Table 7-1. Summary of Qualitative Uncertainty Analysis of Key Elements Affecting the AAPI form of the NOx/SOx Standards.

Source	Description	Potential influence of uncertainty in element: Direction (negative implies less relative protection)	Potential influence of uncertainty in element: Magnitude	Knowledge-Base uncertainty	Comments
Major elements (and sub-models) of the ecological effects to ambient concentration framework					
Biological/ecosystem response to acidification	Clear associations between aquatic acidification (pH, elevated Al) and adverse ecosystem effects (fish mortality, decreased species diversity)	Both	Low	Low (regionally)	The ecosystem level responses are well studied at regional levels. The uncertainty increases at larger scales due to an increasing number of factors influencing the patterns (e.g. latitudinal species gradient, specie-area relationships, etc.).
Linkage between direct acidification species and ecological indicator (ANC)	The relationships across ANC, pH and dissolved Al are controlled by well defined aquatic equilibrium chemistry	Both	Low	Low	ANC is the preferred ecosystem indicator as it has a direct relationship with pH and the deposition species relevant to the NOx/SOx standard.
Linkage between ecological indictor and adverse ecological effects	Direct nonlinear associations between ANC and fish mortality and species diversity	Both	Low-medium	Low	Although the pH dependency on ANC is nonlinear, it is always directionally consistent. In extremely low and high ANC environments the relationship is of minimal value as catchments are in relatively “less sensitive” regimes due to natural conditions or extreme anthropogenic influence (i.e., acid mine drainage). In sensitive areas of concern the relationship essentially is similar to the relationships between direct acidification species and adverse effects.
Deposition to ANC linkage through Critical Load approach	Mass-balance Steady State critical load model is applied to determine critical load values. MAGIC model is used to validate steady State model. The Steady State critical load model formulation is used as the foundation for deriving the AAPI equation.	Both	Low	Low	The model formulation is well conceived and based on a substantial amount of research and applications available in the peer reviewed literature. There is greater uncertainty associated with the availability of data to support certain model components.

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Atmospheric concentrations to deposition	Deposition is a direct function of ambient concentration, influenced by several processes, and handled in the AAPI through air quality modeling.	Both	Low	Low	The model design is appropriate given the spatial and temporal complexities that influence deposition velocity, as well as the variety of atmospheric species that generally are not measured. Greater uncertainty resides in the information (e,g,, ammonia emissions) driving these calculations and availability of observations to evaluate model behavior.
Ecological indicator to changes in the value of ecosystem services	Definitions of public welfare may include economic considerations, based on the tradeoffs people would make to avoid the negative impacts of acidification, through effects on the values of ecosystem services. Empirical estimates of valuation for limited ecosystem service categories are used to inform the discussions of adversity associated with alternative ANC levels.	Negative	Medium-high	Low-medium	There are many studies that estimate the value of increasing services that may be affected by changes in acidification and eutrophication. However, few of these studies focus on the particular impact of acidification and eutrophication on the quality of these services and preferences for avoiding these impacts. Those studies that do are often limited to analyzing the impacts on a narrow population or particular change in environmental quality. The monetized benefits to fishers and to New York residents for ecosystem improvements in the Adirondacks associated with improvements to the ecological indicator are significant underestimates of the total benefits in the U.S. This is because those living outside New York would value improvements to the Adirondacks and similar natural environments elsewhere. The methodologies used in the studies that underlie the estimates of the value of changes in ecosystem services in the Adirondacks region are sound and have been subject to peer review. The method of aligning the improvements valued in the Banzhaf et al. study with estimates of eliminating current damages leads to may lead to an over or underestimate of the benefits. The range of this difference is difficult to know a priori, but the total improvements in the share of lakes that improve above an ANC threshold of 20 µeq/L are consistent.

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Sub-components and data of individual models					
Atmospheric Components					
Dep_{SOx}	Annual deposition of sulfur mass from dry deposition of (SO_2 and SO_4) and wet SO_4 derived from CMAQ 12km horizontal grid resolution averaged over 5 years	both	low	low	The treatment of SOx deposition in EPA air quality models has evolved over the last two decades. There is general consensus that the overall mass balance of S is treated well with difficulties in spatial pairing of observations and modeled results of wet deposition. This spatial pairing has improved with the more recent PRISM adjustments.
Dep_{NOy}	Annual deposition of oxidized nitrogen mass from dry deposition of (all NOy species) and wet NO_3 derived from CMAQ 12 km horizontal grid resolution averaged over 5 years	both	low	low-medium	The treatment of oxidized nitrogen deposition in EPA air quality models has evolved over the last two decades. There is general consensus that the overall mass balance of oxidized N is treated well. However, the broad range of deposition velocities across NOy species, and especially uncertainties regarding the deposition of significant species such as NO_2 pose ongoing challenges. Similarly, a shortage of NOy species measurements as well a lack of techniques to directly measure dry deposition impede progress on improving parameterization of N dry deposition.
Dep_{NHx}	Annual deposition of reduced nitrogen mass from dry deposition of (NH_3 and SO_4) and wet NH_4 derived from CMAQ 12km horizontal grid resolution averaged over 5 years	both	low	medium	NHx deposition also is quantified through CMAQ applications. The well dispersed nature of agricultural based emissions that are influenced strongly by meteorological and surface /soil characteristics continues to challenge characterization of ammonia emissions. Recent incorporation of a bi-directional flux process in CMAQ improves consistency with available scientific understanding and yields improved time and space pairing of limited observations with model results. A lack of both ammonia and ammonium ambient observations continues to compromise our ability to characterize uncertainty in our treatment of NHx. As with all dry deposition estimates, technologies for direct measurements are not available routinely. Both NHx deposition and NOx deposition are assigned low values of magnitude based on a general dominating role of sulfur

