Exhibit 11
Land Use Area (km^2) by Ozone Reduction Category (ppb)

Category	-0.8-0.0	0-0.4	0.4-0.8	0.8-1.2	1.2-1.6	1.6-2	2-2.4	> 2.4	No Data	Total
Urban	3,814	41,527	11,763	5,010	3,692	2,183	448	1,336	60	69,834
Agricultural	96,987	601,665	193,945	80,948	46,256	21,480	8,372	13,500	2,519	1,065,672
Rangeland	0	16	0	0	0	0	0	0	0	16
Deciduous Forest	24,737	282,866	118,800	101,307	52,467	26,304	10,232	20,982	6,118	643,814
Coniferous Forest	13,104	88,458	19,797	12,230	5,767	3,860	1,859	2,808	3,857	151,740
Mixed Forest	14,444	204,353	75,687	54,970	35,622	22,557	8,720	16,332	12,990	445,674
Water	12,141	147,049	30,060	10,484	7,464	1,923	769	1,042	12,856	223,788
Barren	0	3	0	0	0	0	0	0	0	3
Non-Forested Wetlands	1,171	11,670	1,149	654	732	93	0	0	0	15,469

Exhibit 12
Land Use Area (km^2) by Total Nitrogen Reduction Category (kg/ha)

Category	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1	1-1.2	1.2-1.4	> 1.4	Total
Urban	10,992	22,580	14,634	8,136	6,669	1,768	1,987	3,137	69,834
Agricultural	372,725	263,240	182,837	103,672	64,001	28,604	17,593	32,999	1,065,672
Rangeland	0	16	0	0	0	0	0	0	16
Deciduous Forest	142,720	131,469	136,522	106,522	58,159	27,372	16,236	24,814	643,814
Coniferous Forest	78,310	51,702	13,328	2,887	1,923	383	1,129	2,079	151,740
Mixed Forest	160,675	170,975	61,822	21,482	16,172	3,953	3,369	7,227	445,674
Water	96,769	57,944	41,787	15,692	6,646	1,919	1,287	1,743	223,788
Barren	0	0	0	0	0	0	0	0	3
Non-Forested Wetlands	11,479	1,277	1,871	810	31	0	0	0	15,469

Exhibit 13
Land Use Area (km^2) by Nitric Acid Reduction Category($\mu g/m_3$)

Category	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	> 0.7	Total
Urban	3,231	10,860	18,545	8,136	6,669	1,768	1,987	3,137	69,834
Agricultural	298,572	164,520	205,472	103,672	64,001	28,604	17,593	32,999	1,065,672
Rangeland	0	0	16	0	0	0	0	0	16
Deciduous Forest	101,391	60,292	103,175	106,522	58,159	27,372	16,236	24,814	643,814
Coniferous Forest	15,890	72,933	43,652	2,887	1,923	383	1,129	2,079	151,740
Mixed Forest	86,919	92,712	129,272	21,482	16,172	3,953	3,369	7,227	445,674
Water	40,388	58,248	52,882	15,692	6,646	1,919	1,287	1,743	223,788
Barren	3	0	0	0	0	0	0	0	3
Non-Forested Wetlands	7,208	4,441	588	810	31	0	0	0	15,469

on agricultural, deciduous forest, and mixed forest lands. This tendency somewhat follows the distribution of total acreage across the land use categories, with agriculture, forest, and water land uses showing the greatest acreage estimates. The distribution of changes by land use categories is significant, for it is likely that these land uses would support the ecosystems explored in the physical effects inventory. Exhibit 11 illustrates that most acreage in the affected area experiences a reduction in maximum daily ozone concentration of approximately 0 to 0.4 ppb. Exhibits 12 and 13 reveal similar distributions of changes in total nitrogen deposition and nitric acid concentration across land use categories, with the majority of acreage experiencing modest changes and greatest changes occurring on agriculture and forest lands.

Additional exhibits have been prepared to better represent the data presented in Exhibits 11, 12, and 13. Land use distributions have been mapped using the percentage of acreage that makes up different cells. Land use is modeled in this way because, as noted earlier, the SAI data are stored in a grid format[3]. Exhibits 14, 15, 16, and 17 present the following combinations of emissions change and land use data: ozone changes and forest lands, nitric acid changes and water, total nitrogen changes and wetlands, and total nitrogen changes and water. In each of these exhibits, the color of the cells indicates the reduction category, with red showing greater changes and the shading of the cell reveals the fraction of land within the cell covered by the land use category, with more solid cells conveying higher percentages of the land

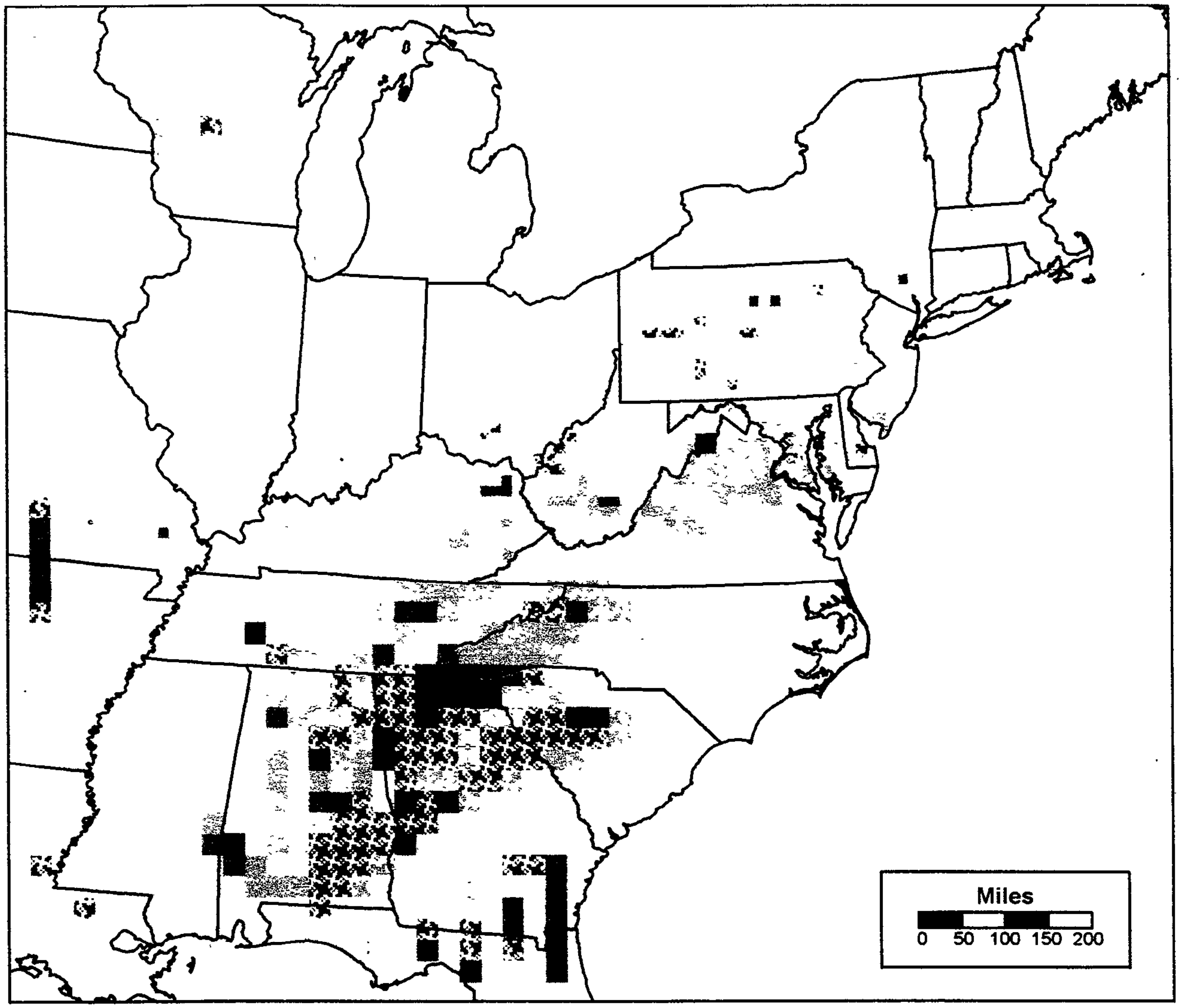
[3] The land use estimates that appear in Exhibit 4 are calculated by combining the percentage composition land use and land area estimates by cell with the type of emissions change by cell. The final estimates are produced by aggregated over all cells.

Exhibit 14

Change in Annual Average of Daily Maximum Ozone Concentrations

Base Case (E1) - High NOx Control Case (E4) for the Year 2000

& Degree of Forestation



Reduction in Ozone Concentration (ppb)

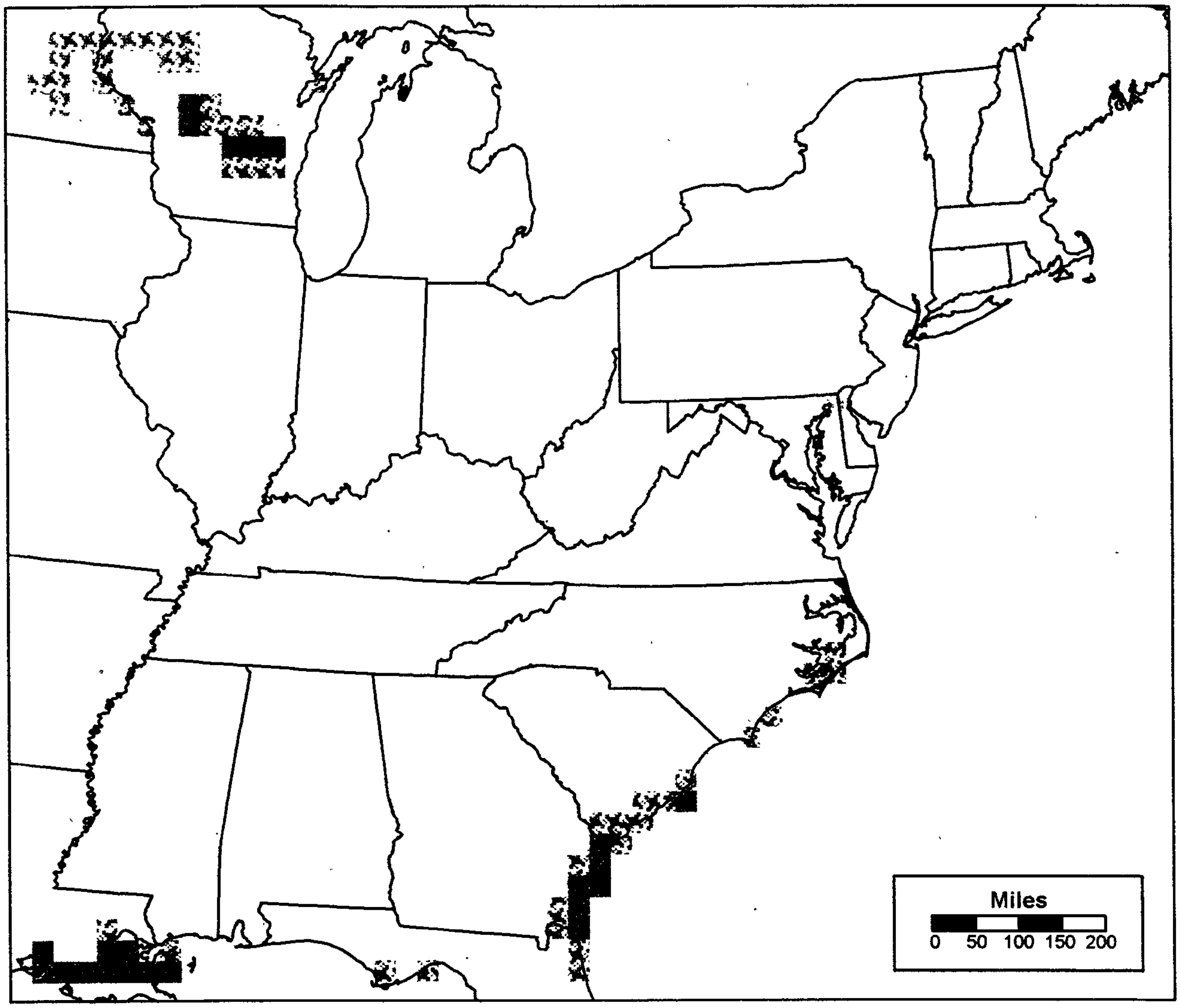
■	-.80	to	.00
□	.00	to	.40
□	.40	to	.80
□	.80	to	1.20
▒	1.20	to	1.60
▓	1.60	to	2.00
■	2.00	to	2.40
■	2.40	to	6.96

