3	CALK = -37; ANC = 55; Cl = 726
BJ55	1,3	CALK = -13; ANC = 18; Cl = 344
BJ34	1,3	CALK = 6; ANC = 64; Cl = 428
BJ27	1	CALK = 36; ANC = 14
BJ17	1	CALK = 35; ANC = 13
BJ02	1	CALK = 24; ANC = 4
BJ70	1	CALK = 30; ANC = 12
VT45	2	CALK = 51; ANC = 39
VT77	2	CALK = 51; ANC = 44
VT04	2	CALK = 52; ANC = 34
BJ06	1	CALK = 127; ANC = 178
BJ47	1	CALK = 100; ANC = 74
BJ31	1	CALK = 120; ANC = 87
BJ20	1	CALK = 84; ANC = 52
BJ37	1	CALK = 67; ANC = 37
BJ04	1	CALK = 114; ANC = 88
BJ52	1	CALK = 60; ANC = 32
BJ57	2	CALK = 51; ANC = 36
BJ80	1	CALK = 137; ANC = 92
2A068048U	2	CALK = 53; ANC = 43
2A07825U	2	CALK = 51; ANC = 41
WV754S	1	CALK = 34; ANC = 82
2B041032U	1	CALK = 71; ANC = 39
2B047032U	1,3	CALK = 69; ANC = 102; Cl = 1323
FN2	1	CALK = -5; ANC = 18
WV529S	1,3,4	CALK = -1115; ANC = -326; SO_4 = 3767; Cl = 128
WV794S	1,4	CALK = -436; ANC = -194; SO_4 = 1370
WV797S	1,4	CALK = -3579; ANC = -1460; SO_4 = 5719
2C041040U	1	CALK = 39; ANC = 64
2C088003U	3,6	Cl = 202; NO_3 = 202
2C46050	3	Cl = 279
2B088020L	3	Cl = 130
2C040006U	3	Cl = 103
2C046018U	1	CALK = 57; ANC = 81
2C046050L	1,3	CALK = 54; ANC = 87; Cl = 279
2C047007U	1	CALK = 67; ANC = 120
2C088003L	3	Cl = 100

Table C-1. Continued		
Site	Criteria for Deletion[a]	Data Used as Basis for Deletion
2C088004L	3	Cl = 128
SP41	5	pH = 4.7; CALK = 102
2C46041	3	Cl = 207
BJ13	3	Cl = 182
BJ22	3	Cl = 178
VA532S	3,4,6	Cl = 183; NO_3 = 1373
WV545S	3	Cl = 110
2C046030U	6	NO_3 = 129
2B088020U	5,6	NO_3 = 157; pH = 5.6; CALK = 79
WV521S	4	SO_4 = 3997
2C046046L	4	SO_4 = 2384
2C046018L	4	SO_4 = 551
2C046018U	4	SO_4 = 444
VA789S	4	pH = 6.1; CALK = 114
BJ02	1	CALK=23; ANC=4
BJ04	1	CALK = 114; ANC = 88
BJ06	1	CALK = 127; ANC = 178
BJ15	1,3	CALK = -37; ANC = 55; Cl=726
BJ17	1	CALK = 35; ANC = 13
BJ20	1	CALK = 84; ANC = 52
BJ21	1	CALK = 88; ANC = 65
BJ27	1	CALK = 36; ANC = 14
BJ28	1	CALK = 138; ANC = 116
BJ31	1	CALK = 120; ANC = 87
BJ34	1,3	CALK = 6; ANC = 64; Cl=428
BJ36	1	CALK = 91; ANC = 68
BJ47	1	CALK = 100; ANC = 74
BJ51	1,3	CALK = -28; ANC = 125, Cl=783
BJ55	1,3	CALK = -13; ANC = 18; Cl=344
BJ70	1	CALK = 30; ANC = 12
BJ71	1	CALK = 19; ANC = 2
BJ80	1	CALK = 137; ANC = 92
SP10	1	CALK=49; ANC=80

[a] Criteria for deletion
1. discrepancy between CALK and titrated ANC is too large and cannot be explained by Al
2. discrepancy between CALK and titrated ANC would place the stream into two different bins and there are other good candidate streams to choose in place of this stream
3. Cl is too high and suggests road salt contamination
4. geological sulfur, based on streamwater SO_4^{2-} > 400 µeq/L in WV or Va, or > 300 µeq/L elsewhere
5. discrepancy between pH and CALC is too large and cannot be explained by Al
6. NO_3^- is too high to be reasonably attributable to atmospheric deposition

APPENDIX D

CORRESPONDENCE BETWEEN CANDIDATE REGIONAL MAGIC MODELING SITES AND THOSE SELECTED FOR MODELING

An objective of the regional modeling site-selection process was to select watersheds for inclusion in the regional modeling effort in a way that would maximize heterogeneity for several key parameters. First, all Tier I sites (those having watershed-specific soils data) were selected. Then additional sites were added, as necessary, to provide good geographical distribution along the longitudinal axis of the SAMI domain and to provide a range of within-bin ANC values. Finally, consideration was given to obtaining a wide distribution within each bin in sulfate and nitrate concentrations and elevation. Within each of the 12 modeling bins, sites were sequentially selected to maximize heterogeneity in terms of these parameters.

Most bins had an adequate number of candidate sites (Figure D-1). Bin 4 (BR50-150) included over 20 Tier I sites, and over 90 sites in total. Most other bins included between 10 and 25 candidate sites.

The distribution of candidate sites across modeling bins (1-12) and tier (I-III reflecting availability of site-specific soils data) is graphically illustrated in Figure D-2. Of the candidates, 10 to 12 sites were selected for modeling from most of the bins (Figure D-3). The site selection process captured the range of heterogeneity available within the candidate set for the key variables. This can be seen by visual comparison (for a given bin) between Figure D-1 and Figure D-4.

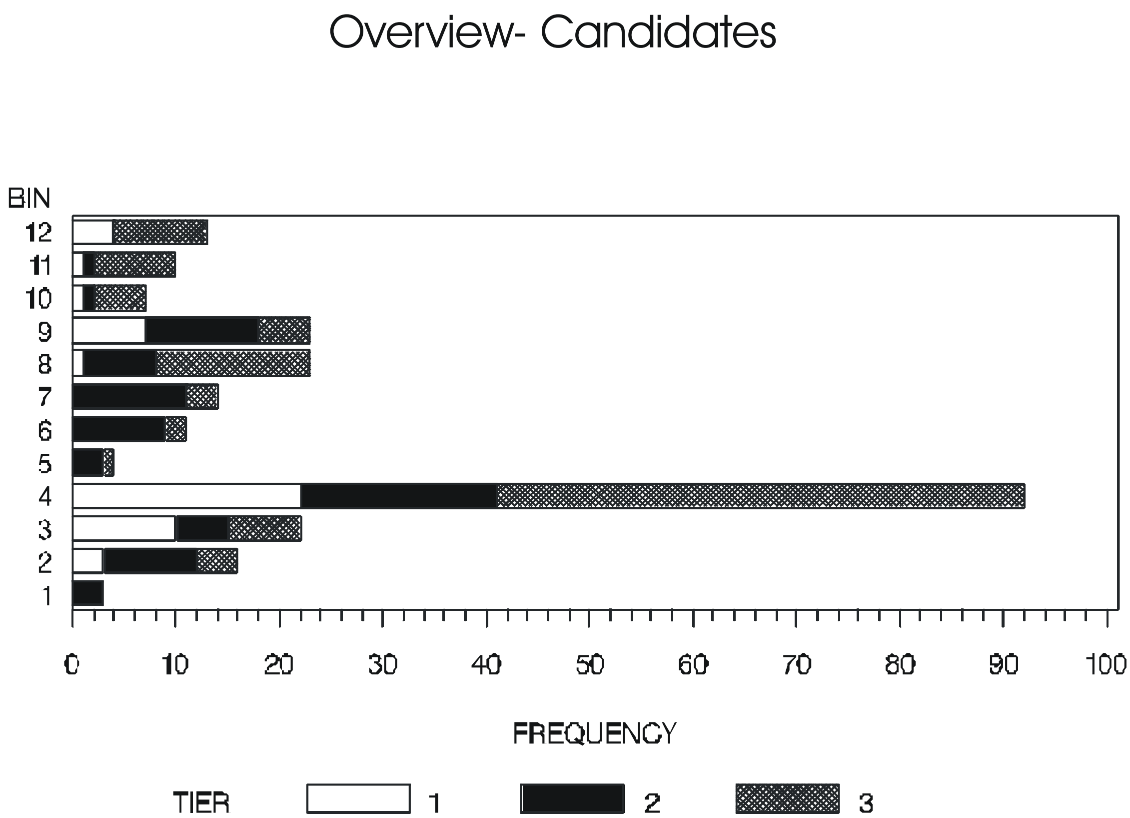
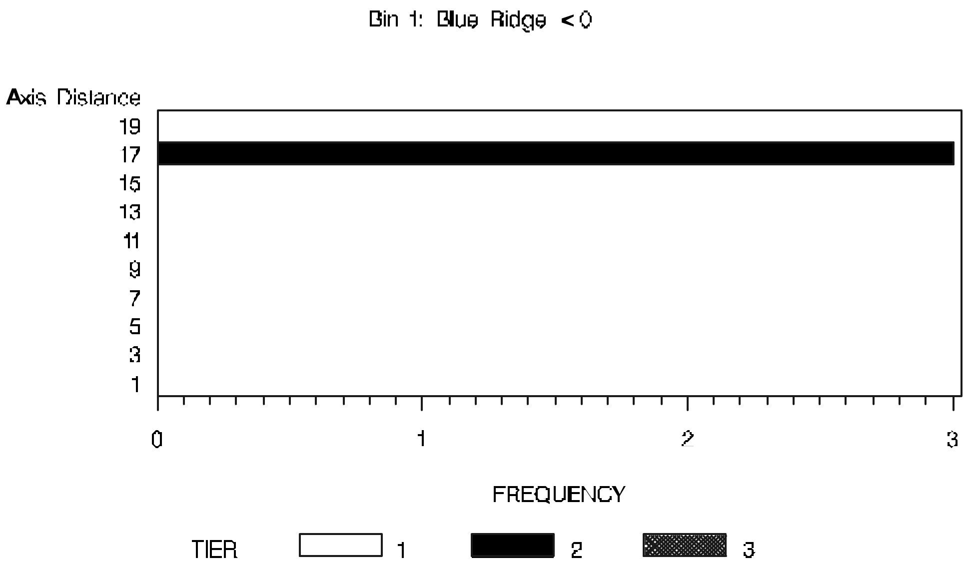
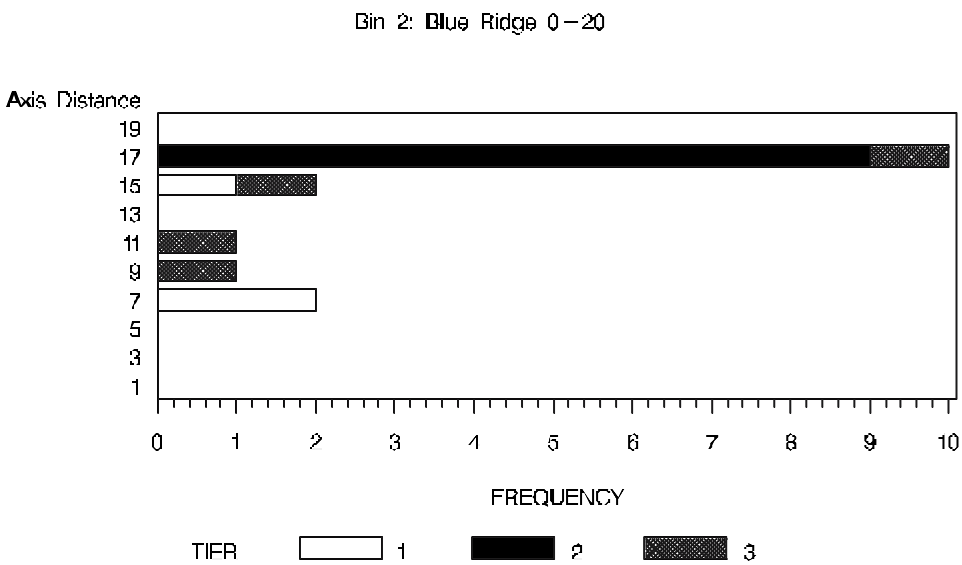


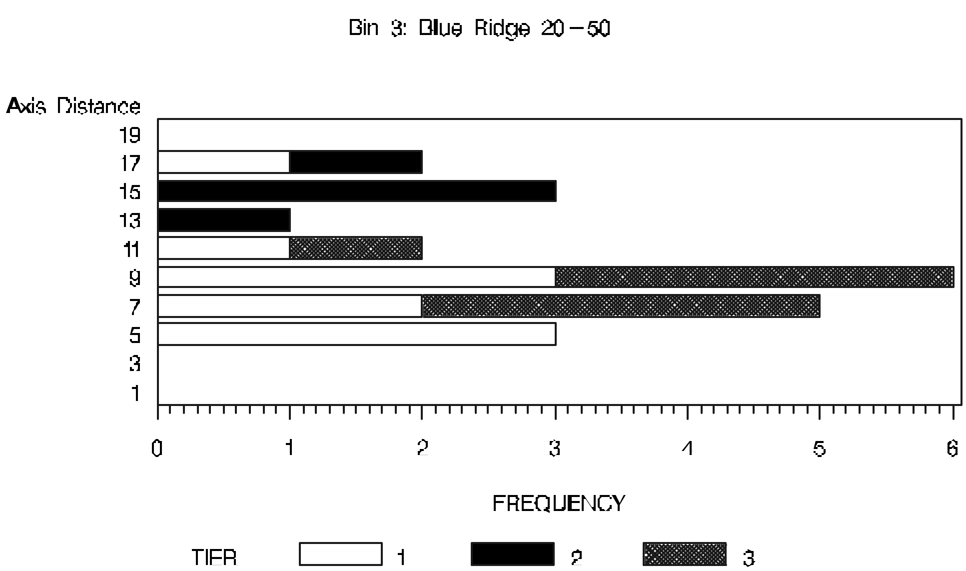
Figure D.1. Distribution of regional MAGIC modeling candidate sites across modeling bins, stratified by Tier.

Figure D-2. Distribution of MAGIC modeling candidate sites, by bin, across geographical location (longitudinal axis of SAMI domain, stratified into 19 equal-length sections), calculated ANC, sulfate, nitrate, and elevation.

Axis - Candidates

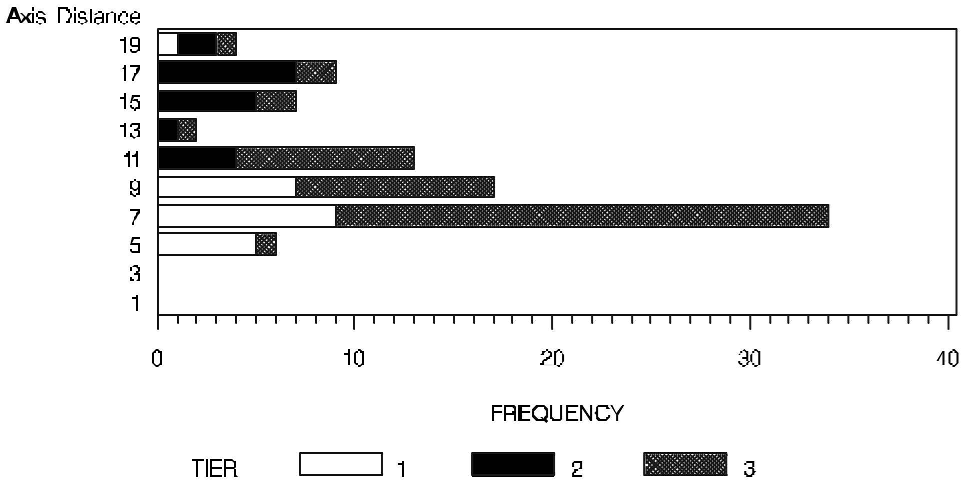




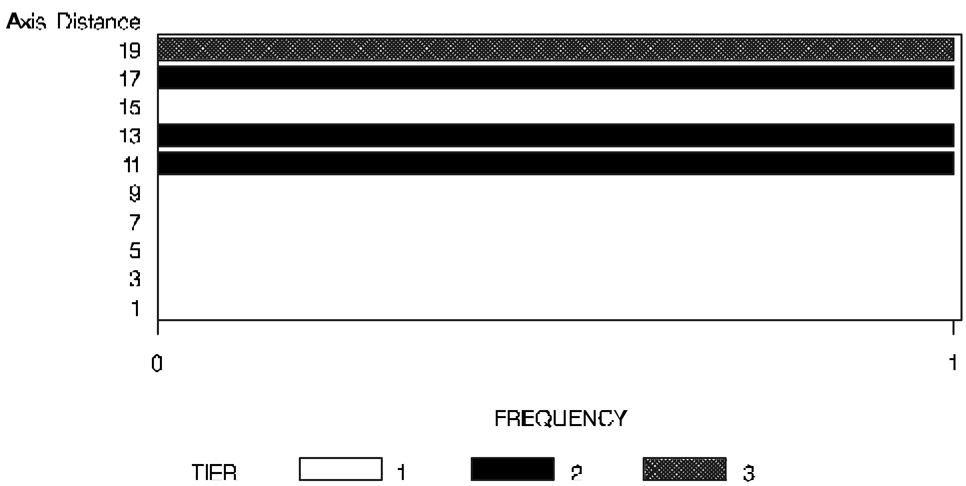


Axis - Candidates

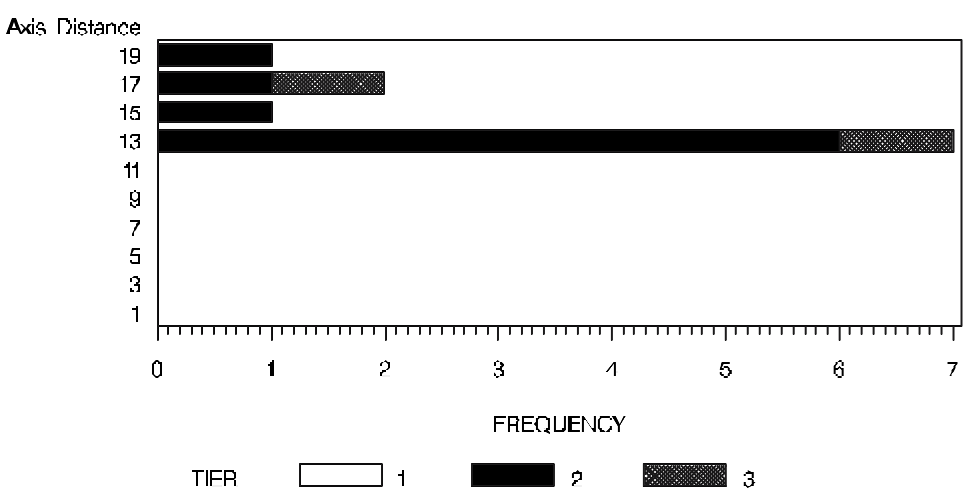
Bin 4: Blue Ridge 50-150



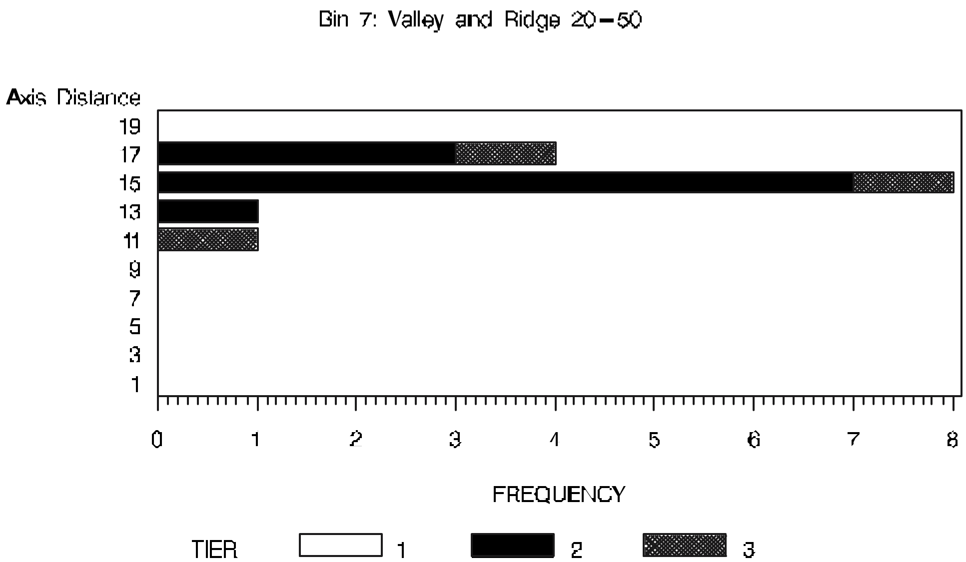
Bin 5: Valley and Ridge <0

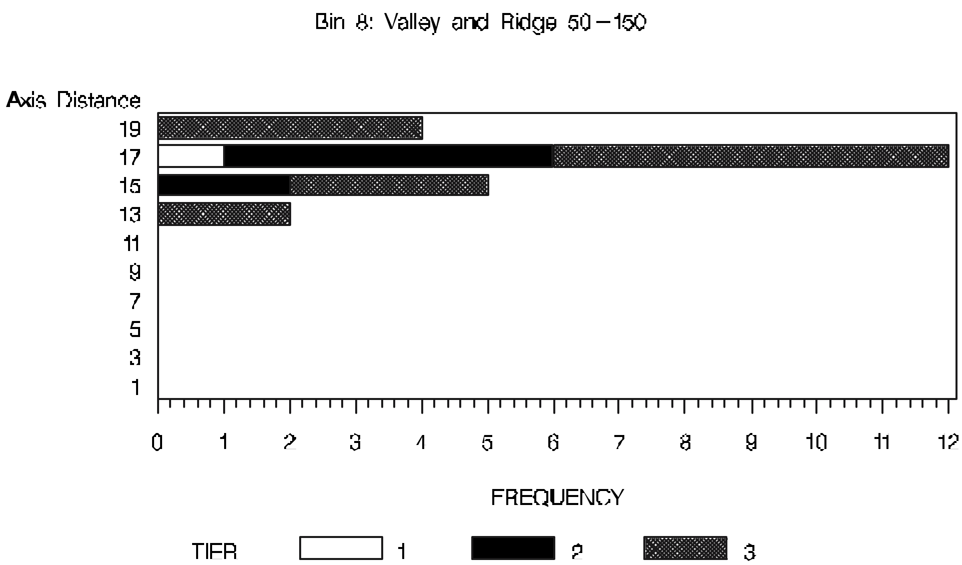


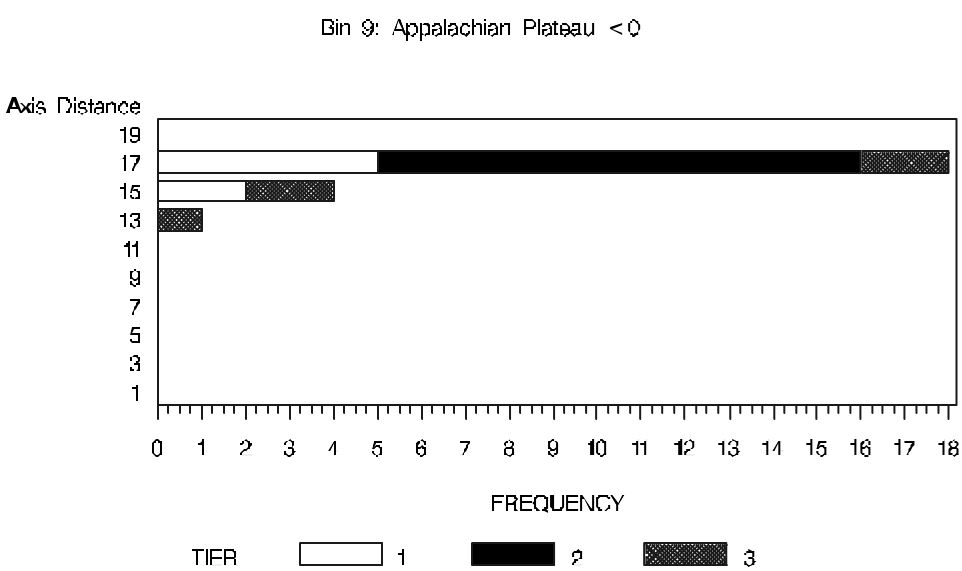
Bin 6: Valley and Ridge 0-20



Axis - Candidates

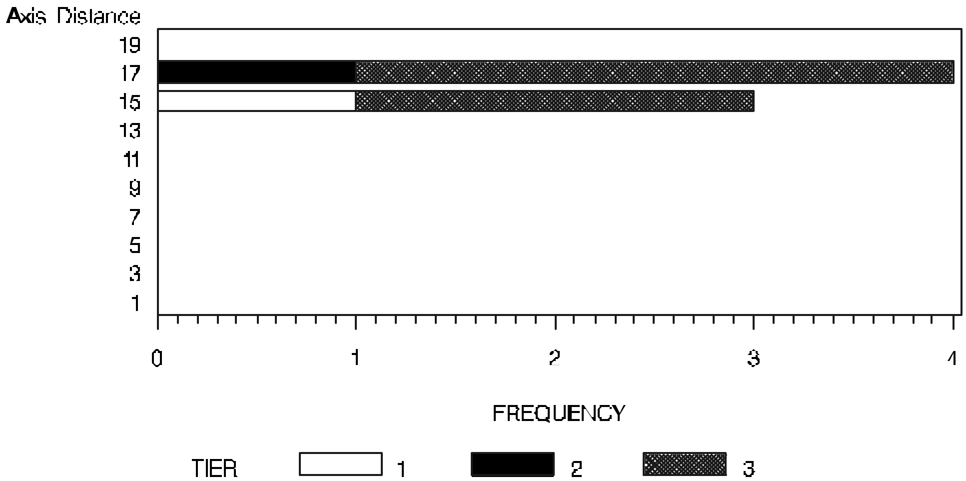




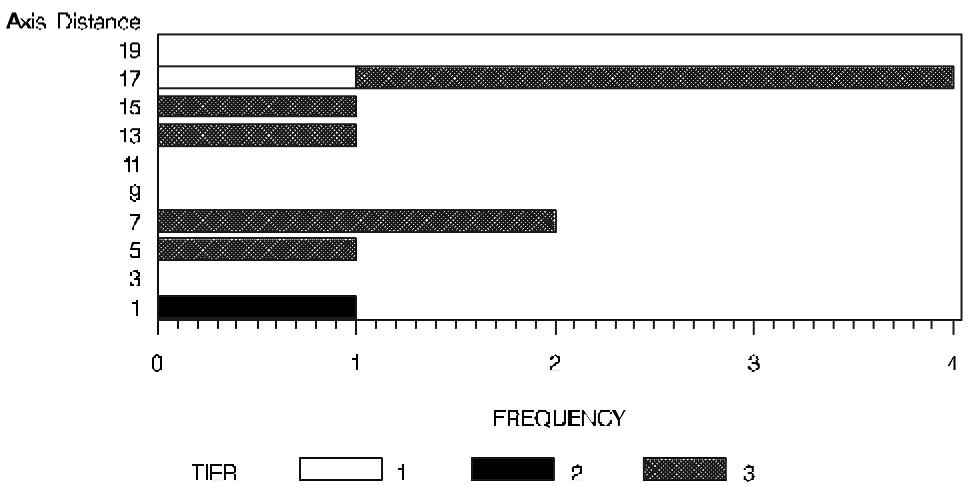


Axis - Candidates

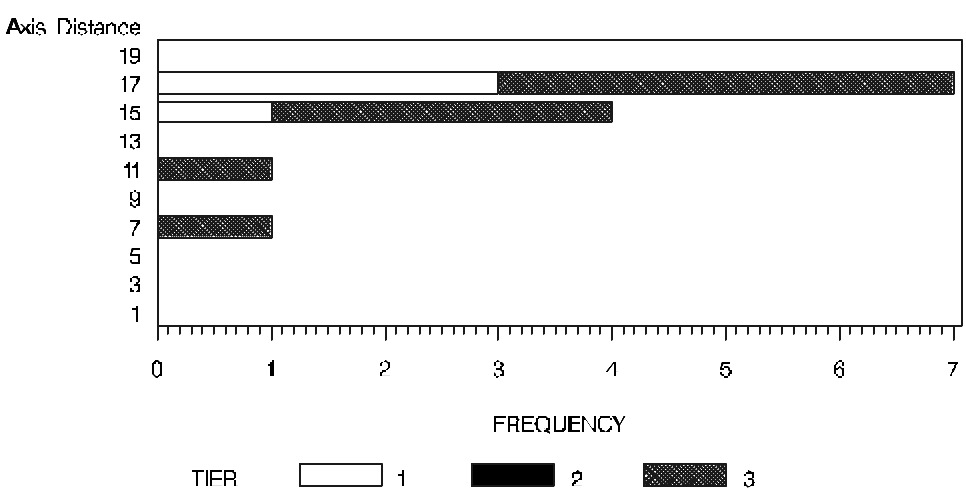
Bin 10: Appalachian Plateau 0-20



Bin 11: Appalachian Plateau 20-50

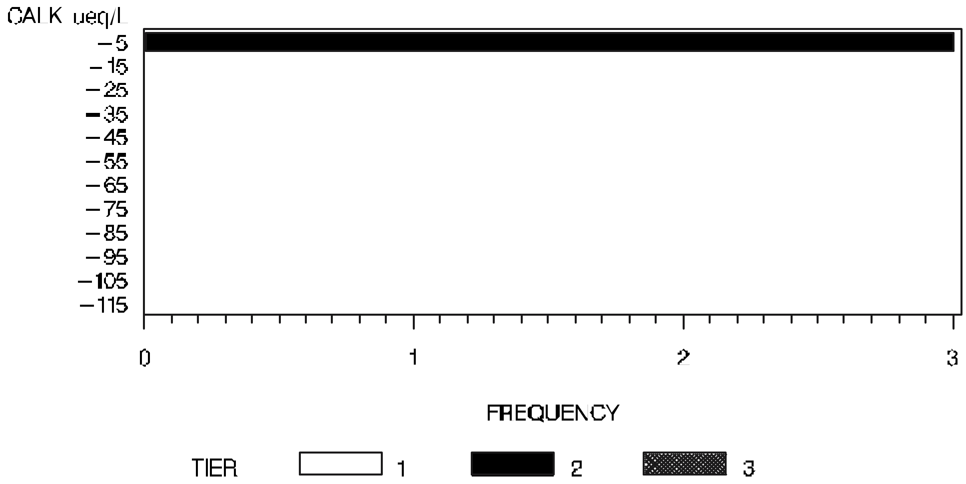


Bin 12: Appalachian Plateau 50-150

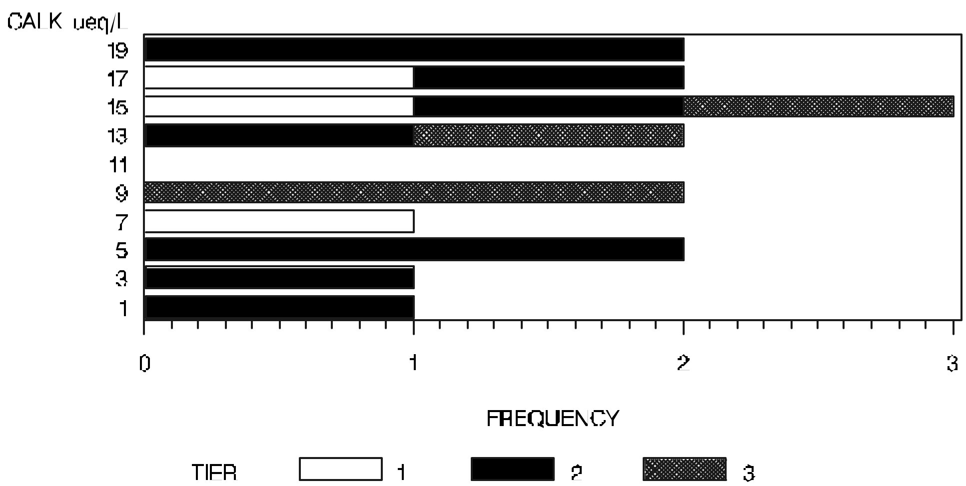


CALK - Candidates

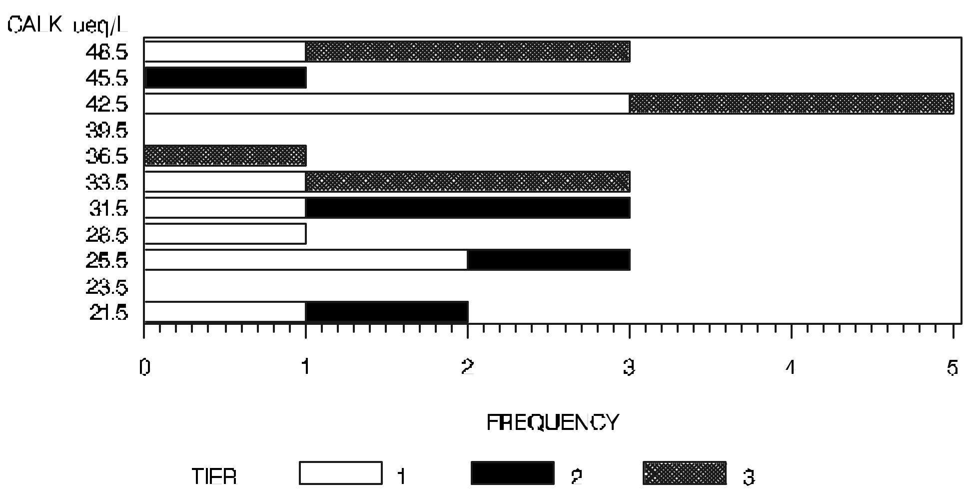
Bin 1: Blue Ridge < 0



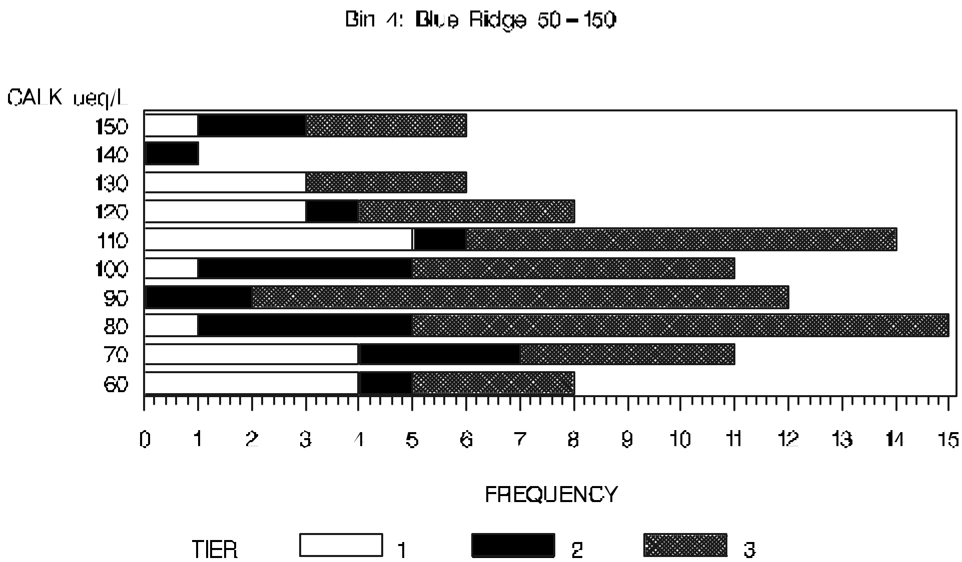
Bin 2: Blue Ridge 0-20

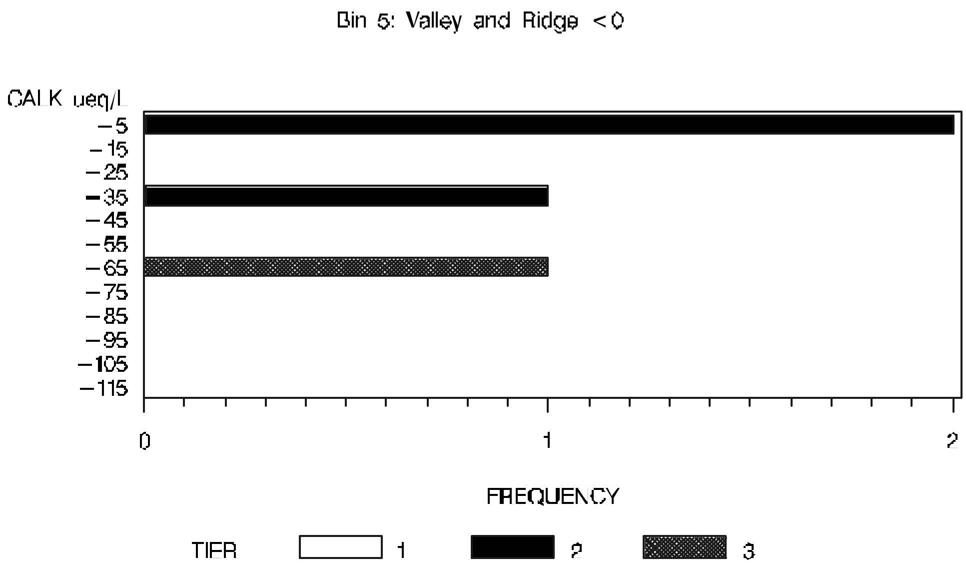


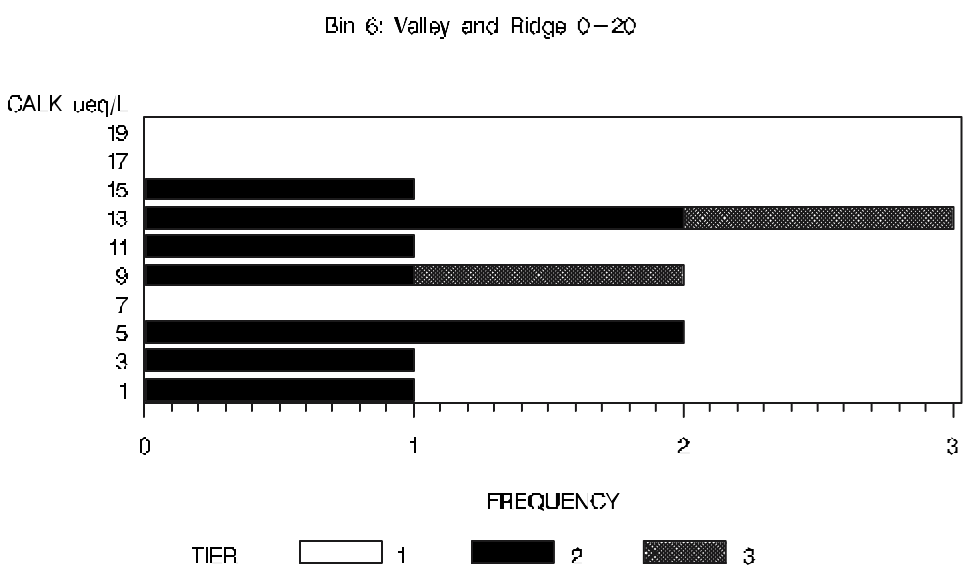
Bin 3: Blue Ridge 20-50



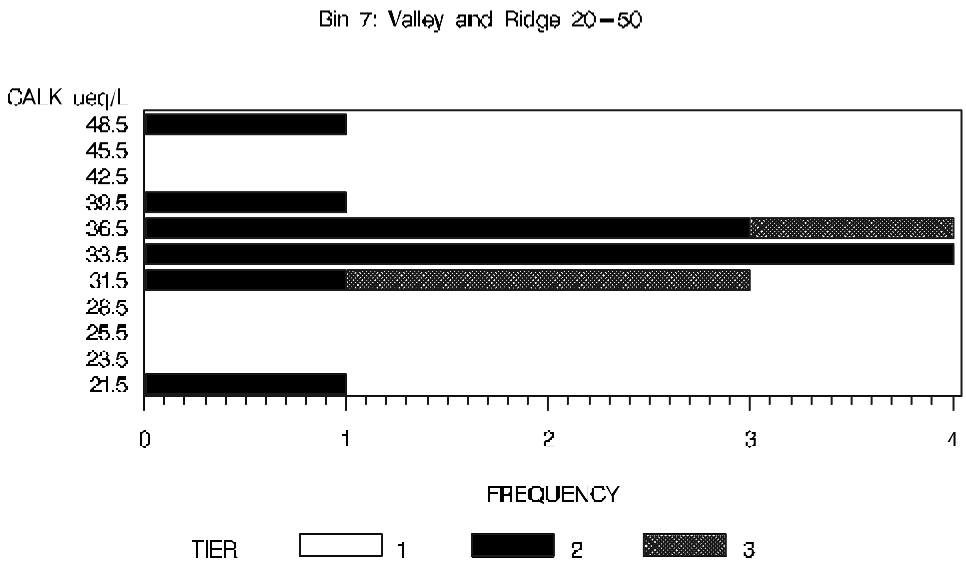
CALK - Candidates

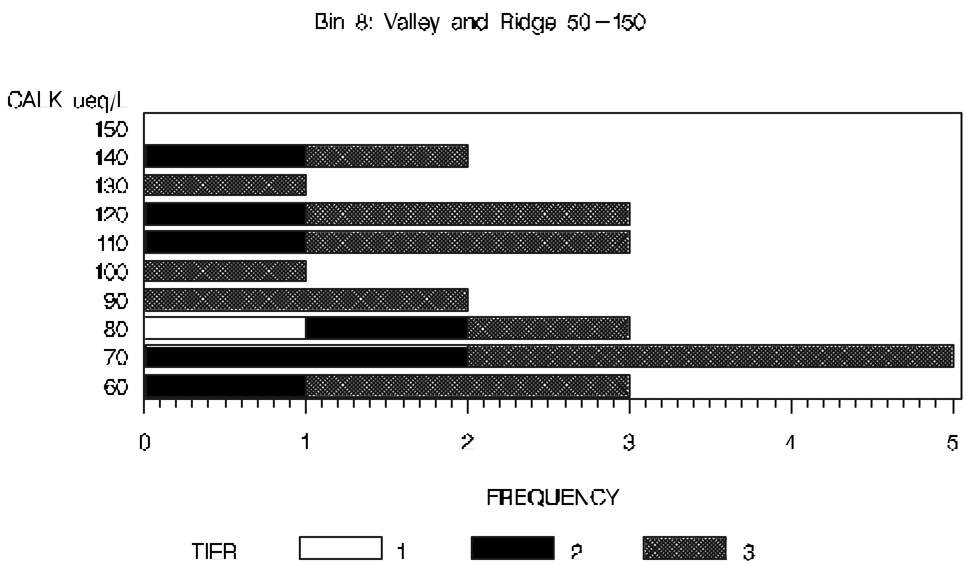


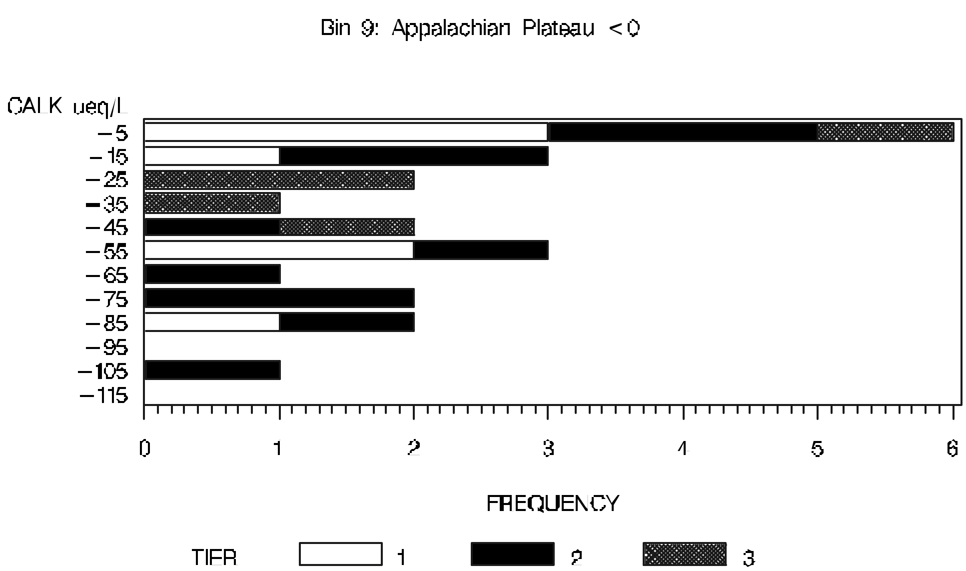




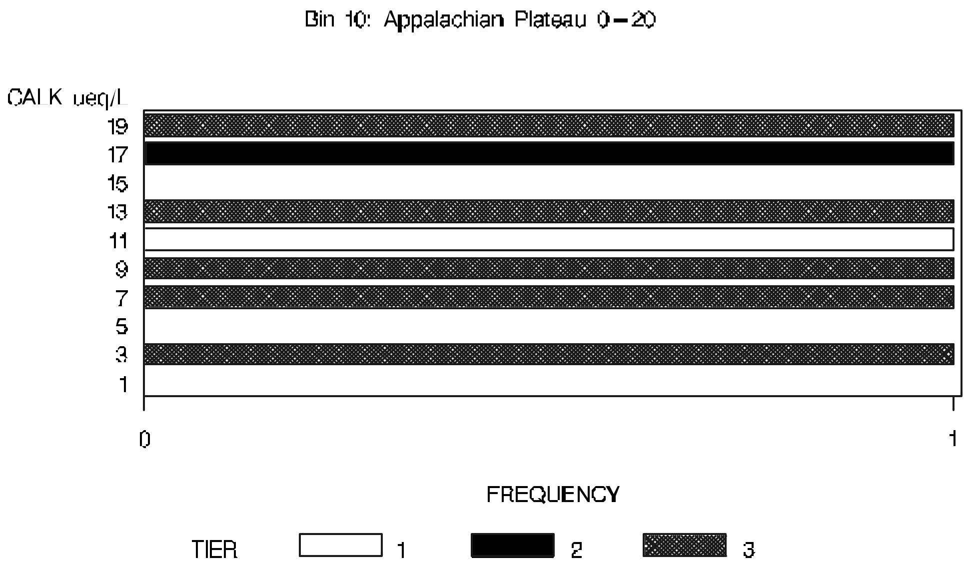
CALK - Candidates

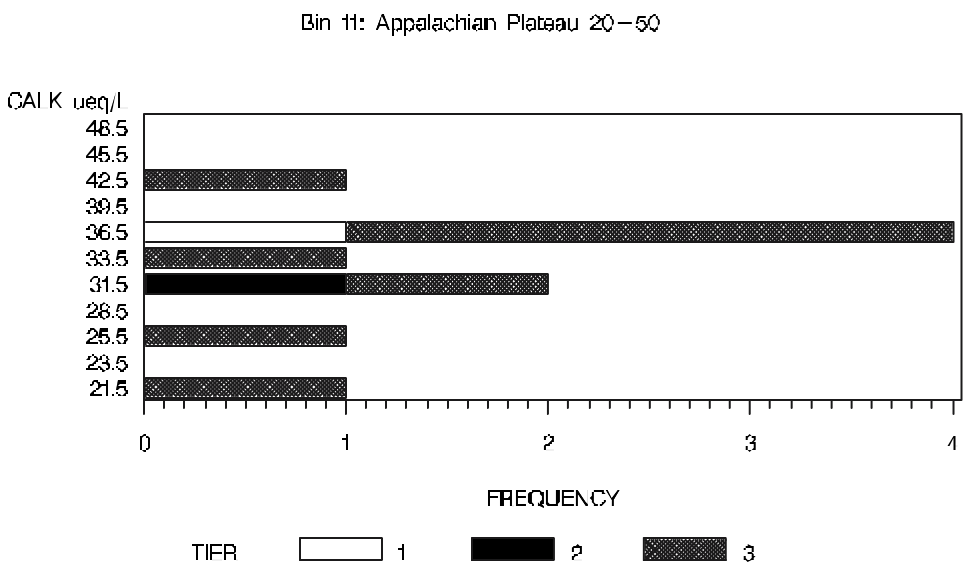


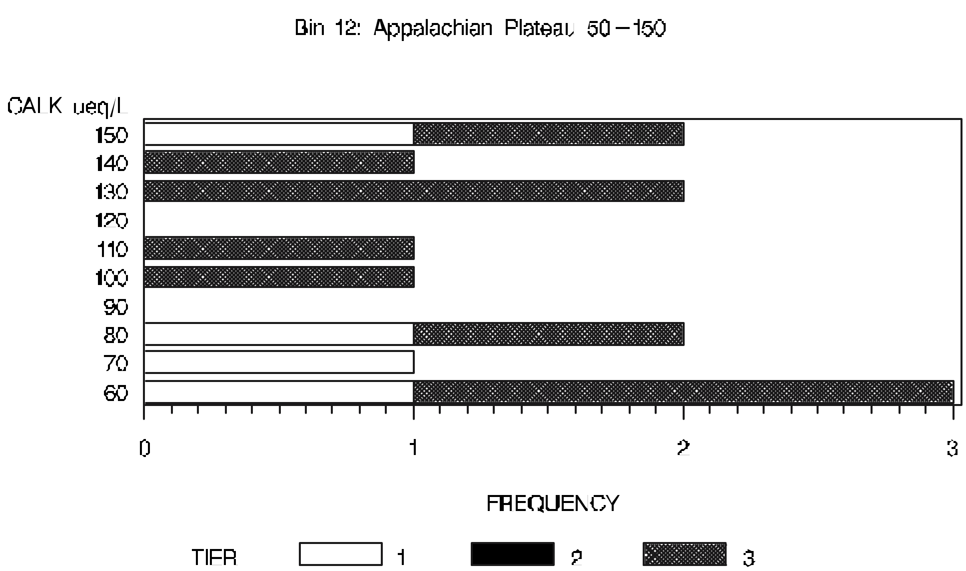




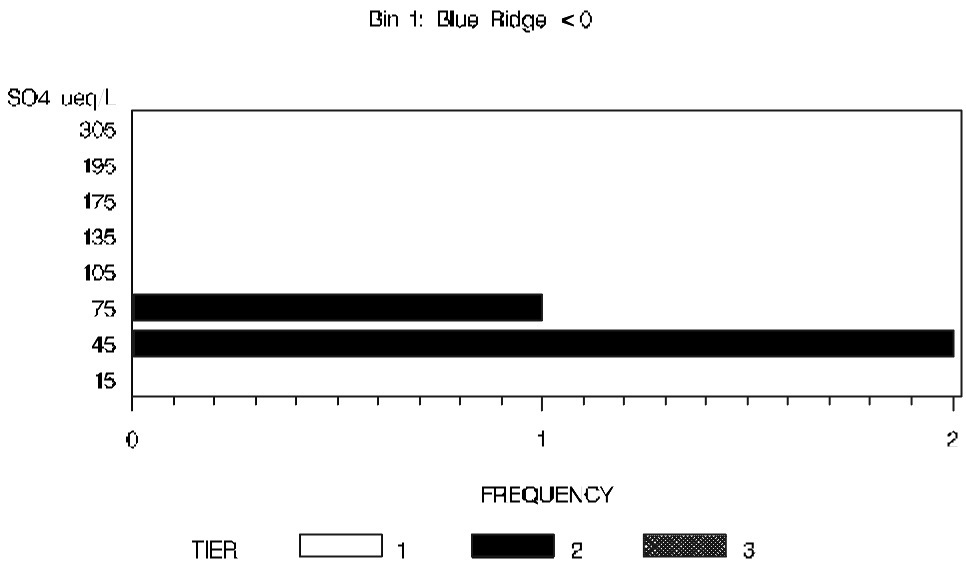
CALK - Candidates

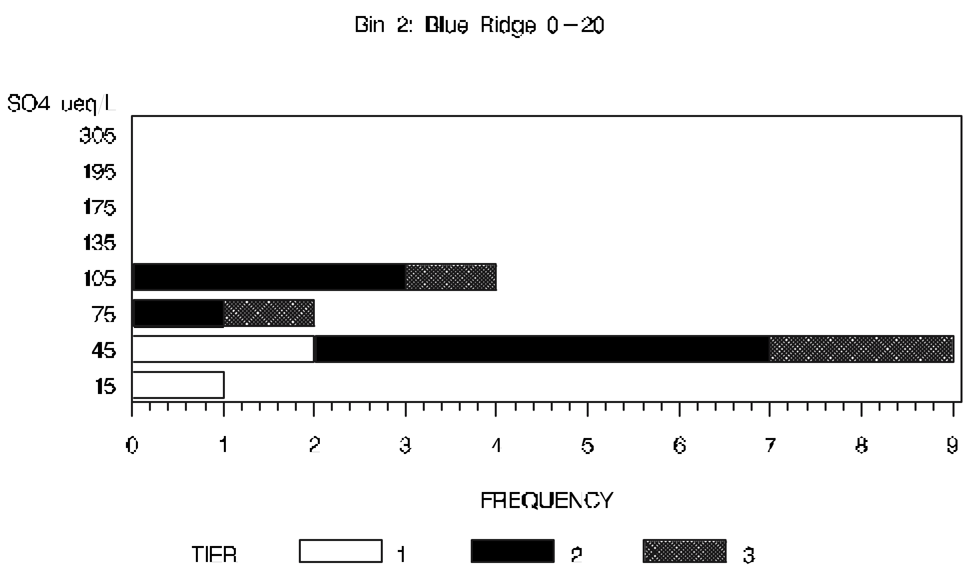


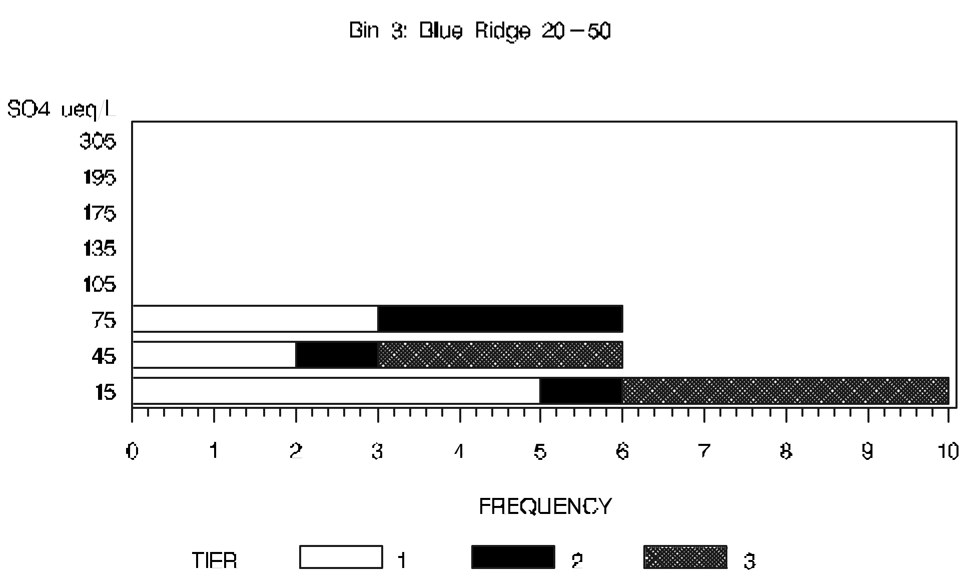




SO4 - Candidates

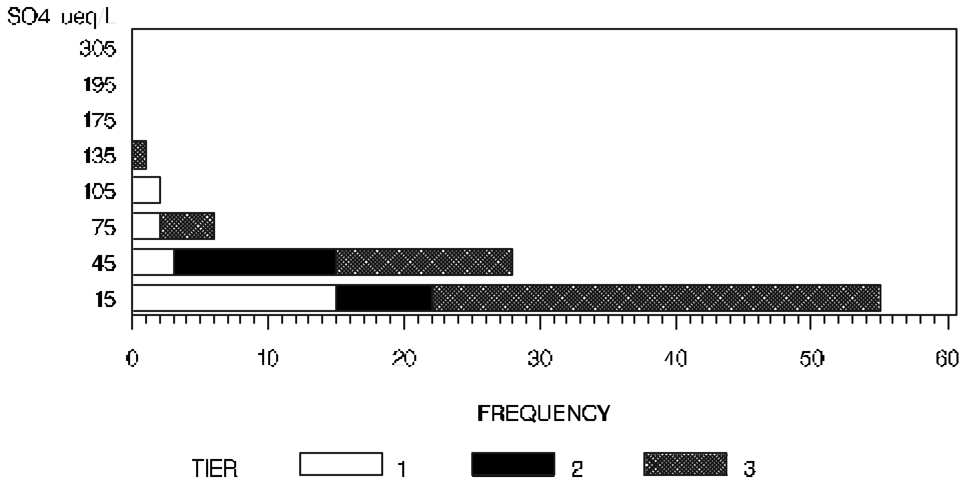




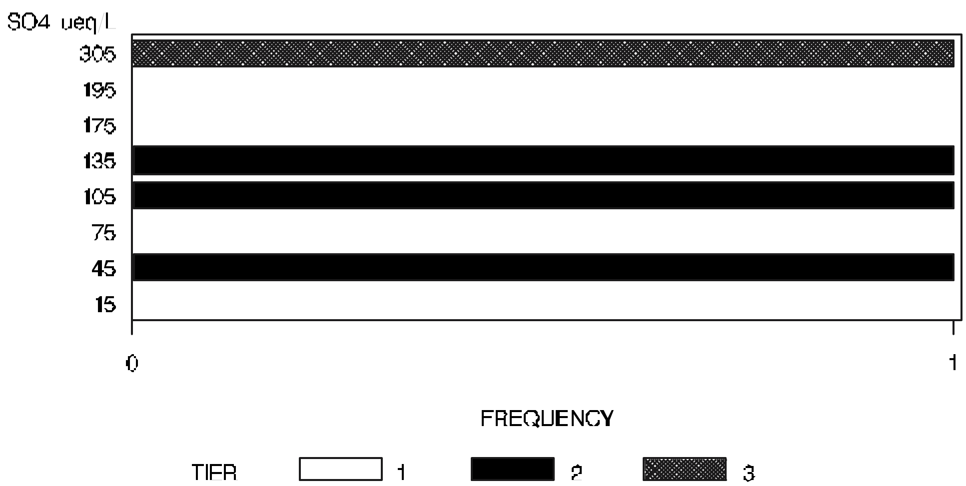


SO4 - Candidates

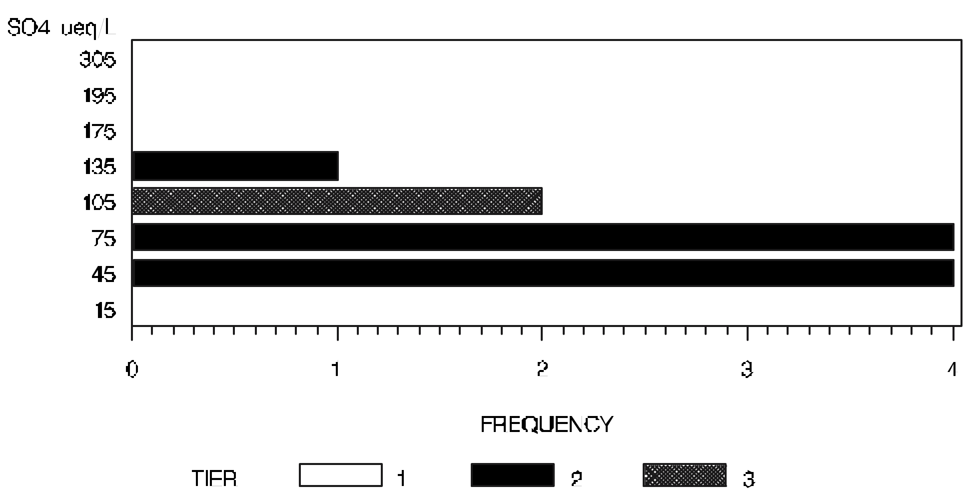
Bin 4: Blue Ridge 50 - 150



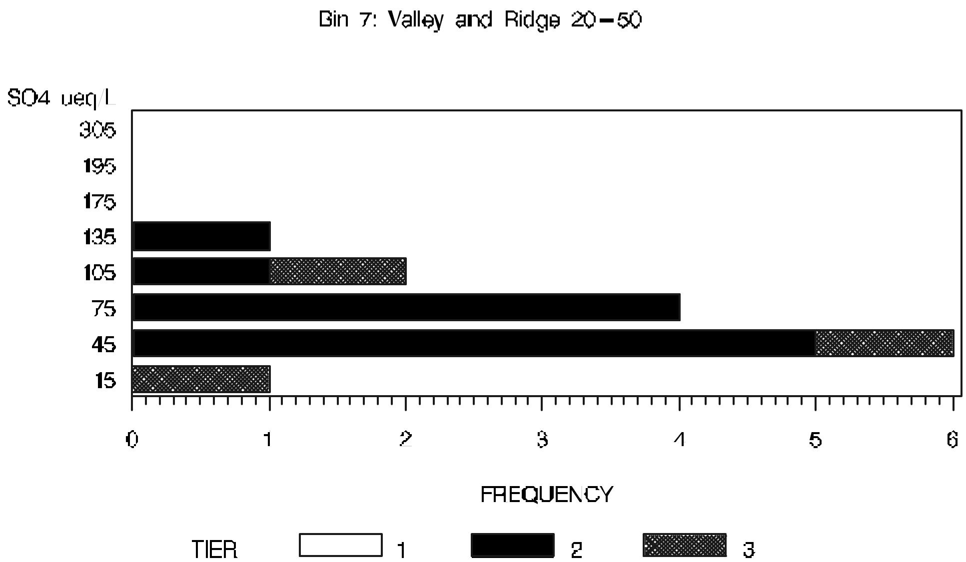
Bin 5: Valley and Ridge < 0

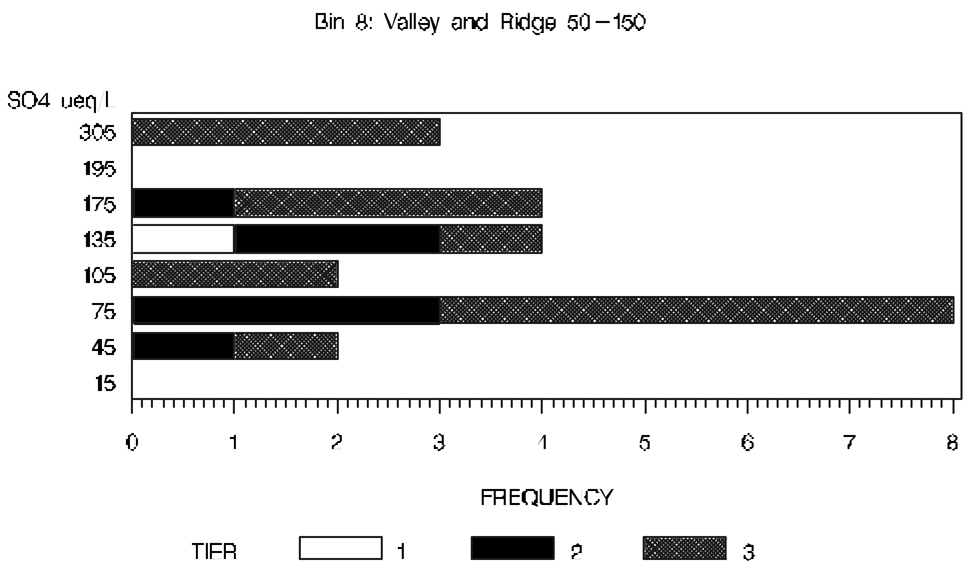


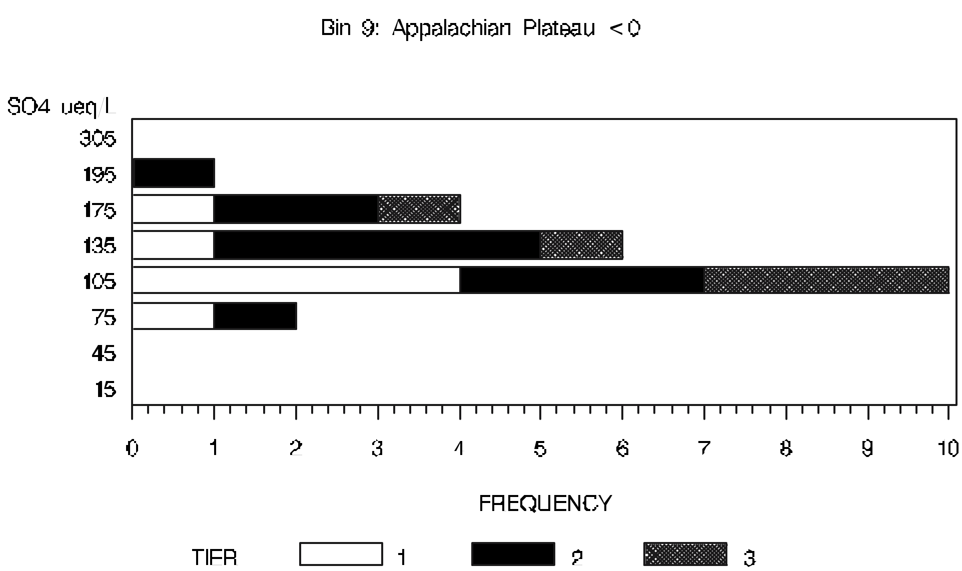
Bin 6: Valley and Ridge 0 - 20



SO4 - Candidates

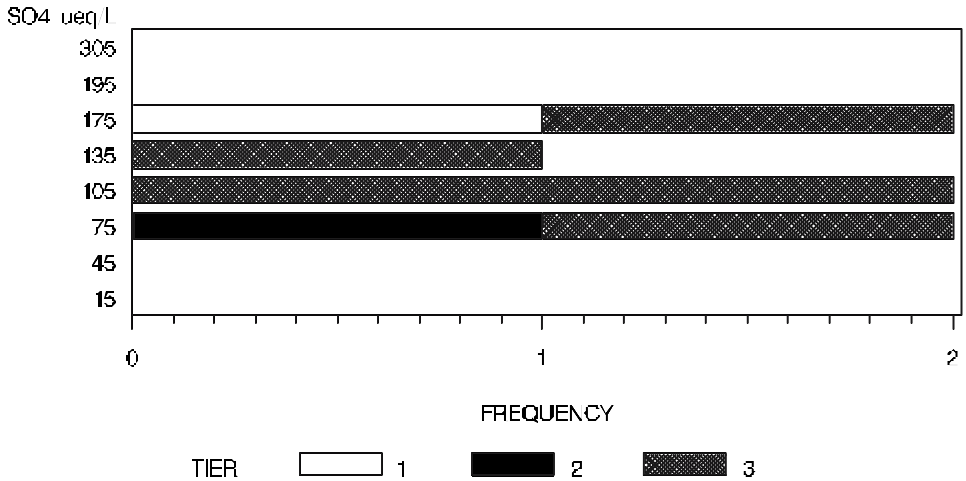




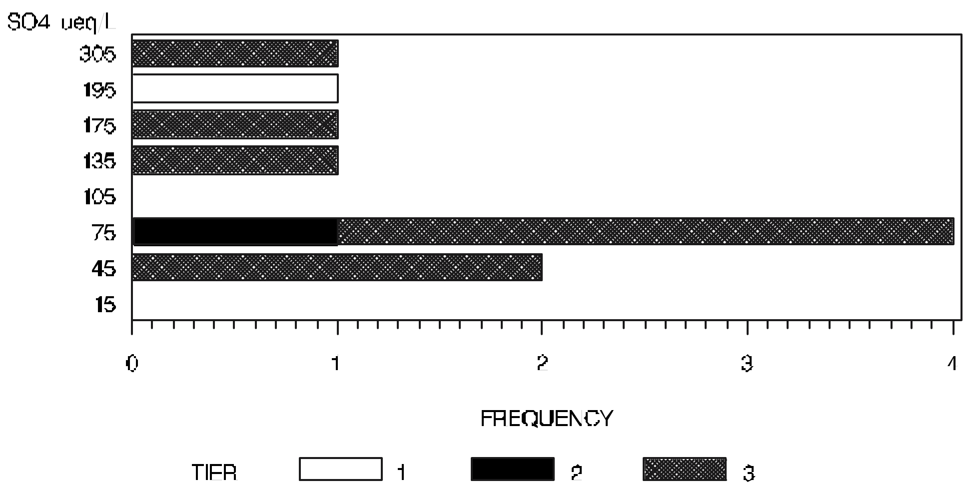


SO4 - Candidates

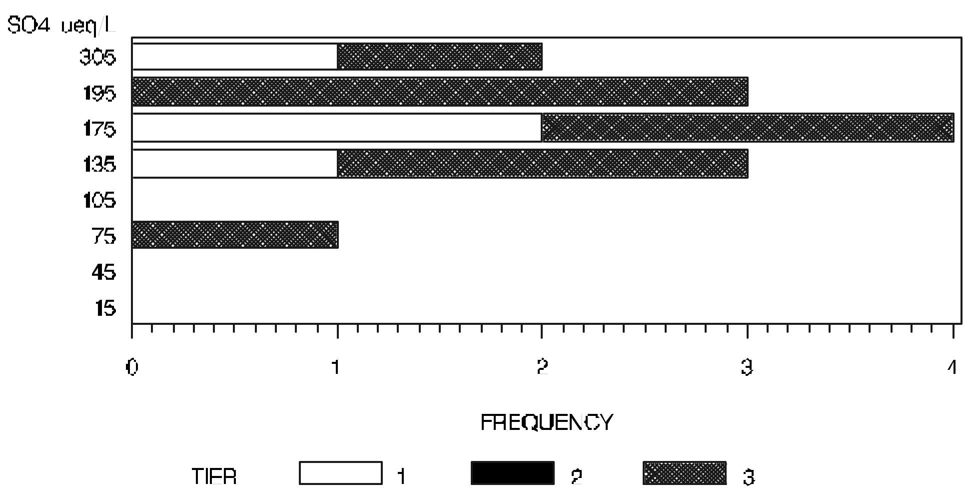
Bin 10: Appalachian Plateau 0–20



Bin 11: Appalachian Plateau 20–50

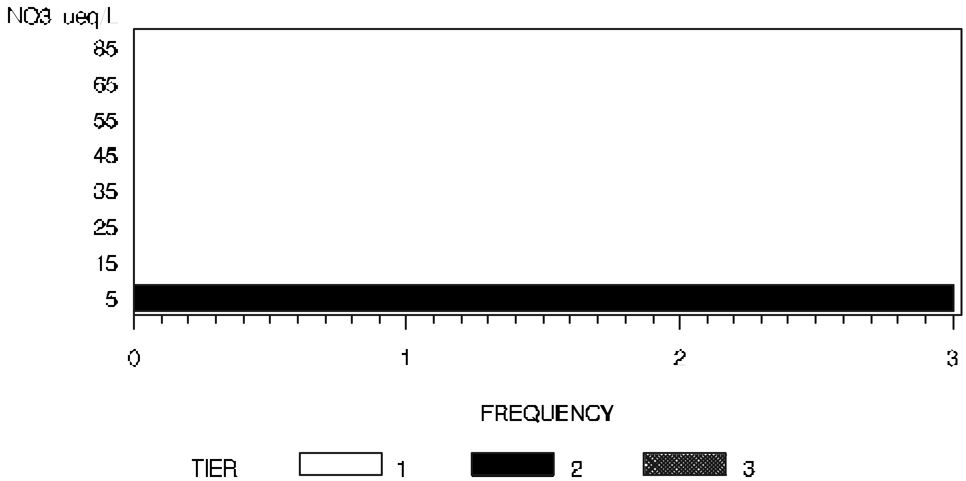


Bin 12: Appalachian Plateau 50–150

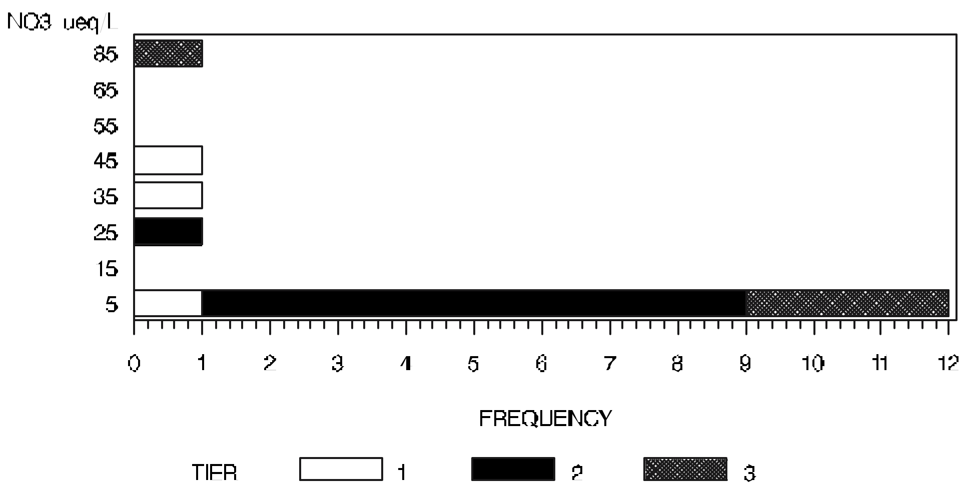


NO3 - Candidates

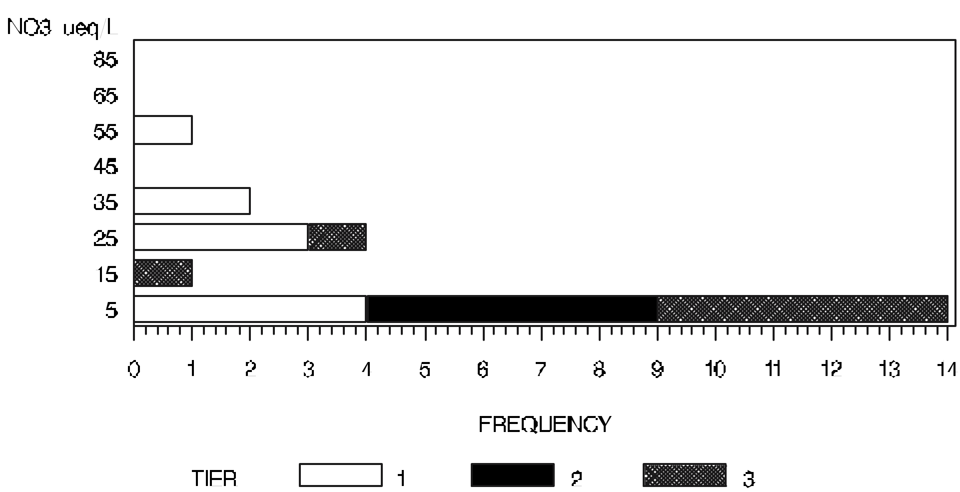
Bin 1: Blue Ridge < 0



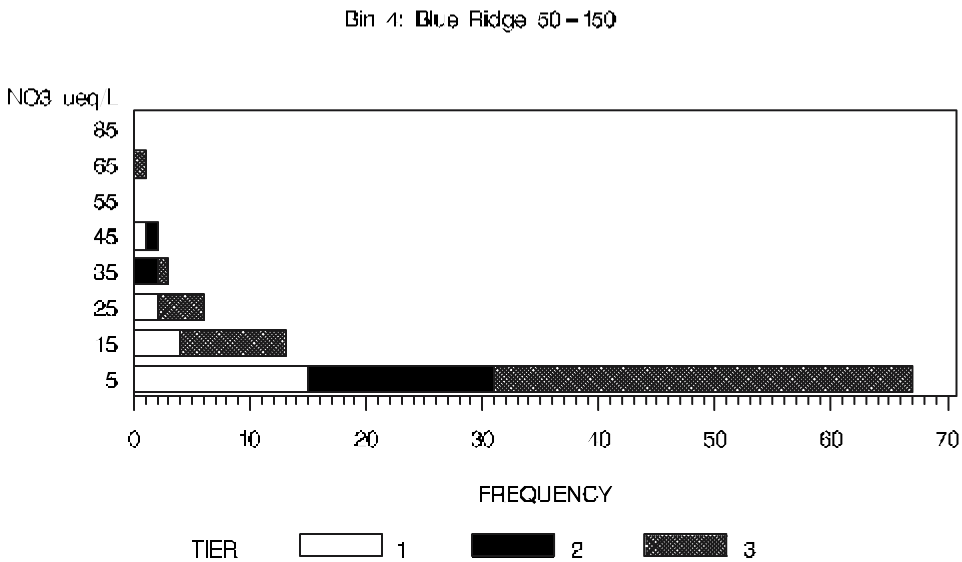
Bin 2: Blue Ridge 0 – 20

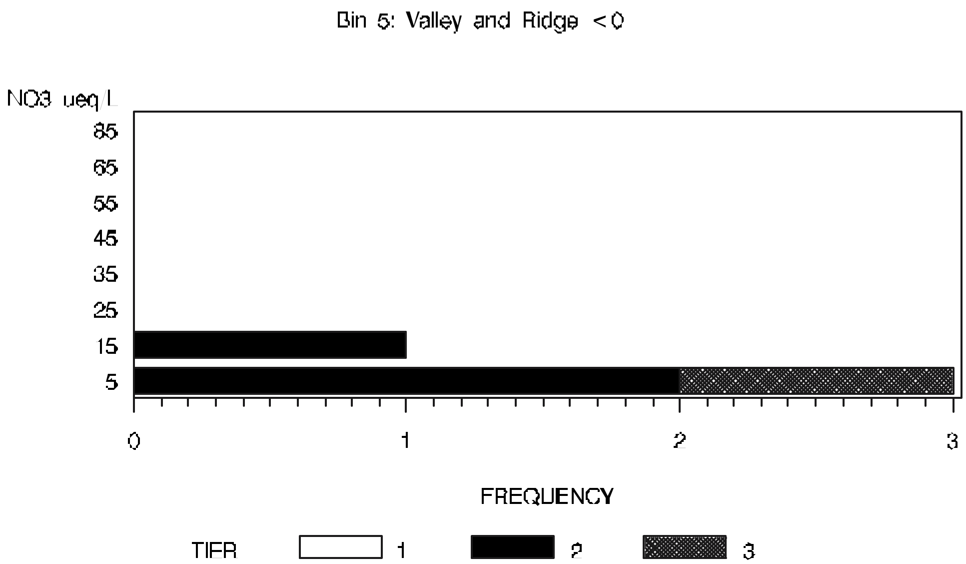


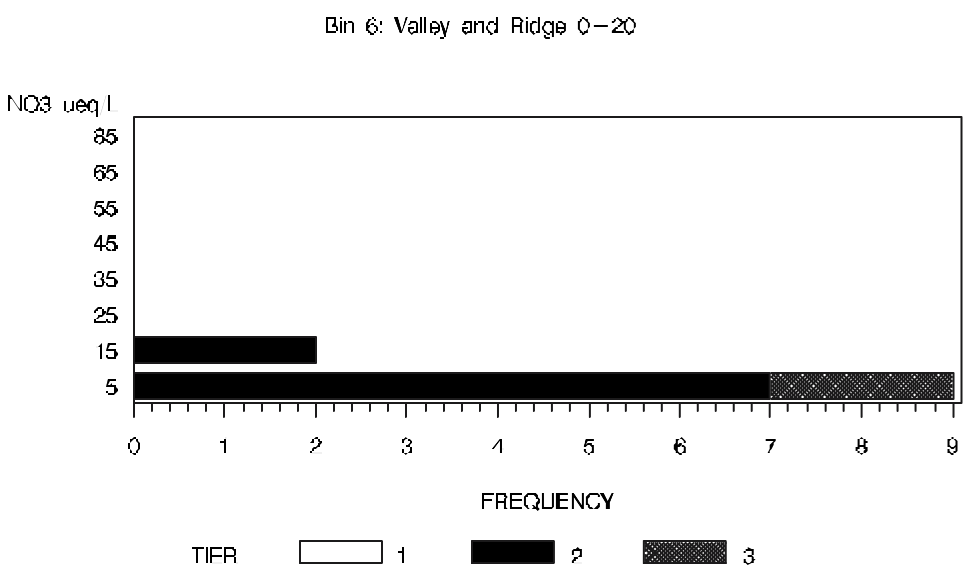
Bin 3: Blue Ridge 20 – 50



NO3 - Candidates

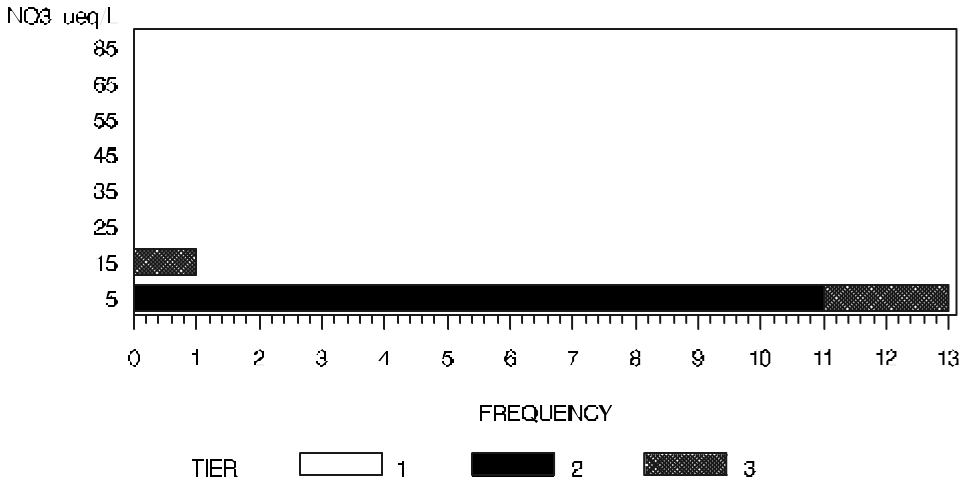




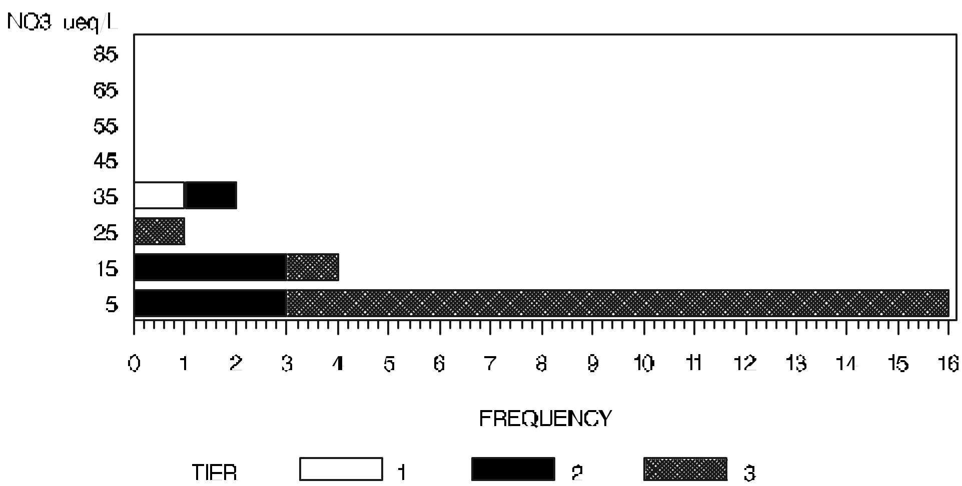


NO3 - Candidates

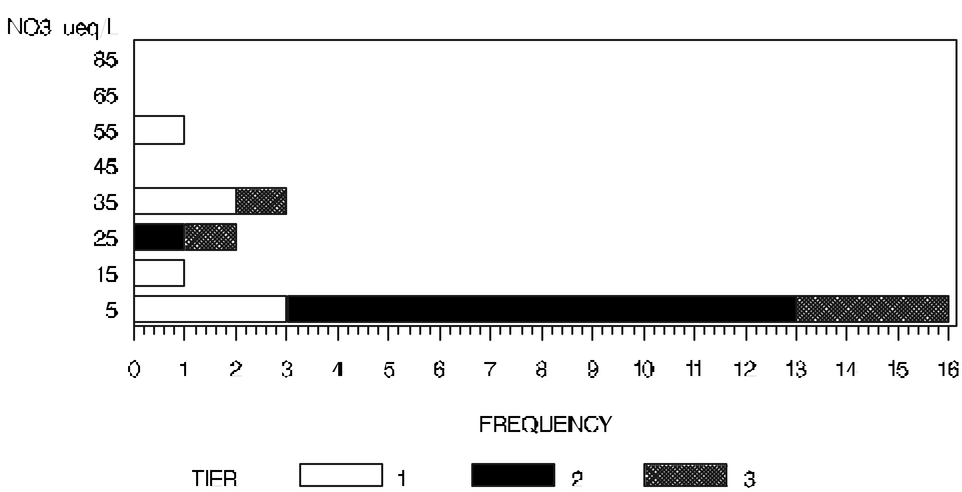
Bin 7: Valley and Ridge 20–50



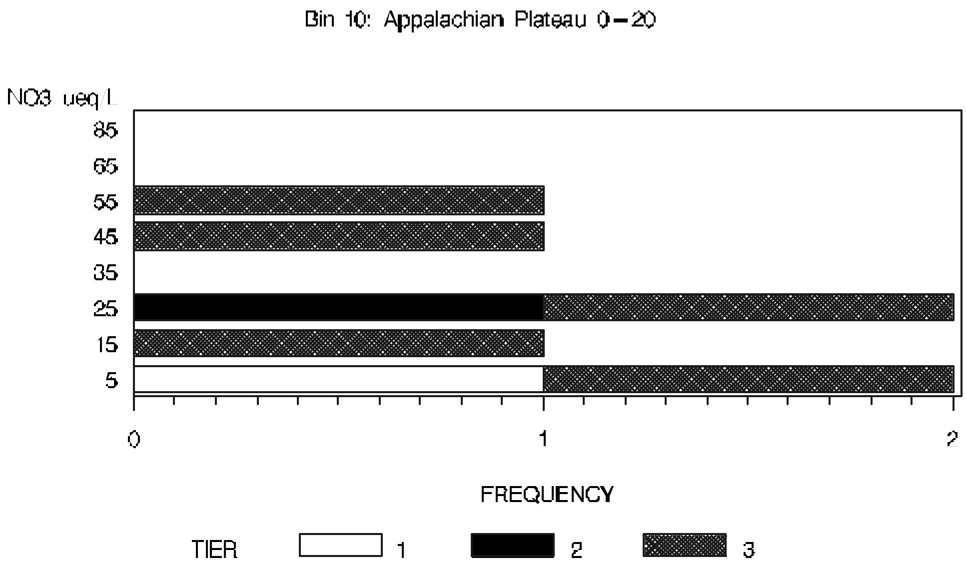
Bin 8: Valley and Ridge 50–150

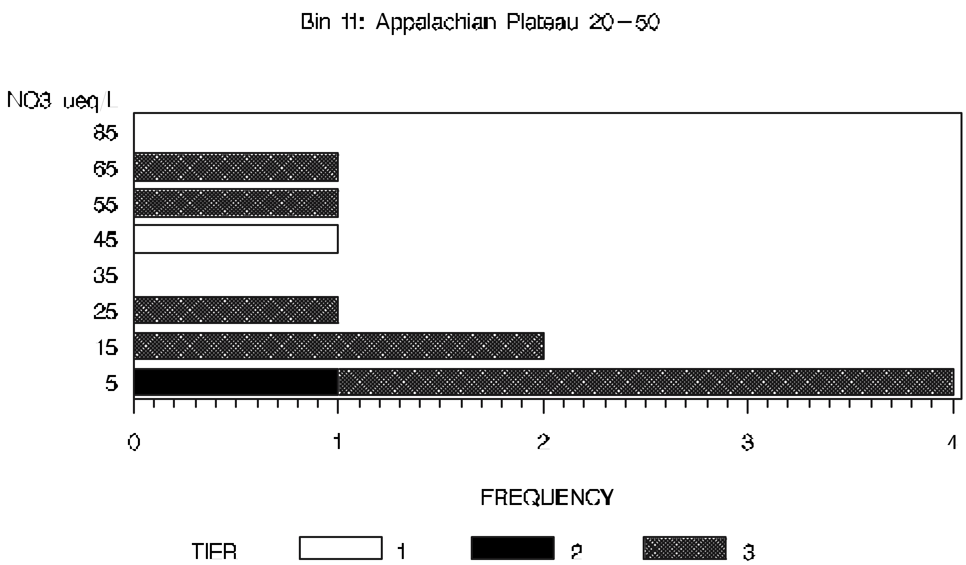


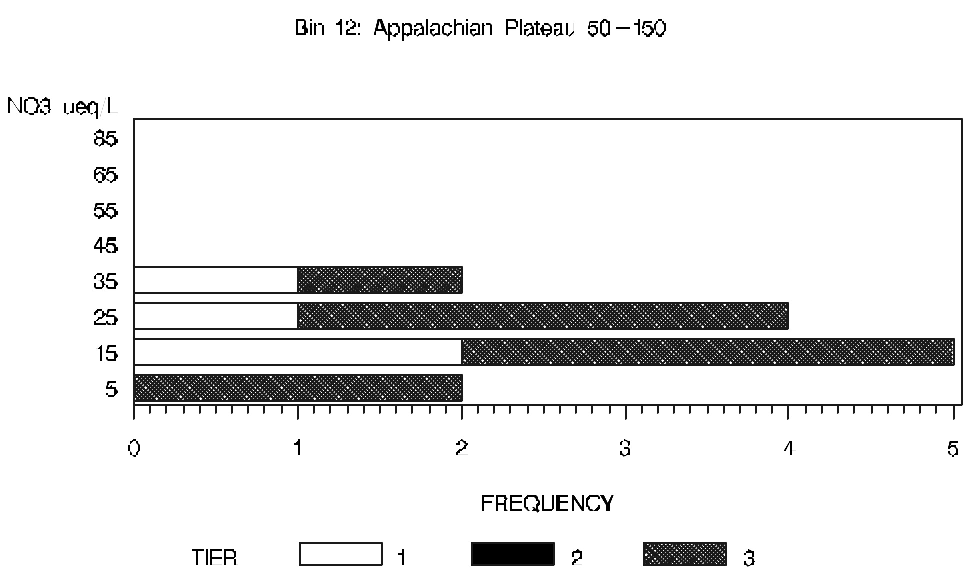
Bin 9: Appalachian Plateau <0



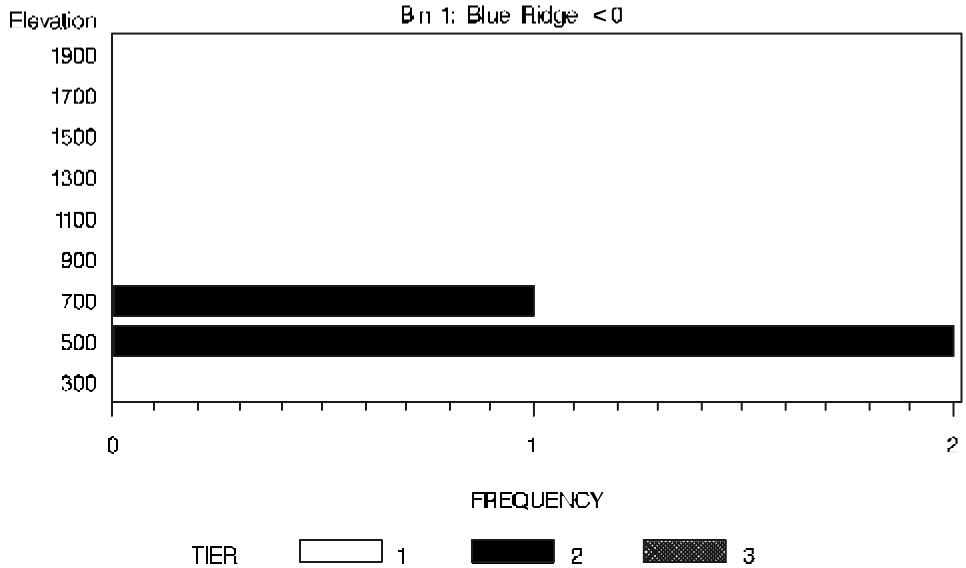
NO3 - Candidates

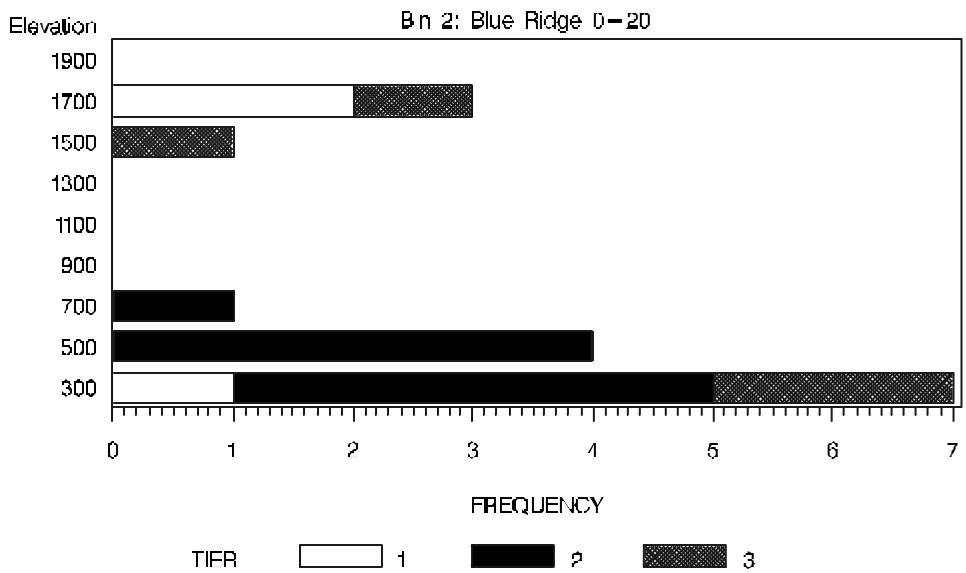


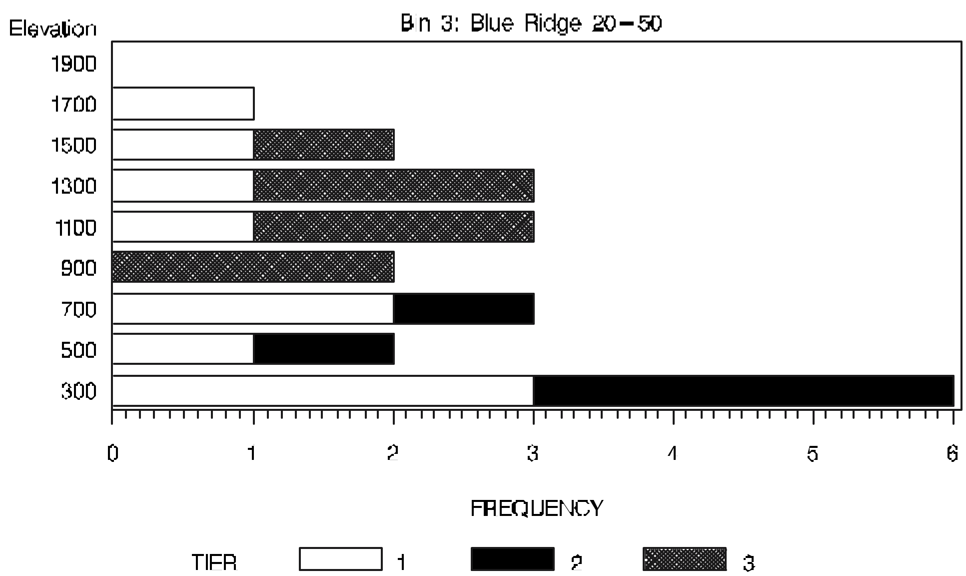




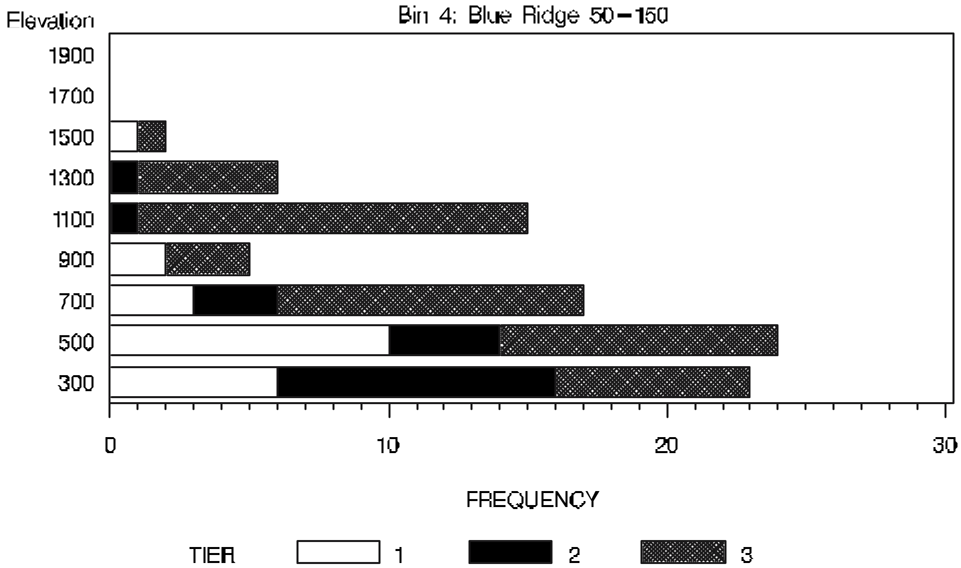
Elev - Candidates

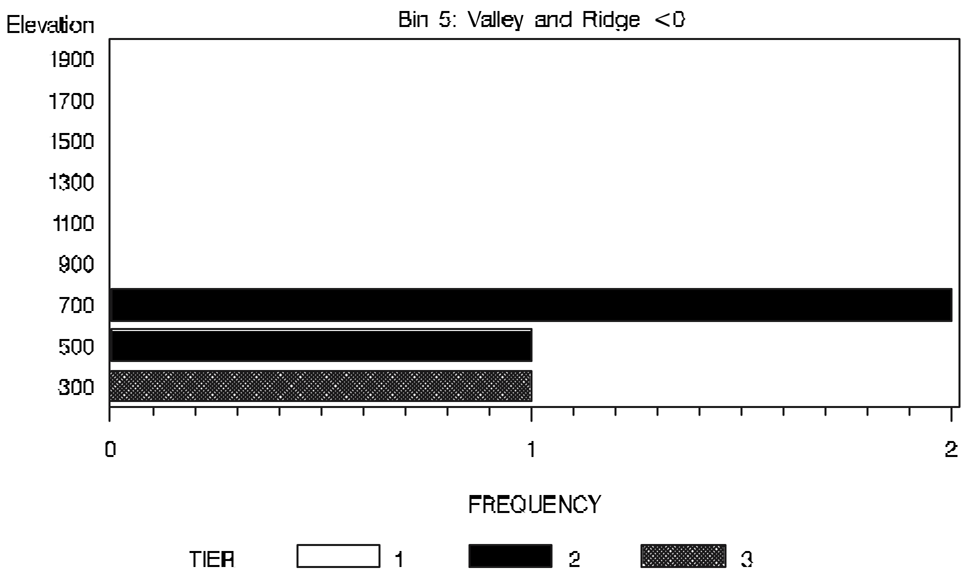


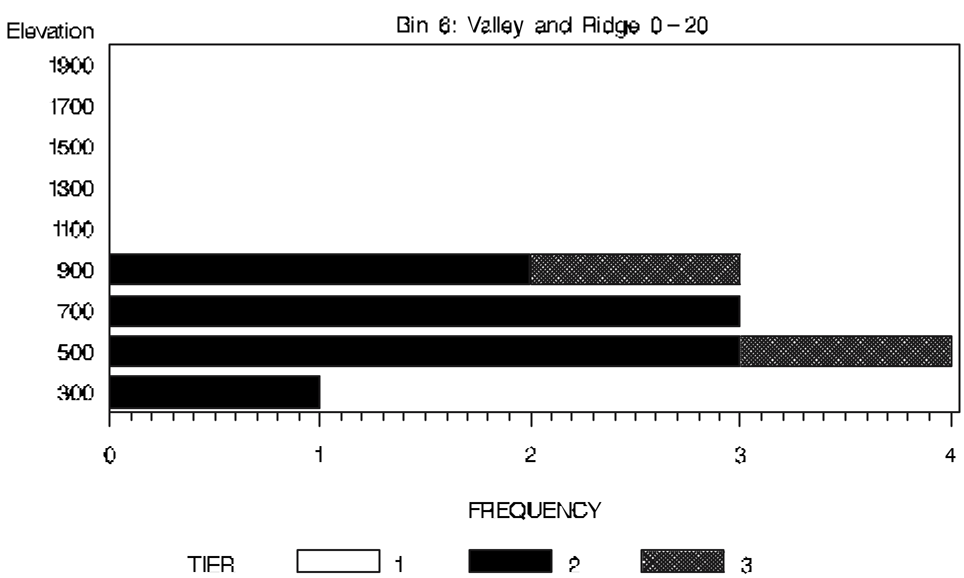




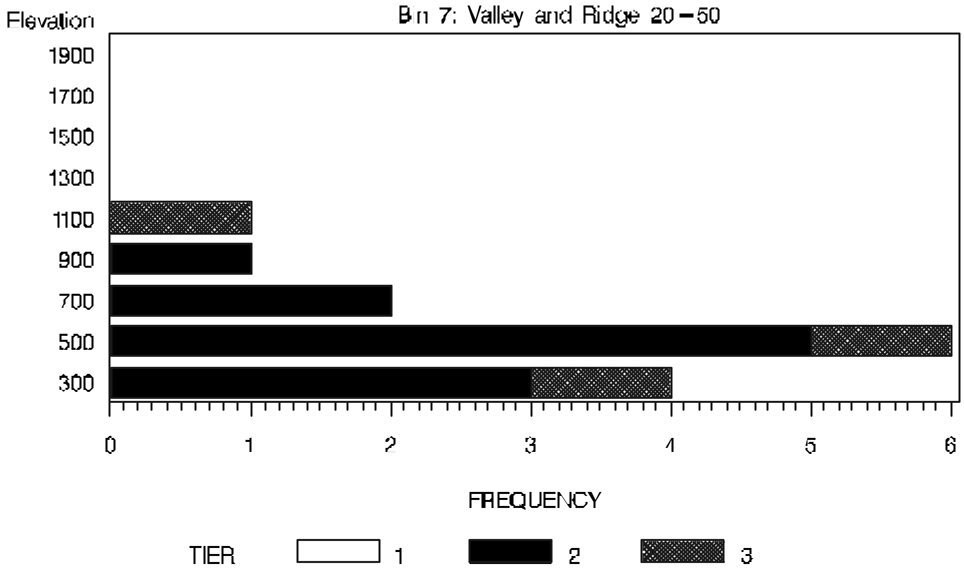
Elev - Candidates

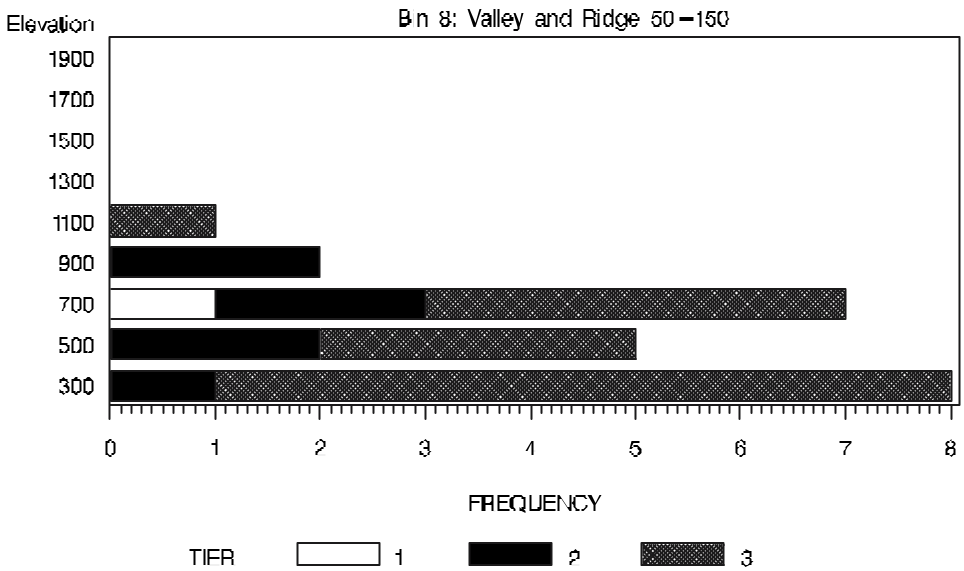


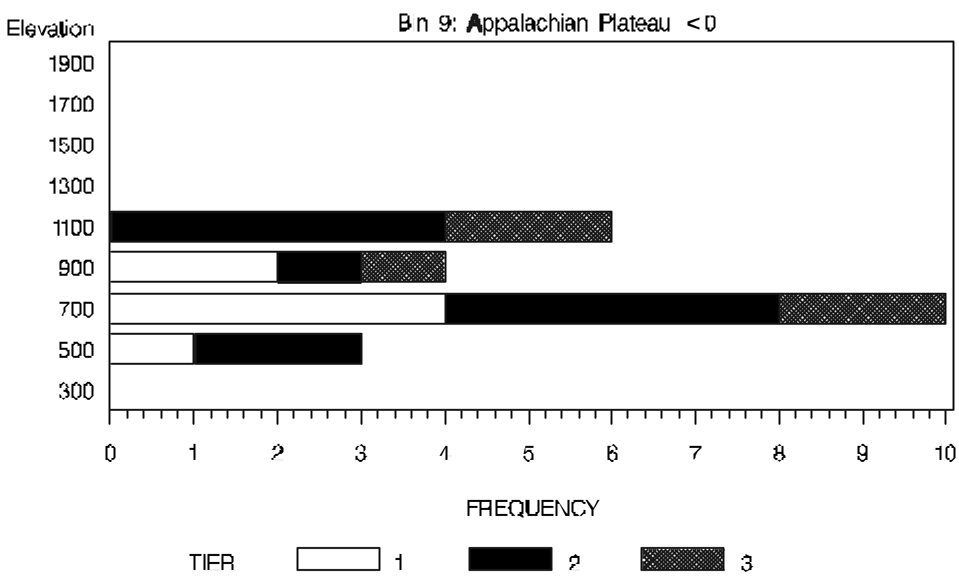




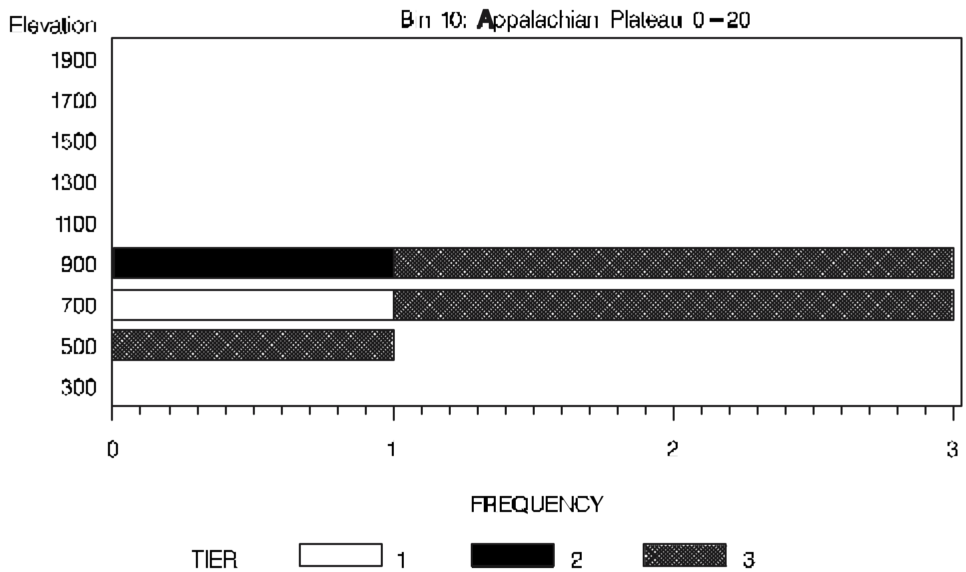
Elev - Candidates

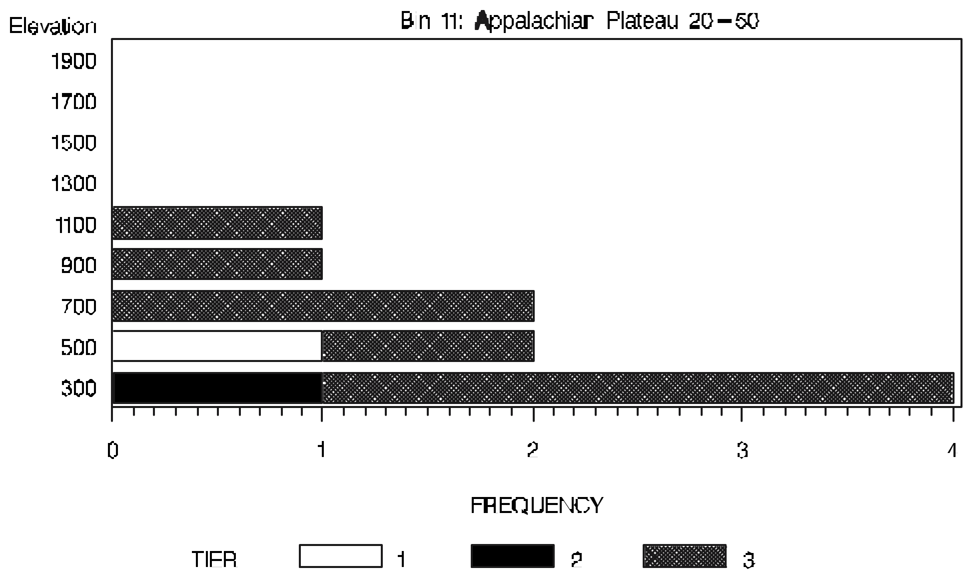


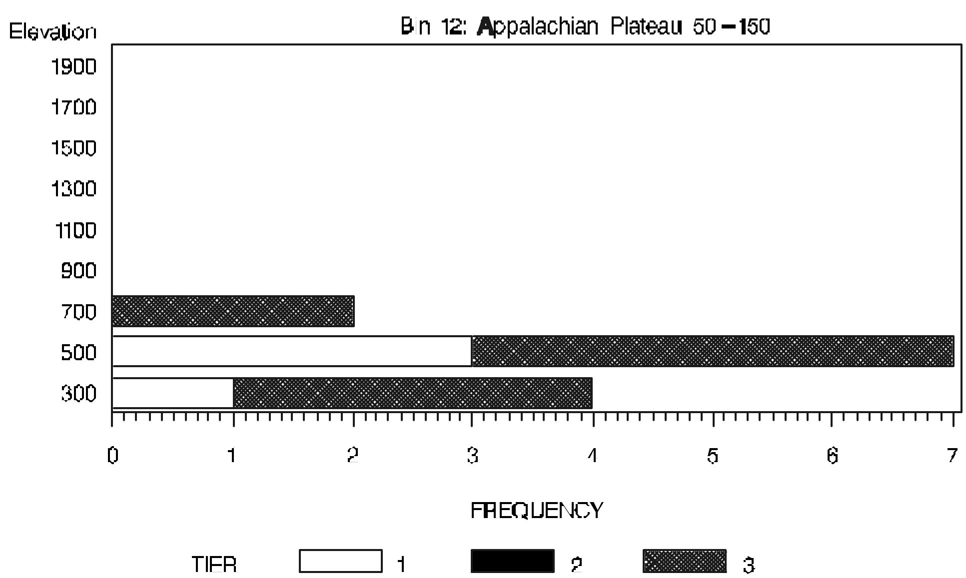




Elev - Candidates







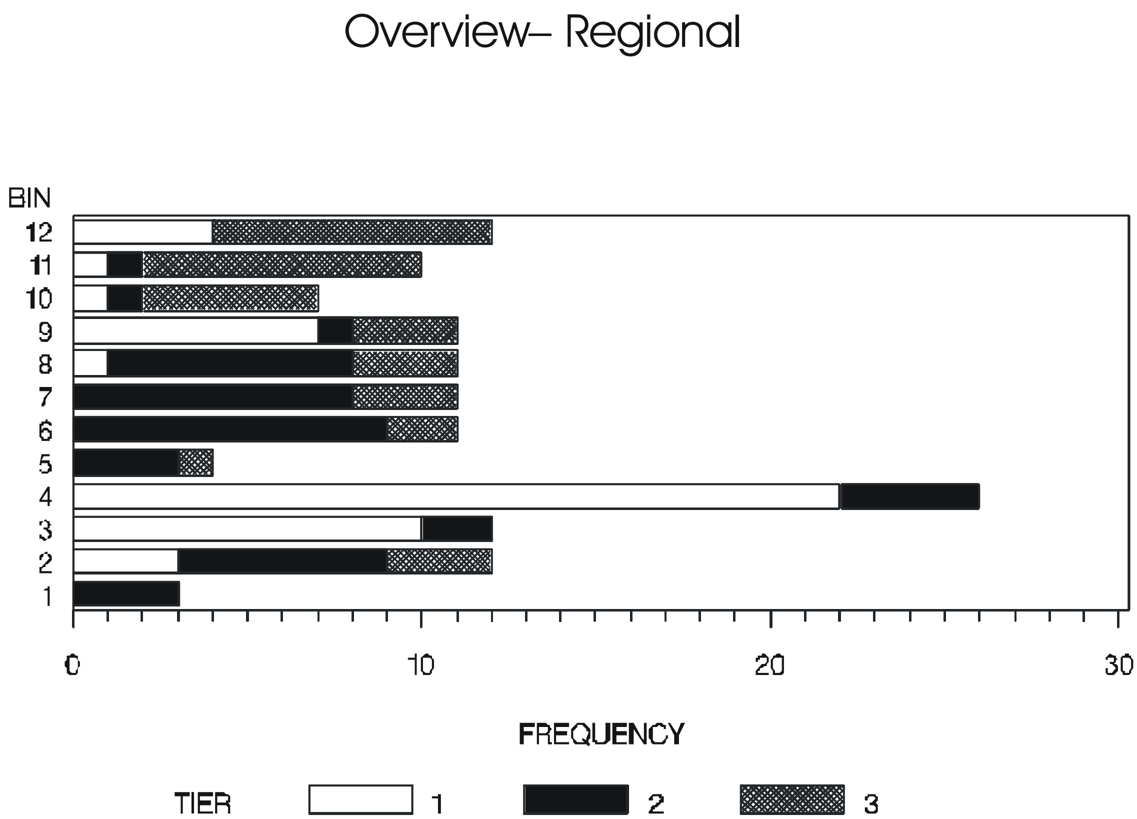
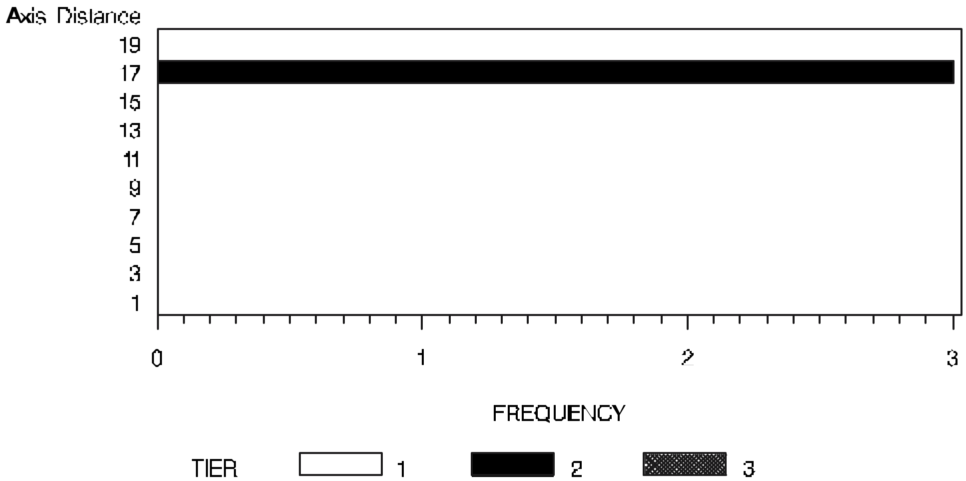


Figure D-3. Distribution of sites selected for regional modeling across modeling bins, stratified by tier.

