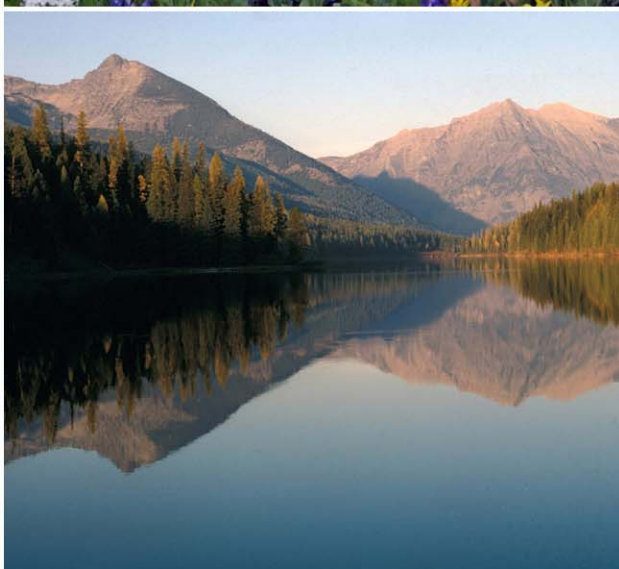




Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition

Rocky Mountain Network (ROMN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/324



ON THE COVER

Some ecosystems, such as arid shrublands, subalpine meadows, remote high elevation lakes, and wetlands, are sensitive to the effects of nutrient enrichment from atmospheric nitrogen 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.

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Rocky Mountain Network (ROMN)

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

There are three parks in the Rocky Mountain Network that are larger than 100 square miles: Glacier (GLAC), Great Sand Dunes (GRSA), and Rocky Mountain (ROMO). In addition, there are three smaller parks.

Total annual N emissions, by county, are shown in Map C for lands in and surrounding the Rocky Mountain Network. County-level emissions within the network ranged from less than 1 ton per square mile to 5 to 20 tons per square mile. Limited smaller areas had higher emissions than that. In general, annual county N emissions were less than 5 tons per square mile throughout most of the network. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N are shown in Map D. There are several relatively large (larger than about 2,000 tons per year) sources of oxidized N within and near the network, especially in the southern half of the network. Urban centers within the network and within a 300 mile buffer around the network are shown in Map E. Human population centers are sparse, except along the eastern edge of the Colorado Front Range. ROMO is located in close proximity to several population centers. GLAC and GRSA are not.

Total N deposition in and around the network is shown in Map F. Included in this analysis are both wet and dry forms of N deposition and both the oxidized and reduced N species. Total N deposition within the network ranged from as low as 2 to 5 kg N/ha/yr to as high as 5 to 10 kg N/ha/yr. Throughout most of the network, estimated total N deposition was in the range of 2 to 5 kg N/ha/yr.

Land cover in and around the network is shown in Map G. The predominant cover types within this network are generally highly mixed. Much of the network is covered with shrubland and grassland/herbaceous vegetation. Forests predominate in the northwest and southwest. Row crops are also common in some areas.

Map H shows the distribution within the larger (larger than 100 square miles) parks that occur in this network of the five vegetation types thought to be most responsive to nutrient N enrichment effects (arctic, alpine, grassland and meadow, wetland, and arid and semi-arid). In general, the predominant sensitive vegetation types within these parks are alpine, wetland, and grassland and meadow; arid and semi-arid vegetation types are also fairly common.

Park lands requiring special protection against potential adverse impacts associated with nutrient N enrichment from atmospheric N deposition are shown in Map I. Also shown on Map I are all federal lands designated as wilderness, both lands managed by NPS and also lands managed by other federal agencies. The land designations used to identify this heightened protection included Class I designation under the CAAA and wilderness designation. The three largest parks in this network are all Class I. There is also considerable wilderness area within the network, outside NPS jurisdiction.

Park-specific maps are shown for the two largest parks in this network (GLAC and ROMO) in Maps J-1 through J-4. Alpine lands are widely distributed throughout both parks. The sensitive vegetation types wetlands and to a lesser extent grassland and meadow are common in GLAC. Grassland and meadow and arid and semi-arid lands are both common in ROMO.

High-elevation lakes within GLAC and ROMO, which might be more prone than lakes at lower elevation to N-limitation, and therefore potentially more susceptible to eutrophication in response to atmospheric N input, are shown in Maps J-3 and J-4. Both parks have many high-elevation lakes.

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 Rocky Mountain Network ranks in the second lowest quintile, among networks, in N Pollutant Exposure (Figure A). Nitrogen emissions and N deposition within the network are both relatively low. However, the network Ecosystem Sensitivity ranking is in the second highest quintile among networks (Figure B). This is because there are many high-elevation lakes in some of the parks that occur in this network, and some vegetation types in the parks in this network are among those expected to be especially sensitive to nutrient enrichment effects from N deposition. ROMO has 102 high elevation lakes; GLAC has 9; and GRSA has 5. This network also ranks in the second 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 yield an overall Network Risk ranking that is in the bottom of the highest quintile among all networks (Figure D). This is despite the relatively low levels of N emissions and deposition. The overall level of concern for nutrient N enrichment effects on I&M parks within this network is considered High.

Similarly, park rankings are given in Figures E through H for the same metrics. 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 B. 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.

All parks in this network are ranked in the lowest quintile (including GRSA) to the middle quintile (including ROMO) for Pollutant Exposure. In contrast, all parks in the network except Florissant Fossil Beds (FLFO) are ranked either in the highest quintile (including GRSA and ROMO) or second highest quintile (including GLAC) for Ecosystem Sensitivity. ROMO, GLAC, and GRSA all contain high elevation lakes. Park Protection rankings are variable by park size. The three large parks (GLAC, GRSA, ROMO) are all ranked in the highest quintile for this theme, whereas the smaller parks are all ranked in the middle quintile.

Table A. Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and Summary Risk from atmospheric nutrient N enrichment.

I&M Parks ² in Network	Relative Ranking of Individual Parks ¹			
	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Florissant Fossil Beds	Moderate	Moderate	Moderate	Very Low
Glacier	Low	High	Very High	Very High
Grant-Kohrs Ranch	Very Low	High	Moderate	Very Low
Great Sand Dunes	Very Low	Very High	Very High	Very High
Little Bighorn Battlefield	Very Low	Very High	Moderate	Low
Rocky Mountain	Moderate	Very High	Very High	Very High

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).

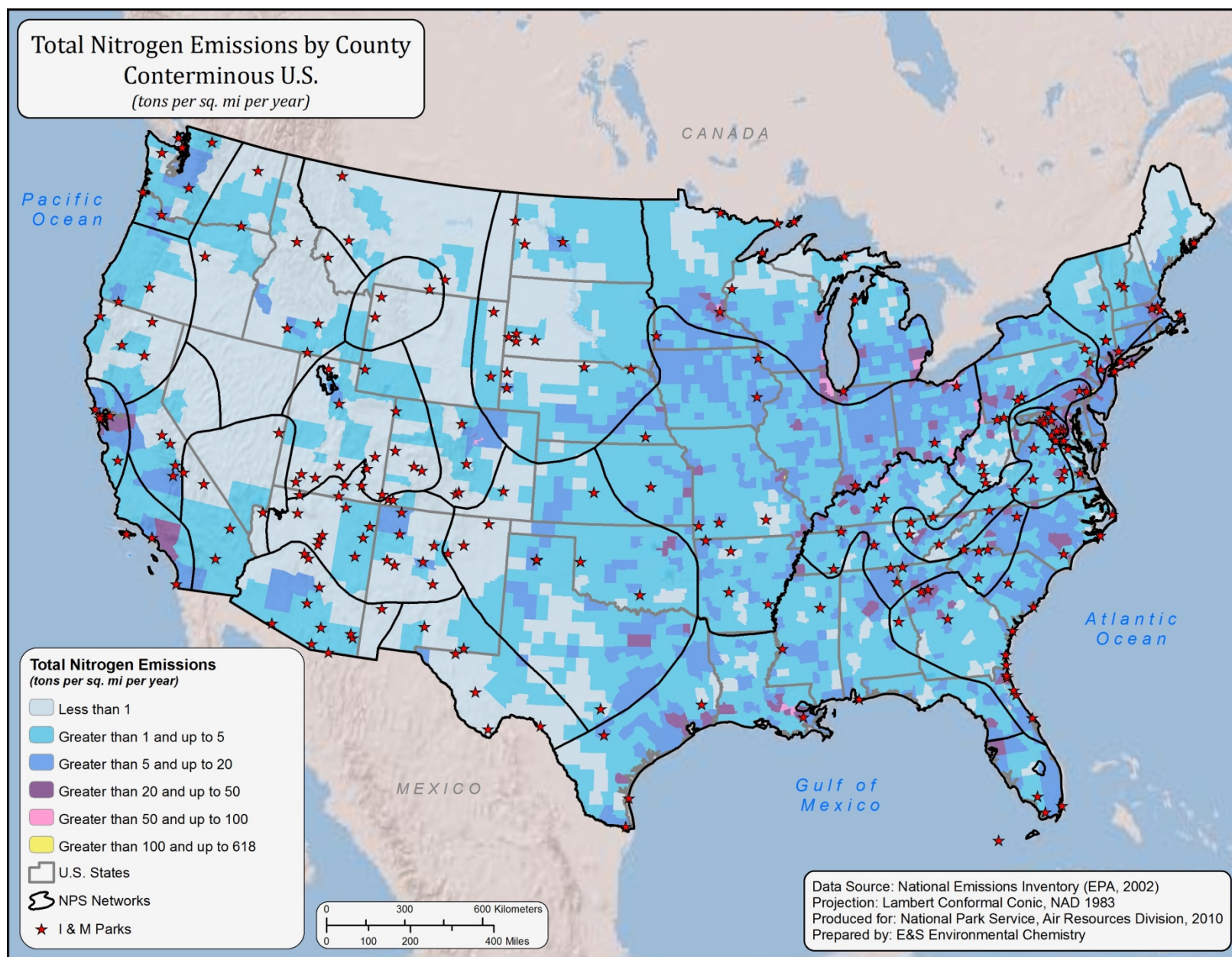
² Park name is printed in bold italic for parks larger than 100 square miles.

The Summary Risk ranking also varied by park size. The three large parks are all ranked in the highest quintile, showing Very High risk of nutrient N enrichment. The three smaller parks are all ranked in the lowest or second lowest quintile, showing Very Low or Low Summary Risk.