Fraction of Land Covered By Forest

□	.00	to	.10
⊠	.10	to	.50
▓	.50	to	.80
■	.80	to	1.00

Exhibit 15

Change in the Annual Average Deposition of Total Nitrogen
Base Case (E1) - High NOx Control Case (E4) for the Year 2000
& By Fraction of Land Covered by Non-Forested Wetlands



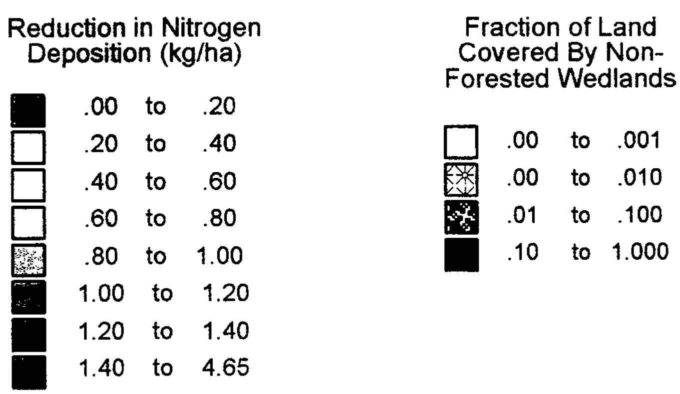
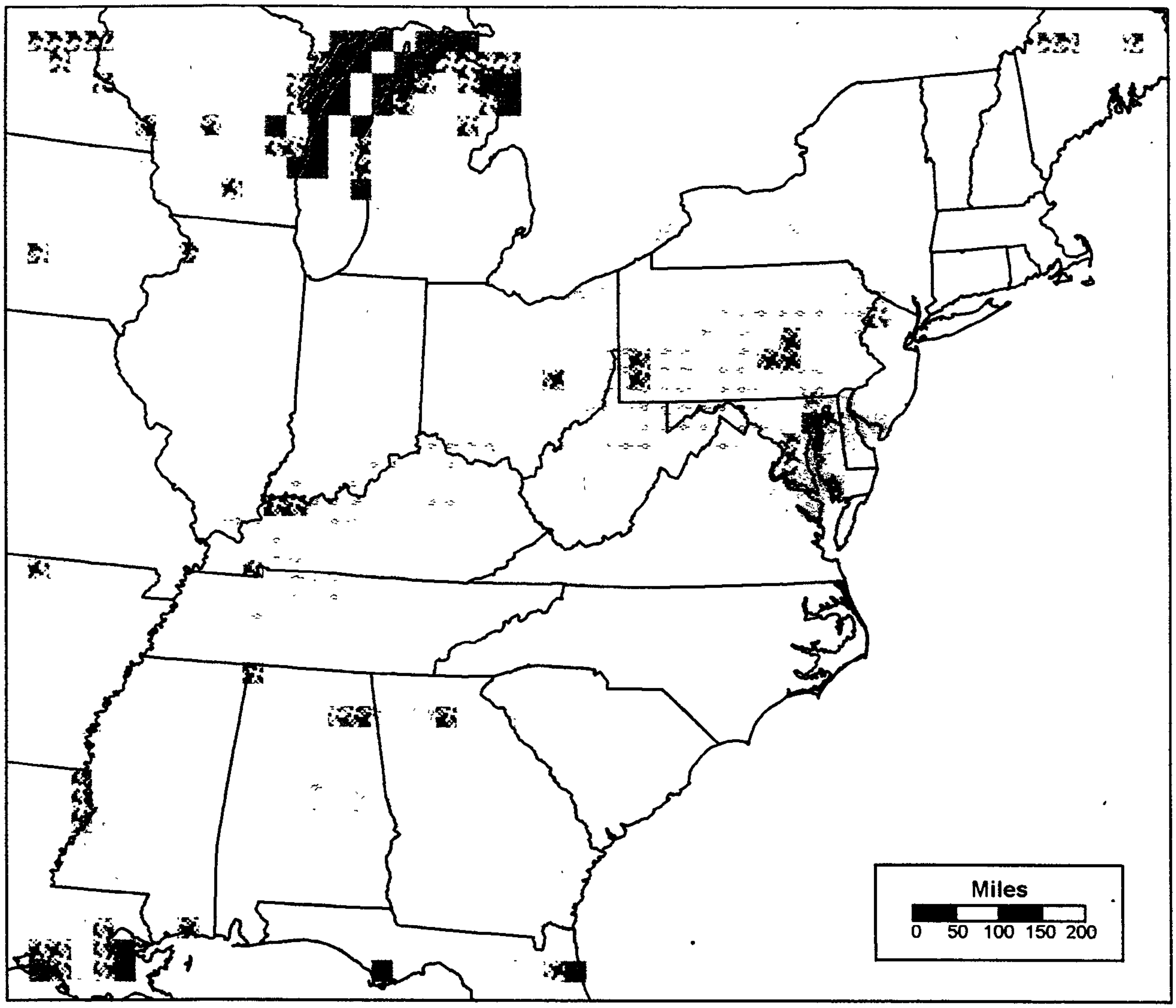


Exhibit 16

Change in the Annual Average Concentration of Nitric Acid

Base Case (E1) - High NOx Control Case (E4) for the Year 2000
& By Fraction of Land Covered by Water



Reduction in Nitric Acid Concentration (µg/m3)

■	.00	to	.10
□	.10	to	.20
□	.20	to	.30
□	.30	to	.40
▒	.40	to	.50
▓	.50	to	.60
■	.60	to	.70
■	.70	to	1.50

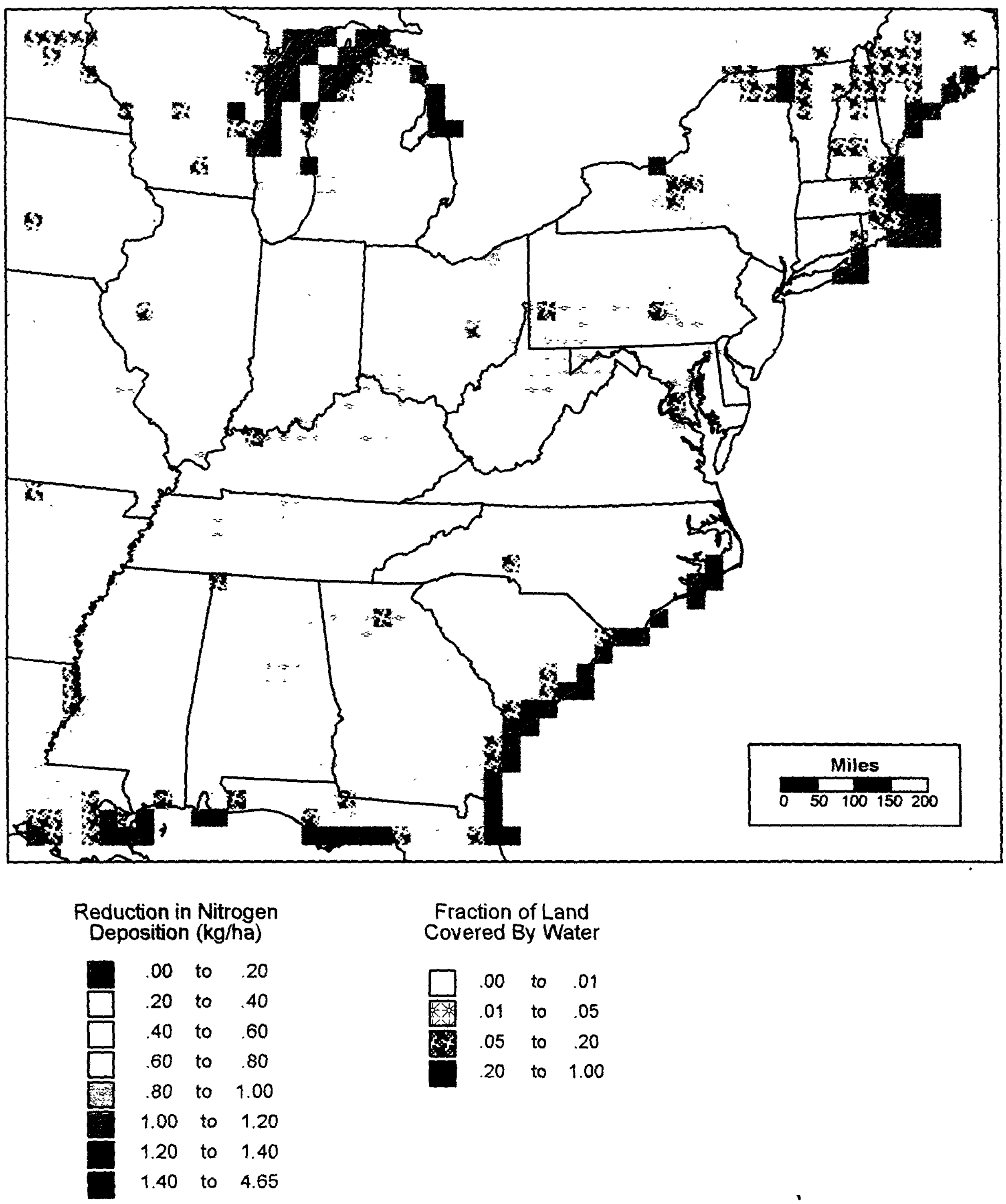
Fraction of Land Covered By Water

□	.00	to	.01
▒	.01	to	.05
▓	.05	to	.20
■	.20	to	1.00

Exhibit 17

Change in the Annual Average Deposition of Total Nitrogen

Base Case (E1) - High NOx Control Case (E4) for the Year 2000
& By Fraction of Land Covered by Water



use of interest. For example, Exhibit 14 presents the change in annual average daily ozone concentrations and the degree of forested land use by cell. The coloring scheme for the reduction in ozone concentrations is identical to that used in Exhibit 10, with darker reds demonstrating larger reductions. Exhibit 14 offers additional information in conveying the fraction of land covered by forest land uses within the cells. Solid cells in Exhibit 14 indicate cells that have 80 percent or higher forested acreage. These four combinations of pollutant and land use estimates were selected to facilitate the following discussion between emissions changes and economic and scientific research.