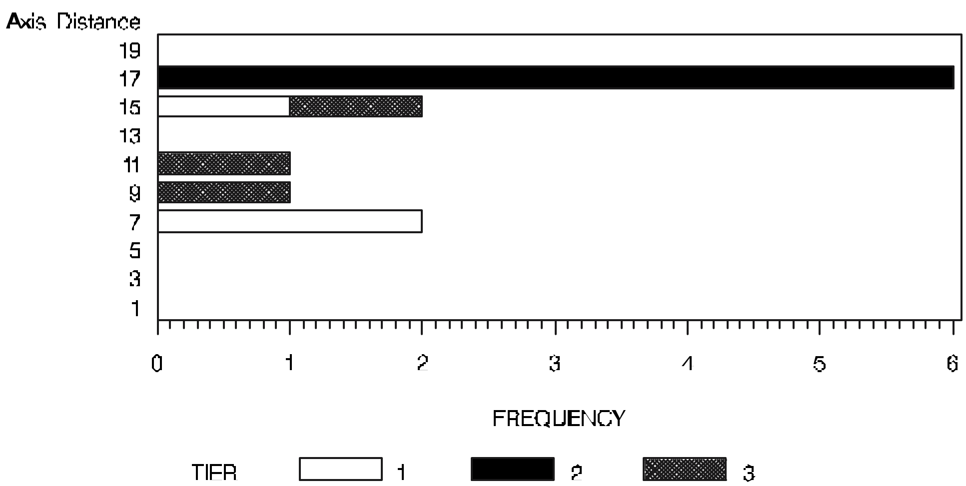
Figure D-4. Distribution of sites selected for regional MAGIC modeling by bin, across geographical location (longitudinal axis of SAMI domain, stratified into 19 equal-length sections), calculated ANC, sulfate, nitrate, and elevation.

Axis - Regional

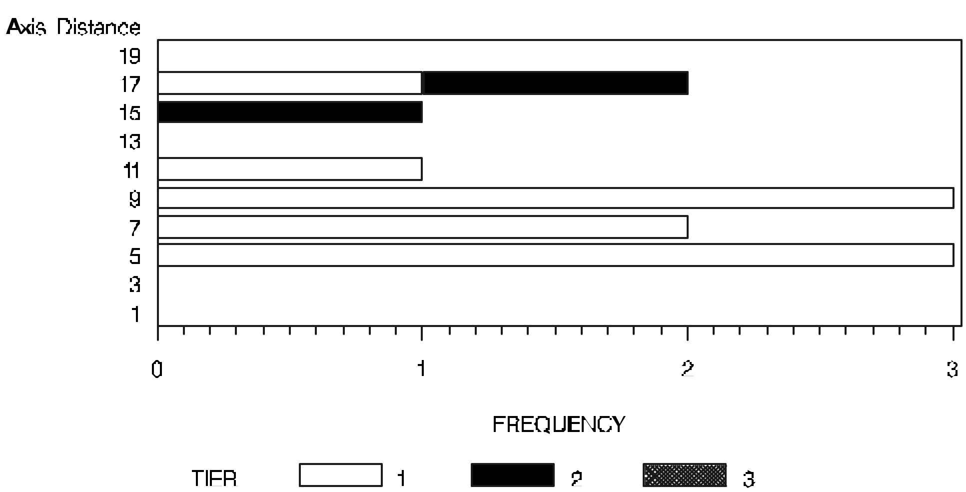
Bin 1: Blue Ridge < 0



Bin 2: Blue Ridge 0 – 20

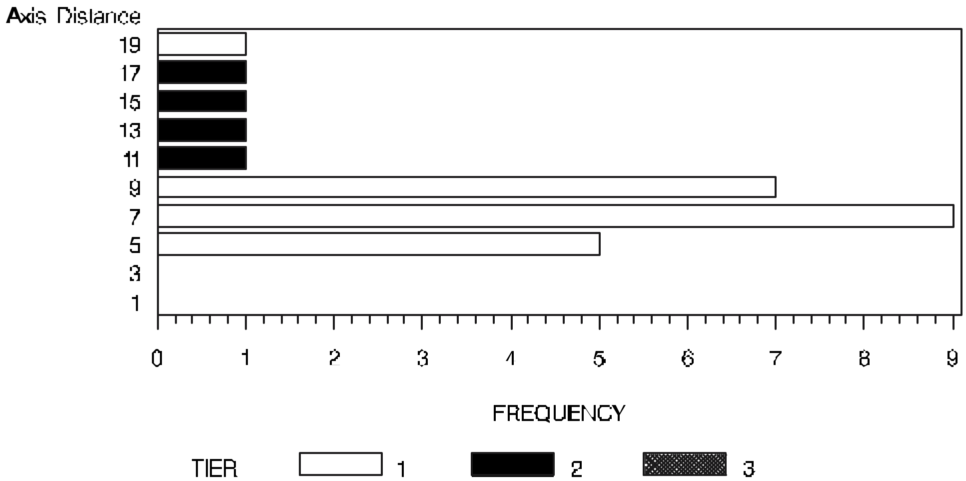


Bin 3: Blue Ridge 20 – 50

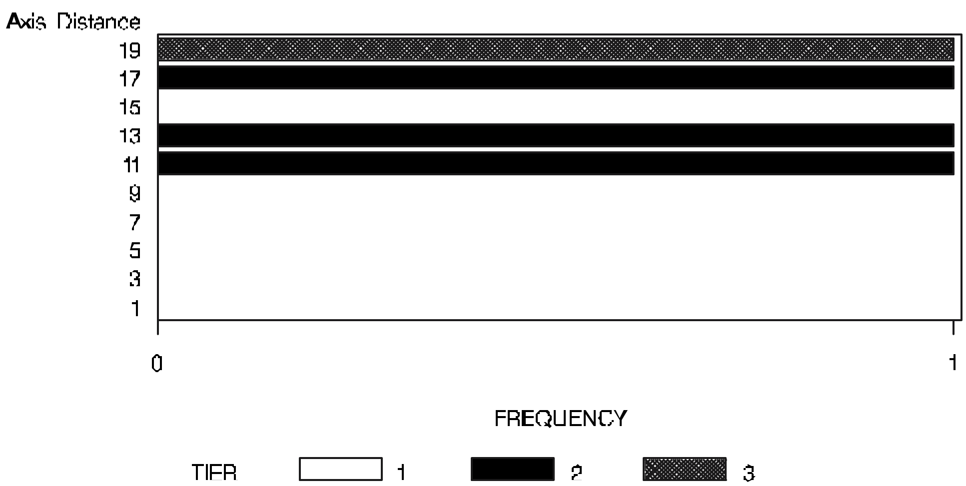


Axis - Regional

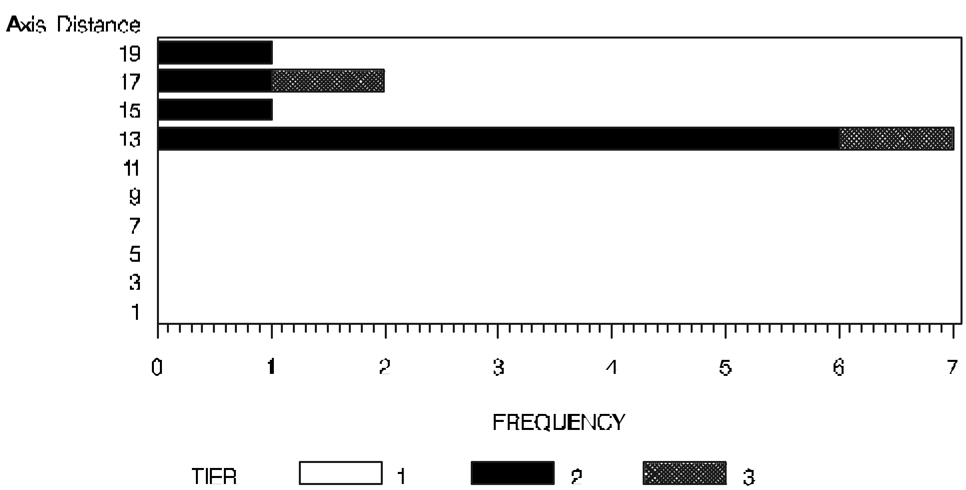
Bin 4: Blue Ridge 50 – 150



Bin 5: Valley and Ridge < 0

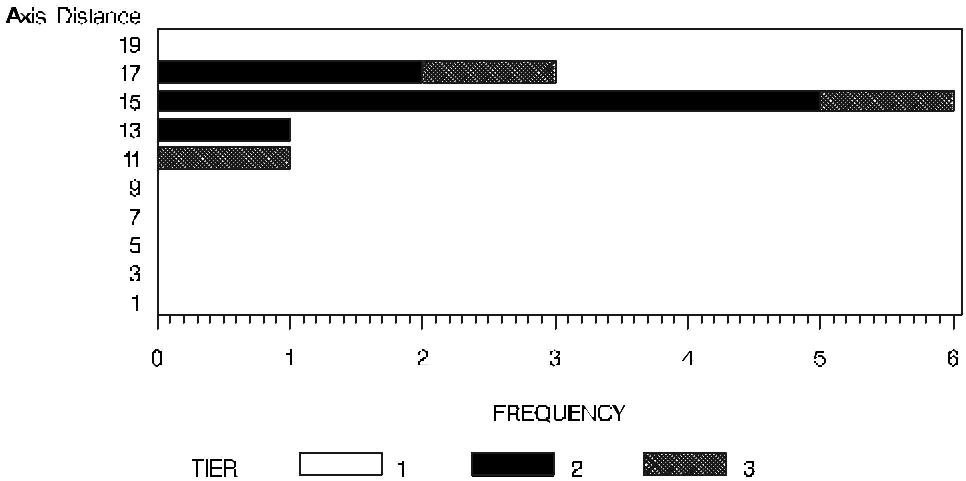


Bin 6: Valley and Ridge 0 – 20

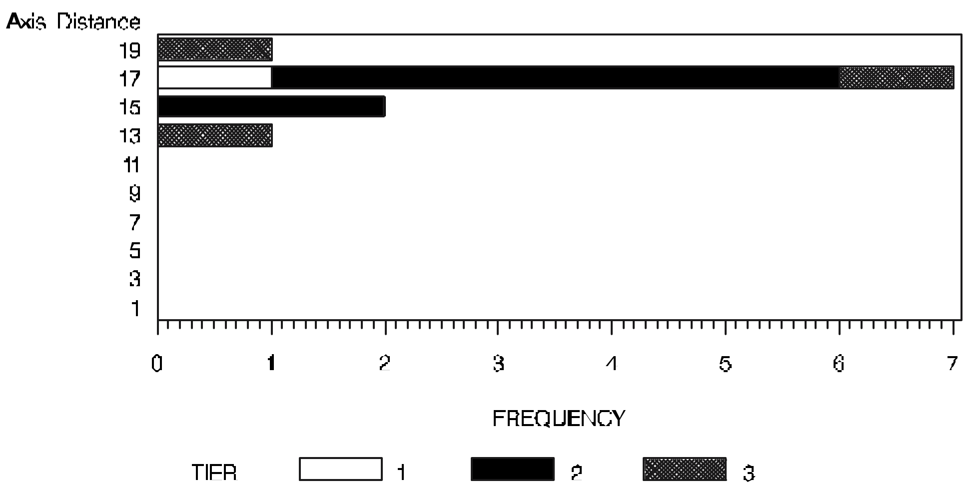


Axis - Regional

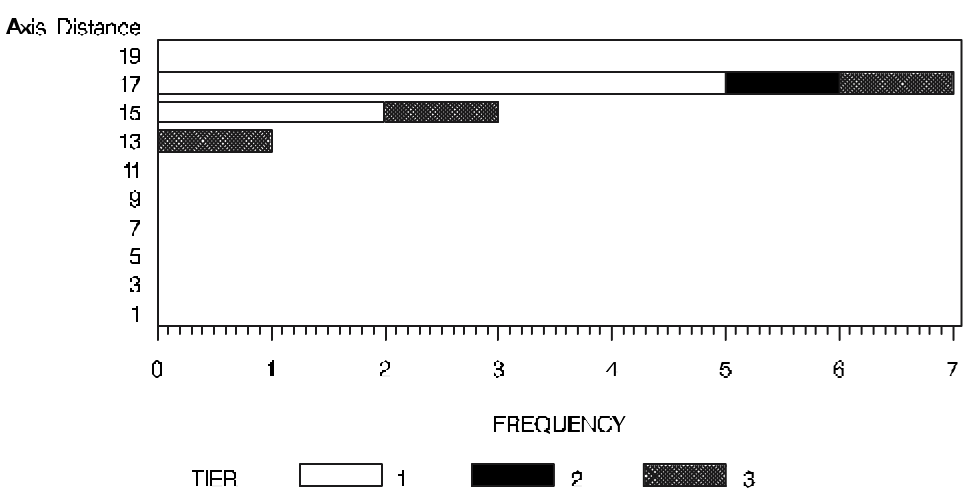
Bin 7: Valley and Ridge 20–50



Bin 8: Valley and Ridge 50–150

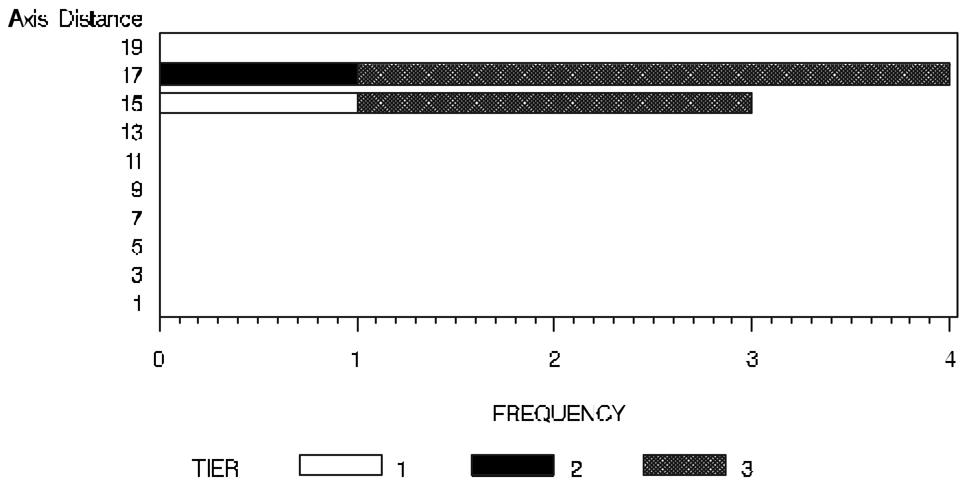


Bin 9: Appalachian Plateau <0

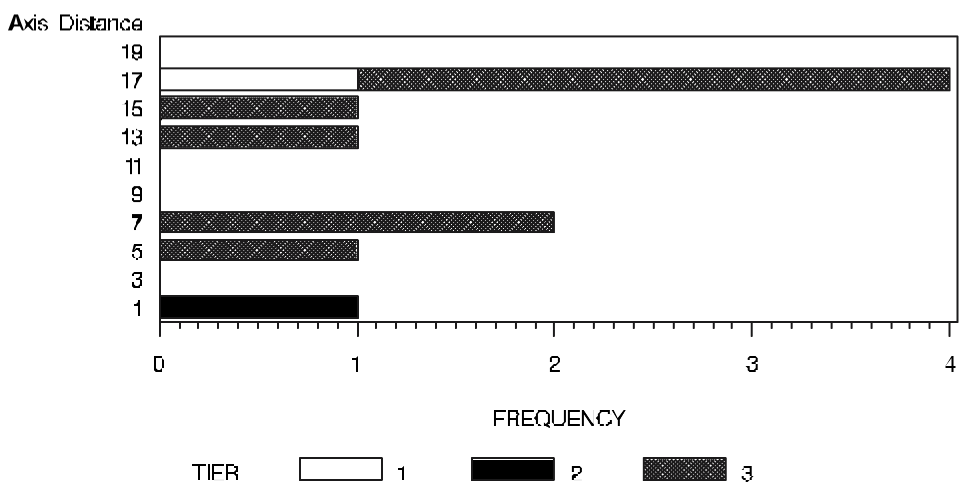


Axis - Regional

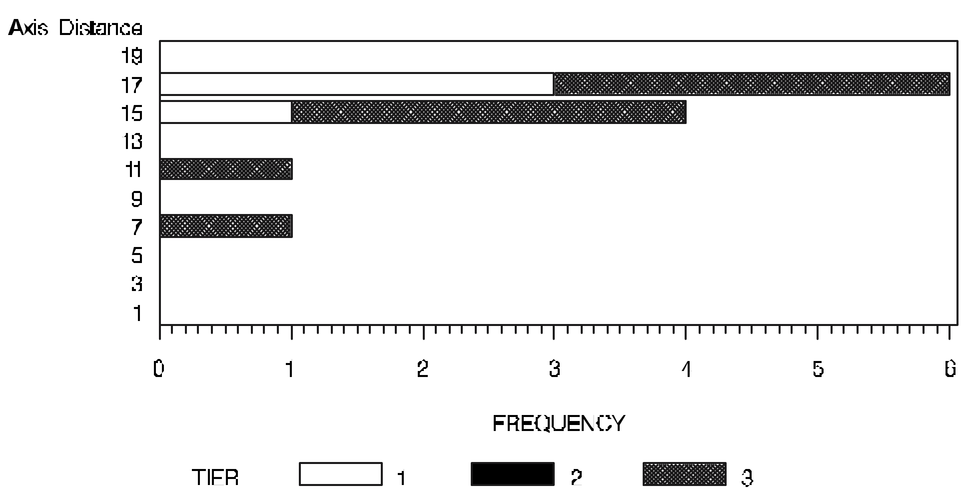
Bin 10: Appalachian Plateau 0 – 20



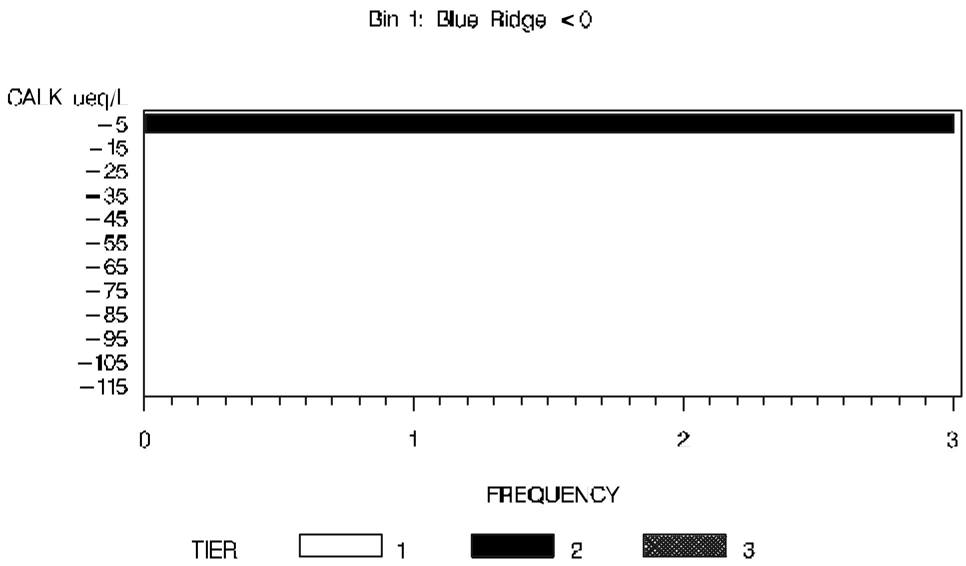
Bin 11: Appalachian Plateau 20 – 50

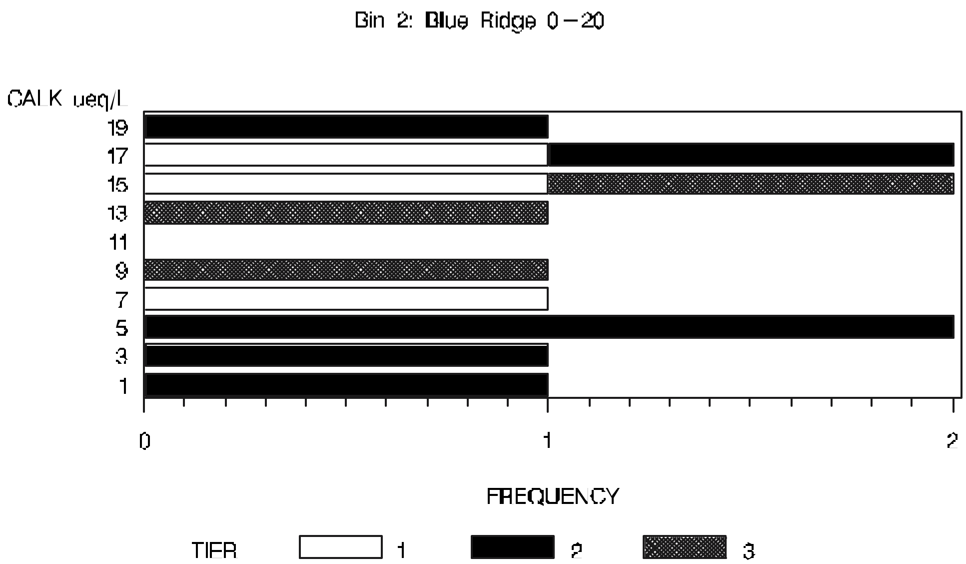


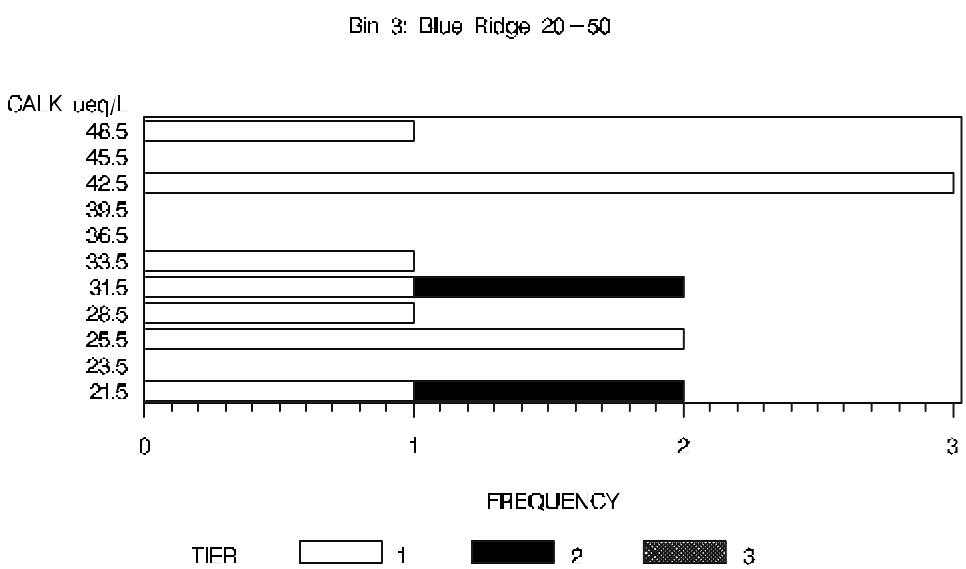
Bin 12: Appalachian Plateau 50 – 150



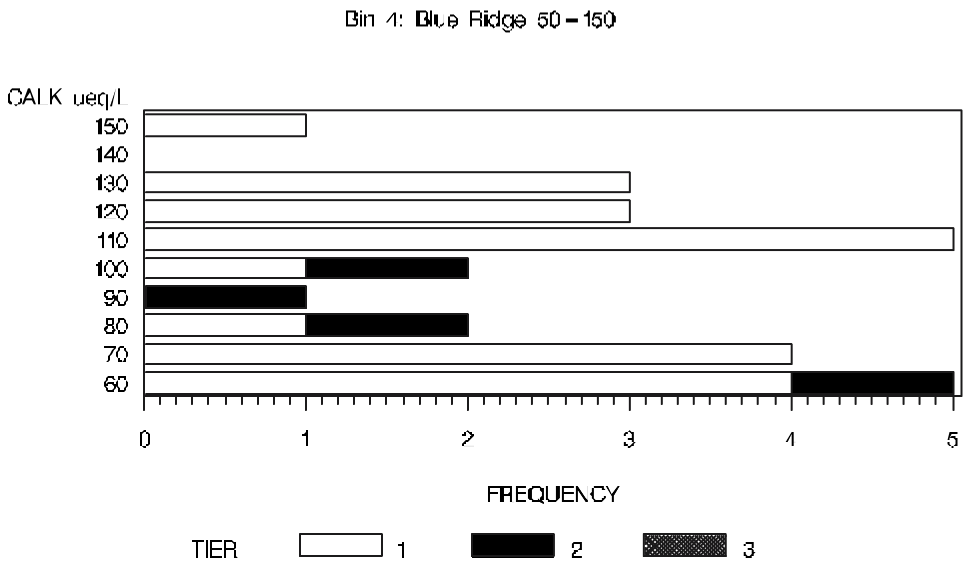
CALK - Regional

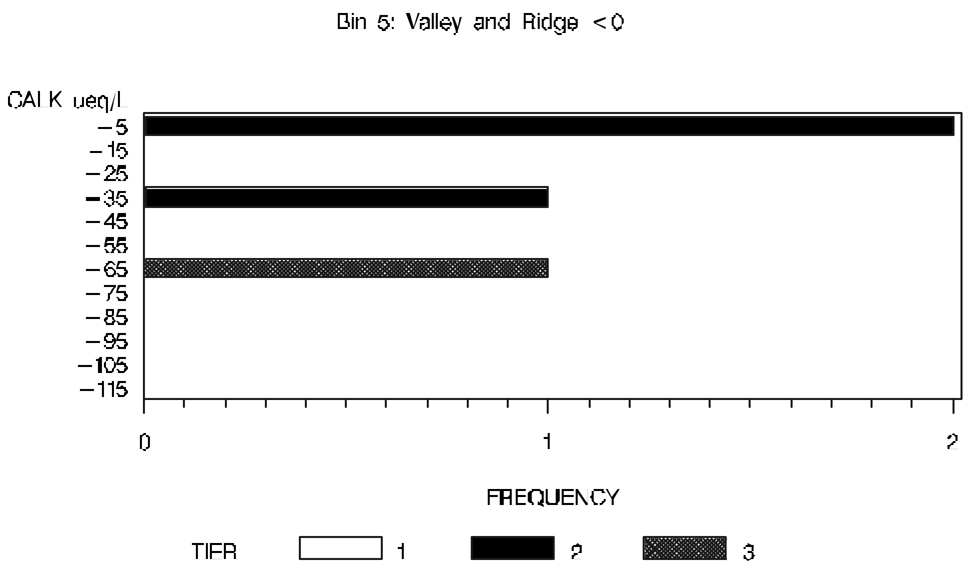


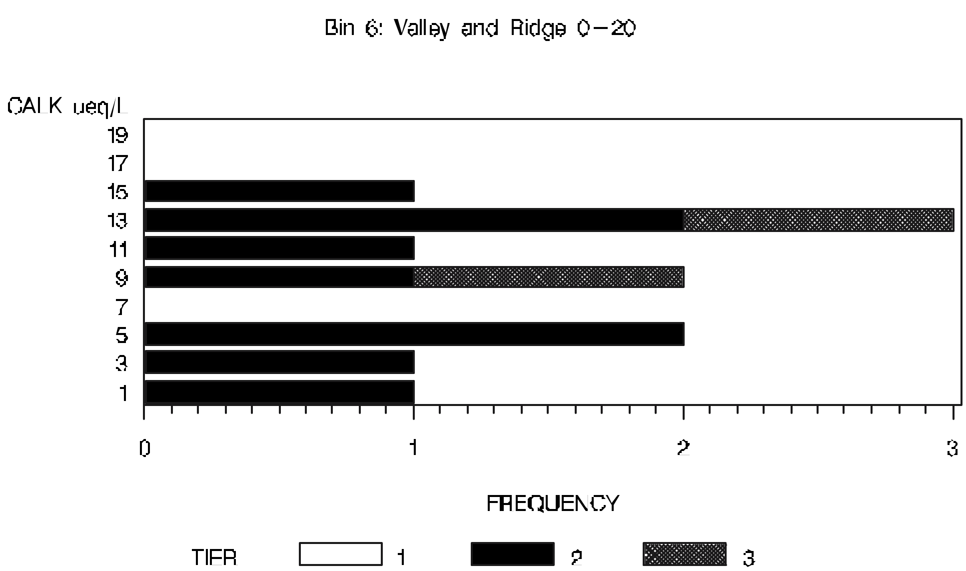




CALK - Regional

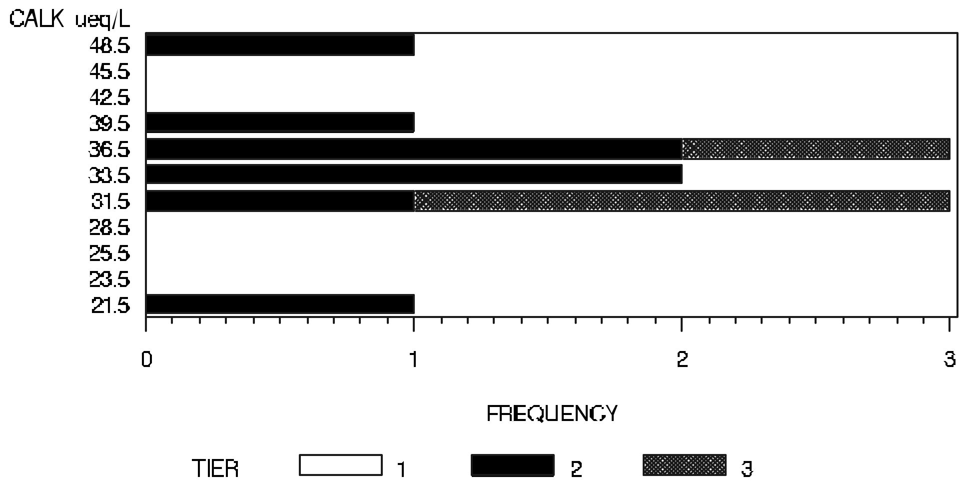




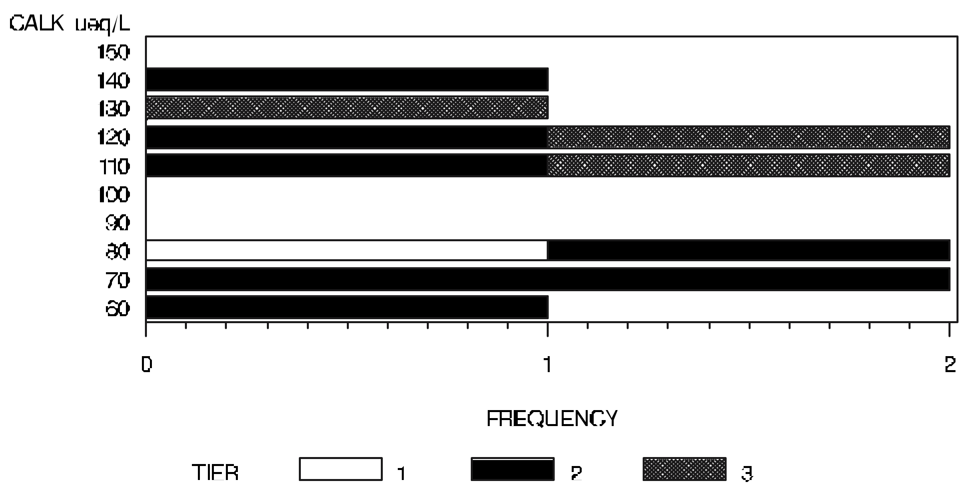


CALK - Regional

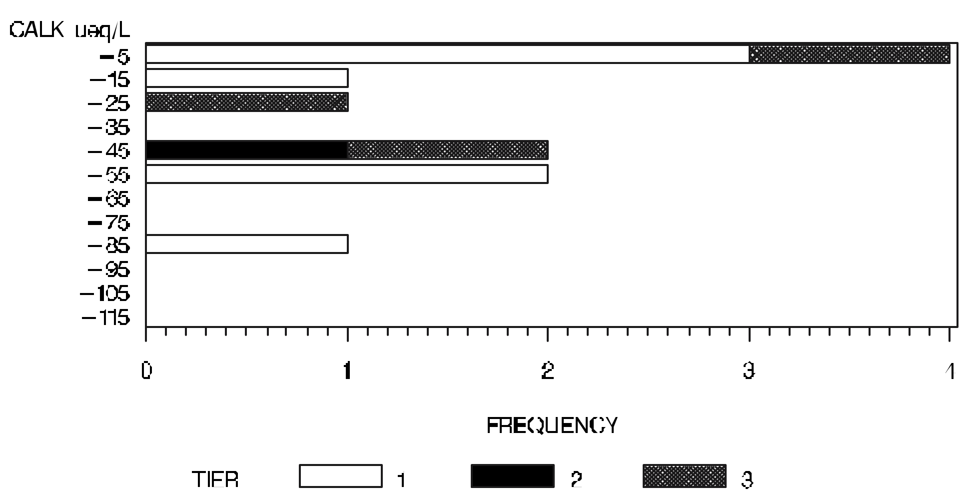
Bin 7: Valley and Ridge 20 – 50



Bin 8: Valley and Ridge 50 – 150

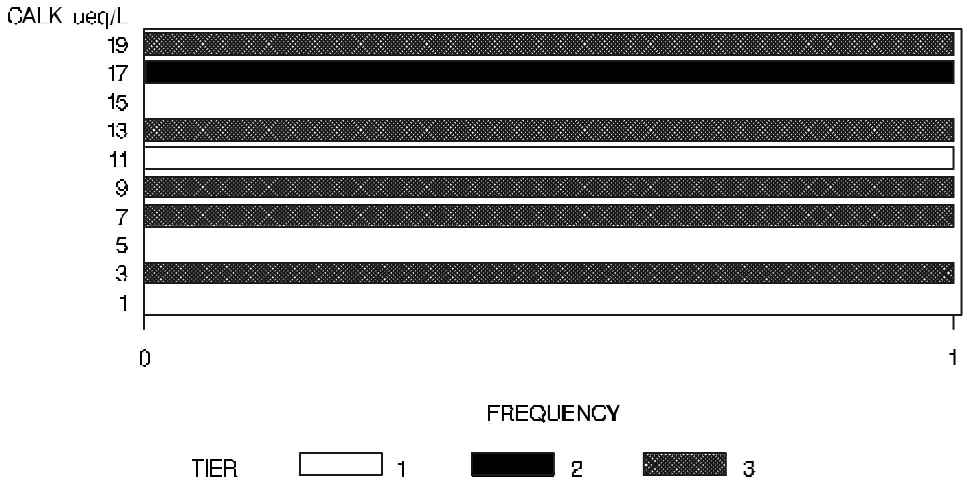


Bin 9: Appalachian Plateau < 0

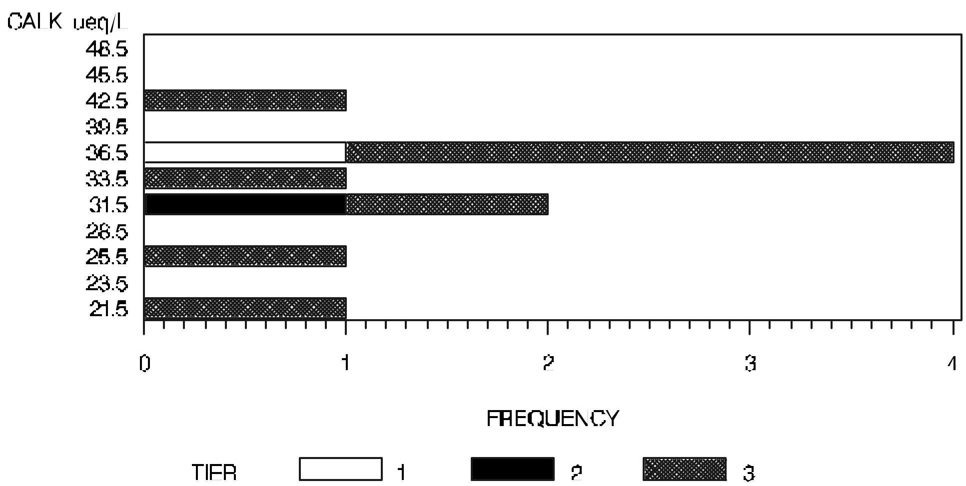


CALK - Regional

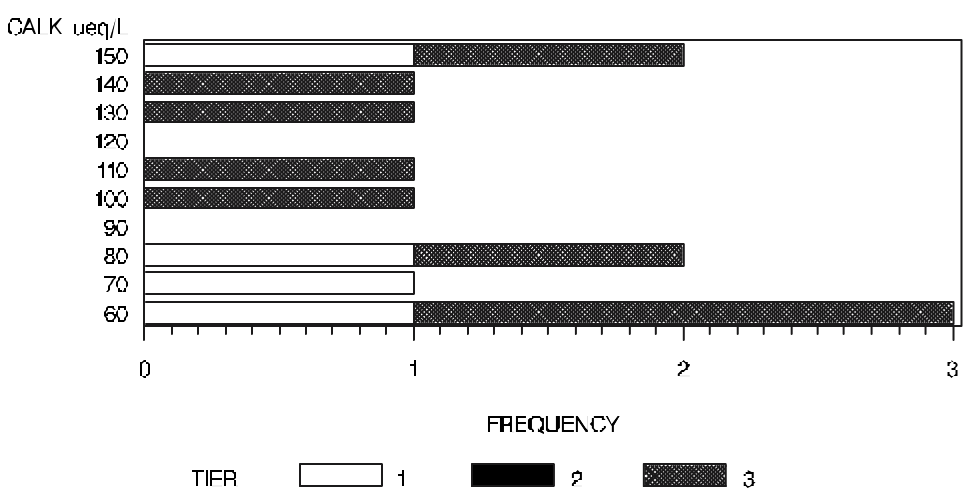
Bin 10: Appalachian Plateau 0–20



Bin 11: Appalachian Plateau 20–50

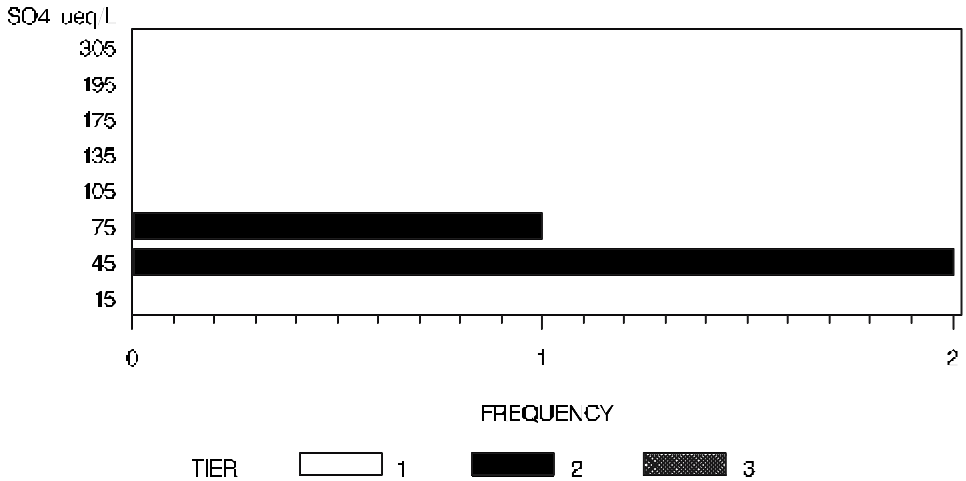


Bin 12: Appalachian Plateau 50–150

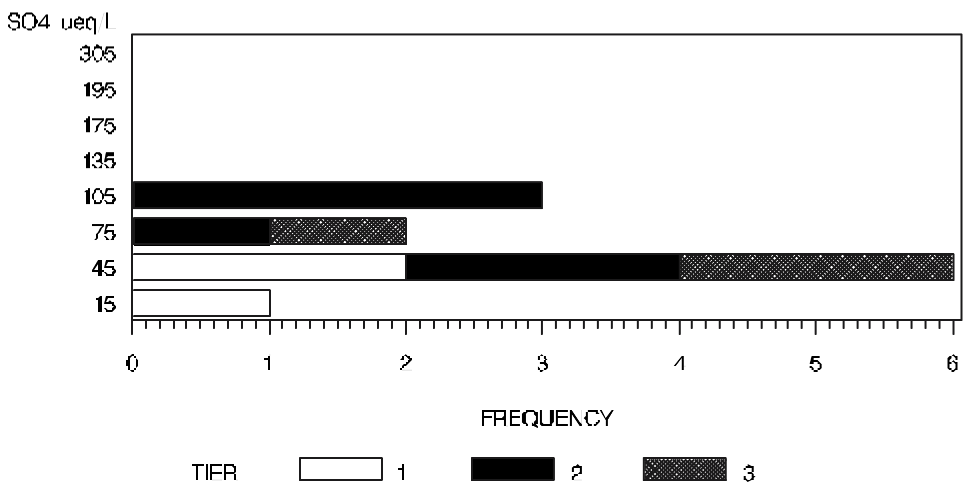


SO4 - Regional

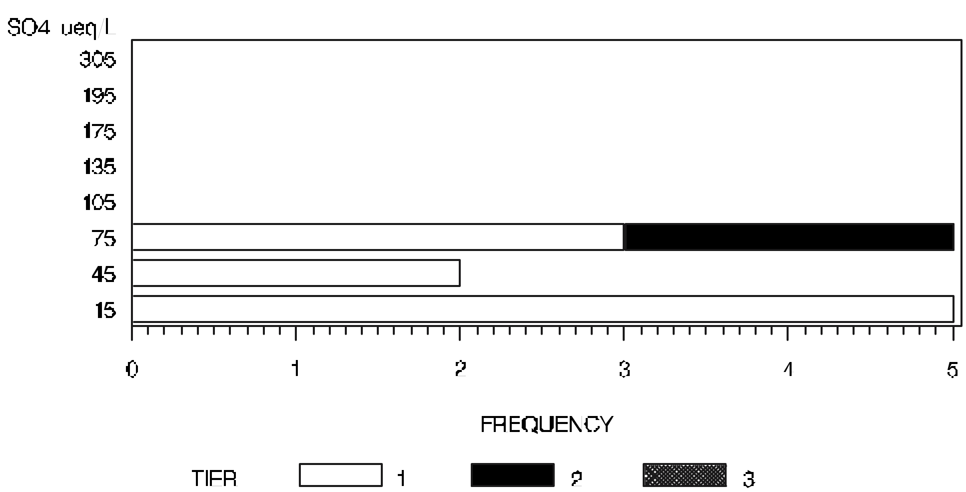
Bin 1: Blue Ridge < 0



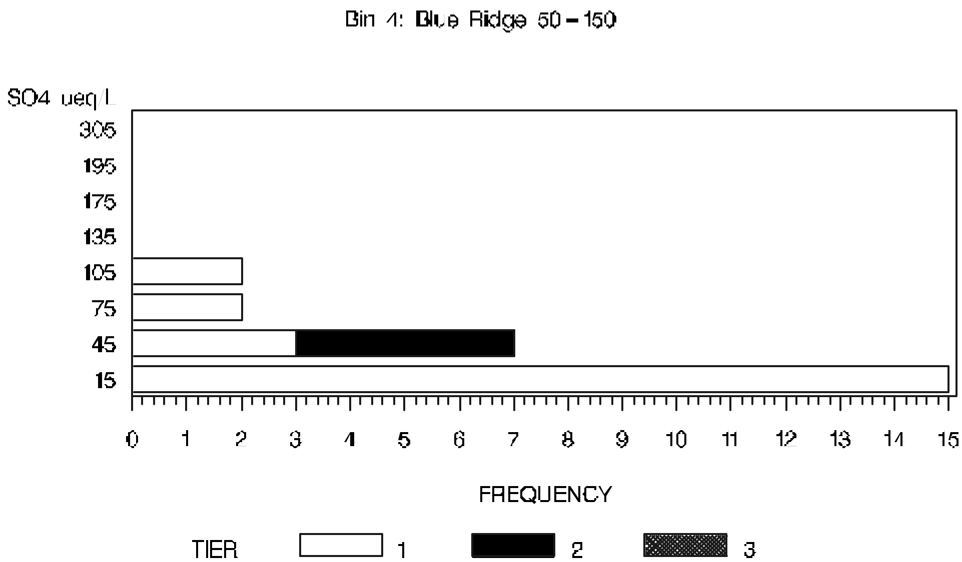
Bin 2: Blue Ridge 0 − 20

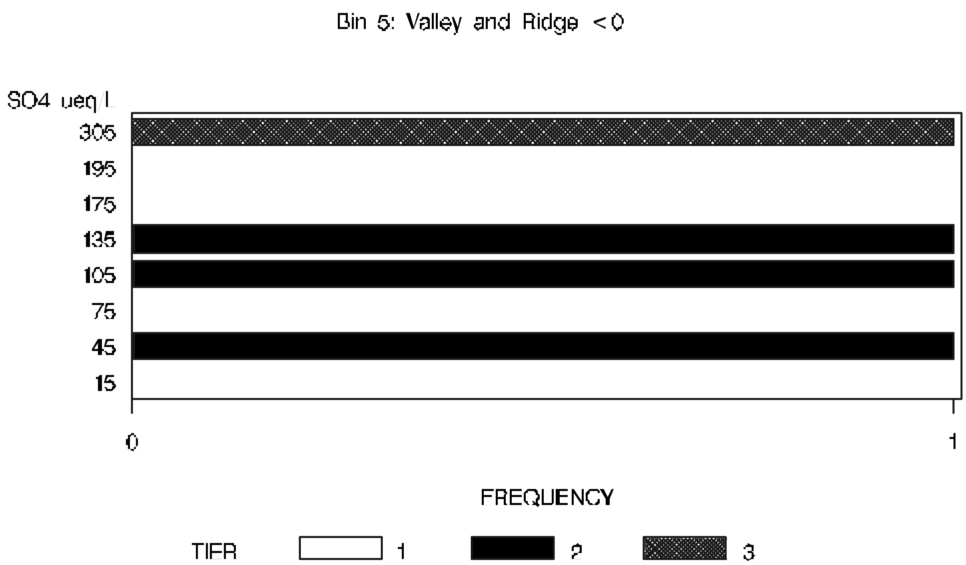


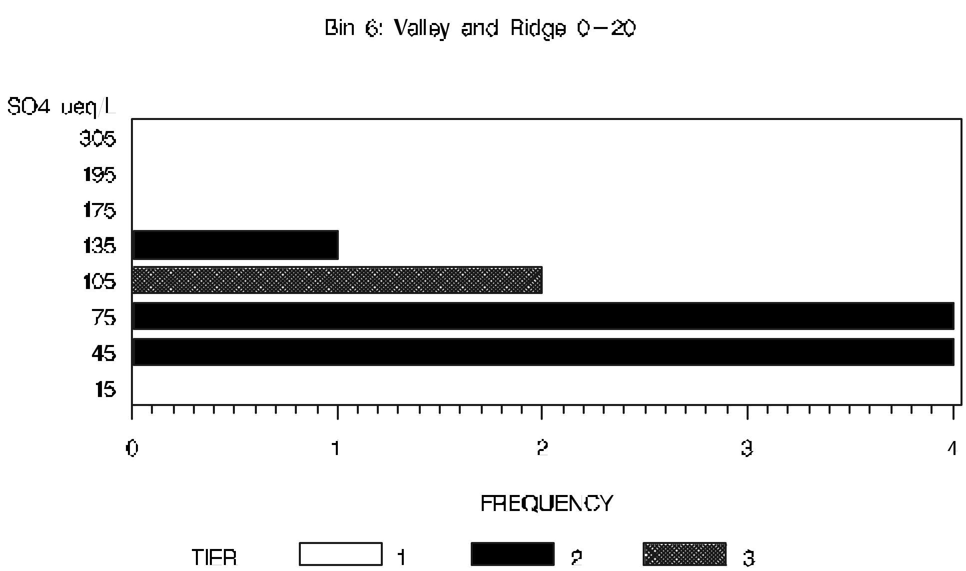
Bin 3: Blue Ridge 20 − 50



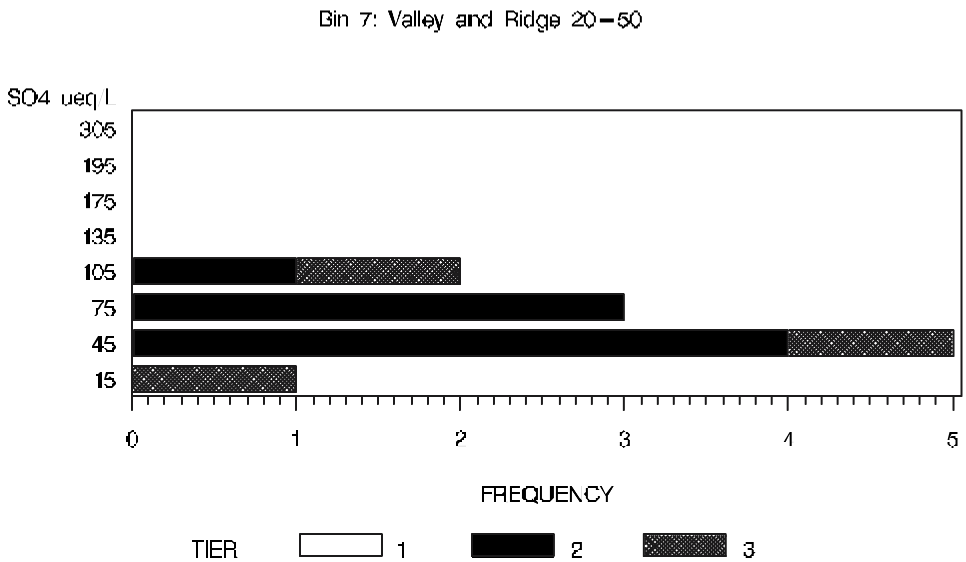
SO4 - Regional

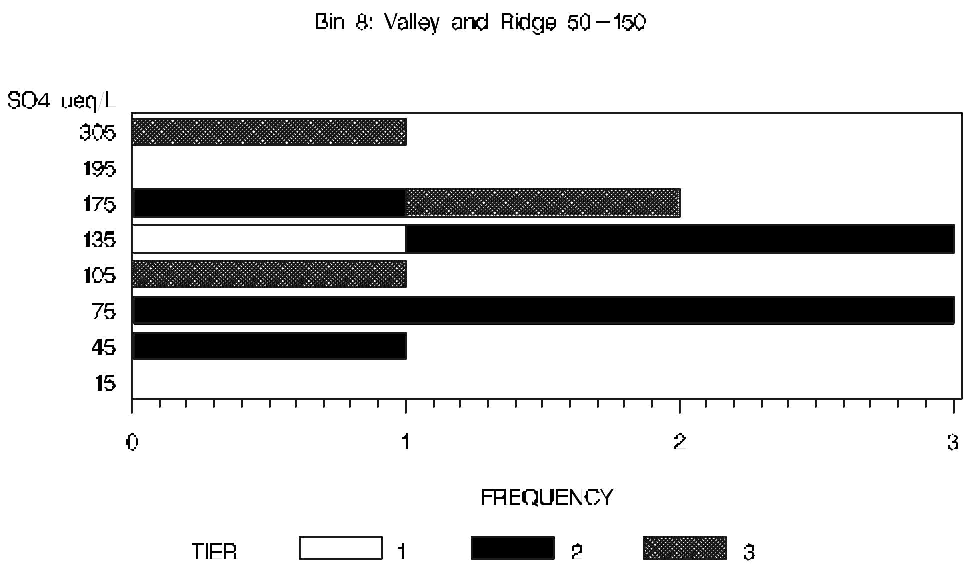


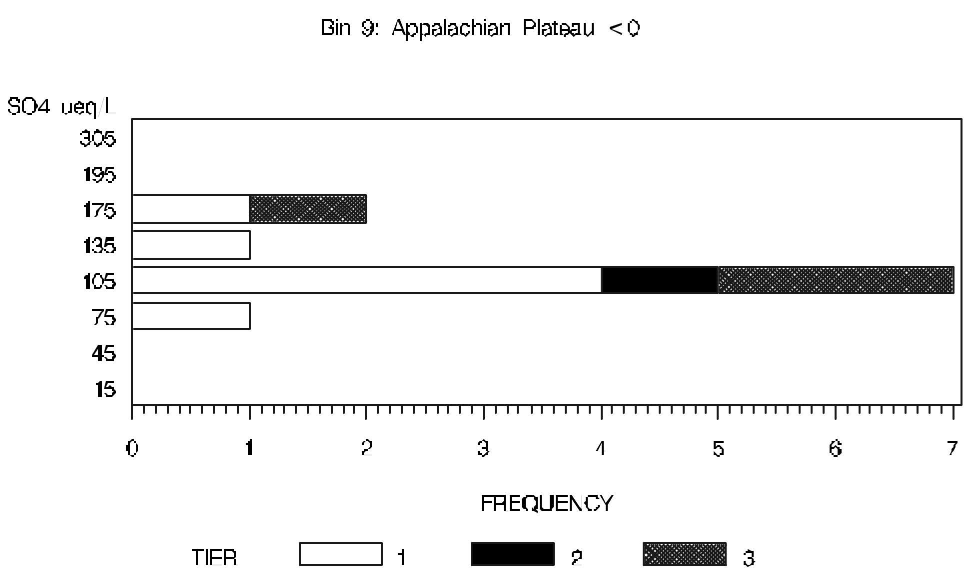




SO4 - Regional

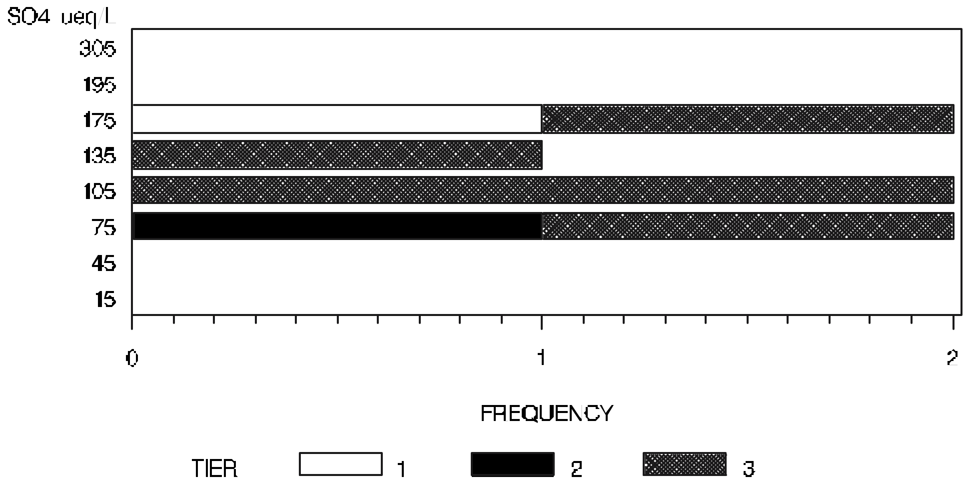




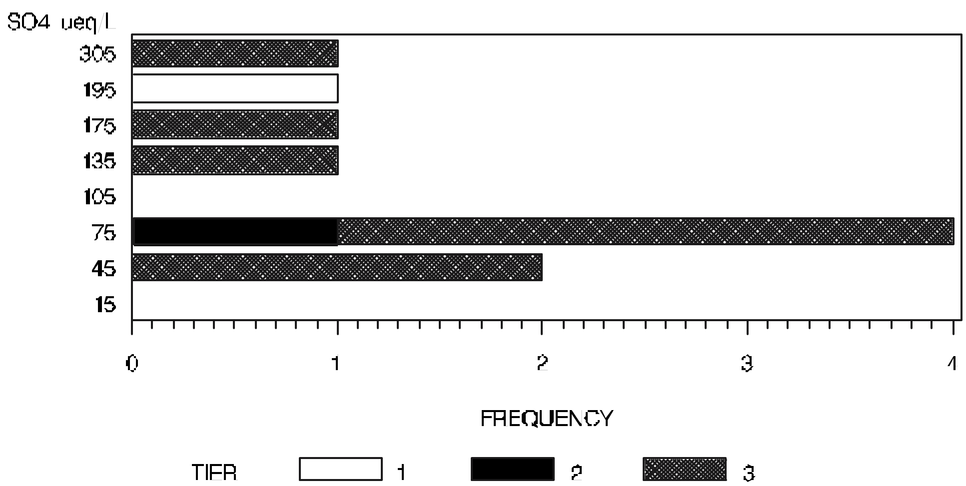


SO4 - Regional

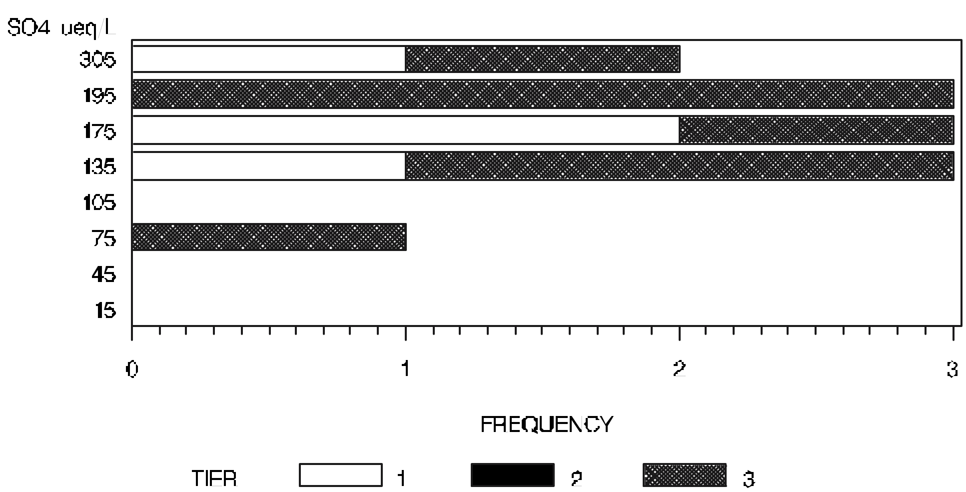
Bin 10: Appalachian Plateau 0–20



Bin 11: Appalachian Plateau 20–50

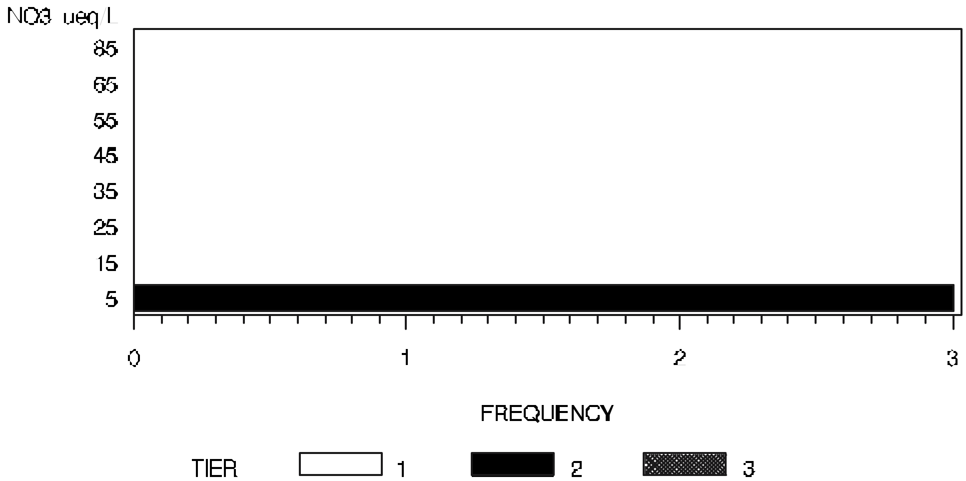


Bin 12: Appalachian Plateau 50–150

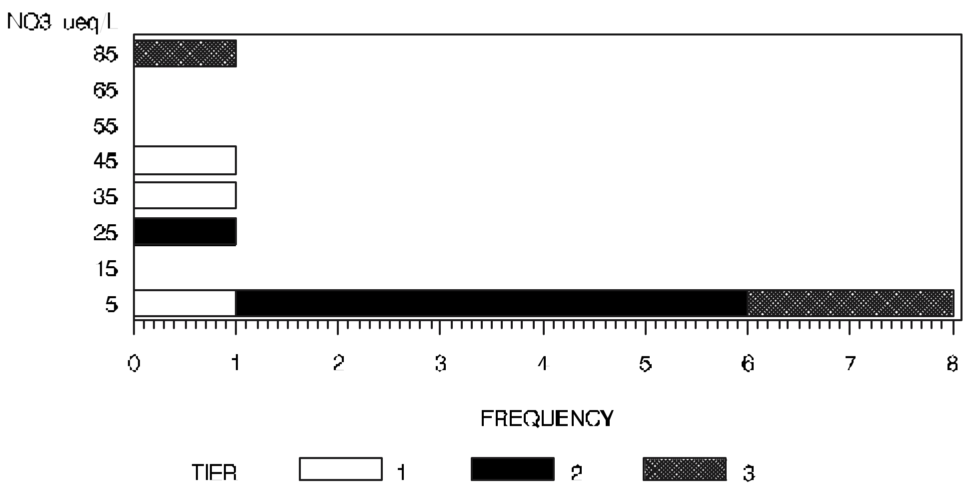


NO3 - Regional

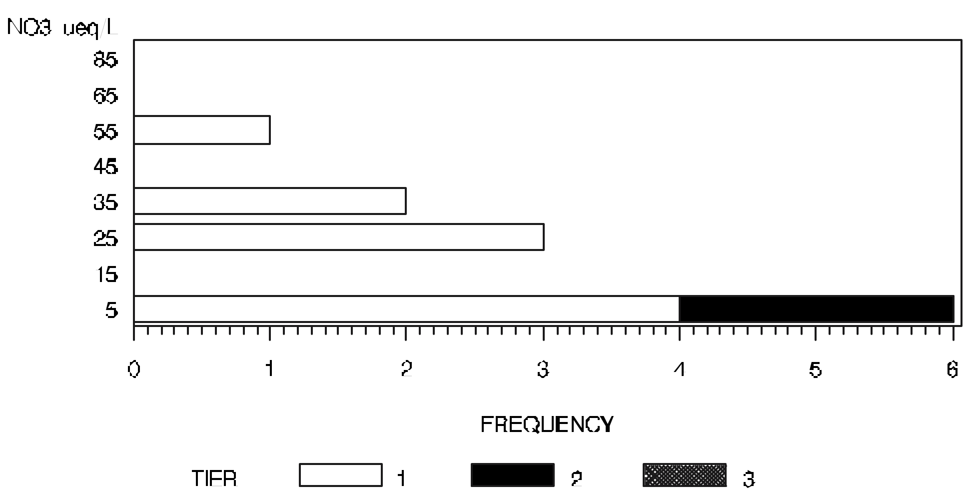
Bin 1: Blue Ridge < 0



Bin 2: Blue Ridge 0 - 20

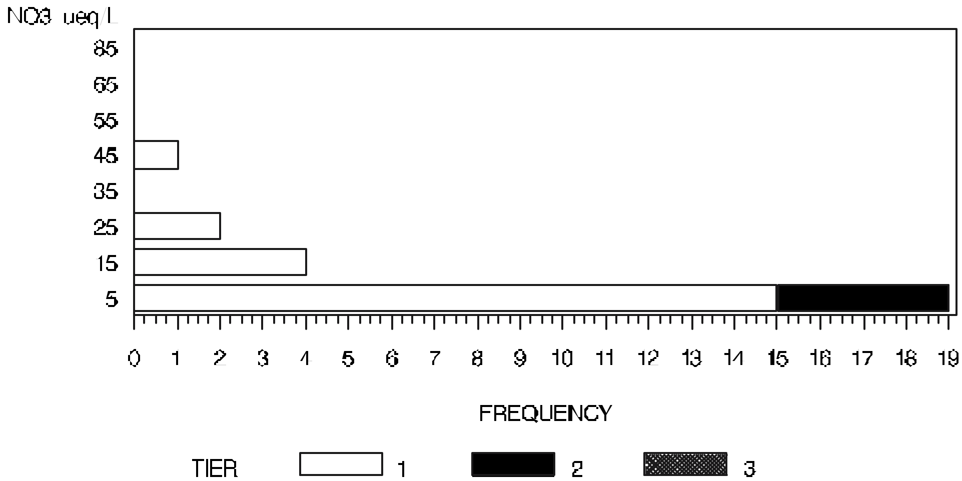


Bin 3: Blue Ridge 20 - 50

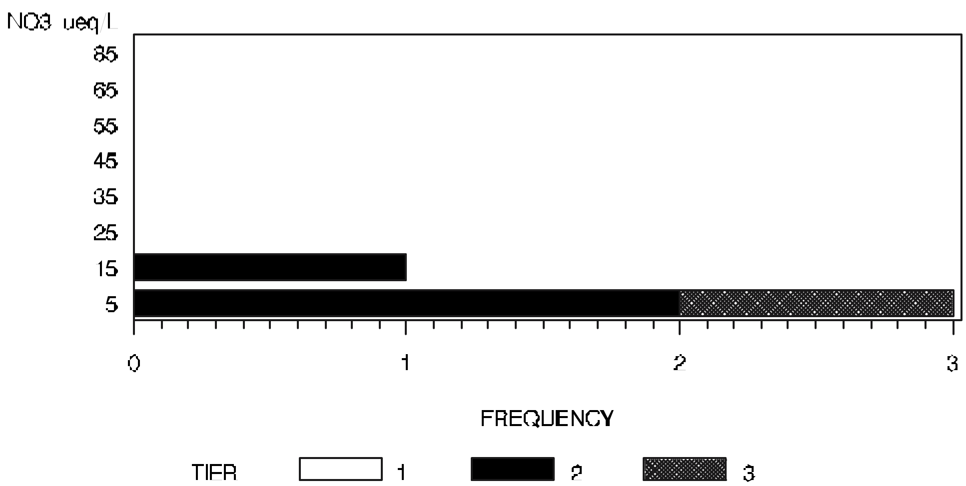


NO3 - Regional

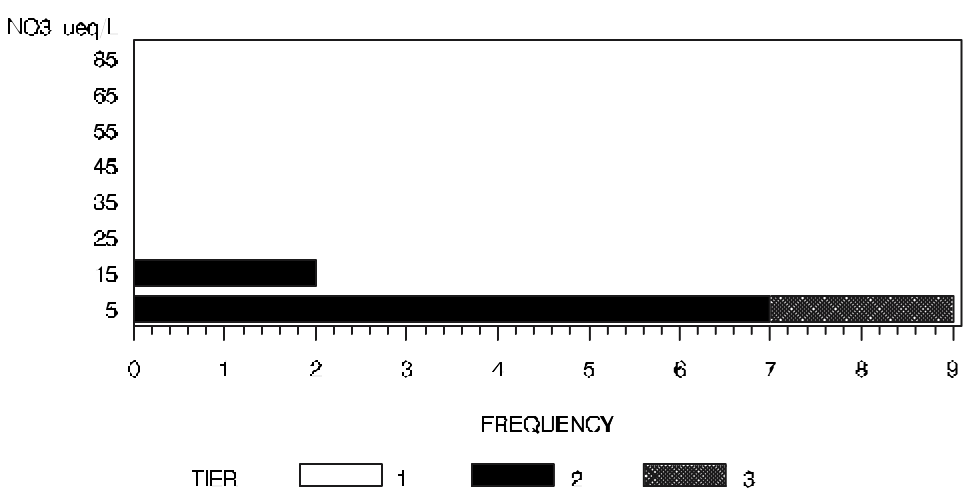
Bin 4: Blue Ridge 50-150



Bin 5: Valley and Ridge <0

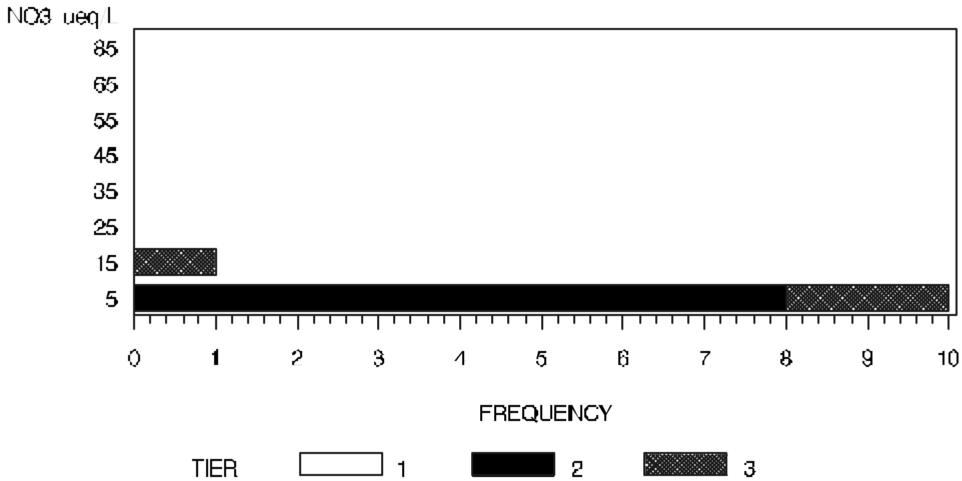


Bin 6: Valley and Ridge 0-20

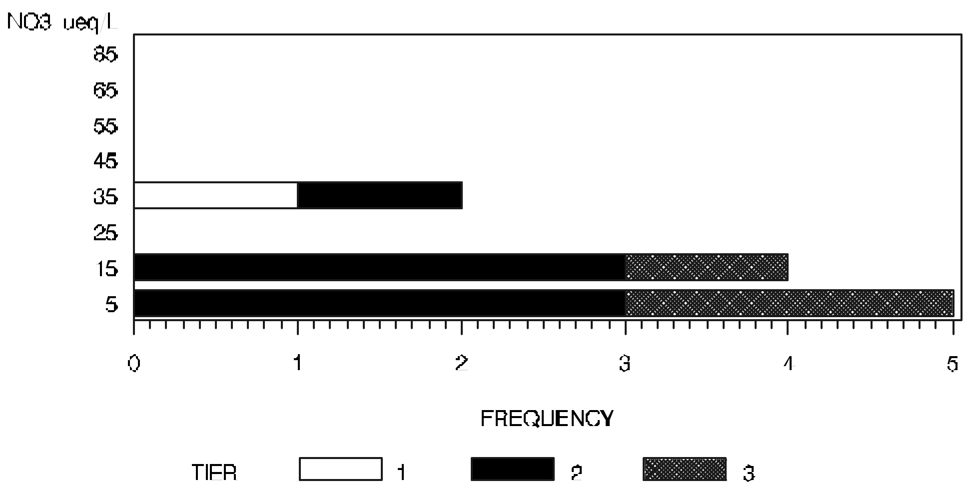


NO3 - Regional

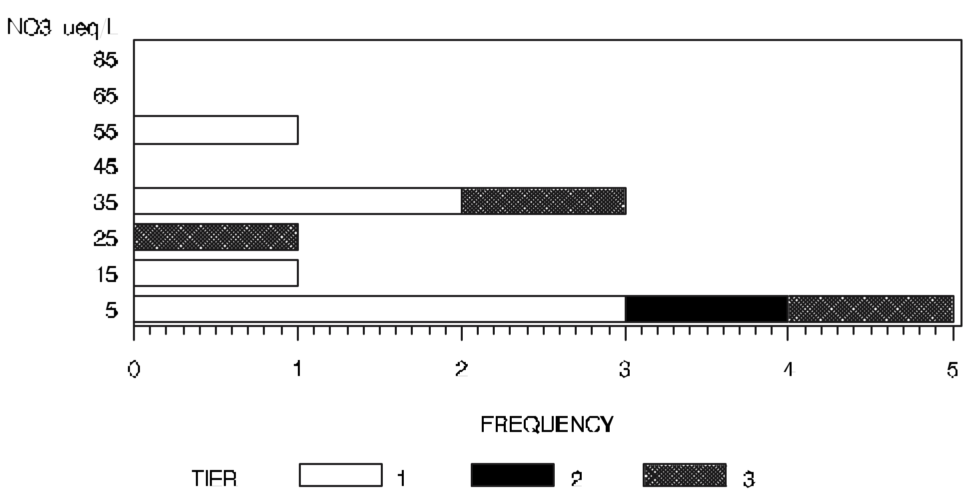
Bin 7: Valley and Ridge 20−50



Bin 8: Valley and Ridge 50−150

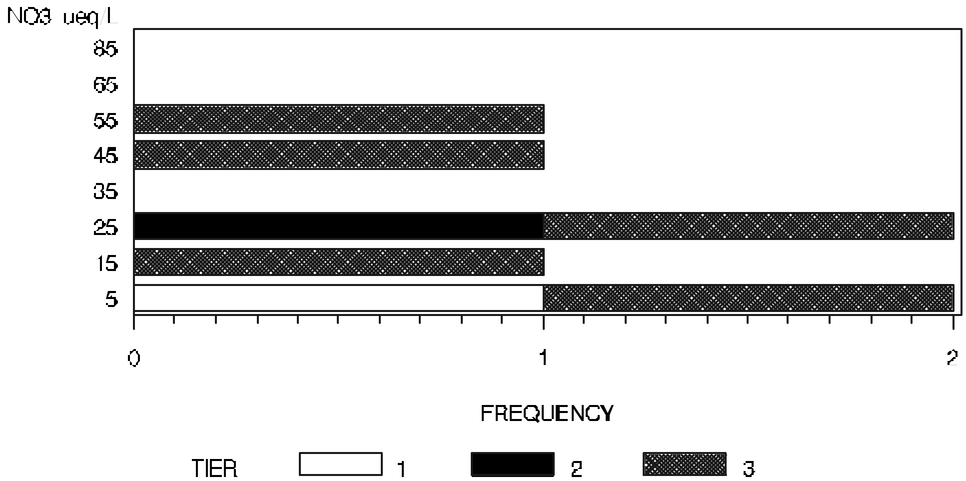


Bin 9: Appalachian Plateau <0

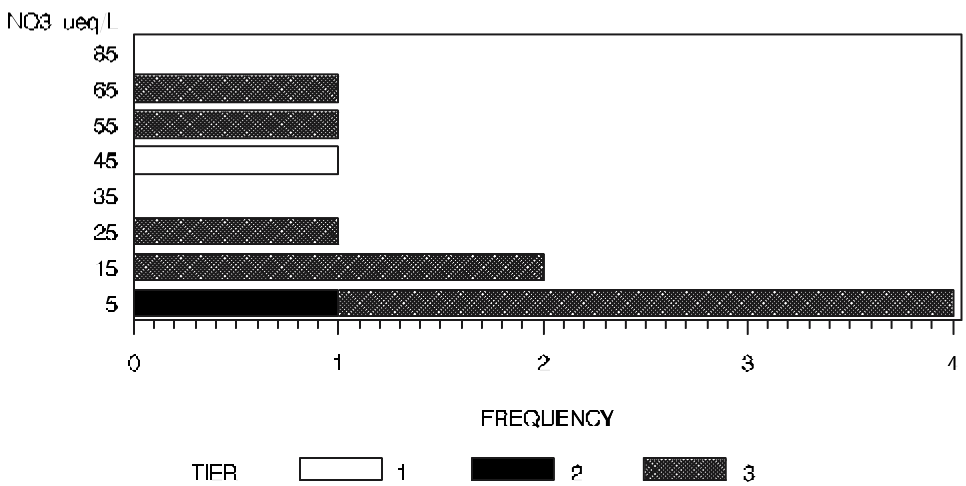


NO3 - Regional

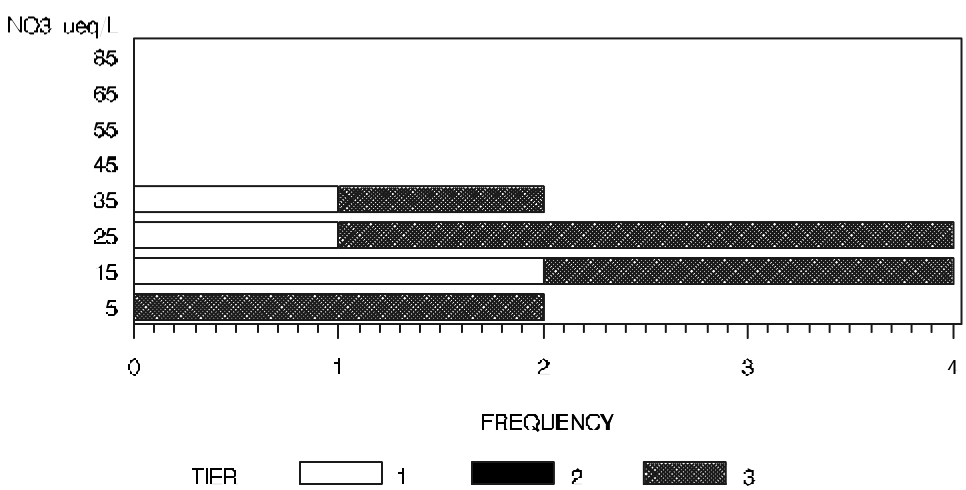
Bin 10: Appalachian Plateau 0-20



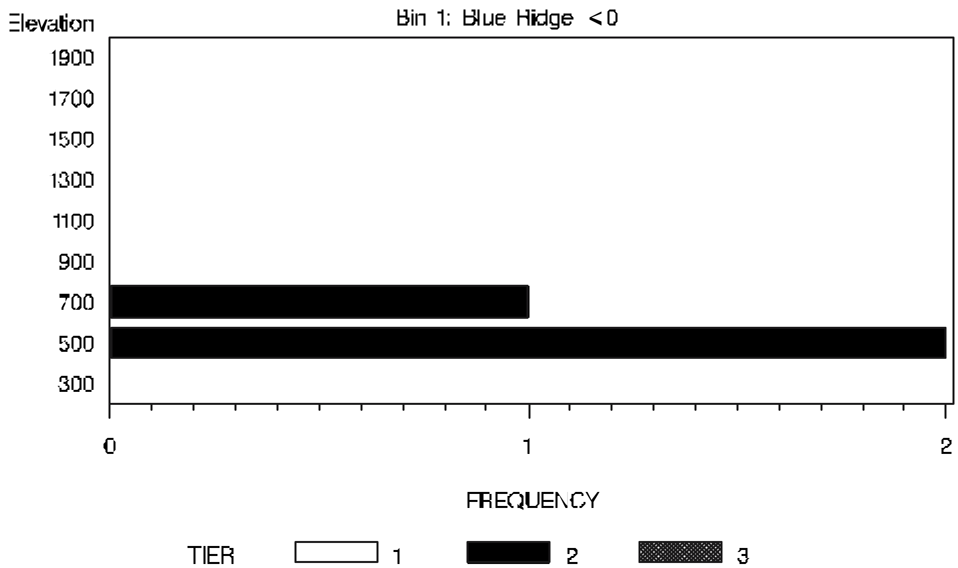
Bin 11: Appalachian Plateau 20-50

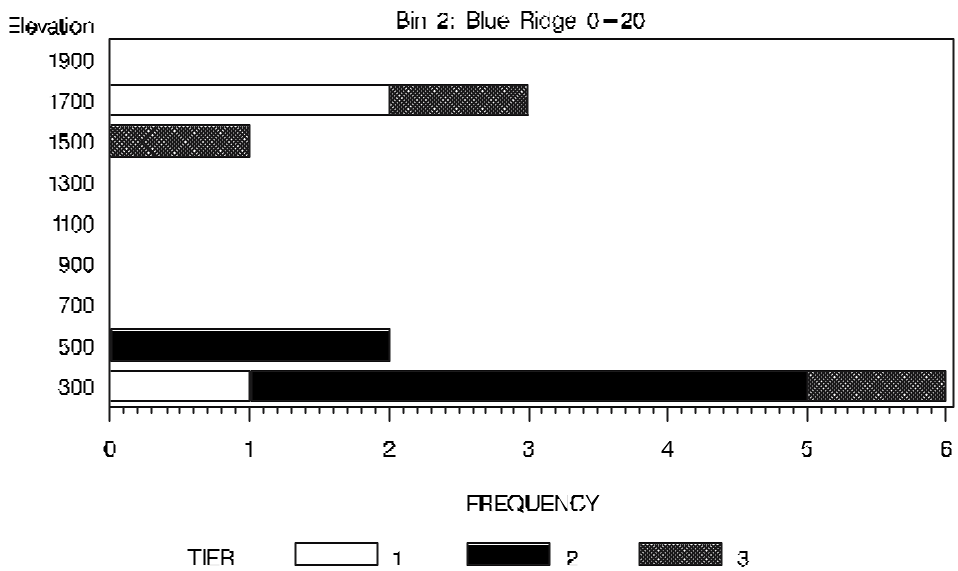


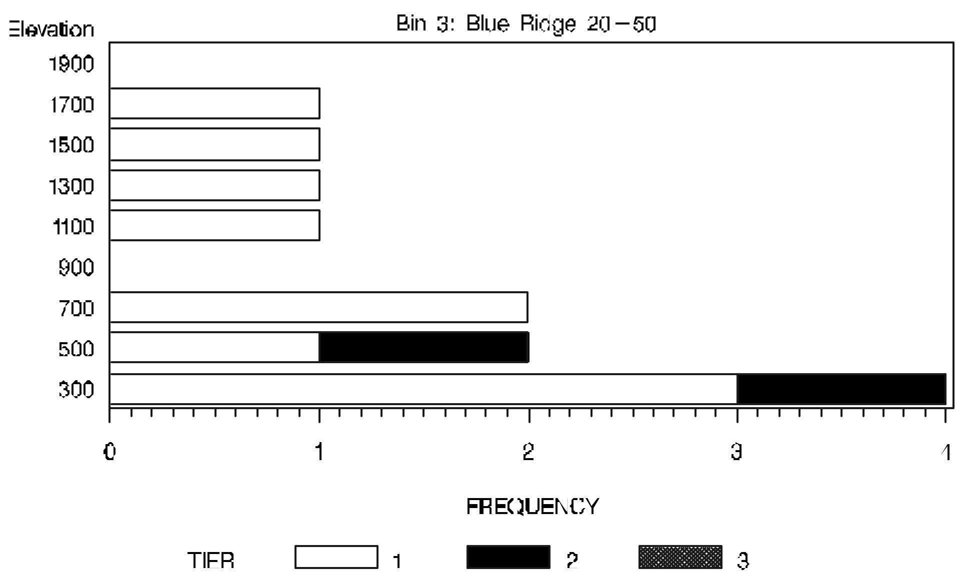
Bin 12: Appalachian Plateau 50-150



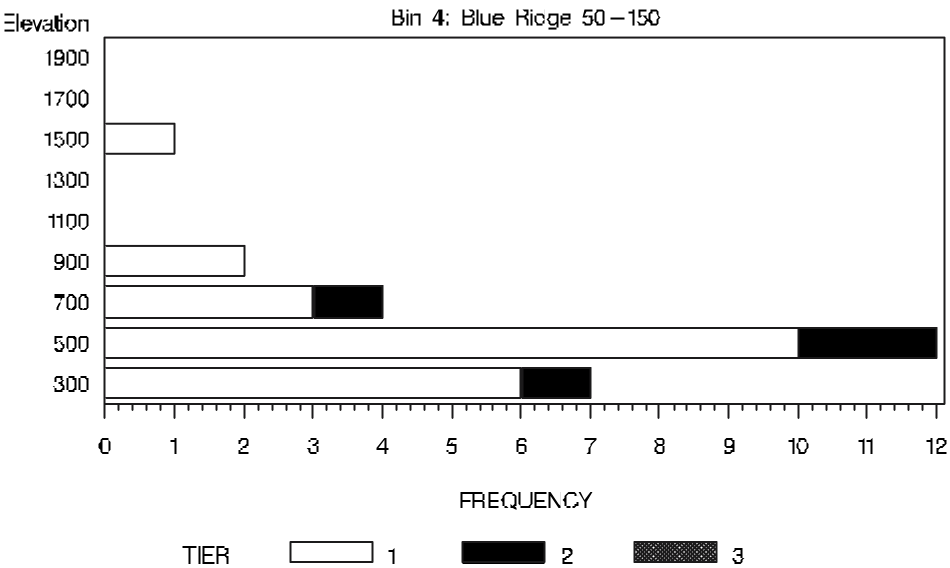
Elev - Regional

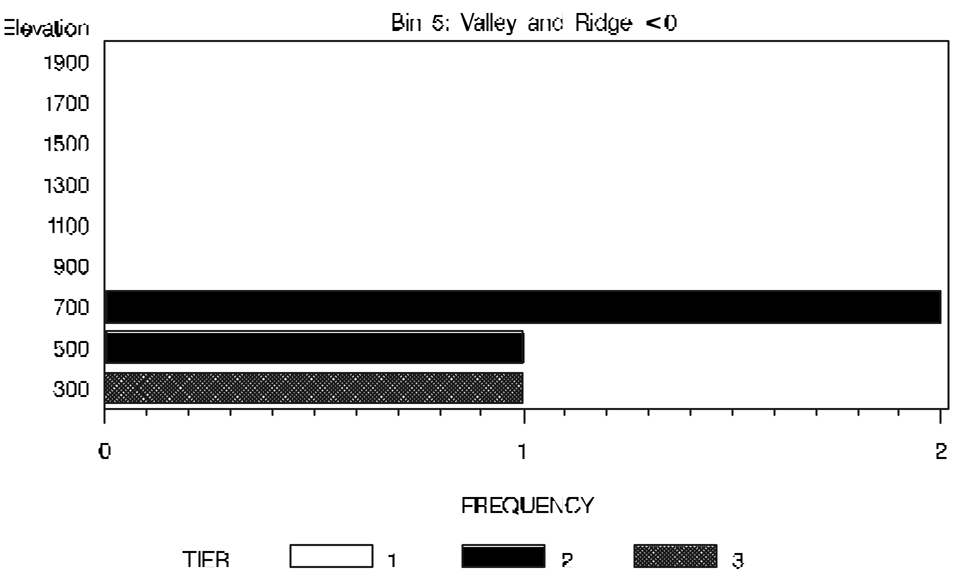


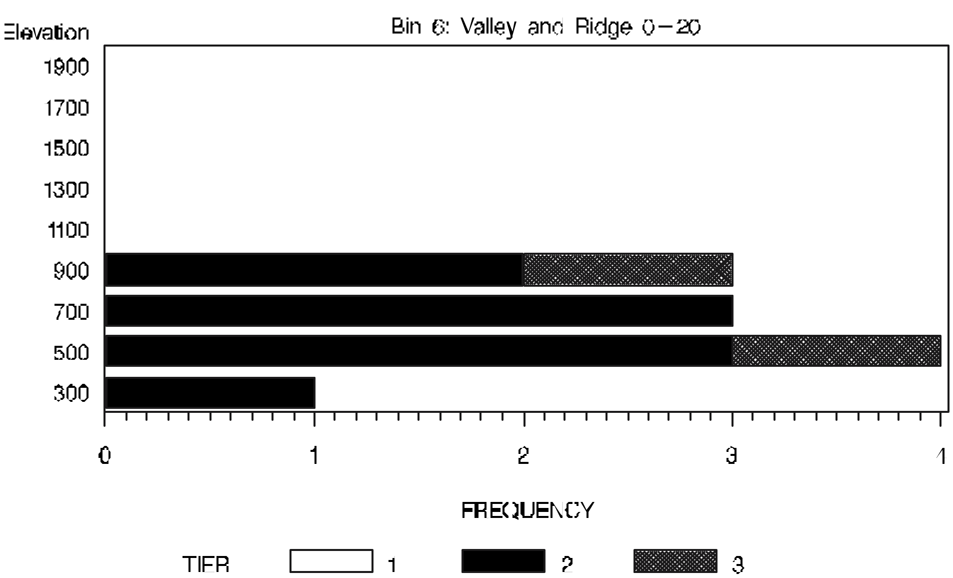




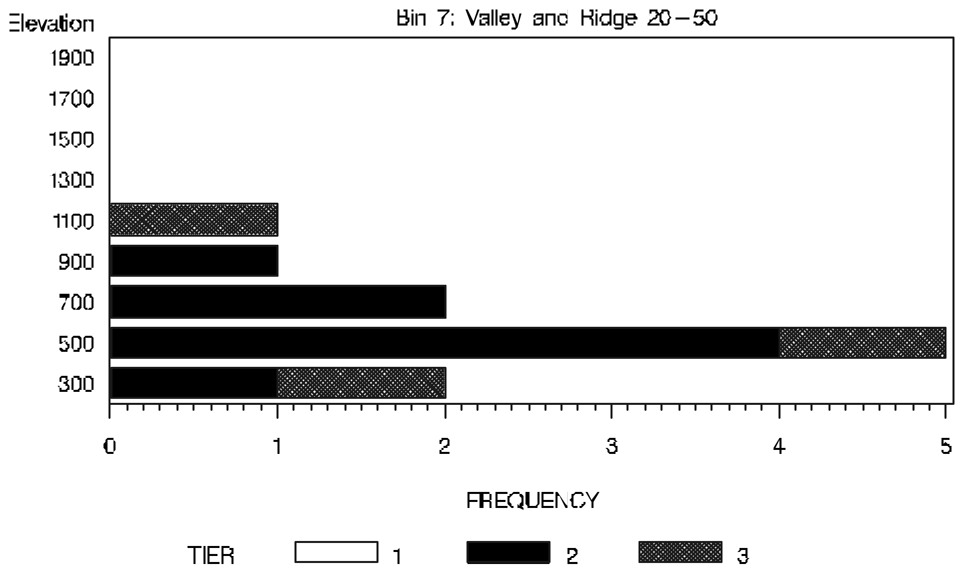
Elev - Regional

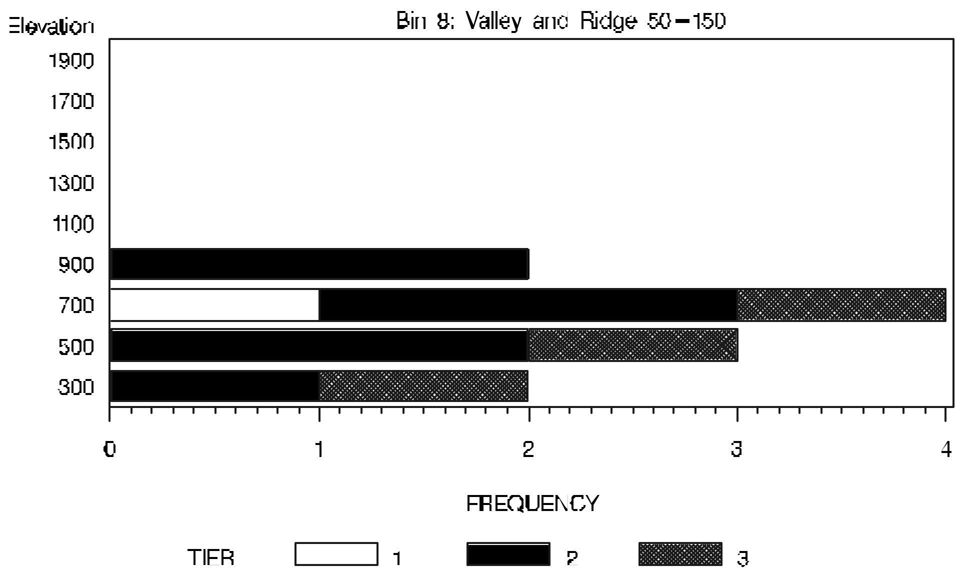


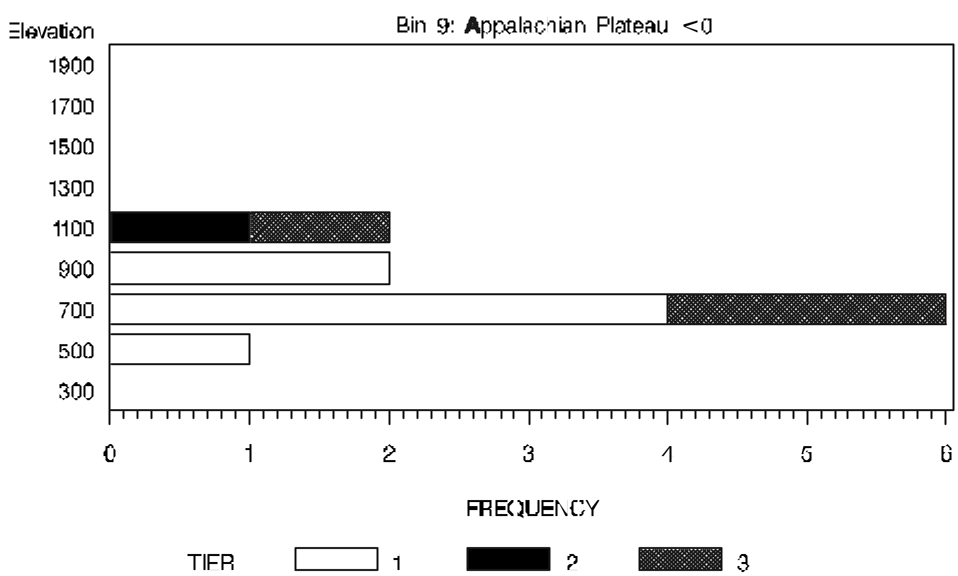




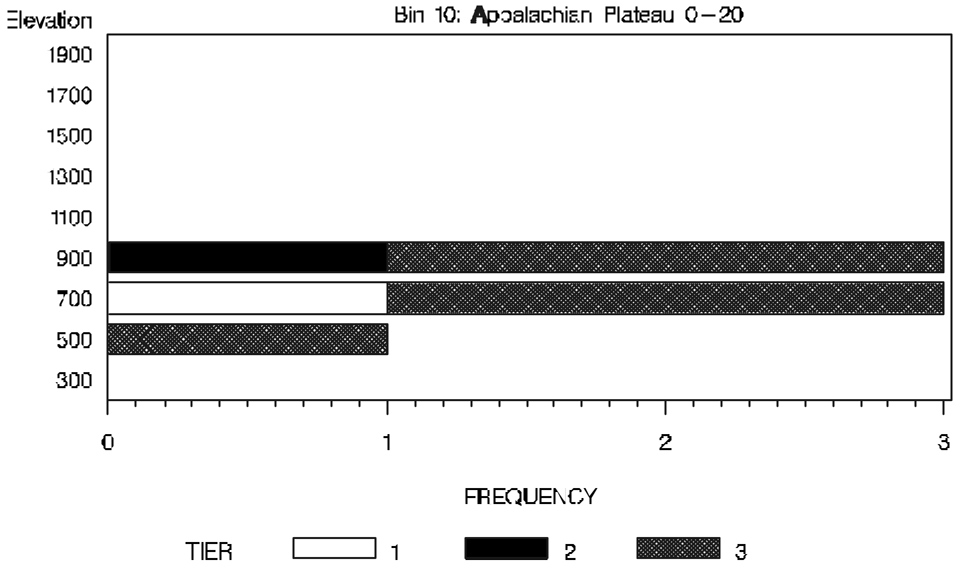
Elev - Regional

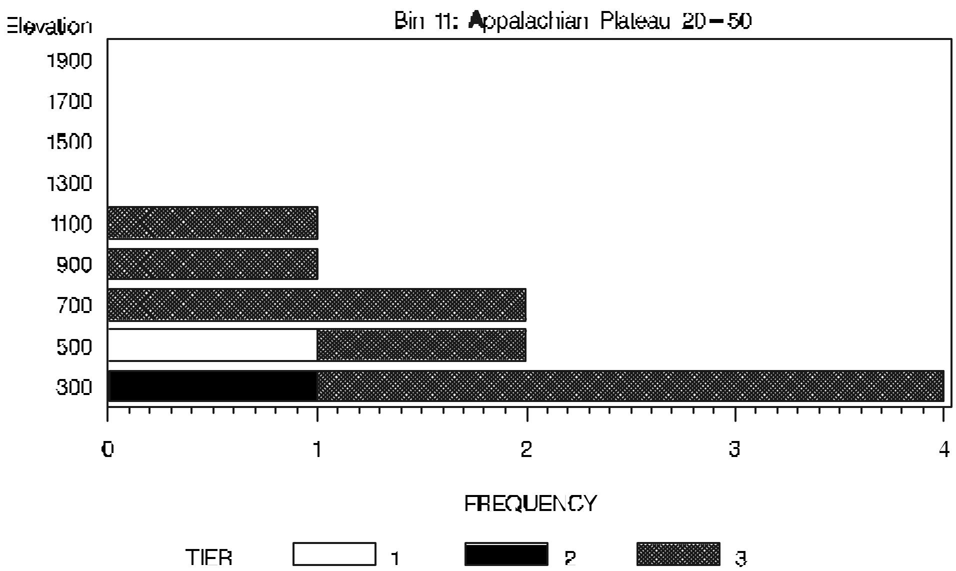


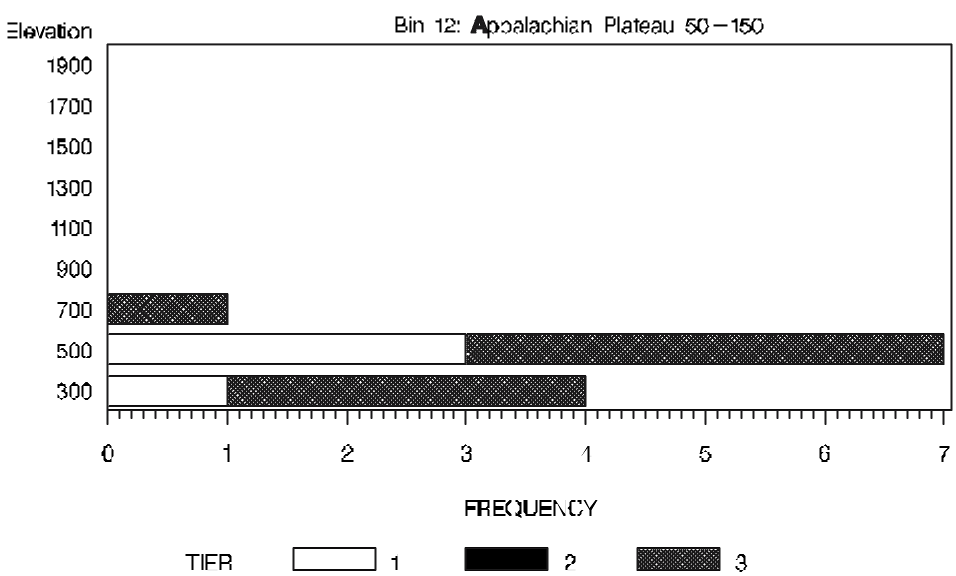




Elev - Regional







APPENDIX E

SITES SELECTED FOR REGIONAL MAGIC MODELING

Table E-1. Sites selected for regional modeling.

