Additional materials provided by OAQPS on September 23, 2010 for the October 6-7, 2010 CASAC Panel review of the Second Draft Policy Assessment for the NO_x and SO_x Secondary Standards Review

1) An errata sheet that corrects a few errors in the Second Draft PA

2) A discussion to be inserted in Chapter 5 related to the implications of a range of choices of the target percent of lakes and streams to protect for alternative target ANC levels, including discussion of the impact of various spatial aggregations choices on these implications.

3) A table (to be inserted in Chapter 7) summarizing key uncertainties related to the review of the NO_x and SO_x secondary standards

5) A table (to be inserted in Chapter 9) summarizing the options for elements of the NO_x and SO_x secondary standards

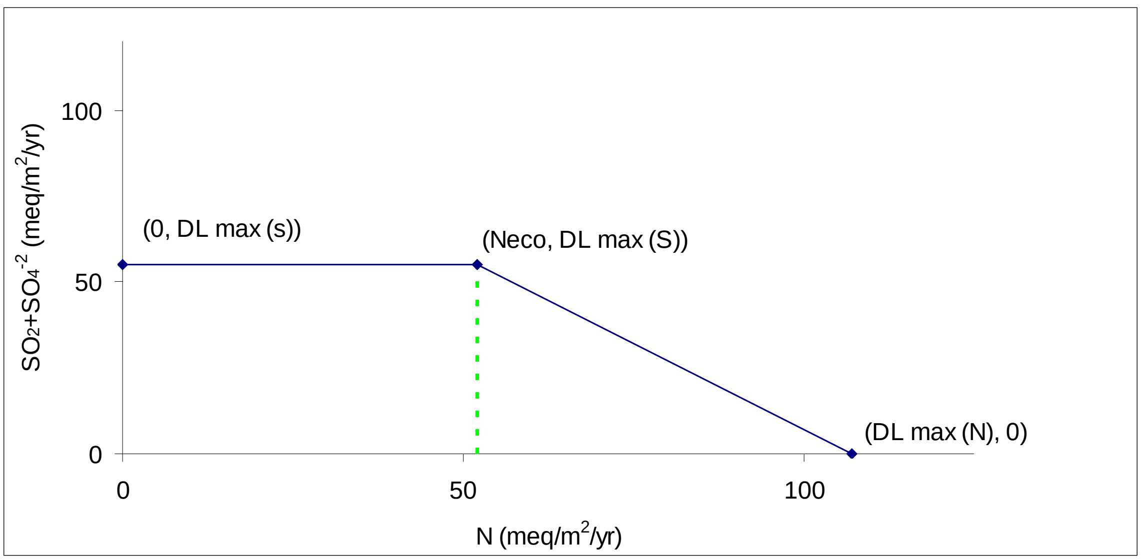
Errata Chapter 5:

Section 5.3.2.8 Deposition metric: Developing N and S tradeoff curves from the deposition metrics for the acid-sensitive categories

Pg 5-47 line 3-4 It is incorrectly stated that "The deposition metric for a category will be a single, specified value for the deposition of N and S". The deposition metric results from the distribution of critical loads based on equation 1.

$$CL_{ANC\lim}\left(N+S\right)=\left(\left[BC\right]_O^* - \left[ANC_{\lim}\right]\right)Q \qquad (1)$$

Equation 1 represents that maximum amount of SOx that can be deposited to an ecosystem, when N deposition is $\leq$ Neco, before exceeding its critical load ($DL_{SOx}^{\max}$). Once the deposition metric is selected, Neco is added to calculate the maximum amount of nitrogen that can be deposited to an ecosystem before exceeding its critical load ($DL_N^{\max}$). Three sets of coordinates define the N + S tradeoff curves: (0, $DL_{SOx}^{\max}$), (Neco, $DL_{SOx}^{\max}$) and ($DL_N^{\max}$,0).



Section 5.3.3.4 Oxidized Sulfur and Nitrogen Pollutant Species
Pg 56 line 17-18 It is incorrectly stated that "CMAQ does not currently provide simulations of coarse particulate sulfate and nitrate". The current version of CMAQ does include this process.

This addendum is intended to provide additional information on the implications of alternative choices of the percent of waterbodies to target when establishing a depositional load ($DL_{\%ECO}$) for a target ANC, either for the whole country or for acid-sensitivity categories. For the purposes here, we use the $DL_{\%ECO}$. This topic is introduced in Section 5.5 and is expanded on here for the four aggregation scenarios (one population, sensitive and less sensitive categories, ecoregions, and a cluster method based on log ANC), using a target ANC of 50 μeq/L and three example percentiles (90%, 75%, and 50%). These percentiles represent the $DL_{\%ECO}$ values for ANC 50 μeq/L calculated to protect 90%, 75% and 50% of waterbodies under each aggregation scenario. While those waterbodies with CL less than the selected $DL_{\%ECO}$ would not likely receive the same degree of protection as the targeted waterbodies, they would likely receive some benefit from the reductions in deposition necessary to meet the selected DL. Thus while they would not achieve an ANC of 50, they will see some improvement in the ANC. This section focuses on the expected level of protection that would be afforded these waterbodies with CL less than the $DL_{\%ECO}$ for ANC 50 μeq/L in each aggregation scenario.

ONE POPULATION

This aggregation method looks at the entire country as one population of waterbodies and would allow a single $DL_{\%ECO}$ for the whole population. The following table is identical to the table presented in Chapter 5 as Table 5-12. It is included here to provide detail for the figures A-1 through A-4.

Table 5-12. Comparison of percentage protection from ANC values less than 50 μeq/L and less than 20 μeq/L using DL that result when the US is considered one population.

	DL (meq/m^2/yr)	Total number of Sites in Analysis	Total Number of Sites protected from ANC <50	Total % Sites protected from ANC <50	Total Number of Sites protected from ANC <20	Total % Sites protected from ANC <20
DL 90% ANC 50	27	5280	4778	90	5145	97
DL 75% ANC 50	55	5280	3973	75	4394	83
DL 50% ANC 50	118	5280	2654	50	2947	56

Table 5-12 shows a comparison between the percent of waterbodies that would be protected from ANC<50 μeq/L using 90%, 75% and 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L for the one population approach (see Chapter 5 for discussion of one population aggregation method) and those that, while not protected from an ANC <50 μeq/L would be protected from at least an ANC<20 μeq/L under the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L. These waterbodies would have an ANC between 20 and 50 μeq/L. The selection of the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L representing 90% of the waterbodies (27 meq/m^2/yr) would likely protect 97% of all waterbodies from having an ANC<20 μeq/L. If the 75% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen (55 meq/m^2/yr), 83% of waterbodies would likely be protected from an ANC<20 μeq/L and if the 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen (118 meq/m^2/yr) only 56% of waterbodies would likely be protected against an ANC <20 μeq/L. This is an important distinction as severe degradation is likely to occur in lakes and streams with ANC<20 μeq/L.

Figures A-1 through A-3 below show maps of those waterbodies with critical loads for a target ANC of 50 μeq/L that are less than the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L calculated to protect 90%, 75% and 50% of the population when the US is considered one population. Thus, the waterbodies shown on the map represent the 10%, 25% and 50% of waterbodies that would not be protected from ANC <50 μeq/L. The intent is to determine what percentage of those remaining waterbodies, while not protected from ANC <50 μeq/L would be protected from ANC <20 μeq/L under each $DL_{\%ECO}$ scenario. This is shown on the maps with blue and red dots representing those waterbodies with ≥ ANC20 μeq/L and <ANC 20 μeq/L respectively. Under each scenario, the waterbodies that would likely fall below ANC 20 μeq/L are spread throughout the US and varied in type and function. Figure A-4 is a graphical breakdown of the percent of waterbodies at each ANC level (50, 20-50, and less than 20 μeq/L) under the one population approach.

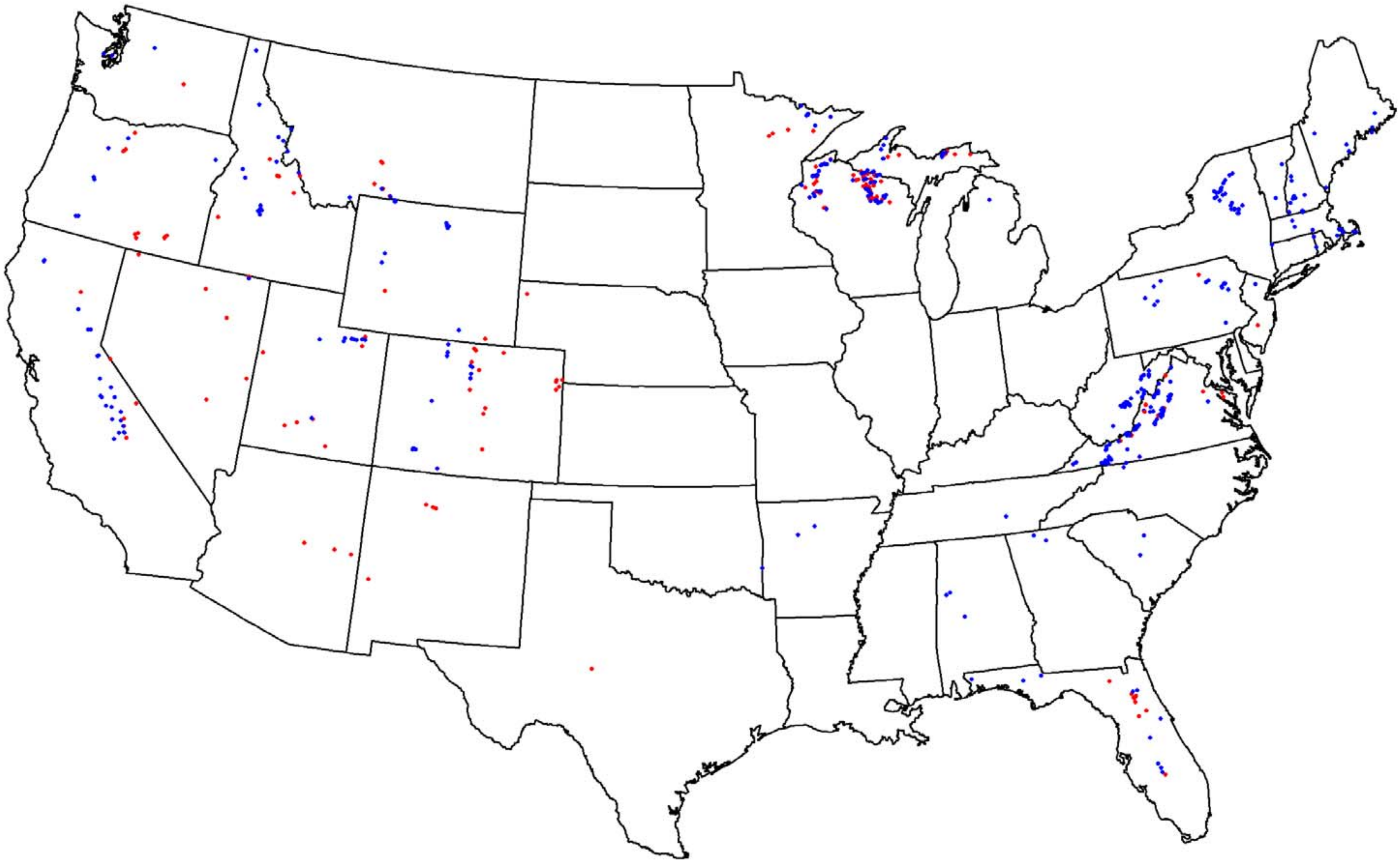


Figure A-1 Map of waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 90% of the population. The US is considered one population. The dots indicate the 10% of the population that would not likely achieve an ANC of 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20 μeq/L.

