



Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition

Sierra Nevada Network (SIEN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/378



ON THE COVER

Some ecosystems and vegetation types, such as remote high-elevation lakes, sugar maple trees, headwater streams, and red spruce trees, are sensitive to the effects of acidification from atmospheric nitrogen and sulfur deposition.

Photograph by: National Park Service

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This report received peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Air Resources Division of the NPS (<http://www.nature.nps.gov/air/Permits/ARIS/networks/acidification-eval.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

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Sierra Nevada Network (SIEN)

National maps of atmospheric S and N emissions and deposition are provided in Maps A through D as context for subsequent network data presentations. Maps A and B show county level emissions of total S and total N for the year 2002. Maps C and D show total S and total N deposition, again for the year 2002.

There are four parks in the Sierra Nevada Network. Three of them (Kings Canyon, KICA; Sequoia, SEQU; and Yosemite, YOSE) are larger than 100 square miles. The one smaller park is Devils Postpile (DEPO).

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Sierra Nevada Network. County-level S emissions within the network were mostly less than 1 ton per square mile, with somewhat higher emissions in the westernmost portion of the network and further to the west in the San Francisco Bay area (Map E). County-level N emissions within the network generally ranged from less than 1 ton per square mile in and around YOSE to 1 to 20 tons per square mile in and around SEQU and KICA (SEKI; Map F). A small area of higher N emissions occurs to the west. Annual county N emissions were less than 5 tons per square mile throughout much of the network. Emissions near SEQU were somewhat higher than that. Point source emissions of S are shown in Map G. Point sources within and near the network are mostly located to the west of the parks, within about 100 miles of the coast; essentially all of the S point sources are relatively small (less than 5,000 tons per year). Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map H. There are very few point sources of N of any magnitude in this network.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. There are several population centers larger than 100,000 people within the network. There are also several large population centers outside of, but in proximity to, the network, including San Francisco, San Jose, and Los Angeles.

Total S and N deposition in and around the network are shown in Maps J and K, respectively. Included in this analysis are both wet and dry forms of deposition, and both the oxidized and reduced N species. Total S deposition is low throughout virtually the entire network (less than 2 kg S/ha/yr). Total N deposition within the network ranged from less than 2 kg N/ha/yr to higher than 15 kilograms N per hectare per year. Most of the lands occupied by the I&M parks received an estimated 2 to 5 kg N/ha/yr of total N deposition. Deposition of N in the western portion of SEQU was somewhat higher.

Land cover in and around the network is shown in Map L. The predominant cover types within this network are generally arranged in bands that run from north to south. Lands in and around the I&M parks are largely forested. To the west is a band of largely grassland/herbaceous land cover. To the west of that is a mix of row crops, pasture/hay, and developed areas. The agricultural and developed lands are potential sources of acidifying pollutants (especially N) to the parks in this network.

Land slope within parks that occur in this network is shown in Map M. Most of the land in SEKI is very steep, in the range of 40° to 50°. Lands within YOSE are also generally steep; most are 30° to 40°, with some HUCs averaging 40° to 50° slope.

Park lands requiring special protection against potential adverse impacts associated with acidic deposition are shown on Map N. Also shown on Map N are all federal lands designated as wilderness, including lands managed by NPS and lands managed by other federal agencies. The land designations used to identify this heightened protection include Class I designation under the Clean Air Act Amendments and wilderness designation. The three largest parks in the network are all Class I, and each is largely comprised of designated wilderness. In addition, most of the higher elevation areas of the Sierra Nevada within this network are designated wilderness, mostly managed by the USDA Forest Service.

Maps P-1 through P-4 are park-specific maps for SEKI and YOSE which show high-elevation lakes and streams (Maps P-1 and P-2), and low-order streams (Maps P-3 and P-4). High-elevation lakes and streams might be more prone to acidification than lakes and streams at lower elevation. There are many high-elevation lakes and streams in these parks. Many of those might be expected to be acid-sensitive.

Nearly all streams in SEKI and YOSE are first through third order and occur on steep terrain. The vast majority are first-order streams, with relatively small drainage areas. Such streams tend to be more likely to be sensitive to acidification than the larger, higher-order streams found at lower elevation.

Network rankings are given in Figures A through C as the average ranking of the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection metrics, respectively. Figure D shows the overall network Summary Risk ranking. In each figure, the rank for this particular network is highlighted to show its relative position compared with the ranks of the other 31 networks.

The Sierra Nevada Network ranked at the bottom of the third quintile, among networks, in S and N-Pollutant Exposure (Figure A). Sulfur emissions and deposition within the network are both low, but N emissions and deposition are somewhat higher. However, the network Ecosystem Sensitivity ranking was very high, one of the highest among the 32 I&M networks (Figure B). This is mainly because there are many high-elevation lakes and streams in the parks that occur in this network, the terrain is very steep, and the region is known to be acid-sensitive based on geology and available water chemistry data. This network ranked in the highest quintile in Park Protection, having substantial amounts of protected lands (Figure C).

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yielded an overall Network Risk ranking that is among the highest of the 32 I&M networks (Figure D).

Similarly, park rankings are given in Figures E through H for the same metrics as were used to rank the networks. In the case of the park rankings, we only show in the figures the parks that are larger than 100 square miles. Relative ranks for all parks, including the smaller parks, are given in Table A and Appendix A. As for the network ranking figures, the park ranking figures highlight those parks that occur in this network to show their relative position compared with

parks in the other 31 networks. Note that the rankings shown in Figures E through H reflect the rank of a given park compared with all other parks, irrespective of size.

The four I&M parks in the Sierra Nevada Network were ranked low (DEPO, KICA, SEQU) or Moderate (YOSE) in Pollutant Exposure (Figure E, Table A). Ecosystem Sensitivity for all three of the larger parks was ranked in the highest quintile (Figure F). All three contain high-elevation lakes and streams, low-order streams, and steep terrain; in addition, all three occur within a region of known acid-sensitivity. The smaller park (DEPO) was ranked in the second highest quintile for Ecosystem Sensitivity (Table A). Park Protection rankings for all four parks were in the highest quintile (Figure G, Table A).

In combination, the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection rankings yielded an overall park Summary Risk ranking for the three larger parks that was Very High for YOSE and High for KICA and SEQU (Figure H). The Summary Risk ranking for DEPO was also High (Table A), indicating a High to Very High concern for acidification effects in the parks that are found in this network.

Table A. Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and overall Summary Risk from acidic deposition.				
I&M Parks² in Network	Relative Ranking of Individual Parks¹			
	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Big Hole	Very Low	High	Moderate	Very Low
City of Rocks	Low	High	Moderate	Low
<i>Craters of the Moon</i>	Low	Moderate	High	Moderate
Hagerman Fossil Beds	Moderate	Very High	Moderate	Moderate
John Day Fossil Beds	Very Low	Very High	Moderate	Low
<i>Lake Roosevelt</i>	Very Low	Moderate	Moderate	Very Low
Nez Perce	Very Low	High	Moderate	Very Low
Whitman Mission	Moderate	Low	Moderate	Very Low
¹ Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (very low risk) to the highest quintile (very high risk).				
² Park name is printed in bold italic for parks larger than 100 square miles.				

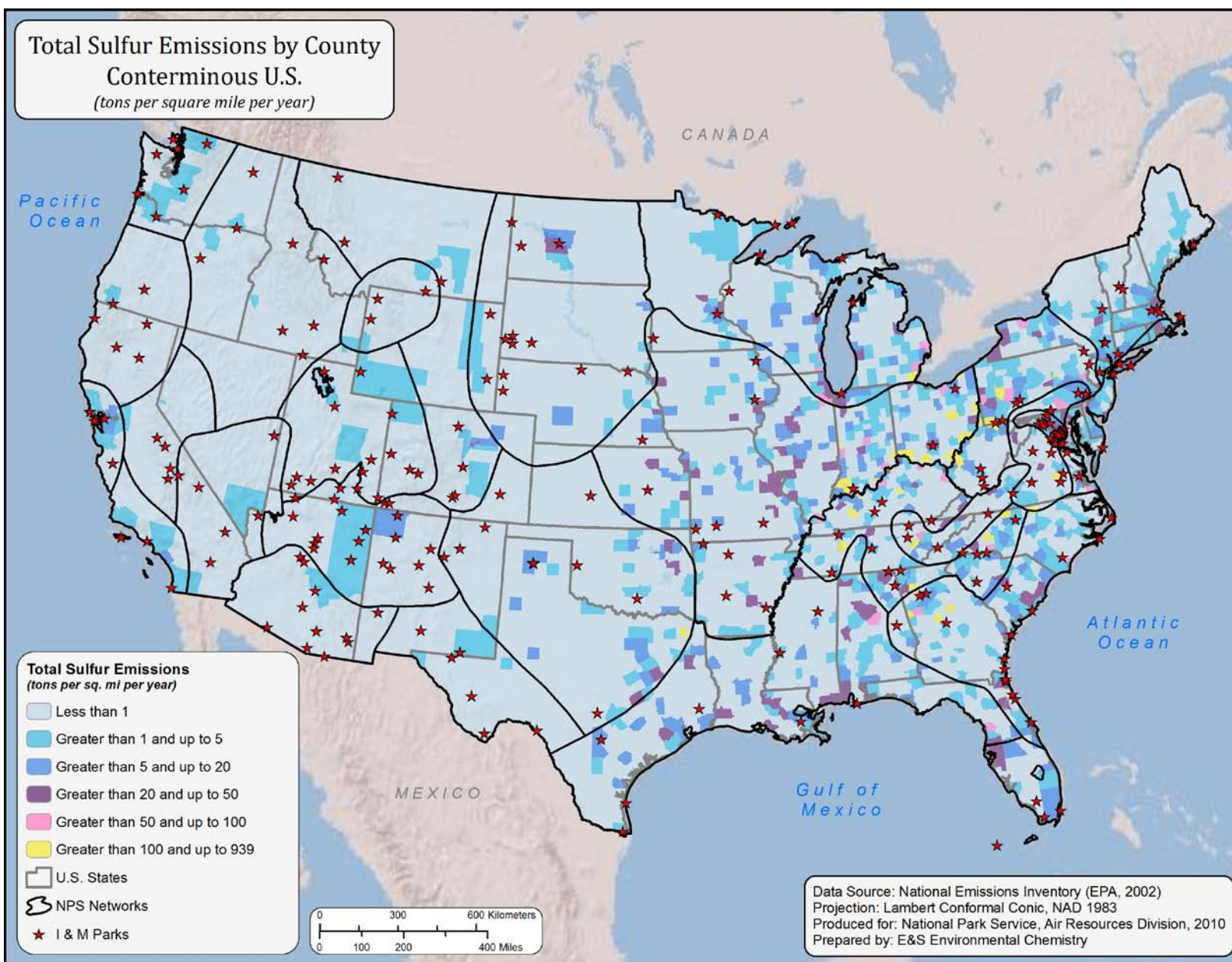
Map A. National map of total S emissions by county for the year 2002, in units of tons of S per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)

Map B. National map of total N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) forms of N are included. The total is expressed in tons per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)

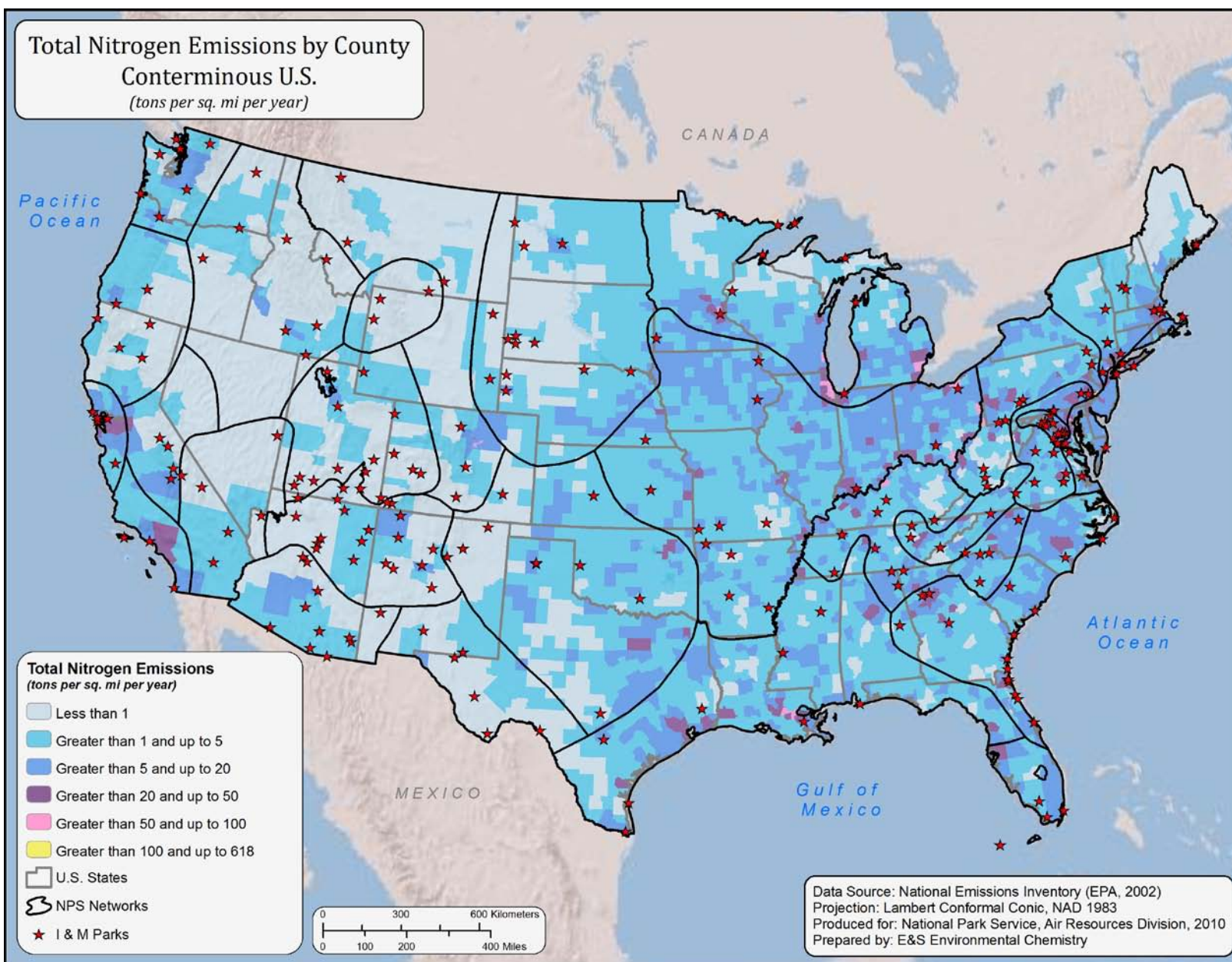
- Map C. Total S deposition for the conterminous United States for the year 2002, expressed in units of kilograms of S deposited from the atmosphere to the Earth surface per hectare per year. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP (three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.
- Map D. Total N deposition for the conterminous United States for the year 2002, expressed in units of kilograms of N deposited from the atmosphere to the Earth surface per hectare per year. Wet and dry forms of both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N are included. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP (three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.
- Map E. Total S emissions by county for lands surrounding the network, expressed as tons of S emitted into the atmosphere per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map F. Total N emissions by county for lands surrounding the network, expressed as tons of N emitted into the atmosphere per square mile per year. The total includes both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map G. Major point source emissions of SO₂ for lands surrounding the network. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map H. Major point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N in and around the network. The base of each vertical bar is positioned in the map at the approximate location of the source. The height of the bar is proportional to the magnitude of the source. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map I. Urban centers having more than 10,000 people within the network and within a 300-mile buffer around the perimeter of the network. (Source of data: U.S. Census 2000)