Site ID	Tier	ANC (μeq/L) Titrated	ANC (μeq/L) Calculated	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Elevation (m)	Primary Reason Selected[1]
BIN BR ≤ 0							
VT39	2	-8.6	-7.3	55	0.1	561	A
VT68	2	-8.2	-6.9	54	0.1	725	A
VT72	2	-9.3	-2.6	66	0.1	689	A
BIN BR 0-20							
GS01	1	6.4	7.5	41	42.6	1740	B
GS02	1	17.1	16.4	28	37.2	1800	B
VT76	1	8.7	14.0	51	0.3	317	B,D
VT36	2	-1.0	0.8	89	0.1	451	E,D,F
VT41	2	5.8	9.4	64	0.1	530	C,E
VT53	2	10.0	18.1	99	0.2	372	D,F
VT74	2	1.3	5.4	59	0.1	579	C,E
BJ 35	3	-2.1	10.0	48	95.8	1420	C,H
BJ 72	3	5.4	15.5	34	5.5	1717	C
2B058015U	3	9.5	12.7	74	0.1	500	E
VT70	2	13.1	17.8	46	0.1	677	E
VT35	2	2.2	5.3	111	22.4	424	C,D,E,F,H
BIN BR 20-50							
2A07811	1	16.2	26.2	44	39.4	549	B,D
2A07817	1	30.4	42.7	24	20.8	732	B
CO01	1	37.7	22.2	24	1.9	707	B
CO05	1	43.6	42.8	77	4.6	390	B
CO10	1	62.4	48.8	83	3.1	472	B
GS05	1	27.9	42.8	20	0.3	1248	B
GS07	1	21.2	24.5	25	26.6	1800	B
GS08	1	31.2	34.2	17	24.1	1500	B
VT02	1	24.3	30.2	43	50.6	1103	B
M037	2	26.1	31.1	69	0.3	427	C,D
VT73	2	16.6	22.9	74	0.3	628	C,F
WOR	2	21.1	28.4	83	5.5	451	D
BIN BR 50-150							
2A07701	1	89.3	106.1	27	13.0	610	B
2A07805	1	98.8	103.0	41	24.8	436	B
2A07806	1	104.4	118.8	29	16.2	671	B
2A07812	1	102.7	114.1	23	3.7	884	B,D
2A07816	1	56.5	56.4	20	7.6	579	B,D
2A07821	1	126.5	126.6	17	7.6	552	B

Table E-1. Continued.

Site ID	Tier	ANC (μeq/L)		SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Elevation (m)	Primary Reason Selected[1]
		Titrated	Calculated				
2A07823	1	102.5	119.9	66	3.4	549	B
2A07828	1	48.2	57.7	18	4.3	960	B
2A07829	1	64.8	65.8	15	9.8	689	B
2A07834	1	43.2	52.5	17	2.9	838	B
2A07835	1	96.3	101.9	25	1.5	329	B
2A07882	1	106.5	100.4	22	15.5	936	B
2A08802	1	87.8	100.9	15	6.2	506	B
2A08804	1	58.6	60.9	23	3.2	567	B
2A08805	1	118.2	123.5	33	7.0	488	B,D
2A08810	1	138.0	143.6	21	14.8	448	B
2A08901	1	120.5	124.2	17	6.7	596	B
CO06	1	56.6	65.6	20	0.7	427	B
GS04	1	69.3	67.2	76	41.9	1600	B
GS06	1	77.9	94.5	40	3.9	570	B
LB01	1	45.0	54.1	106	1.0	900	B
NFDR	1	67.1	77.1	99	28.5	488	B,D,H
VT05	2	66.9	77.1	37	0.4	835	C
VT46	2	71.7	83.9	39	3.6	506	C
VT48	2	46.1	56.9	57	0.3	658	C
VT59	2	79.6	96.2	44	5.0	308	C,D
BIN RV ≤ 0							
VT26	2	-4.7	0.0	92	0.9	725	A
VT50	2	-18.1	-36.3	141	10.1	524	A
VT78	2	-8.1	-7.9	56	5.3	799	A
2B041049U	3	-24.0	-63.8	229	0.2	378	A
BIN RV 0-20							
VT07	2	-5.5	3.9	82	13.5	930	H
VT09	2	5.9	15.0	69	3.1	664	C,E
VT25	2	5.2	12.2	41	0.1	561	C,E
VT28	2	0.7	12.1	41	0.1	835	C,E
VT49	2	5.9	10.0	123	2.8	466	C,E
VT56	2	-0.5	5.8	77	0.5	594	C,E
VA524S	3	7.0	8.9	120	4.6	914	E,H
VT29	2	-0.5	10.3	34	0.8	707	E,F,G
VT31	2	-4.6	0.5	41	0.1	735	E
VT32	2	-1.3	5.5	76	13.9	942	E,G,H
2B047076L	3	5	9.5	109	0.2	354	C

Table E-1. Continued.

Site ID	Tier	ANC (μeq/L) Titrated	ANC (μeq/L) Calculated	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Elevation (m)	Primary Reason Selected[1]
BIN RV 20-50							
VT08	2	6.7	22.7	78	9.6	930	C,E,H
VT10	2	23.1	29.9	46	0.1	725	C,E
VT11	2	26.7	38.3	35	2.1	619	C,E
VT24	2	23.9	32.5	53	0.6	567	F
VT34	2	39.9	49.3	70	0.1	387	E
VT37	2	23.6	37.1	73	3.7	811	C,E
VT57	2	22.6	33.1	113	7.6	524	H
2A068015U	3	40.3	35.4	26	16.5	1048	C,E,F,G,H
VA548S	3	24.3	29.6	117	5.7	445	E,G
VA555S	3	31.3	29.7	43	0.4	694	E
VT15	2	20.9	37.9	31	0.3	604	E
BIN RV 50-150							
2B047032	1	93.5	78.4	124	36.3	823	B
VT12	2	119.9	137.4	32	1.8	619	C,E,F
VT18	2	48.5	63.7	80	15.9	957	C,E
VT19	2	44.3	64.5	70	31.2	957	C
VT20	2	107.4	114.6	84	0.1	335	C,E,G
VT38	2	62.0	74.1	129	0.6	707	C,E
VT54	2	46.0	55.6	130	12.4	762	C,E
VT55	2	90.9	102.2	164	17.8	646	C,E,H
2B041020L	3	105.8	102.8	369	4.2	168	C,F,G
2B047044U	3	126.8	127.1	96	11.3	899	E,H
VA821S	3	128.0	115.6	163	0.0	591	C,F
BIN AP $\leq$ 0							
2C041051	1	-9.6	-16.8	162	2.5	558	B
2C046033	1	6.2	-6.5	85	39.9	704	B
2C046034	1	4.6	-9.5	110	34.3	879	B
DS04	1	-58.9	-53.8	117	6.7	932	B
FN3	1	9.0	-0.6	105	51.8	744	B
OC02	1	-25.2	-57.0	123	19.2	923	B
OC09	1	-85.4	-89.7	118	0.7	853	B
DS09	2	-41.5	-41.9	105	2.8	1115	D,E
WV523S	3	-13.0	-41.2	95	26.7	1170	G
WV785S	3	-7.0	-20.7	164	0.0	847	C
WV548S	3	-6.6	-7.3	108	31.1	768	E,H
2C066027U	3	-9.9	-9.5	58	0.3	489	C

Table E-1. Continued.

Site ID	Tier	ANC (μeq/L) Titrated	ANC (μeq/L) Calculated	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Elevation (m)	Primary Reason Selected[1]
BIN AP 0-20							
2C057004	1	16.0	11.0	169	6.9	721	A
OC79	2	10.7	17.9	74	23.2	950	A
2C041033U	3	22.1	12.1	159	41.1	671	A
2C046043L	3	12.3	9.4	141	29.7	937	A
2C047010L	3	27.7	20.0	74	52.9	920	A
WV531S	3	0.3	3.2	120	8.0	847	A,D
WV788S	3	9.1	7.0	96	15.7	857	A
BIN AP 20-50							
2C041040	1	48.5	35.3	184	42.8	658	A
2C046053L	3	46.5	37.9	138	26.1	823	A
2C047010U	3	33.7	22.8	73	54.5	969	A
2C066026L	3	28.8	30.4	71	11.9	488	A
2C066027L	3	26.0	25.5	57	3.0	454	A
2C077022U	3	51.7	42.7	51	2.4	555	A
WV769S	3	35.6	33.0	170	19.5	719	A
WV796S	3	34.0	36.9	85	0.0	1127	A
SP39	2	50.0	31.3	75	0.0	250	A
BIN AP 50-150							
2C041039	1	76.3	63.7	174	33.1	576	B
2C041045	1	144.0	140.3	154	27.1	485	B
2C046050	1	86.8	59.9	140	15.4	603	B
2C047007	1	91.9	76.6	223	13.4	607	B
2C041043U	3	110.7	102.6	209	33.2	671	E
2C046013L	3	76.2	73.7	137	28.4	448	E
2C046062L	3	124.6	129.5	234	26.7	866	E
2C066039L	3	49.4	53.3	72	4.2	527	C,H
VA526S	3	132.0	130.8	123	1.3	463	H
WV770S	3	95.0	94.8	208	12.2	621	E
WV771S	3	152.0	141.2	171	17.5	469	E
WV547S	3	69.7	55.8	200	22.8	650	E

[1] Primary reasons sites were selected:

- A All candidates were selected
- B Site was Tier I
- C Location along longitudinal axis of SAMI domain
- D Location in Class I area
- E Position along ANC distribution
- F Position along SO_4^{2-} distribution
- G Position along elevation distribution
- H Position along NO_3^- distribution

APPENDIX F

SPECIAL INTEREST SITES SELECTED FOR MAGIC MODELING

Table F-1. Special interest watersheds for MAGIC modeling.

Site ID	Site Name	Location	ANC		SO_4^{2-} (µeq/L)	NO_3^- (µeq/L)	Elevation (m)
			Titrated	Calculated			
DS50	Unnamed	Dolly Sods WA	-29.9	-14.6	73	3.6	1097
DS19	Fisher Spring Run	Dolly Sods WA	-20.8	-17.9	97	5.5	1011
DS06	Stonecoal Run (left branch)	Dolly Sods WA	-66.2	-63	112	6.6	1127
FN1	WS10	Fernow	16	-1.3	195	7.7	713
FN2	WS13	Fernow	17.5	-4.7	157	29.5	695
2A07810L	Little River	Great Smoky Mtns. NP	68	73	36	16.8	433
M039	Little Hellgate Creek	James River Face WA	19.4	23.8	42	0.3	317
M038	Big Hellgate Creek	James River Face WA	23.7	30.7	76	0.3	317
VT77	Matts Creek	James River Face WA	44.3	51.4	57	0	412
OC08	Unnamed	Otter Creek WA	-44.8	-74.1	129	2.1	871
OC32	Moores Run	Otter Creek WA	-62.3	-75.6	124	2.7	798
OC35	Coal Run	Otter Creek WA	-38.8	-55.7	158	2.1	688
OC31	Possession Camp Run	Otter Creek WA	-94.7	-109.6	148	1.3	798
OC05	Yellow Creek	Otter Creek WA	-85.3	-82.8	123	1.8	911
VT62	Hazel Run	Shenandoah NP	84.1	105.5	39	4.3	329
VA531S	Ragged Run	Shenandoah NP	65.5	67.8	48	20.3	505
VT66	Rose River	Shenandoah NP	131.7	148.3	53	31.8	341
VT58	Brokenback Run	Shenandoah NP	76.3	90	40	6.8	329
VT75	White Oak Canyon R	Shenandoah NP	122	140.7	53	33.2	354
SP10	Un-named Trib btwn 8 and 9	Sipsey WA	79.9	49.3	94	1.8	186
SP41	Quillan Creek	Sipsey WA	99.9	102.1	70	6	183
BJ76	CDB	Shining Rock WA	37.4	48.5	26	6.9	971
BJ77	BEFPR	Shining Rock WA	31.1	42.7	23	3.2	971

APPENDIX G

DEPOSITION ESTIMATES FOR FUTURE PROJECTIONS BASED ON THE SAMI STRATEGIES

G.1 Introduction

The responses of the SAMI sites to changes in future deposition were assessed by simulating site response to three future deposition patterns based on three emissions control strategies. The strategies (described in the body of this report) were designated as On-The-Way (OTW), Bold-With-Constraints (BWC), and Beyond Bold (BYB). OTW is the reference strategy that represents SAMI's best estimates for acidic deposition controls that have been promulgated and are relatively certain. BWC and BYB assume progressively larger emissions reductions.

This appendix contains tables of deposition-related variables for each site in the SAMI analysis. In these tables, each site is identified by a unique ID number assigned for the SAMI project. Table G-1 gives this same SAMI ID number along with the full name, location, and SAMI landscape classification group (bin number) for each site as a reference aid.

G.2 Implementation of Future Strategies

For each strategy simulation, the deposition in future years is specified as a fraction of the deposition in the reference year 1995. For the strategy simulations, the deposition changes have a spatial component and different sequences of future changes are used for different SAMI sites.

G.2.1 Changes in S and N

The atmospheric modelling subcontractor specified percentage changes (relative to the 1995 Reference Year values) in **total deposition** of S, oxidized N and Reduced N for the years 2010 and 2040, for each of the three strategies. It was assumed that the changes in deposition were linear between 1995 and 2010, and between 2010 and 2040. The percentage changes in S were applied to SO_4 deposition, the changes in oxidized N were applied to NO_3 deposition, and the changes in reduced N were applied to NH_4 deposition. The relative changes simulated are changes in total deposition. These are implemented in MAGIC by assuming that wet, dry and occult deposition all change by the same relative amount. These percent changes in total deposition were the revised strategy changes provided in October of 2001.

The percentage changes from the atmospheric models for each scenario and each SAMI site are given in Tables G-2, G-3 and G-4. These percent changes were applied to the 1995 Reference Year total deposition for each SAMI site to produce the future deposition in 2010 and 2040 for each site and each scenario (Tables G-5, G-6, and G-7). The distributions of the percentage changes across all SAMI sites is presented for all three strategies in Figures G-1, G-2, and G-3). The distributions of the total deposition across all SAMI sites is presented for the Reference Year, 1995 in Figure G-4, and the final year, 2040, of all three strategies in Figures G-5, G-6, and G-7.

G.2.2 Changes in Base Cations

The atmospheric modelling subcontractor also specified percentage changes in deposition of some base cations. These changes were specified as percent changes in wet deposition and separate percent changes in dry deposition, for the years 2010 and 2040, for each of the three strategies. It was assumed that the changes in deposition were linear between 1995 and 2010, and between 2010 and 2040. These percent changes were provided in June of 2001, and were not subsequently modified (as were the changes in S, reduce N and oxidized N).

These percent changes were very small compared to the percent changes in S, reduced N, and oxidized N, and are thus not plotted as distributions in this appendix. The percent changes in total deposition (resulting from the individual changes in wet and dry plus occult) are tabulated in Tables G-2, G-3, and G-4.

Table G-1. Names, locations, and ID's of SAMI sites. The SAMI ID is a unique identifier assigned to each site. This ID is used in other tables in this appendix without the name and location data. Elevations are in meters. The "Bin Number" identifies the landscape classification unit to which each site belongs (all sites used in the regional analysis have a non-zero bin number, special interest sites have bin number zero). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
GRASSES CREEK-DRY BRANCH	2A068015U	36.701	81.622	1048	VA	7	regional
Sugar Cove Branch Of N. River	2A07701	35.320	84.100	610	TN	4	regional
Cosby Creek	2A07805	35.790	83.240	436	TN	4	regional
Roaring Fork	2A07806	35.820	82.890	670	NC	4	regional
LITTLE RIVER	2A07810L	35.670	83.677	433	TN	0	special
LITTLE RIVER	2A07810U	35.628	83.541	811	TN	0	special
False Gap Prong	2A07811	35.700	83.380	549	TN	3	regional
Correll Branch	2A07812	35.680	83.090	884	NC	4	regional
Eagle Creek	2A07816	35.500	83.760	579	NC	4	regional
Forney Creek	2A07817	35.510	83.560	732	NC	3	regional
Grassy Creek	2A07821	35.460	82.280	552	NC	4	regional
Brush Creek	2A07823	35.320	83.520	549	NC	4	regional
Whiteoak Creek	2A07828	35.230	83.620	960	NC	4	regional
Catheys Creek	2A07829	35.210	82.790	689	NC	4	regional
Brush Creek	2A07834	35.110	83.260	838	NC	4	regional
Middle Saluda River	2A07835	35.120	82.540	329	SC	4	regional
Little Branch Creek	2A07882	35.450	83.060	936	NC	4	regional
Dunn Mill Creek	2A08802	34.950	84.440	506	GA	4	regional
Bear Creek	2A08804	34.820	84.570	567	GA	4	regional
Weaver Creek	2A08805	34.870	84.300	488	GA	4	regional
Bryant Creek	2A08810	34.610	84.000	448	GA	4	regional
Persimmon Creek	2A08901	34.910	83.500	596	GA	4	regional
SPRIGS HOLLOW	2B041020L	39.562	78.424	168	WV	8	regional
NO NAME	2B041049U	39.110	78.441	378	VA	5	regional
Elk Run	2B047032	38.632	79.586	823	WV	8	regional
STRAIGHT FORK	2B047044U	38.498	79.611	899	VA	8	regional
LOWER LEWIS RUN	2B047076L	38.305	78.746	354	VA	0	special
LOWER LEWIS RUN	2B047076U	38.285	78.719	543	VA	6	regional
WHITES RUN	2B058015U	37.780	79.291	500	VA	2	regional
NO NAME	2C041033U	39.363	79.735	671	WV	10	regional
Buffalo Creek	2C041039	39.261	79.755	576	WV	12	regional
Thunderstruck Creek	2C041040	39.249	79.601	658	WV	11	regional
NO NAME	2C041043U	39.238	79.167	671	WV	12	regional
Right Fork Clover Run	2C041045	39.148	79.715	485	WV	12	regional
Coal Run	2C041051	39.040	79.616	558	WV	9	regional
RIGHT FORK HOLLY RIVER	2C046013L	38.569	80.418	448	WV	12	regional
Johnson Run	2C046033	38.347	80.408	704	WV	9	regional
Hateful Run	2C046034	38.351	80.259	879	WV	9	regional
NORTH FORK CHERRY RIVER	2C046043L	38.231	80.416	937	WV	10	regional
NORTH FORK CHERRY RIVER	2C046043U	38.233	80.407	954	WV	0	special
Hedricks Creek	2C046050	38.125	80.982	603	WV	12	regional

Table G-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
LAUREL CREEK	2C046053L	38.129	80.553	823	WV	11	regional
LITTLE CLEAR CREEK	2C046062L	37.998	80.569	866	WV	12	regional
Crawford Run	2C047007	38.759	79.923	607	WV	12	regional
CLUBHOUSE RUN	2C047010L	38.632	79.760	920	WV	10	regional
CLUBHOUSE RUN	2C047010U	38.630	79.745	969	WV	11	regional
Butler Branch	2C057004	37.956	80.943	721	WV	10	regional
JOHNSON MILL BRANCH	2C066026L	36.247	85.038	488	TN	11	regional
NO NAME	2C066027L	36.270	84.865	454	TN	11	regional
NO NAME	2C066027U	36.245	84.872	489	TN	9	regional
WALLACE BRANCH	2C066039L	36.002	85.005	527	TN	12	regional
GLADY FORK	2C077022U	35.525	85.475	555	TN	11	regional
1306	BJ35	36.118	82.084	1420	TN	2	regional
M_S3_N2_2	BJ72	35.331	82.672	1717	NC	2	regional
CDB	BJ76	35.358	83.383	971	NC	0	special
BEFPR	BJ77	35.368	82.935	971	NC	0	special
Belfast Creek	BLFC	37.580	79.467	317	VA	0	special
Un-named eastern Trib	CO01	34.876	84.600	707	GA	3	regional
Hickory Creek	CO05	34.940	84.648	390	GA	3	regional
Bear Brook	CO06	34.921	84.532	427	GA	4	regional
Beech Creek	CO10	34.979	84.566	472	GA	3	regional
Deep Run	DR	38.266	78.743	415	VA	0	special
Deep Run	DR01	38.266	78.743	415	VA	6	regional
Little Stonecoal Run	DS04	38.991	79.396	932	WV	9	regional
Stonecoal Run (left branch)	DS06	39.002	79.388	1127	WV	0	special
Stonecoal Run (right branch)	DS09	39.007	79.383	1115	WV	9	regional
Fisher Spring Run	DS19	39.002	79.360	1011	WV	0	special
Unnamed	DS50	39.026	79.363	1097	WV	0	special
Fernow - WS10	FN1	39.064	79.681	713	WV	0	special
Fernow - WS13	FN2	39.063	79.679	695	WV	0	special
Fernow - WS4	FN3	39.056	79.688	744	WV	9	regional
GSMNP Noland Creek - NE fork	GS01	35.565	83.480	1740	NC	2	regional
GSMNP Noland Creek - NW fork	GS02	35.564	83.480	1800	NC	2	regional
GSMNP Deep Creek	GS04	35.608	83.442	1600	NC	4	regional
GSMNP Jay Bird Branch	GS05	35.680	83.597	1248	TN	3	regional
GSMNP LeConte Creek	GS06	35.687	83.503	570	TN	4	regional
GSMNP Raven Fork	GS07	35.610	83.254	1800	NC	3	regional
GSMNP Enloe Creek	GS08	35.614	83.270	1500	NC	3	regional
Laurel Branch Downstream	LB01	35.339	84.083	900	TN	4	regional
Lewis Fork	LEWF	36.671	81.525	1103	VA	0	special
Sulphur Spring Creek	M037	37.577	79.438	427	VA	3	regional
Big Hellcat Creek	M038	37.611	79.451	317	VA	0	special
Little Hellgate Creek	M039	37.603	79.465	317	VA	0	special
North Fork of Dry Run	NFD	38.623	78.355	488	VA	0	special
North Fork of Dry Run	NFDR	38.623	78.355	488	VA	4	regional
Condon Run	OC02	38.942	79.670	923	WV	9	regional

Table G-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
Yellow Creek	OC05	38.953	79.664	911	WV	0	special
Unnamed	OC08	38.980	79.639	871	WV	0	special
Devils Gulch	OC09	38.983	79.643	853	WV	9	regional
Possession Camp Run	OC31	39.000	79.645	798	WV	0	special
Moores Run	OC32	39.000	79.646	798	WV	0	special
Coal Run	OC35	39.033	79.620	688	WV	0	special
Otter Creek (upper)	OC79	38.938	79.660	950	WV	10	regional
Paine Run	PAIN	38.201	78.769	424	VA	0	special
Un-named Trib between 8 and 9	SP10	34.298	87.429	186	AL	0	special
Un-named Trib above 38	SP39	34.369	87.438	250	AL	11	regional
Quillan Creek	SP41	34.317	87.481	183	AL	0	special
Staunton River	STAN	38.457	78.399	308	VA	0	special
NONAME TRIB STONY CR.	VA524S	37.423	80.630	914	VA	6	regional
BEARPEN BRANCH	VA526S	37.201	82.486	463	VA	12	regional
RAGGED RUN	VA531S	38.537	78.306	505	VA	0	special
NONAME TRIB GAP CR	VA548S	38.699	78.596	445	VA	7	regional
LITTLE MILL CR	VA555S	38.080	79.499	694	VA	7	regional
LITTLE WALKER CR	VA821S	37.148	80.823	591	VA	8	regional
Lewis Fork	VT02	36.671	81.525	1103	VA	3	regional
Raccoon Branch	VT05	36.739	81.449	835	VA	4	regional
Cove Branch	VT07	37.072	81.433	930	VA	6	regional
Roaring Fork-Upper	VT08	37.064	81.418	930	VA	7	regional
Roaring Fork-Lower	VT09	37.055	81.458	664	VA	6	regional
Laurel Run	VT10	38.176	79.679	725	VA	7	regional
Mare Run	VT11	38.013	79.786	619	VA	7	regional
Panther Run	VT12	38.007	79.775	619	VA	8	regional
Porters Creek	VT15	37.979	79.787	604	VA	7	regional
Bearwallow Run	VT18	38.547	79.655	957	VA	8	regional
Lost Run	VT19	38.549	79.644	957	VA	8	regional
Hipes Branch	VT20	37.679	79.941	335	VA	8	regional
Shawvers Run	VT24	37.600	80.175	567	VA	7	regional
Cove Branch	VT25	37.584	80.161	561	VA	6	regional
Pine Swamp Branch	VT26	37.430	80.613	725	VA	5	regional
Nf Stony Creek	VT28	37.460	80.546	835	VA	6	regional
War Spur Branch	VT29	37.395	80.493	707	VA	6	regional
Nobusiness Creek	VT31	37.255	80.875	735	VA	5	regional
Laurel Creek	VT32	37.378	80.603	942	VA	6	regional
Laurel Run	VT34	37.916	79.472	387	VA	7	regional
Paine Run	VT35	38.201	78.769	424	VA	6	regional
Meadow Run	VT36	38.170	78.785	451	VA	1	regional
North River	VT37	38.421	79.266	811	VA	7	regional
Ramseys Draft	VT38	38.346	79.332	707	VA	8	regional
Kennedy Creek	VT39	37.946	79.034	561	VA	1	regional
St Marys R-Lower	VT41	37.928	79.092	530	VA	0	special
Little Cove Creek	VT46	37.738	79.211	506	VA	4	regional

Table G-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
Big Mack Creek	VT48	36.946	80.635	658	VA	4	regional
Little Stony Creek	VT49	38.958	78.627	466	VA	6	regional
Laurel Run	VT50	38.918	78.729	524	VA	5	regional
Two Mile Run	VT53	38.319	78.655	372	VA	2	regional
German River-Upper	VT54	38.674	79.078	762	VA	8	regional
Beech Lick Run	VT55	38.703	79.023	646	VA	8	regional
Wolf Run	VT56	38.438	79.169	594	VA	6	regional
Black Run-Lower	VT57	38.512	79.110	524	VA	7	regional
Brokenback Run	VT58	38.570	78.330	329	VA	0	special
Staunton River	VT59	38.457	78.399	308	VA	4	regional
Hazel Run	VT62	38.624	78.293	329	VA	0	special
Rose River	VT66	38.522	78.402	341	VA	0	special
St Marys R-Upper	VT68	37.935	79.060	725	VA	1	regional
Bear Branch (Smr)	VT70	37.922	79.078	677	VA	2	regional
Hogback Br (Smr)	VT72	37.945	79.096	689	VA	5	regional
Sugartree Br (Smr)	VT73	37.912	79.111	628	VA	3	regional
St Marys R-Middle	VT74	37.932	79.083	579	VA	2	regional
White Oak Canyon R	VT75	38.567	78.365	354	VA	0	special
Belfast Creek	VT76	37.578	79.476	317	VA	2	regional
Matts Creek	VT77	37.588	79.433	256	VA	0	special
Little Tumbling Creek	VT78	36.957	81.738	799	VA	5	regional
White Oak Run	WOR	38.234	78.742	451	VA	0	special
White Oak Run	WOR1	38.234	78.742	451	VA	7	regional
NONAME TRIB STONY	WV523S	39.152	79.323	1170	WV	9	regional
OTTER CR	WV531S	39.011	79.646	847	WV	10	regional
GAULEY	WV547S	38.399	80.493	650	WV	12	regional
NONAME TRIB SOUTH FORK CHERRY R.	WV548S	38.214	80.479	768	WV	9	regional
NNT LAUREL RUN	WV769S	38.879	79.956	719	WV	11	regional
MOSS RUN	WV770S	38.715	79.961	621	WV	12	regional
LEFT FORK CLOVER RUN	WV771S	39.163	79.713	469	WV	12	regional
NNT GLADE CR	WV785S	37.714	81.047	847	WV	9	regional
WHITE OAK FORK	WV788S	38.357	80.383	857	WV	10	regional
RED CR	WV796S	39.039	79.337	1127	WV	11	regional

Table G-2. The percentage changes in total deposition of S, reduced N, oxidized N, and base cations (relative to the Reference Year, 1995), for each SAMI site for the OTW strategy. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Year 2010							Year 2040						
	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K
Average	-27.8	-24.7	13.5	0.1	3.8	0.6	0.9	-54.6	-22.2	28.9	0.1	10.0	2.3	2.2
Std. Dev.	13.3	8.9	5.6	0.1	0.9	1.0	0.9	11.3	9.4	12.8	0.2	2.0	1.2	1.2
Maximum	-2.4	-8.1	27.6	0.3	8.4	2.7	6.6	-21.7	-5.1	64.8	0.5	18.9	5.0	7.9
Minimum	-62.7	-43.6	3.1	-0.1	1.7	-0.9	0.0	-76.5	-44.3	6.5	-0.4	5.4	0.2	0.1

	Year 2010							Year 2040						
Site ID	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K
2A068015U	-24.9	-15.3	6.3	0.1	4.7	1.4	1.3	-55.2	-14.2	14.1	-0.2	11.7	2.9	2.9
2A07701	-10.0	-11.8	10.9	0.1	4.3	2.6	1.5	-38.5	-9.4	21.1	-0.2	11.0	4.5	3.0
2A07805	-16.8	-15.6	8.8	0.1	4.6	2.6	1.2	-46.0	-13.7	14.8	-0.1	11.1	3.6	2.7
2A07806	-14.0	-16.1	12.9	0.0	4.4	2.2	1.2	-46.1	-13.3	22.6	-0.1	11.4	4.1	2.7
2A07810L	-11.8	-12.5	9.2	0.1	8.4	2.5	1.3	-39.8	-10.1	16.2	-0.1	14.6	3.6	2.7
2A07810U	-11.5	-12.2	8.1	0.1	5.4	2.0	1.2	-38.8	-9.2	14.9	-0.1	12.4	2.7	2.5
2A07811	-15.0	-12.9	10.0	0.1	4.8	2.2	1.2	-42.0	-10.7	18.4	-0.1	11.4	3.0	2.5
2A07812	-11.6	-12.9	11.0	0.1	4.5	2.3	1.2	-40.5	-9.7	20.6	0.0	11.4	3.5	2.5
2A07816	-14.2	-10.0	6.9	0.1	5.9	2.0	1.3	-41.7	-7.9	12.2	-0.1	12.4	3.5	2.6
2A07817	-8.3	-11.8	9.3	0.0	5.4	2.0	1.2	-38.8	-7.5	17.3	0.0	12.7	3.5	2.6
2A07821	-6.1	-16.6	9.7	-0.1	6.1	1.8	2.5	-43.7	-14.8	23.0	-0.3	18.9	4.4	5.7
2A07823	-8.6	-11.8	14.0	0.1	4.3	2.5	1.4	-39.2	-8.9	27.0	0.0	11.4	4.1	2.8
2A07828	-5.0	-11.8	10.1	0.1	3.8	2.7	1.4	-33.7	-9.1	19.4	-0.2	10.5	4.6	2.9
2A07829	-4.1	-11.2	7.2	0.0	3.8	2.0	2.2	-34.4	-7.3	12.5	-0.3	11.3	4.2	3.7
2A07834	-2.4	-11.7	11.4	0.0	3.7	2.4	1.2	-31.2	-8.6	20.3	-0.2	10.8	4.3	2.6
2A07835	-3.8	-12.0	11.8	-0.1	4.2	1.3	2.9	-36.8	-9.1	24.8	-0.4	14.9	4.5	5.8
2A07882	-8.8	-8.5	7.8	0.0	4.1	2.6	1.6	-36.4	-5.1	14.1	-0.2	11.5	4.5	3.2
2A08802	-7.5	-15.1	18.0	0.1	4.2	2.1	0.9	-39.4	-15.0	33.2	-0.3	11.6	4.4	2.6
2A08804	-7.8	-14.4	16.7	0.1	3.9	2.1	0.7	-39.6	-15.3	33.7	-0.3	11.7	4.7	2.5
2A08805	-4.0	-10.9	14.6	0.1	3.7	1.9	1.2	-34.9	-11.2	26.3	-0.2	10.6	4.4	3.0
2A08810	-2.5	-15.1	19.2	0.2	4.1	2.1	0.8	-35.9	-14.1	35.2	-0.1	11.8	4.4	2.7
2A08901	-3.1	-13.1	15.5	0.1	4.0	2.4	0.6	-33.2	-10.5	30.0	-0.1	11.6	5.0	2.1
2B041020L	-44.3	-38.4	25.8	0.2	2.6	0.9	0.6	-67.6	-38.1	64.8	0.4	8.3	2.2	2.0
2B041049U	-51.8	-38.6	27.6	0.3	3.4	1.0	0.8	-71.6	-38.3	63.6	0.5	10.1	2.8	2.4
2B047032	-39.1	-37.3	18.6	0.0	3.7	-0.3	0.6	-64.6	-36.0	45.7	0.2	8.9	1.5	1.5
2B047044U	-36.5	-33.8	14.7	0.0	3.6	-0.2	0.6	-63.2	-30.0	34.1	0.2	8.9	1.7	1.6
2B047076L	-29.3	-24.3	16.9	0.0	3.9	-0.5	0.9	-56.7	-19.4	37.6	0.0	11.8	2.6	3.6
2B047076U	-29.3	-24.3	17.0	0.0	3.9	-0.5	0.9	-56.7	-19.4	37.7	0.0	11.9	2.6	3.7
2B058015U	-24.6	-25.0	19.0	0.1	4.3	-0.7	0.9	-56.2	-18.5	38.2	0.2	11.6	1.1	2.6
2C041033U	-42.8	-37.5	12.1	0.0	3.7	1.5	0.7	-68.2	-38.5	22.5	0.0	9.4	4.1	2.0
2C041039	-44.5	-37.3	10.7	-0.1	3.6	1.2	0.7	-68.2	-37.8	21.4	0.0	9.4	3.8	1.8
2C041040	-40.9	-34.5	9.0	-0.1	3.4	1.0	0.6	-64.6	-34.6	17.1	-0.1	8.7	3.2	1.6
2C041043U	-62.7	-43.6	16.3	0.3	3.7	0.8	0.7	-74.3	-44.3	40.8	0.4	9.3	2.7	1.8
2C041045	-43.1	-35.4	8.7	0.0	3.5	0.9	0.6	-66.4	-35.4	18.0	0.0	8.8	3.1	1.7
2C041051	-40.6	-33.1	6.6	-0.1	3.1	0.4	0.5	-63.3	-32.5	15.0	0.0	8.2	2.3	1.5
2C046013L	-34.1	-32.8	3.2	-0.1	4.0	-0.1	0.7	-59.1	-30.9	6.9	-0.1	9.4	2.4	1.8
2C046033	-31.5	-30.8	5.1	-0.1	4.2	0.0	0.9	-57.9	-29.2	12.4	0.0	9.9	2.2	2.0
2C046034	-32.5	-32.5	7.6	0.0	4.2	-0.1	0.8	-58.8	-29.8	18.7	0.0	10.0	1.8	1.9
2C046043L	-32.4	-31.6	7.8	-0.1	4.3	0.0	0.9	-58.7	-29.5	18.6	0.0	9.9	1.9	2.0

Table G-2. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
2C046043U	-32.4	-31.6	7.8	-0.1	4.3	0.0	0.9	-58.8	-29.5	18.6	0.0	9.9	1.9	2.0
2C046050	-26.7	-29.5	6.3	0.0	5.5	0.6	1.3	-53.1	-28.3	6.5	0.0	11.5	3.3	2.7
2C046053L	-32.2	-31.1	7.3	0.0	4.5	0.2	1.0	-58.4	-29.3	17.8	0.1	10.2	2.4	2.2
2C046062L	-31.0	-30.8	9.9	0.0	4.5	0.4	1.1	-58.4	-27.7	24.8	0.1	10.2	2.4	2.4
2C047007	-37.6	-32.1	3.1	-0.1	3.3	-0.1	0.6	-61.5	-31.5	11.7	0.0	8.5	1.7	1.5
2C047010L	-37.0	-33.3	7.0	-0.1	3.2	-0.3	0.6	-61.2	-31.8	20.6	0.0	8.5	1.4	1.5
2C047010U	-37.0	-33.3	7.0	-0.1	3.2	-0.3	0.6	-61.2	-31.8	20.7	0.0	8.5	1.4	1.5
2C057004	-26.4	-29.9	6.4	0.0	5.7	1.1	1.5	-55.7	-30.5	11.9	0.0	12.0	3.4	3.1
2C066026L	-30.7	-19.9	21.6	0.0	4.3	2.6	2.0	-50.2	-21.2	43.2	-0.3	10.2	4.9	3.6
2C066027L	-32.5	-19.8	16.9	0.0	4.0	2.3	1.8	-51.1	-22.1	36.6	-0.3	9.7	4.5	3.3
2C066027U	-32.5	-19.8	16.9	0.0	4.0	2.3	1.8	-51.1	-22.1	36.6	-0.3	9.7	4.5	3.4
2C066039L	-30.7	-19.9	21.6	0.0	4.4	2.7	2.0	-50.2	-21.2	43.2	-0.3	10.2	5.0	3.6
2C077022U	-26.1	-17.0	18.9	0.1	3.5	2.6	2.3	-44.5	-18.6	41.0	-0.2	9.3	4.7	4.0
BJ 35	-19.1	-14.9	6.1	0.0	4.3	1.1	0.8	-50.7	-12.4	15.9	0.1	11.2	2.2	1.7
BJ 72	-3.2	-11.6	9.2	0.0	3.3	1.2	1.1	-33.9	-6.9	16.5	-0.1	10.1	2.3	2.0
BJ 76	-8.4	-12.9	12.7	0.1	4.1	1.5	0.9	-38.7	-9.4	24.4	-0.2	11.0	2.3	1.7
BJ 77	-7.2	-9.9	8.5	0.1	3.4	1.5	1.0	-36.3	-7.2	15.1	0.1	10.0	2.6	2.0
BLFC	-21.7	-24.9	17.1	0.2	3.7	-0.4	0.8	-51.8	-19.8	34.0	0.3	10.4	1.1	2.2
CO01	-7.7	-14.1	15.7	0.1	3.8	1.6	0.7	-38.8	-15.0	30.5	-0.4	11.2	4.0	2.4
CO05	-8.7	-14.5	16.9	0.1	4.1	1.6	0.7	-40.3	-14.9	32.7	-0.3	11.7	3.6	2.4
CO06	-7.7	-14.0	15.7	0.1	3.8	1.6	0.7	-38.8	-15.0	30.4	-0.4	11.3	4.0	2.4
CO10	-8.6	-14.5	16.9	0.1	4.1	1.6	0.7	-40.2	-14.9	32.6	-0.3	11.7	3.6	2.4
DR	-29.3	-24.3	16.9	0.0	3.7	-0.4	0.8	-56.7	-19.3	37.6	0.1	11.3	2.4	3.3
DR01	-29.3	-24.3	16.9	0.0	3.6	-0.4	0.7	-56.7	-19.3	37.6	0.1	10.7	2.1	2.9
DS04	-48.6	-39.1	18.0	0.3	2.5	0.0	0.1	-70.6	-38.8	46.3	0.5	6.0	0.2	0.1
DS06	-48.6	-39.1	18.0	0.3	2.5	0.0	0.1	-70.6	-38.8	46.3	0.5	6.0	0.2	0.1
DS09	-47.7	-37.8	13.8	0.3	2.3	0.0	0.1	-68.3	-38.4	33.7	0.5	5.8	0.2	0.1
DS19	-47.7	-37.8	13.8	0.3	2.3	0.0	0.1	-68.3	-38.4	33.7	0.5	5.8	0.2	0.1
DS50	-47.7	-37.8	13.8	0.3	2.3	0.0	0.1	-68.3	-38.4	33.7	0.5	5.8	0.2	0.1
FN1	-42.0	-34.5	6.7	0.0	2.5	0.3	0.3	-65.5	-33.8	14.6	0.0	6.7	1.2	0.7
FN2	-42.0	-34.5	6.7	0.0	2.5	0.3	0.3	-65.5	-33.8	14.6	0.0	6.7	1.2	0.7
FN3	-42.0	-34.4	6.7	0.0	2.5	0.3	0.3	-65.5	-33.8	14.6	0.0	6.7	1.2	0.7
GS01	-8.3	-11.8	9.3	0.0	5.1	1.5	0.9	-38.8	-7.5	17.3	0.0	12.2	2.5	1.9
GS02	-8.3	-11.8	9.3	0.0	5.1	1.5	0.9	-38.8	-7.5	17.3	0.0	12.2	2.5	1.9
GS04	-9.4	-11.2	7.9	0.1	4.7	1.5	0.8	-35.8	-8.3	14.7	0.0	11.2	2.2	1.8
GS05	-17.8	-14.4	12.1	0.0	6.6	1.6	1.1	-44.5	-14.0	22.8	-0.2	13.9	2.1	2.4
GS06	-17.2	-13.2	11.3	0.1	5.6	1.2	0.9	-43.9	-11.7	21.2	-0.1	12.1	1.7	2.0
GS07	-8.2	-11.1	8.9	0.1	4.3	1.6	0.9	-35.3	-7.6	16.5	0.0	10.9	2.3	2.0
GS08	-8.2	-11.1	8.9	0.1	4.3	1.6	0.9	-35.3	-7.6	16.5	0.0	10.8	2.3	2.0
LB01	-10.0	-11.8	10.9	0.1	4.2	2.5	1.5	-38.5	-9.4	21.1	-0.2	11.0	4.5	3.0
LEWF	-22.8	-16.8	8.7	0.2	4.9	1.0	0.9	-55.0	-15.4	20.6	0.2	12.0	2.1	2.1
M037	-23.3	-24.1	20.2	0.2	3.7	-0.4	0.8	-55.0	-16.0	33.7	0.4	10.5	1.0	2.1
M038	-24.9	-24.8	19.1	0.2	3.8	-0.5	0.7	-55.6	-16.7	36.1	0.4	10.4	0.9	1.9
M039	-21.8	-24.9	17.1	0.2	3.7	-0.5	0.8	-51.9	-19.8	34.0	0.3	10.4	1.1	2.2
NFD	-41.0	-33.2	21.8	0.2	3.7	-0.1	0.8	-64.8	-30.3	52.3	0.4	11.5	2.5	2.7
NFDR	-41.0	-33.2	21.8	0.2	3.6	-0.1	0.7	-64.8	-30.3	52.3	0.5	11.0	2.2	2.4
OC02	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
OC05	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1

Table G-2. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
OC08	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
OC09	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
OC31	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
OC32	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
OC35	-40.6	-33.1	6.6	-0.1	1.8	0.0	0.0	-63.3	-32.5	15.0	0.1	5.4	0.2	0.1
OC79	-41.5	-31.5	5.5	-0.1	1.7	0.0	0.0	-64.5	-30.2	13.2	0.1	5.4	0.2	0.1
PAIN	-28.3	-24.3	17.4	0.0	3.9	-0.7	0.8	-56.7	-18.4	37.4	0.2	11.7	1.9	3.3
SP10	-13.2	-8.2	13.2	0.1	2.6	1.3	6.6	-21.7	-9.2	28.4	-0.2	6.8	3.9	7.9
SP39	-13.2	-8.2	13.2	0.1	2.6	1.3	6.6	-21.7	-9.2	28.4	-0.2	6.8	3.8	7.9
SP41	-13.2	-8.1	13.2	0.1	2.6	1.3	6.6	-21.7	-9.2	28.4	-0.2	6.8	3.8	7.9
STAN	-36.8	-32.0	18.1	0.2	3.7	-0.2	0.8	-61.8	-27.4	41.0	0.4	11.5	2.4	2.9
VA524S	-21.0	-22.6	15.0	0.2	4.3	0.7	1.2	-55.9	-20.0	33.8	0.3	11.2	2.7	2.8
VA526S	-33.2	-20.2	16.2	0.1	5.3	2.4	1.3	-58.4	-21.1	27.9	0.1	11.1	4.5	2.6
VA531S	-41.0	-33.2	21.8	0.2	3.9	-0.2	0.8	-64.8	-30.3	52.3	0.4	12.0	2.7	3.0
VA548S	-40.1	-27.0	19.2	0.1	3.5	0.3	1.0	-62.2	-24.7	39.4	0.2	11.0	3.6	3.6
VA555S	-28.3	-26.0	13.3	0.0	3.7	-0.8	0.7	-56.9	-18.9	26.9	0.1	9.7	1.0	2.0
VA821S	-18.4	-24.3	12.7	0.1	4.3	0.8	1.1	-56.2	-21.1	30.7	0.3	11.7	2.5	2.7
VT02	-22.8	-16.8	8.7	0.2	5.0	1.1	1.0	-55.0	-15.4	20.6	0.2	12.1	2.2	2.2
VT05	-24.7	-17.7	6.2	0.2	4.6	0.9	1.0	-56.0	-16.5	16.1	0.0	11.1	2.3	2.3
VT07	-25.9	-16.4	6.8	0.3	4.4	1.0	0.9	-57.3	-16.5	14.2	0.1	10.4	2.6	2.1
VT08	-25.9	-16.4	6.8	0.3	4.4	1.0	0.9	-57.3	-16.5	14.2	0.1	10.4	2.6	2.1
VT09	-25.8	-16.4	6.8	0.3	4.4	1.0	0.9	-57.3	-16.5	14.1	0.1	10.4	2.6	2.1
VT10	-29.7	-28.5	13.6	0.1	3.3	-0.2	0.5	-58.4	-22.7	28.1	0.2	8.4	1.3	1.4
VT11	-24.9	-23.3	15.8	0.0	3.8	-0.2	0.6	-53.2	-18.7	29.0	0.0	9.3	1.1	1.7
VT12	-24.9	-23.3	15.8	0.0	3.8	-0.2	0.6	-53.2	-18.7	29.0	0.0	9.3	1.1	1.7
VT15	-24.9	-23.3	15.8	0.0	3.8	-0.2	0.6	-53.2	-18.6	28.9	0.0	9.3	1.1	1.7
VT18	-36.4	-33.7	14.6	0.0	3.3	-0.1	0.4	-63.1	-29.9	34.0	0.2	8.2	1.3	1.2
VT19	-36.5	-33.8	14.7	0.0	3.3	-0.1	0.4	-63.2	-30.0	34.0	0.2	8.2	1.3	1.2
VT20	-24.1	-25.3	14.9	0.1	4.1	-0.4	0.7	-53.1	-19.3	31.9	0.3	10.4	1.3	1.8
VT24	-22.8	-28.7	18.7	0.3	4.2	0.1	0.8	-56.5	-25.4	45.8	0.4	10.3	1.9	2.0
VT25	-22.8	-28.7	18.7	0.3	4.2	0.1	0.8	-56.5	-25.4	45.8	0.4	10.3	2.0	2.0
VT26	-21.1	-22.6	15.0	0.2	4.0	0.6	0.9	-55.9	-20.1	33.9	0.4	10.5	2.0	2.1
VT28	-21.9	-23.3	17.6	0.1	3.7	0.4	0.9	-51.7	-20.7	40.6	0.3	9.6	2.2	2.0
VT29	-21.9	-23.5	14.2	0.2	3.9	0.5	0.8	-56.6	-20.9	33.2	0.4	10.6	2.3	2.1
VT31	-22.6	-25.0	13.7	0.2	4.2	0.9	0.9	-57.9	-22.9	32.3	0.4	10.6	2.0	1.9
VT32	-21.0	-22.6	15.0	0.2	4.0	0.6	0.9	-55.9	-20.0	33.7	0.4	10.4	2.0	2.1
VT34	-26.3	-25.7	13.4	0.1	3.7	-0.9	0.6	-54.9	-18.2	30.7	0.3	9.7	0.3	1.8
VT35	-28.3	-24.3	17.4	0.0	3.7	-0.6	0.7	-56.7	-18.4	37.4	0.2	11.1	1.6	2.9
VT36	-28.3	-24.3	17.4	0.0	3.7	-0.6	0.7	-56.6	-18.4	37.4	0.2	11.1	1.7	2.9
VT37	-31.7	-29.9	14.1	0.0	3.1	-0.2	0.5	-59.3	-25.5	29.7	0.1	8.4	1.4	1.4
VT38	-29.7	-28.5	15.3	0.0	3.2	-0.2	0.5	-58.0	-22.8	31.5	0.2	8.7	1.4	1.5
VT39	-29.4	-23.6	18.2	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.9	0.3	10.3	1.1	2.2
VT41	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.8	0.3	10.2	1.1	2.1
VT46	-24.6	-25.0	19.1	0.1	4.1	-0.6	0.7	-56.2	-18.5	38.2	0.3	10.8	0.9	2.2
VT48	-19.8	-21.0	13.3	0.1	4.0	0.4	0.9	-54.2	-17.4	30.3	0.2	11.3	1.8	2.4
VT49	-48.7	-32.6	21.9	0.3	3.2	0.5	0.6	-70.0	-29.8	43.6	0.5	9.1	2.6	2.0
VT50	-50.2	-34.9	27.2	0.3	3.3	0.5	0.6	-70.9	-34.4	61.3	0.5	9.0	2.5	1.8
VT53	-32.4	-27.2	19.3	0.1	3.6	-0.2	0.8	-58.5	-22.3	43.0	0.3	11.1	2.4	3.0

Table G-2. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
VT54	-44.4	-33.7	24.5	0.2	3.1	0.0	0.6	-67.9	-32.6	55.8	0.4	8.2	1.8	1.6
VT55	-44.4	-33.7	24.5	0.2	3.1	0.0	0.6	-68.0	-32.6	55.8	0.4	8.2	1.8	1.6
VT56	-30.9	-30.9	17.5	0.0	3.2	-0.3	0.5	-59.0	-25.6	37.4	0.2	8.7	1.4	1.6
VT57	-34.1	-31.0	20.6	0.1	3.1	-0.1	0.5	-60.6	-25.8	42.0	0.2	8.7	1.6	1.7
VT58	-41.0	-33.2	21.8	0.2	3.6	-0.1	0.7	-64.8	-30.3	52.3	0.5	11.0	2.2	2.4
VT59	-36.8	-32.0	18.1	0.2	3.6	-0.2	0.7	-61.8	-27.4	41.0	0.5	11.0	2.1	2.5
VT62	-43.2	-30.8	22.8	0.2	3.3	0.1	0.7	-66.0	-28.7	54.6	0.4	10.3	2.2	2.5
VT66	-41.0	-33.2	21.8	0.2	3.6	-0.1	0.7	-64.8	-30.3	52.3	0.5	11.0	2.2	2.4
VT68	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.8	0.3	10.3	1.1	2.2
VT70	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.8	0.3	10.2	1.1	2.2
VT72	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.8	0.3	10.2	1.1	2.1
VT73	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.1	-16.9	34.8	0.3	10.2	1.1	2.1
VT74	-29.4	-23.6	18.1	0.1	3.7	-0.6	0.7	-58.2	-16.9	34.8	0.3	10.2	1.1	2.1
VT75	-41.0	-33.2	21.8	0.2	3.6	-0.1	0.7	-64.8	-30.3	52.3	0.5	11.0	2.2	2.4
VT76	-21.7	-24.9	17.1	0.2	3.8	-0.5	0.9	-51.8	-19.8	33.9	0.3	10.8	1.3	2.5
VT77	-23.3	-24.1	20.2	0.2	3.8	-0.5	0.9	-55.0	-16.0	33.7	0.3	10.9	1.2	2.4
VT78	-23.9	-18.5	9.9	0.2	4.6	1.1	1.0	-58.7	-18.7	19.3	0.0	11.1	2.9	2.4
WOR	-29.3	-24.3	16.9	0.0	3.7	-0.4	0.8	-56.7	-19.3	37.6	0.1	11.3	2.4	3.3
WOR1	-29.3	-24.3	16.9	0.0	3.6	-0.4	0.7	-56.7	-19.3	37.6	0.1	10.7	2.1	3.0
WV523S	-58.6	-42.0	18.7	0.2	3.5	0.4	0.6	-76.5	-42.9	45.2	0.3	8.9	2.5	1.6
WV531S	-41.5	-31.5	5.5	-0.1	3.1	0.3	0.5	-64.5	-30.2	13.2	0.0	8.2	2.2	1.5
WV547S	-31.4	-30.7	5.2	-0.1	4.2	0.0	0.9	-57.8	-29.1	12.4	0.0	9.9	2.2	2.0
WV548S	-32.3	-31.4	7.8	-0.1	4.2	0.0	0.9	-58.6	-29.4	18.6	0.0	9.9	2.0	2.0
WV769S	-38.8	-33.8	4.5	-0.1	3.4	0.1	0.6	-62.6	-32.9	12.5	0.0	8.7	2.1	1.5
WV770S	-37.6	-32.1	3.2	-0.1	3.3	-0.1	0.6	-61.4	-31.4	11.7	0.0	8.5	1.7	1.5
WV771S	-43.1	-35.4	8.7	0.0	3.5	0.9	0.6	-66.4	-35.4	18.0	0.0	8.9	3.1	1.7
WV785S	-27.7	-26.0	11.8	0.2	4.9	1.2	1.5	-58.2	-23.1	27.8	0.3	11.1	3.1	2.7
WV788S	-31.6	-30.8	5.1	-0.1	4.2	0.0	0.9	-57.9	-29.2	12.4	0.0	10.0	2.2	2.0
WV796S	-53.2	-41.3	20.8	0.3	3.7	0.4	0.6	-74.1	-41.6	50.1	0.4	9.0	2.5	1.6

Table G-3. The percentage changes in total deposition of S, reduced N, oxidized N, and base cations (relative to the Reference Year, 1995), for each SAMI site for the BWC strategy. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Year 2010							Year 2040						
	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K
Average	-44.1	-25.2	14.8	0.0	2.8	0.5	0.4	-64.0	-26.3	10.1	0.1	8.9	1.8	0.5
Std. Dev.	9.8	9.1	7.3	0.1	0.7	0.9	0.8	9.3	8.5	8.0	0.2	2.1	1.2	1.0
Maximum	-16.7	-8.3	30.8	0.2	8.0	2.5	5.9	-27.7	-9.7	38.0	0.6	19.1	4.6	4.9
Minimum	-68.0	-44.8	1.9	-0.3	1.6	-0.9	-1.1	-79.5	-45.2	-4.1	-0.3	5.0	-0.3	-3.0

	Year 2010							Year 2040						
Site ID	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K	Tot_S	Ox_N	Red_N	Ca	Mg	Na	K
2A068015U	-39.3	-16.4	5.6	-0.1	3.1	0.8	0.6	-65.0	-19.5	-3.9	0.0	10.3	2.4	0.7
2A07701	-32.3	-12.6	11.0	-0.1	2.8	2.0	0.7	-51.2	-14.0	5.7	-0.3	10.1	4.2	0.4
2A07805	-36.4	-15.3	7.1	-0.1	3.3	2.3	0.7	-56.7	-17.7	-1.1	-0.1	10.5	3.5	1.0
2A07806	-36.2	-15.9	11.9	-0.1	2.9	1.9	0.6	-58.7	-17.5	3.8	-0.1	10.4	3.6	0.6
2A07810L	-31.3	-12.5	8.3	0.0	8.0	2.5	0.7	-50.1	-13.7	0.7	-0.2	19.1	4.6	0.8
2A07810U	-31.2	-11.9	7.5	-0.1	4.1	1.7	0.5	-50.4	-13.0	1.0	-0.1	12.4	2.5	0.5
2A07811	-33.2	-12.9	9.8	-0.1	3.6	2.1	0.6	-52.6	-14.4	2.3	-0.1	11.2	3.0	0.7
2A07812	-32.4	-12.5	11.4	-0.1	3.0	2.0	0.6	-52.5	-13.1	6.3	-0.1	10.5	3.3	0.6
2A07816	-33.1	-10.7	5.9	0.0	4.8	1.7	0.6	-52.3	-11.8	-1.5	-0.2	13.4	3.2	0.4
2A07817	-32.6	-10.7	8.8	-0.1	4.2	1.9	0.6	-52.1	-11.5	3.6	-0.1	13.0	3.1	0.6
2A07821	-26.0	-17.8	10.5	-0.2	2.9	1.3	1.1	-56.9	-23.6	6.8	-0.2	17.5	3.6	2.5
2A07823	-34.1	-12.1	15.0	0.0	2.8	2.0	0.6	-52.5	-12.6	12.0	-0.1	10.5	3.8	0.4
2A07828	-29.2	-11.9	9.8	0.0	2.5	2.2	0.5	-47.8	-13.7	5.3	-0.3	9.4	4.4	0.1
2A07829	-25.1	-10.7	6.1	-0.1	2.3	1.9	0.7	-48.4	-11.0	0.5	-0.2	10.0	3.4	-1.3
2A07834	-26.1	-11.4	10.8	-0.1	2.1	2.0	0.1	-45.7	-12.0	6.8	-0.2	9.4	3.8	-1.0
2A07835	-27.2	-13.4	13.3	-0.2	1.6	0.8	0.9	-54.0	-16.6	8.4	-0.3	13.5	3.8	-0.2
2A07882	-30.1	-8.3	7.0	-0.1	2.5	2.1	0.8	-49.6	-9.7	1.7	-0.2	10.5	4.3	0.9
2A08802	-33.2	-17.2	19.1	0.0	2.5	1.5	-0.5	-53.9	-20.6	13.9	-0.2	10.0	3.9	-2.0
2A08804	-35.7	-17.7	18.5	0.0	2.2	1.5	-1.1	-54.4	-23.1	12.7	-0.2	9.9	4.0	-3.0
2A08805	-31.7	-13.6	14.3	0.0	2.1	1.5	0.0	-51.3	-17.7	8.2	-0.2	9.2	4.0	-0.9
2A08810	-34.4	-16.9	20.0	0.1	2.3	1.6	-0.7	-53.1	-19.9	14.0	0.0	10.2	3.6	-2.1
2A08901	-29.1	-13.5	16.7	0.1	2.4	1.9	-1.0	-49.0	-14.6	10.4	-0.1	9.8	4.0	-2.8
2B041020L	-52.6	-38.6	29.2	0.0	2.1	1.2	0.2	-72.3	-40.0	38.0	0.3	7.1	1.7	0.7
2B041049U	-61.8	-40.0	30.8	0.0	2.7	0.9	0.2	-76.9	-40.6	30.9	0.4	8.5	2.1	0.5
2B047032	-53.5	-37.6	23.1	0.0	3.1	-0.2	0.3	-70.3	-36.6	26.8	0.1	7.8	1.0	0.6
2B047044U	-51.6	-33.5	17.7	0.0	3.0	-0.1	0.3	-69.5	-31.2	17.6	0.1	7.7	1.1	0.7
2B047076L	-48.6	-25.4	20.3	0.0	2.5	-0.8	0.1	-72.2	-28.1	9.8	0.1	10.5	1.9	1.4
2B047076U	-48.6	-25.4	20.3	0.0	2.5	-0.8	0.1	-72.2	-28.1	9.8	0.1	10.5	1.9	1.4
2B058015U	-46.2	-24.3	22.6	0.1	3.3	-0.4	0.1	-69.4	-24.5	17.1	0.2	9.6	0.5	0.3
2C041033U	-55.0	-39.1	9.8	-0.2	3.2	1.5	0.2	-71.5	-41.5	7.1	0.1	7.9	3.3	0.4
2C041039	-55.2	-38.9	8.7	-0.3	3.2	1.3	0.3	-71.6	-40.7	6.2	0.1	8.0	3.1	0.5
2C041040	-51.5	-35.8	6.8	-0.1	3.0	1.2	0.3	-68.0	-36.5	5.1	0.0	7.4	2.5	0.5
2C041043U	-68.0	-44.8	18.0	0.2	3.2	1.1	0.3	-76.5	-45.2	21.6	0.3	7.9	2.2	0.7
2C041045	-53.6	-36.6	6.8	-0.2	3.0	1.0	0.3	-69.9	-38.0	4.8	0.1	7.6	2.5	0.6
2C041051	-51.0	-33.7	5.1	-0.2	2.7	0.6	0.2	-66.8	-34.6	4.1	0.1	7.3	1.9	0.6
2C046013L	-46.3	-33.4	1.9	-0.3	3.4	0.0	0.4	-64.5	-33.2	-3.2	-0.1	8.5	1.9	0.8
2C046033	-44.3	-31.4	4.8	-0.3	3.6	-0.1	0.5	-63.3	-30.5	0.2	0.0	9.0	1.7	0.8
2C046034	-45.4	-32.9	8.4	-0.2	3.6	-0.1	0.4	-64.3	-30.8	5.2	0.1	8.9	1.2	0.6
2C046043L	-45.0	-32.0	8.9	-0.1	3.6	-0.1	0.4	-64.2	-30.9	5.1	0.0	8.8	1.4	0.6

Table G-3. Continued.														
	Year 2010							**Year 2040**						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
2C046043U	-45.0	-32.1	8.9	-0.1	3.6	-0.1	0.4	-64.2	-30.9	5.1	0.0	8.8	1.4	0.6
2C046050	-40.8	-30.2	3.8	-0.1	4.3	0.2	0.7	-59.2	-31.7	-3.7	-0.2	10.5	3.0	1.2
2C046053L	-44.6	-32.0	8.2	0.0	3.7	0.0	0.5	-64.0	-31.2	3.8	0.0	9.0	1.8	0.6
2C046062L	-44.9	-30.9	12.1	0.0	3.7	0.2	0.6	-65.3	-30.1	7.2	0.1	9.0	1.9	0.6
2C047007	-48.8	-32.9	2.8	-0.2	2.9	0.1	0.3	-65.7	-33.0	1.6	0.1	7.6	1.2	0.6
2C047010L	-49.6	-33.6	8.5	-0.3	2.8	-0.1	0.3	-66.2	-32.6	7.8	0.1	7.5	0.9	0.6
2C047010U	-49.6	-33.7	8.5	-0.3	2.8	-0.1	0.3	-66.2	-32.7	7.8	0.1	7.5	0.9	0.6
2C057004	-42.2	-31.5	5.4	0.0	4.2	0.4	0.8	-62.8	-34.1	-0.5	-0.1	11.0	3.0	1.2
2C066026L	-41.1	-20.6	23.2	-0.1	3.2	2.2	1.3	-61.0	-24.7	14.3	-0.2	9.0	4.3	1.5
2C066027L	-42.0	-20.5	18.6	-0.2	2.9	1.9	1.2	-59.7	-25.3	12.4	-0.3	8.6	3.9	1.4
2C066027U	-42.0	-20.5	18.6	-0.2	2.9	1.9	1.3	-59.7	-25.3	12.4	-0.3	8.6	4.0	1.4
2C066039L	-41.1	-20.6	23.2	-0.1	3.2	2.2	1.4	-61.0	-24.7	14.3	-0.2	9.1	4.4	1.6
2C077022U	-37.4	-19.3	22.3	0.0	2.3	2.3	1.6	-57.6	-23.7	17.3	-0.1	8.2	4.0	1.8
BJ 35	-35.7	-15.2	6.4	-0.2	2.7	0.8	0.4	-61.5	-17.6	2.1	0.1	10.1	1.8	0.5
BJ 72	-25.5	-10.4	8.4	-0.2	2.1	1.0	0.4	-48.2	-10.8	4.3	-0.1	9.0	2.0	-0.2
BJ 76	-32.5	-12.9	12.8	-0.2	2.7	1.3	0.4	-52.1	-14.2	9.9	-0.2	10.4	2.2	0.4
BJ 77	-29.7	-9.6	7.5	-0.1	2.1	1.2	0.5	-50.2	-11.7	1.9	0.0	9.2	2.5	0.6
BLFC	-43.0	-24.8	19.5	0.1	2.6	-0.4	0.3	-66.0	-26.3	12.3	0.2	8.9	0.7	0.5
CO01	-33.9	-17.2	16.8	-0.1	2.2	1.2	-0.8	-53.5	-22.3	11.0	-0.3	9.6	3.4	-2.4
CO05	-33.5	-17.2	18.5	0.0	2.4	1.2	-0.7	-54.3	-22.2	12.3	-0.2	10.1	3.3	-2.2
CO06	-33.9	-17.2	16.8	-0.1	2.2	1.2	-0.8	-53.4	-22.3	11.0	-0.3	9.6	3.4	-2.4
CO10	-33.4	-17.2	18.5	0.0	2.4	1.2	-0.7	-54.3	-22.2	12.3	-0.2	10.1	3.3	-2.2
DR	-48.6	-25.3	20.3	0.0	2.5	-0.8	0.1	-72.2	-28.1	9.8	0.1	10.1	1.7	1.3
DR01	-48.6	-25.3	20.3	0.0	2.4	-0.7	0.1	-72.2	-28.1	9.8	0.1	9.5	1.5	1.1
DS04	-59.8	-39.6	21.3	0.2	2.2	0.0	0.0	-74.4	-40.3	26.8	0.6	5.5	0.1	0.1
DS06	-59.8	-39.6	21.3	0.2	2.2	0.0	0.0	-74.4	-40.3	26.8	0.6	5.5	0.1	0.1
DS09	-57.4	-39.2	14.6	0.2	2.2	0.1	0.0	-71.7	-39.7	18.6	0.5	5.3	0.2	0.1
DS19	-57.4	-39.2	14.6	0.2	2.2	0.1	0.0	-71.7	-39.7	18.6	0.5	5.3	0.2	0.1
DS50	-57.4	-39.2	14.6	0.2	2.2	0.1	0.0	-71.7	-39.7	18.6	0.5	5.3	0.2	0.1
FN1	-52.9	-35.5	4.7	-0.3	2.2	0.3	0.1	-69.0	-36.3	3.1	0.1	6.0	1.0	0.3
FN2	-52.9	-35.5	4.7	-0.3	2.2	0.3	0.1	-69.0	-36.3	3.1	0.1	6.0	1.0	0.3
FN3	-52.9	-35.5	4.7	-0.3	2.2	0.3	0.1	-69.0	-36.2	3.1	0.1	6.0	1.0	0.3
GS01	-32.6	-10.7	8.8	-0.1	3.9	1.3	0.5	-52.1	-11.5	3.6	-0.1	12.4	2.2	0.4
GS02	-32.6	-10.7	8.8	-0.1	3.9	1.3	0.5	-52.1	-11.5	3.6	-0.1	12.4	2.2	0.4
GS04	-29.1	-11.1	7.1	-0.2	3.5	1.5	0.4	-47.6	-12.0	2.0	-0.2	11.1	2.1	0.4
GS05	-34.7	-15.5	12.0	-0.2	5.2	1.3	0.7	-53.5	-18.5	2.7	-0.3	14.7	2.0	1.1
GS06	-34.2	-14.0	11.2	-0.1	4.6	1.0	0.5	-53.5	-15.7	2.9	-0.2	12.8	1.6	0.6
GS07	-28.8	-10.7	8.2	-0.1	3.0	1.5	0.5	-47.7	-11.8	3.8	-0.1	10.3	2.3	0.6
GS08	-28.8	-10.7	8.2	-0.1	3.0	1.5	0.5	-47.7	-11.8	3.8	-0.1	10.3	2.3	0.6
LB01	-32.3	-12.6	11.0	-0.1	2.8	2.0	0.6	-51.2	-14.0	5.7	-0.3	10.1	4.2	0.4
LEWF	-38.5	-17.8	8.9	0.0	3.2	0.6	0.4	-65.2	-20.1	1.4	0.3	10.8	1.7	0.6
M037	-45.3	-22.2	21.6	0.1	2.6	-0.3	0.2	-68.1	-22.8	11.9	0.3	9.0	0.7	0.4
M038	-46.1	-22.9	22.4	0.1	2.8	-0.4	0.1	-68.5	-22.3	15.1	0.3	8.9	0.5	0.2
M039	-43.0	-24.8	19.6	0.1	2.6	-0.4	0.3	-66.1	-26.3	12.3	0.2	8.9	0.7	0.5
NFD	-55.1	-34.3	27.2	0.1	2.7	-0.3	0.0	-73.3	-34.1	20.6	0.3	9.1	1.2	0.3
NFDR	-55.1	-34.3	27.2	0.1	2.6	-0.2	0.0	-73.3	-34.1	20.6	0.3	8.7	1.1	0.3
OC02	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
OC05	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1

Table G-3. Continued.														
	Year 2010							**Year 2040**						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
OC08	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
OC09	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
OC31	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
OC32	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
OC35	-51.0	-33.7	5.1	-0.3	1.6	0.1	0.0	-66.8	-34.6	4.1	0.2	5.0	0.2	0.1
OC79	-52.2	-32.3	4.1	-0.3	1.6	0.0	0.0	-68.2	-33.1	2.6	0.3	5.0	0.2	0.1
PAIN	-48.5	-24.9	20.6	0.0	2.6	-0.9	0.1	-72.1	-26.8	12.0	0.2	10.3	1.2	1.2
SP10	-16.7	-8.6	15.4	0.0	1.9	1.2	5.9	-27.7	-11.7	16.4	-0.2	5.8	2.7	4.9
SP39	-16.7	-8.6	15.4	0.0	1.9	1.2	5.9	-27.7	-11.7	16.4	-0.2	5.8	2.7	4.9
SP41	-16.7	-8.6	15.4	0.0	1.9	1.2	5.9	-27.7	-11.7	16.4	-0.2	5.8	2.7	4.9
STAN	-51.7	-32.4	21.8	0.1	2.7	-0.4	0.1	-71.2	-31.7	14.7	0.3	9.4	1.3	0.5
VA524S	-39.4	-23.5	18.1	0.0	3.1	0.6	0.5	-66.5	-26.0	12.4	0.2	9.4	2.1	0.7
VA526S	-43.5	-21.9	15.7	-0.1	4.3	2.2	0.8	-66.4	-27.7	11.2	0.1	10.0	4.4	0.9
VA531S	-55.1	-34.3	27.2	0.0	2.8	-0.3	0.0	-73.3	-34.1	20.6	0.2	9.4	1.4	0.3
VA548S	-53.1	-29.3	21.2	0.0	2.4	-0.2	0.2	-71.2	-34.8	8.2	0.2	9.5	2.9	1.3
VA555S	-45.8	-24.8	16.0	0.0	3.0	-0.6	0.2	-66.8	-22.6	11.8	0.0	8.0	0.3	0.4
VA821S	-41.0	-24.9	15.2	0.0	3.1	0.6	0.4	-68.2	-25.8	7.2	0.2	9.7	1.8	0.4
VT02	-38.5	-17.8	8.9	0.0	3.2	0.6	0.5	-65.2	-20.1	1.4	0.3	10.8	1.8	0.6
VT05	-39.0	-18.5	6.1	0.0	3.1	0.5	0.4	-65.5	-21.0	-2.8	0.1	9.8	1.8	0.4
VT07	-38.0	-17.6	7.0	0.1	3.0	0.7	0.3	-65.4	-20.4	-3.3	0.3	9.2	2.2	0.3
VT08	-38.0	-17.6	7.0	0.1	3.0	0.7	0.3	-65.5	-20.4	-3.3	0.3	9.2	2.2	0.3
VT09	-37.9	-17.6	7.0	0.1	3.0	0.7	0.3	-65.4	-20.4	-3.4	0.3	9.2	2.2	0.3
VT10	-46.3	-27.6	16.3	0.0	2.7	-0.2	0.2	-66.6	-25.2	13.2	0.1	7.3	0.8	0.4
VT11	-45.5	-23.6	17.0	0.0	3.0	-0.1	0.2	-69.3	-22.7	12.6	0.0	8.0	0.6	0.5
VT12	-45.5	-23.6	17.0	0.0	3.0	-0.1	0.2	-69.3	-22.7	12.6	0.0	8.0	0.6	0.5
VT15	-45.5	-23.6	16.9	0.0	3.0	-0.1	0.2	-69.3	-22.7	12.5	0.0	8.0	0.6	0.5
VT18	-51.5	-33.4	17.7	0.0	2.8	-0.1	0.2	-69.5	-31.1	17.5	0.2	7.2	0.9	0.5
VT19	-51.6	-33.4	17.7	0.0	2.8	-0.1	0.2	-69.5	-31.2	17.5	0.2	7.2	0.9	0.5
VT20	-43.1	-24.0	17.6	0.1	3.2	-0.2	0.3	-64.5	-23.5	13.6	0.3	8.6	0.7	0.4
VT24	-43.2	-28.5	23.6	0.1	3.3	0.2	0.4	-68.2	-28.4	20.5	0.4	8.8	1.4	0.5
VT25	-43.2	-28.5	23.6	0.1	3.3	0.2	0.4	-68.2	-28.4	20.5	0.4	8.8	1.5	0.5
VT26	-39.5	-23.5	18.2	0.0	2.8	0.5	0.4	-66.5	-26.0	12.5	0.2	8.9	1.6	0.5
VT28	-39.0	-23.3	21.6	0.0	2.8	0.4	0.4	-61.0	-24.5	18.9	0.1	8.1	1.7	0.5
VT29	-41.0	-24.3	17.8	0.0	2.8	0.5	0.3	-67.9	-27.8	12.7	0.3	8.8	1.7	0.3
VT31	-42.6	-25.7	16.5	0.1	3.1	0.7	0.4	-68.5	-27.9	12.1	0.2	8.9	1.6	0.4
VT32	-39.4	-23.5	18.1	0.0	2.8	0.5	0.4	-66.5	-25.9	12.4	0.2	8.8	1.6	0.5
VT34	-45.9	-24.5	16.9	0.1	2.9	-0.7	0.1	-67.6	-23.2	12.6	0.1	7.9	-0.3	0.2
VT35	-48.5	-24.9	20.6	0.0	2.5	-0.8	0.1	-72.1	-26.8	12.0	0.2	9.8	1.0	1.0
VT36	-48.5	-24.9	20.6	0.0	2.5	-0.8	0.1	-72.1	-26.8	12.0	0.2	9.8	1.0	1.1
VT37	-46.9	-29.8	16.1	0.0	2.6	-0.1	0.1	-66.2	-27.6	13.3	0.3	7.1	0.8	0.3
VT38	-45.9	-28.0	17.9	0.0	2.6	-0.2	0.1	-65.9	-25.6	13.0	0.2	7.3	0.7	0.3
VT39	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.8	14.2	0.2	8.5	0.5	0.3
VT41	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT46	-46.2	-24.3	22.6	0.1	3.1	-0.4	0.1	-69.4	-24.5	17.2	0.2	9.0	0.4	0.2
VT48	-40.7	-22.5	15.6	0.0	2.8	0.2	0.3	-67.0	-25.1	6.3	0.1	9.7	1.2	0.4
VT49	-59.8	-33.6	23.3	0.1	2.5	0.4	0.2	-74.9	-34.0	16.9	0.4	7.7	1.9	0.5
VT50	-61.2	-36.1	30.8	0.1	2.6	0.4	0.1	-75.9	-37.0	26.8	0.4	7.6	1.9	0.3
VT53	-49.4	-28.1	23.1	0.0	2.4	-0.5	0.1	-70.5	-28.8	12.8	0.2	9.7	1.7	0.9

Table G-3. Continued.														
	Year 2010							**Year 2040**						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
VT54	-57.0	-34.9	28.1	0.1	2.6	0.0	0.2	-73.3	-34.3	25.6	0.4	7.1	1.4	0.4
VT55	-57.0	-34.9	28.1	0.1	2.6	0.0	0.2	-73.4	-34.3	25.6	0.4	7.2	1.4	0.4
VT56	-46.9	-31.0	20.1	0.0	2.6	-0.2	0.1	-67.0	-28.2	13.8	0.3	7.4	0.8	0.3
VT57	-49.2	-31.1	22.8	0.1	2.5	-0.2	0.1	-68.5	-28.2	15.9	0.3	7.5	1.0	0.3
VT58	-55.1	-34.3	27.2	0.1	2.6	-0.3	0.0	-73.3	-34.1	20.6	0.3	8.7	1.1	0.3
VT59	-51.7	-32.4	21.8	0.1	2.6	-0.3	0.1	-71.2	-31.7	14.7	0.4	9.0	1.2	0.5
VT62	-56.6	-32.4	28.3	0.1	2.5	-0.1	0.2	-73.8	-34.6	21.5	0.3	8.5	1.4	0.7
VT66	-55.1	-34.3	27.2	0.1	2.6	-0.3	0.0	-73.3	-34.1	20.6	0.3	8.7	1.1	0.3
VT68	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT70	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT72	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT73	-48.0	-22.5	20.8	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT74	-48.1	-22.5	20.9	0.1	2.8	-0.5	0.1	-69.1	-21.7	14.2	0.2	8.5	0.5	0.3
VT75	-55.1	-34.3	27.2	0.1	2.6	-0.3	0.0	-73.3	-34.1	20.6	0.3	8.7	1.1	0.3
VT76	-43.0	-24.8	19.5	0.1	2.7	-0.4	0.3	-66.0	-26.3	12.3	0.2	9.2	0.8	0.6
VT77	-45.4	-22.2	21.6	0.1	2.7	-0.4	0.2	-68.1	-22.8	11.9	0.3	9.3	0.8	0.4
VT78	-36.0	-20.2	10.0	0.0	3.1	0.8	0.3	-67.8	-24.0	-4.1	0.2	9.6	2.3	0.3
WOR	-48.6	-25.3	20.3	0.0	2.5	-0.8	0.1	-72.2	-28.0	9.8	0.1	10.1	1.7	1.3
WOR1	-48.6	-25.3	20.3	0.0	2.4	-0.7	0.1	-72.2	-28.0	9.8	0.1	9.5	1.5	1.1
WV523S	-67.5	-43.0	21.2	0.1	3.2	0.7	0.2	-79.5	-44.2	26.9	0.2	7.6	2.0	0.6
WV531S	-52.2	-32.3	4.1	-0.2	2.7	0.4	0.2	-68.2	-33.1	2.6	0.1	7.4	1.8	0.7
WV547S	-44.2	-31.3	4.8	-0.3	3.6	-0.1	0.5	-63.2	-30.4	0.1	0.0	9.0	1.7	0.8
WV548S	-44.9	-31.9	8.9	-0.1	3.6	-0.1	0.4	-64.1	-30.8	5.0	0.0	8.8	1.5	0.6
WV769S	-49.4	-34.3	3.7	-0.2	3.1	0.3	0.2	-66.6	-34.8	1.9	0.1	7.7	1.6	0.5
WV770S	-48.8	-32.8	2.9	-0.2	3.0	0.1	0.3	-65.7	-33.0	1.6	0.1	7.6	1.3	0.6
WV771S	-53.6	-36.6	6.8	-0.2	3.0	1.0	0.3	-69.9	-38.0	4.8	0.1	7.6	2.5	0.6
WV785S	-43.2	-26.8	14.2	0.1	3.8	0.9	0.7	-66.5	-27.1	11.5	0.2	9.5	2.4	0.4
WV788S	-44.4	-31.5	4.8	-0.3	3.6	-0.1	0.5	-63.4	-30.6	0.2	0.0	9.0	1.7	0.8
WV796S	-63.9	-41.8	23.7	0.1	3.3	0.7	0.3	-77.8	-42.6	29.2	0.3	7.8	1.9	0.6

Table G-4. The percentage changes in total deposition of S, reduced N, oxidized N, and base cations (relative to the Reference Year, 1995), for each SAMI site for the BYB strategy. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Year 2010							Year 2040						
	Tot_S	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
Average	-61.5	-29.6	-4.0	0.0	1.8	-0.4	-2.6	-70.7	-30.0	-3.9	0.0	6.8	0.8	-2.2
Std. Dev.	7.0	8.8	4.4	0.1	1.2	1.1	2.1	8.9	8.3	6.8	0.1	2.3	1.4	2.2
Maximum	-24.8	-12.3	6.6	0.3	8.1	2.0	1.3	-29.1	-12.6	18.5	0.4	18.1	4.1	1.2
Minimum	-74.3	-49.9	-16.9	-0.2	-0.4	-2.7	-11.0	-88.5	-51.7	-21.7	-0.3	3.9	-1.9	-11.7
	Year 2010							**Year 2040**						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
2A068015U	-63.5	-21.1	-13.5	0.0	2.5	-0.1	-2.8	-71.0	-23.0	-17.3	-0.1	8.4	1.3	-2.2
2A07701	-54.1	-17.1	-4.8	0.0	2.8	1.5	-3.4	-59.8	-17.7	-6.3	-0.1	9.1	3.4	-3.0
2A07805	-59.0	-20.1	-10.5	0.1	3.5	1.7	-2.0	-64.2	-21.3	-13.0	-0.1	9.6	3.1	-1.3
2A07806	-61.2	-19.7	-7.8	0.0	2.7	1.1	-2.6	-66.4	-21.5	-10.5	-0.1	8.8	2.8	-2.2
2A07810L	-53.7	-16.7	-8.5	-0.0	8.1	2.0	-2.4	-58.1	-16.7	-10.2	-0.1	18.1	4.1	-1.9
2A07810U	-53.7	-15.9	-7.5	-0.0	4.3	1.0	-2.5	-58.5	-16.3	-9.0	-0.1	11.2	2.0	-2.0
2A07811	-55.2	-16.4	-7.5	0.0	3.8	1.5	-2.2	-60.2	-16.6	-8.9	-0.1	10.2	2.5	-1.7
2A07812	-55.4	-15.6	-3.5	0.0	3.0	1.3	-2.3	-60.4	-16.2	-4.6	-0.0	9.3	2.7	-1.9
2A07816	-54.1	-14.4	-9.1	0.0	4.7	1.0	-3.0	-59.6	-14.4	-11.0	-0.1	12.2	2.5	-2.7
2A07817	-56.5	-15.1	-5.7	-0.1	4.3	1.1	-2.3	-61.0	-15.8	-7.2	-0.2	11.8	2.4	-1.8
2A07821	-59.7	-27.2	-4.3	-0.1	4.7	1.3	-3.4	-64.4	-30.2	-6.9	-0.3	16.8	3.9	-1.6
2A07823	-56.1	-15.3	1.2	-0.1	2.8	1.3	-3.1	-61.0	-15.7	0.6	-0.1	9.2	3.2	-2.7
2A07828	-51.6	-16.4	-4.0	-0.0	2.2	1.5	-4.0	-56.6	-17.6	-5.5	-0.1	8.1	3.7	-3.7
2A07829	-52.1	-14.4	-7.4	0.0	2.2	0.6	-8.7	-57.3	-15.5	-9.5	-0.0	8.4	2.8	-9.7
2A07834	-50.3	-15.2	-2.6	-0.0	1.8	1.1	-6.0	-54.8	-16.0	-3.8	-0.1	7.8	3.1	-6.2
2A07835	-57.1	-20.7	-2.5	0.0	2.9	0.5	-10.2	-63.0	-23.0	-5.2	-0.1	12.6	3.9	-10.4
2A07882	-52.1	-12.3	-5.8	-0.0	2.8	1.4	-2.7	-57.1	-12.6	-7.1	-0.1	9.5	3.7	-2.0
2A08802	-58.2	-23.7	0.5	0.1	2.5	0.8	-8.4	-64.0	-25.9	-1.4	-0.0	8.7	2.8	-8.7
2A08804	-59.9	-25.8	-0.6	0.2	2.3	0.8	-11.0	-65.4	-29.1	-3.6	0.1	8.8	3.0	-11.7
2A08805	-56.9	-20.2	-3.1	0.1	2.2	0.9	-6.6	-62.5	-23.3	-6.0	-0.0	8.1	3.1	-6.6
2A08810	-60.8	-23.3	-0.9	0.3	2.0	0.6	-9.1	-65.8	-25.3	-3.6	0.2	8.3	2.5	-9.5
2A08901	-54.5	-17.8	-2.8	0.2	1.6	0.4	-9.8	-59.2	-18.9	-5.0	0.1	7.5	2.9	-10.7
2B041020L	-59.4	-41.6	6.6	0.0	0.6	0.0	-2.0	-75.6	-42.7	18.5	0.1	5.2	0.7	-1.4
2B041049U	-69.8	-43.1	0.2	0.0	0.5	-0.5	-3.2	-81.2	-43.5	6.1	0.2	5.4	0.6	-2.7
2B047032	-66.7	-39.4	6.0	-0.1	1.5	-1.2	-1.4	-76.5	-39.5	13.9	-0.0	5.4	-0.0	-0.9
2B047044U	-65.6	-35.2	2.1	-0.0	1.5	-1.1	-1.4	-75.8	-34.1	7.2	-0.0	5.4	0.0	-0.9
2B047076L	-66.6	-32.8	-10.0	0.1	1.7	-1.9	-3.7	-78.2	-33.2	-12.5	0.1	8.2	0.5	-2.2
2B047076U	-66.6	-32.8	-10.0	0.1	1.7	-1.9	-3.7	-78.2	-33.2	-12.5	0.1	8.3	0.5	-2.2
2B058015U	-67.8	-29.5	1.2	0.2	0.8	-2.1	-4.0	-77.8	-29.7	0.8	0.1	5.8	-1.4	-3.5
2C041033U	-63.3	-43.5	-4.0	0.0	1.1	-0.0	-2.7	-77.0	-45.5	-4.6	-0.0	5.2	1.5	-2.4
2C041039	-63.1	-43.1	-4.8	-0.0	1.3	-0.1	-2.2	-76.9	-44.7	-5.3	-0.1	5.5	1.5	-1.8
2C041040	-59.5	-39.1	-4.0	-0.1	1.2	0.0	-1.8	-73.1	-39.5	-3.5	-0.1	5.3	1.2	-1.4
2C041043U	-72.7	-49.9	1.7	0.1	1.4	-0.1	-1.5	-88.5	-51.7	1.7	0.4	5.7	1.0	-1.0
2C041045	-61.6	-40.6	-5.2	0.0	1.3	-0.2	-1.8	-75.0	-41.3	-5.0	-0.0	5.4	1.1	-1.4
2C041051	-58.9	-37.6	-4.7	0.0	1.4	-0.3	-1.3	-71.6	-37.3	-3.1	-0.1	5.4	0.8	-0.9
2C046013L	-59.5	-37.1	-8.4	0.1	2.4	-1.0	-1.4	-72.3	-36.6	-9.8	-0.1	6.5	0.4	-0.9
2C046033	-59.1	-34.1	-7.6	0.1	2.7	-0.9	-1.7	-71.0	-33.2	-8.6	-0.2	6.8	0.2	-1.3
2C046034	-60.3	-35.0	-5.1	0.1	2.3	-1.1	-1.9	-71.5	-33.4	-4.5	-0.2	6.4	-0.2	-1.6
2C046043L	-60.5	-34.6	-4.9	0.1	2.5	-0.9	-2.0	-71.5	-33.2	-4.7	-0.2	6.6	0.0	-1.7

Table G-4. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
2C046043U	-60.6	-34.6	-4.9	0.1	2.5	-0.9	-2.0	-71.5	-33.2	-4.7	-0.2	6.6	0.0	-1.7
2C046050	-58.0	-35.0	-7.5	0.1	3.8	-0.6	-2.2	-70.2	-36.6	-12.9	-0.1	8.6	1.5	-1.4
2C046053L	-60.5	-34.9	-5.4	0.1	2.5	-0.9	-2.6	-71.3	-33.8	-5.8	-0.2	6.6	0.1	-2.3
2C046062L	-63.2	-34.0	-5.3	0.0	2.3	-0.8	-2.7	-72.4	-33.7	-4.9	-0.0	6.6	0.2	-2.4
2C047007	-59.2	-35.9	-6.2	0.1	1.7	-0.9	-1.4	-71.6	-35.5	-4.9	-0.1	5.6	0.2	-1.0
2C047010L	-61.4	-35.3	-3.6	-0.0	1.4	-1.1	-1.4	-72.2	-35.2	-0.8	-0.2	5.3	-0.0	-0.9
2C047010U	-61.5	-35.4	-3.6	-0.0	1.4	-1.1	-1.4	-72.2	-35.2	-0.7	-0.2	5.3	-0.0	-0.9
2C057004	-61.0	-36.8	-6.4	0.1	3.8	-0.1	-2.6	-72.2	-38.9	-10.9	-0.0	9.0	1.6	-1.8
2C066026L	-59.1	-25.4	-7.2	-0.1	2.4	1.4	-1.6	-65.7	-28.1	-8.3	-0.2	7.3	3.1	-1.1
2C066027L	-58.4	-25.5	-6.0	-0.0	2.3	1.1	-1.6	-64.0	-28.6	-6.3	-0.2	6.9	2.8	-1.0
2C066027U	-58.4	-25.5	-6.0	-0.0	2.3	1.1	-1.6	-64.0	-28.6	-6.3	-0.2	6.9	2.8	-1.0
2C066039L	-59.1	-25.4	-7.2	-0.1	2.4	1.4	-1.7	-65.7	-28.1	-8.3	-0.2	7.4	3.2	-1.1
2C077022U	-56.1	-24.7	-1.9	0.1	1.9	1.3	-1.4	-63.3	-27.8	-2.3	-0.0	6.6	2.8	-0.7
BJ 35	-61.2	-19.8	-6.8	-0.2	2.4	0.3	-1.4	-67.7	-21.9	-8.7	0.0	8.5	1.1	-1.1
BJ 72	-51.9	-14.0	-4.5	-0.1	1.8	0.5	-3.3	-56.9	-15.0	-5.5	-0.1	7.6	1.7	-3.3
BJ 76	-56.2	-17.9	-1.2	-0.1	2.9	0.8	-1.5	-60.7	-18.7	-2.0	-0.2	9.2	1.9	-1.2
BJ 77	-52.5	-13.9	-5.7	-0.1	2.2	0.9	-1.7	-57.9	-14.8	-7.3	-0.1	8.2	2.2	-1.3
BLFC	-66.1	-30.4	-1.9	0.0	1.0	-1.2	-2.6	-75.8	-31.8	-4.4	0.0	6.1	-0.4	-2.0
CO01	-58.1	-25.1	-1.3	0.1	2.5	0.7	-9.1	-63.8	-27.8	-3.8	-0.0	8.8	2.7	-9.4
CO05	-58.1	-24.5	-0.5	0.1	2.8	0.7	-8.6	-64.1	-27.5	-3.3	0.0	9.4	2.6	-8.8
CO06	-58.1	-25.1	-1.3	0.1	2.5	0.7	-9.1	-63.7	-27.8	-3.8	-0.0	8.8	2.7	-9.5
CO10	-58.0	-24.5	-0.5	0.1	2.8	0.7	-8.6	-64.0	-27.5	-3.3	0.0	9.4	2.6	-8.8
DR	-66.6	-32.8	-10.0	0.1	1.7	-1.7	-3.4	-78.2	-33.2	-12.6	0.1	7.9	0.5	-2.0
DR01	-66.6	-32.8	-10.0	0.1	1.6	-1.5	-3.0	-78.2	-33.2	-12.6	0.1	7.5	0.4	-1.8
DS04	-68.6	-43.2	5.4	0.1	1.3	-0.1	-0.1	-79.2	-43.2	14.7	0.3	4.2	0.0	-0.1
DS06	-68.6	-43.2	5.4	0.1	1.3	-0.1	-0.1	-79.2	-43.2	14.7	0.3	4.2	0.0	-0.1
DS09	-65.2	-42.9	2.2	-0.0	1.3	-0.0	-0.1	-76.6	-42.6	9.8	0.3	4.3	0.1	-0.1
DS19	-65.2	-42.9	2.2	-0.0	1.3	-0.0	-0.1	-76.6	-42.6	9.8	0.3	4.3	0.1	-0.1
DS50	-65.2	-42.9	2.2	-0.0	1.3	-0.0	-0.1	-76.6	-42.6	9.8	0.3	4.3	0.1	-0.1
FN1	-60.8	-39.4	-5.9	0.1	1.2	-0.2	-0.7	-74.0	-39.4	-5.2	0.0	4.7	0.4	-0.5
FN2	-60.8	-39.4	-5.9	0.1	1.2	-0.2	-0.7	-74.0	-39.4	-5.2	0.0	4.7	0.4	-0.5
FN3	-60.8	-39.4	-5.9	0.1	1.2	-0.2	-0.7	-74.0	-39.4	-5.2	0.0	4.7	0.4	-0.5
GS01	-56.5	-15.1	-5.7	-0.2	4.0	0.8	-1.7	-61.0	-15.8	-7.2	-0.2	11.1	1.8	-1.3
GS02	-56.5	-15.1	-5.7	-0.2	4.0	0.8	-1.7	-61.0	-15.8	-7.2	-0.2	11.1	1.8	-1.3
GS04	-50.9	-15.1	-6.3	-0.1	3.6	0.9	-1.7	-55.6	-15.1	-7.4	-0.2	10.1	1.6	-1.3
GS05	-56.3	-21.0	-9.5	-0.1	5.8	1.2	-1.5	-60.8	-22.1	-12.1	-0.2	13.9	1.8	-0.8
GS06	-55.9	-17.7	-7.9	0.0	4.8	0.6	-1.7	-60.8	-17.7	-9.5	-0.1	12.0	1.4	-1.3
GS07	-50.9	-14.7	-4.7	-0.1	3.1	0.9	-1.6	-55.6	-15.4	-6.0	-0.1	9.3	1.9	-1.1
GS08	-50.9	-14.7	-4.7	-0.1	3.1	0.9	-1.6	-55.6	-15.4	-6.0	-0.1	9.2	1.9	-1.1
LB01	-54.1	-17.1	-4.8	0.0	2.8	1.4	-3.3	-59.8	-17.7	-6.3	-0.1	9.1	3.4	-3.0
LEWF	-64.3	-21.7	-10.2	0.0	2.7	-0.1	-1.9	-71.5	-23.4	-13.3	0.1	8.8	0.9	-1.5
M037	-67.3	-27.4	-1.5	0.1	1.0	-1.2	-2.6	-77.2	-27.9	-5.3	0.1	6.2	-0.6	-2.2
M038	-67.2	-27.4	0.8	0.0	0.9	-1.3	-2.8	-77.1	-26.9	-0.8	0.0	5.7	-0.8	-2.4
M039	-66.1	-30.4	-1.9	0.0	1.0	-1.2	-2.6	-75.8	-31.8	-4.3	0.0	6.1	-0.4	-2.0
NFD	-67.2	-38.2	-6.3	-0.0	-0.3	-2.4	-4.3	-78.2	-36.9	-4.3	0.1	4.8	-1.0	-3.8
NFDR	-67.2	-38.2	-6.3	-0.1	-0.2	-2.2	-3.8	-78.2	-36.9	-4.3	0.1	4.7	-0.9	-3.3
OC02	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.0	-36.1	-4.5	0.0	3.9	0.1	-0.1
OC05	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.0	-36.1	-4.5	0.0	3.9	0.1	-0.1

Table G-4. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
OC08	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.1	-36.1	-4.5	0.0	3.9	0.1	-0.1
OC09	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.1	-36.1	-4.5	0.0	3.9	0.1	-0.1
OC31	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.1	-36.1	-4.5	0.0	3.9	0.1	-0.1
OC32	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.1	-36.1	-4.5	0.0	3.9	0.1	-0.1
OC35	-58.9	-37.6	-4.7	0.0	1.0	-0.0	-0.1	-71.6	-37.3	-3.1	-0.0	3.9	0.1	-0.1
OC79	-60.6	-36.9	-5.7	0.1	1.1	-0.0	-0.1	-73.1	-36.1	-4.5	0.0	3.9	0.1	-0.1
PAIN	-67.0	-31.9	-6.5	0.1	1.6	-1.9	-3.4	-78.4	-32.5	-8.5	0.2	7.9	-0.2	-2.1
SP10	-24.8	-12.8	2.1	0.1	1.7	0.3	1.3	-29.1	-14.4	6.2	0.0	5.2	2.3	1.2
SP39	-24.8	-12.8	2.1	0.1	1.7	0.3	1.3	-29.1	-14.4	6.2	0.0	5.2	2.3	1.2
SP41	-24.8	-12.8	2.1	0.1	1.7	0.3	1.3	-29.1	-14.4	6.2	0.0	5.2	2.3	1.2
STAN	-65.2	-36.9	-6.8	0.0	0.2	-2.3	-4.1	-76.8	-34.7	-6.4	0.2	5.6	-0.7	-3.4
VA524S	-66.2	-27.7	-1.5	0.0	1.2	-0.6	-2.9	-73.4	-29.8	-2.6	0.1	6.2	0.5	-2.3
VA526S	-63.2	-31.3	-2.0	0.0	3.3	1.4	-2.1	-71.8	-33.4	-1.5	0.0	7.9	3.2	-1.6
VA531S	-67.2	-38.2	-6.3	-0.0	-0.4	-2.7	-4.8	-78.2	-36.9	-4.3	0.1	4.9	-1.1	-4.2
VA548S	-64.7	-37.8	-12.4	0.1	1.1	-1.3	-3.8	-76.1	-40.5	-15.7	0.1	7.0	1.3	-2.5
VA555S	-62.9	-28.0	0.3	-0.1	0.8	-2.0	-2.5	-73.5	-25.1	2.2	-0.1	5.0	-1.5	-2.0
VA821S	-68.3	-28.7	-8.3	-0.0	1.0	-0.9	-3.4	-75.8	-30.3	-11.4	0.1	6.1	-0.1	-2.9
VT02	-64.3	-21.7	-10.2	0.0	2.7	-0.1	-2.1	-71.5	-23.4	-13.3	0.1	8.9	1.0	-1.6
VT05	-63.8	-22.8	-13.4	0.1	2.1	-0.4	-2.8	-71.4	-24.2	-17.2	-0.0	7.4	0.7	-2.4
VT07	-62.9	-20.9	-13.0	0.2	2.1	-0.2	-2.6	-70.6	-24.0	-17.1	0.0	6.8	0.9	-2.2
VT08	-62.9	-20.9	-13.0	0.2	2.1	-0.2	-2.6	-70.6	-24.0	-17.1	0.0	6.8	0.9	-2.2
VT09	-62.9	-20.9	-13.1	0.2	2.1	-0.2	-2.6	-70.6	-23.9	-17.1	0.0	6.8	0.9	-2.2
VT10	-62.4	-30.3	1.0	-0.1	1.1	-1.2	-1.5	-73.3	-28.0	3.0	-0.1	4.9	-0.4	-1.1
VT11	-65.4	-27.3	0.9	-0.0	1.3	-1.0	-1.8	-75.8	-26.8	2.7	-0.1	5.3	-0.8	-1.3
VT12	-65.4	-27.3	0.9	-0.0	1.3	-1.0	-1.8	-75.8	-26.8	2.7	-0.1	5.3	-0.8	-1.3
VT15	-65.4	-27.3	0.9	-0.0	1.3	-1.0	-1.8	-75.8	-26.7	2.7	-0.1	5.3	-0.8	-1.3
VT18	-65.6	-35.2	2.0	-0.0	1.5	-0.9	-1.1	-75.7	-34.1	7.1	-0.0	5.1	0.0	-0.7
VT19	-65.6	-35.2	2.0	-0.0	1.5	-0.9	-1.1	-75.7	-34.1	7.1	-0.0	5.1	0.0	-0.7
VT20	-65.7	-28.0	-0.5	0.0	1.0	-1.3	-2.2	-74.5	-28.5	-0.1	0.0	5.3	-0.9	-1.9
VT24	-67.5	-30.4	0.8	0.0	1.3	-0.9	-2.1	-75.6	-31.7	2.2	0.0	5.7	-0.1	-1.7
VT25	-67.5	-30.4	0.8	0.0	1.3	-0.9	-2.1	-75.6	-31.7	2.2	0.0	5.7	-0.1	-1.7
VT26	-66.2	-27.7	-1.4	0.0	1.2	-0.5	-2.2	-73.4	-29.8	-2.5	0.1	6.0	0.4	-1.8
VT28	-61.2	-26.8	2.3	-0.0	1.0	-0.7	-2.2	-66.8	-27.6	3.5	-0.1	5.2	0.4	-1.8
VT29	-66.8	-30.1	-2.0	0.0	0.8	-0.7	-2.7	-74.6	-32.2	-2.1	0.1	5.5	0.2	-2.3
VT31	-68.2	-29.8	-2.1	0.1	1.6	-0.3	-2.2	-75.4	-31.4	-2.8	0.1	6.4	0.4	-1.8
VT32	-66.2	-27.6	-1.5	0.0	1.2	-0.5	-2.2	-73.4	-29.7	-2.6	0.1	6.0	0.4	-1.8
VT34	-64.9	-28.0	-0.4	0.1	0.7	-1.9	-2.7	-74.9	-27.0	-0.0	0.1	4.8	-1.9	-2.3
VT35	-67.0	-31.9	-6.5	0.1	1.6	-1.7	-3.0	-78.4	-32.5	-8.5	0.2	7.5	-0.2	-1.8
VT36	-67.0	-31.9	-6.5	0.1	1.6	-1.7	-3.0	-78.4	-32.5	-8.5	0.2	7.5	-0.2	-1.8
VT37	-60.9	-32.5	-0.4	0.0	0.9	-1.1	-1.8	-72.6	-30.0	2.2	0.1	4.6	-0.4	-1.4
VT38	-61.3	-30.3	-1.1	0.0	0.8	-1.3	-2.0	-72.6	-27.4	0.3	0.1	4.6	-0.6	-1.7
VT39	-65.5	-26.4	-0.4	0.1	0.7	-1.9	-3.2	-75.9	-25.0	-1.1	0.1	5.3	-1.2	-2.7
VT41	-65.5	-26.4	-0.4	0.1	0.7	-1.8	-3.2	-75.9	-25.0	-1.2	0.1	5.3	-1.2	-2.7
VT46	-67.8	-29.5	1.2	0.2	0.9	-1.7	-3.3	-77.8	-29.7	0.8	0.1	5.6	-1.2	-2.9
VT48	-66.5	-28.5	-9.3	0.0	1.2	-0.9	-3.0	-73.9	-29.4	-11.8	0.1	6.6	-0.2	-2.6
VT49	-68.6	-38.4	-4.6	0.1	0.7	-0.7	-2.4	-79.7	-37.2	-3.2	0.2	5.0	0.7	-1.9
VT50	-70.0	-39.8	-2.3	0.0	0.7	-0.8	-2.6	-80.6	-39.7	1.7	0.1	4.8	0.5	-2.4
VT53	-64.8	-34.0	-10.1	0.1	1.2	-1.5	-3.8	-76.5	-33.4	-12.5	0.2	7.2	0.4	-2.7

Table G-4. Continued.