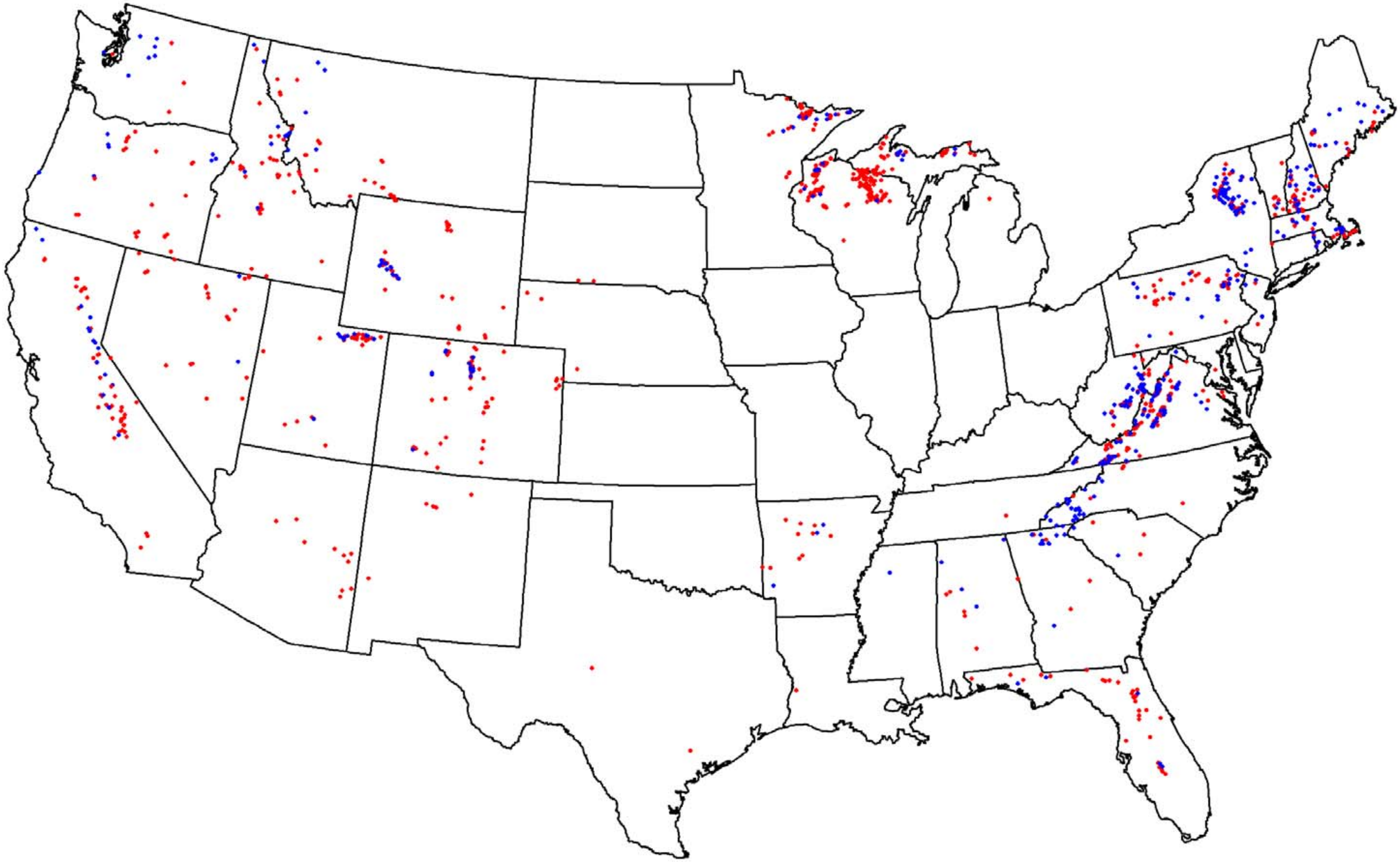


Figure A-2 Map of waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 75% of the population. The US is considered one population. The dots indicate the 25% of the population that would not likely achieve an ANC of 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20 μeq/L.

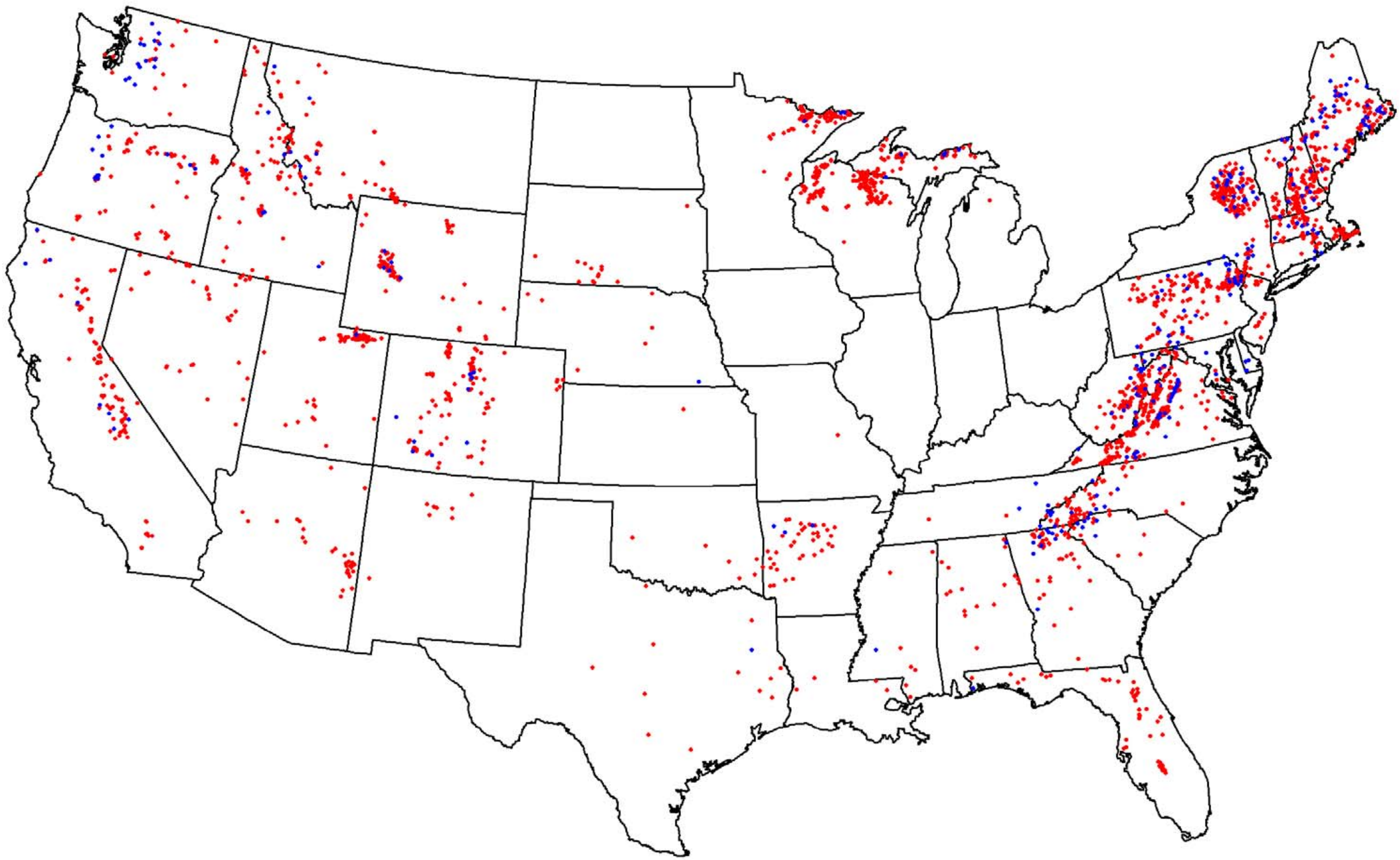


Figure A-3 Map of waterbodies with critical loads for an ANC limit of 50 µeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 µeq/L calculated to protect 50% of the population. The US is considered one population. The dots indicate the 50% of the population that would not likely achieve an ANC of 50 µeq/L. Given that the country would meet the DL established for a target ANC of 50 µeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 µeq/L and blue dots show waterbodies that would likely be protected from ANC <20 µeq/L.

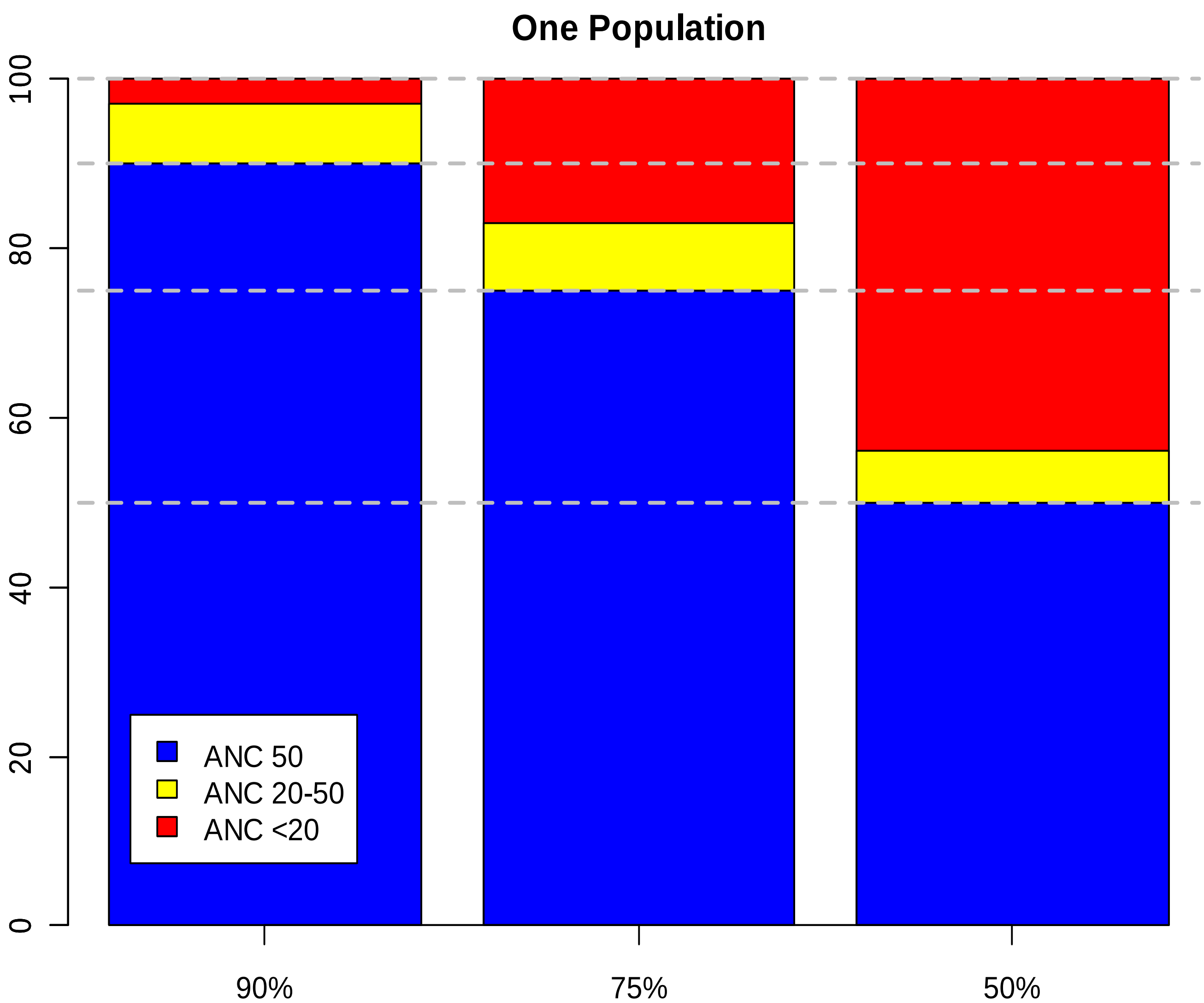


Figure A-4. Expected ANC values resulting from a target ANC of 50 μeq/L for specific target percentages of waterbodies. Blue represents the percent of lakes expected meet or exceed the ANC 50 μeq/L and by definition is equal to the target percentage indicated on the x-axis. Yellow represents the additional percentage of lakes expected to exceed the ANC 20 μeq/L. The remaining lakes, indicated in red, would potentially be below the ANC 20 μeq/L level.

SENSITIVE AND LESS SENSITIVE CATEGORIES

This aggregation method divides the country into two categories based on sensitivity (further discussion of this method can be found in Chapter 5) and would allow two $DL_{\%ECO}$ values for the whole population. The following table is identical to the table presented in Chapter 5 as Table 5-13. It is included here to provide detail for the figures A-5 through A-11.

Table 5-13. Comparison of percentage protection from ANC values less than 50 μeq/L and less than 20 μeq/L using DL that result when the US is divided into two categories, sensitive and less sensitive based on ANC data.

		DL (meq/m^2/yr)	Total number of Sites in Analysis	Total Number of Sites protected from ANC <50	Total % Sites protected from ANC <50	Total Number of Sites protected from ANC <20	Total % Sites protected from ANC <20
Sensitive	DL 90% ANC 50	26	4553	4104	90	4451	98
	DL 75% ANC 50	51	4553	3428	75	3841	84
	DL 50% ANC 50	106	4553	2284	50	2575	57
Less sensitive	DL 90% ANC 50	53	727	655	90	672	92
	DL 75% ANC 50	117	727	546	75	560	77
	DL 50% ANC 50	277	727	364	50	377	52

Table 5-13 shows a comparison between the percent of waterbodies that would be protected from ANC<50 μeq/L using 90%, 75% and 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L for the two category approach and those that, while not protected from an ANC <50 μeq/L would be protected from at least an ANC<20 μeq/L under the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L. These waterbodies would have an ANC between 20 and 50 μeq/L. The selection of the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L representing 90% of the sensitive waterbodies would likely protect 98% of sensitive waterbodies from having an ANC<20 μeq/L. If the 75% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen, 84% of sensitive waterbodies would likely be protected from an ANC<20 μeq/L and if the 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen only 57% of sensitive waterbodies would likely be protected against an ANC <20 μeq/L. The selection of the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L representing 90% of the less sensitive waterbodies would likely protect 92% of less sensitive waterbodies from having an ANC<20 μeq/L. If the 75% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen, 77% of less sensitive waterbodies would likely be protected from an ANC<20 μeq/L and if the 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L was chosen only 52% of less sensitive waterbodies would likely be protected against an ANC <20 μeq/L.

