Wyoming Department of Environmental Quality-Air Quality Division 2015 Network Assessment

Wyoming Department of Environmental Quality – Air Quality Division

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Acronyms

AQD	Wyoming Department of Environmental Quality – Air Quality Division
AQS	EPA's Air Quality System database
ArcGIS	Geographic Information System used for mapping
BAM	Beta Attenuation Monitor
BLM	United States Department of the Interior-Bureau of Land Management
CASTNET	Clean Air Status and Trends Network
CFR	United States Code of Federal Regulations
CH_4	Methane
CO	Carbon Monoxide
EI	Emission Inventory
EJView	Environmental Justice Geographic Assessment Tool
EPA	United States Environmental Protection Agency
ESRI	Environmental Systems Research Institute
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory
IMPROVE	Interagency Monitoring of Protected Visual Environments
km	Kilometer
m	Meters
m/s	Meters per second
MDL	Method Detection Limit
METAR	Meteorological Aviation Reports
µSA	Micropolitan Statistical Area
MOVES	Motor Vehicle Emission Simulator
MSA	Metropolitan Statistical Area
$\mu g/m^3$	Micrograms per cubic meter
NAAQS	National Ambient Air Quality Standards
NCore	National Core Multi-Pollutant Monitoring Station
NEI	EPA's National Emissions Inventory
NEPA	National Environmental Policy Act
NMHC	Non-Methane Hydrocarbons
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NPS	United States Department of the Interior-National Park Service
NSR	AQD's New Source Review permitting program
O_3	Ozone
OAQPS	EPA's Office of Air Quality Planning and Standards
OMB	Office of Management and Budget
PM_{10}	Particulate Matter less than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	Particulate Matter less than 2.5 micrometers in aerodynamic diameter
POC	Parameter Occurrence Code
ppb	Parts per billion
ppm	Parts per million
PQAO	Primary Quality Assurance Organization
PRB	Powder River Basin
RAWS	Remote Automatic Weather Stations

SLAMS	State and Local Air Monitoring Station(s)
SO_2	Sulfur Dioxide
SPM	Special Purpose Monitor(s)
SPRB	Southern Powder River Basin (Portions of Campbell, Converse, Johnson, and Natrona Counties)
STI	Sonoma Technology, Inc.
TEOM	Tapered Element Oscillating Microbalance
THC	Total Hydrocarbons (Methane + Non-Methane Hydrocarbons)
TSD	Technical Support Document
UGRB	Upper Green River Basin (Portions of Lincoln and Sweetwater Counties and all of Sublette County)
UV	Ultraviolet
VOCs	Volatile Organic Compounds
WAAQS	Wyoming Ambient Air Quality Standards
WARMS	BLM's Wyoming Air Resource Monitoring System
WRAP-FETS	Western Regional Air Partnership-Fire Emissions Tracking System
WyVisNet	The DEQ-AQD's monitoring website, http://www.wyvisnet.com

Executive Summary

The Wyoming Department of Environmental Quality-Air Quality Division has the responsibility to protect, conserve, and enhance the quality of Wyoming's air resource. The AQD helps ensure that the ambient air quality in Wyoming is maintained in accordance with the National Ambient Air Quality Standards. To achieve this goal, the AQD operates and maintains a network of ambient air quality monitors and requires industrial sources of air pollution to conduct source specific ambient air monitoring.

The AQD presents the 2015 Network Assessment as required every fifth year by the United States Environmental Protection Agency. A Network Assessment is a comprehensive review that uses multiple types of analyses and data sources to assist an air quality agency in determining: the current status of the monitoring network, where additional monitoring could be beneficial, and where monitoring could justifiably be removed. Before implementing any finding(s) of this Network Assessment, the AQD will need to evaluate resources and prioritize needs.

There are three general findings from the 2015 Network Assessment:

- There is a need to review and reconcile site objectives for each AQD monitoring station.
- The AQD needs to examine current monitoring at the Wind River Reservation.
- The AQD revisited 2010 Network Assessment findings.

The following findings suggest additional monitoring needs in Wyoming AQD's Network:

- There is a need for long-term monitoring in central Converse County.
- There is a need for monitoring in the city of Torrington.
- There is a need for monitoring in eastern Johnson County.
- There is a need for population-based monitoring in Laramie beyond what presently exists.
- There is a need for population-based monitoring in Sheridan beyond what presently exists.
- The AQD should conduct further analyses to determine the need for gaseous pollutant monitoring in all micropolitan statistical areas that have not already been studied.
- Carbon monoxide monitoring data would be beneficial in eastern Johnson County or central Converse County.
- The city of Buffalo has been identified as a potential location for population exposure and upwind background monitoring.

- The Moneta Divide is a region of planned oil and gas development identified as a potential location for AQD monitoring pending examination of current industrially-operated monitoring.

The findings where monitors could justifiably shut down in Wyoming AQD's Network:

- Murphy Ridge has shown consistent monitored concentrations and has not shown significant trends since monitoring operations began in 2007. Additionally, modeling background data needs have changed.
- The Farson Meteorological Station has successfully characterized meteorological conditions along the southeastern boundary of the Upper Green River Basin for four years.
- The instrument used to collect PM_{10} at Boulder has not recorded any exceedances since monitoring operations began in 2005. Due to the rising cost to maintain and repair the instrument, removal could be warranted.
- Similarly, other stations (Daniel South, Wamsutter, Murphy Ridge, and Campbell County) employ older instruments to measure PM_{10} requiring more site visits and maintenance. There is a need to conduct site specific evaluations, which would inform potential removal or replacement.
- Cheyenne has multiple monitoring stations that measure PM_{10} and $PM_{2.5}$. The data from both sites correlate well (>90%) with each other. The AQD will conduct more analyses regarding the possible removal of one of these sites, which would require federal approval.
- The monitoring station at Campbell County has data from multiple pollutants that correlates well with sites owned by the AQD and by industry. Further analyses are needed to determine if removal is warranted.
- The Wright Jr.-Sr. High School monitoring station has PM_{10} data that correlates well with multiple industrial monitors nearby. Further evaluation is warranted regarding potential removal.
- Data for the Moxa Arch has not shown any significant trends since operation started in 2010 and modeling needs have changed. Additionally, the O_3 data is highly correlated with other AQD stations in southwest Wyoming. Further analyses are needed to determine if removal is warranted.

1. Introduction

1.1 Network Assessment and Past Results

The United States Environmental Protection Agency (EPA) charges state, tribal, and local air monitoring agencies to perform a periodic network assessment of their monitoring network. Title 40, Part 58.10(d) of the Code of Federal Regulations (CFR) states:

"*...agency shall perform and submit to the EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in appendix D to this part, whether new sites are needed, whether existing sites are no longer needed and can be terminated, and whether new technologies are appropriate for incorporation into the ambient monitoring network.*"

A Network Assessment is required to be performed and submitted to the EPA every five (5) years. This Network Assessment must include detailed monitoring network information along with analyses to evaluate monitoring sites and their objectives. The overall objective of this Network Assessment is to determine the most efficient and effective network for monitoring criteria pollutants, precursors, and meteorology. This Network Assessment presents the Wyoming Department of Environmental Quality-Air Quality Division (AQD) with a unique opportunity to comprehensively examine the monitoring network under various circumstances and scenarios in order to responsibly manage the resources entrusted to the AQD. In addition to the management of the AQD's resources, the air monitoring agency is also mandated to consider individuals and with respiratory health challenges. In summary, the AQD must consider many factors when reviewing the monitoring network and in planning for future monitoring concerns.

In order to thoroughly evaluate Wyoming's ambient and meteorological monitoring network with respect to the AQD's monitoring site objectives for each monitoring station, the AQD used miscellaneous statistical, graphical, and geographic spatial analyses. The AQD used the EPA's "Ambient Air Monitoring Network Assessment Guidance" along with other tools and ideas presented by the EPA's Office of Air Quality Planning and Standards (OAQPS).[1]

Results of this Network Assessment will be used to guide future monitor placement, reconfiguration, and improvements in the Wyoming monitoring network. The AQD may also determine, based on supporting data evaluation, potential areas where the monitors are no longer meeting their objective and could be removed. Before implementing any finding(s) of this Network Assessment, the AQD will need to evaluate resources and prioritize needs.

[1] http://www.epa.gov/ttn/amtic/network-assessment.html

The Network Assessment was designed by the AQD to use tools that were applicable to Wyoming's unique nature with respect to population density, geographic area, complex topography, and concentration of industrial sources.

The EPA required state, tribal, and local air monitoring agencies to submit a Network Assessment of their respective monitoring network beginning in 2010. The AQD's conclusions from the 2010 Network Assessment were:

- Currently operating monitoring stations in the Wyoming Monitoring Network are meeting their intended objective(s).
- Currently operating monitoring stations in the Wyoming Monitoring Network are not redundant with each other.
- There is a need for population-based ozone monitoring in Pinedale, Casper, Rock Springs, and Gillette.
- There is a need for population-based monitoring for PM_{10} in Star Valley.
- Monitoring stations should be deployed to monitor impacts from the Hiawatha and LaBarge Gas Fields.
- A monitoring station in the Wyoming Range would assist in quantifying transport from the west.
- Meteorological monitoring is needed in Farson and the northern portion of the Wyoming Range.
- The AQD will consider using trace-level gaseous monitors when deploying future stations with NO_2 or SO_2.

Based on the results of the 2010 Network Assessment, the AQD implemented several changes in its ambient and meteorological monitoring network. First, the AQD purchased three (3) mobile stations all capable of monitoring gaseous pollutants (O_3, NO, NO_2, NO_x, CH_4, NMHC, THC, and, in some cases, SO_2) and meteorological parameters. The mobile stations are sited at a location typically for one (1) year; siting is determined by the monitoring objective chosen for that deployment. To implement the findings of the 2010 Network Assessment, mobile gaseous stations were operated in Gillette, Big Piney, and Rock Springs. The AQD also outfitted a mobile station with PM_{10}, $PM_{2.5}$, and meteorological equipment. This mobile station (referred to as the "BAM station") was used for population-based PM_{10} monitoring near Star Valley. Population-based O_3 monitoring was also addressed by adding a long-term gaseous station in Casper beginning in 2013. In 2011, the AQD started monitoring at the Hiawatha and LaBarge Gas Fields. The Hiawatha station started collection on May 2011. Due to the lack of available power, the Hiawatha station is the AQD's first monitoring station to solely use renewable power in the form of solar and wind energy. The AQD sited one of its new mobile stations to Big Piney in 2011 to investigate impacts from the LaBarge Gas Field. In 2013, the AQD replaced the mobile station with a long-term station at this location. The AQD established a long-term station at Wyoming Range from 2011-2013 in order to determine the extent of regional pollutant

transport and to collect meteorological data, in fulfillment of the Wyoming Range finding. Finally, a meteorological tower was placed at Farson in May 2011 to address the meteorological differences first noted in the 2008 Southwest Wyoming Network Assessment. These modifications illustrate the AQD's commitment to acting on the conclusions of the 2010 Network Assessment.

1.2 Wyoming Ambient Monitoring Responsibilities

As part of the 2015 Network Assessment, it is imperative to address the AQD's primary ambient monitoring responsibilities. The first and utmost responsibility is determining and demonstrating compliance with the National Ambient Air Quality Standards (NAAQS). As of July 2015, the NAAQS, as defined by Table 1, are:

Pollutant	Primary/Secondary	Averaging Time	Level	Form
CO	primary	8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	
Lead	primary and secondary	Rolling 3-month average	0.15 µg/m^3	Not to be exceeded
NO_2	primary	1-hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	primary and secondary	Annual	53 ppb	Annual Mean
O_3	primary and secondary	8-hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
$PM_{2.5}$	primary	Annual	12 µg/m^3	annual mean, averaged over 3 years
	secondary	Annual	15 µg/m^3	annual mean, averaged over 3 years
	primary and secondary	24-hour	35 µg/m^3	98th percentile, averaged over 3 years
PM_{10}	primary and secondary	24-hour	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years
SO_2	primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Table 1. National Ambient Air Quality Standards

In addition to the NAAQS, the AQD has the statewide Wyoming Ambient Air Quality Standards (WAAQS). The WAAQS, as shown below in Table 2, use the same form as the NAAQS.

Pollutant	Averaging Time	Level
$PM_{2.5}$	24-hour	35 µg/m^3
	Annual Mean	15 µg/m^3
PM_{10}	24-hour	150 µg/m^3
	Annual Mean	50 µg/m^3
NO_2	1-hour	100 ppb
	Annual Mean	53 ppb
O_3	8-hour	75 ppb
SO_2	1-hour	75 ppb
CO	1-hour	35 ppm
	8-hour	9 ppm

Table 2. Wyoming Ambient Air Quality Standards

Repeated and persistent exceedances of the NAAQS that are not attributed to exceptional events (e.g., wildfires, high wind events, etc.) can develop into cities or regions being designated nonattainment. At the time of the 2010 Network Assessment, Wyoming had one nonattainment area, the city limits of Sheridan was classified as a moderate nonattainment area for annual PM_{10} designated on November 15, 1990. Since the 2010 Network Assessment, the EPA designated all of Sublette County and small portions of Lincoln and Sweetwater Counties, as a marginal nonattainment area for O_3 on July 20, 2012. Collectively, the three (3) county region is termed the Upper Green River Basin (UGRB) Ozone Nonattainment Area. Figure 1 below shows the two (2) nonattainment areas in Wyoming.

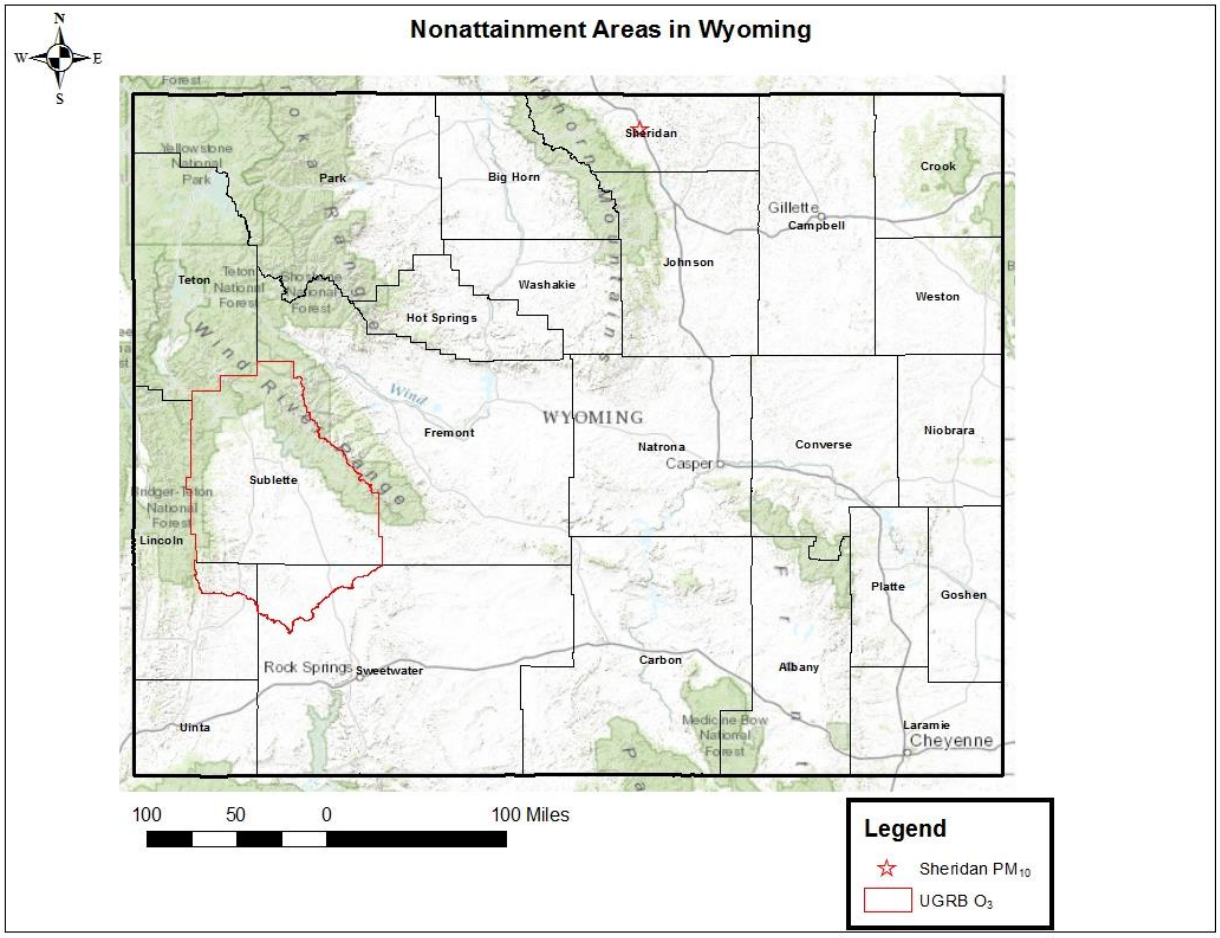

Figure 1. Nonattainment Areas in Wyoming

One objective of the AQD's monitoring network is population based monitoring. Since Wyoming is sparsely populated, the AQD not only considers large and small towns, but also rural populations intermingled with energy development when siting population-based monitoring. However, national monitoring rules are based on more densely populated areas and, therefore, larger cities are a focus of this Network Assessment. The Office of Management and Budget (OMB) categorizes metropolitan areas into five groups. Wyoming, due to being the least populated state, only has two of these groups: Metropolitan Statistical Areas (MSA) and Micropolitan Statistical Areas. The OMB defines a MSA as one or more adjacent counties with at least one urban core area with a minimum population of 50,000. In Wyoming, the cities of Casper and Cheyenne meet the MSA definition. Further, a Micropolitan Statistical Area is defined by the OMB as one or more adjacent counties with at least one urban core area with a population ranging from 10,000-49,999. The Micropolitan Statistical Areas in Wyoming are: Evanston, Gillette, Jackson, Laramie, Riverton, Rock Springs, and Sheridan.

The AQD's evaluation of population concentrated on total population and density, as well as growth. The AQD also evaluated sensitive populations, such as the young and elderly. In Table 3, below, the U.S. Census Bureau's population and demographic statistics provide 2010 population data, 2013 and 2014 estimates, and percentages of people in specific age groups, which will be discussed in further detail. Following Table 3 are Figures 2 and 3. Figure 2 is the population density in Wyoming in map form derived from the 2010 Census. Figure 3 is the block population change in Wyoming from 2000-2010.

Category	Wyoming	USA
Population, 2014 estimate	584,153	318,857,056
Population, 2013 estimate	583,223	316,497,531
Population, 2010	563,626	308,745,538
Persons under 5 years, percent, 2013	6.6%	6.3%
Persons 65 years and over, percent, 2013	13.5%	14.1%

Table 3. Population and Age Demographics of Wyoming and the USA

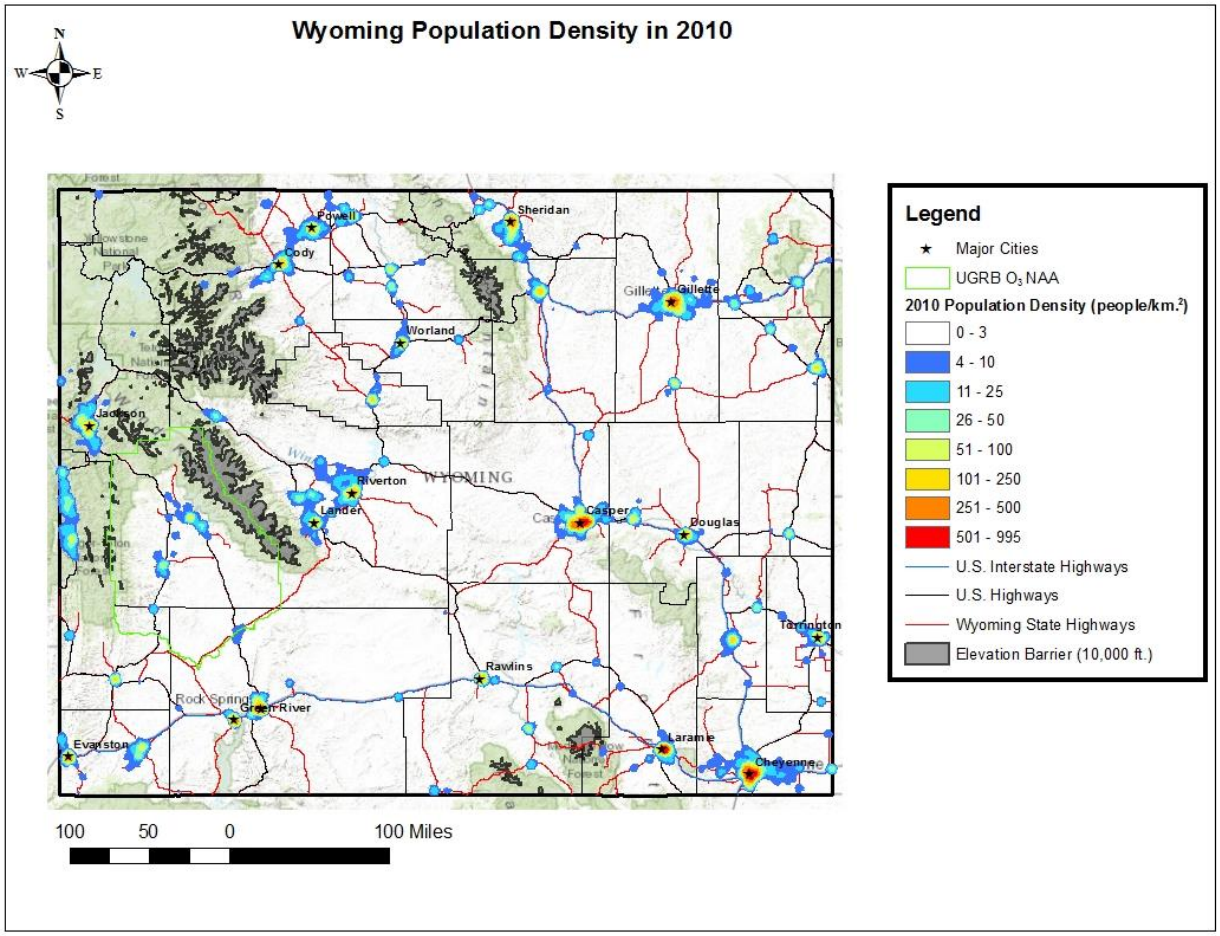

Figure 2. Wyoming 2010 Population Density

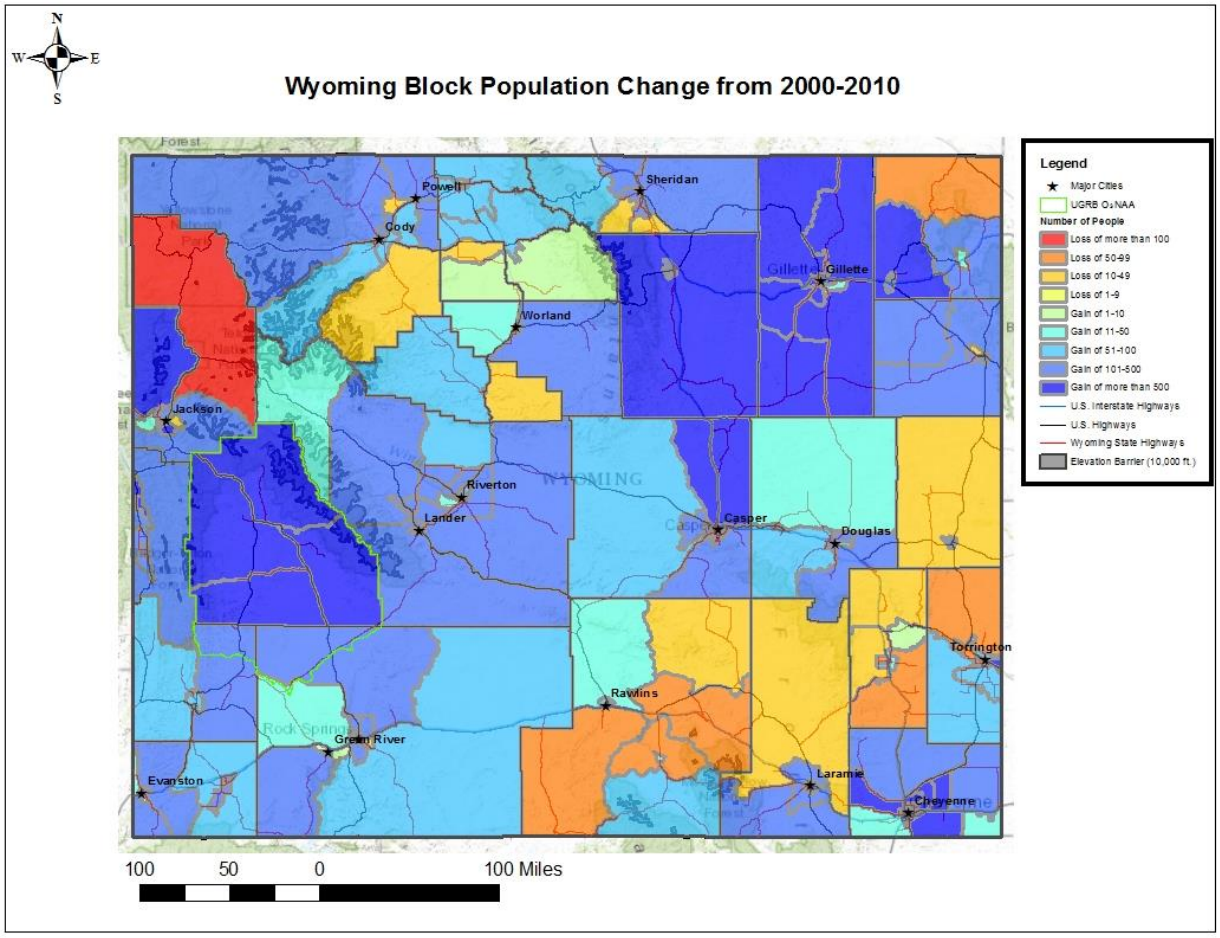

Figure 3. Block Population Change in Wyoming from 2000-2010

The greatest increase in population (more than 500 people) occurred in large portions of Campbell, Johnson, and Sublette Counties. Crook, Laramie, Natrona, and Teton Counties also showed similar growth in smaller portions of the counties. With the exception of Teton County, the other counties mentioned have strong development with respect to coal, oil, and natural gas. Teton County displayed both growth and loss of population over the decade, dependent on the location. In Figure 4, there is clear, consistent population growth outside of the city limits of the seven Micropolitan Statistical Areas and two MSAs in Wyoming. Some of the cities show a large population decrease within the city limits.

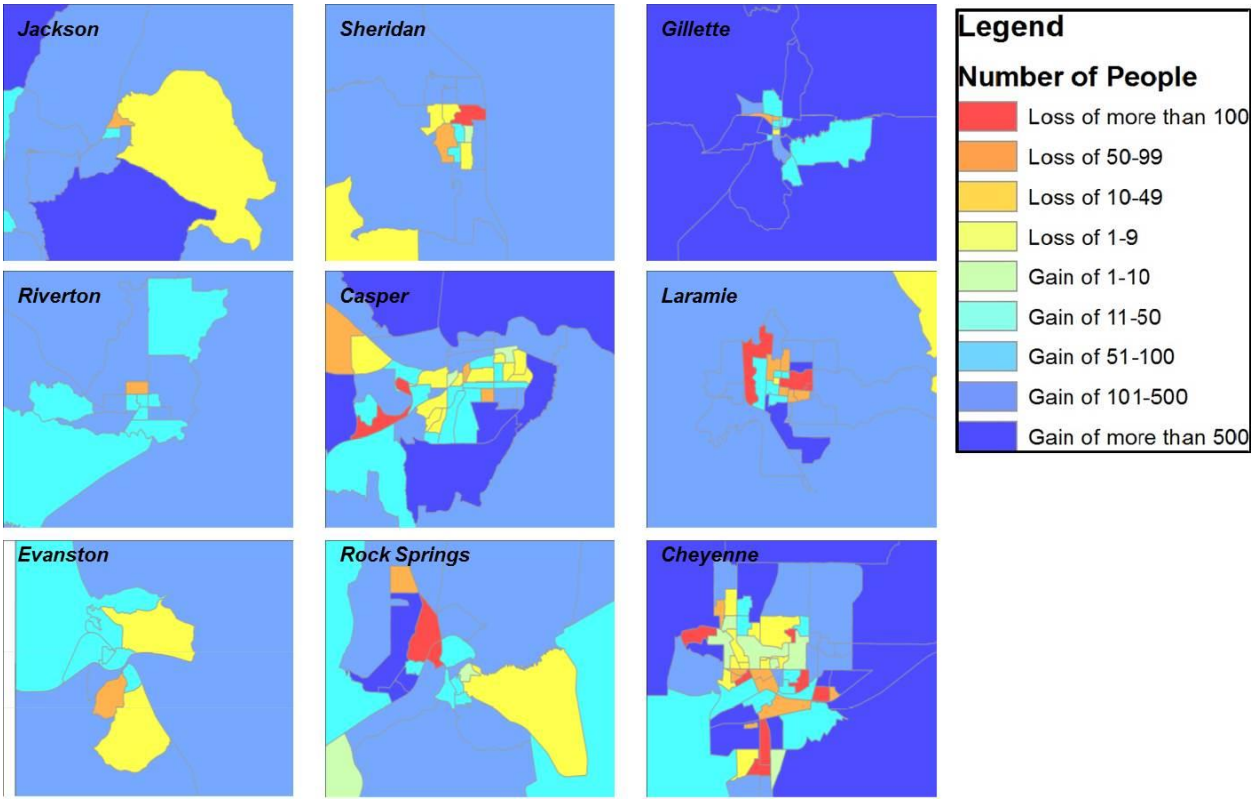

Figure 4. Population Change of Wyoming's Micropolitan and Metropolitan Statistical Areas

Within these populated areas are groups of people defined as sensitive populations. With respect to air quality, sensitive populations include: senior citizens, young children, and individuals with respiratory health concerns. Returning to Table 3, interpolation of the 2013 estimates shows that there are over 38,000 persons under the age of five (5) years and over 78,000 persons at or above the age of sixty-five (65) years. Table 3 reveals that almost 20% of Wyoming's population consists of those that would qualify as a sensitive population for air quality solely due to age.

In addition to the raw numbers, it is important to view key population demographics in Wyoming with a geographic perspective. In order to isolate and view population demographics in Wyoming, the AQD utilized EJView. EJView is an online mapping tool provided by the EPA. EJView allows users to create maps and generate detailed reports based on the geographic areas and data sets chosen. EJView uses U.S. Census Bureau data from multiple factors that may affect public health including: demographic, health, and environmental.[2]

Beyond age, those individuals with respiratory health issues are also a part of the definition of a sensitive population. For Wyoming as a whole, EJVIEW shows a low respiratory risk by county

[2] Access to EJView may be found here (http://epamap14.epa.gov/ejmap/entry.html). A full list of all the data layers and links to their metadata may be found here (http://epamap14.epa.gov/ejmap/help/EJlayersDescription.html).

using the sum of hazard quotients that affect the same target organ. Laramie and Natrona Counties have a slightly higher risk than the remaining counties of Wyoming. Interpreting just from total population, this is due to Casper and Cheyenne being the only MSAs located in Natrona and Laramie Counties, respectively. The Micropolitan Statistical Areas are located in counties with the lowest respiratory risk. According to the census data that has been visualized on the EJView tool, Wyoming's air quality is minimally impacting public health.

Through the Network Assessment, the AQD is also charged to review Environmental Justice issues with respect to air monitoring. Environmental Justice, as defined by the EPA, "*is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.*"

The EPA's EJView tool, which uses 2010 Census data from the U.S. Census Bureau, reveals that Wyoming's population is 86.5% white and 13.5% minority. At a county level, Carbon and Fremont Counties have the highest percentages of minorities at 20.2% and 28.5%, respectively, of the overall population. It should be noted that Fremont County contains most of the Wind River Indian Reservation along with a small portion of Hot Springs County. Minorities comprise 5.4% of the total population in Hot Springs County. Albany, Big Horn, Campbell, Goshen, Laramie, Natrona, Sweetwater, Teton, Uinta, and Washakie Counties have a minority population somewhere in the range of 10-20% according to the U.S. Census Bureau data projected on EJView.

Two (2) of the economic indicators from the 2010 Census, per capita income and the percentage of the population below the poverty level, show Fremont County trending towards the bottom amongst the 23 counties. Teton County has the most per capita income of Wyoming's 23 counties at $42,224.00 while Niobrara County is at the minimum with $22,885.00. Sublette County has the least amount of people living below the poverty line at 4.2%. Albany County has the most living below the poverty line at 21.5%. Albany County also leads the state with the highest population living in rental units at 50.1% while Crook County is the lowest at 20.7%. One possible reason for Albany County's maximum rankings with respect to poverty and rental units is that Wyoming's only four (4) year university, the University of Wyoming, is located in the county seat, Laramie.

1.3 Ambient Air Monitoring in Wyoming

Sites owned and operated by the AQD are the primary focus of this Network Assessment. There are four (4) types of monitoring in Wyoming.

First, the AQD owns and operates several State and Local Air Monitoring Stations (SLAMS). The SLAMS are used for supplying general monitoring data for criteria pollutants and determining compliance with the NAAQS. The SLAMS are long-term stations that must meet and follow specific quality assurance, monitoring methodology, sampling objectives and siting requirements. The AQD SLAMS stations have been placed in Wyoming's most populous towns with the purpose of determining compliance with NAAQS for the protection of public health.

Next, the AQD employs Special Purpose Monitoring (SPM) stations. The SPM stations provide additional information needed by state and local air quality agencies to support air program activities and fulfill the objectives of the air monitoring network. The SPMs can be adjusted to accommodate changing circumstances, needs, and priorities.

Thirdly, the AQD operates a fleet of three (3) mobile monitoring stations capable of monitoring particulate (continuous PM_{10} and $PM_{2.5}$), gaseous (NO_x, O_3, CH_4, and NMHC) and meteorological parameters. The mobile monitoring stations are self-contained monitoring shelters that may be moved to different locations in a relatively short time frame. The mobile monitoring stations may be used to monitor and characterize events, trends in air quality or areas downwind of industrial development. The AQD locates and operates the mobile monitoring stations at a location for approximately one (1) year at a time.

Finally, the AQD, as required by 40 CFR Part 58 Appendix D3, operates a National Core (NCore) Multi-Pollutant Monitoring Station within the city limits of Cheyenne at the North Soccer Complex Park. Title 40, Part 58, Appendix D2. of the CFR defines NCore criteria as the following:

"The NCore multipollutant sites are sites that measure multiple pollutants in order to provide support to integrated air quality management data needs. NCore sites include both neighborhood and urban scale measurements in general, in a selection of metropolitan areas and a limited number of more rural locations."

The NCore monitoring station was established during the summer of 2010 and became fully operational January 1, 2011. This station was incorporated as part of the National Core Monitoring Network. The NCore stations will be the basis for developing a representative report card on air quality across the nation, capable of delineating differences among geographic and climatological regions. The monitored data will be used to characterize and monitor trends in air quality, air quality standards' compliance, and may be used for national healthy assessments, model evaluations, and comparison with other ambient air monitoring data.

Each monitor that is owned and operated by the AQD has a specific monitoring objective. The entire monitoring network is designed to meet the following seven (7) basic ambient air monitoring objectives:

1. Determine representative concentrations in areas of high population density.

2. Determine impact on ambient air quality from significant sources.
3. Determine general background concentration levels.
4. Determine the extent of regional pollutant transport among populated areas and in rural and remote areas.
5. Determine welfare-related impacts in support of secondary standards.
6. Determine highest concentration expected to occur in the area covered by the network.
7. Research pollutant and meteorological behaviors in areas of concern.

It is unlikely that an individual monitor will meet every objective listed, but the complete, statewide monitoring network will accommodate every objective. The AQD invites the public to visit WyVisNet (http://www.wyvisnet.com) to view near real-time monitoring throughout Wyoming and historical monitoring data.

In addition to ambient air monitoring conducted by the AQD, there are several monitoring sites owned and operated by industry and the federal government. Historically, the AQD has required several industrial sources in Wyoming to conduct ambient monitoring for criteria pollutants in and around specific facilities. The AQD's largest industrial network is at the Powder River Basin (PRB) coal mines and consists of approximately 50 PM_{10} monitoring locations. The AQD also requires extensive networks of PM_{10} monitoring at the trona facilities outside of Green River and coal mines in southwest Wyoming. As the AQD's New Source Review (NSR) Program issues construction or modification permits to the facilities, they are often required to monitor for compliance with the ambient air quality standards downwind of their facilities. The monitoring program receives these data on a quarterly basis, and checks for compliance with the NAAQS as well as confirming that the facilities are following appropriate quality assurance measures.

The purpose of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network is to establish current visibility and aerosol conditions along with characterization of broad regional trends and visibility conditions using monitoring data collected in or near Class I areas, national wilderness areas larger than 5,000 acres, or national parks larger than 6,000 acres, across the United States. Wyoming has five (5) IMPROVE locations which include: Yellowstone National Park, Est. 1988; Bridger Wilderness Area, Est. 1988; North Absaroka Wilderness Area, Est. 2000; Thunder Basin National Grasslands, Est. 2002; and Cloud Peak Wilderness Area, Est. 2002. The Clean Air Status and Trends Network (CASTNET) is a national air quality monitoring network that provides data and assesses trends in air quality and atmospheric deposition. The United States Department of the Interior-Bureau of Land Management (BLM) and National Park Service (NPS) serve as the PQAO for multiple CASTNET sites in Wyoming. Each agency also manages sites outside of CASTNET. The BLM, for example, oversees multiple stations as part of their Wyoming Air Resource Monitoring System (WARMS).

Table 4, below, provides the metadata for the AQD stations that operated between 2009-2013. Table 5, following, lists parameters that are monitored at each site. Other stations and monitors not owned by the AQD were used in the evaluation for monitoring coverage are listed in Appendix A.

AQS ID	Site Name	Site Type	Site Objective(s)	County	Start Date	End Date
56-001-0006	Laramie SLAMS	SLAMS	Population Exposure	Albany	1/1/1989	
56-005-0099	Wright Jr.-Sr. High School	SPM	General/Background	Campbell	11/1/2002	
56-005-0123	Thunder Basin	SPM	General/Background	Campbell	10/1/1999	
56-005-0456	Campbell County	SPM	Source Oriented	Campbell	6/1/2003	
56-005-0800	Gillette (Mobile #3)	Mobile	Population Exposure	Campbell	10/1/2011	12/12/2012
56-005-0891	Black Thunder BTM-36-2 (PRB $PM_{2.5}$ Network)	SPM	General/Background	Campbell	7/1/1999	
56-005-0892	Belle Ayr BA-4 (PRB $PM_{2.5}$ & NO_x Network)	SPM	Highest Concentration	Campbell	7/1/1999	
56-005-1002	Gillette SLAMS	SLAMS	Population Exposure	Campbell	1/1/1991	
56-005-1899	Buckskin North (PRB $PM_{2.5}$ Network)	SPM	Upwind Background	Campbell	9/3/2008	
56-007-0099	Atlantic Rim Met	SPM	Source Oriented	Carbon	10/1/2007	9/30/2012
56-007-1000	Sinclair (Mobile #2)	Mobile	Source Oriented	Carbon	12/11/2013	
56-009-0801	Converse County (Mobile #3)	Mobile	Population Exposure	Converse	12/17/2012	
56-009-0819	Antelope Site 3 (PRB $PM_{2.5}$ & NO_x Network)	SPM	General/Background	Converse	7/1/1999	
56-013-0099	South Pass	SPM	General/Background	Fremont	3/12/2007	
56-013-0900	Pavillion (Mobile #1)	SPM	Population Exposure	Fremont	1/27/2011	4/17/2012
56-013-1003	Lander SLAMS	SLAMS	Population Exposure	Fremont	1/1/1989	
56-021-0001	Cheyenne SLAMS	SLAMS	Population Exposure	Laramie	1/1/1991	
56-021-0100	Cheyenne NCore	SPM	Population Exposure	Laramie	1/1/2011	
56-025-0001	Casper SLAMS	SLAMS	Population Exposure	Natrona	1/1/1991	
56-025-0100	Casper Gaseous	SPM	Population Exposure	Natrona	3/1/2013	
56-029-0001	Cody SLAMS	SLAMS	Population Exposure	Park	1/1/1988	
56-033-0002	Sheridan Police Station SLAMS	SLAMS	Population Exposure	Sheridan	1/1/1985	
56-033-0003	Sheridan Highland Park SLAMS	SLAMS	Population Exposure	Sheridan	1/1/2005	5/30/2012
56-033-1003	Sheridan Meadowlark SLAMS	SLAMS	Population Exposure	Sheridan	7/1/2012	
56-035-0097	Wyoming Range	SPM	General/Background	Sublette	1/1/2011	10/1/2013
56-035-0099	Boulder	SPM	Source Oriented	Sublette	2/1/2005	

AQS ID	Site Name	Site Type	Site Objective(s)	County	Start Date	End Date
56-035-0100	Daniel South	SPM	Upwind Background	Sublette	7/1/2005	
56-035-0101	Pinedale Gaseous	SPM	Population Exposure	Sublette	1/1/2009	
56-035-0700	Big Piney Site #3	SPM	Source Oriented	Sublette	3/30/2011	
56-035-0705	Pinedale $PM_{2.5}$	SPM	General/Background	Sublette	7/1/2005	6/30/2012
56-035-1002	Juel Spring	SPM	Source Oriented	Sublette	12/11/2009	
56-037-0007	Rock Springs SLAMS	SLAMS	Population Exposure	Sweetwater	1/1/1989	
56-037-0077	Hiawatha	SPM	Source Oriented	Sweetwater	5/1/2011	
56-037-0100	Rock Springs (Mobile #1)	Mobile	Population Exposure	Sweetwater	3/2/2013	3/31/2014
56-037-0200	Wamsutter	SPM	Source Oriented	Sweetwater	3/13/2006	
56-037-0300	Moxa Arch	SPM	Source Oriented	Sweetwater	5/28/2010	
56-037-1000	Farson Met	SPM	Other	Sweetwater	4/27/2011	
56-039-1006	Jackson SLAMS	SLAMS	Population Exposure	Teton	1/1/2001	
56-041-0101	Murphy Ridge	SPM	Upwind Background	Uinta	1/1/2007	
NOT IN AQS	Sinclair BAM Station	Mobile	General/Background	Carbon	3/16/2011	5/31/2011
NOT IN AQS	Worland BAM Station	Mobile	General/Background	Washakie	11/1/2011	12/31/2012

Table 4. AQD Monitoring Sites (2009-2013 Operation)

Site Name	Site Type	Parameters									
		CH_4/NMHC	CO	NO_2	O_3	PM_{10} LC	PM_{10} STP	$PM_{2.5}$ LC	$PM_{2.5}$ SPEC	SO_2	Met
Laramie SLAMS	SLAMS					X	X	X			
Wright Jr.-Sr. High School	SPM					X	X				
Thunder Basin	SPM			X	X	X			X		X
Campbell County	SPM			X	X		X				X
Gillette (Mobile #3)	Mobile	X		X	X		X	X			X
Black Thunder BTM-36-2 (PRB $PM_{2.5}$ Network)	SPM					X	X	X			
Belle Ayr BA-4 (PRB $PM_{2.5}$ & NO_x Network)	SPM			X				X			
Gillette SLAMS	SLAMS					X	X				
Buckskin North (PRB $PM_{2.5}$ Network)	SPM							X			
Atlantic Rim Met	SPM										
Sinclair (Mobile #2)	Mobile	X		X	X		X	X		X	X
Converse County (Mobile #3)	Mobile	X		X	X		X	X			X
Antelope Site 3 (PRB $PM_{2.5}$ & NO_x Network)	SPM							X			
South Pass	SPM			X	X		X			X	X
Pavillion (Mobile #1)	Mobile	X		X	X		X	X			X
Lander SLAMS	SLAMS					X	X	X			
Cheyenne SLAMS	SLAMS					X	X	X			
Cheyenne NCore	SPM		X	X	X		X	X	X	X	X
Casper SLAMS	SLAMS					X	X	X			
Casper Gaseous	SPM			X	X						X
Cody SLAMS	SLAMS					X	X	X			
Sheridan Police Station SLAMS	SLAMS						X	X			X

Site Name	Site Type	Parameters									
		CH_4/NMHC	CO	NO_2	O_3	PM_{10} LC	PM_{10} STP	$PM_{2.5}$ LC	$PM_{2.5}$ SPEC	SO_2	Met
Sheridan Police Station SLAMS	SLAMS						X	X			X
Sheridan Highland Park SLAMS	SLAMS					X	X	X			
Sheridan Meadowlark SLAMS	SLAMS					X	X	X			
Wyoming Range	SPM			X	X	X	X	X			X
Boulder	SPM	X		X	X		X				X
Daniel South	SPM			X	X	X	X				X
Pinedale Gaseous	SPM			X	X			X			X
Big Piney Site #3	SPM			X	X		X	X			X
Pinedale $PM_{2.5}$	SPM							X			
Juel Spring	SPM			X	X						X
Rock Springs SLAMS	SLAMS					X	X	X			
Hiawatha	SPM				X						X
Rock Springs (Mobile #1)	Mobile	X		X	X		X	X			X
Wamsutter	SPM	X		X	X		X			X	X
Moxa Arch	SPM			X	X		X			X	X
Farson Met	SPM										X
Jackson SLAMS	SLAMS					X	X	X			
Murphy Ridge	SPM			X	X	X	X			X	X
Afton BAM Station	Mobile					X	X	X			X
Worland BAM Station	Mobile					X	X	X			X

Table 5. Parameters Measured at AQD sites (2009-2013 Operation)

1.3.1 Monitoring Network Changes

There have been various changes to the AQD monitoring network since the submittal of the 2010 Network Assessment on April 28, 2011. Many of these have been associated with the mobile gaseous monitoring stations, since they are typically only deployed in a location for a one (1) year period of study. Further, stationary SPM sites have either closed or relocated. This section briefly describes the changes to the network.

1.3.1.1 Wyoming Range

The primary objective of the Wyoming Range monitoring station was to monitor transported pollutants entering the UGRB from the west. Also, the 2010 Network Assessment recommended meteorological monitoring at Wyoming Range to study the unique meteorology attributed to Wyoming's topography. The Wyoming Range site started data acquisition on January 1, 2011 and was shut down on October 31, 2013. The data generated from the Wyoming Range station was found to be redundant with respect to the nearby Daniel South station. The equipment from Wyoming Range was used to outfit a long-term monitoring station at Big Piney Site #3, replacing the gaseous mobile station located there.

1.3.1.2 Hiawatha

The AQD began operation of the Hiawatha monitoring station in May 2011 with a primary objective of source-oriented monitoring. The monitoring station is sited in a region of proposed oil and gas development based on the recommendation from the 2010 Network Assessment. Due to the remote location of the Hiawatha station, renewable energy is the primary power source.

1.3.1.3 Farson Meteorological Tower

Another recommendation from the 2010 Network Assessment was the installation of a meteorological tower for modeling purposes in the town of Farson in May 2011. Farson is located along the southern border of the UGRB O_3 nonattainment area. The placement of the meteorological tower in Farson assists in providing coverage in necessary meteorological data for modeling.

1.3.1.4 Casper Gaseous

In March 2013, the Casper Gaseous monitoring station began operation. The monitoring station was sited in Casper – Wyoming's second largest city, and a MSA. The 2010 Network Assessment revealed population-based O_3 monitoring as a priority.

1.3.1.5 Sheridan Elementary School SLAMS

In addition to the SLAMS monitoring station at the Sheridan Police Station, a neighborhood scale and population oriented station has moved several times. From 1998 to 2005, PM_{10} and $PM_{2.5}$ monitoring was conducted at the Sheridan Middle School. Next, the station was located at the Highland Park School from 2005-2012. Due to the demolition of the school, the SLAMS site was placed at the Meadowlark Elementary School beginning in July 2012. The AQD complied with the EPA SLAMS requirements when the site was relocated.

1.3.1.6 Pinedale $PM_{2.5}$ Station

Beginning in 2005, $PM_{2.5}$ sampling started at the Pinedale $PM_{2.5}$ SPM, a filter-based site. In January 2009, the AQD added a gaseous monitoring station in Pinedale for NO_2 and O_3. This new station also employed a continuous BAM to measure $PM_{2.5}$ concentration. The AQD determined that there was redundancy in operating both $PM_{2.5}$ monitors in Pinedale. Operational differences, budgetary considerations, and data comparability also led the AQD to reach a decision to cease operation for the Pinedale $PM_{2.5}$ station on June 30, 2012.

1.3.1.7 Cloud Peak

Operations at the Cloud Peak station started in October 1999. This station was located approximately fifteen (15) miles west of Buffalo in Johnson County. This station was used to track visibility and meteorology near the Cloud Peak Wilderness Area. On July 1, 2014, the AQD decommissioned the meteorological parameters and camera. The AQD conducted an internal assessment and found the meteorological data and camera images to be of low priority. The AQD transferred ownership of the camera to the USFS.

1.3.1.8 Converse County Long-Term Station

In order to evaluate ambient air quality data in a region of oil and gas development, the AQD established the Converse County Long-Term Station in April 2015. The long-term station is centrally located in the oil and gas in Converse County and monitors for gaseous, particulate, and meteorological parameters.

1.3.1.9 Powder River Basin-Antelope Relocation

As part of the PRB Network, the Antelope Site 3 station, established in January 2001, monitored $PM_{2.5}$ and NO_2 upwind of the Antelope Mine. In 2013, construction of an oilfield service road within 100 feet from the Antelope Site 3 station comprised the siting criteria at this location. The station was shut down on July 1, 2013 and moved to a new location, in the same area, called Antelope Site 7. The Antelope Site 7 station became operational in February 2015.

1.3.1.10 Mobile Gaseous Monitoring Stations

Mobile Station #1: This mobile station was initially deployed a few miles east of the small town of Pavillion in Fremont County from January 2011 to April 2012. The primary objective was to monitor this rural residential area intermingled with gas development. The mobile station was then relocated to Rock Springs for population-based monitoring to fulfill the 2010 Network Assessment finding and operated through March 2014. The mobile station was then transported to the town of Lovell in northwest Wyoming. The objective at Lovell is population-based monitoring in a previously unmonitored area with several Title V sources in the area. Monitoring started at Lovell in July 2014 and concluded at the end of August 2015.

Mobile Station #2: This station was utilized for ambient air and meteorological monitoring in Big Piney, in the UGRB O_3 nonattainment area. The 2010 Network Assessment noted that a monitoring station would be positioned near the LaBarge Gas Field. The AQD initiated operations for the station in March 2011. In 2013, the AQD determined that that it would be beneficial to continue monitoring some parameters at the Big Piney location to achieve the primary objective of monitoring downwind of the Big Piney and LaBarge Gas Fields. The long-term Big Piney monitor began operations in December 2013. The mobile station was moved to Sinclair, in south central Wyoming located next to a Title V oil refinery. The mobile station is sited to monitor SO_2 and other pollutants in populated area of the town of Sinclair. The station is still located at Sinclair, but is likely to be sited in Torrington later in 2015. Torrington is a town

in eastern Wyoming with a population of approximately 6,500 people. At the time of the decision, there was a Title V source located close to the city limits.

Mobile Station #3: The initial location of this station was in the Micropolitan Statistical Area of Gillette. This was a recommendation from the 2010 Network Assessment concerning population-based ozone monitoring in populated areas. Operations in Gillette started in October 1, 2011 and ended on December 12, 2012. The station was moved near the town of Douglas in Converse County and began operations on December 17, 2012. This station was sited due to citizen concerns about oil and gas development in an area of rural residential population. The AQD continued operation at this location beyond the anticipated one (1) year while evaluating the need for a long-term monitoring station in Converse County. The AQD terminated operations at the Converse County mobile station on July 8, 2015. The mobile station at Converse County was moved to Newcastle, which is in the northeastern portion of Wyoming. Newcastle is a mid-sized town with just over 3,500 people that has a Title V oil refinery and associated industrial monitoring located adjacent to the town's school. The Newcastle Mobile station began operation on July 10, 2015.

1.3.1.11 BAM Station

The AQD outfitted a mobile monitoring station with continuous BAM PM_{10} and $PM_{2.5}$ monitoring devices for deployment in communities that may be impacted by smoke or wildfire activity, or agricultural burning. Additionally, meteorological conditions are also monitored. The station was first located for a brief period of time in 2011 in Sinclair. Later, the station was moved to Worland and sited at Newell Sargent Park. Data collection began on October 1, 2011. The Worland monitoring objective was to monitor in a populated areas that may be affected by agricultural burning. Sampling at Worland concluded on December 31, 2012. Following Worland, the station was sited in Afton, based on a recommendation from the 2010 Network Assessment citing a need for population-based PM_{10} monitoring in Afton. Data collection began on January 1, 2014 and concluded on March 16, 2015. The station was then moved back to Worland and data collection started in July 2015. In 2012, there was a burn ban in effect due to dry conditions persistent in Washakie County and throughout the state. Therefore, the AQD relocated the BAM station to Worland in order to monitor ambient particulate and meteorological data under normal burning conditions.

2. Data Sources and Products in the 2015 Network Assessment

The AQD has used a variety of different data sources and products to evaluate Wyoming's ambient air monitoring network. The data products presented are mostly illustrated in a graphical format to inform the reader. It is important to illustrate that the overwhelming majority of the data products used average data grouped by a season, a year, or multiple years. The aim is to investigate trends instead of specific days or incidents. Using all data products provides a firm illustration of what has happened at a monitoring station and what conclusions can be made. The AQD, due to limited internal resources, utilized the services of STI to assist in the analysis of monitoring data and generation of data products. The data products and sources will be introduced here. STI produced an extensive Technical Support Document (TSD) that discusses in details the data sources and procedures used in generating the data products. This TSD can be found in Appendix B.

2.1 Data Sources

2.1.1 Ambient Monitoring Data

The primary data source used for acquiring ambient monitor pollutant data in the Network Assessment was AQS. As mentioned earlier, AQS is the EPA's repository of ambient air monitoring and meteorological data collected by Federal, State, local, and Tribal air agencies, as well as industrial sources. The AQD uploads validated data from its monitors, as well as industrial monitors operated in Wyoming, on a quarterly basis. Prior to beginning to assemble and evaluate data products, the AQD conducted an extensive data completeness review for each county to verify and, if necessary, remedy data completeness issues in AQS.

2.1.2 Emission Inventory Data

The AQD used the following emission inventory (EI) data sources: the 2013 Title V EI, the 2013 UGRB Oil and Gas EI, the 2013 Southern Powder River Basin (SPRB) Oil and Gas EI, the 2013 Prescribed and Wildfire EI from the Western Regional Air Partnership-Fire Emissions Tracking System (WRAP-FETS), the 2011 Triennial Oil and Gas EI, the 2011 Triennial Non-Oil and Gas EI, the 2011 On-Road EI, and the 2011 Non-Road EI. The On-Road and Non-Road EI come from the EPA's National Emissions Inventory (NEI). The Title V, UGRB, and SPRB are annual inventories collected by the AQD. The WRAP-FETS EI data comes from the AQD's Smoke Management Program, where basic prescribed fire (broadcast area size or pile volume and fuel type) and wildfire data is uploaded to the WRAP-FETS system. Through various

models and emission factors, the output from the WRAP-FETS system is an EI of the uploaded prescribed fire and wildfire data. On-Road EI data was computed using the EPA's Motor Vehicle Emission Simulator (MOVES) software program at the county level. Non-Road EI data includes the following non-industrial sources: residential fuel combustion, commercial cooking, construction, and agricultural processes.

2.1.3 Meteorological Data

The meteorological data used in the Network Assessment comes from three (3) sources: AQS, Remote Automatic Weather Stations (RAWS), and Meteorological Aviation Reports (METAR). The AQS meteorological data comes from AQD, industrial, and federal monitoring stations. Like the ambient monitoring pollutant data, STI inspected the sources for at least 85% data completeness. They determined that fifty-three (53) AQS and twenty-one (21) METAR sites passed the criteria. STI classified the data into annual and seasonal groups. In the event of spatial gaps in the meteorological coverage provided by AQS and METAR locations, data from RAWS was used.

2.2 Mapping

2.2.1 Thiessen Polygons

The AQD and its contractor used the specific Geographic Information System (GIS) known as ArcGIS and ArcMap, the software program commonly associated with ArcGIS. This is a product originally developed by the Environmental Systems Research Institute (ESRI). Besides common mapping, ArcGIS offers advanced features. One of these features is the generation of Thiessen (Voronoi) polygons. Thiessen polygons denote a zone of influence around a given point such as a monitoring station. The calculation of these polygons draws a line equidistant between each pair of monitors. The polygons are then generated from the intersections of the lines. With the resulting polygons, the area served by a monitor can be inferred. Thiessen polygons are, however, limited in that they do not take topography or meteorology into account. One improvement made to the polygons was to take elevation into account. The contractor designated and marked elevation up to 10,000 feet to mostly take elevation into consideration. Figure 5, below, shows Thiessen polygons and elevation for all monitoring stations that measured ozone at any time during 2009-2013.