- Map J. Total S deposition in and around the network. Values are expressed as kilograms of S deposited per hectare per year. (Source of data: Interpolated NADP wet and CMAQ Model dry deposition data for 2002; see information for Map C above for details)
- Map K. Total N deposition in and around the network. Included in the total are wet plus dry forms of both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N. Values are expressed as kilograms of N deposited per hectare per year. (Source of data: Interpolated NADP wet and CMAQ Model dry deposition data for 2002; see information for Map D above for details)
- Map L. Land cover types in and around the network, based on the National Land Cover dataset. (Source of data: National Land Cover Dataset, http://www.mrlc.gov/nlcd_multizone_map.php)
- Map M. Average land slope within park units that occur within the network, by 10-digit HUC. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>])
- Map N. Lands within the network that are classified as Class I or wilderness area. (Source of data: USGS 2005 [National Atlas; <http://nationalatlas.gov>] and NPS)
- Map P-1. Park-specific map: high-elevation lakes and streams in SEKI. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>] and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-2. Park-specific map: high-elevation lakes and streams in YOSE. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>] and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-3. Park-specific map: low-order streams in SEKI. (Source of data: U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-4. Park-specific map: low-order streams in YOSE. (Source of data: U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Figure A. Network rankings for Pollutant Exposure, calculated as the average of scores for all Pollutant Exposure variables.
- Figure B. Network rankings for Ecosystem Sensitivity, calculated as the average of scores for all Ecosystem Sensitivity variables.
- Figure C. Network rankings for Park Protection, calculated as the average of scores for all Park Protection variables.
- Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.

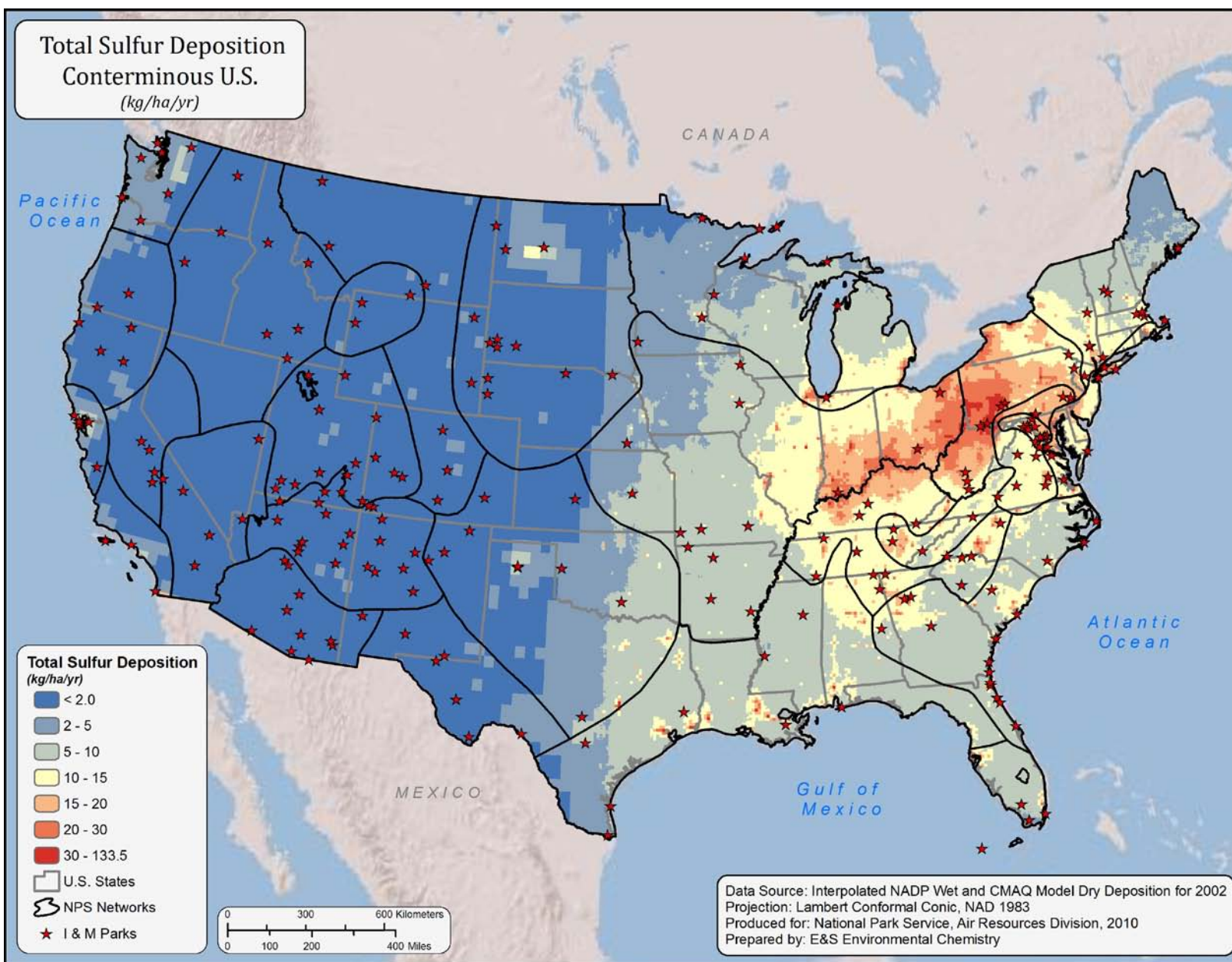
- Figure E. Park rankings for Pollutant Exposure for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Pollutant Exposure variables.
- Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.
- Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.
- Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.