Figures A-5 through A-10 below show maps of those waterbodies with critical loads for a target ANC of 50 μeq/L that are less than the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L calculated to protect 90%, 75% and 50% of the population when the US is considered as two categories based on sensitivity. Thus, the waterbodies shown on the map represent the 10%, 25% and 50% of waterbodies that would not be protected from ANC <50 μeq/L. The intent is to determine what percentage of those remaining waterbodies, while not protected from ANC <50 μeq/L would be protected from ANC <20 under each $DL_{\%ECO}$ scenario. This is shown on the maps with blue and red dots representing those waterbodies with ≥ ANC20 μeq/L and <ANC 20 μeq/L respectively. Again under each scenario, the waterbodies that would likely fall below ANC 20 μeq/L are geographically diverse and likely represent many types of waterbodies. Figure A-11 is a graphical breakdown of the percent of waterbodies at each ANC level (50, 20-50, and less than 20 μeq/L) under the two category approach based on sensitivity.

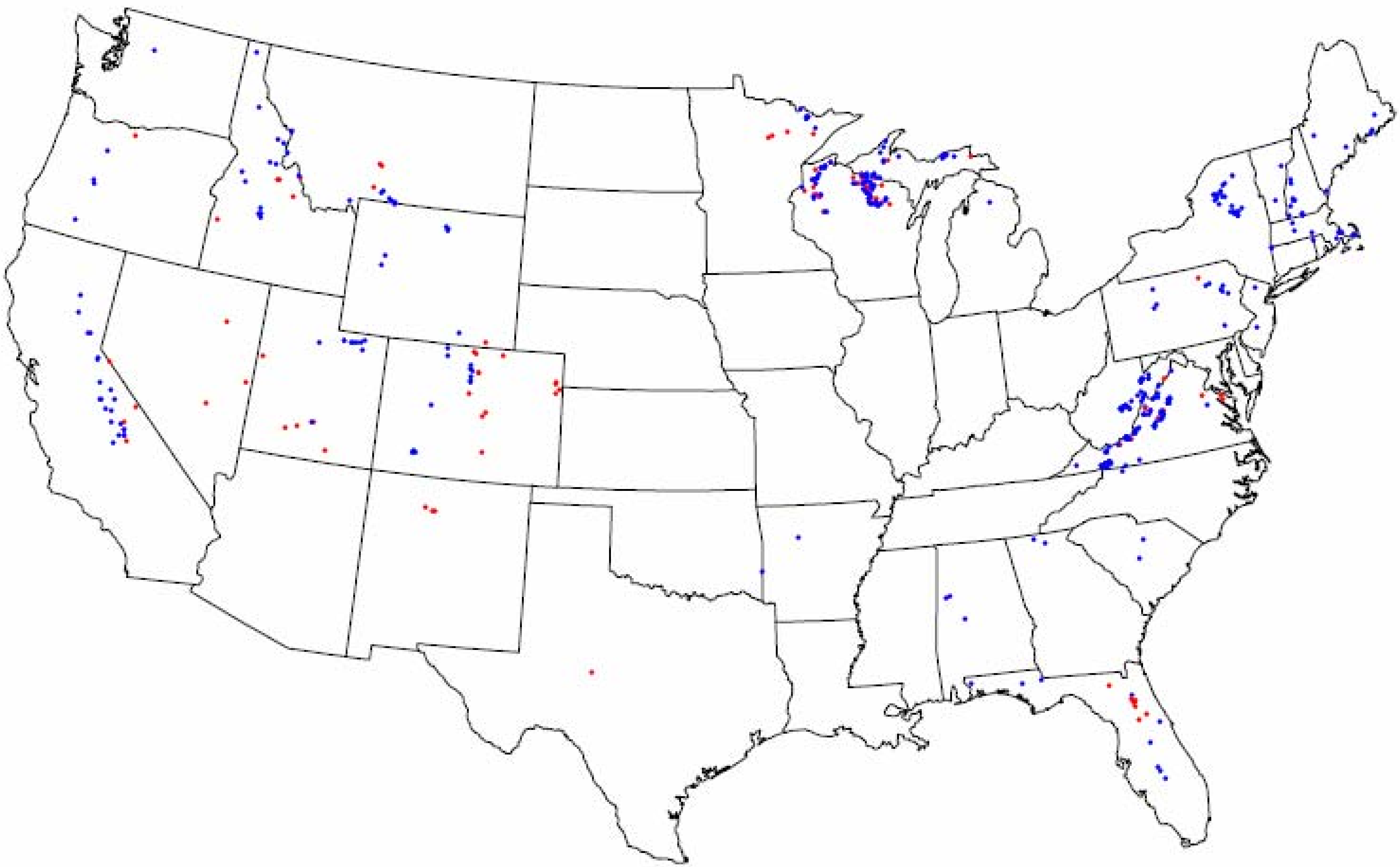


Figure A-5 Map of sensitive waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 90% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 10% of the population that would not likely achieve an ANC 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

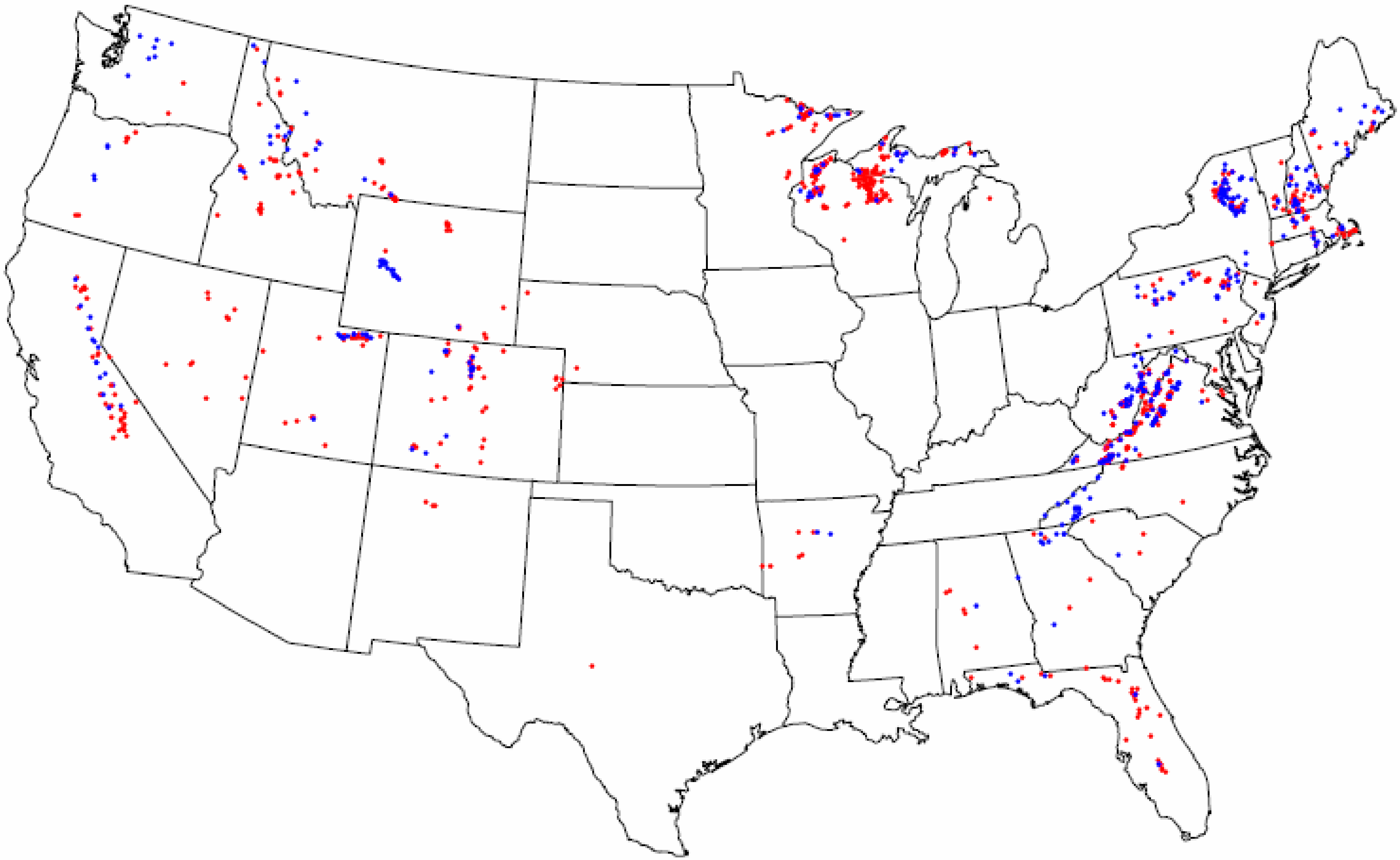


Figure A-6 Map of sensitive waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 75% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 25% of the population that would not likely achieve an ANC 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

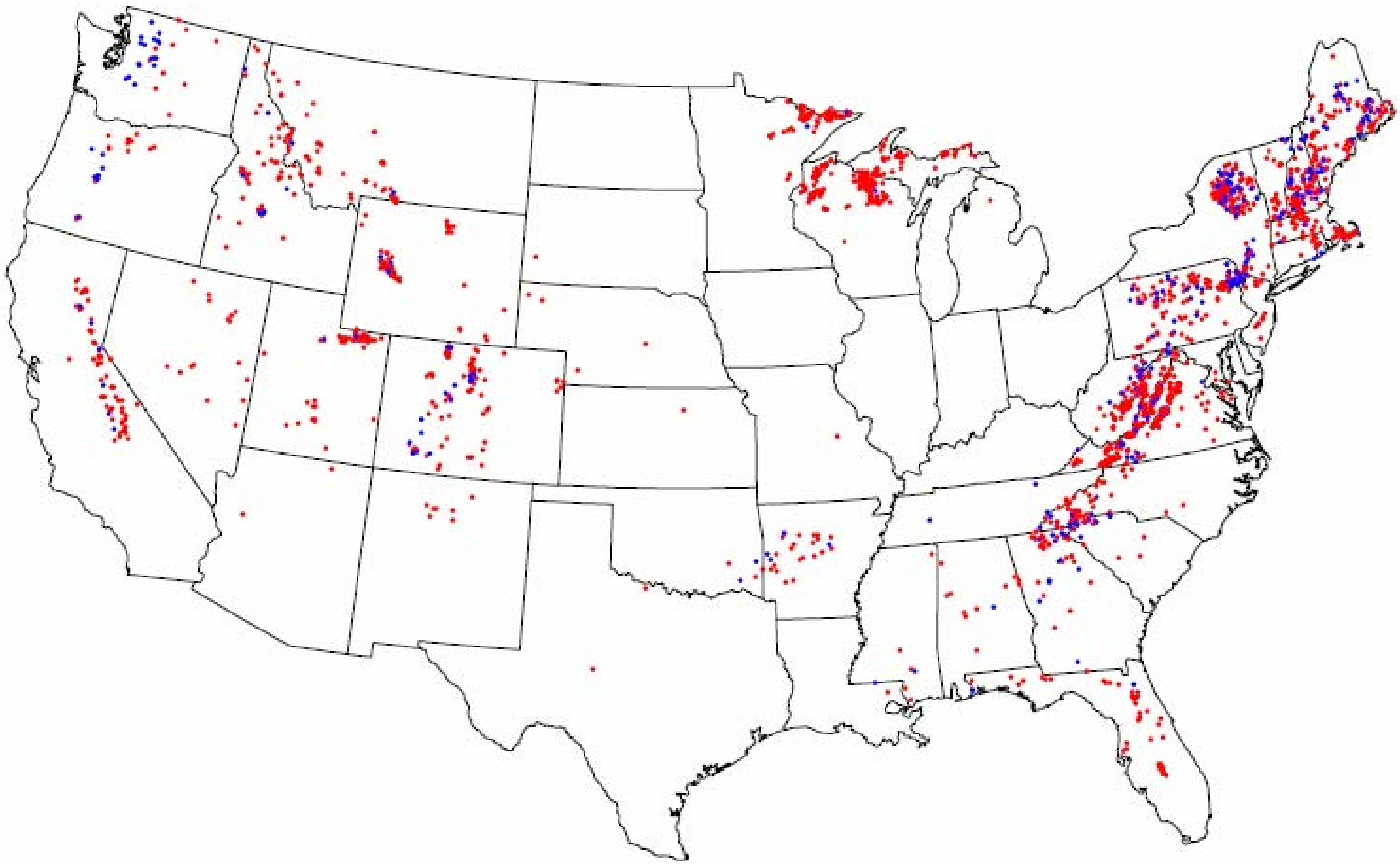


Figure A-7 Map of sensitive waterbodies with critical loads for an ANC limit of 50 µeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 µeq/L calculated to protect 50% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 50% of the population that would not likely achieve an ANC 50 µeq/L. Given that the country would meet the DL established for a target ANC of 50 µeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 µeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