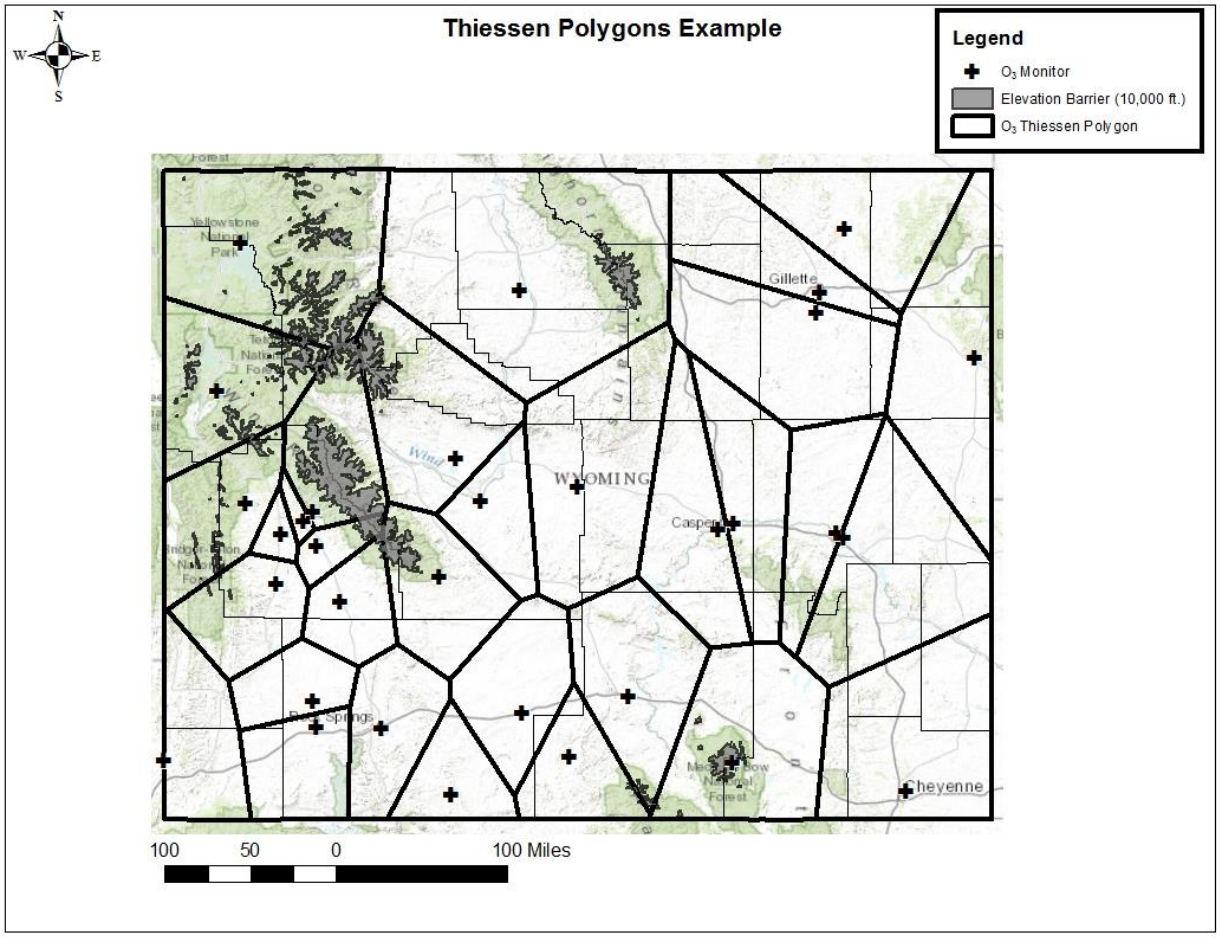

Figure 5. Thiessen Polygon Example

2.2.2 Gridded Emission Inventory

Another important data product generated by STI for the Network Assessment was a Gridded Emission Inventory (EI). The AQD provided a variety of EI data to the contractor as discussed in Section 2.1.2. STI placed the EI data into 4 kilometer (km) by 4 km grids according to the location provided. Emissions data were categorized into five (5) types: ALL (all emission sources), PT (2013 Title V and 2011 Non-Oil and Gas), OR (On-Road), NP_NR (Non-Point, Non-Road, and Fire Sources), and OG (Oil and Gas Sources). The pollutants assessed were: PM_{10}, $PM_{2.5}$, NO_x, CO, SO_2, and VOCs. The OR and NP_NR sources were gridded based on land use, land cover, transportation networks, and census data. Table 6 provides a summary of the EI data and what to expect when viewing maps. Figure 6 shows the gridded EI of VOCs from all sources as an example.

Map Type	EI Sources
ALL	All 2011 and 2013 sources
PT	2013 Title V, 2011 Non-Oil and Gas EI
OR	2011 NEI On-Road
NP_NR	2011 NEI Non-Road, 2013 WRAP-FETS EI
OG	2011 Oil and Gas EI, 2013 SPRB EI, 2013 UGRB EI

Table 6. Emission Inventory Map Types and Data Sources

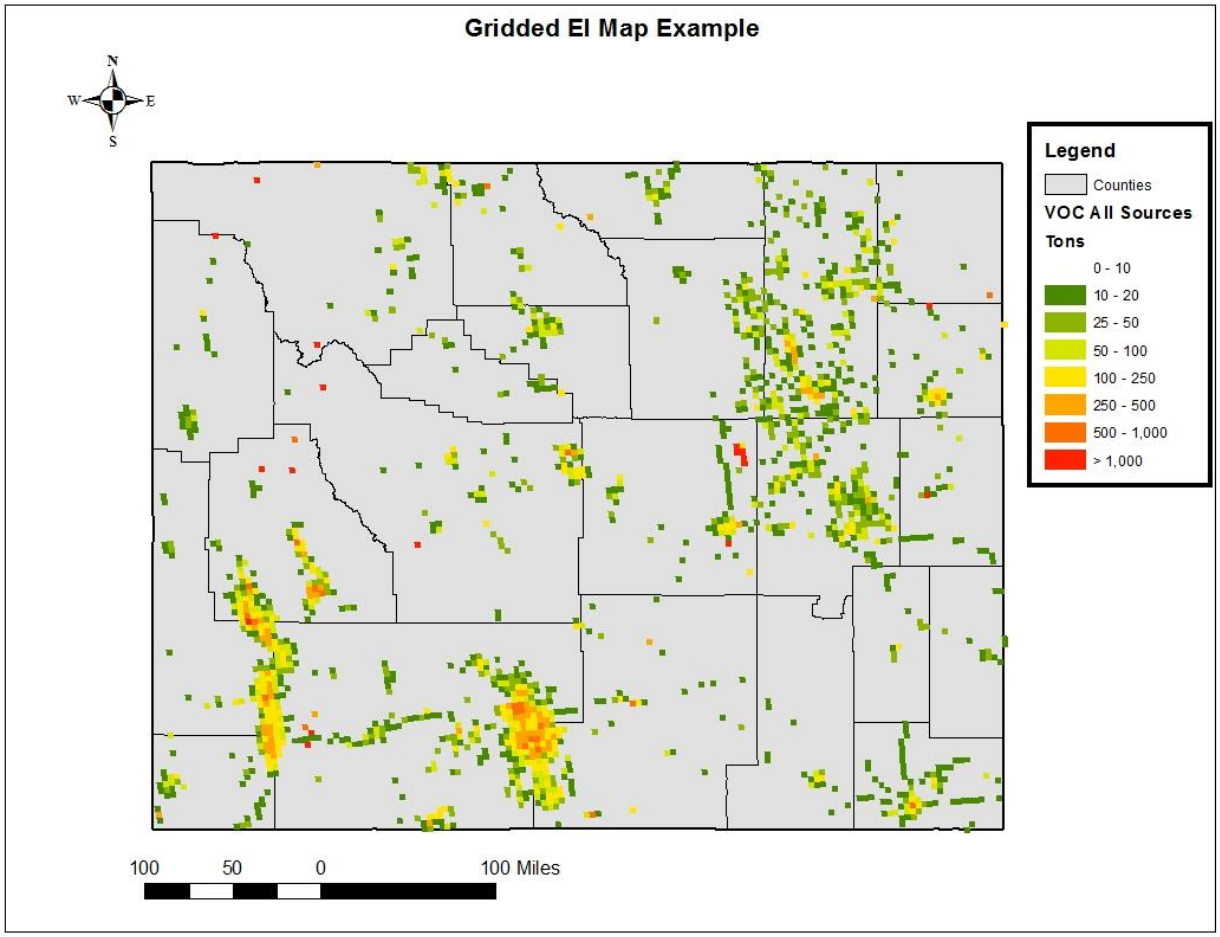

Figure 6. Gridded Emission Inventory Example

2.2.3 Population Change and Density

As shown in Figures 2 and 3 of the Introduction, the contractor acquired spatially resolved population data at the block level from the U.S. Census Bureau to generate population density

and block population change. The population density is from the 2010 Census and is in the units of people/km.^{2}. The block population change investigates any changes in population for designated census areas during 2000-2010. Figure 7 shows the overall process of generating the population-served analysis.

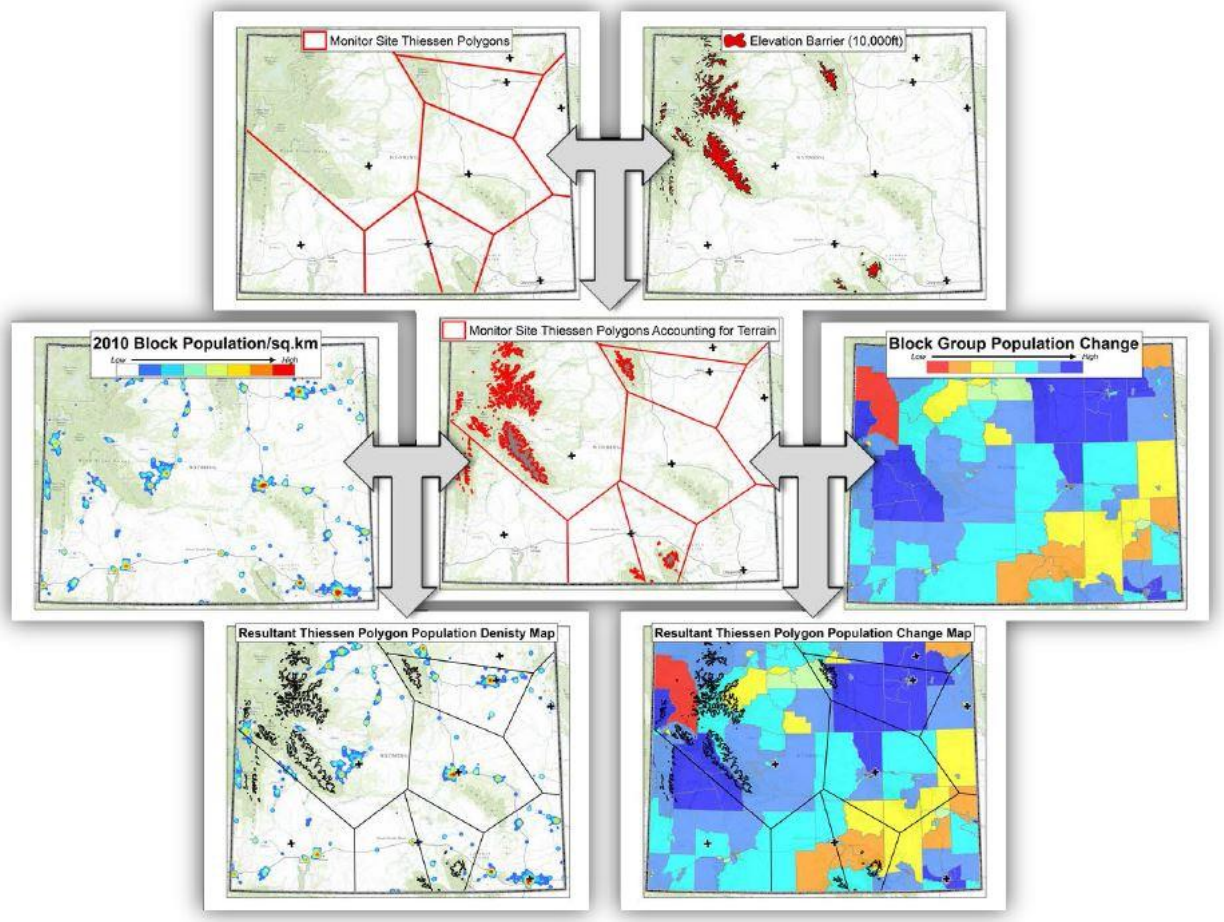

Figure 7. Population-Served Analysis Process

2.3 Statistical Analyses

2.3.1 Box and Whisker Plots

The Network Assessment used pollutant and meteorological data from 2009-2013. One effective way to compare data is a notched box and whisker plot (hereafter referred to as a boxplot). The boxplots are generated by using SYSTAT, an advanced statistical software package. These boxplots can be used to assess statistical significance between two or more sets of data. They

can be used to assess the trend in concentrations at a monitoring station by evaluating data collected in different years. These boxplots can also be used to determine whether two or more chosen stations monitor significantly different concentrations. For the boxplots, STI analyzed O_3, NO_2, PM_{10}, $PM_{2.5}$, SO_2, and CO. The boxplots are best utilized when there are multiple years of data for a given pollutant at a given site to compare and study. Figure 8, as seen below, illustrates what a boxplot is and provides instructions for interpretation.

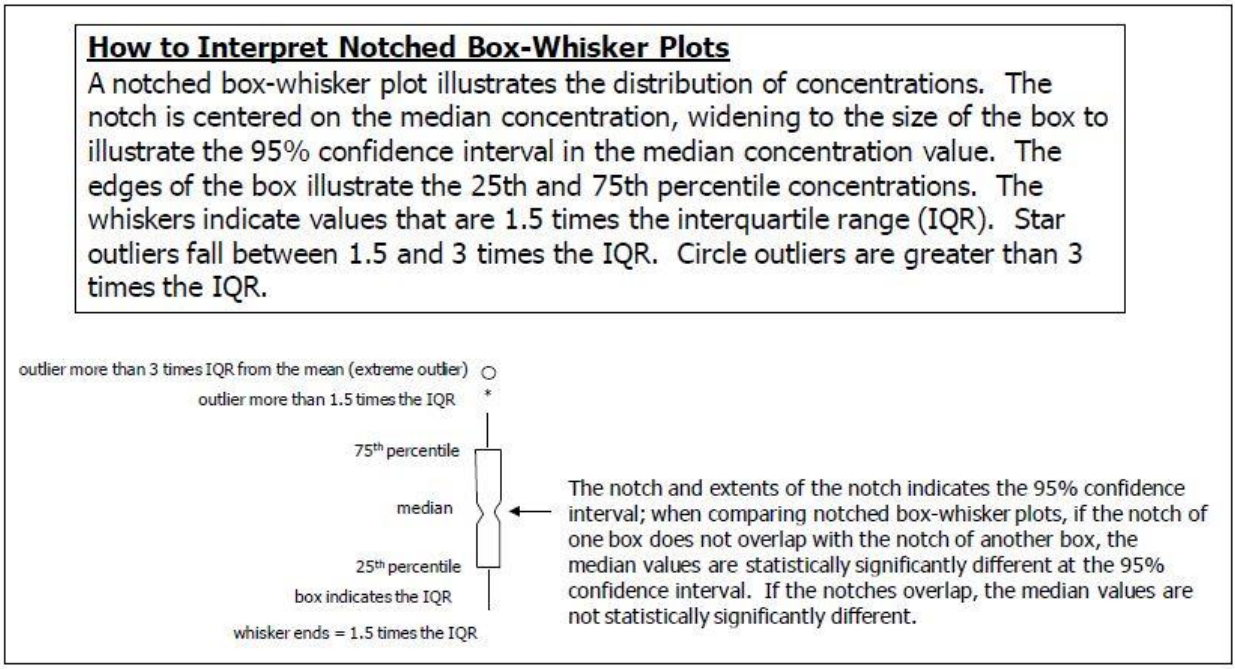

Figure 8. Instructions for Interpreting Box-Whisker Plots

2.3.2 Monitor-To-Monitor Correlation Analysis

Another method used to examine pollutant data was a correlation analysis. In a correlation analysis, the pollutant of interest is compared across multiple sites along identical time periods where both sites operated. This is called a pairwise frequency. The data for the two sites is then subjected to a Pearson Correlation. Pearson Correlation values of ≥0.8 indicate high correlation between the two monitors. Highly correlated values can indicate redundancy in monitors. For example, as demonstrated in Table 7 there is a brief example for CO between the W1-Sand Draw-01 (56-013-6001) and Cheyenne NCore (56-021-0100) stations. Both stations monitored CO simultaneously from 10/1/2013 to 12/31/2013. Table 7 shows that there were 1,898 occurrences when both sites measured CO out of 2,208 possible hours in 2013 Q4. It also shows a Pearson Correlation value of -0.37 indicating a poor correlation.

Site ID	Compare with 56-021-0100	
56-013-6001	1,898	Pairwise Frequency
	-0.37	Pearson Correlation Value

Table 7. Correlation Table Example

2.4 Meteorological Analyses

2.4.1 Wind Rose

The AQD and its contractor evaluated ground-based meteorological data primarily via generation of wind roses. A wind rose is a compilation of the speed and direction of where the wind emanates over a specific time period. Figure 9, below, provides an illustrative example of how to properly interpret a wind rose. Once these wind roses are plotted onto a map, they serve a useful purpose in identifying wind patterns by region and show changes based on topography.

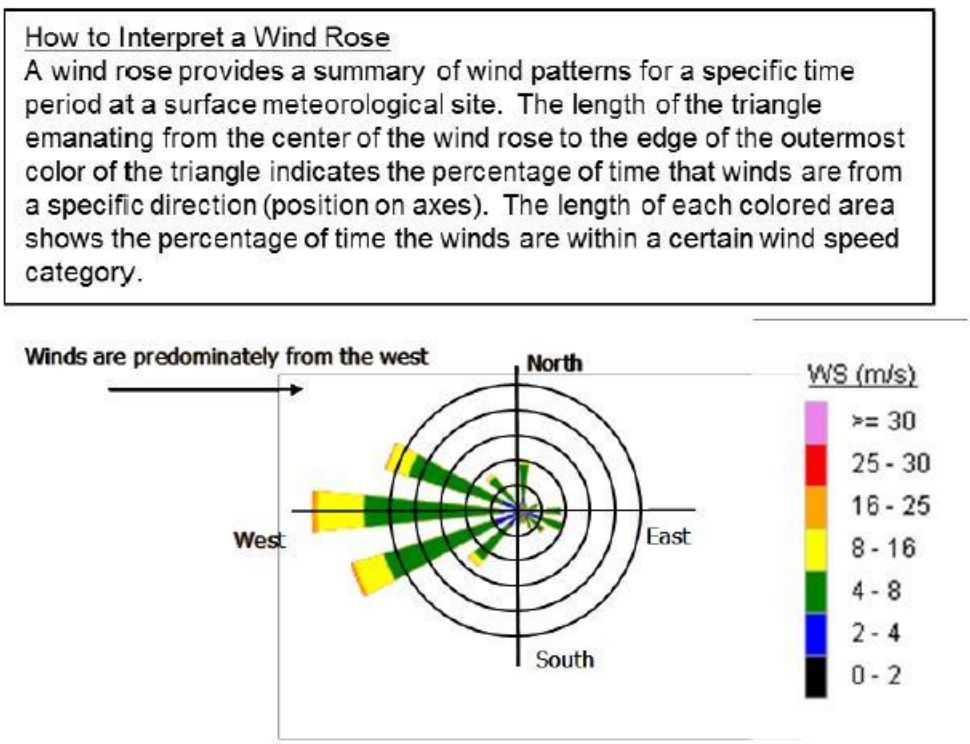

Figure 9. Wind Rose Example

2.4.2 HYSPLIT Model

The other meteorological analysis conducted for the Network Assessment is the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT). The HYSPLIT model generates wind trajectories up to forty-eight (48) hours prior (backwards trajectory) to and after (forwards trajectory) a chosen start date of interest. The backwards trajectory is a valuable indicator of what could affect a stationary location such as a city or monitoring station. A forwards trajectory is beneficial to view possible dispersion from an emission source. The contractor computed both trajectories at two (2) starting heights: 250 m and 500 m. The AQD requested ten (10) HYSPLIT model runs. The AQD consulted with meteorologists to determine representative meteorological days to evaluate HYSPLIT. The locations, starting dates, and trajectory information is found below in Table 8.

Site Location	County	Start Date	Trajectory Type
Cody	Park	5/15/2010	Backwards
Crossbow	Campbell	8/17/2013	Forwards
Evanston	Uinta	8/18/2011	Backwards
Jackson	Teton	6/18/2010	Backwards
Laramie	Albany	11/1/2009	Backwards
Moneta Divide	Fremont	6/3/2011	Forwards
Riverton	Fremont	8/19/2013	Backwards
Sheridan	Sheridan	5/22/2009	Backwards
Torrington	Goshen	11/9/2011	Backwards
Wheatland	Platte	11/30/2010	Forwards

Table 8. HYSPLIT Run Information

The Crossbow and Moneta Divide site locations are proposed National Environmental Policy Act (NEPA) projects for oil and gas development. Figure 10 reveals the backwards trajectory for Laramie as an example of what the HYSPLIT model looks like on a map.

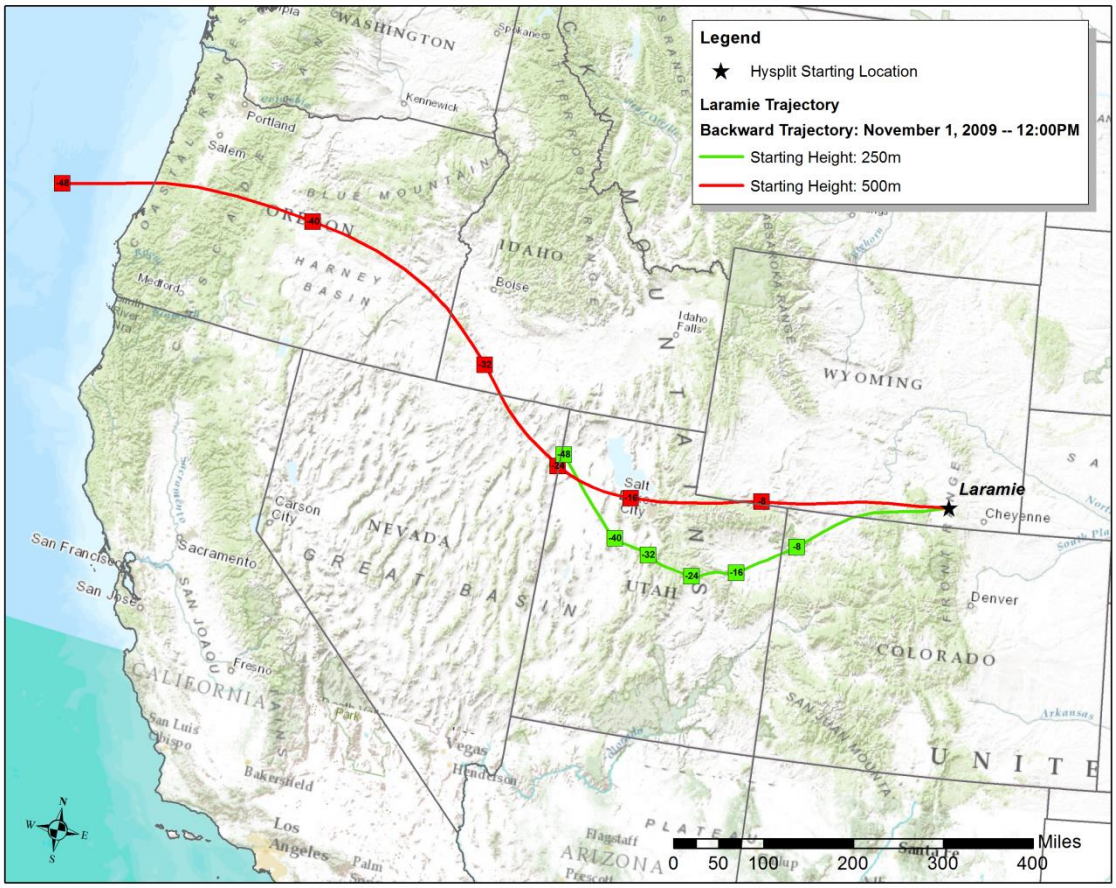

Figure 10. HYSPLIT Model Run Example.

3. Network Assessment Evaluation

3.1 Evaluation Strategy

The AQD chose to evaluate Wyoming's ambient air monitoring network by parameter in the following categories: CO, NO_2, O_3, PM_{10}, $PM_{2.5}$, SO_2, and meteorological. From there, several questions are posed pertaining to monitoring objectives, priorities for the AQD, and the results of the data products. The questions that the AQD posed are below.

General Question

1. Is the current monitoring meeting its objectives? If not, what objective is the monitor meeting and what type of monitor is it (SLAMS, SPM, etc.)?

Data Analysis

1. Are there any monitors where the mean is >75% of the NAAQS?
2. Are there any monitors where the mean is <25% of the NAAQS?
3. Are there any monitors with more than 50% of the values below detection limits?
4. Are there any monitors with more than one (1) exceedance in the last five (5) years?
5. Are there any monitors with statistically significant increasing or decreasing trends?
6. Are there any monitors that are highly correlated?

Population Analysis

1. Are areas with a large population increase currently monitored?
2. Are there any areas with a large population decrease currently monitored?
3. Are there any areas with a large total population (Micropolitan Statistical Area or larger) unmonitored? If so, are there areas of large emissions of your pollutant upwind?

Emission Analysis

1. Are there any areas with large emissions and population not currently monitored?
2. Are there sensitive population areas with emissions that are not currently monitored?
3. Are there areas with large emissions that are not currently monitored (either by the AQD or industrial monitors)? If so, what is downwind?
4. Are there areas with planned oil and gas development that are not currently monitored?

Other Monitoring Objective Analyses

1. Are there areas where there is a need for background data?

2. Are there areas where there are needs for monitoring to support modeling performance evaluations?
3. Are there areas where there are needs for new or enhanced meteorological data?

Prioritization

1. What new monitoring is needed in the AQD network?
2. What is the priority of current monitoring?
3. What monitors could be justifiably shut down?

3.2 Data Analysis by Pollutant or Parameter

The following sections comprise a summary of the AQD's analysis by pollutant or parameter and include data products utilized to answer the preceding questions.

3.2.1 PM_{10}

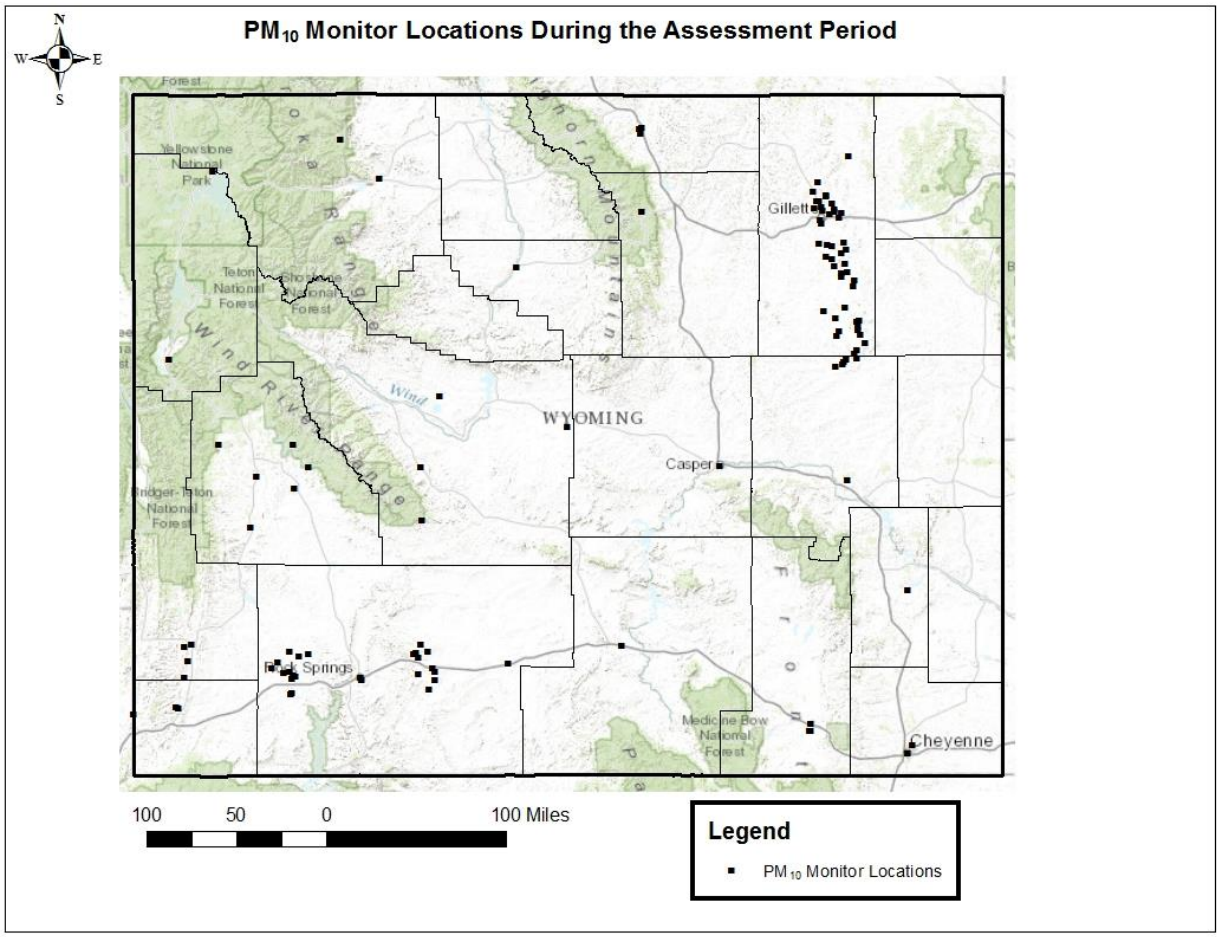

Figure 11. PM_{10} Monitor Locations, 2009 to 2013

3.2.1.1 Data Analysis

An analysis of PM_{10} data collected during the assessment period found no monitors with mean or median data significantly close to (>75% of) the NAAQS. Indeed, the mean and median values for every AQD-run PM_{10} monitor were found to be significantly below (<25% of) the NAAQS. However, these mean and median values were above the Minimum Detection Limit (MDL) of the monitors in question. No AQD monitors were found to have measured more than one (1) exceedance of the NAAQS during the assessment period. Wyoming was influenced by smoke from multiple wildfires in 2012 and some exceedances were flagged as Exceptional Events with documentation submitted to the EPA for concurrence.

Data for the Wright Jr.-Sr. High School SPM, Casper SLAMS AQS Parameter Occurrence Code (POC) 5, and the Daniel South SPM were found to display slight increasing trends during the assessment period. The mean and median values for all of these sites were below 20 µg/m^3. Hourly PM_{10} data for the Boulder SPM were found to be consistent since monitoring began in 2005, with no exceedances or significant increasing or decreasing trends observed during the assessment period.

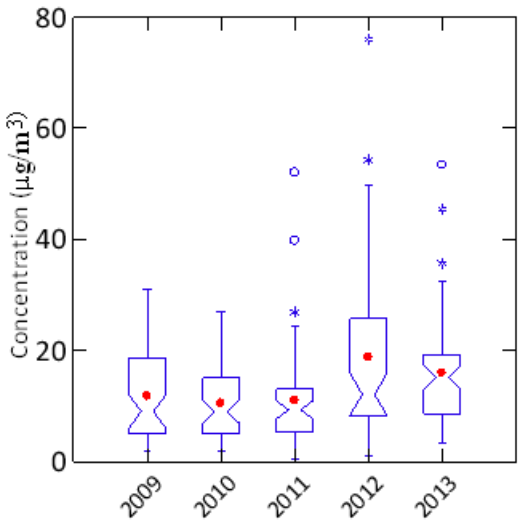

Figure 12. Box and Whisker Plot for Wright Jr.-Sr. High School, 2009-2013

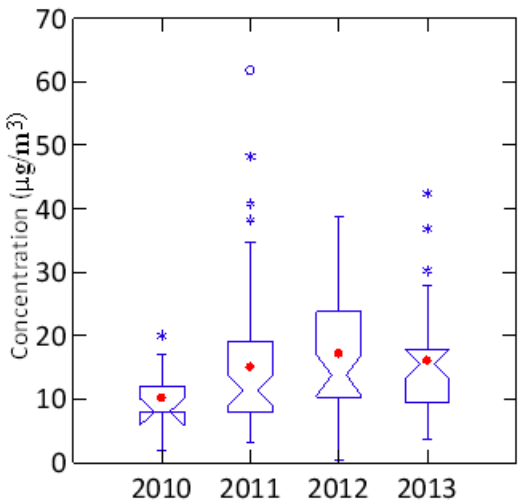

Figure 13. Box and Whisker Plot for Casper SLAMS (POC-5), 2009-2013

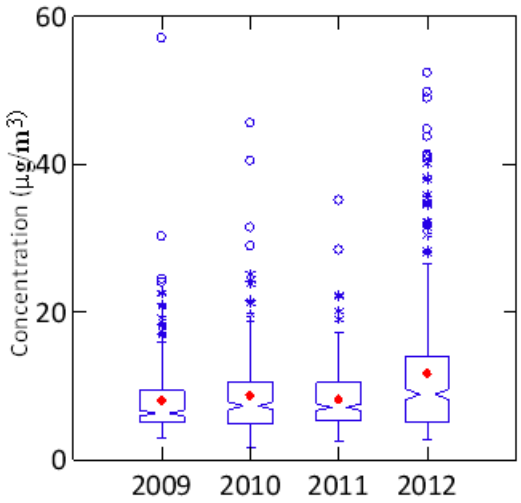

Figure 14. Box and Whisker Plot for Daniel South SPM, 2009-2012

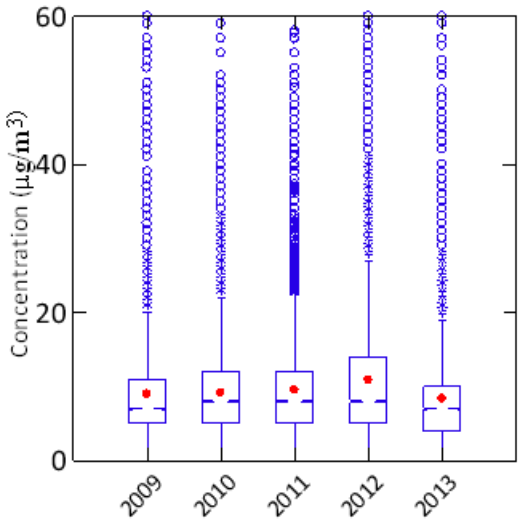

Figure 15. Box and Whisker Plot for Hourly Data at the Boulder SPM, 2009-2013

The data for the Wright Jr.-Sr. High School SPM were found to correlate highly (>80%) with data for six (6) nearby industrial PM_{10} monitors. Data for the Campbell County SPM were found to correlate highly (>80%) with data for twelve (12) nearby industrial monitors. Data for the Gillette SLAMS were found to correlate highly (>80%) with data for one (1) nearby industrial monitor.

Site Name	School Creek SC-1	Wright Jr.-Sr. High School	Campbell County	Belle Ayr BA-1	Coal Creek Mine Site 7	Buckskin West	Belle Ayr BA-3	Belle Ayr Ranch House	Eagle Butte Site EB-2	Gillette SLAMS	Cordero Rojo CRC-W11	Cordero Rojo CRC-S11	NARM NA-7	Eagle Butte Site EB-31	Black Thunder Mine Site 9-1/2	Eagle Butte Mine Rawhide Elementary	Wyodak Site 5
School Creek SC-1																	
Wright Jr.-Sr. High School	0.84																
Campbell County	0.85	0.79															
Belle Ayr BA-1	0.81	0.70	0.82														
Coal Creek Mine Site 7	0.78	0.77	0.80	0.82													
Buckskin West	0.78	0.78	0.86	0.73	0.73												
Belle Ayr BA-3	0.80	0.71	0.81	0.88	0.80	0.73											
Belle Ayr Ranch House	0.80	0.20	0.84	0.81	0.54	0.60	0.61										
Eagle Butte Site EB-2	0.00	0.86	0.75	0.80	0.82	0.72	0.79	0.00									
Gillette SLAMS	0.60	0.54	0.57	0.52	0.58	0.52	0.50	0.24	0.51								
Cordero Rojo CRC-W11	0.82	0.84	0.84	0.81	0.82	0.79	0.82	0.59	0.00	0.58							
Cordero Rojo CRC-S11	0.79	0.76	0.80	0.78	0.85	0.70	0.78	0.62	0.00	0.59	0.87						
NARM NA-7	0.92	0.86	0.86	0.76	0.75	0.81	0.77	0.66	0.73	0.51	0.80	0.76					
Eagle Butte Site EB-31	0.81	0.71	0.86	0.80	0.80	0.83	0.82	0.78	0.00	0.57	0.84	0.79	0.80				
Black Thunder Mine Site 9-1/2	0.85	0.86	0.81	0.73	0.79	0.74	0.74	0.57	0.75	0.53	0.77	0.74	0.87	0.75			
Eagle Butte Mine Rawhide Elementary	0.79	0.61	0.86	0.72	0.70	0.84	0.68	0.52	0.00	0.56	0.66	0.71	0.81	0.87	0.66		
Wyodak Site 5	0.65	0.85	0.67	0.78	0.84	0.73	0.70	0.70	0.00	0.86	0.75	0.79	0.64	0.57	0.69	0.53	

Table 9. PM_{10} Correlation Chart for Sites with at Least 80% Data Correlation

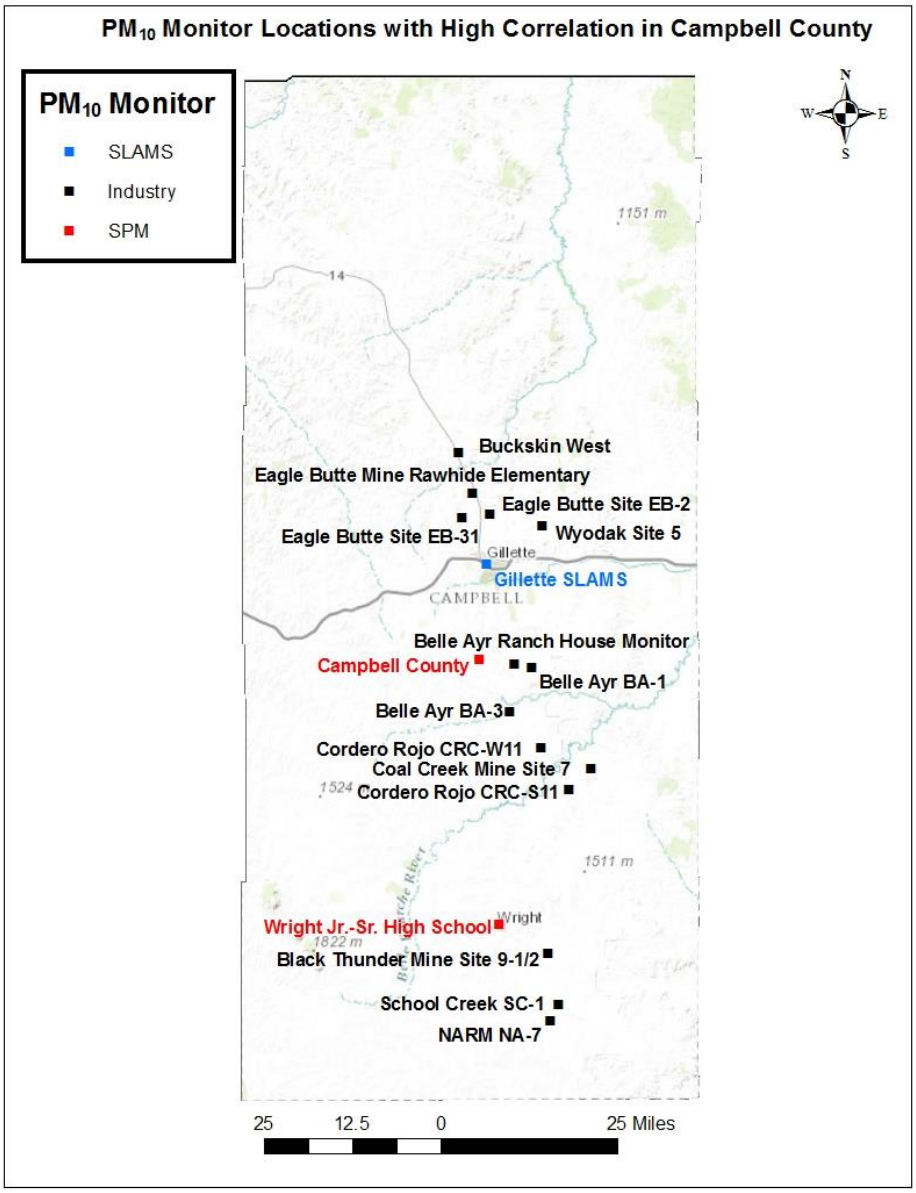

Figure 16. PM_{10} Monitor Locations with at Least 80% Data Correlation

3.2.1.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. Areas with a large (>500) population increase that lacked proximate PM_{10} monitoring coverage during the assessment period were Johnson County, southwest Crook County, and the city of Torrington. No areas with a large population decrease were found to be currently monitored, except for small pockets within major cities.

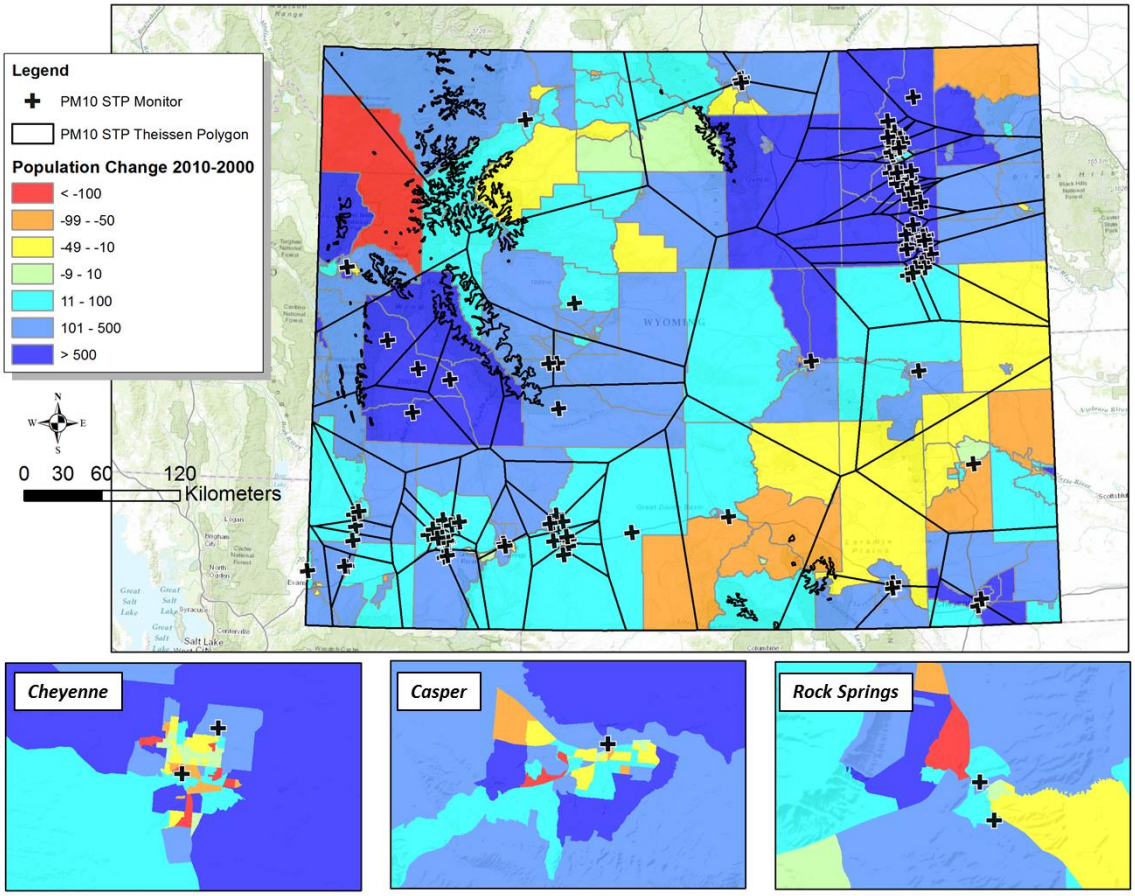

Figure 17. Population Change from 2000-2010 and PM_{10} Monitor Locations

Both Metropolitan Statistical Areas in the state, Laramie and Natrona Counties, were found to have current PM_{10} monitoring close to or within heavily populated areas. All heavily populated areas in Micropolitan Statistical Areas also had appropriate PM_{10} coverage.

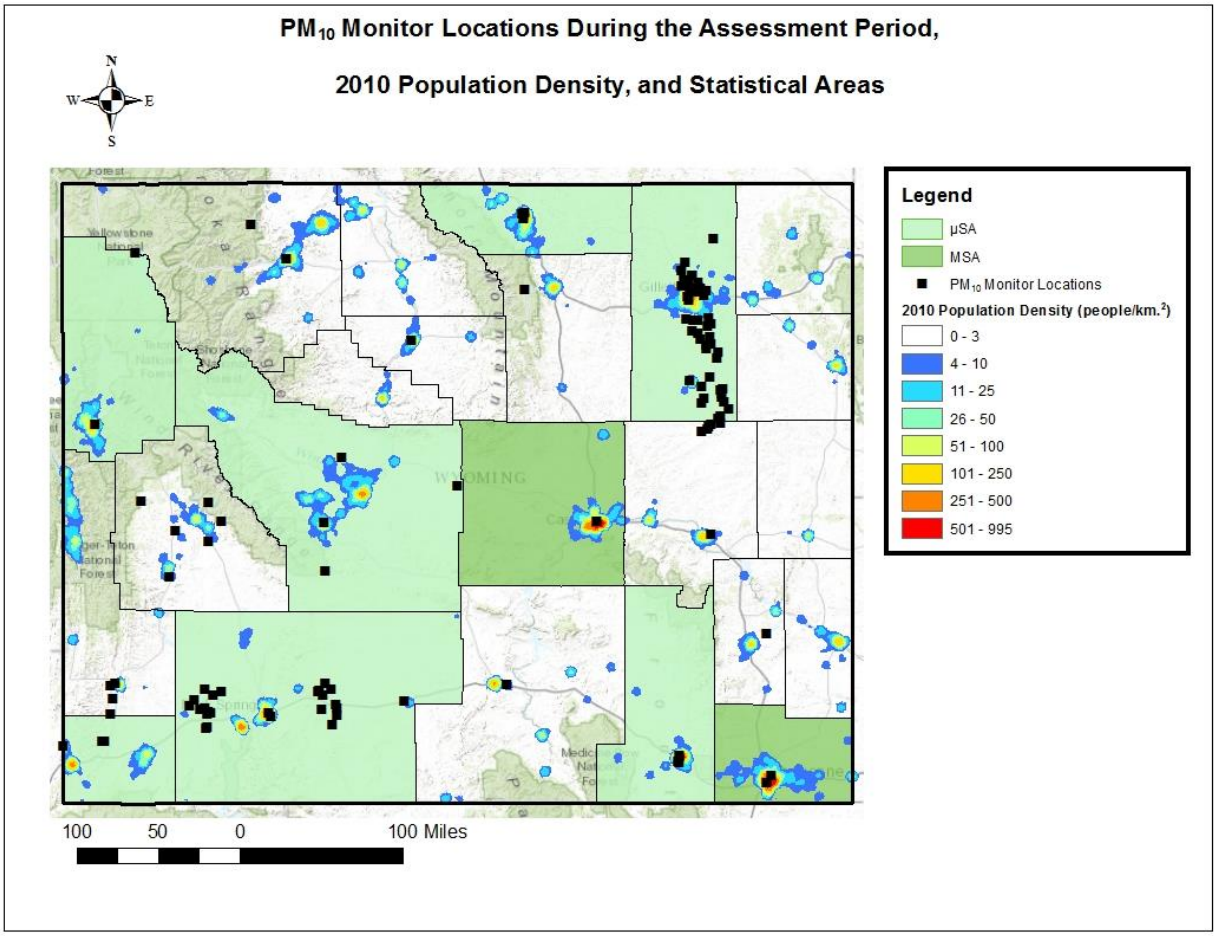

Figure 18. Statistical Areas in Wyoming with Population Density and PM_{10} Monitor Locations

3.2.1.3 Emission Analysis

The AQD examined emission inventory maps for PM_{10} in tandem with wind rose data to assess potential downwind receptors of emissions.

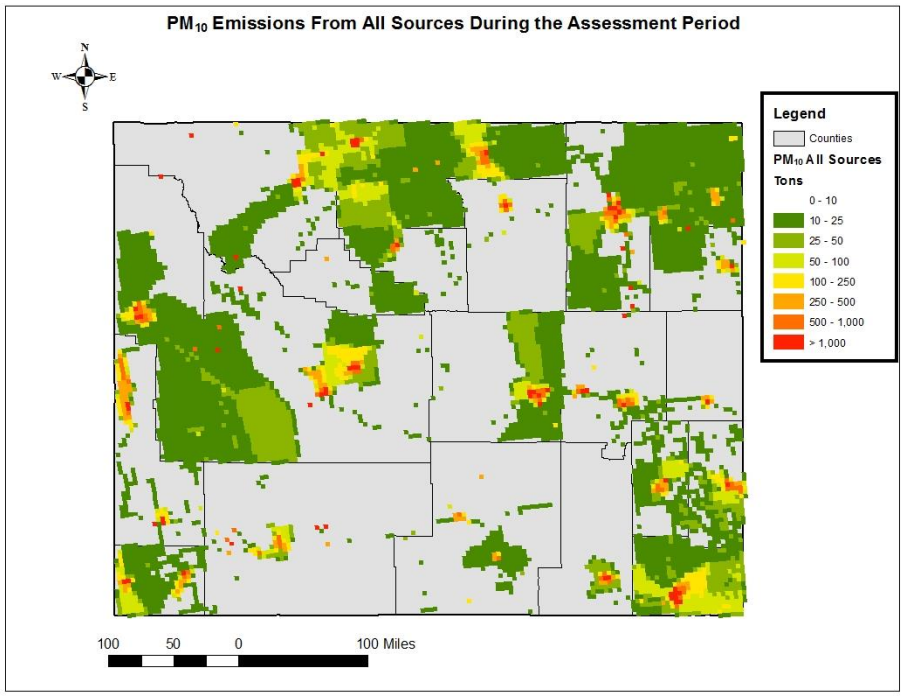

Figure 19. PM_{10} Emissions from All Sources

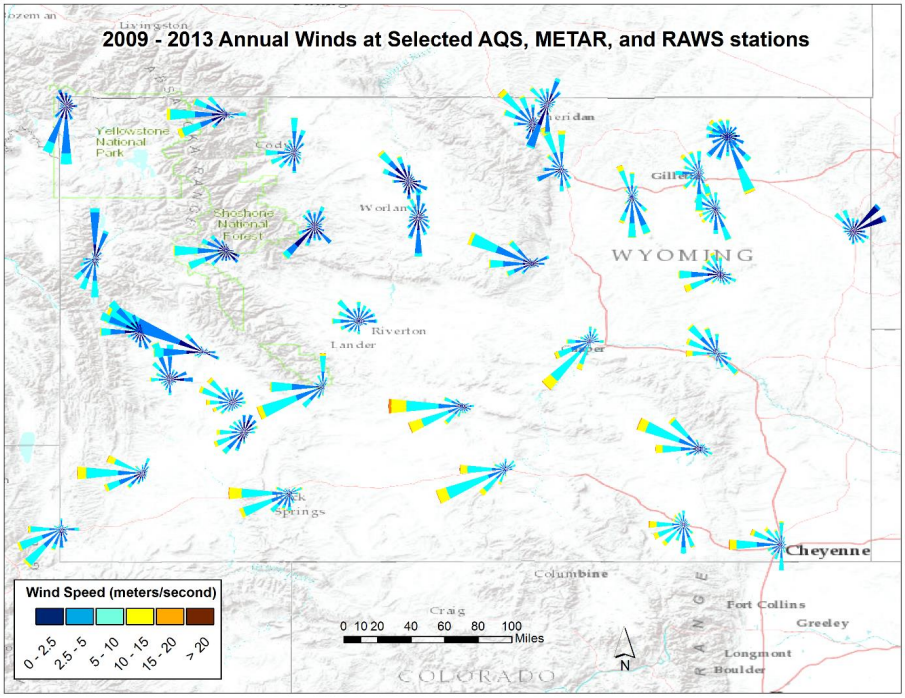

Figure 20. 2009-2013 Annual Wind Rose Map

According to the emissions inventory and wind rose maps, there are many non-point and non-road sources of PM_{10} emissions scattered around the cities of Torrington, Lovell, Afton, and southeast Sublette County.

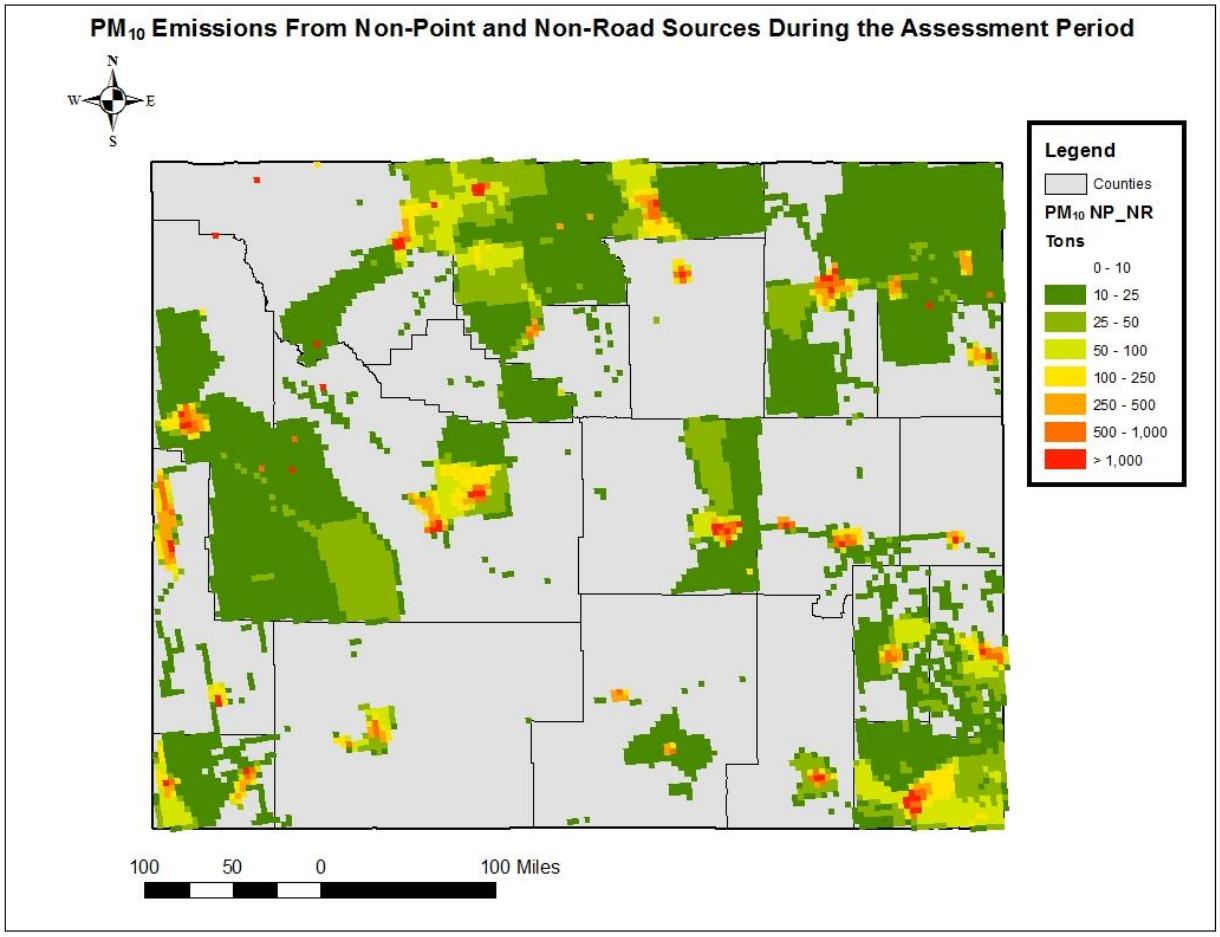

Figure 21. PM_{10} Emissions from Non-Point and Non-Road Sources

3.2.2 $PM_{2.5}$

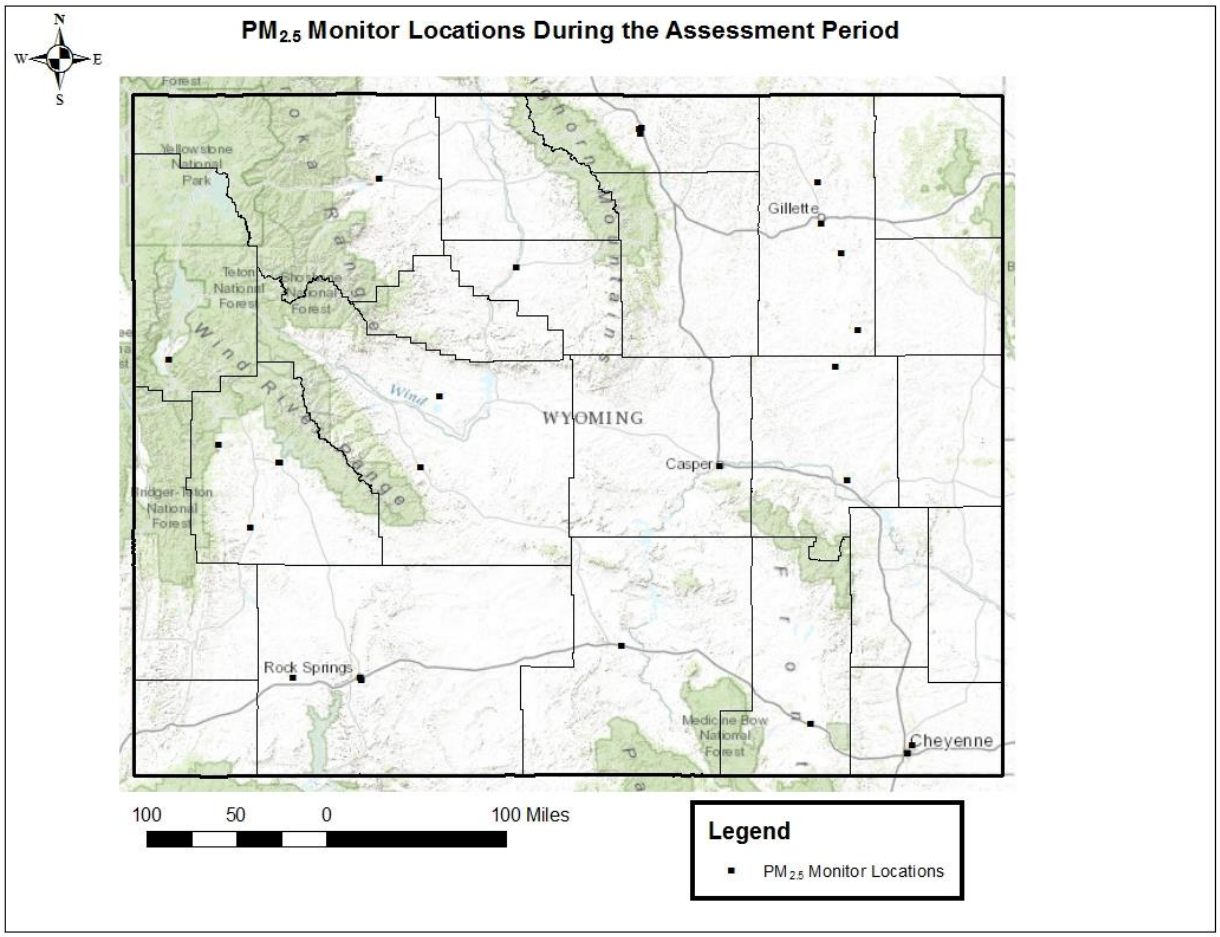

Figure 22. $PM_{2.5}$ Monitor Locations, 2009-2013

3.2.2.1 Data Analysis

An analysis of $PM_{2.5}$ data collected during the assessment period found no monitors with mean or median data significantly close to (>75% of) the NAAQS. Indeed, the mean and median values for every $PM_{2.5}$ monitor were found to be significantly below (<25% of) the NAAQS. However, these mean and median values were above the Minimum Detection Limit (MDL) of the monitors in question. No data displayed significant increasing or decreasing trends.