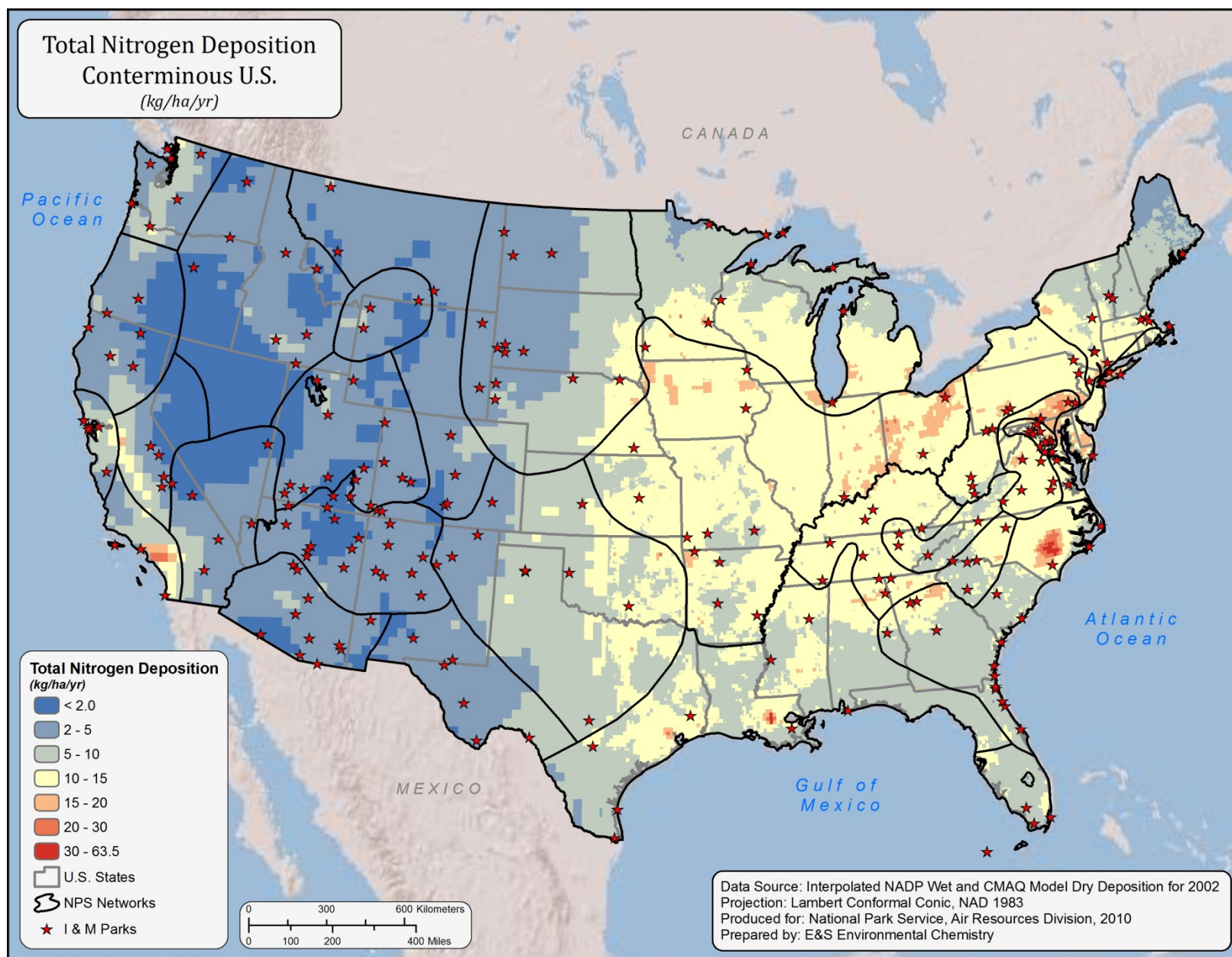
- Map A. National map of total N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) forms of N are included. The total is expressed in tons per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map B. 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 C. 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 D. 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 E. 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 F. 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: CMAQ Model wet and dry deposition data for 2002; see information for Map B above for details)
- Map G. 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 H. Distribution within the larger parks that occur in this network of the five terrestrial vegetation types thought to be most sensitive to N-nutrient enrichment effects: arctic, alpine, meadow, wetland, and arid and semi-arid. (Source of data: See Appendix A)
- Map I. 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 J-1. Park-specific map: sensitive vegetation types in GLAC. (Source of data: See Appendix A)
- Map J-2. Park-specific map: sensitive vegetation types in ROMO. (Source of data: See Appendix A)
- Map J-3. Park-specific map: high-elevation lakes in GLAC. (Source of data: U.S. EPA National Elevation Dataset and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map J-4. Park-specific map: high-elevation lakes in ROMO. (Source of data: U.S. EPA National Elevation Dataset and 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.

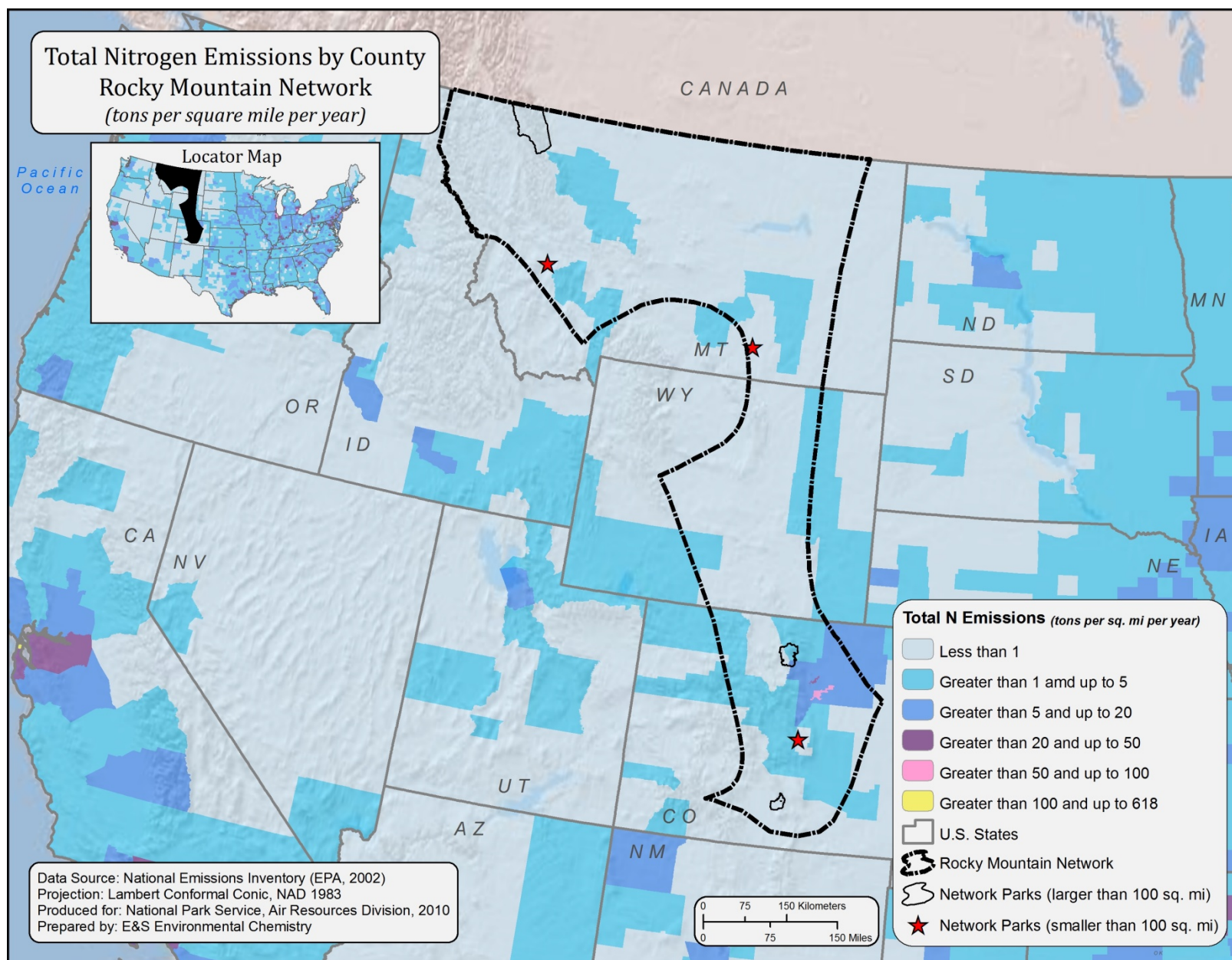
- Figure C. Network rankings for Park Protection, calculated as the average of scores for all Park Protection variables.
- Figure D. Network Summary Risk ranking, calculated as the sum of the averages of the scores for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection.
- Figure E. Park rankings 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 scores for all Summary Risk variables.