B. Linkages Between Emissions Changes and Economic/Scientific Research

In previous sections of this inventory, the discussion of physical effects proceeded almost independently of the Title IV NO_x controls. Prominent physical effects identified by this inventory included: (1) forest yield, and/or foliar damages from ozone; (2) acidification of freshwater lakes and streams; (3) eutrophication of ocean or estuarine waters; and (4) nitrogen loadings induced species changes in wetlands. There is some correspondence between the composition of acreage in the study area and those ecosystem categories more likely to be affected by changes in nitrogen oxides emissions. As presented earlier, acreage (km^2) within the affected area is divided across the following land uses: urban (69,834); agricultural (1,065,672); rangeland (16); deciduous forest (643,814); coniferous forest (151,740); mixed forest (445,674); water (223,788); barren land (3); and non forest wetlands (15,469).

The characterization of the linkages between emission, deposition, or concentration changes and physical effects as well as behavioral responses is dependent on scientific and economic research. The following sections address the feasibility of modeling the more prominent effects by ecosystem category. Within each section, the likelihood of physical effects occurring and the ability to capture the human response to such effects are discussed. In some cases, possible modeling approaches are offered. It is important to note that for the purposes of this regulation, the "reversibility" of physical effects caused by increased nitrogen oxides emissions must be asserted. For example, it must be assumed that reduced nitrogen oxide emissions would result in increased forest yields, reduced foliar damage, reduced acidity of waters (and reversed species change), reduced eutrophication (and improved water quality), and a reversal in species change within wetlands. In most instances, scientific research cannot substantiate the likelihood of such reversals. Exhibit 18 presents the service flows deemed at stake from changes in nitrogen oxides emissions, reiterating the framework adopted to consider the quantification of "ecosystem benefits".

1. Forest Ecosystems

Exhibit 14 presents the change in annual average daily ozone concentrations and the degree of forestation. The greatest reductions in ozone concentrations do appear to occur on forested lands, particularly those located in Alabama, Georgia, and South Carolina. The greatest reductions in the annual average of daily maximum ozone concentrations range from 2.40 to 6.96 parts per billion (ppb) under scenario (E4). These changes are of limited magnitude

Exhibit 18
Summary of Impacted Service Flows

End Points or Services	Forests	Freshwater Wetlands	Coastal Wetlands	Streams & Lakes	Oceans	Deserts	Grass Lands
Direct Services							
Hiking/ Hunting/ Camping	X	X	X				
Birdwatching/ Wildlife Viewing	X	X	X	X	X		
Scenic Beauty	X	X	X	X	X		
Boating/ Water Activities		X	X	X	X		
Commercial Fishing		X	X	X	X		
Recreational Fishing		X	X	X	X		
Waste Sink							
Indirect Services							
Storm Protection/ Wave Buffering		X	X				
Flood Control		X					
Nutrient Removal Recreation Drinking Water	X	X	X				
Pollutant Uptake Recreation Drinking Water Industrial	X	X					
Sediment Control	X	X	X				
Biodiversity Preservation	X	X	X	X	X		

'X' indicates potential affect from nitrogen oxide controls.

relative to the baseline concentrations occurring in these areas which near 100 ppb. For example, in the northern portion of Georgia where the greatest decreases in concentration occur, the baseline concentration is approximately 100 parts per billion (ppb). This implies that the greatest changes imposed by the (E4) scenario represent 2.4 to 6.96 percent changes in annual average daily concentration. Scientific research on the effects of ozone on tree species suggests that SUM06 (where SUM06 = cumulative sum of all hourly O_3 concentrations greater than 0.06ppm) exposure of 31.5 ppm*hour over 92 days (a mean concentration of approximately 0.055 ppm) results in a less than 10% yield reduction in 50% of the cases on seedlings (Hogsett et al. (1993)). Observing the magnitude of the changes in ozone levels from the Title IV controls, it appears very unlikely that the modest reductions in ozone will have significant physical effects of any sort. In addition, although research has produced some dose-response information for ozone and tree seedlings, such results do not translate easily to changes in the health and yield of forests.

As noted previously, changes in the yield or characteristics of forest ecosystems will affect service flow provision[4]. Recreational service flows such as hiking/hunting/camping, birdwatching, and scenic beauty are likely to be affected as tree growth and appearances change. The demand for such recreational activities is linked with forest attributes such as species composition and health. Flood control, nutrient removal, pollutant uptake, and sediment control are likely to be affected by both changes in tree characteristics and soil chemistry. Biodiversity within forest ecosystems is also likely to be affected by changes in tree characteristics and soil chemistry, as well as by shifts in species composition. Even if significant physical effects were caused by the imposition of the Title IV controls, it is unlikely that changes in many of the associated service flows other than the recreation service flows could be accounted for. The difficulty of modeling these other types of service flows is related to their dependence on specific physical attributes above and beyond those of the forest and the indirectness of the service flow provision. These types of service flows are often examined in regional or site specific studies rather than broader, nationally focused studies. Recreation and commercial service flows are far more feasible to model. Without precise scientific information on the physical effects, assumptions on changes in yield or in forest quality might be made to allow for some form of economic estimates to be generated. This type of modeling framework is adopted by several economic studies characterizing the effects of air pollution on forests (refer to NAPAP (1991), Peterson (1987), Callaway (1985), Crocker (1985), and Haynes and Adams (1992)). This approach does not seem applicable to the Title IV Controls because of the unlikely nature of physical effects within forest ecosystems.

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[4] Commercial service flows from forest ecosystems are directly affected by changes in yield. These flows are not discussed here, as they are not typically considered to be ecosystem effects.

2. Freshwater Wetlands

Exhibit 15 presents the change in annual average deposition of total nitrogen and the degree of land covered by non-forested wetlands. It is important to note that only non-forested wetlands have been separated from other land uses in the SAI modeling grid framework. Nonforested wetlands comprise only a small portion of freshwater wetlands. Exhibit 15 reveals that only minor reductions in annual average deposition (0.00 to 0.20 kg/ha) of total nitrogen occur on non-forested wetlands. Scientific research conducted by Logofet and Alexandrov (1984) Suggest that a treeless oligotrophic (nutrient-poor) bog may undergo succession to a forested bog as a result of input of as small as 7 kg N/ha/yr. This lower limit on the change in deposition exceeds the change categories displayed in Exhibit 14 as well as Exhibit 8 (0 to 4.65 kg/ha). Accordingly, it appears unlikely that changes imposed by the Title IV Controls will have significant effects on non-forested wetlands. A stronger understanding of the effects on freshwater wetlands would require more spatial information on the location of freshwater wetlands and nitrogen deficient plant species.

Changes in the species composition of flora in freshwater wetlands will potentially affect service flow provision. If changes in flora involve endangered species, there are likely to be significant losses associated with the loss of such plants and in the biodiversity of wetland ecosystems. Recreational service flows such as hiking/hunting/camping, birdwatching/wildlife viewing, scenic beauty, boating or water activities, and fishing might also depend on the species composition of the wetland ecosystem. Flood control, storm protection, nutrient removal, pollutant uptake, and sediment control may vary with the nutrient dynamics of wetlands as well as the species comprising the ecosystem. Even if changes in species composition might be documented, it is unlikely that changes in many of the associated service flows other than the biodiversity service flow could be accounted for. The difficulty of modeling these other types of service flows is related to their dependence on specific physical attributes above and beyond those of the freshwater wetland as well as the indirectness of the service flow provision. Studies that economically address wetland service flow provision tend to be site specific studies that employ assumptions on changes in the appearance or size of the wetlands or in some cases assume complete destruction of the freshwater wetland. Numerous economic studies have been completed in this fashion to estimate the value of wetland services (refer to Whitehead and Blomquist (1991), Raphael and Jaworski (1981), Hamm (1991), and Bowker and Stoll (1988). This type of approach may not seem.applicable to the Title IV Controls because of the unlikely nature of physical effects within freshwater wetland ecosystems.

3. Lakes and Streams

Exhibit 16 presents the change in annual average concentration of nitric acid and the fraction of land covered by water[5]. With the exception of the Mid-Atlantic Region, there

[5] It is difficult to interpret what types of water bodies are included in the land use data.

appear to be only very moderate reductions (0.30 $\mu g/m^3$ or less) in concentration on these lands. Even within the Mid-Atlantic Region, the majority of reductions on water covered lands are approximately 0.50 to 0.60 $\mu g/m^3$. As noted previously, baseline annual average concentrations range from 0.7 to 7.9 $\mu g/m^3$ within the entire affected area, with a baseline mean annual average concentration of 3.11 $\mu g/m^3$. It is difficult to assert what the effects of nitrogen oxide reductions on lake and stream ecosystem service flows might be under the E4 scenario without more detailed knowledge of the water and soil chemistry as well as the fish populations of the affected region. It does not appear that these changes in the Mid-Atlantic Region would result in acidification of lake and stream waters.

Areas within the United States that have encountered acidification problems and fish loss include the Adirondacks and Catskills mountain areas as well as the Northern Appalachian Plateau of Pennsylvania (US EPA, 1993). The National Surface Water Survey (NSWS) indicates that 8% of lakes (mostly in northeastern Pennsylvania) and 6% of streams (mostly in watersheds above 300 m in elevation) in the Mid-Atlantic Highlands region are acidic. Sulfate is the predominant anion in all the acidic lakes and streams in this region, and nitrate does not appear to be important for portions of the Mid-Atlantic Highlands. Some effects on fish have been observed in streams in the Catskills, Appalachian Plateau, Virginia, West Virginia, and western Maryland (NAPAP 1991b, 36-37). The NSWS also shows that 6% of the streams in the Mid-Atlantic Coastal Plain are acidic, and sulphate is the dominant anion in this region rather than nitrate. Field evidence has shown no linkage between fish decline and acidic deposition in this region (NAPAP 1991b, 37). Because of the limited role of nitrates in the acidification of waters in this region, it appears that the changes imposed by the Title IV controls will have little effect on aquatic ecosystems.

Nitric acid (HNO_3) was selected as an indicator of potential water acidification. The annual average concentration estimates of nitric acid reflect ambient rather than water concentrations. Additional information on water and soil chemistry might allow for prediction of changes in the pH or acid neutralizing capacity (ANC) of lakes and streams which would then allow for estimates of the effects on fish stocks and/or water quality. As part of the NAPAP research effort, several models were developed to simulate changes in water chemistry, but many of these models (i.e., MAGIC) are quite data intensive (i.e., water body specific data) and do not specifically recognize the contributions of nitrogen oxides to changes in water chemistry. Many of these models were designed to assess the contributions of sulfates rather than nitrates. Both steady-state and dynamic models (ETD, ILWAS, and MAGIC) are discussed in NAPAP (1990a). It might be feasible to make assumptions regarding the effects of nitrates on changes in acidity as well as to extrapolate regional chemical responses from these past modeling efforts. This type of modeling would require a broader spatial and temporal understanding of changes in concentration of nitric acid as well as other factors.