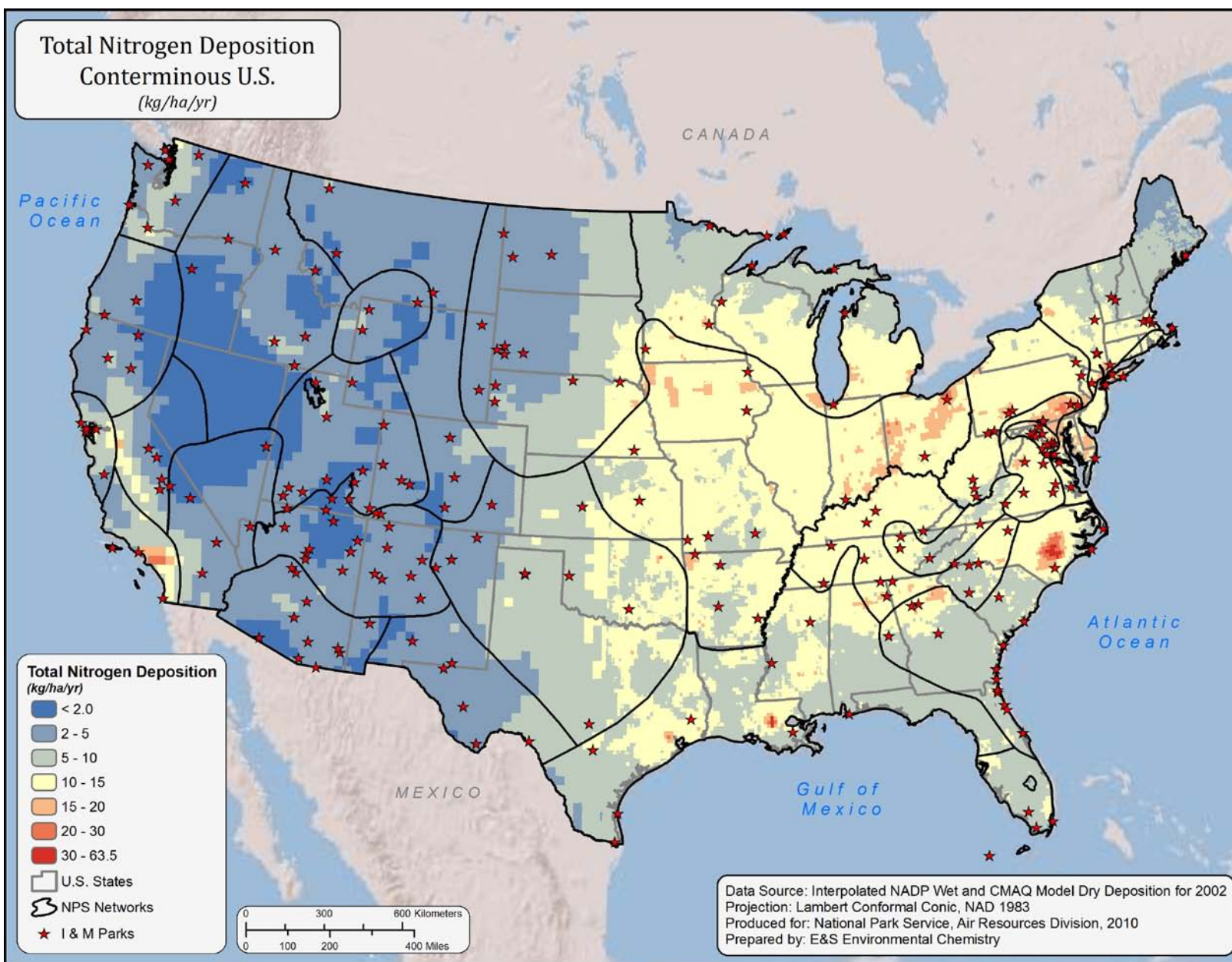
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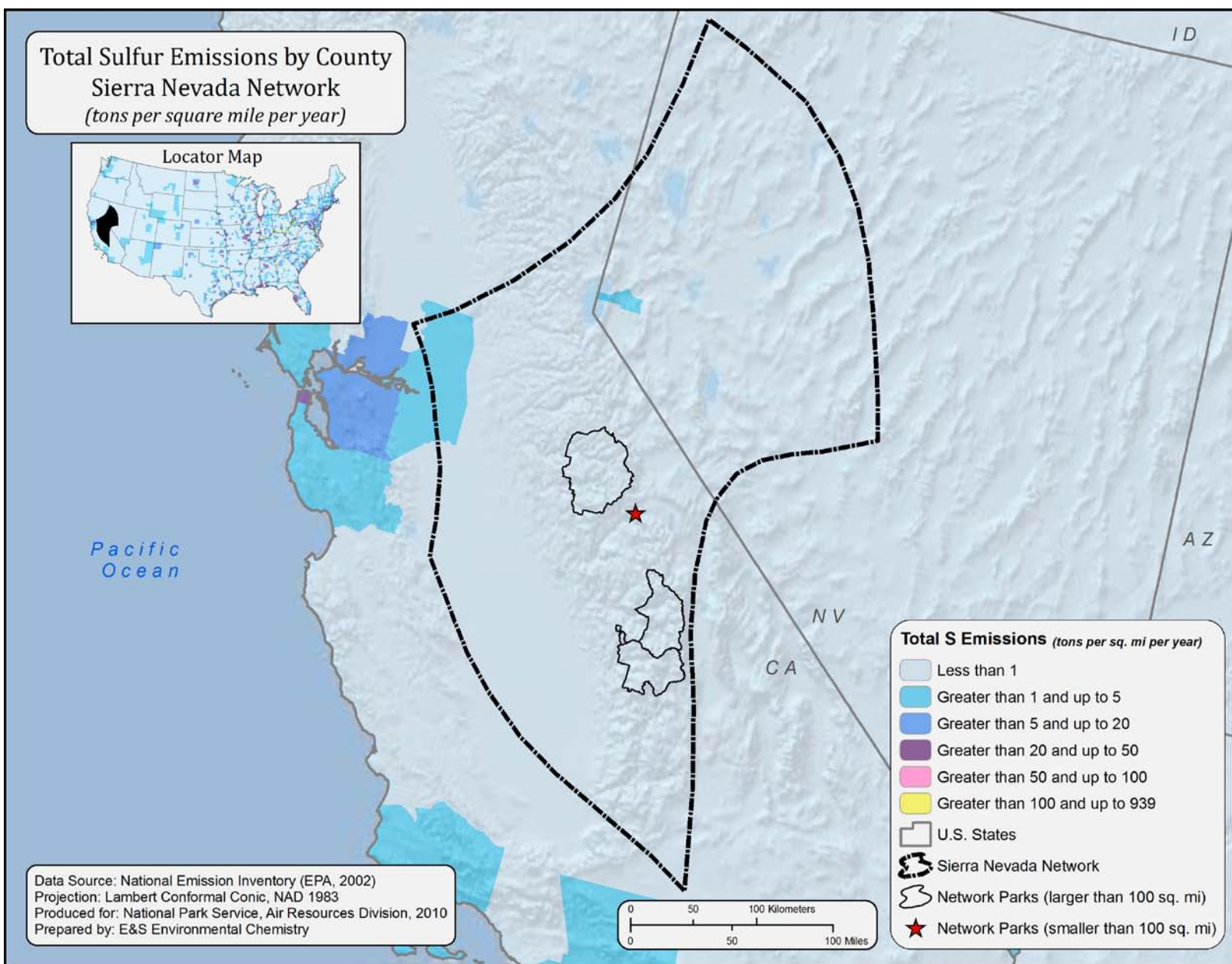
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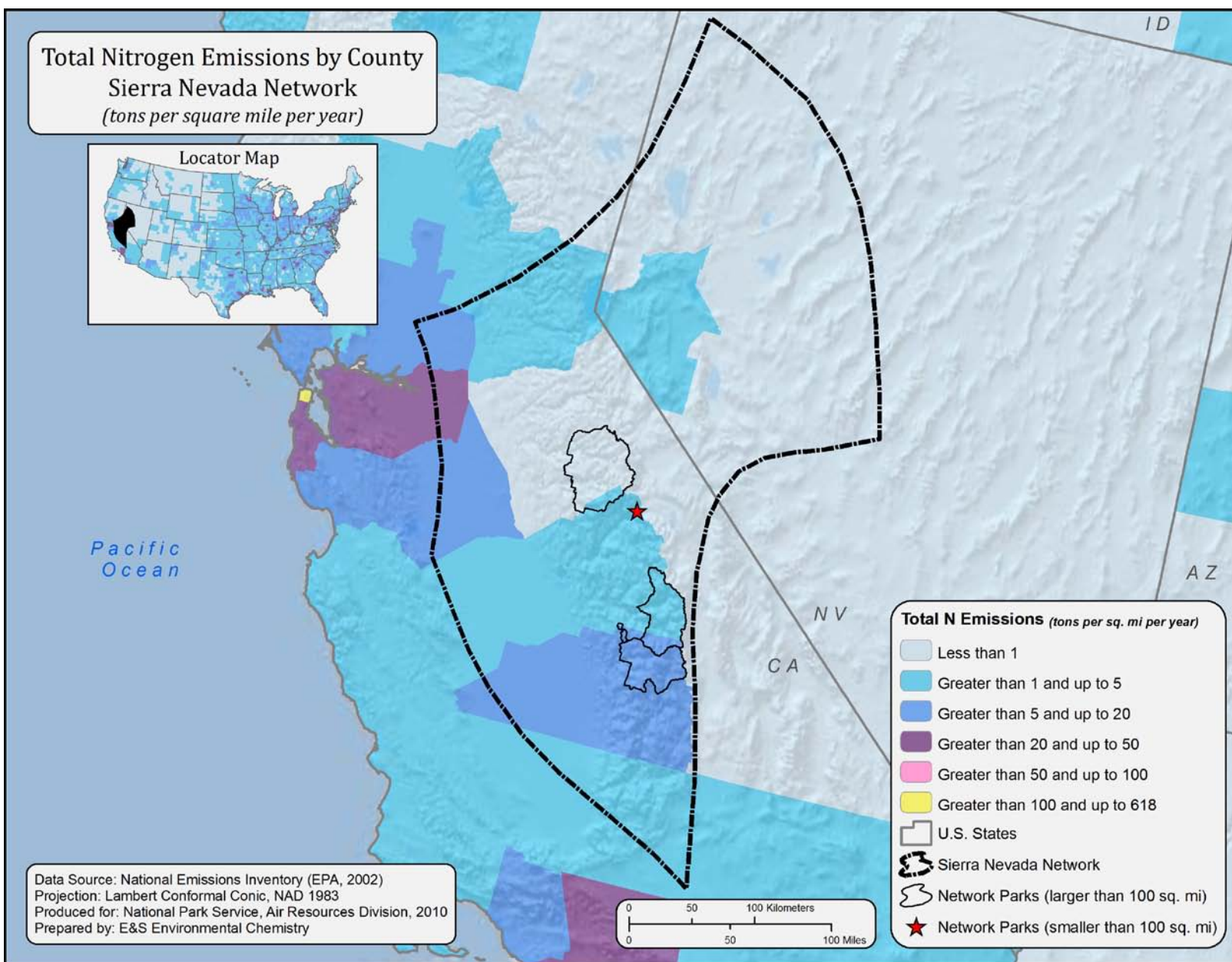
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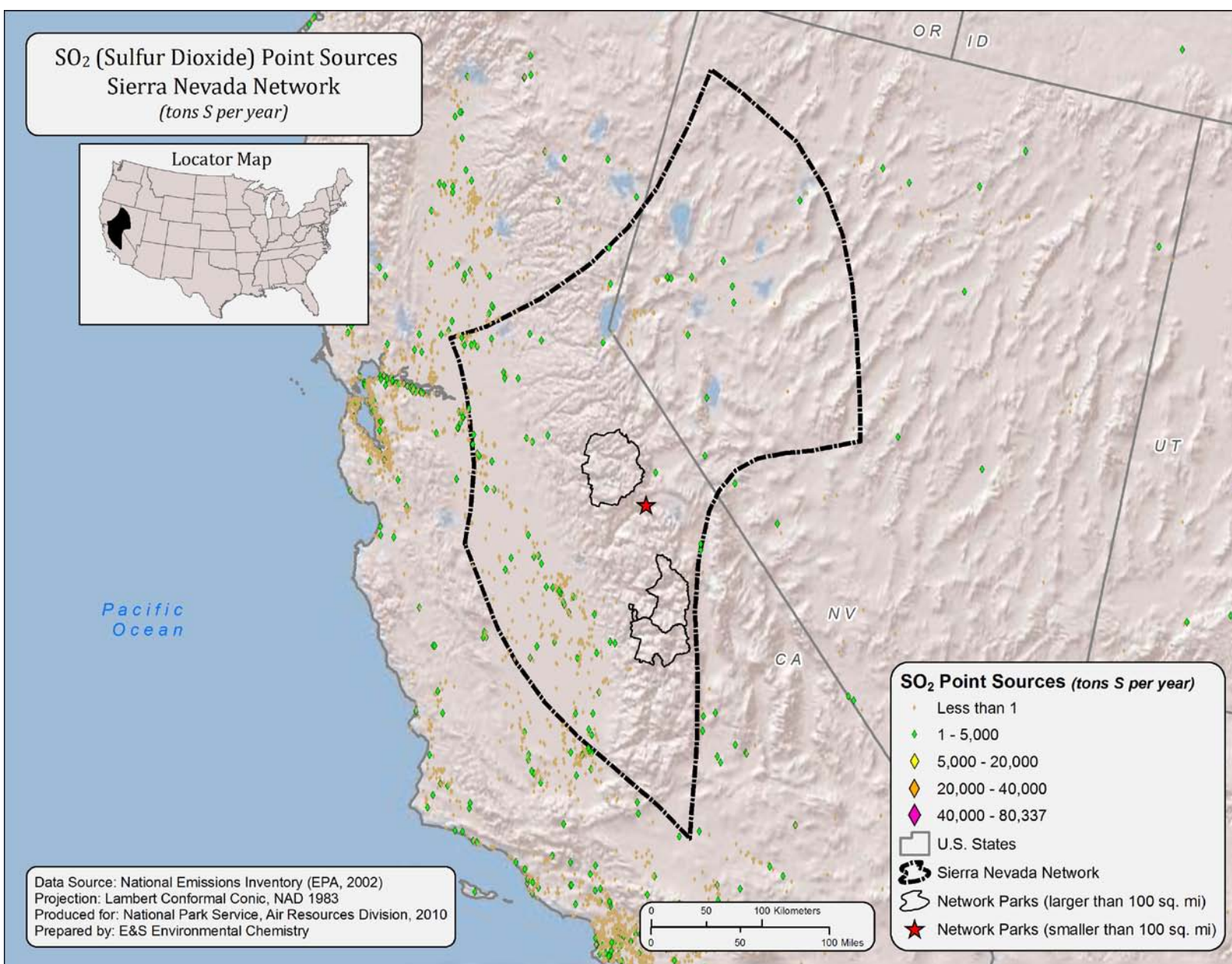
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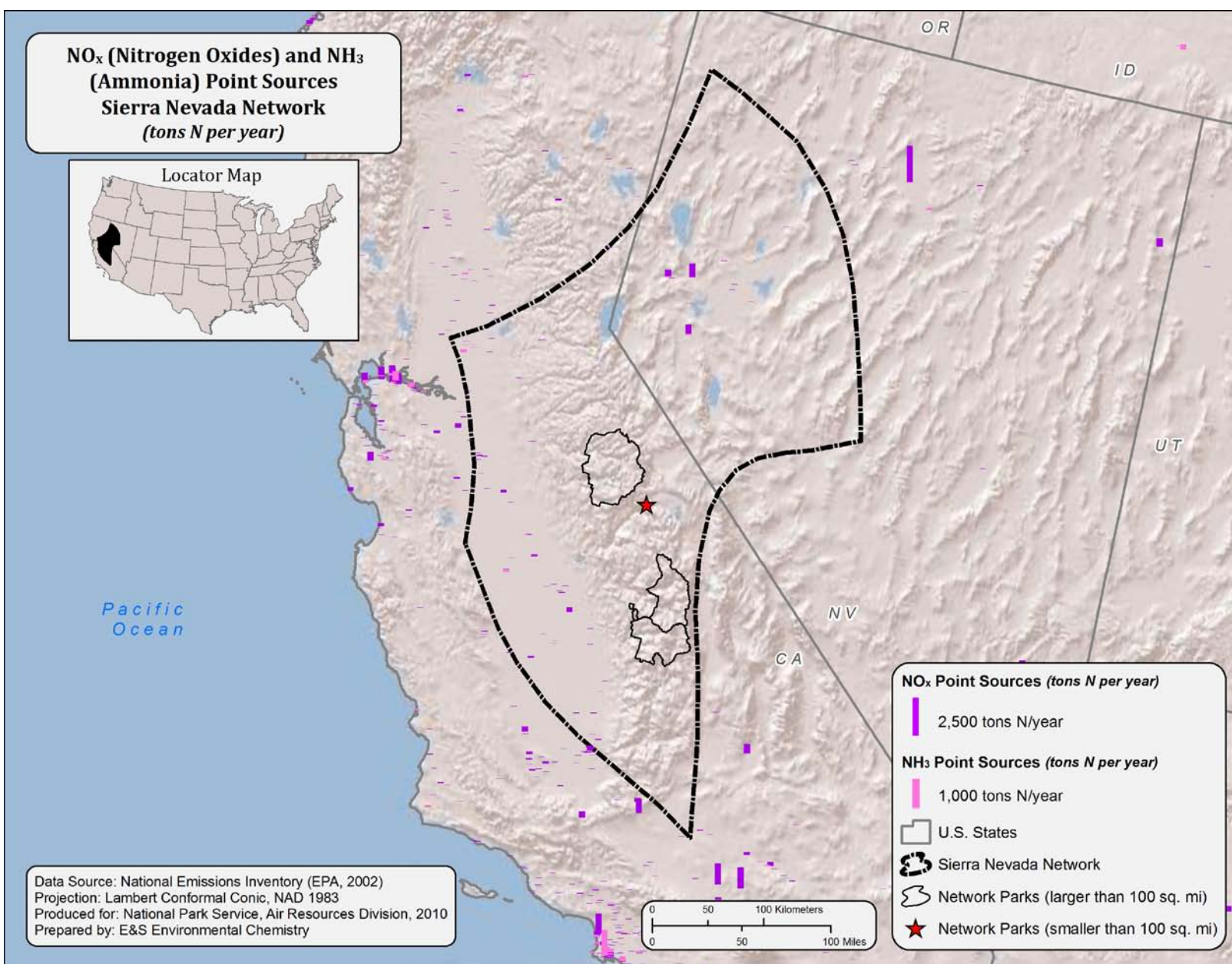