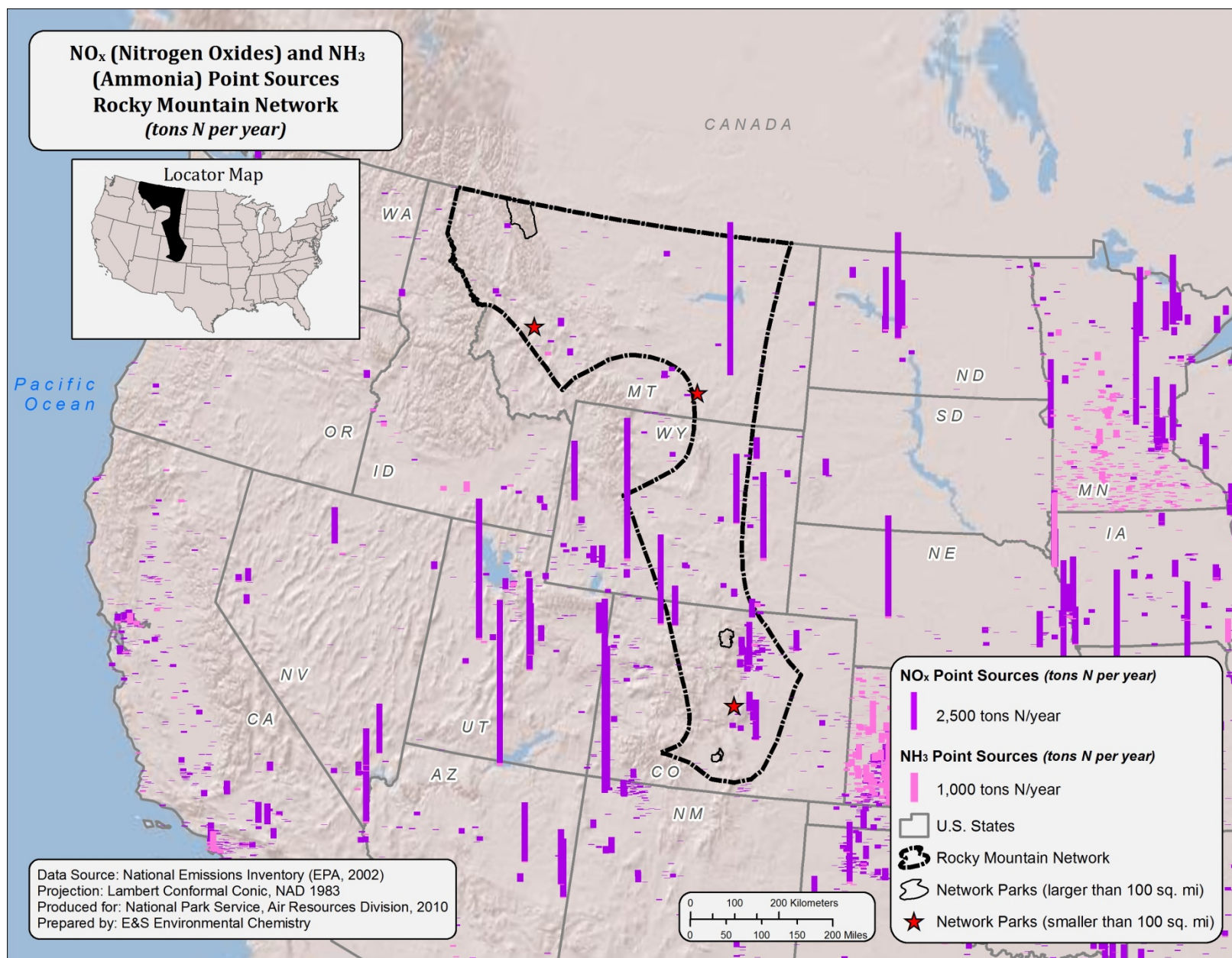
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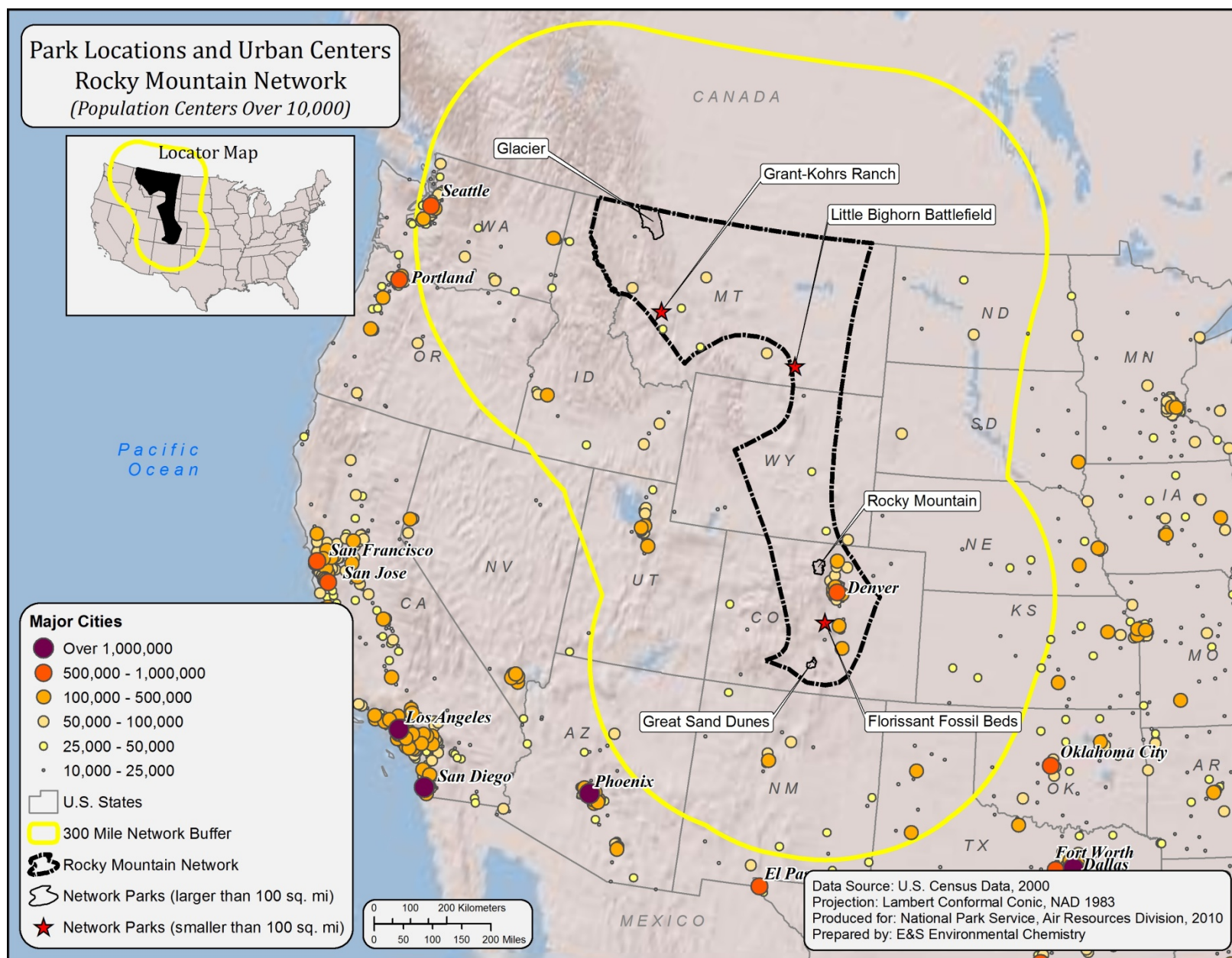
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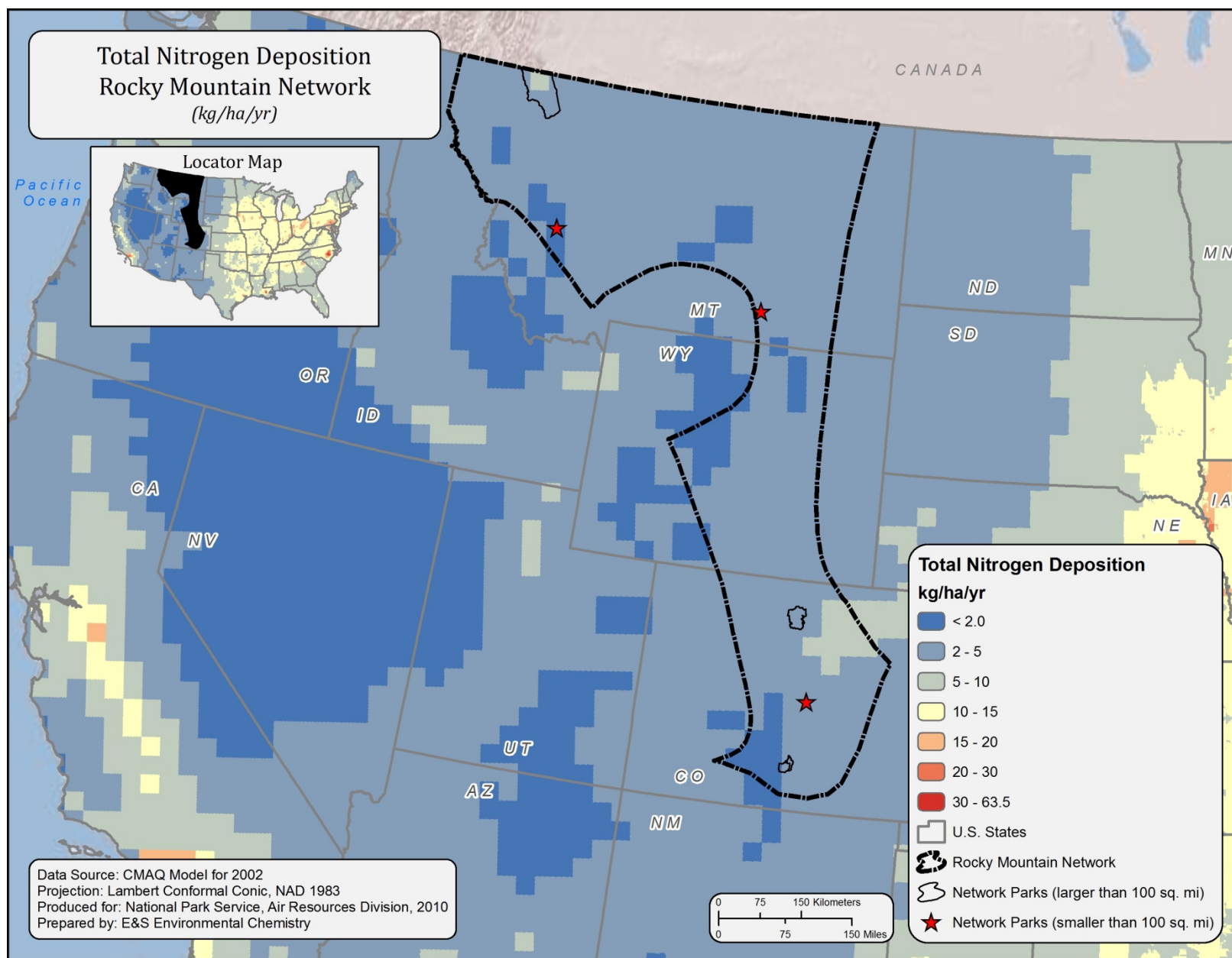