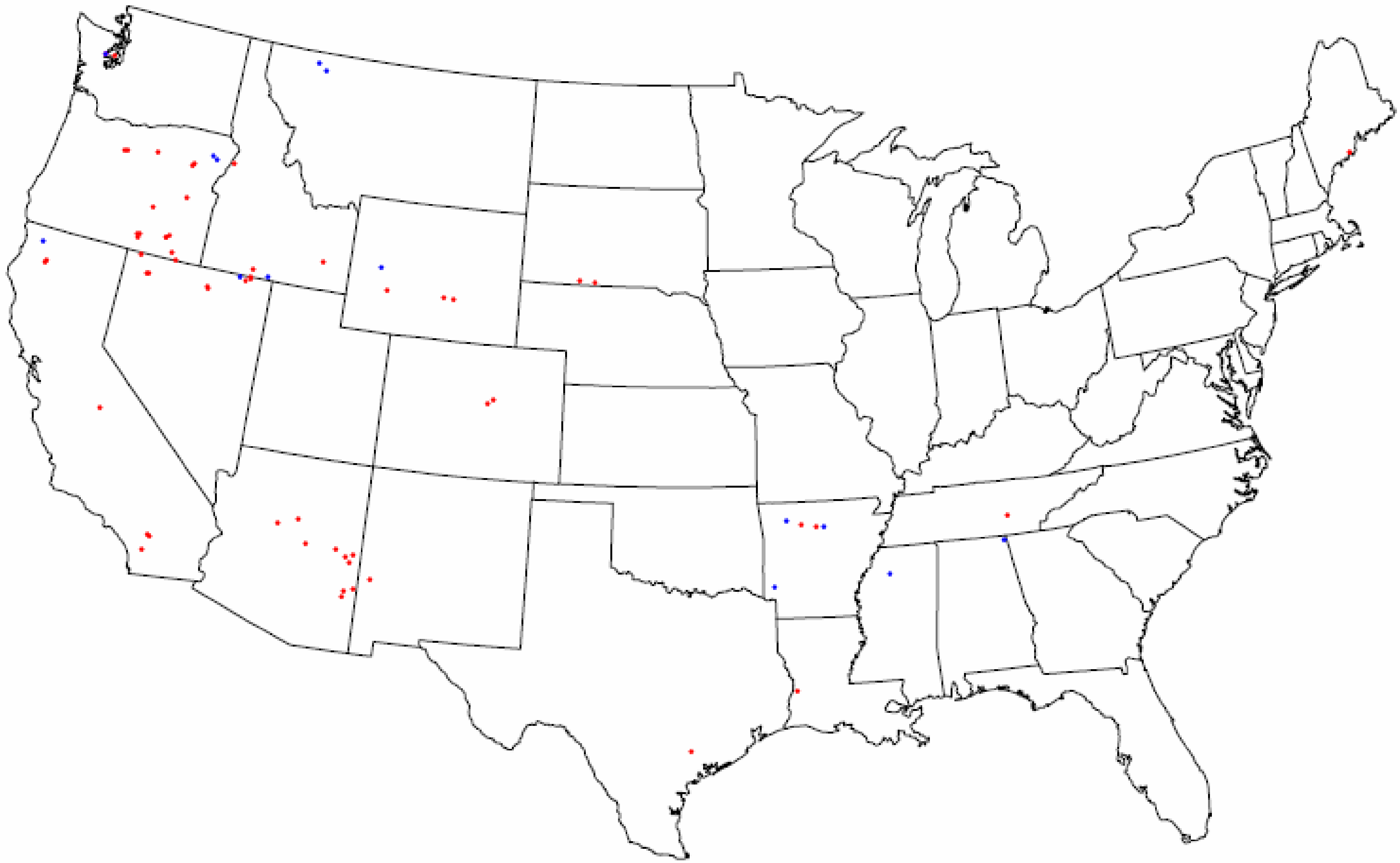


Figure A-8 Map of less sensitive waterbodies with critical loads for an ANC limit of 50 µeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 µeq/L calculated to protect 90% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 10% of the population that would not likely achieve an ANC 50 µeq/L. Given that the country would meet the DL established for a target ANC of 50 µeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 µeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

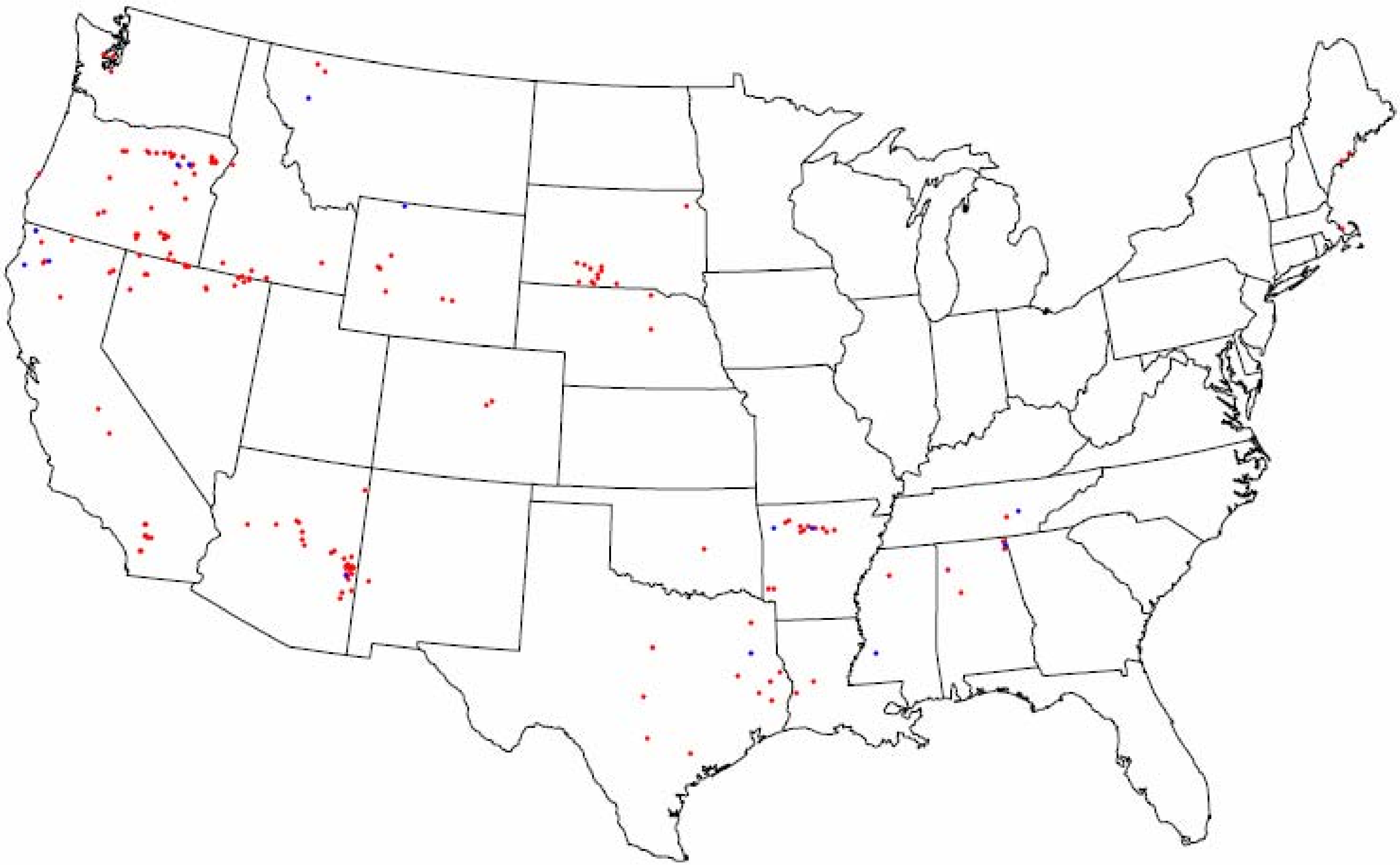


Figure A-9 Map of less sensitive waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ `values for the target ANC of 50 μeq/L calculated to protect 75% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 25% of the population that would not likely achieve an ANC 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

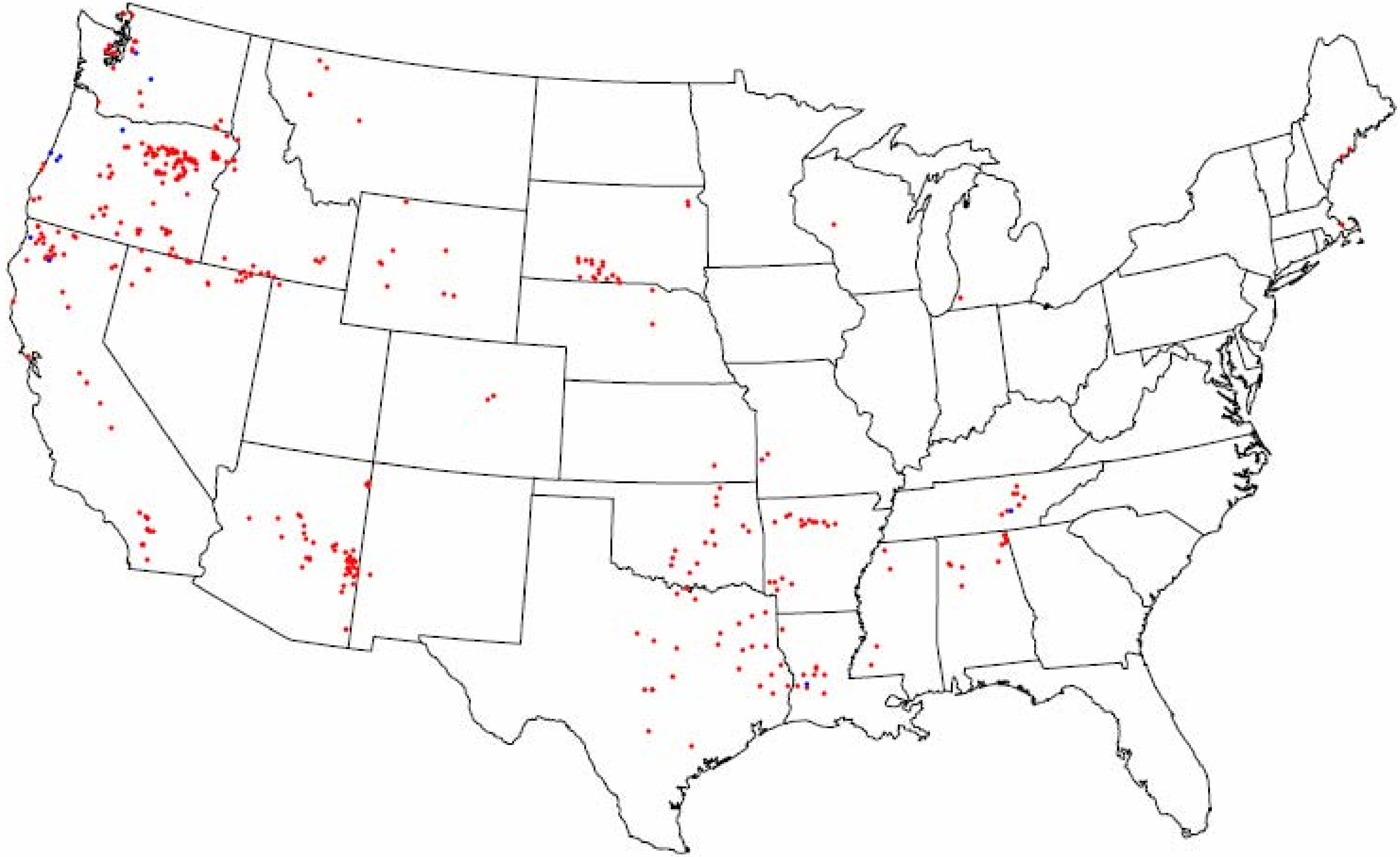


Figure A-10 Map of less sensitive waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ `values for the target ANC of 50 μeq/L calculated to protect 50% of the population. The US is divided into sensitive and less sensitive categories based on ANC values. The dots indicate the 50% of the population that would not likely achieve an ANC 50 μeq/L. Given that the country would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20.