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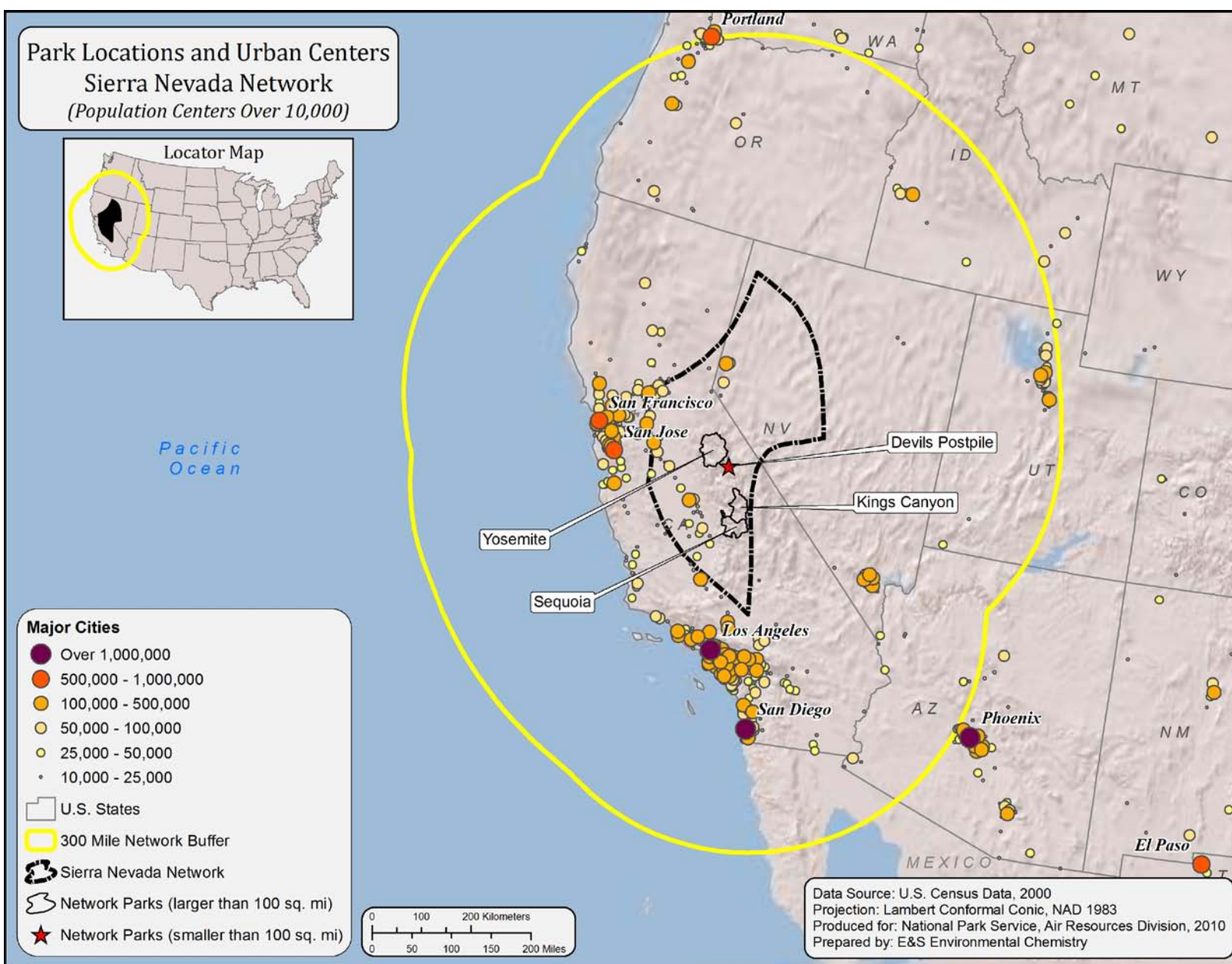
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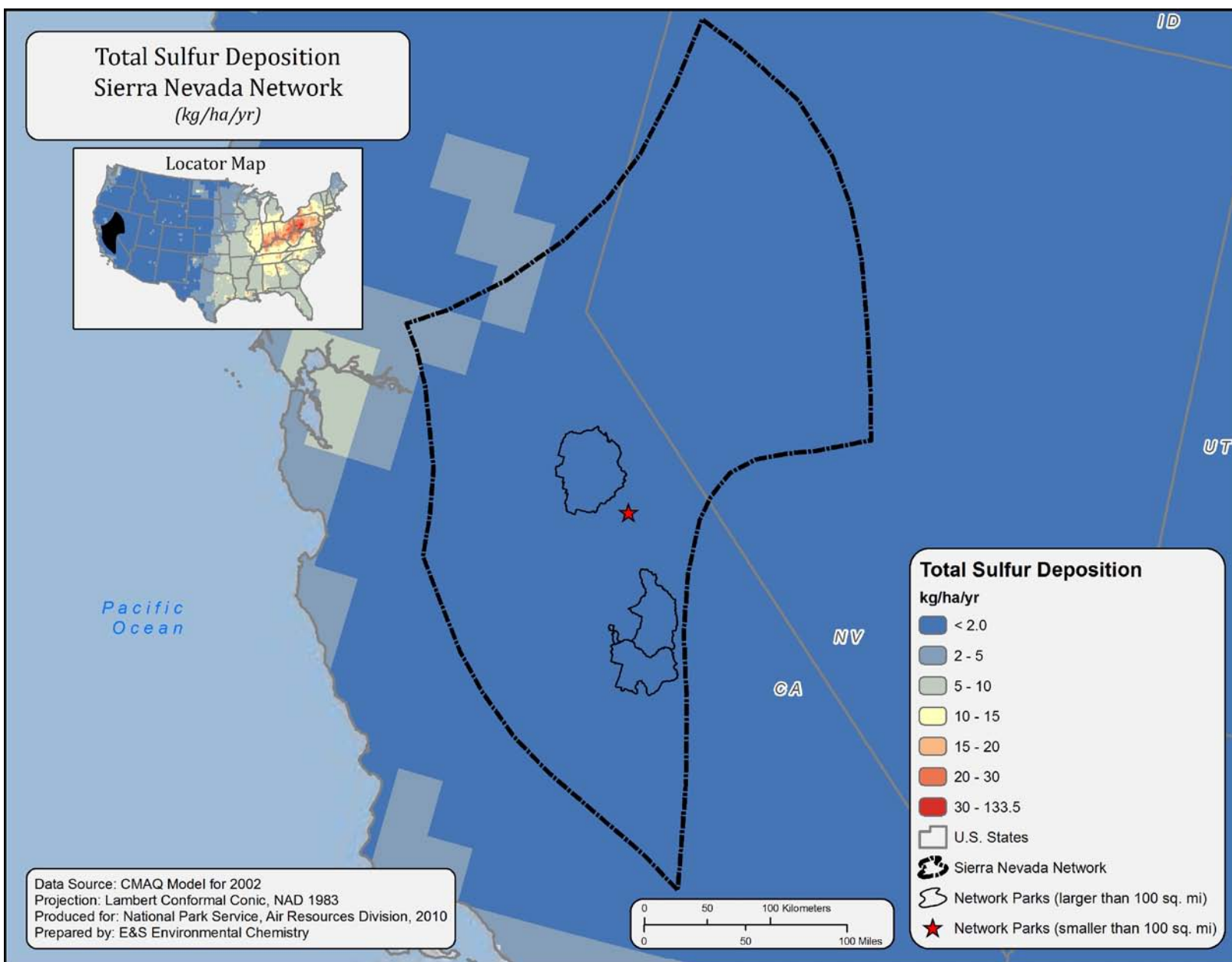
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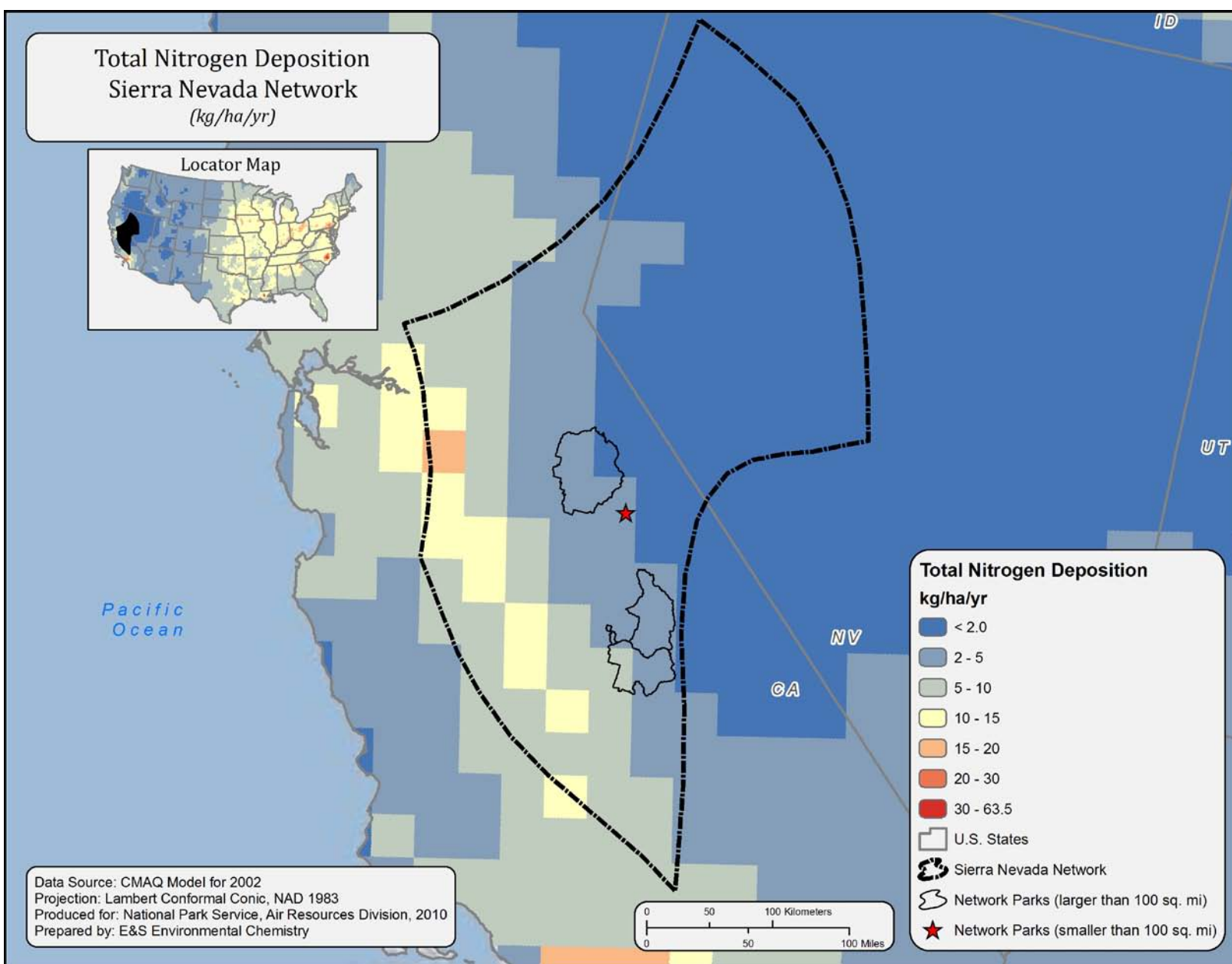
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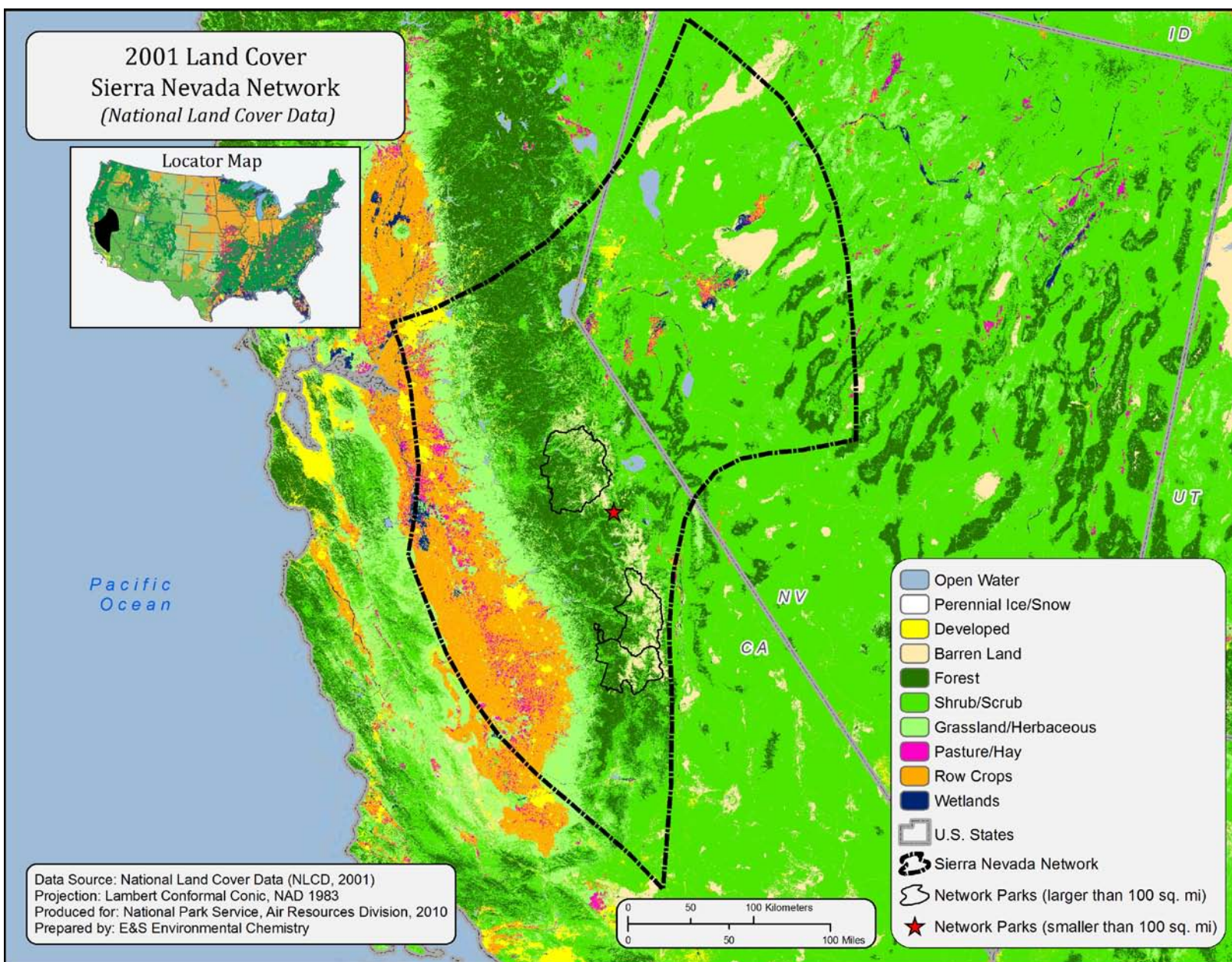
Map I