	Year 2010							Year 2040						
Site ID	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**	**Tot_S**	**Ox_N**	**Red_N**	**Ca**	**Mg**	**Na**	**K**
VT54	-67.3	-37.9	-0.5	0.1	1.2	-0.9	-2.0	-78.2	-36.3	4.3	0.2	4.9	0.4	-1.7
VT55	-67.3	-37.9	-0.5	0.1	1.2	-0.9	-2.0	-78.2	-36.3	4.3	0.2	4.9	0.4	-1.7
VT56	-61.7	-32.8	-4.3	0.1	0.9	-1.3	-2.2	-73.5	-30.1	-3.1	0.2	5.0	-0.4	-1.8
VT57	-62.7	-33.3	-4.5	0.1	1.0	-1.2	-2.5	-74.6	-30.0	-3.1	0.2	5.2	-0.0	-2.2
VT58	-67.2	-38.2	-6.3	-0.1	-0.2	-2.2	-3.9	-78.2	-36.9	-4.3	0.1	4.7	-0.9	-3.4
VT59	-65.2	-36.9	-6.8	0.0	0.3	-2.0	-3.6	-76.8	-34.7	-6.4	0.2	5.4	-0.6	-3.0
VT62	-67.7	-37.5	-5.6	0.0	0.2	-1.6	-3.1	-78.5	-37.8	-4.0	0.1	5.1	-0.2	-2.4
VT66	-67.2	-38.2	-6.3	-0.1	-0.2	-2.2	-3.9	-78.2	-36.9	-4.3	0.1	4.7	-0.9	-3.4
VT68	-65.5	-26.4	-0.4	0.1	0.7	-1.9	-3.2	-75.9	-25.0	-1.1	0.1	5.3	-1.2	-2.7
VT70	-65.5	-26.4	-0.4	0.1	0.7	-1.9	-3.2	-75.9	-25.0	-1.2	0.1	5.3	-1.2	-2.7
VT72	-65.5	-26.4	-0.4	0.1	0.7	-1.8	-3.2	-75.9	-25.0	-1.1	0.1	5.3	-1.2	-2.7
VT73	-65.5	-26.4	-0.4	0.1	0.7	-1.8	-3.2	-75.9	-25.0	-1.2	0.1	5.3	-1.1	-2.7
VT74	-65.5	-26.4	-0.4	0.1	0.7	-1.9	-3.2	-75.9	-25.0	-1.2	0.1	5.3	-1.2	-2.7
VT75	-67.2	-38.2	-6.3	-0.1	-0.2	-2.2	-3.9	-78.2	-36.9	-4.3	0.1	4.7	-0.9	-3.4
VT76	-66.1	-30.4	-1.9	0.0	1.0	-1.4	-2.9	-75.7	-31.8	-4.4	0.0	6.3	-0.5	-2.3
VT77	-67.4	-27.4	-1.5	0.1	1.0	-1.4	-3.0	-77.2	-27.9	-5.3	0.1	6.3	-0.6	-2.5
VT78	-65.6	-24.9	-16.9	0.1	2.1	-0.2	-3.0	-72.9	-27.2	-21.7	-0.0	7.2	0.9	-2.7
WOR	-66.6	-32.8	-10.0	0.1	1.7	-1.7	-3.4	-78.2	-33.2	-12.6	0.1	8.0	0.5	-2.0
WOR1	-66.6	-32.8	-10.0	0.1	1.6	-1.5	-3.0	-78.2	-33.2	-12.6	0.1	7.5	0.4	-1.8
WV523S	-74.3	-47.3	6.1	-0.0	1.3	-0.3	-1.6	-84.6	-48.9	16.3	0.2	5.4	0.7	-1.2
WV531S	-60.6	-36.9	-5.7	0.1	1.7	-0.4	-1.1	-73.0	-36.1	-4.5	-0.1	5.7	0.9	-0.6
WV547S	-59.0	-34.0	-7.7	0.1	2.7	-0.8	-1.7	-71.0	-33.1	-8.6	-0.2	6.8	0.3	-1.3
WV548S	-60.5	-34.4	-4.9	0.1	2.5	-0.9	-2.0	-71.5	-33.1	-4.8	-0.2	6.6	0.0	-1.7
WV769S	-58.9	-37.8	-5.9	0.1	1.6	-0.8	-1.6	-72.2	-37.3	-5.1	-0.1	5.5	0.3	-1.3
WV770S	-59.2	-35.8	-6.2	0.1	1.7	-0.9	-1.4	-71.6	-35.5	-4.9	-0.1	5.6	0.2	-1.0
WV771S	-61.6	-40.6	-5.2	0.0	1.3	-0.2	-1.8	-75.0	-41.3	-5.0	-0.0	5.4	1.1	-1.4
WV785S	-64.3	-30.3	-0.3	0.1	2.0	-0.5	-3.7	-73.2	-31.0	-0.0	0.1	6.6	0.6	-3.6
WV788S	-59.1	-34.1	-7.6	0.1	2.7	-0.9	-1.7	-71.1	-33.2	-8.6	-0.2	6.9	0.2	-1.3
WV796S	-72.1	-45.9	5.4	0.1	1.4	-0.5	-1.7	-82.5	-46.3	16.1	0.2	5.2	0.6	-1.3

Table G-5. The total deposition of SO_4, NH_4, NO_3 and Total N for each SAMI site for the Reference Year and year 2040 of the OTW strategy. Deposition is in kg/ha/yr (as S or N).The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Reference Year 1995				Year 2040			
	SO_4	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
Average	15.1	6.8	4.1	11.0	6.9	5.3	5.3	10.6
Std. Dev.	5.2	2.4	1.4	3.8	3.5	2.2	1.7	3.7
Maximum	43.7	20.3	12.7	33.0	26.7	18.8	14.9	33.7
Minimum	8.3	3.6	2.7	6.5	2.9	2.5	3.2	6.9
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
2A068015U	12.2	5.6	3.6	9.2	5.5	4.8	4.1	8.9
2A07701	12.5	5.3	3.5	5.3	7.7	4.8	4.3	4.8
2A07805	9.9	4.4	2.8	7.1	5.4	3.8	3.2	6.9
2A07806	11.9	5.3	3.4	8.8	6.4	4.6	4.2	8.8
2A07810L	10.7	4.8	3.0	7.8	6.4	4.3	3.5	7.8
2A07810U	12.9	5.7	3.6	9.3	7.9	5.2	4.1	9.3
2A07811	9.5	4.2	2.7	6.9	5.5	3.7	3.2	6.9
2A07812	15.7	7.1	4.5	11.6	9.3	6.4	5.4	11.8
2A07816	13.9	6.1	3.9	10.0	8.1	5.6	4.4	10.0
2A07817	14.8	6.5	4.2	10.7	9.1	6.0	4.9	11.0
2A07821	9.7	4.2	3.0	7.2	5.4	3.6	3.7	7.3
2A07823	10.8	4.9	3.2	8.1	6.5	4.5	4.1	8.5
2A07828	13.3	6.0	4.0	10.0	8.8	5.5	4.7	10.2
2A07829	14.5	6.5	4.4	10.9	9.5	6.0	5.0	10.9
2A07834	9.8	4.5	3.0	7.5	6.8	4.1	3.6	7.7
2A07835	11.5	5.1	3.6	8.6	7.2	4.6	4.4	9.1
2A07882	14.0	6.3	4.2	10.5	8.9	6.0	4.8	10.8
2A08802	17.1	7.4	5.3	12.7	10.4	6.3	7.0	13.3
2A08804	19.3	8.3	6.2	14.6	11.7	7.1	8.3	15.4
2A08805	14.2	6.2	4.5	10.7	9.3	5.5	5.6	11.1
2A08810	16.0	7.0	5.2	12.2	10.2	6.1	7.0	13.0
2A08901	12.7	5.7	3.9	9.6	8.5	5.1	5.1	10.2
2B041020L	13.4	6.1	4.0	10.1	4.3	3.8	6.6	10.4
2B041049U	10.5	4.7	3.2	7.9	3.0	2.9	5.3	8.2
2B047032	15.0	6.9	3.7	10.7	5.3	4.4	5.4	9.9
2B047044U	14.6	6.7	3.7	10.4	5.4	4.7	4.9	9.6
2B047076L	11.7	5.3	3.5	8.8	5.1	4.2	4.9	9.1
2B047076U	13.5	6.1	4.1	10.2	5.8	4.9	5.6	10.5
2B058015U	13.2	6.1	3.7	9.9	5.8	5.0	5.1	10.1
2C041033U	21.5	9.7	4.9	14.6	6.8	6.0	6.0	12.0
2C041039	19.9	9.0	4.5	13.5	6.3	5.6	5.4	11.0
2C041040	18.2	8.3	4.2	12.5	6.4	5.4	4.9	10.3
2C041043U	14.6	6.6	3.8	10.4	3.8	3.7	5.3	9.0
2C041045	17.5	8.0	3.9	11.9	5.9	5.1	4.6	9.8
2C041051	19.7	9.1	4.5	13.6	7.2	6.1	5.2	11.3

Table G-5. Continued

	Reference Year 1995				Year 2040			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
2C046013L	16.5	7.7	3.9	11.6	6.8	5.4	4.1	9.5
2C046033	15.5	7.4	3.8	11.1	6.5	5.2	4.2	9.4
2C046034	17.2	8.1	4.2	12.3	7.1	5.7	5.0	10.7
2C046043L	15.8	7.5	3.9	11.4	6.5	5.3	4.6	9.9
2C046043U	15.1	7.2	3.7	10.9	6.2	5.1	4.4	9.5
2C046050	12.3	6.1	3.1	9.2	5.8	4.4	3.3	7.7
2C046053L	14.0	6.7	3.5	10.2	5.8	4.8	4.1	8.9
2C046062L	13.6	6.6	3.4	10.0	5.6	4.8	4.3	9.1
2C047007	17.0	7.9	4.0	11.8	6.6	5.4	4.4	9.8
2C047010L	16.8	7.8	4.1	11.9	6.5	5.3	4.9	10.2
2C047010U	16.9	7.8	4.1	11.9	6.6	5.4	4.9	10.3
2C057004	11.4	5.7	2.9	8.6	5.0	4.0	3.3	7.2
2C066026L	20.7	7.6	5.1	12.7	10.3	6.0	7.3	13.3
2C066027L	20.9	7.7	5.0	12.6	10.2	6.0	6.8	12.7
2C066027U	20.3	7.4	4.8	12.2	9.9	5.8	6.6	12.4
2C066039L	21.2	7.7	5.2	12.9	10.6	6.1	7.4	13.5
2C077022U	18.1	7.6	5.7	13.3	10.0	6.2	8.0	14.2
BJ 35	12.4	5.4	3.7	9.1	6.1	4.7	4.3	9.0
BJ 72	13.5	5.9	4.1	10.0	8.9	5.5	4.7	10.3
BJ 76	12.5	5.7	3.7	9.4	7.7	5.1	4.6	9.7
BJ 77	12.1	5.4	3.6	9.0	7.7	5.0	4.2	9.2
BLFC	12.4	5.7	3.5	9.3	6.0	4.6	4.7	9.3
CO01	15.4	6.6	4.9	11.5	9.4	5.6	6.4	12.0
CO05	11.7	5.0	3.7	8.7	7.0	4.3	4.9	9.2
CO06	19.1	8.2	6.0	14.2	11.7	7.0	7.8	14.7
CO10	13.2	5.7	4.2	9.9	7.9	4.8	5.5	10.4
DR	12.6	5.7	3.8	9.5	5.4	4.6	5.2	9.8
DR01	12.5	5.7	3.8	9.4	5.4	4.6	5.2	9.7
DS04	16.9	7.9	4.2	12.1	5.0	4.9	6.1	11.0
DS06	16.9	7.9	4.2	12.1	5.0	4.8	6.1	10.9
DS09	17.0	8.0	4.2	8.0	5.4	4.9	5.6	4.9
DS19	17.0	7.9	4.2	12.1	5.4	4.9	5.6	10.5
DS50	16.9	7.9	4.2	12.1	5.4	4.9	5.6	10.4
FN1	21.2	9.7	4.8	14.5	7.3	6.4	5.5	11.9
FN2	20.8	9.5	4.7	14.2	7.2	6.3	5.4	11.7
FN3	21.4	9.8	4.8	14.6	7.4	6.5	5.5	12.0
GS01	43.2	20.1	12.6	32.7	26.5	18.6	14.8	33.4
GS02	43.7	20.3	12.7	33.0	26.7	18.8	14.9	33.7
GS04	37.0	17.2	10.8	28.0	23.8	15.8	12.4	28.1
GS05	26.6	12.8	8.0	20.8	14.8	11.0	9.8	20.8
GS06	9.9	4.4	2.8	7.2	5.5	3.9	3.4	7.2
GS07	29.2	13.5	8.7	22.2	18.9	12.5	10.1	22.6
GS08	33.5	15.5	9.9	25.4	21.7	14.3	11.5	25.8
LB01	14.0	5.9	3.9	9.8	8.6	5.3	4.8	10.1

Table G-5. Continued								
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
LEWF	12.9	5.7	3.7	9.4	5.8	4.8	4.5	9.2
M037	12.7	5.9	3.6	9.5	5.7	5.0	4.9	9.8
M038	12.7	5.9	3.6	9.5	5.7	4.9	5.0	9.9
M039	12.5	5.8	3.6	9.3	6.0	4.6	4.8	9.4
NFD	11.9	5.2	4.1	9.3	4.2	3.6	6.3	9.9
NFDR	11.9	5.2	4.1	9.3	4.2	3.6	6.3	9.9
OC02	18.7	8.6	4.3	13.0	6.7	6.0	4.9	10.9
OC05	19.0	8.8	4.4	13.1	6.7	6.1	5.0	11.1
OC08	18.8	8.7	4.3	13.0	6.7	6.0	4.9	10.9
OC09	18.7	8.6	4.3	12.9	6.6	6.0	4.9	10.9
OC31	18.9	8.7	4.4	13.1	6.7	6.1	4.9	11.0
OC32	18.8	8.7	4.3	13.0	6.7	6.1	4.9	11.0
OC35	19.1	8.8	4.4	13.2	7.0	5.9	5.1	11.0
OC79	18.9	8.7	4.4	13.1	6.7	6.1	4.9	11.0
PAIN	13.0	6.0	3.8	9.8	5.6	4.9	5.2	10.1
SP10	12.5	5.7	4.6	10.3	9.8	5.2	6.0	11.1
SP39	12.8	5.9	4.8	10.6	10.1	5.3	6.1	11.4
SP41	12.6	5.8	4.7	10.5	9.8	5.2	6.0	11.3
STAN	9.5	4.1	3.3	7.4	3.6	3.0	4.6	7.6
VA524S	12.2	5.5	3.2	8.7	5.4	4.4	4.3	8.7
VA526S	11.8	5.6	3.1	8.7	4.9	4.4	3.9	8.4
VA531S	8.3	3.6	2.9	6.5	2.9	2.5	4.4	6.9
VA548S	10.1	4.4	3.3	7.7	3.8	3.3	4.6	7.9
VA555S	13.4	6.2	3.6	9.8	5.8	5.1	4.5	9.6
VA821S	11.1	5.0	3.1	8.0	4.8	3.9	4.0	7.9
VT02	13.0	5.7	3.7	9.4	5.8	4.8	4.5	9.3
VT05	11.1	5.2	3.4	8.5	4.9	4.3	3.9	8.2
VT07	13.3	5.9	3.6	9.6	5.7	5.0	4.1	9.1
VT08	12.7	5.7	3.4	9.1	5.4	4.7	3.9	8.7
VT09	13.1	5.8	3.5	9.3	5.6	4.9	4.0	8.9
VT10	13.8	6.5	3.6	10.1	5.7	5.0	4.6	9.6
VT11	14.3	6.8	3.8	10.6	6.7	5.5	4.9	10.4
VT12	13.8	6.5	3.7	10.2	6.4	5.3	4.7	10.0
VT15	12.7	6.1	3.4	9.4	6.0	4.9	4.4	9.3
VT18	16.1	7.5	4.0	11.6	5.9	5.3	5.4	10.7
VT19	16.8	7.8	4.2	12.0	6.2	5.5	5.6	11.1
VT20	11.6	5.5	3.2	8.6	5.4	4.4	4.2	8.6
VT24	12.0	5.5	3.2	8.8	5.2	4.1	4.7	8.8
VT25	12.2	5.6	3.3	8.9	5.3	4.2	4.8	9.0
VT26	12.4	5.6	3.3	8.9	5.5	4.5	4.4	8.9
VT28	12.1	5.5	3.2	8.7	5.8	4.3	4.5	8.8
VT29	12.7	5.7	3.4	9.2	5.5	4.5	4.5	9.1
VT31	12.1	5.4	3.3	8.7	5.1	4.2	4.3	8.5
VT32	12.8	5.7	3.4	9.1	5.7	4.6	4.6	9.1

Table G-5. Continued								
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
VT34	12.5	5.8	3.4	9.2	5.6	4.8	4.5	9.2
VT35	13.0	6.0	3.8	9.8	5.6	4.9	5.2	10.1
VT36	14.3	6.6	4.2	10.8	6.2	5.4	5.7	11.1
VT37	13.7	6.4	3.7	10.1	5.6	4.7	4.9	9.6
VT38	14.5	6.8	3.9	10.7	6.1	5.3	5.2	10.4
VT39	13.9	6.6	4.0	10.6	5.8	5.5	5.4	10.9
VT41	14.5	6.8	4.1	6.8	6.1	5.7	5.6	5.7
VT46	13.5	6.3	3.8	10.2	5.9	5.2	5.3	10.4
VT48	12.1	5.3	3.5	8.8	5.6	4.4	4.6	9.0
VT49	10.6	4.7	3.2	8.0	3.2	3.3	4.6	8.0
VT50	10.6	4.7	3.2	7.9	3.1	3.1	5.1	8.2
VT53	11.6	5.2	3.6	8.8	4.8	4.0	5.1	9.2
VT54	13.9	6.3	3.9	10.2	4.5	4.2	6.1	10.3
VT55	12.4	5.6	3.5	9.1	4.0	3.8	5.5	9.2
VT56	12.5	5.7	3.5	9.2	5.1	4.3	4.8	9.1
VT57	11.7	5.4	3.3	8.6	4.6	4.0	4.7	8.6
VT58	8.8	3.8	3.1	6.9	3.1	2.7	4.7	7.3
VT59	9.5	4.1	3.3	7.4	3.6	3.0	4.6	7.6
VT62	9.9	4.3	3.4	7.7	3.4	3.1	5.3	8.4
VT66	9.1	3.9	3.2	7.1	3.2	2.7	4.9	7.6
VT68	15.3	7.2	4.3	11.5	6.4	5.9	5.8	11.8
VT70	14.7	6.9	4.1	11.0	6.1	5.7	5.6	11.3
VT72	15.8	7.4	4.4	11.8	6.6	6.1	6.0	12.1
VT73	15.3	7.1	4.3	11.4	6.4	5.9	5.8	11.7
VT74	15.0	7.0	4.2	11.2	6.3	5.8	5.7	11.5
VT75	9.3	4.0	3.2	7.3	3.3	2.8	4.9	7.8
VT76	12.7	5.9	3.7	9.5	6.1	4.7	4.9	9.6
VT77	13.1	6.1	3.8	9.9	5.9	5.1	5.1	10.2
VT78	11.6	5.5	3.3	8.9	4.8	4.5	4.0	8.5
WOR	13.3	6.0	3.9	10.0	5.8	4.9	5.4	10.3
WOR1	13.2	6.0	3.9	9.9	5.7	4.8	5.4	10.2
WV523S	21.4	9.9	5.3	15.2	5.0	5.7	7.7	13.4
WV531S	19.1	8.6	4.3	12.9	6.8	6.0	4.9	10.9
WV547S	15.1	7.2	3.6	10.8	6.4	5.1	4.1	9.2
WV548S	14.9	7.1	3.7	10.8	6.2	5.0	4.3	9.4
WV769S	19.4	8.9	4.4	13.4	7.3	6.0	5.0	11.0
WV770S	16.5	7.6	3.8	11.4	6.4	5.2	4.3	9.5
WV771S	17.4	7.9	3.9	11.8	5.8	5.1	4.6	9.7
WV785S	10.9	5.3	2.8	8.1	4.6	4.0	3.6	7.7
WV788S	16.0	7.6	3.9	11.4	6.7	5.4	4.3	9.7
WV796S	19.0	8.8	4.7	13.6	4.9	5.1	7.1	12.3

Table G-6. The total deposition of SO_4, NH_4, NO_3 and Total N for each SAMI site for the Reference Year and year 2040 of the BWC strategy. Deposition is in kg/ha/yr (as S or N). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Reference Year 1995				Year 2040			
	SO_4	NO_3	NH_4	Total N	SO_4	NO_3	NH_4	Total N
Average	15.1	6.8	4.1	11.0	5.5	5.0	4.5	9.6
Std. Dev.	5.2	2.4	1.4	3.8	2.9	2.1	1.5	3.5
Maximum	43.7	20.3	12.7	33.0	20.9	18.0	13.2	31.1
Minimum	8.3	3.6	2.7	6.5	2.2	2.4	2.7	5.8

	Reference Year 1995				Year 2040			
Site ID	SO_4	NO_3	NH_4	Total N	SO_4	NO_3	NH_4	Total N
2A068015U	12.2	5.6	3.6	9.2	4.3	4.5	3.5	8.0
2A07701	12.5	5.3	3.5	8.8	6.1	4.5	3.7	8.3
2A07805	9.9	4.4	2.8	7.1	4.3	3.6	2.7	6.3
2A07806	11.9	5.3	3.4	8.8	4.9	4.4	3.6	8.0
2A07810L	10.7	4.8	3.0	7.8	5.3	4.2	3.1	7.2
2A07810U	12.9	5.7	3.6	9.3	6.4	5.0	3.6	8.6
2A07811	9.5	4.2	2.7	6.9	4.5	3.6	2.7	6.3
2A07812	15.7	7.1	4.5	11.6	7.5	6.1	4.8	10.9
2A07816	13.9	6.1	3.9	10.0	6.6	5.4	3.9	9.2
2A07817	14.8	6.5	4.2	10.7	7.1	5.8	4.3	10.1
2A07821	9.7	4.2	3.0	7.2	4.2	3.2	3.2	6.4
2A07823	10.8	4.9	3.2	8.1	5.1	4.3	3.6	7.9
2A07828	13.3	6.0	4.0	10.0	7.0	5.2	4.2	9.4
2A07829	14.5	6.5	4.4	10.9	7.5	5.7	4.4	10.2
2A07834	9.8	4.5	3.0	7.5	5.3	3.9	3.2	7.1
2A07835	11.5	5.1	3.6	8.6	5.3	4.2	3.9	8.1
2A07882	14.0	6.3	4.2	10.5	7.0	5.7	4.2	10.0
2A08802	17.1	7.4	5.3	12.7	7.9	5.9	6.0	11.9
2A08804	19.3	8.3	6.2	14.6	8.8	6.4	7.0	13.4
2A08805	14.2	6.2	4.5	10.7	6.9	5.1	4.8	9.9
2A08810	16.0	7.0	5.2	12.2	7.5	5.6	5.9	11.5
2A08901	12.7	5.7	3.9	9.6	6.5	4.9	4.3	9.2
2B041020L	13.4	6.1	4.0	10.1	3.7	3.7	5.5	9.2
2B041049U	10.5	4.7	3.2	7.9	2.4	2.8	4.2	7.0
2B047032	15.0	6.9	3.7	10.7	4.4	4.4	4.7	9.1
2B047044U	14.6	6.7	3.7	10.4	4.4	4.6	4.3	9.0
2B047076L	11.7	5.3	3.5	8.8	3.3	3.8	3.9	7.7
2B047076U	13.5	6.1	4.1	10.2	3.8	4.4	4.5	8.9
2B058015U	13.2	6.1	3.7	9.9	4.1	4.6	4.3	9.0
2C041033U	21.5	9.7	4.9	14.6	6.1	5.7	5.2	10.9
2C041039	19.9	9.0	4.5	13.5	5.7	5.3	4.7	10.1
2C041040	18.2	8.3	4.2	12.5	5.8	5.3	4.4	9.7
2C041043U	14.6	6.6	3.8	10.4	3.4	3.6	4.6	8.2
2C041045	17.5	8.0	3.9	11.9	5.3	4.9	4.1	9.0
2C041051	19.7	9.1	4.5	13.6	6.5	5.9	4.7	10.6

Table G-6. Continued.

	Reference Year 1995				Year 2040			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
2C046043L	15.8	7.5	3.9	11.4	5.6	5.2	4.1	9.3
2C046043U	15.1	7.2	3.7	10.9	5.4	5.0	3.9	8.9
2C046050	12.3	6.1	3.1	9.2	5.0	4.2	3.0	7.2
2C046053L	14.0	6.7	3.5	10.2	5.0	4.6	3.6	8.2
2C046062L	13.6	6.6	3.4	10.0	4.7	4.6	3.7	8.3
2C047007	17.0	7.9	4.0	11.8	5.8	5.3	4.0	9.3
2C047010L	16.8	7.8	4.1	11.9	5.7	5.3	4.4	9.7
2C047010U	16.9	7.8	4.1	11.9	5.7	5.3	4.4	9.7
2C057004	11.4	5.7	2.9	8.6	4.2	3.7	2.9	6.7
2C066026L	20.7	7.6	5.1	12.7	8.1	5.7	5.8	11.5
2C066027L	20.9	7.7	5.0	12.6	8.4	5.7	5.6	11.3
2C066027U	20.3	7.4	4.8	12.2	8.2	5.5	5.4	11.0
2C066039L	21.2	7.7	5.2	12.9	8.3	5.8	5.9	11.7
2C077022U	18.1	7.6	5.7	13.3	7.7	5.8	6.7	12.5
BJ 35	12.4	5.4	3.7	9.1	4.8	4.4	3.8	8.2
BJ 72	13.5	5.9	4.1	10.0	7.0	5.3	4.2	9.5
BJ 76	12.5	5.7	3.7	9.4	6.0	4.9	4.1	8.9
BJ 77	12.1	5.4	3.6	9.0	6.0	4.8	3.7	8.5
BLFC	12.4	5.7	3.5	9.3	4.2	4.2	4.0	8.2
CO01	15.4	6.6	4.9	11.5	7.2	5.1	5.5	10.6
CO05	11.7	5.0	3.7	8.7	5.3	3.9	4.2	8.1
CO06	19.1	8.2	6.0	14.2	8.9	6.4	6.6	13.0
CO10	13.2	5.7	4.2	9.9	6.0	4.4	4.7	9.1
DR	12.6	5.7	3.8	9.5	3.5	4.1	4.1	8.2
DR01	12.5	5.7	3.8	9.4	3.5	4.1	4.1	8.2
DS04	16.9	7.9	4.2	12.1	4.3	4.7	5.3	10.0
DS06	16.9	7.9	4.2	12.1	4.3	4.7	5.3	10.0
DS09	17.0	8.0	4.2	12.1	4.8	4.8	5.0	9.8
DS19	17.0	7.9	4.2	12.1	4.8	4.8	5.0	9.8
DS50	16.9	7.9	4.2	12.1	4.8	4.8	4.9	9.7
FN1	21.2	9.7	4.8	14.5	6.6	6.2	4.9	11.1
FN2	20.8	9.5	4.7	14.2	6.5	6.1	4.8	10.9
FN3	21.4	9.8	4.8	14.6	6.6	6.2	4.9	11.2
GS01	43.2	20.1	12.6	32.7	20.7	17.8	13.0	30.8
GS02	43.7	20.3	12.7	33.0	20.9	18.0	13.2	31.1
GS04	37.0	17.2	10.8	28.0	19.4	15.1	11.0	26.1
GS05	26.6	12.8	8.0	20.8	12.4	10.4	8.2	18.6
GS06	9.9	4.4	2.8	7.2	4.6	3.7	2.9	6.6
GS07	29.2	13.5	8.7	22.2	15.3	11.9	9.0	21.0
GS08	33.5	15.5	9.9	25.4	17.5	13.6	10.3	23.9
LB01	14.0	5.9	3.9	9.8	6.8	5.1	4.2	9.2
LEWF	12.9	5.7	3.7	9.4	4.5	4.5	3.8	8.3
M037	12.7	5.9	3.6	9.5	4.1	4.6	4.1	8.6
M038	12.7	5.9	3.6	9.5	4.0	4.6	4.2	8.8

Table G-6. Continued.

	Reference Year 1995				Year 2040			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
M039	12.5	5.8	3.6	9.3	4.2	4.2	4.0	8.3
NFD	11.9	5.2	4.1	9.3	3.2	3.4	5.0	8.4
NFDR	11.9	5.2	4.1	9.3	3.2	3.4	5.0	8.4
OC02	18.7	8.6	4.3	13.0	6.0	5.8	4.4	10.2
OC05	19.0	8.8	4.4	13.1	6.0	5.9	4.5	10.4
OC08	18.8	8.7	4.3	13.0	6.0	5.8	4.4	10.2
OC09	18.7	8.6	4.3	12.9	5.9	5.8	4.4	10.2
OC31	18.9	8.7	4.4	13.1	6.0	5.8	4.5	10.3
OC32	18.8	8.7	4.3	13.0	6.0	5.8	4.5	10.3
OC35	19.1	8.8	4.4	13.2	6.3	5.7	4.6	10.3
OC79	18.9	8.7	4.4	13.1	6.0	5.8	4.5	10.3
PAIN	13.0	6.0	3.8	9.8	3.6	4.4	4.3	8.6
SP10	12.5	5.7	4.6	10.3	9.0	5.0	5.4	10.4
SP39	12.8	5.9	4.8	10.6	9.3	5.2	5.6	10.7
SP41	12.6	5.8	4.7	10.5	9.1	5.1	5.5	10.6
STAN	9.5	4.1	3.3	7.4	2.7	2.8	3.7	6.6
VA524S	12.2	5.5	3.2	8.7	4.1	4.1	3.6	7.7
VA526S	11.8	5.6	3.1	8.7	4.0	4.1	3.4	7.5
VA531S	8.3	3.6	2.9	6.5	2.2	2.4	3.5	5.8
VA548S	10.1	4.4	3.3	7.7	2.9	2.9	3.6	6.5
VA555S	13.4	6.2	3.6	9.8	4.4	4.8	4.0	8.8
VA821S	11.1	5.0	3.1	8.0	3.5	3.7	3.3	7.0
VT02	13.0	5.7	3.7	9.4	4.5	4.5	3.8	8.3
VT05	11.1	5.2	3.4	8.5	3.8	4.1	3.3	7.4
VT07	13.3	5.9	3.6	9.6	4.6	4.7	3.5	8.2
VT08	12.7	5.7	3.4	9.1	4.4	4.5	3.3	7.8
VT09	13.1	5.8	3.5	9.3	4.5	4.6	3.4	8.0
VT10	13.8	6.5	3.6	10.1	4.6	4.9	4.1	8.9
VT11	14.3	6.8	3.8	10.6	4.4	5.2	4.3	9.5
VT12	13.8	6.5	3.7	10.2	4.2	5.1	4.1	9.2
VT15	12.7	6.1	3.4	9.4	3.9	4.7	3.8	8.5
VT18	16.1	7.5	4.0	11.6	4.9	5.2	4.7	9.9
VT19	16.8	7.8	4.2	12.0	5.1	5.4	4.9	10.3
VT20	11.6	5.5	3.2	8.6	4.1	4.2	3.6	7.8
VT24	12.0	5.5	3.2	8.8	3.8	4.0	3.9	7.8
VT25	12.2	5.6	3.3	8.9	3.9	4.0	3.9	8.0
VT26	12.4	5.6	3.3	8.9	4.2	4.1	3.7	7.8
VT28	12.1	5.5	3.2	8.7	4.7	4.1	3.8	7.9
VT29	12.7	5.7	3.4	9.2	4.1	4.1	3.8	8.0
VT31	12.1	5.4	3.3	8.7	3.8	3.9	3.7	7.6
VT32	12.8	5.7	3.4	9.1	4.3	4.2	3.8	8.1
VT34	12.5	5.8	3.4	9.2	4.0	4.5	3.8	8.3
VT35	13.0	6.0	3.8	9.8	3.6	4.4	4.3	8.6
VT36	14.3	6.6	4.2	10.8	4.0	4.8	4.7	9.5

Table G-6. Continued.								
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
VT37	13.7	6.4	3.7	10.1	4.6	4.6	4.2	8.8
VT38	14.5	6.8	3.9	10.7	4.9	5.1	4.4	9.5
VT39	13.9	6.6	4.0	10.6	4.3	5.1	4.6	9.7
VT41	14.5	6.8	4.1	10.9	4.5	5.3	4.7	10.0
VT46	13.5	6.3	3.8	10.2	4.1	4.8	4.5	9.3
VT48	12.1	5.3	3.5	8.8	4.0	4.0	3.8	7.7
VT49	10.6	4.7	3.2	8.0	2.7	3.1	3.8	6.9
VT50	10.6	4.7	3.2	7.9	2.6	3.0	4.0	7.0
VT53	11.6	5.2	3.6	8.8	3.4	3.7	4.0	7.8
VT54	13.9	6.3	3.9	10.2	3.7	4.1	4.9	9.0
VT55	12.4	5.6	3.5	9.1	3.3	3.7	4.4	8.1
VT56	12.5	5.7	3.5	9.2	4.1	4.1	4.0	8.1
VT57	11.7	5.4	3.3	8.6	3.7	3.8	3.8	7.7
VT58	8.8	3.8	3.1	6.9	2.4	2.5	3.7	6.2
VT59	9.5	4.1	3.3	7.4	2.7	2.8	3.8	6.6
VT62	9.9	4.3	3.4	7.7	2.6	2.8	4.2	7.0
VT66	9.1	3.9	3.2	7.1	2.4	2.6	3.9	6.4
VT68	15.3	7.2	4.3	11.5	4.7	5.6	4.9	10.5
VT70	14.7	6.9	4.1	11.0	4.5	5.4	4.7	10.1
VT72	15.8	7.4	4.4	11.8	4.9	5.8	5.1	10.8
VT73	15.3	7.1	4.3	11.4	4.7	5.6	4.9	10.5
VT74	15.0	7.0	4.2	11.2	4.6	5.5	4.8	10.3
VT75	9.3	4.0	3.2	7.3	2.5	2.7	3.9	6.6
VT76	12.7	5.9	3.7	9.5	4.3	4.3	4.1	8.4
VT77	13.1	6.1	3.8	9.9	4.2	4.7	4.2	8.9
VT78	11.6	5.5	3.3	8.9	3.7	4.2	3.2	7.4
WOR	13.3	6.0	3.9	10.0	3.7	4.4	4.3	8.7
WOR1	13.2	6.0	3.9	9.9	3.7	4.3	4.3	8.6
WV523S	21.4	9.9	5.3	15.2	4.4	5.5	6.7	12.3
WV531S	19.1	8.6	4.3	12.9	6.1	5.8	4.4	10.2
WV547S	15.1	7.2	3.6	10.8	5.6	5.0	3.6	8.6
WV548S	14.9	7.1	3.7	10.8	5.3	4.9	3.8	8.8
WV769S	19.4	8.9	4.4	13.4	6.5	5.8	4.5	10.3
WV770S	16.5	7.6	3.8	11.4	5.6	5.1	3.9	9.0
WV771S	17.4	7.9	3.9	11.8	5.2	4.9	4.1	9.0
WV785S	10.9	5.3	2.8	8.1	3.7	3.8	3.2	7.0
WV788S	16.0	7.6	3.9	11.4	5.9	5.3	3.9	9.1
WV796S	19.0	8.8	4.7	13.6	4.2	5.1	6.1	11.2

Table G-7. The total deposition of SO_4, NH_4, NO_3 and Total N for each SAMI site for the Reference Year and year 2040 of the BYB strategy. Deposition is in kg/ha/yr (as S or N). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Reference Year 1995				**Year 2040**			
	SO_4	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
Average	15.1	6.8	4.1	11.0	4.5	4.8	4.0	8.8
Std. Dev.	5.2	2.4	1.4	3.8	2.5	2.0	1.4	3.3
Maximum	43.7	20.3	12.7	33.0	17.0	17.1	11.8	28.9
Minimum	8.3	3.6	2.7	6.5	1.7	2.3	2.4	5.0
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
2A068015U	12.2	5.6	3.6	9.2	3.5	4.3	3.0	7.3
2A07701	12.5	5.3	3.5	8.8	5.0	4.3	3.3	7.7
2A07805	9.9	4.4	2.8	7.1	3.6	3.4	2.4	5.8
2A07806	11.9	5.3	3.4	8.8	4.0	4.2	3.1	7.3
2A07810L	10.7	4.8	3.0	7.8	4.5	4.0	2.7	6.7
2A07810U	12.9	5.7	3.6	9.3	5.4	4.8	3.3	8.1
2A07811	9.5	4.2	2.7	6.9	3.8	3.5	2.4	5.9
2A07812	15.7	7.0	4.5	11.6	6.2	5.9	4.3	10.2
2A07816	13.9	6.1	3.9	10.0	5.6	5.2	3.5	8.7
2A07817	14.8	6.5	4.2	10.7	5.8	5.5	3.9	9.4
2A07821	9.7	4.2	3.0	7.2	3.4	2.9	2.8	5.7
2A07823	10.8	4.9	3.2	8.1	4.2	4.1	3.2	7.4
2A07828	13.3	6.0	4.0	10.0	5.8	5.0	3.7	8.7
2A07829	14.5	6.5	4.4	10.9	6.2	5.5	4.0	9.4
2A07834	9.8	4.5	3.0	7.5	4.4	3.7	2.9	6.6
2A07835	11.5	5.1	3.6	8.6	4.2	3.9	3.4	7.3
2A07882	14.0	6.3	4.2	10.5	6.0	5.5	3.9	9.4
2A08802	17.1	7.4	5.3	12.7	6.1	5.5	5.2	10.7
2A08804	19.3	8.3	6.2	14.6	6.7	5.9	6.0	11.9
2A08805	14.2	6.2	4.5	10.7	5.3	4.8	4.2	9.0
2A08810	16.0	7.0	5.2	12.2	5.5	5.3	5.0	10.2
2A08901	12.7	5.7	3.9	9.6	5.2	4.6	3.7	8.3
2B041020L	13.4	6.1	4.0	10.1	3.3	3.5	4.7	8.3
2B041049U	10.5	4.7	3.2	7.9	2.0	2.7	3.4	6.1
2B047032	15.0	6.9	3.7	10.7	3.5	4.2	4.2	8.4
2B047044U	14.6	6.7	3.7	10.4	3.5	4.4	3.9	8.4
2B047076L	11.7	5.3	3.5	8.8	2.6	3.5	3.1	6.6
2B047076U	13.5	6.1	4.1	10.2	2.9	4.1	3.6	7.6
2B058015U	13.2	6.1	3.7	9.9	2.9	4.3	3.7	8.1
2C041033U	21.5	9.7	4.9	14.6	5.0	5.3	4.7	10.0
2C041039	19.9	9.0	4.5	13.5	4.6	5.0	4.2	9.2
2C041040	18.2	8.3	4.2	12.5	4.9	5.0	4.0	9.0
2C041043U	14.6	6.6	3.8	10.4	1.7	3.2	3.8	7.0
2C041045	17.5	8.0	3.9	11.9	4.4	4.7	3.7	8.4
2C041051	19.7	9.1	4.5	13.6	5.6	5.7	4.4	10.0

Table G-7. Continued.

	Reference Year 1995				Year 2040			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
2C046013L	16.5	7.7	3.9	11.6	4.6	4.9	3.5	8.4
2C046033	15.5	7.4	3.8	11.1	4.5	4.9	3.4	8.4
2C046034	17.2	8.1	4.2	12.3	4.9	5.4	4.0	9.4
2C046043L	15.8	7.5	3.9	11.4	4.5	5.0	3.7	8.7
2C046043U	15.1	7.2	3.7	10.9	4.3	4.8	3.5	8.3
2C046050	12.3	6.1	3.1	9.2	3.7	3.9	2.7	6.6
2C046053L	14.0	6.7	3.5	10.2	4.0	4.5	3.3	7.7
2C046062L	13.6	6.6	3.4	10.0	3.7	4.4	3.3	7.6
2C047007	17.0	7.9	4.0	11.8	4.8	5.1	3.8	8.8
2C047010L	16.8	7.8	4.1	11.9	4.7	5.1	4.0	9.1
2C047010U	16.9	7.8	4.1	11.9	4.7	5.1	4.1	9.1
2C057004	11.4	5.7	2.9	8.6	3.2	3.5	2.6	6.1
2C066026L	20.7	7.6	5.1	12.7	7.1	5.5	4.6	10.1
2C066027L	20.9	7.7	5.0	12.6	7.5	5.5	4.6	10.1
2C066027U	20.3	7.4	4.8	12.2	7.3	5.3	4.5	9.8
2C066039L	21.2	7.7	5.2	12.9	7.3	5.5	4.7	10.3
2C077022U	18.1	7.6	5.7	13.3	6.6	5.5	5.5	11.0
BJ 35	12.4	5.4	3.7	9.1	4.0	4.2	3.4	7.6
BJ 72	13.5	5.9	4.1	10.0	5.8	5.0	3.8	8.9
BJ 76	12.5	5.7	3.7	9.4	4.9	4.6	3.6	8.2
BJ 77	12.1	5.4	3.6	9.0	5.1	4.6	3.4	8.0
BLFC	12.4	5.7	3.5	9.3	3.0	3.9	3.4	7.3
CO01	15.4	6.6	4.9	11.5	5.6	4.8	4.7	9.5
CO05	11.7	5.0	3.7	8.7	4.2	3.6	3.6	7.2
CO06	19.1	8.2	6.0	14.2	6.9	5.9	5.7	11.6
CO10	13.2	5.7	4.2	9.9	4.8	4.1	4.0	8.2
DR	12.6	5.7	3.8	9.5	2.7	3.8	3.3	7.1
DR01	12.5	5.7	3.8	9.4	2.7	3.8	3.3	7.1
DS04	16.9	7.9	4.2	12.1	3.5	4.5	4.8	9.3
DS06	16.9	7.9	4.2	12.1	3.5	4.5	4.8	9.3
DS09	17.0	8.0	4.2	12.1	4.0	4.6	4.6	9.2
DS19	17.0	7.9	4.2	12.1	4.0	4.6	4.6	9.2
DS50	16.9	7.9	4.2	12.1	3.9	4.5	4.6	9.1
FN1	21.2	9.7	4.8	14.5	5.5	5.9	4.5	10.4
FN2	20.8	9.5	4.7	14.2	5.4	5.8	4.4	10.2
FN3	21.4	9.8	4.8	14.6	5.6	5.9	4.5	10.5
GS01	43.2	20.1	12.6	32.7	16.9	16.9	11.7	28.6
GS02	43.7	20.3	12.7	33.0	17.0	17.1	11.8	28.9
GS04	37.0	17.2	10.8	28.0	16.4	14.6	10.0	24.6
GS05	26.6	12.8	8.0	20.8	10.4	10.0	7.0	17.0
GS06	9.9	4.4	2.8	7.2	3.9	3.6	2.5	6.1
GS07	29.2	13.5	8.7	22.2	13.0	11.4	8.2	19.6
GS08	33.5	15.5	9.9	25.4	14.9	13.1	9.3	22.4
LB01	14.0	5.9	3.9	9.8	5.6	4.9	3.7	8.5

Table G-7. Continued.

	Reference Year 1995				Year 2040			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
LEWF	12.9	5.7	3.7	9.4	3.7	4.3	3.2	7.5
M037	12.7	5.9	3.6	9.5	2.9	4.2	3.5	7.7
M038	12.7	5.9	3.6	9.5	2.9	4.3	3.6	7.9
M039	12.5	5.8	3.6	9.3	3.0	3.9	3.4	7.3
NFD	11.9	5.2	4.1	9.3	2.6	3.3	4.0	7.2
NFDR	11.9	5.2	4.1	9.3	2.6	3.3	4.0	7.2
OC02	18.7	8.6	4.3	13.0	5.1	5.5	4.1	9.6
OC05	19.0	8.8	4.4	13.1	5.1	5.6	4.2	9.8
OC08	18.8	8.7	4.3	13.0	5.0	5.5	4.1	9.7
OC09	18.7	8.6	4.3	12.9	5.0	5.5	4.1	9.6
OC31	18.9	8.7	4.4	13.1	5.1	5.6	4.2	9.7
OC32	18.8	8.7	4.3	13.0	5.1	5.5	4.1	9.7
OC35	19.1	8.8	4.4	13.2	5.4	5.5	4.3	9.8
OC79	18.9	8.7	4.4	13.1	5.1	5.6	4.2	9.7
PAIN	13.0	6.0	3.8	9.8	2.8	4.0	3.5	7.5
SP10	12.5	5.7	4.6	10.3	8.8	4.9	4.9	9.8
SP39	12.8	5.9	4.8	10.6	9.1	5.0	5.1	10.1
SP41	12.6	5.8	4.7	10.5	8.9	4.9	5.0	9.9
STAN	9.5	4.1	3.3	7.4	2.2	2.7	3.1	5.7
VA524S	12.2	5.5	3.2	8.7	3.3	3.9	3.2	7.0
VA526S	11.8	5.6	3.1	8.7	3.3	3.8	3.0	6.8
VA531S	8.3	3.6	2.9	6.5	1.8	2.3	2.8	5.0
VA548S	10.1	4.4	3.3	7.7	2.4	2.6	2.8	5.4
VA555S	13.4	6.2	3.6	9.8	3.5	4.7	3.7	8.3
VA821S	11.1	5.0	3.1	8.0	2.7	3.5	2.7	6.2
VT02	13.0	5.7	3.7	9.4	3.7	4.4	3.2	7.6
VT05	11.1	5.2	3.4	8.5	3.2	3.9	2.8	6.7
VT07	13.3	5.9	3.6	9.6	3.9	4.5	3.0	7.5
VT08	12.7	5.7	3.4	9.1	3.7	4.3	2.9	7.2
VT09	13.1	5.8	3.5	9.3	3.9	4.4	2.9	7.3
VT10	13.8	6.5	3.6	10.1	3.7	4.7	3.7	8.4
VT11	14.3	6.8	3.8	10.6	3.5	5.0	3.9	8.9
VT12	13.8	6.5	3.7	10.2	3.3	4.8	3.8	8.5
VT15	12.7	6.1	3.4	9.4	3.1	4.4	3.5	7.9
VT18	16.1	7.5	4.0	11.6	3.9	5.0	4.3	9.3
VT19	16.8	7.8	4.2	12.0	4.1	5.2	4.5	9.7
VT20	11.6	5.5	3.2	8.6	3.0	3.9	3.2	7.1
VT24	12.0	5.5	3.2	8.8	2.9	3.8	3.3	7.1
VT25	12.2	5.6	3.3	8.9	3.0	3.9	3.3	7.2
VT26	12.4	5.6	3.3	8.9	3.3	3.9	3.2	7.1
VT28	12.1	5.5	3.2	8.7	4.0	4.0	3.3	7.3
VT29	12.7	5.7	3.4	9.2	3.2	3.9	3.3	7.2
VT31	12.1	5.4	3.3	8.7	3.0	3.7	3.2	6.9
VT32	12.8	5.7	3.4	9.1	3.4	4.0	3.3	7.4

Table G-7. Continued.								
	Reference Year 1995				**Year 2040**			
Site ID	**SO_4**	**NO_3**	**NH_4**	**Total N**	**SO_4**	**NO_3**	**NH_4**	**Total N**
VT34	12.5	5.8	3.4	9.2	3.1	4.2	3.4	7.7
VT35	13.0	6.0	3.8	9.8	2.8	4.0	3.5	7.5
VT36	14.3	6.6	4.2	10.8	3.1	4.5	3.8	8.3
VT37	13.7	6.4	3.7	10.1	3.7	4.5	3.8	8.3
VT38	14.5	6.8	3.9	10.7	4.0	4.9	3.9	8.9
VT39	13.9	6.6	4.0	10.6	3.4	4.9	4.0	8.9
VT41	14.5	6.8	4.1	10.9	3.5	5.1	4.1	9.2
VT46	13.5	6.3	3.8	10.2	3.0	4.5	3.9	8.3
VT48	12.1	5.3	3.5	8.8	3.2	3.7	3.1	6.9
VT49	10.6	4.7	3.2	7.9	2.1	3.0	3.1	6.1
VT50	10.6	4.7	3.2	7.9	2.1	2.9	3.2	6.1
VT53	11.6	5.2	3.6	8.8	2.7	3.5	3.1	6.6
VT54	13.9	6.3	3.9	10.2	3.0	4.0	4.1	8.1
VT55	12.4	5.6	3.5	9.1	2.7	3.5	3.7	7.2
VT56	12.5	5.7	3.5	9.2	3.3	4.0	3.4	7.4
VT57	11.7	5.3	3.3	8.6	3.0	3.7	3.2	6.9
VT58	8.8	3.8	3.1	6.9	1.9	2.4	2.9	5.3
VT59	9.5	4.1	3.3	7.4	2.2	2.7	3.1	5.8
VT62	9.9	4.3	3.4	7.7	2.1	2.7	3.3	6.0
VT66	9.1	3.9	3.2	7.1	2.0	2.5	3.1	5.5
VT68	15.3	7.2	4.3	11.5	3.7	5.4	4.3	9.6
VT70	14.7	6.9	4.1	11.0	3.5	5.1	4.1	9.2
VT72	15.8	7.4	4.4	11.8	3.8	5.5	4.4	9.9
VT73	15.3	7.1	4.3	11.4	3.7	5.3	4.2	9.6
VT74	15.0	7.0	4.2	11.2	3.6	5.2	4.2	9.4
VT75	9.3	4.0	3.2	7.3	2.0	2.5	3.1	5.7
VT76	12.7	5.9	3.7	9.5	3.1	4.0	3.5	7.5
VT77	13.1	6.1	3.8	9.9	3.0	4.4	3.6	8.0
VT78	11.6	5.5	3.3	8.9	3.1	4.0	2.6	6.6
WOR	13.3	6.0	3.9	10.0	2.9	4.0	3.4	7.5
WOR1	13.2	6.0	3.9	9.9	2.9	4.0	3.4	7.4
WV523S	21.4	9.9	5.3	15.2	3.3	5.1	6.2	11.2
WV531S	19.1	8.6	4.3	12.9	5.2	5.5	4.1	9.6
WV547S	15.1	7.2	3.6	10.8	4.4	4.8	3.3	8.1
WV548S	14.9	7.1	3.7	10.8	4.2	4.8	3.5	8.2
WV769S	19.4	8.9	4.4	13.4	5.4	5.6	4.2	9.8
WV770S	16.5	7.6	3.8	11.4	4.7	4.9	3.7	8.5
WV771S	17.4	7.9	3.9	11.8	4.3	4.6	3.7	8.3
WV785S	10.9	5.3	2.8	8.1	2.9	3.6	2.8	6.5
WV788S	16.0	7.6	3.9	11.4	4.6	5.1	3.5	8.6
WV796S	19.0	8.8	4.7	13.6	3.3	4.7	5.5	10.2

APPENDIX H

MAGIC MODEL DESCRIPTION AND APPLICATION METHODS

H.1 Introduction

The major tools available for evaluating the potential response of aquatic resources to changes in atmospheric deposition of sulfur and nitrogen are mathematical models. One of the prominent models developed to estimate acidification of lakes and streams is MAGIC (Model of Acidification of Groundwater In Catchments, Cosby et al., 1985a-c). MAGIC was the principal model used by the National Acid Precipitation Assessment Program (NAPAP) in assessment of potential future damage to lakes and streams in the eastern United States (NAPAP 1991, Thornton et al. 1990). The validity of the model has been confirmed by comparison with estimates of lake acidification inferred from paleolimnological reconstructions of historical lake changes in pH (Sullivan et al. 1991, 1996) and with the results of several catchment-scale experimental acidification and de-acidification experiments (e.g., Cosby et al. 1995, 1996). MAGIC has been used to reconstruct the history of acidification and to simulate future trends on a regional basis and in a large number of individual catchments in both North America and Europe (e.g., Lepisto et al. 1988; Whitehead et al. 1988; Cosby et al. 1989, 1990, 1994, 1996; Hornberger et al. 1989; Jenkins et al. 1990a-c; Wright et al. 1990, 1994; Norton et al. 1992).

H.2 Conceptual Basis of the Model

MAGIC is a lumped-parameter model of intermediate complexity, developed to predict the long-term effects of acidic deposition on surface water chemistry. The model simulates soil solution chemistry and surface water chemistry to predict the monthly and annual average concentrations of the major ions in these waters. MAGIC consists of: 1) a section in which the concentrations of major ions are assumed to be governed by simultaneous reactions involving sulfate adsorption, cation exchange, dissolution-precipitation- speciation of aluminum and dissolution-speciation of inorganic carbon; and 2) a mass balance section in which the flux of major ions to and from the soil is assumed to be controlled by atmospheric inputs, chemical weathering, net uptake and loss in biomass and losses to runoff. At the heart of MAGIC is the size of the pool of exchangeable base cations in the soil. As the fluxes to and from this pool change over time owing to changes in atmospheric deposition, the chemical equilibria between soil and soil solution shift to give changes in surface water chemistry. The degree and rate of change of surface water acidity thus depend both on flux factors and the inherent characteristics of the affected soils.

Cation exchange is modeled using equilibrium (Gaines-Thomas) equations with selectivity coefficients for each base cation and aluminum. Sulfate adsorption is represented by a Langmuir isotherm. Aluminum dissolution and precipitation are assumed to be controlled by equilibrium with a solid phase of aluminum trihydroxide. Aluminum speciation is calculated by considering hydrolysis reactions as well as complexation with sulfate and fluoride. Effects of carbon dioxide on pH and on the speciation of inorganic carbon are computed from equilibrium equations. Organic acids are represented in the model as tri-protic analogues. First-order rates are used for retention (uptake) of nitrate and ammonium in the catchment. Weathering rates are assumed to be constant. A set of mass balance equations for base cations and strong acid anions are included. Given a description of the historical deposition at a site, the model equations are solved numerically to give long-term reconstructions of surface water chemistry (for complete details of the model see Cosby et al., 1985 a-c, 1989).

H.3 Equilibrium Equations in the Model

H.3.1 Cation and Anion Exchange in Soil Water

Cation exchange reactions between the soil matrix and soil solution are assumed to result in an equilibrium partitioning of calcium, magnesium, sodium, potassium and trivalent aluminum between solid and aqueous phases. The equilibrium expressions for cation exchange (Table H-1) are constructed using a Gaines-Thomas expression (Gaines and Thomas, 1953). E represents exchangeable fractions of each base cation on the soil (equivalents of each base cation per total cation exchange capacity of the soil). The sum of all exchangeable fractions must equal 1.0. Base saturation of the soil is defined as the sum of the exchangeable fractions of the base cations (Table H-2). The selectivity coefficients (Table H-3) must be calibrated for each aggregated soil layer in the model. The calibration procedure relies on observations of the exchangeable fractions of base cations in soils and measured base cation concentrations in streamwater (see Cosby et al. 1984, 1985a,b for details).

Anion exchange reactions are assumed to occur only for sulfate ion. The relationship between dissolved and adsorbed sulfate (Table H-1) is assumed to follow a Langmuir isotherm (Couto et al. 1979, Hasan et al. 1970). MAGIC is a catchment-scale model and it is often the case that the effective values of aggregated parameters intended to represent large-scale function cannot be derived by a direct scaling-up of similar parameters measured in a laboratory setting

Table H-1. Equations in the MAGIC model.

Equilibrium Equations

Cation and Anion Exchange in Soil Water

$$E_{Ca} + E_{Mg} + E_{Na} + E_K + E_{Al} = 1.0$$

$$\frac{\{Ca^{2+}\}^3 E_{Al}^2}{\{Al^{3+}\}^2 E_{Ca}^3} = S_{AlCa} \qquad \frac{\{Mg^{2+}\}^3 E_{Al}^2}{\{Al^{3+}\}^2 E_{Mg}^3} = S_{AlMg} \qquad \frac{\{Na^{+}\}^3 E_{Al}}{\{Al^{3+}\} E_{Na}^3} = S_{AlNa} \qquad \frac{\{K^{+}\}^3 E_{Al}}{\{Al^{3+}\} E_{K}^3} = S_{AlK} \qquad \frac{\{SO_4^{2-}\}}{C_{1/2} + \{SO_4^{2-}\}} * E_{mx} = E_{SO4}$$

Inorganic Aluminum in Soil Water and Surface Water

$$\{Al^{3+}\} = [K_{Al}] * \{H^+\}^{S_{Al}}$$

$$\frac{\{Al(OH)^{2+}\}\{H^+\}}{\{Al^{3+}\}} = K_{Al_1} \qquad \frac{\{Al(OH)_2^{+}\}\{H^+\}^2}{\{Al^{3+}\}} = K_{Al_2} \qquad \frac{\{Al(OH)_3^{0}\}\{H^+\}^3}{\{Al^{3+}\}} = K_{Al_3} \qquad \frac{\{Al(OH)_4^{-}\}\{H^+\}^4}{\{Al^{3+}\}} = K_{Al_4}$$

$$\frac{\{AlF^{2+}\}}{\{Al^{3+}\}\{F^-\}} = K_{Al_5} \qquad \frac{\{AlF_2^{+}\}}{\{Al^{3+}\}\{F^-\}^2} = K_{Al_6} \qquad \frac{\{AlF_3^{0}\}}{\{Al^{3+}\}\{F^-\}^3} = K_{Al_7} \qquad \frac{\{AlF_4^{-}\}}{\{Al^{3+}\}\{F^-\}^4} = K_{Al_8}$$

$$\frac{\{AlF_5^{2-}\}}{\{Al^{3+}\}\{F^-\}^5} = K_{Al_9} \qquad \frac{\{AlF_6^{3-}\}}{\{Al^{3+}\}\{F^-\}^6} = K_{Al_{10}} \qquad \frac{\{Al(SO_4)^{+}\}}{\{Al^{3+}\}\{SO_4^{2-}\}} = K_{Al_{11}} \qquad \frac{\{Al(SO_4)_2^{-}\}}{\{Al^{3+}\}\{SO_4^{2-}\}^2} = K_{Al_{12}}$$

Inorganic and Organic Carbon in Soil Water and Surface Water; Dissociation of Water

$$\{H^+\}\{OH^-\} = K_w \qquad \frac{\{H_2CO_3^*\}}{P_{CO2}} = K_{CO2_1} \qquad \frac{\{HCO_3^-\}\{H^+\}}{\{H_2CO_3^*\}} = K_{CO2_2} \qquad \frac{\{CO_3^{2-}\}\{H^+\}}{\{HCO_3^-\}} = K_{CO2_3} \qquad \frac{\{H_2A^-\}\{H^+\}}{\{H_3A\}} = K_{OA_1}$$

$$\frac{\{HA^{2-}\}\{H^+\}}{\{H_2A^-\}} = K_{OA_2} \qquad \frac{\{A^{3-}\}\{H^+\}}{\{HA^{2-}\}} = K_{OA_3} \qquad \frac{\{AlA\}}{\{Al^{3+}\}\{A^{3-}\}} = K_{OA_4} \qquad \frac{\{Al(H)A^+\}}{\{Al^{3+}\}\{H^+\}\{A^{3-}\}} = K_{OA_5}$$

Braces denote activities (calculated from concentrations using the extended Debye-Huckel equation)

Mass and Ionic Balance Equations

Ionic Balance in Soil Water and Surface Water (parentheses denote molar concentrations)

$$\begin{aligned} & 2(Ca^{2+}) + 2(Mg^{2+}) + (Na^+) + (K^+) + (NH_4^+) + (H^+) + 3(Al^{3+}) + 2(AlOH^{2+}) + (Al(OH)_2^+) + 2(AlF^{2+}) + (AlF_2^+) + (AlSO_4^+) + (Al(H)A^+) \\ = \; & 2(SO_4^{2-}) + (Cl^-) + (NO_3^-) + (F^-) + (OH^-) + (HCO_3^-) + 2(CO_3^{2-}) + (H_2A^-) + 2(HA^{2-}) + 3(A^{3-}) + (Al(OH)_4^-) + (AlF_4^-) + 2(AlF_5^{2-}) \\ & + 3(AlF_6^{3-}) + (Al(SO_4)_2^-) \end{aligned}$$

Mass Balance for Ions in Soil Water and Surface Water (rates of change in eq m^{-2} yr^{-1})

$$\frac{dCa_T}{dt} = AD_{Ca} + W_{Ca} + SS_{Ca} - Q*2(Ca^{2+}) \qquad \frac{dNO_{3T}}{dt} = AD_{NO3} + W_{NO3} + SS_{NO3} + NIT - IM_{NO3} - UP_{NO3} - DEN - Q*(NO_3^-)$$

$$\frac{dMg_T}{dt} = AD_{Mg} + W_{Mg} + SS_{Mg} - Q*2(Mg^{2+}) \qquad \frac{dNH_{4T}}{dt} = AD_{NH4} + W_{NH4} + SS_{NH4} + MIN - IM_{NH4} - UP_{NH4} - NIT - Q*(NH_4^+)$$

$$\frac{dNa_T}{dt} = AD_{Na} + W_{Na} + SS_{Na} - Q*(Na^+) \qquad \frac{dSO_{4T}}{dt} = AD_{SO4} + W_{SO4} + SS_{SO4} - Q*2\left[(SO_4^{2-}) + (AlSO_4^+) + 2(Al(SO_4)_2^-)\right]$$

$$\frac{dK_T}{dt} = AD_K + W_K + SS_K - Q*(K^+) \qquad \frac{dCl_T}{dt} = AD_{Cl} + W_{Cl} + SS_{Cl} - Q*(Cl^-)$$

$$\frac{dF_T}{dt} = AD_F + W_F + SS_F - Q*\left[(F^-) + (AlF^{2+}) + 2(AlF_2^+) + 3(AlF_3^0) + 4(AlF_4^-) + 5(AlF_5^{2-}) + 6(AlF_6^{3-})\right]$$

Table H-2. Variables in the MAGIC model.

State Variables (functions of time, calculated by model)

Aqueous Phase - Ionic Concentrations in Soil Water and Surface Water (mol m^{-3})

Base Cations: $(Ca^{2+})(Mg^{2+})(Na^{+})(K^{+})(NH_4^{+})$ Strong Acid Anions: $(SO_4^{2-})(Cl^{-})(NO_3^{-})(F^{-})$

Hydrogen and Hydroxyl Ions: $(H^{+})(OH^{-})$ Inorganic Carbon: $(H_2CO_3^{*})(HCO_3^{-})(CO_3^{2-})$

Aluminum: $(Al^{3+})(AlOH^{2+})(Al(OH)_2^{+})(Al(OH)_3^{0})(Al(OH)_4^{-})(AlF^{2+})(AlF_2^{+})(AlF_3^{0})(AlF_4^{-})(AlF_5^{2-})(AlF_6^{3-})(AlSO_4^{+})(Al(SO_4)_2^{-})$

Organic Carbon: $(H_3A)(H_2A^{-})(HA^{2-})(A^{3-})(AlA)(Al(H)A^{+})$

Solid Phase - Exchangeable Ions on Soil Matrix; Soil Organic Matter Constituents

Exchangeable Cations (fraction): $E_{Ca}, E_{Mg}, E_{Na}, E_K, E_{Al}$ Exchangeable Sulphate (eq kg^{-1}): E_{SO4}

Organic Carbon and Nitrogen (mol m^{-2}): C_{Org}, N_{Org}

Defined Variables (derived from state variables)

Total Ions for Mass Balance (eq m^{-2})

$SO_{4T} = SM*E_{SO4} + SV*TOT_{SO4}$

$Ca_T = SM*CEC*E_{Ca} + SV*2(Ca^{2+})$ $Na_T = SM*CEC*E_{Na} + SV*(Na^{+})$ $NO_{3T} = SV*(NO_3^{-})$ $Cl_T = SV*(Cl^{-})$

$Mg_T = SM*CEC*E_{Mg} + SV*2(Mg^{2+})$ $K_T = SM*CEC*E_K + SV*(K^{+})$ $NH_{4T} = SV*(NH_4^{+})$ $F_T = SV*TOT_F$

Total Aqueous Concentrations (eq m^{-3})

$SBC = 2(Ca^{2+}) + 2(Mg^{2+}) + (Na^{+}) + (K^{+})$ $TOT_{Al} = 3(Al)_{TOT}$ $TOT_F = (AlF^{2+}) + 2(AlF_2^{+}) + 3(AlF_3^{0}) + 4(AlF_4^{-}) + 5(AlF_5^{2-}) + 6(AlF_6^{3-})$

$SAA = 2(SO_4^{2-}) + (Cl^{-}) + (NO_3^{-}) + (F^{-})$ $DOC_{Al} = 3(Al)_{DOC}$ $TOT_{SO4} = 2(SO_4^{2-}) + 2(AlSO_4^{+}) + 4(Al(SO_4)_2^{-})$

Summed Species (mol m^{-3})

$(Al)_{SO4} = (AlSO_4^{+}) + (Al(SO_4)_2^{-})$ $(Al)_{DOC} = (AlA) + (Al(H)A^{+})$

$(Al)_{OH} = (AlOH^{2+}) + (Al(OH)_2^{+}) + (Al(OH)_3^{0}) + (Al(OH)_4^{-})$ $(Al)_F = (AlF^{2+}) + (AlF_2^{+}) + (AlF_3^{0}) + (AlF_4^{-}) + (AlF_5^{2-}) + (AlF_6^{3-})$

$(Al)_{TOT} = (Al^{3+}) + (Al)_{SO4} + (Al)_{OH} + (Al)_F + (Al)_{DOC}$ $(OA)_{TOT} = (H_3A) + (H_2A^{-}) + (HA^{2-}) + (A^{3-}) + (AlA) + (Al(H)A^{+})$

Charge Balance Alkalinity (eq m^{-3}) $CALK = SBC + (NH_4^{+}) - SAA$ *Soil C/N ratio* $C/N = \frac{C_{Org}}{N_{Org}}$

Solution pH, pAl $pH = -\log_{10}(H^{+})$ $pAl = -\log_{10}(Al^{3+})$ *Soil Base Saturation* $BS = E_{Ca} + E_{Mg} + E_{Na} + E_K$

Table H-3. Parameters in the MAGIC model.

Parameters (constant values that must be specified)

Soil Physical/Chemical Properties		*Surface Water Properties*
D = depth (m)	CEC = cation exchange capacity (eq kg^{-1})	RT = retention time (yr)
P = porosity (fraction)	$C_{1/2}$ = sulphate adsorption half saturation (eq m^{-3})	RA = relative area of lake/stream (fraction)
BD = bulk density (kg m^{-3})	E_{mx} = sulphate adosrption maximum (eq kg^{-1})	K_{Al} = aluminum solubility constant ($\log_{10}$)
SM = soil mass (D*BD)	K_{Al} = aluminum solubility constant ($\log_{10}$)	S_{Al} = slope of pH-pAl relationship
SV = soil pore volume (D*P)	S_{Al} = slope of pH-pAl relationship	

Aqueous Phase - Equilibrium Constants ($\log_{10}$)

Organic Acid: pK_1, pK_2, pK_3 $[\,-\log_{10}(K_{OA_1}, K_{OA_2}, K_{OA_3})\,]$ Organic Aluminum: K_{OA_4}, K_{OA_5}

Inorganic Aluminum Speciation: $K_{Al_1}, K_{Al_2}, K_{Al_3}, K_{Al_4}, K_{Al_5}, K_{Al_6}, K_{Al_7}, K_{Al_8}, K_{Al_9}, K_{Al_{10}}, K_{Al_{11}}, K_{Al_{12}}$

Inorganic Carbon Speciation and Dissociation of Water: $K_{CO2_1}, K_{CO2_2}, K_{CO2_3}, K_w$

Solid Phase - Weathering and Exchange Constants

Cation Exchange Selectivity Coefficients ($\log_{10}$): $S_{AlCa}, S_{AlMg}, S_{AlNa}, S_{AlK}$

Weathering Rates (eq m^{-2} yr^{-1}): $W_{Ca}, W_{Mg}, W_{Na}, W_K, W_{NH4}, W_{SO4}, W_{Cl}, W_{NO3}, W_F$ (can be pH dependent)

(see Rastetter et al. 1992). The sulfate adsorption parameters (Table H-3) used in MAGIC must, therefore, be calibrated for each site. Cosby et al. (1986) described a method for calibrating sulfate adsorption parameters in whole catchment simulations based on input/output budgets and deposition histories for the site.

H.3.2 Inorganic Aluminum in Soil Water and Surface Water

Inorganic aluminum speciation consists of one reaction involving the equilibrium dissolution of a solid phase of aluminum trihydroxide and twelve reactions involving formation of aqueous complexes of Al^{3+}. These reactions are assumed to occur both in soil solution and in surface waters in the model and can be represented by a series of equilibrium equations (Table H-1). Values of the equilibrium constants for the aqueous phase complexation reactions (Table H-3) can be found in the literature. The aluminum solubility constants for the soils in the model are represented by aggregated values. These values are not, therefore, necessarily associated with a particular crystalline form of $Al(OH)_3$ and must be selected as part of the calibration process.

H.3.3 Inorganic and Organic Carbon in Soil Water and Surface Water; and Dissociation of Water

Inorganic carbon reactions in MAGIC consist of dissolution of CO_2 to form carbonic acid, followed by dissociation to bicarbonate and carbonate. These reactions are assumed to occur both in soil solution and in surface waters in the model and can be represented by equilibrium equations (Table H-1) whose "constants" are temperature-dependent. Values of the equilibrium constants for the carbonate-bicarbonate system and for the dissociation of water (Table H-3) and their temperature dependencies can be found in the literature.

Organic acids are the dominant form of dissolved organic material in natural waters (e.g., McKnight et al. 1985, David and Vance 1991). Organic acids are effective hydrogen ion buffers and can form complexes with inorganic aluminum. Considerable evidence has accumulated suggesting that organic acids influence the response of surface waters to changes in strong acid inputs, most likely by changes in the protonation of the organic acid anions (see Wright 1989). Organic acids were not included in the original formulation of MAGIC because specification (and calibration) of organic acid analog models was hampered by lack of data on organic acid behavior (e.g., Jenkins and Cosby 1989). In 1994, Driscoll et al. (1994) compared several organic acid analog models (mono-, di-, and triprotic organic acid analogs and the model of Oliver et al. 1983) with respect to their abilities to resolve mass balance discrepancies in measured water samples from Adirondack lakes. They concluded that organic acids were important buffers in surface waters even when dissolved organic carbon was low. They obtained the best agreement between predicted and observed pH values using a triprotic organic acid analog model. The triprotic organic acid analog model can also be used to describe the complexation of Al by organic solutes (Schecher and Driscoll 1993, Driscoll et al. 1994). A triprotic organic acid analog model is currently incorporated into the structure of MAGIC.

H.4 Mass and Ionic Balance Equations

Mass balance is required for the total amounts of base cations and strong acid anions in each compartment of the simulated catchment (Table H-1). That is, input minus output of each mass balance ion must equal the rate of change of the total amount of that ion in each compartment of the model. Total amounts in surface water compartments are calculated from concentrations and the water volume. In soil compartments, total amounts include both dissolved amounts in the pore water and adsorbed amounts (if applicable) on the soil matrix. Process-related inputs (Table H-4) are by atmospheric deposition, primary mineral weathering (in soil compartments) and biological production (decomposition and mineralization). Process-related outputs are by drainage water discharge or biological removal (uptake or immobilization). Unspecified sources and sinks of each ion are also available in the model. These may be used to simulate processes or perturbations not explicitly represented in the model (such as experimental additions of ions, losses of ions resulting from land use changes, etc.). At each time step during model simulation, inputs and outputs are added or subtracted from each compartment, new total amounts are calculated, and the equilibrium equations are solved subject to the constraint of ionic balance (Table H-1) to derive the concentrations of the state variables (Table H-2) for that time step.

H.5 Model implementation

Atmospheric deposition and net uptake-release fluxes for the base cations and strong acid anions are required as inputs to the model. These inputs are generally assumed to be uniform over the catchment. Atmospheric fluxes are calculated from concentrations of the ions in

Table H-4. Inputs to the MAGIC model.

Input Fluxes and Conditions (functions of time that must be specified)	
Conditions are annual averages (monthly averages are specified for seasonal simulations)	
Temperature (°C), Carbon Dioxide (atm), Organic Acid (mol m^{-3}):	TEMP, P_{CO2}, $(OA)_{TOT}$
[CO_2 partial pressure and Organic Acid concentration control the weak inorganic and organic carbon buffers]	
Fluxes are annual values (monthly fractions of annual fluxes are specified for seasonal simulations)	
Catchment Discharge (m yr^{-1}) and Flow Fractions:	Q, F_1, F_2, F_3
[Flow fractions specify the pathway of water flux through the modelled system and can vary seasonally]	
Atmospheric Deposition (eq m^{-2} yr^{-1}):	AD_{Ca}, AD_{Mg}, AD_{Na}, AD_K, AD_{NH4}, AD_{SO4}, AD_{Cl}, AD_{NO3}, AD_F
[Deposition is specified as the product of precipitation concentrations and amount, scaled by a dry deposition factor]	
Sources and Sinks of Ions (eq m^{-2} yr^{-1}):	SS_{Ca}, SS_{Mg}, SS_{Na}, SS_K, SS_{NH4}, SS_{SO4}, SS_{Cl}, SS_{NO3}, SS_F
[Sources and sinks are distinct and represent processes, inputs or outputs not explicitly included in the model]	
The flow fractions determine atmospheric deposition fluxes into each soil and surface water compartment. Other fluxes and conditions must be specified separately for each model compartment (if appropriate).	
Initial Values	
Initial values of these state variables must be specified for each model compartment (if appropriate)	
Cation and Anion Concentrations (mol m^{-3}):	$(Ca^{2+}),(Mg^{2+}),(Na^+),(K^+),(NH_4^+),(SO_4^{2-}),(Cl^-),(NO_3^-),(F^-)$
Exchangeable Ions (fraction):	$E_{Ca}, E_{Mg}, E_{Na}, E_K$

precipitation and the rainfall volume into the catchment. The atmospheric fluxes of the ions must be corrected for dry deposition of gas, particulates and aerosols and for inputs in cloud/fog water. An estimate of the streamflow volume of the catchment must also be provided to the model. In general, the model is implemented using average hydrologic conditions and meteorological conditions in annual or seasonal simulations. Mean annual or mean monthly deposition, precipitation and streamflow are used to drive the model. The model is not designed to provide temporal resolution greater than monthly. Most simulations are based on annual average conditions. Values for soil and streamwater temperature, partial pressure of carbon dioxide in the soil and streamwater and organic acid concentrations in soilwater and streamwater must also be provided.

As implemented in this project, the model is a two-compartment representation of a catchment. Atmospheric deposition enters the soil compartment and the equilibrium equations are used to calculate soil water chemistry. The water is then routed to the stream compartment, and the appropriate equilibrium equations are reapplied to calculate streamwater chemistry.

Once initial conditions (initial values of variables in the equilibrium equations) have been established, the equilibrium equations are solved for soil water and streamwater concentrations of the remaining variables. These concentrations are used to calculate the streamwater output fluxes of the model for the first time step. The mass balance equations are (numerically) integrated over the time step, providing new values for the total amounts of base cations and strong acid anions in the system. These in turn are used to calculate new values of the remaining variables, new streamwater fluxes, and so forth. The output from MAGIC is thus a time trace for all major chemical constituents for the period of time chosen for the integration. Details of the numerical integration and a computer code for implementing the model are given by Cosby et al. [1984a, 2001].

H.6 Model Calibration Procedure

The aggregated nature of the model requires that it be calibrated to observed data from a system before it can be used to examine potential system response. Calibration is achieved by setting the values of certain parameters within the model which can be directly measured or observed in the system of interest (called "fixed" parameters). The model is then run (using observed atmospheric and hydrologic inputs) and the output (stream water and soil chemical variables, called “criterion” variables) are compared to observed values of these variables. If the observed and simulated values differ, the values of another set of parameters in the model (called “optimized” parameters) are adjusted to improve the fit. After a number of iterations, the simulated-minus-observed values of the criterion variables usually converge to zero (within some specified tolerance). The model is then considered calibrated. If new assumptions (or values) for any of the fixed variables or inputs to the model are subsequently adopted, the model must be re-calibrated by re-adjusting the optimized parameters until the simulated-minus-observed values of the criterion variables again fall within the specified tolerance.

Because the estimates of the fixed parameters and deposition inputs are subject to uncertainties, a "fuzzy" optimization procedure can be implemented for calibrating the model. The fuzzy optimization procedure consists of multiple calibrations of each catchment using random values of the fixed parameters drawn from the observed possible range of values, and random values of deposition from the range of model estimates. Each of the multiple calibrations begins with (1) a random selection of values of fixed parameters and deposition, and (2) a random selection of the starting values of the adjustable parameters. The adjustable parameters are then optimized using the Rosenbrock (1960) algorithm to achieve a minimum error fit to the target variables. This procedure is undertaken ten times for each stream. The final calibrated model is represented by the ensemble of parameter values and variable values of the successful calibrations.

Calibrations are based on volume-weighted mean annual fluxes for a given period of observation. The length of the period of observation used for calibration is variable, but model output will be more reliable if the annual flux estimates used in calibration are based on a number of years rather than just one year. There is a lot of year-to-year variability in atmospheric deposition and catchment runoff. Averaging over a number of years reduces the likelihood that an “outlier” year (very dry, etc.) constitutes the primary data on which model forecasts are based. On the other hand, averaging over too long a period may remove important trends in the data that need to be simulated by the model. For the study here, the model was calibrated using five-year average values of deposition and up to three years of streamwater chemistry data, if that length of observation were available.

The results discussed in this report are based on the **median** values of the simulated water quality variables from the multiple calibrations of each site. The use of median values for each stream helps to assure that the simulated responses are neither over- or underestimates, but approximate the most likely behavior of each stream (given the assumptions inherent in the model and the data used to constrain and calibrate the model). The uncertainty analyses in this report make use of the maximum and minimum simulated values from the multiple calibrations for each site to calculate uncertainty "widths" (or confidence intervals) around the median simulated values.

H.7 Coupling atmospheric deposition changes with MAGIC for SAMI applications

In order for MAGIC to be calibrated, we require data describing: a) the absolute amount of total (wet plus dry and occult) deposition for the year in which surface water data are available at a site, and b) the historical changes in total deposition at the site. These data should be available for each site for which the model will be calibrated. The outputs of the atmospheric deposition models employed in SAMI for the future scenarios do not directly provide the required data for MAGIC calibration for two reasons.

First, the SAMI deposition models give average deposition over a fairly large grid area. Local geographical characteristics, however, can give rise to substantial spatial variation in the amount of deposition within these grids. Elevation especially can produce sharp departures from the "grid average" deposition. The calibration of MAGIC requires as precise an estimate of the absolute amount of total deposition as possible for each site. For this reason we use the spatial extrapolation model of Grimm and Lynch (1997) to provide a geographically-explicit, elevation-corrected estimate of wet deposition at each site. This model is based on observed wet deposition values from the NADP wet collection network, and observed precipitation amounts from climate stations.

Once relatively precise estimates of wet deposition are generated for a site, the dry and cloud component of deposition must be estimated. For this, we must rely on atmospheric models because of the scarcity of empirical observations. We use the ratio of wet to (dry plus cloud) deposition from the atmospheric models to calculate dry and cloud deposition amount for our sites from the spatially-explicit wet deposition estimates. Our reasoning is thus: while the absolute deposition amount within a grid square (for which the atmospheric models provide only an average value) may vary quite a lot in the "real world", the ratio of wet to dry deposition within the grid may be more uniform. That is, if wet deposition is larger at high elevations compared to low elevations within the grid, then dry deposition is likely to be larger at high elevations. While absolute amounts vary considerably within grids, relative amounts are more uniform. So using wet to dry ratios from the models along with interpolated empirical observations of absolute wet deposition amounts provides the most accurate and precise estimate of total deposition at a site.

The second limitation of the atmospheric models used in SAMI for future scenarios concerns the years simulated. The future scenario models only simulate deposition for the SAMI Reference Year and future years. In order to calibrate MAGIC, we need deposition information for years prior to the SAMI Reference Year. In part, this is due to the necessity of using historical patterns of deposition in the calibration procedure, and in part it is due to the fact that observed surface water data used for calibration of MAGIC are often only available in years other than the SAMI Reference Year.

To overcome this problem, output from the ASTRAP atmospheric model (Shannon 1998) was used to provide the following data for each site being calibrated: a) the ratio of wet to (dry plus cloud) deposition for the calibration year; and b) the relative changes in wet deposition and the wet to (dry plus cloud) ratio that have occurred historically. These data are based on a number of historical runs made using ASTRAP. The model output (wet, dry, and cloud deposition) was provided by Shannon (1998) for a network of sites within the SAMI region for every 5 years from 1900 to 1990. Each SAMI site calibrated to MAGIC is associated with one of the ASTRAP sites. The paired sites can be used to provide estimates of the wet-to-(dry plus cloud) ratio in the Calibration Year, the relative historical variations in wet deposition, and the relative historical variations in the wet-to-(dry plus cloud) ratio for each particular MAGIC site.

H.7.1 Calibration Year Deposition

The Calibration Year for a given site may not be the same as the SAMI Reference Year (for instance, the DDRP data are calibrated for 1985). In that case, once a site has been calibrated, the model is run forward from the MAGIC Calibration Year to the SAMI Reference Year using the relative changes in deposition known to have occurred based on the NADP data and Lynch's model. In this way, all sites being modeled are "positioned" at the SAMI Reference Year following calibration, and we can then use the modeled changes in future deposition as described in the next section.

H.7.2 Deposition for Future Strategies and Scenarios.

In order to run simulations into the future using MAGIC, we require data describing the change in total (wet plus dry and cloud) deposition at a particular MAGIC site for every year of the future simulation period. The outputs of the atmospheric deposition models employed in SAMI for the future strategies provide these estimates.

SAMI has defined a Reference Year for atmospheric modeling. All future strategies of change in atmospheric deposition are expressed as the % change in total deposition in any year relative to the Reference Year.

The Reference Year for MAGIC has been defined as the same as the SAMI Reference Year (all MAGIC simulations are "positioned" at the SAMI Reference Year following calibration as described above). Therefore, when the atmospheric modelers provide % change in total deposition relative to the SAMI Reference Year, those % changes are applied directly to the total (wet, dry, and occult) deposition amounts used in MAGIC beginning in the SAMI (MAGIC) Reference Year.

H.8 Comments on Model Applicability

The MAGIC model of acidification is a model that has been extensively subjected to the process of testing and confirmation over a 15-year period and thousands of applications (see references cited in the discussion above and additional citations in the References Section of this appendix that are a partial listing of published research using the MAGIC model). MAGIC has been used in scientific studies, as a tool in establishing management practices, and as an aid in making policy decisions regarding controls on emissions and deposition. Overall the model has proven to be robust, reliable, and useful in all of these activities. The longevity and utility of MAGIC results as much from the philosophical approach to its formulation (empirically-based, compatible with readily available data, technically easy to implement, and capable of being tested), as from the soundness of the hydrobiogeochemical concepts and understanding on which the model is based. The success of this conceptual approach in the qualitative and quantitative description of acidification responses of ecosystems suggests that it is also an appropriate tool for examining the recovery responses as well.

H.9 References for Appendix H

Note: The reference list below contains the citations in Appendix H. Following this list is a second reference list containing references to applications of MAGIC. The extra references are included as a partial bibliography of previous MAGIC applications, intended for the general information of the reader.

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APPENDIX I

MAGIC CALIBRATION INPUT DATA AND CALIBRATION RESULTS.

I.1 Introduction

The aggregated nature of the MAGIC model requires that it be calibrated to observed data from a system before it can be used to examine potential system response. Calibration is achieved by setting the values of certain parameters within the model that can be directly measured or observed in the system of interest (called "fixed" parameters). The model is then run (using observed and/or assumed atmospheric and hydrologic inputs) and the outputs (stream water and soil chemical variables, called "criterion" variables) are compared to observed values of these variables. If the observed and simulated values differ, the values of another set of parameters in the model (called "optimized" parameters) are adjusted to improve the fit. After a number of iterations, the simulated-minus-observed values of the criterion variables usually converge to zero (within some specified tolerance). The model is then considered calibrated. If new assumptions (or values) for any of the fixed variables or inputs to the model are subsequently adopted, the model must be re-calibrated by re-adjusting the optimized parameters until the simulated-minus-observed values of the criterion variables again fall within the specified tolerance.

I.2 Implementation of the MAGIC model for SAMI sites

As implemented in this project, the MAGIC model is a two-compartment representation of a catchment. Atmospheric deposition enters the soil compartment and the equilibrium equations are used to calculate soil water chemistry. The water is then routed to the stream compartment, and the appropriate equilibrium equations are reapplied to calculate streamwater chemistry.

Atmospheric deposition, soil physical and chemical characteristics, and net uptake-release fluxes for the base cations and strong acid anions are required as inputs to the model. These inputs are generally assumed to be uniform over the catchment. Atmospheric fluxes are calculated from concentrations of the ions in precipitation and the rainfall volume into the catchment. The atmospheric fluxes of the ions must be corrected for dry deposition of gas, particulates and aerosols and for inputs in cloud/fog water. The volume streamflow of the catchment must also be provided to the model. In general, the model is implemented using average hydrologic conditions and meteorological conditions in annual or seasonal simulations, i.e., mean annual or mean monthly deposition, precipitation and streamflow are used to drive the model. The model is not designed to provide temporal resolution greater than monthly. Values for soil and streamwater temperature, partial pressure of carbon dioxide in the soil and streamwater and organic acid concentrations in soilwater and streamwater must also be provided.

Once initial conditions (initial values of variables in the equilibrium equations) have been established, the equilibrium equations are solved for soil water and streamwater concentrations of the remaining variables. These concentrations are used to calculate the streamwater output fluxes of the model for the first time step. The mass balance equations are (numerically) integrated over the time step, providing new values for the total amounts of base cations and strong acid anions in the system. These in turn are used to calculate new values of the remaining variables, new streamwater fluxes, and so forth. The output from MAGIC is thus a time trace for all major chemical constituents for the period of time chosen for the integration. Details of the equations in the model are given in Appendix H.

I.3 Calibration Input Data

The calibration procedure requires that stream water quality data, atmospheric deposition data, and soils data are available for each SAMI stream. The availability of the required data varied from site to site in this study. Appendix B reports on the data acquisition activities for the project. The body of the report describes the selection procedure by which sites were chosen for analysis, and summarizes the water quality characteristics of the sites. For the selected sites, derivation of the atmospheric deposition at each site for the SAMI Reference Year is described in Appendix L. The procedure for assigning soils data to those sites for which no soils observations were available is described in the body of the report. This appendix tabulates and summarizes the input data used to calibrate MAGIC for each SAMI site, and documents the ggodness-of-fit of the calibration for each site.

This appendix contains tables of model inputs and outputs for each site in the SAMI analysis. In these tables, each site is identified by a unique ID number assigned for the SAMI project. Table I-1 gives this same SAMI ID number along with the full name, location, and SAMI landscape classification group (bin number) for each site as a reference aid.

I.3.1 Deposition Data for the Calibration Year

Atmospheric deposition to each SAMI site is needed for calibration and application of MAGIC. The model requires input fluxes of the base cations, sulfate, nitrate and ammonia. The fluxes must be total atmospheric deposition.

The years for which observed streamwater chemistry was available determined the years for which the SAMI sites could be calibrated. The timing of available observed data ranged from the years 1985 to 2000. The SAMI reference year for deposition is 1995. The deposition used for sites that were calibrated in years other than 1995 had, therefore, to be estimated using the time-series scaling procedures described in Appendix L.

The calibration procedure for MAGIC at each site assumed that chloride mass balance occurs at each site. That is, that the atmospheric inputs and stream outputs of Cl are equal. To achieve this assumption during calibration, the Cl deposition interpolated from the SAMI Reference Year was increased to provide a balance with stream outputs of Cl at each site (if necessary). The additional Cl deposition was accompanied by additional deposition of base cations (in sea salt ratio) to conserve charge balance. The added deposition was thus in the form of neutral salt and was neither acidifying nor alkalizing with respect to catchment processes. The added deposition was achieved by adjusting the dry deposition factors (DDF's) for the base cations and Cl. The DDF's for SO_4, NO_3, and NH_4 were not adjusted and remained as described in Appendix L.

The total deposition values (calculated from wet deposition and DDF) used for the calibration year at each site are tabulated and summarized in Table I-2.

I.3.2 Past Deposition Patterns

Given total deposition for the calibration year at each site, the calibration required a temporal sequence of how that deposition has varied historically for the period over which anthropogenic deposition to the site has been occurring. That is, the total historical loading to a site and the temporal pattern of that loading must be provided to the model. The MAGIC model is sensitive to assumptions about past deposition. The pattern of the past deposition determines the total loading of acidic deposition that the site has received, and thus affects how the model simulates responses to future changes in loading. The temporal sequences used for past deposition are described in Appendix L.

I.3.3 Soils and Watershed Data

The model requires data describing a number of physical and chemical characteristics at each site. For some sites, soils data were directly available. In general, soils data that were stratified by depth or horizon were vertically aggregated using a bulk-density weighted scheme to provide a single value for each soil parameter at a site. If more than one soil sampling site were available for a site, the vertically aggregated data were further averaged horizontally (using a weighting procedure based on relative areas of bedrock or vegetation, if possible). For sites where soils data were not available, the soils parameters were interpolated from sites having soils data using the scheme described in the body of the text.

The soil parameter values and watershed characteristics used for calibration at each site are tabulated and summarized in Table I-3. The observed soil variable values used as targets for calibration at each site are tabulated and summarized in Table I-7.

I.3.4 Stream Water Quality Data

The calibration procedure requires that observed stream water quality data be available as targets for the calibration procedure. All sites in the SAMI analysis (by definition) had appropriate data available. There were however, differences among sites in the quantity of data available. Some sites had only a single survey value, while other sites had partial or multiple years of monitoring data. If less than one year of data were available, the observations were volume-weighted to provide an estimate of water quality for that year. If data were available for multiple years, an appropriate time span (2-3 years) of the data were volume-weighted to provide a single annual average value for calibration.

The observed stream water values used as targets for calibration at each site are tabulated and summarized in Table I-4.

I.4 Calibration Results

All sites included in this project were successfully calibrated. The simulated values for each site in the calibration year are summarized in Table I-5 for stream variables and Table I-8 for soil variables. Good fits were obtained for the model applied to each of the study sites as measured by the magnitude of the simulated minus observed values for both stream water and soil variables (Tables I-6 and I-9). Errors between simulated and observed annual volume-weighted average concentrations were all less than 3 ueq/L for the calibration period. Simulation of soil variables was equally good with errors between simulated and observed exchangeable cation concentrations all less than 0.2%.

The calibrated values of the "optimized" soil parameters at each site are presented in Table I-10. Plots of simulated versus observed values for all ions and sites are presented in Figures I-1 and I-2.