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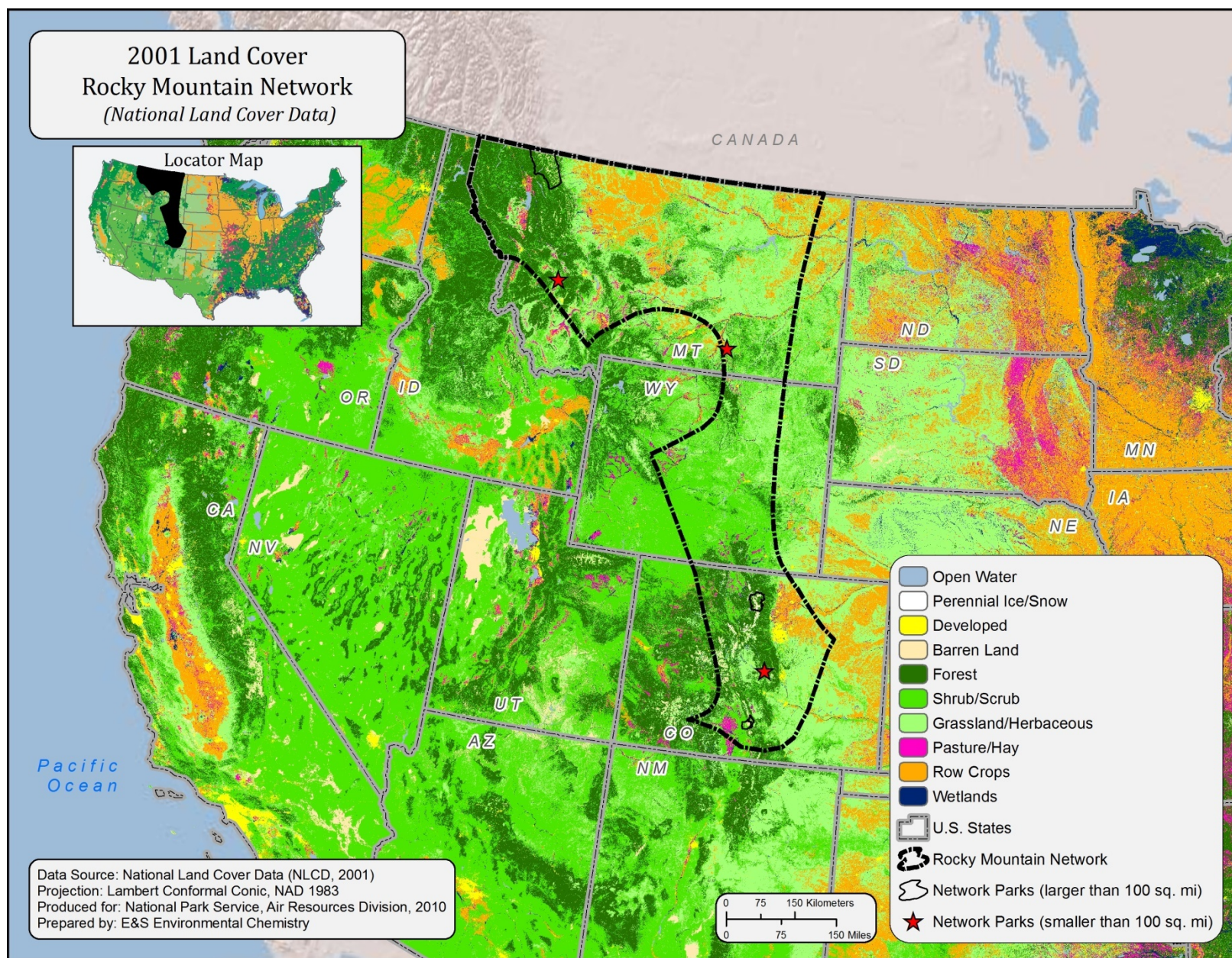
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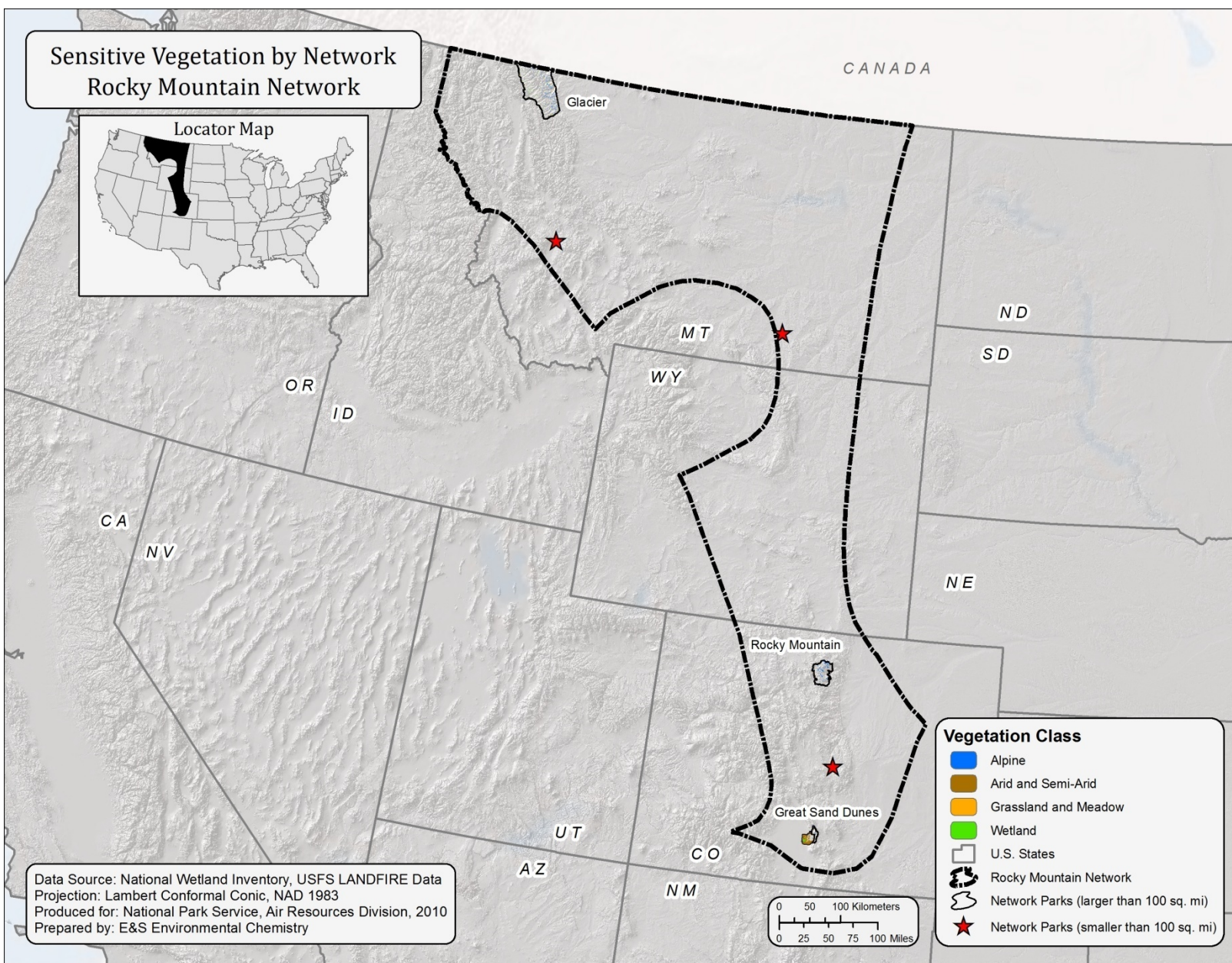
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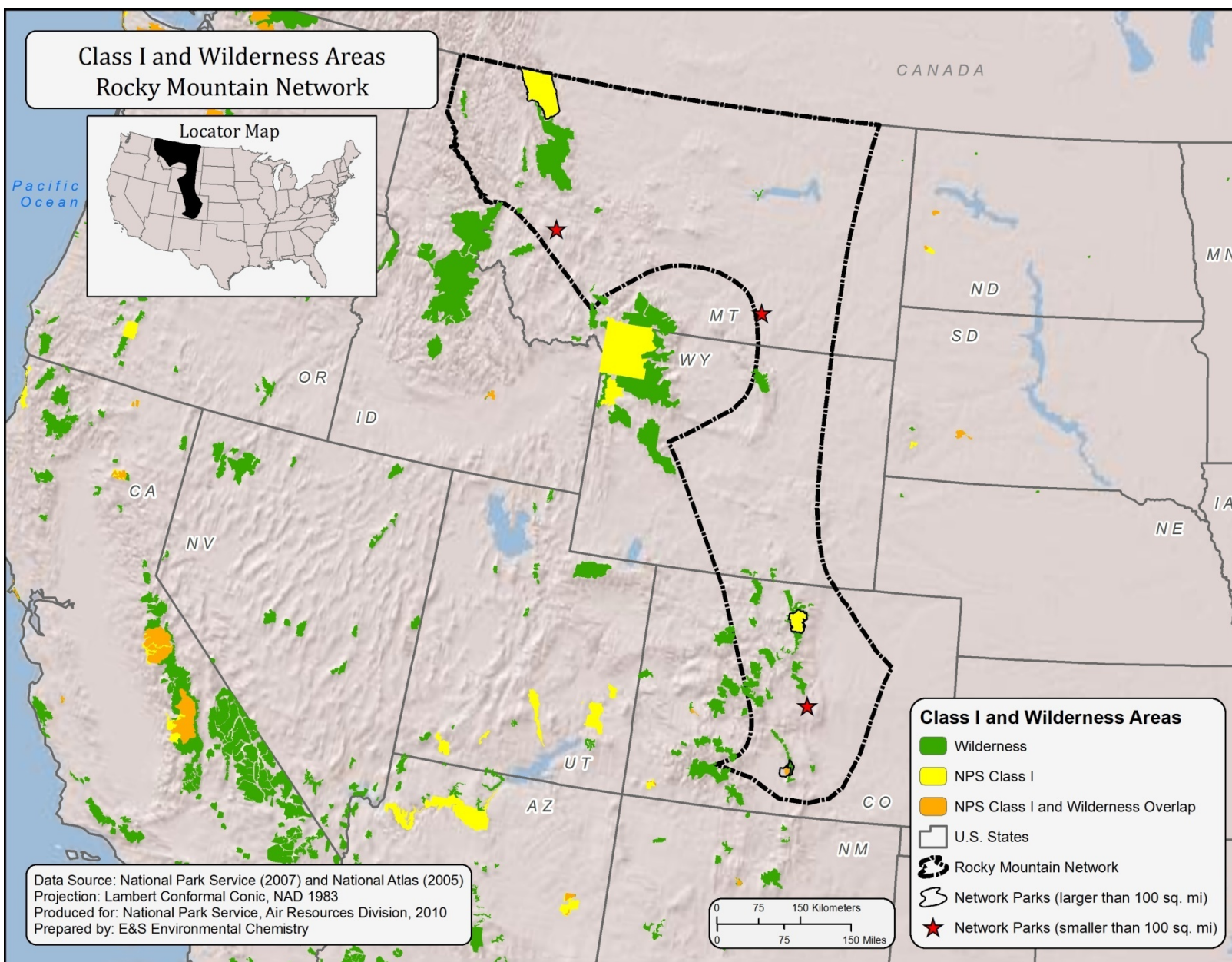