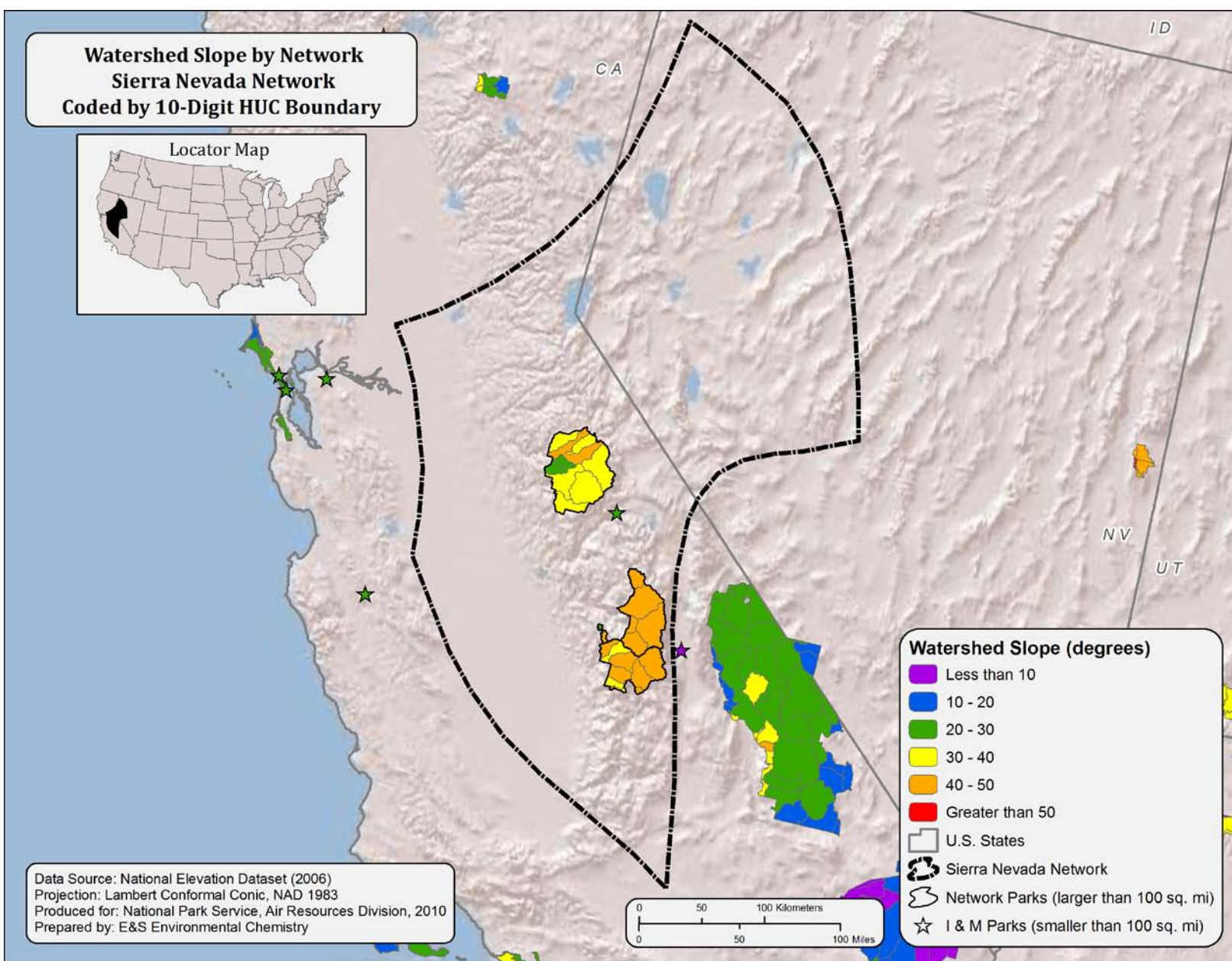
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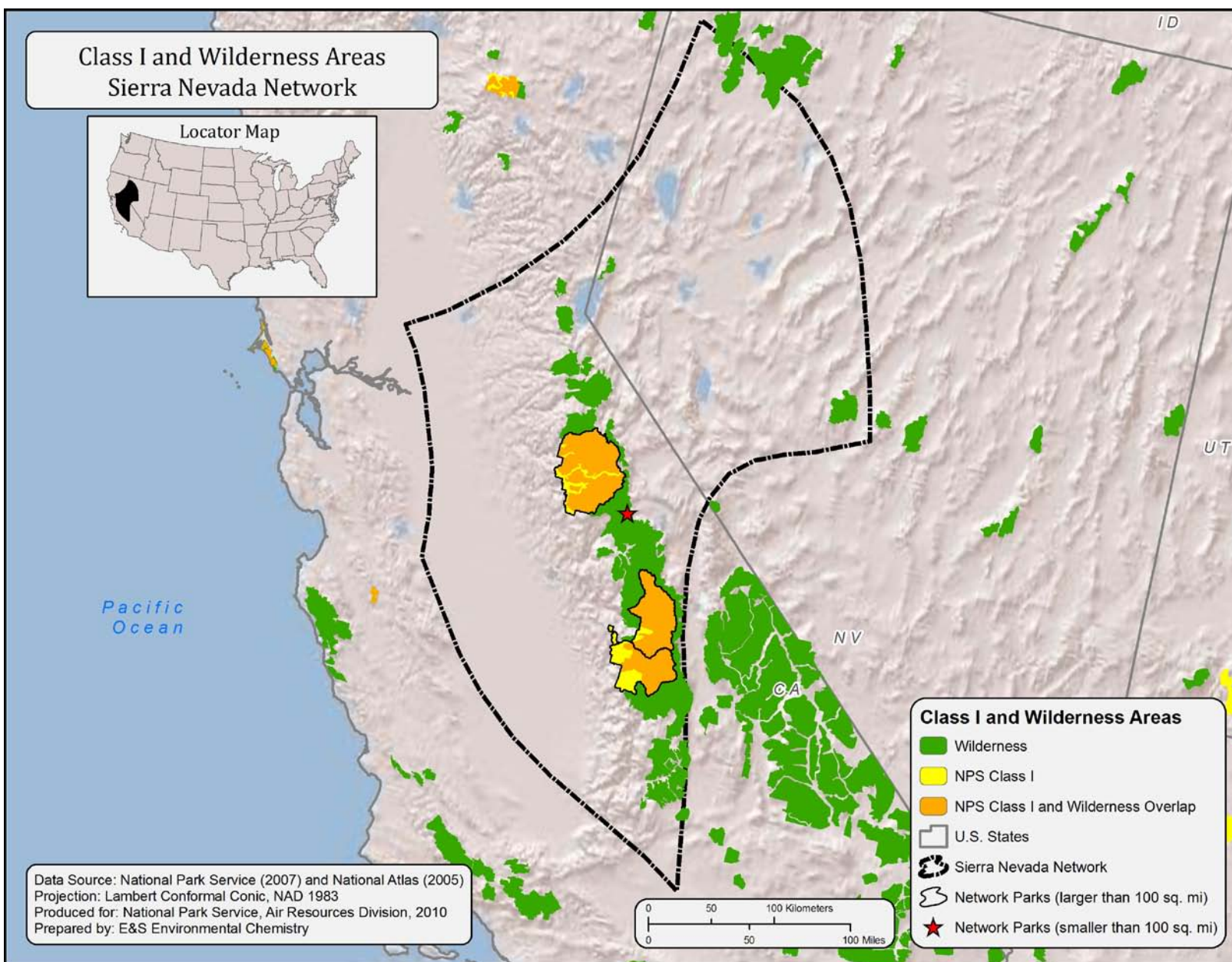
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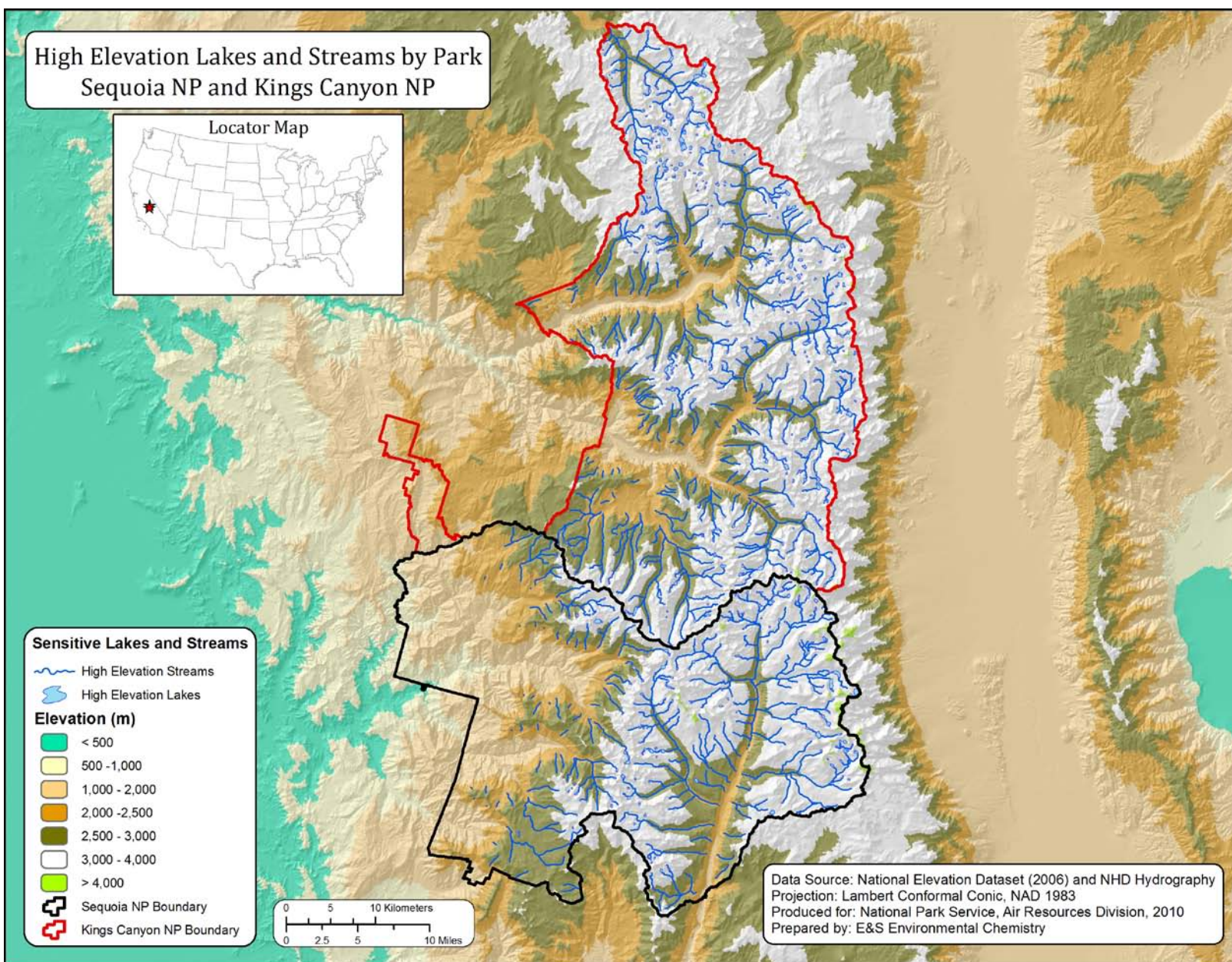