Changes in the water chemistry of streams and lakes are likely to impact the provision of service flows by these ecosystems. These changes will occur from direct deposition of nitrogen oxides to these waters as well as runoff from terrestrial ecosystems (which varies with soil chemistry). As the species living in these waters and the quality of the waters change, the provision of service flows are likely to be altered. Recreational service flows such as birdwatching/wildlife viewing, scenic beauty, boating and other water activities, and fishing and biodiversity services might be affected by such changes in species and water quality. If physical effects could be modeled or perhaps assumed, significant economic research exists to facilitate estimation of the value of the changes in service flow provision. The tendency revealed in existing works has been to assume the loss of certain fishing sites or fish species rather than to explicitly model the physical effects (refer to Mullen and Menz (1985), Callaway (1990), and Morey and Shaw (1990)). This modeling approach may not prove appropriate for the Title IV Controls because of the reduced likelihood of acidification effects from nitrogen within the Mid-Atlantic Region.

4. Ocean and Estuarine Ecosystems

Exhibit 17 presents the changes in annual average deposition of total nitrogen and the fraction of land covered by water. Again, it is evident that only modest changes in deposition (kg/ha) occur on coastal lands (no change to 0.20 kg/ha) with the exception of the Mid-Atlantic region that reveals some larger reductions on the order of 0.60 to 0.80 kg/ha. Baseline deposition estimates for the Mid-Atlantic Region appear to be approximately 8 kg/ha, intimating reductions of 7 to 10 percent relative to baseline.

Changes in nitrogen levels within ocean and estuarine ecosystems will potentially affect eutrophication processes. The Mid-Atlantic Region, more specifically the Chesapeake Bay, has been the target of much research on the contributions of various sources to eutrophication. Comprehensive attempts at describing the contributions of atmospheric deposition to the overall nutrient budget of the Chesapeake Bay include the Environmental Defense Fund (Fisher et al. (1988)) and Tyler (1988) nitrogen budgets. US EPA (1991) discusses these two budgets as well as a refined budget (see 10-238 in US EPA 1991). These three budgets estimate the proportion of the total NO_3^- load to the Bay attributable to nitrogen deposition ranges from 18% to 31% The Alliance for the Chesapeake Bay (1993) report that future computer modeling efforts indicate even greater contributions from deposition. The computer modeling intimates that air pollution could account for nearly 40% of the Bay's total nitrogen load. With more information from the Chesapeake Bay studies, it might be possible to extrapolate the likelihood of reduced eutrophication from the Title IV Controls. NERA (1994) estimate that annual reductions in nitrogen deposition would be 3,840 tons and 1,720 under scenarios E4 and E3 respectively.

Eutrophication affects the provision of service flows by ocean and estuarine ecosystems by altering water quality and species composition. Recreational service flows such as birdwatching/wildlife viewing, scenic beauty, boating/water activities, and fishing might potentially be altered with such changes. A modeling approach similar to that used by Bockstael et al. 1989 might be appropriate where changes in the demand for boating, beach use, and striped bass fishing were linked with changes in water quality measures.

10. Conclusion

Task 3 of the current work assignment calls for the quantification of economic damages avoided by reductions in NO_x emissions. At this juncture we are supposed to identify economic damages that are amenable to further development. Because the scope of our efforts was broad, covering all potentially affected ecosystems, an initial objective of our work was to identify significant improvements in benefit estimation and not replicate earlier work. Unfortunately, the existing work provided only a limited foundation for estimating ecosystem benefits. For example, in the most recent work that is relevant, NERA (1994) evaluates ecosystem benefits in three areas: (1) reduced nitrification of estuaries and other surface waters, using the Chesapeake Bay as the prime example; (2) reduced acidification of lakes and streams; and (3) reduced damage to forests from acid deposition and ozone. Exhibit 19 summarizes the conclusions provided by NERA in each of these areas. Benefits were estimated for only one category of physical effects (eutrophication) and then only for the Chesapeake Bay. Given the limited quantification achieved in the NERA work, our perspective had to remain very broad.

The result is a reasonably comprehensive inventory of the potential ecosystem benefits and of the information available on the associated physical and economic linkages needed to quantify these benefits. Critical information gaps have, however, proven to be commonplace. The combination of the physical, effects inventory and GIS modeling of the SAI Title IV Scenarios resulted in little reward in terms of quantifying ecosystem benefits. In most cases, the changes were too small to result in physical effects or in some cases the larger changes simply did not correspond to the geographic areas at risk[6]. Other research efforts in this same area have reached similar conclusions about modeling the effects of nitrogen oxides. For example, NAPAP (1991, 1992) publications note the need for further research on the effects of air pollutants on forest and terrestrial ecosystems throughout the State of Science volumes (NAPAP 1990a, 1990b) prepared on acid rain which give little attention to nitrogen oxides.

Our conclusion from constructing the inventory is that no single ecosystem benefit category provides a reasonably well-founded basis for making new NO_x benefit estimates. Speculative assumptions will be required in many instances. In some cases, they will be needed for both the physical and the economic linkages. There do appear to be some avenues for future research but the returns from such research remain highly uncertain. For example, the economic estimates by Bockstael et al. (1989) could be applied to changes in water quality in the Chesapeake Bay through the use of informed but still ad hoc assumptions. Since NERA's report already provides an estimate for this benefit category, albeit based upon avoided costs, it is not clear how informative a highly uncertain benefit estimate based upon the work Bockstael et al. would be. Another alternative would be to examine methods for characterizing potential effects

[6] It is important to note that the E4 scenario discussed throughout this summary represents greater controls than those of the Title IV regulations. E4 establishes an additional 75% NO_x emission controls on Title IV sources and therefore represents a higher bound on potential ecosystem benefits.

on nitrogen deficient plant species within freshwater wetlands. This potential impact may be worth exploring in the long run because very little attention has been given to it in the past. However, in the short run, very little basic information exists.

These findings pose a serious dilemma for the implementation of Task 3. We have identified a limited number of opportunities to construct very speculative estimates of ecosystem benefits from NO_x emission reductions. Such speculations might be warranted if the benefit estimates were expected to be large but they are not. Furthermore, because the scope of our inventory was broad, the information that we have been able to collect is sufficient for "back-of-the-envelope" estimates at best. Our view, is that such estimates do not qualify as the basis for the results expected from Task 3. Clearly the absence of any alternative estimates makes this a difficult position but we are very concerned about the quality of the estimates that can be constructed based upon current knowledge. We have made substantial efforts to find a way around this dilemma but without success.

We suggest meeting with you to discuss our findings and conclusion in greater depth and to consider possible next steps. Please contact us once you have had a chance to review this memorandum.

Exhibit 19
Estimates of Benefits Associated with Unmanaged Ecosystems

Physical Effect	**Method**	**Estimate**
Eutrophication	Estimate the benefits of controlling emissions by using the costs of alternative controls. Estimates reflect costs to achieve the goals of the Chesapeake Bay Agreement. Point source control estimates are based on Camacho (1993), while non point source control estimates are based on Shuyler (1992).	Avoided Cost (1990 $ millions) Proposed Rule (1,720 tons reduction) Chemical Addition (16.5-35.1) Biological Removal (6.9-56.1) Management Practices (1.7-490.2) Advanced Technology (3,840 tons reduction) Chemical Addition (36.9-78.3) Biological Removal (15.4-125.2) Management Practices (3.8-1094.4)
Forests	No quantitative evidence on which to base an estimate of benefits.	–
Acidic Deposition of Surface Waters	Too little information available on how many fish or how many lakes or how many species a given change in deposition will affect. Unable to provide a quantitative estimate of the potential damages to surface waters.	-

[1] Source: NERA (1994). The Benefits of Reducing Emissions of Nitrogen Oxides Under Phase I of Title IV of the 1990 Clean Air Act Amendments.

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Appendix 1
Inventory of Relevant NO_x Scientific Studies

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Inventory of Relevant NO_x Scientific Studies

Pollutant	Ecosystem	Dose Response/Findings	Cite
NO_x	Forest	Red spruce and fir forests have been affected by acidic cloud water in high-elevation areas of the Eastern United States.	NAPAP (1991b). 1990 Integrated Assessment Report. Washington, DC: NAPAP.
NO_x	Freshwater Wetlands	Large declines in sphagnum moss populations have occurred as a result of atmospheric pollution in Great Britain.	Ferguson et al. (1984) and Lee et al. (1986) as cited in US EPA (1991). Air Quality Criteria for Oxides of Nitrogen, EPA 600/8-91/049bA. August 1991, External Review Draft, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Research Triangle Park, NC: Office of Research and Development.
NO_x	Freshwater Wetlands	Research suggests that a treeless oligotrophic bog may undergo succession to a forested bog with as little as 7 kg N/ha/yr.	Logofet and Alexandrov (1984). Modelling of matter cycle in a mesotrophic bog ecosystem: II. dynamic model and ecological succession. Ecological Modelling 21: 259-276.

Appendix 1
Inventory of Relevant NO_x Scientific Studies

Pollutant	Ecosystem	Dose Response/Findings	Cite
NO_x	Streams and Lakes	US EPA Eastern Lake Survey suggests that 14% of the lakes greater than 4 hectares in surface area are acidic. This suggests that approximately 179 lakes are acidic. Variation in ANC across lakes is due to differences in the supply of base cations to drainage waters. Atmospheric deposition of chemicals is relatively uniform. Acidic lakes are typically located at high elevations in basins with shallow deposits of glacial till. Episodic acidification is an important process in this region. 53 species of fish have been collected in Adirondack lakes from surveys conducted by ALSC. Brook trout are the only game fish and considered most susceptible to acidification. Four fish species were found with pH less than 4.5 and 11 were found with pH less than 5.0 indicating that several existing species are tolerant. Species richness does decrease with pH. No fish were caught in 24% of 1,469 lakes surveyed by the ALSC. Fishless lakes had lower pH, ANC, Ca, and 02 and higher A1. Absence of fish did appear correlated with low PH.	Driscoll et al. (1991)in Charles, Donald F., editor (1991). Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	Within Maine, fewer man 100 nondystrophic lakes larger than 0.4 hectares are presently acidic. 12 of 90 lakes above 600 meter elevation were acidic in 1987. 30 percent of the seepage lakes sampled during 1986-1987 were acidic. It is estimated that 30% of the acidic lakes are so because of organic acidity and about 60% are so from acidic deposition. Chronic acidic lakes in streams are unknown. Episodic acidification does occur. Existing research suggests that fewer than 100 lakes are potentially at risk of further acidification at current deposition levels. Although numerous lakes are fishless, no lakes have been shown to be fishless because of acidification. Many of the fishless lakes are small, isolated high elevation lakes that have poor breeding habitat.	Kahl et al. (1991). in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.