Four (4) AQD monitors, Lander SLAMS, Wyoming Range SPM, Pinedale Gaseous SPM, and Big Piney SPM were found to have measured at least two (2) exceedances of the NAAQS during

the assessment period. Wyoming was influenced by smoke from multiple wildfires in 2012 and some exceedances were flagged as Exceptional Events with documentation submitted to the EPA for concurrence.

AQS ID	Site Name	24-hr $PM_{2.5}$ Average ($\mu g/m^3$)	Date of Exceedance	Exceptional Event Submitted to the EPA (Y/N)?	Type of Exceptional Event*[3]
56-013-1003	Lander SLAMS	37.8	12/9/2009	N	N/A
		37.8	12/15/2009	N	N/A
		41.8	6/29/2012	Y	*RT
56-035-0101	Pinedale Gaseous	47.0	6/26/2012	Y	*RT
		44.8	9/20/2012	Y	*RT
56-035-0097	Wyoming Range	52.3	9/20/2012	Y	*RT
		39.1	9/18/2012	Y	*RT
56-035-0700	Big Piney Site #3	143.7	6/30/2012	Y	*RT
		110.6	6/29/2012	Y	*RT
		97.4	7/2/2012	Y	*RT
		85.4	7/1/2012	Y	*RT
		74.7	7/3/2012	Y	*RT
		68.4	7/4/2012	Y	*RT
		53.8	6/28/2012	Y	*RT
		38.6	7/5/2012	Y	*RT

Table 10. AQD Sites with Two (2) or More $PM_{2.5}$ Exceedances, 2009-2013

The data for the Cheyenne NCore monitor were found to correlate highly (>80%) with data for Cheyenne SLAMS and Laramie SLAMS.

Site Name	Laramie SLAMS	Cheyenne SLAMS	Cheyenne NCore
Laramie SLAMS			
Cheyenne SLAMS	0.47		
Cheyenne NCore	0.81	0.98	

Table 11. $PM_{2.5}$ Correlation Chart for Sites with at Least 80% Data Correlation

[3] *RT is an AQS data qualifier code requesting an exceptional event exclusion due to a U.S. Wildfire

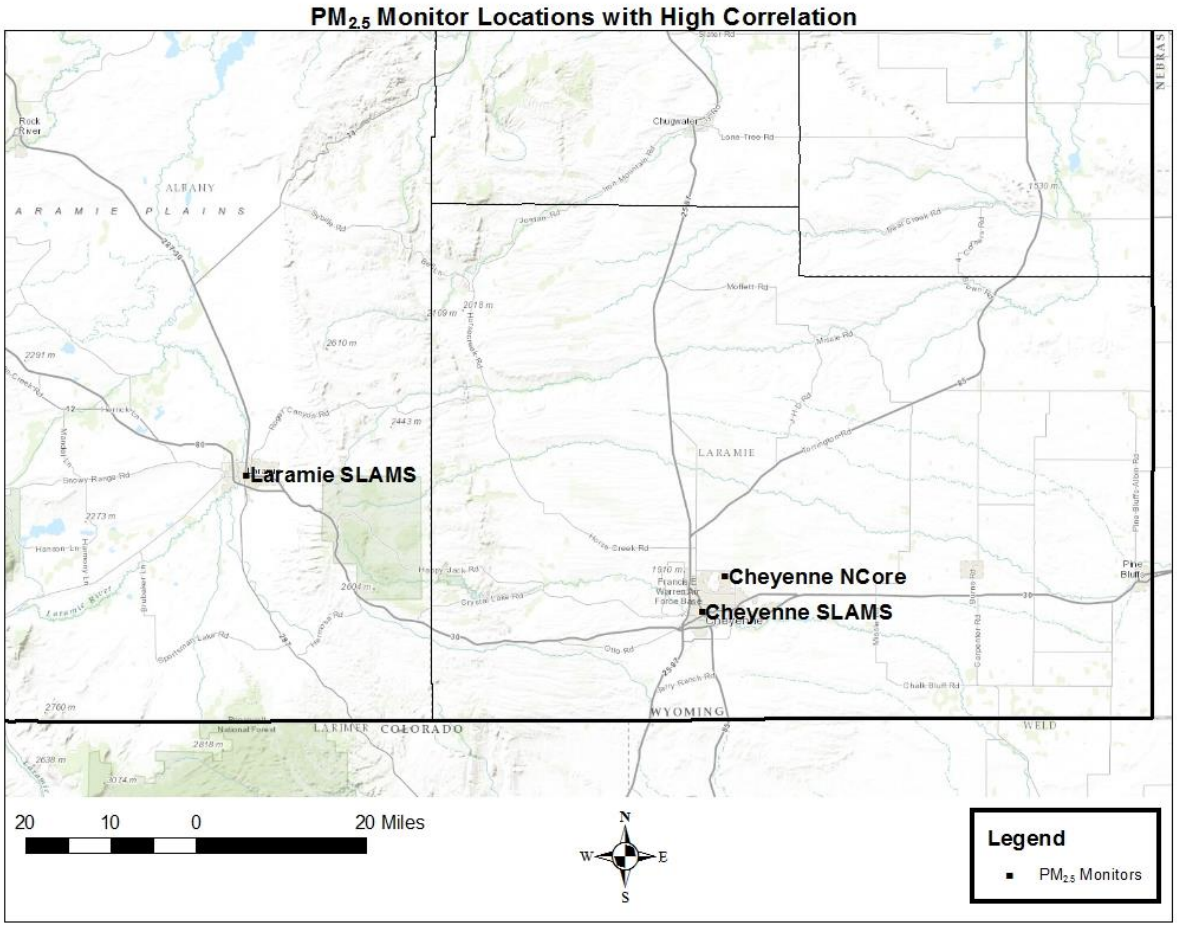

Figure 23. $PM_{2.5}$ Monitor Locations with at Least 80% Data Correlation

3.2.2.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. Areas with a large (>500) population increase that lacked proximate $PM_{2.5}$ monitoring coverage during the assessment period were Johnson County, southwest Crook County, and the cities of Torrington and Afton. No areas with a large population decrease were found to be currently monitored, except for small pockets within major cities.

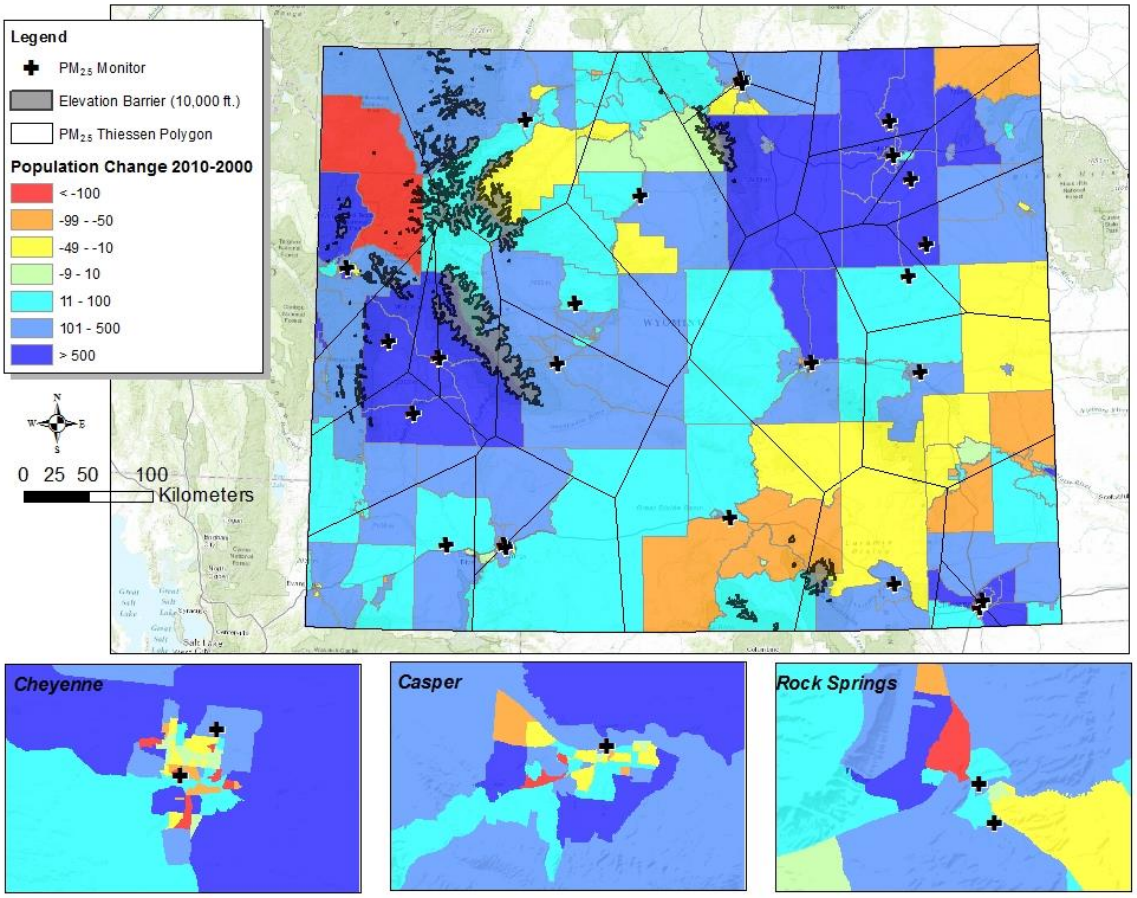

Figure 24. Population Change from 2000-2010 and $PM_{2.5}$ Monitor Locations

Both Metropolitan Statistical Areas in the state, Laramie and Natrona Counties, were found to have current $PM_{2.5}$ monitoring close to or within heavily populated areas. All heavily populated areas in Micropolitan Statistical Areas also had appropriate $PM_{2.5}$ coverage with the exception of Evanston in Uinta County.

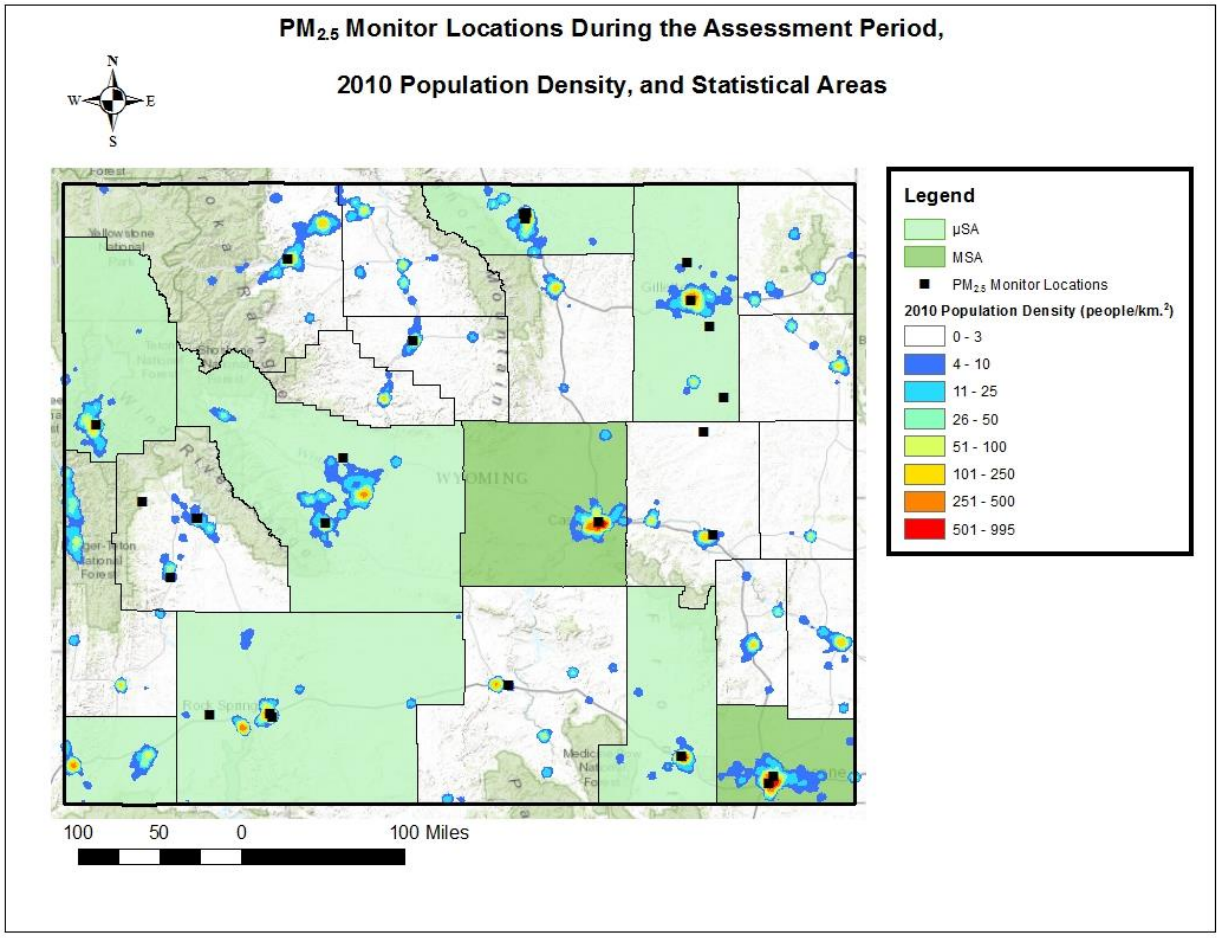

Figure 25. Statistical Areas in Wyoming with Population Density and $PM_{2.5}$ Monitor Locations

3.2.2.3 Emission Analysis

The AQD examined emission inventory maps for $PM_{2.5}$ in tandem with wind rose data to assess potential downwind receptors of emissions.

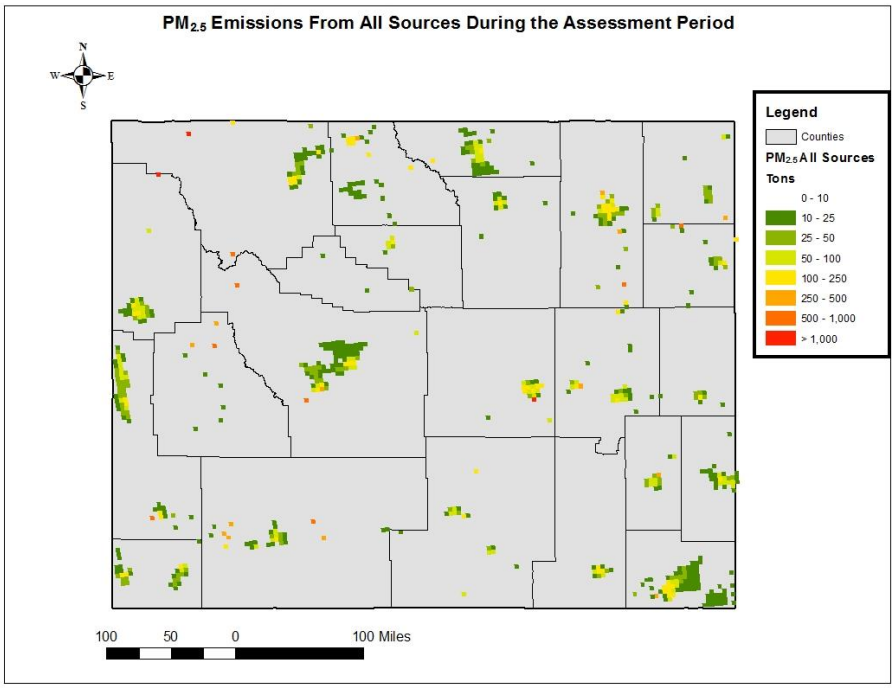

Figure 26. $PM_{2.5}$ Emissions from All Sources

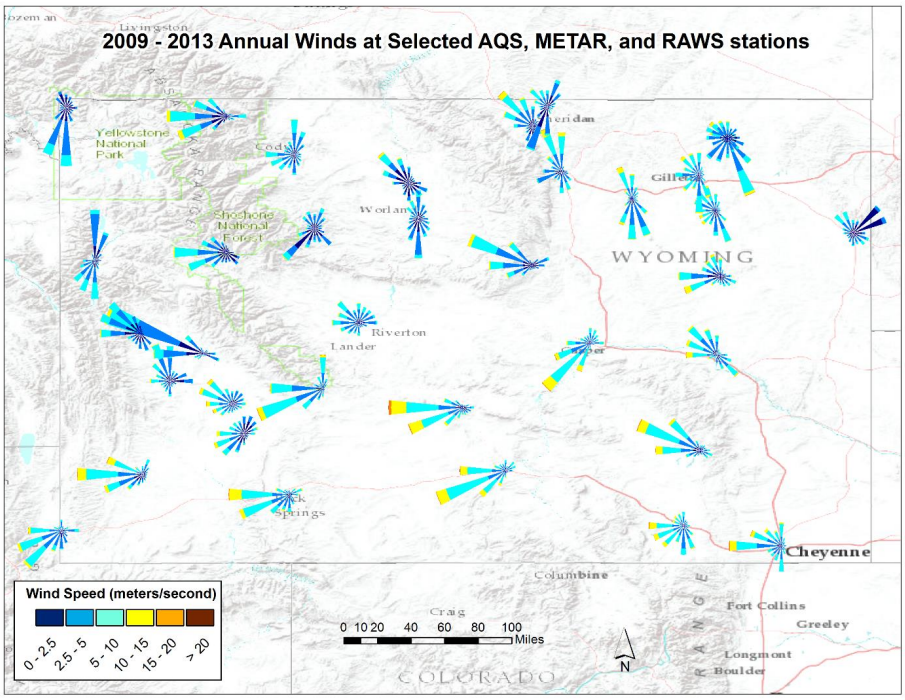

Figure 27. 2009-2013 Annual Wind Rose Map

According to the emission inventory and wind rose maps, there are somewhat large, currently unmonitored non-point, non-road $PM_{2.5}$ emissions around the cities of Afton, Torrington, Evanston, and Wheatland.

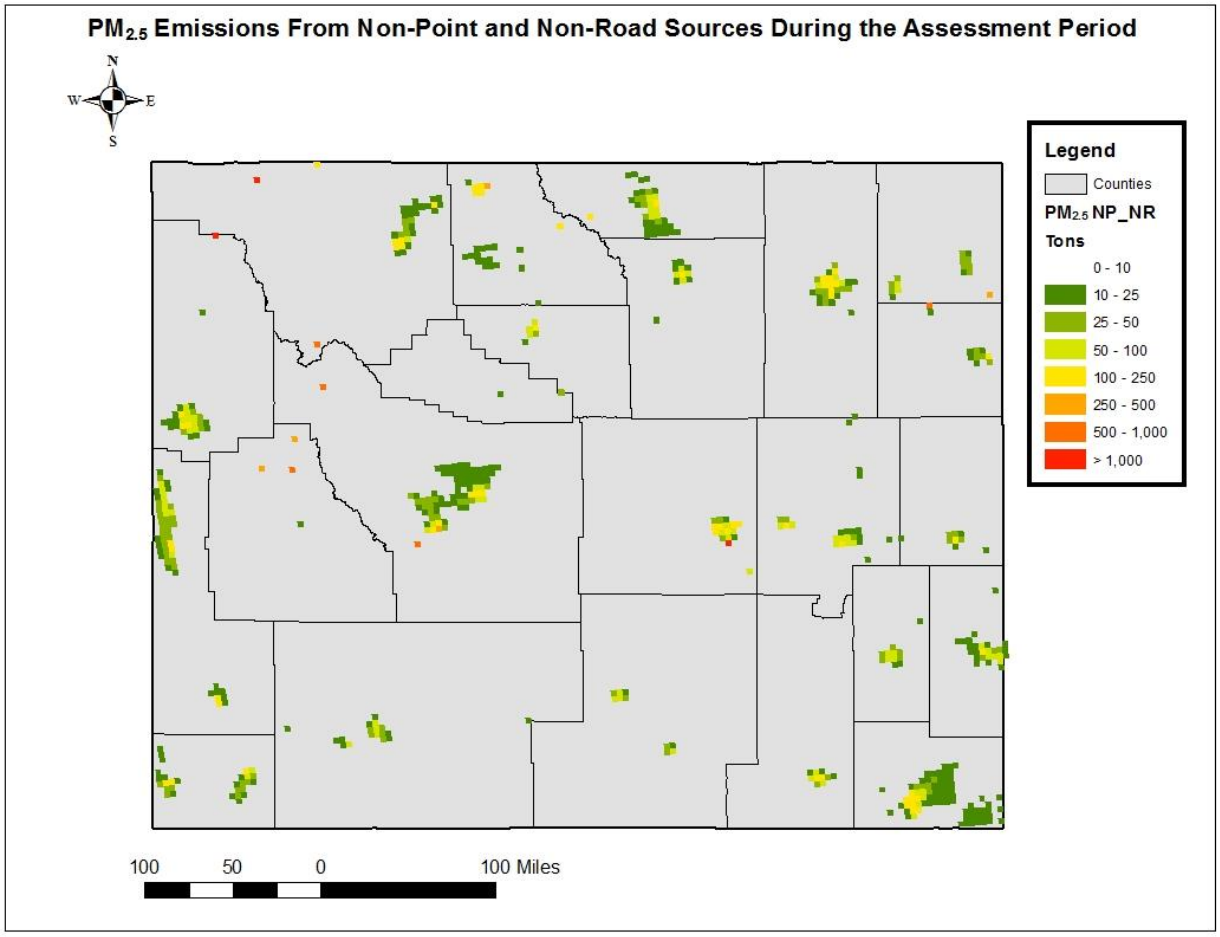

Figure 28. $PM_{2.5}$ Emissions from Non-Point and Non-Road Sources

The AQD ran a HYSPLIT Backward Trajectory from Torrington, which indicated that this town might see $PM_{2.5}$ impacts not only from local sources but also from current and future oil and gas emissions in Converse, Campbell, and Johnson Counties.

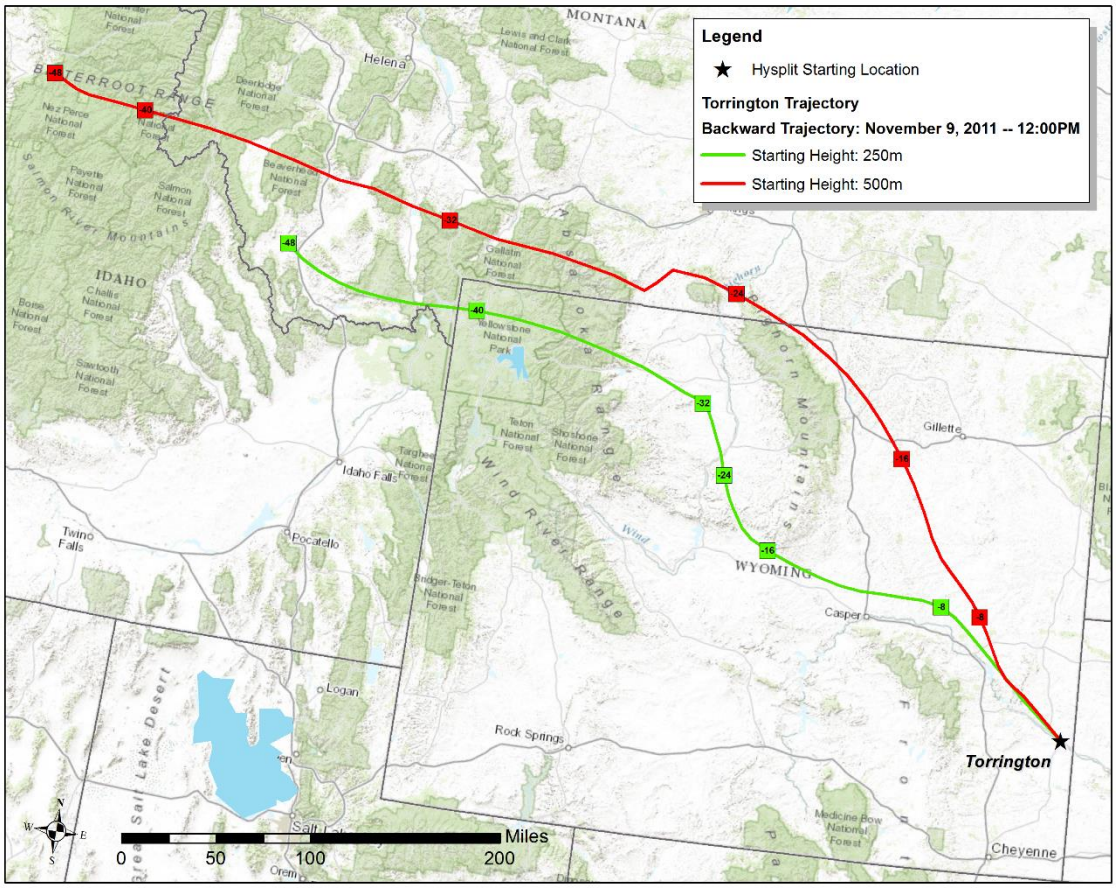

Figure 29. Torrington HYSPLIT Backward Trajectory

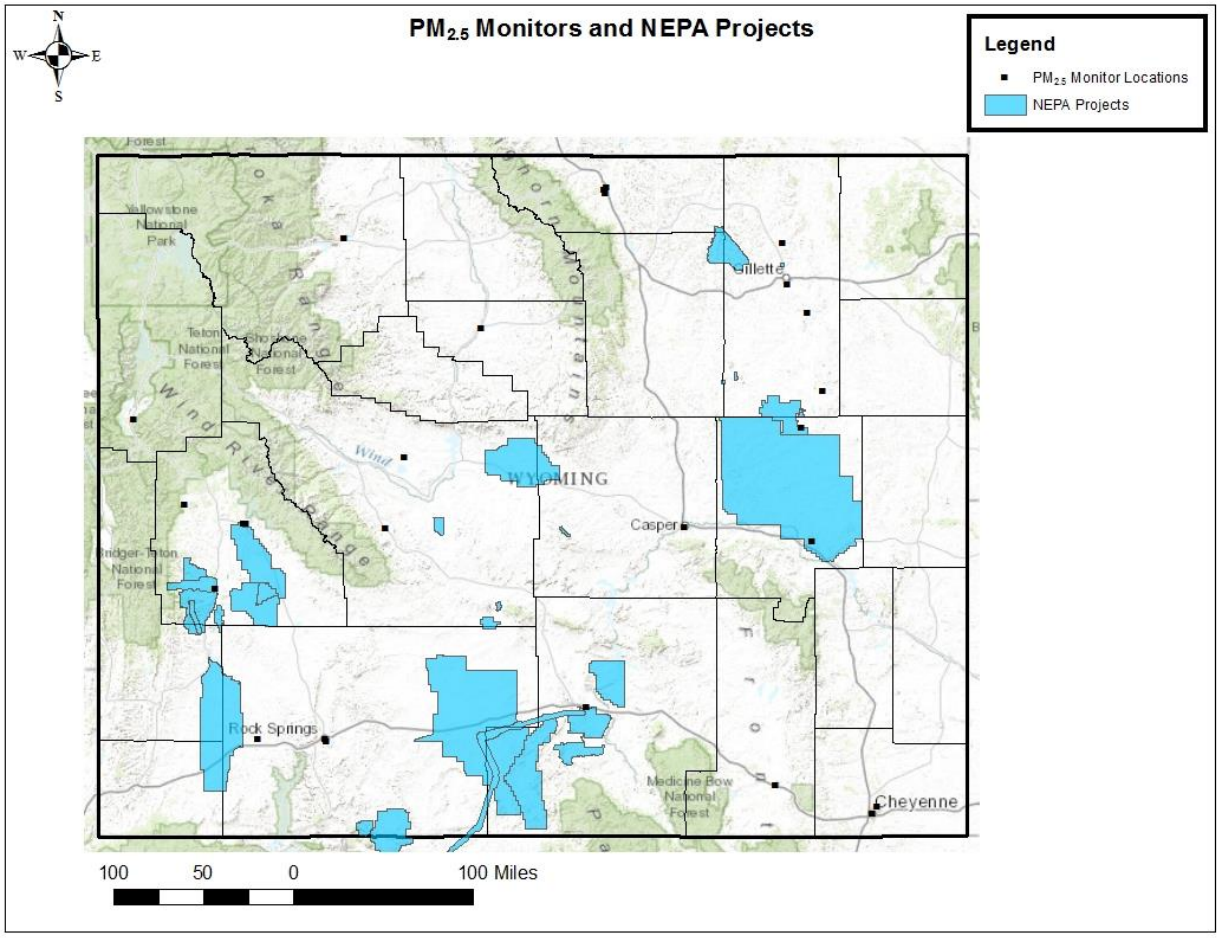

Figure 30. NEPA Project Map with $PM_{2.5}$ Monitor Locations

A Backward Trajectory run for Evanston indicated that in addition to local $PM_{2.5}$ sources, this city is potentially exposed to pollution transported from neighboring states. The present emissions analysis did not include out of state emissions.

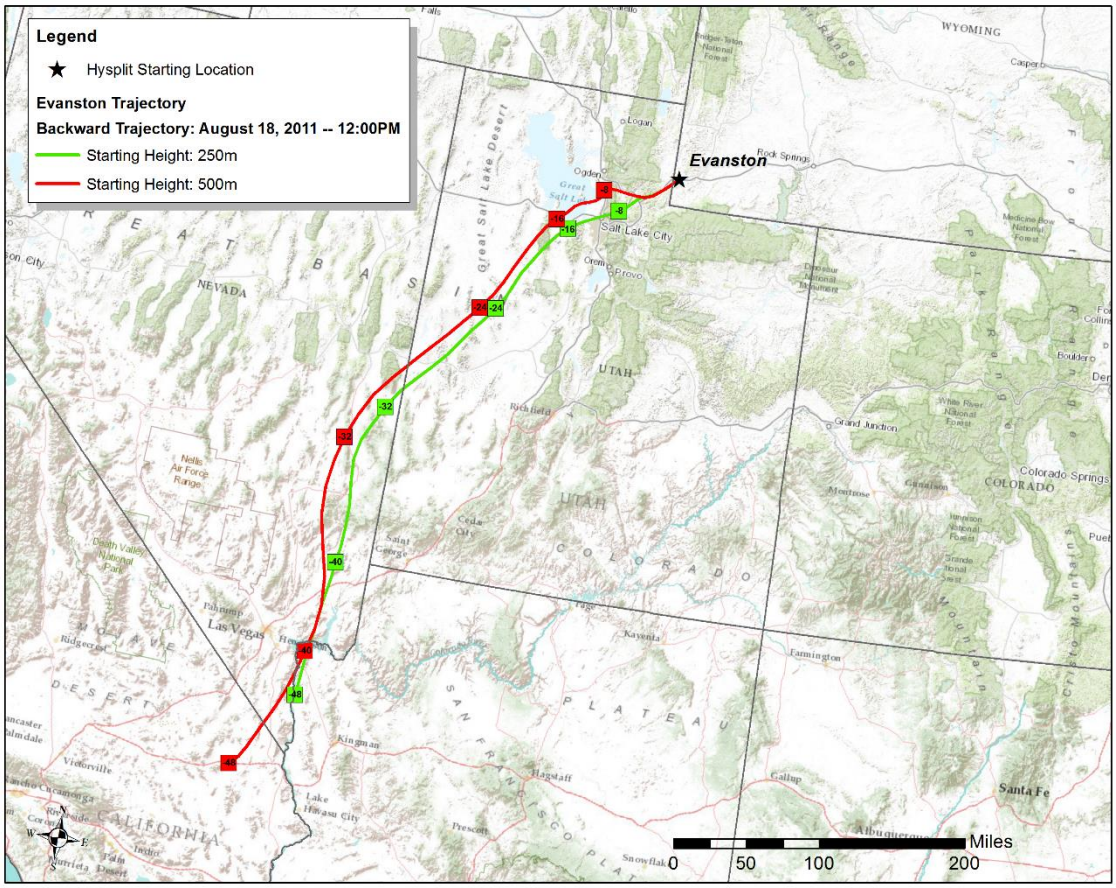

Figure 31. Evanston HYSPLIT Backward Trajectory

3.2.3 O_3

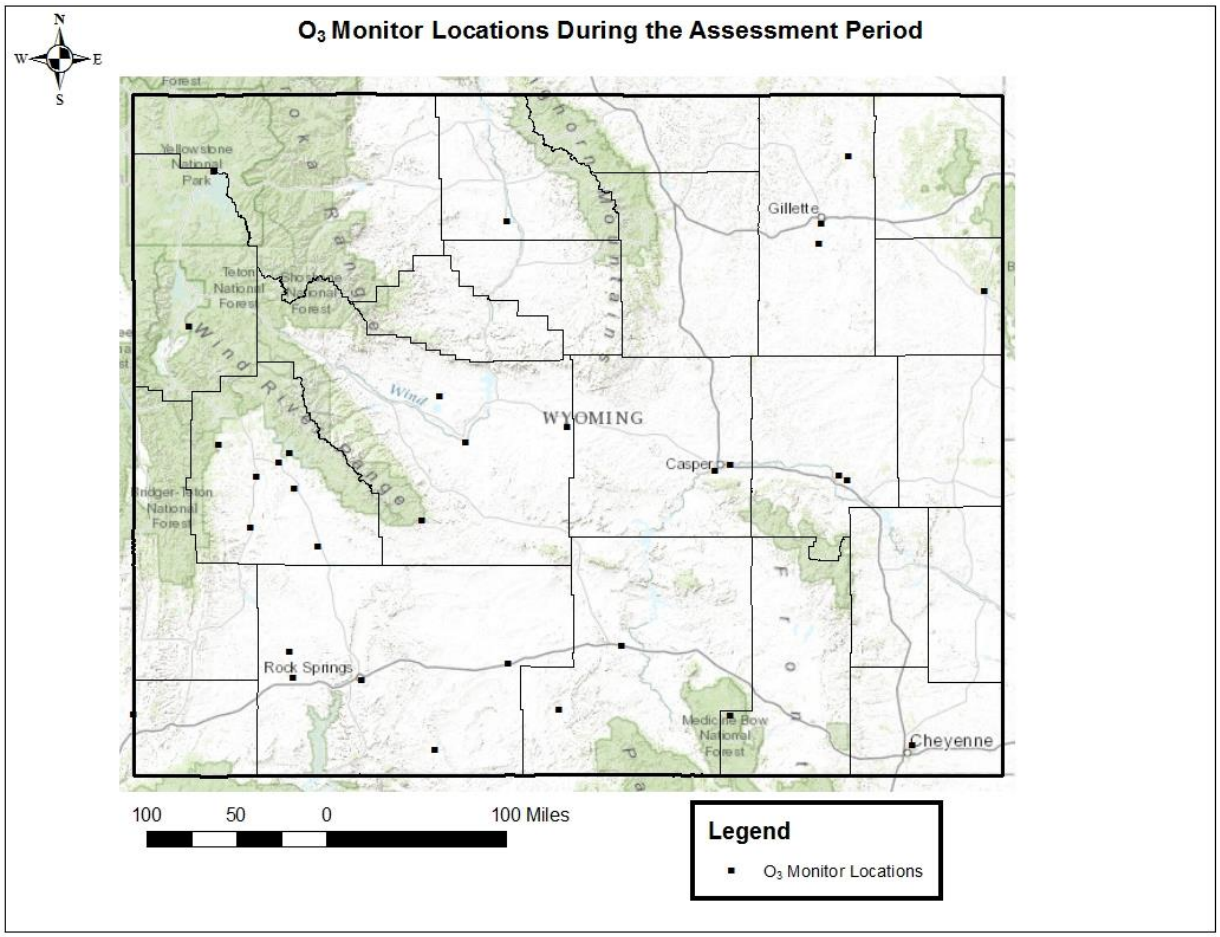

Figure 32. O_3 Monitor Locations, 2009-2013

3.2.3.1 Data Analysis

An analysis of O_3 data collected during the assessment period found no monitors with mean or median data significantly close to (>75% of), or below (<25% of), the NAAQS. Mean and median values for all stations were found to be around 0.040 ppm. However, six AQD monitors were found to have measured at least two (2) exceedances of the NAAQS during the assessment period. Five of the six of these exceeding monitors are within Wyoming's Nonattainment Area for O_3, and are being addressed. The AQD has also flagged several exceptional events for stratospheric intrusion and forwarded the request to EPA for concurrence.

AQS ID	Site Name	8-hr O_3 Average (ppm)	Date of Exceedance	Exceptional Event Submitted to the EPA (Y/N)?	Type of Exceptional Event*[4]
56-013-0099	South Pass	0.093	3/11/2009	Y	*RO
		0.089	3/10/2009	Y	*RO
		0.083	3/12/2009	Y	*RO
		0.080	3/13/2009	Y	*RO
		0.079	3/7/2009	Y	*RO
		0.078	2/28/2009	Y	*RO
		0.077	3/6/2009	Y	*RO
		0.081	5/30/2011	Y	*RO
56-035-0097	Wyoming Range	0.083	3/10/2011	N	N/A
		0.080	2/15/2011	N	N/A
		0.079	3/2/2011	N	N/A
56-035-0099	Boulder	0.123	3/2/2011	N	N/A
		0.121	3/12/2011	N	N/A
		0.120	3/1/2011	N	N/A
		0.103	3/5/2011	N	N/A
		0.087	2/14/2011	N	N/A
		0.084	3/3/2011	N	N/A
		0.078	3/14/2011	N	N/A
		0.076	2/21/2011	N	N/A
		0.076	6/14/2012	Y	*RO
56-035-0100	Daniel South	0.084	3/10/2011	N	N/A
		0.079	3/14/2011	N	N/A
		0.077	3/6/2011	N	N/A
56-035-0101	Pinedale Gaseous	0.089	3/2/2011	N	N/A
		0.083	3/1/2011	N	N/A
		0.080	3/5/2011	N	N/A
		0.076	3/9/2011	N	N/A
56-035-1002	Juel Spring	0.094	3/2/2011	N	N/A
		0.085	3/12/2011	N	N/A
		0.085	3/15/2011	N	N/A
		0.076	3/5/2011	N	N/A

Table 12. AQD Monitors with Two (2) or More O_3 Exceedances, 2009-2013

Data from the Hiawatha monitor were found to exhibit a statistically significant increasing trend at a 98% confidence level. However, a visual inspection of the distribution of data found that this trend equates roughly to a 3 ppb increase in median values from 2011 to 2013.

[4] *RO is an AQS data qualifier code requesting an exceptional event exclusion due to a stratospheric O_3 intrusion.

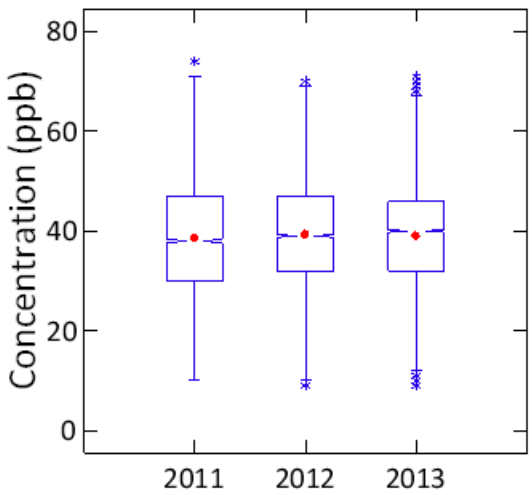

Figure 33. Box and Whisker Plot for Hiawatha, 2011-2013

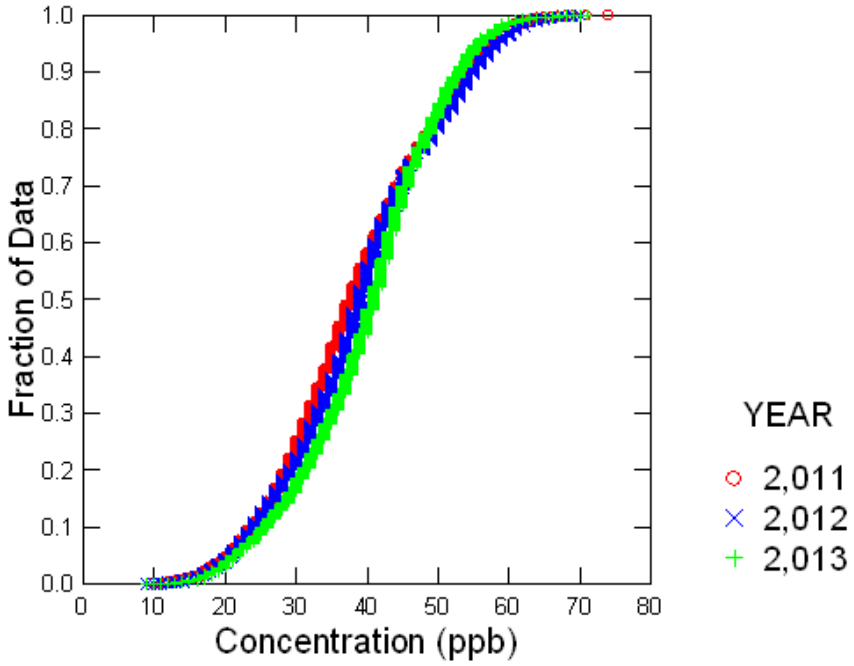

Figure 34. Cumulative Distribution Function by Year for Hiawatha

O_3 data from many AQD stations were found to correlate highly (>80%) with at least one other station. Given the spatial distribution of sites in the statewide network with a large amount of monitors clustered around and within the Upper Green River Basin nonattainment area, these correlations are unsurprising.

Site Name	Thunder Basin	Campbell County	Tallgrass Gaseous	Converse County (Mobile #3)	Casper Gaseous	Sinclair Casper Refinery	Wyoming Range	Boulder	Daniel South	Pinedale Gaseous	Big Piney Site #3	Juel Spring	Pinedale CASTNET	Hiawatha	Rock Springs (Mobile #1)	Wamsutter	Moxa Arch	Murphy Ridge
Thunder Basin																		
Campbell County	0.83																	
Tallgrass Gaseous	0.70	0.74																
Converse County (Mobile #3)	0.74	0.73	0.87															
Casper Gaseous	0.63	0.66	0.69	0.73														
Sinclair Casper Refinery	0.64	0.66	0.78	0.75	0.82													
Wyoming Range	0.34	0.32	0.43	0.35	0.34	0.27												
Boulder	0.68	0.66	0.63	0.66	0.63	0.61	0.58											
Daniel South	0.65	0.65	0.63	0.61	0.62	0.62	0.58	0.85										
Pinedale Gaseous	0.60	0.61	0.57	0.56	0.58	0.61	0.48	0.81	0.92									
Big Piney Site #3	0.67	0.66	0.65	0.65	0.64	0.65	0.52	0.87	0.90	0.87								
Juel Spring	0.68	0.65	0.65	0.67	0.64	0.63	0.60	0.85	0.83	0.78	0.85							
Pinedale CASTNET	0.51	0.47	0.45	0.51	0.49	0.39	0.80	0.71	0.65	0.56	0.60	0.72						
Hiawatha	0.64	0.66	0.65	0.65	0.63	0.67	0.39	0.74	0.79	0.77	0.79	0.76	0.50					
Rock Springs (Mobile #1)	0.68	0.68	0.66	0.70	0.68	0.73	0.43	0.80	0.77	0.73	0.81	0.78	0.55	0.79				
Wamsutter	0.64	0.65	0.68	0.69	0.69	0.69	0.37	0.70	0.75	0.73	0.76	0.74	0.48	0.83	0.78			
Moxa Arch	0.67	0.67	0.65	0.68	0.65	0.65	0.51	0.84	0.80	0.75	0.84	0.83	0.63	0.79	0.87	0.74		
Murphy Ridge	0.63	0.60	0.60	0.63	0.58	0.59	0.59	0.77	0.73	0.66	0.76	0.78	0.68	0.69	0.75	0.66	0.80	

Table 13. O_3 Correlation Chart for Sites with at Least 80% Data Correlation

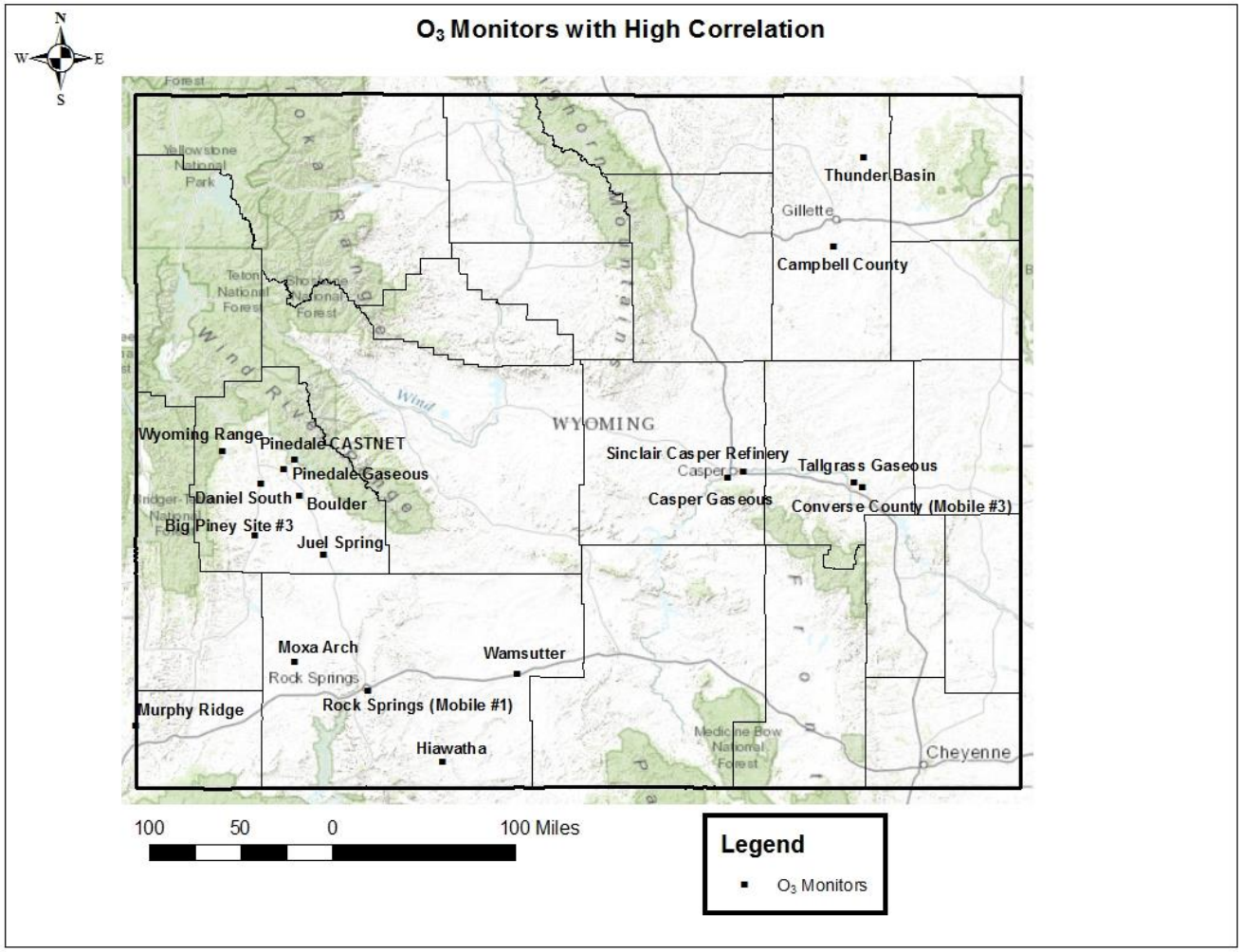

Figure 35. O_3 Monitor Locations with at Least 80% Data Correlation

3.2.3.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. The only area with a large (>500) population increase that lacked proximate O_3 monitoring coverage during the assessment period was Johnson County. No areas with a large population decrease were found to be currently monitored, except for small pockets within major cities.

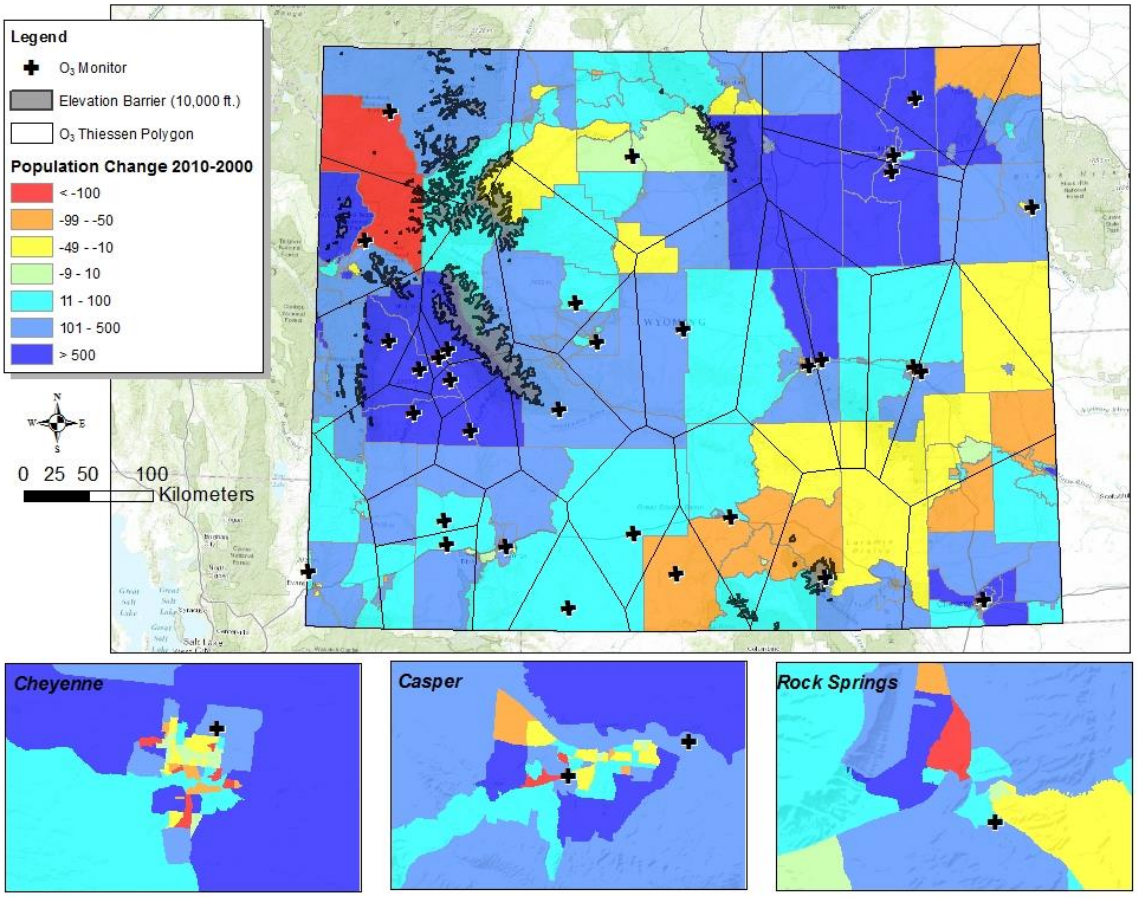

Figure 36. Population Change from 2000-2010 and O_3 Monitor Locations

Both Metropolitan Statistical Areas in the state, Laramie and Natrona Counties, were found to have current O_3 monitoring close to or within heavily populated areas. All heavily populated areas in Micropolitan Statistical Areas also had appropriate O_3 coverage with the exception of the cities of Laramie and Sheridan.

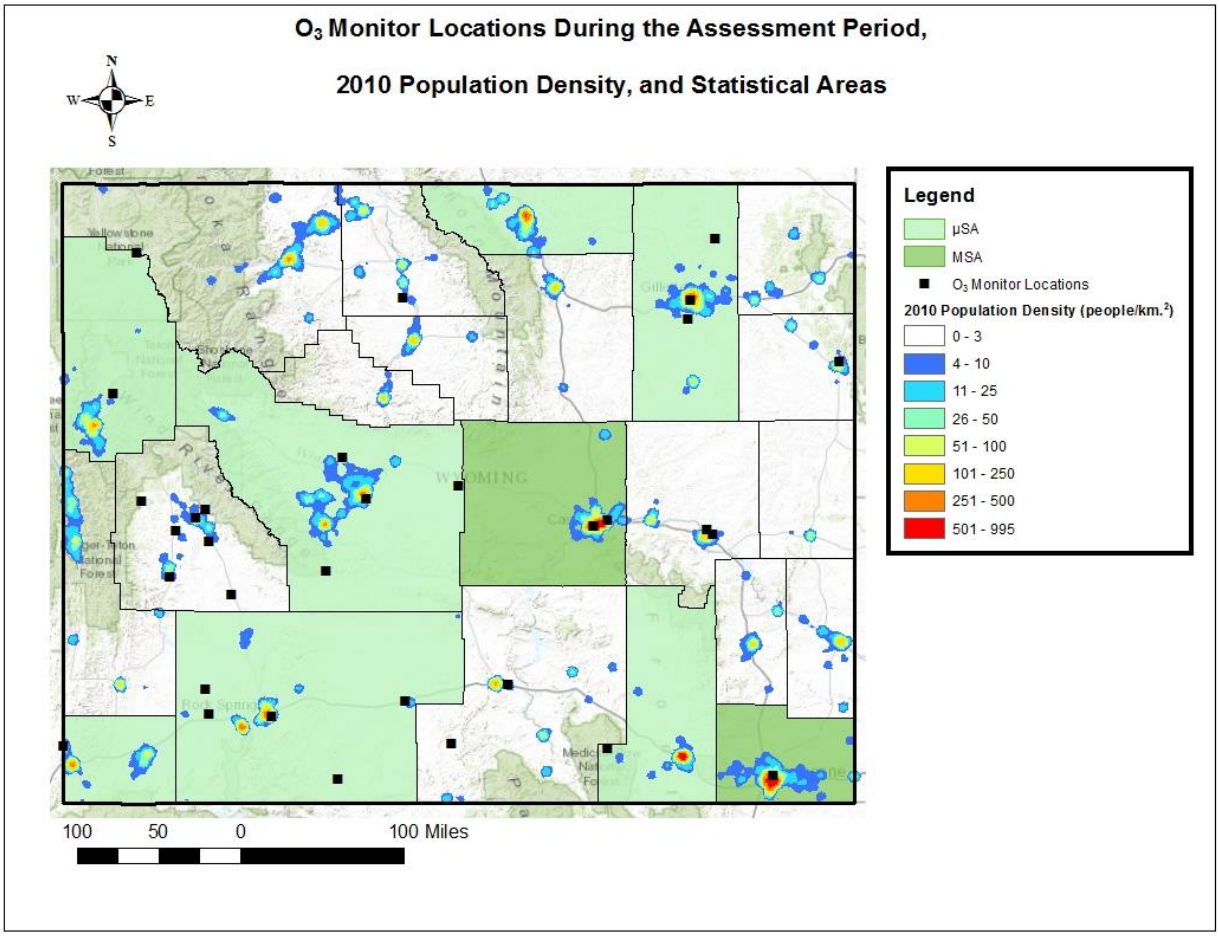

Figure 37. Statistical Areas in Wyoming with Population Density and O_3 Monitor Locations

The AQD considered potential impacts to at-risk minority populations that might exist in currently unmonitored locations across the state. An analysis of demographic information from 2010 revealed that 21.5% of the population of Albany County lives below the poverty level, with 46.5% of individuals residing in rental units. These percentages are the highest in the state for both of these indices. It was also recognized that the city of Sheridan has a sizeable Veteran's Affairs Hospital, serving a population potentially more susceptible to the adverse effects of O_3.

3.2.3.3 Emission Analysis

Because O_3 is a secondary pollutant formed through chemical interactions with precursor pollutants including NO_x and VOC emissions, the AQD examined gridded emission inventory data maps for NO_x and VOCs as approximate temporal indications of O_3 formation. These emission inventory maps were examined in tandem with wind rose data to assess potential downwind receptors of emissions.