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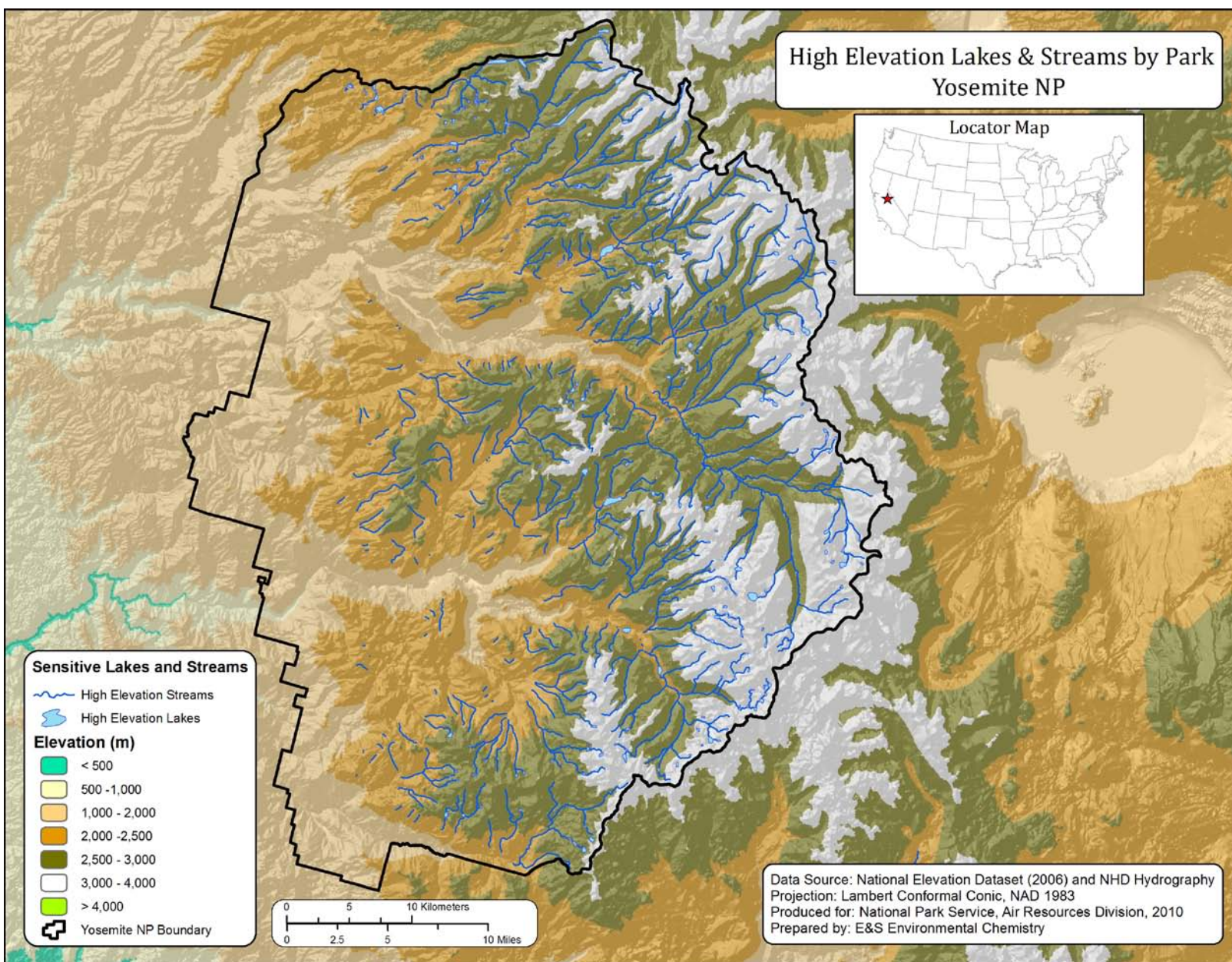
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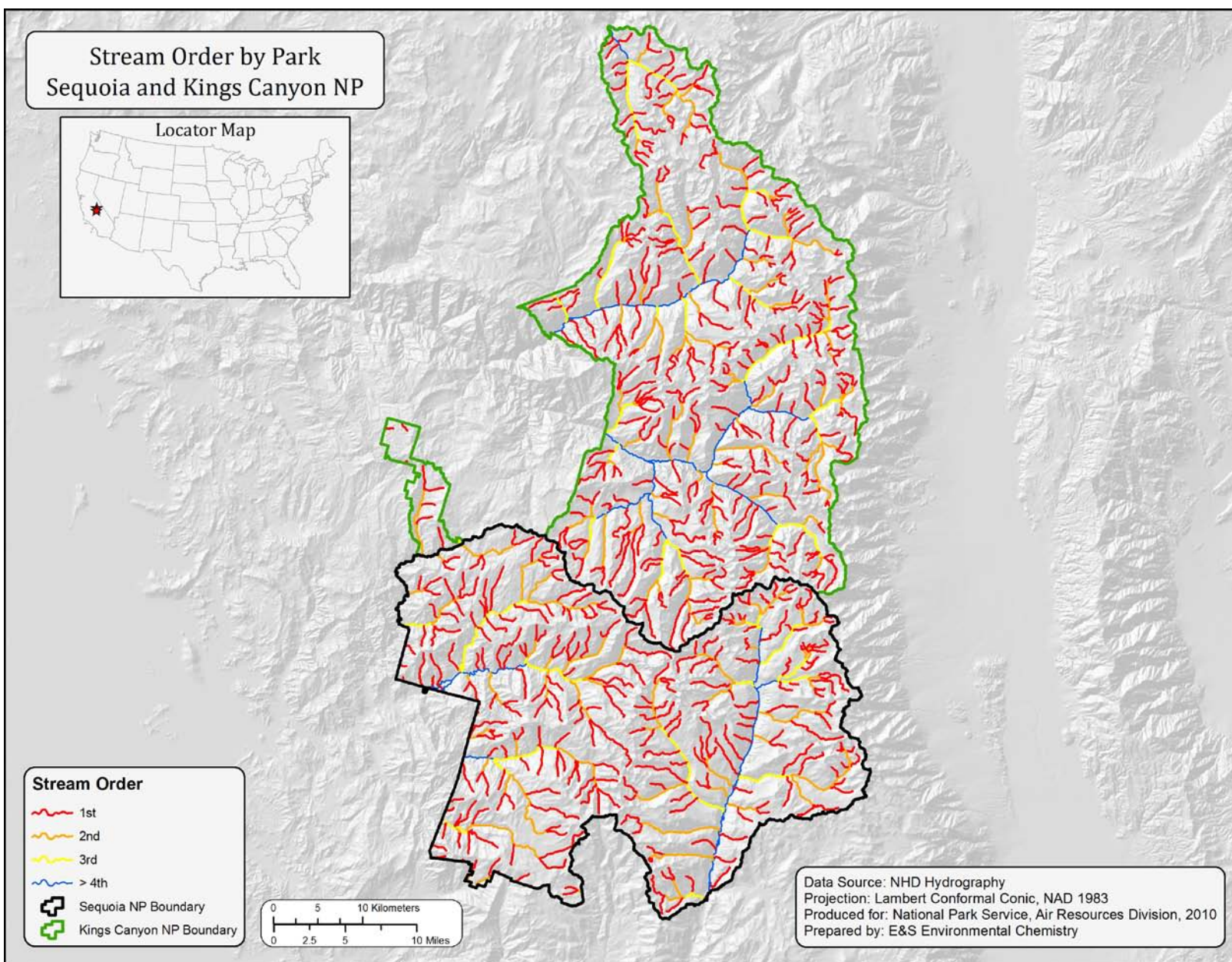
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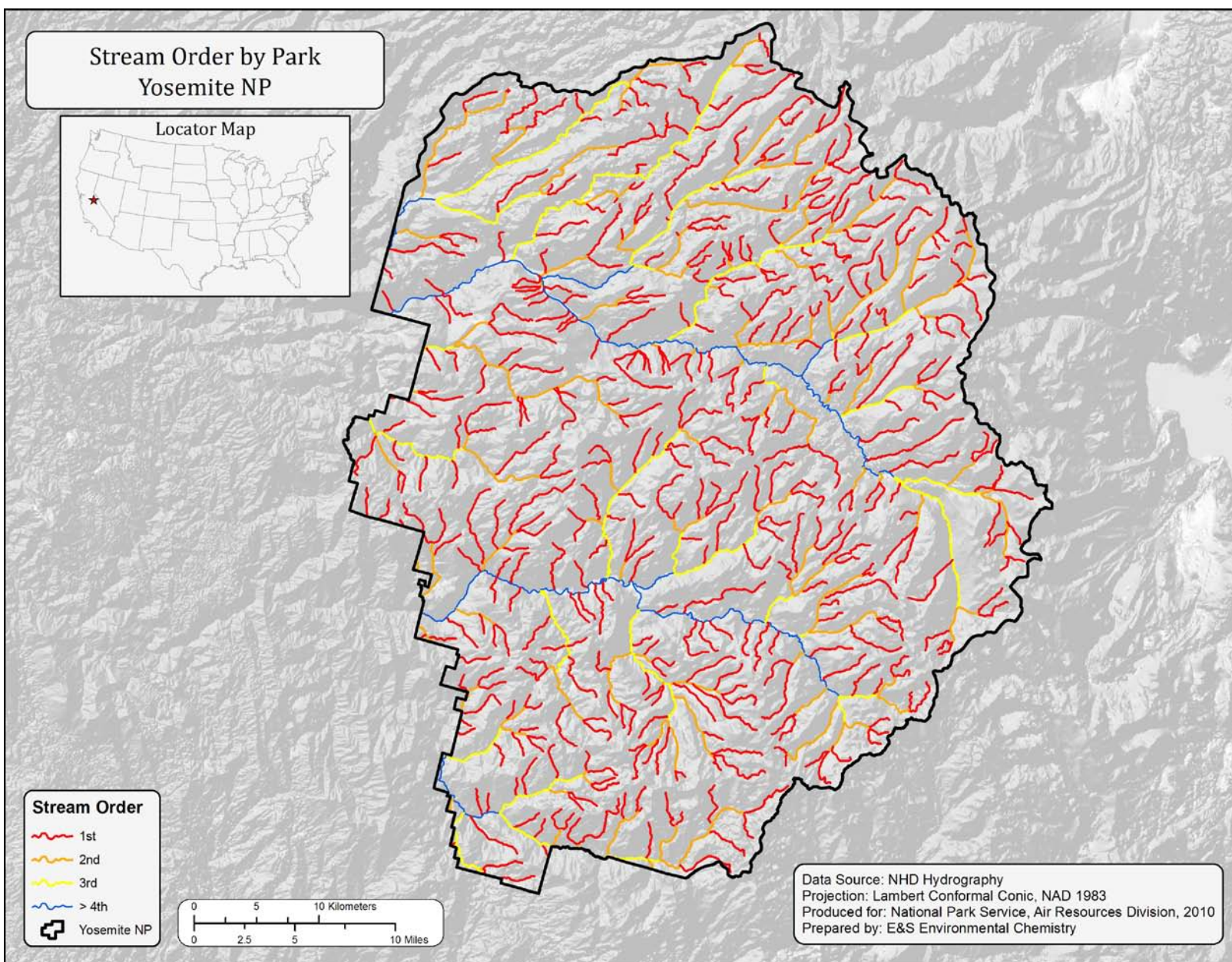
Map P-1