Table I-1. Names, locations, and ID's of SAMI sites. The SAMI ID is a unique identifier assigned to each site. This ID is used in other tables in this appendix without the name and location data. Elevations are in meters. The "Bin Number" identifies the landscape classification unit to which each site belongs (all sites used in the regional analysis have a non-zero bin number, special interest sites have bin number zero). The table is arranged alphabetically alphabetically in ascending order by SAMI ID. The number of sites is 164.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
Grasses Creek-Dry Branch	2A068015U	36.701	81.622	1048	VA	7	regional
Sugar Cove Branch of N. River	2A07701	35.320	84.100	610	TN	4	regional
Cosby Creek	2A07805	35.790	83.240	436	TN	4	regional
Roaring Fork	2A07806	35.820	82.890	670	NC	4	regional
Little River	2A07810L	35.670	83.677	433	TN	0	special
Little River	2A07810U	35.628	83.541	811	TN	0	special
False Gap Prong	2A07811	35.700	83.380	549	TN	3	regional
Correll Branch	2A07812	35.680	83.090	884	NC	4	regional
Eagle Creek	2A07816	35.500	83.760	579	NC	4	regional
Forney Creek	2A07817	35.510	83.560	732	NC	3	regional
Grassy Creek	2A07821	35.460	82.280	552	NC	4	regional
Brush Creek	2A07823	35.320	83.520	549	NC	4	regional
Whiteoak Creek	2A07828	35.230	83.620	960	NC	4	regional
Catheys Creek	2A07829	35.210	82.790	689	NC	4	regional
Brush Creek	2A07834	35.110	83.260	838	NC	4	regional
Middle Saluda River	2A07835	35.120	82.540	329	SC	4	regional
Little Branch Creek	2A07882	35.450	83.060	936	NC	4	regional
Dunn Mill Creek	2A08802	34.950	84.440	506	GA	4	regional
Bear Creek	2A08804	34.820	84.570	567	GA	4	regional
Weaver Creek	2A08805	34.870	84.300	488	GA	4	regional
Bryant Creek	2A08810	34.610	84.000	448	GA	4	regional
Persimmon Creek	2A08901	34.910	83.500	596	GA	4	regional
Sprigs Hollow	2B041020L	39.562	78.424	168	WV	8	regional
No Name	2B041049U	39.110	78.441	378	VA	5	regional
Elk Run	2B047032	38.632	79.586	823	WV	8	regional
Straight Fork	2B047044U	38.498	79.611	899	VA	8	regional
Lower Lewis Run	2B047076L	38.305	78.746	354	VA	0	special
Lower Lewis Run	2B047076U	38.285	78.719	543	VA	6	regional
Whites Run	2B058015U	37.780	79.291	500	VA	2	regional
No Name	2C041033U	39.363	79.735	671	WV	10	regional
Buffalo Creek	2C041039	39.261	79.755	576	WV	12	regional
Thunderstruck Creek	2C041040	39.249	79.601	658	WV	11	regional
No Name	2C041043U	39.238	79.167	671	WV	12	regional
Right Fork Clover Run	2C041045	39.148	79.715	485	WV	12	regional
Coal Run	2C041051	39.040	79.616	558	WV	9	regional
Right Fork Holly River	2C046013L	38.569	80.418	448	WV	12	regional
Johnson Run	2C046033	38.347	80.408	704	WV	9	regional
Hateful Run	2C046034	38.351	80.259	879	WV	9	regional
North Fork Cherry River	2C046043L	38.231	80.416	937	WV	10	regional

Table I-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
North Fork Cherry River	2C046043U	38.233	80.407	954	WV	0	special
Hedricks Creek	2C046050	38.125	80.982	603	WV	12	regional
Laurel Creek	2C046053L	38.129	80.553	823	WV	11	regional
Little Clear Creek	2C046062L	37.998	80.569	866	WV	12	regional
Crawford Run	2C047007	38.759	79.923	607	WV	12	regional
Clubhouse Run	2C047010L	38.632	79.760	920	WV	10	regional
Clubhouse Run	2C047010U	38.630	79.745	969	WV	11	regional
Butler Branch	2C057004	37.956	80.943	721	WV	10	regional
Johnson Mill Branch	2C066026L	36.247	85.038	488	TN	11	regional
No Name	2C066027L	36.270	84.865	454	TN	11	regional
No Name	2C066027U	36.245	84.872	489	TN	9	regional
Wallace Branch	2C066039L	36.002	85.005	527	TN	12	regional
Glady Fork	2C077022U	35.525	85.475	555	TN	11	regional
1306	BJ35	36.118	82.084	1420	TN	2	regional
M_S3_N2_2	BJ72	35.331	82.672	1717	NC	2	regional
CDB	BJ76	35.358	83.383	971	NC	0	special
BEFPR	BJ77	35.368	82.935	971	NC	0	special
Belfast Creek	BLFC	37.580	79.467	317	VA	0	special
Un-named Eastern Trib	CO01	34.876	84.600	707	GA	3	regional
Hickory Creek	CO05	34.940	84.648	390	GA	3	regional
Bear Brook	CO06	34.921	84.532	427	GA	4	regional
Beech Creek	CO10	34.979	84.566	472	GA	3	regional
Deep Run	DR	38.266	78.743	415	VA	0	special
Deep Run	DR01	38.266	78.743	415	VA	6	regional
Little Stonecoal Run	DS04	38.991	79.396	932	WV	9	regional
Stonecoal Run (Left Branch)	DS06	39.002	79.388	1127	WV	0	special
Stonecoal Run (Right Branch)	DS09	39.007	79.383	1115	WV	9	regional
Fisher Spring Run	DS19	39.002	79.360	1011	WV	0	special
Unnamed	DS50	39.026	79.363	1097	WV	0	special
Fernow - WS10	FN1	39.064	79.681	713	WV	0	special
Fernow - WS13	FN2	39.063	79.679	695	WV	0	special
Fernow - WS4	FN3	39.056	79.688	744	WV	9	regional
Gsmnp Noland Creek - NE Fork	GS01	35.565	83.480	1740	NC	2	regional
Gsmnp Noland Creek - NW Fork	GS02	35.564	83.480	1800	NC	2	regional
GSMNP Deep Creek	GS04	35.608	83.442	1600	NC	4	regional
GSMNP Jay Bird Branch	GS05	35.680	83.597	1248	TN	3	regional
GSMNP Leconte Creek	GS06	35.687	83.503	570	TN	4	regional
GSMNP Raven Fork	GS07	35.610	83.254	1800	NC	3	regional
GSMNP Enloe Creek	GS08	35.614	83.270	1500	NC	3	regional
Laurel Branch Downstream	LB01	35.339	84.083	900	TN	4	regional
Lewis Fork	LEWF	36.671	81.525	1103	VA	0	special
Sulphur Spring Creek	M037	37.577	79.438	427	VA	3	regional
Big Hellcat Creek	M038	37.611	79.451	317	VA	0	special
Little Hellgate Creek	M039	37.603	79.465	317	VA	0	special

Table I-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
North Fork of Dry Run	NFD	38.623	78.355	488	VA	0	special
North Fork of Dry Run	NFDR	38.623	78.355	488	VA	4	regional
Condon Run	OC02	38.942	79.670	923	WV	9	regional
Yellow Creek	OC05	38.953	79.664	911	WV	0	special
Unnamed	OC08	38.980	79.639	871	WV	0	special
Devils Gulch	OC09	38.983	79.643	853	WV	9	regional
Possession Camp Run	OC31	39.000	79.645	798	WV	0	special
Moores Run	OC32	39.000	79.646	798	WV	0	special
Coal Run	OC35	39.033	79.620	688	WV	0	special
Otter Creek (Upper)	OC79	38.938	79.660	950	WV	10	regional
Paine Run	PAIN	38.201	78.769	424	VA	0	special
Un-named Trib Between 8 and 9	SP10	34.298	87.429	186	AL	0	special
Un-named Trib above 38	SP39	34.369	87.438	250	AL	11	regional
Quillan Creek	SP41	34.317	87.481	183	AL	0	special
Staunton River	STAN	38.457	78.399	308	VA	0	special
Noname Trib Stony Cr.	VA524S	37.423	80.630	914	VA	6	regional
Bearpen Branch	VA526S	37.201	82.486	463	VA	12	regional
Ragged Run	VA531S	38.537	78.306	505	VA	0	special
Noname Trib Gap Cr	VA548S	38.699	78.596	445	VA	7	regional
Little Mill Cr	VA555S	38.080	79.499	694	VA	7	regional
Little Walker Cr	VA821S	37.148	80.823	591	VA	8	regional
Lewis Fork	VT02	36.671	81.525	1103	VA	3	regional
Raccoon Branch	VT05	36.739	81.449	835	VA	4	regional
Cove Branch	VT07	37.072	81.433	930	VA	6	regional
Roaring Fork-upper	VT08	37.064	81.418	930	VA	7	regional
Roaring Fork-lower	VT09	37.055	81.458	664	VA	6	regional
Laurel Run	VT10	38.176	79.679	725	VA	7	regional
Mare Run	VT11	38.013	79.786	619	VA	7	regional
Panther Run	VT12	38.007	79.775	619	VA	8	regional
Porters Creek	VT15	37.979	79.787	604	VA	7	regional
Bearwallow Run	VT18	38.547	79.655	957	VA	8	regional
Lost Run	VT19	38.549	79.644	957	VA	8	regional
Hipes Branch	VT20	37.679	79.941	335	VA	8	regional
Shawvers Run	VT24	37.600	80.175	567	VA	7	regional
Cove Branch	VT25	37.584	80.161	561	VA	6	regional
Pine Swamp Branch	VT26	37.430	80.613	725	VA	5	regional
NF Stony Creek	VT28	37.460	80.546	835	VA	6	regional
War Spur Branch	VT29	37.395	80.493	707	VA	6	regional
Nobusiness Creek	VT31	37.255	80.875	735	VA	5	regional
Laurel Creek	VT32	37.378	80.603	942	VA	6	regional
Laurel Run	VT34	37.916	79.472	387	VA	7	regional
Paine Run	VT35	38.201	78.769	424	VA	6	regional
Meadow Run	VT36	38.170	78.785	451	VA	1	regional
North River	VT37	38.421	79.266	811	VA	7	regional

Table I-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Bin No.	SiteType
Ramseys Draft	VT38	38.346	79.332	707	VA	8	regional
Kennedy Creek	VT39	37.946	79.034	561	VA	1	regional
St Marys R-lower	VT41	37.928	79.092	530	VA	0	special
Little Cove Creek	VT46	37.738	79.211	506	VA	4	regional
Big Mack Creek	VT48	36.946	80.635	658	VA	4	regional
Little Stony Creek	VT49	38.958	78.627	466	VA	6	regional
Laurel Run	VT50	38.918	78.729	524	VA	5	regional
Two Mile Run	VT53	38.319	78.655	372	VA	2	regional
German River-upper	VT54	38.674	79.078	762	VA	8	regional
Beech Lick Run	VT55	38.703	79.023	646	VA	8	regional
Wolf Run	VT56	38.438	79.169	594	VA	6	regional
Black Run-lower	VT57	38.512	79.110	524	VA	7	regional
Brokenback Run	VT58	38.570	78.330	329	VA	0	special
Staunton River	VT59	38.457	78.399	308	VA	4	regional
Hazel Run	VT62	38.624	78.293	329	VA	0	special
Rose River	VT66	38.522	78.402	341	VA	0	special
St Marys R-upper	VT68	37.935	79.060	725	VA	1	regional
Bear Branch (SMR)	VT70	37.922	79.078	677	VA	2	regional
Hogback Br (SMR)	VT72	37.945	79.096	689	VA	5	regional
Sugartree Br (SMR)	VT73	37.912	79.111	628	VA	3	regional
St Marys R-middle	VT74	37.932	79.083	579	VA	2	regional
White Oak Canyon R	VT75	38.567	78.365	354	VA	0	special
Belfast Creek	VT76	37.578	79.476	317	VA	2	regional
Matts Creek	VT77	37.588	79.433	256	VA	0	special
Little Tumbling Creek	VT78	36.957	81.738	799	VA	5	regional
White Oak Run	WOR	38.234	78.742	451	VA	0	special
White Oak Run	WOR1	38.234	78.742	451	VA	7	regional
Noname Trib Stony	WV523S	39.152	79.323	1170	WV	9	regional
Otter Cr	WV531S	39.011	79.646	847	WV	10	regional
Gauley	WV547S	38.399	80.493	650	WV	12	regional
Noname Trib South Fork Cherry R.	WV548S	38.214	80.479	768	WV	9	regional
Nnt Laurel Run	WV769S	38.879	79.956	719	WV	11	regional
Moss Run	WV770S	38.715	79.961	621	WV	12	regional
Left Fork Clover Run	WV771S	39.163	79.713	469	WV	12	regional
Nnt Glade Cr	WV785S	37.714	81.047	847	WV	9	regional
White Oak Fork	WV788S	38.357	80.383	857	WV	10	regional
Red Cr	WV796S	39.039	79.337	1127	WV	11	regional

Table I-2. The total deposition of all ions in the calibration year for each SAMI site. Deposition fluxes are in $meq/m^2/yr$ (the model units). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk
	Average	8.0	2.5	6.5	1.1	29.5	94.1	11.9	48.8	47.6	154.8	-107.2
	Std. Dev.	2.1	0.6	3.1	0.3	10.2	32.5	4.4	17.3	12.9	50.1	39.3
	Maximum	14.5	4.9	16.2	2.3	90.9	273.2	26.9	145.2	116.9	434.4	-53.6
	Minimum	4.2	1.4	2.7	0.6	19.2	51.9	4.7	25.7	30.9	92.2	-317.5
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**
2A068015U	1985	7.3	2.1	5.0	1.1	25.6	75.5	9.6	39.8	41.1	124.9	-83.8
2A07701	1985	7.6	2.6	7.6	1.2	25.3	78.4	13.8	37.7	44.3	129.9	-85.6
2A07805	1985	5.7	1.7	4.6	0.8	19.6	61.8	8.5	31.0	32.5	101.3	-68.8
2A07806	1985	6.6	2.1	6.3	1.0	24.8	74.9	11.0	38.2	40.8	124.1	-83.3
2A07810L	1985	6.3	1.7	4.5	1.0	21.6	66.7	8.5	34.3	35.0	109.5	-74.5
2A07810U	1985	7.0	2.0	5.0	1.1	25.3	79.4	9.4	40.2	40.4	129.0	-88.6
2A07811	1985	5.4	1.5	4.1	0.8	19.2	60.0	7.6	30.1	31.0	97.8	-66.8
2A07812	1985	8.6	2.7	7.8	1.3	32.1	97.9	13.9	50.2	52.6	162.0	-109.4
2A07816	1985	8.4	2.5	7.1	1.4	28.1	87.7	13.1	43.8	47.5	144.6	-97.2
2A07817	1985	8.5	2.6	7.1	1.4	30.0	92.6	13.0	46.8	49.6	152.3	-102.8
2A07821	1985	5.0	2.1	7.6	1.0	21.6	60.3	11.9	29.9	37.3	102.1	-64.8
2A07823	1985	6.6	2.4	7.5	1.2	22.9	67.4	12.8	35.2	40.6	115.4	-74.8
2A07828	1985	8.0	3.1	10.0	1.5	27.5	81.0	16.7	41.8	50.1	139.5	-89.5
2A07829	1985	7.9	3.5	12.3	1.6	31.3	89.8	19.2	45.7	56.5	154.8	-98.2
2A07834	1985	6.2	2.8	9.9	1.2	21.7	61.8	15.4	32.0	41.7	109.2	-67.5
2A07835	1985	6.1	2.8	10.0	1.3	25.0	70.3	15.5	35.5	45.2	121.3	-76.2
2A07882	1985	7.8	2.9	9.3	1.4	29.7	87.3	15.5	45.2	51.2	148.1	-96.9
2A08802	1985	10.4	4.1	13.5	1.9	37.6	106.2	22.8	52.4	67.4	181.3	-113.9
2A08804	1985	11.9	4.9	16.2	2.3	44.3	120.3	26.9	59.2	79.4	206.4	-127.0
2A08805	1985	8.7	3.6	11.9	1.7	31.9	89.1	19.8	44.4	57.9	153.3	-95.5
2A08810	1985	9.7	4.5	15.7	2.2	36.4	98.5	24.8	49.7	68.4	172.9	-104.6
2A08901	1985	8.0	3.7	13.5	1.7	27.5	78.0	20.9	39.9	54.4	138.8	-84.4
2B041020L	1985	7.3	2.3	4.2	1.0	28.1	82.2	10.8	42.9	42.9	135.9	-93.0
2B041049U	1985	5.8	2.0	4.8	0.8	22.9	64.6	9.8	33.2	36.2	107.6	-71.4
2B047032	1985	9.5	2.3	4.5	0.9	26.8	94.3	10.8	49.9	43.9	155.0	-111.1
2B047044U	1985	8.8	2.3	4.6	0.9	26.3	91.5	10.5	48.4	42.9	150.4	-107.5
2B047076L	1985	6.0	2.5	7.9	0.8	25.2	73.3	13.2	37.6	42.6	124.2	-81.6
2B047076U	1985	7.0	3.1	10.1	1.0	29.2	84.5	16.4	43.5	50.4	144.4	-94.0
2B058015U	1985	7.4	2.8	7.6	1.1	27.2	85.0	13.8	45.0	46.2	143.8	-97.6
2C041033U	1985	13.5	2.9	4.1	1.3	35.4	136.4	12.7	70.3	57.2	219.4	-162.2
2C041039	1985	12.6	2.6	3.6	1.1	31.4	122.2	11.4	63.2	51.3	196.7	-145.5
2C041040	1985	11.9	2.5	3.6	1.1	30.3	115.8	11.0	60.3	49.4	187.1	-137.7
2C041043U	1985	8.6	2.2	3.6	1.0	26.8	91.1	9.8	47.3	42.2	148.2	-106.0
2C041045	1985	11.4	2.2	3.2	0.9	27.7	108.6	9.7	56.4	45.4	174.7	-129.2
2C041051	1985	12.7	2.5	3.8	1.0	31.6	120.4	11.0	63.3	51.6	194.7	-143.1
2C046013L	1985	9.7	2.2	3.8	0.9	27.2	101.6	9.7	54.4	43.8	165.7	-121.8
2C046033	1985	9.4	2.2	4.1	1.0	26.8	96.9	10.1	52.6	43.4	159.6	-116.2
2C046034	1985	10.4	2.5	4.6	1.1	29.9	107.7	11.4	57.9	48.6	177.0	-128.5
2C046043L	1985	9.2	2.2	4.2	1.0	27.2	97.1	10.0	52.9	43.8	160.0	-116.2
2C046043U	1985	9.1	2.2	4.1	1.0	26.9	96.1	9.9	52.3	43.3	158.3	-115.0

Table I-2. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk
2C046050	1985	7.3	1.8	3.3	0.8	21.9	75.5	8.0	42.7	35.0	126.3	-91.3
2C046053L	1985	8.1	2.0	3.7	0.9	24.3	85.5	8.9	47.0	39.0	141.4	-102.4
2C046062L	1985	7.8	2.0	3.8	0.9	23.7	81.7	8.8	45.3	38.2	135.8	-97.5
2C047007	1985	10.4	2.2	3.7	0.9	27.1	101.8	10.0	53.6	44.4	165.3	-121.0
2C047010L	1985	10.4	2.4	4.4	1.0	29.1	105.3	10.9	55.9	47.3	172.1	-124.8
2C047010U	1985	10.5	2.4	4.5	1.0	29.4	106.3	11.1	56.4	47.9	173.8	-126.0
2C057004	1985	6.9	1.7	3.3	0.8	21.4	72.3	7.9	41.4	34.2	121.6	-87.4
2C066026L	1985	11.5	3.4	8.6	1.4	36.0	128.8	17.6	54.1	60.8	200.6	-139.7
2C066027L	1985	11.5	3.4	8.3	1.4	35.3	129.8	17.5	54.4	59.8	201.7	-141.9
2C066027U	1985	11.6	3.4	8.4	1.4	35.6	131.3	17.8	54.9	60.5	203.9	-143.4
2C066039L	1985	11.7	3.6	9.5	1.5	37.1	133.0	19.0	55.1	63.3	207.1	-143.9
2C077022U	1985	11.3	3.8	11.6	1.6	40.3	112.4	20.9	54.0	68.6	187.4	-118.7
BJ35	1999	5.5	1.9	5.7	0.8	26.3	77.5	8.7	38.5	40.2	124.7	-84.5
BJ72	1999	5.8	2.5	8.6	1.1	28.9	84.1	12.5	42.1	46.9	138.7	-91.8
BJ76	1999	5.8	2.1	6.5	1.0	25.9	76.6	10.0	39.8	41.3	126.3	-85.1
BJ77	1999	5.5	2.2	7.2	1.0	26.3	76.4	10.7	38.9	42.2	126.1	-83.9
BLFC	1991	6.4	2.4	6.1	1.0	26.0	79.5	10.6	42.0	41.9	132.1	-90.2
CO01	1993	9.6	3.8	12.3	1.8	36.0	98.9	20.8	48.5	63.6	168.2	-104.7
CO05	1993	7.6	2.9	9.5	1.4	28.0	77.2	16.2	37.8	49.5	131.3	-81.8
CO06	1993	11.6	4.6	15.1	2.1	42.4	118.8	25.5	58.3	75.8	202.6	-126.8
CO10	1993	8.4	3.2	10.5	1.5	30.7	85.1	17.9	41.9	54.3	144.8	-90.6
DR	1994	6.9	3.0	9.6	1.0	26.9	78.6	16.0	40.7	47.3	135.3	-88.0
DR01	1990	5.9	2.6	8.2	0.8	26.9	78.6	13.0	40.7	44.4	132.4	-88.0
DS04	1994	7.2	1.6	2.9	0.6	30.0	106.2	4.9	56.8	42.3	167.9	-125.6
DS06	1994	7.2	1.6	2.9	0.6	30.0	106.2	4.9	56.8	42.3	167.9	-125.6
DS09	1994	7.2	1.6	2.9	0.6	30.0	106.2	4.9	56.8	42.3	167.9	-125.6
DS19	1994	7.2	1.6	2.9	0.6	30.0	106.2	4.9	56.8	42.3	167.9	-125.6
DS50	1994	7.2	1.6	2.9	0.6	30.0	106.2	4.9	56.8	42.3	167.9	-125.6
FN1	1994	11.3	2.2	3.2	0.8	34.8	135.7	7.3	70.9	52.3	213.9	-161.5
FN2	1994	11.0	2.1	3.2	0.8	33.8	132.0	7.2	69.0	50.9	208.1	-157.2
FN3	1994	11.3	2.2	3.3	0.9	34.8	136.0	7.4	71.0	52.5	214.4	-162.0
GS01	2000	11.4	3.4	9.1	2.0	90.9	273.2	16.1	145.2	116.9	434.4	-317.5
GS02	2000	11.4	3.4	9.2	2.0	90.9	273.1	16.1	145.1	116.9	434.3	-317.4
GS04	2000	9.6	2.8	7.4	1.6	77.3	232.0	13.1	123.2	98.7	368.3	-269.6
GS05	2000	7.4	2.0	5.1	1.2	56.8	165.8	9.2	91.2	72.5	266.2	-193.7
GS06	2000	5.1	1.4	3.6	0.8	19.9	61.8	6.5	31.5	30.9	99.8	-68.9
GS07	2000	7.5	2.3	6.6	1.2	62.1	182.0	11.1	96.3	79.7	289.5	-209.8
GS08	2000	8.4	2.6	7.3	1.4	69.2	204.7	12.4	108.1	88.9	325.2	-236.3
LB01	1987	7.4	2.5	7.4	1.2	28.1	87.6	12.8	42.1	46.6	142.5	-95.9
LEWF	1991	7.2	2.2	5.2	1.2	26.6	81.1	9.4	40.6	42.3	131.1	-88.8
M037	1991	6.4	2.4	6.1	1.0	26.0	79.5	10.6	42.0	41.9	132.1	-90.2
M038	1991	6.4	2.4	6.1	1.0	26.0	79.5	10.6	42.0	41.9	132.1	-90.2
M039	1991	6.4	2.4	6.1	1.0	26.0	79.5	10.6	42.0	41.9	132.1	-90.2
NFD	1994	7.0	3.4	12.8	1.1	29.7	74.7	19.1	37.2	53.9	131.0	-77.1
NFDR	1990	5.9	2.9	10.9	0.9	29.7	74.7	15.5	37.2	50.3	127.4	-77.1
OC02	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC05	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6

Table I-2. Continued.													
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**
OC08	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC09	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC31	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC32	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC35	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
OC79	1994	8.4	1.7	2.7	0.7	31.2	118.2	4.7	62.2	44.6	185.2	-140.6
PAIN	1994	7.1	3.2	10.1	1.0	27.1	81.2	16.8	42.6	48.4	140.6	-92.1
SP10	1992	9.7	3.9	14.1	1.5	33.1	77.8	22.0	40.6	62.3	140.4	-78.1
SP39	1992	9.9	3.9	14.2	1.5	34.0	80.2	22.2	41.7	63.6	144.2	-80.6
SP41	1993	9.9	3.9	14.3	1.5	33.6	78.6	22.3	41.3	63.2	142.3	-79.0
STAN	1994	5.2	2.9	11.7	0.8	23.3	59.4	16.5	29.5	43.9	105.3	-61.4
VA524S	1994	8.6	2.3	4.3	1.7	23.2	76.8	9.9	39.4	40.0	126.0	-86.0
VA526S	1994	9.1	2.0	3.9	0.9	21.7	73.7	8.9	40.1	37.5	122.7	-85.2
VA531S	1994	4.9	2.5	9.8	0.8	20.6	51.9	14.5	25.7	38.6	92.2	-53.6
VA548S	1994	6.3	2.5	7.6	0.9	23.9	64.0	13.4	32.3	41.2	109.6	-68.4
VA555S	1994	8.3	2.7	6.4	1.1	25.6	83.7	13.2	44.7	44.0	141.6	-97.6
VA821S	1994	7.7	2.1	4.4	1.5	21.7	68.6	9.7	35.1	37.4	113.3	-75.9
VT02	1990	7.2	2.2	5.2	1.2	26.6	81.1	9.4	40.6	42.3	131.1	-88.8
VT05	1990	6.3	1.9	4.5	1.0	24.0	69.3	8.2	37.1	37.7	114.6	-76.8
VT07	1990	7.6	2.0	4.3	1.1	25.8	83.0	8.3	42.2	40.8	133.5	-92.8
VT08	1990	7.2	1.9	4.1	1.1	24.5	79.1	8.0	40.4	39.0	127.5	-88.5
VT09	1990	7.4	2.0	4.2	1.1	25.3	82.1	8.2	41.6	40.0	131.8	-91.8
VT10	1990	7.3	2.1	4.7	0.9	25.8	86.6	9.5	46.6	40.8	142.7	-101.9
VT11	1990	7.8	2.3	5.2	1.0	27.6	91.1	10.3	49.5	44.0	150.9	-106.9
VT12	1990	7.4	2.2	5.0	1.0	26.1	86.0	9.9	46.7	41.7	142.6	-100.9
VT15	1990	6.8	2.1	4.6	0.9	24.2	79.6	9.1	43.2	38.7	131.9	-93.3
VT18	1990	9.1	2.3	4.5	0.9	28.6	100.4	10.0	53.7	45.4	164.0	-118.6
VT19	1990	9.3	2.3	4.7	0.9	29.3	102.8	10.3	54.9	46.5	168.0	-121.4
VT20	1990	6.4	2.0	4.5	1.0	22.5	72.1	8.7	38.8	36.4	119.6	-83.1
VT24	1990	6.7	1.9	4.1	1.1	22.9	74.6	8.2	39.6	36.8	122.4	-85.6
VT25	1990	6.9	2.0	4.3	1.2	23.2	75.9	8.5	40.1	37.6	124.5	-86.9
VT26	1990	7.4	2.0	3.7	1.4	23.3	77.1	7.6	39.6	37.8	124.3	-86.5
VT28	1990	7.2	1.9	3.7	1.4	22.9	75.4	7.5	39.1	37.1	121.9	-84.9
VT29	1990	7.8	2.1	4.1	1.6	24.3	79.0	8.2	41.0	39.9	128.3	-88.4
VT31	1990	7.1	1.9	3.8	1.3	23.1	74.8	7.5	38.2	37.2	120.5	-83.3
VT32	1990	7.9	2.1	3.9	1.7	24.5	80.5	8.0	41.1	40.1	129.6	-89.5
VT34	1990	6.4	2.2	5.5	0.9	24.5	78.1	10.0	41.7	39.3	129.8	-90.4
VT35	1990	6.0	2.7	8.6	0.9	27.1	81.2	13.7	42.6	45.3	137.5	-92.1
VT36	1990	6.6	3.1	9.8	1.0	29.4	88.4	15.5	46.7	49.8	150.7	-100.9
VT37	1990	7.3	2.3	5.5	0.8	26.7	85.3	10.5	45.4	42.6	141.2	-98.6
VT38	1990	7.7	2.4	5.9	0.9	27.8	89.4	11.3	48.0	44.8	148.8	-104.0
VT39	1990	6.8	2.9	8.4	1.0	28.4	86.5	14.0	46.6	47.5	147.2	-99.6
VT41	1990	7.1	2.9	8.3	1.0	29.2	89.7	14.0	48.1	48.5	151.9	-103.4
VT46	1990	6.7	2.8	8.0	1.1	27.3	84.2	13.5	45.2	46.0	142.8	-96.9
VT48	1990	6.9	2.2	4.7	1.5	25.1	75.4	8.8	37.7	40.3	121.8	-81.5
VT49	1990	5.5	1.9	4.7	0.7	23.5	67.2	9.0	34.2	36.3	110.4	-74.1
VT50	1990	5.5	1.8	4.4	0.7	22.7	66.2	8.6	33.7	35.1	108.5	-73.4

Table I-2. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk
VT53	1990	5.5	2.5	8.2	0.8	26.1	74.1	12.8	37.9	43.1	124.7	-81.6
VT54	1990	7.6	2.3	5.6	0.9	28.3	88.2	10.8	45.8	44.6	144.8	-100.2
VT55	1990	6.4	2.0	4.8	0.7	24.8	76.6	9.3	39.2	38.8	125.1	-86.3
VT56	1990	6.5	2.1	5.3	0.8	24.9	77.8	10.0	40.9	39.6	128.6	-89.0
VT57	1990	6.1	2.0	5.0	0.7	23.4	72.6	9.4	38.1	37.3	120.1	-82.9
VT58	1990	4.2	2.2	8.5	0.7	22.0	55.2	11.8	27.4	37.6	94.4	-56.9
VT59	1990	4.4	2.5	9.9	0.7	23.3	59.4	13.4	29.5	40.8	102.3	-61.4
VT62	1990	4.8	2.4	8.6	0.7	24.5	61.9	12.5	30.8	41.1	105.2	-64.1
VT66	1990	4.4	2.4	9.7	0.7	23.0	57.3	13.1	28.3	40.2	98.6	-58.4
VT68	1990	7.3	3.1	9.1	1.1	30.8	95.5	15.1	51.0	51.4	161.5	-110.1
VT70	1990	7.0	3.0	8.7	1.0	29.5	91.7	14.4	49.0	49.3	155.1	-105.9
VT72	1990	7.6	3.1	9.0	1.1	31.6	98.3	15.1	52.4	52.4	165.9	-113.4
VT73	1990	7.4	3.0	8.7	1.1	30.7	95.6	14.7	50.9	51.0	161.2	-110.2
VT74	1990	7.2	3.0	8.5	1.1	30.2	93.8	14.3	49.8	49.9	157.9	-108.1
VT75	1990	4.5	2.4	9.4	0.7	23.1	57.8	12.9	28.7	40.1	99.4	-59.3
VT76	1990	6.6	2.4	6.3	1.1	26.0	79.5	11.2	42.0	42.4	132.6	-90.2
VT77	1990	6.8	2.6	6.9	1.1	26.9	81.3	12.0	43.4	44.2	136.7	-92.5
VT78	1990	7.0	1.8	4.0	0.9	24.0	73.0	7.7	39.7	37.8	120.4	-82.6
WOR	1994	7.2	3.2	10.4	1.0	28.0	82.7	17.2	43.0	49.9	142.9	-93.0
WOR1	1990	6.2	2.8	8.9	0.9	28.0	82.7	14.0	43.0	46.7	139.7	-93.0
WV523S	1994	14.5	3.3	5.6	1.4	38.0	133.5	15.9	70.7	62.8	220.1	-157.3
WV531S	1994	13.3	2.6	4.0	1.0	31.5	121.5	12.1	62.5	52.4	196.1	-143.7
WV547S	1994	10.0	2.3	4.2	1.0	26.4	96.1	11.0	52.1	43.9	159.1	-115.2
WV548S	1994	9.5	2.3	4.3	1.0	25.9	92.4	11.0	50.4	43.1	153.8	-110.6
WV769S	1994	13.3	2.8	4.4	1.1	31.6	120.9	12.8	63.6	53.1	197.4	-144.2
WV770S	1994	10.9	2.4	4.0	1.0	27.1	101.5	11.2	53.2	45.4	165.8	-120.5
WV771S	1994	11.9	2.3	3.3	0.9	27.3	106.9	10.6	55.3	45.7	172.9	-127.2
WV785S	1994	7.5	1.8	3.6	1.0	20.5	69.1	8.6	38.0	34.4	115.8	-81.4
WV788S	1994	10.3	2.4	4.5	1.1	27.3	99.2	11.5	53.7	45.5	164.4	-118.9
WV796S	1994	13.0	3.0	5.2	1.2	33.8	118.7	14.3	62.8	56.3	195.9	-139.6

Table I-3. The "fixed" soil parameter values and watershed characteristics used for calibration of each SAMI site. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Runoff m/yr	Rainfall m/yr	Yield %	Riparian Area %	Depth m	Bulk Dens kg/m^3	CEC meq/kg	Half Sat. ueq/L	Al Solub log(KAl)
Average	0.7	1.3	52.7	0.1	0.9	1327.3	78.3		9.0
Std. Dev.	0.2	0.3	11.9	0.0	0.3	119.3	20.6		0.0
Maximum	1.6	2.5	83.4	0.1	1.9	1632.9	124.9		9.1
Minimum	0.3	0.9	29.7	0.1	0.4	937.2	16.1		8.9
Site ID	**Runoff m/yr**	**Rainfall m/yr**	**Yield %**	**Riparian Area %**	**Depth m**	**Bulk Dens kg/m^3**	**CEC meq/kg**	**Half Sat. ueq/L**	**Al Solub log(KAl)**
2A068015U	0.95	1.28	73.94	0.11	0.72	1225.0	81.0	129.9	9.06
2A07701	0.88	1.28	67.68	0.12	0.97	1288.5	75.6	124.7	9.02
2A07805	0.40	1.17	34.72	0.13	0.80	1277.2	78.0	125.2	8.99
2A07806	0.79	1.47	52.23	0.12	1.21	1325.4	62.4	128.4	8.99
2A07810L	0.63	1.17	56.41	0.13	0.76	1210.7	61.6	124.6	9.00
2A07810U	0.69	1.38	50.37	0.13	0.76	1210.8	62.0	112.4	9.03
2A07811	0.60	1.05	57.08	0.13	0.72	1226.4	80.9	130.5	8.99
2A07812	1.16	1.87	61.51	0.12	0.89	1324.8	76.5	121.8	9.01
2A07816	1.13	1.51	71.11	0.12	0.64	1142.8	89.9	94.3	9.02
2A07817	1.15	1.65	70.91	0.13	0.78	1225.6	82.2	123.0	9.00
2A07821	0.44	1.29	33.92	0.13	1.13	1336.7	61.4	126.8	9.04
2A07823	0.52	1.36	37.19	0.13	0.93	1360.7	74.1	121.1	9.00
2A07828	1.26	1.68	75.76	0.10	1.06	1233.6	68.5	106.5	8.97
2A07829	1.17	1.99	58.01	0.13	1.11	1302.8	64.7	123.2	8.98
2A07834	0.68	1.37	49.59	0.11	1.09	1280.3	65.1	125.0	8.95
2A07835	0.61	1.54	39.66	0.14	1.12	1364.1	59.7	121.2	9.03
2A07882	0.82	1.83	44.64	0.13	0.97	1233.6	74.1	122.7	8.99
2A08802	1.21	1.84	64.45	0.12	1.15	1393.4	54.4	122.1	8.99
2A08804	1.41	2.09	67.82	0.13	1.08	1318.5	62.9	126.3	8.98
2A08805	0.73	1.59	46.14	0.13	1.13	1341.2	59.9	124.2	9.02
2A08810	0.80	1.95	41.23	0.11	1.20	1362.3	57.4	113.6	8.94
2A08901	0.93	1.75	52.51	0.12	1.19	1345.7	59.8	118.5	9.05
2B041020L	0.51	0.97	54.13	0.14	0.58	1483.4	73.4	144.5	9.00
2B041049U	0.38	0.94	38.49	0.10	1.44	1232.3	56.7	111.9	9.02
2B047032	0.84	1.23	65.84	0.10	0.47	1434.3	71.6	133.7	9.11
2B047044U	1.07	1.23	83.38	0.15	0.48	1416.2	74.4	129.6	9.01
2B047076L	0.57	1.13	50.78	0.13	0.87	1344.0	124.9	123.8	8.99
2B047076U	0.75	1.31	56.88	0.13	0.87	1338.6	124.3	124.8	9.01
2B058015U	0.74	1.15	65.40	0.13	1.12	1116.5	36.1	128.2	9.12
2C041033U	0.78	1.38	55.74	0.14	0.64	1413.4	92.1	126.6	8.95
2C041039	0.57	1.29	44.23	0.12	0.71	1429.7	88.0	138.6	8.96
2C041040	0.52	1.22	40.51	0.13	0.63	1453.0	90.9	141.1	9.04
2C041043U	0.35	1.08	32.15	0.12	0.69	1473.3	87.6	123.3	9.05
2C041045	0.61	1.15	52.07	0.11	0.67	1445.5	87.7	117.3	9.07

Table I-3. Continued.									
Site ID	**Runoff m/yr**	**Rainfall m/yr**	**Yield %**	**Riparian Area %**	**Depth m**	**Bulk Dens kg/m^3**	**CEC meq/kg**	**Half Sat. ueq/L**	**Al Solub log(KAl)**
2C041051	1.00	1.36	73.90	0.14	1.26	1632.9	57.3	120.3	8.94
2C046013L	0.68	1.29	54.88	0.12	0.77	1478.9	67.7	125.6	9.00
2C046033	0.75	1.29	58.33	0.12	0.84	1495.7	82.8	126.1	8.99
2C046034	0.92	1.42	65.72	0.12	0.62	1518.0	71.6	125.3	9.00
2C046043L	0.73	1.36	55.29	0.14	0.70	1501.0	72.5	124.8	9.00
2C046043U	0.71	1.30	52.89	0.13	0.86	1494.8	82.3	132.7	9.07
2C046050	0.59	1.14	51.91	0.13	0.77	1516.8	67.6	117.7	8.94
2C046053L	0.72	1.24	56.16	0.10	0.81	1507.9	68.1	131.7	8.92
2C046062L	0.58	1.25	45.59	0.14	0.57	1504.5	74.9	112.9	9.12
2C047007	0.65	1.28	48.96	0.12	0.56	1498.6	74.7	115.7	9.06
2C047010L	0.73	1.35	55.08	0.12	0.65	1437.5	93.4	126.3	9.02
2C047010U	0.82	1.36	58.68	0.13	0.63	1458.6	92.9	115.3	8.95
2C057004	0.48	1.10	43.21	0.14	0.71	1509.4	72.6	137.4	8.99
2C066026L	0.48	1.49	32.21	0.13	0.93	1372.7	74.1	128.3	9.01
2C066027L	1.07	1.49	72.51	0.13	0.48	1176.9	54.3	120.5	9.06
2C066027U	1.10	1.45	76.64	0.14	0.47	1237.1	55.2	137.9	9.08
2C066039L	0.56	1.55	36.73	0.13	0.94	1386.9	73.6	125.8	9.00
2C077022U	0.57	1.67	34.70	0.12	0.91	1399.0	74.4	124.5	8.99
BJ35	0.73	1.52	47.75	0.13	0.57	1154.7	82.8	126.8	9.02
BJ72	1.10	1.86	60.93	0.13	0.48	1138.9	54.2	112.0	9.03
BJ76	0.74	1.56	46.04	0.12	0.77	1242.7	81.4	117.9	9.04
BJ77	1.03	1.61	64.91	0.13	1.09	1302.4	65.5	123.5	8.98
BLFC	0.59	1.10	51.65	0.13	1.07	1119.4	34.4	139.2	9.02
CO01	0.95	1.59	60.37	0.12	1.93	1260.3	72.6	135.0	9.00
CO05	0.70	1.20	59.37	0.10	0.94	1385.4	76.3	136.7	9.11
CO06	1.42	2.03	69.66	0.13	1.82	1287.9	71.5	116.1	8.97
CO10	0.83	1.37	60.35	0.15	0.93	1416.1	75.1	123.6	9.00
DR	0.63	1.21	49.94	0.13	0.86	1351.3	102.5	142.6	9.08
DR01	0.57	1.20	47.04	0.12	0.85	1339.1	102.4	121.8	8.95
DS04	0.42	1.34	31.62	0.12	1.33	1345.0	64.2	123.8	9.01
DS06	0.42	1.33	31.65	0.13	1.33	1346.5	63.8	122.0	9.01
DS09	0.49	1.34	38.41	0.13	1.34	1331.3	64.6	128.5	8.99
DS19	0.44	1.34	33.28	0.13	1.32	1340.5	64.3	124.1	8.99
DS50	0.59	1.33	44.72	0.13	1.33	1346.6	64.5	128.0	9.00
FN1	0.62	1.43	43.72	0.11	0.48	1171.2	53.6	139.9	9.13
FN2	0.60	1.41	41.29	0.12	0.49	1243.0	57.2	141.3	9.07
FN3	0.52	1.45	35.25	0.12	0.49	1230.0	54.8	105.5	9.00
GS01	1.28	2.50	50.94	0.12	0.59	1165.2	82.8	120.8	9.00
GS02	1.56	2.52	63.53	0.11	0.49	1204.8	55.2	109.7	8.98
GS04	1.08	2.10	50.68	0.13	0.57	1160.4	82.0	124.6	8.99
GS05	0.98	1.53	62.24	0.12	0.96	1190.1	60.7	127.7	9.01
GS06	0.51	1.08	47.10	0.12	0.75	1214.6	61.5	127.0	9.00
GS07	0.97	1.76	55.28	0.12	1.19	1303.3	111.1	121.7	8.99

Table I-3. Continued.

Site ID	Runoff m/yr	Rainfall m/yr	Yield %	Riparian Area %	Depth m	Bulk Dens kg/m^3	CEC meq/kg	Half Sat. ueq/L	Al Solub log(KAl)
GS08	1.06	2.00	53.23	0.11	1.17	1327.1	109.1	142.1	9.07
LB01	0.77	1.42	55.41	0.13	0.98	1207.9	16.1	125.2	8.99
LEWF	0.76	1.35	53.92	0.12	0.75	937.2	52.6	124.7	8.98
M037	0.58	1.13	50.47	0.13	1.08	1107.7	35.1	129.8	9.02
M038	0.63	1.13	56.41	0.13	1.09	1099.4	34.7	126.5	8.99
M039	0.61	1.10	53.43	0.13	1.07	1099.9	34.4	121.5	9.06
NFD	0.68	1.46	46.65	0.13	1.26	993.5	80.1	122.9	9.01
NFDR	0.53	1.46	36.79	0.13	1.41	1234.0	74.5	128.2	9.02
OC02	0.47	1.35	33.52	0.12	1.45	1176.9	57.0	119.7	9.00
OC05	0.60	1.37	43.82	0.13	1.46	1168.7	57.5	125.4	9.00
OC08	0.53	1.35	39.53	0.12	1.44	1174.3	57.3	123.5	8.98
OC09	0.74	1.34	54.96	0.12	1.45	1168.6	57.1	128.0	9.02
OC31	0.60	1.36	44.43	0.12	1.45	1175.4	57.6	121.4	9.00
OC32	0.61	1.35	44.30	0.12	1.45	1178.8	57.2	129.1	8.97
OC35	0.59	1.37	42.94	0.13	1.45	1177.9	57.2	121.6	9.00
OC79	0.48	1.36	35.14	0.12	1.44	1167.2	57.5	122.5	8.99
PAIN	0.67	1.20	54.27	0.14	0.87	1324.9	104.8	118.3	8.96
SP10	0.69	1.55	43.99	0.12	1.02	1427.5	62.3	126.1	9.00
SP39	0.66	1.59	42.66	0.13	1.14	1460.3	53.6	124.4	9.01
SP41	0.70	1.58	44.73	0.13	0.99	1410.1	62.8	119.0	8.98
STAN	0.68	1.15	58.56	0.12	1.41	1229.3	73.8	127.7	9.01
VA524S	0.47	1.11	41.28	0.13	0.71	1511.0	72.9	126.6	8.99
VA526S	0.50	1.20	41.11	0.12	0.78	1510.5	68.6	128.8	8.99
VA531S	0.64	1.00	62.98	0.13	1.26	992.9	80.0	123.9	8.99
VA548S	0.34	1.13	31.19	0.14	0.44	1359.3	72.0	132.7	8.93
VA555S	0.70	1.15	60.52	0.12	1.08	1100.8	35.0	128.8	9.00
VA821S	0.56	1.05	51.96	0.14	0.79	1507.0	69.1	137.1	9.00
VT02	0.76	1.36	56.41	0.13	1.42	1234.3	74.3	126.5	9.01
VT05	0.70	1.17	59.21	0.12	0.87	1349.6	104.2	124.3	8.98
VT07	0.62	1.30	47.49	0.13	0.87	1348.0	104.2	122.3	9.01
VT08	0.59	1.24	47.76	0.13	0.87	1333.5	104.0	112.6	8.98
VT09	0.62	1.28	46.87	0.12	0.87	1344.9	104.1	126.6	9.02
VT10	0.63	1.18	53.60	0.12	0.87	1337.2	103.2	128.9	9.01
VT11	0.78	1.26	59.90	0.12	0.88	1342.5	104.2	119.2	9.05
VT12	0.71	1.21	60.30	0.13	0.86	1354.2	103.2	121.0	8.99
VT15	0.70	1.12	61.81	0.12	0.86	1349.8	104.1	126.1	9.02
VT18	0.85	1.36	64.42	0.13	0.74	1379.7	69.3	123.1	8.99
VT19	0.82	1.42	57.86	0.12	0.74	1397.8	70.5	138.9	9.02
VT20	0.51	1.06	47.95	0.12	0.86	1351.2	103.8	124.1	9.01
VT24	0.48	1.08	44.80	0.13	0.87	1350.9	104.4	124.5	9.00
VT25	0.54	1.11	49.12	0.13	0.87	1356.9	104.0	122.8	8.99
VT26	0.35	1.13	29.71	0.12	0.87	1354.7	103.8	125.8	8.98
VT28	0.54	1.10	47.28	0.11	0.85	1353.3	102.6	139.2	8.97

Table I-3. Continued.

Site ID	Runoff m/yr	Rainfall m/yr	Yield %	Riparian Area %	Depth m	Bulk Dens kg/m^3	CEC meq/kg	Half Sat. ueq/L	Al Solub log(KAl)
VT29	0.57	1.17	45.71	0.12	0.87	1343.4	103.9	125.1	9.01
VT31	0.56	1.12	50.07	0.12	0.85	1358.7	102.2	137.8	8.97
VT32	0.42	1.17	35.98	0.13	0.87	1342.8	103.7	128.4	8.99
VT34	0.61	1.08	56.83	0.13	0.88	1349.7	101.2	120.5	9.00
VT35	0.60	1.20	50.06	0.12	0.87	1371.1	103.6	138.9	9.00
VT36	0.70	1.32	54.08	0.13	0.85	1325.6	103.7	126.7	8.96
VT37	0.69	1.25	55.11	0.13	0.75	1369.1	68.3	117.0	9.03
VT38	0.71	1.33	55.17	0.12	0.75	1353.6	69.4	143.6	9.02
VT39	0.97	1.24	77.89	0.13	0.86	1352.2	103.8	126.0	9.01
VT41	0.92	1.28	71.71	0.12	0.87	1342.1	104.0	123.0	8.98
VT46	0.61	1.19	50.07	0.12	1.41	1240.3	74.3	125.5	8.99
VT48	0.53	1.12	47.64	0.12	0.86	1346.6	104.4	123.6	9.00
VT49	0.47	1.02	45.74	0.11	0.85	1345.2	103.4	132.7	8.96
VT50	0.40	1.02	38.85	0.13	0.84	1341.8	105.7	142.8	8.95
VT53	0.57	1.16	50.08	0.13	0.85	1347.9	103.8	123.3	9.03
VT54	0.70	1.30	55.46	0.11	0.72	1359.3	70.4	138.6	9.03
VT55	0.48	1.16	41.28	0.12	0.75	1389.8	68.6	139.6	8.97
VT56	0.70	1.16	58.88	0.12	0.85	1371.4	103.4	117.0	9.02
VT57	0.55	1.10	50.06	0.12	0.74	1375.8	69.4	121.5	9.02
VT58	0.51	1.08	46.81	0.13	1.42	1235.4	74.4	122.5	8.99
VT59	0.57	1.15	49.61	0.12	1.41	1246.4	74.7	121.8	9.02
VT62	0.51	1.17	43.73	0.13	1.41	1239.8	74.8	124.4	9.00
VT66	0.41	1.16	35.34	0.12	1.18	1336.1	107.1	126.6	9.00
VT68	1.06	1.32	81.62	0.13	0.87	1344.3	104.6	127.2	9.00
VT70	1.01	1.27	81.29	0.13	0.86	1347.1	104.3	120.9	9.00
VT72	1.01	1.36	72.97	0.12	0.86	1343.8	104.5	126.9	8.98
VT73	0.92	1.32	71.43	0.12	0.86	1341.2	104.6	128.0	8.99
VT74	0.97	1.28	73.15	0.13	0.87	1355.2	104.1	122.5	9.02
VT75	0.47	1.17	40.66	0.12	1.18	1331.5	107.7	126.0	9.01
VT76	0.63	1.13	56.45	0.13	0.86	1352.7	104.0	125.9	9.01
VT77	0.67	1.17	56.91	0.13	0.86	1352.1	103.1	119.1	9.01
VT78	0.75	1.22	61.75	0.13	0.86	1353.6	104.4	125.9	9.00
WOR	0.74	1.24	58.09	0.13	0.87	1342.1	124.6	122.5	9.00
WOR1	0.65	1.23	53.07	0.13	0.86	1343.3	103.8	126.8	8.98
WV523S	1.07	1.60	66.24	0.12	1.33	1336.5	63.8	130.6	9.00
WV531S	0.95	1.30	69.01	0.14	0.86	1526.7	83.0	133.0	8.95
WV547S	0.48	1.24	38.50	0.14	0.80	1551.0	69.2	130.4	9.01
WV548S	0.73	1.29	55.57	0.12	0.62	1518.5	71.2	120.3	8.99
WV769S	0.91	1.41	63.66	0.12	0.65	1402.6	89.4	125.0	9.14
WV770S	0.60	1.25	49.18	0.14	0.57	1476.6	72.5	139.3	8.98
WV771S	0.40	1.14	35.46	0.13	0.69	1487.0	84.4	112.4	9.03
WV785S	0.56	1.07	55.72	0.12	0.65	1508.0	68.6	142.5	8.97
WV788S	0.97	1.33	73.08	0.13	0.71	1528.4	71.8	112.8	9.04

Table I-3. Continued.

Site ID	Runoff m/yr	Rainfall m/yr	Yield %	Riparian Area %	Depth m	Bulk Dens kg/m^3	CEC meq/kg	Half Sat. ueq/L	Al Solub log(KAl)
WV796S	1.11	1.47	74.46	0.12	0.69	1451.2	88.9	126.0	9.01

Table I-4. The observed stream variable values (µeq/L) used for calibration of each SAMI site. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
	Average	60.5	47.2	31.6	16.5	0.4	85.0	21.1	12.2	156.2	118.3	37.8	6.1
	Std. Dev.	40.1	30.3	23.4	10.0	0.7	55.8	23.4	15.2	82.8	68.0	51.5	0.8
	Maximum	198.7	204.1	205.9	52.6	6.0	368.5	278.6	95.8	519.4	434.3	148.3	7.2
	Minimum	9.3	10.7	6.8	2.3	0.0	14.7	6.5	0.0	35.3	29.7	-109.6	4.1
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	NH_4	SO_4	**Cl**	NO_3	**SBC**	**SAA**	**Calk**	**pH**
2A068015U	1985	23.4	24.9	20.9	16.9	1.1	26.2	9.1	16.5	87.2	51.7	35.4	6.4
2A07701	1985	81.3	29.2	38.3	12.9	0.3	27.2	15.7	13.0	162.1	56.0	106.1	7.1
2A07805	1985	85.5	38.7	53.2	10.6	2.1	40.8	21.5	24.8	190.1	87.0	103.0	7.0
2A07806	1985	68.5	22.2	71.6	14.2	0.8	28.5	13.9	16.2	177.4	58.6	118.8	7.0
2A07810L	1985	63.9	27.8	34.5	12.1	0.8	35.8	13.4	16.8	139.0	66.0	73.0	6.9
2A07810U	1985	45.0	23.0	47.6	11.7	0.9	28.2	14.0	19.0	128.2	61.2	67.0	6.8
2A07811	1985	52.9	30.3	27.9	10.3	0.6	43.6	12.7	39.4	121.9	95.7	26.2	6.4
2A07812	1985	53.6	26.5	58.7	13.4	0.9	23.2	12.1	3.7	153.1	39.0	114.1	7.1
2A07816	1985	33.7	16.5	34.5	10.5	0.6	20.1	11.8	7.6	95.8	39.4	56.4	6.8
2A07817	1985	39.6	19.2	29.7	9.4	0.5	23.6	11.3	20.8	98.3	55.7	42.7	6.6
2A07821	1985	59.1	26.0	79.0	13.8	0.4	17.4	26.6	7.6	178.2	51.6	126.6	7.1
2A07823	1985	71.7	50.3	70.0	21.1	0.7	65.7	24.8	3.4	213.8	93.9	119.9	7.1
2A07828	1985	29.8	20.6	32.4	10.1	0.8	18.0	13.6	4.3	93.6	35.9	57.7	6.8
2A07829	1985	31.0	18.8	43.0	11.2	2.9	14.7	16.5	9.8	106.8	41.0	65.8	6.9
2A07834	1985	27.3	18.7	40.1	8.4	0.7	17.3	22.5	2.9	95.2	42.7	52.5	6.8
2A07835	1985	41.4	29.9	71.5	10.3	0.5	24.8	25.2	1.5	153.5	51.5	101.9	7.0
2A07882	1985	60.5	32.7	51.3	11.5	0.6	21.8	18.9	15.5	156.6	56.2	100.4	7.0
2A08802	1985	36.4	49.4	39.3	14.9	0.9	15.0	18.9	6.2	141.0	40.1	100.9	6.6
2A08804	1985	28.0	26.9	38.2	12.0	0.9	22.7	19.2	3.2	106.0	45.1	60.9	6.8
2A08805	1985	66.5	50.6	57.3	15.8	0.5	33.1	27.1	7.0	190.7	67.2	123.5	6.9
2A08810	1985	72.0	59.6	61.6	16.8	0.6	21.5	30.8	14.8	210.6	67.0	143.6	7.2
2A08901	1985	57.2	32.8	62.8	15.6	1.3	16.6	22.2	6.7	169.8	45.5	124.2	7.2
2B041020L	1985	198.7	204.1	74.3	41.6	0.7	368.5	43.8	4.3	519.4	416.6	102.8	6.7
2B041049U	1985	60.3	86.7	23.0	20.1	0.5	229.3	24.8	0.2	190.6	254.3	-63.8	4.7
2B047032	1985	111.3	84.1	37.6	17.6	0.9	124.0	12.8	36.3	251.4	173.1	78.4	6.8
2B047044U	1985	113.8	74.0	38.4	17.6	1.0	96.4	10.0	11.3	244.8	117.7	127.1	6.9
2B047076L	1985	27.0	47.0	26.6	41.1	0.2	108.7	23.3	0.2	141.8	132.2	9.6	5.6
2B047076U	1985	34.1	40.8	26.5	52.6	0.0	111.5	22.1	6.6	153.9	140.2	13.7	5.9
2B058015U	1985	11.6	39.1	21.6	32.8	0.0	73.8	18.6	0.1	105.1	92.4	12.7	5.9
2C041033U	1985	129.5	71.9	34.9	22.0	0.7	159.1	46.6	41.1	258.9	246.7	12.2	5.7
2C041039	1985	141.5	91.3	38.2	19.3	0.8	174.5	19.8	33.1	291.1	227.4	63.7	6.7
2C041040	1985	116.0	104.1	36.0	26.9	1.4	184.2	22.1	42.8	284.4	249.1	35.3	6.4
2C041043U	1985	149.5	132.9	57.2	31.7	2.0	209.4	28.1	33.2	373.2	270.6	102.6	6.4
2C041045	1985	172.2	104.5	93.1	19.8	1.1	154.1	69.1	27.1	390.6	250.3	140.3	7.0
2C041051	1985	89.6	39.7	21.0	7.1	0.9	161.8	10.8	2.5	158.3	175.1	-16.8	4.9
2C046013L	1985	111.5	107.8	43.6	16.9	0.7	136.7	41.8	28.4	280.5	206.8	73.7	6.8
2C046033	1985	61.4	52.0	7.9	10.0	0.9	85.4	13.4	39.9	132.1	138.6	-6.5	5.7
2C046034	1985	77.3	52.9	7.4	8.3	0.8	109.6	12.3	34.3	146.7	156.2	-9.5	5.5
2C046043L	1985	126.8	55.4	82.4	8.1	0.8	140.9	93.7	29.7	273.6	264.2	9.4	5.8
2C046043U	1985	117.0	53.7	70.9	8.1	0.9	137.9	79.1	29.8	250.6	246.8	3.7	5.6

Table I-4. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
2C046050	1985	153.7	91.4	205.9	37.2	6.0	140.3	278.6	15.4	494.2	434.3	59.9	6.4
2C046053L	1985	103.5	81.8	15.4	12.5	0.7	137.5	12.5	26.1	214.0	176.1	37.9	6.5
2C046062L	1985	186.6	169.5	29.5	17.6	1.9	234.0	14.9	26.7	405.1	275.6	129.5	7.0
2C047007	1985	141.7	109.8	49.2	26.5	1.3	222.8	15.8	13.4	328.5	251.9	76.6	6.8
2C047010L	1985	70.1	50.1	22.5	18.0	1.3	74.1	15.1	52.9	162.1	142.1	20.0	6.5
2C047010U	1985	71.9	49.9	22.2	18.5	0.9	72.6	13.5	54.5	163.4	140.6	22.8	6.5
2C057004	1985	75.9	92.7	17.1	16.9	0.7	169.3	16.1	6.9	203.2	192.3	11.0	5.7
2C066026L	1985	55.9	51.3	24.4	18.2	1.3	71.4	37.2	11.9	151.0	120.6	30.4	6.2
2C066027L	1985	27.0	37.4	20.2	15.1	2.0	56.8	16.3	3.0	101.6	76.2	25.5	5.9
2C066027U	1985	9.3	25.2	18.8	10.4	0.9	57.7	16.1	0.3	64.5	74.1	-9.5	5.1
2C066039L	1985	73.9	39.2	29.0	17.9	3.4	71.8	33.9	4.2	163.2	109.9	53.3	6.4
2C077022U	1985	44.6	42.9	32.1	11.9	1.2	51.2	36.4	2.4	132.8	90.0	42.7	6.3
BJ35	1999	87.9	38.7	32.9	6.6	0.0	48.3	11.9	95.8	166.0	156.1	10.0	5.4
BJ72	1999	19.7	12.9	25.9	6.6	0.0	33.8	10.2	5.5	65.1	49.6	15.5	5.7
BJ76	1999	30.8	19.9	35.3	9.2	0.0	26.1	13.7	6.9	95.2	46.7	48.5	6.4
BJ77	1999	23.9	16.9	30.9	8.2	0.0	22.7	11.3	3.2	79.9	37.2	42.7	6.4
BLFC	1991	11.5	27.8	20.6	24.4	0.0	51.3	18.7	0.3	84.4	70.3	14.1	6.0
CO01	1993	11.2	24.4	13.3	21.3	0.0	23.5	22.7	1.9	70.3	48.1	22.2	6.5
CO05	1993	54.4	55.1	12.6	30.7	0.0	76.7	28.6	4.6	152.8	109.9	42.8	6.5
CO06	1993	31.2	30.2	19.8	22.7	0.0	19.8	17.7	0.7	103.8	38.2	65.6	6.4
CO10	1993	54.6	63.0	11.8	32.3	0.0	83.2	26.7	3.1	161.7	112.9	48.8	6.5
DR	1994	24.3	47.1	24.2	42.9	0.0	105.9	25.3	3.9	138.6	135.2	3.4	5.4
DR01	1990	22.3	44.8	24.6	44.7	0.0	109.3	23.3	0.1	136.4	132.7	3.7	5.5
DS04	1994	35.2	30.0	9.0	6.1	1.2	116.8	11.7	6.7	81.5	135.3	-53.8	4.3
DS06	1994	26.7	24.6	9.5	4.7	1.3	111.6	11.6	6.6	66.8	129.8	-63.0	4.2
DS09	1994	37.1	23.1	9.3	5.1	1.2	104.9	10.0	2.8	75.8	117.7	-41.9	4.4
DS19	1994	53.9	26.5	8.7	5.3	1.2	96.8	11.3	5.5	95.6	113.5	-17.9	4.7
DS50	1994	37.2	18.8	8.7	4.1	1.3	72.8	8.3	3.6	70.1	84.7	-14.6	4.5
FN1	1994	85.9	80.8	31.4	15.5	0.0	195.3	11.7	7.7	213.5	214.8	-1.3	6.0
FN2	1994	88.3	66.9	21.1	17.9	0.0	157.0	12.4	29.5	194.2	198.9	-4.7	6.1
FN3	1994	78.8	62.1	14.5	14.5	0.3	104.8	14.1	51.8	170.1	170.7	-0.6	5.8
GS01	2000	49.5	23.8	22.1	8.5	0.0	41.4	12.4	42.6	103.8	96.3	7.5	5.9
GS02	2000	45.0	18.4	22.8	5.8	0.0	28.4	10.1	37.2	92.1	75.7	16.4	6.1
GS04	2000	98.8	49.9	41.4	7.2	0.0	76.0	12.2	41.9	197.3	130.1	67.2	6.7
GS05	2000	19.6	12.0	27.1	13.8	0.0	19.9	9.5	0.3	72.5	29.7	42.8	6.2
GS06	2000	67.0	29.3	44.5	10.4	0.0	40.1	12.8	3.9	151.2	56.7	94.5	6.3
GS07	2000	32.3	16.7	31.2	7.6	0.0	25.3	11.4	26.6	87.9	63.4	24.5	6.3
GS08	2000	31.4	16.9	30.8	8.0	0.0	16.9	11.9	24.1	87.1	52.9	34.2	6.4
LB01	1987	117.8	34.1	21.1	20.9	1.3	106.5	33.7	1.0	195.3	141.2	54.1	6.5
LEWF	1991	54.4	25.8	44.1	11.8	0.0	42.9	12.5	50.6	136.1	105.9	30.2	6.4
M037	1991	20.8	40.8	30.2	27.0	0.0	68.8	18.6	0.3	118.9	87.7	31.1	6.3
M038	1991	27.3	42.0	25.8	28.3	0.0	75.6	16.8	0.3	123.4	92.7	30.7	6.3
M039	1991	13.2	24.7	19.4	26.2	0.0	42.0	17.5	0.3	83.6	59.8	23.8	6.2
NFD	1994	94.2	54.9	73.7	10.3	0.0	99.4	28.1	28.6	233.1	156.0	77.1	6.5
NFDR	1990	87.9	50.6	75.1	9.6	0.0	98.7	29.5	33.4	223.1	161.7	61.5	6.4
OC02	1994	54.1	26.0	8.0	6.2	1.3	123.2	10.2	19.2	95.6	152.6	-57.0	4.6
OC05	1994	22.5	15.2	7.4	3.4	1.4	122.9	7.9	1.8	49.9	132.7	-82.8	4.1

Table I-4. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
OC08	1994	28.7	23.7	7.1	5.0	1.2	128.8	8.9	2.1	65.7	139.8	-74.1	4.4
OC09	1994	14.2	10.7	6.8	2.3	1.2	117.8	6.5	0.7	35.3	125.0	-89.7	4.1
OC31	1994	21.1	14.9	7.4	3.2	1.1	148.1	7.9	1.4	47.7	157.3	-109.6	4.1
OC32	1994	28.0	18.3	7.3	4.2	1.1	124.1	7.8	2.7	58.9	134.5	-75.6	4.2
OC35	1994	61.3	30.5	14.7	5.2	1.1	158.3	8.0	2.1	112.7	168.4	-55.7	4.5
OC79	1994	70.5	36.1	9.7	8.2	1.1	74.4	9.9	23.2	125.5	107.6	17.9	6.0
PAIN	1994	34.1	60.0	22.4	47.3	0.0	111.3	24.8	22.4	163.8	158.5	5.3	5.6
SP10	1992	63.4	60.8	26.0	26.4	0.0	93.7	31.7	1.8	176.5	127.2	49.3	6.2
SP39	1992	34.2	54.4	29.9	21.5	0.0	74.9	33.7	0.0	139.9	108.6	31.3	6.8
SP41	1993	70.9	70.2	39.7	29.1	0.0	69.7	32.1	6.0	209.9	107.8	102.1	4.7
STAN	1994	68.4	30.9	59.6	10.4	0.0	43.6	24.5	5.0	169.3	73.1	96.2	6.6
VA524S	1994	63.9	52.6	18.7	18.7	0.6	120.0	21.0	4.6	154.5	145.6	8.9	5.5
VA526S	1994	132.2	94.6	27.4	18.9	0.0	123.0	18.0	1.3	273.1	142.3	130.8	7.1
VA531S	1994	49.9	39.5	60.5	9.2	0.0	48.0	23.0	20.3	159.1	91.3	67.8	6.7
VA548S	1994	39.9	79.8	50.9	20.7	0.0	117.0	39.0	5.7	191.3	161.7	29.6	5.7
VA555S	1994	32.9	31.3	16.1	11.8	0.0	43.0	19.0	0.4	92.1	62.4	29.7	6.3
VA821S	1994	143.7	116.0	53.5	19.4	0.0	163.0	54.0	0.0	332.6	217.0	115.6	7.0
VT02	1990	54.6	24.8	43.9	13.7	0.0	47.8	12.3	38.7	137.0	98.8	38.2	6.5
VT05	1990	32.1	43.2	29.1	21.7	0.0	37.1	11.6	0.4	126.1	49.1	77.1	6.8
VT07	1990	58.1	28.1	18.0	8.4	0.0	82.0	13.4	13.5	112.7	108.8	3.9	5.1
VT08	1990	66.3	30.5	17.9	8.9	0.0	77.8	13.6	9.6	123.5	100.9	22.7	5.8
VT09	1990	47.9	28.5	15.4	8.9	0.0	69.1	13.4	3.1	100.7	85.6	15.0	5.8
VT10	1990	31.3	30.5	17.1	12.2	0.0	45.9	15.2	0.1	91.1	61.2	29.9	6.3
VT11	1990	32.1	31.9	13.4	11.7	0.0	35.3	13.4	2.1	89.1	50.8	38.3	6.2
VT12	1990	85.0	71.9	14.5	14.2	0.0	32.5	13.8	1.9	185.5	48.1	137.4	6.9
VT15	1990	29.0	25.5	15.5	11.8	0.0	30.6	13.0	0.3	81.8	44.0	37.9	6.2
VT18	1990	69.5	55.5	28.5	18.0	0.0	80.2	11.7	15.9	171.5	107.8	63.7	6.6
VT19	1990	73.7	59.4	25.4	19.6	0.0	69.7	12.7	31.2	178.0	113.5	64.5	6.6
VT20	1990	125.7	52.5	22.5	14.5	0.0	83.5	16.9	0.1	215.1	100.6	114.6	7.0
VT24	1990	47.8	25.9	16.9	12.7	0.0	53.1	17.2	0.6	103.3	70.8	32.5	6.3
VT25	1990	22.0	23.9	14.0	9.3	0.0	41.1	15.9	0.1	69.2	57.0	12.2	5.8
VT26	1990	49.8	36.4	14.8	13.4	0.0	91.6	21.8	0.9	114.3	114.3	0.0	5.3
VT28	1990	22.4	24.0	12.3	9.2	0.0	41.3	14.3	0.1	67.9	55.8	12.1	5.5
VT29	1990	19.6	20.5	11.3	8.6	0.0	34.5	14.5	0.8	60.0	49.8	10.3	5.5
VT31	1990	14.7	21.8	13.7	8.0	0.0	41.0	16.6	0.1	58.2	57.7	0.5	5.2
VT32	1990	58.2	34.6	12.2	9.9	0.0	76.4	19.0	13.9	114.8	109.4	5.5	5.4
VT34	1990	66.1	38.5	18.8	12.2	0.0	69.5	16.7	0.1	135.6	86.3	49.3	6.6
VT35	1990	25.9	48.1	24.1	44.9	0.0	111.4	22.7	0.5	143.0	134.6	8.4	5.9
VT36	1990	23.8	40.4	21.8	26.2	0.0	89.1	22.2	0.1	112.2	111.4	0.8	5.5
VT37	1990	39.7	47.3	24.1	17.6	0.0	72.8	15.0	3.7	128.7	91.5	37.1	6.4
VT38	1990	82.8	79.0	36.9	20.5	0.0	128.8	15.7	0.6	219.2	145.1	74.1	6.8
VT39	1990	11.4	20.1	16.3	14.4	0.0	54.9	14.5	0.1	62.2	69.4	-7.3	5.1
VT41	1990	24.6	29.4	17.4	17.6	0.0	64.4	15.1	0.1	89.0	79.7	9.4	5.8
VT46	1990	65.1	22.0	56.3	5.6	0.0	39.3	22.2	3.6	149.1	65.1	83.9	6.7
VT48	1990	23.3	39.8	31.6	36.0	0.0	56.9	16.5	0.3	130.6	73.7	56.9	6.7
VT49	1990	49.1	68.3	21.3	16.5	0.0	123.3	19.2	2.8	155.2	145.2	10.0	5.8
VT50	1990	31.0	67.3	18.6	19.3	0.0	140.6	21.9	10.1	136.2	172.5	-36.3	4.8

Table I-4. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
VT53	1990	27.6	46.8	27.4	38.2	0.0	98.6	23.0	0.3	140.0	121.8	18.1	6.1
VT54	1990	80.3	78.0	33.9	21.9	0.0	130.4	15.7	12.4	214.1	158.5	55.6	6.5
VT55	1990	94.1	117.5	68.8	23.2	0.0	164.0	19.6	17.8	303.6	201.4	102.2	6.7
VT56	1990	21.7	40.8	16.3	18.8	0.0	76.9	14.3	0.6	97.6	91.7	5.9	5.7
VT57	1990	52.3	68.5	28.2	21.4	0.0	112.5	17.1	7.6	170.3	137.2	33.1	6.4
VT58	1990	55.7	34.2	60.7	9.6	0.0	40.4	23.0	6.8	160.2	70.1	90.0	6.8
VT59	1990	59.4	24.3	61.4	9.4	0.0	41.1	23.6	2.9	154.5	67.6	87.0	6.7
VT62	1990	59.0	41.2	63.2	10.2	0.0	39.3	24.5	4.3	173.7	68.1	105.5	6.7
VT66	1990	113.3	88.1	59.0	4.9	0.0	53.3	31.9	31.8	265.3	117.0	148.3	6.9
VT68	1990	13.9	19.2	15.3	12.6	0.0	53.6	14.3	0.1	61.0	67.9	-7.0	5.1
VT70	1990	19.8	21.8	16.9	19.9	0.0	46.4	14.2	0.1	78.5	60.7	17.8	5.9
VT72	1990	18.7	23.7	15.8	20.6	0.0	66.2	15.0	0.1	78.7	81.3	-2.6	5.1
VT73	1990	30.2	36.3	21.8	25.2	0.0	74.2	16.0	0.3	113.5	90.6	22.9	6.1
VT74	1990	21.6	25.6	15.9	15.6	0.0	58.5	14.8	0.1	78.8	73.4	5.4	5.6
VT75	1990	109.5	86.4	53.9	4.6	0.0	53.1	27.5	33.2	254.4	113.7	140.7	6.7
VT76	1990	14.0	30.9	23.1	28.1	0.0	59.7	17.9	0.1	96.0	77.6	18.4	6.0
VT77	1990	23.7	40.9	33.5	28.4	0.0	57.4	17.8	0.0	126.6	75.2	51.4	6.7
VT78	1990	23.6	22.8	10.5	6.8	0.0	56.1	10.2	5.3	63.7	71.6	-7.9	5.1
WOR	1994	35.6	57.9	21.5	40.4	0.0	74.8	23.5	32.0	155.3	130.3	25.0	5.9
WOR1	1990	28.3	49.2	22.6	38.3	0.0	83.1	21.4	5.5	138.4	110.0	28.4	6.0
WV523S	1994	51.4	26.3	8.3	9.5	0.0	95.0	15.0	26.7	95.5	136.7	-41.2	4.8
WV531S	1994	104.3	23.9	9.6	6.4	0.0	120.0	13.0	8.0	144.2	141.0	3.2	5.5
WV547S	1994	141.2	102.8	40.5	16.1	0.0	200.0	22.0	22.8	300.6	244.8	55.8	7.0
WV548S	1994	70.4	53.5	10.4	12.5	0.0	108.0	15.0	31.1	146.8	154.1	-7.3	5.3
WV769S	1994	122.3	87.2	10.4	16.6	0.0	170.0	14.0	19.5	236.5	203.5	33.0	6.6
WV770S	1994	138.2	109.4	56.5	29.9	0.0	208.0	19.0	12.2	334.0	239.2	94.8	6.9
WV771S	1994	191.6	96.2	48.7	19.2	0.0	171.0	26.0	17.5	355.7	214.5	141.2	7.0
WV785S	1994	65.9	65.8	26.5	17.1	0.0	164.0	32.0	0.0	175.3	196.0	-20.7	4.9
WV788S	1994	71.4	39.5	9.1	10.7	0.0	96.0	12.0	15.7	130.7	123.7	7.0	5.9
WV796S	1994	80.3	33.7	10.0	4.9	0.0	85.0	7.0	0.0	128.9	92.0	36.9	6.2

Table I-5 The simulated stream variable values resulting from the calibration of each SAMI site (median values of multiple calibrations at each site). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
	Average	60.6	47.2	31.5	16.4	0.0	84.9	21.2	13.0	155.6	119.2	36.5	6.2
	Std. Dev.	40.1	30.3	23.4	10.0	0.0	55.8	23.8	15.7	82.4	69.0	51.2	0.8
	Maximum	199.1	204.2	205.9	52.6	0.0	368.3	283.7	86.2	518.4	443.1	142.5	7.2
	Minimum	11.3	10.8	6.9	2.4	0.0	14.6	6.3	0.2	34.5	29.7	-110.8	4.6
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**	**pH**
2A068015U	1985	23.2	25.1	21.0	16.8	0.0	26.0	10.3	16.0	86.9	52.5	33.4	6.5
2A07701	1985	81.4	29.3	38.3	12.8	0.0	27.1	15.9	12.9	161.9	56.3	105.7	7.0
2A07805	1985	85.2	38.6	53.2	10.6	0.0	40.7	21.1	24.6	187.7	86.1	101.1	7.0
2A07806	1985	68.9	22.2	71.6	14.4	0.0	28.6	14.3	16.3	177.8	58.2	118.1	7.1
2A07810L	1985	64.0	27.9	34.6	12.3	0.0	35.8	12.9	17.0	138.7	65.9	72.0	6.9
2A07810U	1985	44.7	22.9	47.5	11.4	0.0	28.3	13.7	18.9	126.9	61.5	64.7	6.8
2A07811	1985	53.2	30.4	27.6	10.2	0.0	43.5	12.7	38.6	122.0	94.8	29.0	6.5
2A07812	1985	53.7	26.7	58.8	13.3	0.0	23.1	12.2	3.8	152.3	39.0	113.3	7.1
2A07816	1985	33.1	16.1	34.2	10.3	0.0	20.4	12.2	8.1	93.9	40.6	52.9	6.7
2A07817	1985	39.8	19.4	29.7	9.5	0.0	23.6	11.1	21.1	98.2	55.5	41.8	6.6
2A07821	1985	59.5	26.0	79.1	13.9	0.0	17.2	27.4	7.4	178.2	52.0	125.9	7.1
2A07823	1985	71.9	50.5	69.8	21.0	0.0	65.5	25.1	3.8	213.4	94.7	118.7	7.1
2A07828	1985	29.5	21.1	32.7	10.2	0.0	17.9	13.5	4.5	93.1	35.5	57.2	6.8
2A07829	1985	30.6	18.7	43.0	11.2	0.0	14.6	16.8	10.0	103.9	41.0	63.5	6.8
2A07834	1985	26.9	18.8	40.0	8.6	0.0	17.1	22.5	3.1	94.5	42.6	52.1	6.7
2A07835	1985	41.6	29.8	71.4	10.1	0.0	25.0	25.9	1.7	152.7	52.2	100.0	7.0
2A07882	1985	60.3	32.6	51.3	11.4	0.0	21.9	19.0	15.8	155.7	56.1	98.6	7.0
2A08802	1985	36.5	49.4	39.3	14.8	0.0	15.0	19.3	6.3	140.3	40.7	101.3	7.0
2A08804	1985	28.3	27.5	38.2	12.2	0.0	22.5	19.0	3.1	106.2	45.2	59.8	6.8
2A08805	1985	66.8	50.9	57.3	15.5	0.0	33.1	27.0	7.0	191.0	66.6	123.6	7.1
2A08810	1985	72.3	59.5	61.5	16.8	0.0	21.3	31.2	15.0	210.0	67.4	142.5	7.2
2A08901	1985	57.2	32.7	62.7	15.7	0.0	16.6	23.2	7.4	168.2	47.2	121.6	7.1
2B041020L	1985	199.1	204.2	73.7	41.2	0.0	368.3	45.0	4.9	518.4	418.1	101.2	7.0
2B041049U	1985	60.9	86.5	22.2	19.8	0.0	229.1	27.3	0.5	189.4	256.8	-68.1	4.6
2B047032	1985	111.1	84.1	37.4	17.9	0.0	124.3	13.2	41.6	250.6	178.0	73.1	6.9
2B047044U	1985	113.9	74.2	38.3	17.7	0.0	96.3	10.2	12.8	243.3	119.4	125.0	7.1
2B047076L	1985	27.8	46.8	26.3	40.7	0.0	108.6	23.0	0.5	141.3	132.4	8.8	5.9
2B047076U	1985	34.3	41.1	26.6	52.6	0.0	111.8	22.0	7.3	154.2	141.3	12.7	6.1
2B058015U	1985	11.5	39.2	21.7	32.9	0.0	73.8	17.9	0.3	105.8	91.8	12.9	6.1
2C041033U	1985	129.4	71.9	34.8	22.2	0.0	159.0	45.7	43.8	258.9	248.6	10.0	6.0
2C041039	1985	140.6	91.3	37.8	19.3	0.0	174.2	20.3	36.6	289.4	231.1	58.7	6.8
2C041040	1985	116.0	104.1	35.6	27.1	0.0	184.5	22.0	45.9	282.5	252.7	30.3	6.5
2C041043U	1985	149.1	132.7	56.6	31.5	0.0	209.3	28.2	36.8	369.9	275.1	96.8	7.0
2C041045	1985	172.2	104.5	92.8	19.5	0.0	154.2	70.9	30.2	389.6	255.2	134.4	7.1
2C041051	1985	89.7	39.9	20.6	7.0	0.0	161.9	11.1	2.9	157.5	176.4	-18.6	4.9
2C046013L	1985	111.9	107.7	43.2	16.9	0.0	136.5	42.1	30.6	279.9	208.4	70.2	6.8
2C046033	1985	61.5	52.1	7.9	9.9	0.0	85.1	13.4	43.9	132.0	143.1	-11.5	5.0
2C046034	1985	77.4	53.0	7.2	8.2	0.0	109.4	12.2	37.4	145.9	158.9	-13.1	5.0
2C046043L	1985	127.0	55.6	82.7	8.1	0.0	140.8	94.7	32.7	272.6	268.8	4.4	5.7

Table I-5. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
2C046043U	1985	117.0	53.6	70.5	7.8	0.0	137.8	81.6	34.4	249.5	253.8	-5.8	5.2
2C046050	1985	153.9	91.8	205.9	37.1	0.0	140.4	283.7	17.5	488.4	443.1	46.6	6.7
2C046053L	1985	103.5	81.9	15.5	12.2	0.0	138.1	13.0	29.8	212.8	180.2	31.8	6.5
2C046062L	1985	186.7	170.3	29.2	17.4	0.0	233.6	16.0	31.3	403.7	280.8	122.4	7.1
2C047007	1985	142.1	110.4	48.8	26.3	0.0	222.9	16.7	15.5	326.8	255.2	73.0	6.9
2C047010L	1985	70.1	50.4	22.5	18.3	0.0	74.0	14.6	56.3	161.4	145.4	17.4	6.2
2C047010U	1985	72.1	50.0	21.8	18.4	0.0	72.3	13.8	60.9	162.4	147.4	17.5	6.2
2C057004	1985	76.4	93.1	16.8	17.4	0.0	169.7	16.3	7.9	203.6	193.2	7.7	5.9
2C066026L	1985	55.8	51.2	24.4	18.0	0.0	71.2	36.9	11.3	149.4	119.0	29.8	6.5
2C066027L	1985	26.9	36.8	20.0	14.9	0.0	56.9	16.3	3.0	98.7	76.0	22.3	6.3
2C066027U	1985	11.3	25.2	18.9	10.4	0.0	58.0	15.5	0.5	65.4	73.9	-8.3	5.1
2C066039L	1985	73.9	38.9	29.1	17.8	0.0	71.6	33.3	4.1	159.7	109.1	50.3	6.7
2C077022U	1985	44.4	42.7	32.0	11.9	0.0	51.0	36.3	2.6	131.1	89.7	40.7	6.6
BJ35	1999	87.9	38.6	32.8	6.6	0.0	48.2	12.0	86.2	165.6	146.7	20.2	6.3
BJ72	1999	19.7	12.6	25.9	6.5	0.0	33.8	11.1	5.3	65.2	50.6	14.4	6.1
BJ76	1999	30.7	19.9	35.5	9.1	0.0	26.0	14.3	7.0	94.4	46.5	48.6	6.7
BJ77	1999	24.7	17.1	31.1	8.5	0.0	22.6	10.2	3.2	81.5	35.9	44.5	6.7
BLFC	1991	12.2	27.7	20.3	24.3	0.0	51.1	18.3	0.6	84.9	69.9	15.5	6.2
CO01	1993	11.8	24.6	13.2	21.4	0.0	23.6	21.2	1.9	70.0	46.6	24.8	6.4
CO05	1993	54.6	54.6	13.5	30.8	0.0	76.6	21.5	3.5	154.0	102.2	51.8	6.7
CO06	1993	31.8	30.2	19.7	23.1	0.0	19.8	18.1	0.8	104.6	38.3	66.5	6.8
CO10	1993	54.5	63.0	14.3	32.4	0.0	83.2	21.0	2.5	163.4	107.2	57.1	6.8
DR	1994	26.0	46.7	24.2	42.5	0.0	105.9	26.6	4.4	138.6	136.1	2.9	5.6
DR01	1990	22.1	45.1	24.6	45.0	0.0	109.2	23.0	0.4	136.0	132.9	3.5	5.6
DS04	1994	35.1	30.0	9.0	6.0	0.0	116.6	11.5	7.3	79.9	135.6	-55.4	4.7
DS06	1994	27.1	24.6	9.5	4.5	0.0	111.7	11.5	7.3	65.6	130.6	-65.8	4.6
DS09	1994	37.0	23.0	9.3	5.0	0.0	104.9	9.5	3.2	74.5	117.9	-43.8	4.7
DS19	1994	53.9	26.6	8.7	5.3	0.0	96.6	11.0	5.9	94.6	113.7	-19.2	4.9
DS50	1994	37.1	18.7	8.9	4.1	0.0	72.7	8.2	4.0	68.6	85.1	-16.7	4.9
FN1	1994	85.3	80.9	30.6	14.9	0.0	195.4	11.5	8.1	212.0	214.7	-3.8	5.2
FN2	1994	87.9	66.9	21.0	18.0	0.0	156.9	12.2	29.6	194.1	198.3	-4.5	5.2
FN3	1994	79.0	62.0	14.3	14.6	0.0	104.6	14.2	53.5	169.6	172.0	-2.9	5.3
GS01	2000	49.1	23.7	22.0	8.5	0.0	41.5	12.5	41.3	103.5	95.1	7.9	5.9
GS02	2000	45.3	18.9	22.7	6.0	0.0	28.7	10.0	35.7	92.7	75.3	18.0	6.2
GS04	2000	99.0	49.8	41.3	7.2	0.0	76.1	12.3	40.5	197.2	128.4	69.8	6.8
GS05	2000	19.6	12.3	27.1	13.8	0.0	19.9	9.7	0.6	72.8	29.7	42.4	6.6
GS06	2000	67.1	29.3	44.4	10.4	0.0	39.6	12.8	3.9	151.3	56.9	94.6	7.0
GS07	2000	32.1	16.6	31.1	7.7	0.0	25.2	11.5	25.9	87.1	62.2	25.1	6.4
GS08	2000	32.1	17.0	30.7	8.1	0.0	16.8	11.9	23.1	87.5	52.1	36.3	6.6
LB01	1987	117.7	33.9	21.0	20.9	0.0	106.5	33.1	1.2	193.1	140.9	52.0	6.7
LEWF	1991	54.2	25.7	44.0	11.6	0.0	42.8	12.8	51.5	135.3	107.5	28.9	6.4
M037	1991	21.0	40.4	30.1	26.7	0.0	68.7	18.8	0.6	118.4	87.9	30.3	6.5
M038	1991	27.1	41.9	25.8	28.2	0.0	75.4	16.8	0.6	122.4	92.8	29.6	6.5
M039	1991	13.4	24.5	19.1	26.1	0.0	42.0	17.7	0.6	83.2	59.3	23.6	6.4
NFD	1994	94.5	54.8	73.5	10.1	0.0	99.4	28.0	29.8	233.0	157.1	76.9	6.9
NFDR	1990	87.8	50.7	74.4	9.5	0.0	98.7	28.9	40.3	222.9	168.0	54.7	6.7
OC02	1994	54.3	25.8	8.2	6.1	0.0	123.1	10.4	20.6	94.4	153.7	-58.4	4.7

Table I-5. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
OC05	1994	22.5	15.2	7.4	3.4	0.0	123.0	7.9	2.2	48.5	132.8	-84.6	4.6
OC08	1994	28.5	23.6	7.1	5.0	0.0	128.8	8.8	2.5	64.5	139.9	-76.1	4.6
OC09	1994	14.6	10.8	6.9	2.4	0.0	117.8	6.3	1.0	34.5	125.3	-90.5	4.6
OC31	1994	21.5	14.7	7.3	3.0	0.0	148.2	7.8	1.7	46.6	157.6	-110.8	4.6
OC32	1994	27.8	18.0	7.3	4.1	0.0	123.9	7.8	3.1	57.4	134.7	-77.3	4.6
OC35	1994	61.2	30.6	14.2	5.2	0.0	158.3	8.1	2.5	111.0	169.0	-58.1	4.7
OC79	1994	70.2	35.7	9.5	8.0	0.0	74.4	9.9	24.3	123.9	109.0	15.7	6.2
PAIN	1994	34.8	60.2	22.1	47.2	0.0	111.2	25.9	24.2	163.4	161.5	3.8	5.7
SP10	1992	63.5	61.2	26.0	26.4	0.0	93.8	32.2	2.0	176.7	128.1	48.6	6.7
SP39	1992	34.2	54.2	29.8	21.4	0.0	74.8	32.9	0.2	139.5	107.8	31.1	6.5
SP41	1993	70.7	70.2	39.7	29.0	0.0	69.7	31.6	6.0	210.1	106.9	102.8	7.0
STAN	1994	68.6	31.2	59.4	10.4	0.0	43.6	24.5	5.4	170.2	73.6	96.6	7.0
VA524S	1994	64.2	52.8	18.3	18.8	0.0	120.0	21.5	5.0	153.6	146.0	7.4	5.9
VA526S	1994	132.3	94.6	27.0	18.7	0.0	122.8	18.1	1.6	272.5	142.8	130.2	7.1
VA531S	1994	49.5	39.3	60.3	9.1	0.0	47.8	23.1	21.4	158.5	92.9	67.7	6.8
VA548S	1994	40.7	79.5	50.8	21.0	0.0	116.9	37.4	6.1	190.4	160.5	30.9	6.5
VA555S	1994	32.8	30.9	15.9	11.6	0.0	42.9	18.9	0.6	91.6	62.8	28.5	6.4
VA821S	1994	143.8	115.9	53.2	19.3	0.0	163.0	55.8	0.2	331.8	218.7	112.7	7.1
VT02	1990	55.4	25.1	43.6	13.9	0.0	47.6	12.3	38.2	137.4	98.3	39.0	6.6
VT05	1990	32.0	43.0	29.0	21.7	0.0	36.8	11.8	0.6	125.7	49.3	76.1	6.9
VT07	1990	58.2	28.0	17.8	8.2	0.0	82.0	13.5	14.2	112.9	109.4	3.6	5.6
VT08	1990	66.6	30.7	17.8	8.6	0.0	77.2	13.5	10.0	123.2	101.2	20.9	6.3
VT09	1990	47.7	28.2	15.0	8.9	0.0	69.1	13.6	3.4	100.1	85.8	14.2	6.1
VT10	1990	31.2	30.3	16.9	12.1	0.0	45.9	15.0	0.3	90.3	61.3	29.4	6.5
VT11	1990	31.8	31.9	13.5	11.7	0.0	35.5	13.5	2.5	88.9	50.7	36.7	6.6
VT12	1990	84.9	71.7	14.2	14.0	0.0	32.3	13.5	2.2	185.0	48.4	136.9	7.2
VT15	1990	28.7	25.5	15.5	11.8	0.0	30.6	13.2	0.6	81.8	44.6	37.4	6.6
VT18	1990	69.0	54.9	28.5	17.8	0.0	80.2	11.5	18.0	170.3	109.9	59.7	6.8
VT19	1990	73.1	59.5	25.1	19.7	0.0	69.6	12.8	36.1	177.9	118.3	59.0	6.8
VT20	1990	125.5	52.2	22.5	14.3	0.0	83.5	17.1	0.4	214.5	101.0	113.1	7.1
VT24	1990	47.3	25.5	16.9	12.5	0.0	53.0	16.9	0.9	102.8	71.0	32.1	6.5
VT25	1990	21.8	24.0	13.7	9.2	0.0	41.0	15.6	0.3	68.7	57.2	11.1	6.0
VT26	1990	49.7	36.0	14.7	13.3	0.0	91.6	22.8	1.4	113.6	115.0	-0.2	5.4
VT28	1990	22.4	23.8	12.4	9.0	0.0	41.2	14.5	0.3	67.5	55.8	11.4	6.0
VT29	1990	19.8	20.9	11.2	8.5	0.0	34.3	15.4	1.1	60.7	50.1	10.0	6.0
VT31	1990	15.4	21.8	13.4	8.0	0.0	41.1	13.5	0.3	58.8	55.2	4.2	5.7
VT32	1990	58.2	34.7	12.2	9.9	0.0	76.3	19.0	15.3	114.9	111.1	3.6	5.6
VT34	1990	66.1	38.7	18.6	12.1	0.0	69.2	16.3	0.3	135.1	85.7	49.9	6.7
VT35	1990	25.8	48.2	24.0	44.7	0.0	111.1	22.9	0.8	143.0	134.9	7.8	5.9
VT36	1990	23.9	40.3	21.6	25.9	0.0	88.9	22.1	0.3	112.0	112.4	0.8	5.5
VT37	1990	39.4	46.9	23.8	17.4	0.0	72.8	15.3	4.5	128.1	92.4	35.7	6.5
VT38	1990	82.3	78.8	36.4	20.2	0.0	128.9	15.6	1.0	217.5	145.1	72.2	6.9
VT39	1990	11.7	20.1	16.3	14.1	0.0	54.8	14.7	0.3	62.3	69.8	-6.8	5.1
VT41	1990	24.6	29.6	17.4	17.3	0.0	64.4	15.4	0.3	89.3	80.5	8.7	5.9
VT46	1990	65.4	22.1	56.0	5.4	0.0	39.1	22.7	4.3	149.1	66.0	82.9	6.9
VT48	1990	23.1	39.4	31.2	35.7	0.0	56.8	16.6	0.6	129.7	73.7	55.8	6.8
VT49	1990	48.9	68.2	21.0	16.7	0.0	123.0	18.9	3.6	155.2	145.7	9.1	5.9

Table I-5. Continued.													
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**	**pH**
VT50	1990	31.2	67.5	18.7	19.3	0.0	140.5	21.8	12.2	136.5	174.8	-37.6	4.8
VT53	1990	28.4	46.3	27.0	37.9	0.0	98.4	21.5	0.5	138.8	120.5	18.0	6.2
VT54	1990	79.8	77.5	33.2	21.9	0.0	130.4	14.8	13.7	213.1	158.6	53.0	6.7
VT55	1990	94.1	117.2	68.4	22.9	0.0	164.1	19.7	21.0	301.9	204.9	97.9	7.0
VT56	1990	21.6	40.7	15.5	18.6	0.0	77.0	14.7	0.9	97.1	92.2	4.2	5.7
VT57	1990	51.7	68.1	27.6	21.4	0.0	112.5	17.1	9.0	168.9	138.5	29.7	6.5
VT58	1990	55.6	34.4	60.6	9.6	0.0	40.0	23.4	8.7	160.0	71.8	87.7	7.0
VT59	1990	59.7	24.3	61.0	9.2	0.0	41.1	23.6	3.7	154.9	68.1	86.4	6.9
VT62	1990	59.0	41.2	63.2	10.3	0.0	39.3	24.3	5.4	173.6	69.0	103.8	7.0
VT66	1990	113.4	88.1	59.1	4.9	0.0	53.1	31.6	39.3	266.0	124.4	140.8	7.2
VT68	1990	13.8	19.5	15.3	12.7	0.0	53.5	14.1	0.3	61.0	68.2	-6.4	5.1
VT70	1990	19.7	21.9	16.9	19.9	0.0	46.3	14.0	0.3	78.3	61.0	18.0	6.2
VT72	1990	18.5	23.7	15.8	20.7	0.0	66.2	15.3	0.3	78.7	81.5	-2.6	5.3
VT73	1990	30.4	36.3	21.3	25.1	0.0	74.3	15.6	0.5	113.5	90.3	23.0	6.3
VT74	1990	21.6	25.5	15.5	15.6	0.0	58.5	15.3	0.3	78.9	73.6	4.7	5.7
VT75	1990	109.6	86.5	54.2	4.5	0.0	52.8	27.4	41.3	254.2	121.6	133.1	7.1
VT76	1990	15.3	30.4	22.8	27.9	0.0	59.7	17.6	0.3	96.2	77.1	19.2	6.3
VT77	1990	23.3	40.8	33.4	28.5	0.0	57.3	18.1	0.2	126.2	76.1	50.3	6.7
VT78	1990	23.6	22.9	10.5	6.8	0.0	56.0	10.1	5.6	64.5	71.8	-7.7	5.1
WOR	1994	35.4	58.1	21.3	40.3	0.0	74.5	24.0	33.7	154.5	132.0	23.6	6.4
WOR1	1990	28.2	48.9	22.2	38.2	0.0	82.9	21.4	6.3	137.9	111.0	27.0	6.4
WV523S	1994	51.3	26.2	8.3	9.5	0.0	94.9	15.0	27.7	95.9	137.7	-43.3	4.7
WV531S	1994	104.4	24.1	9.2	6.6	0.0	120.0	13.2	8.5	143.9	141.4	3.1	5.6
WV547S	1994	141.4	102.9	39.5	16.3	0.0	200.3	22.5	24.3	300.5	247.8	52.7	6.7
WV548S	1994	70.6	53.5	10.2	12.4	0.0	108.0	15.4	33.1	146.4	156.3	-8.3	5.1
WV769S	1994	122.8	87.2	10.5	16.6	0.0	170.4	14.4	20.7	237.2	204.9	32.1	6.5
WV770S	1994	138.1	109.8	56.2	29.9	0.0	208.0	18.5	12.3	334.0	239.3	94.5	7.0
WV771S	1994	191.2	96.6	49.1	18.9	0.0	170.8	26.8	18.9	354.9	216.0	138.3	7.1
WV785S	1994	66.1	65.9	26.1	17.2	0.0	164.3	32.0	0.2	176.1	196.7	-21.0	4.9
WV788S	1994	71.5	39.4	9.1	10.6	0.0	96.0	12.0	16.3	130.2	124.6	5.9	5.8
WV796S	1994	80.4	33.6	10.2	4.8	0.0	84.8	13.1	0.2	129.3	98.4	31.3	6.5

Table I-6. The differences between simulated and observed (sim-obs) stream variable values resulting from the calibration of each SAMI site (simulated values are median values of multiple calibrations at each site). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
	Average	0.07	-0.01	-0.12	-0.06	-0.44	-0.05	0.06	0.82	-0.54	0.83	-1.37	0.15
	Std. Dev.	0.38	0.24	0.32	0.17	0.75	0.16	1.13	1.75	0.94	2.24	2.68	0.30
	Maximum	2.06	0.82	2.50	0.50	0.00	0.58	6.11	8.19	1.71	8.75	10.26	2.30
	Minimum	-0.90	-0.59	-1.00	-0.56	-5.98	-0.53	-7.08	-9.60	-5.74	-9.40	-13.21	-0.87
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**	**pH**
2A068015U	1985	-0.16	0.22	0.13	-0.08	-1.10	-0.21	1.21	-0.44	-0.28	0.75	-2.07	0.15
2A07701	1985	0.08	0.14	-0.03	-0.13	-0.31	-0.17	0.19	-0.12	-0.17	0.31	-0.41	-0.05
2A07805	1985	-0.27	-0.13	0.03	0.03	-2.05	-0.13	-0.35	-0.12	-2.34	-0.97	-1.94	-0.03
2A07806	1985	0.38	-0.09	0.01	0.18	-0.79	0.03	0.36	0.11	0.36	-0.44	-0.66	0.05
2A07810L	1985	0.08	0.06	0.14	0.17	-0.75	-0.05	-0.51	0.16	-0.29	-0.09	-1.03	-0.07
2A07810U	1985	-0.23	-0.19	-0.06	-0.36	-0.88	0.06	-0.24	-0.06	-1.29	0.35	-2.27	0.04
2A07811	1985	0.32	0.12	-0.22	-0.08	-0.61	-0.09	-0.03	-0.82	0.09	-0.90	2.83	0.07
2A07812	1985	0.13	0.11	0.03	-0.04	-0.86	-0.09	0.07	0.10	-0.74	-0.06	-0.74	-0.02
2A07816	1985	-0.53	-0.42	-0.33	-0.19	-0.63	0.35	0.33	0.53	-1.90	1.21	-3.52	-0.07
2A07817	1985	0.23	0.22	-0.06	0.06	-0.52	0.00	-0.16	0.32	-0.16	-0.19	-0.85	-0.01
2A07821	1985	0.48	0.09	0.10	0.04	-0.38	-0.18	0.76	-0.16	-0.02	0.42	-0.76	0.03
2A07823	1985	0.22	0.22	-0.19	-0.12	-0.72	-0.18	0.27	0.37	-0.36	0.74	-1.21	0.02
2A07828	1985	-0.23	0.52	0.31	0.12	-0.78	-0.13	-0.04	0.20	-0.45	-0.38	-0.45	-0.04
2A07829	1985	-0.39	-0.06	0.09	-0.03	-2.85	-0.12	0.36	0.23	-2.85	-0.03	-2.27	-0.05
2A07834	1985	-0.45	0.05	-0.08	0.14	-0.69	-0.20	-0.05	0.18	-0.73	-0.15	-0.40	-0.05
2A07835	1985	0.21	-0.09	-0.11	-0.20	-0.47	0.14	0.62	0.20	-0.75	0.67	-1.98	-0.02
2A07882	1985	-0.15	-0.12	-0.04	-0.14	-0.61	0.04	0.13	0.31	-0.97	-0.09	-1.79	-0.03
2A08802	1985	0.07	0.05	-0.01	-0.12	-0.94	-0.02	0.45	0.10	-0.63	0.58	0.39	0.43
2A08804	1985	0.32	0.56	0.06	0.22	-0.94	-0.21	-0.13	-0.05	0.20	0.08	-1.15	-0.03
2A08805	1985	0.29	0.26	-0.03	-0.22	-0.48	-0.01	-0.08	-0.04	0.26	-0.51	0.09	0.16
2A08810	1985	0.31	-0.11	-0.16	0.00	-0.56	-0.15	0.43	0.19	-0.61	0.47	-1.09	-0.01
2A08901	1985	-0.04	-0.16	-0.13	0.04	-1.32	0.00	0.91	0.70	-1.57	1.61	-2.62	-0.05
2B041020L	1985	0.39	0.02	-0.65	-0.40	-0.67	-0.17	1.21	0.68	-0.97	1.55	-1.65	0.32
2B041049U	1985	0.53	-0.27	-0.79	-0.27	-0.50	-0.24	2.43	0.35	-1.12	2.41	-4.36	-0.04
2B047032	1985	-0.15	0.00	-0.14	0.30	-0.89	0.31	0.38	5.29	-0.87	4.95	-5.26	0.04
2B047044U	1985	0.12	0.25	-0.15	0.08	-1.01	-0.13	0.16	1.50	-1.47	1.69	-2.07	0.21
2B047076L	1985	0.87	-0.21	-0.32	-0.42	-0.17	-0.04	-0.35	0.25	-0.50	0.22	-0.77	0.32
2B047076U	1985	0.14	0.27	0.15	0.06	0.00	0.26	-0.10	0.70	0.25	1.05	-1.00	0.14
2B058015U	1985	-0.09	0.15	0.06	0.08	0.00	-0.01	-0.66	0.20	0.71	-0.59	0.21	0.16
2C041033U	1985	-0.13	0.06	-0.11	0.24	-0.67	-0.05	-0.83	2.71	0.03	1.85	-2.15	0.29
2C041039	1985	-0.90	-0.03	-0.41	0.07	-0.81	-0.30	0.47	3.53	-1.67	3.69	-5.00	0.07
2C041040	1985	0.02	0.06	-0.37	0.25	-1.44	0.31	-0.15	3.08	-1.86	3.60	-4.99	0.10
2C041043U	1985	-0.31	-0.15	-0.60	-0.24	-2.00	-0.05	0.17	3.61	-3.28	4.49	-5.76	0.55
2C041045	1985	0.04	0.07	-0.29	-0.30	-1.12	0.13	1.81	3.07	-1.03	4.96	-5.97	0.12
2C041051	1985	0.12	0.17	-0.40	-0.18	-0.86	0.13	0.31	0.47	-0.84	1.30	-1.80	-0.01
2C046013L	1985	0.36	-0.06	-0.40	0.01	-0.71	-0.16	0.36	2.18	-0.65	1.60	-3.50	0.08
2C046033	1985	0.13	0.05	-0.02	-0.07	-0.87	-0.30	0.00	4.03	-0.14	4.46	-4.97	-0.64
2C046034	1985	0.06	0.11	-0.19	-0.07	-0.82	-0.18	-0.15	3.07	-0.87	2.74	-3.65	-0.50
2C046043L	1985	0.21	0.18	0.23	-0.05	-0.81	-0.02	1.05	3.00	-0.95	4.61	-5.03	-0.14

Table I-6. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
2C046043U	1985	-0.07	-0.11	-0.38	-0.30	-0.88	-0.10	2.42	4.62	-1.08	7.00	-9.55	-0.41
2C046050	1985	0.19	0.37	0.02	-0.04	-5.98	0.05	5.11	2.14	-5.74	8.75	-13.21	0.23
2C046053L	1985	-0.03	0.16	0.09	-0.36	-0.66	0.58	0.45	3.74	-1.21	4.08	-6.03	-0.02
2C046062L	1985	0.06	0.82	-0.39	-0.18	-1.91	-0.40	1.06	4.65	-1.41	5.15	-7.06	0.14
2C047007	1985	0.35	0.55	-0.33	-0.14	-1.33	0.16	0.85	2.14	-1.66	3.22	-3.58	0.09
2C047010L	1985	0.01	0.26	-0.01	0.29	-1.27	-0.17	-0.45	3.43	-0.63	3.27	-2.56	-0.31
2C047010U	1985	0.26	0.14	-0.42	-0.13	-0.94	-0.29	0.25	6.37	-1.07	6.81	-5.37	-0.27
2C057004	1985	0.59	0.38	-0.26	0.50	-0.72	0.43	0.20	1.01	0.39	0.92	-3.25	0.14
2C066026L	1985	-0.12	-0.09	0.03	-0.17	-1.26	-0.25	-0.33	-0.66	-1.60	-1.55	-0.59	0.28
2C066027L	1985	-0.10	-0.54	-0.20	-0.20	-2.02	0.06	-0.06	-0.05	-2.94	-0.20	-3.16	0.45
2C066027U	1985	2.06	0.05	0.08	0.06	-0.91	0.32	-0.59	0.12	0.86	-0.17	1.23	-0.02
2C066039L	1985	0.08	-0.22	0.12	-0.08	-3.38	-0.19	-0.59	-0.09	-3.50	-0.79	-3.06	0.35
2C077022U	1985	-0.21	-0.28	-0.13	-0.05	-1.17	-0.19	-0.09	0.17	-1.63	-0.38	-2.06	0.29
BJ35	1999	-0.06	-0.11	-0.03	-0.01	0.00	-0.14	0.12	-9.60	-0.40	-9.40	10.26	0.89
BJ72	1999	-0.01	-0.31	0.09	-0.15	0.00	-0.03	0.86	-0.22	0.18	1.07	-1.11	0.45
BJ76	1999	-0.09	0.05	0.13	-0.07	0.00	-0.11	0.56	0.17	-0.83	-0.20	0.15	0.28
BJ77	1999	0.74	0.25	0.16	0.26	0.00	-0.13	-1.16	0.02	1.56	-1.30	1.88	0.30
BLFC	1991	0.68	-0.14	-0.28	-0.09	0.00	-0.19	-0.41	0.23	0.52	-0.44	1.47	0.18
CO01	1993	0.60	0.13	-0.12	0.08	0.00	0.05	-1.55	-0.02	-0.36	-1.48	2.60	-0.09
CO05	1993	0.24	-0.51	0.95	0.15	0.00	-0.17	-7.08	-1.09	1.22	-7.76	9.01	0.19
CO06	1993	0.58	0.06	-0.09	0.42	0.00	0.05	0.41	0.15	0.81	0.12	0.84	0.44
CO10	1993	-0.10	0.00	2.50	0.10	0.00	0.03	-5.66	-0.57	1.71	-5.74	8.31	0.29
DR	1994	1.71	-0.41	0.00	-0.46	0.00	-0.09	1.22	0.51	0.08	0.93	-0.49	0.19
DR01	1990	-0.27	0.30	0.00	0.27	0.00	-0.03	-0.32	0.27	-0.35	0.25	-0.17	0.16
DS04	1994	-0.12	0.00	-0.01	-0.11	-1.16	-0.28	-0.16	0.57	-1.58	0.37	-1.63	0.41
DS06	1994	0.42	-0.04	-0.07	-0.12	-1.27	0.07	-0.06	0.74	-1.20	0.82	-2.80	0.45
DS09	1994	-0.10	-0.15	0.01	-0.10	-1.22	-0.01	-0.48	0.35	-1.31	0.17	-1.93	0.35
DS19	1994	-0.05	0.02	-0.03	-0.01	-1.16	-0.14	-0.33	0.45	-1.01	0.17	-1.25	0.24
DS50	1994	-0.04	-0.10	0.12	-0.05	-1.27	-0.11	-0.10	0.38	-1.47	0.44	-2.07	0.46
FN1	1994	-0.56	0.08	-0.72	-0.56	0.00	0.06	-0.25	0.40	-1.52	-0.09	-2.49	-0.71
FN2	1994	-0.34	0.07	-0.05	0.03	0.00	-0.03	-0.29	0.13	-0.09	-0.54	0.27	-0.87
FN3	1994	0.21	-0.10	-0.18	0.06	-0.26	-0.16	0.09	1.74	-0.51	1.28	-2.29	-0.55
GS01	2000	-0.32	-0.04	-0.06	-0.03	0.00	0.09	0.14	-1.24	-0.32	-1.29	0.43	0.00
GS02	2000	0.31	0.51	-0.14	0.22	0.00	0.25	-0.03	-1.45	0.59	-0.34	1.54	0.10
GS04	2000	0.19	-0.05	-0.05	-0.08	0.00	0.08	0.07	-1.38	-0.12	-1.74	2.58	0.14
GS05	2000	-0.01	0.25	-0.06	0.04	0.00	-0.01	0.16	0.26	0.29	0.02	-0.40	0.47
GS06	2000	0.09	0.04	-0.12	-0.05	0.00	-0.45	0.03	0.04	0.11	0.13	0.06	0.65
GS07	2000	-0.26	-0.13	-0.13	0.08	0.00	-0.12	0.06	-0.70	-0.78	-1.12	0.59	0.06
GS08	2000	0.69	0.08	-0.04	0.07	0.00	-0.08	-0.06	-0.93	0.47	-0.81	2.16	0.15
LB01	1987	-0.15	-0.26	-0.14	0.02	-1.33	0.02	-0.58	0.14	-2.20	-0.26	-2.07	0.26
LEWF	1991	-0.20	-0.17	-0.08	-0.25	0.00	-0.10	0.33	0.92	-0.83	1.53	-1.33	0.05
M037	1991	0.14	-0.45	-0.05	-0.31	0.00	-0.07	0.17	0.27	-0.46	0.17	-0.78	0.14
M038	1991	-0.22	-0.10	0.00	-0.11	0.00	-0.16	-0.04	0.22	-0.93	0.10	-1.06	0.12
M039	1991	0.19	-0.22	-0.31	-0.16	0.00	-0.06	0.25	0.25	-0.37	-0.47	-0.17	0.13
NFD	1994	0.33	-0.04	-0.24	-0.23	0.00	0.05	-0.16	1.24	-0.11	1.05	-0.21	0.35
NFDR	1990	-0.17	0.11	-0.65	-0.12	0.00	-0.04	-0.63	6.85	-0.25	6.36	-6.81	0.29
OC02	1994	0.23	-0.22	0.27	-0.12	-1.33	-0.04	0.19	1.38	-1.22	1.16	-1.42	0.07

Table I-6. Continued.