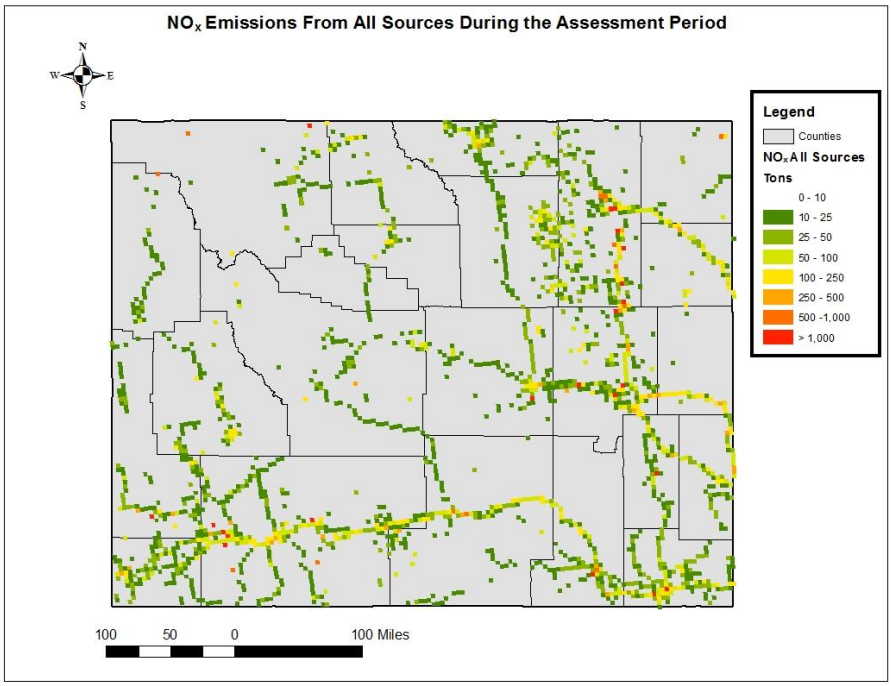

Figure 38. NO_x Emissions from All Sources

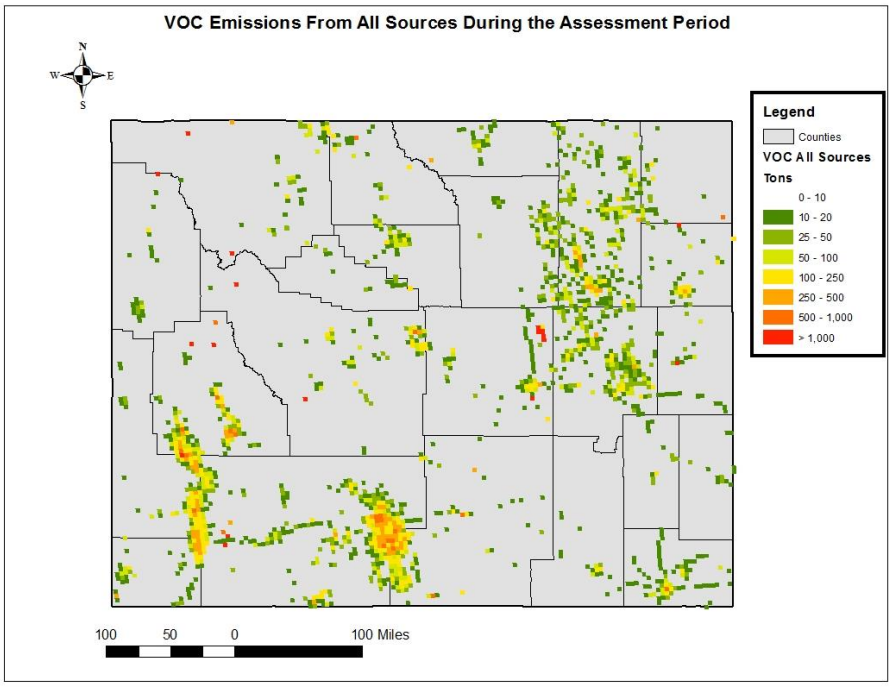

Figure 39. VOC Emissions from All Sources

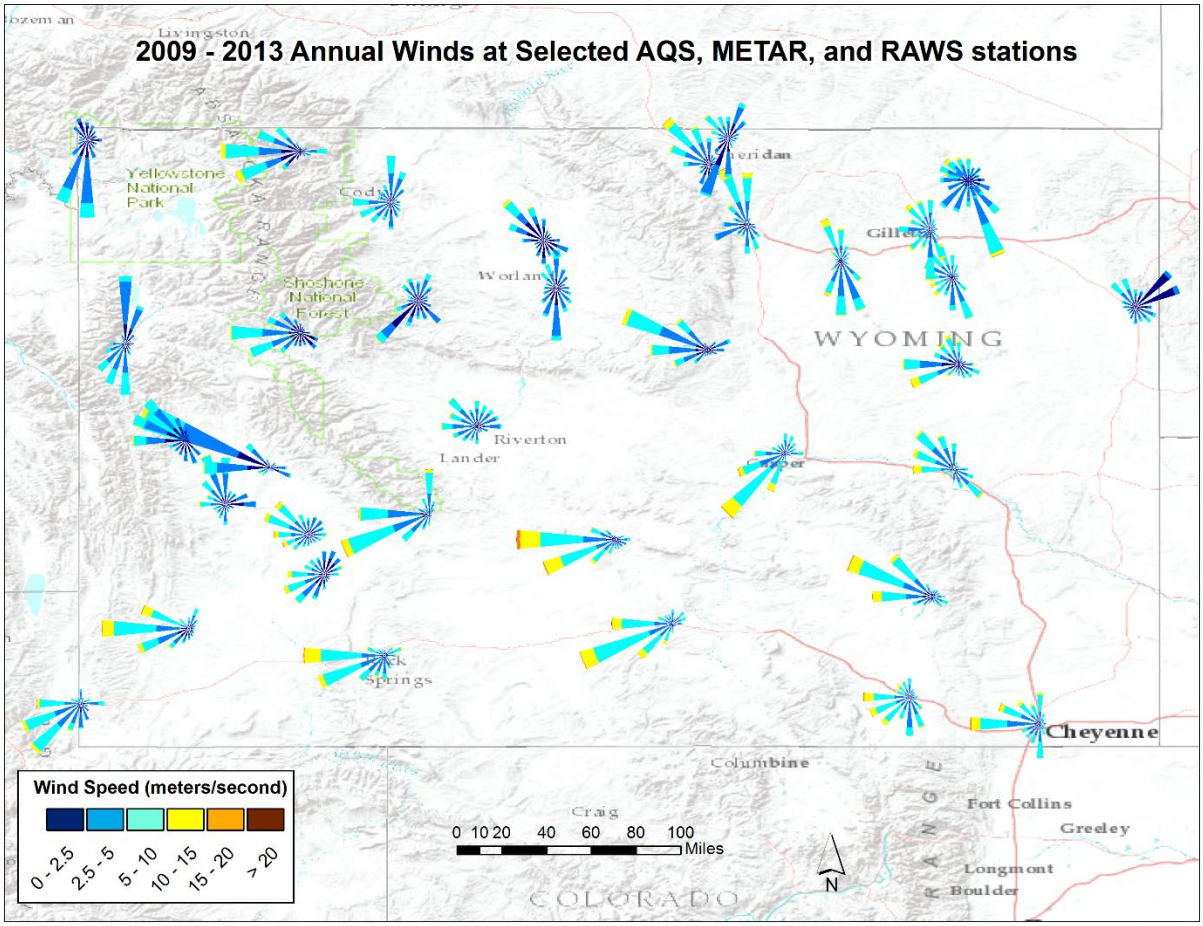

Figure 40. 2009-2013 Annual Wind Rose Map

According to the emissions inventory and wind rose maps, there are many small sources of both pollutants scattered north (generally upwind) of Sheridan. These maps also indicate that Torrington is downwind of a large point source near Wheatland. The AQD ran a HYSPLIT Backward Trajectory from Torrington, which indicated that this town might see O_3 impacts not only from this source, but, given the long atmospheric residency time of O_3, also from oil and gas and point emissions in Converse, Campbell, and Johnson Counties.

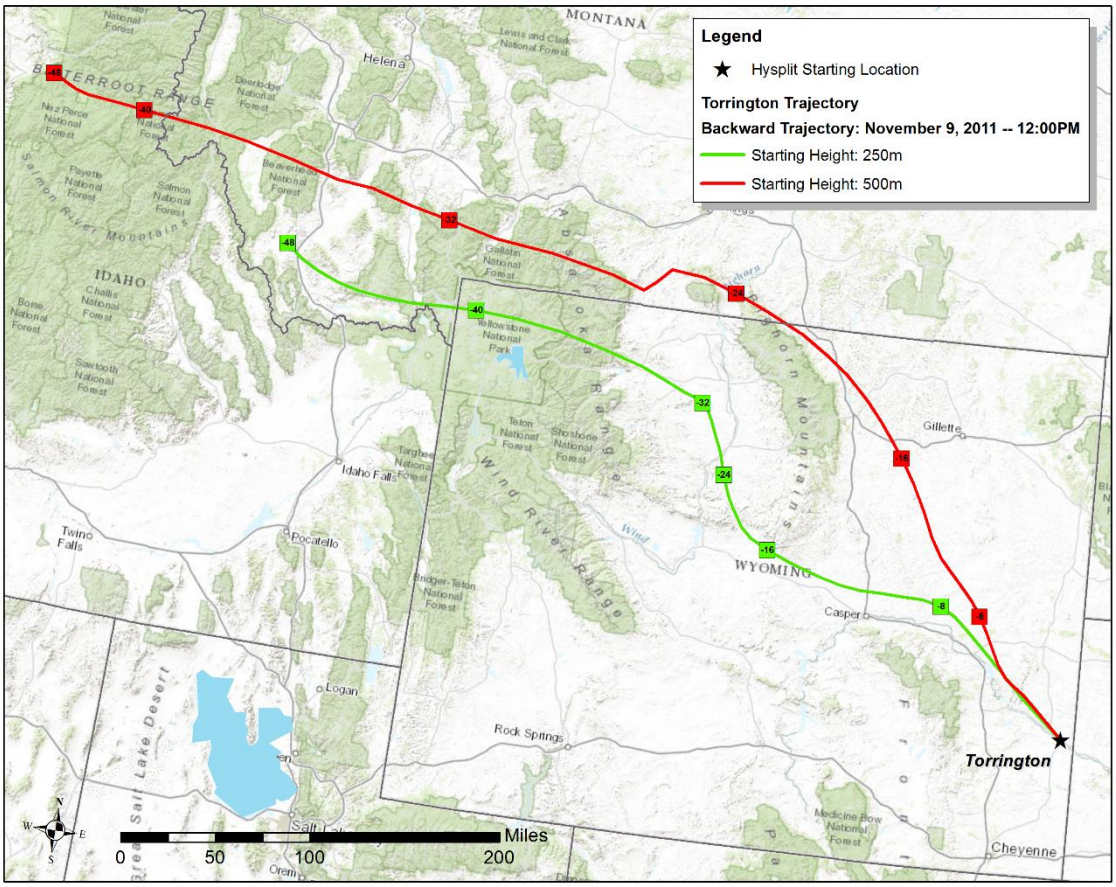

Figure 41. Torrington HYSPLIT Backward Trajectory

A large cluster of oil and gas and point sources for both parameters were identified in eastern Johnson County, Campbell County, and north-central Converse County. The AQD also noted a lack of point or oil and gas source NO_x and VOC emissions in the vicinity of the Hiawatha monitor. There is also a large (>1,000 TPY) point source for NO_x upwind of the city of Laramie in Albany County.

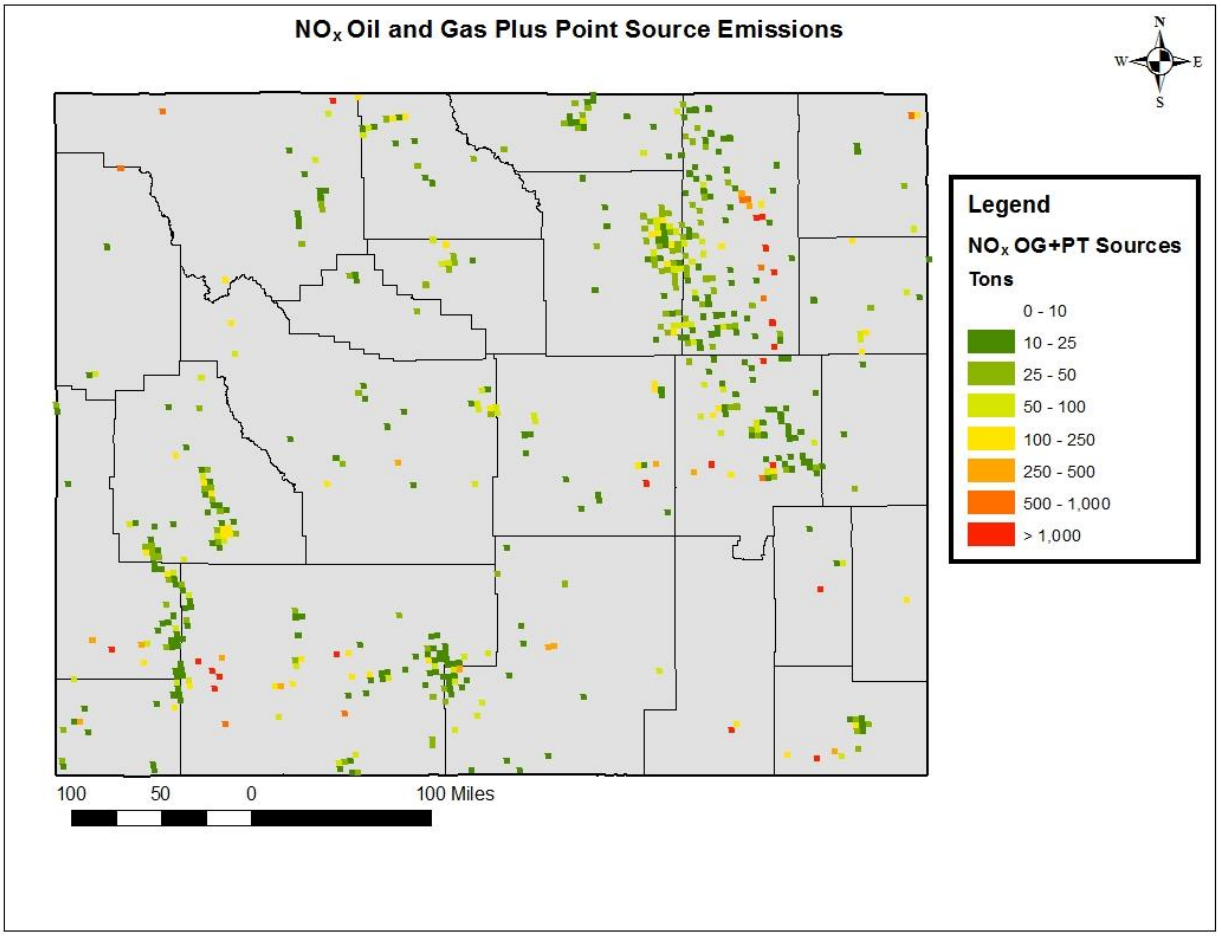

Figure 42. NO_x Emissions from Point and Oil and Gas Sources

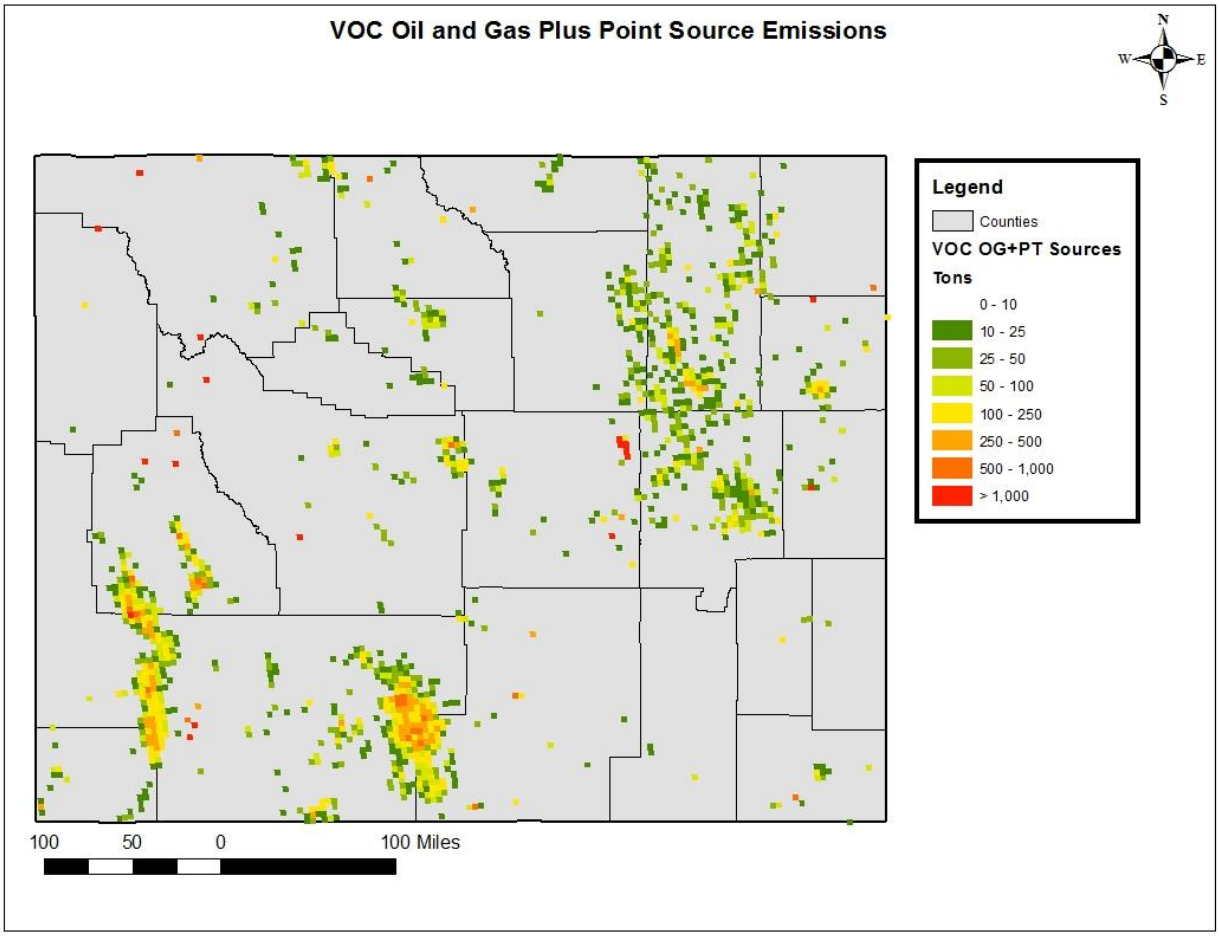

Figure 43. VOC Emissions from Point and Oil and Gas Sources

The AQD compared O_3 monitoring coverage against areas with planned oil and gas development. In addition to current and future development in Converse, Campbell, and Johnson Counties, a large NEPA project was identified in the Moneta Divide area, straddling the borders of Fremont and Natrona Counties. However, this monitor is run on a voluntary basis and the AQD is currently unaware of the quality assurance practices employed.

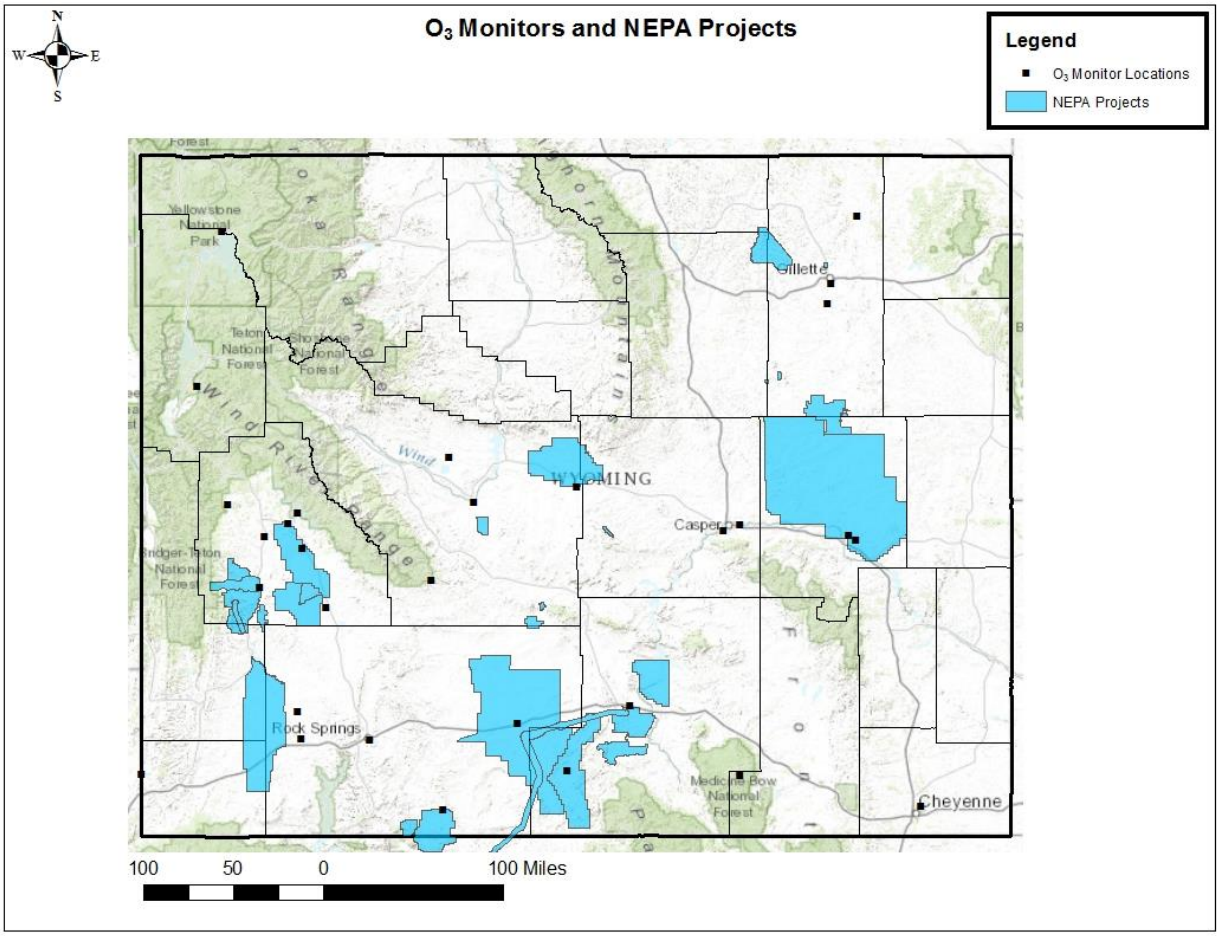

Figure 44. NEPA Project Map with O_3 Monitor Locations

Additional HYSPLIT Backward Trajectories were run for the cities of Laramie and Sheridan. Both trajectories suggest that in addition to upwind point or oil and gas sources, these cities are potentially exposed to pollution transported from neighboring states. The present emissions analysis did not include out-of-state emissions.

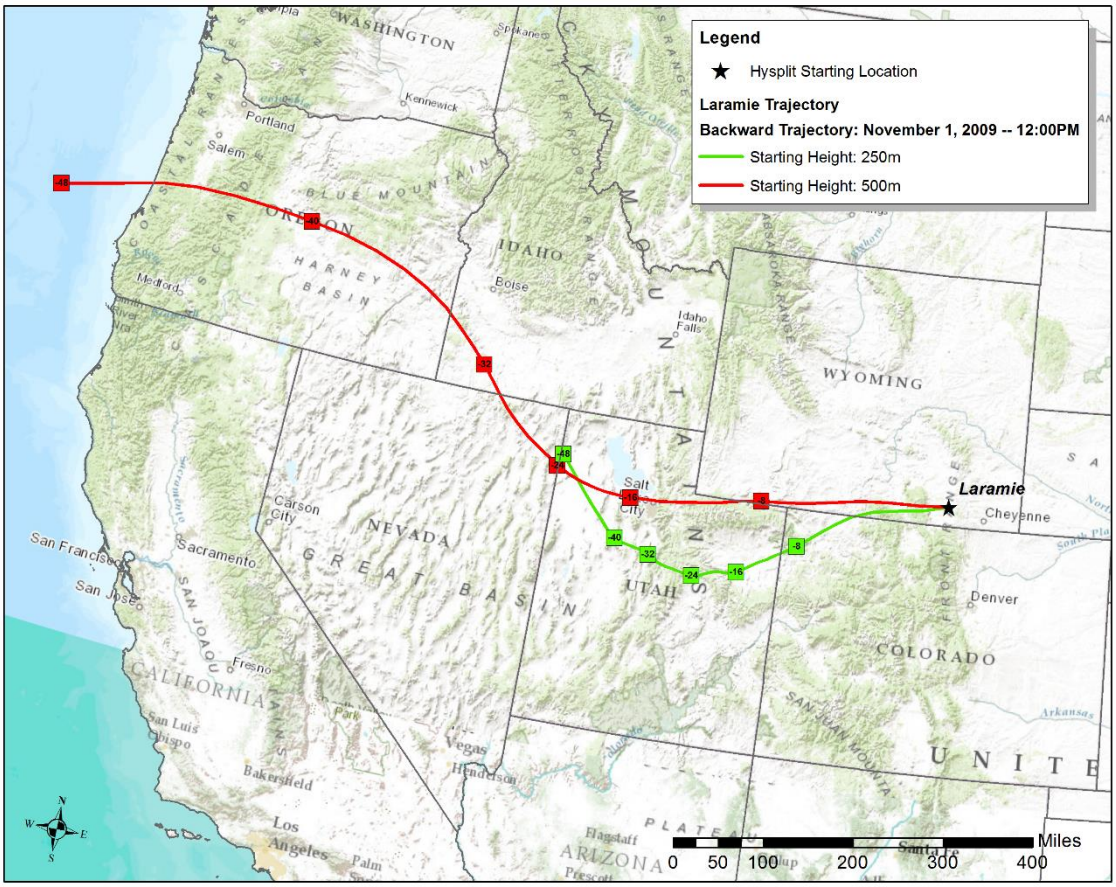

Figure 45. Laramie HYSPLIT Backward Trajectory

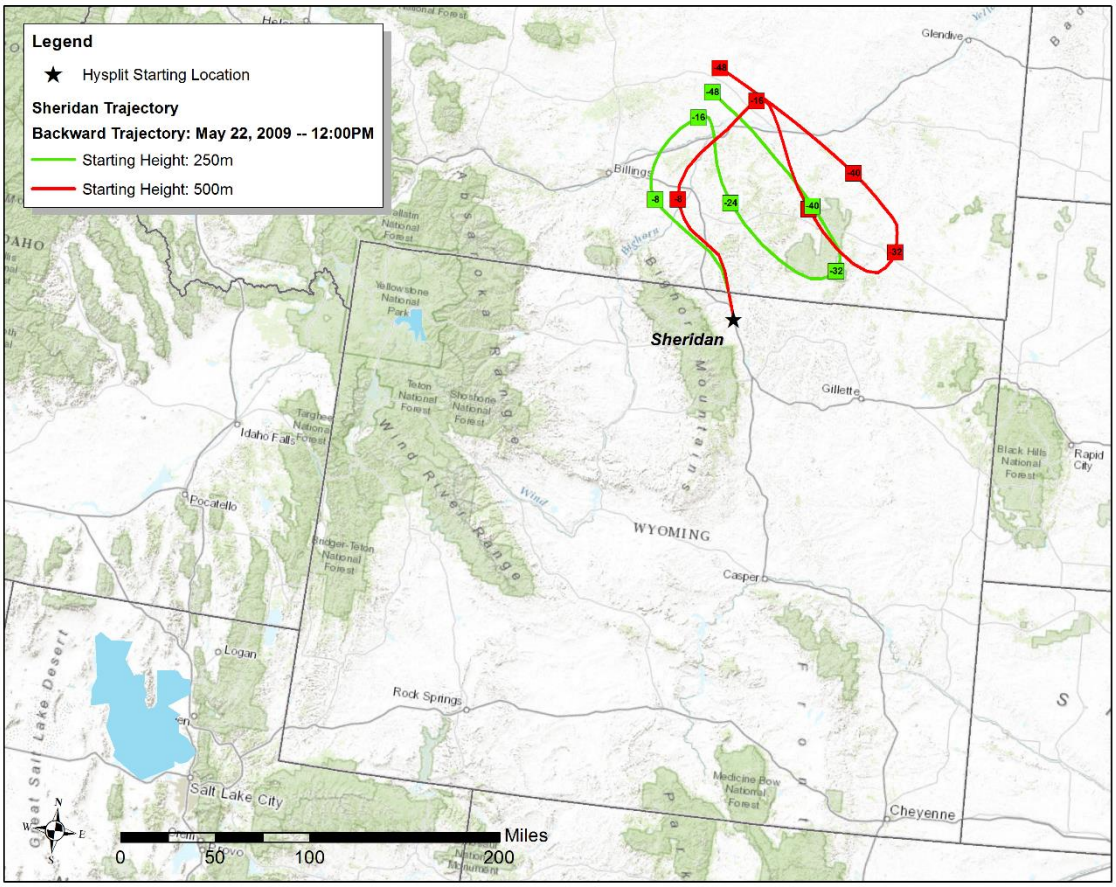

Figure 46. Sheridan HYSPLIT Backward Trajectory

3.2.4 NO_2

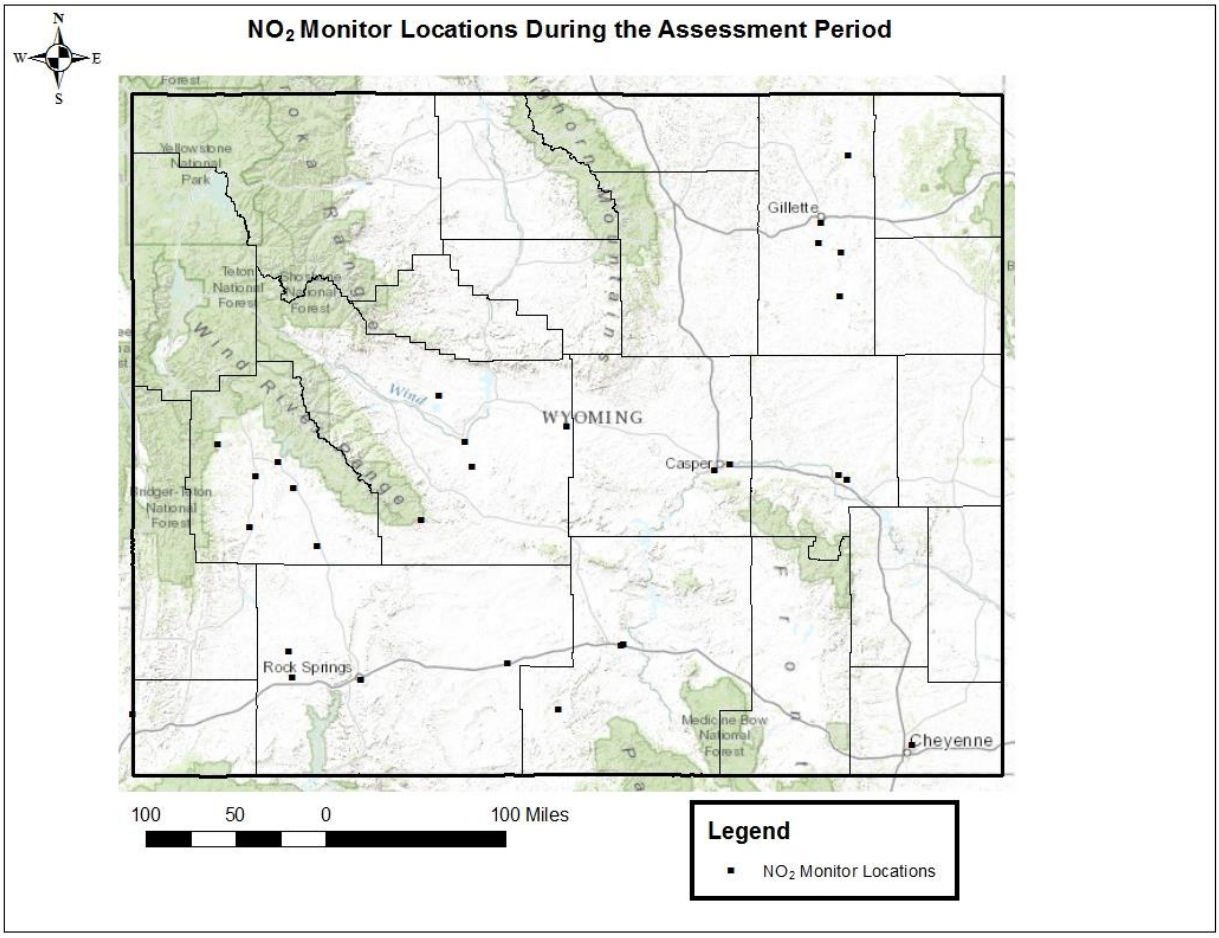

Figure 47. NO_2 Monitor Locations, 2009-2013

3.2.4.1 Data Analysis

An analysis of NO_2 data collected during the assessment period found no monitors with mean or median data significantly close to (>75% of) the NAAQS. In fact, the majority of data collected for all 21 monitors were found to be well below (<25% of) the NAAQS. Indeed, the mean and median values for 12 of these monitors were at or below the Minimum Detection Limit (MDL) of the monitor in question.

AQS ID	Site Name	Average Mean (ppb)	Average Median (ppb)	MDL (ppb)
56-005-0123	Thunder Basin	1.75	1.20	1
56-005-0456	Campbell County	2.90	1.46	1
56-005-0800	Gillette (Mobile #3)	5.10	3.20	2.7
56-005-0892	Belle Ayr BA-4 (PRB NO_x Network)	6.34	3.36	2.7
56-007-1000	Sinclair (Mobile #2)	4.37	2.90	2.7
56-009-0801	Converse County (Mobile #3)	3.03	2.00	2.7
56-009-0819	Antelope Site 3 (PRB NO_x Network)	1.97	0.00	2.7
56-013-0099	South Pass	0.54	0.38	1
56-013-0900	Pavillion (Mobile #1)	0.97	0.50	2.7
56-021-0100	Cheyenne NCore	3.85	2.13	2.7
56-025-0100	Casper Gaseous	2.70	0.00	2.7
56-035-0097	Wyoming Range	0.76	0.63	1
56-035-0099	Boulder	2.58	1.09	2.7
56-035-0100	Daniel South	0.29	0.10	2.7
56-035-0101	Pinedale Gaseous	2.80	1.75	2.7
56-035-0700	Big Piney Site #3	1.40	1.00	2.7
56-035-1002	Juel Spring	1.40	1.01	2.7
56-037-0100	Rock Springs (Mobile #1)	4.48	2.90	2.7
56-037-0200	Wamsutter	4.71	2.82	1
56-037-0300	Moxa Arch	1.82	0.98	2.7
56-041-0101	Murphy Ridge	1.90	1.26	2.7

Table 14. Mean, Median, and MDL Values for All AQD NO_2 Monitors During the Network Assessment Period

There were no NO_2 exceedances recorded during the assessment period. No monitors' data were observed to exhibit statistically significant trends or were highly correlated with data collected by other monitors.

3.2.4.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. The only areas with a large (>500) population increase that lacked proximate NO_2 monitoring coverage during the assessment period were Johnson County and southwest Teton County. Somewhat significant increases (101-500) in unmonitored areas occurred in Weston, Crook, southern Albany, northern Park, and west Sheridan Counties. No areas with a large (<-100) population decrease were found to be currently monitored, except for small pockets within major cities.

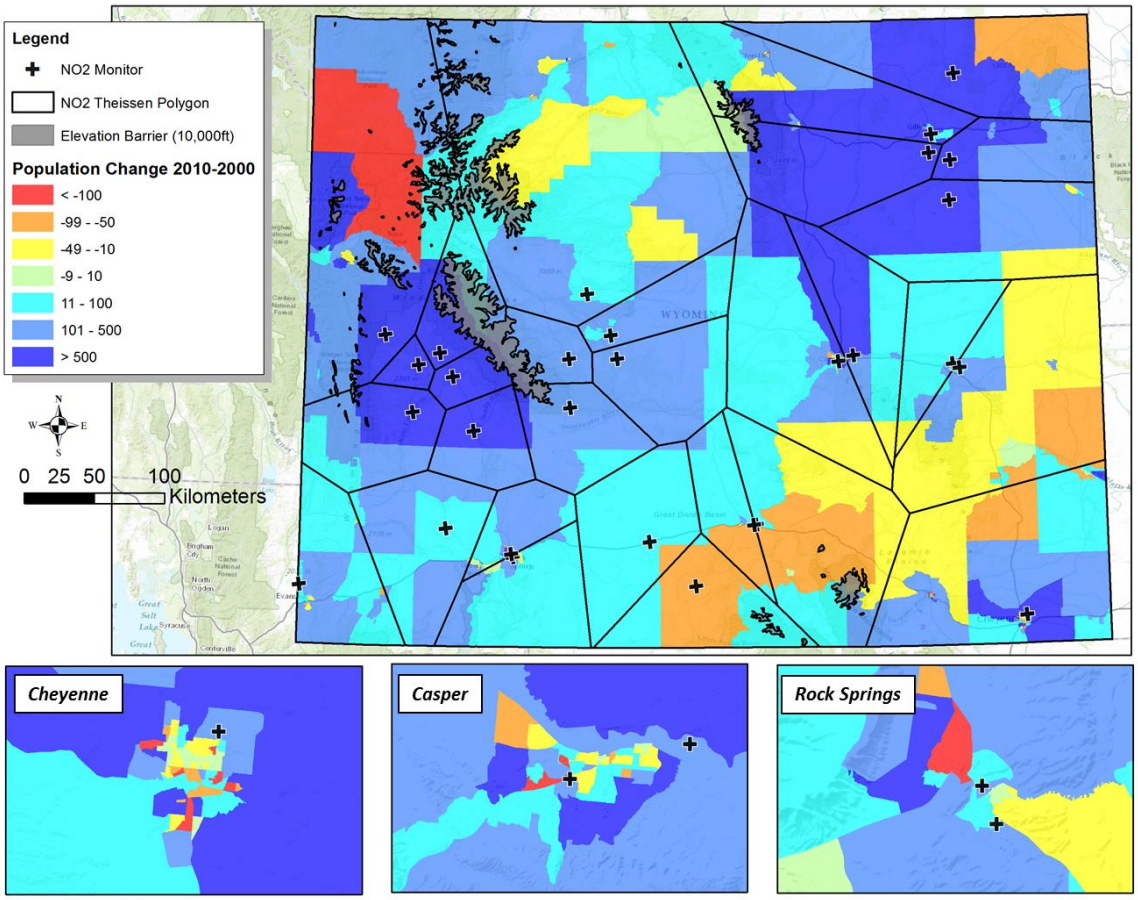

Figure 48. Population Change from 2000-2010 and NO_2 Monitor Locations

Both Metropolitan Statistical Areas in the state, Laramie and Natrona Counties, were found to have current NO_2 monitoring close to, or within, heavily populated areas. All heavily populated areas in Micropolitan Statistical Areas also had appropriate NO_2 coverage, with the exception of the cities of Jackson, Laramie, and Sheridan.

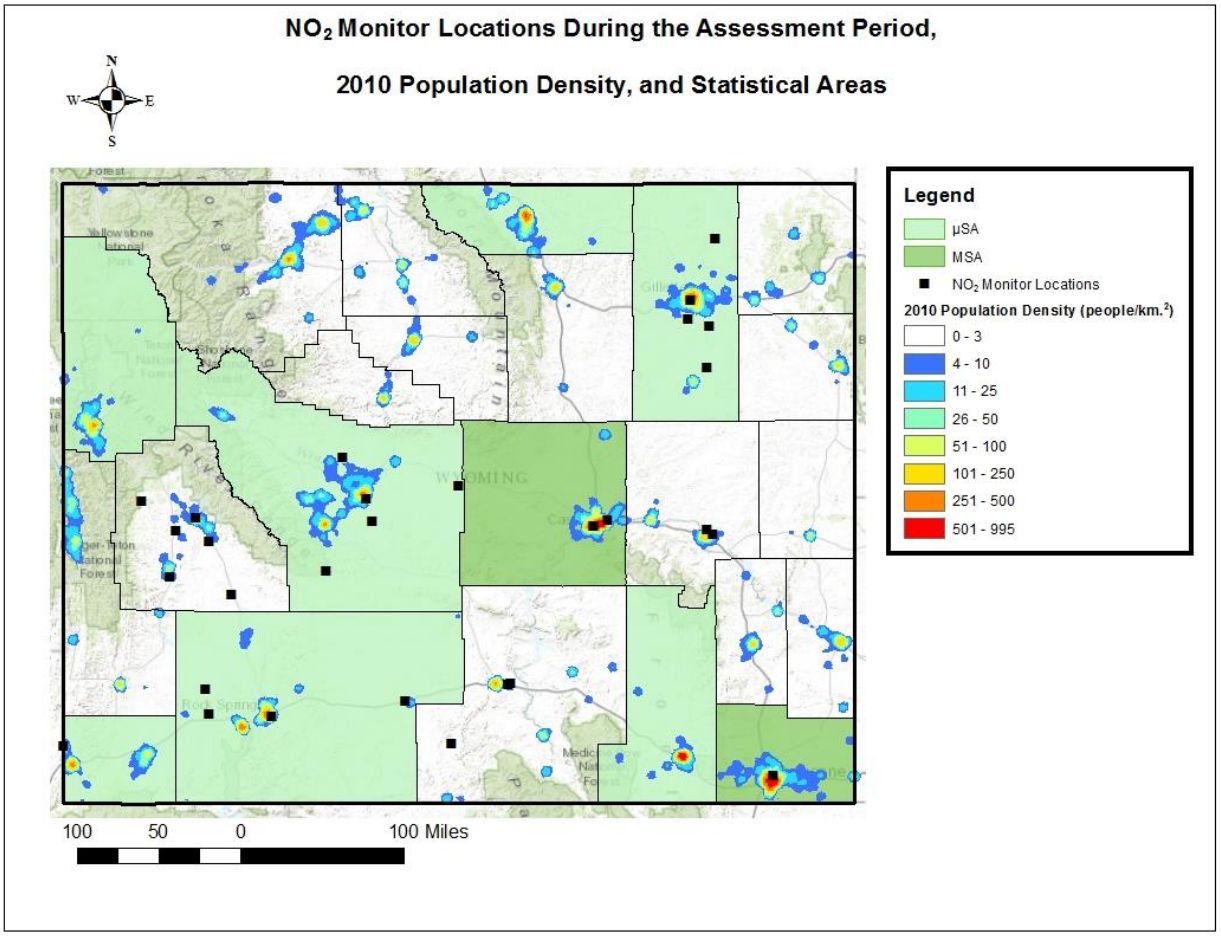

Figure 49. Statistical Areas in Wyoming with Population Density and NO_2 Monitor Locations

The AQD considered potential impacts to at-risk minority populations that might exist in currently unmonitored locations across the state. An analysis of demographic information from 2010 revealed that 21.5% of the population of Albany County lives below the poverty level, with 46.5% of individuals residing in rental units. These percentages are the highest in the state for both of these indices. It was also recognized that the city of Sheridan has a sizeable Veteran's Affairs Hospital, serving a population potentially more susceptible to the adverse effects of NO_2.

3.2.4.3 Emission Analysis

The AQD examined emission inventory maps for NO_2 in tandem with wind rose data to assess potential downwind receptors of emissions.

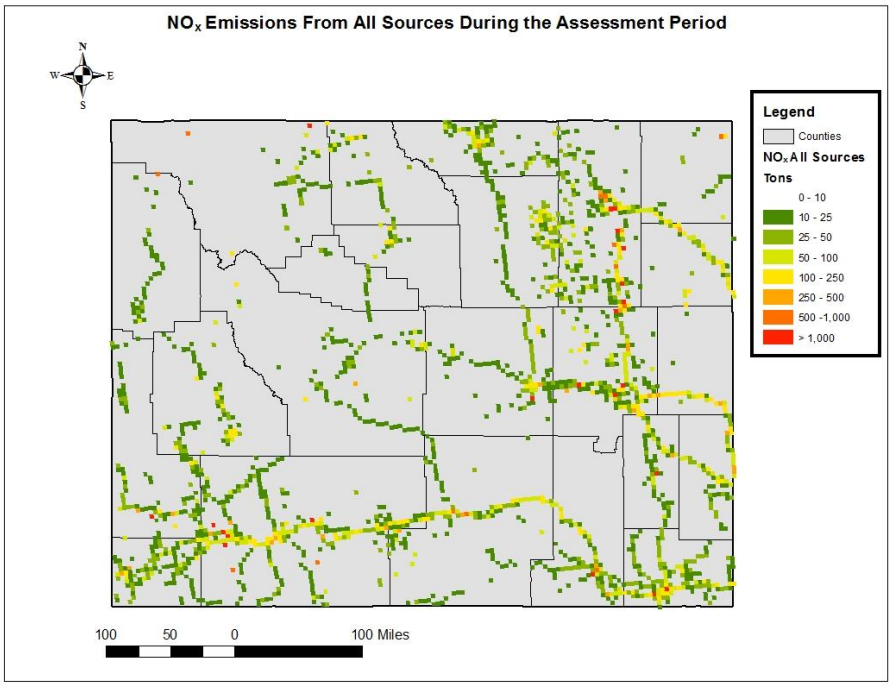

Figure 50. NO_x Emissions from All Sources

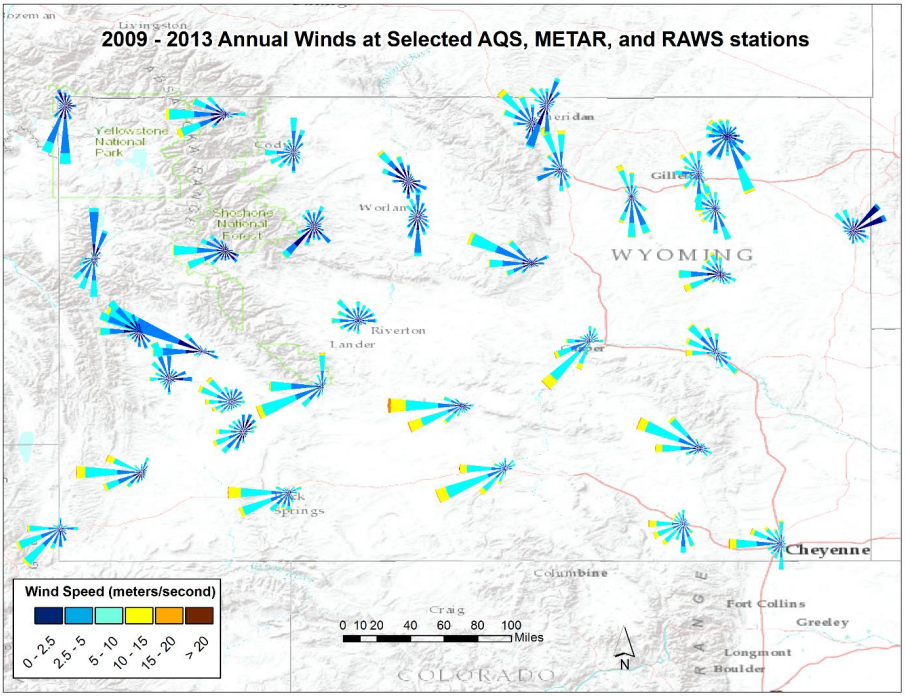

Figure 51. 2009-2013 Annual Wind Rose Map

According to the emissions inventory and wind rose maps, there are many small sources of NO_2 emissions scattered north (generally upwind) of Sheridan. These maps also indicate that Torrington is downwind of a large point source near Wheatland. The AQD ran a HYSPLIT Backward Trajectory from Torrington, which indicated that this town might see NO_2 impacts not

only from this source but potentially from oil and gas and point emissions in Converse, Campbell, and Johnson Counties.

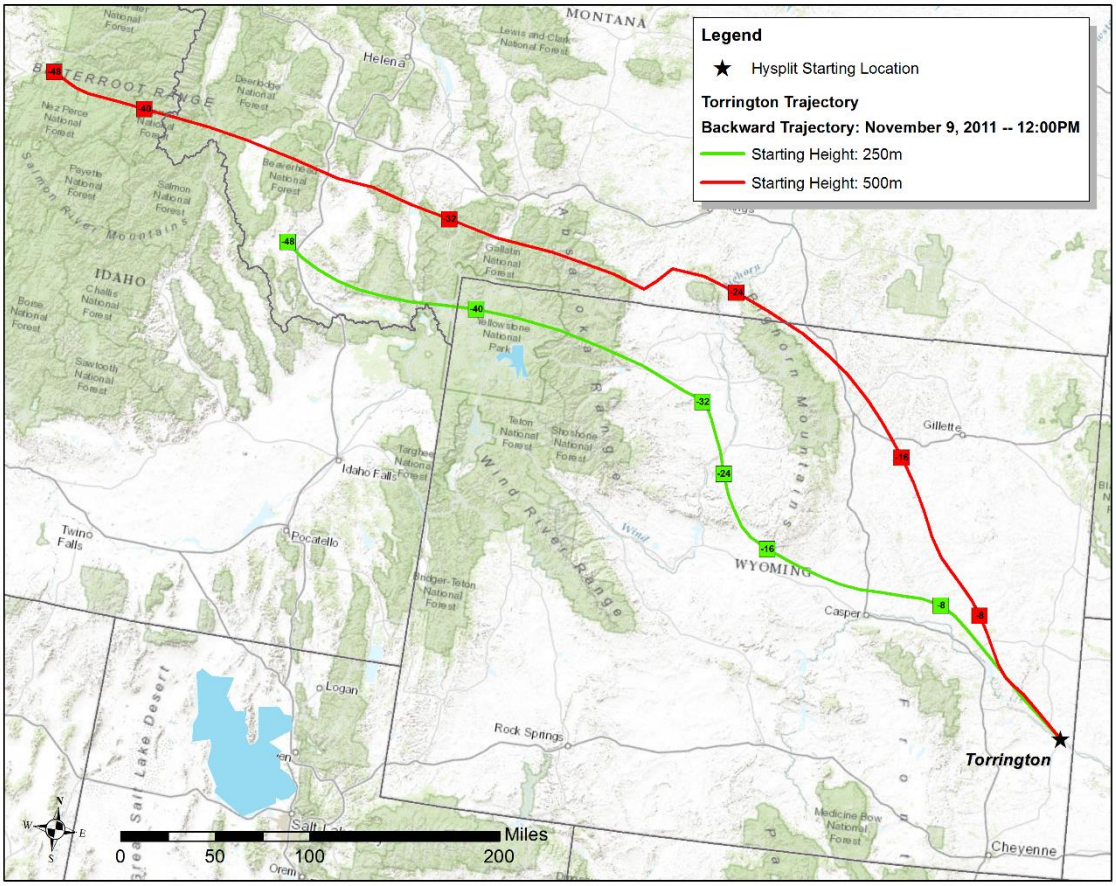

Figure 52. Torrington HYSPLIT Backward Trajectory

The AQD also identified a large (>1,000 TPY) point source upwind of the city of Laramie in Albany County.

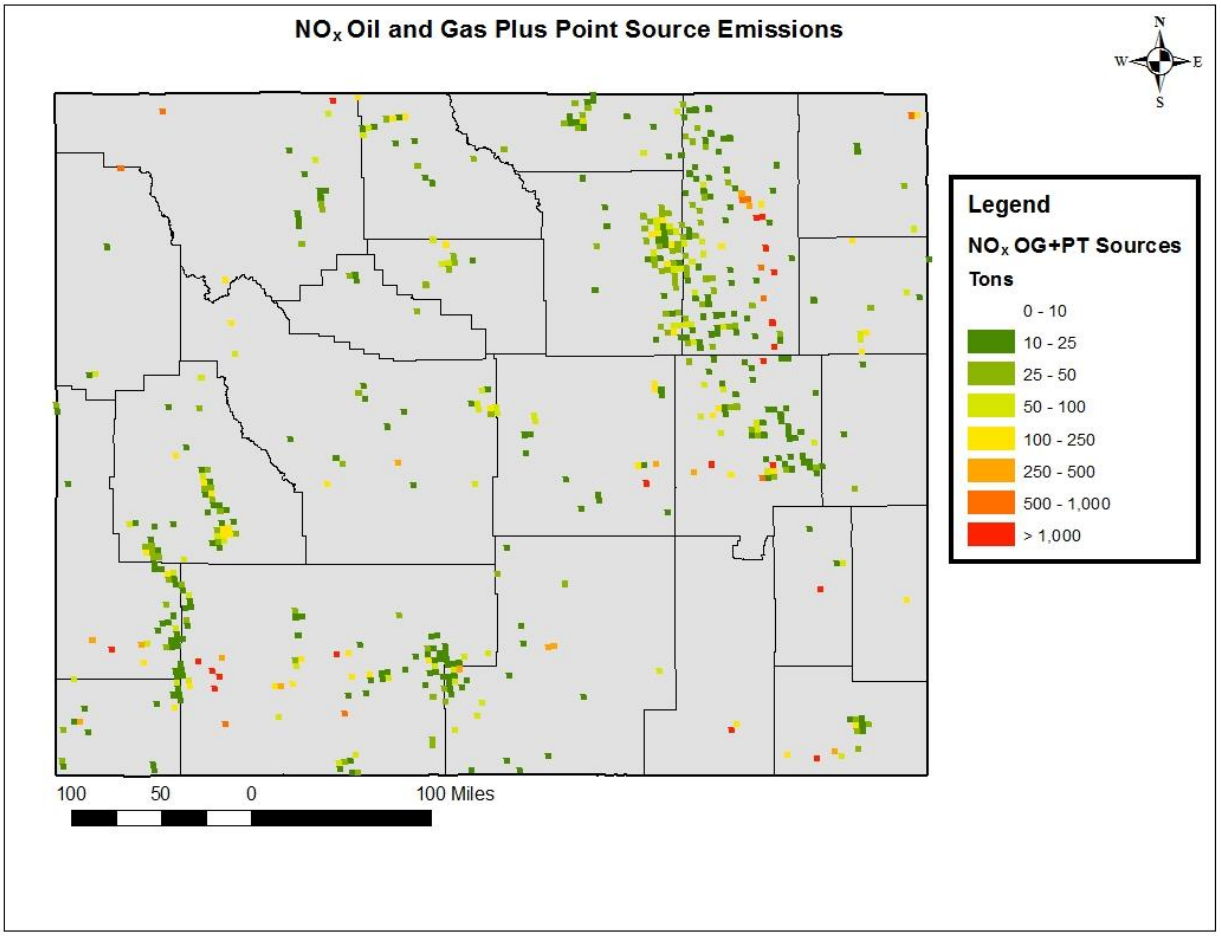

Figure 53. NO_x Emissions from Point and Oil and Gas Sources

The AQD compared NO_2 monitoring coverage against areas with planned oil and gas development. In addition to current and future development in Converse, Campbell, and Johnson Counties, a large unmonitored NEPA project was identified in the Moneta Divide area, straddling the borders of Fremont and Natrona Counties.

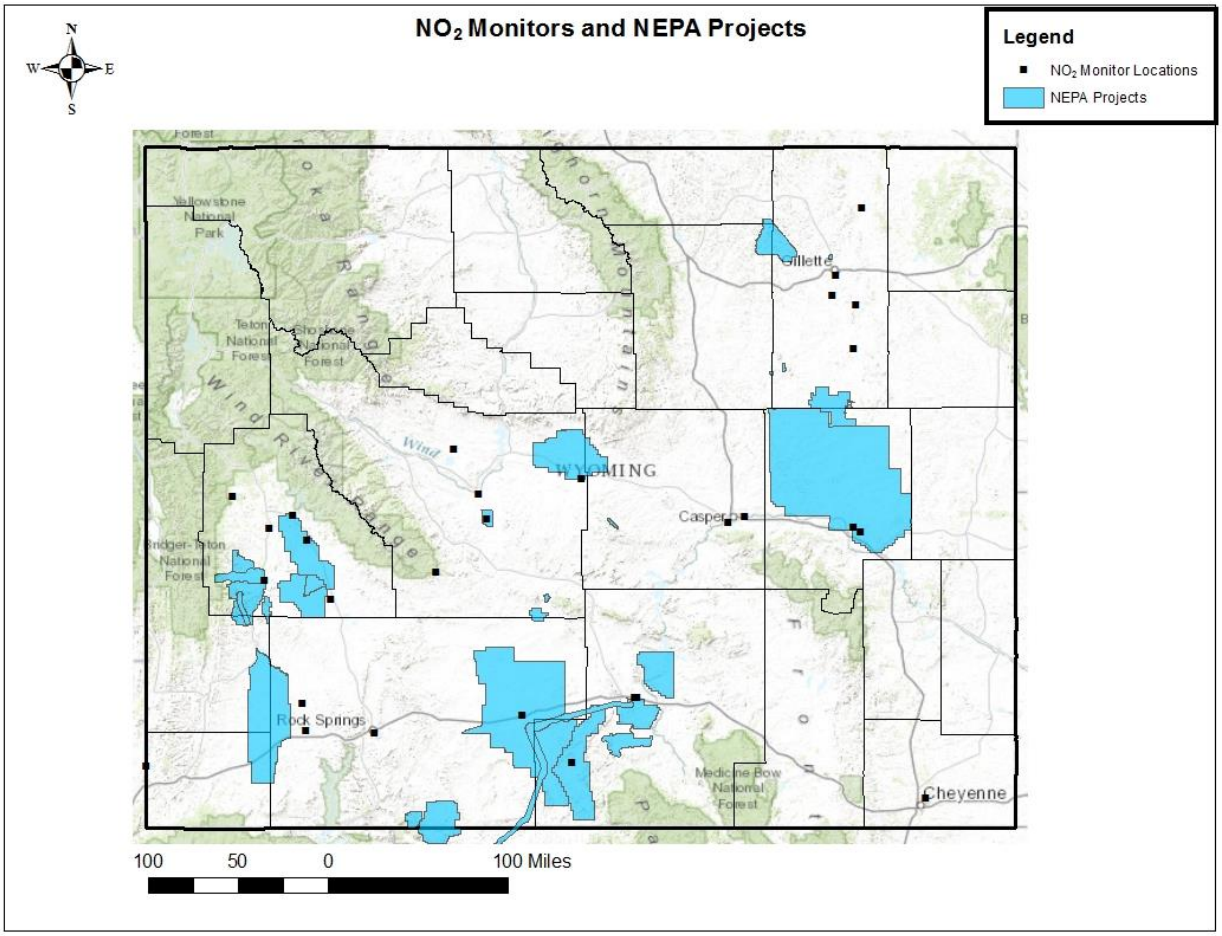

Figure 54. NEPA Project Map with NO_2 Monitors

Additional HYSPLIT Backward Trajectories were run for the cities of Laramie and Sheridan. Both trajectories suggest that, in addition to upwind point or oil and gas sources, these cities are potentially exposed to pollution transported from neighboring states. The present emissions analysis did not include out-of-state emissions.