Map P-2



Map P-3



Map P-4

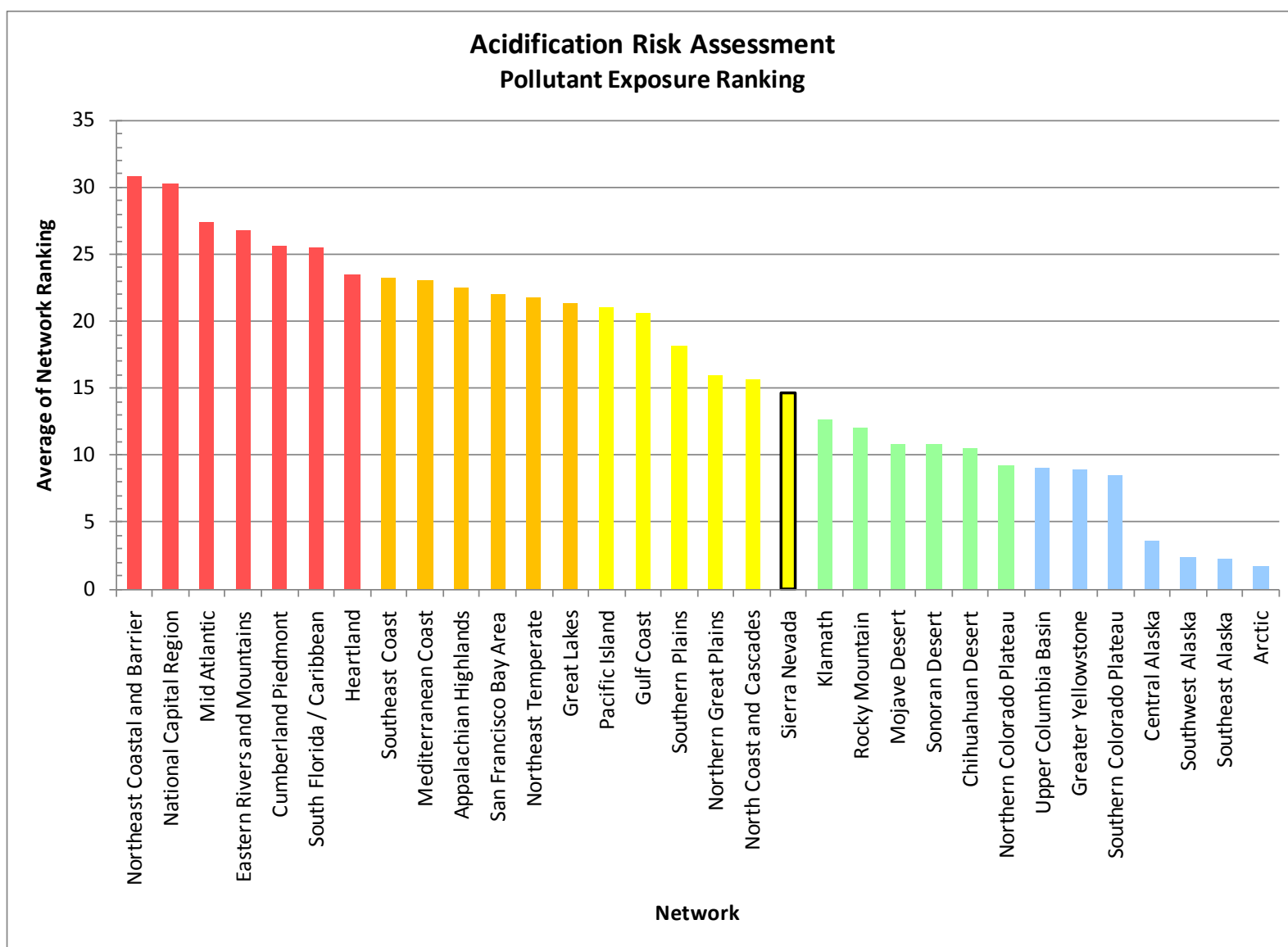


Figure A

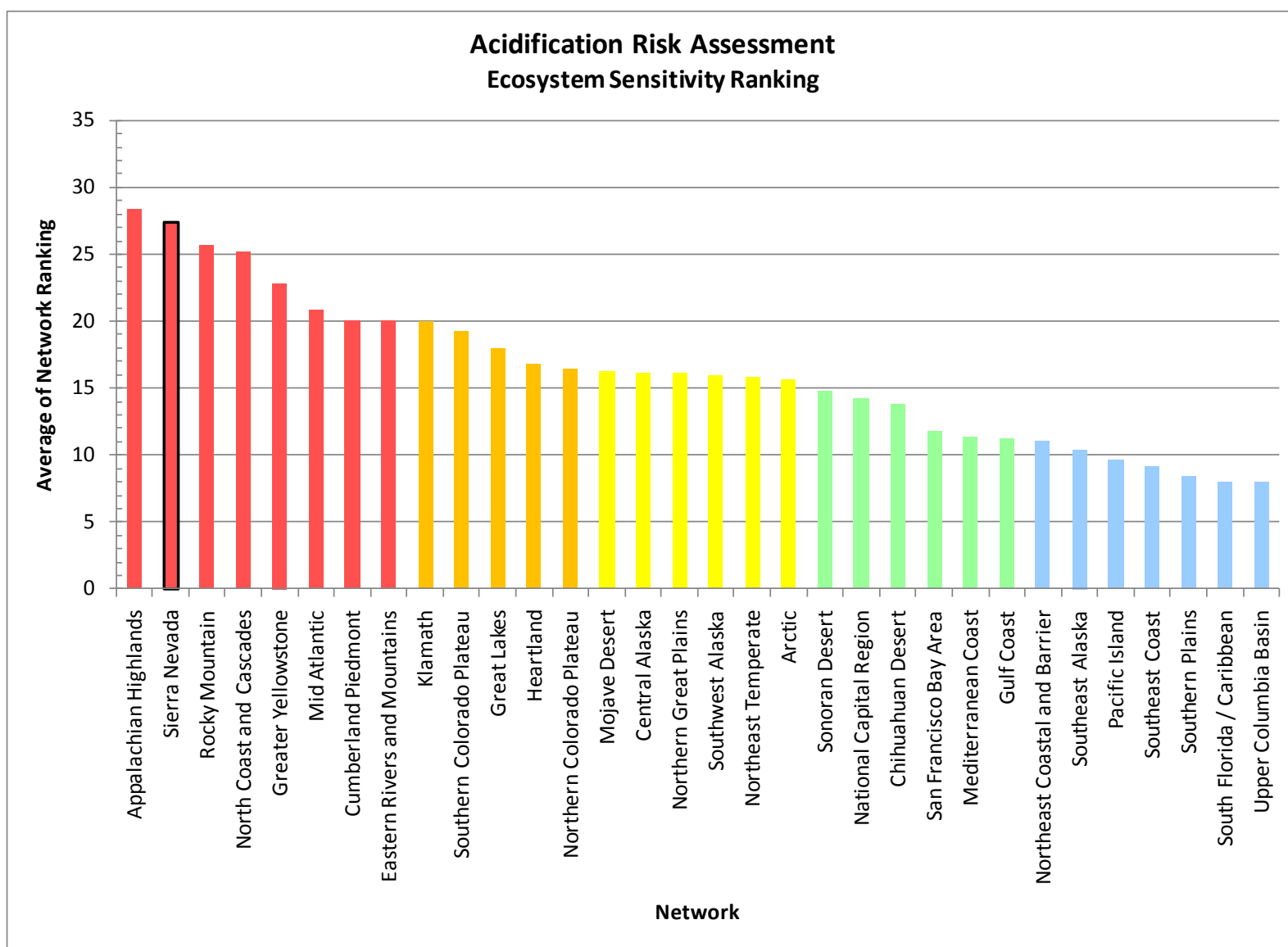


Figure B

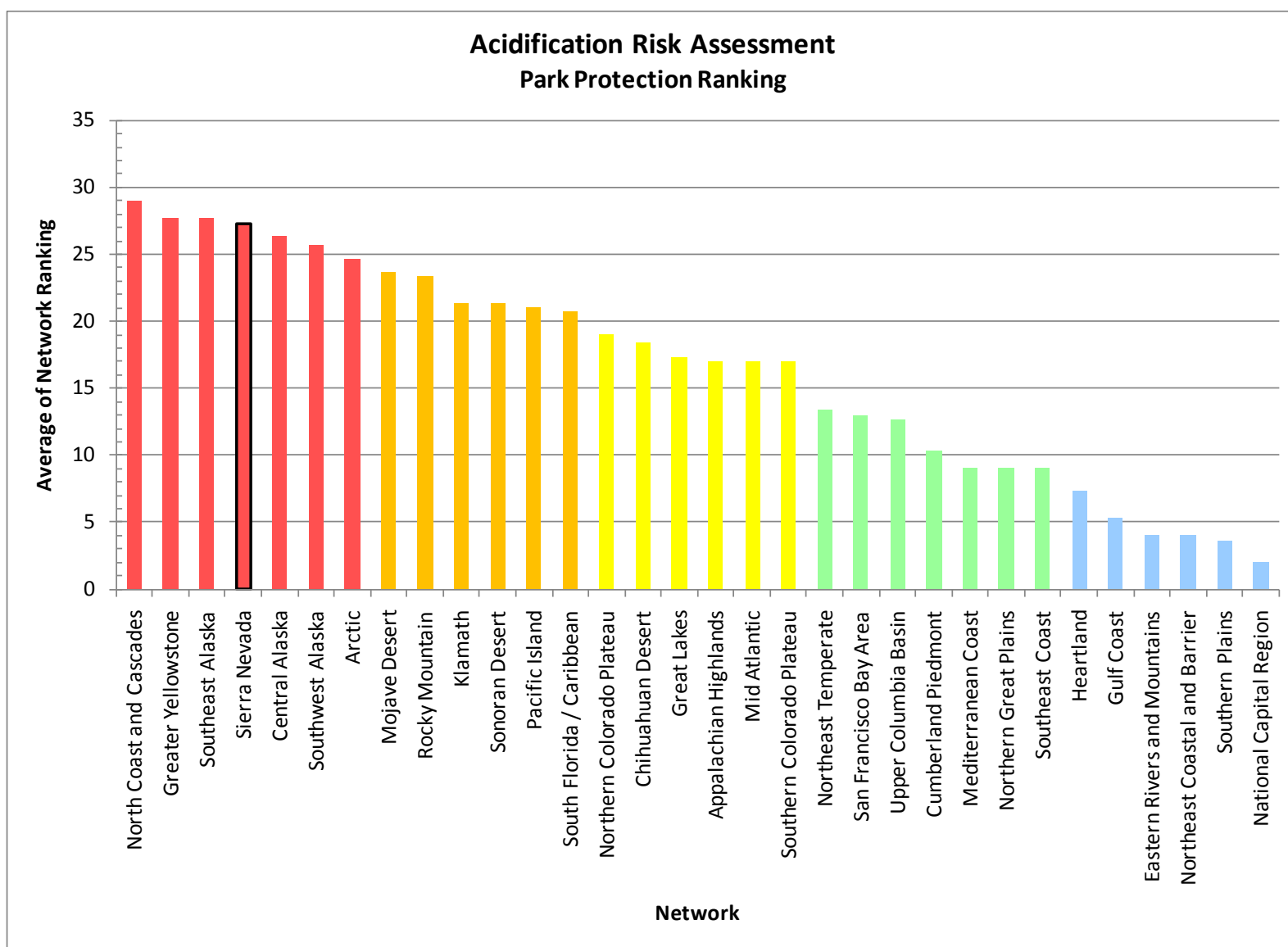


Figure C

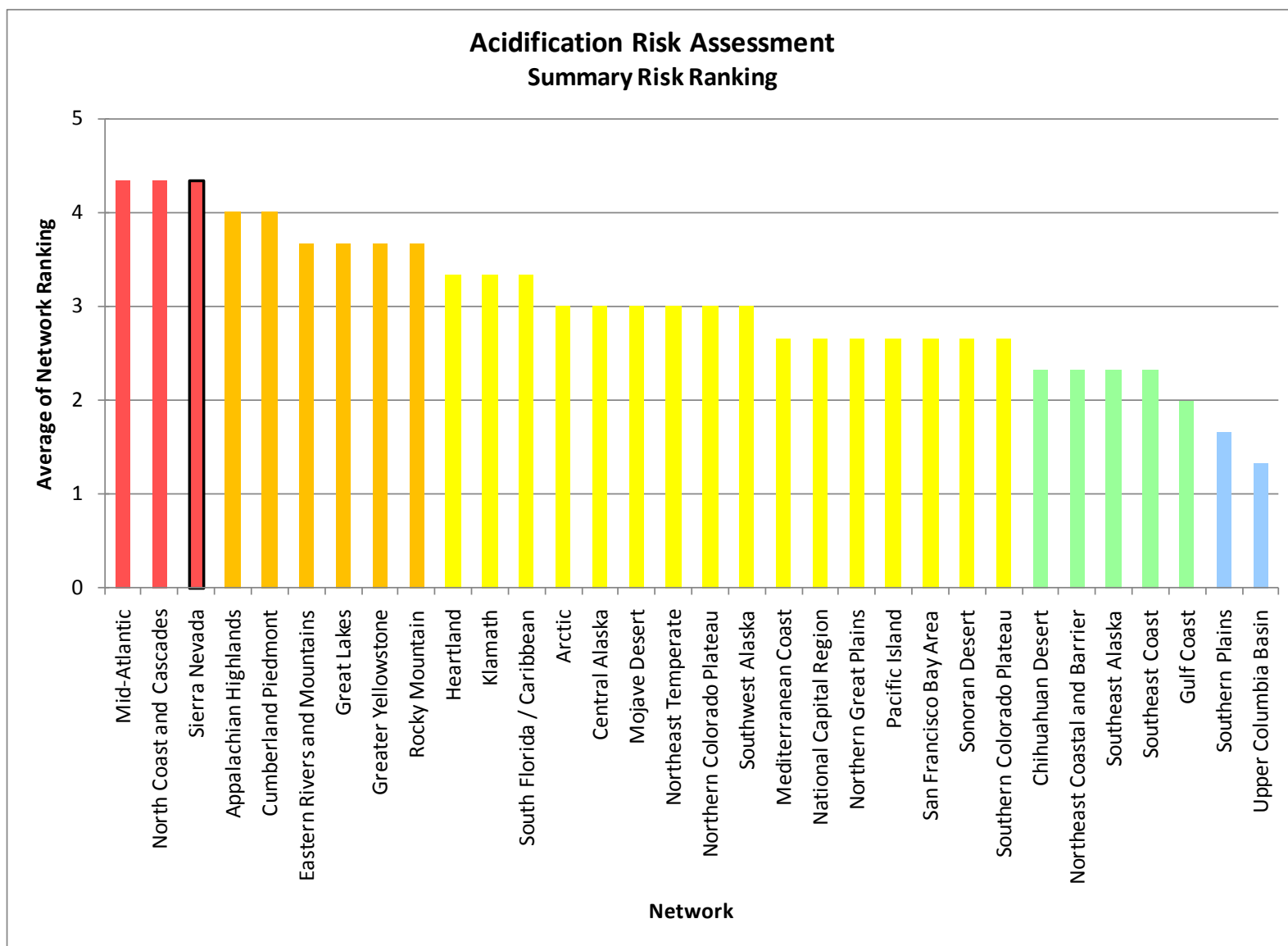


Figure D

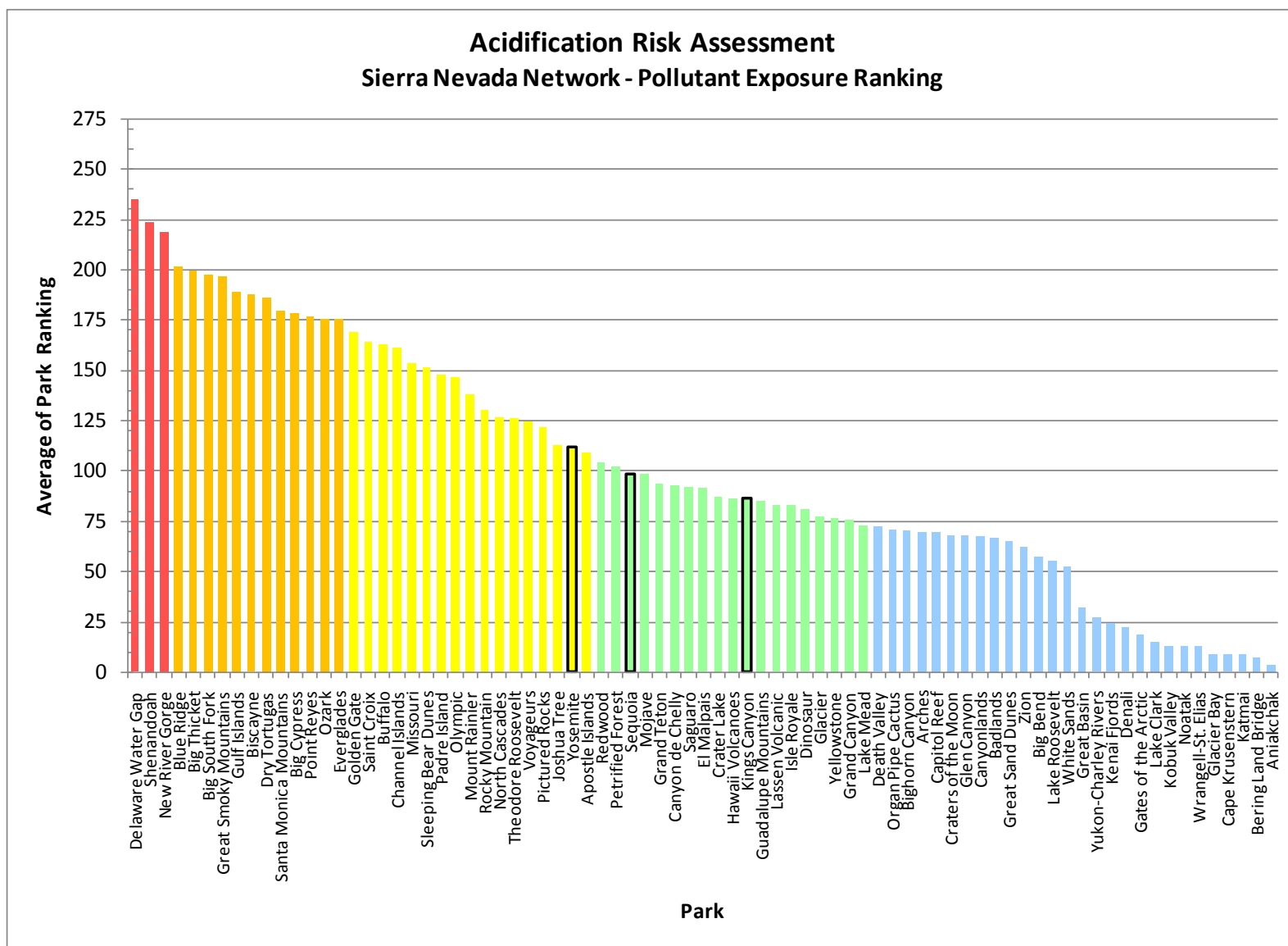


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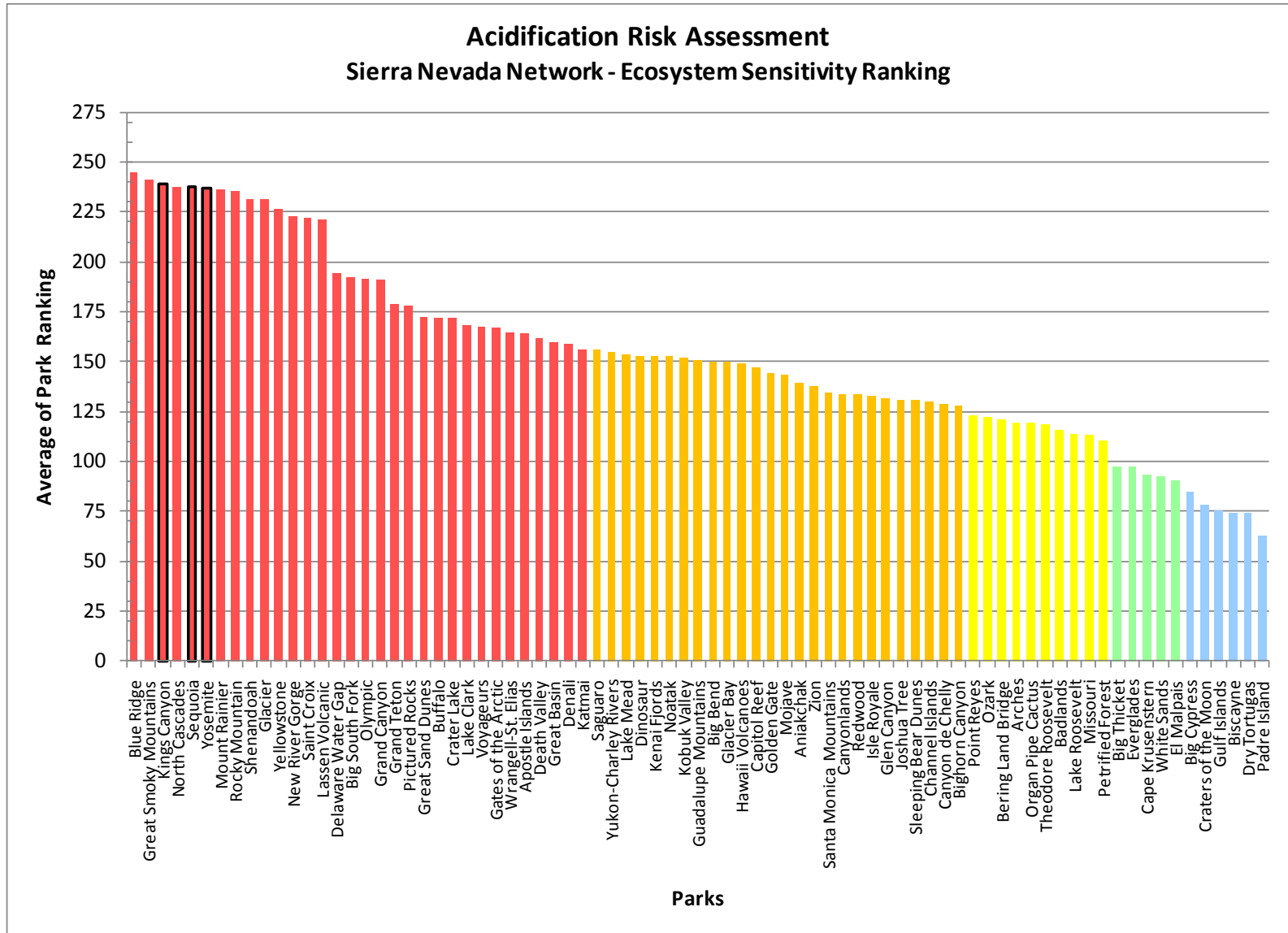