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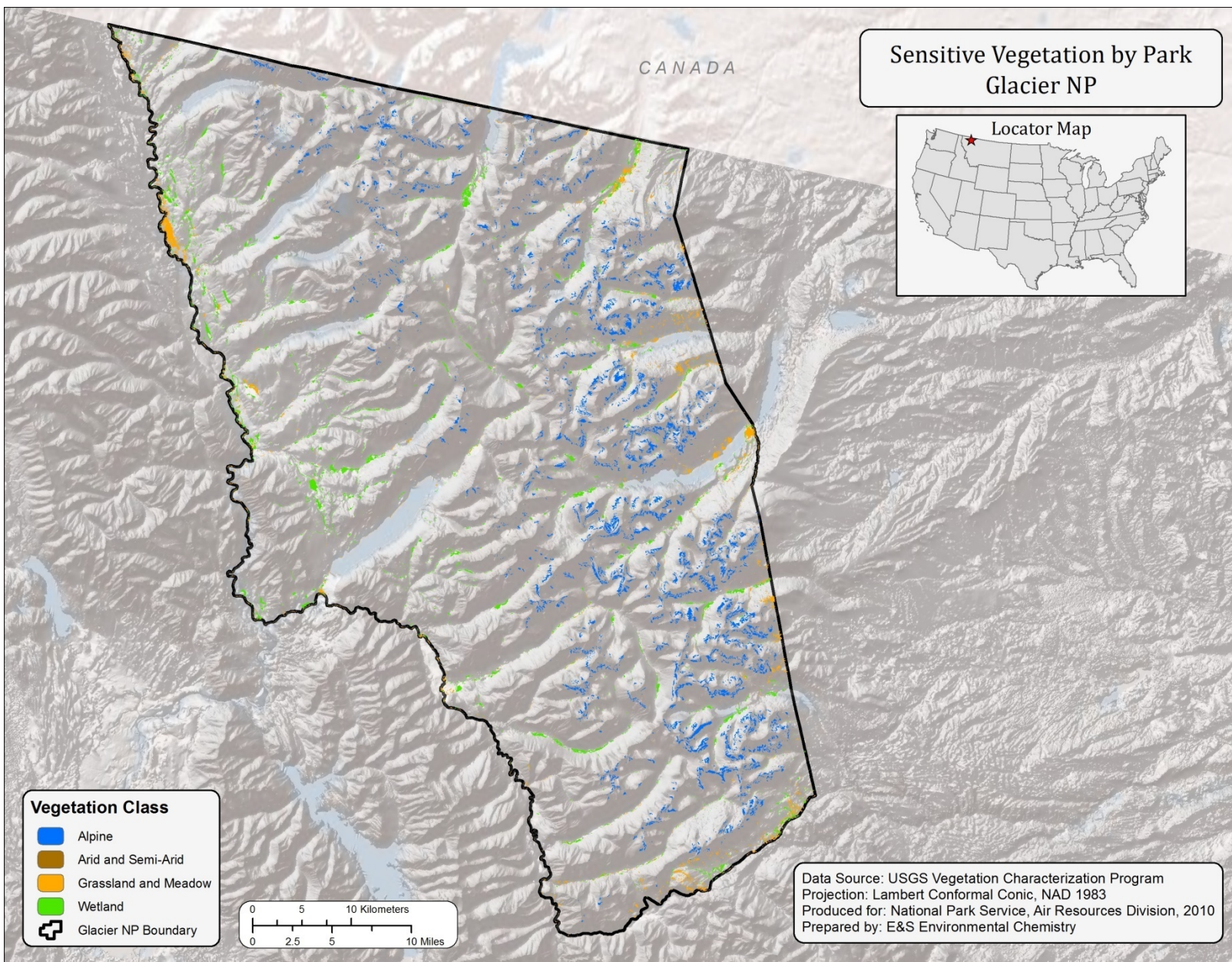
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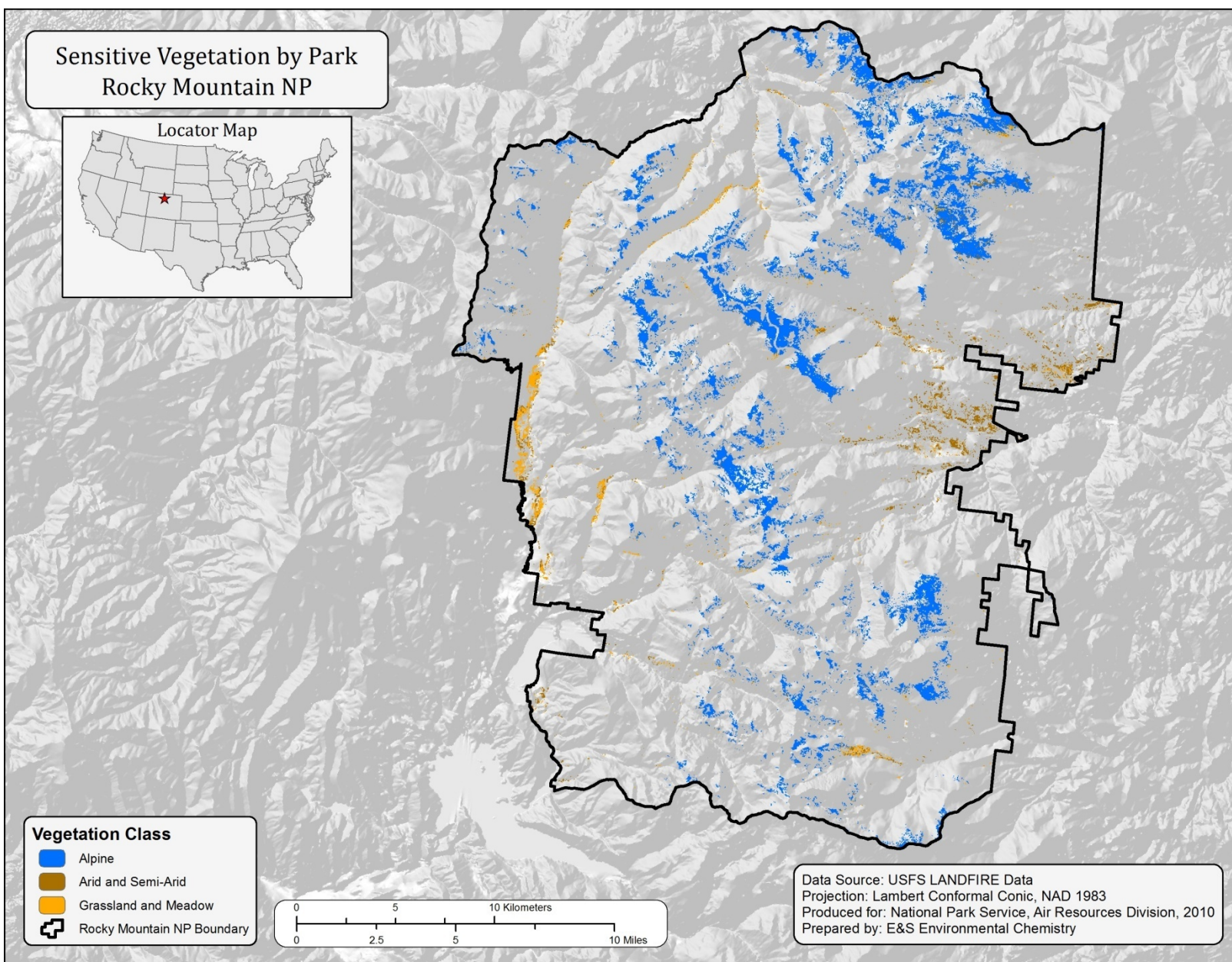
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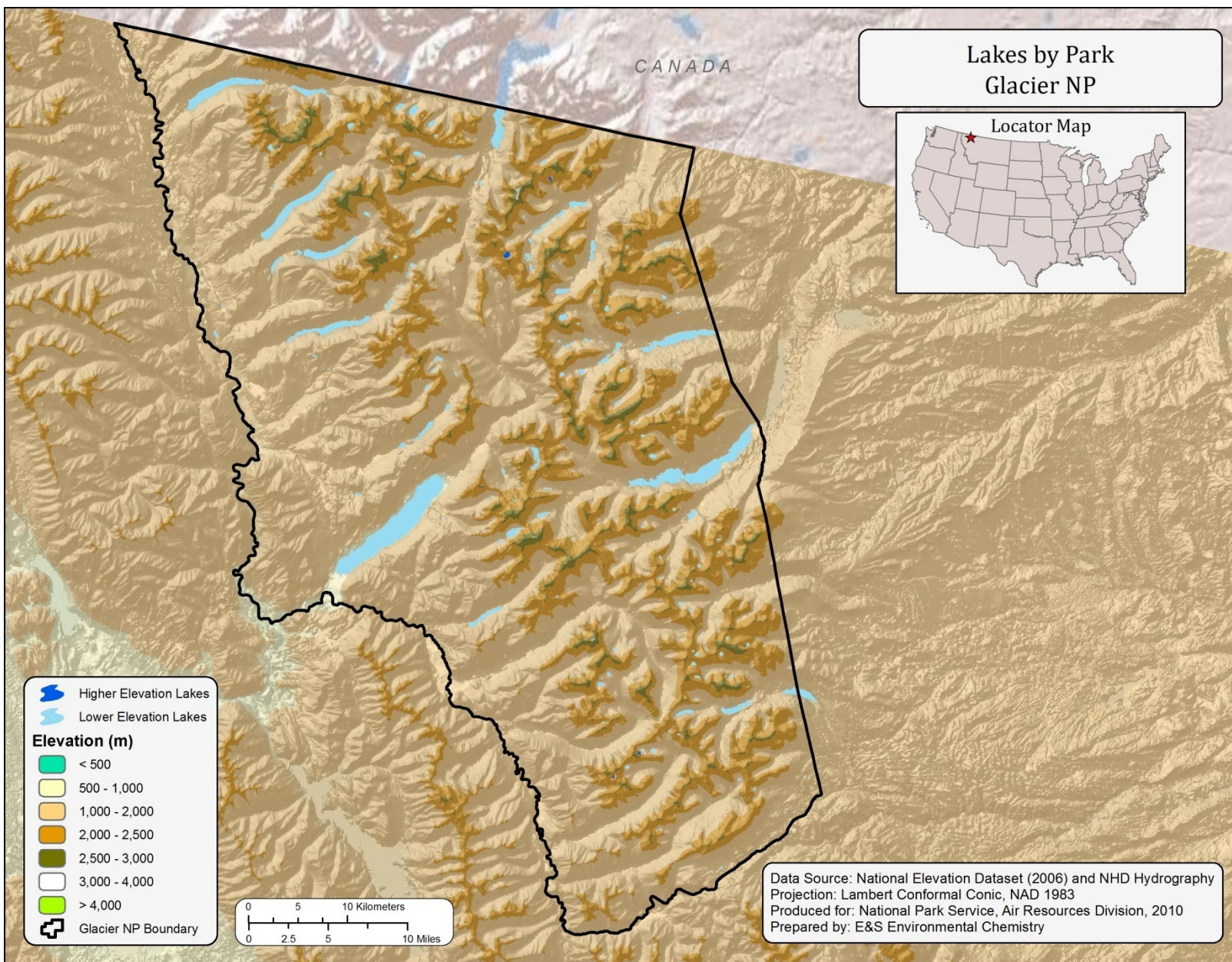
Map I