Appendix I
Inventory of Relevant NO_x Scientific Studies

Pollutant	Ecosystem	Dose Response/Findings	Cite
NO_x	Streams and Lakes	The Catskills Mountain Region experiences the highest rates of acidic deposition of any region of the United States with low ANC surface waters (Sulfate 605, NO3 404, and H+ 663 eq ha per year). Most surface waters are streams. Many of these (16%) exhibit ANC < 0 during high-flow events and some at baseflow (8%). Differences in ANC across the region are attributed to variability in base cations, rather than variability in acid anion concentrations. There is no direct evidence showing that fish have been adversely affected by acidic deposition.	Stoddard and Murdoch (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	Data suggests that the mountain streams of Virginia are at considerable risk to damage from acidic deposition. Sulphate is the major anion in most streams with low ANC. Stream surveys implied that 93% had ANC < 200; 49% < 50; and 10% were acidic ANC < 0. Bedrock geology appears to account for the variability in ANC in this region. Potential problems for fish populations in the mountain streams are evident. The high elevated streams at risk are dominated mostly by the eastern brook trout. At present, most streams have Ph values above the critical values for the fish. The common shiner and fathead minnow might currently be affected. Further increase in deposition could threaten small-mouth and rock bass. One study (Mohn 1988) links decline of fish populations with acidification.	Cosby et al. (1991) in Charles, Donald F. ed.. Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	Sulphate and NO3 are the dominant anions in the few acidic streams known to occur in the Southern Blue Ridge. The present chemistry of streams and lakes suggests that mineral acidity, primarily SO4, is having an effect on acid-based chemistry. Some evidence of episodic acidification exists. Documented declines in the distribution of brook trout populations in Southern Blue Ridge streams are probably not due to acidification because brook trout are now concentrated in the high elevated streams where acidic conditions are more likely to exist.	Elwood et al. (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.

Appendix 1
Inventory of Relevant NO_x Scientific Studies

Pollutant	Ecosystem	Dose Response/Findings	Cite
NO_x	Streams and Lakes	Available data suggests that there has been no widespread biological damage due to acidic precipitation in Florida. No fishery losses have been verified in Florida despite the very low pH values (less than 5) observed in many Florida lakes. Acidic Florida lakes do appear to support fewer plant and animal species are generally less productive than nonacidic lakes. Difficult to disentangle the effects of pH from other factors related to nutrient status.	Pollman and Canfield (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag: Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	Wet deposition rates increases from west to east in the Upper Midwest, but ANC levels do not share the same spatial pattern in this region. Data suggests some lakes have experienced a pH loss of 0.2 to 0.3 units. However, atmospheric deposition cannot be singled out as the cause of these losses. The distribution of phytoplankton, zooplankton, and fishes IS related to lake pH. Low pH lakes in WI and MI tend to have fewer fish species than do comparable high pH lakes. Fish declines have occurred but cannot be linked exclusively with acidification.	Cook and Jager (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	Western trout species could potentially be at risk. There is no evidence, however, of impact from acidification on the fishery resources of high-elevation Rocky Mountain Lakes. Impacts that have been recorded happen with heavy flow events when runoff waters contain toxic acid and inorganic A1 concentrations. Most of the acidic high-elevation lakes were fishless and only contain fish now because of stocking efforts.	Turk and Spahr (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.

Appendix 1
Inventory of Relevant NO_x Scientific Studies

Pollutant	Ecosystem	Dose Response/Findings	Cite
NO_x	Streams and Lakes	Surface waters show no signs of chronic acidification but are dilute and susceptible to the effects of acidification in the Sierra Nevada. Episodic events of low pH and NAC are associated with dilution by large volumes of dilute runoff and elevated levels of strong acid anion relative to basic cation concentrations. Weathering of granitic minerals is the major source of ANC to Sierra Nevada lakes. Species of fish, zooplankton, and stream invertebrates that are considered sensitive to acidification are common throughout the region. It is unlikely that their distribution has been affected.	Melack and Stoddard (1991) in Charles, Donald F. ed.. Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verfag. Characterizing Regional Effects from Acid Rain.
NO_x	Streams and Lakes	No lakes were found to be acidic within the Cascade Mountains. Seasonal trends in lake chemistry are linked with snowmelt events. ANC and base cation composition are acquired from the weathering of basic minerals in lake watersheds. Aquatic biota have not been well characterized or studied for impacts from acidification. No discernable impacts are expected under current conditions.	Nelson (1991) in Charles, Donald F. ed., Acidic Deposition and Aquatic Ecosystems. New York: Springer-Verlag. Characterizing Regional Effects from Acid Rain.

Appendix 2
Inventory of Relevant O_3 Scientific Studies

Appendix 2
Inventory of Relevant Ozone Scientific Studies

Pollutant	Endpoint	Dose Response/Findings	Cite
Ozone	Forest	Fit Exposure Response Equations Relating Total Biomass (Foliage, Stem, and Root) to 24-Hour SUM06 Exposures Adjusted to 92 Days (ppm-h/year) The following represent groupings of results by categories. All results are for weibull equations. All 51 Seedling Studies 50th percentile PRYL= 1-exp(-[SUM06/176.342]**1.34962) 75th percentile PRYL= 1-exp(-[SUM06/104.281]**1.46719) 27 Fast-Growing Seedling Studies 50th percentile PRYL= 1-exp(-[SUM06/150.636]**1.43220) 75th percentile PRYL= 1-exp(-[SUM06/89.983]**1.49261) 24 Slow to Moderate Growth Seedling Studies 50th percentile PRYL= 1-exp(-[SUM06/190.900]**1.49986) 75th percentile PRYL= 1-exp(-[SUM06/172.443]**1.14634) 28 Deciduous Seedling Studies 50th percentile PRYL= 1-exp(-[SUM06/142.709]**1.48845) 75th percentile PRYL= 1-exp(-[SUM06/87.724]**1.53324) 23 Evergreen Seedling Studies 50th percentile PRYL= 1-exp(-[SUM06/262.911]**1.23673) 75th percentile PRYL= 1-exp(-[SUM06/201.372]**1.01470) where PRYL = percent yield loss SUM06 = cumulative sum of all hourly 0, concentrations greater than 0.06 ppm FAST = aspen, red alder, tulip poplar, loblolly SLOW = douglas fir, ponderosa pine, red maple, sugar maple, eastern white pine, Virginia pine	Hogsett et al. (1993). as discussed in US EPA (1993) Hogsett et al. (1993). Ecosystem Exposure Assessment: Ozone Risks to Forests. In: Comparative Risk Analysis and Priority Setting of Air Pollution Issues. Pittsburgh, PA: Air and Waste Management Association.

Appendix 2
Inventory of Relevant Ozone Scientific Studies

Pollutant	Endpoint	Dose Response/Findings	Cite
Ozone	Forest	Chronic O_3 exposures over a period of 50 years or more caused major changes in the San Bernardino Forest Ecosystem. Certain species such as ponderosa and Jeffrey pine were no longer able to effectively compete for essential nutrients, water, light, and space and more tolerant species benefited relative to these sensitive species.	Miller et al. (1991). as discussed in US EPA (1993) Miller, P.R.. McBride, J.R., and S.L. Schilling (1991). Chronic Ozone Injury and Associated Stresses Affect Relative Competitive Capacity of Species Comprising the California Mixed Conifer Forest Type. In: Memorias del primer simposial national; Agricultura sostenible: Una option para desarollo sin detenoro ambiental. Montecillo, Edo. Mexico, Mexico: Comision de Estudios Ambientales, Colegio de Postgraduados; 161-172.
Ozone	Forest	Injury to more sensitive species (i.e., ponderosa and Jeffrey pines) has also been documented in the Sierra Nevada Mountains.	Peterson et al. (1991). as discussed in US EPA (1993) Peterson, D.I., Arbaugh, M.J., and J.R. Linday (1991). Regional Growth Changes in Ozone-Stressed Ponderosa Pine in the Sierra Nevada, California. Holocene 1: 50-61.

Appendix 2
Inventory of Relevant Ozone Scientific Studies

Pollutant	Endpoint	Dose Response/Findings	Cite
Ozone	Forest	Injury to more sensitive species has also been documented for the Appalachian Mountains where needle blight and other oxidant induced stresses have been observed.	McLaughlin et al. (1982). as discussed in US EPA (1993) McLaughlin, S.B., McConathy, R.K., Duvick, D., and L.K. Mann (1982). Effects of Chronic Air Pollution Stress on Photosynthesis, Carbon Allocation, and Growth of White Pine Trees. Forest Science 28: 60-70.

Appendix 3
Sampling of Relevant Economic Studies

Appendix 3
Sampling of Relevant Economic Studies

Pollutant	Ecosystem Category/ Service Flow	Results	Citation
Ozone	Forest	Values reflect changes in consumer and producer welfare from simulated reductions in tree growth in the Southeast due to ozone. Using the TAMM model, changes in annualized economic surplus for planted pines and natural and planted pines for the period of 1985-2040 are estimated. For various growth changes, the values estimated for planted pines include $18.5 million (+2), -$9.1 million (-2), -$25 million (-5), and -$61 million (-10). The same values for natural and planted pines are $39.3 million, -$0.3 million, -$42.4 million, and -$108.5 million.	NAPAP (1991b, 1990b).
Ozone	Forest	Value estimates reflect additional willingness to pay measures for access to areas with high, medium and low damages from ozone in the San Bernardino National Forest. CV analysis with representative photographs were used. The mean additional willingness to pay measures per trip for access to areas with varying levels of damages were $2.09 (light damages), $0.66 (moderate damages), and $0.74 (severe damages).	Crocker (1985).
Ozone	Forest	Value estimates reflect ozone-induced changes in the appearance of national forests outside of Los Angeles. Recreationists and property owners/residents were asked their willingness to pay to prevent degradation. The mean-willingness to pay to prevent the drop of forest quality down one step on the forest quality ladder were $37.61 for residents and $119.48 per household. Annual damages were estimated for a one-step drop on the quality ladder for Los Angeles Area residents. These estimates ranged from $27 million to $144 million.	Peterson, D.C. (1987).
All pollutants	Forest	Value estimates reflect assumed scenarios involving growth reductions of 10%, 15%, and 20% for hardwood and softwood species. Annual damages or benefits of control in 1984 dollars ranged from -$270 million to $563 million.	Callaway et al. (1985).
Acid Deposition	Forest	Value estimate reflects a 5% reduction in products due to acid deposition. Assumes pristine background of pH of 5.2. Annual estimate of damages in 1978 dollars was $1,750 million.	Crocker (1985b).
Air Pollutants	Forest	Value estimates reflect assumed loss of 5 to 10% for softoods and hardwoods. Annual damage estimates were generated using the TAMM model ranging from $1,500 million to $7,200 million in 1986 dollars.	Haynes and Adams (1992).
Fire	Forests	Evaluated individual preferences for forest recreation on burned and unburned sites. Photographs were used to display the condition of various sites. The sample consisted of 1,200 recreationists in the Northern Rocky Mountains and willingness to pay for access to different quality sites was elicited. The contingent valuation study revealed a loss in recreation value (net present value over ten years, 1978 $) ranging from $0.13 to $4.74 per acre.	Flowers, P. J., Vaux, H. J., Gardner, P. D., and T.J. Mills (1985).