Figure F

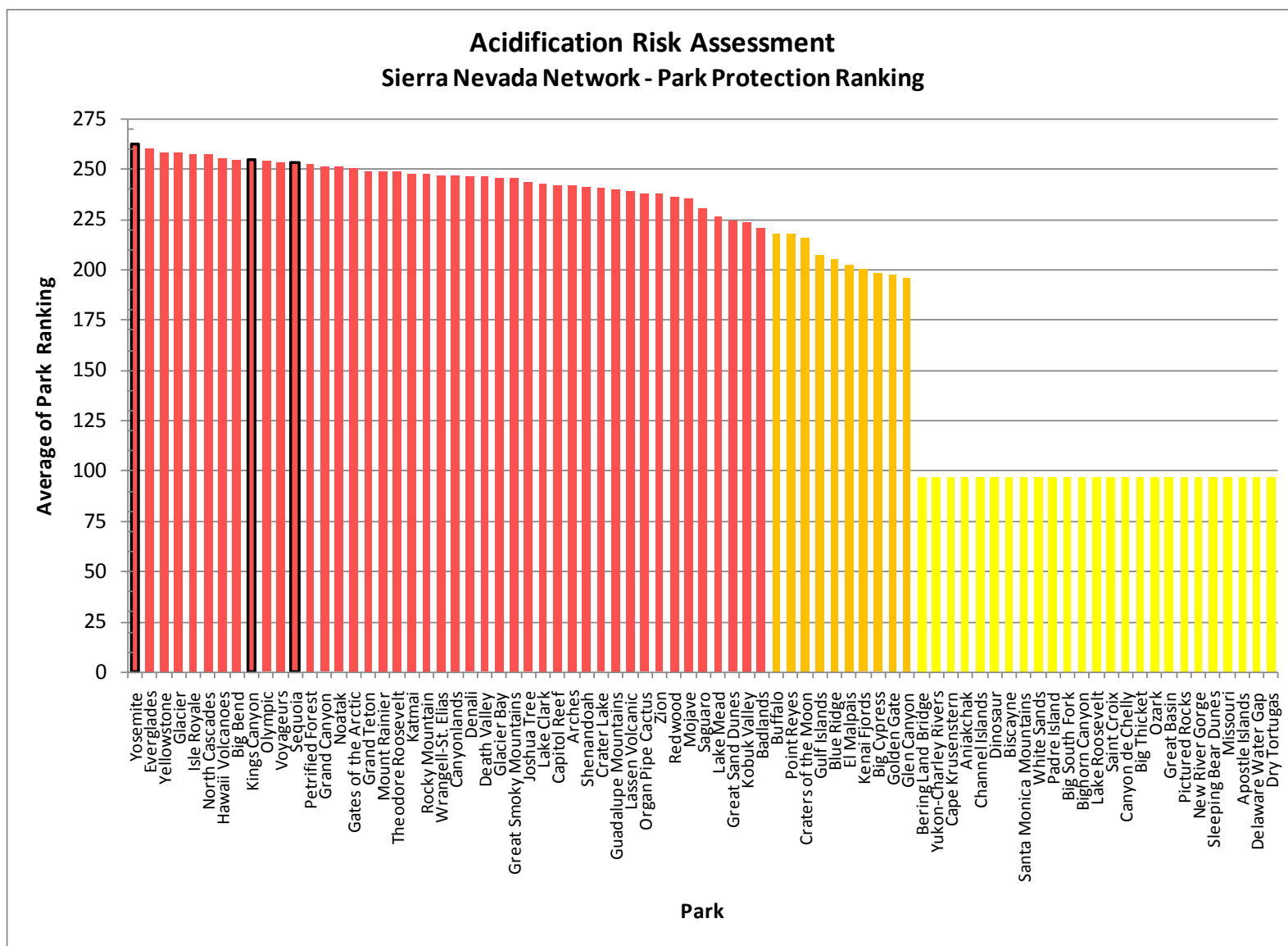


Figure G

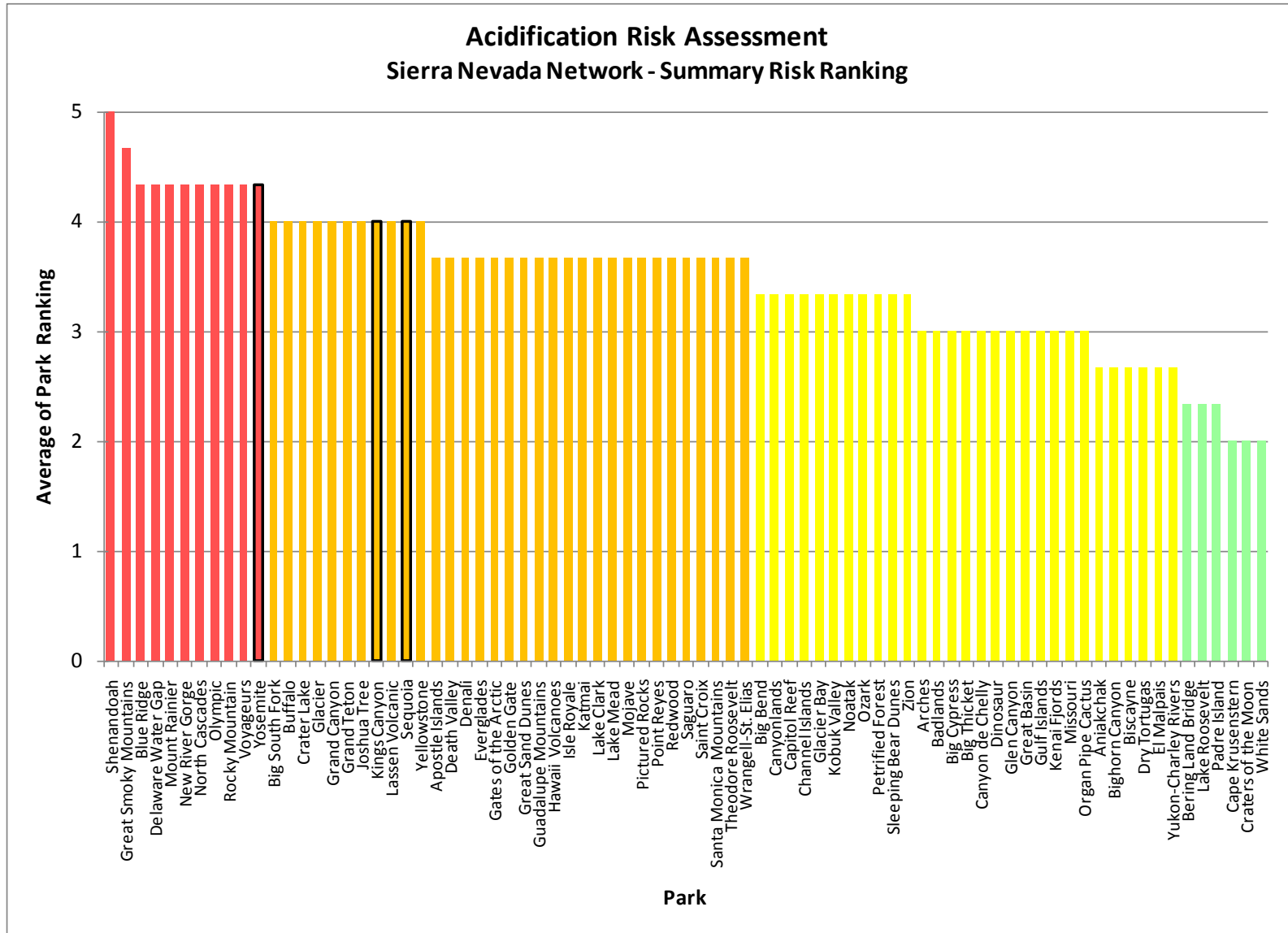


Figure H

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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U.S. Department of the Interior



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