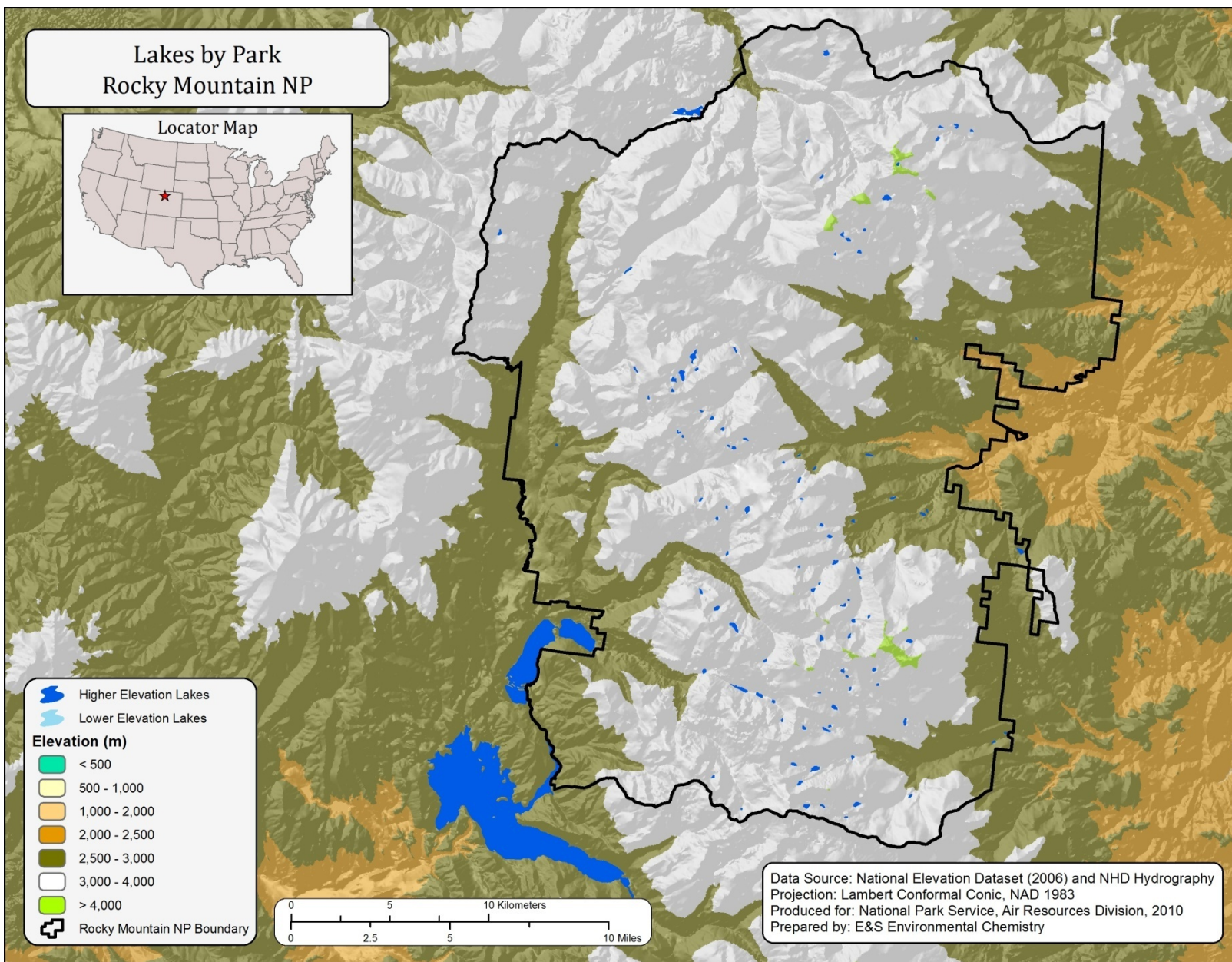
Map J-1



Map J-2



Map J-3



Map J-4

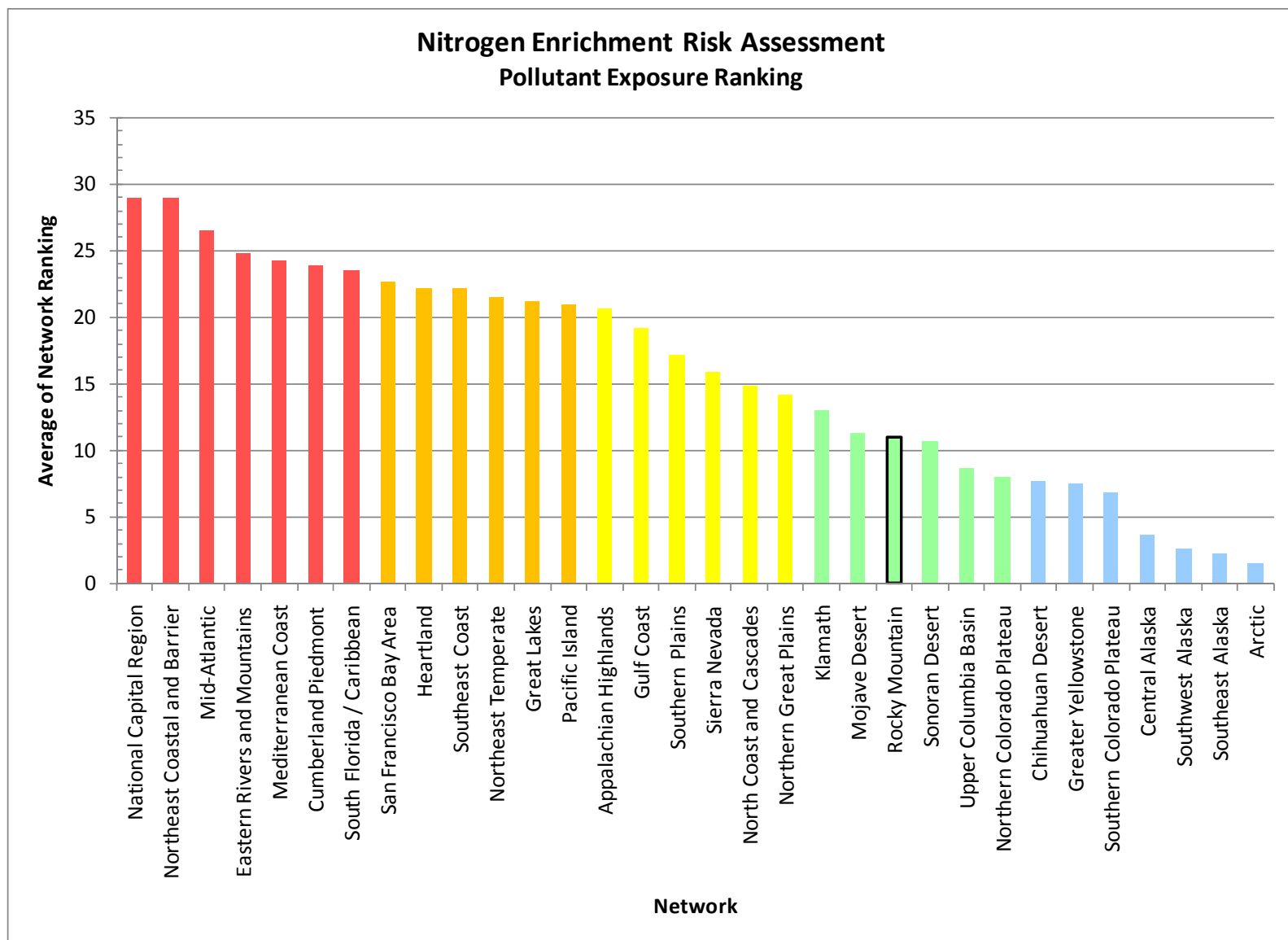


Figure A

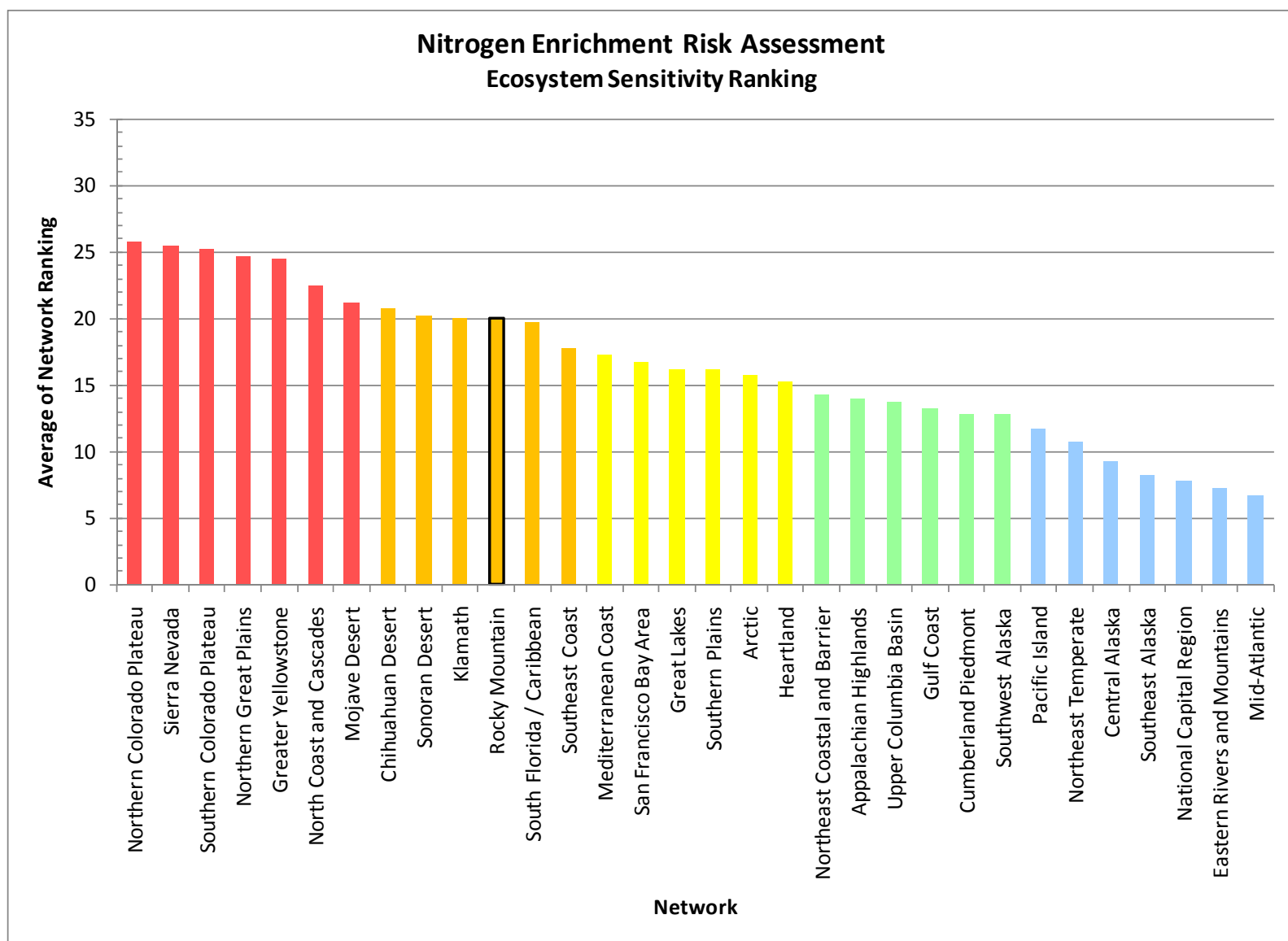


Figure B

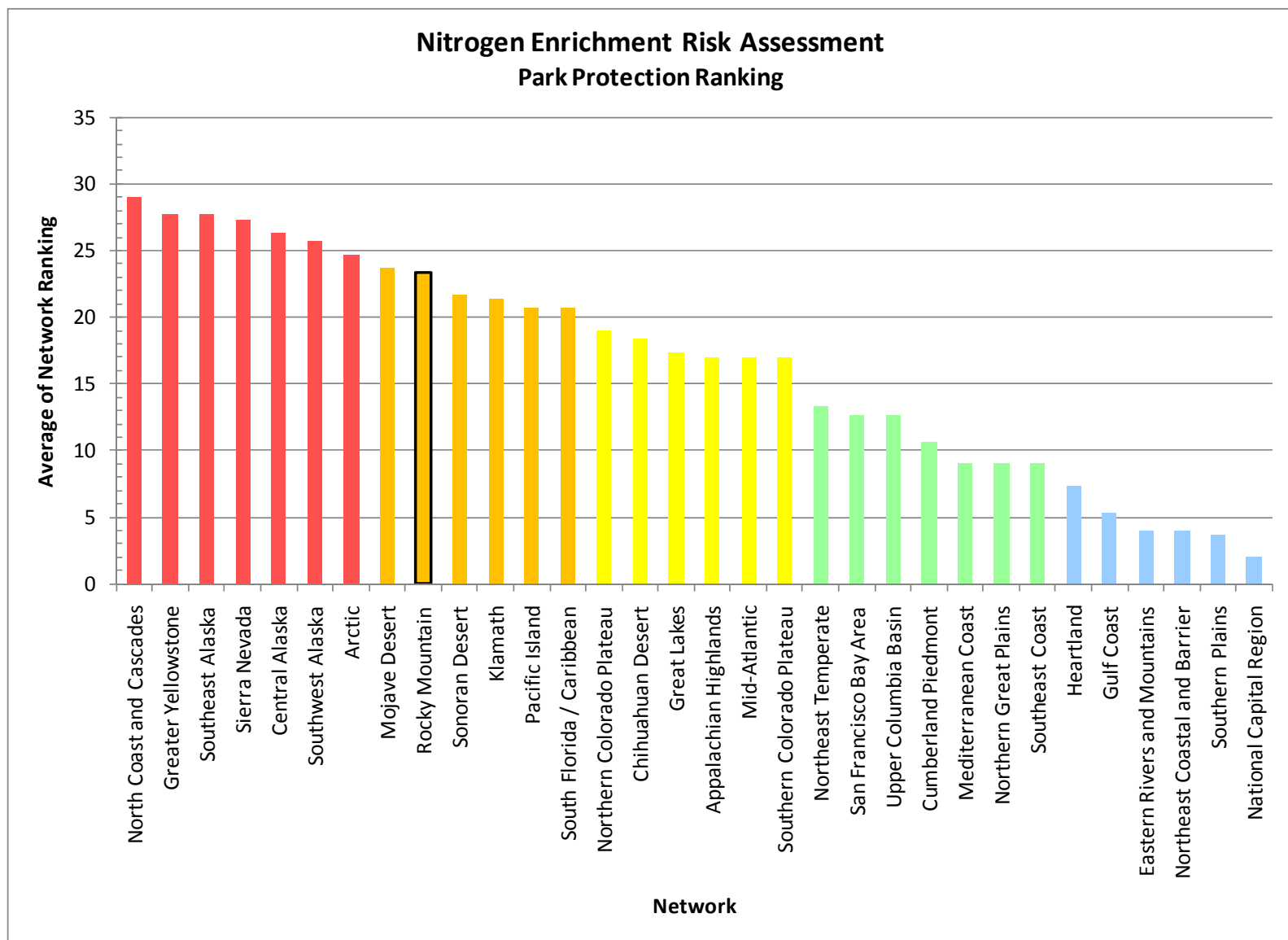