Appendix 3
Sampling of Relevant Economic Studies

Pollutant	Ecosystem Category/ Service Flow	Results	Citation
Scenic Beauty	Forests	Evaluated the relationship between ratings of scenic beauty and willingness to pay for access to various sites using photographs. The sample consisted of 1,464 recreationists at 10 sites in Arizona. The study revealed that scenic beauty accounted for 33% of the variation in willingness to pay,	Brown, T. C., Richards, M. T., and T.C. Daniel (1989).
Insect Damage	Forests	Evaluated effects of pine beetle damage on forest recreation demand. Study used contingent valuation and travel cost models on sites in Colorado. Results showed 10%, 20%, and 30% decreases in tree densities resulted in decreases in total benefits of 7%, 15%, and 24%.	Walsh, R. G., Ward, F. A., and J.P. Olienyck (1989).
Insect Damage	Forests	Assessed the effect of insect damage on recreational forest benefits. Site evaluated was the Targee National Forest in Idaho. Consumer surplus dropped from $17.90 to $15.50 because of insect infestation at campgrounds.	Michelson, E.L. (1975).
Insect Damage	Forests	Evaluated the effect of insect damage at a reservoir based site in Texas. If tree crown was reduced by 10%, the travel cost model employed predicted a total loss m recreational benefits at each site of 6% to 7%.	Leuschner, W.A. and R.L. Young (1978).
Commercial Development	Freshwater Wetlands	Contingent valuation method was used to derive household values for natural wetlands in Clear Creek, Kentucky. Annual per household preservation values ranged from $5 to $17 ($1991).	Whitehead and Blomquist (1991).
Generic	Freshwater Wetlands	Using recreational expenditures as a proxy for willingness to pay, these authors derived per acre values for various service flows provided by Michigan wetlands. Per acre value estimates its $1991 were as follows: waterfowl hunting ($49.59); nonconsumptive recreation ($244.63); water quality and nutrient uptake ($930-$1,124); and water supply services ($10.71).	Raphael and Jaworski (198 1).
Generic	Freshwater Wetlands	Using the contingent valuation method, the authors assessed the value of fishing and hunting service flows provided by wetlands. These service flows were valued at $281.30 per acre ($1991).	Thibodeau and Ostro (1981).
Generic	Freshwater Wetlands	Using the contingent valuation method, the value of nonconsumptive recreation, education, water quality, and nutrient uptake services were examined for South Carolina wetlands. In 1991$, the services were valued at $0.5 to $1.2 million (nonconsumptive recreation); $0.08 million (education); and $4.9 to $5.7 million (water quality and nutrient uptake services) respectively.	Harem (1991).
Generic	Freshwater Wetlands	Existence value estimates were calculated for wetlands located in the Arkansas Wildlife Refuge. Per person values ($1991) ranged from $28.17 to $73.65 using the contingent valuation method.	Bowker and Stoll (1988).
Generic	Freshwater Wetlands	Using avoided cost methods, the water quality and nutrient services provided by freshwater marshes were evaluated. Estimates ($1991) ranged from $47,500 to $81,000.	Tilton et al. (1977)

Appendix 3
Sampling of Relevant Economic Studies

Pollutant	Ecosystem Category/ Service Flow	Results	Citation
Generic	Freshwater Wetlands	Using avoided cost methods, the value of water supply services were approximated ($1991) at $800,000.	Wharton (1970).
Generic	Freshwater Wetlands	Using hedonic price regression analysis, the preservation value of Michigan wetlands was examined. The analysis revealed a value of approximately $38.99 ($1991) per acre.	Amacher et al. (1989).
Generic	Coastal Wetlands	On-site recreational services provided by coastal wetlands along the coast of Louisiana were evaluated using contingent valuation methods. In 1987 dollars, annual average consumer surplus per acre was estimated to be $8.42 ; while aggregate consumer surplus on an annual basis neared $118 million.	Bergstrom et al. (1990).
Acidic Deposition	Lakes and Streams	Value reflects changes in the welfare of cold-water recreational anglers in New York, New Hampshire, Vermont, and Maine. Both random utility and hedonic travel-cost models are used to assess three scenarios: 50% reduction in Deposition ($14.7 million, $4.2 million), No Change (-$5.3 million, -$27.5 million), and 30% increase in Deposition (-$10.3 million, -$97.7 million). These values represent the total welfare in 1990 minus the total welfare in 2040. Total welfare is calculated as the average WTP per trip multiplied by the average number of trips per individual multiplied by the population.	NAPAP (1990b).
Acidic Deposition	Lakes and Streams	Acidification damages were assumed to cause the loss of certain angling sites in the Adirondack Mountain Region. Loss of sites occurred when pH levels fell below 5.0. Coldwater and "other" species were distinguished. A travel cost method was used where visitation was modeled as a function of an index of habitat availability weighted by travel cost. Estimated Losses in Angler Days and Net Economic Value were 79.176 and $1,073,364.	Mullen, J.K. and F.C. Menz (1985).
Acidic Deposition	Lakes and Streams	Acidification was linked to reductions in catch rates and fishable acreage. Participation and varying parameter travel cost models were estimated. Increases of acreage by 3.2% and 10% were valued at $700,000 and $4,600,00 respectively. These same increases in acreage accompanied by increases in catch rates were valued at $4,800,000 and $12,000,000 respectively.	Callaway et al. (1990).
Acidic Deposition	Lakes and Streams	A contingent valuation study was conducted to evaluate option values associated with reductions in damages from acid rain. Respondents in Wisconsin revealed that they would be willing to pay an average of $10 per month to reduce damages.	Bishop and Heberlein (1984).
Acidic Deposition	Lakes and Streams	Acid rain was linked with changes in fish stocks and catch rates. Reductions in acidity were linked with increases in catch rates of 5%, 25 % , and 50%. A travel cost model was specified and the mean annual expected CCV for increases in catch rates of 5%, 25%, and 50% were $1.91, $8.68, and $15.51.	Morey and Shaw (1990).

Appendix 3
Sampling of Relevant Economic Studies

Pollutant	Ecosystem Category/ Service Flow	Results	Citation
Eutrohpication/Water Quality	Oceans and Estuarine Ecosystems	Authors examined the effects of nutrient over enrichment, toxic substances, and the decline of submerged aquatic vegetation on water quality in the Chesapeake Bay. For beach use and boating, the authors modeled water quality using the product of nitrogen and phoshorous; wherease for evaluating striped bass fishing, the authors evaluated catch rates. The effects of changes in water quality on the demand for these services was evaluated. Contingent valuation results were compared with travel cost results for a "20%" improvement in water quality. The average travel cost aggregate benefits (1987%) were $35 million for beach use, $5 million for boat use, and $1 million for striped bass fishing. Average aggregate benefits from the contingent valuation study was approximately $91 million ($1987).	Bockstael et al. (1989).

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MEMORANDUM

To: Willard Smith

From: Greg Michaels, Kathleen Bell, and Leland Deck

Subject: Speculative Estimates of the Effects of Title IV Nitrogen Oxide Controls on Recreational Fishing

Date: June 27,1995

In this memorandum we present an illustration of the estimation of economic benefits associated with an ecological impact from Title IV No_x controls. It is important to note that the resulting estimates have large uncertainties attached to them because of the necessity of making assumptions about critical but missing parameters. For this reason, we call these estimates "speculative." These speculative estimates primarily serve the following purposes: (1) to illustrate the tenuous nature of the information currently available and where gaps need to be filled, and (2) to provide a rough indication of the potential size of economic benefits that could be estimated with greater confidence if these gaps could be filled. With respect to the first purpose, it is also useful to note that we were confronted with the necessity of calibrating four basic linkages in order to attempt to derive benefit estimates from Title IV NO_x controls. These linkages are outlined in Exhibit 1.

Exhibit 1 **Critical Linkages**
Changes in NO_x Emissions ------> Changes in Air Quality
Changes in Air Quality -------> Physical Effects on Ecosystems
Physical Effects on Ecosystems -------> Changes in Ecosystem Service Flows
Changes in Ecosystem Service Flows --------> Economic Damages or Benefits

The remainder of this memorandum has the following organization. Section I addresses the first two linkages. It presents a characterization of ambient conditions of different land uses in the baseline and with NO_x controls. Section II addresses the last two linkages. An overview is provided of the economic model used to derive benefit estimates associated with water bodies rendered fishable because of reduced acidification. Section III presents the resulting benefit estimates.

I. Ambient Conditions in Baseline and with NO_x Controls

The Title IV NO_x controls are designed to reduce emissions from power plants operating dry bottom wall-fired or tangentially fired boilers. Approximately 179 boilers at 110 facilities will be affected by the Phase I Title IV requirements. The speculative estimates presented within this memorandum indirectly rely on expected changes in emissions of NO, NO_2, and NH_3 but are directly dependent on expected changes in average concentration ($\mu g/m^3$) of nitric acid or HNO_3. Within this analysis, nitric acid serves as the indicator for potential acidification impacts on aquatic ecosystems. The welfare effects of such acidification impacts are examined with specific focus on effects imposed on recreational fishing opportunities. The estimates recognize the impact of the controls by comparing predicted results for year 2000 base case emission estimates (E1) with those emission estimates for the year 2000 with an additional 75 percent NO_x emission controls on Title IV sources (E4). As such, the speculative estimates are definitely in excess of those effects that would be generated using the Title IV Control Scenario (E3). The welfare effects are based on assumed changes in available fishing acreage due to the loss of fish species in acidified waters.