Site ID	Calibration Year	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	pH
OC05	1994	0.01	-0.08	0.01	0.06	-1.38	0.08	0.00	0.39	-1.34	0.12	-1.83	0.51
OC08	1994	-0.19	-0.09	0.02	0.00	-1.22	-0.09	-0.16	0.42	-1.23	0.05	-1.94	0.25
OC09	1994	0.35	0.06	0.08	0.05	-1.22	0.02	-0.15	0.22	-0.82	0.32	-0.87	0.48
OC31	1994	0.41	-0.20	-0.08	-0.14	-1.11	0.04	-0.04	0.30	-1.12	0.28	-1.20	0.47
OC32	1994	-0.17	-0.30	0.00	-0.11	-1.14	-0.11	0.08	0.38	-1.44	0.17	-1.68	0.38
OC35	1994	-0.09	0.16	-0.46	-0.03	-1.11	-0.04	0.07	0.39	-1.67	0.56	-2.41	0.22
OC79	1994	-0.22	-0.42	-0.13	-0.16	-1.05	-0.07	-0.05	1.08	-1.59	1.41	-2.23	0.13
PAIN	1994	0.68	0.26	-0.28	-0.11	0.00	-0.07	1.07	1.73	-0.41	2.97	-1.48	0.10
SP10	1992	0.10	0.40	-0.01	0.00	0.00	0.09	0.50	0.19	0.15	0.90	-0.73	0.44
SP39	1992	-0.03	-0.16	-0.06	-0.08	0.00	-0.05	-0.83	0.23	-0.42	-0.80	-0.20	-0.34
SP41	1993	-0.16	0.05	-0.07	-0.07	0.00	0.04	-0.48	-0.02	0.18	-0.90	0.72	2.30
STAN	1994	0.22	0.33	-0.22	-0.06	0.00	-0.04	0.02	0.45	0.85	0.48	0.38	0.37
VA524S	1994	0.27	0.19	-0.37	0.12	-0.60	0.03	0.52	0.44	-0.91	0.43	-1.52	0.39
VA526S	1994	0.06	-0.04	-0.39	-0.16	0.00	-0.17	0.12	0.25	-0.62	0.46	-0.60	0.07
VA531S	1994	-0.42	-0.18	-0.17	-0.07	0.00	-0.19	0.05	1.09	-0.60	1.62	-0.06	0.09
VA548S	1994	0.83	-0.26	-0.09	0.26	0.00	-0.07	-1.58	0.40	-0.94	-1.19	1.34	0.73
VA555S	1994	-0.13	-0.36	-0.21	-0.22	0.00	-0.08	-0.07	0.20	-0.50	0.42	-1.21	0.17
VA821S	1994	0.13	-0.11	-0.27	-0.14	0.00	0.00	1.82	0.21	-0.81	1.65	-2.94	0.01
VT02	1990	0.80	0.28	-0.25	0.21	0.00	-0.21	-0.06	-0.51	0.46	-0.50	0.78	0.10
VT05	1990	-0.06	-0.24	-0.13	0.02	0.00	-0.23	0.11	0.18	-0.42	0.25	-0.95	0.05
VT07	1990	0.08	-0.14	-0.26	-0.19	0.00	0.01	0.17	0.70	0.21	0.58	-0.31	0.50
VT08	1990	0.31	0.13	-0.07	-0.30	0.00	-0.53	-0.03	0.47	-0.32	0.33	-1.79	0.47
VT09	1990	-0.15	-0.31	-0.45	-0.01	0.00	-0.02	0.20	0.34	-0.61	0.20	-0.83	0.33
VT10	1990	-0.07	-0.17	-0.20	-0.18	0.00	0.00	-0.20	0.24	-0.82	0.09	-0.50	0.15
VT11	1990	-0.31	0.00	0.05	0.03	0.00	0.12	0.07	0.41	-0.26	-0.11	-1.61	0.37
VT12	1990	-0.02	-0.27	-0.24	-0.13	0.00	-0.12	-0.35	0.38	-0.49	0.30	-0.50	0.23
VT15	1990	-0.34	0.02	-0.08	-0.06	0.00	0.03	0.15	0.24	-0.08	0.61	-0.54	0.40
VT18	1990	-0.50	-0.59	-0.05	-0.21	0.00	0.03	-0.24	2.05	-1.12	2.11	-4.02	0.15
VT19	1990	-0.53	0.13	-0.26	0.13	0.00	-0.04	0.16	4.92	-0.04	4.74	-5.50	0.18
VT20	1990	-0.14	-0.29	0.01	-0.14	0.00	0.00	0.18	0.29	-0.59	0.46	-1.42	0.10
VT24	1990	-0.56	-0.33	0.01	-0.17	0.00	-0.13	-0.28	0.35	-0.48	0.20	-0.31	0.18
VT25	1990	-0.26	0.11	-0.27	-0.08	0.00	-0.10	-0.26	0.28	-0.50	0.16	-1.11	0.20
VT26	1990	-0.09	-0.37	-0.04	-0.03	0.00	-0.06	0.96	0.53	-0.73	0.72	-0.16	0.16
VT28	1990	0.03	-0.16	0.04	-0.19	0.00	-0.12	0.12	0.25	-0.36	0.08	-0.72	0.49
VT29	1990	0.21	0.40	-0.08	-0.13	0.00	-0.13	0.90	0.31	0.65	0.39	-0.22	0.52
VT31	1990	0.71	-0.07	-0.25	-0.01	0.00	0.04	-3.14	0.23	0.52	-2.53	3.70	0.51
VT32	1990	-0.04	0.09	0.04	-0.03	0.00	-0.15	-0.04	1.38	0.08	1.73	-1.86	0.29
VT34	1990	-0.03	0.16	-0.20	-0.11	0.00	-0.36	-0.46	0.24	-0.50	-0.59	0.63	0.07
VT35	1990	-0.10	0.03	-0.09	-0.17	0.00	-0.32	0.15	0.31	0.00	0.32	-0.66	-0.04
VT36	1990	0.14	-0.01	-0.15	-0.30	0.00	-0.19	-0.18	0.25	-0.16	1.00	0.02	0.00
VT37	1990	-0.24	-0.42	-0.28	-0.18	0.00	-0.02	0.23	0.84	-0.54	0.90	-1.40	0.14
VT38	1990	-0.57	-0.24	-0.50	-0.33	0.00	0.14	-0.11	0.32	-1.77	-0.02	-1.92	0.11
VT39	1990	0.35	0.00	-0.05	-0.31	0.00	-0.10	0.23	0.17	0.17	0.37	0.48	0.06
VT41	1990	-0.01	0.22	0.00	-0.26	0.00	0.00	0.29	0.19	0.28	0.86	-0.67	0.07
VT46	1990	0.25	0.07	-0.33	-0.18	0.00	-0.24	0.50	0.67	0.01	0.89	-1.00	0.23
VT48	1990	-0.13	-0.32	-0.47	-0.30	0.00	-0.05	0.11	0.24	-0.90	-0.03	-1.14	0.06
VT49	1990	-0.20	-0.05	-0.28	0.12	0.00	-0.30	-0.24	0.80	-0.02	0.49	-0.87	0.10

Table I-6. Continued.													
Site ID	**Calibration Year**	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**	**pH**
VT50	1990	0.24	0.18	0.12	-0.01	0.00	-0.11	-0.08	2.10	0.28	2.27	-1.26	-0.03
VT53	1990	0.76	-0.41	-0.38	-0.27	0.00	-0.18	-1.52	0.28	-1.13	-1.37	-0.09	0.13
VT54	1990	-0.54	-0.51	-0.71	-0.05	0.00	0.01	-0.91	1.36	-0.97	0.12	-2.62	0.25
VT55	1990	-0.04	-0.29	-0.39	-0.27	0.00	0.14	0.03	3.17	-1.78	3.42	-4.28	0.25
VT56	1990	-0.09	-0.09	-0.88	-0.20	0.00	0.09	0.46	0.30	-0.47	0.49	-1.70	0.01
VT57	1990	-0.53	-0.35	-0.64	-0.04	0.00	-0.06	-0.02	1.46	-1.45	1.27	-3.37	0.05
VT58	1990	-0.10	0.17	-0.13	0.06	0.00	-0.39	0.46	1.89	-0.20	1.65	-2.39	0.12
VT59	1990	0.30	0.02	-0.38	-0.20	0.00	-0.03	0.01	0.88	0.43	0.53	-0.55	0.25
VT62	1990	-0.05	-0.07	0.00	0.05	0.00	-0.04	-0.20	1.13	-0.09	0.88	-1.71	0.36
VT66	1990	0.06	0.06	0.09	-0.07	0.00	-0.23	-0.32	7.54	0.78	7.41	-7.45	0.26
VT68	1990	-0.02	0.26	0.00	0.06	0.00	-0.06	-0.18	0.18	0.04	0.24	0.57	0.04
VT70	1990	-0.02	0.06	0.00	-0.01	0.00	-0.15	-0.18	0.16	-0.12	0.27	0.28	0.34
VT72	1990	-0.19	0.08	0.02	0.10	0.00	0.05	0.28	0.19	-0.05	0.21	-0.08	0.15
VT73	1990	0.22	0.05	-0.47	-0.11	0.00	0.03	-0.43	0.21	-0.05	-0.34	0.08	0.25
VT74	1990	-0.02	-0.06	-0.37	-0.04	0.00	-0.01	0.52	0.19	0.14	0.17	-0.67	0.08
VT75	1990	0.15	0.09	0.33	-0.13	0.00	-0.28	-0.07	8.19	-0.15	7.90	-7.55	0.40
VT76	1990	1.26	-0.51	-0.29	-0.15	0.00	0.00	-0.29	0.24	0.21	-0.51	0.86	0.25
VT77	1990	-0.44	-0.10	-0.14	0.04	0.00	-0.07	0.33	0.24	-0.42	0.90	-1.14	0.03
VT78	1990	0.02	0.05	-0.02	0.06	0.00	-0.06	-0.07	0.24	0.79	0.22	0.24	0.03
WOR	1994	-0.17	0.23	-0.20	-0.14	0.00	-0.28	0.49	1.64	-0.81	1.72	-1.46	0.42
WOR1	1990	-0.10	-0.25	-0.40	-0.12	0.00	-0.15	-0.05	0.82	-0.52	1.01	-1.38	0.40
WV523S	1994	-0.12	-0.13	0.00	-0.05	0.00	-0.13	0.02	1.01	0.39	0.99	-2.07	-0.11
WV531S	1994	0.12	0.21	-0.44	0.18	0.00	-0.05	0.24	0.45	-0.34	0.39	-0.07	0.15
WV547S	1994	0.24	0.06	-1.00	0.15	0.00	0.31	0.50	1.52	-0.12	3.02	-3.08	-0.25
WV548S	1994	0.19	-0.01	-0.21	-0.08	0.00	0.00	0.43	2.01	-0.40	2.20	-1.00	-0.26
WV769S	1994	0.48	0.01	0.05	-0.05	0.00	0.40	0.38	1.18	0.69	1.36	-0.89	-0.09
WV770S	1994	-0.08	0.37	-0.35	-0.03	0.00	-0.03	-0.54	0.11	0.02	0.05	-0.30	0.12
WV771S	1994	-0.43	0.36	0.38	-0.34	0.00	-0.21	0.75	1.42	-0.77	1.51	-2.87	0.14
WV785S	1994	0.21	0.13	-0.40	0.10	0.00	0.27	-0.04	0.21	0.80	0.73	-0.32	-0.02
WV788S	1994	0.12	-0.06	0.04	-0.07	0.00	0.02	-0.03	0.56	-0.46	0.93	-1.15	-0.08
WV796S	1994	0.06	-0.09	0.15	-0.07	0.00	-0.20	6.11	0.17	0.41	6.36	-5.65	0.31

Table I-7. The observed soil variable values used for calibration of each SAMI site. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
	Average	4.1	3.0	0.4	4.5	12.0	4.8
	Std. Dev.	3.6	2.5	1.0	8.6	10.4	0.3
	Maximum	18.1	20.1	9.1	49.5	55.8	5.2
	Minimum	1.3	0.8	0.1	0.7	3.8	3.9
Site ID	**Calibration Year**	**Exchg Ca %**	**Exchg Mg %**	**Exchg Na %**	**Exchg K %**	**BS %**	**pH**
2A068015U	1985	4.3	2.4	0.4	1.8	8.9	5.1
2A07701	1985	3.7	2.5	0.4	1.8	8.3	5.1
2A07805	1985	4.2	2.5	0.4	1.7	8.8	5.1
2A07806	1985	4.5	4.3	0.4	2.3	11.4	5.2
2A07810L	1985	2.9	1.2	0.2	2.3	6.6	4.9
2A07810U	1985	2.9	1.2	0.2	2.3	6.6	4.9
2A07811	1985	4.3	2.4	0.4	1.8	8.9	5.1
2A07812	1985	3.3	2.3	0.4	1.7	7.6	5.0
2A07816	1985	2.4	1.8	0.5	1.5	6.0	4.9
2A07817	1985	3.1	2.1	0.4	1.7	7.3	5.0
2A07821	1985	3.4	4.1	0.4	2.4	10.2	5.2
2A07823	1985	3.1	2.2	0.4	1.7	7.4	5.0
2A07828	1985	3.8	3.1	0.4	2.0	9.3	5.1
2A07829	1985	3.2	3.8	0.4	2.3	9.6	5.2
2A07834	1985	3.5	3.7	0.4	2.3	9.8	5.2
2A07835	1985	5.0	4.7	0.4	2.4	12.5	5.2
2A07882	1985	3.0	2.9	0.4	1.9	8.3	5.1
2A08802	1985	5.1	4.3	0.4	1.9	11.7	5.2
2A08804	1985	2.3	4.0	0.4	2.5	9.2	5.2
2A08805	1985	2.7	4.3	0.4	2.5	9.8	5.2
2A08810	1985	2.4	4.4	0.4	2.4	9.5	5.2
2A08901	1985	3.0	4.2	0.4	2.4	10.0	5.2
2B041020L	1985	8.5	3.4	0.2	1.6	13.6	5.0
2B041049U	1985	1.4	0.9	0.4	3.0	5.8	4.4
2B047032	1985	5.4	2.5	0.1	1.4	9.4	5.0
2B047044U	1985	5.4	2.5	0.1	1.4	9.4	5.0
2B047076L	1985	1.8	1.7	0.4	1.9	5.7	4.7
2B047076U	1985	1.8	1.7	0.4	1.9	5.7	4.7
2B058015U	1985	1.5	1.7	1.7	6.0	10.9	4.5
2C041033U	1985	7.5	2.4	0.1	1.5	11.6	5.0
2C041039	1985	8.1	2.8	0.1	1.5	12.5	5.0
2C041040	1985	7.5	2.4	0.1	1.5	11.6	5.0
2C041043U	1985	8.1	2.8	0.1	1.5	12.5	5.0
2C041045	1985	7.4	2.6	0.1	1.5	11.7	5.0
2C041051	1985	5.0	3.7	0.2	1.5	10.3	5.0

Table I-7. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
2C046013L	1985	3.5	2.1	0.1	1.4	7.2	5.0
2C046033	1985	7.0	3.1	0.1	1.4	11.7	5.0
2C046034	1985	4.6	2.7	0.1	1.4	8.9	5.0
2C046043L	1985	5.0	3.4	0.1	1.5	10.1	5.0
2C046043U	1985	7.0	3.1	0.1	1.4	11.7	5.0
2C046050	1985	3.5	2.1	0.1	1.4	7.2	5.0
2C046053L	1985	3.5	2.1	0.1	1.4	7.2	5.0
2C046062L	1985	8.5	3.4	0.2	1.6	13.6	5.0
2C047007	1985	8.5	3.4	0.2	1.6	13.6	5.0
2C047010L	1985	7.5	2.4	0.1	1.5	11.6	5.0
2C047010U	1985	7.5	2.4	0.1	1.5	11.6	5.0
2C057004	1985	5.0	3.4	0.1	1.5	10.1	5.0
2C066026L	1985	2.6	4.2	0.5	36.7	43.9	4.7
2C066027L	1985	1.3	1.2	0.2	1.5	4.3	3.9
2C066027U	1985	3.3	1.9	0.4	4.1	9.6	4.5
2C066039L	1985	2.6	4.2	0.5	36.7	43.9	4.7
2C077022U	1985	2.2	4.2	0.5	36.8	43.7	4.7
BJ35	1999	1.3	1.5	0.2	1.9	4.8	4.4
BJ72	1999	1.3	1.2	0.2	1.5	4.3	3.9
BJ76	1999	3.1	2.1	0.4	1.7	7.3	5.0
BJ77	1999	3.5	3.7	0.4	2.3	9.8	5.2
BLFC	1991	1.5	1.7	1.7	6.0	10.9	4.5
CO01	1993	3.0	2.7	0.5	49.5	55.8	4.7
CO05	1993	2.6	4.2	0.5	36.7	43.9	4.7
CO06	1993	3.6	2.9	0.5	44.2	51.2	4.7
CO10	1993	2.2	4.2	0.5	36.8	43.7	4.7
DR	1994	1.7	1.6	0.3	1.9	5.5	4.7
DR01	1990	2.2	2.1	0.2	2.0	6.4	4.7
DS04	1994	2.1	1.1	0.4	2.7	6.3	4.3
DS06	1994	2.1	1.1	0.4	2.7	6.3	4.3
DS09	1994	2.1	1.1	0.4	2.7	6.3	4.3
DS19	1994	2.1	1.1	0.4	2.7	6.3	4.3
DS50	1994	2.1	1.1	0.4	2.7	6.3	4.3
FN1	1994	3.3	1.9	0.4	4.1	9.6	4.5
FN2	1994	3.3	1.9	0.4	4.1	9.6	4.5
FN3	1994	3.3	1.9	0.4	4.1	9.6	4.5
GS01	2000	1.3	1.5	0.2	1.9	4.8	4.4
GS02	2000	1.3	1.2	0.2	1.5	4.3	3.9
GS04	2000	1.3	1.5	0.2	1.9	4.8	4.4
GS05	2000	2.1	0.8	0.2	0.7	3.8	4.7
GS06	2000	2.9	1.2	0.2	2.3	6.6	4.9
GS07	2000	18.1	8.7	9.1	5.4	41.3	4.7
GS08	2000	18.1	8.7	9.1	5.4	41.3	4.7

Table I-7. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
LB01	1987	7.6	5.5	1.3	7.0	21.4	4.9
LEWF	1991	7.5	2.3	1.3	5.9	17.0	4.5
M037	1991	1.5	1.7	1.7	6.0	10.9	4.5
M038	1991	1.5	1.7	1.7	6.0	10.9	4.5
M039	1991	1.5	1.7	1.7	6.0	10.9	4.5
NFD	1994	3.1	4.8	0.2	2.1	10.2	5.0
NFDR	1990	14.1	7.3	0.2	2.9	24.4	5.2
OC02	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC05	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC08	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC09	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC31	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC32	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC35	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC79	1994	1.4	0.9	0.4	3.0	5.8	4.4
PAIN	1994	1.7	1.6	0.3	1.9	5.5	4.7
SP10	1992	2.0	2.7	0.4	34.1	39.3	4.9
SP39	1992	2.7	2.0	0.4	27.4	32.5	4.7
SP41	1993	2.1	2.9	0.5	35.1	40.5	4.9
STAN	1994	11.3	7.0	0.2	2.9	21.5	5.2
VA524S	1994	5.0	3.4	0.1	1.5	10.1	5.0
VA526S	1994	3.5	2.1	0.1	1.4	7.2	5.0
VA531S	1994	3.1	4.8	0.2	2.1	10.2	5.0
VA548S	1994	5.4	2.5	0.1	1.4	9.4	5.0
VA555S	1994	1.5	1.7	1.7	6.0	10.9	4.5
VA821S	1994	3.5	2.1	0.1	1.4	7.2	5.0
VT02	1990	14.1	7.3	0.2	2.9	24.4	5.2
VT05	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT07	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT08	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT09	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT10	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT11	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT12	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT15	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT18	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT19	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT20	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT24	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT25	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT26	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT28	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT29	1990	2.2	2.1	0.2	2.0	6.4	4.7

Table I-7. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
VT31	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT32	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT34	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT35	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT36	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT37	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT38	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT39	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT41	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT46	1990	14.1	7.3	0.2	2.9	24.4	5.2
VT48	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT49	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT50	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT53	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT54	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT55	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT56	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT57	1990	3.8	5.7	0.2	2.9	12.5	4.6
VT58	1990	14.1	7.3	0.2	2.9	24.4	5.2
VT59	1990	14.1	7.3	0.2	2.9	24.4	5.2
VT62	1990	14.1	7.3	0.2	2.9	24.4	5.2
VT66	1990	17.7	20.1	0.3	0.8	39.0	5.2
VT68	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT70	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT72	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT73	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT74	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT75	1990	17.7	20.1	0.3	0.8	39.0	5.2
VT76	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT77	1990	2.2	2.1	0.2	2.0	6.4	4.7
VT78	1990	2.2	2.1	0.2	2.0	6.4	4.7
WOR	1994	1.8	1.7	0.4	1.9	5.7	4.7
WOR1	1990	2.2	2.1	0.2	2.0	6.4	4.7
WV523S	1994	2.1	1.1	0.4	2.7	6.3	4.3
WV531S	1994	7.0	3.1	0.1	1.4	11.7	5.0
WV547S	1994	3.5	2.1	0.1	1.4	7.2	5.0
WV548S	1994	4.6	2.7	0.1	1.4	8.9	5.0
WV769S	1994	7.5	2.4	0.1	1.5	11.6	5.0
WV770S	1994	8.5	3.4	0.2	1.6	13.6	5.0
WV771S	1994	7.4	2.6	0.1	1.5	11.7	5.0
WV785S	1994	4.6	2.7	0.1	1.4	8.9	5.0
WV788S	1994	5.0	3.4	0.1	1.5	10.1	5.0
WV796S	1994	8.1	2.8	0.1	1.5	12.5	5.0

Table I-8. The simulated soil variable values resulting from the calibration of each SAMI site (median values of multiple calibrations at each site). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
	Average	4.1	3.0	0.5	4.5	12.0	4.7
	Std. Dev.	3.6	2.5	1.0	8.6	10.4	0.2
	Maximum	18.1	20.1	9.2	49.5	55.7	5.3
	Minimum	1.2	0.8	0.1	0.7	3.8	4.4
Site ID	**Calibration Year**	**Exchg Ca %**	**Exchg Mg %**	**Exchg Na %**	**Exchg K %**	**BS %**	**pH**
2A068015U	1985	4.3	2.4	0.4	1.8	8.9	4.8
2A07701	1985	3.7	2.5	0.4	1.8	8.3	4.9
2A07805	1985	4.2	2.5	0.4	1.7	8.8	4.9
2A07806	1985	4.5	4.3	0.4	2.2	11.4	4.7
2A07810L	1985	2.9	1.2	0.2	2.3	6.5	4.8
2A07810U	1985	3.0	1.1	0.2	2.3	6.6	4.8
2A07811	1985	4.3	2.4	0.5	1.8	8.9	4.8
2A07812	1985	3.3	2.3	0.4	1.7	7.6	4.9
2A07816	1985	2.3	1.8	0.5	1.5	6.0	4.9
2A07817	1985	3.1	2.1	0.4	1.7	7.2	4.7
2A07821	1985	3.4	4.0	0.4	2.4	10.2	5.2
2A07823	1985	3.1	2.2	0.4	1.7	7.3	4.7
2A07828	1985	3.8	3.1	0.4	2.0	9.2	5.0
2A07829	1985	3.2	3.7	0.4	2.3	9.6	5.2
2A07834	1985	3.4	3.7	0.4	2.3	9.7	5.0
2A07835	1985	5.0	4.7	0.4	2.4	12.5	5.2
2A07882	1985	3.0	2.9	0.4	1.9	8.2	5.1
2A08802	1985	5.1	4.3	0.4	1.9	11.6	5.1
2A08804	1985	2.3	4.0	0.3	2.5	9.0	4.8
2A08805	1985	2.7	4.3	0.4	2.5	9.8	5.0
2A08810	1985	2.4	4.3	0.4	2.4	9.5	5.1
2A08901	1985	3.0	4.2	0.4	2.4	9.9	5.2
2B041020L	1985	8.5	3.4	0.2	1.6	13.7	4.8
2B041049U	1985	1.3	1.1	0.5	3.0	5.8	4.5
2B047032	1985	5.4	2.4	0.2	1.4	9.3	5.0
2B047044U	1985	5.3	2.4	0.2	1.4	9.2	4.8
2B047076L	1985	1.8	1.7	0.4	1.9	5.7	4.6
2B047076U	1985	1.8	1.7	0.4	1.9	5.7	4.6
2B058015U	1985	1.5	1.7	1.7	6.1	10.9	4.5
2C041033U	1985	7.5	2.4	0.2	1.5	11.7	4.5
2C041039	1985	8.1	2.8	0.2	1.5	12.5	4.9
2C041040	1985	7.5	2.4	0.3	1.5	11.6	4.5
2C041043U	1985	8.1	2.8	0.2	1.5	12.5	4.8
2C041045	1985	7.4	2.6	0.2	1.5	11.7	4.9

Table I-8. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
2C041051	1985	4.9	3.7	0.3	1.5	10.3	4.6

Table I-8. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
2C046013L	1985	3.5	2.1	0.2	1.5	7.2	4.9
2C046033	1985	7.0	3.1	0.1	1.4	11.6	4.7
2C046034	1985	4.6	2.7	0.2	1.4	8.9	4.5
2C046043L	1985	5.0	3.4	0.2	1.5	10.2	4.5
2C046043U	1985	7.0	3.1	0.2	1.4	11.7	4.5
2C046050	1985	3.5	2.1	0.2	1.4	7.2	4.5
2C046053L	1985	3.5	2.1	0.2	1.4	7.2	4.5
2C046062L	1985	8.5	3.4	0.2	1.6	13.6	5.1
2C047007	1985	8.5	3.3	0.2	1.5	13.5	5.2
2C047010L	1985	7.5	2.4	0.2	1.5	11.6	4.5
2C047010U	1985	7.5	2.4	0.2	1.5	11.6	4.7
2C057004	1985	5.0	3.4	0.2	1.5	10.1	4.7
2C066026L	1985	2.5	4.2	0.4	36.7	43.9	4.5
2C066027L	1985	1.3	1.2	0.2	1.5	4.3	4.5
2C066027U	1985	3.3	1.9	0.4	4.1	9.6	4.4
2C066039L	1985	2.6	4.2	0.5	36.7	43.8	4.5
2C077022U	1985	2.2	4.2	0.5	36.8	43.6	4.6
BJ35	1999	1.3	1.5	0.2	1.9	4.8	4.5
BJ72	1999	1.3	1.2	0.2	1.5	4.2	4.5
BJ76	1999	3.1	2.1	0.4	1.7	7.3	4.9
BJ77	1999	3.5	3.6	0.4	2.3	9.8	4.8
BLFC	1991	1.5	1.7	1.7	6.0	10.9	4.4
CO01	1993	3.0	2.7	0.4	49.5	55.7	4.5
CO05	1993	2.6	4.2	0.4	36.7	43.8	4.5
CO06	1993	3.6	2.9	0.4	44.2	51.1	4.6
CO10	1993	2.3	4.2	0.4	36.8	43.7	4.7
DR	1994	1.7	1.7	0.3	1.9	5.5	4.6
DR01	1990	2.2	2.1	0.2	1.9	6.5	4.5
DS04	1994	2.1	1.1	0.4	2.7	6.3	4.4
DS06	1994	2.1	1.1	0.4	2.7	6.3	4.4
DS09	1994	2.1	1.1	0.4	2.7	6.2	4.4
DS19	1994	2.1	1.1	0.4	2.7	6.2	4.4
DS50	1994	2.1	1.1	0.4	2.7	6.2	4.5
FN1	1994	3.3	1.9	0.4	4.1	9.6	4.5
FN2	1994	3.3	1.9	0.4	4.1	9.6	4.5
FN3	1994	3.3	1.9	0.4	4.1	9.6	4.5
GS01	2000	1.3	1.4	0.2	1.9	4.8	4.5
GS02	2000	1.3	1.2	0.2	1.5	4.3	4.5
GS04	2000	1.2	1.5	0.2	1.9	4.8	4.5
GS05	2000	2.1	0.8	0.2	0.7	3.8	4.7
GS06	2000	2.9	1.2	0.2	2.3	6.6	4.8
GS07	2000	18.1	8.7	9.2	5.4	41.3	4.5
GS08	2000	18.1	8.7	9.1	5.4	41.3	4.5
LB01	1987	7.6	5.5	1.3	7.0	21.3	4.7
LEWF	1991	7.5	2.3	1.3	5.9	17.0	4.5
M037	1991	1.5	1.7	1.7	6.0	10.9	4.5
M038	1991	1.5	1.7	1.7	6.0	10.9	4.5

Table I-8. Continued.

Site ID	**Calibration Year**	**Exchg Ca %**	**Exchg Mg %**	**Exchg Na %**	**Exchg K %**	**BS %**	**pH**
M039	1991	1.5	1.7	1.7	6.1	11.0	4.5
NFD	1994	3.1	4.8	0.3	2.1	10.2	4.6
NFDR	1990	14.1	7.3	0.4	2.9	24.5	5.1
OC02	1994	1.4	0.9	0.4	3.0	5.7	4.5
OC05	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC08	1994	1.4	0.9	0.4	3.0	5.8	4.4
OC09	1994	1.4	0.9	0.4	3.0	5.7	4.4
OC31	1994	1.4	0.9	0.4	3.0	5.7	4.4
OC32	1994	1.4	0.9	0.4	3.0	5.7	4.5
OC35	1994	1.3	0.9	0.5	3.0	5.7	4.5
OC79	1994	1.4	0.9	0.4	3.0	5.8	4.5
PAIN	1994	1.7	1.7	0.3	1.9	5.5	4.5
SP10	1992	2.0	2.7	0.4	34.1	39.3	4.5
SP39	1992	2.7	2.0	0.4	27.4	32.4	4.5
SP41	1993	2.1	2.9	0.5	35.1	40.5	4.7
STAN	1994	11.3	7.0	0.2	2.9	21.5	4.6
VA524S	1994	5.0	3.4	0.2	1.5	10.2	4.5
VA526S	1994	3.5	2.0	0.2	1.4	7.2	5.0
VA531S	1994	3.1	4.8	0.2	2.1	10.2	4.9
VA548S	1994	5.4	2.5	0.2	1.5	9.5	4.4
VA555S	1994	1.5	1.7	1.7	6.0	10.9	4.5
VA821S	1994	3.5	2.1	0.2	1.4	7.3	4.8
VT02	1990	14.1	7.3	0.3	2.9	24.5	4.5
VT05	1990	2.2	2.1	0.2	2.0	6.5	4.5
VT07	1990	2.2	2.1	0.3	1.9	6.5	4.5
VT08	1990	2.2	2.1	0.3	2.0	6.4	4.5
VT09	1990	2.1	2.1	0.3	1.9	6.4	4.6
VT10	1990	2.2	2.1	0.2	1.9	6.4	4.5
VT11	1990	2.1	2.0	0.3	1.9	6.4	4.7
VT12	1990	2.2	2.1	0.2	1.9	6.4	4.7
VT15	1990	2.2	2.1	0.2	1.9	6.4	4.6
VT18	1990	3.8	5.7	0.2	2.9	12.4	4.8
VT19	1990	3.8	5.6	0.2	2.9	12.5	4.5
VT20	1990	2.2	2.1	0.3	1.9	6.4	4.8
VT24	1990	2.2	2.1	0.2	1.9	6.4	4.5
VT25	1990	2.2	2.1	0.2	1.9	6.4	4.5
VT26	1990	2.2	2.0	0.3	2.0	6.4	4.4
VT28	1990	2.2	2.0	0.2	2.0	6.4	4.5
VT29	1990	2.1	2.1	0.2	1.9	6.3	4.5
VT31	1990	2.1	2.1	0.3	1.9	6.4	4.4
VT32	1990	2.2	2.1	0.2	1.9	6.4	4.5
VT34	1990	2.2	2.1	0.3	1.9	6.4	4.5
VT35	1990	2.1	2.0	0.3	1.9	6.4	4.5
VT36	1990	2.2	2.1	0.2	1.9	6.4	4.5
VT37	1990	3.8	5.6	0.2	2.9	12.4	4.5
VT38	1990	3.8	5.6	0.2	2.9	12.6	4.7
VT39	1990	2.1	2.1	0.2	2.0	6.5	4.5

Table I-8. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
VT41	1990	2.2	2.1	0.3	2.0	6.4	4.6
VT46	1990	14.1	7.3	0.2	2.9	24.4	4.9
VT48	1990	2.2	2.1	0.3	2.0	6.4	4.6
VT49	1990	2.2	2.1	0.3	2.0	6.5	4.7
VT50	1990	2.1	2.0	0.3	2.0	6.4	4.4
VT53	1990	2.2	2.1	0.3	2.0	6.5	4.6
VT54	1990	3.8	5.7	0.2	2.9	12.5	4.8
VT55	1990	3.8	5.7	0.3	2.9	12.5	4.8
VT56	1990	2.2	2.1	0.3	1.9	6.4	4.6
VT57	1990	3.8	5.6	0.2	2.9	12.5	4.8
VT58	1990	14.1	7.3	0.2	2.9	24.4	5.1
VT59	1990	14.1	7.3	0.2	2.9	24.4	4.6
VT62	1990	14.1	7.3	0.2	2.9	24.4	5.0
VT66	1990	17.7	20.1	0.3	0.8	38.9	4.7
VT68	1990	2.1	2.1	0.2	1.9	6.3	4.5
VT70	1990	2.1	2.1	0.2	1.9	6.4	4.5
VT72	1990	2.2	2.1	0.3	1.9	6.4	4.5
VT73	1990	2.2	2.1	0.3	2.0	6.4	4.6
VT74	1990	2.2	2.1	0.3	1.9	6.4	4.6
VT75	1990	17.8	20.1	0.3	0.8	39.0	5.3
VT76	1990	2.2	2.1	0.3	2.0	6.5	4.5
VT77	1990	2.2	2.1	0.2	2.0	6.4	4.6
VT78	1990	2.1	2.1	0.2	1.9	6.4	4.4
WOR	1994	1.8	1.7	0.4	1.9	5.7	4.5
WOR1	1990	2.2	2.1	0.3	1.9	6.4	4.8
WV523S	1994	2.1	1.1	0.4	2.7	6.3	4.4
WV531S	1994	7.0	3.1	0.2	1.4	11.7	4.7
WV547S	1994	3.5	2.1	0.2	1.4	7.3	4.6
WV548S	1994	4.6	2.7	0.2	1.5	8.9	4.5
WV769S	1994	7.5	2.4	0.2	1.5	11.5	5.0
WV770S	1994	8.4	3.4	0.2	1.6	13.6	4.9
WV771S	1994	7.4	2.6	0.1	1.5	11.6	5.1
WV785S	1994	4.6	2.7	0.2	1.4	9.0	4.7
WV788S	1994	5.0	3.4	0.2	1.6	10.1	4.8
WV796S	1994	8.1	2.8	0.2	1.5	12.5	4.9

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Table I-9 The differences between simulated and observed (sim-obs) soil variable values resulting from the calibration of each SAMI site (simulated values are median values of multiple calibrations at each site). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

		Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
	Average	-0.01	-0.01	0.01	-0.01	-0.01	-0.13
	Std. Dev.	0.02	0.02	0.04	0.01	0.05	0.21
	Maximum	0.03	0.13	0.13	0.05	0.14	0.54
	Minimum	-0.07	-0.08	-0.09	-0.05	-0.15	-0.65
Site ID	**Calibration Year**	**Exchg Ca %**	**Exchg Mg %**	**Exchg Na %**	**Exchg K %**	**BS %**	**pH**
2A068015U	1985	0.00	-0.01	-0.02	-0.01	-0.05	-0.27
2A07701	1985	0.00	-0.01	-0.01	-0.01	-0.06	-0.24
2A07805	1985	-0.01	0.00	-0.05	-0.02	-0.05	-0.11
2A07806	1985	-0.02	-0.02	-0.02	-0.03	-0.07	-0.43
2A07810L	1985	-0.04	-0.01	-0.01	0.00	-0.10	-0.18
2A07810U	1985	0.03	-0.05	0.00	-0.01	0.00	-0.13
2A07811	1985	-0.02	-0.01	0.01	0.01	-0.04	-0.25
2A07812	1985	-0.01	0.00	-0.01	-0.02	-0.04	-0.09
2A07816	1985	-0.03	0.00	0.03	-0.01	0.01	-0.08
2A07817	1985	-0.03	-0.02	-0.01	-0.01	-0.08	-0.32
2A07821	1985	-0.02	-0.02	-0.03	0.01	-0.06	0.06
2A07823	1985	-0.03	0.01	-0.01	-0.01	-0.09	-0.33
2A07828	1985	-0.02	0.00	-0.01	0.00	-0.10	-0.19
2A07829	1985	0.01	-0.01	0.00	0.00	-0.02	0
2A07834	1985	-0.03	-0.01	-0.01	-0.03	-0.06	-0.16
2A07835	1985	-0.01	-0.02	-0.02	-0.04	-0.07	-0.02
2A07882	1985	-0.01	0.00	0.00	-0.02	-0.02	0
2A08802	1985	-0.01	-0.04	-0.01	0.00	-0.14	-0.01
2A08804	1985	-0.04	-0.03	-0.03	-0.01	-0.15	-0.38
2A08805	1985	-0.03	-0.02	0.00	0.00	-0.02	-0.18
2A08810	1985	-0.01	-0.03	-0.02	0.01	-0.03	-0.06
2A08901	1985	0.01	0.00	-0.03	-0.03	-0.02	0
2B041020L	1985	0.00	-0.02	0.07	-0.01	0.06	-0.18
2B041049U	1985	-0.06	0.13	0.01	-0.02	0.03	0.12
2B047032	1985	-0.03	-0.05	0.05	-0.05	-0.06	0.02
2B047044U	1985	-0.07	-0.08	0.04	-0.02	-0.13	-0.16
2B047076L	1985	-0.01	0.01	0.02	0.01	0.00	-0.11
2B047076U	1985	-0.01	-0.01	0.00	0.00	0.01	-0.09
2B058015U	1985	0.00	-0.03	-0.03	0.04	0.01	-0.04
2C041033U	1985	-0.02	-0.01	0.03	0.02	0.09	-0.49
2C041039	1985	0.02	-0.02	0.05	0.00	0.02	-0.09
2C041040	1985	0.00	0.00	0.12	-0.04	0.06	-0.52
2C041043U	1985	-0.01	-0.01	0.06	-0.02	0.04	-0.19
2C041045	1985	0.00	0.00	0.09	-0.02	0.03	-0.11

Table I-9. Continued.							
Site ID	**Calibration Year**	**Exchg Ca %**	**Exchg Mg %**	**Exchg Na %**	**Exchg K %**	**BS %**	**pH**
2C041051	1985	-0.01	0.00	0.07	-0.02	0.01	-0.4
2C046013L	1985	-0.03	0.00	0.04	0.01	0.00	-0.06
2C046033	1985	-0.01	-0.03	0.02	0.01	-0.04	-0.32
2C046034	1985	0.00	0.00	0.04	-0.01	0.01	-0.47
2C046043L	1985	0.00	-0.04	0.08	-0.01	0.09	-0.49
2C046043U	1985	-0.01	0.02	0.09	-0.02	0.08	-0.47
2C046050	1985	-0.03	-0.03	0.06	0.00	0.05	-0.48
2C046053L	1985	-0.02	-0.01	0.08	-0.03	0.01	-0.49
2C046062L	1985	-0.01	-0.01	0.01	0.01	0.02	0.05
2C047007	1985	0.00	-0.04	0.08	-0.04	-0.06	0.24
2C047010L	1985	-0.01	-0.01	0.06	0.00	0.00	-0.52
2C047010U	1985	-0.02	0.00	0.06	-0.02	0.02	-0.26
2C057004	1985	-0.01	-0.03	0.06	-0.04	-0.04	-0.33
2C066026L	1985	-0.02	0.00	-0.01	0.01	-0.03	-0.19
2C066027L	1985	0.01	0.01	0.00	-0.02	-0.04	0.54
2C066027U	1985	-0.01	-0.01	-0.02	-0.02	-0.04	-0.06
2C066039L	1985	-0.01	-0.01	0.00	0.02	-0.04	-0.21
2C077022U	1985	-0.01	0.00	0.00	0.00	-0.06	-0.12
BJ35	1999	0.01	-0.01	0.01	0.00	-0.02	0.1
BJ72	1999	0.00	-0.02	0.01	-0.03	-0.05	0.54
BJ76	1999	-0.01	-0.03	-0.01	0.00	-0.07	-0.17
BJ77	1999	0.00	-0.02	-0.04	-0.02	-0.05	-0.32
BLFC	1991	0.02	-0.04	-0.03	-0.02	-0.03	-0.06
CO01	1993	-0.02	0.00	-0.01	0.00	-0.07	-0.21
CO05	1993	-0.01	-0.02	-0.09	-0.03	-0.13	-0.17
CO06	1993	-0.03	-0.02	-0.01	0.01	-0.08	-0.14
CO10	1993	0.02	0.00	-0.08	-0.02	-0.05	-0.01
DR	1994	-0.01	0.02	0.07	0.03	0.04	-0.07
DR01	1990	0.00	-0.02	-0.01	-0.01	0.04	-0.22
DS04	1994	-0.01	0.00	-0.01	-0.01	0.02	0.15
DS06	1994	0.00	-0.02	-0.01	0.00	-0.02	0.11
DS09	1994	0.00	-0.02	-0.01	-0.01	-0.05	0.12
DS19	1994	-0.01	0.00	-0.02	-0.01	-0.04	0.11
DS50	1994	0.00	0.01	-0.01	-0.01	-0.04	0.19
FN1	1994	-0.02	-0.03	0.04	-0.04	-0.04	0.03
FN2	1994	-0.03	0.04	-0.03	-0.03	0.00	-0.02
FN3	1994	-0.04	-0.01	0.00	-0.02	-0.05	-0.05
GS01	2000	0.01	-0.03	0.02	-0.01	0.00	0.13
GS02	2000	-0.01	-0.03	0.01	-0.02	-0.02	0.53
GS04	2000	-0.07	0.02	0.02	-0.02	-0.04	0.15
GS05	2000	0.02	-0.03	0.00	-0.02	-0.02	-0.05
GS06	2000	-0.01	-0.01	0.00	-0.01	-0.03	-0.19
GS07	2000	-0.01	0.01	0.01	-0.01	0.04	-0.18
GS08	2000	-0.02	-0.01	-0.01	0.02	0.00	-0.18
LB01	1987	0.00	-0.01	0.00	0.00	-0.07	-0.2
LEWF	1991	-0.01	0.00	-0.01	0.00	-0.01	0.02

Table I-9. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
M037	1991	0.00	0.00	0.01	0.00	0.00	-0.03
M038	1991	-0.01	0.00	-0.01	0.00	0.00	-0.04
M039	1991	0.00	0.01	0.02	0.02	0.03	0.02
NFD	1994	-0.02	0.00	0.07	-0.01	-0.02	-0.44
NFDR	1990	0.00	-0.01	0.13	-0.01	0.05	-0.05
OC02	1994	-0.02	0.02	-0.02	-0.01	-0.08	0.05
OC05	1994	-0.01	-0.01	-0.01	0.00	0.00	-0.04
OC08	1994	-0.03	-0.01	-0.02	-0.01	-0.01	-0.04
OC09	1994	0.01	-0.03	-0.03	-0.01	-0.02	0
OC31	1994	0.00	0.00	0.00	-0.01	-0.08	-0.03
OC32	1994	-0.02	-0.01	-0.01	0.00	-0.05	0.04
OC35	1994	-0.07	0.02	0.01	0.00	-0.02	0.06
OC79	1994	-0.01	0.01	0.00	-0.01	-0.01	0.08
PAIN	1994	-0.03	0.04	0.04	0.00	0.01	-0.14
SP10	1992	-0.02	-0.01	-0.01	0.01	0.01	-0.34
SP39	1992	-0.01	0.00	-0.03	0.00	-0.04	-0.27
SP41	1993	-0.02	-0.01	0.00	0.00	0.02	-0.25
STAN	1994	-0.02	-0.02	-0.01	-0.01	-0.02	-0.6
VA524S	1994	0.00	0.00	0.09	0.00	0.04	-0.48
VA526S	1994	-0.03	-0.04	0.05	-0.01	0.01	-0.01
VA531S	1994	-0.02	-0.01	0.00	-0.01	-0.05	-0.18
VA548S	1994	0.00	0.00	0.06	0.05	0.14	-0.57
VA555S	1994	0.01	0.02	0.00	0.01	0.02	0.01
VA821S	1994	-0.02	0.04	0.04	-0.02	0.09	-0.18
VT02	1990	-0.02	-0.01	0.07	0.01	0.07	-0.65
VT05	1990	0.00	-0.02	0.00	0.00	0.06	-0.14
VT07	1990	0.00	-0.01	0.03	-0.01	0.05	-0.22
VT08	1990	-0.01	0.00	0.01	0.00	0.01	-0.17
VT09	1990	-0.02	0.00	0.02	-0.01	-0.05	-0.04
VT10	1990	0.00	-0.01	-0.01	-0.01	0.02	-0.2
VT11	1990	-0.02	-0.03	0.01	-0.02	-0.06	-0.01
VT12	1990	0.00	0.01	-0.01	-0.01	0.02	0
VT15	1990	-0.01	-0.01	-0.02	-0.01	-0.02	-0.09
VT18	1990	-0.01	0.00	0.02	-0.01	-0.05	0.18
VT19	1990	-0.03	-0.01	0.03	0.02	0.00	-0.15
VT20	1990	0.00	0.00	0.02	-0.01	-0.02	0.14
VT24	1990	-0.01	-0.01	-0.02	-0.01	-0.01	-0.2
VT25	1990	-0.01	0.00	0.00	-0.01	-0.05	-0.14
VT26	1990	0.00	-0.03	0.01	0.00	-0.04	-0.25
VT28	1990	0.01	-0.04	-0.01	0.00	-0.01	-0.21
VT29	1990	-0.02	-0.01	-0.01	-0.02	-0.08	-0.22
VT31	1990	-0.03	-0.01	0.01	-0.02	0.01	-0.24
VT32	1990	-0.01	-0.02	-0.02	-0.01	-0.03	-0.18
VT34	1990	-0.01	0.00	0.01	-0.01	0.00	-0.19
VT35	1990	-0.02	-0.03	0.03	-0.01	-0.01	-0.2
VT36	1990	0.01	0.01	-0.02	-0.01	0.02	-0.19

Table I-9. Continued.

Site ID	Calibration Year	Exchg Ca %	Exchg Mg %	Exchg Na %	Exchg K %	BS %	pH
VT37	1990	0.01	-0.01	0.00	-0.02	-0.04	-0.13
VT38	1990	0.02	-0.01	0.07	0.02	0.09	0.09
VT39	1990	-0.02	-0.01	0.00	0.00	0.08	-0.2
VT41	1990	0.00	0.00	0.01	0.00	0.03	-0.06
VT46	1990	-0.01	-0.01	-0.01	-0.01	-0.05	-0.29
VT48	1990	-0.01	0.01	0.01	0.00	-0.03	-0.1
VT49	1990	-0.01	0.02	0.06	0.01	0.05	0.06
VT50	1990	-0.03	-0.04	0.03	0.00	0.00	-0.25
VT53	1990	-0.01	0.00	0.06	0.02	0.10	-0.1
VT54	1990	0.00	0.00	0.06	0.00	-0.03	0.12
VT55	1990	-0.02	0.01	0.10	0.00	0.05	0.18
VT56	1990	0.00	-0.01	0.01	-0.01	-0.01	-0.12
VT57	1990	-0.03	-0.01	0.03	-0.01	0.00	0.18
VT58	1990	-0.01	0.00	0.01	-0.01	-0.01	-0.05
VT59	1990	-0.02	0.00	0.02	0.00	-0.03	-0.52
VT62	1990	-0.01	-0.01	-0.01	0.00	-0.01	-0.13
VT66	1990	-0.01	0.01	-0.01	0.00	-0.08	-0.49
VT68	1990	-0.02	-0.02	-0.02	-0.01	-0.10	-0.22
VT70	1990	-0.02	-0.02	0.00	-0.01	-0.06	-0.19
VT72	1990	0.00	-0.01	0.01	-0.01	-0.02	-0.22
VT73	1990	-0.01	-0.02	0.03	0.00	0.03	-0.06
VT74	1990	-0.01	0.00	0.01	-0.01	-0.05	-0.03
VT75	1990	0.01	-0.01	-0.04	-0.01	-0.01	0.12
VT76	1990	0.00	0.00	0.01	0.00	0.04	-0.13
VT77	1990	0.02	-0.01	-0.01	0.00	0.01	-0.11
VT78	1990	-0.02	-0.01	-0.01	-0.01	-0.06	-0.23
WOR	1994	0.00	-0.02	0.00	-0.02	0.00	-0.13
WOR1	1990	0.00	0.00	0.04	-0.01	0.02	0.12
WV523S	1994	0.00	0.00	-0.01	-0.01	-0.01	0.15
WV531S	1994	0.00	-0.02	0.08	-0.02	0.00	-0.34
WV547S	1994	-0.01	0.02	0.09	0.00	0.12	-0.44
WV548S	1994	-0.01	-0.01	0.05	0.02	0.04	-0.52
WV769S	1994	-0.02	-0.02	0.02	-0.01	-0.05	0.02
WV770S	1994	-0.05	-0.03	0.06	0.00	0.01	-0.12
WV771S	1994	0.00	0.02	-0.04	-0.03	-0.09	0.14
WV785S	1994	0.01	-0.01	0.10	-0.02	0.12	-0.35
WV788S	1994	-0.03	0.00	0.02	0.01	0.01	-0.2
WV796S	1994	-0.01	-0.02	0.04	-0.01	-0.03	-0.08

Table I-10. The "optimized" soil parameter values resulting from the calibration of each SAMI site. Units for weathering are $meq/m^2/yr$. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Max. Capac. meq/kg	Soil DOC $mmol/m^3$	Weathering Ca	Weathering Mg	Weathering Na	Weathering K	Init Exchg Ca %	Init Exchg Mg %	Init Exchg Na %	Init Exchg K %
Average	23	148	19.0	18.8	14.4	8.1	4.9	3.6	0.5	4.6
Std. Dev.	26	71	16.1	11.5	14.9	5.8	4.0	2.6	1.0	8.6
Maximum	228	250	91.5	76.9	117.6	27.9	18.3	20.5	9.3	49.6
Minimum	4	28	0.0	4.9	0.0	0.8	1.5	0.9	0.2	0.7
Site ID	**Max. Capac. meq/kg**	**Soil DOC $mmol/m^3$**	**Weathering Ca**	**Weathering Mg**	**Weathering Na**	**Weathering K**	**Init Exchg Ca %**	**Init Exchg Mg %**	**Init Exchg Na %**	**Init Exchg K %**
2A068015U	39	54	5.5	13.5	13.4	12.5	4.8	2.9	0.5	1.9
2A07701	25	105	51.7	17.1	24.5	8.5	4.3	2.7	0.4	1.8
2A07805	21	93	17.4	8.6	16.0	2.5	4.9	2.7	0.5	1.7
2A07806	18	158	36.9	10.7	49.7	8.9	5.0	4.4	0.4	2.3
2A07810L	28	108	23.5	11.5	16.7	5.3	3.6	1.5	0.2	2.4
2A07810U	36	74	13.1	8.8	27.9	5.0	3.7	1.5	0.3	2.4
2A07811	19	48	9.5	7.1	11.2	3.7	5.3	3.0	0.6	1.8
2A07812	42	101	44.3	23.2	58.7	12.5	3.8	2.5	0.4	1.8
2A07816	56	62	21.7	11.1	30.5	8.3	2.9	2.0	0.6	1.5
2A07817	49	75	25.3	13.0	25.7	7.1	3.9	2.5	0.5	1.7
2A07821	27	84	18.1	7.5	26.5	4.7	3.6	4.1	0.4	2.4
2A07823	11	180	21.5	17.3	27.6	8.2	3.5	2.5	0.4	1.7
2A07828	35	55	21.4	18.1	30.3	9.9	4.2	3.3	0.5	2.1
2A07829	45	42	19.9	12.8	36.8	9.5	3.6	4.0	0.5	2.4
2A07834	28	46	8.2	7.3	17.2	3.7	3.6	3.7	0.4	2.3
2A07835	20	71	13.4	11.1	32.3	4.1	5.3	4.9	0.4	2.4
2A07882	42	76	31.3	16.5	31.6	6.5	3.5	3.2	0.5	2.0
2A08802	51	72	28.3	50.0	33.0	15.3	5.4	4.7	0.4	1.9
2A08804	42	96	21.6	26.1	36.4	12.9	2.6	4.3	0.4	2.5
2A08805	20	104	33.7	26.7	29.9	8.5	3.1	4.6	0.4	2.5
2A08810	32	110	41.5	35.0	32.2	9.6	2.8	4.8	0.4	2.5
2A08901	35	85	37.7	21.9	44.6	11.6	3.3	4.5	0.4	2.4
2B041020L	30	111	51.5	76.9	32.6	15.9	11.4	5.6	0.3	1.9
2B041049U	4	54	3.2	13.3	0.6	3.1	1.9	1.9	0.6	3.1
2B047032	15	55	26.8	35.1	24.6	8.7	10.1	5.9	0.3	1.9
2B047044U	15	129	74.1	58.0	35.0	13.9	9.3	4.7	0.2	1.7
2B047076L	9	161	3.5	15.1	5.1	17.9	1.9	2.0	0.5	2.0
2B047076U	8	98	5.4	12.3	6.6	27.5	2.1	2.1	0.5	2.2
2B058015U	12	250	0.2	23.6	7.7	21.3	1.6	2.0	1.8	6.3
2C041033U	18	125	30.0	26.0	20.8	10.1	10.4	3.8	0.2	1.8
2C041039	14	57	9.1	14.8	16.3	4.8	10.4	4.3	0.3	1.7
2C041040	14	250	20.9	31.9	12.5	9.0	8.7	3.3	0.3	1.6
2C041043U	10	118	9.9	19.2	14.0	6.3	9.2	3.7	0.3	1.6
2C041045	12	133	41.9	34.7	51.9	7.5	9.6	3.8	0.3	1.7
2C041051	6	46	22.2	11.1	15.3	3.4	6.9	4.6	0.4	1.6
2C046013L	13	64	25.3	40.1	24.6	6.3	5.5	4.0	0.3	1.6
2C046033	16	31	5.1	12.2	1.1	3.5	8.2	4.1	0.2	1.6
2C046034	18	121	36.4	31.1	1.1	4.3	6.8	4.2	0.3	1.6

Site ID	Max. Capac. meq/kg	Soil DOC mmol/m^3	Weathering Ca	Weathering Mg	Weathering Na	Weathering K	Init Exchg Ca %	Init Exchg Mg %	Init Exchg Na %	Init Exchg K %
Table I-10. Continued.										
2C046043L	12	169	50.1	21.7	55.0	3.5	6.8	4.3	0.3	1.6
2C046043U	10	151	40.5	20.8	44.6	3.1	8.3	3.7	0.3	1.5
2C046050	8	154	56.7	37.2	117.6	16.8	5.1	2.9	0.2	1.7
2C046053L	9	124	28.2	29.4	5.8	4.5	5.5	3.8	0.3	1.6
2C046062L	22	97	44.6	62.1	11.7	5.5	12.2	6.2	0.3	1.8
2C047007	14	44	18.7	27.8	25.8	9.7	12.3	6.3	0.5	2.0
2C047010L	25	248	26.5	26.0	11.3	10.5	8.4	2.9	0.2	1.6
2C047010U	21	37	6.7	12.4	12.0	8.0	9.4	3.7	0.3	1.8
2C057004	7	78	6.3	17.1	3.6	4.0	6.4	5.1	0.2	1.7
2C066026L	23	225	9.5	15.6	1.8	5.8	2.8	4.4	0.5	36.8
2C066027L	56	211	15.0	35.5	13.3	14.0	1.6	1.6	0.2	1.7
2C066027U	58	231	0.0	23.3	13.1	9.8	3.5	2.1	0.4	4.2
2C066039L	23	231	23.9	14.0	5.9	7.4	2.8	4.4	0.5	36.8
2C077022U	23	156	11.3	17.0	6.2	4.6	2.4	4.4	0.5	36.9
BJ35	36	247	55.1	21.9	18.1	2.9	2.1	2.1	0.3	2.1
BJ72	55	250	15.7	10.8	20.2	5.7	1.5	1.3	0.2	1.5
BJ76	36	57	10.0	8.1	18.2	4.6	3.6	2.3	0.5	1.7
BJ77	26	48	12.3	9.6	24.4	6.2	3.9	3.9	0.4	2.3
BLFC	20	250	0.0	12.2	5.2	12.2	1.6	1.8	1.8	6.1
CO01	22	151	0.2	18.0	0.2	17.6	3.1	2.8	0.5	49.6
CO05	10	183	24.1	27.9	0.0	16.9	2.9	4.5	0.4	36.8
CO06	27	169	30.2	34.6	11.9	27.9	3.7	3.0	0.5	44.2
CO10	9	84	22.2	28.8	0.0	18.1	3.0	5.2	0.5	37.2
DR	11	68	0.0	11.1	4.1	17.8	2.0	2.2	0.4	2.2
DR01	10	225	3.0	17.3	4.4	21.8	2.3	2.3	0.3	2.1
DS04	13	248	3.7	7.9	0.3	1.4	2.2	1.2	0.4	2.7
DS06	12	249	1.6	6.5	0.5	0.9	2.2	1.2	0.4	2.7
DS09	12	249	7.7	7.6	1.2	1.3	2.2	1.2	0.4	2.7
DS19	14	250	12.4	7.7	0.5	1.3	2.2	1.2	0.4	2.7
DS50	16	250	11.5	7.4	1.9	1.4	2.2	1.2	0.4	2.7
FN1	29	107	13.3	29.4	14.1	3.9	7.4	6.0	0.9	4.6
FN2	32	221	29.6	29.5	8.8	6.4	5.5	3.2	0.5	4.5
FN3	41	249	23.4	25.8	3.9	5.2	4.7	2.8	0.5	4.3
GS01	168	250	50.0	25.6	19.1	7.9	1.6	1.8	0.2	2.1
GS02	228	212	59.1	25.5	26.3	7.5	1.8	1.7	0.2	1.7
GS04	79	250	91.5	45.1	36.6	4.0	2.3	2.4	0.3	2.1
GS05	108	98	9.4	8.8	21.4	11.9	2.2	0.9	0.2	0.7
GS06	25	145	22.8	11.0	18.6	3.7	3.5	1.4	0.3	2.4
GS07	62	190	17.2	10.4	19.4	5.2	18.3	8.8	9.3	5.4
GS08	138	187	20.0	12.6	23.1	6.3	18.2	8.8	9.2	5.4
LB01	7	127	64.4	13.7	6.8	10.7	13.3	7.6	1.8	7.8
LEWF	35	236	25.5	13.6	25.7	5.9	8.7	2.8	1.5	6.1
M037	15	250	3.9	18.4	9.9	12.5	1.7	2.0	1.9	6.2
M038	14	250	9.3	22.2	9.2	15.3	1.7	2.0	1.8	6.2
M039	22	191	0.8	10.8	4.5	13.4	1.6	1.9	1.8	6.2
NFD	11	154	32.7	15.3	35.4	3.5	4.3	5.7	0.3	2.2

Table I-10. Continued.

Site ID	Max. Capac. meq/kg	Soil DOC $mmol/m^3$	Weathering Ca	Weathering Mg	Weathering Na	Weathering K	Init Exchg Ca %	Init Exchg Mg %	Init Exchg Na %	Init Exchg K %
NFDR	8	41	8.8	5.5	25.3	2.0	14.9	7.8	0.6	2.9
OC02	13	227	10.6	7.0	0.3	1.5	1.7	1.1	0.5	3.0
OC05	12	247	2.6	5.6	1.3	1.1	1.5	1.0	0.5	3.0
OC08	12	250	3.9	8.5	0.5	1.7	1.5	1.0	0.4	3.0
OC09	12	237	0.1	4.9	2.1	0.9	1.5	1.0	0.4	3.0
OC31	11	250	1.5	5.1	1.0	0.8	1.5	1.0	0.5	3.0
OC32	11	204	4.2	6.7	1.0	1.3	1.6	1.1	0.5	3.0
OC35	10	122	16.1	9.1	4.3	1.1	2.3	1.3	0.6	3.1
OC79	19	250	20.7	12.9	1.2	2.4	1.7	1.1	0.5	3.0
PAIN	10	194	9.3	28.2	4.1	25.2	2.0	2.1	0.4	2.1
SP10	9	147	23.3	26.8	2.2	12.2	2.5	3.3	0.5	34.3
SP39	10	197	7.2	25.7	4.4	9.8	2.9	2.3	0.5	27.5
SP41	13	158	32.9	36.0	12.6	15.7	2.8	3.6	0.6	35.3
STAN	12	211	33.4	14.2	28.1	5.5	11.6	7.1	0.2	3.0
VA524S	11	93	7.3	11.0	3.5	4.9	5.8	4.0	0.3	1.7
VA526S	10	114	32.0	29.3	8.6	6.0	5.0	3.0	0.3	1.6
VA531S	14	74	14.1	11.1	27.8	3.7	3.8	5.3	0.3	2.2
VA548S	21	205	2.7	18.0	9.4	5.0	5.9	3.1	0.2	1.6
VA555S	26	171	12.5	16.9	4.0	6.1	1.7	2.0	1.8	6.1
VA821S	14	125	52.5	51.1	24.6	7.3	5.0	3.2	0.2	1.5
VT02	12	222	23.5	11.6	27.1	7.6	14.5	7.5	0.3	2.9
VT05	21	199	13.7	24.5	15.4	13.0	2.3	2.2	0.3	2.0
VT07	14	232	20.9	10.9	5.5	3.3	2.4	2.3	0.3	2.0
VT08	12	240	24.7	12.4	4.8	3.2	2.5	2.2	0.3	2.0
VT09	13	88	12.3	9.2	3.9	3.0	2.6	2.3	0.3	2.0
VT10	25	200	9.1	14.0	5.6	5.8	2.3	2.2	0.3	2.0
VT11	31	108	12.1	18.0	4.6	6.8	2.4	2.3	0.3	2.0
VT12	31	164	47.0	43.7	4.7	8.3	2.4	2.3	0.3	2.0
VT15	31	155	9.9	12.9	5.9	6.6	2.3	2.2	0.2	2.0
VT18	19	83	24.7	21.2	19.2	9.5	5.4	7.0	0.2	3.1
VT19	27	202	34.9	31.6	15.2	11.6	4.6	6.5	0.3	3.1
VT20	12	125	40.7	15.2	6.0	4.6	2.8	2.4	0.3	2.0
VT24	19	221	13.3	8.5	3.5	4.3	2.3	2.1	0.2	2.0
VT25	23	147	2.6	8.4	2.4	3.2	2.2	2.2	0.3	2.0
VT26	13	247	6.1	7.7	0.9	2.5	2.3	2.2	0.3	2.0
VT28	28	222	3.1	9.0	2.6	2.8	2.2	2.1	0.2	2.0
VT29	27	222	2.1	8.2	1.9	2.8	2.2	2.1	0.2	1.9
VT31	25	249	0.2	9.3	3.6	3.0	2.2	2.1	0.3	1.9
VT32	15	227	12.0	9.6	0.6	1.9	2.3	2.2	0.2	2.0
VT34	14	239	26.6	16.7	5.0	5.1	2.4	2.2	0.3	2.0
VT35	9	219	5.2	20.0	5.0	23.1	2.3	2.4	0.3	2.1
VT36	14	174	5.5	18.7	4.6	14.2	2.3	2.3	0.3	2.0
VT37	18	238	15.1	24.0	10.6	9.8	4.1	6.0	0.2	3.0
VT38	11	93	23.6	24.1	19.5	8.5	5.6	7.4	0.3	3.2
VT39	16	178	2.5	13.8	6.5	12.0	2.3	2.1	0.3	2.0
VT41	17	92	7.8	15.3	6.1	12.1	2.5	2.4	0.3	2.1

Table I-10. Continued.

Site ID	Max. Capac. meq/kg	Soil DOC mmol/m^3	Weathering Ca	Weathering Mg	Weathering Na	Weathering K	Init Exchg Ca %	Init Exchg Mg %	Init Exchg Na %	Init Exchg K %
VT46	19	89	21.5	6.4	25.1	1.7	14.4	7.4	0.3	2.9
VT48	16	123	1.3	12.6	11.6	14.7	2.3	2.3	0.3	2.0
VT49	8	35	1.6	9.5	4.3	3.5	2.6	2.7	0.3	2.0
VT50	8	230	2.8	17.2	1.7	5.4	2.3	2.4	0.3	2.0
VT53	11	94	2.8	12.2	6.2	15.3	2.4	2.5	0.4	2.2
VT54	11	85	19.7	20.5	16.5	8.9	5.9	7.7	0.4	3.2
VT55	9	108	12.2	19.9	27.4	6.0	5.4	7.6	0.5	3.1
VT56	12	134	4.4	20.1	5.1	10.5	2.3	2.3	0.3	2.0
VT57	10	51	4.0	11.6	9.1	6.2	4.8	7.0	0.3	3.1
VT58	13	67	15.4	10.0	21.6	3.3	14.3	7.4	0.3	2.9
VT59	13	164	20.7	7.7	25.1	3.9	14.3	7.4	0.3	2.9
VT62	15	85	17.2	13.1	22.9	3.7	14.3	7.4	0.3	2.9
VT66	11	186	28.3	22.8	13.4	1.1	18.1	20.4	0.4	0.8
VT68	19	225	5.8	15.1	6.8	11.2	2.2	2.1	0.2	2.0
VT70	21	202	10.6	16.9	8.0	18.3	2.3	2.2	0.3	2.0
VT72	17	194	6.8	16.3	6.0	17.4	2.3	2.2	0.3	2.1
VT73	16	134	9.6	18.3	9.2	17.0	2.5	2.4	0.4	2.1
VT74	17	79	5.9	13.6	5.8	11.4	2.4	2.4	0.3	2.0
VT75	12	83	30.4	24.9	14.6	0.9	18.2	20.5	0.4	0.8
VT76	17	135	0.0	11.6	7.5	13.9	2.3	2.2	0.3	2.1
VT77	18	200	5.7	19.8	14.5	15.9	2.3	2.3	0.3	2.0
VT78	14	232	8.7	13.1	3.4	3.5	2.3	2.2	0.2	2.0
WOR	14	149	9.9	27.2	3.7	23.2	2.1	2.2	0.5	2.0
WOR1	13	53	1.9	12.8	4.0	16.7	2.5	2.7	0.3	2.2
WV523S	13	188	29.4	19.3	2.0	6.8	2.5	1.4	0.4	2.8
WV531S	14	62	32.9	6.9	3.8	3.1	9.4	3.7	0.3	1.5
WV547S	11	145	20.5	22.1	14.1	3.6	5.3	3.5	0.3	1.6
WV548S	18	205	28.8	28.1	2.9	6.3	5.8	3.6	0.3	1.6
WV769S	22	28	28.2	40.1	3.7	7.9	11.4	5.0	0.3	1.8
WV770S	19	92	21.4	31.2	28.9	11.8	11.9	5.8	0.3	2.0
WV771S	15	107	25.8	17.8	16.1	4.5	9.2	3.5	0.2	1.6
WV785S	21	44	13.3	22.1	11.0	6.5	6.0	4.0	0.4	1.6
WV788S	17	30	16.0	10.9	3.5	5.4	7.6	4.9	0.3	1.7
WV796S	23	39	29.8	15.9	5.4	2.3	10.3	3.7	0.2	1.6

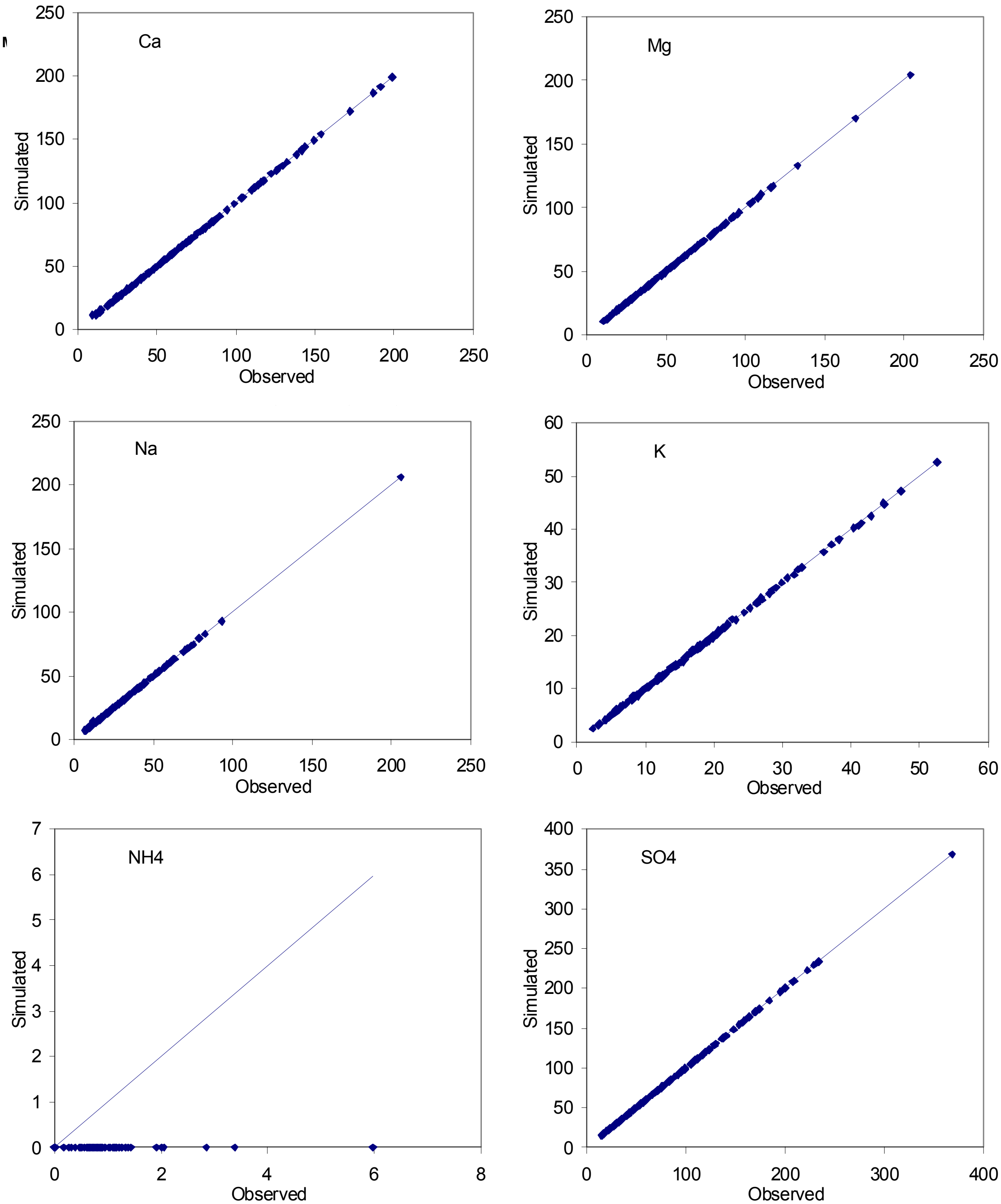

Figure I-1. Comparison of simulated and observed stream water variables for the calibration year at each SAMI site. The units are ueq/L. The number of sites is 164.

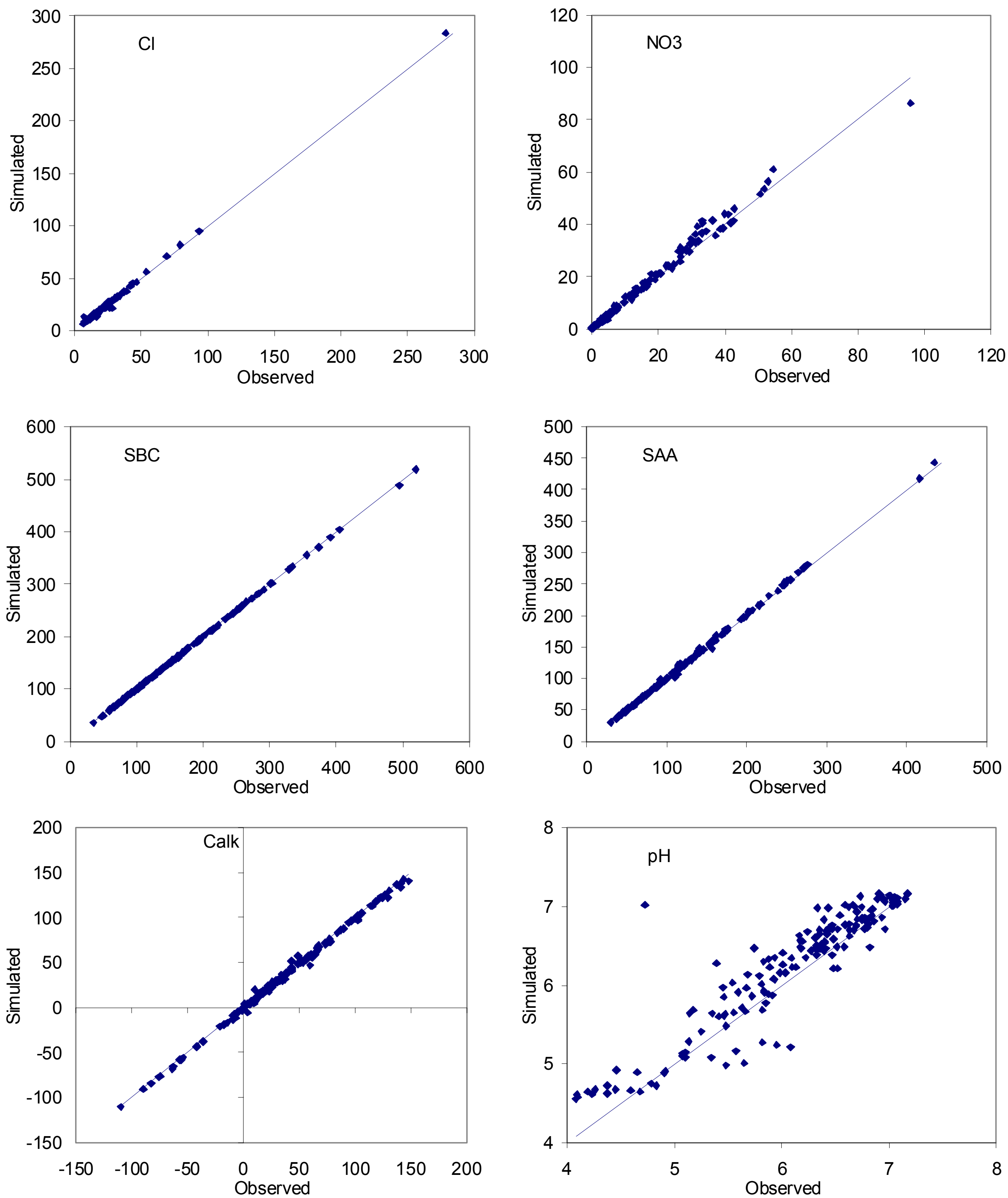

Figure I-1. Continued.

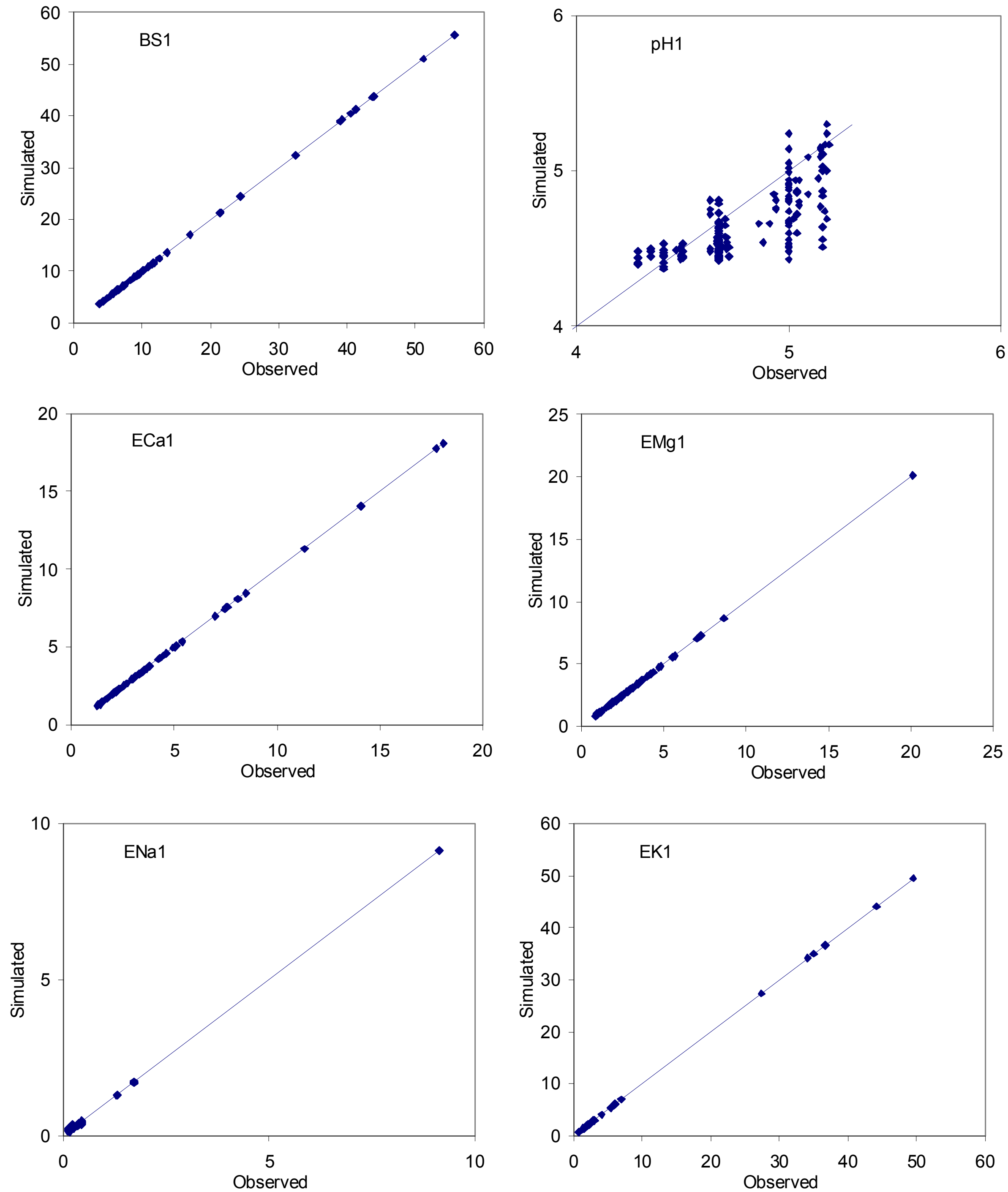

Figure I-2. Comparison of simulated and observed soil variables for the calibration year at each SAMI site. Units are % of CEC. The number of sites is 164.

APPENDIX J

SENSITIVITY OF AQUATIC BIOTA TO ACIDIFICATION

Extensive information is available on the effects of acidification on aquatic communities. Whole system experiments, mesocosm experiments, and field surveys have demonstrated major shifts in species composition and decreases in species richness with increasing acidity. The range of sensitivity to acidification varies among fish species, and to a greater extent among invertebrate species. Some sensitive species are lost at even moderate pH levels. In lakes, some important zooplankton predators are affected at pH 5.6-5.9. Some sensitive mayflies and fish (e.g. *Baetis lapponicus*, fathead minnow) are lost at pH 5.6- 6.0 (Baker and Christensen 1991). Toxic mechanisms are well established for fish, and for invertebrates to a lesser degree (Baker et al. 1991).

Direct hydrogen ion toxicity occurs in all aquatic taxa tested, but sensitivity varies greatly among species and higher taxa (and life history stages), which accounts for the graded response in species loss from communities. Ionoregulatory failure caused by acid stress leads to death in invertebrates as well as fish.

Sensitivity of Fish to Acidification

<u>Mechanisms of acid toxicity to fish</u>

Both elevated concentrations of hydrogen ion (measured by low pH) and aluminum (mobilized by low pH) are directly toxic to fish. Aluminum is the most abundant metal on the earth's surface, and the third most abundant element. It is non-toxic and insoluble under acid-neutral conditions, but very toxic to fish and some other aquatic species when it is found in solution. The solubility of aluminum increases dramatically as pH falls below 5.6; its maximum toxicity occurs at about pH 5.0. The deposition of acids results in the release of aluminum from soils, which is carried in solution to streams and lakes. Both the aluminum and the hydrogen ion (derived from sulfuric and nitric acids) are toxic to fish, but in most streams and lakes the aluminum is the primary lethal agent. The site of the toxic action of both hydrogen ion and aluminum is the fish gill. The gill is a complex organ responsible for oxygen and carbon dioxide exchange, as well as maintaining the proper salt and water balance in the fish's body. It is this latter function which is always compromised by acid and aluminum stress; respiration is also compromised at higher concentrations of aluminum (Bulger et al. 1993).

Freshwater fish maintain salt concentrations in the blood at much higher concentrations than the water in which they swim, so fish constantly lose a small amount of sodium and chloride from the blood by passive diffusion across the thin skin of the gills. The lost sodium and chloride are replaced by an energy-requiring process (active transport) using biochemical "pumps" in the gill membranes which transport sodium and chloride from low concentration in the external stream water to higher concentration in the blood.

Aluminum and hydrogen ion poison the biochemical pumps which transport sodium and chloride into the body. They also weaken the junctions between gill cells, making them leak more sodium and chloride than they would otherwise. The rapid loss without replacement of sodium and chloride produces a cascade of negative physiological effects in the fish's body. When sodium and/or chloride concentrations fall more than 30% below normal, death occurs within hours. Fish may recover from less severe stress, although at substantial metabolic cost.

The proximal cause of death is ionic dilution of the blood plasma. This causes blood and body fluid disturbances which ultimately kill the fish through circulatory collapse. Under normal conditions, plasma ionic (electrolyte) concentrations and body cell ionic concentrations are in equilibrium. Under acute acid stress, ions are lost more rapidly from the blood plasma than from blood and muscle cells; as a result, there is an osmotically-driven shift of water to the cells from the plasma. Blood plasma volume may drop as much as 30%; at the same time, the red cells swell due to the osmotically-driven shift of water from the plasma; the result is a doubling of blood viscosity. The heart is unable to circulate this much thicker blood at a rate sufficient to supply oxygen to body tissues, including the heart itself, so the fish dies of circulatory collapse secondary to ionic imbalance (Wood 1989).

Differential fish species sensitivity

Although there are known differences among fish species in acid sensitivity, experimentally determined acid sensitivities are only available for a minority of freshwater fish species. For example, of 28 species of fish found in Shenandoah National Park, the critical pH is known for only nine. Baker and Christensen (1991) reported critical pH values for 25 species of fish. The critical pH is the threshold for significant demonstrated adverse effects on populations. The range of pH values represents the authors' estimate of the uncertainty of this threshold. The range of response within species depends on differences in sensitivity among life stages, and on different exposure concentrations of calcium and aluminum. These ranges are based on multiple studies for each species shown in Table J-1. To cite a few examples, blacknose dace is regarded

Table J-1. Fish Species of Shenandoah National Park and the known critical pH thresholds for serious adverse impacts (Source: Bulger et al. 1999).

Common Name	Latin Name	Family	"Critical pH" Thresholds**
American Eel	*Anguilla rostrata*	Anguillidae	
Mtn. Redbelly Dace	*Phoxinus oreas*	Cyprinidae	
Rosyside Dace	*Clinostomus funduloides*	Cyprinidae	
Longnose Dace	*Rhinichthys cataractae*	Cyprinidae	
Blacknose Dace	*Rhinichthys atratulus*	Cyprinidae	5.6 to 6.2
Central Stoneroller	*Campostoma anomalum*	Cyprinidae	
Fallfish	*Semotilus corporalis*	Cyprinidae	
Creek Chub	*Semotilus atromaculatus*	Cyprinidae	5.0 to 5.4
Cutlips Minnow	*Exoglossum maxillingua*	Cyprinidae	
River Chub	*Nocomis micropogon*	Cyprinidae	
Bluehead Chub	*Nocomis leptocephalus*	Cyprinidae	
Common Shiner	*Luxilus cornutus*	Cyprinidae	5.4 to 6.0
Northern Hogsucker	*Hypentelium nigricans*	Catostomidae	
Torrent Sucker	*Thoburnia rhothocea*	Catostomidae	
White Sucker	*Catastomus commersoni*	Catostomidae	4.7 to 5.2
Margined Madtom	*Noturus insignis*	Ictaluridae	
Brook Trout	*Salvelinus fontinalis*	Salmonidae	4.7 to 5.2
Brown Trout	*Salmo trutta*	Salmonidae	4.8 to 5.4
Tiger Trout*	*Salmo X Salvelinus*	Salmonidae	
Rainbow Trout	*Oncorhynchus mykiss*	Salmonidae	4.9 to 5.6
Mottled Sculpin	*Cottus bairdi*	Cottidae	
Rock Bass	*Ambloplites rupestris*	Centrarchidae	4.7 to 5.2
Smallmouth Bass	*Micropterus dolomieui*	Centrarchidae	5.0 to 5.5
Largemouth Bass	*Micropterus salmoides*	Centrarchidae	
Redbreast Sunfish	*Lepomis auritus*	Centrarchidae	
Pumpkinseed	*Lepomis gibbosus*	Centrarchidae	
Johnny Darter	*Etheostoma nigrum*	Percidae	
Tesselated Darter	*Etheostoma olmstedi*	Percidae	
Fantail Darter	*Etheostoma flabellare*	Percidae	
Greenside Darter*	*Etheostoma blennioides*	Percidae	

* Tiger trout (a hybrid) and greenside darter are rare in the park; 10 or fewer individuals have been documented.

** Thresholds taken from Baker and Christensen (1991) as very sensitive to acid stress, because population loss due to acidification has been documented in this species at pH values as high as 6.1; in field bioassays, embryo mortality has been attributed to acid stress at pH values as high as 5.9. Embryo mortality has occurred in common shiner at pH values as high as 6.0. Although the critical pH range for rainbow trout is recorded as 5.6, adult and juvenile mortality have occurred at pH values as high as 5.9. Brown trout population loss has occurred over the range of 4.8-6.0, and brook trout fry mortality has occurred over the range of 4.8-5.9 (Baker and Christensen 1991). Relative sensitivities can be suggested by regional surveys as well. For example, about half of the 53 fish species found in Adirondack waters never occur at pH values below 6.0 (Kretzer et al. 1989, Driscoll et al. 2001a); for those species whose acid tolerances are unknown, it is likely that acid sensitivity is responsible for at least some of these absences.

It is the difference in acid tolerance among species that produces a gradual decline in species richness (the total number of fish species in a lake or stream) as acidification progresses, as the most sensitive species are lost first. Southern Blue Ridge streams can become too acid even for brook trout, as evidenced by the absence of the species from streams with mean pH $<$ 5.0 in Great Smoky Mountains National Park (Elwood et al. 1991).

Species richness, biomass, density, and condition.

A direct outcome of fish population loss as a result of acidification is a decline in species richness. This appears to be a highly predictable outcome of regional acidification, although the pattern and rate of species loss varies from region to region. Baker et al. (1990) discussed 10 selected studies which documented this phenomenon, with sample sizes ranging from 12 to nearly 3000 lakes and streams analyzed per study. An excellent example occurs in the Adirondacks. Fully 346 of 1469 lakes surveyed supported no fish at all. These lakes were significantly lower in pH, dissolved calcium, and ANC than lakes hosting one or more species of fish. Among lakes with fish, there is an unambiguous relationship between the number of species and lake pH (Kretzer et al. 1989, Driscoll et al. 2001b).

Relatively less is known about changes in fish biomass, density and condition (robustness of individual fish) which occur in the course of acidification. Loss of sensitive individuals within species (including early life stages) may reduce competition for food among the survivors, resulting in better growth rates, survival, or condition. Similarly, competitive release may result from the loss of a sensitive species, with positive effects on the density, growth, or survival of competitor population(s) of other species (Baker et al. 1990). In some cases where acidification continued, positive effects on size of surviving fish were shortly followed by extirpation (Bulger et al. 1993).

Acidification effects on fish in the SAMI region

Shenandoah National Park, Virginia

A recent three-year study on stream acidification in Shenandoah National Park (SHEN) demonstrated negative effects on fish from both chronic and episodic acidification (Bulger et al. 1999). Biological differences in low- ANC versus high-ANC streams included species richness, population density, condition factor, age, size, and field bioassay survival. Of particular note is that both episodic and chronic mortality occurred in young brook trout exposed in a low- ANC stream, but not in a high-ANC stream (MacAvoy and Bulger 1995), and that blacknose dace in low-ANC streams were in poor condition relative to blacknose dace in higher-ANC streams (Dennis et al. 1995, Dennis and Bulger 1995).

Acidification has been shown to reduce fish species richness in many regions by eliminating sensitive species initially, followed by more tolerant species as acidification proceeds (Baker et al. 1990). A statistically robust relationship between acid-base status of stream water and fish species richness has been shown in the SAMI region as well. As an element of the Shenandoah National Park:Fish in Sensitive Habitats (FISH) project (Bulger et al. 1999), numbers of fish species were compared among 13 SHEN streams spanning a range of pH/ANC conditions. There was a highly significant ($p<0.0001$) relationship between stream acid-base status (during the seven-year period of record) and fish species richness among the 13 streams, such that the streams having the lowest ANC hosted the fewest species (Figure J-1). Although the number of streams in the study was small, the results were consistent with other studies (Baker et al. 1990); this was the first, however, to provide a statistically robust analysis among multiple streams in the southeastern US.

As another component of the FISH project (Bulger et al. 1999), condition factor (a measure of robustness in individual fish) was compared in populations of blacknose dace in 11 streams spanning a range of pH/ANC conditions in the park. Figure J-2 shows the highly significant relationship between mean stream pH and condition factor in blacknose dace. Note that the 4

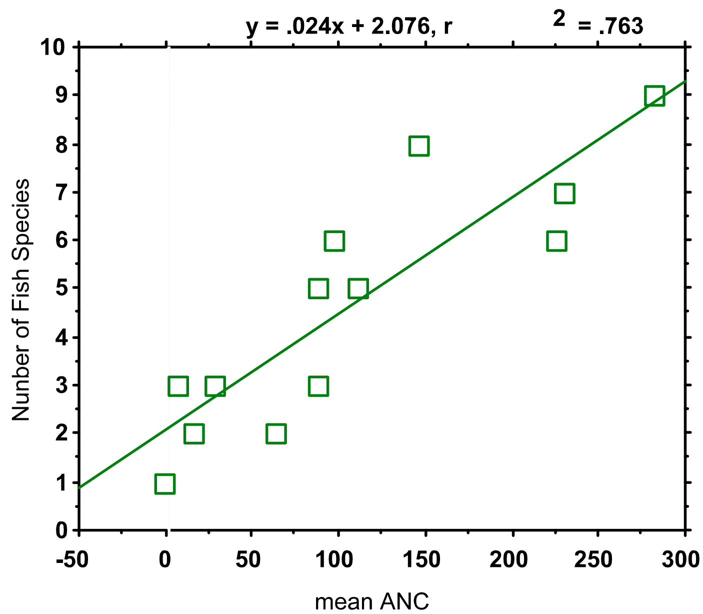

Figure J-1. Number of fish species among 13 streams in Shenandoah National Park. Values of Acid Neutralizing Capacity (ANC) are means based on quarterly measurements, 1987-94. The regression analysis showed a highly significant relationship ($p = 0.0001$) between mean stream ANC and species number, such that acidified streams host fewer fish species than circumneutral streams.

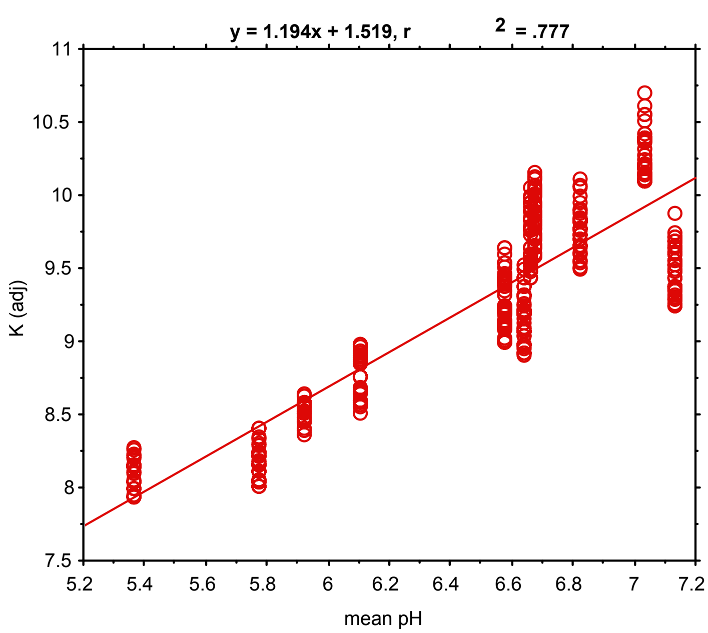

Figure J-2. Condition factor (K), a measure of body size in blacknose dace (*Rhinichthys atratulus*) among 11 populations ($n = 442$) in Shenandoah National Park. Values of pH are means based on quarterly measurements, 1991-94; K was measured in 1994. The regression analysis showed a highly significant relationship ($p = 0.0001$) between mean stream pH and body size, such that fish from acidified streams are smaller than fish from circumneutral streams.

populations represented on the left side of the figure all had mean pH values within or below the range of critical pH values for the species, at which negative populations effects are likely (Baker and Christensen 1991). That poor condition is related to population survival is suggested by the extirpation in 1997 of the blacknose dace population from the stream with the lowest pH and ANC (J. Atkinson, pers. comm.; Figure J-2).

The results of the condition factor comparisons among the 11 streams indicated that the mean length-adjusted condition factor of fish from the stream with the lowest pH and ANC was about 20% lower than that of the fish in best condition. No previous studies have reported changes in condition factor of blacknose dace during acidification. However, dramatic changes were associated with a 12% reduction in lake trout condition factor in a long-term acidification study (Schindler 1987). Comparisons with the work of Schofield and Driscoll (1987) and Kretser et al. (1989) suggest that pH in the low-pH Shenandoah National Park streams is near or below the limits of occurrence for blacknose dace populations in the Adirondack region.

Smaller body size could result from direct toxicity (e.g., elevated energy use to compensate for sublethal ionoregulatory stress) or from reduced access to food or lower food quality (Baker et al. 1990). Primary productivity is low in headwater streams and lower still in softwater headwaters, which are more likely to be acidified. Production of invertebrates is likely to be low in such streams as well (Wallace et al. 1992). Therefore, lower food availability cannot be ruled out as a potential contributor to lowered condition in Shenandoah National Park blacknose dace populations. Nevertheless, reduced growth rates have been attributed to acid stress in a number of fish species, including Atlantic salmon, chinook salmon, lake trout, rainbow trout, brook trout, brown trout, and Arctic char. Furthermore, the blacknose dace population in poorest condition in the park occurred in a stream with a mean pH below the minimum recorded for blacknose dace populations in Vermont, New Hampshire, Maine and New York (Baker et al. 1990). The four blacknose dace populations in poorest condition occur in streams at or below the critical pH for the species where adverse effects due to acidification are likely to be detectable at the population level (Baker et al 1990). Consequently, acid stress is probably at least partly responsible for the lower condition of blacknose dace populations in Shenandoah National Park, though lower food availability, either resulting from the nature of softwater streams, or exacerbated by acidification, cannot be ruled out.

It is possible that smaller body size in blacknose dace is the result of energy transfer from somatic growth to physiological maintenance, in response to chronic sublethal acidification stress. It is well known that chronic sublethal stress reduces growth in fish, as well as reproductive success (Wedemeyer et al. 1990). Chronic sublethal stress caused by pH levels up to 6.0 may have serious effects on wild trout populations (Kelso et al. 1986). There is an energetic cost in maintaining physiological homeostasis; the calories used to respond to stress are a part of the total energy budget which is unavailable for other functions, such as growth (Schreck 1981, 1982).

The energy costs to fish for active iono-osmoregulation can be substantial (Farmer and Beamish 1969, Bulger 1986). The concentrations of serum electrolytes (such as sodium and chloride) are many times higher (often 100-fold higher) in fish blood than in the freshwaters they live in. The active uptake of these ions occurs at the gills. Because of the steep gradient in sodium and chloride concentration between the blood and freshwater, there is constant diffusional loss of these ions, which must be replaced by energy-requiring active transport. Low pH increases the rate of passive loss of blood electrolytes (especially sodium and chloride); and aluminum elevates losses of sodium and chloride above the levels due to acid stress alone (Wood 1989). Since dace in an acidified stream maintain whole-body sodium at levels similar to dace in a high-ANC stream (Dennis and Bulger 1995), despite probable higher gill losses of electrolytes due to acid/aluminum stress, then the homeostatic mechanisms at the gill responsible for maintaining blood electrolyte levels must work harder and use more energy to maintain these levels.

An additional component of the FISH project used multiple bioassays over three years in one of the low ANC streams to determine the effect of stream baseflow and acid episode stream chemistry on the survival of brook trout eggs and fry (MacAvoy and Bulger 1995). Simultaneous bioassays took place in mid- and higher-ANC reference streams. Acid episodes (with associated low pH and elevated aluminum concentrations, and high streamwater discharge) induced rapid mortality in the low-ANC stream, while the test fish in the higher-ANC stream, experiencing only the high streamwater discharge, survived (Bulger et al. 1999).

St. Marys River, Virginia

St. Marys River occurs in the St. Marys Wilderness, George Washington and Jefferson National Forests in Augusta County, Virginia. In Virginia, records of stream pH and species richness are longest for St. Marys River. Fish abundance and diversity have been altered dramatically as a result of stream acidification (Bugas et al. 1999). In particular, the extirpation of rainbow trout and sharp decline in abundance of blacknose dace are symptomatic of acidified waters. Stream pH values in the St. Marys River in 1938-1976 were 6.7-7.0. The stream acidified over the next decade, such that pH values were 5.1-5.7 in 1989-1997. Fourteen fish species have been collected in St. Marys River since 1976; only four remain (1998). Rosyside dace and torrent sucker were last present in 1996; Johnny darter and brown trout were last present in 1994. Rainbow trout and longnose dace were last present in 1992; bluehead chub and smallmouth bass were last present in 1990 and 1988, respectively; white sucker and central stoneroller were last present in 1986. Of the four remaining species, three (blacknose dace, fantail darter, and mottled sculpin) have declined in density and/or biomass; the fourth remaining species is brook trout, the region's most acid tolerant species; this population has fluctuated, and reproductive success has been sporadic. Blacknose dace, once abundant throughout the river, remain only in the lowest station of the stream, which has the highest pH, and at such low numbers (five individuals in 1998) that they might be strays from downstream. For some of the species (smallmouth bass, white sucker, the three trout, and blacknose dace) the critical pH is known, and their decline and/or extirpation, given the pH of the river, is not surprising. Based on trend analysis over the period 1987-1997, St. Marys River is continuing to acidify (Webb and Deviney 1999).

After much public debate and discussion, the Forest Service has decided to lime St. Marys River, to prevent further biodiversity loss in this wilderness area. Elsewhere, following liming, if water quality improves to levels not toxic to fish, surviving remnant fish populations often successfully reproduce and increase in abundance; populations of acid-sensitive species may be stocked successfully. Growth rates of restocked fish are often temporarily higher than in non-acidified waters, suggesting that food availability played a minor role in fish decline (Baker et al. 1990). Although there are no records of restoration of an entire fish community to pre-acidification conditions, clear improvement is typical (Driscoll et al. 2001a). Given maintenance of improved acid-base status, improvement of the fish community in St. Marys River is likely.

Sensitivity of Invertebrates to Acidification

As in fish, invertebrates experience a net loss of sodium and chloride with acidification, which in some cases has been shown to result from both increased efflux and decreased influx of ions. In crustaceans and mollusks, salt and water balance stress is compounded by failure to take up calcium for shell maintenance. Also as in fish, low calcium levels exacerbate acid stress, but unlike fish, aluminum toxicity is less clear and ubiquitous, and macroinvertebrates show heterogeneous responses to aluminum and heavy metal exposure (Baker et al. 1990).

Species richness of benthic invertebrates is positively related to stream pH regionally, especially among aquatic insects such as mayflies, stoneflies, and caddisflies (Elwood et al. 1991). Among invertebrates, differences in acid sensitivity appear to span a wider range than in fish. In invertebrates as well as fish, life stages within species also differ in sensitivity. Molting in crayfish, for example, appears to be an especially acid-sensitive period, and among aquatic insects, early nymphal stages and emergence may be particularly sensitive stages (Baker et al. 1990). Acidity has dramatic effects on snail production in high-gradient SA streams. Gastropod production ranged from 1.8 to 12.5 gDW/m^2/year, with lowest pH sections having the lowest production; in general gastropods are rare or absent from streams draining crystalline bedrock, whereas they may comprise up to 95% of the invertebrate biomass in calcium-rich dolomite catchments (Wallace et al. 1992). Mussel as well as snail species require calcium for shell and carapace integrity; surface waters susceptible to acidification have low calcium levels. It is clear, however, that waters with low calcium which have not acidified have higher diversity than low-calcium waters which have acidified.

Relatively insensitive species appear to include some dragonflies, some mayflies, some caddisflies and stoneflies (Odonata, Ephemeroptera, Trichoptera, Plecoptera), whereas other stoneflies, caddisflies and mayflies are very sensitive (Baker et. al. 1990). In North American streams, acid-sensitive species typically include some mayflies (Ephemeroptera, e.g. *Baetis* spp., *Heptagenia* spp., *Ephemerella* spp., *Epeorus* spp., *Stenonema* spp.,). *Ephemerella*, for example, appears to be absent from steams with pH 5.5 or less. Other mayflies, such as *Leptophlebia*, and the stoneflies *Leuctra* and *Isoperla* appear tolerant of low pH, and therefore tend to dominate at low-pH sites. All of these insects are well represented in the SAMI region (Baker et. al. 1990, Elwood et al. 1991).

Synoptic surveys comparing circumneutral waters with waters that have pH 6 or less have demonstrated, without exception, that some populations of mayflies, amphipods, snails, and clams are lost with acidification. Within many taxonomic groups, there is a sharp drop in diversity between pH 6 and pH 5 (Baker et. al. 1990). Evidence comes from many studies, including many geographic regions (North America, Europe, and New Zealand). There is no doubt that decrease of one pH unit or more will result in the loss of sensitive species.

Although there are relatively few experimental studies of the effects of acidification on invertebrates, they confirm the acid sensitivity of species that tend to be absent from acidified waters. Short-term (hours to days) experimental acidification of streams consistently results in loss of sensitive invertebrates due to rapid drift responses (drift is passive downstream movement of displaced organisms). For example, experimental acidification of a third order stream in New Hampshire resulted in losses of the mayflies *Ephemerella* and *Epeorus*, while more tolerant forms, such as the stonefly *Leuctra*, did not respond; emergence of some mayflies, stoneflies and true flies (*Diptera*) decreased. Experiments in streamside channels, using replicated acidification treatments, have yielded similar results. Experimental acidification with a small pH drop (0.1 unit, or a doubling of hydrogen ion concentration) also significantly increased drift, suggesting that only slight depression in pH can have detrimental effects on invertebrate communities. The taxa that increase in drift after experimental acidification are the same as those that disappear from streams following long-term acidification (Baker et. al. 1990).

Synoptic surveys of invertebrates have also revealed negative correlations between acid-base status and biotic indicators such as species richness, species diversity, functional group diversity, and sometimes total biomass and density. Indices which only count species or individuals, such as measures of density, diversity and richness, may mask early acidification effects when acid-tolerant species replace acid-sensitive species. For a time, the community may be much altered, while species number or total density changes little (Baker et al. 1990).

Changes in species richness are, however, often very dramatic under acidification, especially when comparisons are made within individual taxonomic groups, such as orders of insects. Studies in Ontario and New York have shown dramatic differences in the numbers of stoneflies, caddisflies and or mayflies in acidified versus circumneutral streams. In Ontario, higher pH streams (5.3-6.7) had five genera of mayflies, five stonefly genera, and fifteen caddisfly genera, whereas acid (4.3-4.8) streams had one or no mayfly genera, only two stonefly genera, and only five genera of caddisflies. Results were similar over the same pH range in the Adirondacks. In a study of Pennsylvania streams, the index of species diversity was 50% lower in a low pH stream (pH 4.6-6.0) than in a high pH stream (pH 6.1-7.4; Baker et al. 1990).

Most surveys of lakes and streams have revealed low total biomass of benthic invertebrates at low pH. Reduced growth rates of acid stressed populations of invertebrates have been documented; these could result from direct toxicity (e.g., elevated energy use to compensate for sublethal ionoregulatory stress) or from reduced access to food or lower food quality (Baker et al. 1990).

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APPENDIX K

DESCRIPTION OF THE NATIONAL STREAM SURVEY (NSS)

To understand how the NSS data will serve as a regional framework for population estimation requires some background on the design and objectives of the NSS. In the spring of 1986, the U.S. Environmental Protection Agency (EPA) conducted the NSS on a probability sample of 446 streams in the mid-Atlantic and southeastern United States (Kaufmann et al. 1988, 1991; Sale et al. 1988). This full-scale field effort was preceded a year earlier by a pilot survey of 54 streams in the Southern Blue Ridge. The pilot survey demonstrated the feasibility of the design, logistics, and analytical protocols used in the full-scale survey (Messer et al. 1986, 1988). The objectives of the NSS were to:

- determine the percentage, extent (number and length), location, and chemical characteristics of streams in the Survey regions that are presently acidic, or that have low ANC and thus might become acidic in the future (Figure K-1 summarizes NSS results),
- identify streams representative of important classes in each region that might be selected for more intensive study or long-term monitoring.

The NSS is unique in that it employed a randomized systematic sampling design to make unbiased population estimates of the chemical status of an explicitly defined population of streams. These design properties are important if one wishes to make definitive statements about regional surface water quality.

Site Selection and Sample Weighting

Sampling units for the NSS were stream reaches defined as blue-line headwater segments or segments between confluences on 1:250,000-scale U.S. Geological Survey (USGS) topographic maps. The hierarchical nature of stream networks makes sampling and population extrapolation somewhat more difficult than for resources such as lakes, which comprise discrete, countable units. It is very important to note that the number and total length of mapped stream reaches is strongly dependent on map scale. The maps chosen establish the explicit identity of the population of stream reaches being described.

Within the NSS study area, the targeted resource was identified as those streams draining land areas less than 155 km^2, but large enough to be represented as blue lines on 1:250,000-scale USGS topographic maps. This size range includes streams large enough to be important for fish habitat, yet still small enough to represent the principal resource at risk from acidic deposition.