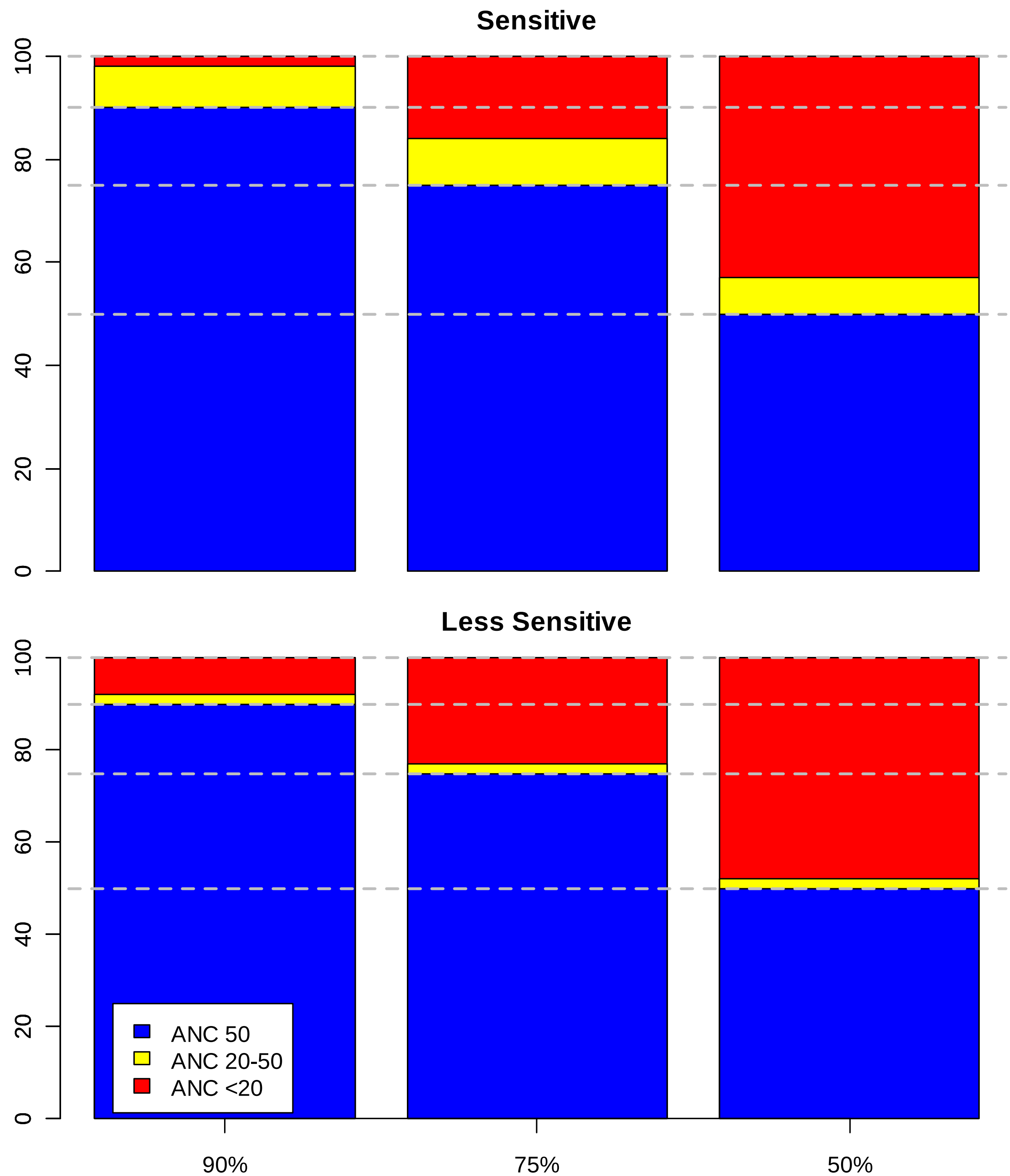


Figure A-11**.** Expected ANC resulting from a target ANC of 50 μeq/L for specific target percentages of waterbodies. This classification of lakes categorizes the lakes based on sensitivity.

ECOREGIONS

This aggregation method divides the country into Omernick Ecoregion Level 3 categories and would allow $DL_{\%ECO}$ values for each ecoregion or some combination of ecoregions. This method of aggregation is useful in that it provides a biologically relevant grouping of waterbodies but is also data intensive. For this example, only ecoregions with greater than 50 observations were included as fewer observations lead to large variations in the value of $DL_{\%ECO}$ depending on whether this value was calculated by fitted distribution or ranking the observations. This is described more fully in Figure A-12. Table A-1 shows a comparison between the percent of waterbodies that would be protected from an ANC<50 μeq/L using 90%, 75% and 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L for each ecoregion with greater than 50 observations and those that, while not protected from an ANC <50 μeq/L would likely be protected from an ANC<20 μeq/L.

Figures A-13 through A-15 below show maps of those waterbodies with critical loads for a target ANC of 50 μeq/L that are less than the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L calculated to protect 90%, 75% and 50% of the population by ecoregion. Thus, the waterbodies shown on the map represent the 10%, 25% and 50% of waterbodies that would not be protected from ANC <50 μeq/L. The intent is to determine what percentage of those remaining waterbodies, while not protected from ANC <50 μeq/L would be protected from ANC <20 μeq/L under each $DL_{\%ECO}$ scenario. This is shown on the maps with blue and red dots representing those waterbodies with ≥ ANC20 μeq/L and <ANC 20 μeq/L respectively. Figure A-16 is a graphical breakdown of the percent of waterbodies at each ANC level (50, 20-50, and less than 20 μeq/L) under the ecoregion approach using mean values for all ecoregions.

Table A-1 Comparison of percentage protection from ANC values less than 50 μeq/L and less than 20μeq/L using DL that result when ecoregions with greater than 50 observations are used.

Ecoregion	Ecoregion Waterbodies N=	% Protected ANC 50 90%	Total % Sites protected from ANC<20 Using ANC 50 90% DL	% Protected ANC 50 75%	Total % Sites protected from ANC<20 Using ANC 50 75% DL	% Protected ANC 50 50%	Total % Sites protected from ANC<20 Using ANC 50 50% DL
5.3.1	735	90%	98%	75%	87%	50%	60%
8.4.1	510	90%	97%	75%	86%	50%	56%
5.2.1	469	90%	100%	75%	91%	50%	56%
8.4.4	379	90%	100%	75%	92%	50%	69%
6.2.10	202	91%	98%	76%	84%	50%	53%
8.4.2	200	91%	100%	76%	99%	51%	63%
6.2.14	186	90%	96%	76%	85%	51%	57%
8.1.7	169	91%	95%	76%	83%	51%	62%
8.3.4	168	90%	96%	76%	85%	51%	57%
5.3.3	159	91%	99%	75%	86%	50%	62%
8.1.8	143	91%	97%	76%	90%	50%	63%
6.2.5	133	91%	98%	76%	86%	51%	56%
6.2.9	108	91%	92%	76%	78%	51%	52%
6.2.12	105	91%	100%	76%	96%	51%	57%
6.2.7	88	91%	95%	76%	88%	51%	63%
8.1.3	88	91%	95%	76%	81%	51%	55%
6.2.11	86	91%	92%	76%	76%	51%	53%
6.2.15	86	91%	100%	76%	91%	51%	65%
6.2.13	78	91%	96%	76%	90%	51%	64%
8.3.5	75	92%	100%	76%	87%	51%	59%
6.2.3	73	92%	97%	77%	78%	52%	55%
7.1.8	68	91%	94%	76%	78%	51%	56%
8.5.3	53	92%	100%	77%	87%	53%	57%
13.1.1	52	92%	92%	77%	79%	52%	52%

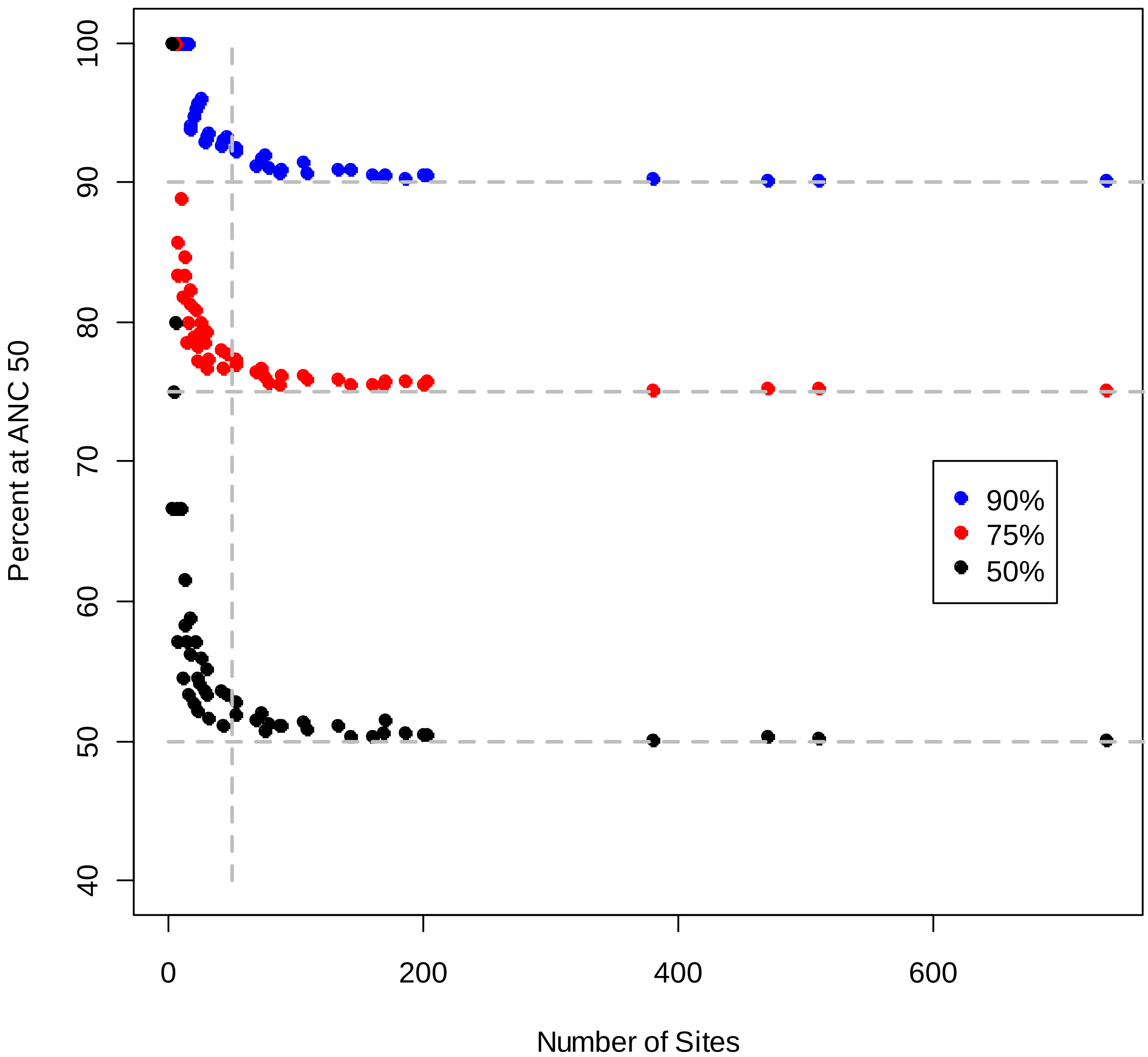


Figure A-12. Percent of lakes within an Ecoregion (n = 76) expected to equal or exceed ANC 50 μeq/L compared to the number of sites sampled within the Ecoregion. Horizontal gray lines are provided for reference to the 50%, 75% and 90% target levels. The vertical gray line shows the cutoff level of n = 50 which was used for analyses.

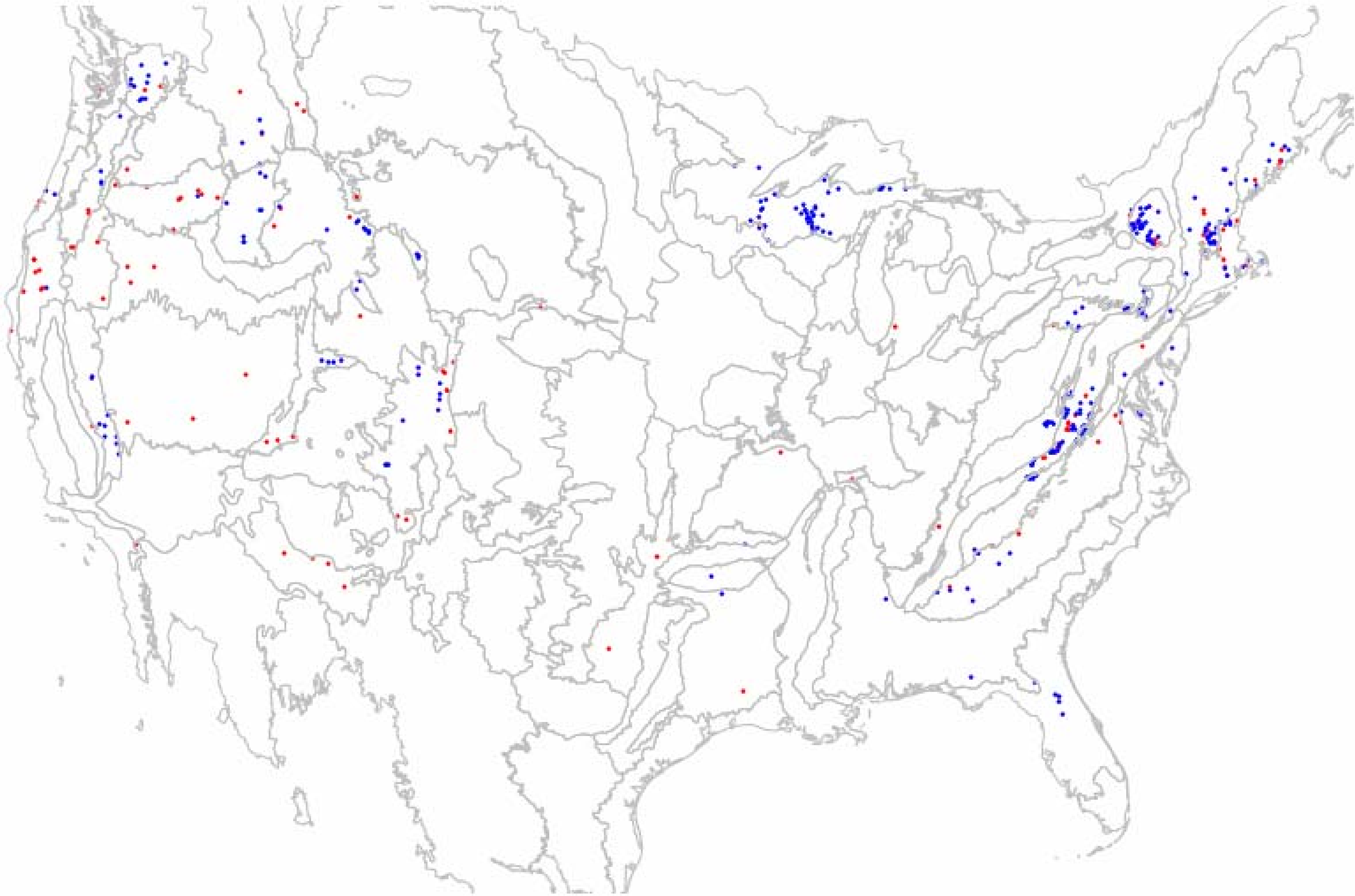


Figure A-13 Map of waterbodies by ecoregion with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 90% of the population. The US is divided into level 3 ecoregions. The dots indicate the 10% of the population that would not likely achieve an ANC of 50 μeq/L. Given that each ecoregion would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20 μeq/L.