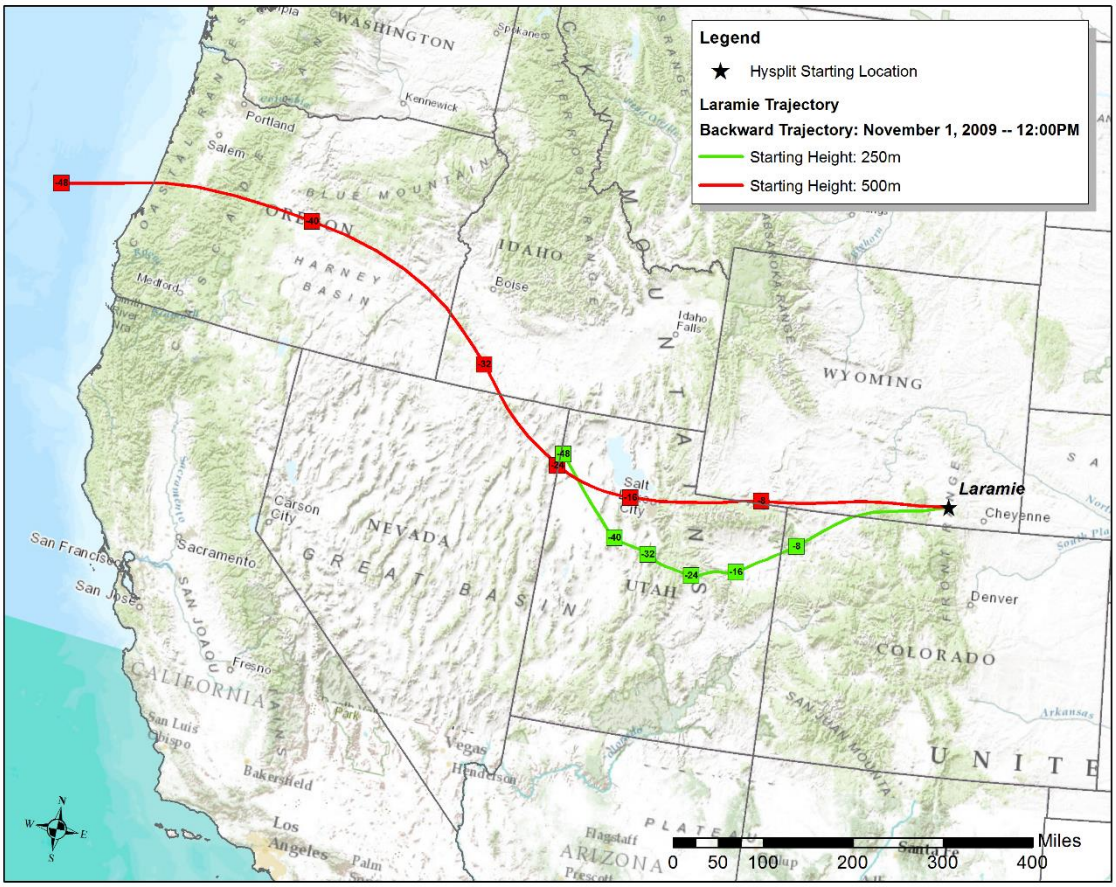

Figure 55. Laramie HYSPLIT Backward Trajectory

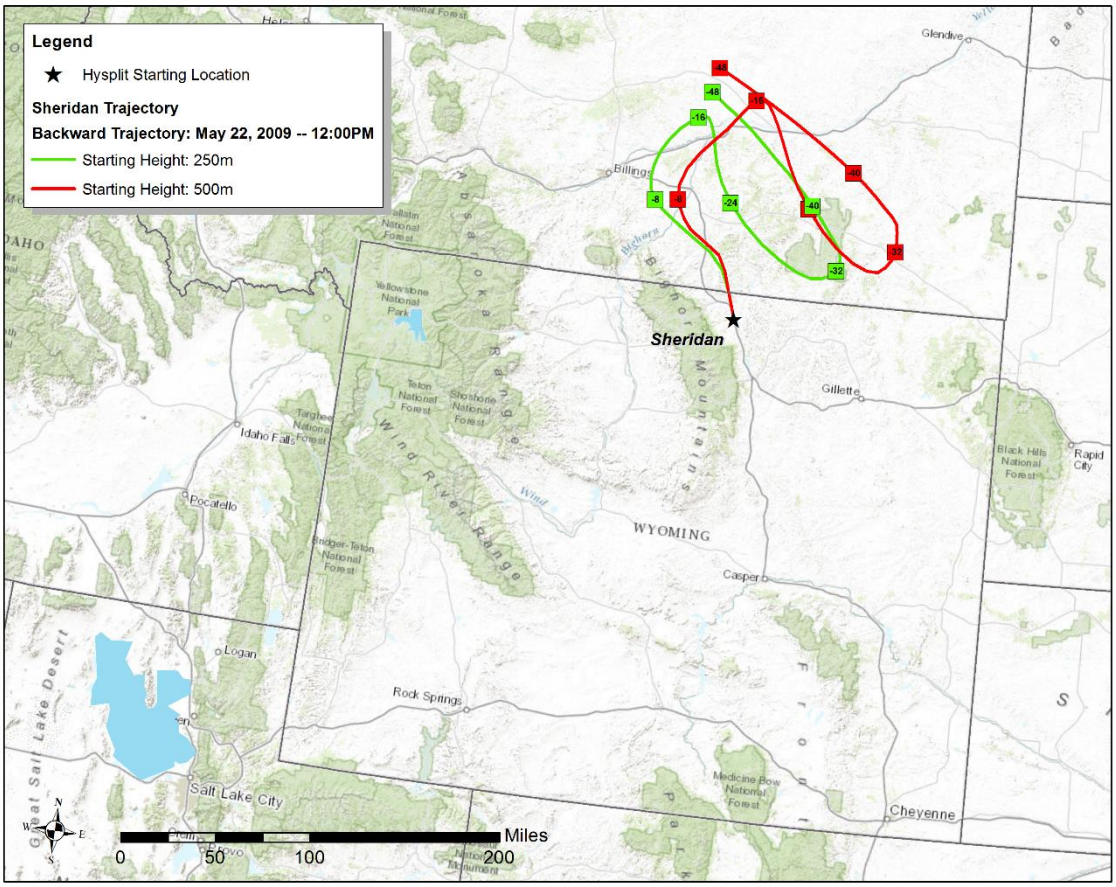

Figure 56. Sheridan HYSPLIT Backward Trajectory

3.2.5 CO

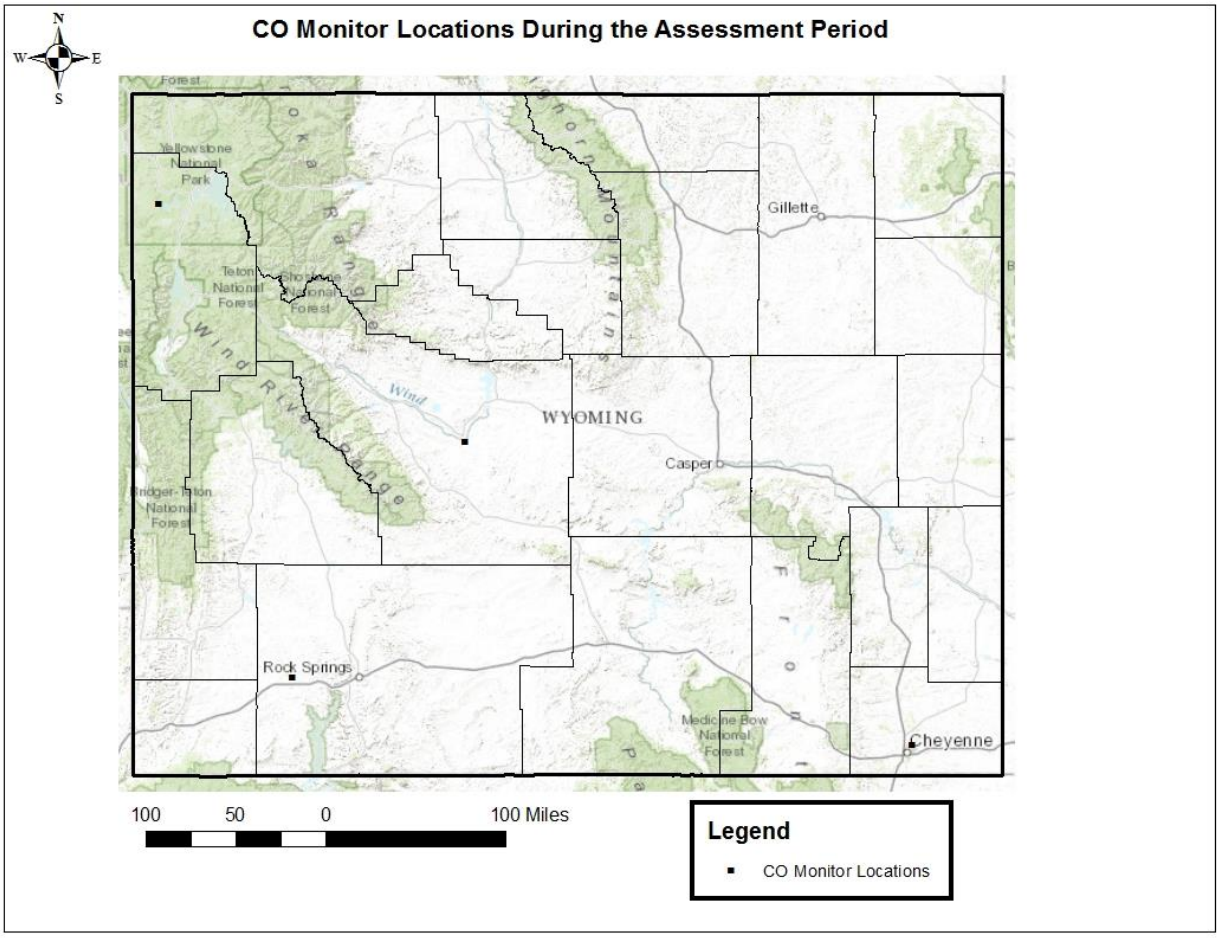

Figure 57. CO Monitor Locations, 2009-2013

3.2.5.1 Data Analysis

The AQD only operates one CO monitor in the state, at the Cheyenne NCore station. An analysis of CO data collected at the NCore station during the assessment period found that mean and median values were not significantly close to (>75% of) the NAAQS. The majority of data collected by this monitor were found to be well below (<25% of) the NAAQS. However, these mean and median values were above the Minimum Detection Limit (MDL) of the monitor in question. No exceedances were recorded by this CO monitor during the assessment period. No significantly increasing or decreasing trend in NCore CO data was discerned. The data for this monitor did not correlate strongly with the other non-AQD CO monitors in the state.

3.2.5.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. Large (>500), unmonitored population increases occurred in Campbell, Johnson, northeast Natrona, and Sublette Counties. One area with a large (<-100) population decrease (Teton County) was found to be currently monitored. However, this monitor is not operated by the AQD.

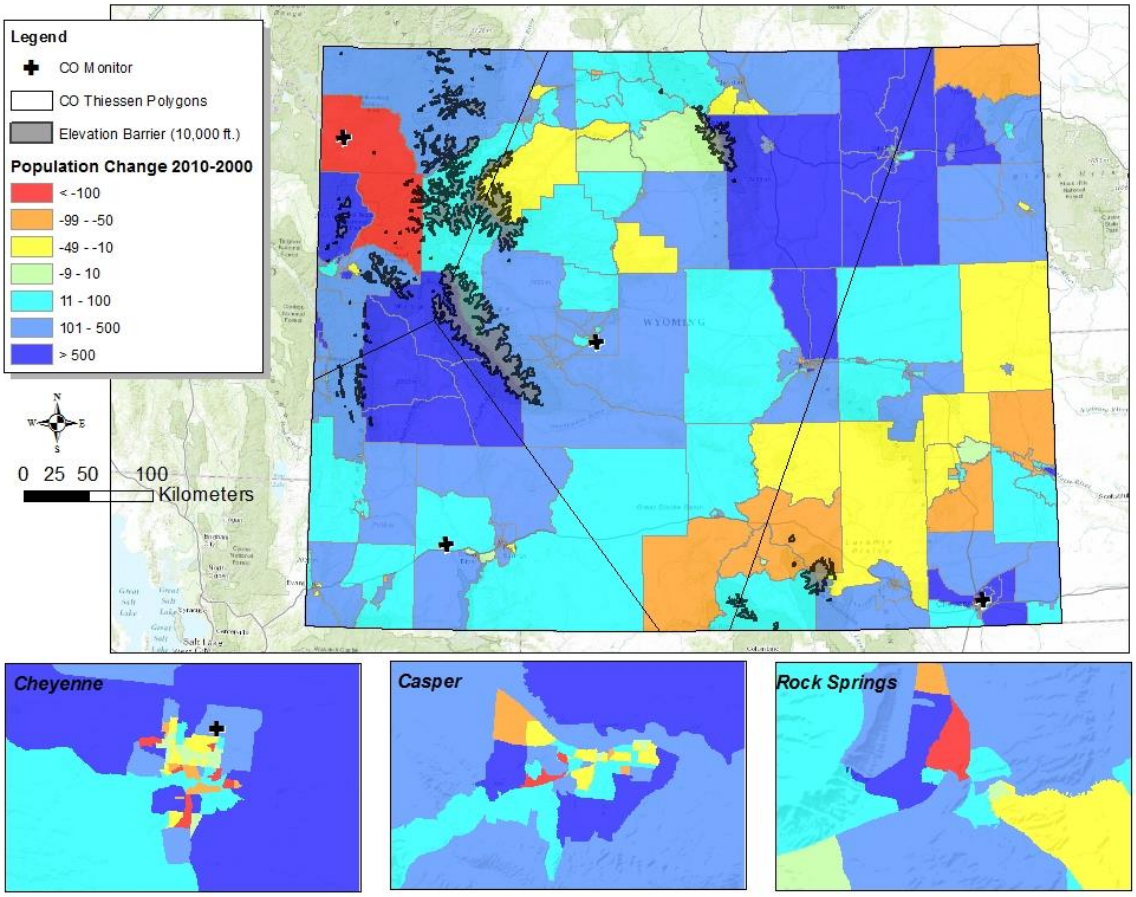

Figure 58. Population Change from 2000-2010 and CO Monitor Locations

One Metropolitan Statistical Area, Natrona County, does not have CO monitoring. Several Micropolitan Statistical Areas in the state (Laramie, Uinta, Sheridan, and Campbell Counties) do not have proximate CO coverage.

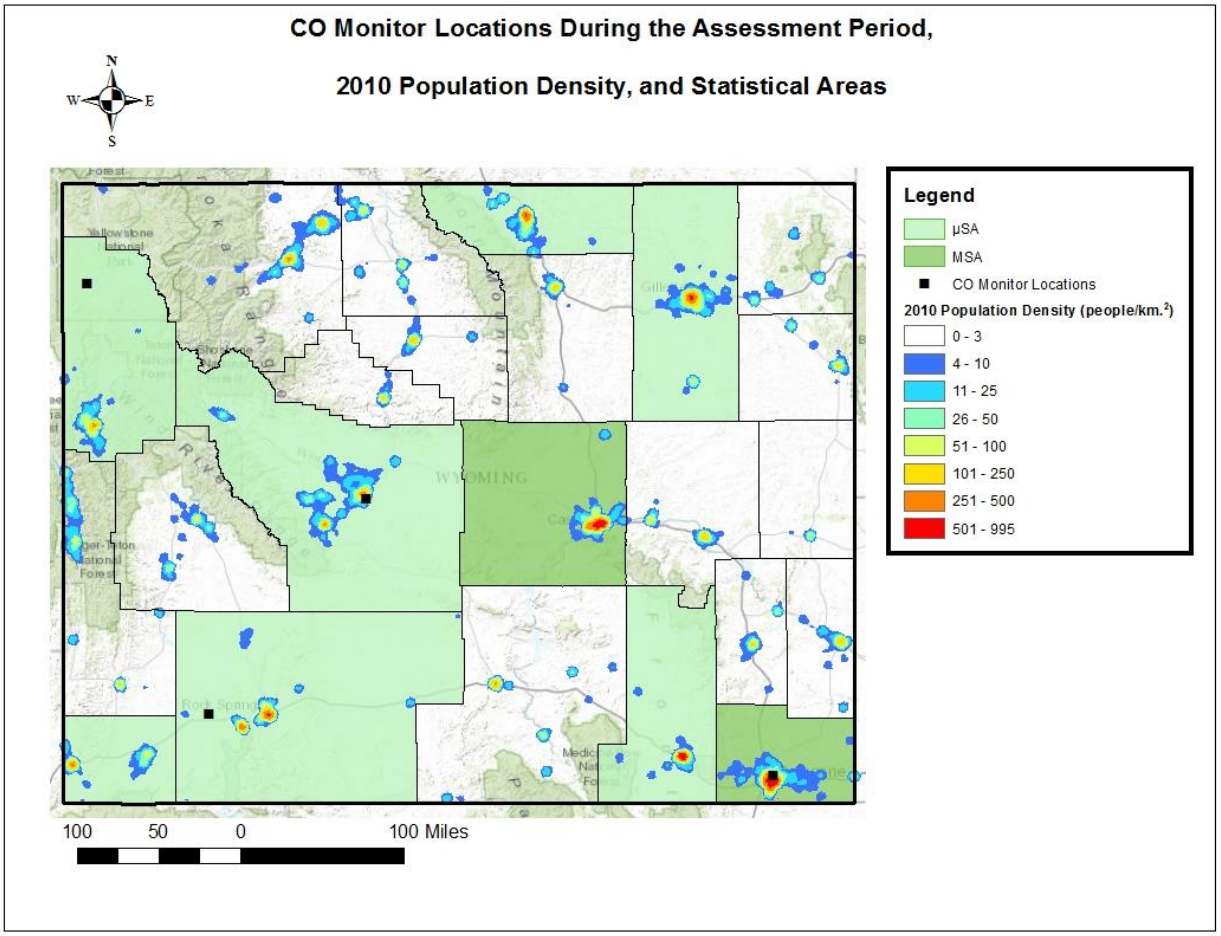

Figure 59. Statistical Areas in Wyoming with Population Density and CO Monitor Locations

3.2.5.3 Emission Analysis

The AQD examined emission inventory maps for CO in tandem with wind rose data to assess potential downwind receptors of emissions.

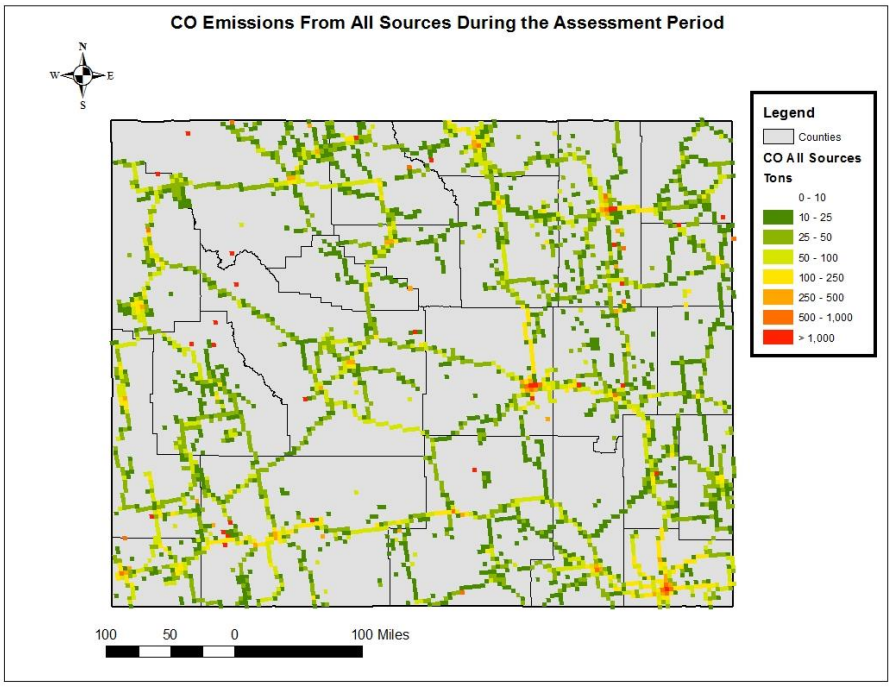

Figure 60. CO Emissions from All Sources

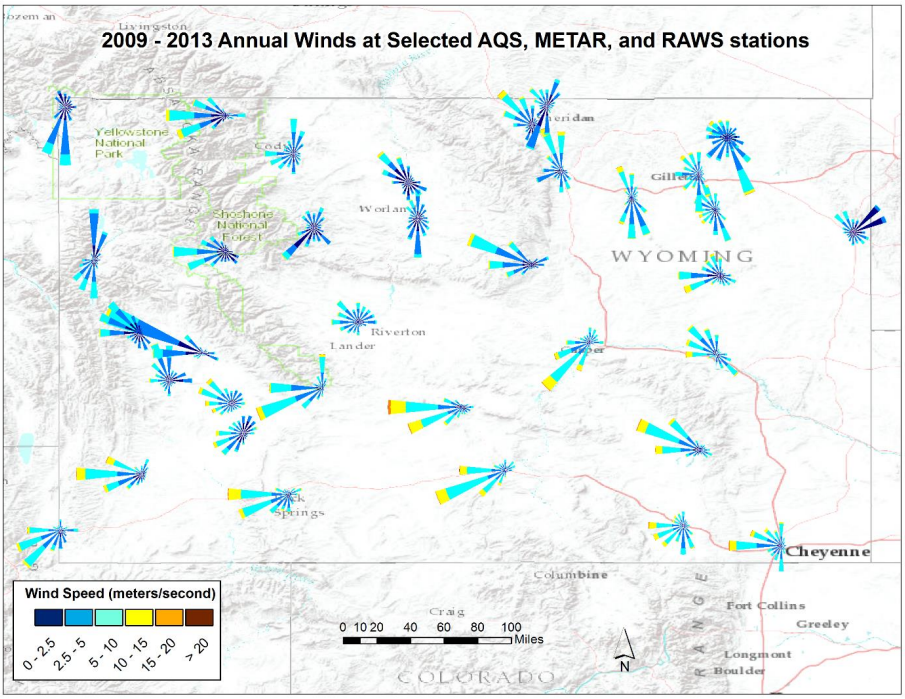

Figure 61. 2009-2013 Annual Wind Rose Map

There is one major area in the state, northeast Wyoming, which lacks appropriate CO monitoring according to the emissions inventory and wind rose maps. A large cluster of point and oil and gas emissions sources were identified in Johnson, Campbell, and Converse Counties in the northeast.

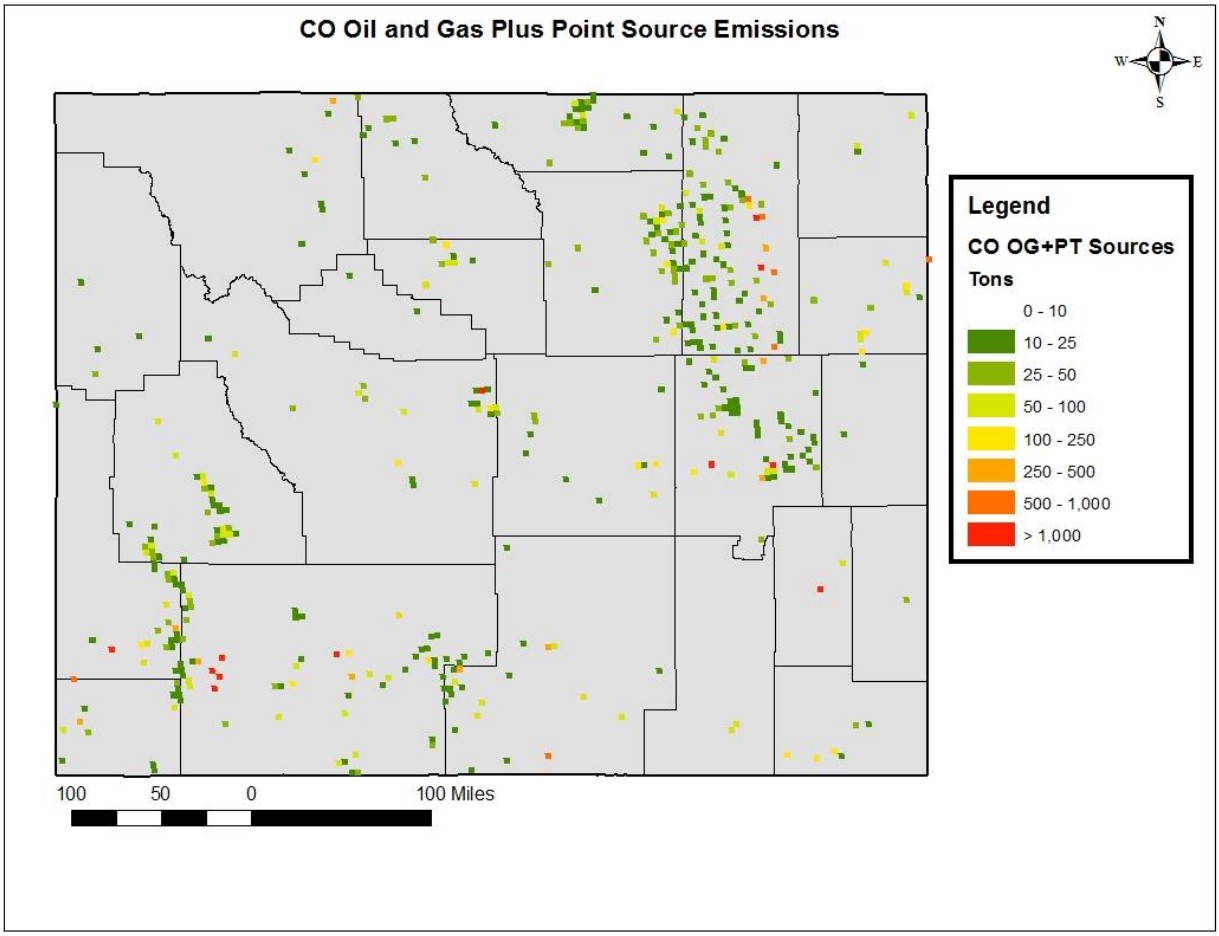

Figure 62. CO Emissions from Point and Oil and Gas Sources

The AQD ran HYSPLIT Backward Trajectories to assess impacts from these areas of concern. The trajectory from Torrington indicated that this town might see CO impacts from the previously identified sources in Converse, Campbell, and Johnson Counties.

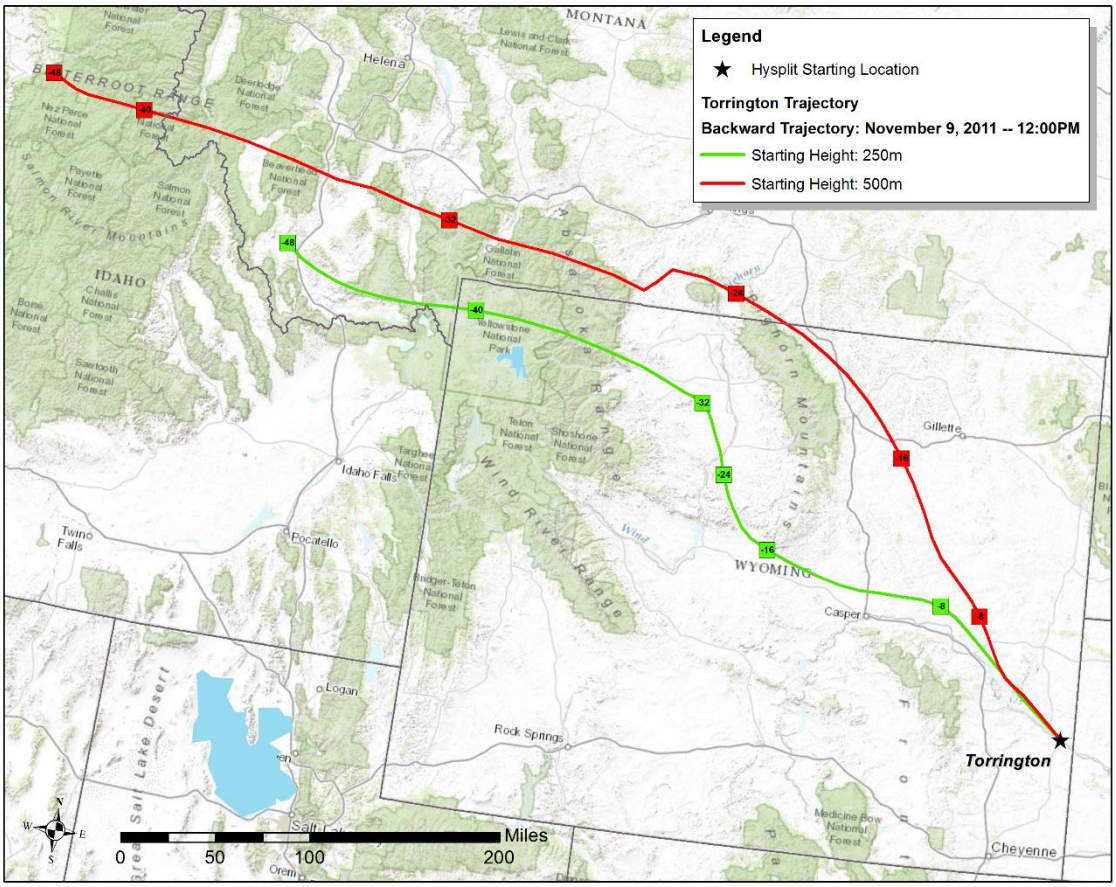

Figure 63. Torrington HYSPLIT Backward Trajectory

The AQD compared CO monitoring coverage against areas with planned oil and gas development. In addition to current development in northeast Wyoming, this area also has two significant planned NEPA projects (Converse County Oil and Gas and Greater Crossbow) that are currently unmonitored for CO.

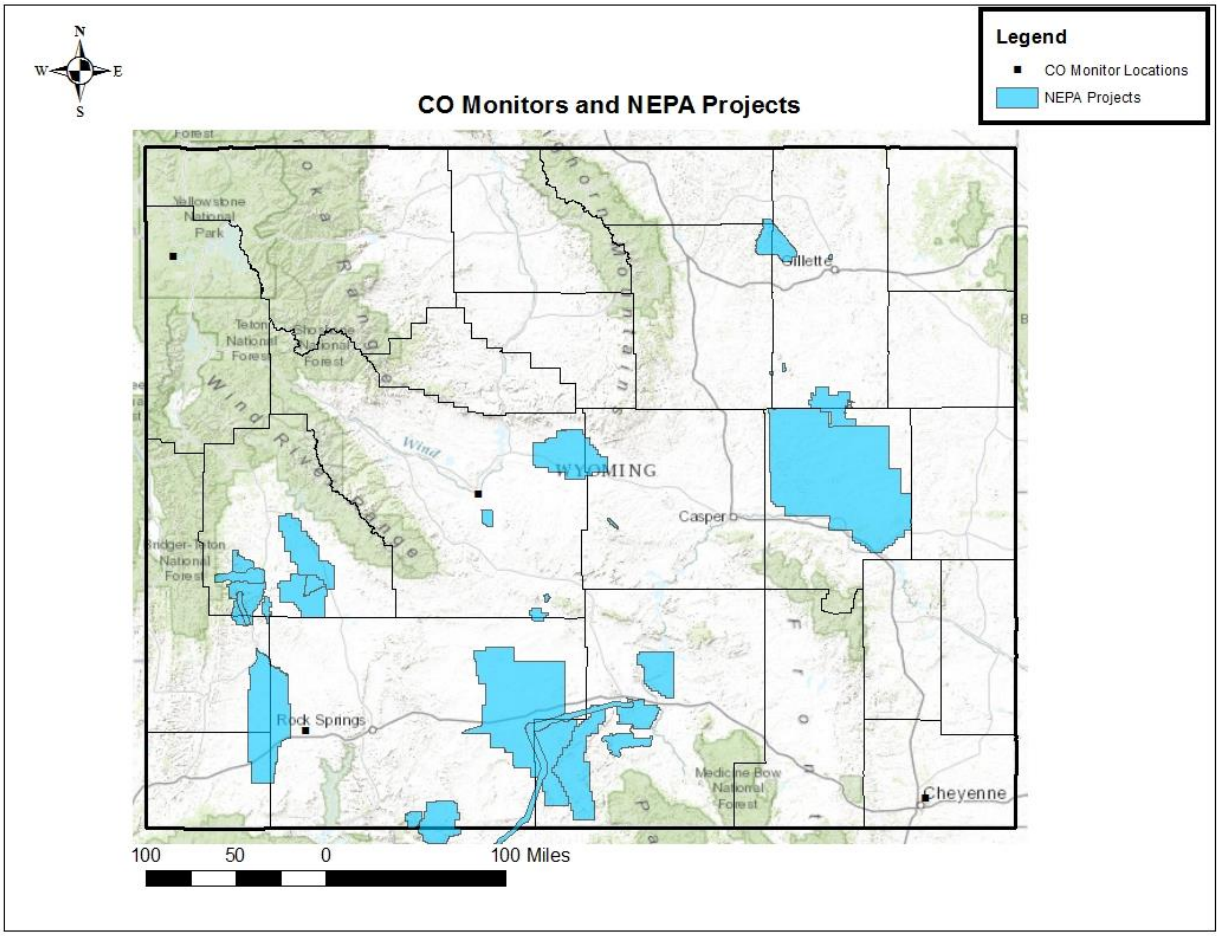

Figure 64. NEPA Project Map with CO Monitor Locations

3.2.6 SO_2

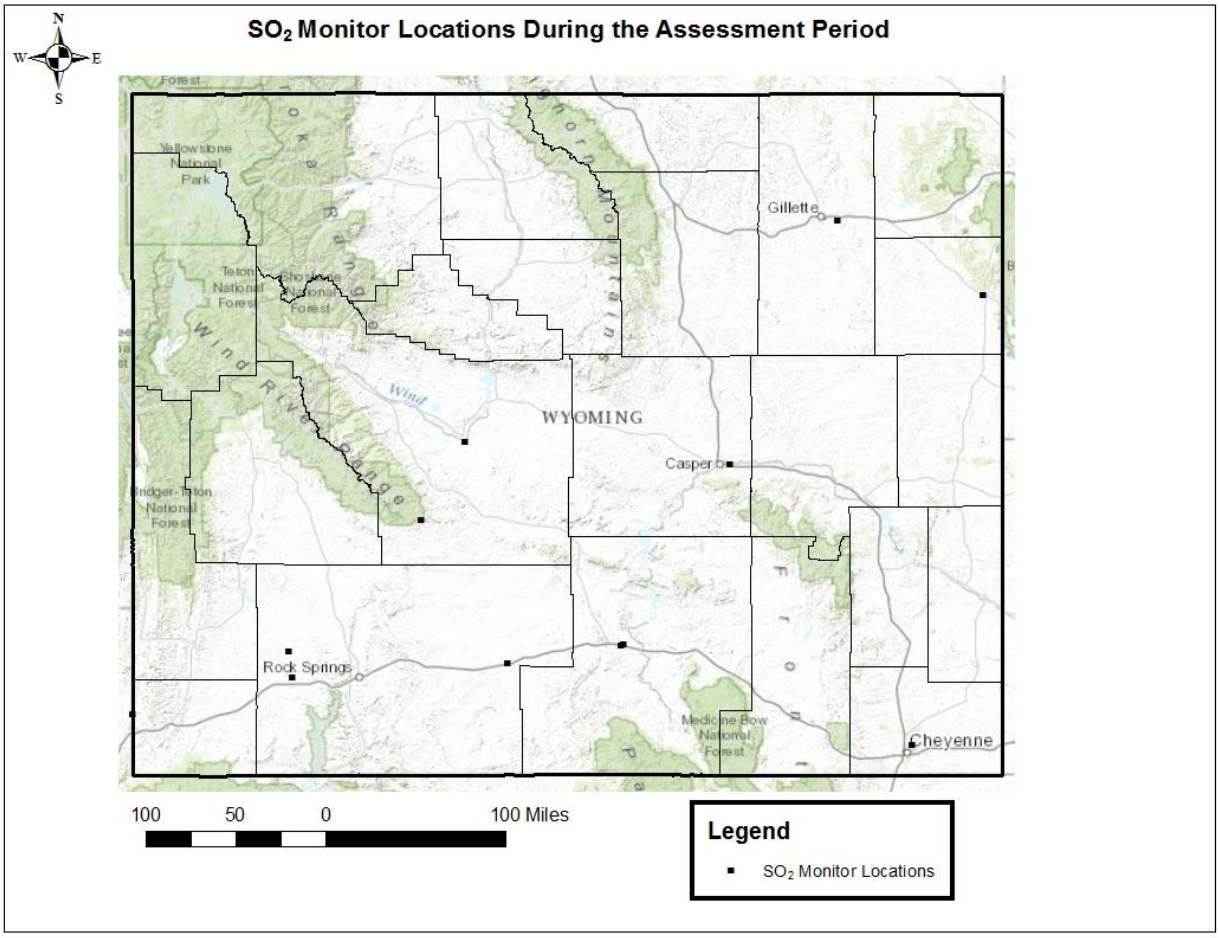

Figure 65. SO_2 Monitor Locations, 2009-2013

3.2.6.1 Data Analysis

An analysis of SO_2 data collected during the assessment period found no monitors with mean or median data significantly close to (>75%) the NAAQS. The majority of data collected for all AQD monitors were found to be well below (<25%) the NAAQS, and were at, or below, the Minimum Detection Limit (MDL) of the monitor in question. No AQD monitors measured an SO_2 exceedance during the assessment period.

Data for the Moxa Arch monitor were found to exhibit a statistically significant increase in mean and median values from 2012 to 2013. However, this followed a statistically significant decrease in mean and median values from 2010 to 2011, and the trend occurred below the instrument's MDL of 2 ppb.

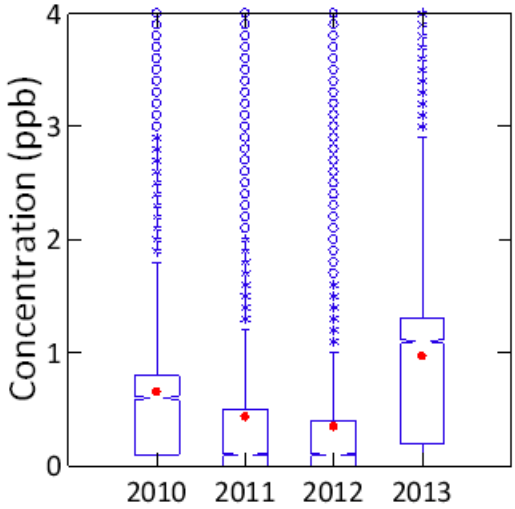

Figure 66. Box and Whisker Plot for Moxa Arch, 2010-2013

None of the data for the SO_2 monitors in the state were found to correlate strongly with other monitors.

3.2.6.2 Population Analysis

The AQD looked at population changes from 2000 to 2010 in relation to monitoring sites that operated during the assessment period. Large (>500), unmonitored population increases occurred in Johnson, west Teton, and Sublette Counties. No areas with a large (<-100) population decrease were found to be currently monitored, except for small pockets within major cities.

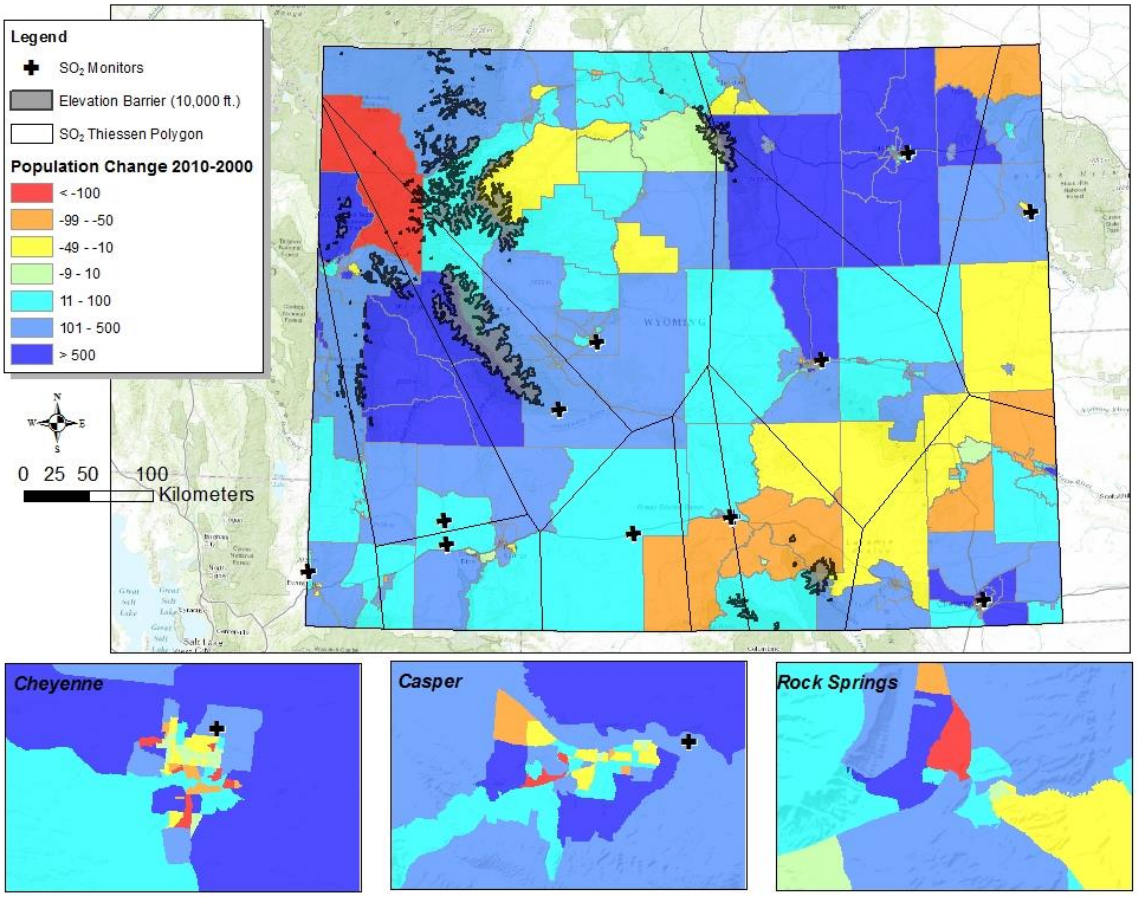

Figure 67. Population Change from 2000-2010 and SO_2 Monitor Locations

Both Metropolitan Statistical Areas in the state, Laramie and Natrona Counties, were found to have current SO_2 monitoring close to, or within, heavily populated areas. All heavily populated areas in Micropolitan Statistical Areas also had appropriate SO_2 coverage, with the exception of the cities of Jackson, Laramie, Evanston and Sheridan.

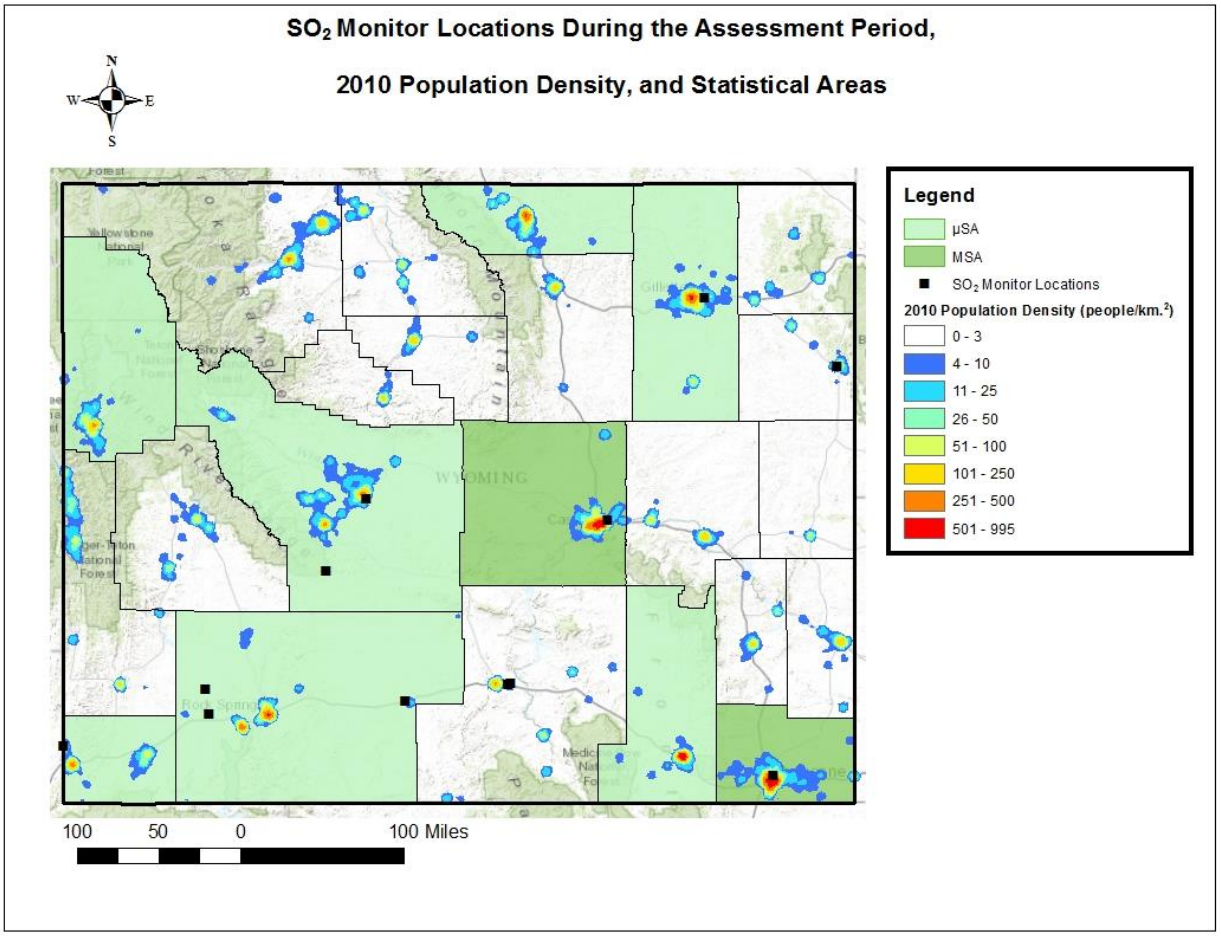

Figure 68. Statistical Areas in Wyoming with Population Density and SO_2 Monitor Locations

3.2.6.3 Emission Analysis

The AQD examined emission inventory maps for SO_2 in tandem with wind rose data to assess potential downwind receptors of emissions.

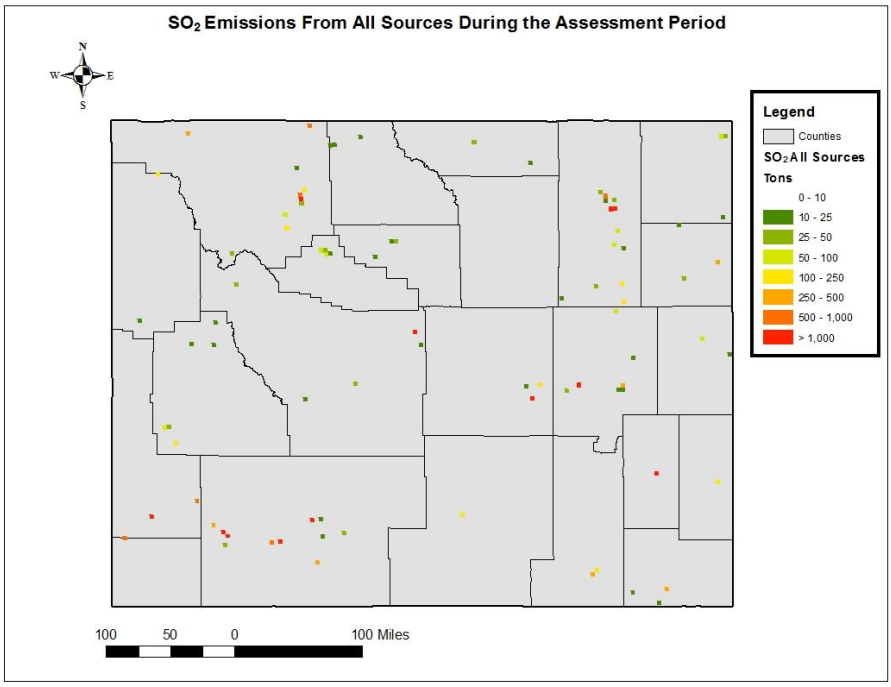

Figure 69. SO_2 Emissions from All Sources

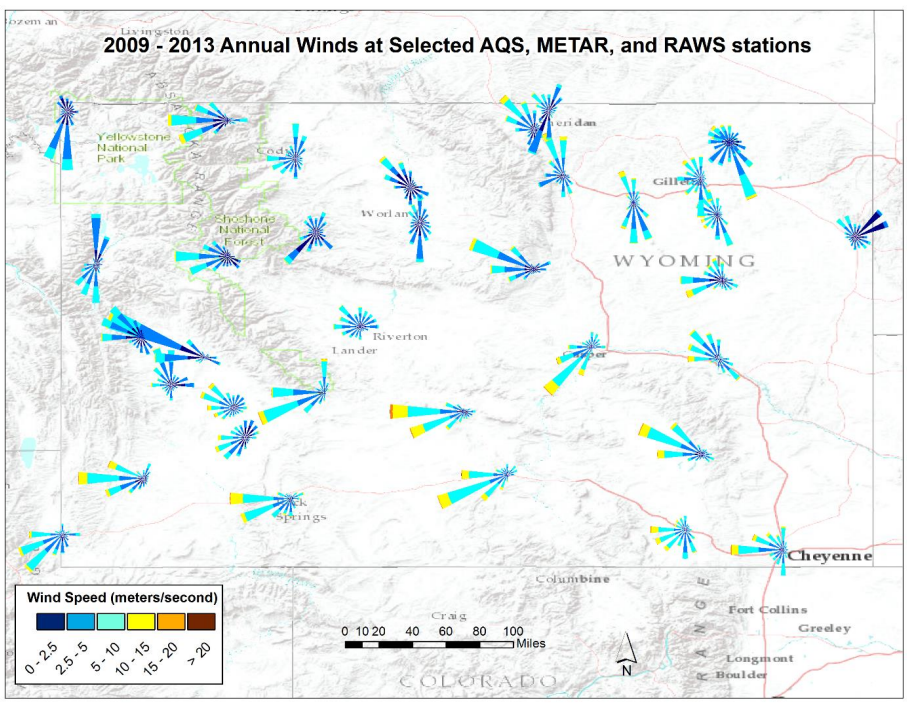

Figure 70. 2009-2013 Annual Wind Rose Map

According to the emissions inventory and wind rose maps, Torrington is downwind of a large point source near Wheatland. The AQD ran a HYSPLIT Backward Trajectory from Torrington, which

indicated that this town might see SO_2 impacts not only from this source, but potentially from oil and gas and point emissions in Converse, Campbell, and Johnson Counties.

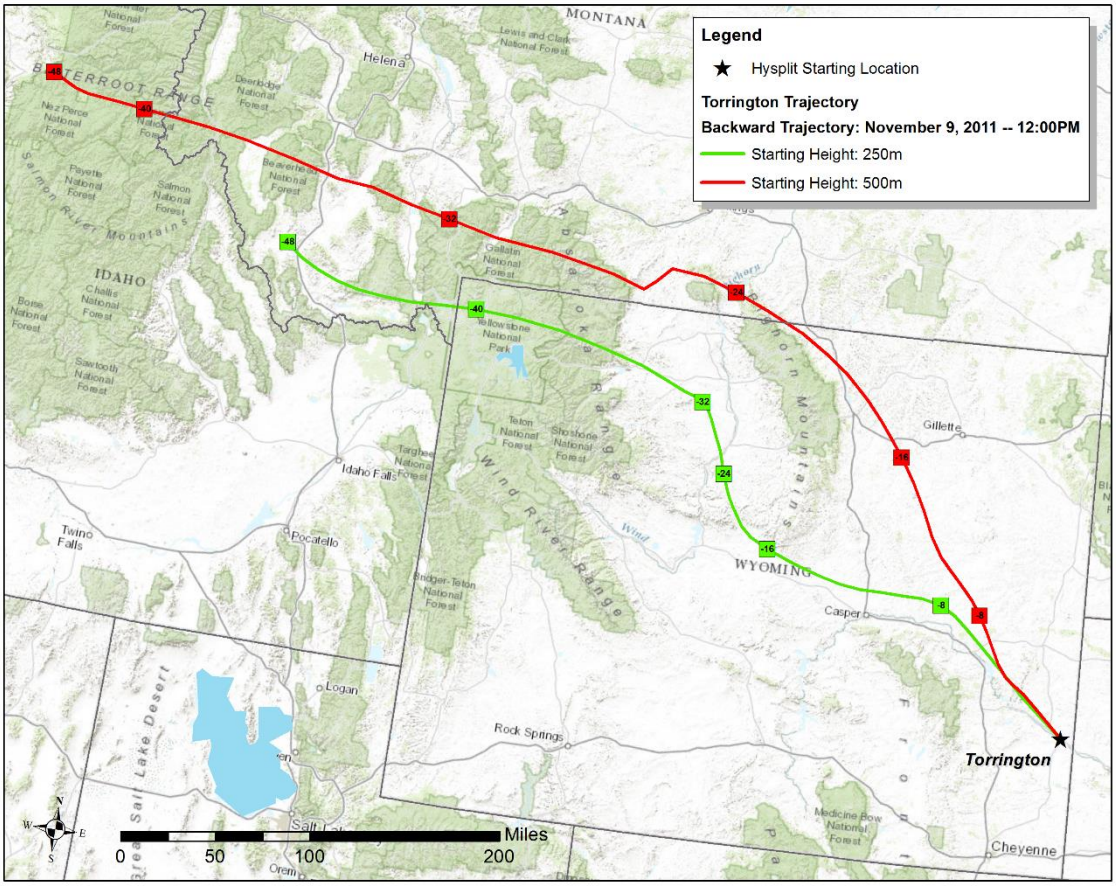

Figure 71. Torrington HYSPLIT Backward Trajectory

A large cluster of point and oil and gas emissions sources were identified in eastern Johnson County, Campbell County, north-central Converse County, Sublette County, and along the borders of Sweetwater and Lincoln Counties. No significant SO_2 emissions sources were identified upwind of the city of Jackson.

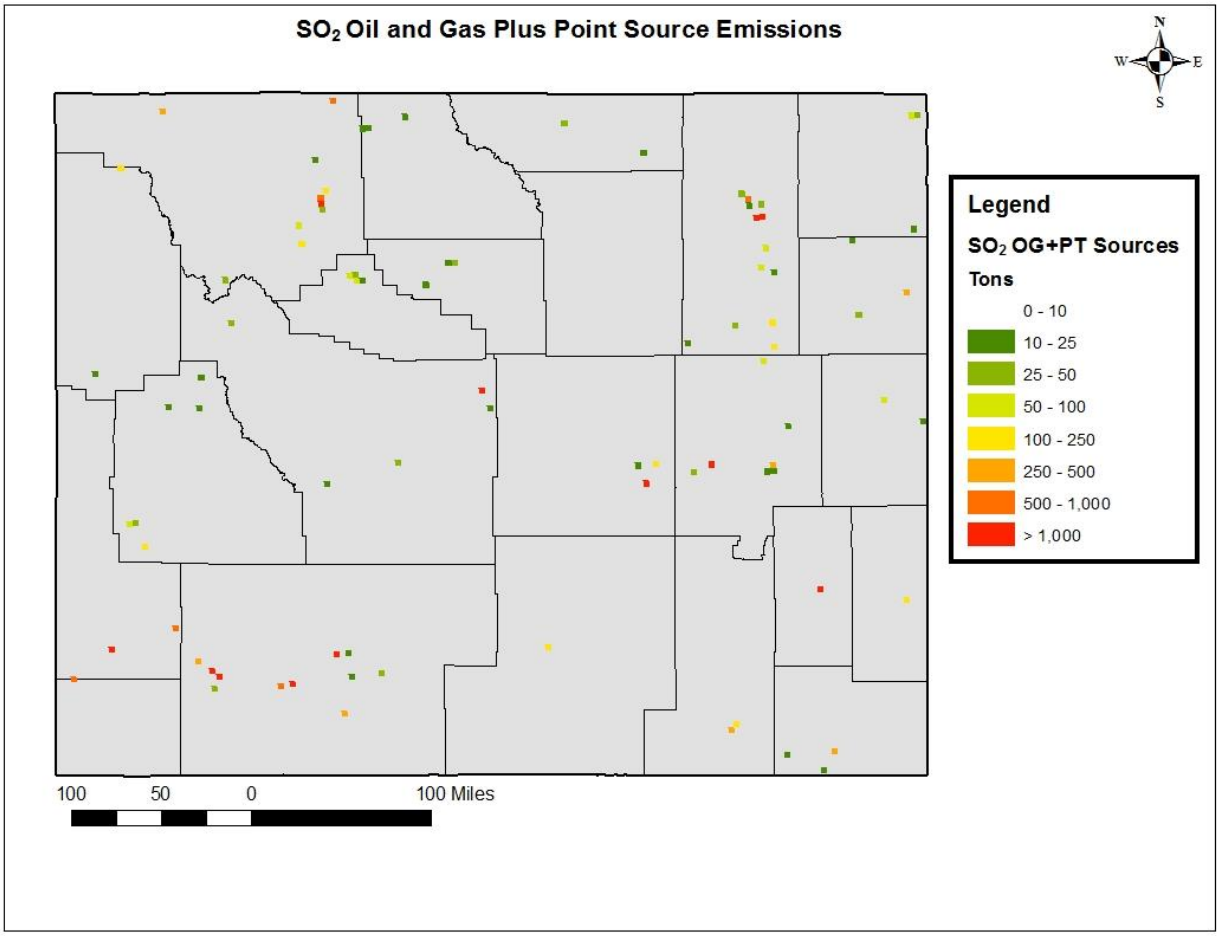

Figure 72. SO_2 Emissions from Point and Oil and Gas Sources

A significant amount of oil and gas and point sources were observed near the city of Cody. A Backward Trajectory was run for Cody. This trajectory suggests that in addition to upwind point or oil and gas sources, this city is potentially exposed to pollution transported from neighboring states. The present emissions analysis did not include out-of-state emissions.