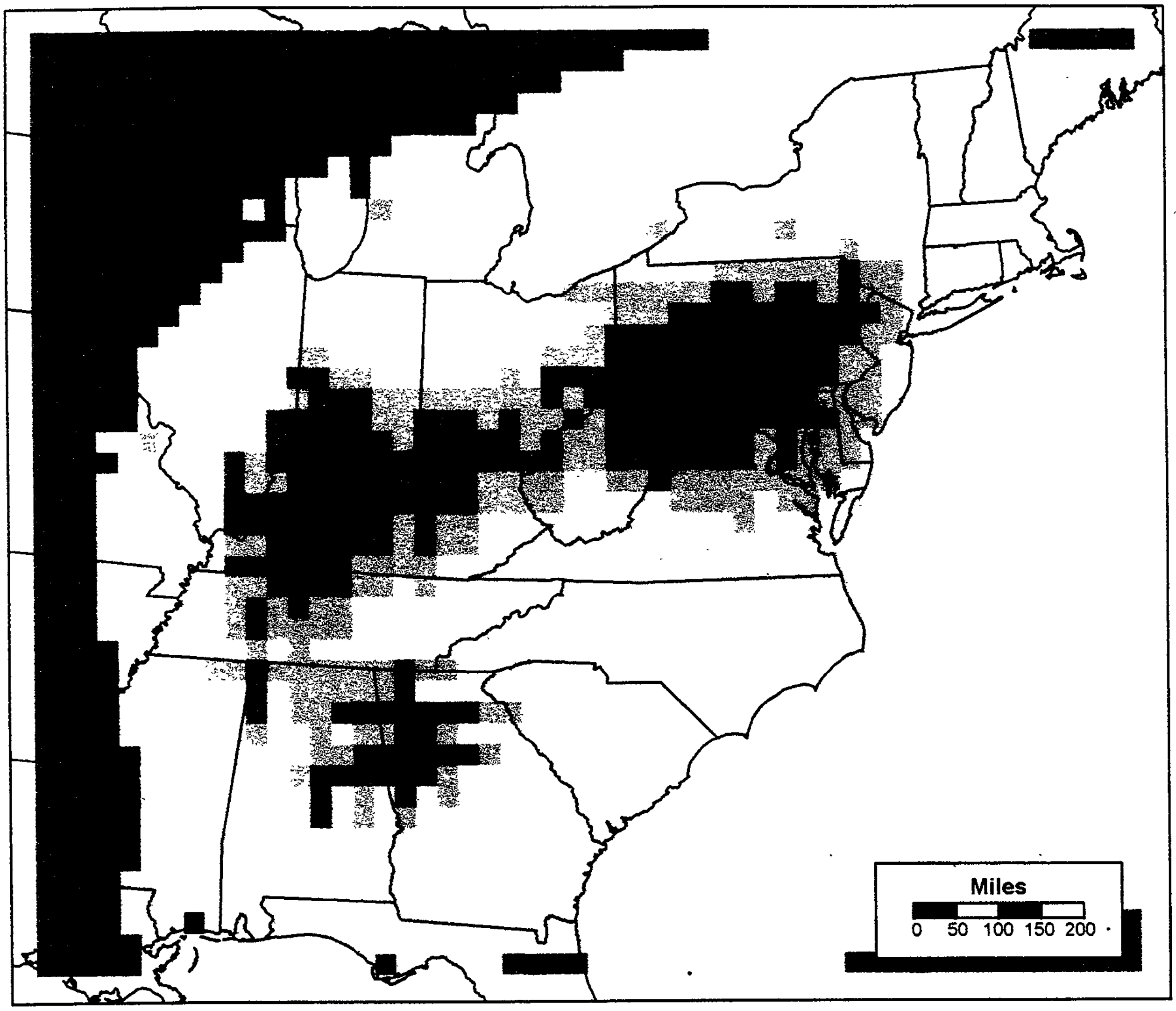
Predicted changes in annual average concentration ($\mu g/m^3$) of nitric acid for the Year 2000 are presented in Exhibit 2. Spatially, the largest reductions in nitric acid concentration (0.70 to 1.50 $\mu g/m^3$) relative to baseline are found in southern Pennsylvania, northern West Virginia, northern Kentucky, northern Tennessee, northern Virginia,, southern Ohio, northern Georgia, and northern Alabama Baseline annual average concentrations of nitric acid range from 0.7 $\mu g/m^3$ to 7.9 $\mu g/m^3$, with a mean concentration of approximately 3.1 $\mu g/m^3$. On average this suggests that the greatest changes in annual average concentration represent changes from baseline ranging from 23 to 48 percent. With some exceptions, there appear to be only very moderate reductions (0.30 $\mu g/m^3$ or less) in concentration on water covered lands and even within the Mid-Atlantic and Southeastern Regions the majority of reductions on water covered lands are approximately 0.50 to 0.60 $\mu g/m^3$.

To generate estimates of recreational fishing impacts, the data presented within Exhibits 2 and 3 are combined and input into an economic model of U.S. recreational fishing behavior. Exhibit 3 presents land use acreage by nitric acid concentration change category. The estimates reflect impacts from only the largest change in nitric acid concentration (0.70 to 1.50 $\mu g/m^3$). In order to generate “sound” estimates of the effects of these reductions on lake and stream ecosystem service flows, detailed knowledge of the water and soil chemistry as well as the fish populations of the affected region are necessary. Without such information, the estimates presented here are limited

Exhibit 2

Change in the Annual Average Concentration of Nitric Acid

Base Case (E1) - High NOx Control Case (E4) for the Year 2000



Reduction in Nitric Acid
Concentration (µg/m3)

- .00 to .10
- .10 to .20
- .20 to .30
- .30 to .40
- .40 to .50
- .50 to .60
- .60 to .70
- .70 to 1.50

Exhibit 3

Land Use Area (km^2) by Nitric Acid Reduction Category($\mu g/m_3$)

Category	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	> 0.7	Total
Urban	3,231	10,860	18,545	8,136	6,669	1,768	1,987	3,137	69,834
Agricultural	298,572	164,520	205,472	103,672	64,001	28,604	17,593	32,999	1,065,672
Rangeland	0	0	16	0	0	0	0	0	16
Deciduous Forest	101,391	60,292	103,175	106,522	58,159	27,372	16,236	24,814	643,814
Coniferous Forest	15,890	72,933	43,652	2,887	1,923	383	1,129	2,079	151,740
Mixed Forest	86,919	92,712	129,272	21,482	16,172	3,953	3,369	7,227	445,674
Water	40,388	58,248	52,882	15,692	6,646	1,919	1,287	1,743	223,788
Barren	3	0	0	0	0	0	0	0	3
Non-Forested Wetlands	7,208	4,441	588	810	31	0	0	0	15,469

in their scientific and economic validity and therefore speculative. Instead, it is postulated that acidification impacts occur on all acreage that is covered by water and falls where the greatest reductions in nitric acid concentration occur. In effect all of this acreage is assumed to be lost fishing acreage. This assumption results in additional positive bias on the estimates for several scientific and economic reasons. First, the nitric acid (HNO_3) concentration was selected as an indicator of potential water acidification. The annual average concentration estimates of nitric acid reflect ambient rather than water concentrations. The capacity of this concentration to serve as an indicator of acidified waters is thus limited. Second, there is no consideration of baseline nitric acid concentration or baseline conditions in the waters of the affected states. Research suggests that changes in nitric acid concentration have markedly different effects in waters according to such factors as their acid neutralizing capacity (ANC). Approximately 1,743 square kilometers (430,703 acres) of water covered lands are found in the largest change category (above 0.7 $\mu g/m^3$). Adjusting this estimate of affected acreage to address these positive biases may involve scaling the estimates downwards according to the distribution of sensitive waters (i.e., ANC < 50) within the affected region, the apparent linkages between ambient and water concentrations, or the likelihood of acid sensitive species to reside in a region's waters.

The final estimates represent the benefits of improving recreational fishing opportunities in terms of acreage within the eight affected states (AL, GA, KY, OH, PA, TN, VA, and WV). This benefit, however, is modeled as the recovering of lost fish opportunities. As the species living in the water acreage change, the provision of recreational service flows are likely to be altered. These and other impacts are modeled by the economic model described in the subsequent section.

II. Design of the Economic Model

The speculative estimates are generated using an Abt Associates model developed to assess the welfare effects of global climate change on recreational fishing opportunities in the United States. Following the design employed by Vaughan and Russell (1982a), the economic model is a reduced form model that characterizes the repercussions of changes in water quality on recreational fishing behavior using a three stage estimation process. The first stage describes the probability of general fishing participation. The second stage predicts the conditional probability of doing one or some combination of coldwater, coolwater/warmwater, and rough fishing activities. The third stage characterizes the average number of person-days devoted to coldwater, coolwater/warmwater, and rough fishing per year.

Implementation of the economic model requires large amounts of data for it is run on a national scale. While consistent and comprehensive data on the general population are available, similar data are not readily available for categorical angler and recreation populations. Because of such significant information constraints, the economic model does not calculate coefficients for each of these stages. Rather, the economic model uses coefficients derived by Vaughan and Russell (1982a) in their national analysis of water pollution controls. In the implementation process, the economic model relies on information from several sources including input data provided by a habitat model that characterizes the recreational fishing opportunities, input data acquired from empirical sources describing the relevant populations, and estimated coefficients communicating the likelihood of different behavioral adjustments. Input data are maintained at a state level, and when possible, inputs to the model have been updated to reflect current national and angler population characteristics (i.e., 1990-1991). Combining input values with the Vaughan and Russell coefficients, the economic model produces average estimates of the probability of fishing by category, the number of anglers by category, and the number of fishing days by category.

The link between recreational fishing behavioral responses and water quality is established in the structure of the three stages of the economic model. The water quality dynamics of the nitrogen oxide control scenario might potentially shift the availability of types of fishing opportunities. These transitions are expressed as changes in the optimal use for a given water body, such as changing from being suitable for coldwater fishing to being suitable only for rough fishing. These changes are reflected in the number of acres available for each of four fish categories (cold, cool, warm, and rough). As acreage shifts occur, the input values to each of the three stages change, and it is these adaptations that explain the different numbers and compositions of fishing days associated with the nitrogen oxide control scenario. The implications of the changes in best use acreage are made clearer by understanding the different stages of the estimation process.

III. Results

The implementation of the economic model concludes with the derivation of several basic results for each regulatory scenario. These outputs include changes in acreage, changes in fishing days, and changes in value (benefits or damages). Exhibit 4 presents the results for the relevant nitrogen oxides control scenario. Several important assumptions that affect the nature of these results are outlined below:

(1) Water covered acreage with nitric acid concentration changes (E1 - E4) in excess of 0.70 $\mu g/m^3$ is assumed to be at risk from acidification. This criterion singles out lands contained in the eight states of Alabama, Georgia, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

(2) Approximately 400,000 acres are assumed to be acidified to the point of not being fishable. These acidified waters are then assumed to be approximately evenly distributed throughout the eight states listed previously.

(3) Acidified water acres as defined by (1) and (2) are then assumed to be lost fishing acres. It is further assumed that fishing in these acres could be recovered. The acreage changes appear as cold-water fishing losses in Ohio, Pennsylvania, Virginia, and West Virginia, as cool-water fishing losses in Alabama, Kentucky, and Tennessee and as warm -water fishing losses in Georgia.

(4) Estimated fishing days by fish guild category (cold, cool, warm, and rough) are generated using the changes in available fishing acreage.

The results presented in Exhibit 4 depend on several additional assumptions. First, the following fishing day values (in 1993 dollars) were adopted: cold-water fishing ($45.93), cool-water ($29.08), warm-water ($29.08), and rough ($20.66). Second, losses in fishing acreage were assumed to be distributed as follows: cold-water (OH (44,869), PA (50,646), VA (53,838), and WV (53,838)), cool-water (AL (53,838), KY (53,838), and TN (58,838)), and warm-water (GA 53,838).

The estimates indicate that reduced acidification would lead to an increase of $38 million in overall fishing-day value, an increase of about 88,000 in the number of anglers, and a loss of approximately 19 million fishing days.[1] As emphasized previously, the speculative benefit estimate of $38 million is an ad hoc estimate with several inherent positive biases introduced by assumptions

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[1] A loss in the number of fishing days is attributable to the model's prediction of anglers' switching from types of fishing that have lower value per day but is done with greater frequency (such as warm-water fishing) to cold-water fishing which is done less frequently but valued more highly. In the example presented in Exhibit 4, cold-water fishing days increase and all other fishing days decline but the overall value of recreational fishing increases.

made in the absence of more concrete information. For example, we have assumed that all waters in the areas of greatest NO, reduction will be rendered habitable as the result of the E4 scenario NO_x controls. However, sketchy evidence suggests that only 25% of the waters have acid neutralizing capacity below 50 μeq/L. Scaling the acidication factor down by 75% results in a benefit estimate of $9.5 million. Additional adjustments or refinements to the model are likely to lower this estimate even further.

Exhibit 4

Speculative Benefit Estimates for Changes in Recreational Fishing Behavior

Scenario	Fishing Days (Millions)	Number of Anglers (Thousands)	Dollar Value (Millions)
Baseline Assuming Acidification in 8 States	**1,851**	**86,638**	**58,275**
Cold	445		
Cool	726		
Warm	353		
Rough	327		
Reductions in Acidification from NO_x Controls (E4)	**1,832**	**86,726**	**58,313**
Cold	460		
Cool	706		
Warm	347		
Rough	319		
Estimated Changes Attributable to NO_x Controls (E4)	**-19**	**88**	**38**
Cold	15		
Cool	-20		
Warm	-6		
Rough	-8		

Notes:

(1) Assumed benefits reflect the potential recovery of lost fishing opportunities within the Eastern United States from reduced acidification caused by nitrogen oxide emissions.