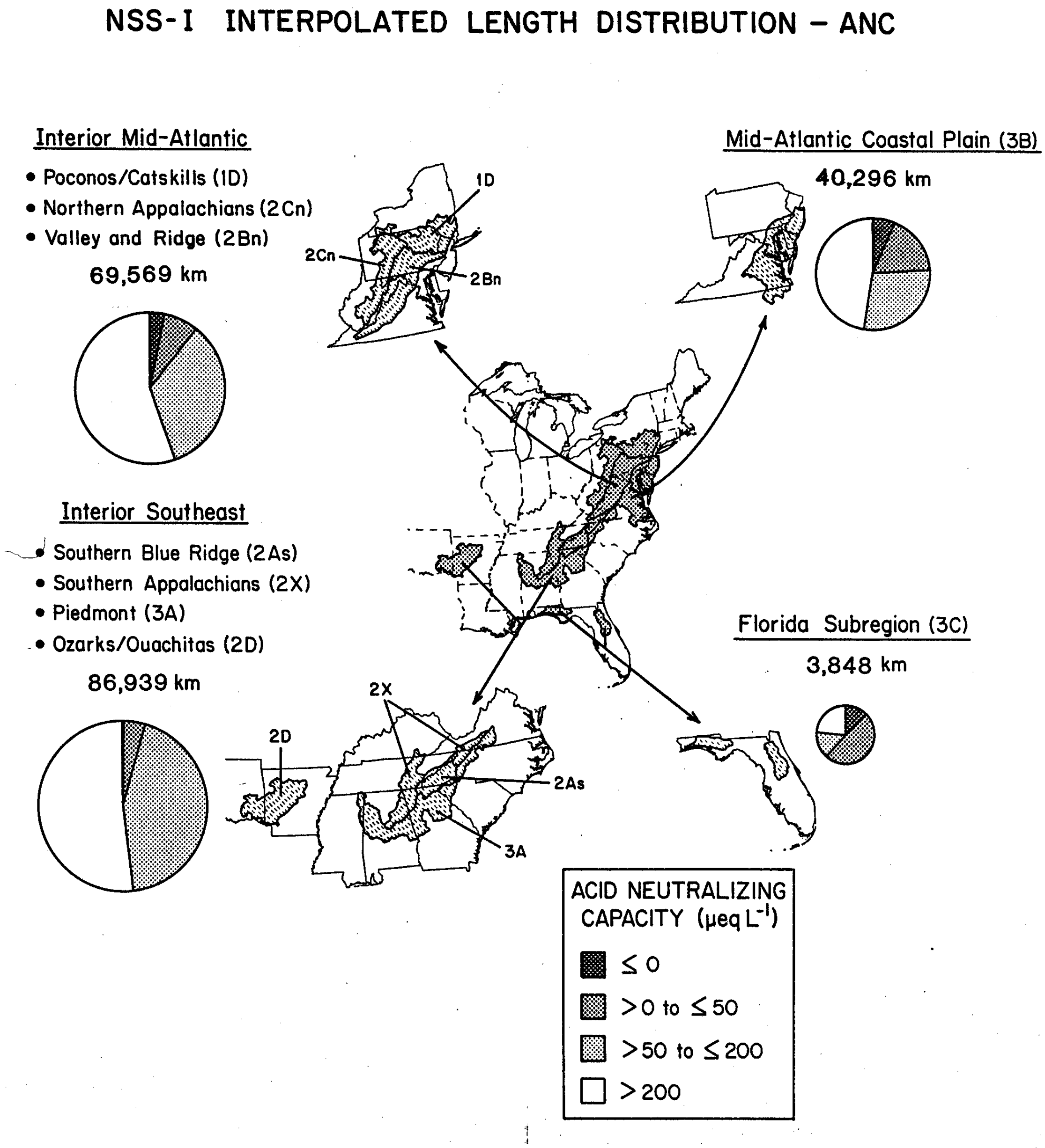

Figure K-1. Map showing the location of the 9 NSS subregions and pie diagrams showing the estimated stream length in 4 ANC classes.

Tidal reaches or reaches within mapped (1:250,000) urban areas were excluded from sampling because they were expected to be subject to influences that would largely mask the effects of acidic deposition.

A two-stage sampling procedure was used to obtain a randomized, systematic sample of 500 reaches with good spatial distribution (Figure K-2) over each of the nine NSS subregions (Overton 1987, Kaufmann et al. 1988). In the first stage of sampling, reaches were systematically selected by randomly placing an acetate grid (with dots in a square pattern at 8 mile intervals) on 1:250,000-scale USGS maps. Grid dots falling within the direct drainage area of a given reach identified that reach for sampling. Due to the impracticality of sampling all 2,301 stream reaches chosen in this manner in Stage I, a second stage subsample of 500 reaches was chosen for field sampling and chemical measurements. In Stage I, reach inclusion probabilities were directly proportional to the product of the sampling grid point density (number of dots per area) and the land area draining directly into each particular reach. The Stage II subsample (reaches to be visited) was chosen with site inclusion probabilities inversely related to their first stage inclusion probabilities. The final sample inclusion probabilities for reaches visited in the field (Stage II sample) were calculated as the product of inclusion probabilities in Stage I and Stage II. The two-stage procedure resulted in roughly equal final sample inclusion probabilities within geographic subregions, which were used as sampling strata (Overton 1987; Kaufmann et al. 1988).

To increase the precision of population estimation of high-interest streams at the low end of the ANC distribution, all Stage I sites located in mapped areas expected to have surface waters with ANC predominantly less than 50 μeq/L (Omernik and Powers 1983) were placed within a separate sampling stratum within each subregion stratum. All such sites were included for field sampling and thus they had Stage II inclusion probabilities of 1.0, yielding final inclusion probabilities equal to their Stage I inclusion probabilities. Thus, a map of sampled NSS streams shows a higher density of sample sites in areas of low stream ANC. These sites had higher probability of selection and thus lower sample weights used in the regional extrapolation.

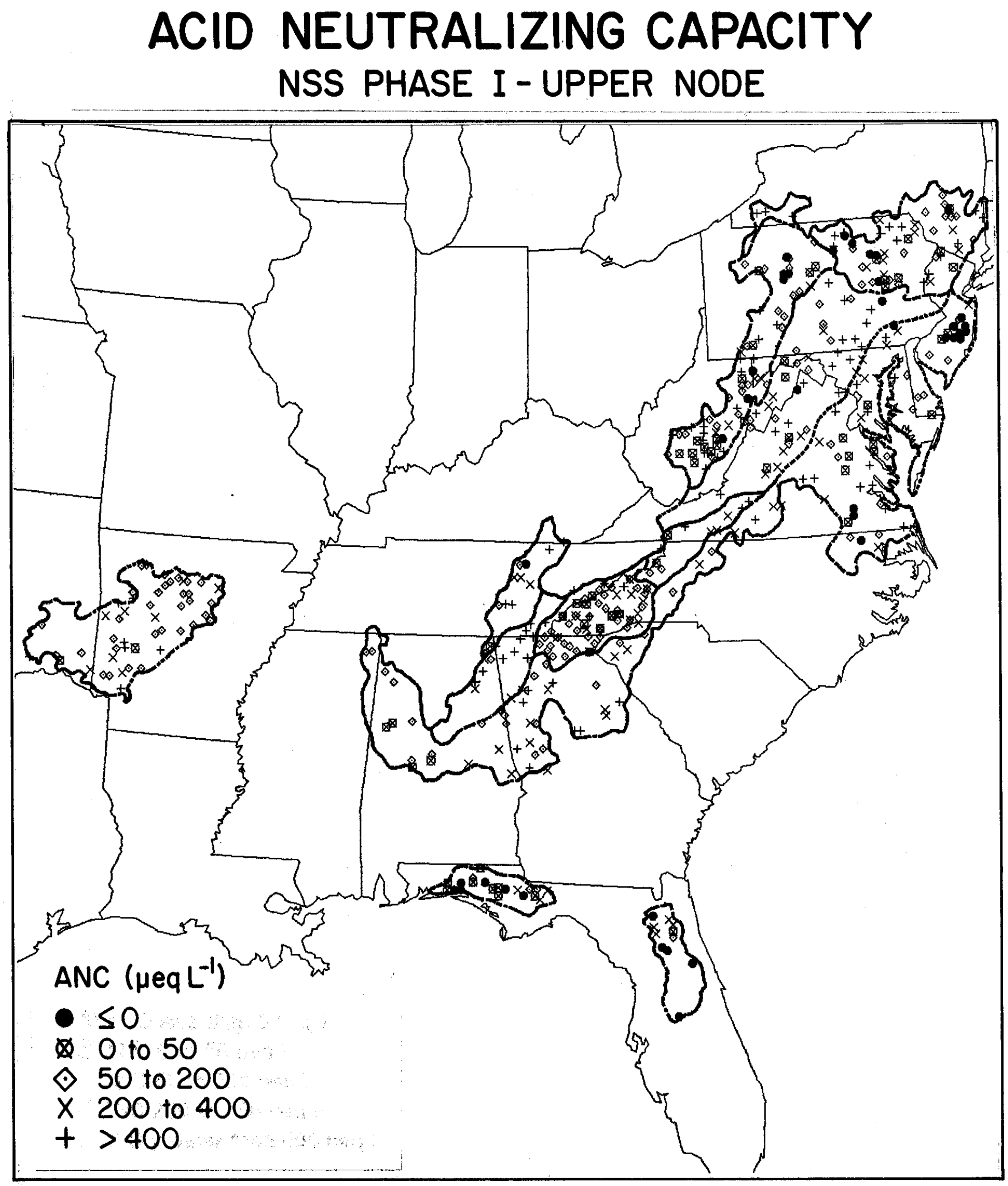

Figure K-2. Location and upstream reach end ANC class of NSS sample sites.

Field Sampling and Chemical Analyses

Stream reaches were visited and chemical measurements were made at each sample reach during spring baseflow between snowmelt and leafout (between March 15 and May 15). Reaches were sampled three times during 1985 spring baseflow in the Southern Blue Ridge subregion (Figure K-1). During spring baseflow of the following year (1986), measurements were made twice in the Mid-Atlantic (includes Virginia and West Virginia in SAMI), and once in the remaining Southeast subregions. Because the inclusion of storm-induced pH depressions would not accurately depict chronic conditions, hydrologic episodes were explicitly avoided during field sampling.

Chemical measurements were made at both ends of each stream reach in the Stage II sample. This meant that measurements were made at the downstream end of the reach just above the point of confluence with another stream identified as a blue line on 1:250,000-scale maps. Similarly, measurements at the upstream end of the sample reach were made far enough downstream of a blue-line confluence to allow adequate mixing. If the sample reach was identified as a headwater reach on the 1:250,000-scale maps, the upstream sampling location was the headward extent of blue-line representation for that particular reach.

All water samples were collected at mid-stream, stored at 4°C, and preserved at the central processing laboratory within 36 hours of collection (Cougan et al. 1988; Kaufmann et al. 1988). ANC was measured by Gran analysis of acid titration data, pH by potentiometric analysis of a closed headspace sample, SO_4^{2-}, NO_3^-, and Cl^- by ion chromatography, base cations by atomic absorption spectroscopy, and dissolved organic carbon (DOC) by infrared spectroscopy after acidification. Inorganic monomeric aluminum was calculated as the difference between total monomeric and organic (nonexchangeable) monomeric aluminum measured by pyrocatechol violet colorimetry on a closed headspace sample before and after passing it through a strong cation exchange column (Hillman et al. 1987). Standardized quality control and quality assurance protocols were followed during sample handling, chemical analysis, and data base manipulation (Cougan et al. 1988).

Chemical Index Values

Population estimates were based on separate chemical index values for the upstream and downstream ends of each sample stream reach. These index values were calculated as the arithmetic mean of the one to three spring chemical measurements made at each field sampling location. These index water chemistry values are sufficiently robust to represent each stream for the purposes of classification and regional extrapolations. Results of the NSS Pilot Survey in the Southern Blue Ridge showed very little difference in separate population distributions of pH, ANC, and major cations and anions based on three successive spring baseflow samples during the spring sampling window (Messer et al. 1986, 1988). Chemical variability was greater in streams of the Mid-Atlantic region, but differences between population distributions based on first and second sample visits were well within the 95% confidence bounds of estimates based on the spring baseflow average (Kaufmann et al. 1988).

The choice of spring as the sampling period for indexing stream chemistry involved a trade-off between minimizing within-season and episodic chemical variability and maximizing the probability of sampling chemical conditions potentially limiting for aquatic organisms. Studies of seasonal chemical variation in Mid-Atlantic and Southeastern streams indicate that spring is generally the season with the lowest streamwater ANC and pH (Kaufmann et al. 1988). In addition, spring is the time when acid-sensitive swim-up fry of important sport fish are present in the NSS-I study area, although fry of some trout (Salmo sp.) populations may also be present at other times of the year.

Population Extrapolation Procedures

All NSS population estimates (numbers, length, median chemistry) are based on weighted extrapolation from characteristics measured on individual sample reaches. Sample weights were calculated for each reach as the inverse of the reach's probability of being selected and are equivalent to the number of reaches each represents in the target population. Any regional statistics (mean, SD, percentiles) were all weighted. A population extrapolation procedure was used to estimate both the population totals and the fraction of those populations with chemical index values within criteria ranges. Details of estimation, and the statistical foundation of the methods, are provided elsewhere (Overton 1987; Kaufmann et al. 1988). The general form of the estimator is provided by:

$$\hat{T}_y = \sum_{S} w\, y \qquad (1)$$

where $\hat{T}_y$ is the estimate of the total of any attribute, y, over the population and w is the sample reach weight. The variable y is any stream reach attribute of interest (e.g., number, length, or direct drainage area) known over the set of sample stream reaches, S.

By assigning different definitions to y, and by summing over different sets of sample reaches, S, all of the various population attributes can be estimated from this one equation. For example, the number ($\hat{N}$) of upstream reach ends in Virginia with pH $\leq$ 5 is estimated by summing the sample weights (w) of all NSS upstream reach ends in Virginia with index pH $\leq$ 5 (for number estimates y equals one, for direct drainage area estimates, y=direct drainage area). Note that the upstream reach ends and the downstream reach ends are two separate populations and must be estimated separately as they are different attributes of the same reach.

The estimates of stream length with concentrations of a chemical constituent below reference values presented in this report are interpolated length estimates ($\hat{L}(x)$) calculated as follows:

$$\hat{L}(x) = \sum_{S} w\, L\, P_{ref} \tag{2}$$

where L is the length of the stream segment on the map and w again is the sample weight. P_{ref} is the proportion of the length of each stream reach having concentrations below the reference value as estimated by linear interpolation between index chemistries measured at the upstream and downstream reach end sampling locations. If both reach ends have chemistry below the reference value, then P_{ref}=1. If both reach ends exceed the reference value then P_{ref}=0.

Variances in the population estimates, leading to estimated standard errors (SE) of the attributes (stream numbers or length), were obtained using an original application of the Horvitz-Thompson variance estimator (Overton 1987) shown in equation (3).

$$\mathrm{Var}(\hat{T}_y) = \sum_{S} y^2 w\,(w - 1) + \sum_{i \in S} \sum_{\substack{j \in S \\ j \neq i}} y_i\, y_j\, v_{ij} \tag{3}$$

where $v_{ij} = ((w_i + w_j)/2 - w_i w_j)/(n - 1)$, if i and j are from the same stratum; if i and j are from different strata, then $v_{ij} = 0$. The variable n is the effective sample size for that strata (see Mitch et al. 1990). For interpolated length estimates, the attribute "y" is equal to P_{ref}*L.

Refining the NSS Target Population

After field sampling, the set of sample reaches representing the NSS target population was further refined by excluding stream reach ends that were dry, had intermittent flow, or had no stream channel (e.g., swamp). In addition, streams that were grossly impacted by anthropogenic activities (in situ conductivity greater than 500 µS/cm), or affected by tidal influences (conductivity greater than 250 µS/cm in coastal areas) were also excluded. Finally, streams that were acidic due to acid mine drainage (Herlihy et al. 1990) were also excluded from the NSS target population. These deletions removed less than 10% of the sites in most subregions.

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APPENDIX L

REFERENCE YEAR AND HISTORICAL DEPOSITION ESTIMATES FOR SAMI SITES

L.1 Introduction

MAGIC and NuCM require, as atmospheric inputs for each SAMI site, estimates of the total annual deposition (eq/ha/yr) of eight ions, and the annual precipitation volume (m/yr). The eight ions are: Ca, Mg, Na, K, NH_4, SO_4, Cl, and NO_3. These total deposition data are required for each year of the calibration period at each site (the years for which observed stream-water data are used for calibrating the model to each site). Estimated total deposition data are also required for the 140 years preceding the calibration period as part of the calibration protocol for MAGIC and NuCM. This appendix discusses the procedures used for generating these required long-term sequences of total ionic deposition for each SAMI site, and tabulates and summarizes the individual site values.

This appendix contains tables of deposition-related variables for each site in the SAMI analysis. In these tables, each site is identified by a unique ID number assigned for the SAMI project. Table L-1 gives this same SAMI ID number along with the full name, location, and SAMI landscape classification group (bin number) for each site as a reference aid.

L.1.1 Definition of Deposition Components

Total deposition of an ion at a particular SAMI site for any year can be represented as follows. First, total deposition is represented as combined wet deposition, dry deposition, and occult deposition (cloud and fog):

$$\text{TotDep} = \text{WetDep} + \text{DryDep} + \text{OccDep}.$$

Inputs to the models are specified as wet deposition (the annual flux in $meq/m_2/yr$) and a dry deposition factor (DDF, unitless) used to multiply the wet deposition in order to get total deposition:

$$\text{TotDep} = \text{WetDep} * \text{DDF},$$

where

$$\text{DDF} = 1. + \text{DryDep} / \text{WetDep} + \text{OccDep} / \text{WetDep}.$$

Thus, given an annual wet deposition flux (WetDep), the ratio of dry deposition to wet deposition (DryDep / WetDep), and the ratio of occult deposition to wet deposition (OccDep / WetDep) for a given year at a site, the total deposition for that site and year is uniquely determined. (NOTE: the DDF calculated as above is the ratio of total-to-wet deposition for a site).

L.1.2 SAMI Reference Year Deposition

All future and past values of deposition used for model simulation in the SAMI project are expressed relative to the “SAMI Reference Year Deposition”. This Reference Year Deposition is defined as the average deposition for the 5 year period 1991-1995.

In order to calibrate MAGIC, time-series of the total deposition at each site are needed for each year of: a) the calibration periods and b) the historical reconstructions. Such long-term observations do not exist. The procedure used to provide these input data (based on the SAMI Reference Year) was as follows.

The absolute values of wet deposition and DDF (calculated from the DryDep/WetDep and OccDep/WetDep ratios) for each ion were averaged over the period 1991-1995. The averages at a site were used as Reference Year deposition values for the site (the Reference Year was designated as 1995). These absolute values for the Reference Year wet deposition for each site were derived from observed wet deposition data as described in Section L.2. The absolute values of the DDF for each site were derived from DryDep/WetDep and OccDep/WetDep ratios as described in Section L.3.

Given the Reference Year values, the deposition data for calibration periods can be calculated using the Reference Year absolute values and scaled time series of wet deposition and DDF that give the values for a given year as a fraction of the Reference Year value. For instance, to calculate the total deposition of a particular ion in year j:

$$\text{TotDep}(j) = [\ \text{WetDep}(0) * \text{WetDepScale}(j)\ ] * [\ \text{DDF}(0) * \text{DDF Scale}(j)\ ]\ ,$$

where WetDep(0) is the Reference Year wet deposition ($meq/m^2/yr$) of the ion, WetDepScale(j) is the scaled value of wet deposition in year j (expressed as a fraction of the wet deposition in the Reference Year), DDF(0) is the dry deposition factor for the ion for the Reference Year, and DDFScale(j) is the scaled value of the dry deposition factor in year j (expressed as a fraction of the DDF in the Reference Year). The long-term scaling sequences for wet deposition and DDF for each site were derived from the ASTRAP model as described in Section L.4

L.1.3 Deposition Inputs for the Models

Therefore, four inputs are required for each of the eight deposition ions in MAGIC in order to set the total deposition for all years required in the calibrations. These inputs are:

1) the absolute value of wet deposition at the site for the Reference Year ($meq/m^2/yr$);
2) the absolute value of DDF (calculated from DryDep/WetDep and OccDep/WetDep ratios) for the site for the Reference Year, (unitless);
3) time series of scaled values of wet deposition covering all years of interest; and
4) time series of scaled values of DDF covering all years of interest.

The *absolute* value of wet deposition is highly time and space specific - varying geographically within the SAMI region, varying locally with elevation, and varying from year to year. It is desirable to have the estimates of wet deposition take into account the geographic location and elevation of the site as well as the year for which calibration data are available. Therefore estimates of wet deposition used for the SAMI Reference Year should be derived from a procedure (model) that has a high spatial resolution and considers elevation effects.

The *absolute* value of the dry deposition factor specifies the ratio between the absolute amounts of wet and total deposition. This ratio is less variable in time and space. That is, if in a given year the wet deposition goes up, then the total deposition usually goes up also (and conversely); and if the elevation or aspect of a given site results in lower wet deposition, the total deposition will be lower also (and conversely). Estimates of DDF used for MAGIC calibrations may, therefore, be derived from a procedure (model) that has a lower spatial resolution and/or temporally smoothes the data.

Similarly, the *long-term sequences* used for model simulations do not require detailed spatial or temporal resolution. That is, if for any given year the deposition goes up at one site, it also goes up at neighboring sites. Thus, *scaled sequences* of deposition (normalized to the same year) at neighboring sites will be very similar, even if the absolute deposition at the sites is very different due to local aspect, elevation, etc. MAGIC and NuCM require scaled long-term sequences of wet and total deposition. Therefore, if the scaled long-term patterns of wet deposition and DDF do not vary much from place to place or year to year, estimates of the *scaled sequences* may be derived from a procedure (model) that has a relatively low spatial resolution and/or temporally smoothes the data.

L.2 Reference Year Wet Deposition Values

The absolute values of wet deposition used for defining the SAMI Reference Year and for the MAGIC calibrations must be highly site specific. We used estimated wet deposition data for each site derived from the spatial extrapolation model of Grimm and Lynch (1997) referred to here as the Lynch model. The Lynch model is based on observed wet deposition at NADP monitoring stations, and provides a spatially interpolated value of wet deposition of each of the eight ions needed for MAGIC. The model also makes a correction for changes in precipitation volume (and thus wet deposition) based on the altitude at a given site. This correction arises from a model of orographic effects on precipitation volumes derived from regional climatological data.

The latitude, longitude, and elevation of MAGIC-SAMI sites were provided as inputs for Lynch model. The model outputs were quarterly and annual wet deposition estimates for each MAGIC site. The annual data are used for definition of the SAMI Reference Year and for MAGIC calibration and simulation. The NADP data (and thus the estimates provided by Lynch's model) cover the period 1983 to 1998. This period includes the SAMI reference period, all calibration periods for MAGIC sites.

The wet deposition values for the five years 1991-1995 were average for each SAMI site to define the Reference Year Deposition for each site. The Reference Year wet deposition values are tabulated for each site in Table L-2.

L.3 Reference Year DDF values

The ASTRAP model provided estimates of wet, dry, and occult deposition of SO_4 and NO_x at 33 sites in and around the SAMI region. The ASTRAP sites included 21 existing NADP deposition monitoring stations, 7 sites in Class I areas, and 5 sites that were neither NADP nor Class I. A number of these sites were outside the boundaries of SAMI and at a much lower elevation than the sites being modeled by MAGIC or NuCM. A subset of 17 ASTRAP sites was used to set deposition inputs for the models. The ASTRAP sites used for estimating deposition inputs are listed in Table L-3.

ASTRAP produced wet, dry, and occult deposition estimates of SO4 and NOx every ten years starting in 1900 and ending in 1990. The model outputs are smoothed estimates of deposition roughly equivalent to a ten-year moving average centered on each of the output years. The outputs of ASTRAP were used to estimate the absolute dry deposition factor for each ASTRAP site using:

$$DDF = 1. + DryDep / WetDep + OccDep / WetDep$$

where the DryDep/WetDep and OccDep/WetDep ratios were calculated from the ASTRAP output. This provided time series of DDF for SO4 and NOx for each ASTRAP site extending from 1900 to 1990. The values of DDF values for 1990 were used as the absolute values of DDF the SAMI Reference Year (Figures L-1 and L-2). SAMI modelling sites were assigned the Reference Year values of the DryDep/WetDep and OccDep/WetDep ratios, and of DDF from the nearest ASTRAP site (Table L-3).

NOTE: The high elevation sites in the Great Smoky Mountain National Park used DryDep/WetDep and OccDep/WetDep ratios taken from the "Integrated Forestry Study" results for the site, rather than the ratios taken from the ASTRAP model. This difference for these sites is reflected in the vales in Table L-3.

L.4 Long-term Scaled Sequences of Wet Deposition and DDF

Estimates of past deposition values at each SAMI site are needed for the calibration of MAGIC. ASTRAP produced wet, dry, and occult deposition estimates of SO4 and NOx every ten years starting in 1900 and ending in 1990. These data were used to set up the scaled sequences of past wet deposition and DDF for the calibration of each SAMI site.

The wet, dry, and occult deposition estimates provided by ASTRAP for each year (for both SO_4 and NOx) at each ASTRAP site were used to calculate the DDF for each year and each site. This provided time series of wet deposition and DDF for SO4 and NOx for each ASTRAP site extending from 1900 to 1990. These time series were normalized to the 1990 value at each site for to provide scaled sequences of wet deposition and DDF These sequences are shown in Figures L-3 and L-4. SAMI modellng sites were assigned scaled sequences from the nearest ASTRAP site (these assignments are noted in Table L-1).

For each site, it was necessary to couple the past scaled sequences (used for the MAGIC calibration at the site) to the future scaled sequences (used for the scenario or strategy simulations). The past scaled sequences are tied to ASTRAP's past deposition estimates which end in 1990. The future scaled sequences are based on the SAMI Reference Year, 1995. For each SAMI site, it was necessary to provide estimates of the changes in deposition that occurred between 1990 and 1995. These changes were derived from the site specific deposition data provided by the Lynch model.

L.5 Total Deposition for each site for the SAMI Reference Year

Using the estimated wet deposition, and the estimated DryDep/WetDep and OccDep/WetDep ratios for the Reference Year, the wet, dry and occult components, and the total deposition for each SAMI site were calculated for the Reference Year. The total deposition of all ions at each site is summarized in Table L-4. The individual wet, dry and occult components (along with total deposition) for SO4, NO3 and NH4 are tabulated for each site in Table L-5.

Table L-1. Names, locations, and ID's of SAMI sites. The SAMI ID is a unique identifier assigned to each site. This ID is used in other tables in this appendix without the name and location data. Elevations are in meters. The "Air Site" identifies for each SAMI site the ASTRAP location used to assign dry and occult deposition ratios and past scaled sequences (see Table L-3 for further information). The "Bin Number" identifies the landscape classification unit to which each site belongs (all sites used in the regional analysis have a non-zero bin number, special interest sites have bin number zero). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Air Site	Bin No.	SiteType
Grasses Creek-dry Branch	2A068015U	36.701	81.622	1048	VA	6	7	regional
Sugar Cove Branch Of N. River	2A07701	35.320	84.100	610	TN	11	4	regional
Cosby Creek	2A07805	35.790	83.240	436	TN	8	4	regional
Roaring Fork	2A07806	35.820	82.890	670	NC	15	4	regional
Little River	2A07810L	35.670	83.677	433	TN	8	0	special
Little River	2A07810U	35.628	83.541	811	TN	8	0	special
False Gap Prong	2A07811	35.700	83.380	549	TN	8	3	regional
Correll Branch	2A07812	35.680	83.090	884	NC	15	4	regional
Eagle Creek	2A07816	35.500	83.760	579	NC	8	4	regional
Forney Creek	2A07817	35.510	83.560	732	NC	8	3	regional
Grassy Creek	2A07821	35.460	82.280	552	NC	15	4	regional
Brush Creek	2A07823	35.320	83.520	549	NC	5	4	regional
Whiteoak Creek	2A07828	35.230	83.620	960	NC	5	4	regional
Catheys Creek	2A07829	35.210	82.790	689	NC	15	4	regional
Brush Creek	2A07834	35.110	83.260	838	NC	5	4	regional
Middle Saluda River	2A07835	35.120	82.540	329	SC	15	4	regional
Little Branch Creek	2A07882	35.450	83.060	936	NC	15	4	regional
Dunn Mill Creek	2A08802	34.950	84.440	506	GA	4	4	regional
Bear Creek	2A08804	34.820	84.570	567	GA	4	4	regional
Weaver Creek	2A08805	34.870	84.300	488	GA	4	4	regional
Bryant Creek	2A08810	34.610	84.000	448	GA	4	4	regional
Persimmon Creek	2A08901	34.910	83.500	596	GA	5	4	regional
Sprigs Hollow	2B041020L	39.562	78.424	168	WV	7	8	regional
No Name	2B041049U	39.110	78.441	378	VA	7	5	regional
Elk Run	2B047032	38.632	79.586	823	WV	14	8	regional
Straight Fork	2B047044U	38.498	79.611	899	VA	14	8	regional
Lower Lewis Run	2B047076L	38.305	78.746	354	VA	3	0	special
Lower Lewis Run	2B047076U	38.285	78.719	543	VA	3	6	regional
Whites Run	2B058015U	37.780	79.291	500	VA	10	2	regional
No Name	2C041033U	39.363	79.735	671	WV	14	10	regional
Buffalo Creek	2C041039	39.261	79.755	576	WV	14	12	regional
Thunderstruck Creek	2C041040	39.249	79.601	658	WV	14	11	regional
No Name	2C041043U	39.238	79.167	671	WV	7	12	regional
Right Fork Clover Run	2C041045	39.148	79.715	485	WV	14	12	regional
Coal Run	2C041051	39.040	79.616	558	WV	14	9	regional
Right Fork Holly River	2C046013L	38.569	80.418	448	WV	1	12	regional
Johnson Run	2C046033	38.347	80.408	704	WV	1	9	regional
Hateful Run	2C046034	38.351	80.259	879	WV	1	9	regional
North Fork Cherry River	2C046043L	38.231	80.416	937	WV	1	10	regional
North Fork Cherry River	2C046043U	38.233	80.407	954	WV	1	0	special
Hedricks Creek	2C046050	38.125	80.982	603	WV	1	12	regional
Laurel Creek	2C046053L	38.129	80.553	823	WV	1	11	regional
Little Clear Creek	2C046062L	37.998	80.569	866	WV	1	12	regional
Crawford Run	2C047007	38.759	79.923	607	WV	14	12	regional

Table L-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Air Site	Bin No.	SiteType
Clubhouse Run	2C047010L	38.632	79.760	920	WV	14	10	regional
Clubhouse Run	2C047010U	38.630	79.745	969	WV	14	11	regional
Butler Branch	2C057004	37.956	80.943	721	WV	1	10	regional
Johnson Mill Branch	2C066026L	36.247	85.038	488	TN	17	11	regional
No Name	2C066027L	36.270	84.865	454	TN	17	11	regional
No Name	2C066027U	36.245	84.872	489	TN	17	9	regional
Wallace Branch	2C066039L	36.002	85.005	527	TN	17	12	regional
Glady Fork	2C077022U	35.525	85.475	555	TN	4	11	regional
1306	BJ35	36.118	82.084	1420	TN	6	2	regional
M_S3_N2_2	BJ72	35.331	82.672	1717	NC	13	2	regional
CDB	BJ76	35.358	83.383	971	NC	13	0	special
BEFPR	BJ77	35.368	82.935	971	NC	13	0	special
Belfast Creek	BLFC	37.580	79.467	317	VA	10	0	special
Un-named eastern Trib	CO01	34.876	84.600	707	GA	4	3	regional
Hickory Creek	CO05	34.940	84.648	390	GA	4	3	regional
Bear Brook	CO06	34.921	84.532	427	GA	4	4	regional
Beech Creek	CO10	34.979	84.566	472	GA	4	3	regional
Deep Run	DR	38.266	78.743	415	VA	3	0	special
Deep Run	DR01	38.266	78.743	415	VA	3	6	regional
Little Stonecoal Run	DS04	38.991	79.396	932	WV	7	9	regional
Stonecoal Run (left branch)	DS06	39.002	79.388	1127	WV	7	0	special
Stonecoal Run (right branch)	DS09	39.007	79.383	1115	WV	7	9	regional
Fisher Spring Run	DS19	39.002	79.360	1011	WV	7	0	special
Unnamed	DS50	39.026	79.363	1097	WV	7	0	special
Fernow - WS10	FN1	39.064	79.681	713	WV	14	0	special
Fernow - WS13	FN2	39.063	79.679	695	WV	14	0	special
Fernow - WS4	FN3	39.056	79.688	744	WV	14	9	regional
GSMNP Noland Creek - NE fork	GS01	35.565	83.480	1740	NC	8	2	regional
GSMNP Noland Creek - SW fork	GS02	35.564	83.480	1800	NC	8	2	regional
GSMNP Deep Creek	GS04	35.608	83.442	1600	NC	8	4	regional
GSMNP Jay Bird Branch	GS05	35.680	83.597	1248	TN	8	3	regional
GSMNP LeConte Creek	GS06	35.687	83.503	570	TN	8	4	regional
GSMNP Raven Fork	GS07	35.610	83.254	1800	NC	15	3	regional
GSMNP Enloe Creek	GS08	35.614	83.270	1500	NC	15	3	regional
Laurel Branch Downstream	LB01	35.339	84.083	900	TN	11	4	regional
Lewis Fork	LEWF	36.671	81.525	1103	VA	10	0	special
Sulphur Spring Creek	M037	37.577	79.438	427	VA	10	3	regional
Big Hellcat Creek	M038	37.611	79.451	317	VA	10	0	special
Little Hellgate Creek	M039	37.603	79.465	317	VA	10	0	special
North Fork of Dry Run	NFD	38.623	78.355	488	VA	2	0	special
North Fork of Dry Run	NFDR	38.623	78.355	488	VA	2	4	regional
Condon Run	OC02	38.942	79.670	923	WV	14	9	regional
Yellow Creek	OC05	38.953	79.664	911	WV	14	0	special
Unnamed	OC08	38.980	79.639	871	WV	14	0	special
Devils Gulch	OC09	38.983	79.643	853	WV	14	9	regional
Possession Camp Run	OC31	39.000	79.645	798	WV	14	0	special
Moores Run	OC32	39.000	79.646	798	WV	14	0	special
Coal Run	OC35	39.033	79.620	688	WV	14	0	special
Otter Creek (upper)	OC79	38.938	79.660	950	WV	14	10	regional

Table L-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Air Site	Bin No.	SiteType
Paine Run	PAIN	38.201	78.769	424	VA	3	0	special
Un-named Trib between 8 and 9	SP10	34.298	87.429	186	AL	16	0	special
Un-named Trib above 38	SP39	34.369	87.438	250	AL	16	11	regional
Quillan Creek	SP41	34.317	87.481	183	AL	16	0	special
Staunton River	STAN	38.457	78.399	308	VA	3	0	special
Noname Trib Stony Cr.	VA524S	37.423	80.630	914	VA	9	6	regional
Bearpen Branch	VA526S	37.201	82.486	463	VA	12	12	regional
Ragged Run	VA531S	38.537	78.306	505	VA	2	0	special
Noname Trib Gap Cr	VA548S	38.699	78.596	445	VA	2	7	regional
Little Mill Cr	VA555S	38.080	79.499	694	VA	10	7	regional
Little Walker Cr.	VA821S	37.148	80.823	591	VA	9	8	regional
Lewis Fork	VT02	36.671	81.525	1103	VA	10	3	regional
Raccoon Branch	VT05	36.739	81.449	835	VA	6	4	regional
Cove Branch	VT07	37.072	81.433	930	VA	9	6	regional
Roaring Fork-Upper	VT08	37.064	81.418	930	VA	9	7	regional
Roaring Fork-Lower	VT09	37.055	81.458	664	VA	9	6	regional
Laurel Run	VT10	38.176	79.679	725	VA	10	7	regional
Mare Run	VT11	38.013	79.786	619	VA	10	7	regional
Panther Run	VT12	38.007	79.775	619	VA	10	8	regional
Porters Creek	VT15	37.979	79.787	604	VA	10	7	regional
Bearwallow Run	VT18	38.547	79.655	957	VA	14	8	regional
Lost Run	VT19	38.549	79.644	957	VA	14	8	regional
Hipes Branch	VT20	37.679	79.941	335	VA	10	8	regional
Shawvers Run	VT24	37.600	80.175	567	VA	9	7	regional
Cove Branch	VT25	37.584	80.161	561	VA	9	6	regional
Pine Swamp Branch	VT26	37.430	80.613	725	VA	9	5	regional
Nf Stony Creek	VT28	37.460	80.546	835	VA	9	6	regional
War Spur Branch	VT29	37.395	80.493	707	VA	9	6	regional
Nobusiness Creek	VT31	37.255	80.875	735	VA	9	5	regional
Laurel Creek	VT32	37.378	80.603	942	VA	9	6	regional
Laurel Run	VT34	37.916	79.472	387	VA	10	7	regional
Paine Run	VT35	38.201	78.769	424	VA	3	6	regional
Meadow Run	VT36	38.170	78.785	451	VA	3	1	regional
North River	VT37	38.421	79.266	811	VA	2	7	regional
Ramseys Draft	VT38	38.346	79.332	707	VA	2	8	regional
Kennedy Creek	VT39	37.946	79.034	561	VA	3	1	regional
St Marys R-Lower	VT41	37.928	79.092	530	VA	3	0	special
Little Cove Creek	VT46	37.738	79.211	506	VA	10	4	regional
Big Mack Creek	VT48	36.946	80.635	658	VA	9	4	regional
Little Stony Creek	VT49	38.958	78.627	466	VA	7	6	regional
Laurel Run	VT50	38.918	78.729	524	VA	7	5	regional
Two Mile Run	VT53	38.319	78.655	372	VA	3	2	regional
German River-Upper	VT54	38.674	79.078	762	VA	7	8	regional
Beech Lick Run	VT55	38.703	79.023	646	VA	7	8	regional
Wolf Run	VT56	38.438	79.169	594	VA	2	6	regional
Black Run-Lower	VT57	38.512	79.110	524	VA	2	7	regional
Brokenback Run	VT58	38.570	78.330	329	VA	2	0	special
Staunton River	VT59	38.457	78.399	308	VA	3	4	regional
Hazel Run	VT62	38.624	78.293	329	VA	2	0	special

Table L-1. Continued.

Stream Name	Site ID	Latitude	Longitude	Elev (m)	State	Air Site	Bin No.	SiteType
Rose River	VT66	38.522	78.402	341	VA	2	0	special
St Marys R-Upper	VT68	37.935	79.060	725	VA	10	1	regional
Bear Branch (Smr)	VT70	37.922	79.078	677	VA	10	2	regional
Hogback Br (Smr)	VT72	37.945	79.096	689	VA	10	5	regional
Sugartree Br (Smr)	VT73	37.912	79.111	628	VA	10	3	regional
St Marys R-Middle	VT74	37.932	79.083	579	VA	10	2	regional
White Oak Canyon R	VT75	38.567	78.365	354	VA	2	0	special
Belfast Creek	VT76	37.578	79.476	317	VA	10	2	regional
Matts Creek	VT77	37.588	79.433	256	VA	10	0	special
Little Tumbling Creek	VT78	36.957	81.738	799	VA	6	5	regional
White Oak Run	WOR	38.234	78.742	451	VA	3	0	special
White Oak Run	WOR1	38.234	78.742	451	VA	3	7	regional
Noname Trib Stony	WV523S	39.152	79.323	1170	WV	7	9	regional
Otter Cr	WV531S	39.011	79.646	847	WV	14	10	regional
Gauley	WV547S	38.399	80.493	650	WV	1	12	regional
Noname Trib South Fork Cherry R.	WV548S	38.214	80.479	768	WV	1	9	regional
Nnt Laurel Run	WV769S	38.879	79.956	719	WV	14	11	regional
Moss Run	WV770S	38.715	79.961	621	WV	14	12	regional
Left Fork Clover Run	WV771S	39.163	79.713	469	WV	14	12	regional
Nnt Glade Cr	WV785S	37.714	81.047	847	WV	1	9	regional
White Oak Fork	WV788S	38.357	80.383	857	WV	1	10	regional
Red Cr	WV796S	39.039	79.337	1127	WV	7	11	regional

Table L-2. Reference year wet deposition values for each SAMI site. The units are eq/ha/yr as provided by the spatial extrapolation model of Grimm and Lynch (1997). The wet deposition values for the five years 1991-1995 were average for each SAMI site to define the Reference Year Deposition for each site. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
Average	51.7	15.5	39.2	6.8	137.1	475.3	51.1	228.3	250.3	754.7	-504.4	134.1
Std. Dev.	16.3	2.8	14.9	1.8	22.6	107.8	14.9	54.5	42.8	163.0	128.9	26.1
Maximum	95.6	25.8	85.7	13.2	209.0	740.2	103.3	363.6	384.4	1151.0	-277.4	252.3
Minimum	22.9	9.3	20.6	3.6	89.8	285.7	29.3	131.2	161.2	467.1	-827.9	93.2
Site ID	**Ca**	**Mg**	**Na**	**K**	NH_4	SO_4	**Cl**	NO_3	**SBC**	**SAA**	**Calk**	**Precip Vol (cm/yr)**
2A068015U	45.6	13.3	31.7	7.0	119.6	398.1	38.5	186.0	217.1	622.6	-405.5	126.8
2A07701	41.7	14.1	42.2	6.8	118.2	405.3	53.2	176.0	223.0	634.5	-411.5	128.3
2A07805	33.8	9.9	27.5	4.9	91.7	316.2	32.7	145.1	167.8	494.0	-326.2	116.0
2A07806	38.2	12.2	36.1	5.7	112.0	393.7	42.3	172.8	204.2	608.9	-404.7	147.8
2A07810L	38.9	10.6	27.6	6.0	101.0	341.6	33.9	160.4	184.2	535.8	-351.6	116.7
2A07810U	43.8	12.3	31.4	7.0	118.5	406.5	37.7	187.9	213.0	632.1	-419.1	136.2
2A07811	32.7	9.3	24.6	4.8	89.8	307.4	29.3	140.9	161.2	477.6	-316.4	105.4
2A07812	49.9	15.8	45.3	7.8	145.4	514.5	53.6	227.1	264.2	795.2	-531.0	186.2
2A07816	48.6	14.8	41.1	7.9	131.6	448.9	50.5	205.0	244.0	704.3	-460.3	151.8
2A07817	50.3	15.3	41.9	8.5	140.1	473.9	50.1	218.7	256.2	742.6	-486.5	164.9
2A07821	26.4	11.4	40.6	5.1	97.6	317.1	45.8	135.1	181.2	498.0	-316.8	128.3
2A07823	36.9	13.3	41.5	6.5	107.7	366.0	49.1	165.8	206.0	580.9	-374.9	136.8
2A07828	43.7	16.8	54.4	8.0	129.3	439.5	64.4	196.8	252.3	700.7	-448.4	163.6
2A07829	42.1	18.5	65.2	8.5	141.5	472.0	74.0	206.9	275.7	753.0	-477.3	197.2
2A07834	32.6	14.6	52.1	6.5	102.1	335.6	59.1	150.6	207.8	545.3	-337.5	137.9
2A07835	32.2	14.6	52.9	6.9	113.0	369.5	59.7	160.7	219.6	590.0	-370.3	151.4
2A07882	43.3	16.1	51.7	7.7	134.5	459.1	59.8	204.6	253.3	723.4	-470.1	182.9
2A08802	55.1	21.8	71.4	10.1	168.0	551.1	87.6	234.4	326.5	873.0	-546.5	183.3
2A08804	62.9	25.8	85.7	12.0	198.0	624.6	103.3	265.0	384.4	992.9	-608.5	208.1
2A08805	46.3	19.0	63.2	9.0	142.8	462.6	76.2	198.6	280.2	737.4	-457.2	159.2
2A08810	50.6	23.4	82.0	11.3	162.7	511.1	95.4	222.2	330.0	828.7	-498.7	192.9
2A08901	41.4	19.5	70.5	8.8	129.4	423.3	80.5	187.9	269.6	691.7	-422.1	172.3
2B041020L	41.3	13.0	23.8	5.9	144.0	447.7	43.1	220.3	228.0	711.0	-483.0	95.3
2B041049U	32.2	11.2	26.5	4.3	117.4	351.8	39.1	170.3	191.7	561.2	-369.5	93.2
2B047032	57.9	14.2	27.5	5.5	137.1	511.7	41.5	255.6	242.2	808.7	-566.5	124.3
2B047044U	54.5	14.1	28.6	5.5	134.8	496.5	42.0	247.9	237.5	786.4	-548.9	123.6
2B047076L	32.5	13.8	43.0	4.5	126.9	396.8	52.9	189.2	220.7	638.9	-418.1	113.2
2B047076U	37.4	16.7	54.1	5.3	146.7	457.1	65.5	218.8	260.3	741.4	-481.1	131.1
2B058015U	41.6	16.0	43.0	6.3	133.1	441.4	55.1	220.1	240.1	716.7	-476.6	117.7
2C041033U	87.7	18.8	26.5	8.6	181.3	740.2	51.0	359.8	323.0	1151.0	-827.9	139.7
2C041039	81.8	16.7	23.7	7.2	160.5	663.2	43.7	323.3	289.8	1030.3	-740.5	126.8
2C041040	76.8	15.9	23.4	6.9	155.3	628.4	42.4	308.8	278.4	979.6	-701.2	123.9
2C041043U	53.5	13.4	22.4	5.9	137.5	496.2	39.1	242.5	232.6	777.7	-545.1	107.6
2C041045	75.7	14.6	21.1	5.9	141.9	589.3	37.2	288.6	259.3	915.2	-655.9	114.3
2C041051	84.4	16.4	25.2	6.4	161.5	653.2	42.2	324.1	294.0	1019.5	-725.5	133.5
2C046013L	63.0	14.3	24.5	6.1	135.8	533.1	38.8	271.3	243.6	843.1	-599.5	127.0
2C046033	58.9	13.9	25.4	6.1	133.5	508.5	38.8	262.3	237.8	809.6	-571.8	129.2
2C046034	65.1	15.5	28.9	6.7	149.3	565.3	43.7	289.0	265.5	898.0	-632.5	142.4
2C046043L	58.5	14.2	26.7	6.3	135.9	509.6	40.0	263.8	241.5	813.4	-571.9	133.6

Table L-2. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
2C046043U	57.7	14.0	26.4	6.2	134.2	504.3	39.6	260.7	238.6	804.6	-566.0	132.1
2C046050	45.5	11.0	20.6	4.9	109.2	396.4	30.8	213.1	191.1	640.3	-449.1	111.5
2C046053L	51.4	12.6	23.8	5.8	121.3	448.5	35.4	234.6	214.9	718.5	-503.6	121.6
2C046062L	49.9	12.4	24.1	6.0	118.3	428.9	35.0	225.8	210.7	689.7	-479.0	120.1
2C047007	66.8	14.4	24.0	5.8	138.8	552.2	38.4	274.3	249.8	864.9	-615.1	122.5
2C047010L	66.5	15.4	28.4	6.1	148.9	571.2	43.6	286.1	265.4	900.9	-635.6	135.4
2C047010U	67.0	15.6	28.9	6.2	150.7	576.9	44.3	288.9	268.4	910.2	-641.8	137.0
2C057004	42.9	10.6	20.7	4.9	106.7	379.3	30.4	206.4	185.8	616.1	-430.3	111.9
2C066026L	65.7	19.6	49.2	8.0	160.3	581.1	70.6	241.2	302.9	893.0	-590.0	148.5
2C066027L	66.1	19.4	47.5	8.0	157.2	585.9	69.8	242.5	298.2	898.3	-600.1	148.1
2C066027U	66.6	19.6	48.3	8.1	158.8	592.3	71.0	244.8	301.4	908.1	-606.7	149.9
2C066039L	65.8	20.1	53.5	8.5	165.2	600.1	76.0	245.7	313.1	921.8	-608.7	155.5
2C077022U	62.9	21.3	64.6	9.0	180.3	583.6	83.6	241.8	338.1	908.9	-570.8	166.0
BJ 35	38.8	13.3	39.7	5.9	123.1	408.5	46.0	180.2	220.8	634.6	-413.8	152.1
BJ 72	39.2	16.6	57.8	7.5	132.7	445.1	65.7	193.5	253.7	704.2	-450.5	185.0
BJ 76	39.8	14.4	45.0	7.1	119.0	405.3	52.8	182.7	225.4	640.8	-415.4	152.4
BJ 77	37.4	14.8	49.2	6.8	120.9	404.6	56.4	178.9	229.2	639.9	-410.7	162.2
BLFC	41.5	15.4	39.7	6.8	127.2	412.8	50.7	205.5	230.6	669.0	-438.4	112.5
CO01	51.4	20.2	65.8	9.5	161.3	513.4	80.1	216.9	308.2	810.4	-502.2	163.1
CO05	40.7	15.7	50.8	7.3	125.5	400.8	62.4	169.3	240.0	632.5	-392.5	127.0
CO06	61.6	24.5	80.0	11.4	189.5	616.8	97.9	260.9	366.9	975.6	-608.7	201.6
CO10	45.0	17.3	55.9	8.1	137.2	441.8	68.8	187.2	263.5	697.8	-434.4	141.1
DR	34.8	15.2	48.5	4.9	135.3	425.6	59.3	204.5	238.7	689.4	-450.6	120.6
DR01	34.8	15.2	48.5	4.9	135.3	425.6	59.3	204.5	238.7	689.4	-450.6	120.6
DS04	69.3	15.7	27.6	6.2	153.7	578.0	44.4	291.6	272.4	914.0	-641.6	133.9
DS06	69.3	15.7	27.6	6.2	153.7	578.0	44.4	291.6	272.4	914.0	-641.6	133.9
DS09	69.3	15.7	27.6	6.2	153.7	578.0	44.4	291.6	272.4	914.0	-641.6	133.9
DS19	69.3	15.7	27.6	6.2	153.7	578.0	44.4	291.6	272.4	914.0	-641.6	133.9
DS50	69.3	15.7	27.6	6.2	153.7	578.0	44.4	291.6	272.4	914.0	-641.6	133.9
FN1	95.6	18.1	27.3	7.1	177.9	736.3	45.8	362.7	326.1	1144.9	-818.8	146.3
FN2	93.1	17.7	26.6	7.0	173.2	716.4	44.7	353.1	317.5	1114.2	-796.7	142.6
FN3	95.6	18.2	27.5	7.2	178.3	738.3	46.1	363.6	326.8	1148.0	-821.1	147.3
GS01	75.7	22.8	60.6	13.2	209.0	736.3	73.1	333.8	381.3	1143.2	-761.8	252.3
GS02	75.7	22.8	60.7	13.2	208.9	736.1	73.2	333.7	381.3	1142.9	-761.7	252.3
GS04	63.9	18.9	49.5	10.7	177.6	625.3	59.5	283.2	320.6	968.0	-647.4	210.9
GS05	50.6	13.7	34.5	8.3	130.5	446.8	41.8	209.7	237.6	698.3	-460.7	153.1
GS06	34.8	9.5	24.7	5.3	93.0	316.4	29.6	147.2	167.3	493.2	-325.9	107.9
GS07	48.8	15.3	43.0	8.1	142.7	490.6	50.6	221.4	258.0	762.6	-504.7	175.4
GS08	54.8	17.1	47.6	9.2	159.2	551.7	56.2	248.5	287.9	856.5	-568.6	195.9
LB01	46.4	15.5	46.0	7.5	131.0	452.9	58.1	196.6	246.4	707.7	-461.3	142.3
LEWF	48.2	14.5	35.3	7.9	130.0	421.2	42.8	198.6	235.9	662.6	-426.7	136.2
M037	41.5	15.4	39.7	6.8	127.2	412.8	50.7	205.5	230.6	669.0	-438.4	112.5
M038	41.5	15.4	39.7	6.8	127.2	412.8	50.7	205.5	230.6	669.0	-438.4	112.5
M039	41.5	15.4	39.7	6.8	127.2	412.8	50.7	205.5	230.6	669.0	-438.4	112.5
NFD	35.1	17.2	64.3	5.4	151.6	410.8	70.6	190.2	273.5	671.6	-398.1	146.2
NFDR	35.1	17.2	64.3	5.4	151.6	410.8	70.6	190.2	273.5	671.6	-398.1	146.2
OC02	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC05	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0

Table L-2. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
OC08	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC09	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC31	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC32	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC35	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
OC79	81.1	16.3	26.1	6.4	159.5	641.5	42.9	318.6	289.5	1003.1	-713.6	136.0
PAIN	35.4	16.0	50.5	5.1	136.4	439.3	62.3	214.0	243.4	715.7	-472.3	120.0
SP10	52.2	20.8	75.4	8.1	149.7	379.7	84.6	183.4	306.1	647.8	-341.6	155.1
SP39	53.2	21.0	76.2	8.2	153.6	391.5	85.5	188.5	312.2	665.6	-353.3	158.6
SP41	53.2	21.1	76.4	8.2	151.8	384.0	85.8	186.6	310.7	656.4	-345.7	157.9
STAN	25.7	14.3	57.7	4.1	117.2	321.3	61.1	148.1	219.1	530.5	-311.4	114.8
VA524S	52.8	13.9	26.1	10.2	111.4	386.6	34.0	188.9	214.5	609.5	-395.1	111.2
VA526S	57.1	12.4	24.7	5.4	103.9	385.2	30.7	191.6	203.5	607.5	-404.0	119.7
VA531S	22.9	12.0	46.2	3.6	105.0	285.7	50.2	131.2	189.7	467.1	-277.4	100.2
VA548S	31.1	12.3	37.4	4.3	122.3	352.0	46.1	164.8	207.4	562.9	-355.5	114.5
VA555S	43.9	14.1	33.8	5.6	125.1	434.9	45.6	218.5	222.5	699.0	-476.5	115.5
VA821S	45.9	12.8	26.3	9.0	104.0	345.4	33.3	168.4	198.0	547.2	-349.1	104.1
VT02	48.2	14.5	35.3	7.9	130.0	421.2	42.8	198.6	235.9	662.6	-426.7	136.2
VT05	42.6	12.7	30.4	7.0	112.3	365.6	37.1	173.4	205.0	576.1	-371.0	117.3
VT07	52.9	14.0	29.9	8.0	123.7	418.1	37.6	202.7	228.5	658.4	-430.0	128.9
VT08	50.5	13.4	28.9	7.7	117.8	398.2	36.4	193.8	218.3	628.4	-410.1	124.0
VT09	51.9	13.7	29.5	7.8	121.2	413.3	37.2	199.5	224.1	650.0	-425.9	128.1
VT10	47.7	13.9	31.0	5.7	126.1	450.0	43.3	227.9	224.4	721.2	-496.8	118.6
VT11	51.5	15.2	34.3	6.6	134.9	473.4	47.0	241.9	242.5	762.3	-519.8	128.2
VT12	48.4	14.5	32.7	6.3	127.8	446.7	44.8	228.5	229.6	720.1	-490.4	121.2
VT15	44.8	13.4	30.4	5.8	118.5	413.5	41.5	211.2	213.0	666.3	-453.3	112.2
VT18	61.5	15.4	30.5	6.0	146.5	544.6	45.4	274.8	259.9	864.8	-605.0	135.4
VT19	62.7	15.8	31.4	6.2	150.1	557.7	46.8	281.1	266.2	885.5	-619.3	138.7
VT20	42.6	13.2	29.7	6.7	109.9	374.5	39.4	189.8	202.1	603.7	-401.5	105.5
VT24	45.8	13.2	28.0	7.6	109.8	375.8	37.1	189.9	204.2	602.8	-398.5	108.0
VT25	46.5	13.7	29.2	7.9	111.5	382.0	38.5	192.7	208.8	613.2	-404.5	110.3
VT26	53.1	14.0	26.4	10.3	112.0	388.3	34.4	190.3	215.8	613.0	-397.2	111.9
VT28	51.5	13.7	26.1	9.8	109.7	379.5	34.1	187.4	210.8	601.1	-390.2	109.8
VT29	55.1	15.1	29.1	11.4	116.6	397.9	37.5	196.8	227.4	632.2	-404.7	116.9
VT31	50.3	13.5	26.7	9.4	111.0	376.8	34.1	183.3	210.9	594.2	-383.4	111.4
VT32	56.8	15.3	28.2	12.0	117.6	405.4	36.4	197.1	229.9	639.0	-409.1	117.1
VT34	40.3	13.8	34.5	5.6	119.6	405.6	45.5	203.8	213.8	654.9	-441.1	108.4
VT35	35.4	16.0	50.5	5.1	136.4	439.3	62.3	214.0	243.4	715.7	-472.3	120.0
VT36	38.7	17.9	57.3	5.6	147.6	478.6	70.6	234.8	267.1	784.0	-516.9	130.2
VT37	46.7	14.6	34.9	5.4	136.5	469.1	47.9	232.0	238.1	749.0	-510.9	125.3
VT38	49.2	15.6	37.6	5.8	141.9	492.0	51.4	245.3	250.0	788.8	-538.8	131.7
VT39	40.9	17.2	50.7	6.0	142.8	468.3	63.8	234.3	257.6	766.3	-508.8	122.9
VT41	43.1	17.6	50.2	6.3	146.6	485.7	63.8	242.0	263.7	791.4	-527.7	126.9
VT46	40.5	17.2	48.6	6.4	133.5	437.2	61.4	220.9	246.3	719.5	-473.2	118.9
VT48	47.0	14.9	32.3	10.2	120.4	379.5	40.1	180.7	224.7	600.3	-375.6	111.5
VT49	34.1	11.7	29.0	4.4	120.5	365.8	40.7	175.6	199.7	582.0	-382.3	103.4
VT50	34.1	11.4	27.7	4.3	116.6	360.6	39.0	173.1	194.1	572.6	-378.5	101.4
VT53	32.5	14.7	48.4	4.7	131.3	400.8	58.0	190.4	231.6	649.2	-417.6	118.7

Table L-2. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
VT54	48.2	15.0	35.5	5.5	145.0	480.1	49.3	234.9	249.0	764.2	-515.2	132.3
VT55	41.1	12.8	30.5	4.8	127.3	416.8	42.3	201.2	216.4	660.3	-443.9	114.6
VT56	41.2	13.4	33.5	4.9	127.0	427.9	45.3	208.9	220.0	682.1	-462.1	115.1
VT57	38.4	12.6	31.6	4.5	119.7	399.5	42.8	194.6	206.8	636.9	-430.1	109.9
VT58	24.9	12.9	49.7	3.9	112.3	303.9	53.8	139.8	203.8	497.5	-293.7	107.9
VT59	25.7	14.3	57.7	4.1	117.2	321.3	61.1	148.1	219.1	530.5	-311.4	114.8
VT62	28.3	13.9	50.8	4.3	125.2	340.4	56.7	157.5	222.6	554.7	-332.1	117.4
VT66	25.7	14.0	56.8	4.1	117.6	315.1	59.4	144.3	218.2	518.8	-300.7	117.1
VT68	43.9	18.6	54.4	6.5	150.8	495.9	68.6	249.1	274.1	813.6	-539.4	131.4
VT70	42.4	17.8	52.0	6.3	144.4	476.5	65.6	239.6	262.9	781.6	-518.7	126.9
VT72	45.8	18.9	54.4	6.7	154.4	510.7	68.9	256.2	280.1	835.8	-555.6	136.1
VT73	44.6	18.4	52.6	6.6	150.3	496.5	66.7	248.9	272.5	812.1	-539.7	131.6
VT74	43.2	17.8	51.4	6.3	147.4	487.3	65.1	243.5	266.2	796.0	-529.8	128.2
VT75	26.3	14.0	55.1	4.2	118.0	317.9	58.8	146.7	217.5	523.3	-305.8	116.1
VT76	41.5	15.4	39.7	6.8	127.2	412.8	50.7	205.5	230.6	669.0	-438.4	112.5
VT77	42.1	16.1	42.8	6.9	131.4	422.5	54.4	212.1	239.3	689.0	-449.7	116.3
VT78	48.4	12.6	28.1	6.6	112.3	384.7	34.9	185.9	208.1	605.6	-397.5	122.7
WOR	36.3	16.3	52.2	5.2	140.9	447.4	63.8	216.1	250.9	727.3	-476.4	123.7
WOR1	36.3	16.3	52.2	5.2	140.9	447.4	63.8	216.1	250.9	727.3	-476.4	123.7
WV523S	84.3	19.4	32.5	8.2	194.8	727.0	54.9	362.7	339.2	1144.5	-805.3	159.9
WV531S	82.8	16.2	24.8	6.4	161.1	659.4	41.6	320.1	291.3	1021.2	-729.9	132.1
WV547S	58.6	13.7	24.5	6.0	131.8	504.4	37.8	259.6	234.6	801.8	-567.2	126.6
WV548S	55.6	13.4	25.2	6.0	129.3	484.8	37.8	251.5	229.5	774.1	-544.6	127.8
WV769S	81.3	16.8	26.8	6.8	161.6	656.3	44.2	325.5	293.3	1026.1	-732.7	140.2
WV770S	65.7	14.3	24.1	5.8	138.6	550.6	38.5	272.5	248.6	861.5	-612.9	122.9
WV771S	73.9	14.4	20.8	5.9	139.5	580.1	36.7	283.3	254.5	900.1	-645.6	112.2
WV785S	44.7	11.0	21.3	5.8	102.1	362.7	29.7	189.7	184.9	582.1	-397.2	107.8
WV788S	60.1	14.2	26.1	6.2	136.2	520.7	39.8	267.7	242.7	828.2	-585.4	132.0
WV796S	75.6	17.4	30.3	7.0	173.6	646.3	49.4	322.3	303.9	1018.0	-714.1	146.8

Table L-3. Ratios of dry-to-wet and occult-to-wet deposition, and the calculated dry deposition factor (DDF) for each SAMI site. The ASTRAP "Air Station" assigned to each SAMI site (and its location) are also included. The values are calculated from the1990 values simulated by ASTRAP, and are used for the SAMI Reference Year. The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	DDF-S	dry/wt-S	occ/wt-S	DDF-N	dry/wt-N	occ/wt-N		
Average	1.96	0.62	0.34	2.13	0.76	0.37		
Std. Dev.	0.35	0.17	0.32	0.44	0.30	0.28		
Maximum	3.71	1.05	1.79	4.35	1.95	1.40		
Minimum	1.82	0.41	0.00	1.95	0.41	0.00		
Site ID	**DDF-S**	**dry/wt-S**	**occ/wt-S**	**DDF-N**	**dry/wt-N**	**occ/wt-N**	**Air-Site Number**	**Air-Site Location**
2A068015U	1.90	0.44	0.46	2.14	0.44	0.70	6	Cranberry NC
2A07701	1.93	0.60	0.33	2.14	0.74	0.40	11	Joyce Kilmer/Slickrock Wilderness NC
2A07805	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07806	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A07810L	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07810U	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07811	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07812	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A07816	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07817	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
2A07821	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A07823	1.84	0.65	0.20	2.12	0.83	0.30	5	Coweeta NC
2A07828	1.84	0.65	0.20	2.12	0.83	0.30	5	Coweeta NC
2A07829	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A07834	1.84	0.65	0.20	2.12	0.83	0.30	5	Coweeta NC
2A07835	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A07882	1.90	0.49	0.41	2.21	0.56	0.65	15	Shining Rock Wilderness NC
2A08802	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
2A08804	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
2A08805	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
2A08810	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
2A08901	1.84	0.65	0.20	2.12	0.83	0.30	5	Coweeta NC
2B041020L	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
2B041049U	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
2B047032	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2B047044U	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2B047076L	1.85	0.85	0.00	1.99	0.99	0.00	3	Parsons WV
2B047076U	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
2B058015U	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
2C041033U	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C041039	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C041040	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C041043U	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
2C041045	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C041051	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C046013L	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046033	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046034	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046043L	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV

Table L-3. Continued.								
Site ID	**DDF-S**	**dry/wt-S**	**occ/wt-S**	**DDF-N**	**dry/wt-N**	**occ/wt-N**	**Air-Site Number**	**Air-Site Location**
2C046043U	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046050	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046053L	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C046062L	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C047007	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C047010L	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C047010U	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
2C057004	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
2C066026L	2.22	1.03	0.18	2.24	1.12	0.13	17	Walker Branch TN
2C066027L	2.22	1.03	0.18	2.24	1.12	0.13	17	Walker Branch TN
2C066027U	2.22	1.03	0.18	2.24	1.12	0.13	17	Walker Branch TN
2C066039L	2.22	1.03	0.18	2.24	1.12	0.13	17	Walker Branch TN
2C077022U	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
BJ 35	1.90	0.44	0.46	2.14	0.44	0.70	6	Cranberry NC
BJ 72	1.89	0.41	0.48	2.18	0.41	0.76	13	Mt. Mitchell NC
BJ 76	1.89	0.41	0.48	2.18	0.41	0.76	13	Mt. Mitchell NC
BJ 77	1.89	0.41	0.48	2.18	0.41	0.76	13	Mt. Mitchell NC
BLFC	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
CO01	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
CO05	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
CO06	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
CO10	1.93	0.78	0.14	2.24	1.02	0.22	4	Cohutta Wilderness GA
DR	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
DR01	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
DS04	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
DS06	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
DS09	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
DS19	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
DS50	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
FN1	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
FN2	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
FN3	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
GS01	3.71	0.92	1.79	4.35	1.95	1.40	8	Elkmont - GSMNP NC
GS02	3.71	0.92	1.79	4.35	1.95	1.40	8	Elkmont - GSMNP NC
GS04	3.71	0.92	1.79	4.35	1.95	1.40	8	Elkmont - GSMNP NC
GS05	3.71	0.92	1.79	4.35	1.95	1.40	8	Elkmont - GSMNP NC
GS06	1.95	0.66	0.30	2.14	0.79	0.35	8	Elkmont - GSMNP NC
GS07	3.71	0.92	1.79	4.35	1.95	1.40	15	Shining Rock Wilderness NC
GS08	3.71	0.92	1.79	4.35	1.95	1.40	15	Shining Rock Wilderness NC
LB01	1.93	0.60	0.33	2.14	0.74	0.40	11	Joyce Kilmer/Slickrock Wilderness NC
LEWF	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
M037	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
M038	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
M039	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
NFD	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
NFDR	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
OC02	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC05	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV

Table L-3. Continued.

Site ID	DDF-S	dry/wt-S	occ/wt-S	DDF-N	dry/wt-N	occ/wt-N	Air-Site Number	Air-Site Location
OC08	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC09	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC31	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC32	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC35	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
OC79	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
PAIN	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
SP10	2.05	1.05	0.00	2.21	1.21	0.00	16	Sipsey Wilderness AL
SP39	2.05	1.05	0.00	2.21	1.21	0.00	16	Sipsey Wilderness AL
SP41	2.05	1.05	0.00	2.21	1.21	0.00	16	Sipsey Wilderness AL
STAN	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VA524S	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VA526S	1.91	0.87	0.04	2.09	1.02	0.07	12	Lilley Cornett Woods KY
VA531S	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VA548S	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VA555S	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VA821S	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT02	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT05	1.90	0.44	0.46	2.14	0.44	0.70	6	Cranberry NC
VT07	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT08	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT09	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT10	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT11	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT12	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT15	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT18	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
VT19	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
VT20	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT24	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT25	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT26	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT28	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT29	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT31	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT32	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT34	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT35	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VT36	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VT37	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT38	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT39	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VT41	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VT46	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT48	1.99	0.44	0.55	2.08	0.49	0.59	9	Horton's Station VA
VT49	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
VT50	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
VT53	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA

Table L-3. Continued.

Site ID	DDF-S	dry/wt-S	occ/wt-S	DDF-N	dry/wt-N	occ/wt-N	Air-Site Number	Air-Site Location
VT54	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
VT55	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
VT56	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT57	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT58	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT59	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
VT62	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT66	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT68	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT70	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT72	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT73	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT74	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT75	1.82	0.41	0.41	1.96	0.44	0.51	2	Big Meadows - SNP VA
VT76	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT77	1.92	0.65	0.28	2.05	0.75	0.29	10	James Riverface Wilderness VA
VT78	1.90	0.44	0.46	2.14	0.44	0.70	6	Cranberry NC
WOR	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
WOR1	1.85	0.85	0.00	1.99	0.99	0.00	3	Charlottesville VA
WV523S	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV
WV531S	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
WV547S	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
WV548S	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
WV769S	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
WV770S	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
WV771S	1.84	0.62	0.23	1.95	0.75	0.20	14	Parsons WV
WV785S	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
WV788S	1.91	0.55	0.35	2.01	0.62	0.38	1	Babcock State Park WV
WV796S	1.84	0.47	0.37	1.95	0.57	0.38	7	Dolly Sods Wilderness WV

Table L-4. Total deposition (wet + dry + occult) of all ions for each SAMI site for the SAMI Reference Year (1995). These data were calculated from the Reference Year wet deposition values and the assigned dry and occult ratios. The deposition is in meq/m²/yr (the units used in the effects models). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
Average	5.2	1.5	3.9	0.7	29.5	94.1	5.1	48.8	40.8	148.0	-107.2	134.1
Std. Dev.	1.6	0.3	1.5	0.2	10.2	32.5	1.5	17.3	11.7	50.0	39.3	26.1
Maximum	9.6	2.6	8.6	1.3	90.9	273.2	10.3	145.2	108.1	425.7	-53.6	252.3
Minimum	2.3	0.9	2.1	0.4	19.2	51.9	2.9	25.7	26.3	82.6	-317.5	93.2
Site ID	**Ca**	**Mg**	**Na**	**K**	**NH_4**	**SO_4**	**Cl**	**NO_3**	**SBC**	**SAA**	**Calk**	**Precip Vol (cm/yr)**
2A068015U	4.6	1.3	3.2	0.7	25.6	75.5	3.9	39.8	35.3	119.1	-83.8	126.8
2A07701	4.2	1.4	4.2	0.7	25.3	78.4	5.3	37.7	35.8	121.4	-85.6	128.3
2A07805	3.4	1.0	2.7	0.5	19.6	61.8	3.3	31.0	27.2	96.1	-68.8	116.0
2A07806	3.8	1.2	3.6	0.6	24.8	74.9	4.2	38.2	34.0	117.3	-83.3	147.8
2A07810L	3.9	1.1	2.8	0.6	21.6	66.7	3.4	34.3	29.9	104.4	-74.5	116.7
2A07810U	4.4	1.2	3.1	0.7	25.3	79.4	3.8	40.2	34.8	123.3	-88.6	136.2
2A07811	3.3	0.9	2.5	0.5	19.2	60.0	2.9	30.1	26.3	93.1	-66.8	105.4
2A07812	5.0	1.6	4.5	0.8	32.1	97.9	5.4	50.2	44.0	153.4	-109.4	186.2
2A07816	4.9	1.5	4.1	0.8	28.1	87.7	5.0	43.8	39.4	136.5	-97.2	151.8
2A07817	5.0	1.5	4.2	0.8	30.0	92.6	5.0	46.8	41.6	144.3	-102.8	164.9
2A07821	2.6	1.1	4.1	0.5	21.6	60.3	4.6	29.9	29.9	94.8	-64.8	128.3
2A07823	3.7	1.3	4.2	0.7	22.9	67.4	4.9	35.2	32.7	107.6	-74.8	136.8
2A07828	4.4	1.7	5.4	0.8	27.5	81.0	6.4	41.8	39.8	129.2	-89.5	163.6
2A07829	4.2	1.8	6.5	0.8	31.3	89.8	7.4	45.7	44.7	142.9	-98.2	197.2
2A07834	3.3	1.5	5.2	0.7	21.7	61.8	5.9	32.0	32.3	99.7	-67.5	137.9
2A07835	3.2	1.5	5.3	0.7	25.0	70.3	6.0	35.5	35.6	111.8	-76.2	151.4
2A07882	4.3	1.6	5.2	0.8	29.7	87.3	6.0	45.2	41.6	138.5	-96.9	182.9
2A08802	5.5	2.2	7.1	1.0	37.6	106.2	8.8	52.4	53.4	167.3	-113.9	183.3
2A08804	6.3	2.6	8.6	1.2	44.3	120.3	10.3	59.2	62.9	189.9	-127.0	208.1
2A08805	4.6	1.9	6.3	0.9	31.9	89.1	7.6	44.4	45.7	141.1	-95.5	159.2
2A08810	5.1	2.3	8.2	1.1	36.4	98.5	9.5	49.7	53.1	157.7	-104.6	192.9
2A08901	4.1	1.9	7.1	0.9	27.5	78.0	8.1	39.9	41.5	125.9	-84.4	172.3
2B041020L	4.1	1.3	2.4	0.6	28.1	82.2	4.3	42.9	36.5	129.5	-93.0	95.3
2B041049U	3.2	1.1	2.7	0.4	22.9	64.6	3.9	33.2	30.3	101.7	-71.4	93.2
2B047032	5.8	1.4	2.7	0.5	26.8	94.3	4.1	49.9	37.3	148.4	-111.1	124.3
2B047044U	5.4	1.4	2.9	0.6	26.3	91.5	4.2	48.4	36.6	144.1	-107.5	123.6
2B047076L	3.3	1.4	4.3	0.5	25.2	73.3	5.3	37.6	34.6	116.2	-81.6	113.2
2B047076U	3.7	1.7	5.4	0.5	29.2	84.5	6.5	43.5	40.5	134.5	-94.0	131.1
2B058015U	4.2	1.6	4.3	0.6	27.2	85.0	5.5	45.0	37.9	135.5	-97.6	117.7
2C041033U	8.8	1.9	2.7	0.9	35.4	136.4	5.1	70.3	49.6	211.8	-162.2	139.7
2C041039	8.2	1.7	2.4	0.7	31.4	122.2	4.4	63.2	44.3	189.7	-145.5	126.8
2C041040	7.7	1.6	2.3	0.7	30.3	115.8	4.2	60.3	42.6	180.4	-137.7	123.9
2C041043U	5.3	1.3	2.2	0.6	26.8	91.1	3.9	47.3	36.3	142.3	-106.0	107.6
2C041045	7.6	1.5	2.1	0.6	27.7	108.6	3.7	56.4	39.5	168.7	-129.2	114.3
2C041051	8.4	1.6	2.5	0.6	31.6	120.4	4.2	63.3	44.8	187.9	-143.1	133.5
2C046013L	6.3	1.4	2.4	0.6	27.2	101.6	3.9	54.4	38.0	159.9	-121.8	127.0
2C046033	5.9	1.4	2.5	0.6	26.8	96.9	3.9	52.6	37.2	153.4	-116.2	129.2
2C046034	6.5	1.6	2.9	0.7	29.9	107.7	4.4	57.9	41.6	170.0	-128.5	142.4
2C046043L	5.8	1.4	2.7	0.6	27.2	97.1	4.0	52.9	37.8	154.0	-116.2	133.6

Table L-4. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
2C046043U	5.8	1.4	2.6	0.6	26.9	96.1	4.0	52.3	37.4	152.3	-115.0	132.1
2C046050	4.5	1.1	2.1	0.5	21.9	75.5	3.1	42.7	30.1	121.3	-91.3	111.5
2C046053L	5.1	1.3	2.4	0.6	24.3	85.5	3.5	47.0	33.7	136.0	-102.4	121.6
2C046062L	5.0	1.2	2.4	0.6	23.7	81.7	3.5	45.3	33.0	130.5	-97.5	120.1
2C047007	6.7	1.4	2.4	0.6	27.1	101.8	3.8	53.6	38.2	159.2	-121.0	122.5
2C047010L	6.7	1.5	2.8	0.6	29.1	105.3	4.4	55.9	40.7	165.5	-124.8	135.4
2C047010U	6.7	1.6	2.9	0.6	29.4	106.3	4.4	56.4	41.2	167.2	-126.0	137.0
2C057004	4.3	1.1	2.1	0.5	21.4	72.3	3.0	41.4	29.3	116.7	-87.4	111.9
2C066026L	6.6	2.0	4.9	0.8	36.0	128.8	7.1	54.1	50.2	190.0	-139.7	148.5
2C066027L	6.6	1.9	4.8	0.8	35.3	129.8	7.0	54.4	49.4	191.2	-141.9	148.1
2C066027U	6.7	2.0	4.8	0.8	35.6	131.3	7.1	54.9	49.9	193.3	-143.4	149.9
2C066039L	6.6	2.0	5.3	0.8	37.1	133.0	7.6	55.1	51.9	195.7	-143.9	155.5
2C077022U	6.3	2.1	6.5	0.9	40.3	112.4	8.4	54.0	56.1	174.8	-118.7	166.0
BJ 35	3.9	1.3	4.0	0.6	26.3	77.5	4.6	38.5	36.1	120.6	-84.5	152.1
BJ 72	3.9	1.7	5.8	0.8	28.9	84.1	6.6	42.1	41.0	132.7	-91.8	185.0
BJ 76	4.0	1.4	4.5	0.7	25.9	76.6	5.3	39.8	36.5	121.6	-85.1	152.4
BJ 77	3.7	1.5	4.9	0.7	26.3	76.4	5.6	38.9	37.1	121.0	-83.9	162.2
BLFC	4.1	1.5	4.0	0.7	26.0	79.5	5.1	42.0	36.4	126.6	-90.2	112.5
CO01	5.1	2.0	6.6	1.0	36.0	98.9	8.0	48.5	50.7	155.4	-104.7	163.1
CO05	4.1	1.6	5.1	0.7	28.0	77.2	6.2	37.8	39.5	121.3	-81.8	127.0
CO06	6.2	2.4	8.0	1.1	42.3	118.8	9.8	58.3	60.1	186.9	-126.8	201.6
CO10	4.5	1.7	5.6	0.8	30.7	85.1	6.9	41.8	43.3	133.8	-90.6	141.1
DR	3.5	1.5	4.8	0.5	26.9	78.6	5.9	40.7	37.3	125.3	-88.0	120.6
DR01	3.5	1.5	4.8	0.5	26.9	78.6	5.9	40.7	37.3	125.3	-88.0	120.6
DS04	6.9	1.6	2.8	0.6	30.0	106.2	4.4	56.8	41.8	167.4	-125.6	133.9
DS06	6.9	1.6	2.8	0.6	30.0	106.2	4.4	56.8	41.8	167.4	-125.6	133.9
DS09	6.9	1.6	2.8	0.6	30.0	106.2	4.4	56.8	41.8	167.4	-125.6	133.9
DS19	6.9	1.6	2.8	0.6	30.0	106.2	4.4	56.8	41.8	167.4	-125.6	133.9
DS50	6.9	1.6	2.8	0.6	30.0	106.2	4.4	56.8	41.8	167.4	-125.6	133.9
FN1	9.6	1.8	2.7	0.7	34.8	135.7	4.6	70.9	49.6	211.1	-161.5	146.3
FN2	9.3	1.8	2.7	0.7	33.8	132.0	4.5	69.0	48.3	205.5	-157.2	142.6
FN3	9.6	1.8	2.7	0.7	34.8	136.0	4.6	71.0	49.7	211.7	-162.0	147.3
GS01	7.6	2.3	6.1	1.3	90.9	273.2	7.3	145.2	108.1	425.7	-317.5	252.3
GS02	7.6	2.3	6.1	1.3	90.9	273.1	7.3	145.1	108.1	425.6	-317.4	252.3
GS04	6.4	1.9	4.9	1.1	77.3	232.0	6.0	123.2	91.6	361.1	-269.6	210.9
GS05	5.1	1.4	3.5	0.8	56.8	165.8	4.2	91.2	67.5	261.2	-193.7	153.1
GS06	3.5	1.0	2.5	0.5	19.9	61.8	3.0	31.5	27.3	96.2	-68.9	107.9
GS07	4.9	1.5	4.3	0.8	62.1	182.0	5.1	96.3	73.6	283.4	-209.8	175.4
GS08	5.5	1.7	4.8	0.9	69.2	204.7	5.6	108.1	82.1	318.4	-236.3	195.9
LB01	4.6	1.6	4.6	0.8	28.1	87.6	5.8	42.1	39.6	135.5	-95.9	142.3
LEWF	4.8	1.5	3.5	0.8	26.6	81.1	4.3	40.6	37.2	126.0	-88.8	136.2
M037	4.1	1.5	4.0	0.7	26.0	79.5	5.1	42.0	36.4	126.6	-90.2	112.5
M038	4.1	1.5	4.0	0.7	26.0	79.5	5.1	42.0	36.4	126.6	-90.2	112.5
M039	4.1	1.5	4.0	0.7	26.0	79.5	5.1	42.0	36.4	126.6	-90.2	112.5
NFD	3.5	1.7	6.4	0.5	29.7	74.7	7.1	37.2	41.9	119.0	-77.1	146.2
NFDR	3.5	1.7	6.4	0.5	29.7	74.7	7.1	37.2	41.9	119.0	-77.1	146.2
OC02	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC05	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0

Table L-4. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
OC08	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC09	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC31	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC32	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC35	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
OC79	8.1	1.6	2.6	0.6	31.2	118.2	4.3	62.2	44.2	184.7	-140.6	136.0
PAIN	3.5	1.6	5.1	0.5	27.1	81.2	6.2	42.6	37.8	130.0	-92.1	120.0
SP10	5.2	2.1	7.5	0.8	33.1	77.8	8.5	40.6	48.8	126.8	-78.0	155.1
SP39	5.3	2.1	7.6	0.8	34.0	80.2	8.6	41.7	49.9	130.4	-80.6	158.6
SP41	5.3	2.1	7.6	0.8	33.6	78.6	8.6	41.3	49.5	128.5	-79.0	157.9
STAN	2.6	1.4	5.8	0.4	23.3	59.4	6.1	29.5	33.5	94.9	-61.4	114.8
VA524S	5.3	1.4	2.6	1.0	23.2	76.8	3.4	39.4	33.5	119.5	-86.0	111.2
VA526S	5.7	1.2	2.5	0.5	21.7	73.7	3.1	40.1	31.7	116.9	-85.2	119.7
VA531S	2.3	1.2	4.6	0.4	20.6	51.9	5.0	25.7	29.0	82.6	-53.6	100.2
VA548S	3.1	1.2	3.7	0.4	23.9	64.0	4.6	32.3	32.5	100.9	-68.4	114.5
VA555S	4.4	1.4	3.4	0.6	25.6	83.7	4.6	44.7	35.3	133.0	-97.6	115.5
VA821S	4.6	1.3	2.6	0.9	21.7	68.6	3.3	35.1	31.1	107.0	-75.9	104.1
VT02	4.8	1.5	3.5	0.8	26.6	81.1	4.3	40.6	37.2	126.0	-88.8	136.2
VT05	4.3	1.3	3.0	0.7	24.0	69.3	3.7	37.1	33.3	110.1	-76.8	117.3
VT07	5.3	1.4	3.0	0.8	25.8	83.0	3.8	42.2	36.2	129.0	-92.8	128.9
VT08	5.1	1.3	2.9	0.8	24.5	79.1	3.6	40.4	34.6	123.1	-88.5	124.0
VT09	5.2	1.4	2.9	0.8	25.3	82.1	3.7	41.6	35.5	127.4	-91.8	128.1
VT10	4.8	1.4	3.1	0.6	25.8	86.6	4.3	46.6	35.6	137.6	-101.9	118.6
VT11	5.1	1.5	3.4	0.7	27.6	91.1	4.7	49.5	38.4	145.3	-106.9	128.2
VT12	4.8	1.4	3.3	0.6	26.1	86.0	4.5	46.7	36.3	137.2	-100.9	121.2
VT15	4.5	1.3	3.0	0.6	24.2	79.6	4.2	43.2	33.7	126.9	-93.3	112.2
VT18	6.1	1.5	3.1	0.6	28.6	100.4	4.5	53.7	40.0	158.6	-118.6	135.4
VT19	6.3	1.6	3.1	0.6	29.3	102.8	4.7	54.9	40.9	162.3	-121.4	138.7
VT20	4.3	1.3	3.0	0.7	22.5	72.1	3.9	38.8	31.7	114.8	-83.1	105.5
VT24	4.6	1.3	2.8	0.8	22.9	74.6	3.7	39.6	32.3	117.9	-85.6	108.0
VT25	4.6	1.4	2.9	0.8	23.2	75.9	3.9	40.1	33.0	119.9	-86.9	110.3
VT26	5.3	1.4	2.6	1.0	23.3	77.1	3.4	39.6	33.7	120.2	-86.5	111.9
VT28	5.2	1.4	2.6	1.0	22.9	75.4	3.4	39.1	33.0	117.8	-84.9	109.8
VT29	5.5	1.5	2.9	1.1	24.3	79.0	3.7	41.0	35.4	123.8	-88.4	116.9
VT31	5.0	1.4	2.7	0.9	23.1	74.8	3.4	38.2	33.1	116.4	-83.3	111.4
VT32	5.7	1.5	2.8	1.2	24.5	80.5	3.6	41.1	35.7	125.2	-89.5	117.1
VT34	4.0	1.4	3.4	0.6	24.5	78.1	4.6	41.7	33.9	124.3	-90.4	108.4
VT35	3.5	1.6	5.1	0.5	27.1	81.2	6.2	42.6	37.8	130.0	-92.1	120.0
VT36	3.9	1.8	5.7	0.6	29.4	88.4	7.1	46.7	41.3	142.2	-100.9	130.2
VT37	4.7	1.5	3.5	0.5	26.7	85.3	4.8	45.4	36.9	135.5	-98.6	125.3
VT38	4.9	1.6	3.8	0.6	27.8	89.4	5.1	48.0	38.6	142.6	-104.0	131.7
VT39	4.1	1.7	5.1	0.6	28.4	86.5	6.4	46.6	39.9	139.5	-99.6	122.9
VT41	4.3	1.8	5.0	0.6	29.2	89.7	6.4	48.1	40.9	144.3	-103.4	126.9
VT46	4.0	1.7	4.9	0.6	27.3	84.2	6.1	45.2	38.6	135.5	-96.9	118.9
VT48	4.7	1.5	3.2	1.0	25.1	75.4	4.0	37.7	35.5	117.0	-81.5	111.5
VT49	3.4	1.2	2.9	0.4	23.5	67.2	4.1	34.2	31.4	105.5	-74.1	103.4
VT50	3.4	1.1	2.8	0.4	22.7	66.2	3.9	33.7	30.5	103.9	-73.4	101.4
VT53	3.2	1.5	4.8	0.5	26.1	74.0	5.8	37.9	36.2	117.7	-81.6	118.7

Table L-4. Continued.

Site ID	Ca	Mg	Na	K	NH_4	SO_4	Cl	NO_3	SBC	SAA	Calk	Precip Vol (cm/yr)
VT54	4.8	1.5	3.5	0.5	28.3	88.2	4.9	45.8	38.7	138.9	-100.2	132.3
VT55	4.1	1.3	3.0	0.5	24.8	76.6	4.2	39.2	33.7	120.0	-86.3	114.6
VT56	4.1	1.3	3.3	0.5	24.9	77.8	4.5	40.9	34.2	123.2	-89.0	115.1
VT57	3.8	1.3	3.2	0.5	23.4	72.6	4.3	38.1	32.1	115.0	-82.9	109.9
VT58	2.5	1.3	5.0	0.4	22.0	55.2	5.4	27.4	31.1	88.0	-56.9	107.9
VT59	2.6	1.4	5.8	0.4	23.3	59.4	6.1	29.5	33.5	94.9	-61.4	114.8
VT62	2.8	1.4	5.1	0.4	24.5	61.9	5.7	30.8	34.2	98.4	-64.1	117.4
VT66	2.6	1.4	5.7	0.4	23.0	57.3	5.9	28.3	33.1	91.5	-58.4	117.1
VT68	4.4	1.9	5.4	0.6	30.8	95.5	6.9	51.0	43.2	153.3	-110.1	131.4
VT70	4.2	1.8	5.2	0.6	29.5	91.7	6.6	49.0	41.4	147.3	-105.9	126.9
VT72	4.6	1.9	5.4	0.7	31.6	98.3	6.9	52.4	44.1	157.6	-113.4	136.1
VT73	4.5	1.8	5.3	0.7	30.7	95.6	6.7	50.9	43.0	153.1	-110.2	131.6
VT74	4.3	1.8	5.1	0.6	30.2	93.8	6.5	49.8	42.0	150.1	-108.1	128.2
VT75	2.6	1.4	5.5	0.4	23.1	57.8	5.9	28.7	33.0	92.4	-59.3	116.1
VT76	4.1	1.5	4.0	0.7	26.0	79.5	5.1	42.0	36.4	126.6	-90.2	112.5
VT77	4.2	1.6	4.3	0.7	26.9	81.3	5.4	43.4	37.7	130.1	-92.5	116.3
VT78	4.8	1.3	2.8	0.7	24.0	73.0	3.5	39.7	33.6	116.2	-82.6	122.7
WOR	3.6	1.6	5.2	0.5	28.0	82.7	6.4	43.0	39.0	132.0	-93.0	123.7
WOR1	3.6	1.6	5.2	0.5	28.0	82.7	6.4	43.0	39.0	132.0	-93.0	123.7
WV523S	8.4	1.9	3.3	0.8	38.0	133.5	5.5	70.7	52.4	209.7	-157.3	159.9
WV531S	8.3	1.6	2.5	0.6	31.5	121.5	4.2	62.5	44.5	188.2	-143.7	132.1
WV547S	5.9	1.4	2.5	0.6	26.4	96.1	3.8	52.1	36.7	152.0	-115.2	126.6
WV548S	5.6	1.3	2.5	0.6	25.9	92.4	3.8	50.4	35.9	146.6	-110.6	127.8
WV769S	8.1	1.7	2.7	0.7	31.6	120.9	4.4	63.6	44.7	188.9	-144.2	140.2
WV770S	6.6	1.4	2.4	0.6	27.1	101.5	3.8	53.2	38.1	158.5	-120.5	122.9
WV771S	7.4	1.4	2.1	0.6	27.3	106.9	3.7	55.3	38.8	165.9	-127.2	112.2
WV785S	4.5	1.1	2.1	0.6	20.5	69.1	3.0	38.0	28.7	110.1	-81.4	107.8
WV788S	6.0	1.4	2.6	0.6	27.3	99.2	4.0	53.7	38.0	156.9	-118.9	132.0
WV796S	7.6	1.7	3.0	0.7	33.8	118.7	4.9	62.8	46.9	186.5	-139.6	146.8

Table L-5. The components of SO_4, NO_3, and NH_4 deposition (wet, dry, occult, and total) for each SAMI site for the SAMI Reference Year (1995). These data were calculated from the Reference Year wet deposition values and the assigned dry-to-wet and occult-to-wet ratios from the ASTRAP model (except for the high elevation sites in the Great Smoky Mountains National Park which use ratios from the Integrated Forestry Study). The deposition is in meq/m²/yr (the units used in the effects models). The table is arranged alphabetically in ascending order by SAMI ID. The number of sites is 164.

	SO_4 Wet	SO_4 Dry	SO_4 Occult	SO_4 Total	NO_3 Wet	NO_3 Dry	NO_3 Occult	NO_3 Total	NH_4 Wet	NH_4 Dry	NH_4 Occult	NH_4 Total
Average	47.5	30.0	16.6	94.1	22.8	17.8	8.2	48.8	13.7	10.8	5.0	29.5
Std. Dev.	10.8	11.5	19.1	32.5	5.4	9.2	7.0	17.3	2.3	5.8	4.4	10.2
Maximum	74.0	67.7	131.8	273.2	36.4	65.1	46.7	145.2	20.9	40.7	29.3	90.9
Minimum	28.6	11.7	0.0	51.9	13.1	5.8	0.0	25.7	9.0	4.7	0.0	19.2
Site ID	**SO_4 Wet**	**SO_4 Dry**	**SO_4 Occult**	**SO_4 Total**	**NO_3 Wet**	**NO_3 Dry**	**NO_3 Occult**	**NO_3 Total**	**NH_4 Wet**	**NH_4 Dry**	**NH_4 Occult**	**NH_4 Total**
2A068015U	39.8	17.5	18.2	75.5	18.6	8.2	13.0	39.8	12.0	5.3	8.3	25.6
2A07701	40.5	24.5	13.4	78.4	17.6	13.1	7.0	37.7	11.8	8.8	4.7	25.3
2A07805	31.6	20.7	9.4	61.8	14.5	11.5	5.0	31.0	9.2	7.3	3.2	19.6
2A07806	39.4	19.3	16.3	74.9	17.3	9.8	11.1	38.2	11.2	6.3	7.2	24.8
2A07810L	34.2	22.4	10.2	66.7	16.0	12.7	5.5	34.3	10.1	8.0	3.5	21.6
2A07810U	40.7	26.7	12.1	79.4	18.8	14.9	6.5	40.2	11.9	9.4	4.1	25.3
2A07811	30.7	20.2	9.1	60.0	14.1	11.2	4.9	30.1	9.0	7.1	3.1	19.2
2A07812	51.5	25.2	21.3	97.9	22.7	12.8	14.7	50.2	14.5	8.2	9.4	32.1
2A07816	44.9	29.4	13.4	87.7	20.5	16.2	7.1	43.8	13.2	10.4	4.6	28.1
2A07817	47.4	31.1	14.1	92.6	21.9	17.3	7.6	46.8	14.0	11.1	4.8	30.0
2A07821	31.7	15.5	13.1	60.3	13.5	7.6	8.7	29.9	9.8	5.5	6.3	21.6
2A07823	36.6	23.6	7.2	67.4	16.6	13.7	4.9	35.2	10.8	8.9	3.2	22.9
2A07828	44.0	28.4	8.7	81.0	19.7	16.3	5.9	41.8	12.9	10.7	3.9	27.5
2A07829	47.2	23.1	19.5	89.8	20.7	11.7	13.4	45.7	14.1	8.0	9.1	31.3
2A07834	33.6	21.7	6.6	61.8	15.1	12.4	4.5	32.0	10.2	8.4	3.0	21.7
2A07835	37.0	18.1	15.3	70.3	16.1	9.1	10.4	35.5	11.3	6.4	7.3	25.0
2A07882	45.9	22.5	19.0	87.3	20.5	11.5	13.2	45.2	13.4	7.6	8.7	29.7
2A08802	55.1	43.2	7.9	106.2	23.4	23.9	5.1	52.4	16.8	17.1	3.6	37.6
2A08804	62.5	48.9	8.9	120.3	26.5	27.0	5.7	59.2	19.8	20.2	4.3	44.3
2A08805	46.3	36.2	6.6	89.1	19.9	20.3	4.3	44.4	14.3	14.6	3.1	31.9
2A08810	51.1	40.0	7.3	98.5	22.2	22.7	4.8	49.7	16.3	16.6	3.5	36.4
2A08901	42.3	27.3	8.3	78.0	18.8	15.5	5.6	39.9	12.9	10.7	3.9	27.5
2B041020L	44.8	21.0	16.5	82.2	22.0	12.6	8.3	42.9	14.4	8.2	5.4	28.1
2B041049U	35.2	16.5	12.9	64.6	17.0	9.8	6.4	33.2	11.7	6.7	4.4	22.9
2B047032	51.2	31.6	11.5	94.3	25.6	19.2	5.2	49.9	13.7	10.3	2.8	26.8
2B047044U	49.7	30.6	11.2	91.5	24.8	18.6	5.0	48.4	13.5	10.1	2.7	26.3
2B047076L	39.7	33.6	0.0	73.3	18.9	18.7	0.0	37.6	12.7	12.6	0.0	25.2
2B047076U	45.7	38.7	0.0	84.5	21.9	21.7	0.0	43.5	14.7	14.5	0.0	29.2
2B058015U	44.1	28.6	12.2	85.0	22.0	16.6	6.5	45.0	13.3	10.0	3.9	27.2
2C041033U	74.0	45.7	16.7	136.4	36.0	27.0	7.3	70.3	18.1	13.6	3.7	35.4
2C041039	66.3	40.9	15.0	122.2	32.3	24.3	6.5	63.2	16.0	12.1	3.2	31.4
2C041040	62.8	38.8	14.2	115.8	30.9	23.2	6.2	60.3	15.5	11.7	3.1	30.3
2C041043U	49.6	23.3	18.3	91.1	24.2	13.9	9.1	47.3	13.8	7.9	5.2	26.8
2C041045	58.9	36.4	13.3	108.6	28.9	21.7	5.8	56.4	14.2	10.7	2.9	27.7
2C041051	65.3	40.3	14.7	120.4	32.4	24.4	6.5	63.3	16.2	12.1	3.3	31.6
2C046013L	53.3	29.5	18.7	101.6	27.1	16.9	10.3	54.4	13.6	8.5	5.2	27.2
2C046033	50.8	28.2	17.9	96.9	26.2	16.4	10.0	52.6	13.4	8.3	5.1	26.8

Table L-5. Continued.

Site ID	SO_4 Wet	SO_4 Dry	SO_4 Occult	SO_4 Total	NO_3 Wet	NO_3 Dry	NO_3 Occult	NO_3 Total	NH_4 Wet	NH_4 Dry	NH_4 Occult	NH_4 Total
2C046034	56.5	31.3	19.9	107.7	28.9	18.0	11.0	57.9	14.9	9.3	5.7	29.9
2C046043L	51.0	28.2	17.9	97.1	26.4	16.5	10.1	52.9	13.6	8.5	5.2	27.2
2C046043U	50.4	28.0	17.7	96.1	26.1	16.3	9.9	52.3	13.4	8.4	5.1	26.9
2C046050	39.6	22.0	13.9	75.5	21.3	13.3	8.1	42.7	10.9	6.8	4.2	21.9
2C046053L	44.8	24.9	15.8	85.5	23.5	14.6	8.9	47.0	12.1	7.6	4.6	24.3
2C046062L	42.9	23.8	15.1	81.7	22.6	14.1	8.6	45.3	11.8	7.4	4.5	23.7
2C047007	55.2	34.1	12.5	101.8	27.4	20.6	5.5	53.6	13.9	10.4	2.8	27.1
2C047010L	57.1	35.2	12.9	105.3	28.6	21.5	5.8	55.9	14.9	11.2	3.0	29.1
2C047010U	57.7	35.6	13.0	106.3	28.9	21.7	5.8	56.4	15.1	11.3	3.0	29.4
2C057004	37.9	21.0	13.3	72.3	20.6	12.9	7.9	41.4	10.7	6.7	4.1	21.4
2C066026L	58.1	59.9	10.7	128.8	24.1	27.0	3.0	54.1	16.0	17.9	2.0	36.0
2C066027L	58.6	60.4	10.8	129.8	24.3	27.1	3.0	54.4	15.7	17.6	2.0	35.3
2C066027U	59.2	61.1	10.9	131.3	24.5	27.4	3.1	54.9	15.9	17.8	2.0	35.6
2C066039L	60.0	61.9	11.1	133.0	24.6	27.5	3.1	55.1	16.5	18.5	2.1	37.1
2C077022U	58.4	45.7	8.4	112.4	24.2	24.7	5.2	54.0	18.0	18.4	3.9	40.3
BJ 35	40.8	17.9	18.7	77.5	18.0	7.9	12.6	38.5	12.3	5.4	8.6	26.3
BJ 72	44.5	18.4	21.2	84.1	19.3	8.0	14.7	42.1	13.3	5.5	10.1	28.9
BJ 76	40.5	16.7	19.3	76.6	18.3	7.6	13.9	39.8	11.9	4.9	9.1	25.9
BJ 77	40.5	16.7	19.3	76.4	17.9	7.4	13.6	38.9	12.1	5.0	9.2	26.3
BLFC	41.3	26.8	11.4	79.5	20.6	15.5	6.0	42.0	12.7	9.6	3.7	26.0
CO01	51.3	40.2	7.4	98.9	21.7	22.1	4.7	48.5	16.1	16.4	3.5	36.0
CO05	40.1	31.4	5.7	77.2	16.9	17.3	3.6	37.8	12.5	12.8	2.7	28.0
CO06	61.7	48.3	8.8	118.8	26.1	26.6	5.6	58.3	18.9	19.3	4.1	42.3
CO10	44.2	34.6	6.3	85.1	18.7	19.1	4.0	41.8	13.7	14.0	3.0	30.7
DR	42.6	36.1	0.0	78.6	20.4	20.2	0.0	40.7	13.5	13.4	0.0	26.9
DR01	42.6	36.1	0.0	78.6	20.4	20.2	0.0	40.7	13.5	13.4	0.0	26.9
DS04	57.8	27.1	21.3	106.2	29.2	16.7	11.0	56.8	15.4	8.8	5.8	30.0
DS06	57.8	27.1	21.3	106.2	29.2	16.7	11.0	56.8	15.4	8.8	5.8	30.0
DS09	57.8	27.1	21.3	106.2	29.2	16.7	11.0	56.8	15.4	8.8	5.8	30.0
DS19	57.8	27.1	21.3	106.2	29.2	16.7	11.0	56.8	15.4	8.8	5.8	30.0
DS50	57.8	27.1	21.3	106.2	29.2	16.7	11.0	56.8	15.4	8.8	5.8	30.0
FN1	73.6	45.4	16.6	135.7	36.3	27.3	7.3	70.9	17.8	13.4	3.6	34.8
FN2	71.6	44.2	16.2	132.0	35.3	26.5	7.1	69.0	17.3	13.0	3.5	33.8
FN3	73.8	45.6	16.7	136.0	36.4	27.3	7.3	71.0	17.8	13.4	3.6	34.8
GS01	73.6	67.7	131.8	273.2	33.4	65.1	46.7	145.2	20.9	40.7	29.3	90.9
GS02	73.6	67.7	131.8	273.1	33.4	65.1	46.7	145.1	20.9	40.7	29.2	90.9
GS04	62.5	57.5	111.9	232.0	28.3	55.2	39.7	123.2	17.8	34.6	24.9	77.3
GS05	44.7	41.1	80.0	165.8	21.0	40.9	29.4	91.2	13.0	25.4	18.3	56.8
GS06	31.6	20.7	9.4	61.8	14.7	11.7	5.1	31.5	9.3	7.4	3.2	19.9
GS07	49.1	45.1	87.8	182.0	22.1	43.2	31.0	96.3	14.3	27.8	20.0	62.1
GS08	55.2	50.8	98.8	204.7	24.9	48.5	34.8	108.1	15.9	31.0	22.3	69.2
LB01	45.3	27.3	15.0	87.6	19.7	14.6	7.9	42.1	13.1	9.7	5.2	28.1
LEWF	42.1	27.3	11.6	81.1	19.9	14.9	5.8	40.6	13.0	9.8	3.8	26.6
M037	41.3	26.8	11.4	79.5	20.6	15.5	6.0	42.0	12.7	9.6	3.7	26.0
M038	41.3	26.8	11.4	79.5	20.6	15.5	6.0	42.0	12.7	9.6	3.7	26.0
M039	41.3	26.8	11.4	79.5	20.6	15.5	6.0	42.0	12.7	9.6	3.7	26.0
NFD	41.1	16.8	16.8	74.7	19.0	8.4	9.8	37.2	15.2	6.7	7.8	29.7
NFDR	41.1	16.8	16.8	74.7	19.0	8.4	9.8	37.2	15.2	6.7	7.8	29.7

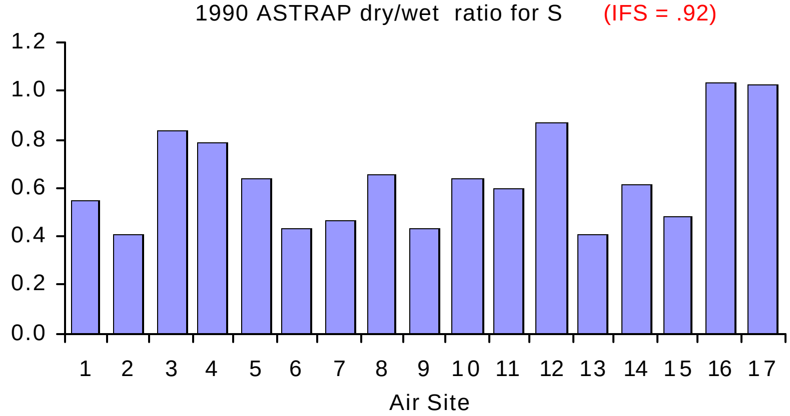
Table L-5. Continued.