Figure C

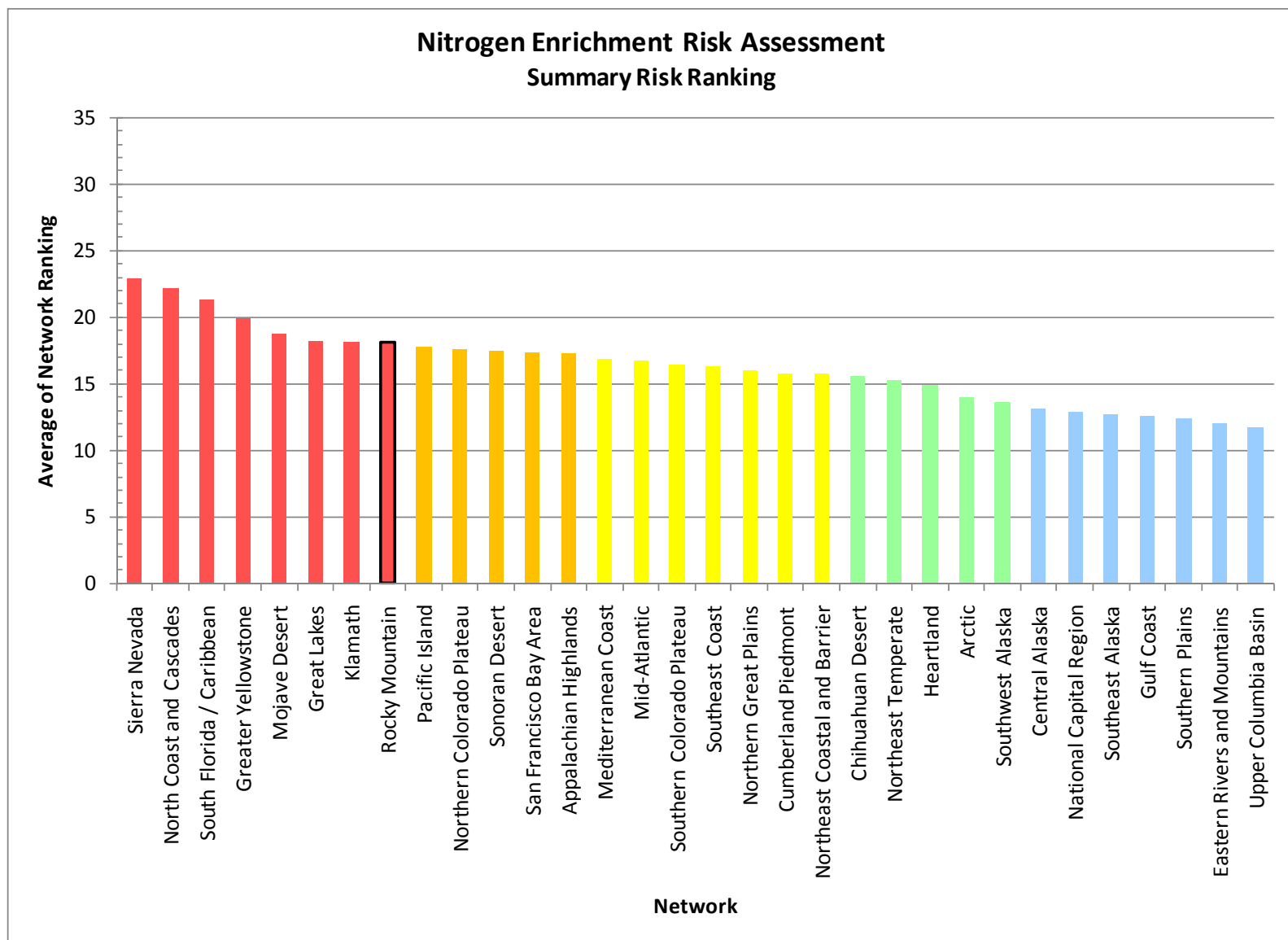


Figure D

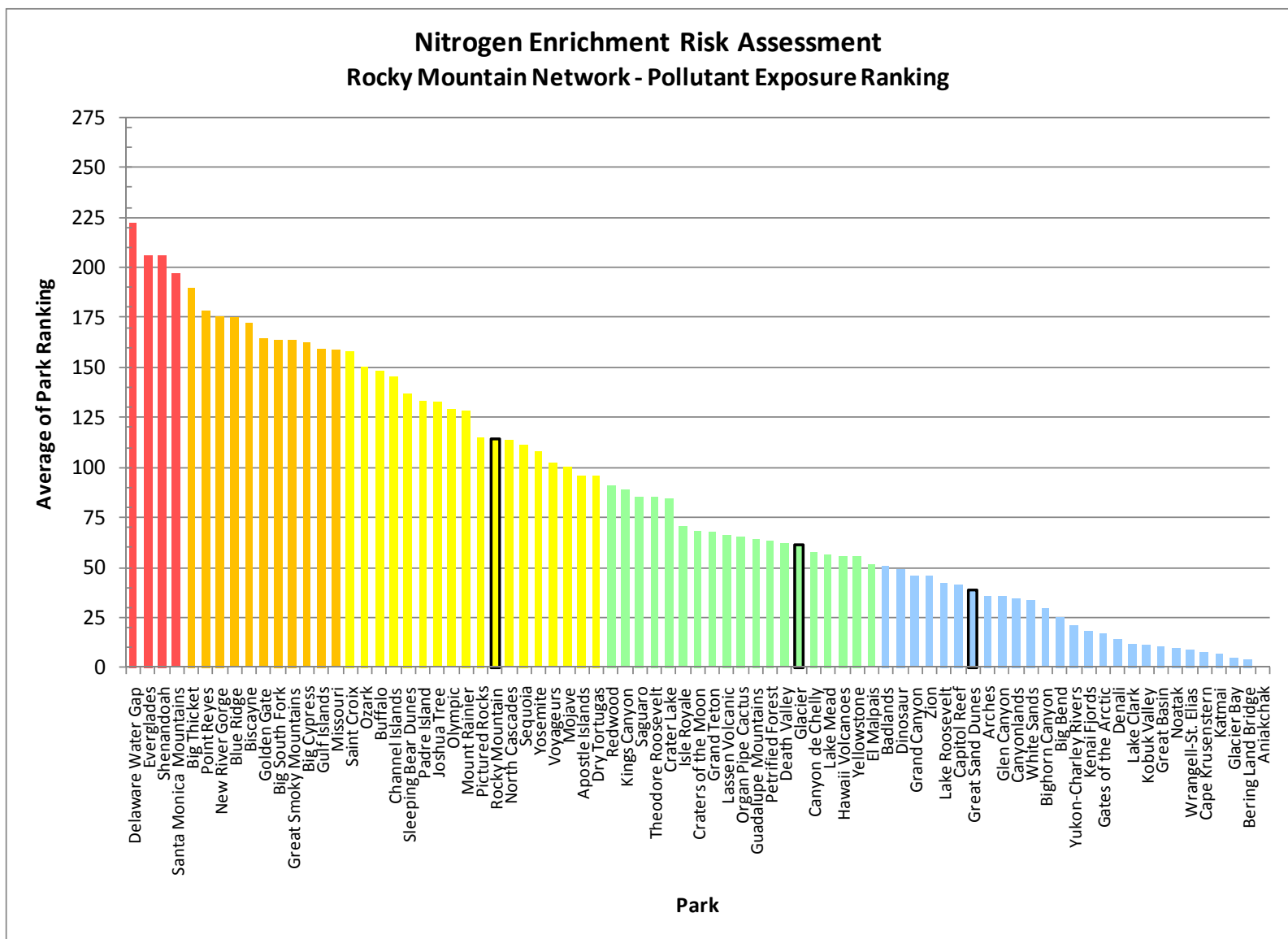


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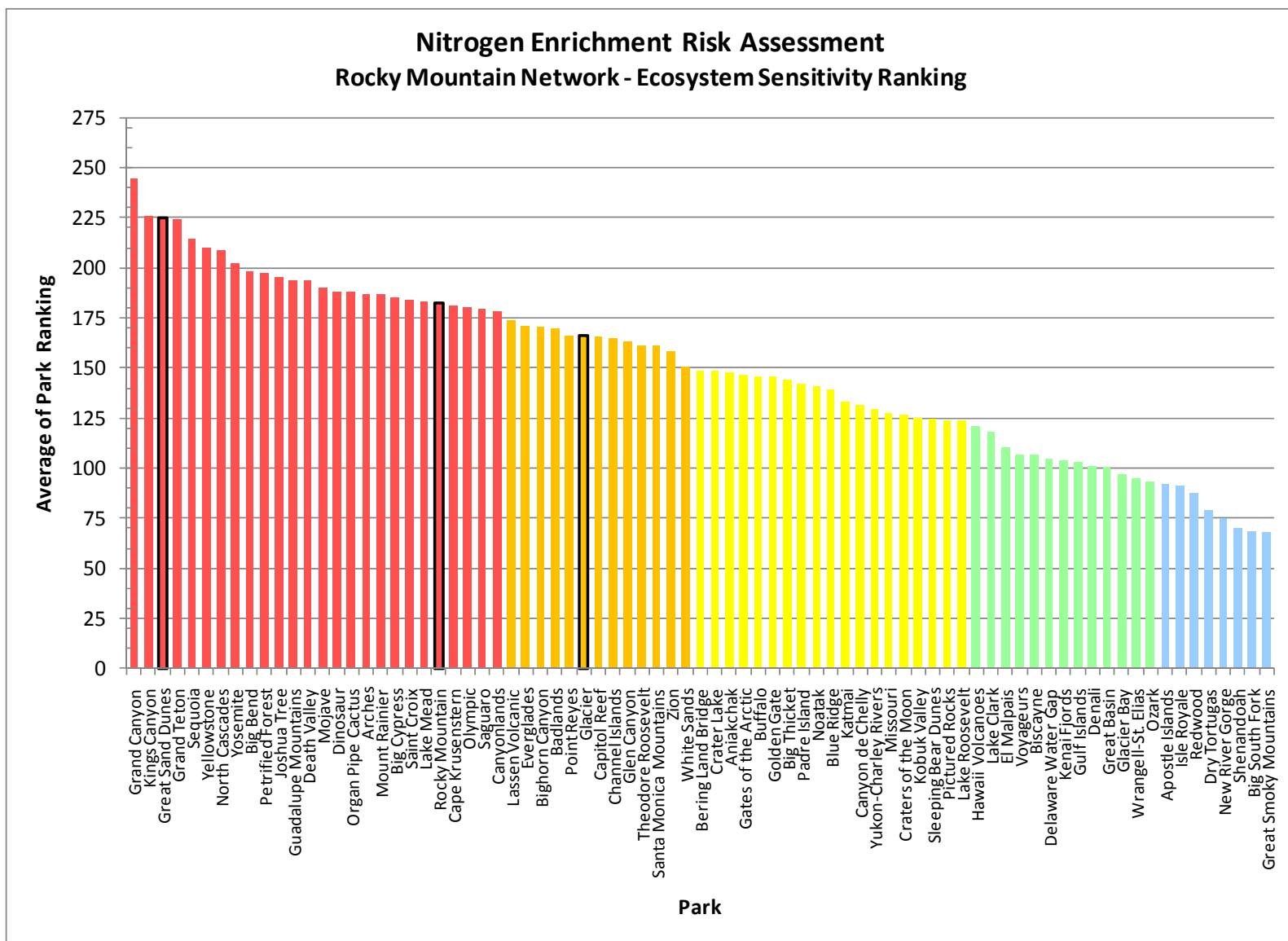