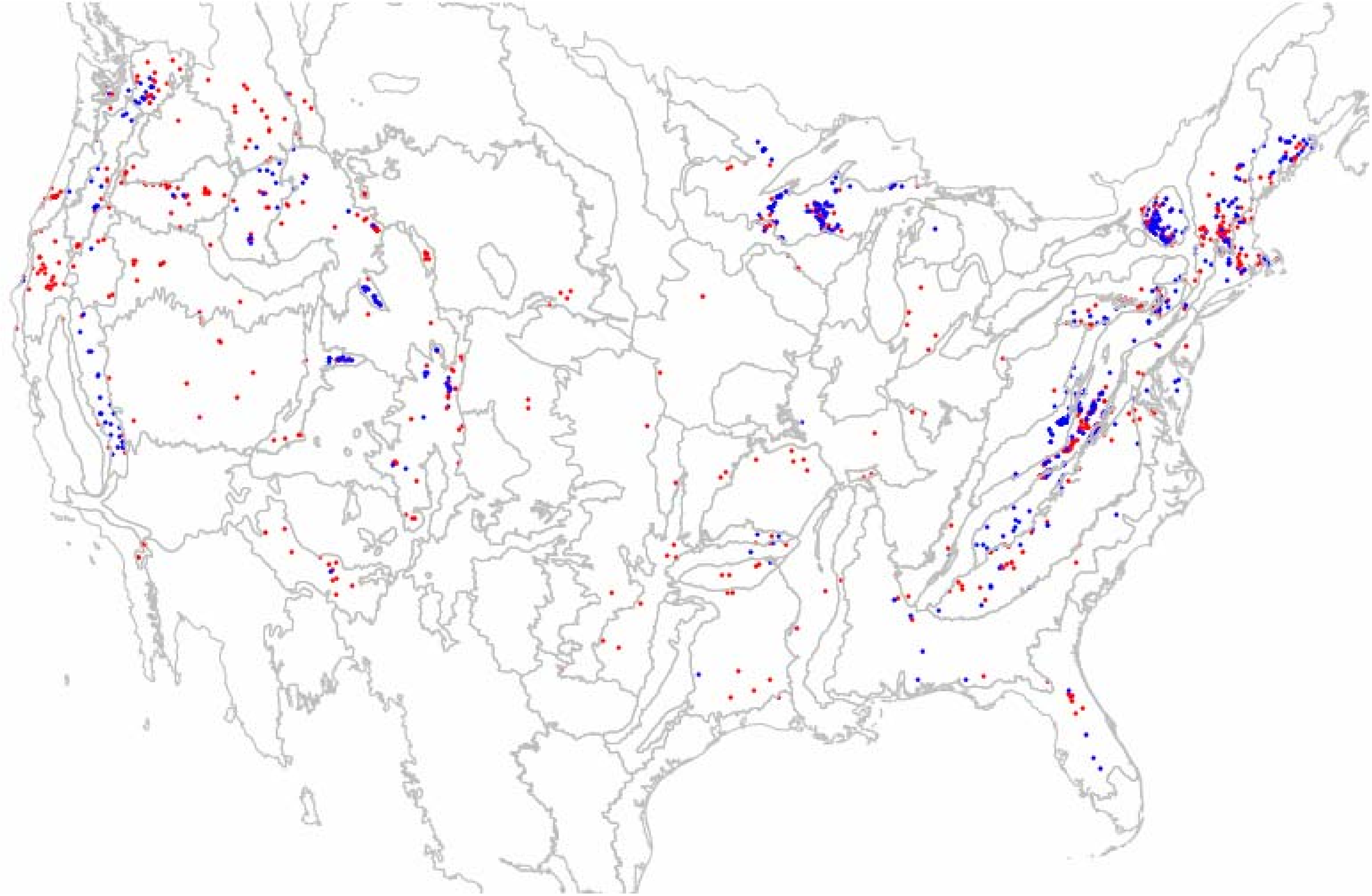


Figure A-14 Map of waterbodies by ecoregion with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the target ANC of 50 μeq/L calculated to protect 75% of the population. The US is divided into level 3 ecoregions. The dots indicate the 25% of the population that would not likely achieve an ANC of 50 μeq/L. Given that each ecoregion would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20 μeq/L.

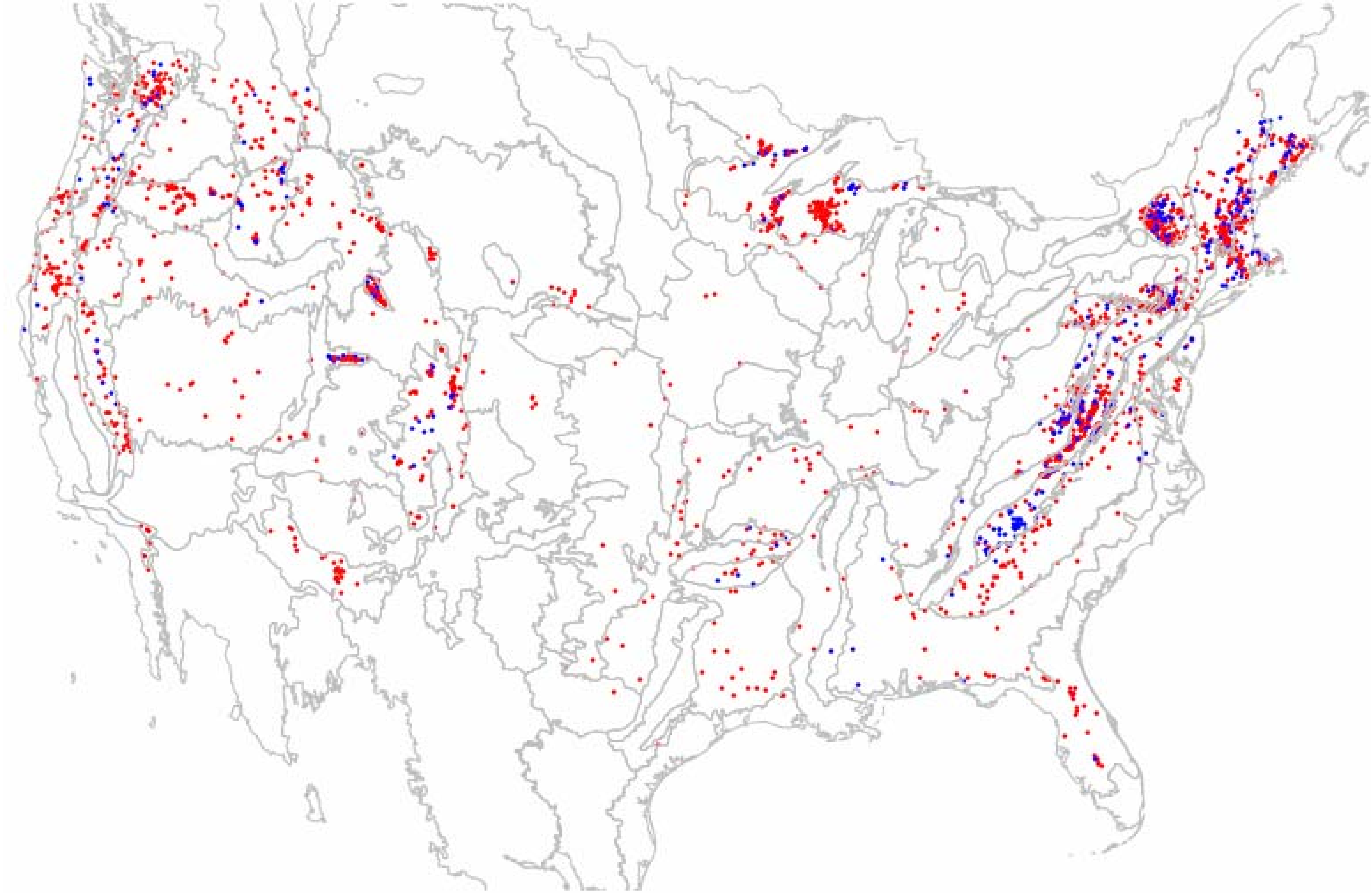


Figure A-15 Map of waterbodies by ecoregion with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ `values for the target ANC of 50 μeq/L calculated to protect 50% of the population. The US is divided into level 3 ecoregions. The dots indicate the 50% of the population that would not likely achieve an ANC of 50 μeq/L. Given that each ecoregion would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 μeq/L and blue dots show waterbodies that would likely be protected from ANC <20 μeq/L.

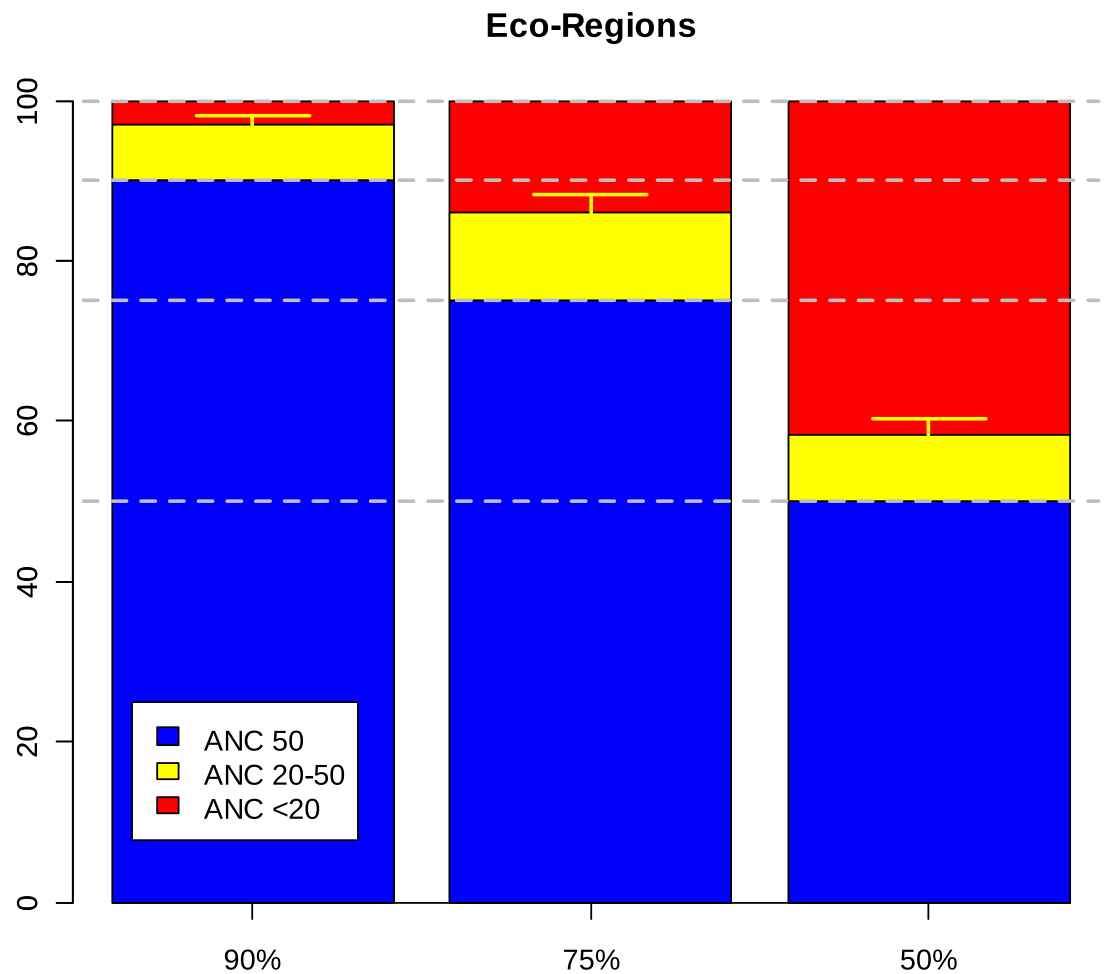


Figure A-16**.** Expected ANC resulting from a target ANC of 50 μeq/L for specific target percentages of waterbodies. The yellow bars represent the mean value of all of the ecoregions. The whiskers associated with the ANC 20 μeq/L (yellow) bars represent the upper confidence interval of the mean values.