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					deposition.
Wet deposition (generically – N and S species)	Wet component of total deposition as described in the Dep terms, above	both	low	low	Wet deposition remains an attribute of relatively high confidence based on the ability to directly measure chemical components in precipitation samples. However, given the stochastic nature of precipitation, models have a difficult time in matching observations. The use of 5 year averages and post-processing PRISM adjustments have reduced uncertainty in spatial pairing of observations and modeled estimates.
Dry deposition (generically – N and S species)	Dry component of total deposition as described in the Dep terms, above	both	medium	Medium-high	The absence of direct dry deposition measurements combined with the significant variability in the parameters that influence dry deposition velocity reduces the confidence level in dry deposition relative to wet deposition.
Deposition Transference Ratios	CMAQ derived ratio of total oxidized deposition to concentration averaged over one year	both	low	unknown	Transference ratios enable the connection between deposition and the policy relevant ambient air indicators, NOy and (SO_2 + SO_4). They are strictly a model construct and cannot be evaluated in a traditional model to observation context. The low sensitivity of these ratios to emission changes and inter annual meteorology combined with low spatial variability indicate that these ratios are necessarily stable.
C_{NOy}	Ambient concentrations of NOy through observations.	negative	low	Low-medium	Adequate spatial coverage of NOy observations does not exist, but will be addressed in the proposed rule. The monitoring technology only over the last 5 years has been perceived as "routine" based on incorporation in the NCore network. However FRM status for NOy instruments currently is not available. The negative bias direction is a standard caveat to any instrument relying on internal air stream conversion of atmospheric species prior to detection.
C_{SOx}	Ambient concentrations of NOy through observations.	both	low	Low	A lack of adequate spatial coverage is the primary concern for SO2 + SO4 observations. FRM status is not available for SO4; although the long track record of accurate and precise CASTNET FP measurements indicates that achieving FRM status is a low hurdle.
Ecosystem Components					

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BC_0^*	Pre-industrial base cation concentrations	negative	Medium-high	high	Both the F-factor approach and process based MAGIC modeling were used to generate BC_0^*. Excellent agreement between both approaches was established in the Shenandoah streams. The more comprehensive data requirements of MAGIC limit its widespread use to the Adirondacks, although for consistency the F-factor approach was applied nationwide. The analyses also illustrated greater divergence at higher critical loads, or areas with greater acid buffering capacity and high bas cation levels. These conditions often are screened out of our population distribution analyses, and when included do not affect the location within the distribution of the more sensitive water bodies. Since MAGIC (the preferred approach) tends to overestimate BC_0^* relative to the F factor approach, and the F-factor is more widely applied nationally, the BC_0^* estimates are viewed as conservative leading to a slight positive bias in estimating critical loads. Although we have many modeled estimates of BC_0^*, there is a lack of direct measurements of BC weathering rates.
Neco		positive	low	medium	The term Neco, as defined, has a relatively medium confidence level and is a direct function of the uncertainty inherent in the deposition estimates from CMAQ and surface measurements of NO_3. However, this "measurement" difference approach reflects the average of all influencing processes (dinitrification, uptake, immobilization) over the time period of measurements. Consequently, there is an inherent assumption of a relatively static system (Neco is applied in a steady state model) that generally is not tested. In concept, a true steady state vision of Neco would be based on a mature forested ecosystem. The relative bias of Neco is related, largely, to the relative productivity of the forest. The challenge in determining any potential bias in Neco is to determine the relative "maturation age" of an ecosystem which requires knowledge of future land use activities. In areas of

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					high land use restrictions of a recovering forest, Neco would be assumed to be overestimated. The relative magnitude of Neco often is mitigated by the dominance of SOx in controlling acidification processes in many systems. Furthermore, it is unclear to what extent any stored N will be released back into the system, which is assumed to not occur in the linked system model.
Q	Annual runoff rate (distance/time) for a catchement.	both	low	high	Data used to calculate Q was compiled in 1985. Streamflow data were collected at over 12,000 gauging stations during 1951-80; 5,951 stations were selected for the analysis. See Gebert and others (1987) for a complete description of how the runoff was determined from the streamflow data. Appropriate maps of the data can show the geographical distribution of runoff in tributary streams for the years 1951-80 and can describe the magnitudes and variations of runoff nationwide. The data was prepared to reflect the runoff of tributary streams rather than in major rivers in order to represent more accurately the local or small scale variation in runoff with precipitation and other geographical characteristics. t, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average annual runoff in the United States, 1951-80: U.S. Geological Survey Hydrologic Investigations Atlas HA-710, scale 1:7,500,000.
DOC	Surface water dissolved organic carbon	negative	low	medium	Water bodies with high DOC levels (> 10mg/l) were screened out of the critical load calculations in order to avoid naturally acidic systems. However, the inherent assumption of ANC = ∑strong CA - ∑strong AN does not explicitly account for contributions of weak organic acids. Consequently, a small positive bias pervades the critical load calculations (i.e., the CL estimates are high). The knowledge base value of M reflects a general shortage of DOC data.