(2) Fishing day values (in $1993) used are as follows: cold (45.93), cool (29.08), warm (29.08), and rough (20.66). Losses in acreage from cold water are as follows: OH (44,869), PA (50,646), VA (53,838), and WV (53,838). Losses in cool water acreage are as follows: AL (53,83), KY (53,838), and TN (58,838). Approximately 53,838 acres of warm water acreage are lost in GA.

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APPENDIX

Brief descriptions of each stage of the economic modelling of recreational fishing follow. Throughout the discussion, emphasis is given to those variables that are assumed to be changing under the nitrogen oxide control scenario.

The first stage calculates the probability of general fishing participation (P_{GF}). Exhibit A.1 presents the variables used in the estimation of the first stage and notes the source of each variable. The variables reflect socioeconomic characteristics as well as broad recreational fishing opportunities. Input variables include the average age and household income of the U.S. population (1990), the percentage of female, metropolitan, western region, central region, southern region, coastal, and head of household residents within the U.S., and the average fishable acreage per capita per state. With the exception of fishable acreage per capita, the input values for this calculation are estimated using the 1992 Statistical Abstract of the United States (U.S. Department of Commerce 1992). Estimates of the fishable acreage per capita per state are produced by the thermal and economic models using U.S. population estimates and the modified Vaughan and Russell (1982a) baseline acreage data. The socioeconomic characteristics do not change across scenarios. The fishable acreage variable is that element which might changes considerably with the control scenario. The input values are combined with the Vaughan and Russell (1982a, Table 3-6, Reduced Model I) coefficients to derive the general fishing participation probability (P_{GF}). Because the coefficients were estimated using a logit specification, the final general fishing participation probability is calculated as follows:

$$P_{GF} = 1/(1+e^{-\Sigma\{\beta * X\}}$$

where the βs are the estimated coefficients and the Xs are the estimated input values.

Exhibit A.1

First Stage: Predicting the Probability of General Fishing Participation[1]

Variable	Source
Intercept	Not Applicable
Age	US Department of Commerce (1992)
Age-Squared	US Department of Commerce (1992)
Gender (Female)	US Department of Commerce (1992)
Metropolitan Area	US Department of Commerce (1992)
Western Region	US Department of Commerce (1992)
Central Region	US Department of Commerce (1992)
Southern Region	US Department of Commerce (1992)
Fishable Acreage Per Capita By State	Abt Economic and Thermal Models
Average Income Per Household	US Department of Commerce (1992)
Head of Household	US Department of Commerce (1992)
Coastal State	US Department of Commerce (1992)

[1] The data employed in the first stage represent the national population and recreational fishing opportunities.

The second stage calculates the conditional probability of participation by fishing category ($P_{FC} \mid P_{GF}$). For the purposes of this analysis, the economic model distinguishes fifteen mutually exclusive fishing categories. Each of these fifteen categories are some combination of the following types of fishing activity T (cold water); BP (coolwater/warmwater); R (rough); and S (salt or Great Lakes). The fifteen categories are as follows: (1) T; (2) BP; (3) R; (4) S; (5) TBP (6) TR; (7) TS; (8) BPR (9) BPS; (10) RS; (11) TBPR; (12) TBPS; (13) TRS; (14) BPRS; and (15) TBPRS. The economic model calculates the conditional probability for each category and then aggregates these probabilities according to designations for cold, cool/warm, and rough fishing activities. For example, any category including T is counted as coldwater fishing, and similarly, all categories with BP and R are treated as warm/cool and rough fishing respectively.

Exhibit A.2 presents the variables used in each of the estimations by category and notes the source of each variable. Similar to those used in the first stage, the input variables reflect socioeconomic characteristics and recreational fishing opportunities. In this stage, however, the data becomes more activity-specific. The socioeconomic data represent the angler population and the catch rates and fishable acreage information are organized by thermal acreage category. The input variables used in the second stage include the average age and annual income of U.S. anglers, the percentage of female, metropolitan residing, and coastal residing anglers, the average numbers of coldwater fish, coolwater/warmwater fish, and rough fish caught per day, and the ratios of warmwater fishing acreage and rough fishing acreage to total fishing acreage.

The input values for the average annual income, age, gender, and percentages in metropolitan areas and along marine coastlines are estimated using the 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (US DOI, 1993). The average catch rates for coldwater, coolwater/warmwater, and rough fishing days were derived using Vaughan and Russell regional data (1982a, Table 4-4). A weighted average is calculated based on the regional averages, with the regional percentages of U.S. anglers serving as the weights. The fishable acreage ratios are gleaned by the economic and thermal models. In practice, the socioeconomic characteristics are held constant and the acreage ratios are permitted to vary across the regulatory scenarios considered. The input values are combined with the coefficient estimates provided by Vaughan and Russell (1982a, Table 4-8) for each fishing category. Since the coefficients were estimated using a weighted least squares approach, the conditional categorical probabilities are calculated as follows: $P_{FC} \mid P_{GF} = \Sigma\, \beta{*}X$ where the βs are the estimated coefficients and the Xs are the estimated input values. The conditional probabilities of participation are estimated for all fifteen categories. These probabilities are then aggregated to predict participation probabilities for the categories of coldwater (P_{CDF}), coolwater/warmwater (P_{CWF}), and rough fishing (P_{RF}).

The third stage calculates the average number of days per year devoted to coldwater (D_{CDF}), coolwater/warmwater (D_{CWF}), and rough fishing (D_R). Separate calculations are completed for each of these three fishing activities. The variables include socioeconomic characteristics and descriptions of recreational fishing opportunities. Exhibit A.3 presents the variables used to predict the number of fishing days. Socioeconomic variables include average age and income by angler type and the percentages of female, metropolitan area residing, and coastal residing individuals by angler type. The recreational fishing opportunity variables include the average number of coldwater fish caught per day, coldwater fishing acreage per capita, average number of coolwater/warmwater fish caught per day, warmwater fishing acreage per capita, average number of rough fish caught per day, and rough fishing acreage per capita.

Exhibit A.2

Stage 2: Predicting the Probability of Participation by Fishing Category[1]

Intercept	Not Applicable
Average Income Per Household	US DOI (1993)
Age	US DOI (1993)
Age-Squared	US DOI (1993)
Gender (Female)	US DOI (1993)
Metropolitan Area	US DOI (1993)
Coastal Area	US DOI (1993)
Average Number of Coldwater Game Fish Caught Per Fishing Day	Vaughan and Russell (1982a)
Average Number of Coolwater and Warmwater Gamefish/Panfish Caught Per Fishing Day	Vaughan and Russell (1982a)
Average Number of Roughfish Caught Per Fishing Day	Vaughan and Russell (1982a)
Ratio of Coolwater and Warmwater Fishing Acreage to Total Fishing Acreage	Abt Associates' Economic and Thermal Models
Ratio of Rough Fishing Acreage to Total Fishing Acreage	Abt Associates' Economic and Thermal Models

[1] The input variables employed in the second stage represent U.S. anglers and thermal categories of recreational fishing. Outputs from the model are derived for 15 mutually exclusive categories using unique sets of category coefficients. These category probabilities are then aggregated to reflect coldwater, coolwater and warmwater, and rough fishing participation estimates.

The majority of the input values used in this stage of the estimation are taken from Vaughan and Russell (1982a, Table 4-12) because of the limited socioeconomic information available on a national basis for anglers by fishing type or category. Implementing the model, most of the socioeconomic and recreational fishing characteristics are held constant across the scenarios. The fishable acreage estimates per capita are exceptions to the rule, as these vary with each climate scenario. The input values are combined with the Vaughan and Russell (1982, Table 4-12, Unrestricted Model) coefficients to derive three estimates of average person days by fishing activity. Because the coefficients are estimated using a weighted least squares approach, the average number of fishing days per person are calculated as follows: $D_{CDF} = \Sigma\, \beta * X$ where the βs are the estimated coefficients and the Xs are the estimated input values. The average days are estimated for the categories of coldwater (D_{CDF}), coolwater/warmwater (D_{CWF}), and rough fishing (D_{RF}).

The output of the economic model combines information from all three stages of the estimation process. To estimate the number of fishing days for one activity such as coldwater fishing, the probability of general fishing participation (i.e., the output of Stage 1) is first multiplied by the conditional probability of fishing for the category of interest (i.e., the output of Stage 2). This probability is then combined with the estimate of the average number of days devoted to the fishing activity per year (i.e., the output of Stage 3) and an appropriate population estimate (i.e., Bureau of Census 1992) to derive the total number of fishing days. For example, the total number of coldwater fishing days predicted under one scenario would be calculated as follows: $TD_{CDF} = P_{GF} * P_{CDF} * D_{CDF}$ * POPULATION. For each run of the economic model, this procedure is adopted to estimate the total number of coldwater, cool/warm water, and rough fishing days (TD_{CDF}, TD_{CLF}, TD_{WMF}, and TD_{RF}). In contrast to Vaughan and Russell (1982a), the economic model distinguishes coolwater and warmwater fishing activities. In doing so, it is assumed that the average number of fishing days per person is the same for coolwater and warmwater fishing and that the ratio of the total number of coolwater fishing days and warmwater fishing days is equal to the ratio of the best use acreage estimates for coolwater and warmwater fishing.

After designating the behavioral responses with the results of the three stages, the economic model values the predicted behavioral responses. The welfare or valuation analysis of the economic model is couched in relative terms, with values being placed on the changes in the number of fishing days relative to baseline estimates (CTD_{CDF}, CTD_{CLF}, CTD_{WMF}, and CTD_{RF}). The fishing day values (in $1993) used by the economic model are as follows: cold ($45.93), cool ($29.08), warm ($29.08), and rough ($20.60). Selection of these fishing day values involved considerable debate and assumptions. This process is described at length in Michaels et al. (1995).

Exhibit A.3

Predicting the Number of Person Days Per Year Devoted to Fishing by Guild[1]

Intercept	Not Applicable
Age	Vaughan and Russell (1982a)
Preference Intensity for Fishing Dummy	Vaughan and Russell (1982a)
Age-Squared	Vaughan and Russell (1982a)
Gender (Female)	Vaughan and Russell (1982a)
Metropolitan Area	Vaughan and Russell (1982a)
Average Income Per Household	Vaughan and Russell (1982a)
Coastal Area	Vaughan and Russell (1982a)
Average Number of Coldwater Gamefish Caught Per Day	Vaughan and Russell (1982a)
Coldwater Fishing Acreage Per Capita	Abt Economic and Thermal Models
Average Number of Warmwater Gamefish/Panfish Caught Per Day	Vaughan and Russell (1982a)
Warmwater Fishing Acreage Per Capita	Abt Economic and Thermal Models
Average Number of Rough Fish Caught Per Day	Vaughan and Russell (1982a)
Rough Fishing Acreage Per Capita	Abt Economic and Thermal Models

[1] The input variables employed in the third stage represent specific types of anglers and specific types of recreational fishing opportunities. Separate predictions are derived for coldwater, coolwater/warmwater, and rough fishing.