LOG ANC CLUSTER

This aggregation method divides the country into statistical clusters based on log ANC values and would allow $DL_{\%ECO}$ values to be determined for each cluster. This method of aggregation is described more fully in Chapter 5 (Section 5.3.2.7). Table A-2 shows a comparison between the percent of waterbodies that would be protected from ANC<50 μeq/L using 90%, 75% and 50% $DL_{\%ECO}$ values for a target ANC of 50 μeq/L for each cluster and those that, while not protected from an ANC <50 μeq/L would likely be protected from an ANC<20 μeq/L.

Figures A-17 through A-19 below show maps of those waterbodies with critical loads for a target ANC of 50 μeq/L that are less than the $DL_{\%ECO}$ values for a target ANC of 50 μeq/L calculated to protect 90%, 75% and 50% of the population. Thus, the waterbodies shown on the map represent the 10%, 25% and 50% of waterbodies that would not be protected from ANC <50 μeq/L. The intent is to determine what percentage of those remaining waterbodies, while not protected from ANC <50 μeq/L would be protected from ANC <20 μeq/L under each $DL_{\%ECO}$ scenario. This is shown on the maps with blue and red dots representing those waterbodies with ≥ ANC20 μeq/L and <ANC 20 μeq/L respectively. Figure A-20 is a graphical breakdown of the percent of waterbodies at each ANC level (50, 20-50, and less than 20 μeq/L) under the cluster approach using mean values for all clusters.

Table A-2 Comparison of percentage protection from ANC values less that 50 μeq/L and less than 20 μeq/L using DL that result when sites are clustered using logANC values.

Cluster	Cluster N=	% Protected ANC 50 90%	Total % Sites protected from ANC <20 using ANC 50 90% DL	% Protected ANC 50 75%	Total % Sites protected from ANC <20 using ANC 50 75% DL	% Protected ANC 50 50%	Total % Sites protected from ANC <20 using ANC 50 50% DL
1	2432	90%	98%	75%	85%	50%	58%
2	1113	90%	98%	75%	85%	50%	58%
3	784	90%	95%	75%	81%	50%	54%
4	655	90%	96%	75%	80%	50%	51%
5	216	90%	91%	75%	76%	50%	51%

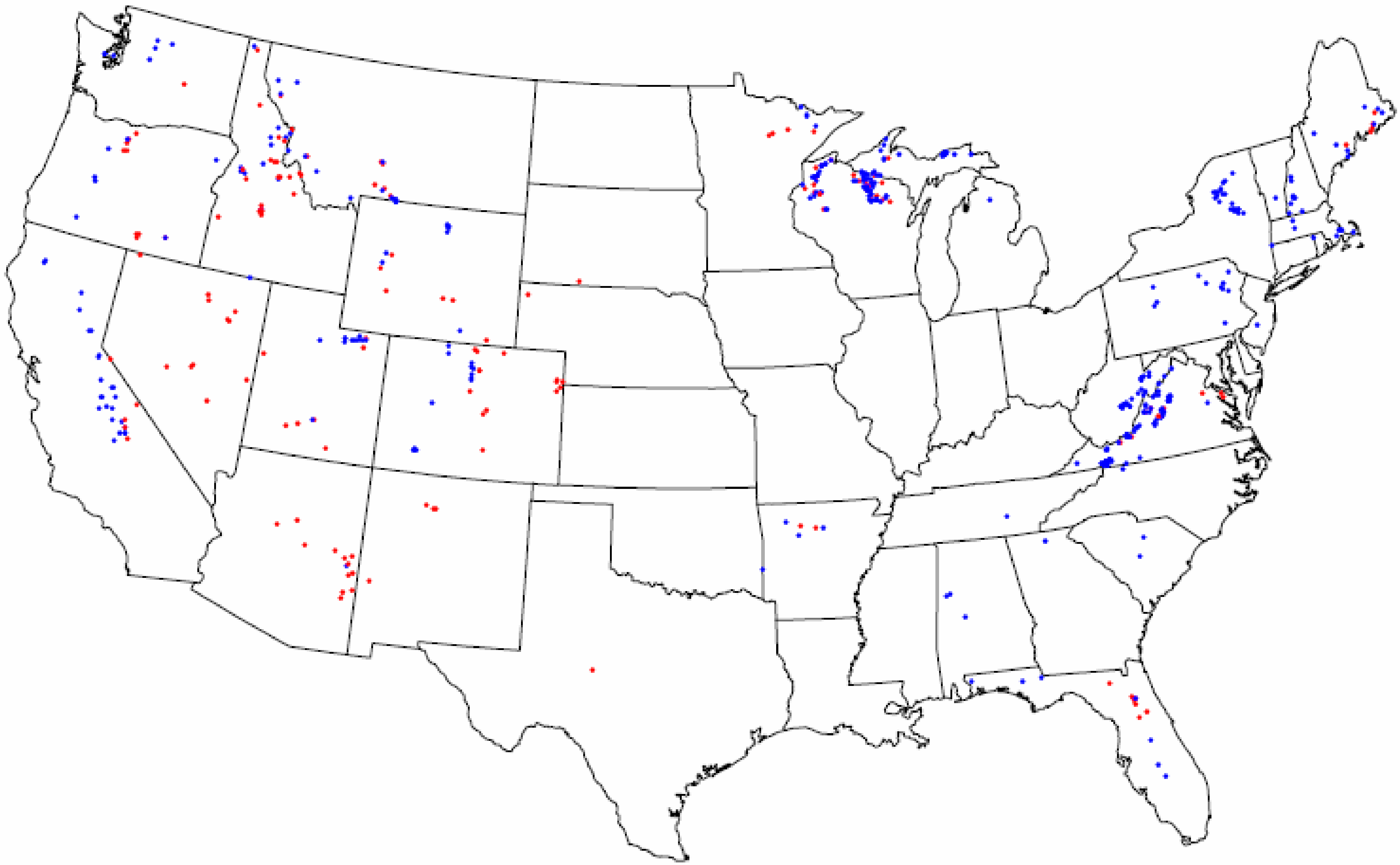


Figure A-17 Map of waterbodies with critical loads for an ANC limit of 50 μeq/L that are less than the $DL_{\%ECO}$ values for the tareget ANC of 50 μeq/L calculated to protect 90% of the population using the cluster method. The US is divided into 5 clusters (see Chapter 5). The dots indicate the 10% of the population that would not likely achieve an ANC of 50 μeq/L. Given that each cluster would meet the DL established for a target ANC of 50 μeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 and blue dots show waterbodies that would likely be protected from ANC <20.

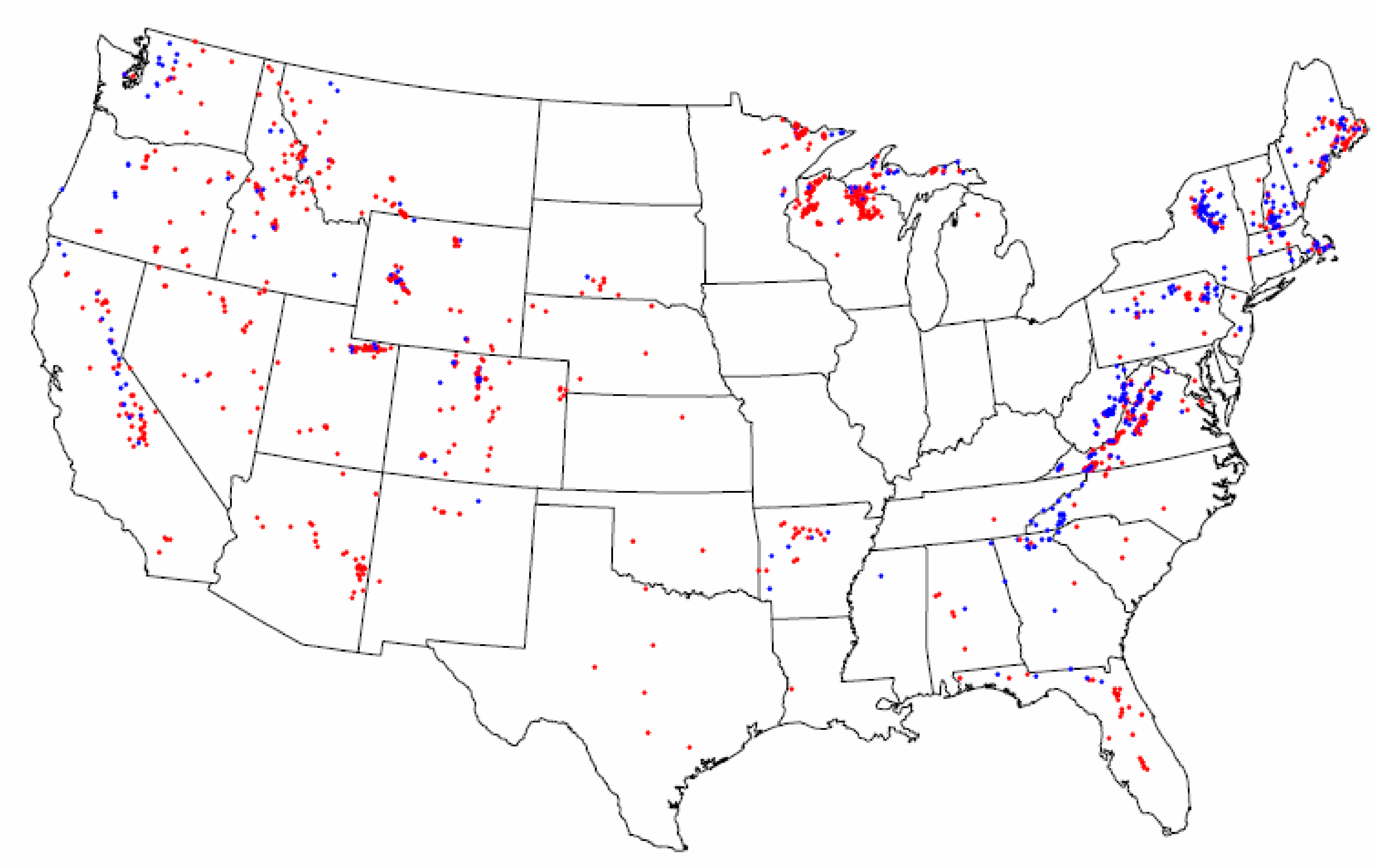


Figure A-18 Map of waterbodies with critical loads for an ANC limit of 50 µeq/L that are less than the $DL_{\%ECO}$ values for the tareget ANC of 50 µeq/L calculated to protect 75% of the population using the cluster method. The US is divided into 5 clusters (see Chapter 5). The dots indicate the 25% of the population that would not likely achieve an ANC of 50 µeq/L. Given that each cluster would meet the DL established for a target ANC of 50 µeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 and blue dots show waterbodies that would likely be protected from ANC <20.