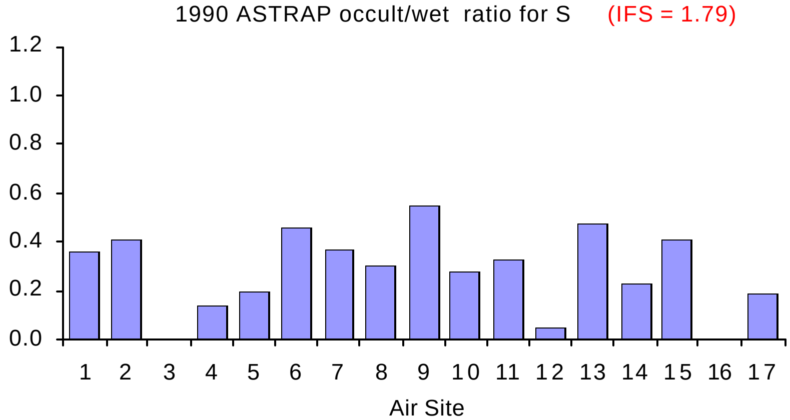
Site ID	SO_4 Wet	SO_4 Dry	SO_4 Occult	SO_4 Total	NO_3 Wet	NO_3 Dry	NO_3 Occult	NO_3 Total	NH_4 Wet	NH_4 Dry	NH_4 Occult	NH_4 Total
OC02	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC05	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC08	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC09	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC31	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC32	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC35	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
OC79	64.1	39.6	14.5	118.2	31.9	24.0	6.4	62.2	15.9	12.0	3.2	31.2
PAIN	43.9	37.2	0.0	81.2	21.4	21.2	0.0	42.6	13.6	13.5	0.0	27.1
SP10	38.0	39.8	0.0	77.8	18.3	22.3	0.0	40.6	15.0	18.2	0.0	33.1
SP39	39.2	41.0	0.0	80.2	18.8	22.9	0.0	41.7	15.4	18.6	0.0	34.0
SP41	38.4	40.2	0.0	78.6	18.7	22.6	0.0	41.3	15.2	18.4	0.0	33.6
STAN	32.1	27.2	0.0	59.4	14.8	14.7	0.0	29.5	11.7	11.6	0.0	23.3
VA524S	38.7	16.8	21.3	76.8	18.9	9.3	11.1	39.4	11.1	5.5	6.6	23.2
VA526S	38.5	33.5	1.7	73.7	19.2	19.5	1.4	40.1	10.4	10.6	0.8	21.7
VA531S	28.6	11.7	11.7	51.9	13.1	5.8	6.7	25.7	10.5	4.7	5.4	20.6
VA548S	35.2	14.4	14.4	64.0	16.5	7.3	8.5	32.3	12.2	5.4	6.3	23.9
VA555S	43.5	28.2	12.0	83.7	21.8	16.4	6.4	44.7	12.5	9.4	3.7	25.6
VA821S	34.5	15.0	19.0	68.6	16.8	8.3	9.9	35.1	10.4	5.1	6.1	21.7
VT02	42.1	27.3	11.6	81.1	19.9	14.9	5.8	40.6	13.0	9.8	3.8	26.6
VT05	36.6	16.0	16.7	69.3	17.3	7.6	12.1	37.1	11.2	4.9	7.8	24.0
VT07	41.8	18.2	23.0	83.0	20.3	10.0	11.9	42.2	12.4	6.1	7.3	25.8
VT08	39.8	17.3	21.9	79.1	19.4	9.6	11.4	40.4	11.8	5.8	6.9	24.5
VT09	41.3	18.0	22.7	82.1	19.9	9.9	11.8	41.6	12.1	6.0	7.1	25.3
VT10	45.0	29.2	12.4	86.6	22.8	17.1	6.7	46.6	12.6	9.5	3.7	25.8
VT11	47.3	30.7	13.1	91.1	24.2	18.2	7.1	49.5	13.5	10.1	4.0	27.6
VT12	44.7	29.0	12.3	86.0	22.9	17.2	6.7	46.7	12.8	9.6	3.7	26.1
VT15	41.4	26.8	11.4	79.6	21.1	15.9	6.2	43.2	11.9	8.9	3.5	24.2
VT18	54.5	33.6	12.3	100.4	27.5	20.7	5.5	53.7	14.6	11.0	3.0	28.6
VT19	55.8	34.4	12.6	102.8	28.1	21.1	5.7	54.9	15.0	11.3	3.0	29.3
VT20	37.4	24.3	10.3	72.1	19.0	14.3	5.6	38.8	11.0	8.3	3.2	22.5
VT24	37.6	16.4	20.7	74.6	19.0	9.4	11.2	39.6	11.0	5.4	6.5	22.9
VT25	38.2	16.6	21.0	75.9	19.3	9.5	11.4	40.1	11.2	5.5	6.6	23.2
VT26	38.8	16.9	21.4	77.1	19.0	9.4	11.2	39.6	11.2	5.5	6.6	23.3
VT28	38.0	16.5	20.9	75.4	18.7	9.3	11.0	39.1	11.0	5.4	6.5	22.9
VT29	39.8	17.3	21.9	79.0	19.7	9.7	11.6	41.0	11.7	5.8	6.9	24.3
VT31	37.7	16.4	20.7	74.8	18.3	9.1	10.8	38.2	11.1	5.5	6.5	23.1
VT32	40.5	17.7	22.3	80.5	19.7	9.7	11.6	41.1	11.8	5.8	6.9	24.5
VT34	40.6	26.3	11.2	78.1	20.4	15.3	6.0	41.7	12.0	9.0	3.5	24.5
VT35	43.9	37.2	0.0	81.2	21.4	21.2	0.0	42.6	13.6	13.5	0.0	27.1
VT36	47.9	40.6	0.0	88.4	23.5	23.2	0.0	46.7	14.8	14.6	0.0	29.4
VT37	46.9	19.2	19.1	85.3	23.2	10.3	11.9	45.4	13.7	6.1	7.0	26.7
VT38	49.2	20.2	20.1	89.4	24.5	10.9	12.6	48.0	14.2	6.3	7.3	27.8
VT39	46.8	39.7	0.0	86.5	23.4	23.2	0.0	46.6	14.3	14.1	0.0	28.4
VT41	48.6	41.2	0.0	89.7	24.2	23.9	0.0	48.1	14.7	14.5	0.0	29.2
VT46	43.7	28.4	12.1	84.2	22.1	16.6	6.5	45.2	13.4	10.0	3.9	27.3
VT48	37.9	16.5	20.9	75.4	18.1	8.9	10.6	37.7	12.0	6.0	7.1	25.1
VT49	36.6	17.1	13.5	67.2	17.6	10.1	6.6	34.2	12.0	6.9	4.5	23.5

Table L-5. Continued.

Site ID	SO_4 Wet	SO_4 Dry	SO_4 Occult	SO_4 Total	NO_3 Wet	NO_3 Dry	NO_3 Occult	NO_3 Total	NH_4 Wet	NH_4 Dry	NH_4 Occult	NH_4 Total
VT50	36.1	16.9	13.3	66.2	17.3	9.9	6.5	33.7	11.7	6.7	4.4	22.7
VT53	40.1	34.0	0.0	74.0	19.0	18.8	0.0	37.9	13.1	13.0	0.0	26.1
VT54	48.0	22.5	17.7	88.2	23.5	13.5	8.8	45.8	14.5	8.3	5.5	28.3
VT55	41.7	19.5	15.3	76.6	20.1	11.5	7.6	39.2	12.7	7.3	4.8	24.8
VT56	42.8	17.5	17.5	77.8	20.9	9.3	10.7	40.9	12.7	5.6	6.5	24.9
VT57	40.0	16.4	16.3	72.6	19.5	8.6	10.0	38.1	12.0	5.3	6.1	23.4
VT58	30.4	12.5	12.4	55.2	14.0	6.2	7.2	27.4	11.2	5.0	5.8	22.0
VT59	32.1	27.2	0.0	59.4	14.8	14.7	0.0	29.5	11.7	11.6	0.0	23.3
VT62	34.0	14.0	13.9	61.9	15.8	7.0	8.1	30.8	12.5	5.6	6.4	24.5
VT66	31.5	12.9	12.9	57.3	14.4	6.4	7.4	28.3	11.8	5.2	6.0	23.0
VT68	49.6	32.2	13.7	95.5	24.9	18.7	7.3	51.0	15.1	11.3	4.4	30.8
VT70	47.6	30.9	13.2	91.7	24.0	18.0	7.0	49.0	14.4	10.9	4.2	29.5
VT72	51.1	33.1	14.1	98.3	25.6	19.3	7.5	52.4	15.4	11.6	4.5	31.6
VT73	49.7	32.2	13.7	95.6	24.9	18.7	7.3	50.9	15.0	11.3	4.4	30.7
VT74	48.7	31.6	13.5	93.8	24.4	18.3	7.1	49.8	14.7	11.1	4.3	30.2
VT75	31.8	13.0	13.0	57.8	14.7	6.5	7.5	28.7	11.8	5.2	6.1	23.1
VT76	41.3	26.8	11.4	79.5	20.6	15.5	6.0	42.0	12.7	9.6	3.7	26.0
VT77	42.3	27.4	11.7	81.3	21.2	15.9	6.2	43.4	13.1	9.9	3.9	26.9
VT78	38.5	16.9	17.6	73.0	18.6	8.2	13.0	39.7	11.2	4.9	7.8	24.0
WOR	44.7	37.9	0.0	82.7	21.6	21.4	0.0	43.0	14.1	13.9	0.0	28.0
WOR1	44.7	37.9	0.0	82.7	21.6	21.4	0.0	43.0	14.1	13.9	0.0	28.0
WV523S	72.7	34.1	26.7	133.5	36.3	20.8	13.7	70.7	19.5	11.2	7.3	38.0
WV531S	65.9	40.7	14.9	121.5	32.0	24.1	6.5	62.5	16.1	12.1	3.3	31.5
WV547S	50.4	28.0	17.7	96.1	26.0	16.2	9.9	52.1	13.2	8.2	5.0	26.4
WV548S	48.5	26.9	17.0	92.4	25.2	15.7	9.6	50.4	12.9	8.1	4.9	25.9
WV769S	65.6	40.5	14.8	120.9	32.6	24.5	6.6	63.6	16.2	12.1	3.3	31.6
WV770S	55.1	34.0	12.4	101.5	27.2	20.5	5.5	53.2	13.9	10.4	2.8	27.1
WV771S	58.0	35.8	13.1	106.9	28.3	21.3	5.7	55.3	14.0	10.5	2.8	27.3
WV785S	36.3	20.1	12.7	69.1	19.0	11.8	7.2	38.0	10.2	6.4	3.9	20.5
WV788S	52.1	28.9	18.3	99.2	26.8	16.7	10.2	53.7	13.6	8.5	5.2	27.3
WV796S	64.6	30.3	23.8	118.7	32.2	18.5	12.1	62.8	17.4	9.9	6.5	33.8

Dry/Wet, Occult/Wet, and Total/Wet ratios for deposition of S





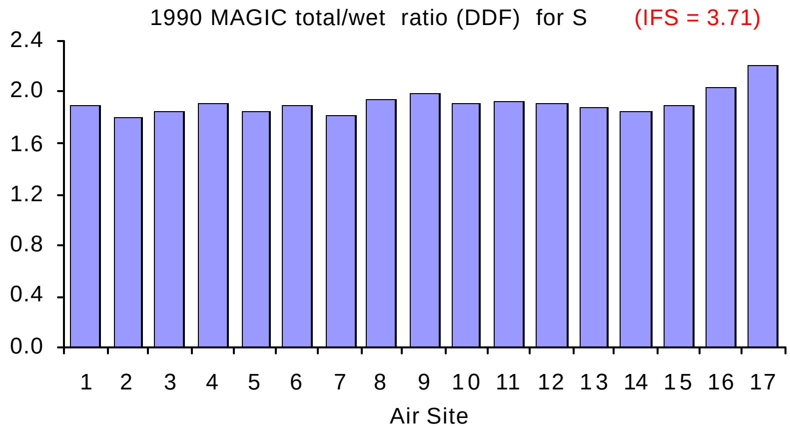


Figure L-1. The values of the dry-to-wet deposition ratios (upper panel), the occult-to-wet deposition values (middle panel) and the dry deposition factor, DDF, calculated from the ratios (lower panel) for each ASTRAP location for S deposition. The ASTRAP locations are identified on the x-axis by Air Site Number. The locations of these air sites are given in Table L-3. The IFS values given in parentheses on each panel were used for the high elevation sites in the Great Smoky Mountains National Park.

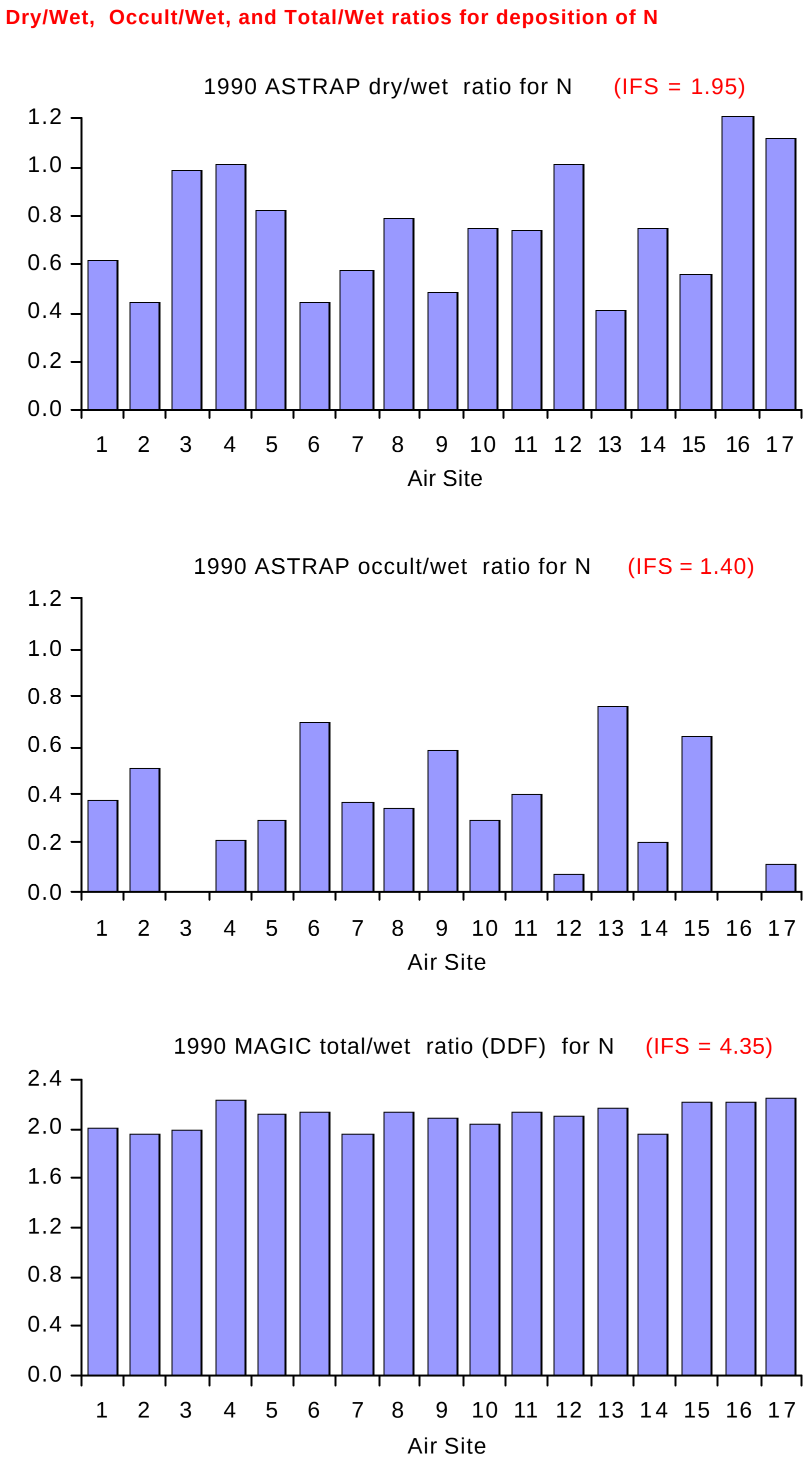


Figure L-2. The values of the dry-to-wet deposition ratios (upper panel), the occult-to-wet deposition values (middle panel) and the dry deposition factor, DDF, calculated from the ratios (lower panel) for each ASTRAP location for N deposition. The ASTRAP locations are identified on the x-axis by Air Site Number. The locations of these air sites are given in Table L-3. The IFS values given in parentheses on each panel were used for the high elevation sites in the Great Smoky Mountains National Park.

Assignment of Historical Scaled Sequences to SAMI sites Based on ASTRAP Modelled Deposition

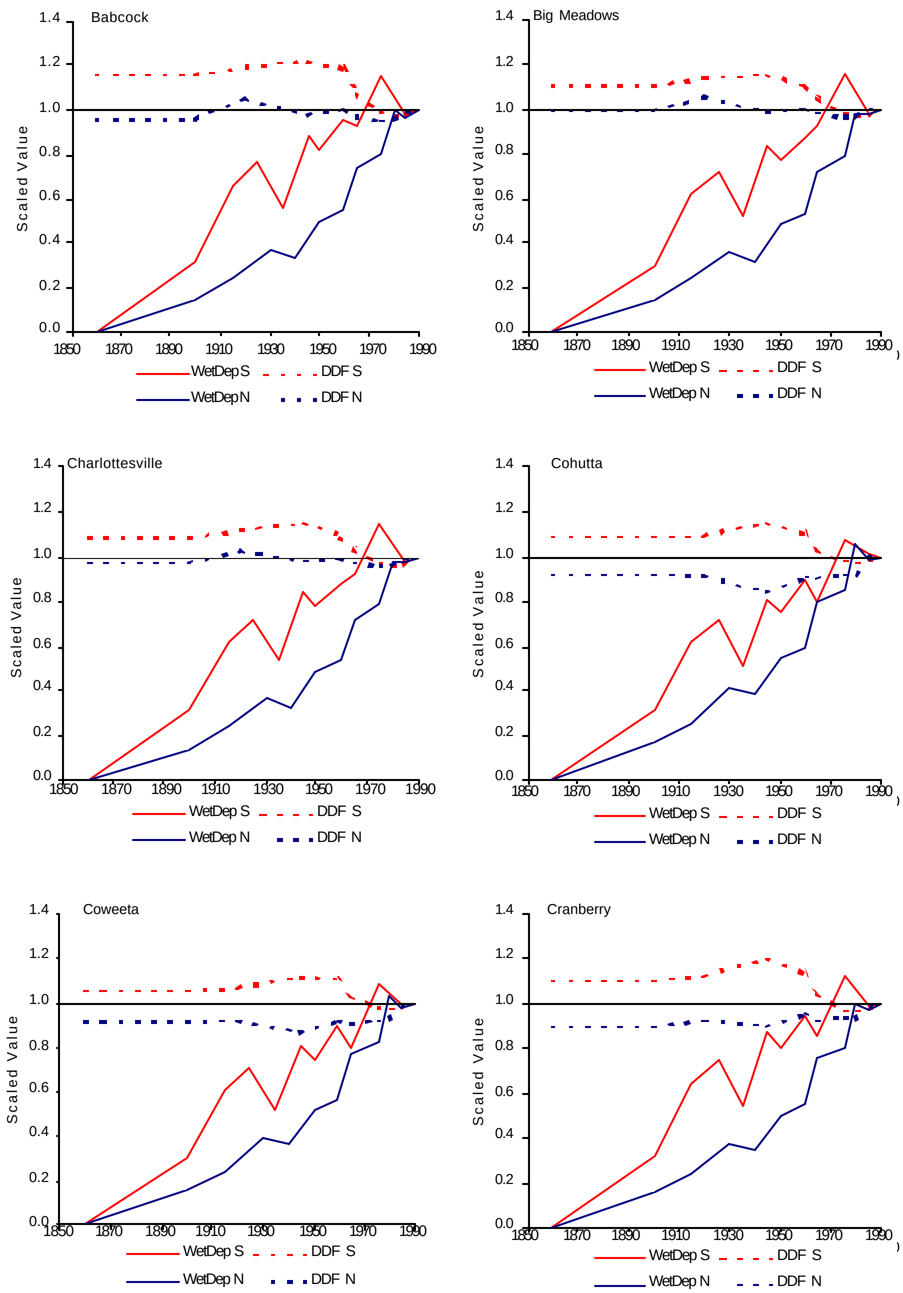


Figure L-3 The scaled past sequences of wet deposition and DDF for both S and N for each ASTRAP location. Each SAMI site was assigned one of these scaled sequences for estimation of past deposition (these assignments are noted in Table L-1).

Assignment of Historical Scaled Sequences to SAMI sites Based on ASTRAP Modelled Deposition

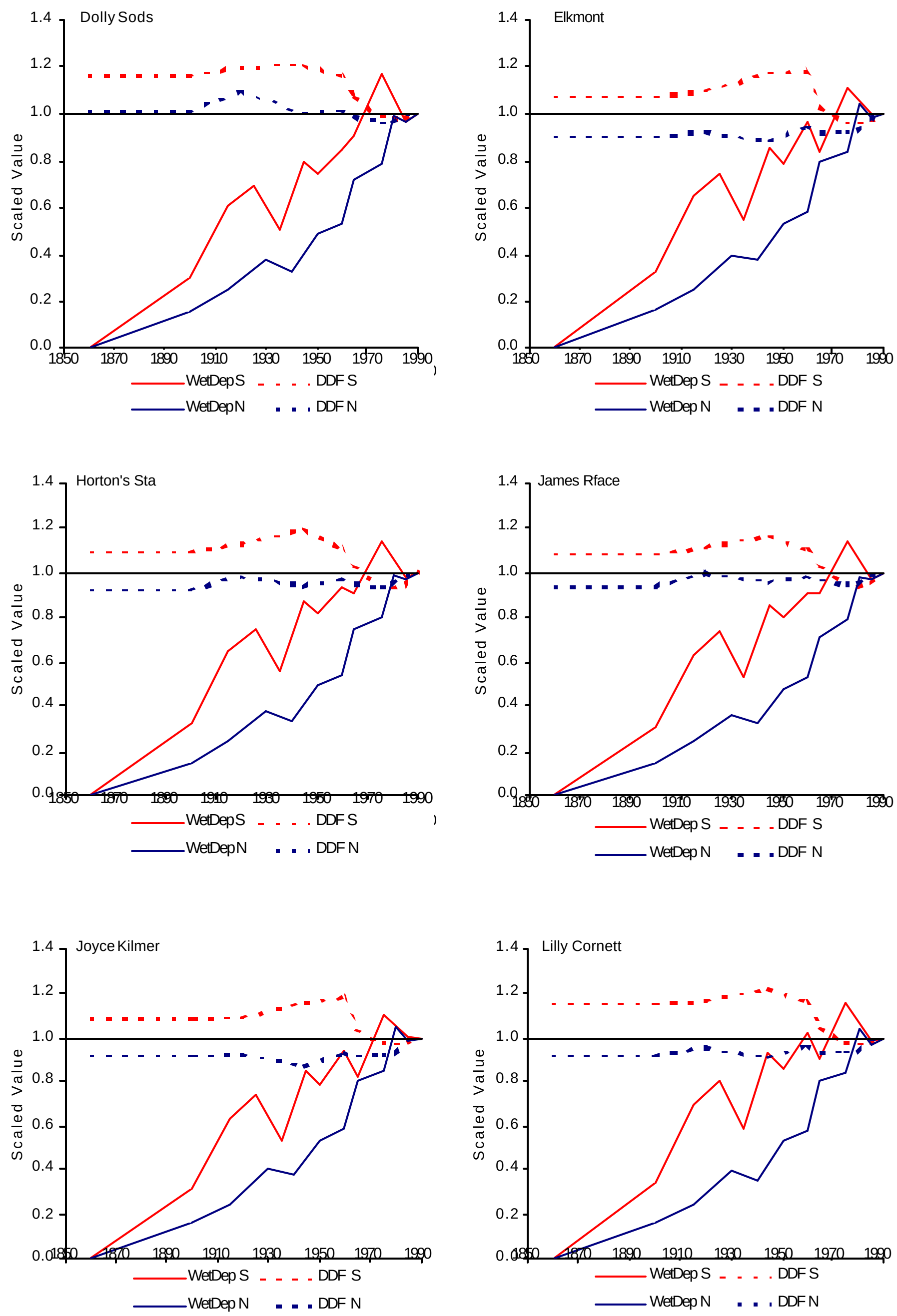


Figure L-3 Continued.

Assignment of Historical Scaled Sequences to SAMI sites Based on ASTRAP Modelled Deposition

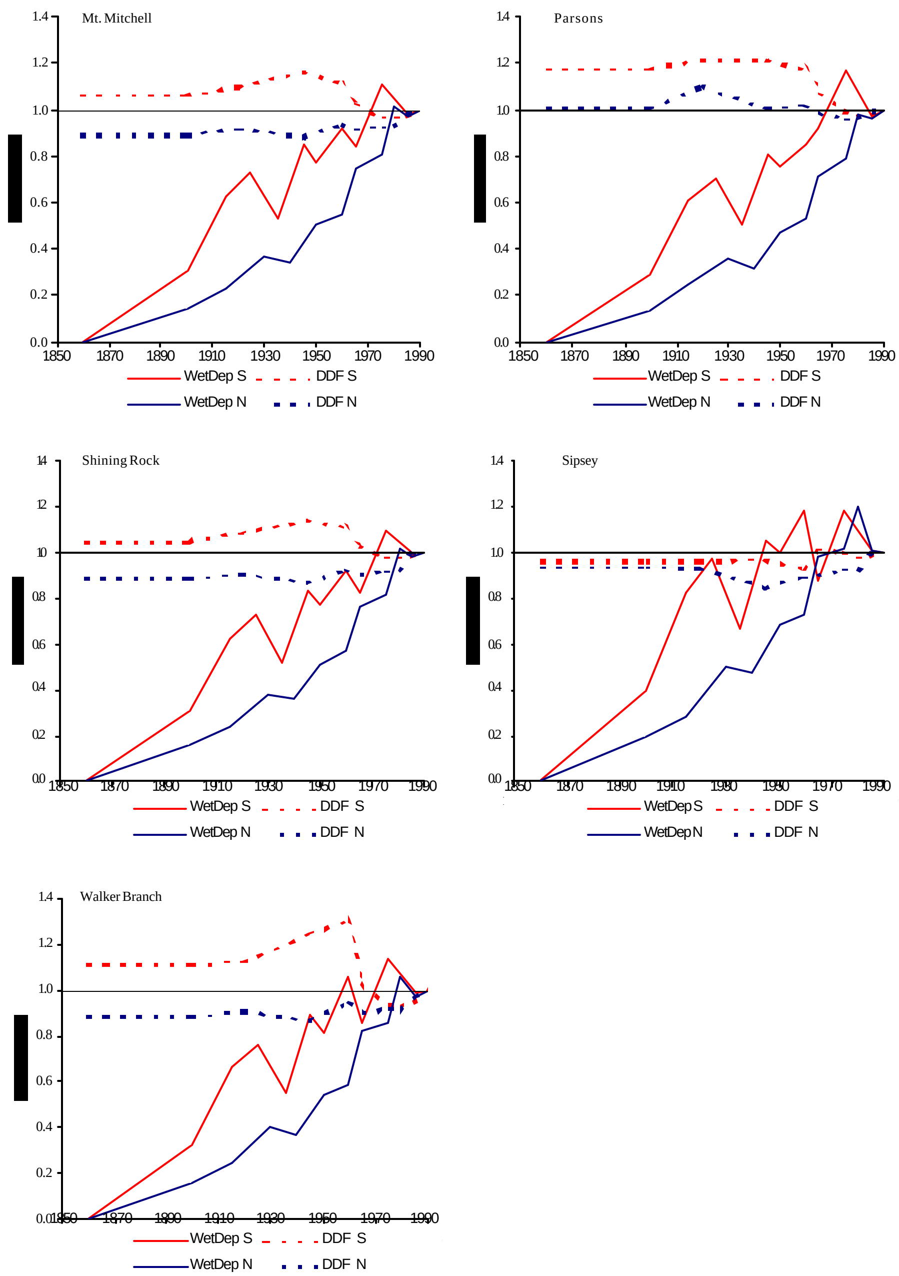
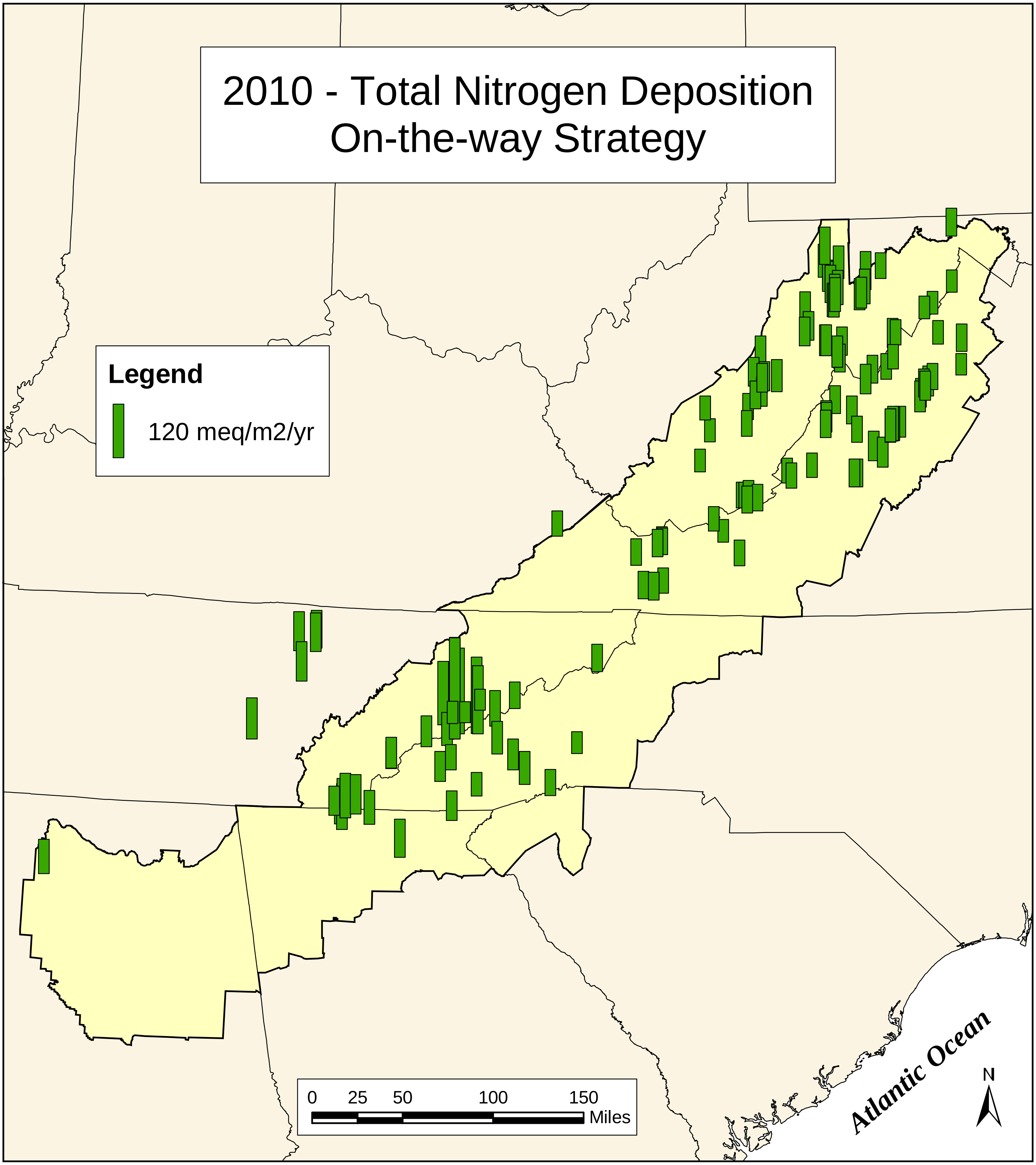
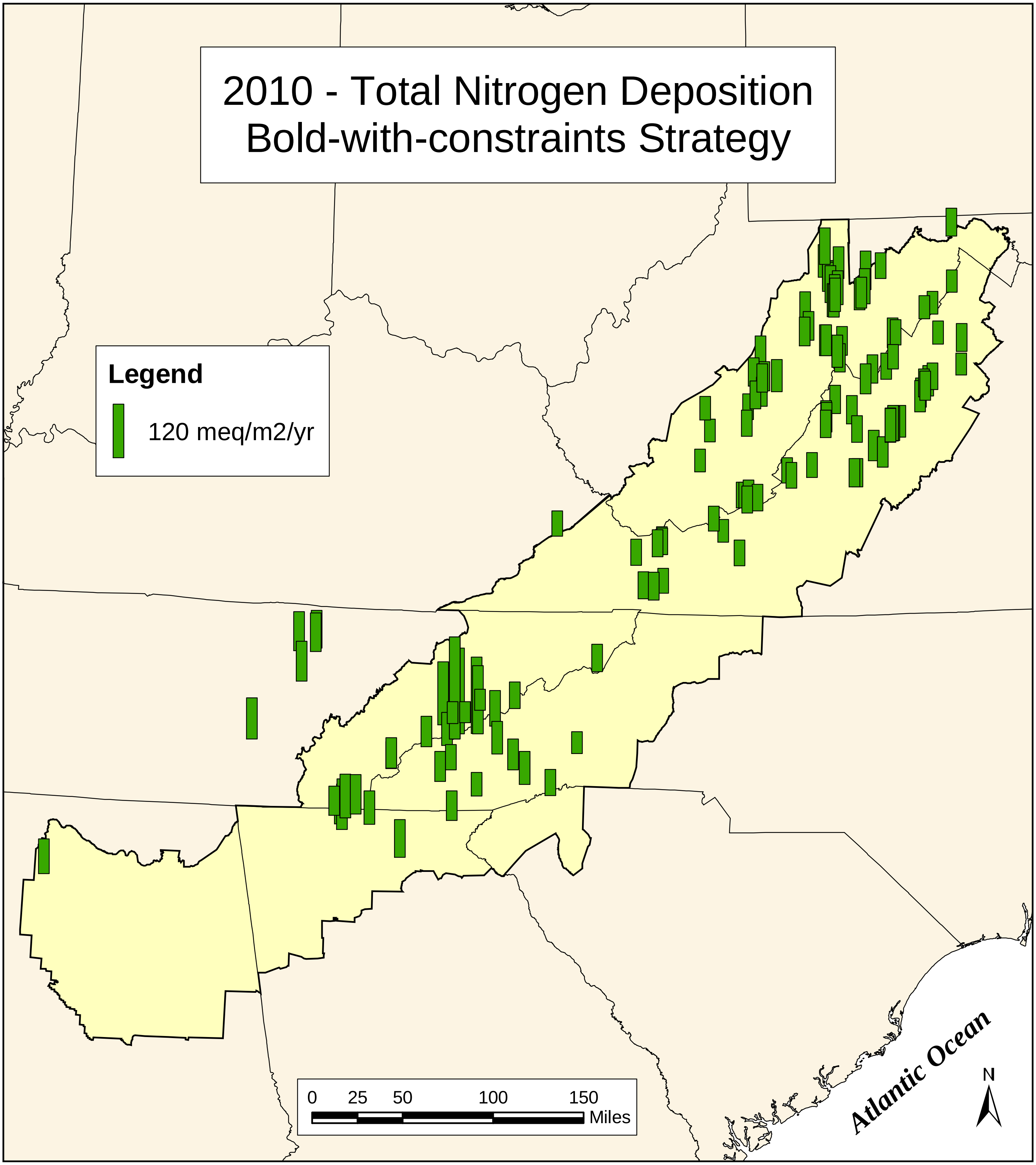


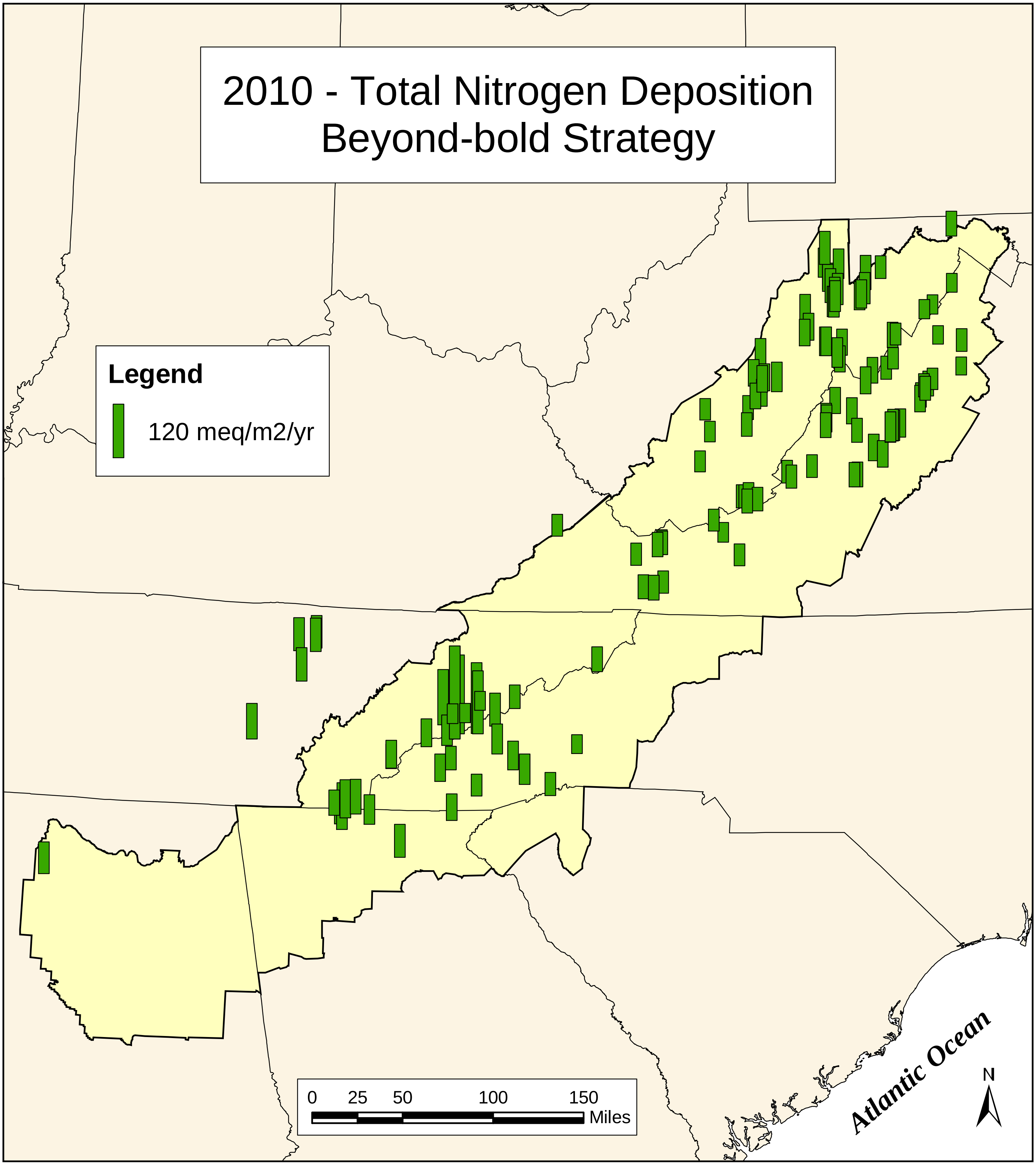
Figure L-3 Continued.

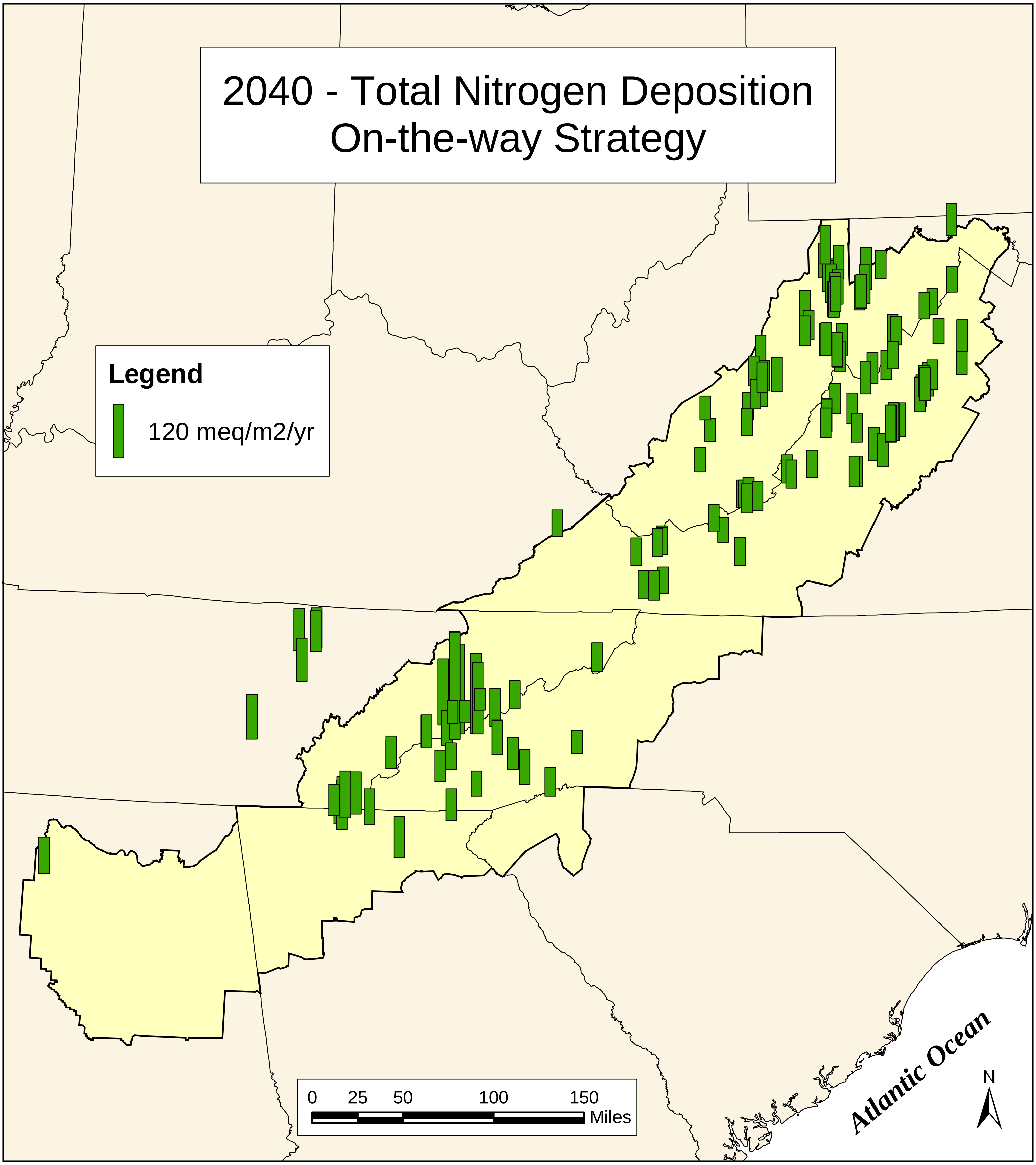
APPENDIX M

MAPS SHOWING ESTIMATED DEPOSITION VALUES AT EACH OF THE REGIONAL MODELING SITES UNDER EACH OF THE EMISSIONS CONTROL STRATEGIES

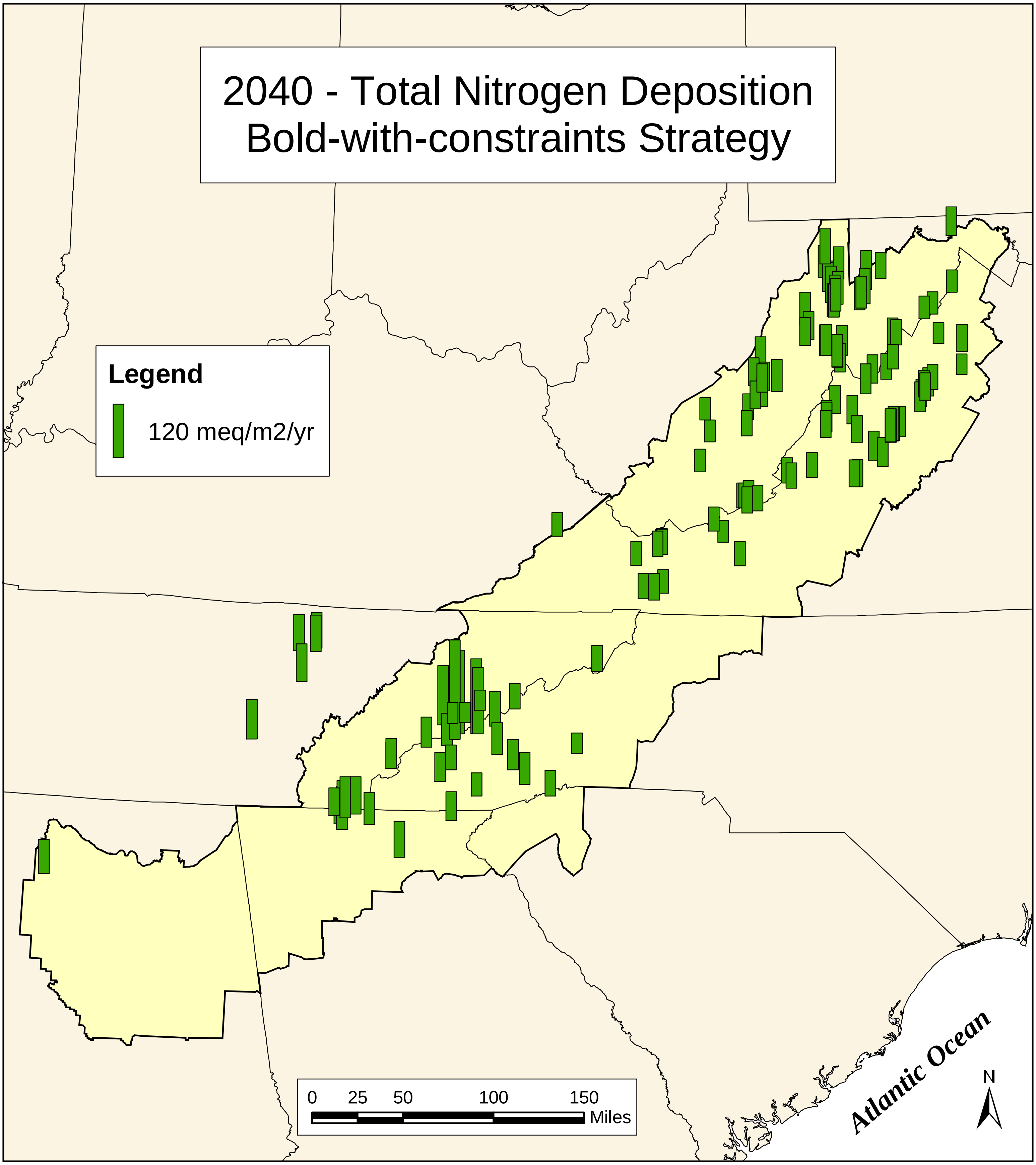

2010 - Total Nitrogen Deposition
On-the-way Strategy
Legend
120 meq/m2/yr
0 25 50 100 150
Miles
Atlantic Ocean
N


2010 - Total Nitrogen Deposition
Bold-with-constraints Strategy
Legend
120 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N

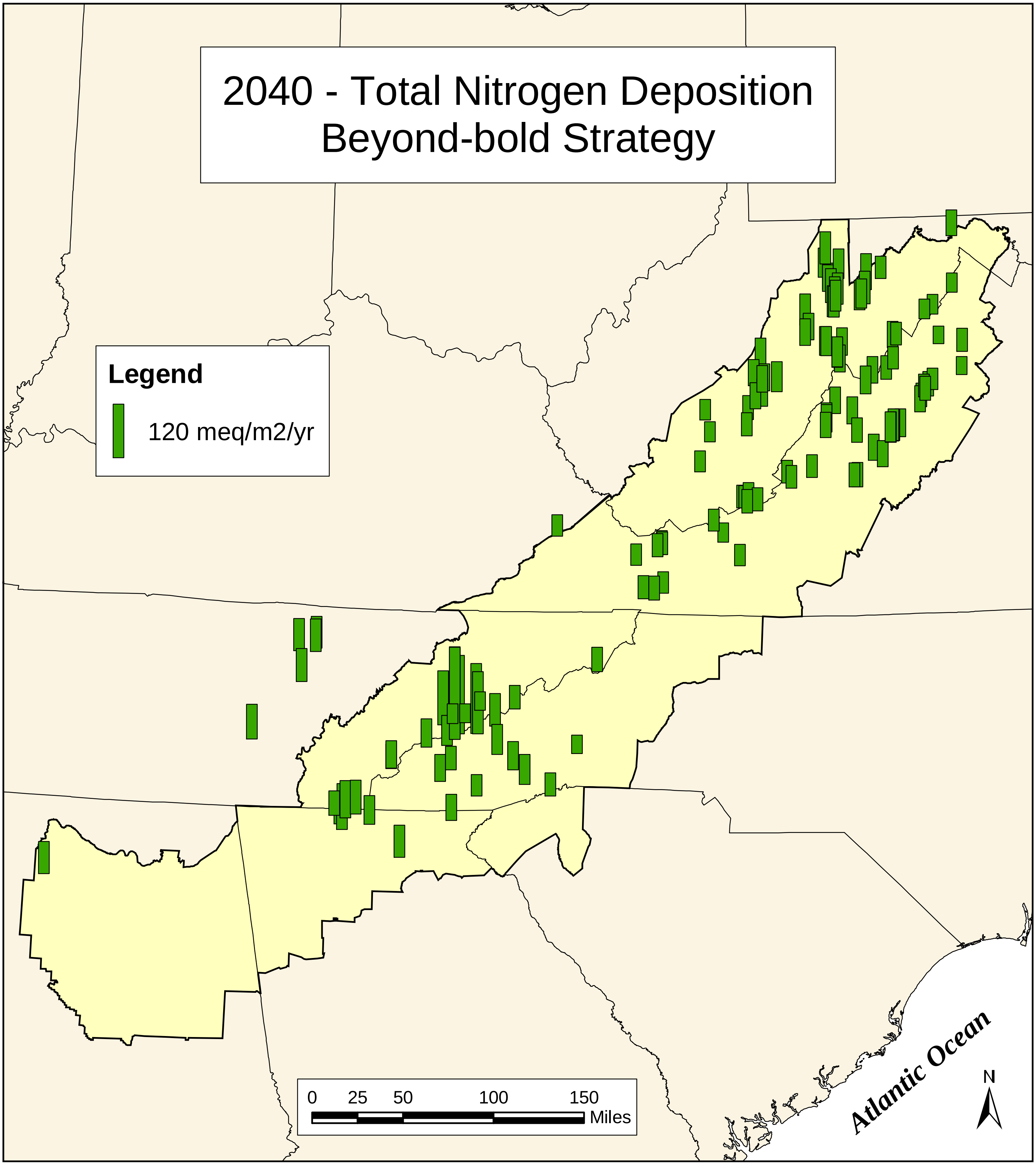

2010 - Total Nitrogen Deposition
Beyond-bold Strategy
Legend
120 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N

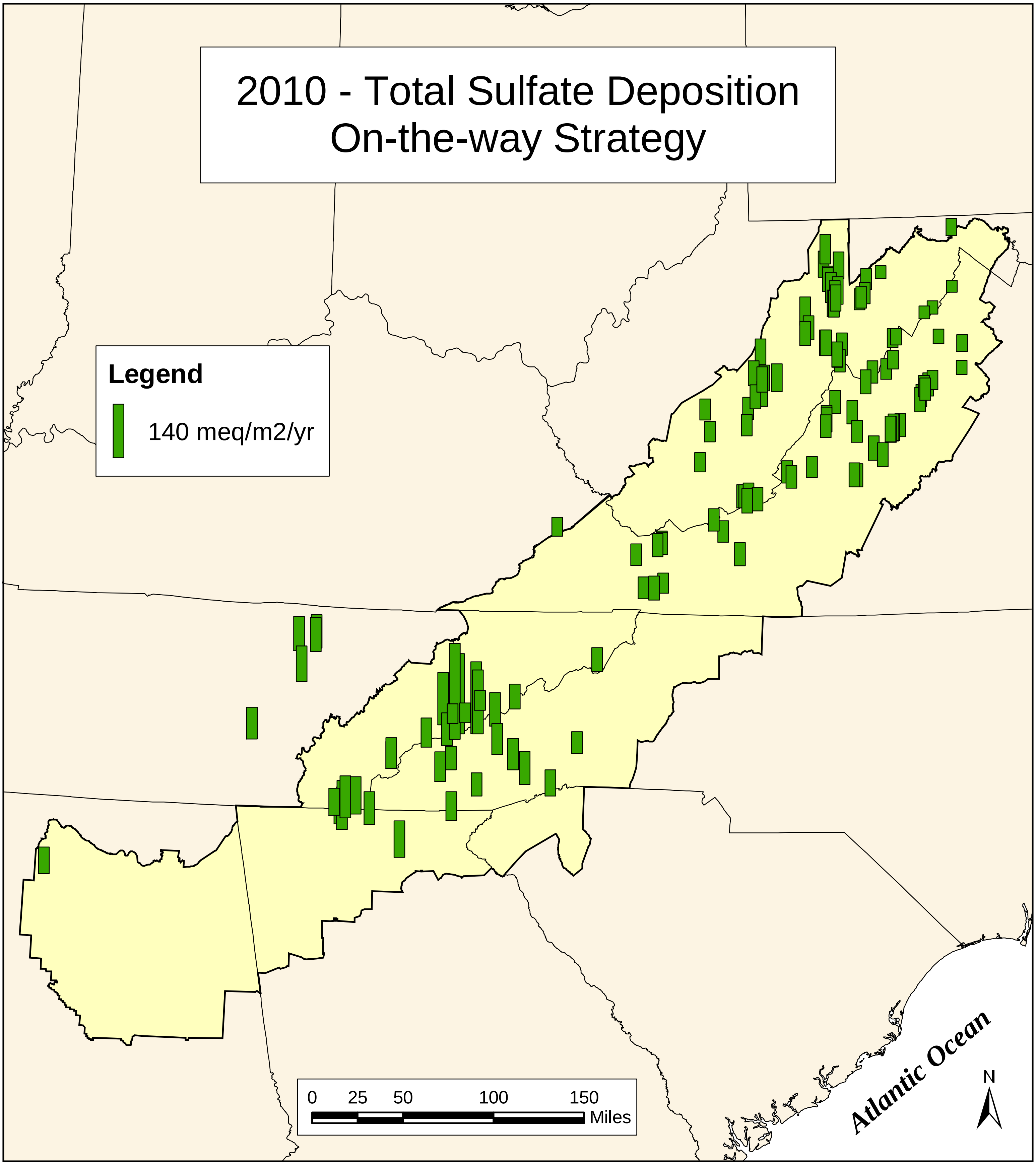


2040 - Total Nitrogen Deposition
On-the-way Strategy
Legend
120 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N

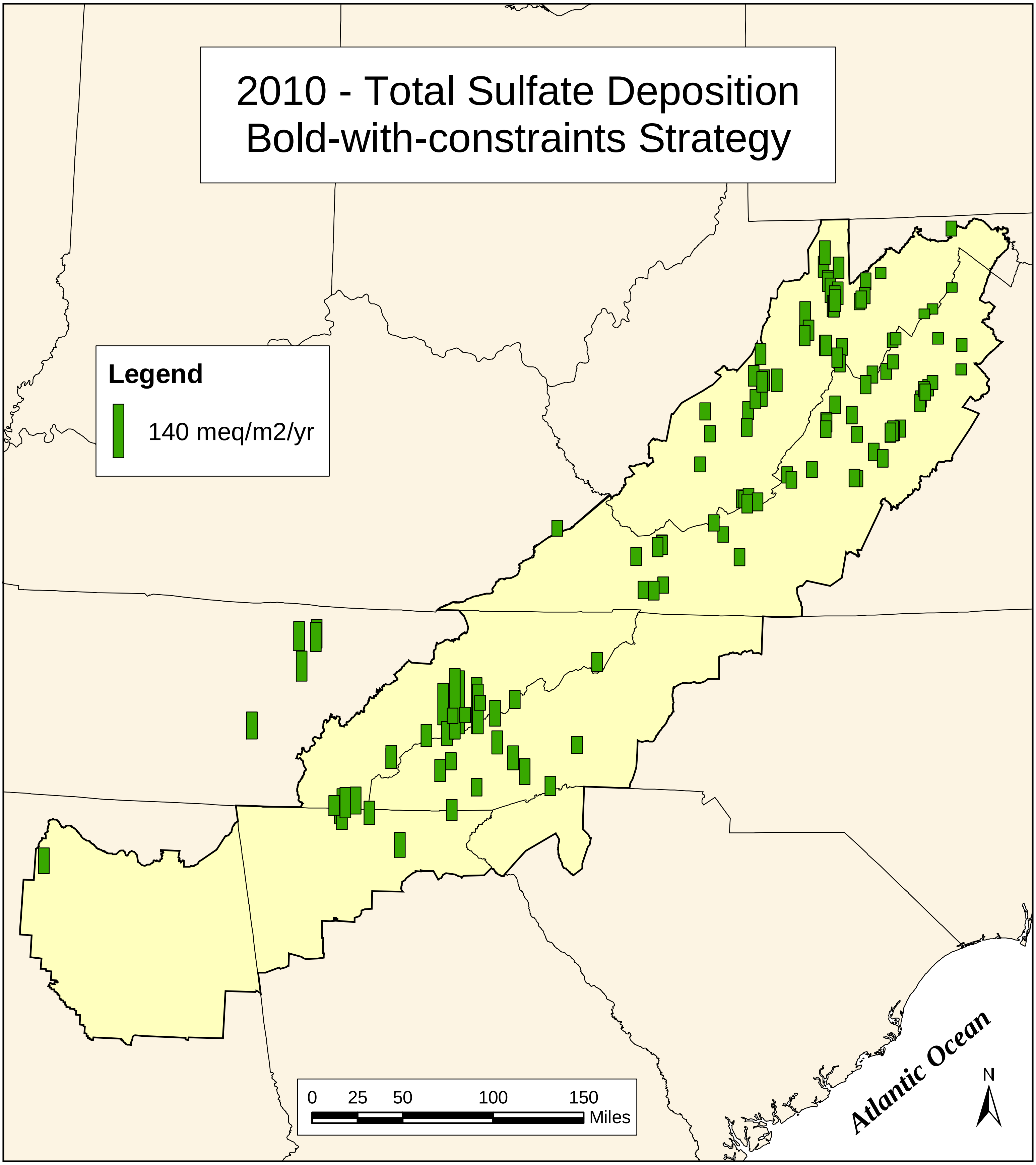


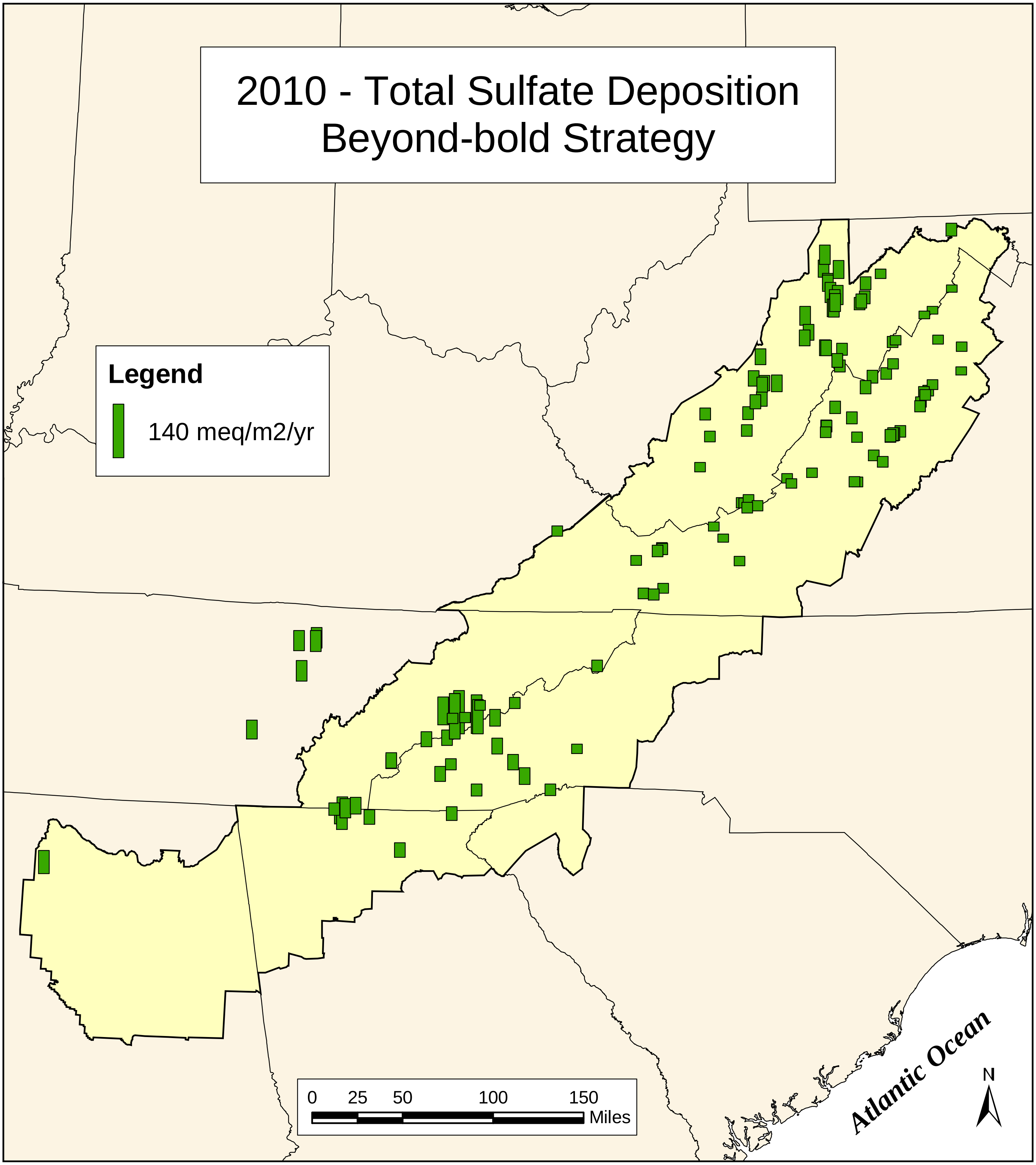
2040 - Total Nitrogen Deposition
Bold-with-constraints Strategy
Legend
120 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N

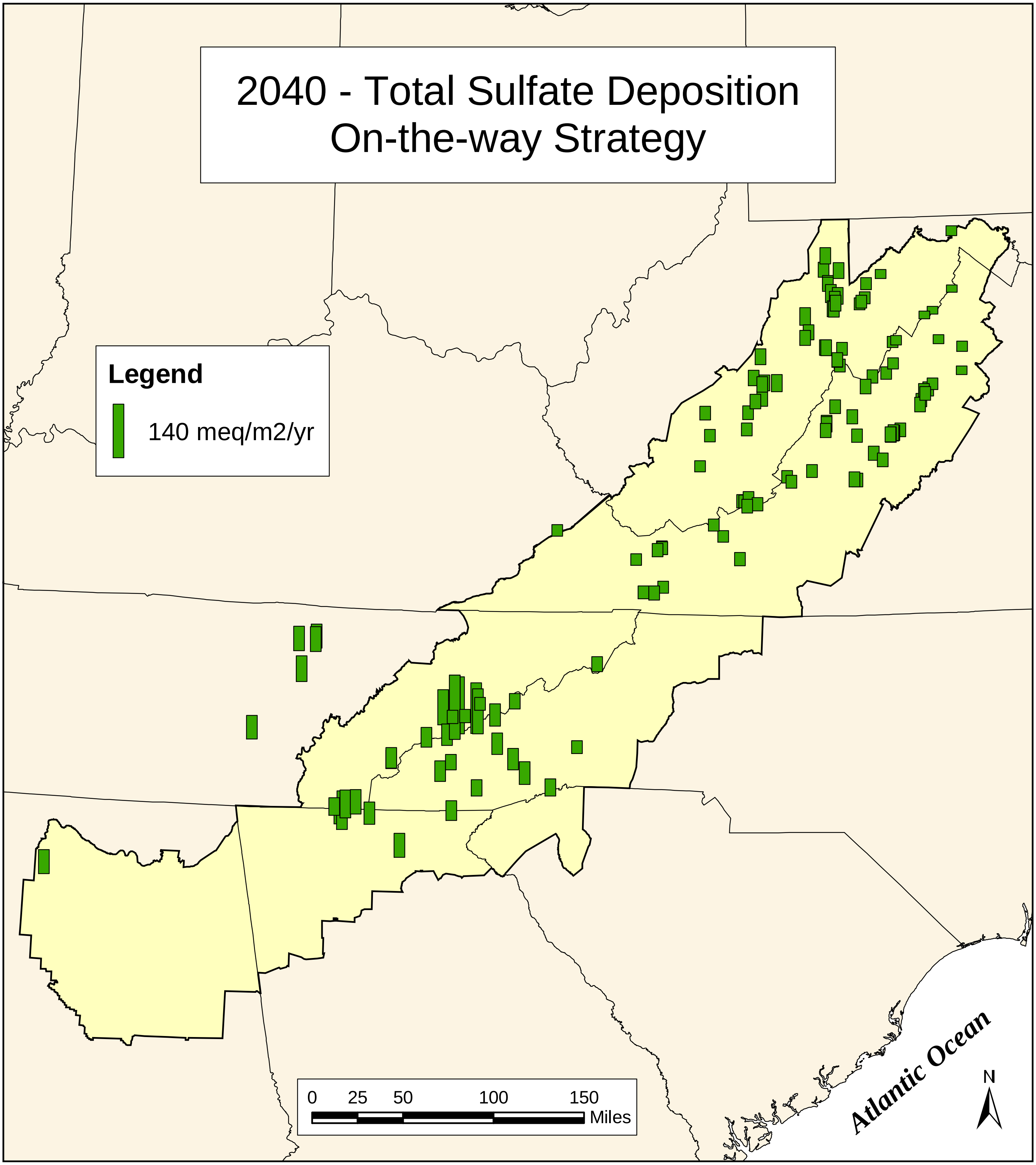

2040 - Total Nitrogen Deposition
Beyond-bold Strategy
Legend
120 meq/m2/yr
0 25 50 100 150
Miles
Atlantic Ocean
N

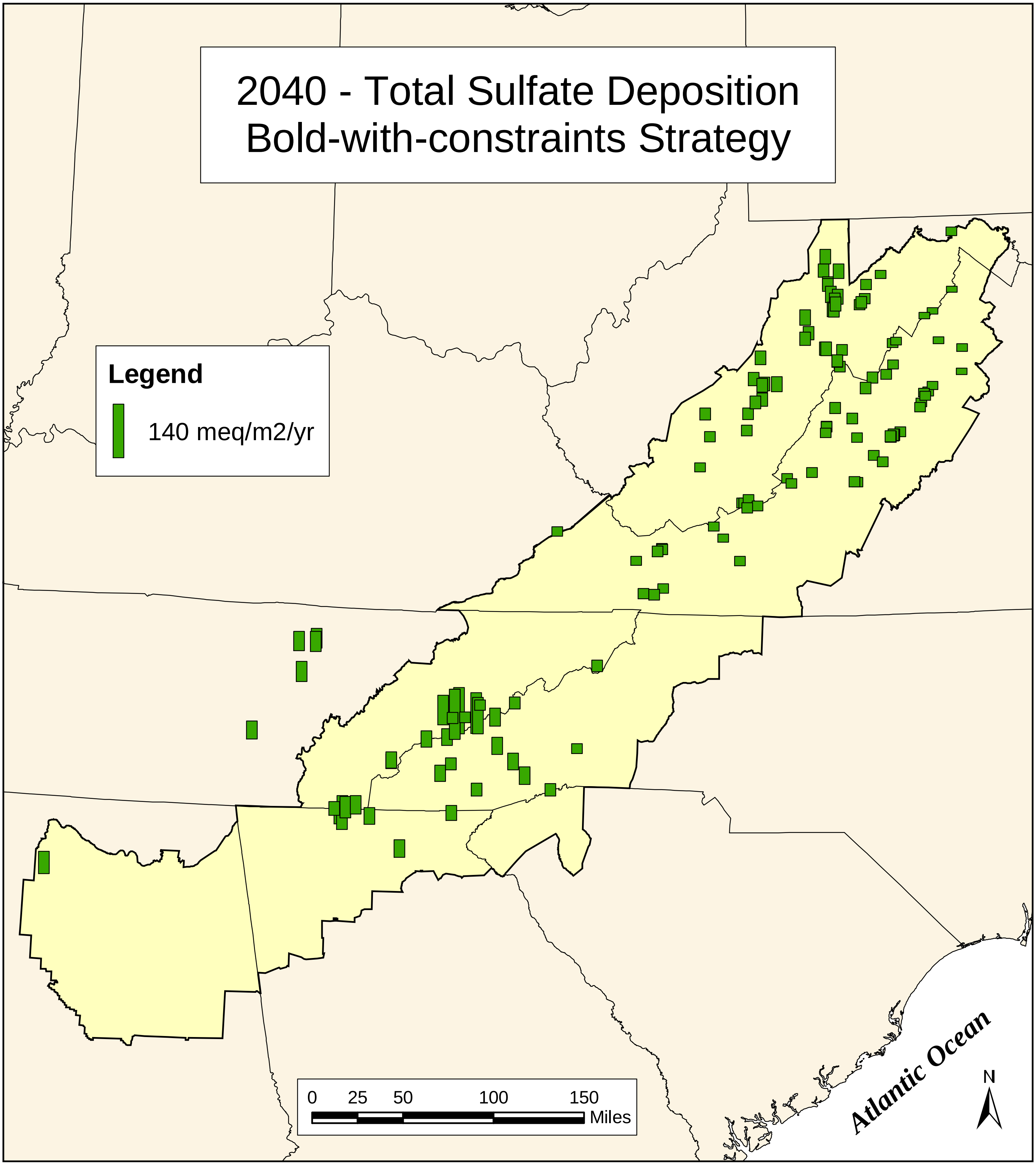


2010 - Total Sulfate Deposition
On-the-way Strategy
Legend
140 meq/m2/yr
0 25 50 100 150
Miles
Atlantic Ocean
N

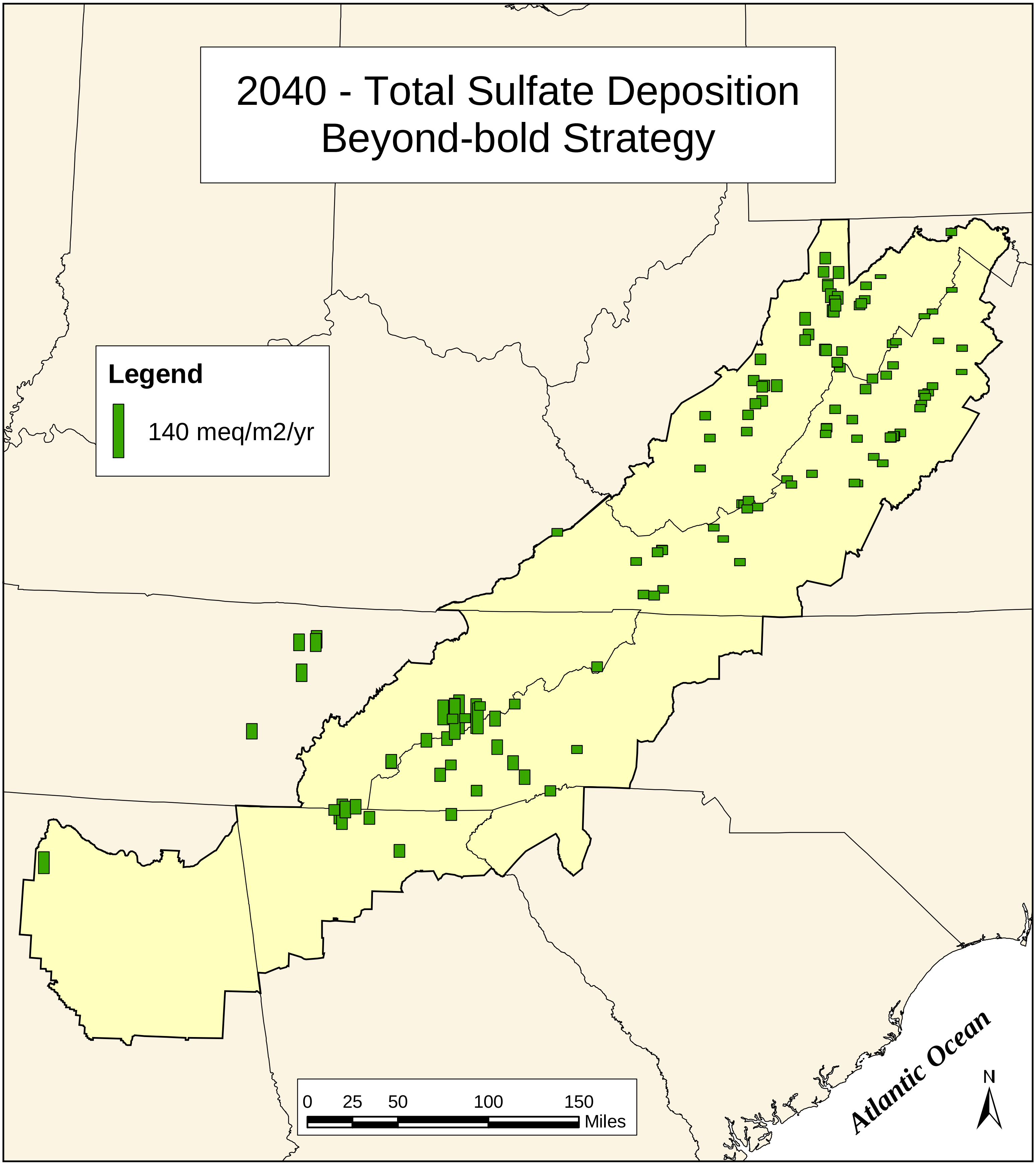

2010 - Total Sulfate Deposition
Bold-with-constraints Strategy
Legend
140 meq/m2/yr
0 25 50 100 150
Miles
Atlantic Ocean
N


2010 - Total Sulfate Deposition
Beyond-bold Strategy
Legend
140 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N


2040 - Total Sulfate Deposition
On-the-way Strategy
Legend
140 meq/m2/yr
0 25 50 100 150
Miles
Atlantic Ocean
N



2040 - Total Sulfate Deposition
Bold-with-constraints Strategy
Legend
140 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N



2040 - Total Sulfate Deposition
Beyond-bold Strategy
Legend
140 meq/m2/yr
0
25
50
100
150
Miles
Atlantic Ocean
N

APPENDIX N

ASSIGNMENT OF LITHOLOGIC UNITS TO ECOLOGICAL SENSITIVITY CLASSES

CLASS	PRIMARY LITHOLOGY	OTHER CLASSIFICATION INFORMATION
Argillaceous	black shale	
Argillaceous	claystone	
Argillaceous	conglomerate	graywacke
Argillaceous	conglomerate	mudstone
Argillaceous	conglomerate	shale
Argillaceous	graywacke	
Argillaceous	meta-argillite	
Argillaceous	metasedimentary rock	
Argillaceous	metasedimentary rock	graywacke
Argillaceous	metasedimentary rock	meta-argillite
Argillaceous	metasedimentary rock	mica schist
Argillaceous	metasedimentary rock	phyllite
Argillaceous	mudstone	
Argillaceous	phyllite	
Argillaceous	schist	
Argillaceous	sedimentary breccia	
Argillaceous	sedimentary breccia	mudstone clasts
Argillaceous	shale	
Argillaceous	siltstone	
Argillaceous	slate	
Carbonate	dolomite (dolostone)	
Carbonate	dolostone (dolomite)	
Carbonate	limestone	
Carbonate	marble	
Felsic	alaskite	
Felsic	augen gneiss	
Felsic	biotite gneiss	
Felsic	conglomerate	arkose
Felsic	dacite	
Felsic	felsic gneiss	
Felsic	felsic metavolcanic rock	
Felsic	felsic volcanic rock	
Felsic	gneiss	
Felsic	granite	
Felsic	granitic gneiss	
Felsic	granodiorite	
Felsic	granulite	
Felsic	mica schist	
Felsic	migmatite	granitic gneiss
Felsic	mylonite	gneiss
Felsic	orthogneiss	

CLASS	PRIMARY LITHOLOGY	OTHER CLASSIFICATION INFORMATION
Felsic	quartz diorite	
Felsic	quartz monzonite	
Felsic	rhyolite	
Felsic	sedimentary breccia	arkose
Felsic	syenite	
Mafic	amphibole schist	
Mafic	amphibolite	
Mafic	anorthosite	
Mafic	basalt	
Mafic	diabase	
Mafic	diorite	
Mafic	dunite	
Mafic	gabbro	
Mafic	greenstone	
Mafic	mafic gneiss	
Mafic	mafic metavolcanic rock	
Mafic	meta-basalt	
Mafic	metavolcanic rock	
Mafic	norite	
Mafic	peridotite	
Mafic	schist	actinolite schist
Mafic	ultramafic intrusive rock	
Siliceous	arenite	
Siliceous	chert	
Siliceous	conglomerate	
Siliceous	conglomerate	sandstone
Siliceous	metasandstone	
Siliceous	orthoquartzite	
Siliceous	quartzite	
Siliceous	sandstone	

APPENDIX O

SITE-SPECIFIC MAGIC MODEL OUTPUT

The major output variable for this project from the MAGIC modeling effort was streamwater ANC, in the 1995 reference year and projected values in the years 2010, 2040, and 2100. These data are listed in the following table for each of the modeled sites. ANC values in 1995 are indicated as REF 1995. Future projections were based on the scenario of constant deposition at 1995 levels (CON) and each of the three Emissions Control Strategies (OTW, BWC, BYB). Sites are also labeled according to ANC class (1, ≤ 0, 2, 0-20 μeq/L; 3, 20-50 μeq/L; 4, 50-150 μeq/L) and physiographic province. The data for 1995, 2010, and 2040 were provided to SAMI's socioeconomic contractor for evaluation of socioeconomic impacts associated with probable impacts on fisheries in the region.

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
VT39	1	-9.0	BLUERIDGE	-12.4	-11.8	-4.9	-11.4	-8.0	1.5	-10.4	-4.5	5.7	-14.7	-23.7	-36.0
VT68	1	-8.7	BLUERIDGE	-12.1	-10.5	-3.6	-10.9	-6.4	2.4	-9.8	-3.3	6.5	-14.0	-23.0	-34.3
VT36	1	-2.5	BLUERIDGE	-8.0	-8.3	1.6	-6.3	-1.2	14.7	-4.7	4.1	20.8	-10.5	-24.6	-47.1
VT74	2	2.2	BLUERIDGE	-2.0	-1.4	1.2	-0.9	2.5	5.8	0.1	5.4	9.5	-4.1	-14.9	-31.0
DR	2	2.4	BLUERIDGE	-2.0	4.2	9.9	0.2	12.0	18.9	2.9	15.9	22.8	-5.9	-19.2	-35.0
PAIN	2	3.5	BLUERIDGE	1.5	8.9	23.8	4.2	20.7	39.6	9.7	28.9	47.7	-4.2	-15.6	-30.8
2B058015U	2	4.5	BLUERIDGE	-0.3	4.9	19.7	2.1	12.5	30.0	4.4	19.2	36.6	-3.1	-13.9	-24.9
VT41	2	6.1	BLUERIDGE	2.2	0.3	8.5	3.4	5.8	14.8	4.2	10.0	18.6	0.2	-10.4	-29.1
GS01	2	9.4	BLUERIDGE	1.8	-11.6	-28.9	2.6	-4.2	-13.9	6.8	2.8	-4.0	0.0	-17.3	-54.0
BLFC	2	13.5	BLUERIDGE	7.1	1.3	-1.5	8.5	6.7	8.0	9.9	10.3	15.3	5.7	-10.2	-36.9
VT53	2	13.7	BLUERIDGE	11.1	13.7	20.9	13.4	19.3	29.3	15.2	23.1	33.7	5.9	-5.3	-26.0
BJ72	2	15.3	BLUERIDGE	10.7	4.6	1.2	11.5	8.5	7.8	12.9	12.2	12.7	10.3	1.3	-11.3
VT70	2	16.0	BLUERIDGE	12.8	11.6	13.6	13.5	14.2	19.5	14.1	16.4	23.3	11.2	2.1	-12.3
VT76	2	16.5	BLUERIDGE	10.7	6.4	6.3	11.9	11.6	14.8	13.3	15.9	20.7	9.2	-5.9	-27.6
GS02	2	17.7	BLUERIDGE	15.0	6.9	-2.7	15.4	12.3	6.2	18.8	16.8	12.7	13.4	4.3	-15.4
VT73	3	20.6	BLUERIDGE	17.3	17.0	20.2	18.1	20.0	26.8	19.2	23.3	31.0	14.7	4.5	-15.8
M039	3	22.0	BLUERIDGE	16.9	11.2	5.2	17.7	14.0	12.8	18.7	16.4	18.4	15.9	1.2	-22.1
BJ35	3	22.3	BLUERIDGE	14.1	2.6	0.6	14.9	12.7	14.7	21.8	22.8	25.9	8.6	-8.5	-32.2
2A07811	3	24.1	BLUERIDGE	18.9	9.9	-2.3	19.6	15.7	6.0	22.5	20.0	11.7	17.3	3.6	-23.2
CO01	3	24.3	BLUERIDGE	20.9	16.1	10.5	21.6	18.9	15.7	22.3	21.1	19.5	20.6	13.4	-0.2
GS07	3	25.2	BLUERIDGE	23.1	18.5	9.8	23.4	21.4	15.4	24.9	22.7	19.4	22.8	16.9	0.2
M038	3	26.7	BLUERIDGE	19.8	20.0	30.1	21.8	27.2	40.6	23.8	33.1	47.7	17.4	1.9	-16.3
LEWF	3	26.9	BLUERIDGE	21.0	9.2	2.2	21.6	15.4	13.6	25.3	22.5	22.6	19.3	0.7	-28.6
M037	3	27.8	BLUERIDGE	19.7	14.0	18.6	21.2	21.4	29.4	22.6	27.2	37.0	18.6	-3.4	-29.4
GS08	3	36.1	BLUERIDGE	34.6	30.4	25.6	34.9	32.6	28.7	36.7	34.8	30.9	33.8	29.8	20.7
VT02	3	37.0	BLUERIDGE	35.3	32.4	32.0	35.8	35.6	38.9	38.2	41.3	43.8	33.6	25.8	10.5
2A07817	3	39.4	BLUERIDGE	36.3	30.3	18.7	36.6	32.1	23.9	37.8	34.5	27.8	36.0	29.0	9.4
GS05	3	43.1	BLUERIDGE	40.8	37.4	31.0	41.1	38.4	33.3	41.5	39.6	35.5	40.5	35.3	23.1
BJ77	3	44.9	BLUERIDGE	43.4	40.4	36.2	43.7	41.3	38.1	43.8	42.3	39.5	43.2	39.3	30.6
LB01	3	46.2	BLUERIDGE	35.7	33.4	41.4	39.6	41.3	53.6	41.8	48.6	62.0	34.1	21.2	4.4

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
VT77	3	48.0	BLUERIDGE	42.7	38.8	37.7	44.0	43.3	45.2	45.3	46.9	50.8	41.3	27.6	5.6
BJ76	3	49.3	BLUERIDGE	46.2	41.9	34.6	46.5	44.2	39.3	47.4	45.1	41.2	46.0	40.5	28.0
2A07816	4	50.3	BLUERIDGE	47.4	42.4	34.3	47.7	44.1	37.5	48.4	45.6	40.0	47.0	39.8	24.1
CO05	4	50.7	BLUERIDGE	44.6	43.3	47.6	47.1	50.8	57.4	49.8	56.9	64.6	43.6	32.8	19.6
2A07834	4	51.3	BLUERIDGE	49.6	46.9	42.9	49.9	47.5	44.7	50.4	48.7	45.6	49.4	46.4	39.1
VT48	4	53.5	BLUERIDGE	48.2	42.2	38.7	49.1	46.2	47.5	50.1	50.2	51.9	47.2	32.6	5.1
NFDR	4	55.2	BLUERIDGE	54.5	54.4	56.3	54.7	56.9	59.9	55.7	58.4	61.6	51.7	48.4	43.1
CO10	4	55.8	BLUERIDGE	51.0	46.9	47.2	53.3	53.1	53.1	55.1	56.5	57.0	50.7	41.0	25.0
2A07828	4	56.4	BLUERIDGE	55.3	52.3	46.6	55.3	53.1	48.8	55.5	53.8	50.2	55.2	51.6	42.8
2A08804	4	57.4	BLUERIDGE	54.7	50.4	42.2	55.0	51.8	46.9	55.4	53.5	50.5	54.6	49.1	35.0
2A07810U	4	62.1	BLUERIDGE	57.8	51.1	35.1	58.3	53.1	41.1	60.1	55.2	45.1	57.5	49.0	22.1
2A07829	4	62.5	BLUERIDGE	61.3	58.4	52.9	61.3	59.2	55.2	61.6	59.9	56.5	61.1	57.3	49.1
CO06	4	66.3	BLUERIDGE	64.0	60.3	55.4	64.4	62.1	59.1	64.9	63.6	61.5	63.8	58.3	47.3
VA531S	4	68.0	BLUERIDGE	66.2	63.9	63.7	66.6	67.2	66.7	68.9	69.5	68.8	63.2	58.0	46.9
2A07810L	4	68.6	BLUERIDGE	64.1	55.1	44.2	64.5	57.7	49.8	65.5	61.0	54.2	63.4	52.1	29.6
GS04	4	73.4	BLUERIDGE	59.6	34.4	15.8	61.2	45.6	35.7	64.4	55.7	50.1	57.5	22.5	-33.0
VT05	4	74.8	BLUERIDGE	71.0	67.2	65.1	71.3	69.3	68.1	72.2	71.8	71.2	70.3	63.1	45.0
NFD	4	77.1	BLUERIDGE	75.4	73.4	69.3	76.2	75.8	75.7	79.0	77.8	80.1	70.3	59.3	36.2
VT46	4	82.1	BLUERIDGE	79.3	77.3	75.2	80.0	78.5	77.9	80.6	80.3	80.4	78.9	74.2	63.8
VT59	4	85.6	BLUERIDGE	83.5	82.1	82.4	83.8	83.9	85.6	84.4	85.2	87.3	82.6	77.0	66.5
VT58	4	87.5	BLUERIDGE	85.9	84.5	84.4	86.2	86.1	86.6	86.9	86.8	88.2	84.8	82.0	76.8
GS06	4	95.8	BLUERIDGE	91.5	85.2	74.6	92.0	86.9	79.5	92.7	88.8	83.4	90.9	82.7	60.1
STAN	4	96.5	BLUERIDGE	94.3	93.8	94.7	94.8	95.7	97.4	95.6	97.0	98.7	92.7	88.7	78.5
2A07882	4	97.1	BLUERIDGE	94.8	89.7	81.1	95.0	91.1	83.6	95.4	92.0	85.2	94.7	88.7	75.0
2A07835	4	98.2	BLUERIDGE	96.3	93.8	89.0	96.5	94.6	91.2	96.8	95.5	92.9	96.3	92.9	84.9
2A07805	4	98.7	BLUERIDGE	94.7	89.6	78.1	95.2	90.8	82.5	96.8	93.4	86.0	93.9	88.0	63.7
2A08802	4	99.8	BLUERIDGE	97.9	94.5	89.2	98.1	95.5	91.2	98.6	96.6	93.2	97.7	93.8	85.9
VT62	4	103.3	BLUERIDGE	102.1	101.1	100.3	102.2	101.8	101.5	102.5	102.3	102.5	101.7	97.0	91.4
2A07701	4	103.9	BLUERIDGE	100.1	94.5	83.6	100.4	95.7	89.0	101.4	98.0	92.6	99.7	93.6	77.1
2A07812	4	111.4	BLUERIDGE	108.4	103.2	94.8	108.7	104.8	98.1	109.2	106.3	100.4	108.1	101.4	87.5

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
2A07823	4	112.8	BLUERIDGE	106.3	98.9	88.2	107.7	103.5	98.6	108.9	106.6	105.5	105.7	90.4	61.7
2A07806	4	115.1	BLUERIDGE	112.7	107.8	101.0	112.9	110.0	106.2	113.7	112.1	109.4	112.1	104.8	89.0
2A08901	4	120.5	BLUERIDGE	118.8	116.5	110.5	119.0	117.1	113.1	119.2	117.6	114.7	118.8	116.0	107.0
2A08805	4	121.3	BLUERIDGE	118.4	113.3	102.3	118.7	114.9	107.2	119.2	116.2	110.6	118.4	112.1	93.9
2A07821	4	124.2	BLUERIDGE	122.8	120.5	116.3	122.9	121.2	117.9	123.2	121.9	119.4	122.6	119.3	113.3
VT75	4	133.7	BLUERIDGE	133.2	131.0	130.7	133.1	133.1	133.0	134.2	134.2	134.4	131.6	126.5	122.3
2A08810	4	140.5	BLUERIDGE	138.7	134.1	122.8	138.9	135.9	127.7	139.4	137.0	131.2	138.7	133.1	118.1
VT66	4	141.6	BLUERIDGE	140.2	137.6	137.2	140.4	140.4	141.0	142.2	142.6	143.6	138.8	133.7	124.8
OC31	1	-111.8	PLATEAU	-112.8	-90.3	-62.0	-109.6	-84.0	-56.2	-107.5	-78.4	-49.7	-124.3	-142.2	-156.0
OC09	1	-91.2	PLATEAU	-92.4	-75.0	-51.8	-90.4	-70.0	-47.2	-88.8	-65.6	-42.0	-100.6	-115.9	-128.2
OC05	1	-85.5	PLATEAU	-91.1	-80.7	-61.0	-89.0	-75.5	-55.5	-87.1	-71.0	-49.5	-99.4	-121.3	-146.3
OC32	1	-78.3	PLATEAU	-84.0	-74.0	-54.8	-82.1	-68.3	-49.4	-80.6	-63.8	-43.5	-92.7	-116.9	-145.2
OC08	1	-77.2	PLATEAU	-85.0	-76.5	-57.2	-82.8	-70.9	-51.2	-81.2	-65.9	-44.5	-94.5	-123.6	-155.8
DS06	1	-66.9	PLATEAU	-75.2	-72.3	-59.2	-73.5	-66.7	-52.8	-71.5	-62.2	-46.5	-83.9	-116.1	-164.5
OC02	1	-59.4	PLATEAU	-70.5	-76.2	-68.6	-68.7	-70.0	-60.4	-66.5	-64.7	-52.1	-81.0	-122.0	-180.8
OC35	1	-59.3	PLATEAU	-68.3	-55.4	-31.8	-65.8	-49.7	-26.1	-63.4	-44.8	-19.6	-77.7	-106.9	-133.6
DS04	1	-56.4	PLATEAU	-65.0	-63.6	-48.3	-63.3	-57.4	-41.1	-61.6	-51.6	-34.2	-74.2	-108.2	-160.3
DS09	1	-44.6	PLATEAU	-52.1	-47.8	-36.5	-50.7	-44.1	-31.9	-49.4	-40.6	-26.5	-59.1	-86.6	-123.5
WV523S	1	-43.5	PLATEAU	-40.6	-31.2	-12.6	-39.6	-27.0	-7.9	-36.8	-22.8	-2.3	-53.0	-66.1	-81.5
2C041051	1	-22.6	PLATEAU	-19.0	-8.8	-1.8	-17.8	-6.1	0.9	-16.9	-3.8	4.0	-24.2	-32.4	-50.2
2C046034	1	-21.6	PLATEAU	-21.3	-16.0	-1.2	-19.8	-10.5	5.1	-17.0	-4.2	12.3	-29.4	-43.0	-54.0
WV785S	1	-21.5	PLATEAU	-26.7	-25.8	-21.0	-25.7	-22.0	-15.5	-24.2	-17.8	-10.6	-28.6	-43.2	-59.9
DS19	1	-20.2	PLATEAU	-30.0	-31.6	-26.0	-28.8	-27.5	-20.8	-27.3	-23.7	-15.0	-36.4	-63.6	-117.5
DS50	1	-17.3	PLATEAU	-22.5	-23.8	-20.4	-21.8	-21.3	-16.9	-21.0	-19.0	-12.9	-27.1	-45.6	-80.2
2C046033	1	-16.5	PLATEAU	-17.7	-20.7	-21.9	-16.8	-16.8	-17.5	-15.1	-12.4	-12.5	-24.1	-38.4	-63.0
2C066027U	1	-14.4	PLATEAU	-19.4	-19.0	-14.6	-18.7	-16.1	-9.0	-17.3	-12.6	-5.1	-22.2	-35.4	-53.2
2C046043U	1	-11.7	PLATEAU	-11.0	-0.3	8.8	-9.2	5.6	14.6	-5.7	12.1	21.7	-17.3	-29.1	-43.9
WV548S	1	-8.4	PLATEAU	-10.8	-8.1	5.4	-9.4	-2.6	12.0	-6.3	3.8	19.7	-18.0	-33.8	-49.0
FN2	1	-6.3	PLATEAU	-18.1	-3.5	27.6	-15.0	4.9	35.3	-11.6	12.1	43.8	-34.8	-71.7	-93.4
FN1	1	-5.6	PLATEAU	-28.4	-10.5	21.9	-24.7	-2.9	27.8	-21.7	3.5	34.6	-43.0	-81.6	-89.6

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
FN3	1	-3.9	PLATEAU	-13.5	-22.5	-15.6	-11.3	-14.7	-6.4	-7.7	-7.9	3.3	-28.5	-77.1	-142.0
2C046043L	1	-2.6	PLATEAU	-1.1	-10.2	5.1	-0.1	-3.5	12.6	1.7	4.2	21.2	-9.8	-30.5	-61.9
2C041033U	1	-2.2	PLATEAU	-2.3	-6.8	1.3	-1.4	0.0	8.5	-0.2	6.0	16.5	-12.5	-38.6	-96.3
2C057004	2	2.4	PLATEAU	4.2	10.3	13.8	7.8	15.9	17.9	10.1	19.2	25.8	-3.0	-7.3	-33.3
WV531S	2	2.8	PLATEAU	1.0	7.0	11.6	1.8	10.5	14.3	2.7	12.8	16.6	-2.9	-16.0	-41.4
WV788S	2	5.8	PLATEAU	3.6	1.8	-2.8	4.3	3.7	1.0	5.3	6.2	5.4	0.3	-11.6	-40.1
2C041040	2	10.3	PLATEAU	7.7	24.7	37.2	11.5	26.9	45.2	15.4	32.1	54.3	-8.5	-38.3	-74.4
2C047010L	2	11.9	PLATEAU	11.8	6.1	1.7	12.5	9.7	8.7	14.4	13.4	15.9	0.7	-18.3	-55.4
2C047010U	2	13.4	PLATEAU	10.4	1.8	-2.9	10.7	6.6	1.9	11.6	12.1	6.3	5.4	-15.9	-54.7
2C066027L	2	15.2	PLATEAU	8.6	7.6	11.3	9.4	10.9	17.6	11.1	14.8	22.0	5.5	-9.9	-28.3
OC79	2	15.2	PLATEAU	8.4	-1.3	-6.8	9.4	3.0	-0.5	11.4	6.8	5.8	2.2	-26.6	-92.5
2C066026L	3	22.1	PLATEAU	12.3	-1.8	-18.0	13.1	3.7	-4.6	15.8	9.3	4.1	9.3	-20.0	-75.9
2C046053L	3	23.7	PLATEAU	26.2	23.4	26.4	27.9	25.2	33.1	30.7	30.8	40.6	18.1	3.5	-35.4
SP39	3	29.9	PLATEAU	23.8	17.0	4.5	24.1	18.1	7.3	24.8	19.5	8.6	22.9	10.6	-10.2
WV796S	3	31.1	PLATEAU	28.5	27.9	27.8	29.0	29.3	29.5	29.3	30.2	31.2	26.7	18.1	-5.9
WV769S	3	31.7	PLATEAU	27.9	21.1	12.2	28.3	22.7	17.1	28.7	24.5	22.2	26.3	9.1	-60.6
2C046050	3	34.6	PLATEAU	28.3	35.9	50.4	30.1	41.4	55.0	32.8	48.6	60.1	23.4	9.2	-9.3
2C077022U	3	36.2	PLATEAU	28.2	17.2	4.0	28.9	21.4	14.9	30.3	25.8	21.5	26.3	9.3	-37.3
2C066039L	3	41.9	PLATEAU	31.7	19.8	7.2	32.5	24.6	18.4	34.4	29.8	24.8	29.0	1.2	-52.9
SP10	3	46.7	PLATEAU	40.8	34.0	25.0	41.1	35.5	29.4	42.1	37.1	31.2	39.3	27.8	6.7
WV547S	4	51.8	PLATEAU	43.8	41.5	42.5	44.8	49.6	47.5	46.1	57.1	53.0	36.1	-1.2	-59.6
2C041039	4	53.3	PLATEAU	50.4	48.5	40.0	50.9	49.9	43.4	51.9	51.5	46.7	47.8	23.8	-85.5
2C046013L	4	61.2	PLATEAU	55.5	47.6	28.3	56.7	50.8	36.4	58.4	53.6	44.6	46.4	24.5	-54.0
2C047007	4	69.8	PLATEAU	66.8	63.0	53.9	67.4	65.1	58.4	68.1	67.1	63.0	64.5	49.5	-42.6
2C041043U	4	86.6	PLATEAU	86.4	92.2	86.9	86.9	93.6	91.5	88.1	96.1	99.0	78.7	51.2	-10.3
WV770S	4	93.7	PLATEAU	90.7	89.9	83.7	92.2	91.2	86.5	93.5	92.6	89.3	84.8	67.5	23.1
SP41	4	101.9	PLATEAU	94.8	86.1	71.5	95.0	87.0	74.7	95.7	88.2	76.4	94.1	81.5	61.5
2C046062L	4	118.4	PLATEAU	114.0	107.9	97.7	114.3	109.5	101.7	115.1	111.5	105.7	111.3	94.9	51.5
2C041045	4	126.0	PLATEAU	120.1	117.2	110.3	120.6	120.1	114.2	121.2	121.7	118.8	117.4	95.3	32.2
VA526S	4	129.9	PLATEAU	123.9	116.6	107.6	124.3	119.6	113.0	125.2	121.6	117.7	122.5	107.2	60.3

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
WV771S	4	137.7	PLATEAU	133.1	128.6	119.0	133.5	129.7	122.1	133.9	130.7	125.3	131.3	116.3	18.7
2B041049U	1	-78.1	VALLEY&RIDGE	-71.0	-46.4	-25.0	-68.7	-41.1	-19.1	-66.8	-37.2	-14.7	-84.0	-97.3	-116.8
VT50	1	-41.7	VALLEY&RIDGE	-41.4	-20.4	2.6	-39.2	-13.1	9.5	-36.1	-7.8	15.0	-50.7	-65.3	-85.1
VT78	1	-10.0	VALLEY&RIDGE	-14.5	-13.3	-5.9	-13.6	-9.2	0.0	-10.5	-4.5	5.0	-16.8	-27.6	-41.6
VT72	1	-5.6	VALLEY&RIDGE	-8.8	-6.7	3.0	-7.2	-1.4	10.4	-5.8	2.8	15.2	-11.5	-21.1	-34.9
VT26	1	-5.2	VALLEY&RIDGE	-17.6	-24.4	-26.0	-14.9	-16.6	-12.7	-11.3	-8.3	-3.6	-20.3	-49.7	-93.8
VT32	1	-0.3	VALLEY&RIDGE	-7.2	-16.4	-19.9	-6.4	-10.2	-8.2	-4.0	-2.1	0.3	-9.3	-34.1	-73.3
DR01	2	0.1	VALLEY&RIDGE	-4.7	-1.2	15.4	-2.7	9.9	30.1	-0.8	16.9	36.3	-7.9	-21.8	-42.8
VT07	2	0.2	VALLEY&RIDGE	-5.5	-9.9	-3.4	-4.3	-4.5	4.8	-1.9	2.4	12.2	-9.6	-25.4	-53.5
2B047076L	2	1.1	VALLEY&RIDGE	-1.4	7.2	21.1	1.2	16.7	33.6	3.9	22.6	38.9	-4.2	-14.8	-32.7
VT31	2	1.5	VALLEY&RIDGE	-3.6	-7.8	-9.4	-2.7	-4.5	-3.7	-1.5	-0.8	0.9	-4.6	-16.6	-38.9
VT56	2	2.0	VALLEY&RIDGE	-2.4	-1.8	9.6	-1.7	4.1	16.3	-0.4	8.8	21.5	-4.1	-16.2	-34.9
VT35	2	4.6	VALLEY&RIDGE	1.6	10.9	27.3	4.2	21.1	40.9	7.0	27.7	47.0	-2.5	-13.8	-29.2
VT49	2	6.2	VALLEY&RIDGE	6.0	11.4	12.7	7.8	12.8	15.0	9.5	14.1	17.0	-0.2	-12.9	-28.4
2B047076U	2	6.6	VALLEY&RIDGE	8.5	15.1	22.8	10.8	23.4	33.9	13.3	28.6	38.8	3.2	-3.9	-24.1
VA524S	2	6.8	VALLEY&RIDGE	-0.3	0.2	3.3	1.9	6.8	13.3	5.3	13.0	21.7	-2.5	-19.9	-45.5
VT29	2	8.2	VALLEY&RIDGE	4.3	-0.3	-5.1	4.8	2.0	-0.3	5.7	4.5	4.0	3.6	-6.1	-27.3
VT25	2	9.1	VALLEY&RIDGE	5.6	1.3	-3.6	6.1	3.2	1.7	6.6	5.8	6.0	5.1	-4.5	-25.6
VT28	2	9.4	VALLEY&RIDGE	4.7	-0.4	-5.0	5.3	2.2	-0.1	6.2	4.9	3.5	3.8	-8.0	-29.9
VT09	2	11.0	VALLEY&RIDGE	5.9	2.5	2.5	6.6	5.2	7.9	8.2	10.2	12.8	3.5	-12.6	-39.2
VT08	2	19.4	VALLEY&RIDGE	13.7	8.7	14.5	14.3	12.6	22.6	16.5	20.5	29.5	11.1	-4.0	-40.6
WOR	3	23.5	VALLEY&RIDGE	18.8	14.0	13.5	20.1	23.5	25.0	25.0	28.9	32.5	14.8	-0.5	-22.0
WOR1	3	24.9	VALLEY&RIDGE	20.4	18.9	16.7	21.1	22.8	22.7	22.9	26.2	26.3	18.1	4.7	-24.8
VT57	3	27.5	VALLEY&RIDGE	25.9	26.4	24.1	27.2	28.4	27.6	28.7	29.9	30.5	22.9	13.4	-7.8
VT10	3	27.6	VALLEY&RIDGE	23.0	18.9	15.8	23.5	21.4	19.9	24.0	23.8	22.7	21.7	9.8	-12.8
VA555S	3	28.1	VALLEY&RIDGE	22.9	18.4	16.0	23.6	21.2	21.1	24.4	23.4	24.8	21.9	9.1	-13.3
VT24	3	29.7	VALLEY&RIDGE	23.5	18.4	14.7	24.2	22.1	22.6	25.9	26.3	27.3	22.9	9.7	-18.2
VA548S	3	30.3	VALLEY&RIDGE	21.5	16.7	19.5	22.5	21.5	30.1	23.9	25.1	36.4	14.5	-15.1	-42.0
2A068015U	3	31.4	VALLEY&RIDGE	29.6	25.6	19.1	29.7	26.7	22.2	30.3	27.9	24.5	28.7	22.2	5.8
VT37	3	33.2	VALLEY&RIDGE	28.5	29.4	34.1	29.7	32.1	39.8	31.0	35.8	44.4	25.8	13.5	-6.5

SITE ID	ANC CLASS	REF 1995	PHYSIOGRAPHIC PROV	OTW 2010	OTW 2040	OTW 2100	BWC 2010	BWC 2040	BWC 2100	BYB 2010	BYB 2040	BYB 2100	CON 2010	CON 2040	CON 2100
VT11	3	35.6	VALLEY&RIDGE	32.7	28.8	22.2	33.3	30.2	28.1	33.6	31.2	32.1	31.9	23.6	4.9
VT15	3	36.2	VALLEY&RIDGE	33.6	30.2	25.5	34.0	32.1	29.2	34.3	33.3	31.8	33.1	25.3	9.7
VT34	3	46.9	VALLEY&RIDGE	40.1	36.8	36.9	41.6	42.4	44.8	43.0	45.3	50.5	38.1	22.0	-1.7
VT54	4	51.4	VALLEY&RIDGE	49.2	53.1	54.8	49.7	56.4	59.1	51.4	58.8	62.7	46.8	33.3	4.1
VT18	4	58.2	VALLEY&RIDGE	54.8	51.6	43.3	55.6	53.3	47.0	56.3	54.9	51.1	52.3	37.3	5.6
VT19	4	58.3	VALLEY&RIDGE	54.1	47.1	40.6	54.4	48.5	47.7	55.3	50.8	54.2	49.8	32.0	-8.0
2B047032	4	62.9	VALLEY&RIDGE	53.1	38.6	38.2	53.7	42.3	45.6	56.3	46.1	52.7	49.4	7.3	-24.6
VT38	4	70.0	VALLEY&RIDGE	67.2	65.3	63.4	68.2	68.4	68.9	69.1	71.3	73.2	65.0	52.6	18.1
2B041020L	4	93.3	VALLEY&RIDGE	90.2	90.4	88.6	91.1	91.9	90.4	92.1	92.9	92.5	85.6	67.3	34.4
VT55	4	94.3	VALLEY&RIDGE	92.2	92.7	89.3	93.7	95.4	93.1	96.1	97.5	96.2	88.4	73.4	31.5
VT20	4	111.0	VALLEY&RIDGE	104.1	97.2	88.1	105.3	100.9	95.2	106.7	104.2	101.4	103.3	87.6	47.3
VA821S	4	112.4	VALLEY&RIDGE	107.9	101.4	104.8	108.5	106.9	114.2	109.1	114.1	121.0	107.1	88.9	63.3
2B047044U	4	116.6	VALLEY&RIDGE	112.6	114.7	120.1	114.0	117.2	124.2	115.8	119.6	128.0	107.8	100.3	86.5
VT12	4	135.9	VALLEY&RIDGE	131.8	125.7	118.8	132.2	128.1	124.0	132.8	129.8	126.7	131.1	122.1	102.0