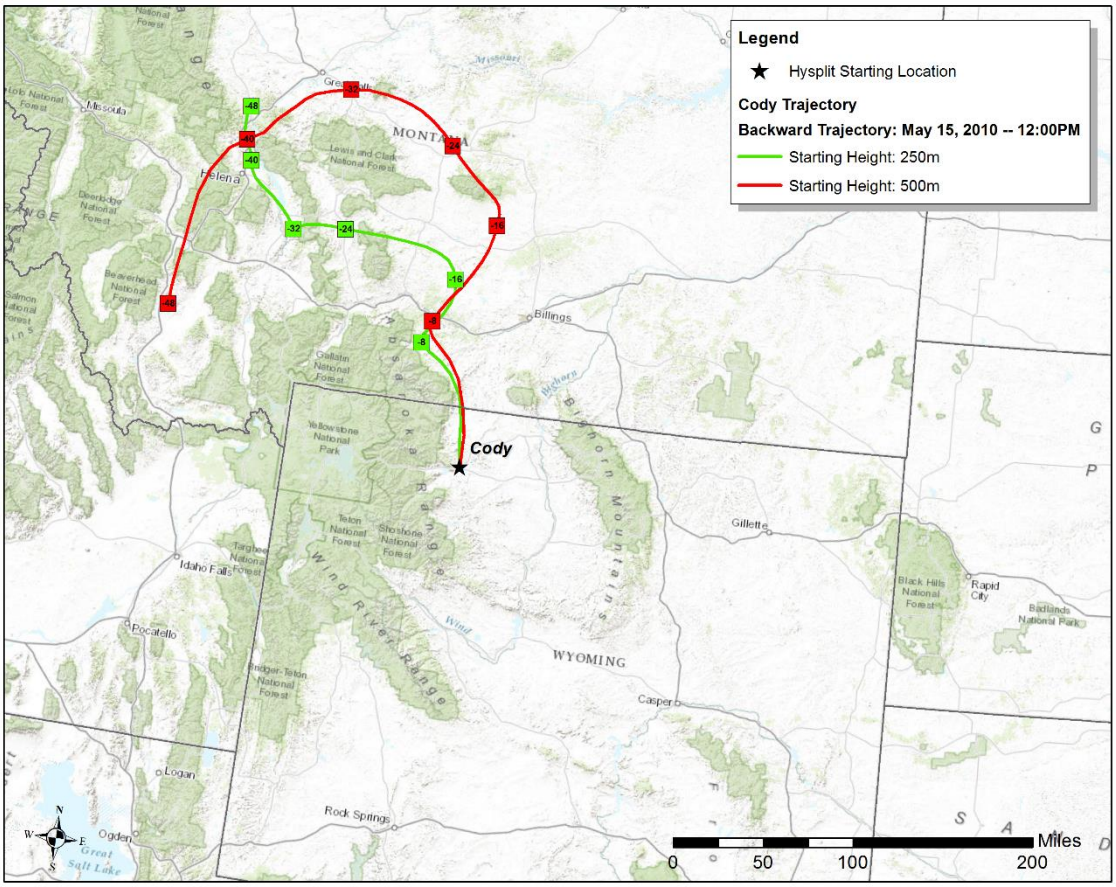

Figure 73. Cody HYSPLIT Backward Trajectory

The AQD compared SO_2 monitoring coverage against areas with planned oil and gas development. In addition to current development in Converse and Sublette Counties, both of these areas also have significant planned NEPA projects that are currently unmonitored for SO_2.

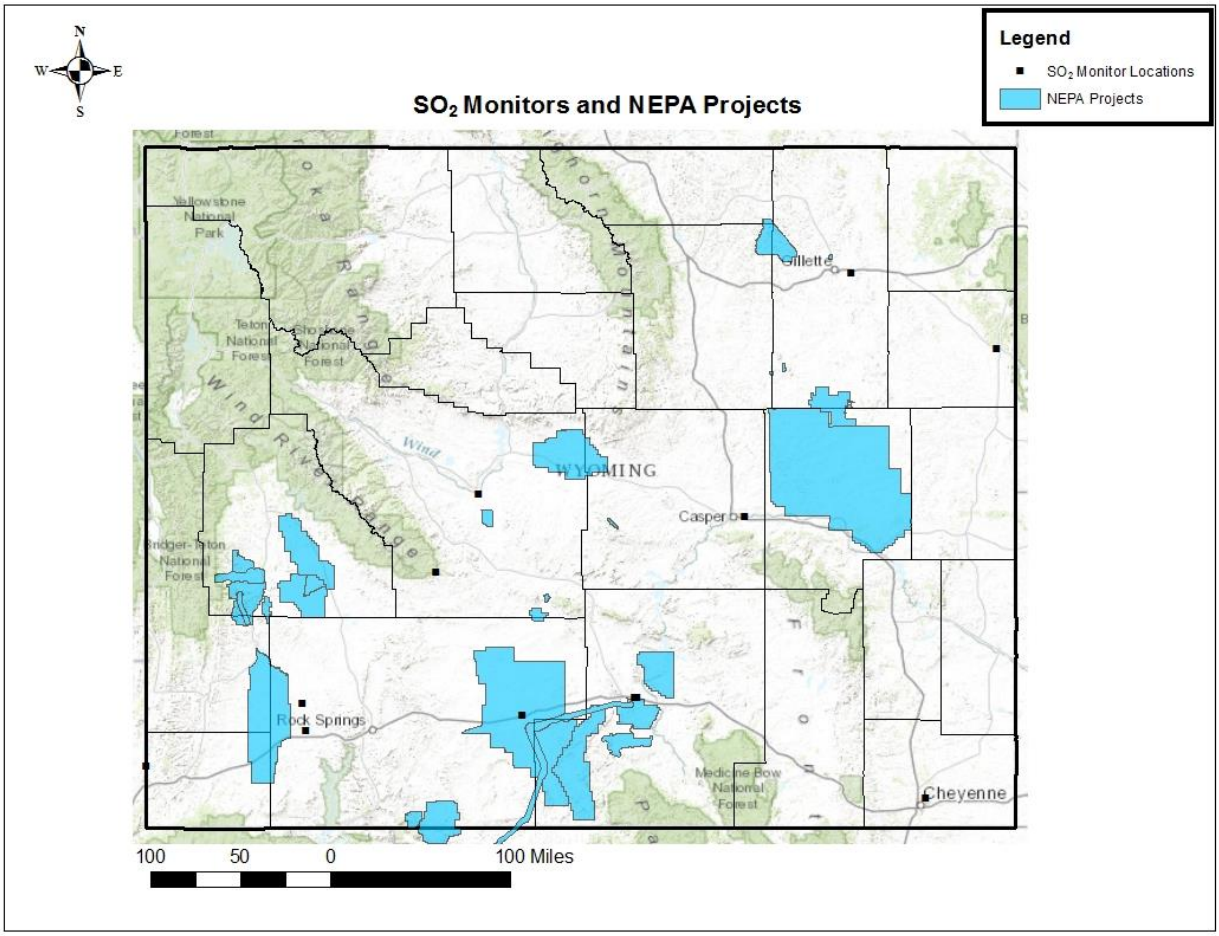

Figure 74. NEPA Project Map with SO_2 Monitor Locations

3.2.7 Meteorological, Modeling, & Background

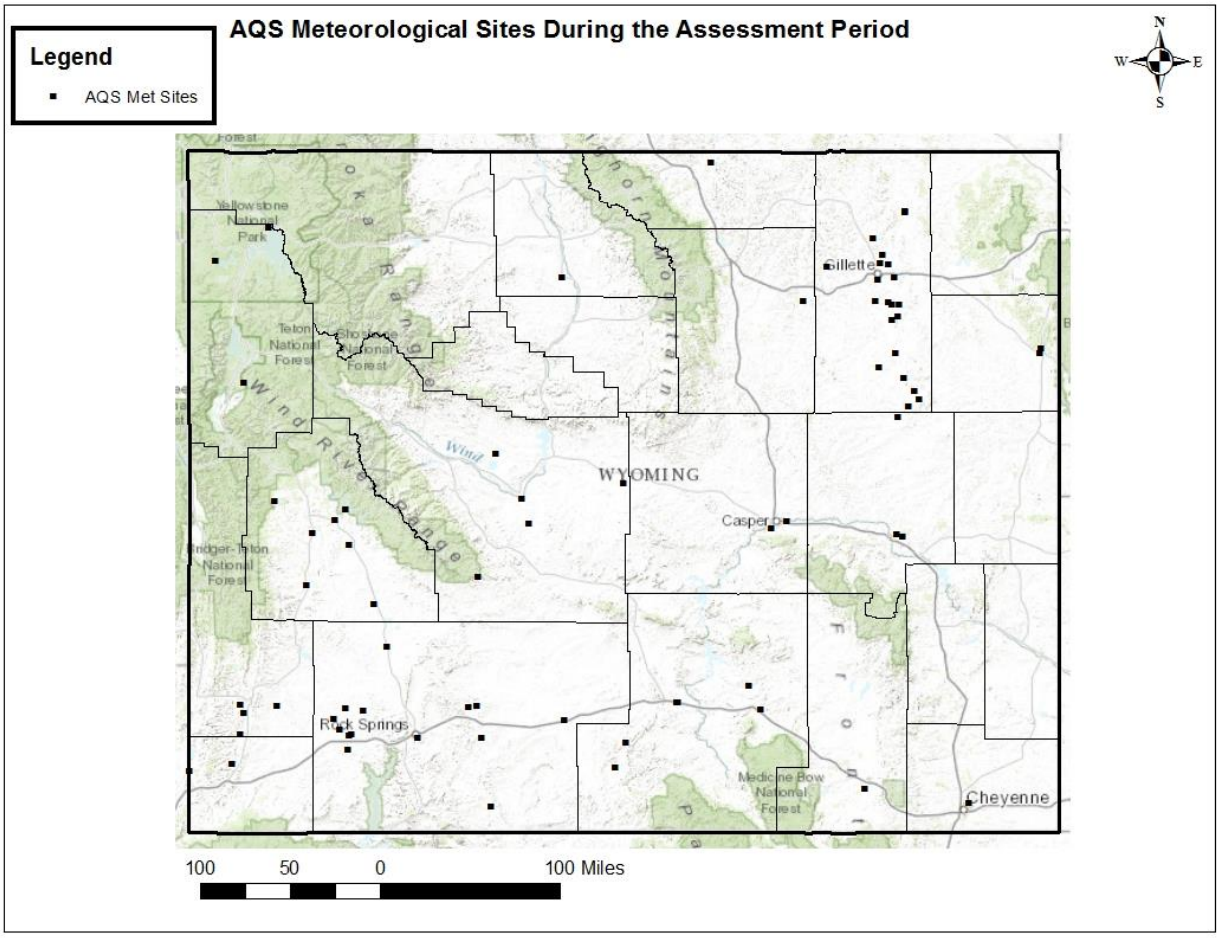

Figure 75. All AQS-Reporting Meteorological Station Locations, 2009-2013

While not explicitly required under the National Ambient Air Monitoring Strategy, the AQD exploited the exercise of the Network Assessment as an opportunity to assess the state's monitoring network in the context of modeling and background needs. The AQD's approach to assessing the monitoring network for these purposes was characteristically different than the approach used for assessing the network's utility in monitoring potential impacts on populated areas. See the "Other Monitoring Objective Analyses" criteria in Section 3.1 to further explore these differences.

The AQD first listed state-run monitors that were sited with a "General/Background" objective. Sites operated during the assessment period under this objective include Thunder Basin, South Pass, Wyoming Range, Daniel South, and Murphy Ridge. The AQD noted that there is a lack of background data in the area of eastern Johnson County and western Campbell County, an area noted in previous sections as having a large amount of current and future oil and gas development.

An analysis of the data collected at each of these background sites revealed a strong correlation between the Wyoming Range and Daniel South stations.

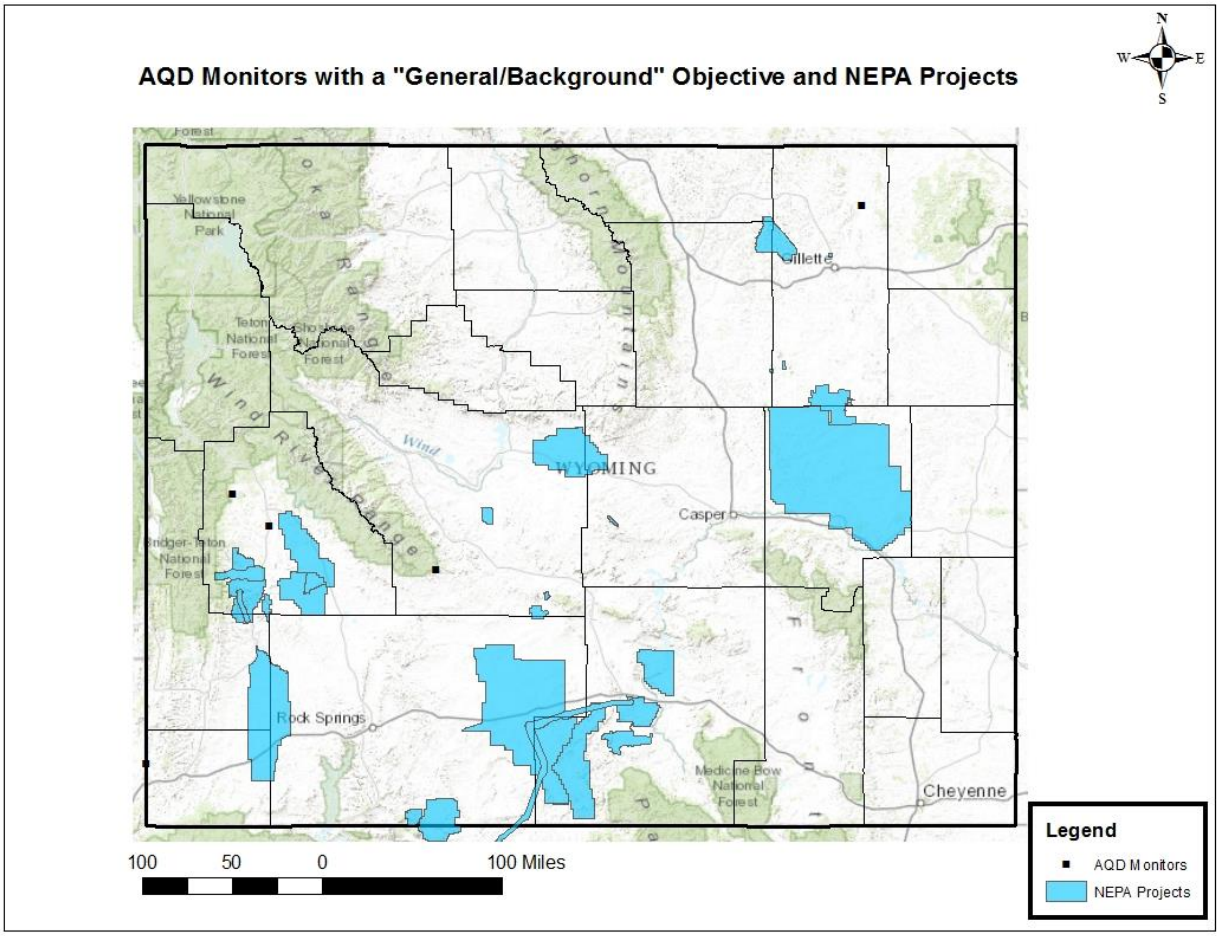

Figure 76. NEPA Project Map and AQD Monitors with a "General/Background" Objective

The AQD considered current modeling applications of background data and found that while it had historically been useful as a general background site, the Murphy Ridge station is now rarely used in modeling. Current modeling practices favor using the closest background monitor to the area being queried.

The AQD further questioned if there were internal needs for additional monitoring to support modeling performance evaluations. It was noted that additional ozone data would be helpful, but not necessary. No other needs were identified for this purpose.

Lastly, the AQD evaluated the need for new or enhanced meteorological data to support model performance. A lack of meteorological data was identified in central Converse County, Goshen and Platte Counties, central Wyoming by the Wind River Reservation, and eastern Johnson/western Campbell Counties, as previously noted. Conversely, the AQD determined that sufficient data has been collected by the Farson meteorological tower to support current and future modeling needs.

4. Findings

4.1 General Findings

In the process of assessing the state's monitoring network, the AQD identified a number of general findings independent of the parameter-specific findings of the Network Assessment exercise.

4.1.1 Review and Reconcile Site Objectives for Each Monitoring Station

Discrepancies were found when comparing the annual Network Plans with objective codes listed in the EPA's AQS database for certain AQD monitors. The information from the Network Plan is considered to be the valid source for site objectives as it constitutes a yearly review and affirmation of the goals for each station. The AQD will make any necessary changes to site objectives in AQS after the Network Assessment is completed.

In its review of site objective applicability, the AQD identified one site that is not currently meeting its original objective. The Hiawatha O_3 monitor's objective is currently "Source Oriented." However, given that development in this area has not occurred as expected, the objective for this station should be changed to "General/Background."

4.1.2 Examine Current Monitoring at the Wind River Reservation

The AQD is aware of ambient monitoring being conducted at the Wind River Reservation, but is unacquainted with the nature and extent of this monitoring. If the monitoring is found to conform to EPA QA/QC requirements, these data could serve as a viable data set available for NEPA and permitting background purposes.

The AQD would need to contact the Wind River Reservation in order to understand what parameters are being monitored, what the site objectives for these parameters are, if there is an approved QAPP for this station, and what nearby emission sources exist. This task will be accomplished after the Network Assessment is completed.

4.1.3 Revisit 2010 Network Assessment Findings

The AQD looked back at the 2010 Network Assessment to determine if the findings contained in that document had been sufficiently addressed. The findings from the 2010 Network Assessment, and the resultant actions the AQD has taken to address them, are summarized in Section 1.1 of this document. The modifications illustrate the AQD's commitment to acting on the conclusions of the 2010 Network Assessment.

4.2 New Monitoring Needs in AQD Network

After analyzing all available data for AQD sites – and taking into consideration coverage from industrial and Federal monitors for each pollutant – the AQD has identified several areas where additional monitoring is needed in the statewide monitoring network. These areas are listed in priority order, with reasoning based on data analysis, and will be considered with respect to the AQD's monitoring resources.

4.2.1 Central Converse County

There is a large amount of current and planned oil and gas development in central and northern Converse County. Bureau of Land Management NEPA documentation currently lists 5,000 new wells to be installed over 10 years in this area. The AQD operated a mobile monitoring station for over two years in southern Converse County. With the expected continued development in this area, there is a need for a longer-term and more centrally located station to monitor air quality.

The AQD recently fulfilled this finding by installing a long-term station in central Converse County. The site became operational in April 2015 and monitors for O_3, NO_2, PM_{10}, and Hydrocarbons (Methane and Non-Methane). Based on the data analysis, which found that there is a current lack of monitoring for CO in the northeast portion of the state, it is possible that the measurement of CO could be added to the current site to satisfy this finding.

4.2.2 Torrington

The data analysis performed revealed that the city of Torrington in southeastern Wyoming is downwind of many emissions sources for multiple pollutants including oil and gas development in Converse and Johnson Counties, a Title V power plant in Wheatland, and local minor and Title V sources within and surrounding the city itself. The population analysis showed that there was substantial growth in this area from 2000-2010. There is also a general lack of historical gaseous or particulate pollutant data for this area.

The AQD is planning to relocate a gaseous mobile trailer in Torrington in late 2015 to fulfill this finding. In the timeframe of performing the current Network Assessment, it was revealed that Torrington's closest Title V source, Western Sugar, will reportedly shut down operations sometime between 2016 and 2017. The AQD is evaluating the possibility of adding SO_2 to the mobile trailer in order to characterize downwind impacts from the power plant in Wheatland, one of the state's largest SO_2 sources.

4.2.3 Eastern Johnson County

Johnson County saw large population increases from 2000-2010. A large amount of oil and gas development in the eastern part of the county was identified during the data analysis. Current meteorological and air quality datasets that can be used for modeling in the area are based on the Campbell County station and the Buffalo airport. These sites may not be representative for eastern Johnson/western Campbell Counties, where the bulk of development is occurring.

According to the AQD New Source Review (NSR) Program, 3-5 years of ambient and meteorological monitoring in this area would be useful for design value calculations and for demonstrating meteorological representativeness to support modeling applications.

This site is another possible location that could, through the installation of a CO monitor in the station, satisfy the finding that monitoring for CO is lacking in the northeast quadrant of the state.

4.2.4 Laramie

The city of Laramie is a micropolitan statistical area without any historical gaseous monitoring. The city is close to a large Title V emissions source for multiple pollutants. Given its inherent nature as a college town, Laramie has the largest proportion of the population in the state living below the poverty level and a large amount of residents who live in rental units.

4.2.5 Sheridan

The city of Sheridan is a micropolitan statistical area without any historical gaseous monitoring. The city is downwind of many small, local, point and oil and gas sources, in addition to out-of-state emissions that are currently unquantified. A Veteran's Affairs hospital is located in town that is likely to serve a population statistically more sensitive to pollution levels.

Further analyses are necessary to better characterize the impact of emissions from Montana on this area.

4.2.6 Gaseous Monitoring for All Micropolitan Statistical Areas

The AQD would like to conduct further analyses to determine the need for monitoring for gaseous pollutants in all micropolitan statistical areas in the state, in addition to those areas previously identified. These analyses would include emissions inventories for adjacent states, additional HYSPLIT trajectory analyses, and a review of all existing and previous monitoring data.

Other micropolitan areas or cities with at least 9,500 people to study would include Jackson (Teton County), Cody (Park County), and Evanston (Uinta County).

4.2.7 CO Monitoring in Northeast Wyoming

There is limited current CO data in Wyoming. CO monitoring is currently conducted at only three locations: Cheyenne, Yellowstone National Park, and the Wind River Reservation. There are noticeable CO emissions along the Campbell-Johnson County border that are therefore currently not being monitored. Possible locations for monitoring CO levels in this area include eastern Johnson County or the Converse County long-term station in central Converse County.

4.2.8 Buffalo

The NSR Program has identified the city of Buffalo as a good location for assessing population exposure and upwind background monitoring for development in Johnson County, which were previously identified as needs for the area. There is no historical particulate or gaseous monitoring in this area.

4.2.9 Moneta Divide

There is a large amount of planned oil and gas development in this region, but no current or historical AQD monitoring. Bureau of Land Management NEPA documentation for the Moneta Divide project currently lists 4,250 new wells to be developed in this area. The AQD is aware of an industrially-operated monitoring station near this development. The data from this station could be used, but the AQD will need to verify the existence of a QAPP and the monitoring practices used to run this site.

4.3 Monitors in the AQD Network That Could Justifiably be Shut Down

After analyzing all available data for AQD sites, taking into consideration coverage from industrial and Federal monitors for each pollutant, the AQD has identified several areas where monitoring could be justifiably shut down in the statewide monitoring network. The monitoring equipment that is shut down would be operationally assessed for potential use elsewhere in the AQD Network. These areas are listed in priority order with reasoning based on data analysis, and will be considered in order to optimize the effectiveness and efficiency of the network.

4.3.1 Murphy Ridge

An analysis of the data collected at the Murphy Ridge station found no significant trends during the station’s operational period (2007- present). Given the shift in current modeling practices by the

AQD NSR Program towards using the closest background site available, this station now has limited use as a background site. Murphy Ridge has served its purpose for characterizing interstate transport of pollutants from Utah. This station also employs an older PM_{10} TEOM instrument that could be considered for shut-down if significant, costly operational issues occur.

4.3.2 Farson Meteorological Station

The Farson Meteorological station has fulfilled its objective of characterizing the meteorological conditions and wind-flow patterns on the southeast boundary of the UGRB O_3 Nonattainment Area. The four years' worth of data is sufficient for use in modeling applications when needed.

4.3.3 Boulder PM_{10}

Boulder PM_{10} data has been very consistent throughout data record, with no exceedances since PM_{10} monitoring began in 2005. The older model TEOM instrument operated at this station failed – and the AQD spent a great deal of resources on trying to replace the unit. Subsequent replacements also failed.

4.3.4 PM_{10} at Stations with Older TEOMs

The older TEOM instrumentation that is used at many AQD sites is no longer supported by the manufacturer. Instruments that are still operational require additional time, resources, and site visits to keep instruments running properly.

The AQD will conduct an evaluation on a site-by-site basis, considering the data record and maintenance record as instruments become inoperable, or begin to demand significant attention. Affected stations include Daniel South, Wamsutter, Murphy Ridge, Boulder, and Campbell County. If it is determined that PM_{10} data is still valuable at a given station, instruments could be replaced with TEOMs from another, decommissioned location. Alternatively, the AQD could purchase new continuous monitors if funding allows.

4.3.5 Cheyenne SLAMS

The data analysis conducted revealed that the data for the Cheyenne SLAMS station correlate well (>90%) with the Cheyenne NCore station for both PM_{10} and $PM_{2.5}$. Because this site is federally mandated, the AQD will need to conduct more analyses prior to making a decision to shut down this site, including an evaluation of high values, other statistics, and cost savings.

If the AQD finds that either parameter is redundant with the Cheyenne NCore station, and could be shut down, the AQD will submit a demonstration for shut down approval to EPA Region 8.

4.3.6 Campbell County

The Campbell County station was originally sited to evaluate impacts from growth in local coal bed methane development. However, trends in oil and gas development have recently shifted with respect to the type and location of production – to the extent that the station is no longer fulfilling its original objective. The O_3 data from this station were found to be closely correlated (>80%) with Thunder Basin. PM_{10} data from this station were found to be closely correlated (>80%) with 12 nearby industrial monitors in the Powder River Basin. NO_2 annual averages are very low at this site (~2 ppb); although this is a low number, the station's NO_2 data are not redundant with other sites. Therefore, these data still have background modeling applicability.

The Campbell County station has an older PM_{10} TEOM instrument that could be considered for shut down if significant operational issues occur.

The termination of this station would be considered if the value added was determined to be less than the pending need for new monitoring elsewhere.

4.3.7 Wright PM_{10}

The data analysis performed found that the PM_{10} data collected at the Wright Jr.-Sr. High School station correlate well (>80%) with six (6) nearby industrial monitors in the Powder River Basin. Further evaluation is warranted with respect to redundancy to other available monitoring data, and nearby future development.

4.3.8 Moxa Arch

Data for the Moxa Arch station have shown no significant trends or findings during the station's operational period (2010-present). O_3 data for this station are highly correlated with five (5) other AQD stations in southwest Wyoming. This station is not often used for background data in NSR Program permitting. The Moxa Arch station was originally sited to track changes during development of Moxa Arch Infill. However, this project has been altered and acquired by a new company, and as a result, it must start over at the scoping phase. Therefore, significant infill activity is not expected in this area for several years.

This station is located near Trona facilities and could still be useful as an upwind monitor for these facilities. Termination of this station would be considered if the value added was determined to be less than the pending need for new monitoring elsewhere.

5. Conclusion

The 2015 Network Assessment used various statistical, graphical, and geographic analyses to evaluate Wyoming's ambient and meteorological monitoring network. The AQD chose to evaluate its monitoring network by parameter in the following categories: CO, NO_2, O_3, PM_{10}, $PM_{2.5}$, SO_2, and meteorological. For each parameter, several questions were posed pertaining to monitoring objectives, priorities for the AQD, and the results of the data products.

The AQD classified findings into three (3) sections: general, new monitoring needs, and monitors that could be justifiably shut down. Detailed information about the findings can be found in Section 4. Before implementing any finding(s) of this Network Assessment, the AQD will need to evaluate resources and prioritize needs.

The general findings are as follows:

1. Review and reconcile site objectives for each monitoring station
2. Examine current monitoring at the Wind River Reservation
3. Revisit 2010 Network Assessment findings

Additional monitoring needs in Wyoming AQD"s Network are presented below and in order of precedence:

1. Central Converse County
2. Torrington
3. Eastern Johnson County
4. Laramie
5. Sheridan
6. Gaseous monitoring for all micropolitan statistical areas
7. CO monitoring in Northeast Wyoming
8. Buffalo
9. Moneta Divide

The AQD identified the following sites and parameters that could justifiably be shut down in order of precedence:

1. Murphy Ridge
2. Farson Meteorological Station
3. Boulder PM_{10}
4. PM_{10} at stations with older TEOMs
5. Cheyenne SLAMS
6. Campbell County
7. Wright PM_{10}
8. Moxa Arch

6. Appendix A: List of Federal, Industrial, and Tribal Monitoring Sites

AQS ID	Site Name	Site Type	County
56-001-0800	Mt. Cement Company East Site...East of Plant	Industry	Albany
56-001-0801	Mt. Cement Company North Site...North of Plant	Industry	Albany
56-001-0802	Mt. Cement Company West Met Site	Industry	Albany
56-001-9991	Centennial	CASTNET	Albany
56-003-0002	Basin BLM-WARMS	CASTNET	Big Horn
56-005-0003	South Coal BLM-WARMS	BLM-WARMS	Campbell
56-005-0011	Hilight-Reno Junction Gas Plant	Industry	Campbell
56-005-0012	Fortification Creek BLM-WARMS	CASTNET	Campbell
56-005-0084	School Creek (SC-1)	Industry	Campbell
56-005-0085	School Creek MET-1	Industry	Campbell
56-005-0086	School Creek SC-3	Industry	Campbell
56-005-0087	School Creek SC-2	Industry	Campbell
56-005-0303	Coal Creek Mine Site 3	Industry	Campbell
56-005-0802	Belle Ayr BA-1	Industry	Campbell
56-005-0808	Eagle Butte EB-3	Industry	Campbell
56-005-0826	Rawhide Hilltop Site	Industry	Campbell
56-005-0841	Coal Creek Mine Site 7	Industry	Campbell
56-005-0857	Black Hills Power Site 4	Industry	Campbell
56-005-0869	North Antelope Rochelle RO-1	Industry	Campbell
56-005-0870	North Antelope NA-5	Industry	Campbell
56-005-0875	Black Thunder Mine Sites 3A & 3B	Industry	Campbell
56-005-0879	Dry Fork DF-1	Industry	Campbell
56-005-0883	Cordero Rojo Site W	Industry	Campbell
56-005-0884	Buckskin West	Industry	Campbell
56-005-0885	Cordero Rojo CRC-E10	Industry	Campbell
56-005-0886	Caballo Mine C-8	Industry	Campbell
56-005-0889	Cordero HV-3/PM-3	Industry	Campbell
56-005-0890	Coal Creek Site 26	Industry	Campbell
56-005-0891	Black Thunder Mine 36; BTM-36-2	Industry	Campbell
56-005-0892	Belle Ayr BA-4	Industry	Campbell
56-005-0893	Belle Ayr BA-3	Industry	Campbell
56-005-0894	Jacobs Ranch Site 4	Industry	Campbell
56-005-0895	Rawhide North Site	Industry	Campbell
56-005-0897	Dry Fork Mine Site 4	Industry	Campbell
56-005-0898	Belle Ayr Ranch House Monitor	Industry	Campbell
56-005-0900	Amax Eagle Butte Site EB-5	Industry	Campbell
56-005-0901	Clovis Point Mine Site CP-1	Industry	Campbell
56-005-0906	Amax Eagle Butte Site EB-2	Industry	Campbell
56-005-0907	Black Thunder Mine 12 Met	Industry	Campbell
56-005-0908	Caballo Mine C-9	Industry	Campbell
56-005-1000	CRC Met Station	Industry	Campbell
56-005-1003	Cordero Rojo CRC-W11	Industry	Campbell
56-005-1009	Cordero Rojo CRC-S11	Industry	Campbell

AQS ID	Site Name	Site Type	County
56-005-1110	Anadarko Spotted Horse Met Station	Industry	Campbell
56-005-1111	NARM Met Station	Industry	Campbell
56-005-1112	Coal Creek Mine Met Station	Industry	Campbell
56-005-1115	Black Thunder Met Station	Industry	Campbell
56-005-1877	Black Thunder Mine Site 25	Industry	Campbell
56-005-1879	Dry Fork Site DF-2	Industry	Campbell
56-005-1895	Rawhide Mine Hill Met Site	Industry	Campbell
56-005-1896	Dry Fork Site DF-2	Industry	Campbell
56-005-1899	Buckskin North/PRB-1	Industry	Campbell
56-005-1900	NARM NA-7	Industry	Campbell
56-005-1906	Amax Eagle Butte Site EB-31	Industry	Campbell
56-005-1915	Black Thunder Mine Site 9-1/2	Industry	Campbell
56-005-1917	Black Thunder Mine – JRM 5	Industry	Campbell
56-005-2900	Eagle Butte Mine EB-5	Industry	Campbell
56-005-2901	Eagle Butte Mine Rawhide Elementary	Industry	Campbell
56-005-2908	Caballo Mine Met.	Industry	Campbell
56-005-2909	Cordero Rojo Met. Station	Industry	Campbell
56-005-5555	Wyodak Site 5	Industry	Campbell
56-005-6666	Wyodak Site 6	Industry	Campbell
56-007-0100	Atlantic Rim Sundog	Industry	Carbon
56-007-0826	Seminoe II Mine 826 Site	Industry	Carbon
56-007-0851	Sinclair Meteorological Monitoring Station	Industry	Carbon
56-007-0852	Sinclair SO_2 Station	Industry	Carbon
56-007-8110	Elk Mountain Site 811UW	Industry	Carbon
56-009-0007	Tallgrass Met	Industry	Converse
56-009-0008	Tallgrass Gaseous	Industry	Converse
56-009-0088	NA-8 North Antelope Rochelle (Near Irwin Ranch Road)	Industry	Converse
56-009-0819	Antelope Site 3	Industry	Converse
56-009-0850	Antelope Site 5	Industry	Converse
56-009-0851	Antelope Site 6	Industry	Converse
56-009-0881	Antelope Site 4	Industry	Converse
56-009-2819	Antelope Mine Met Station	Industry	Converse
56-013-0232	Spring Creek	Industry	Fremont
56-013-0234	Beaver Creek Air Quality Station	Industry	Fremont
56-013-6001	W1-Sand Draw-01	Tribal	Fremont
56-019-0002	Buffalo BLM-WARMS	CASTNET	Johnson
56-019-9000	Cloud Peak	IMPROVE	Johnson
56-023-0800	Kemmerer Mine-800P	Industry	Lincoln
56-023-0814	Kemmerer-814 (SB-III)	Industry	Lincoln
56-023-0815	Kemmerer SB-IV	Industry	Lincoln
56-023-0816	Kemmerer SB-V	Industry	Lincoln
56-023-0820	Naughton Power Plant PM_{10} Site	Industry	Lincoln
56-023-2000	Opal Met Station	Industry	Lincoln
56-025-2601	Sinclair Casper Refinery	Industry	Natrona
56-029-9002	North Absaroka	IMPROVE	Park
56-031-0805	Laramie River	Industry	Platte

AQS ID	Site Name	Site Type	County
56-033-0004	Sheridan BLM-WARMS	CASTNET	Sheridan
56-035-0002	Pinedale BLM-WARMS	CASTNET	Sublette
56-035-9000	Bridger Wilderness	IMPROVE	Sublette
56-035-9001	Boulder Lake	IMPROVE	Sublette
56-035-9991	Pinedale	CASTNET	Sublette
56-037-0010	FMC-Granger Site 1P (Upwind)	Industry	Sweetwater
56-037-0012	Tata Site 3	Industry	Sweetwater
56-037-0013	Tata Site 1	Industry	Sweetwater
56-037-0014	Tata Site 4	Industry	Sweetwater
56-037-0812	OCI-PM_{10} & Met	Industry	Sweetwater
56-037-0847	Solvay Site #1	Industry	Sweetwater
56-037-0848	Solvay Site #2	Industry	Sweetwater
56-037-0849	Solvay Met Tower	Industry	Sweetwater
56-037-0851	Jim Bridger Site 851	Industry	Sweetwater
56-037-0852	Black Butte Mine - Leucite	Industry	Sweetwater
56-037-0860	Bridger Coal JB-4	Industry	Sweetwater
56-037-0862	FMC-Granger Site #7	Industry	Sweetwater
56-037-0866	FMC Westvaco Site 866	Industry	Sweetwater
56-037-0867	Bridger Coal JB-5	Industry	Sweetwater
56-037-0868	Black Butte Mine – Downwind PM_{10}	Industry	Sweetwater
56-037-0870	Tata PM_{10} & Met	Industry	Sweetwater
56-037-0875	Black Butte #875	Industry	Sweetwater
56-037-0898	OCI #4 Site Relocated	Industry	Sweetwater
56-037-0901	Jim Bridger Site 901	Industry	Sweetwater
56-037-1002	FMC Westvaco Site 002 (Upwind)	Industry	Sweetwater
56-037-1236	Black Butte Mine Upwind	Industry	Sweetwater
56-037-1414	Black Butte Mine Pit 14	Industry	Sweetwater
56-037-1868	Black Butte Mine I-80 Site	Industry	Sweetwater
56-037-2004	Black Butte Office Met Station	Industry	Sweetwater
56-037-2851	Jim Bridger Met Site	Industry	Sweetwater
56-037-2860	Bridger Coal JB-2	Industry	Sweetwater
56-039-0008	Grand Teton NP – Science School	NPS	Teton
56-039-1011	Yellowstone National Park – Water Tank	CASTNET	Teton
56-039-1013	Yellowstone National Park – Old Faithful Snow Lodge	NPS	Teton
56-039-9000	Yellowstone NP2	IMPROVE	Teton
56-041-0200	Haystack Coal Mine – Downwind	Industry	Uinta
56-041-0201	Haystack Coal Mine - Upwind	Industry	Uinta
56-045-0003	Newcastle BLM-WARMS	CASTNET	Weston
56-045-0800	Wyoming Refining	Industry	Weston
NOT IN AQS	Black Thunder Tracy Ranch	Industry	Campbell

Table 15. Federal, Industrial, and Tribal Monitoring Sites

7. Appendix B: Technical Support Document from STI

Sonoma Technology, Inc.
Environmental Science and Innovative Solutions

Technical Memorandum

July 24, 2015 STI-915008-6323-TM

To: Leif Paulson, Wyoming Department of Environmental Quality

From: Bryan Penfold, Mike McCarthy, Yuan Du, and Theresa O'Brien

Re: Wyoming Statewide Air Monitoring Network Assessment

Sonoma Technology, Inc. (STI) worked with Wyoming DEQ's Air Quality Division (AQD) to assess AQD's criteria pollutant monitoring network to determine efficient and effective placement of gaseous and particulate monitoring stations throughout the state. This technical memorandum summarizes STI's methods and analyses. Tasks for this project included Task A, data analysis; Task B, gridded emission inventory development; Task C, meteorological analysis; Task D, population analysis; and Task E, additional analyses. Project data, including analysis input data, analysis codes, maps, charts, and resultant information for each task can be found in the task-specific data deliverable files. These files have been sent to AQD staff.

Task A: Data Analysis

We acquired data and associated parameters for all sites in the U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS), including (but not limited to) the site name and location, primary quality assurance organization (PQAO), parameter(s) measured, measurement method, parameter occurrence code (POC), and sample duration. We included all AQD-operated and industrial monitoring sites available in AQS. For the data quality assessment, we compiled a master list of all sites to be included in the network assessment and corresponding data from 2009 through 2013 for ozone, PM_{10} (both manual filter data and continuous tapered element oscillating microbalance, or TEOM, data), $PM_{2.5}$, NO_2, and SO_2. Part of the master list review was intended for use by AQD to verify that the correct codes were provided to AQS and to identify the sites to be included in the data analyses. The data were compiled into Microsoft Access databases, screened for data quality, and processed for use in the data analyses.

Data Completeness

We determined the data completeness of the 2009–2013 dataset for each pollutant on the basis of the total number of expected samples. To perform robust analyses, EPA recommends data

completeness of greater than 85%; that is, a data set must be at least 85% complete to be representative of the sampling period. Data completeness is calculated by dividing the actual number of reported samples by the expected total number of samples. Data completeness was calculated for the data set as a whole and by month. We used individual sampling frequency codes to calculate the data completeness for each site and parameter. Table 1 shows the results of the data completeness assessment for sites and parameters ($PM_{2.5}$, PM_{10}, ozone, SO_2, and NO_2) with at least 5% of samples missing.

A null and invalid data assessment determines how many samples over the time period of interest (2009–2013) are reported with null sampling codes. The percentage of null or invalid samples is calculated from the number of actual data records (rather than the number of expected data records). Table 2 shows the results of the assessment for sites and parameters for which more than 10% of samples are reported as null or invalid.

The MDL (Method Detection Limit) is the value at which a measured concentration is considered statistically distinguishable from zero. An assessment of data above the MDL identifies the number of samples in the 2009–2013 data set that are considered to have concentration values statistically distinguishable from zero. When a significant amount of data is below the MDL, we check individual years to determine whether there are any problems that might limit the use of the data. Samples below the MDL can be used for some purposes, such as stating that a concentration is below the MDL or making comparisons to National Ambient Air Quality Standards (NAAQS), but they are not as useful for quantifying ambient concentrations, analyzing trends, and/or validating air quality models. Table 3 shows the results of the assessment of data above the MDL by site and the parameters for which fewer than 50% of data are reported above the MDL.

Table 1. Data completeness assessment results for the AQD sites in Wyoming with at least 5% of samples missing (sites with greater than 95% data completeness are not shown). For sites with multiple POCs, results were combined when appropriate. All data for 2009-2013 are included in the table.

Site Code	Name	Start Date	End Date	Parameter	POC	Duration/Frequency	No. Expected	No. of Records	% Complete
560010006	406 Ivinson, Laramie, WY	1/1/2009	8/24/2010	PM_{10} STP	2	24-hr every 3rd day	200	169	84
560010006	406 Ivinson, Laramie, WY	1/1/2009	8/27/2010	PM_{10} LC	1	24-hr every 3rd day	201	151	75
560010006	406 Ivinson, Laramie, WY	8/30/2010	12/30/2013	PM_{10} LC	5	24-hr every 3rd day	406	353	87
560050891	BTM-36-2 (Black Thunder Mine)	7/1/2010	12/31/2013	$PM_{2.5}$ LC	3	1-hr daily	30720	26885	88
560050892	Belle Ayr BA-4	4/26/2010	12/31/2013	$PM_{2.5}$ LC	3	1-hr daily	32304	28416	88
560050893	Belle Ayr BA-3	1/1/2009	12/30/2013	PM_{10} LC	1	24-hr every 3rd day	608	577	95
560050893	Belle Ayr BA-3	1/1/2009	12/30/2013	PM_{10} STP	1	24-hr every 3rd day	608	577	95
560050894	Jacobs Ranch Site 4	1/1/2009	6/29/2012	PM_{10} LC	1	24-hr every 3rd day	425	363	85
560050901	Clovis Point Mine Site CP-1	1/1/2009	8/22/2012	PM_{10} LC	1	24-hr every 3rd day/ 24-hr daily	1025	750	73
560051002	Gillette - 1000 West 8th	8/18/2010	12/24/2013	PM_{10} LC	5	24-hr every 6th day	204	186	91
560051899	Buckskin Mine North Site	7/1/2010	12/31/2013	$PM_{2.5}$ LC	3	1-hr daily	30720	28037	91
560070826	Seminoe II Mine Site	1/1/2009	8/25/2012	PM_{10} LC	2	24-hr every 6th day	222	208	94
560070826	Seminoe II Mine Site	1/1/2009	8/25/2012	PM_{10} STP	2	24-hr every 6th day	222	208	94
560070826	Seminoe II Mine Site	4/1/2009	8/25/2012	PM_{10} LC	1	24-hr every 6th day	207	193	93
560070826	Seminoe II Mine Site	4/1/2009	8/25/2012	PM_{10} STP	1	24-hr every 6th day	207	193	93
560078110	Elk Mountain Site 811UW	1/1/2009	10/12/2011	PM_{10} LC	1	24-hr every 6th day	169	155	92
560078110	Elk Mountain Site 811UW	1/1/2009	10/12/2011	PM_{10} STP	1	24-hr every 6th day	169	155	92
560111013		4/1/2009	9/30/2012	O_3	1	1-hr daily	30696	16968	55

Site Code	Name	Start Date	End Date	Parameter	POC	Duration/Frequency	No. Expected	No. of Records	% Complete
560210001	Cheyenne-State Office Bldg 23rd & Central Avenue	1/1/2009	12/30/2013	PM_{10} LC	1	24-hr every 3rd day	608	550	90
560210001	Cheyenne-State Office Bldg 23rd & Central Avenue	1/1/2009	12/30/2013	PM_{10} LC	2	24-hr every 6th day	304	232	76
560210001	Cheyenne-State Office Bldg 23rd & Central Avenue	1/1/2009	12/30/2013	PM_{10} STP	2	24-hr every 6th day	304	262	86
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	1/1/2009	3/28/2011	PM_{10} LC	1	24-hr every 6th day	136	121	89
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	1/1/2009	3/28/2011	PM_{10} LC	2	24-hr every 6th day	136	121	89
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	1/1/2009	3/28/2011	PM_{10} STP	1	24-hr every 6th day	136	121	89
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	1/1/2009	3/28/2011	PM_{10} STP	2	24-hr every 6th day	136	121	89
560250001	Casper -City County Bldg Center and C Streets	9/26/2010	12/30/2013	PM_{10} LC	4	24-hr every 3rd day	397	339	85
560250001	Casper -City County Bldg Center and C Streets	9/26/2010	12/30/2013	PM_{10} LC	5	24-hr every 6th day/ 24-hr every 12th day	175	125	72
560250001	Casper -City County Bldg Center and C Streets	9/26/2010	12/30/2013	PM_{10} STP	5	24-hr every 6th day	199	155	78
560290001	Cody Jr Hi Sch-2901 Cougar Ave	7/16/2010	12/30/2013	PM_{10} LC	3	24-hr every 3rd day	421	366	87

Site Code	Name	Start Date	End Date	Parameter	POC	Duration/Frequency	No. Expected	No. of Records	% Complete
560310805	Laramie River Power Plant Wheatland, WY	1/1/2009	12/30/2013	PM_{10} STP	1	24-hr every 6th day	304	288	95
560310805	Laramie River Power Plant Wheatland, WY	1/1/2009	12/30/2013	PM_{10} STP	2	24-hr every 6th day	304	288	95
560330003	Highland Park	1/1/2009	5/21/2012	PM_{10} LC	1	24-hr every 3rd day	412	353	86
560330003	Highland Park	1/1/2009	5/21/2012	PM_{10} LC	2	24-hr every 6th day	206	177	86
560331003	Meadowlark Elementary School	8/1/2012	12/30/2013	PM_{10} LC	2	24-hr every 6th day/ 24-hr every 12th day	62	44	71
560370007	625 Ahsay Ave Rock Springs WYO	1/1/2009	12/30/2013	PM_{10} LC	2	24-hr every 3rd day	608	550	90
560370010	FMC - Granger Upwind (SW of facility)	1/1/2009	12/30/2013	PM_{10} LC	1	24-hr every 6th day	304	239	79
560370010	FMC - Granger Upwind (SW of facility)	1/1/2009	12/30/2013	PM_{10} STP	1	24-hr every 6th day	304	239	79
560370852	Black Butte #852 (Lucite Hills)	1/1/2009	12/31/2013	PM_{10} LC	1	24-hr daily	1826	1724	94
560370852	Black Butte #852 (Lucite Hills)	1/1/2009	12/31/2013	PM_{10} STP	1	24-hr daily	1826	1724	94
560370860	Bridger Coal JB-4	1/1/2009	12/31/2013	PM_{10} STP	1	24-hr daily	1826	1732	95
560370862	FMC - Granger - Downwind (East of facility)	1/1/2009	12/30/2013	PM_{10} LC	1	24-hr every 6th day	304	239	79
560370862	FMC - Granger - Downwind (East of facility)	1/1/2009	12/30/2013	PM_{10} LC	2	24-hr every 6th day	304	239	79
560370862	FMC - Granger - Downwind (East of facility)	1/1/2009	12/30/2013	PM_{10} STP	1	24-hr every 6th day	304	239	79
560370862	FMC - Granger - Downwind (East of facility)	1/1/2009	12/30/2013	PM_{10} STP	2	24-hr every 6th day	304	183	60
560370867	Bridger Coal JB-5	1/1/2009	12/31/2013	PM_{10} STP	2	24-hr daily	1826	1733	95
560370868	Black Butte #868 Downwind PIT#10	1/1/2009	9/30/2012	PM_{10} LC	1	24-hr daily	1369	1194	87

Site Code	Name	Start Date	End Date	Parameter	POC	Duration/Frequency	No. Expected	No. of Records	% Complete
560370868	Black Butte #868 Downwind PIT#10	1/1/2009	12/31/2013	PM_{10} STP	2	24-hr daily	1826	1651	90
560370868	Black Butte #868 Downwind PIT#10	4/1/2011	12/31/2013	PM_{10} LC	2	24-hr daily	1006	730	73
560370898	OCI - Downwind (East of facility)	7/6/2009	12/30/2013	PM_{10} LC	2	24-hr every 6th day	273	245	90
560391006	Jackson Fire District #1- 40 East Pearl Ave	1/1/2009	12/30/2013	PM_{10} LC	1	24-hr every 3rd day	608	552	91

Table 2. Null and invalid samples for those sites and parameters with more than 10% null or invalid records.

Site Code	Name	Parameter	POC	Duration/Frequency	No. Expected	No. Null/ Invalid	% Null/ Invalid
560019991	Roosevelt National Forest, Centennial, WY 82055	O_3	1	1-hr daily	22680	3241	14
560050099	Wright Jr-Senior High School-220 Wright Blvd	PM_{10} LC	1	24-hr every 6th day	122	15	12
560050099	Wright Jr-Senior High School-220 Wright Blvd	PM_{10} LC	3	24-hr every 6th day	154	16	10
560050099	Wright Jr-Senior High School-220 Wright Blvd	PM_{10} STP	1	24-hr every 6th day	97	10	10
560050099	Wright Jr-Senior High School-220 Wright Blvd	PM_{10} STP	3	24-hr every 6th day	209	26	12
560050123	Thunder Basin	NO_2	1	1-hr daily	43824	5408	12
560050123	Thunder Basin	PM_{10} LC	1	24-hr every 3rd day	609	164	27
560050800	Gillette Mobile	$PM_{2.5}$ LC	1	1-hr daily	10416	1704	16
560050891	BTM-36-2 (Black Thunder Mine)	$PM_{2.5}$ LC	1	24-hr every 3rd day	155	45	29
560050891	BTM-36-2 (Black Thunder Mine)	$PM_{2.5}$ LC	2	24-hr every 6th day	76	15	20
560050891	BTM-36-2 (Black Thunder Mine)	$PM_{2.5}$ LC	3	1-hr daily	26885	10296	38
560050892	Belle Ayr BA-4	$PM_{2.5}$ LC	1	24-hr every 3rd day	152	18	12
560050892	Belle Ayr BA-4	$PM_{2.5}$ LC	3	1-hr daily	28416	13589	48
560050906	Eagle Butte EB-2 REL'D	PM_{10} LC	2	24-hr every 3rd day	42	8	19
560051002	Gillette - 1000 West 8th	PM_{10} LC	5	24-hr every 6th day	186	40	22
560051002	Gillette - 1000 West 8th	PM_{10} STP	5	24-hr every 6th day	217	43	20
560051899	Buckskin Mine North Site	$PM_{2.5}$ LC	3	1-hr daily	28037	9302	33
560052901	EB-RSCH, 200 Prospector Parkway, Gillette	PM_{10} LC	1	24-hr daily	365	69	19
560052901	EB-RSCH, 200 Prospector Parkway, Gillette	PM_{10} STP	1	24-hr daily	365	69	19
560056666	1,008 meters North of I-90 & 361 West of American Ranch Rd	PM_{10} LC	1	24-hr daily	496	57	11

Site Code	Name	Parameter	POC	Duration/Frequency	No. Expected	No. Null/ Invalid	% Null/ Invalid
560056666	1,008 meters North of I-90 & 361 West of American Ranch Rd	PM_{10} STP	1	24-hr daily	496	57	11
560070099	Atlantic Rim Met (Jolly Roger)	NO_2	1	1-hr daily	1319	239	18
560070099	Atlantic Rim Met (Jolly Roger)	O_3	1	1-hr daily	1319	233	18
560070100	Atlantic Rim Sundog Location	NO_2	1	1-hr daily	36744	4425	12
560070826	Seminoe II Mine Site	PM_{10} LC	1	24-hr every 6th day	193	30	16
560070826	Seminoe II Mine Site	PM_{10} LC	2	24-hr every 6th day	208	39	19
560070826	Seminoe II Mine Site	PM_{10} STP	1	24-hr every 6th day	193	30	16
560070826	Seminoe II Mine Site	PM_{10} STP	2	24-hr every 6th day	208	39	19
560078110	Elk Mountain Site 811UW	PM_{10} LC	1	24-hr every 6th day	155	29	19
560078110	Elk Mountain Site 811UW	PM_{10} STP	1	24-hr every 6th day	155	29	19
560078120		PM_{10} LC	1	24-hr every 6th day	167	65	39
560078120		PM_{10} STP	1	24-hr every 6th day	167	65	39
560090008	Tallgrass Gaseous (an industrial site)	NO_2	1	1-hr daily	4176	968	23
560090008	Tallgrass Gaseous (an industrial site)	O_3	1	1-hr daily	4176	799	19
560090819	Antelope Site 3	NO_2	1	1-hr daily	20808	14148	68
560090819	Antelope Site 3	$PM_{2.5}$ LC	1	24-hr every 3rd day	170	26	15
560090819	Antelope Site 3	$PM_{2.5}$ LC	3	1-hr daily	27064	8386	31
560111013		O_3	1	1-hr daily	16968	16255	53
560130099	South Pass	PM_{10} STP	1	1-hr daily	43824	4574	10
560130232	Spring Creek Encana	NO_2	1	1-hr daily	42984	4613	11
560130232	Spring Creek Encana	PM_{10} STP	1	1-hr daily	42984	10735	25

Site Code	Name	Parameter	POC	Duration/Frequency	No. Expected	No. Null/ Invalid	% Null/ Invalid
560136001	90 Gas Hill Road, Riverton, WY	O_3	1	1-hr daily	5880	946	16
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	PM_{10} LC	1	24-hr every 6th day	121	25	21
560230815	Chevron Kemmerer Mine SB-IV (Formerly Pittsburg & Midway Coal), Kemmerer, WY	PM_{10} STP	1	24-hr every 6th day	121	25	21
560250001	Casper -City County Bldg Center and C Streets	PM_{10} LC	1	24-hr every 3rd day	211	33	16
560250001	Casper -City County Bldg Center and C Streets	PM_{10} STP	1	24-hr every 3rd day	210	32	15
560252601	Sinclair-Casper Refinery (an industrial site)	NO_2	1	1-hr daily	21960	3145	14
560252601	Sinclair-Casper Refinery (an industrial site)	O_3	1	1-hr daily	21960	9438	43
560252601	Sinclair-Casper Refinery (an industrial site)	SO_2	1	1-hr daily	21960	3136	14
560290001	CODY JR HI SCH-2901 Cougar Ave	PM_{10} LC	1	24-hr every 3rd day	187	23	12
560290001	CODY JR HI SCH-2901 Cougar Ave	PM_{10} LC	3	24-hr every 3rd day	366	42	11
560290001	CODY JR HI SCH-2901 Cougar Ave	PM_{10} STP	1	24-hr every 3rd day	187	23	12
560290001	CODY JR HI SCH-2901 Cougar Ave	PM_{10} STP	3	24-hr every 3rd day	426	45	11
560299002	North Absaroka	PM_{10} LC	1	24-hr every 3rd day	609	219	36
560330004	WARMS station	O_3	1	1-hr daily	8400	1943	23
560331003	Meadowlark Elementary School	PM_{10} LC	1	24-hr every 3rd day	177	19	11
560331003	Meadowlark Elementary School	PM_{10} STP	1	24-hr every 3rd day	183	19	10
560350101	Pinedale Gaseous	NO_2	1	1-hr daily	43501	6863	16
560350101	Pinedale Gaseous	O_3	1	1-hr daily	43824	5977	14
560350700	Big Piney	NO_2	1	1-hr daily	24072	4438	18
560350705	Pinedale PM2.5	$PM_{2.5}$ LC	1	24-hr every 3rd day	430	55	13

Site Code	Name	Parameter	POC	Duration/Frequency	No. Expected	No. Null/ Invalid	% Null/ Invalid
560370010	FMC - Granger Upwind (SW of facility)	PM_{10} LC	1	24-hr every 6th day	239	29	12
560370010	FMC - Granger Upwind (SW of facility)	PM_{10} STP	1	24-hr every 6th day	239	29	12
560370100	Rock Springs	PM_{10} STP	1	1-hr daily	7320	823	11
560370852	Black Butte #852 (Lucite Hills)	PM_{10} LC	1	24-hr daily	1724	246	14
560370852	Black Butte #852 (Lucite Hills)	PM_{10} STP	1	24-hr daily	1724	246	14
560370862	FMC - Granger - Downwind (East of facility)	PM_{10} LC	1	24-hr every 6th day	239	38	16
560370862	FMC - Granger - Downwind (East of facility)	PM_{10} LC	2	24-hr every 6th day	239	26	11
560370862	FMC - Granger - Downwind (East of facility)	PM_{10} STP	1	24-hr every 6th day	239	38	16
560370862	FMC - Granger - Downwind (East of facility)	PM_{10} STP	2	24-hr every 6th day	183	22	12
560370866	FMC-Westvaco - Downwind (East of facility)	PM_{10} LC	2	24-hr every 6th day	305	34	11
560370866	FMC-Westvaco - Downwind (East of facility)	PM_{10} STP	2	24-hr every 6th day	305	34	11
560370868	Black Butte #868 Downwind PIT#10	PM_{10} LC	1	24-hr daily	1194	185	15
560370868	Black Butte #868 Downwind PIT#10	PM_{10} STP	2	24-hr daily	1651	206	12
560370870	Tata Gaseous	$PM_{2.5}$ LC	1	24-hr every 3rd day	155	20	13
560370870	Tata Gaseous	$PM_{2.5}$ LC	2	24-hr every 3rd day	155	24	15
560371236	Black Butte Upwind	PM_{10} LC	1	24-hr daily	1826	208	11
560371236	Black Butte Upwind	PM_{10} STP	1	24-hr daily	1826	208	11
560410200	Haystack Down-wind	PM_{10} LC	1	24-hr daily	693	93	13
560410200	Haystack Down-wind	PM_{10} STP	1	24-hr daily	693	93	13
560410201	Haystack Mine Up-Wind TEOM and Met	PM_{10} LC	1	24-hr daily	693	165	24
560410201	Haystack Mine Up-Wind TEOM and Met	PM_{10} STP	1	24-hr daily	693	165	24

Table 3. Number of samples below the MDL for those sites and parameters with more than 50% of data below the MDL.