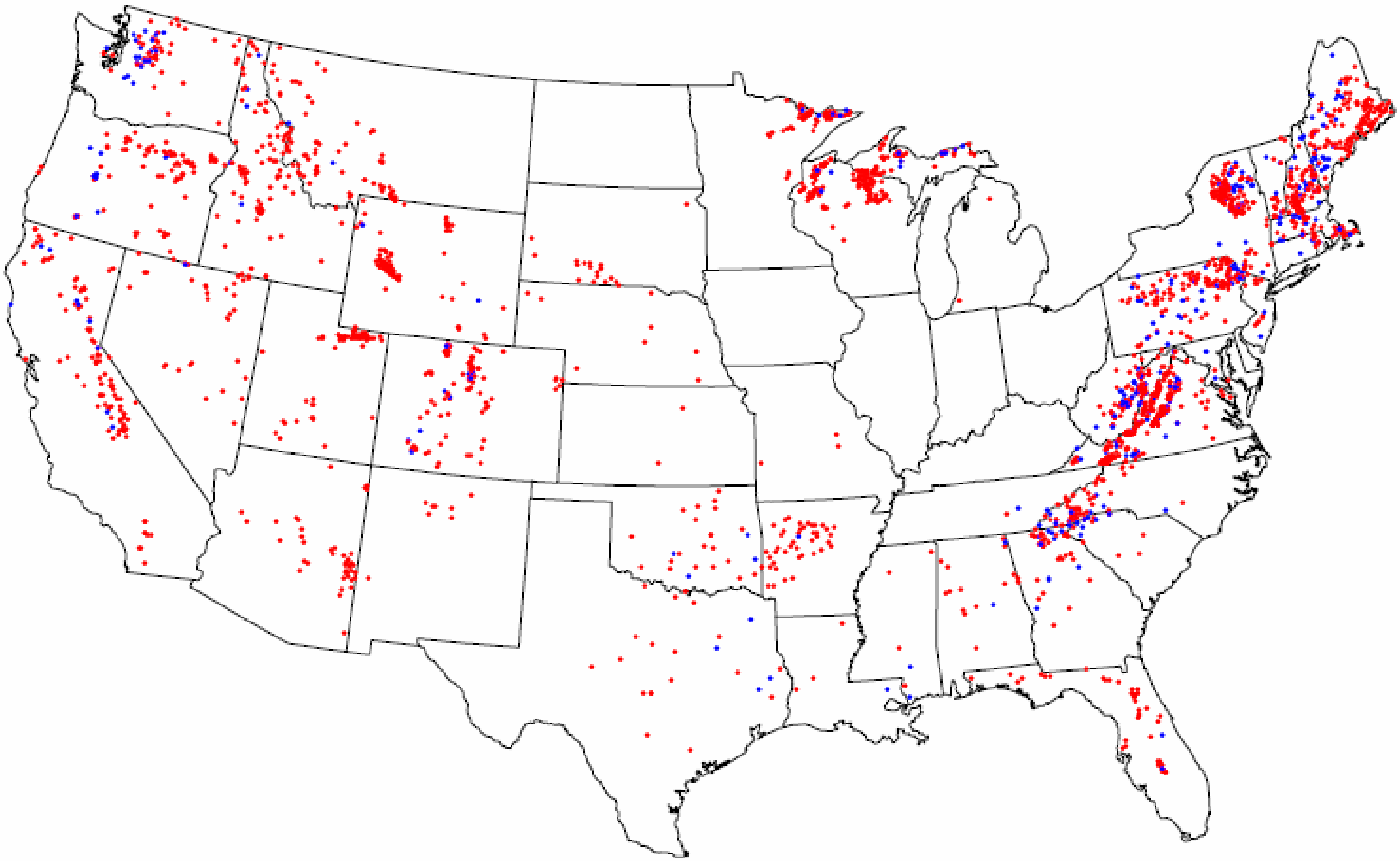


Figure A-19 Map of waterbodies with critical loads for an ANC limit of 50 µeq/L that are less than the $DL_{\%ECO}$ values for the tareget ANC of 50 µeq/L calculated to protect 50% of the population using the cluster method. The US is divided into 5 clusters (see Chapter 5). The dots indicate the 50% of the population that would not likely achieve an ANC of 50 µeq/L. Given that each cluster would meet the DL established for a target ANC of 50 µeq/L, the red dots show waterbodies that would not likely be protected from an ANC of <20 and blue dots show waterbodies that would likely be protected from ANC <20.

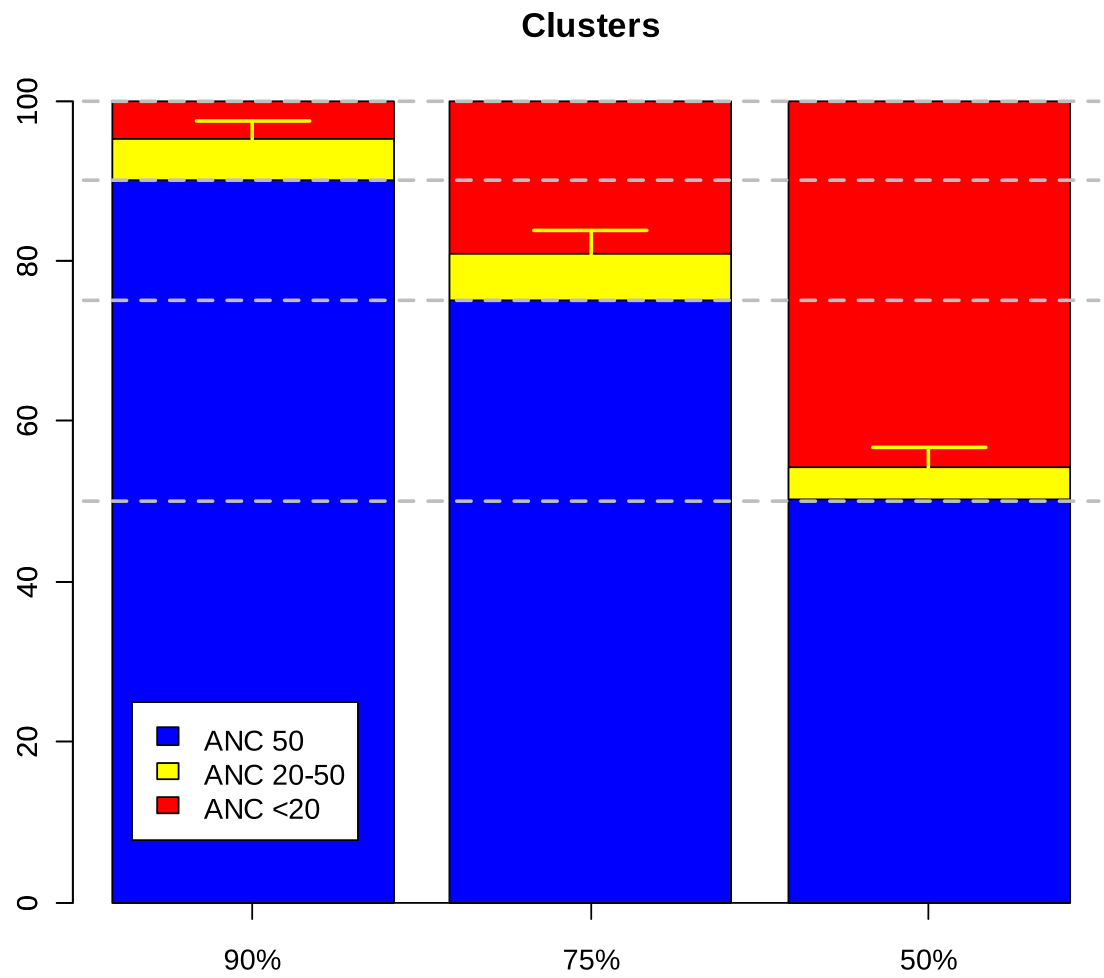


Figure A-20**.** Expected ANC resulting from a target ANC of 50 μeq/L for specific target percentages of waterbodies. The yellow bars represent the mean value of all of the clusters. The whiskers associated with the ANC 20 μeq/L (yellow) bars represent the upper confidence interval of the mean values.

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		Knowledge-Base uncertainty	Comments
		Direction (negative implies less relative protection)	Magnitude		
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.

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
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.

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
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

Source	Description	Potential influence of uncertainty in element		Knowledge-Base uncertainty	Comments
		Direction (negative implies less relative protection)	Magnitude		
					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					

Source	Description	Potential influence of uncertainty in element		Knowledge-Base uncertainty	Comments
		Direction (negative implies less relative protection)	Magnitude		
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

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
					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.

Summary of Suggested Options for the Elements of the Combined NOx and SOx Secondary NAAQS

INDICATOR
NOx: NOy (total oxidized nitrogen, including NO_2 + NO + HNO_3 + PAN +$2N_2O_5$ + HONO + NO_3 + organic nitrates + particulate NO_3) SOx: SO_2 + SO_4
AVERAGING TIME
3 to 5 year averaging time (3 to 5 year averages of annual average NOy and SO2+SO4) selected based on interannual variability in deposition as reflected in components the form (see below).
FORM
The form for the secondary standards incorporates multiple design decisions, including treatment of combined effects of NOx and SOx, selection of an ecological indicator of effects, treatment of reduced forms of nitrogen, and treatment of natural ecological conditions that affect sensitivity to acidification. • Treatment of combined effects of NOx and SOx: Conversion to acid deposition units (in meq/m^2/year) through application of "transference ratios" based on modeled ratios of atmospheric concentrations to deposition. • Ecological Indicator: Acid Neutralizing Capacity • Treatment of reduced forms of nitrogen: Incorporated into the form as an adjustment to the nitrogen balance of the ecosystem • Treatment of natural ecological conditions: In order to focus on sites which are acidic due to atmospheric deposition of NOx and SOx, those sites which are acidic due to low weathering rates of base cations as indicated by modeled pre-industrial base cation weathering $[BC]_O^*$, high organic inputs based on dissolved organic carbon (DOC) concentrations and acid mine drainage based on sulfate concentrations were removed from the critical loads dataset. Of the sites included in further analysis, nitrogen uptake and retention (Neco) are used to account for natural ability of ecosystems to neutralize acid deposition. The result of these design decisions is a form for the ambient air quality standard that ties ANC to deposition and deposition to ambient air concentrations, incorporating ecological conditions and the contribution of reduced nitrogen. To incorporate all of these aspects, we

developed an index that would provide a consistent number nationally that is directly expressed in terms of concentrations of NOx and SOx. This index is called the Atmospheric Acidification Protection Index (AAPI).

The formula for the APPI is derived from the critical load equation for a single catchment (eq 2, section 5.3.2) for a selected target value of ANC (ANC_{lim}):

$$CL_{ANC\,\lim}(N+S) = ([BC]_O^* - [ANC_{\lim}])Q - Neco$$

The AAPI is derived by rearranging Equation 2 to solve for ANC_{lim}, and replacing the values of $[BC]_O^*$, Q, and Neco with the values for waterbodies representing specific percentiles of the distribution of critical loads across a population of catchments.

$$AAPI = \left[[BC]_O^*\right]_{\%eco} + \frac{1}{Q_{\%eco}} \cdot Neco_{average} - \frac{1}{Q_{\%eco}} \cdot Dep_{NHx}^{Total} - \frac{1}{Q_{\%eco}} \cdot \left[T_{NOy} \cdot C_{NOy} + T_{SOx} \cdot C_{SOx}\right]$$

The AAPI is essentially a function that determines whether ambient NOy and SO_2 + SO_4 are expected to achieve a target ANC limit. The AAPI value selected as the level of the standard will be based on the target ANC limit, given uncertainties in the parameters used to calculate the AAPI, and weighing other factors such as time to recovery for ecosystems. (eq 17, section 5.3.4)

For a selected level of AAPI and specific values of the $\left[[BC]_O^*\right]_{\%eco}$, $Q_{\%eco}$, $Neco_{average}$, and Dep_{NHx}^{Total}, the combinations of NOy and SO2+SO4 levels that result in attainment of the AAPI can also be expressed as a tradeoff curve. The level of the AAPI will be one value that applies to the entire nation, however the degree to which the values input to parameterize the equation (e.g. $\left[[BC]_O^*\right]_{\%eco}$, $Q_{\%eco}$, $Neco_{average}$, and Dep_{NHx}^{Total}) will vary according to which options of spatial aggregation are chosen (see below). These options will also affect the variability in the resultant tradeoff curves.

Spatial aggregation options for the components of the AAPI equation						
	Op#1 No subdivision of the U.S.	Op#2a Binary categorization	Op#2b 5 Cluster	Op#2c 1 sensitive category and individual sensitive eco-regions	Op#2d All individual ecoregions	Other options
The critical loads ($CL_{anclim}(N+S)$) from individual catchments will be aggregated to form a population. From the distribution of CL values in the population, a percentile of the distribution will be selected as the deposition metric ($DL_{\%eco}(i)$). The population to which an individual site belongs varies among the spatial aggregation options. The following terms are those associated with the critical load that represents the selected $DL_{\%eco}(i)$. Pre-industrial base cation weathering $\left[[BC]_O^*\right]_{\%eco}$ is the value from the individual critical load that is selected as the $DL_{\%eco}(i)$. Runoff $Q_{\%eco}$ is the value from the individual critical load that is selected as the $DL_{\%eco}(i)$.	X	X	X	X	X	
N removed by an ecosystem($Neco_{average}$) These are calculated from N deposition values averaged over a 3-5 year time period. Staff suggest the spatial area of aggregation should be consistent with $DL_{\%eco}(i)$	X	X	X	X	X	
Reduced N deposition (Dep_{NHx}^{Total})are modeled and averaged over a 3-5 yr time period, options for spatial aggregation are listed on the table					X	Model averaged to match areas of spatial homogeneity (See figure 5-16), so that each ecoregions would possibly have multiple NHx values
Transference ratios (T_{SOx} and T_{NOy}) are the					X	Averaged over the areas represented

aggregated effective deposition velocities. These values are modeled and averaged over a 3-5 yr time period, options for spatial aggregation are listed on the table						by the monitors for C_{SOx} and C_{NOy}
Air concentrations C_{SOx} C_{NOy}						Monitored values to represent air concentration relevant to acid deposition for sensitive water bodies (see previous discussion of air quality indicators)
Target ANC limit						
20 μeq/L: Expected to protect against significant losses due to fish mortality in many sensitive lakes, but will place less weight on protection against losses in aquatic diversity, and will be less protective against acidification episodes 50 μeq/L: Expected to protect against significant mortality in aquatic organisms and loss of fish health and biodiversity in sensitive lakes and streams, including losses due to acidification episodes, and will give weight to considerations of uncertainties in the time to recovery of aquatic ecosystems >50 μeq/L: May provide additional protection beyond 50 μeq/L against declines in fitness of sensitive species (e.g. brook trout, zooplankton), however, overall heath of aquatic communities may not be impacted						
Target for the percentage of water bodies to protect						
Options for selecting a percentile of the waterbodies to protect are informed by comparing levels of protection at alternate ANC levels given spatial aggregation options #1, 2a, 2b and 2d of the form. The number of lakes that would be protected to and ANC 50 and 20 μeq/L are quantified , and the spatial distribution of those lakes that would not receive protection is illustrated, given the 90^{th}, 75^{th} and 50^{th} percentile of the distribution of the critical loads for each population (as defined by the options).						