Figure F

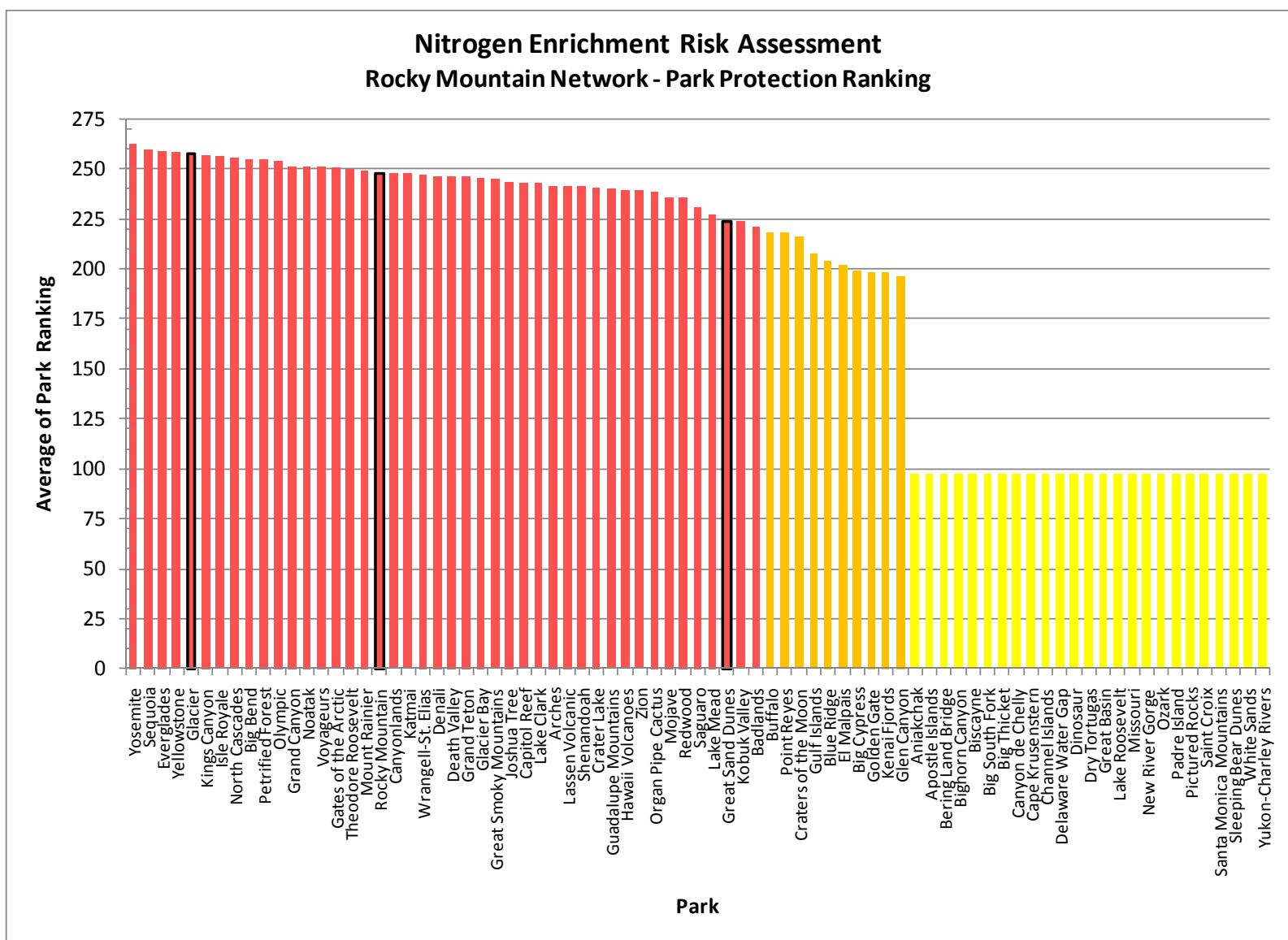


Figure G

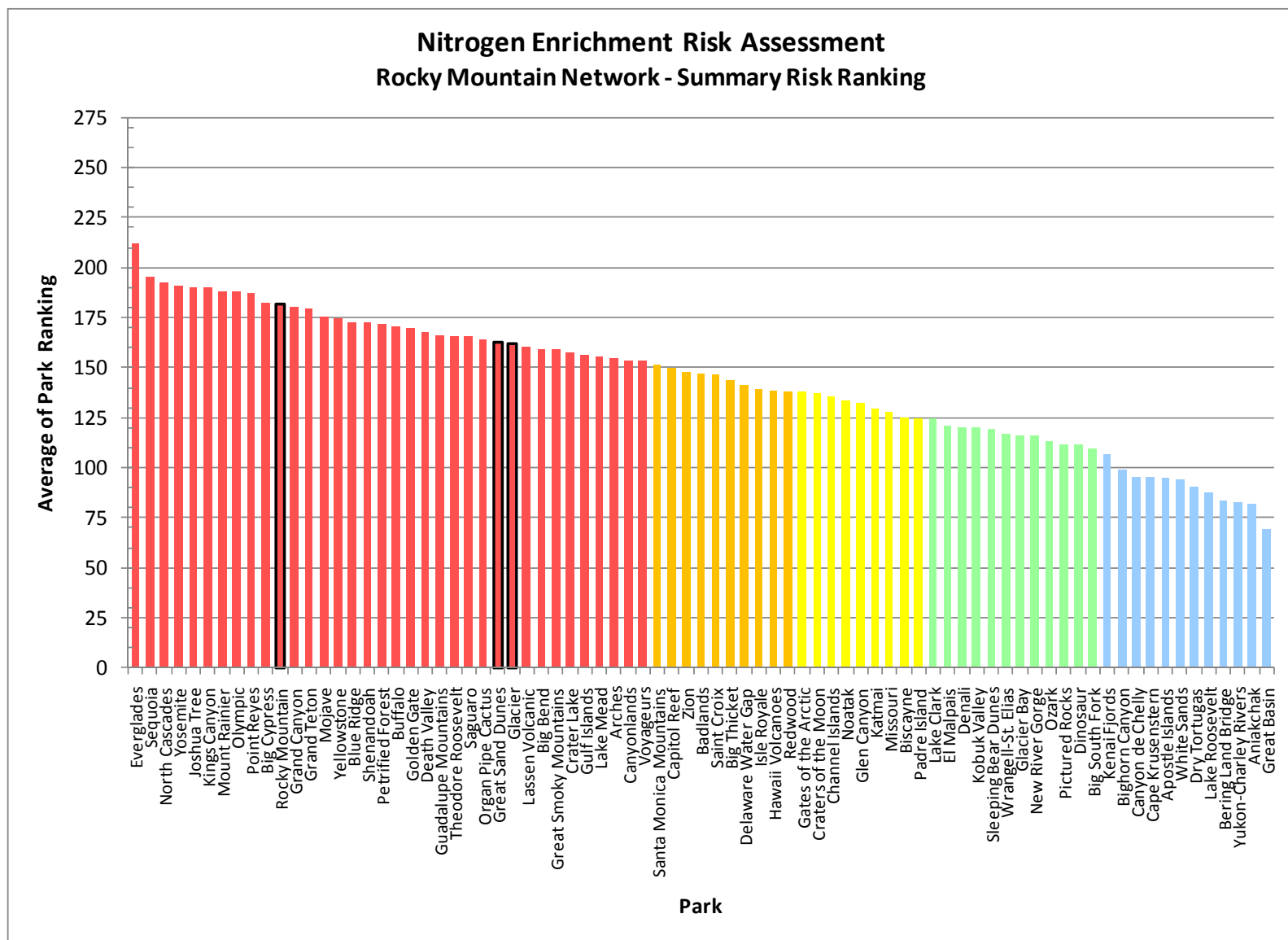


Figure H

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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