Site Code	Name	Parameter	POC	Duration/ Frequency	No. Expected	No. Below MDL	% Below MDL	% Above MDL
560050857	Wyodak Site 4	SO_2	2	1-hr daily	42797	37389	87	13
560071000	Sinclair-Intersection of CCR351 and N. 8th St. (SW corner of intersection)	SO_2	1	1-hr daily	501	501	100	0
560130099	South Pass	SO_2	1	1-hr daily	5329	5299	99	1
560210100	Cheyenne NCore	SO_2	1	1-hr daily	24917	14432	58	42
560252601	Sinclair-Casper Refinery (an industrial site)	SO_2	1	1-hr daily	18824	10422	55	45
560370200	Wamsutter	SO_2	1	1-hr daily	8172	8054	99	1
560370300	Moxa	SO_2	1	1-hr daily	29595	27381	93	7
560370870	Tata Gaseous	SO_2	1	1-hr daily	11267	10508	93	7
560410101	Murphy Ridge	SO_2	1	1-hr daily	7876	5304	67	33
560450800	Wyoming Refining, Rodeo St., Newcastle, WY	SO_2	1	1-hr daily	40316	38339	95	5
560090008	Tallgrass Gaseous (an industrial site)	NO_2	1	1-hr daily	3208	1685	53	47
560090801	Converse County Mobile	NO_2	1	1-hr daily	8563	5256	61	39
560090819	Antelope Site 3	NO_2	1	1-hr daily	6660	4890	73	27
560130099	South Pass	NO_2	1	1-hr daily	41533	31248	75	25
560130234	Beaver Creek Air Quality Station	NO_2	1	1-hr daily	7899	6835	87	13
560130900	Pavillion	NO_2	1	1-hr daily	9963	9030	91	9
560250100	Casper Gaseous	NO_2	1	1-hr daily	7242	5090	70	30
560350097	Wyoming Range	NO_2	1	1-hr daily	23023	17974	78	22

Site Code	Name	Parameter	POC	Duration/ Frequency	No. Expected	No. Below MDL	% Below MDL	% Above MDL
560350099	Boulder	NO_2	1	1-hr daily	40375	28535	71	29
560350100	Daniel South	NO_2	1	1-hr daily	39944	39218	98	2
560350101	Pinedale Gaseous	NO_2	1	1-hr daily	36961	25288	68	32
560350700	Big Piney	NO_2	1	1-hr daily	19706	16746	85	15
560351002	Juel Springs	NO_2	1	1-hr daily	33895	29304	86	14
560370300	Moxa	NO_2	1	1-hr daily	30437	24195	79	21
560410101	Murphy Ridge	NO_2	1	1-hr daily	41784	31885	76	24
560071000	Sinclair-Intersection of CCR351 and N. 8th St. (SW corner of intersection)	$PM_{2.5}$ LC	1	1-hr daily	504	292	58	42

Trend Analysis

The purpose of the trends length analysis is to identify those sites most useful for assessing pollutant trends. For this analysis, sites that have the longest data record are considered the most useful for assessing pollutant trends and are therefore ranked highest; however, additional factors such as the magnitude and direction of trends observed to date can be used to adjust the simple ranking scale.

Trends in 1-hr ozone, 24-hr $PM_{2.5}$, 24-hr PM_{10}, 1-hr SO_2, and 1-hr NO_x and NO_2 were provided in the form of notched box-whisker plots within the *Task A Data Deliverable* file. Developed with SYSTAT software, notched box-whisker plots show the distribution of reported concentrations by year. The entire distribution is shown, and statistically significant differences in median concentrations can be observed between any two years. Figure 1 provides information on how to interpret a notched box-whisker plot.

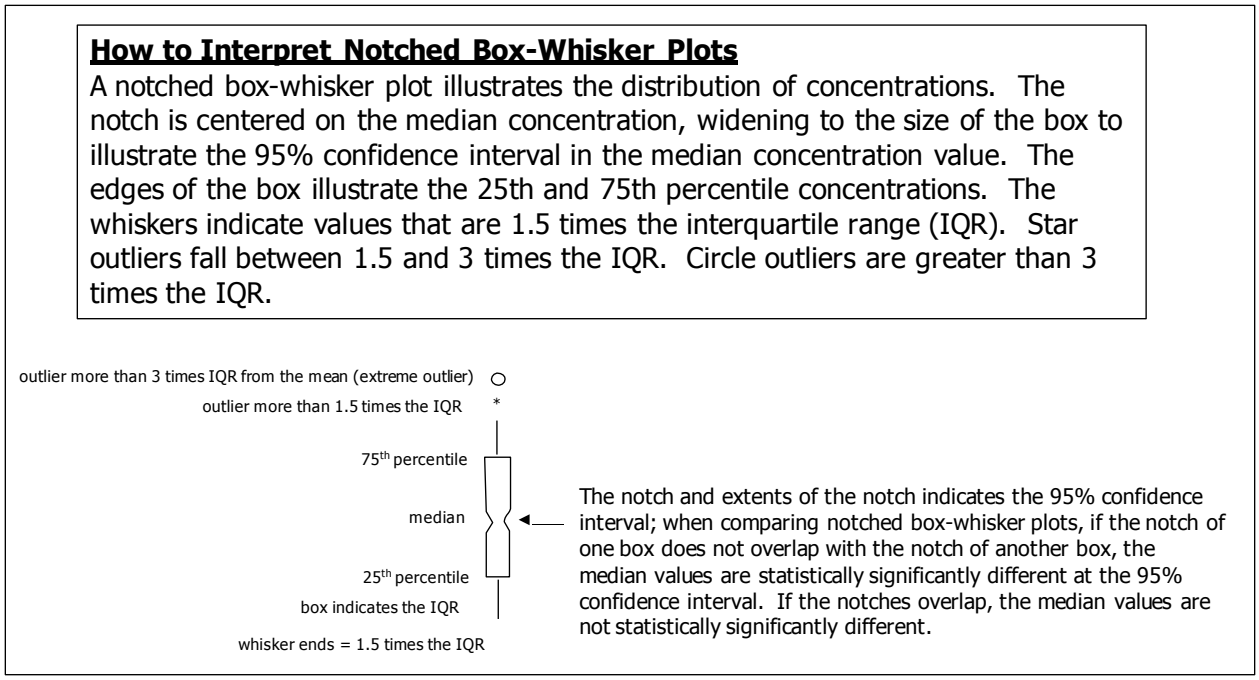

Figure 1. Instructions for interpreting notched box-whisker plots (SYSTAT software).

Trends Summary

Focusing on the central tendencies (mean, median, confidence intervals) in concentrations at sites with at least five years of monitoring data, we found the following:

- NO_2. Concentrations declined at two sites, increased at three sites, and showed no clear trend at six sites. Concentrations at the high end of the ranges showed no trend.

- Ozone. Concentrations showed no clear trend at nine sites and slight decreases at two sites. For concentrations at the high end of the ranges, four sites showed some decline over this period.
- PM_{10}. Concentrations at most sites showed no clear trend; however, there was often significant interannual variability. Concentrations showed decreases at five sites and showed increases at another five sites. For the high end of the ranges, 13 sites showed concentration decreases, while a similar number showed concentration increases.
- $PM_{2.5}$. Concentrations showed no clear trend at eight sites and slight decreases at two sites. For the high end of the ranges, four sites showed concentration increases, and four sites had decreases.
- SO_2. Only two sites have a five-year record and at both sites, most concentrations are below MDL over this period.

Summary Statistics

The purpose of this analysis is to quantify sites within the monitoring network that measure pollutant concentrations that are high, low, or very close to the NAAQS. For each site, the relevant NAAQS was used to determine which concentration duration to assess. All summary statistics are listed in the *Task A Data Deliverable* file; no figures were prepared. Summary statistics were compiled for ozone, CO, NO, NO_2, NO_x, PM_{10}, $PM_{2.5}$, and SO_2.

Monitor-to-Monitor Correlation Analysis

The purpose of the monitor-to-monitor correlation analysis is to determine whether pollutant concentrations correlate temporally across sites. This was achieved by comparing concentrations measured at one monitor to concentrations measured at other monitors. Monitor pairs with correlation coefficient values near 1 are considered highly correlated and should be ranked lower than monitor pairs with correlation coefficient values near 0 (zero). Monitors that do not correlate well with other monitors exhibit unique temporal concentration variations and are likely to be important for assessing local emissions, transport, and spatial coverage. Monitors with concentrations that correlate well with concentrations at another monitor may be redundant and are possible candidates for removal. Data from 2009 through 2013 at all sites for all pollutants were used in the analysis.

The temporal correlation between monitors was determined by calculating Pearson rank correlation coefficients (R) between each monitoring pair. Site pairs with R values greater than 0.9 and between 0.8 and 0.9 were flagged and tabulated as indicators of significant correlation. Environmental monitoring data measured at separate locations with R values greater than 0.9 are very highly correlated. As R values get lower, correlations decrease and the ability to predict concentrations decreases. We arbitrarily chose a low value of 0.8 as the cutoff for tabulating site correlations; an R value in this range still indicates significant correlation. We tabulated the number of site-pairs in

these two categories (>0.9, 0.8-0.9) to show those sites that were most highly correlated. Monitors were then rank-ordered to determine the sites that were most likely to be redundant based on large numbers of highly correlated site pairs.

Figure 2 shows a correlation matrix for ozone measurement sites. The cell at the intersection of a row and column for two sites intersect, the cell shows the R value for those two sites over the 2009-2013 time periods. Cell values are shaded to indicate the degree of correlation; warmer colors indicate higher correlations. The figure shows the entire ozone matrix at a glance with darker colors showing higher correlations. The MS Excel file containing the correlation matrix for each pollutant can be found in the *Task A Data Deliverable* file.

	560019991	560030002	560050123	560050456	560070100	560071000	560090008	560090801	560130099	560130232	560136001	560210100	560250100	560252601	560330004	560350097	560350099	560350100	560350101	560350700
560030002	0.43																			
560050123	0.38	0.75																		
560050456	0.36	0.71	0.83																	
560070100	0.46	0.52	0.57	0.58																
560071000	0.51	0.17	0.31	0.29	0.68															
560090008	0.32	0.64	0.70	0.74	0.54	0.46														
560090801	0.44	0.71	0.74	0.73	0.61	0.62	0.87													
560130099	0.61	0.45	0.48	0.44	0.51	0.45	0.46	0.49												
560130232	0.56	0.73	0.73	0.73	0.66	0.65	0.72	0.76	0.64											
560136001	0.39	0.79	0.71	0.69	0.59	-0.14	0.65	0.68	0.45	0.72										
560210100	0.45	0.60	0.65	0.68	0.56	0.47	0.72	0.71	0.48	0.68	0.66									
560250100	0.39	0.62	0.63	0.66	0.59	0.76	0.69	0.73	0.47	0.72	0.63	0.69								
560252601	0.29	0.63	0.64	0.66	0.56	0.64	0.78	0.75	0.37	0.69	0.74	0.64	0.82							
560330004	0.30	0.81	0.81	0.76	0.57	NA	0.70	0.68	0.39	0.67	0.71	0.63	0.63	0.67						
560350097	0.45	0.39	0.34	0.32	0.51	NA	0.43	0.35	0.66	0.48	0.35	0.32	0.34	0.27	0.33					
560350099	0.41	0.73	0.68	0.66	0.69	0.10	0.63	0.66	0.53	0.71	0.73	0.58	0.63	0.61	0.69	0.58				
560350100	0.35	0.63	0.65	0.65	0.74	0.29	0.63	0.61	0.50	0.70	0.72	0.57	0.62	0.62	0.67	0.58	0.85			
560350101	0.25	0.57	0.60	0.61	0.71	0.10	0.57	0.56	0.41	0.63	0.69	0.52	0.58	0.61	0.64	0.48	0.81	0.92		
560350700	0.30	0.71	0.67	0.66	0.72	0.14	0.65	0.65	0.46	0.70	0.74	0.58	0.64	0.65	0.71	0.52	0.87	0.90	0.87	
560351002	0.47	0.69	0.68	0.65	0.72	0.36	0.65	0.67	0.61	0.76	0.70	0.60	0.64	0.63	0.66	0.60	0.85	0.83	0.78	0.85
560359991	0.60	0.55	0.51	0.47	0.55	0.51	0.45	0.51	0.73	0.65	0.53	0.48	0.49	0.39	0.46	0.80	0.71	0.65	0.56	0.60
560370077	0.36	0.62	0.64	0.66	0.77	0.40	0.65	0.65	0.43	0.70	0.69	0.61	0.63	0.67	0.65	0.39	0.74	0.79	0.77	0.79
560370100	0.35	0.73	0.68	0.68	0.67	0.40	0.66	0.70	0.46	0.69	0.72	0.65	0.68	0.73	0.71	0.43	0.80	0.77	0.73	0.81
560370200	0.35	0.62	0.64	0.65	0.76	0.80	0.68	0.69	0.45	0.73	0.69	0.63	0.69	0.69	0.63	0.37	0.70	0.75	0.73	0.76
560370300	0.39	0.73	0.67	0.67	0.69	0.23	0.65	0.68	0.51	0.71	0.74	0.62	0.65	0.65	0.71	0.51	0.84	0.80	0.75	0.84
560390008	0.31	0.53	0.57	0.53	0.66	0.54	0.56	0.54	0.53	0.63	0.60	0.47	0.51	0.49	0.53	0.64	0.70	0.77	0.72	0.74
560391011	0.44	0.54	0.53	0.46	0.53	0.52	0.47	0.50	0.63	0.61	0.49	0.41	0.48	0.41	0.46	0.67	0.62	0.59	0.51	0.57
560410101	0.48	0.67	0.63	0.60	0.68	0.36	0.60	0.63	0.56	0.69	0.65	0.57	0.58	0.59	0.64	0.59	0.77	0.73	0.66	0.76
560450003	0.51	0.57	0.68	0.60	0.36	0.29	0.51	0.62	0.53	0.64	0.52	0.57	0.47	0.39	0.50	0.31	0.45	0.37	0.29	0.38

Figure 2. Excerpt of correlation matrix for ozone.

Only two pollutants had significant correlations between sites: ozone and PM_{10}. The number of sites that a given site correlated with is shown in Figure 3 for ozone and Figure 4 for PM_{10}. Figure 3 shows the clear spatial pattern in ozone correlations across the state. Monitors in and around the Sublette County area were the most highly correlated, while those in most other population centers in the state were less well correlated. Figure 4 shows correlations for PM_{10} monitors. Monitors within Powder River Basin area were highly correlated with each other, whereas other locations throughout the state showed little correlation.

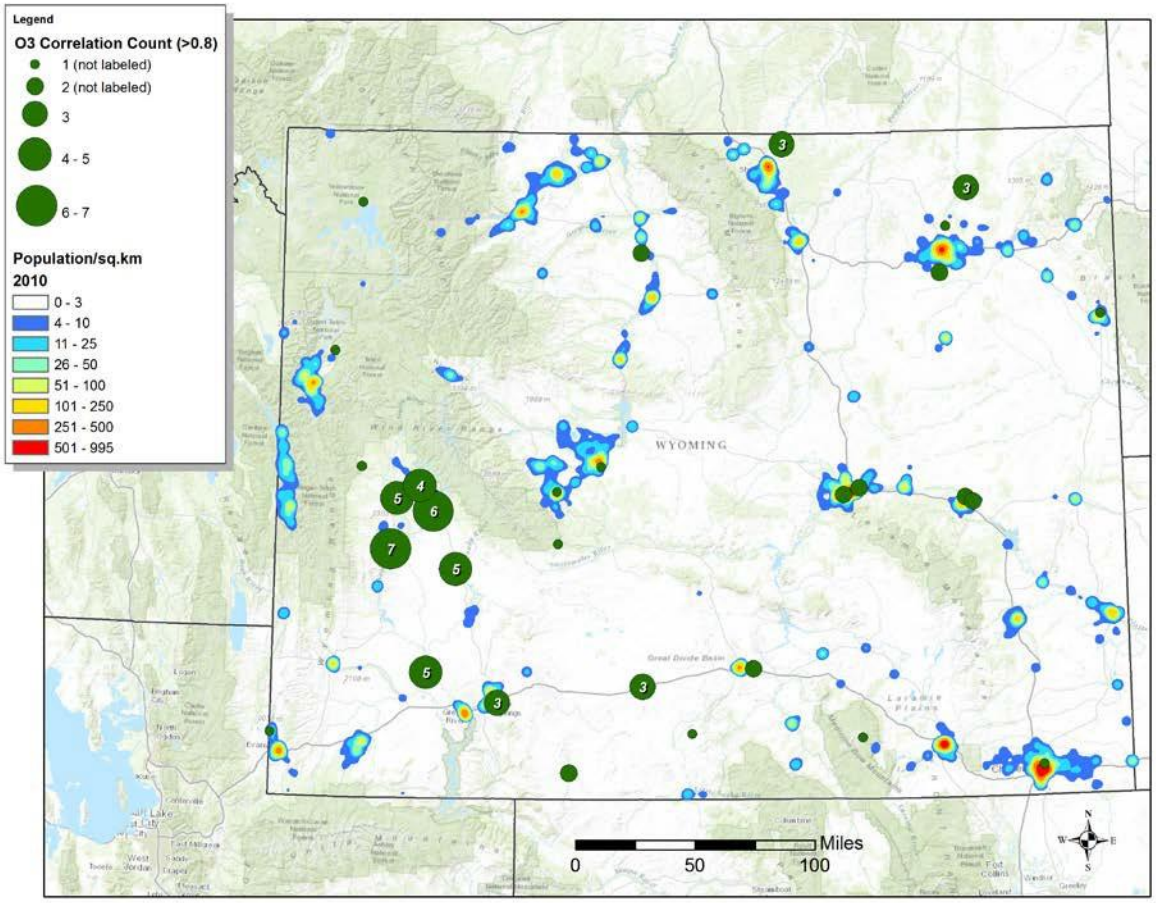

Figure 3. Map showing the number of ozone sites with which another ozone site is highly correlated (R>0.8).

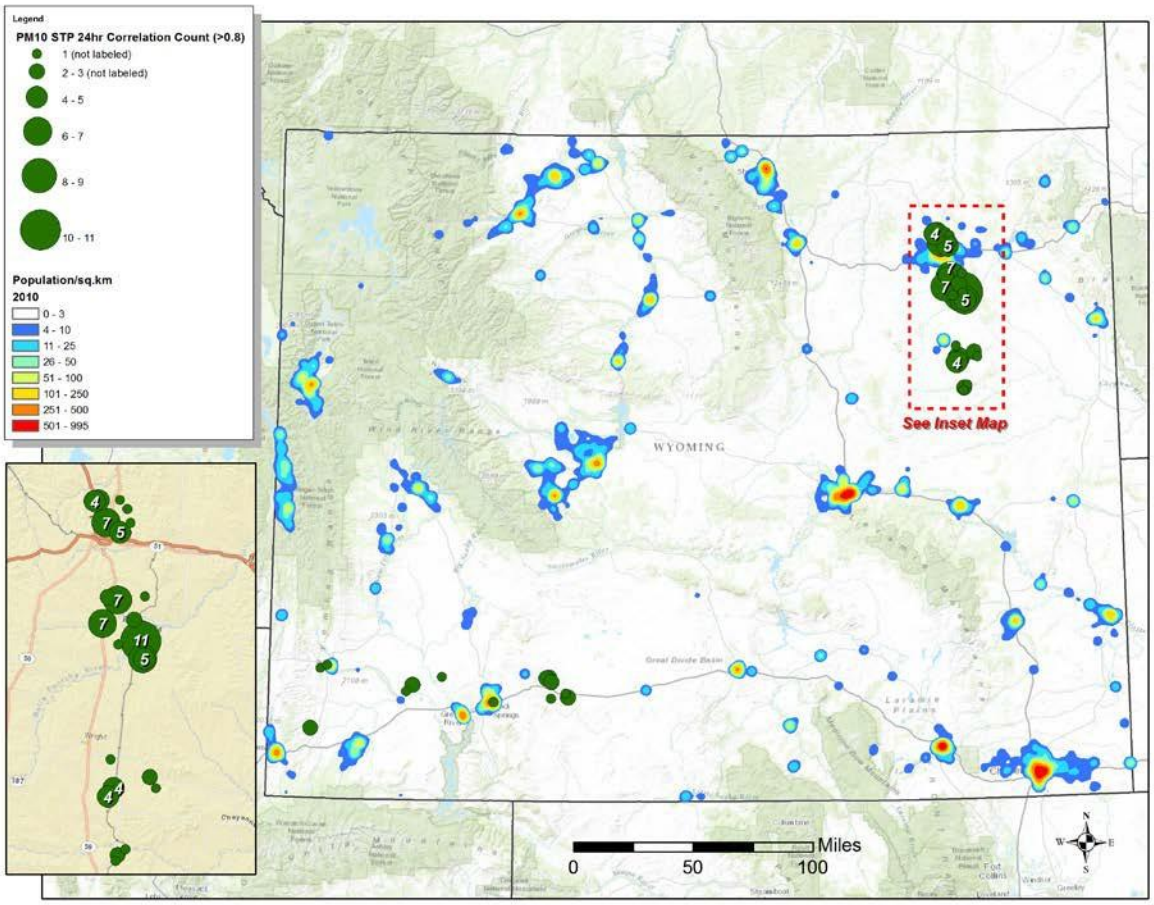

Figure 4. Map showing the number of PM_{10} sites with which another PM_{10} site is highly correlated (R>0.8).

Task B: Gridded Emissions Inventory Development

STI worked with AQD to compile the most recent and complete emissions inventory representing the year 2013 (i.e., 2013 Wyoming statewide emissions inventory) for oil and gas production, on-road and non-road mobile sources, and other emissions sources in the state of Wyoming. Emissions data sources include 2013 emissions estimates collected by AQD and the 2011 National Emissions Inventory (NEI). All emissions data were reviewed to ensure that these data were suitable for use in the gridded emissions inventory. Table 4 summarizes statewide emissions by source category and associated emissions for CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and volatile organic compounds (VOCs).

Table 4. Emissions (tons/year) by source used in the statewide emissions inventory for Wyoming.

Source Sector	Data Source	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	VOC
On-road	2011 AQD	102,256	26,909	1,218	996	101	8,692
Non-road	2011 NEI	38,030	4,390	525	498	12	8,218
Area	2011 NEI	20,253	37,101	360,123	40,734	530	7,943
Major Point	2013 AQD	42,041	72,776	13,049	4,811	58,341	15,260
Minor Point	2011 AQD	31,554	39,323	20,394	3,281	1,415	7,077
Oil & Gas	2013 & 2011 AQD	7,040	11,092	586	494	3,937	119,062
Fire	2013 AQD	687,929	17,054	174,340	95,703	3,240	205,079
Total	--	929,104	208,646	570,236	146,517	67,576	371,332

To prepare the emissions data for use in subsequent analyses, the final statewide inventory was spatially allocated to a 4-km grid domain covering the state of Wyoming. The spatial allocation of emissions was based on known location coordinates for stationary sources and a variety of spatial data sets used as surrogates for the locations of emissions-producing activities. Figure 5 shows the resulting spatial distribution of emissions across Wyoming. The spatial patterns for each pollutant will be discussed in more detail in the following sections, as will the data sets and methodologies that were used to assemble, review, and spatially allocate the statewide emissions inventory.

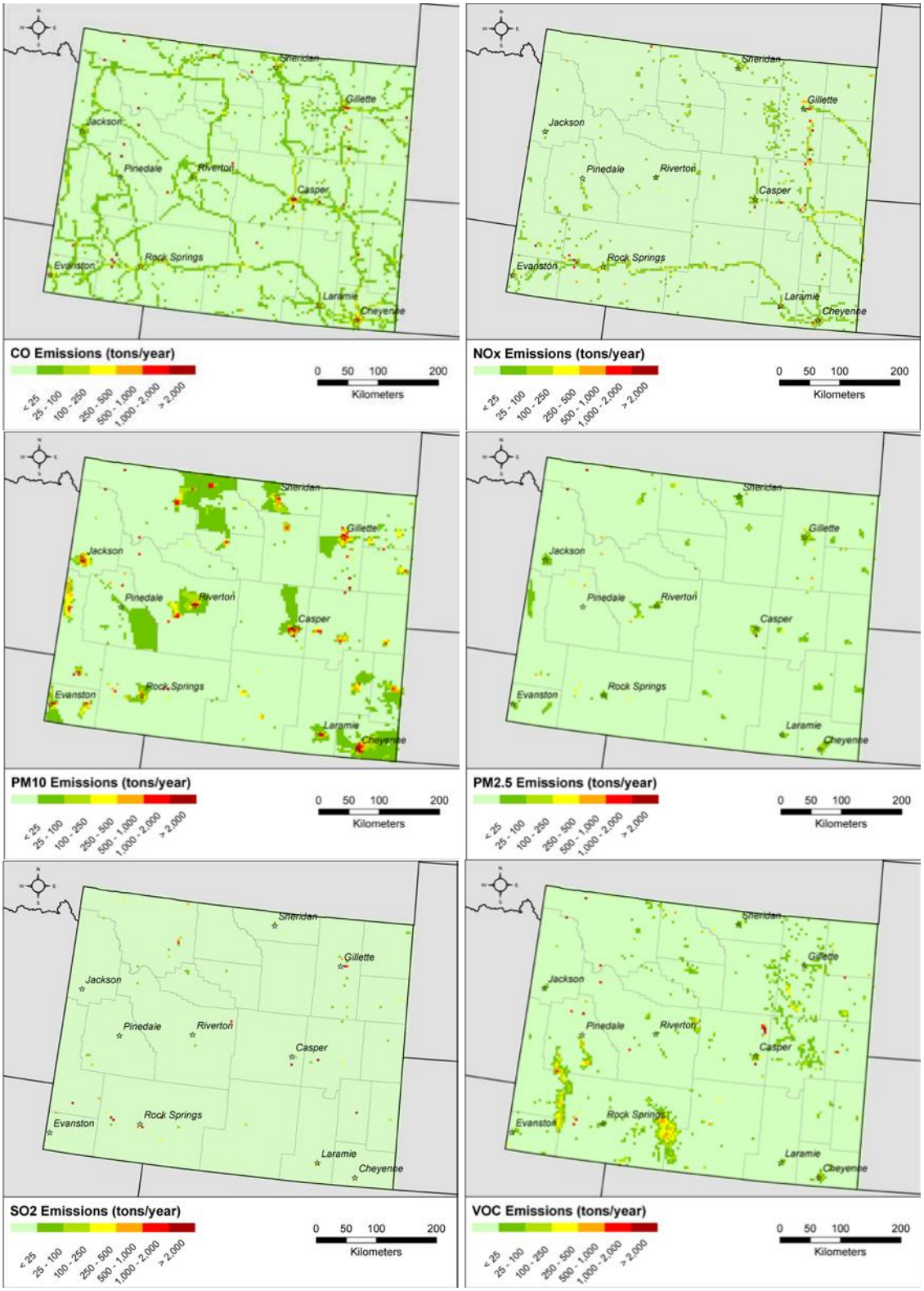

Figure 5. Statewide 4-km gridded emissions (tons/year) for CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and VOC.

Emissions Data Acquisition

The 2013 statewide emissions data compiled for Wyoming were based on the 2013 and 2011 emissions estimates collected by AQD and the U.S. EPA's 2011 National Emissions Inventory (NEI). Specific data sources by source sector can be summarized as follows:

- Oil and gas production. AQD provided three spreadsheets that compose a complete list of oil and gas wells in Wyoming, with well location, well status, well name, and annual total emissions for 2013 (for wells in the Southern Powder River Basin [SPRB] and Upper Green River Basin [UGRB]) or 2011 (for wells in other parts of Wyoming).
- Major and minor point sources. AQD provided a spreadsheet that contained major point source emissions at the facility level (tons per year) and facility locations for 2013. For minor point sources that are not oil and gas wells, a spreadsheet was provided with the 2011 annual emissions at facility level (tons per year) and facility locations.
- On-road mobile sources. AQD provided a spreadsheet with 2011 county level on-road mobile source emissions (tons per year).
- Area and non-road mobile sources. The 2013 data for these source sectors were not currently available from AQD, so 2011 NEI data were used instead.[1] The NEI data were extracted from Access databases downloaded from EPA's website (http://www.epa.gov/ttnchie1/net/2011inventory.html).
- Fire sources. AQD provided the 2013 emissions of "wildfire use" burns and prescribed burns (WFU/Rx) estimated by the Western Regional Air Partnership's Fire Emissions Tracking System (FETS); detailed information included location and date of burn.

To identify any data gaps or inaccuracies (e.g., missing/duplicate emission sources, incorrect source locations), the emissions data described above were reviewed and compared with the previous emissions inventories, the U.S. EPA's 2011 NEI. and the 2008 Wyoming Statewide emissions inventory for the region (Pollard and Reid, 2010). Emissions comparisons were performed at two levels: overall and by source sector. Overall, the 2013 emissions inventory compares well with previous emissions inventories for the region (Figure 6). At the source sector level, the 2013 emissions inventory compares well with the 2011 NEI but has some significant differences from the 2008 emissions inventory, particularly for the following sectors: on-road, non-road, and major and minor point sources. The factors contributing to the difference include:

- Changes in activity, such as VMT, equipment usage, and throughput of point sources.
- Changes in methodology of emissions estimation. For example, EPA's MOBILE6 model was used to estimate 2008 emissions, while the MOVES model was used for 2013 emissions. The two models are substantially different in terms of methodology, assumptions, and default data.

[1] AQD has provided county total non-road emissions for 2011. However, we decided to use Non-Road emissions from 2011 NEI, as (1) AQD data are at an aggregated level (i.e., by fuel type only) without required details for spatial allocation that the 2011 NEI data have (e.g., source classification code or SCC)., and (2) in terms of total non-road emissions, AQD data are similar to the 2011 NEI.

- Implementation of emissions control measures, such as emissions standards and regulations.
- Source sector definitions. For example, the 2008 inventory included fire sources in the area source sector, while the 2013 inventory included fires in the point source sector.

The rest of this section provides the details on the reviews we performed for each source sector.

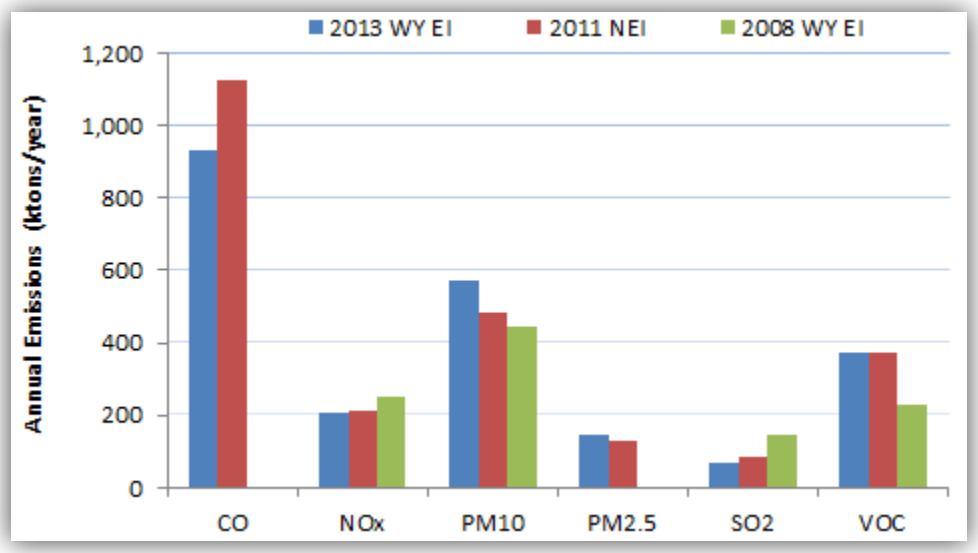

Figure 6. Comparison of 2013 statewide emissions (i.e., 2013 WY EI) with two previous emissions inventories: 2011 NEI and 2008 statewide emissions (i.e., 2008 WY EI). Note: 2008 WY EI does not include $PM_{2.5}$ emissions.

Oil and Gas Production Sources

The oil and gas production inventory was based on AQD's 2013 data for SPRB and UGRB and 2011 data for the remainder of the state, which included location (e.g., latitude/longitude, county name), API number, and emissions information for individual oil and gas wells. Before compiling the final oil and gas emissions inventory, the locations of wells were plotted in ArcGIS with the state/county boundaries to verify that the well locations are correct (i.e., in the right county). Also, the wells from the two years of data were compared based on the API number to ensure there were no duplicates.

Major and Minor Point Sources

For major industrial point sources, the spreadsheet with Title V 2013 emissions provided by AQD was used to compile total emissions by facility and location. Because point source emissions are spatially allocated to the 4-km modeling domain on the basis of location coordinates, we performed checks on reported facility locations by plotting the latitude/longitude coordinates in ArcGIS and Google Earth. These steps enabled us to determine whether any reported facility locations were observably misallocated (e.g., outside state boundaries or within wilderness areas). In addition, locations and

emissions were compared to the 2011 NEI point source totals where possible (based on facility name). Overall, the location coordinates appeared reasonable and corresponded to satellite images of facilities on the ground.

For the minor point source inventory, AQD provided a spreadsheet summarizing 2011 emissions of sources that were not oil and gas production facilities, with facility name and location. The spreadsheet was used to compile the final emissions inventory after the following quality checks:

- The minor source inventory was compared to the major source inventory to check for any duplicate facilities.
- The minor sources were plotted in ArcGIS with the state/county boundaries to verify that the locations were correct (i.e., in the right county).

On-Road Mobile Sources

AQD provided 2011 on-road mobile sources emissions data by county, vehicle category (i.e., light-duty or heavy-duty), and fuel type. To ensure that these data were complete and reasonable, the 2011 AQD emissions were compared to on-road emissions data from the 2011 NEI at the state total and county-levels.

Area and Non-Road Sources

AQD did not provide area emissions for 2013. AQD provided non-road mobile source emissions data for 2011, but at an aggregated level without detailed information for spatial allocation. Therefore, nonpoint and non-road emissions data from the 2011 NEI were used for the area and non-road source sectors. Because the 2011 NEI nonpoint inventory contained emissions for oil and gas production and other industrial source categories, those industrial sources were removed to avoid potential duplication with AQD's minor source inventory. As a result, only non-industrial sources were included in the final inventories (e.g., residential fuel combustion, commercial cooking, construction, and agricultural processes).

Table 5 summarizes NEI pollutant-specific emissions totals (tons per year) for all nonpoint sources, nonpoint industrial sources that were excluded from the final inventories, and non-industrial sources that were included in the final inventories. Note that the 2008 Wyoming area emissions included fires, while 2013 area emissions did not. This is because the 2005 NEI, from which the 2008 Wyoming area emissions were taken, considered fires as nonpoint sources, while fires have been explicitly reported in the "Event" category since the 2008 NEI.

Table 5. Pollutant emissions (tons/year) from 2011 NEI nonpoint sources.

	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	VOC
All nonpoint sources	25,165	45,106	360,516	41,041	3,768	124,477
Industrial sources	4,912	8,004	392	307	3,238	116,534
Non-industrial sources	20,253	37,101	360,123	40,734	530	7,943

Fire Sources

As mentioned above, fires were reported separately from area sources in this development of the statewide emissions inventory. The spreadsheet with 2013 fire emissions from FETS, provided by AQD, was used to compile total emissions by fire and location. The fire sources were plotted in ArcGIS with the state/county boundaries to verify that the locations were correct.

Spatial Allocation of Emissions

Once a final emissions inventory was compiled for all source sectors, the emissions data were gridded to provide a spatially resolved inventory that can be used to evaluate the locations of monitoring sites in relation to known emissions sources. The spatial allocation of the final emissions inventory was performed using a variety of spatial data sets and known source locations. The selected grid domain was based on EPA's nationwide 4-km RPO grid, for which default spatial surrogates are available. EPA's nationwide grid was limited to an extent covering the state of Wyoming (Figure 7).

Figure 7. Spatial extent of 4-km grid for gridding the final emissions inventory.

Since the final statewide emissions inventory is a combination of county total and location-specific emissions, several steps were involved in developing a spatially allocated inventory:

- On-road, area, and non-road sources. County-level emissions were gridded using EPA's default 4-km gridded surrogates for the 2011 NEI-based modeling platform, which are based on land use, land cover, transportation networks, and census data. An EPA cross-reference file was used to match specific emissions sources to appropriate spatial surrogates based on source classification codes (see epa.gov/ttn/chief/emch/index.html#2011).
- Major point, minor point, oil and gas, and fire sources. Facility-, event- and well-specific emissions were allocated directly to the 4-km grid within an ArcGIS environment based on coordinate location.
- QA/QC. After the statewide emissions were spatially allocated, the gridded emissions were reviewed to ensure accuracy with the following steps:
  - Sum gridded emissions and compare with the total emission value before gridding, to ensure that no emissions sources were missing or duplicated.
  - Plot gridded emissions in ArcGIS to review the pattern of their spatial distribution, and spot-check cells with high emission values.

The statewide gridded emissions of each pollutant are shown by source sector in the following map figures (Figures 8 through 13).

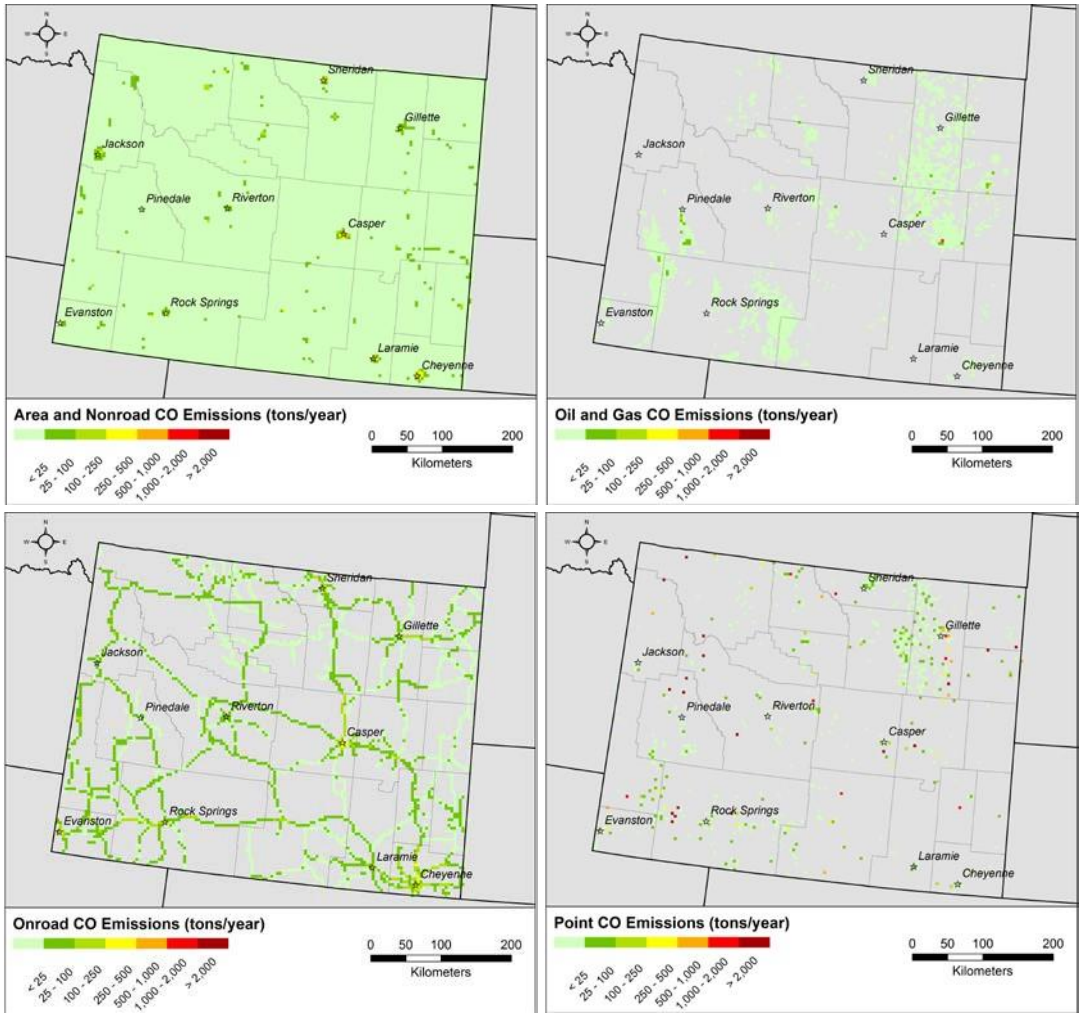

Figure 8. Statewide gridded CO emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.[2]

[2] The point sources include major and minor point sources as well as fire sources.

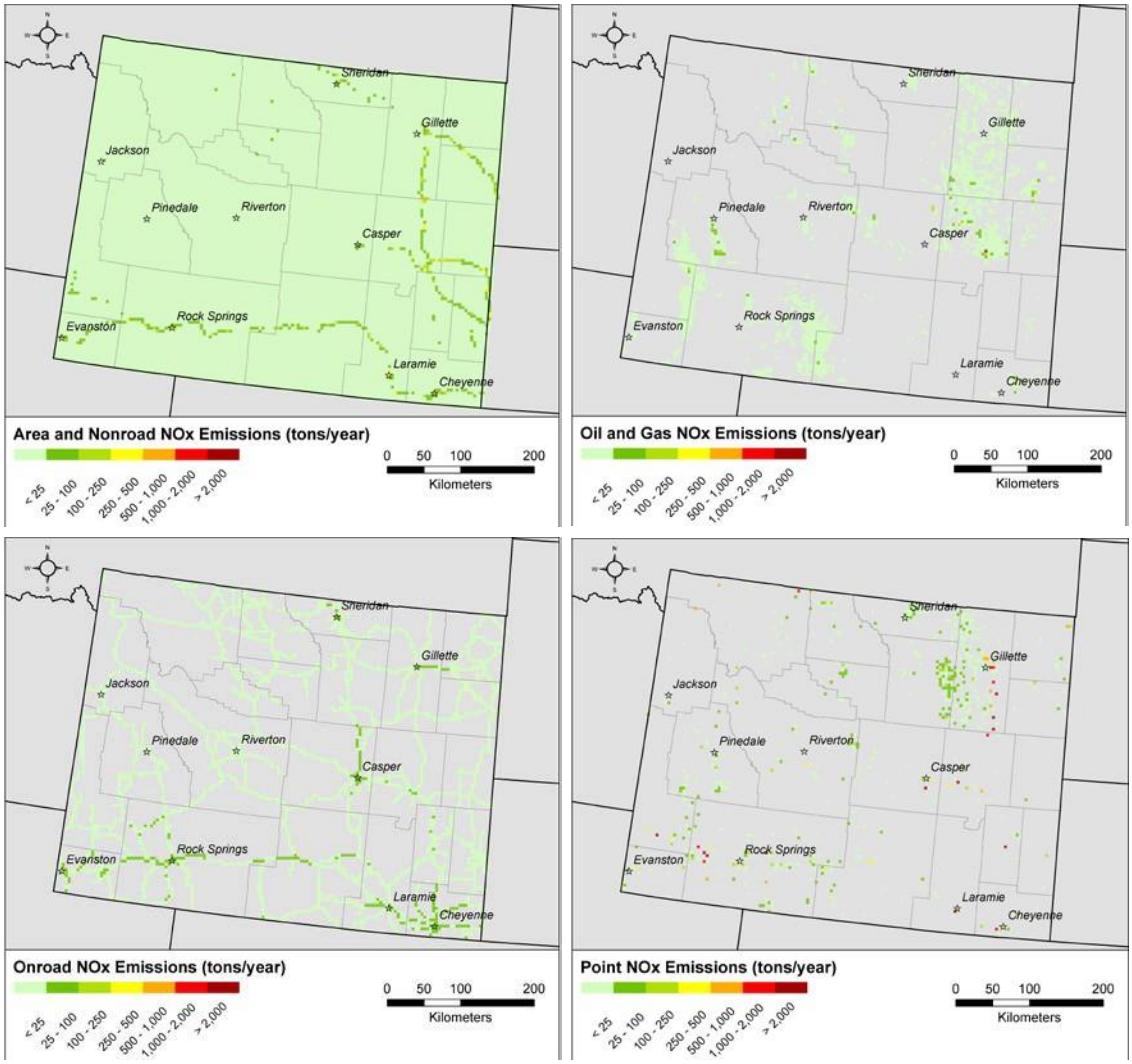

Figure 9. Statewide gridded NO_x emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.

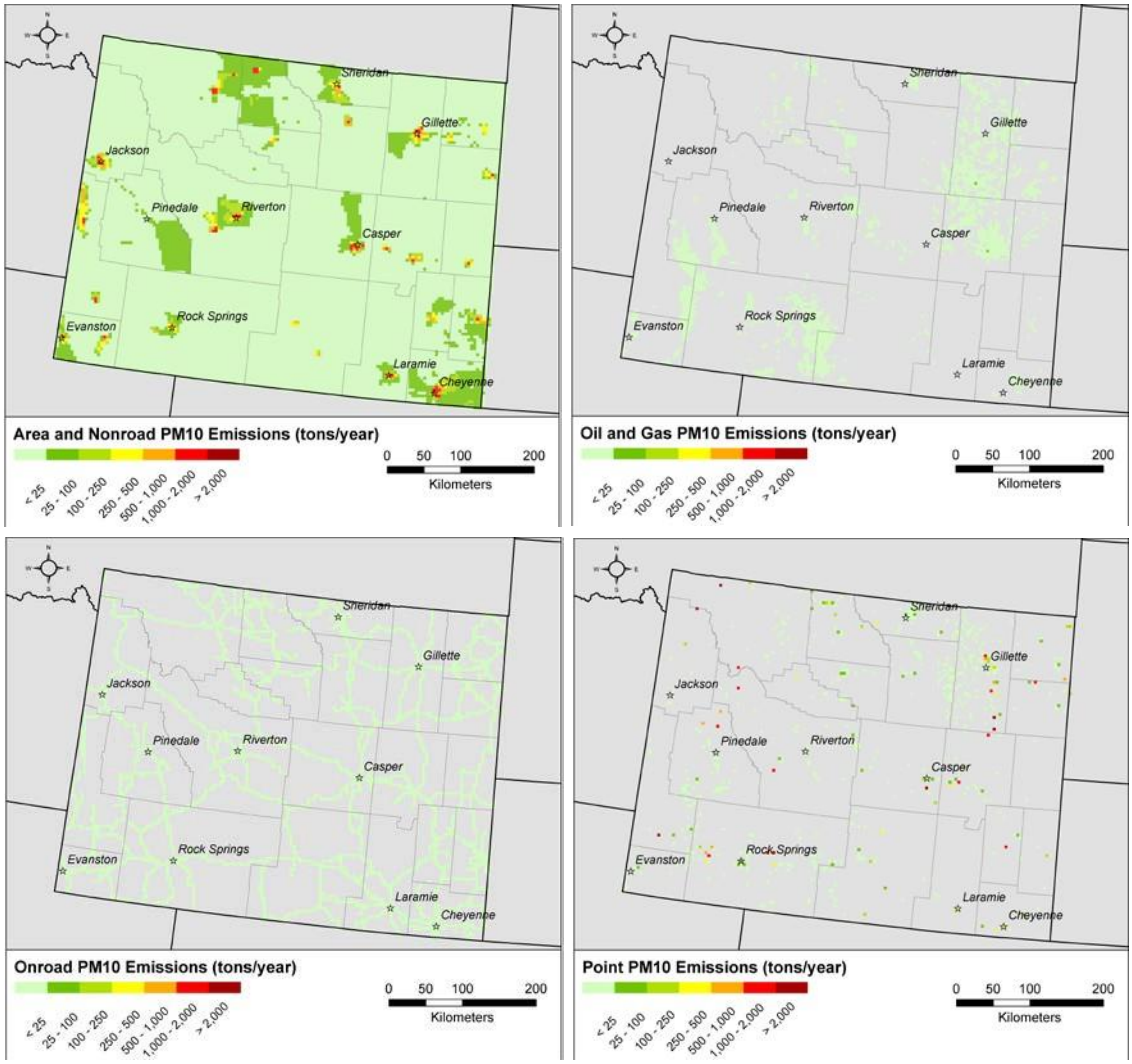

Figure 10. Statewide gridded PM_{10} emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.

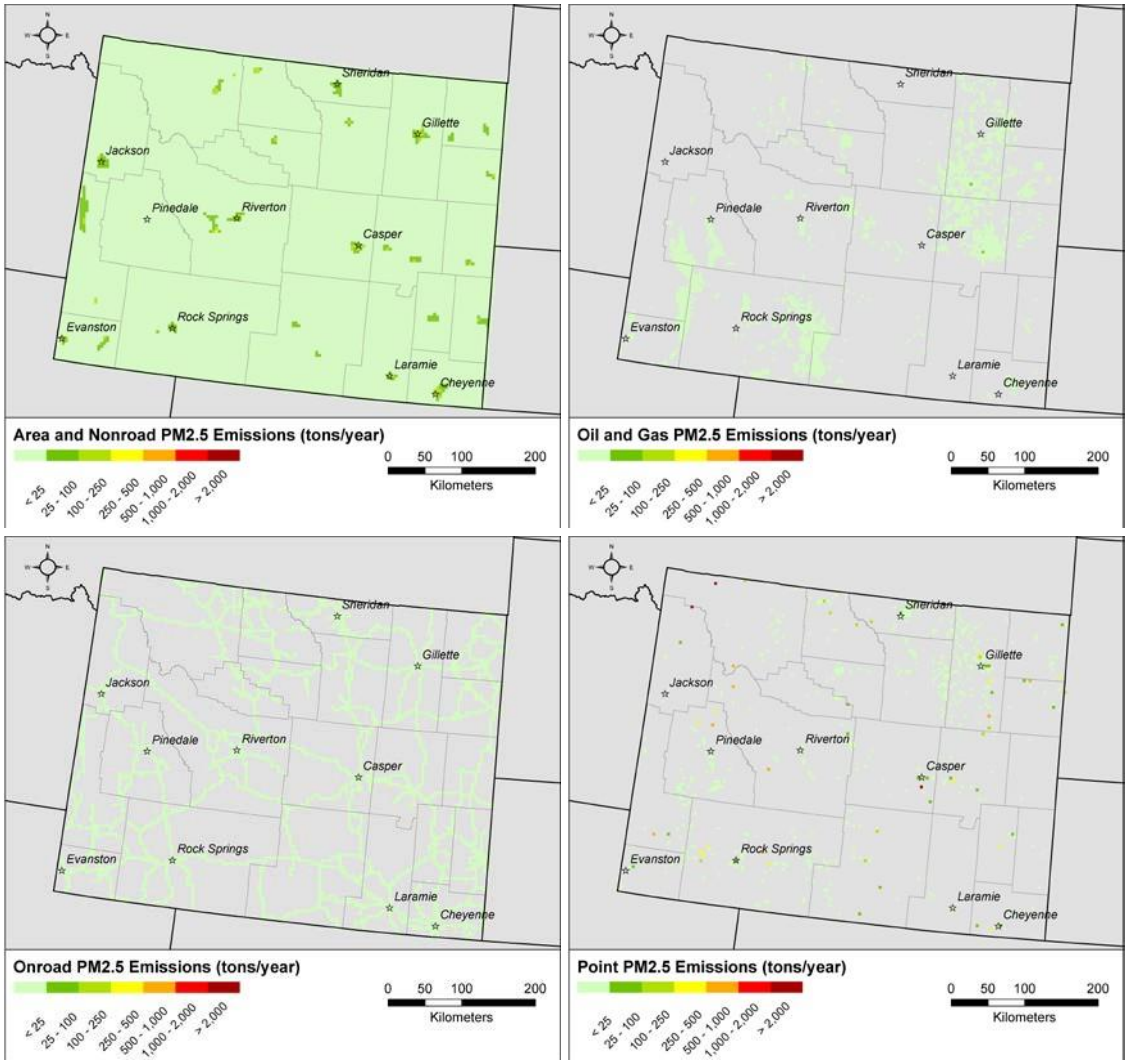

Figure 11. Statewide gridded $PM_{2.5}$ emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.

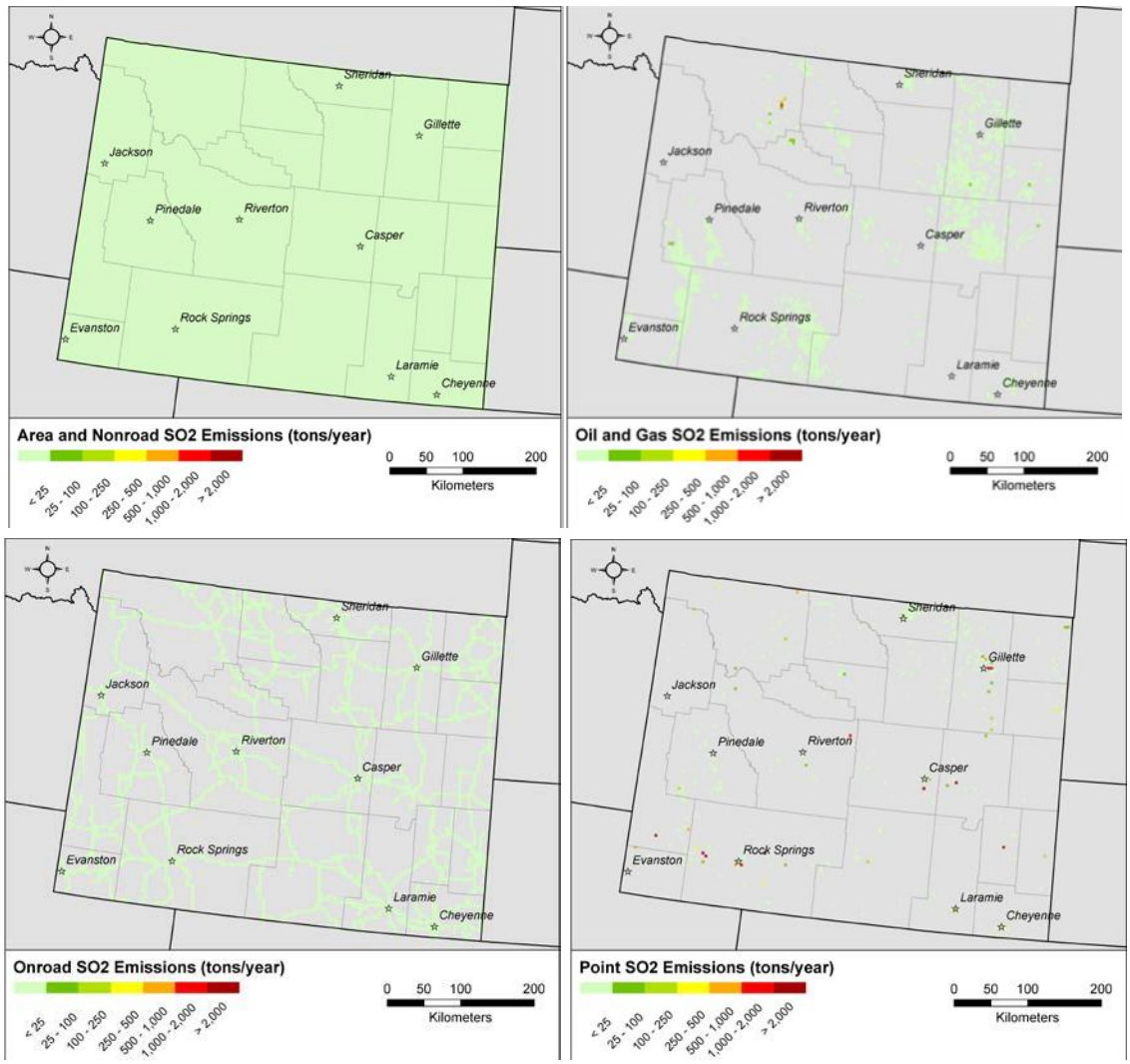

Figure 12. Statewide gridded SO_2 emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.

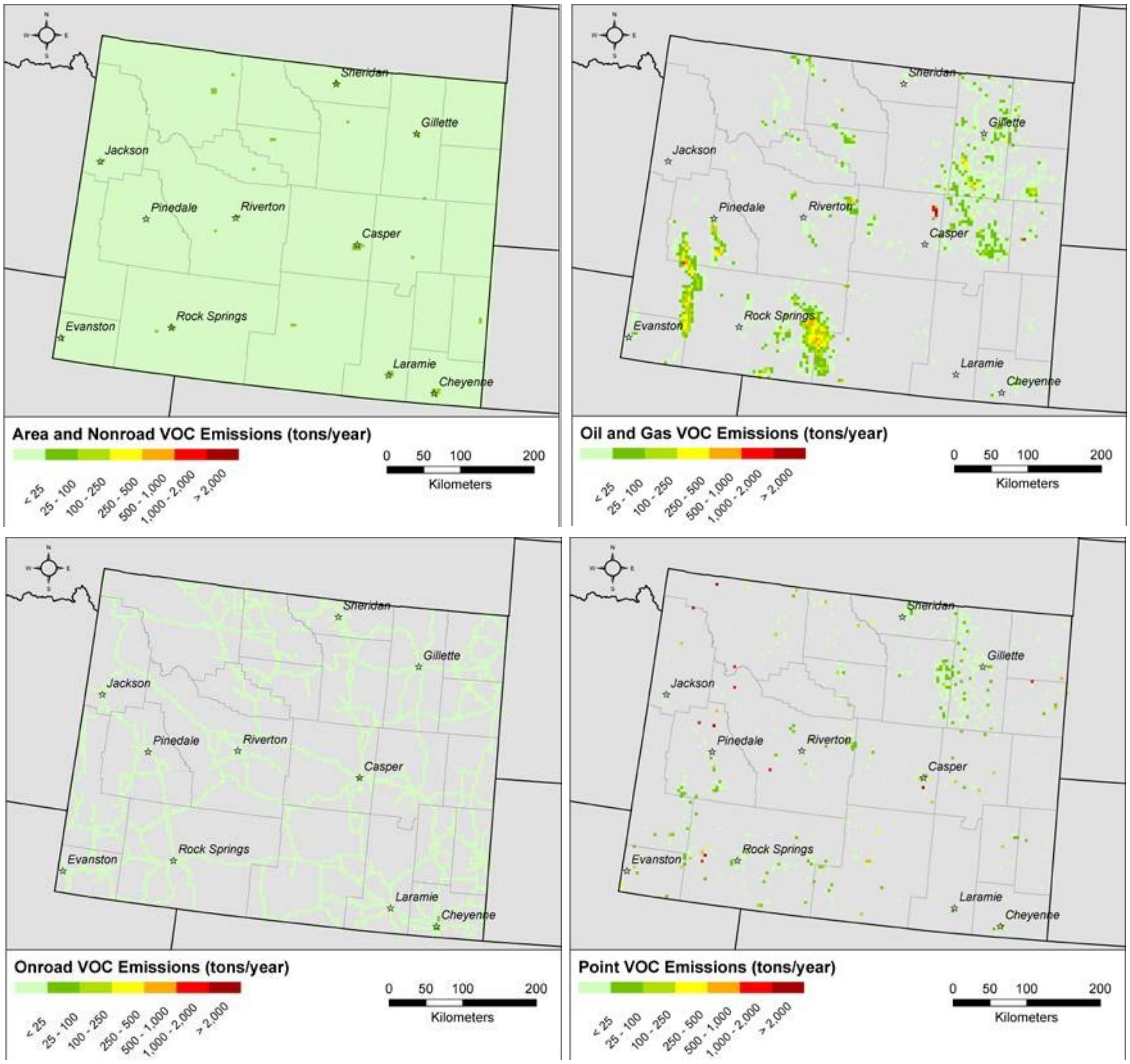

Figure 13. Statewide gridded VOC emissions (tons/year) for area/non-road, oil and gas, on-road, and point sources.

Task C: Meteorological Analysis

Meteorological conditions strongly influence air quality through processes such as transport, recirculation, and vertical mixing. Wind patterns help to determine which emissions sources influence measured pollutant concentrations at a given monitoring site. To provide information on meteorological patterns of interest for air quality management, STI developed a series of wind roses and wind rose maps to illustrate the meteorological conditions across the state. In addition, STI performed a trajectory analysis using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to show incoming and outgoing transport patterns at selected locations within the state.

Wind Rose Analysis

Wind roses provide a view of the distribution of wind speed and direction at a particular site over a defined period. A qualitative analysis of wind roses was performed to help identify potential redundancies or gaps in the network by comparing wind speed and wind direction observations between adjacent meteorological stations. Figure 14 illustrates how to interpret a wind rose. For wind rose development, wind speed and wind direction data were collected from two primary data sources: the EPA's AQS, and the National Weather Service and Federal Aviation Administration's METAR. For the wind rose maps, a select number of sites from the USDA Forest Service's Remote Automated Weather Stations (RAWS) were also collected. The selection of RAWS sites focused on filling gaps within the combined AQS and METAR statewide networks, in order to develop the most spatially comprehensive wind rose map.

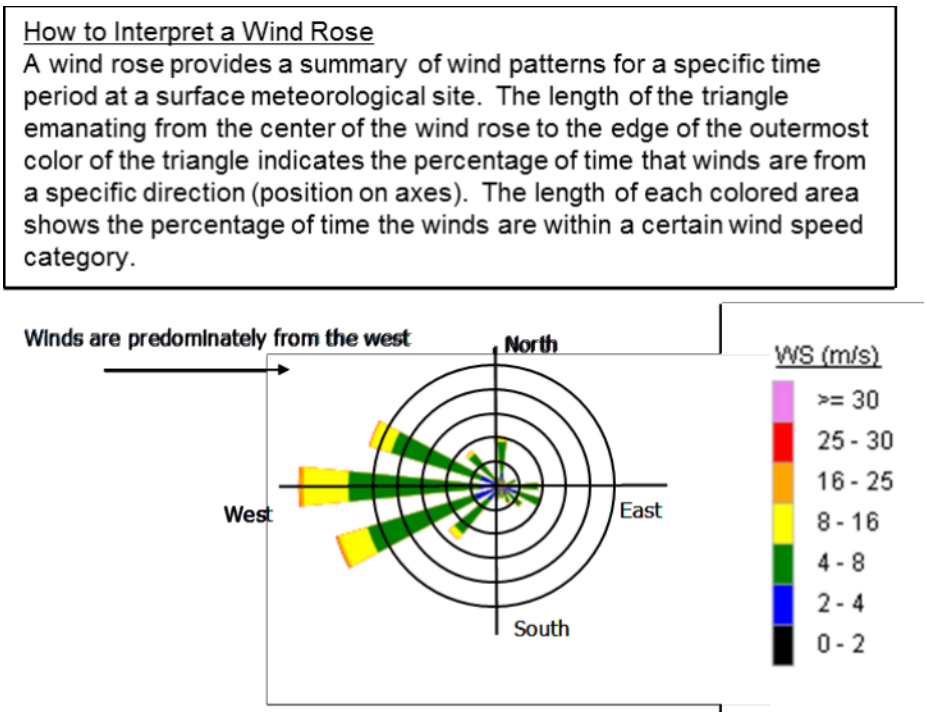

Figure 14. Interpreting wind roses used in our analyses.

Wind roses were generated annually and by season for site-specific data collected from 2009 to 2013. For use in data analysis, the EPA recommends data completeness of greater than 85%; that is, a data set must be at least 85% complete to be representative of the sampling period. The meteorological data were screened for data quality using minimum and maximum value checks; rate of change checks, which evaluate the magnitude of change per hour; and sticking checks, which evaluate whether a monitor is reporting the same value for a given number of hours (i.e., the monitor is "stuck"). Fifty-three AQS and 21 METAR sites passed the screening criteria and thus were used to develop annual and season wind roses. Figure 15 depicts an annual wind rose for a selected AQS

site, while Figure 16 shows a summer season wind rose for a METAR site. For this analysis, seasons were represented as winter (December through February), spring (March through May), summer (June through August), and fall (September through November). The complete list of AQS and METAR wind roses can be found in the *Task C Data Deliverable* file.

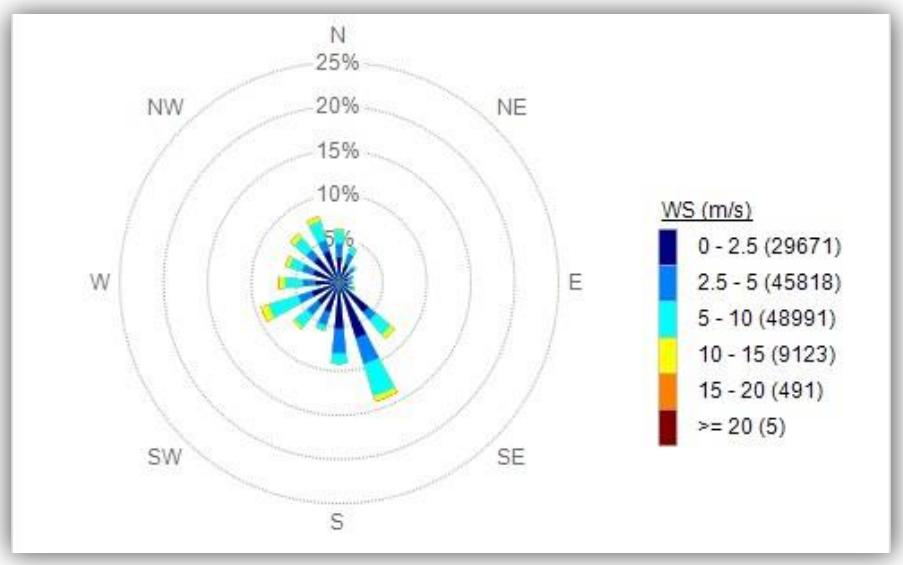

Figure 15. 2009-2013 annual wind rose for AQS site 560010802.

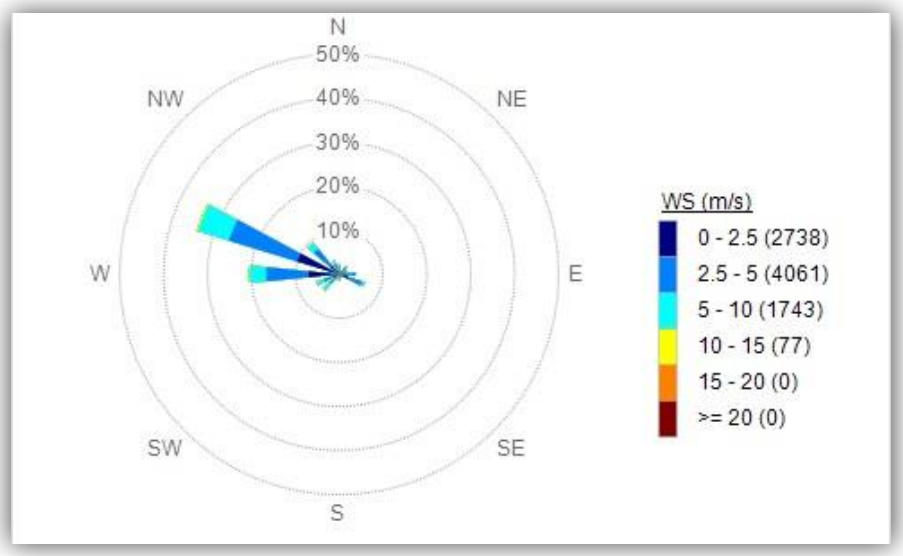

Figure 16. 2009-2013 summer (June through August) wind rose for METAR site KPNA.

Wind rose maps were generated using a selected number of AQS and METAR sites. Site selection was based on developing comprehensive geographic coverage across the state, while maintaining a clear, legible map product. In addition, RAWS sites were included in the analysis where spatial gaps existed within AQS and METAR networks. Unlike the wind roses described above, RAWS data collection and quality control were only completed on the site required for the wind rose maps. Figure 17 depicts the locations of AQS, METAR, and RAWS sites used in the wind rose maps. Like the wind roses described above, annual and seasonal wind rose maps were developed using quality-controlled wind speed and direction data from 2009 to 2013. Figures 18 through 22 show the series of wind rose maps, in which site-specific wind roses are overlaid on a map. These maps allow for greater understanding of wind patterns in relation to various geographic features, population areas, and emission sources.

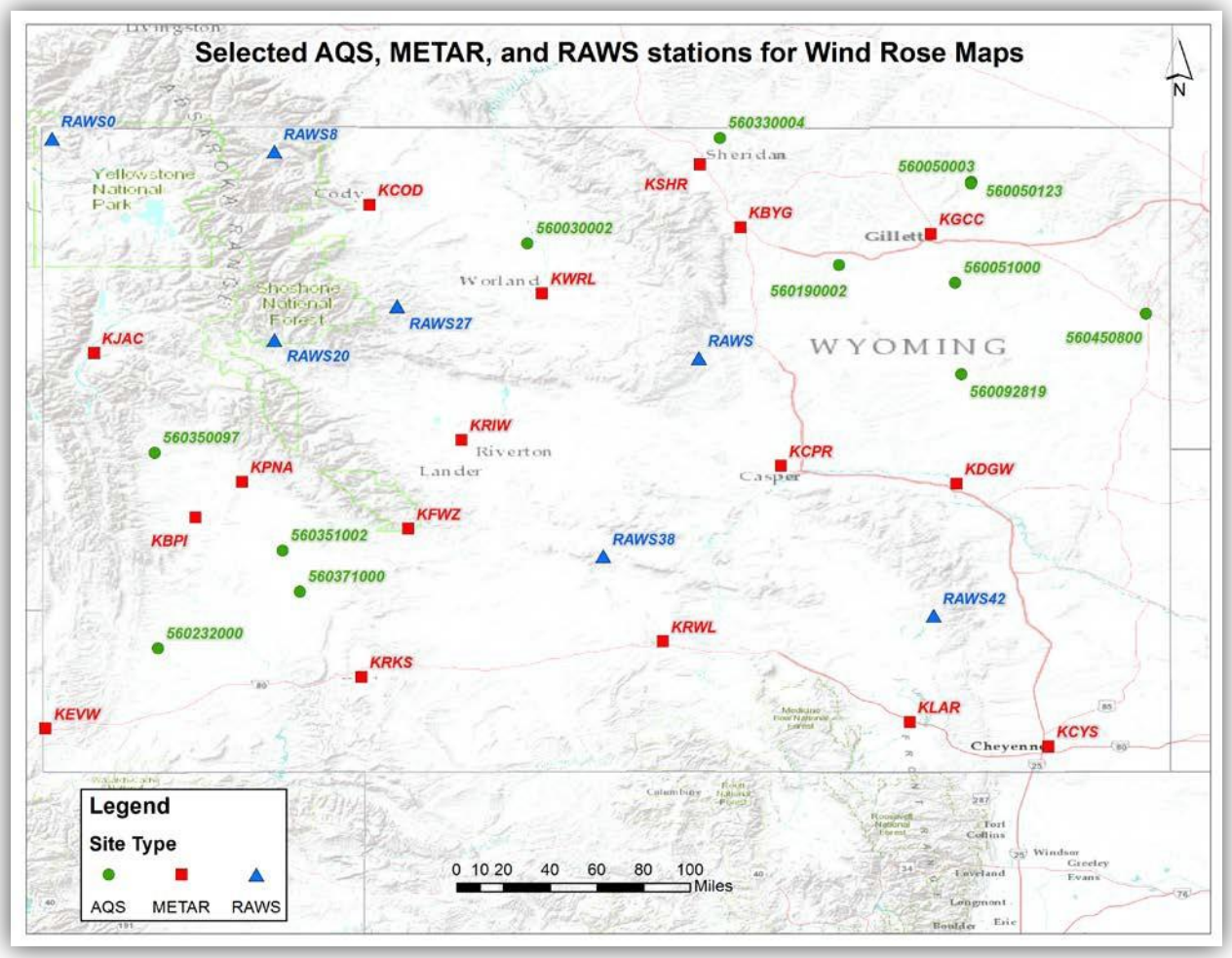

Figure 17. AQS, METAR, and RAWS site locations used in the wind rose maps.

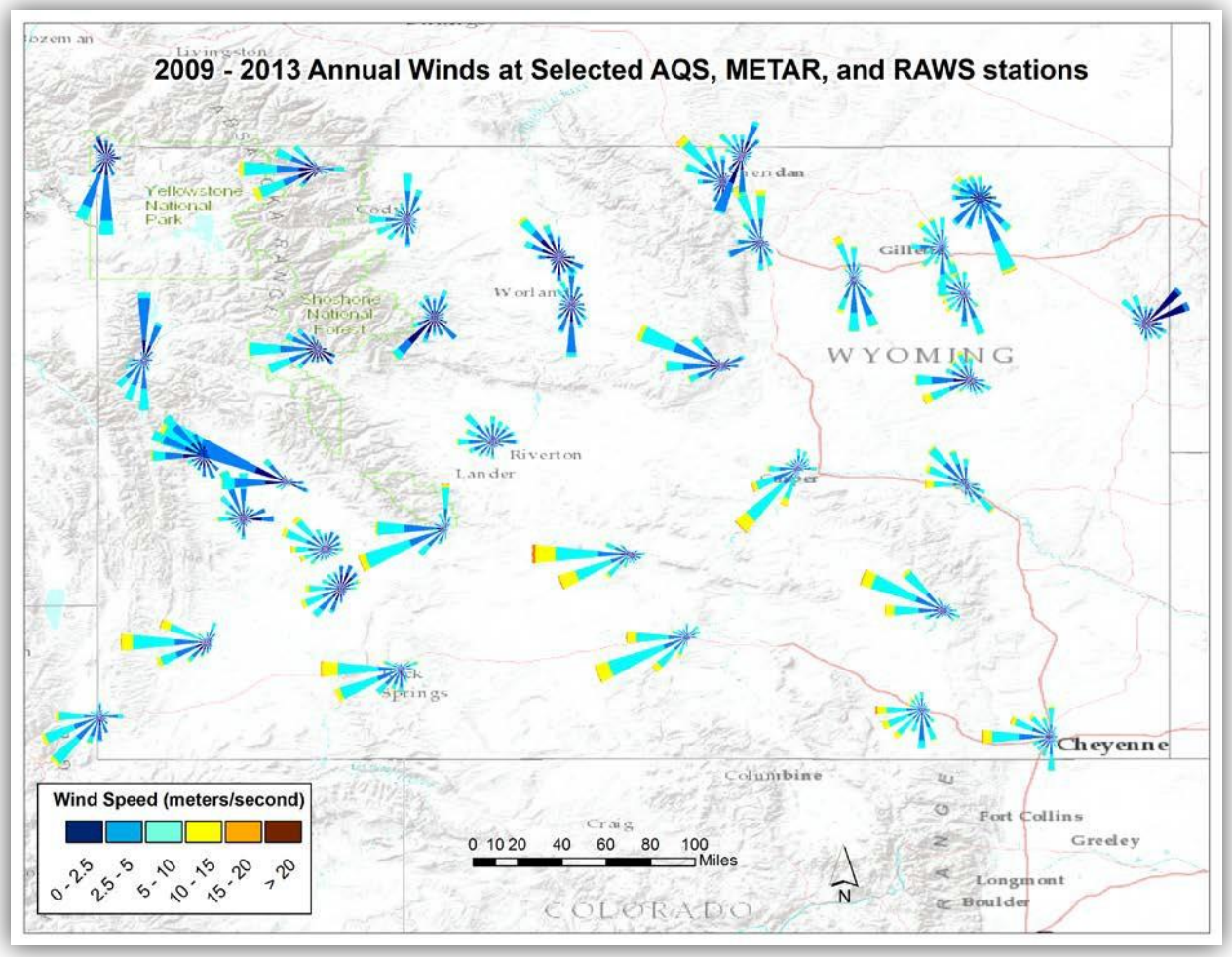

Figure 18. Wind rose map for 2009-2013 annual winds at selected AQS, METAR, and RAWS site locations.

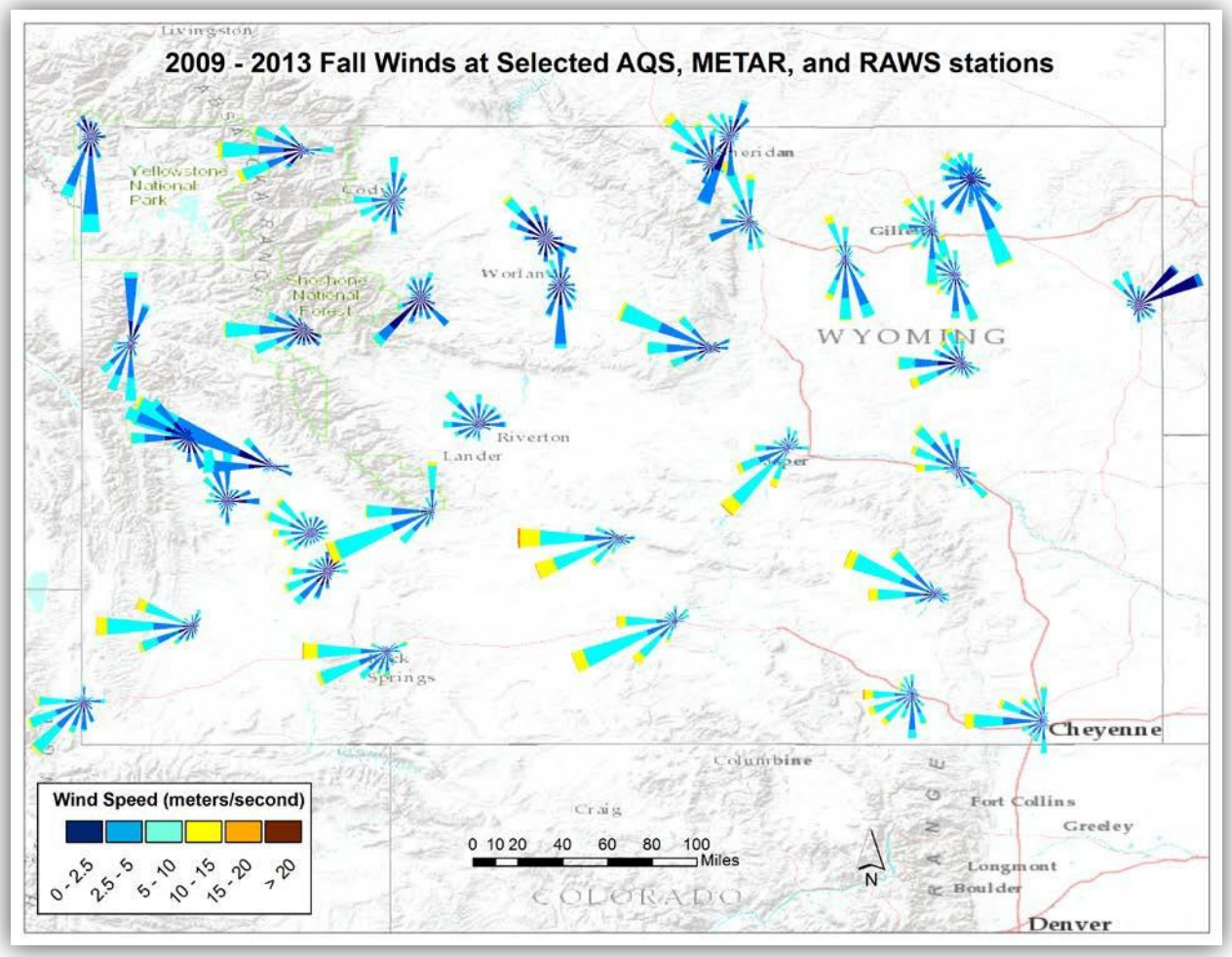

Figure 19. Wind rose map for 2009-2013 winds in the fall season at selected AQS, METAR, and RAWS site locations.

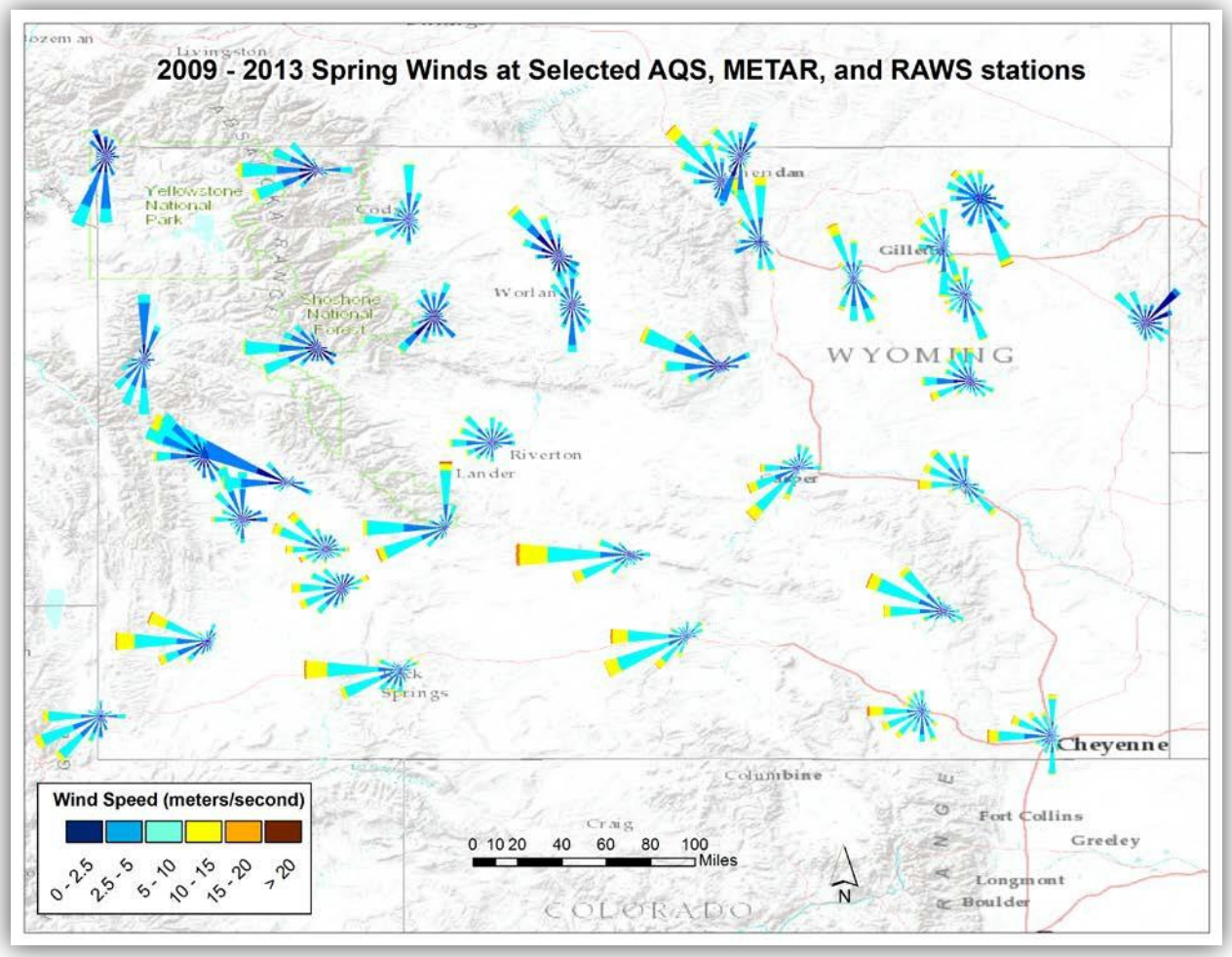

Figure 20. Wind rose map for 2009-2013 winds in the spring season at selected AQS, METAR, and RAWS site locations.

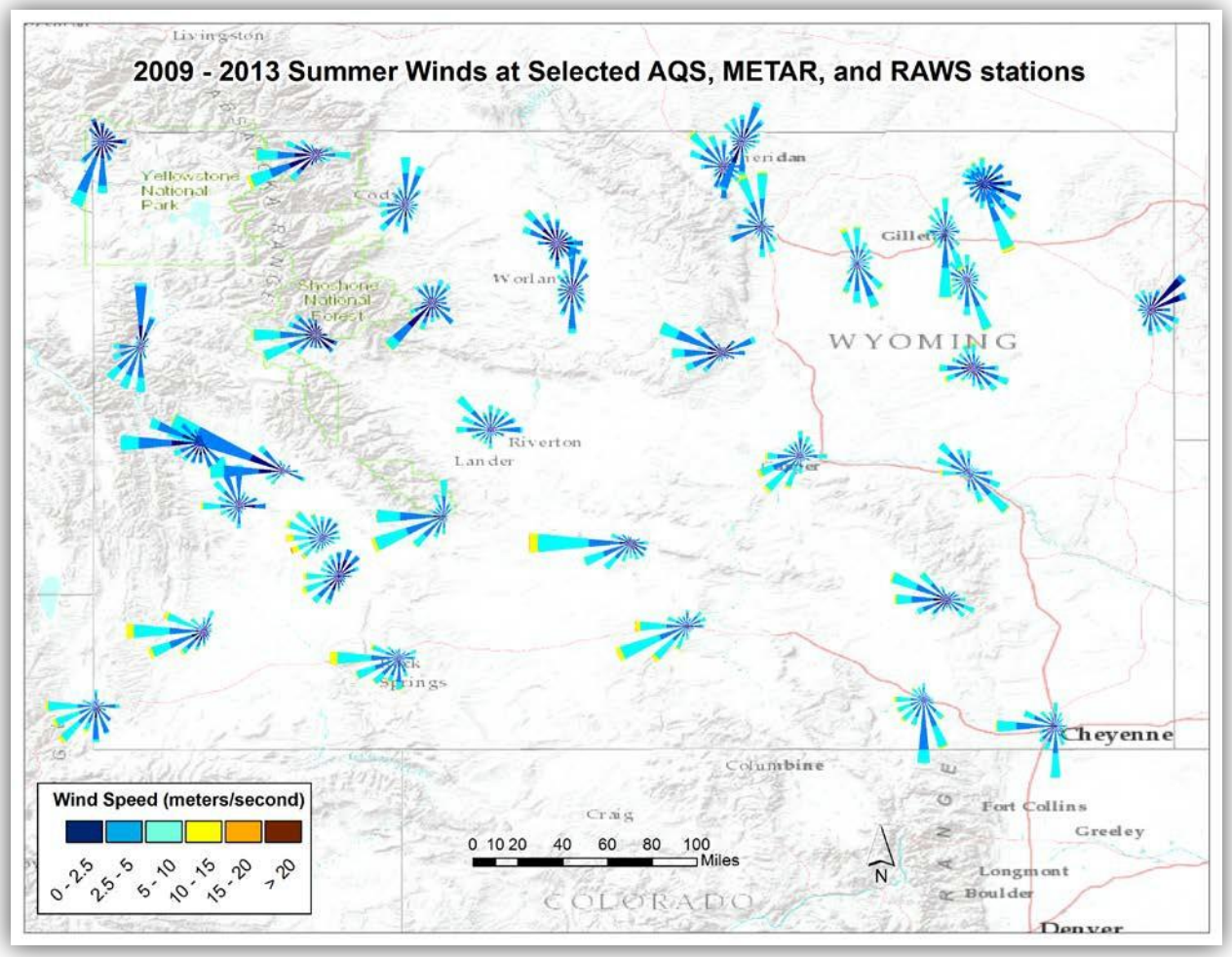

Figure 21. Wind rose map for 2009-2013 winds in the summer season at selected AQS, METAR, and RAWS site locations.

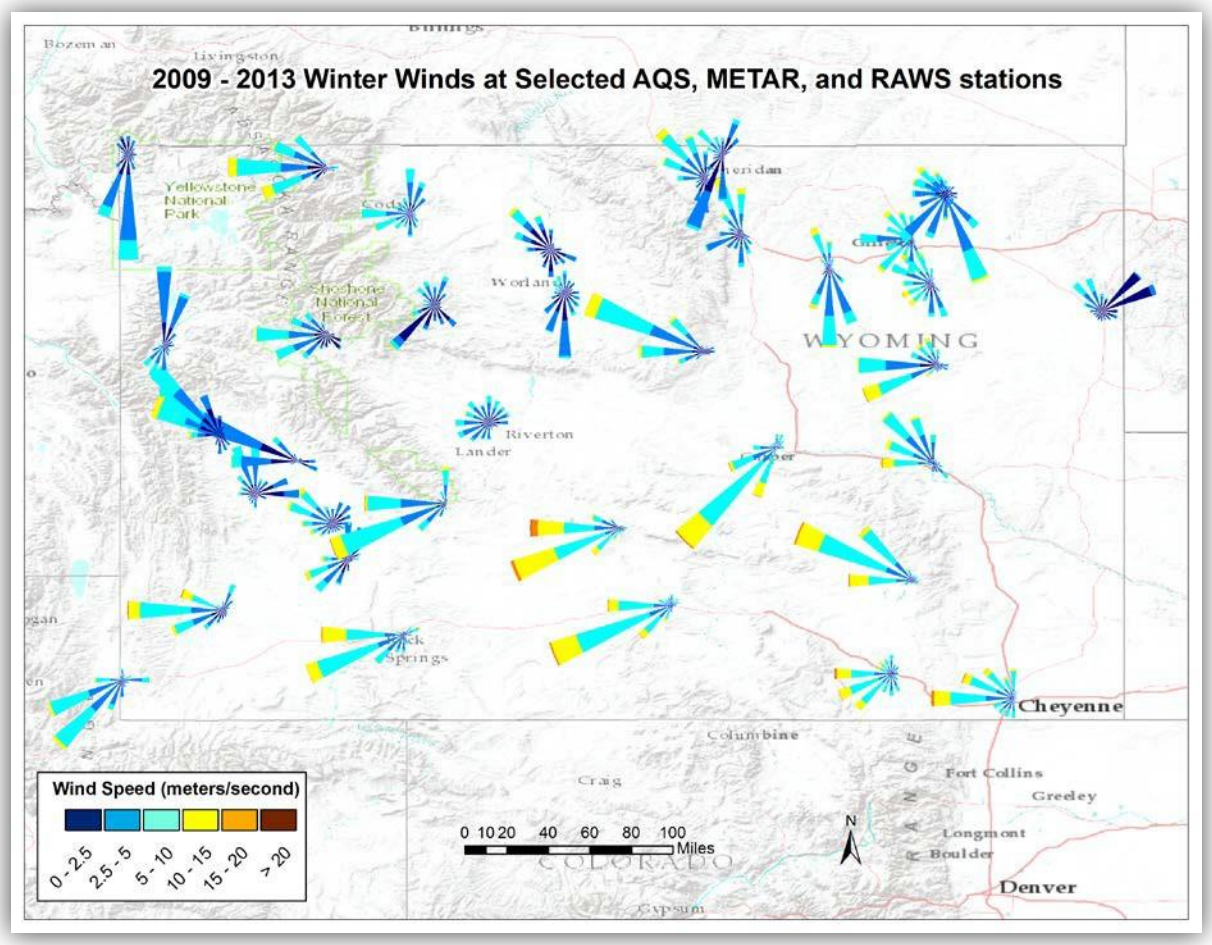

Figure 22. Wind rose map for 2009-2013 winds in the winter season at selected AQS, METAR, and RAWS site locations.

Trajectory Analysis

This task is intended (1) to investigate potential impacts of upwind emissions sources on current monitoring locations and population centers, and (2) to identify areas most likely to be affected by large emissions sources. To meet these objectives, STI generated back and forward trajectories from the HYSPLIT model to assess potential impacts of emissions sources on population centers and monitoring locations across Wyoming.

STI assessed potential emissions impacts on seven municipalities selected by AQD staff: Cody, Evanston, Riverton, Jackson, Sheridan, Laramie, and Torrington (see Figure 23). To identify paths of air parcels arriving at each town, STI performed back trajectory analyses with HYSPLIT using the NAMS meteorological data model, which has a horizontal resolution of 12 km. Based on the site-specific date and time (provided by AQD staff), STI calculated 48-hour back trajectories with two starting elevations to capture transport paths at different altitudes in the atmospheric boundary layer (see Table 6). Figures 24 through 30 show the backward trajectory maps for each municipality.

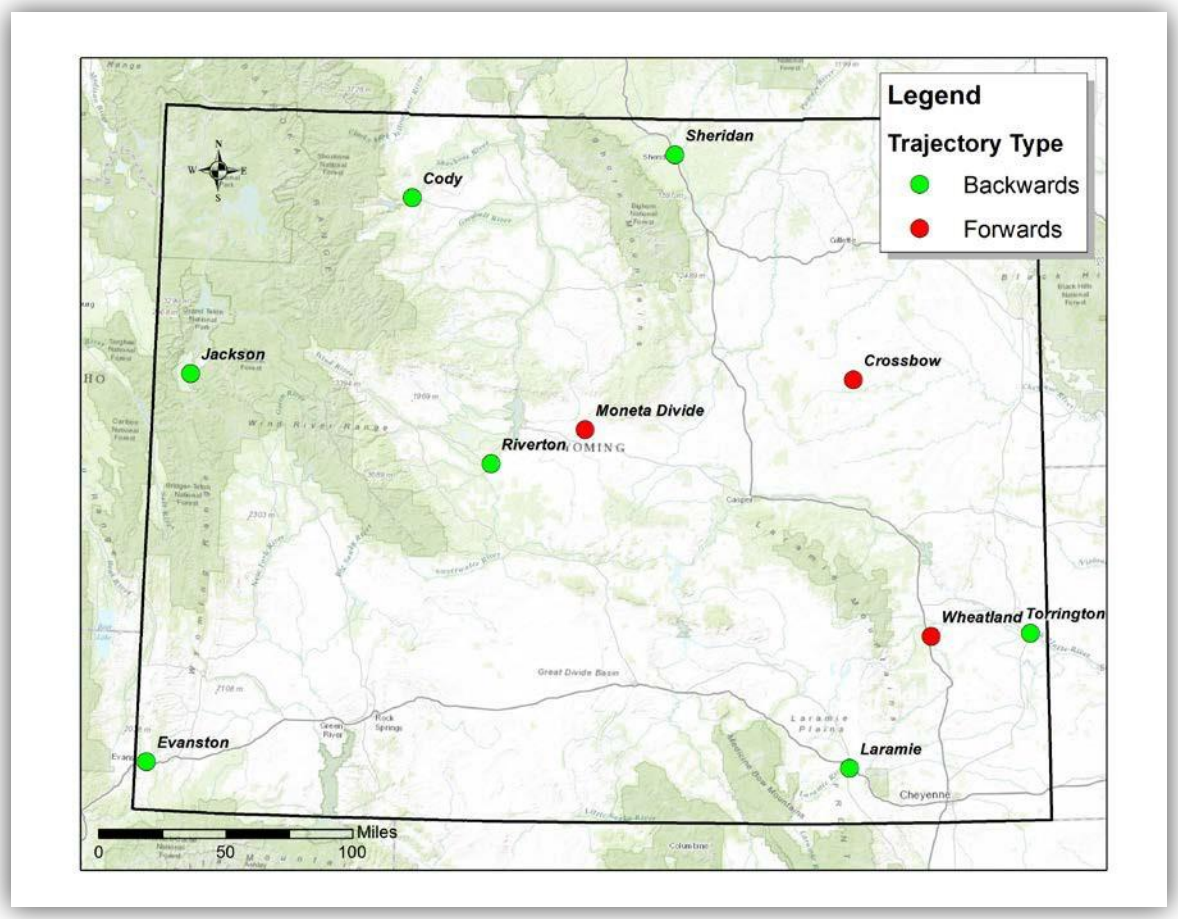

Figure 23. Locations of backward and forward trajectory starting locations.

Table 6. Input parameters used to run the HYSPLIT model for backward trajectory sites.

Starting Location (Municipality)	Starting Date	HYSPLIT Parameters
Cody	May 15, 2010	Starting Heights: 250 and 500 m Starting Time: 12 PM MST Trajectory Run Time: 48 hours Model: NAMS 12-km Vertical motion: Sigma (constant height)
Evanston	August 18, 2011	
Riverton	Aug 19, 2013	
Jackson	June 18, 2010	
Sheridan	May 22, 2009	
Laramie	November 1, 2009	
Torrington	November 9, 2011	

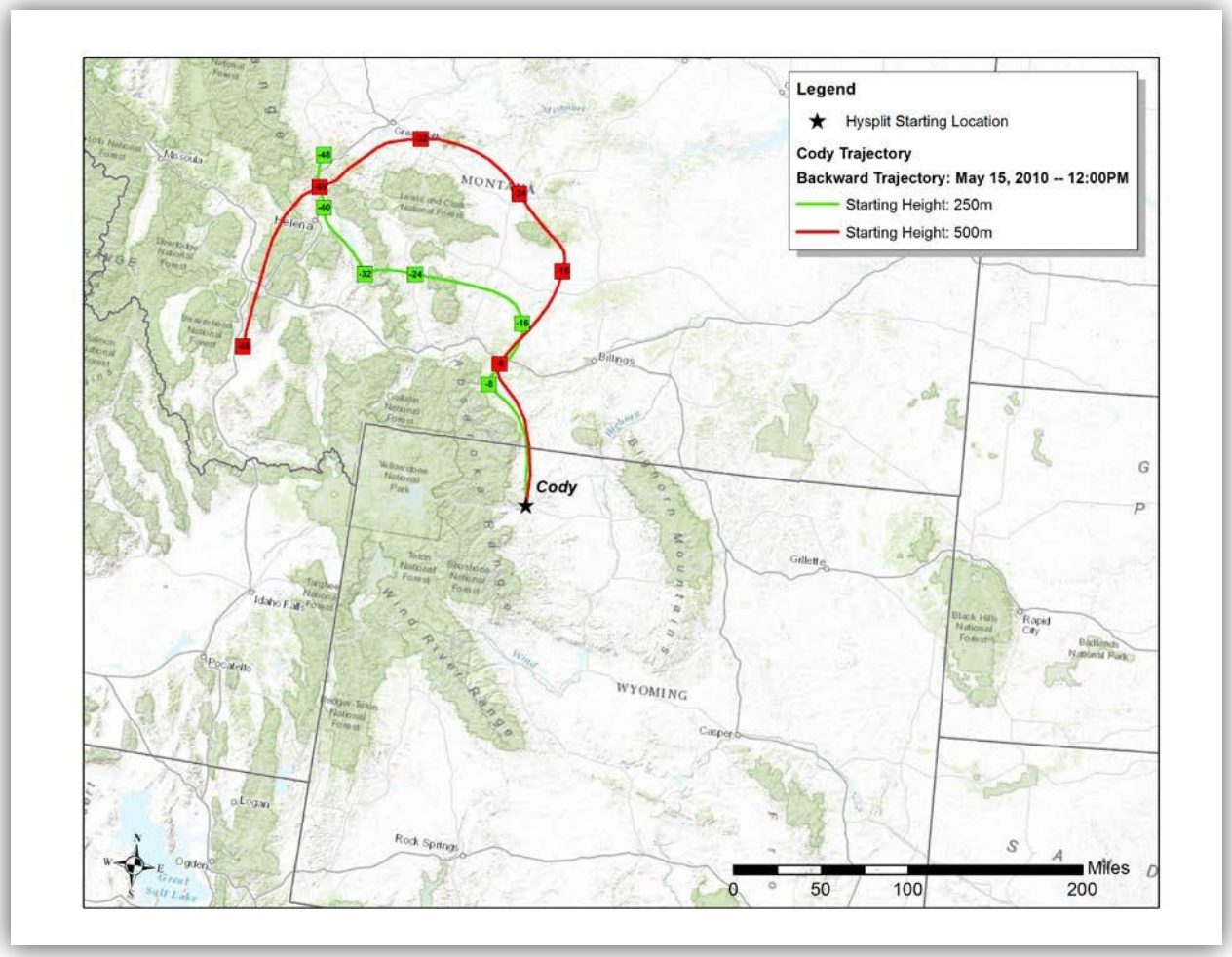

Figure 24. Backward trajectory map for Cody, Wyoming.

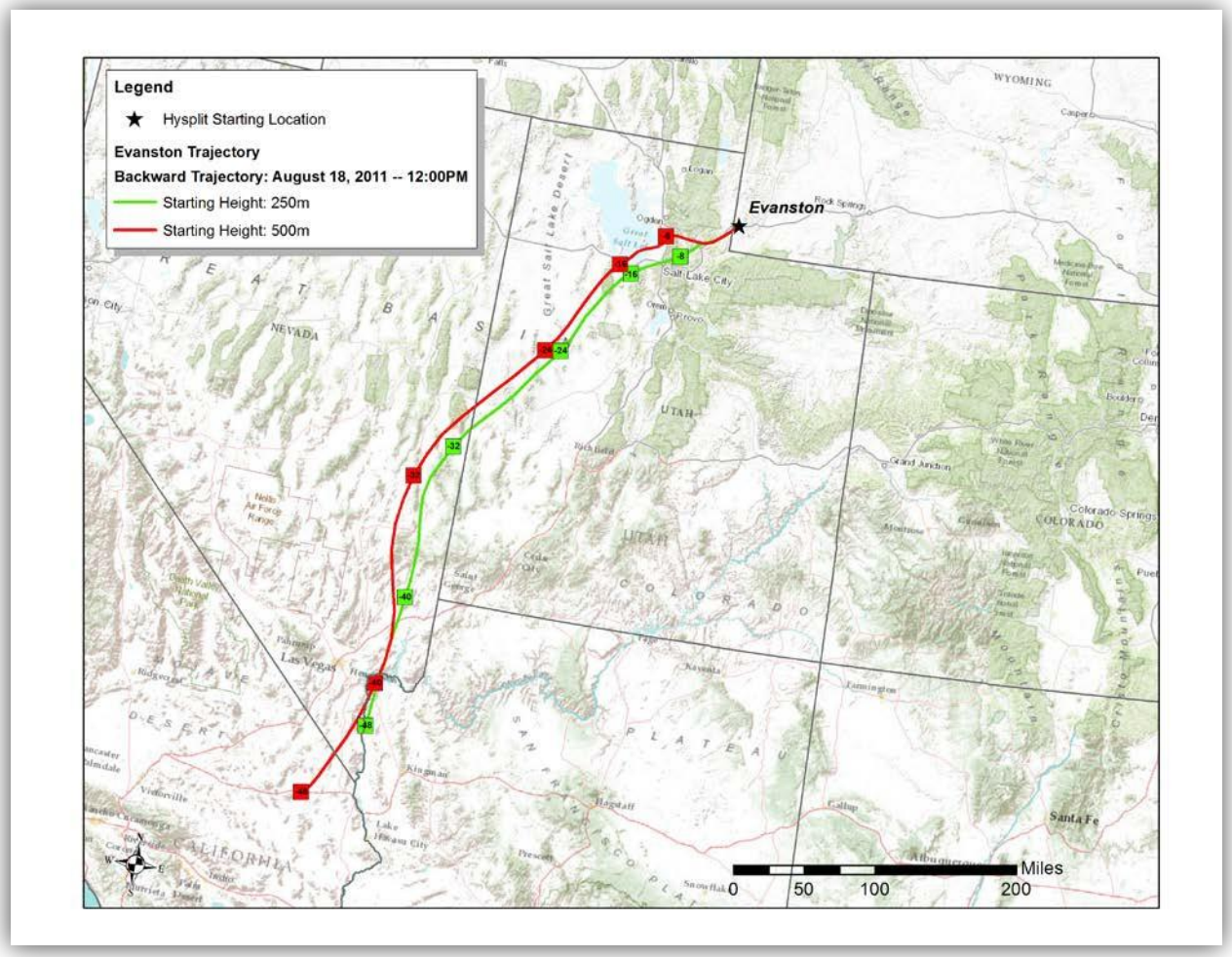

Figure 25. Backward trajectory map for Evanston, Wyoming.

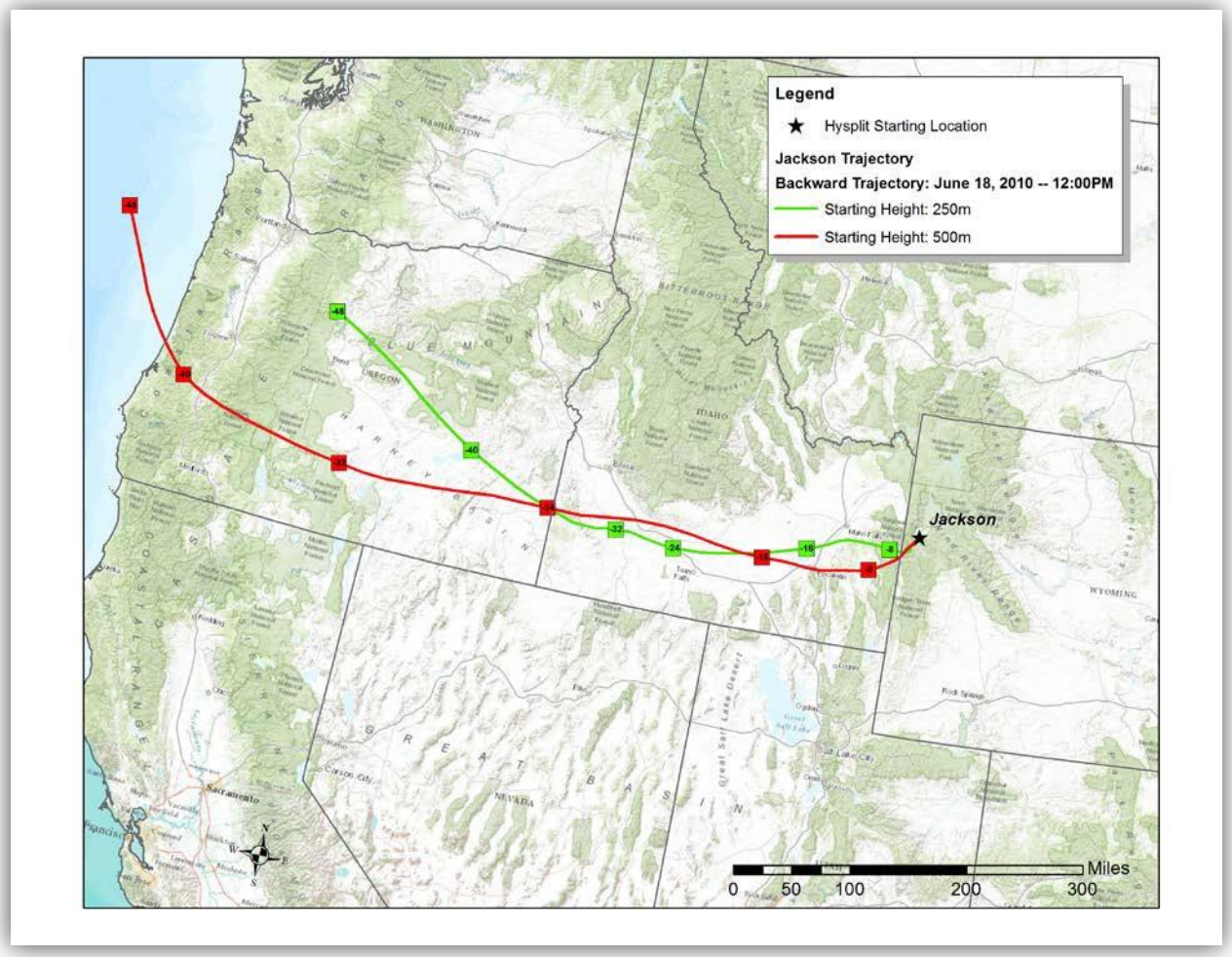

Figure 26. Backward trajectory map for Jackson, Wyoming.

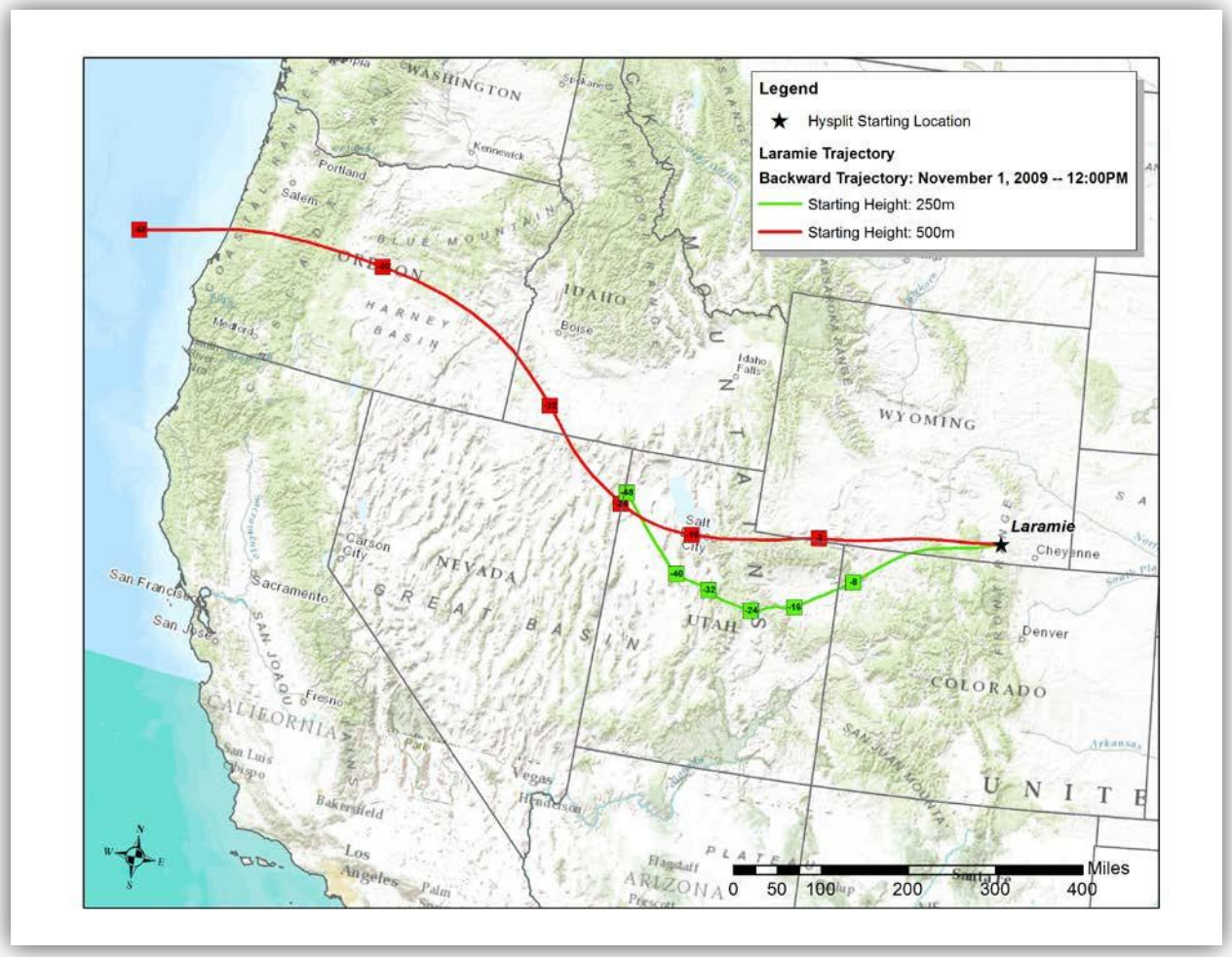

Figure 27. Backward trajectory map for Laramie, Wyoming.

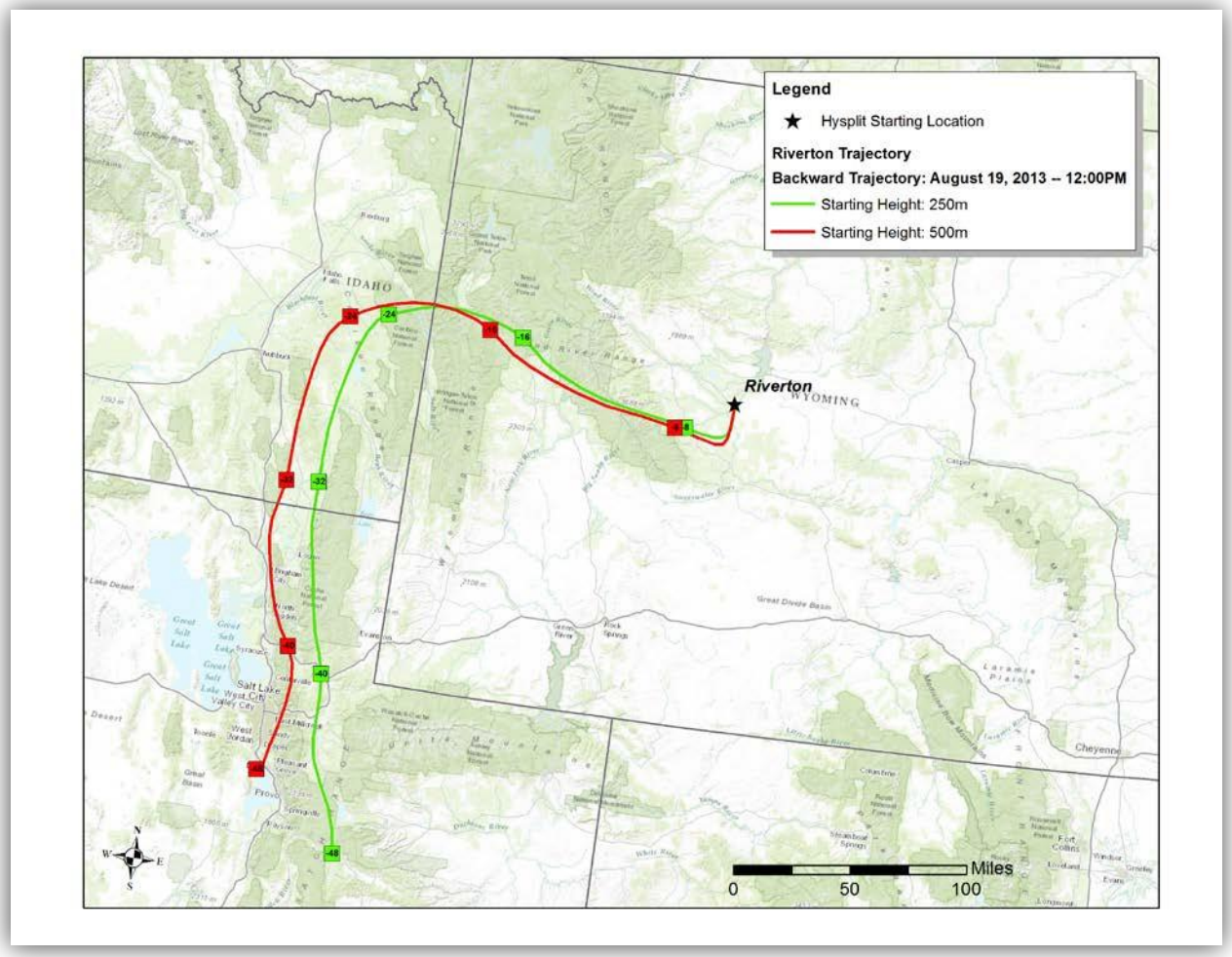

Figure 28. Backward trajectory map for Riverton, Wyoming.

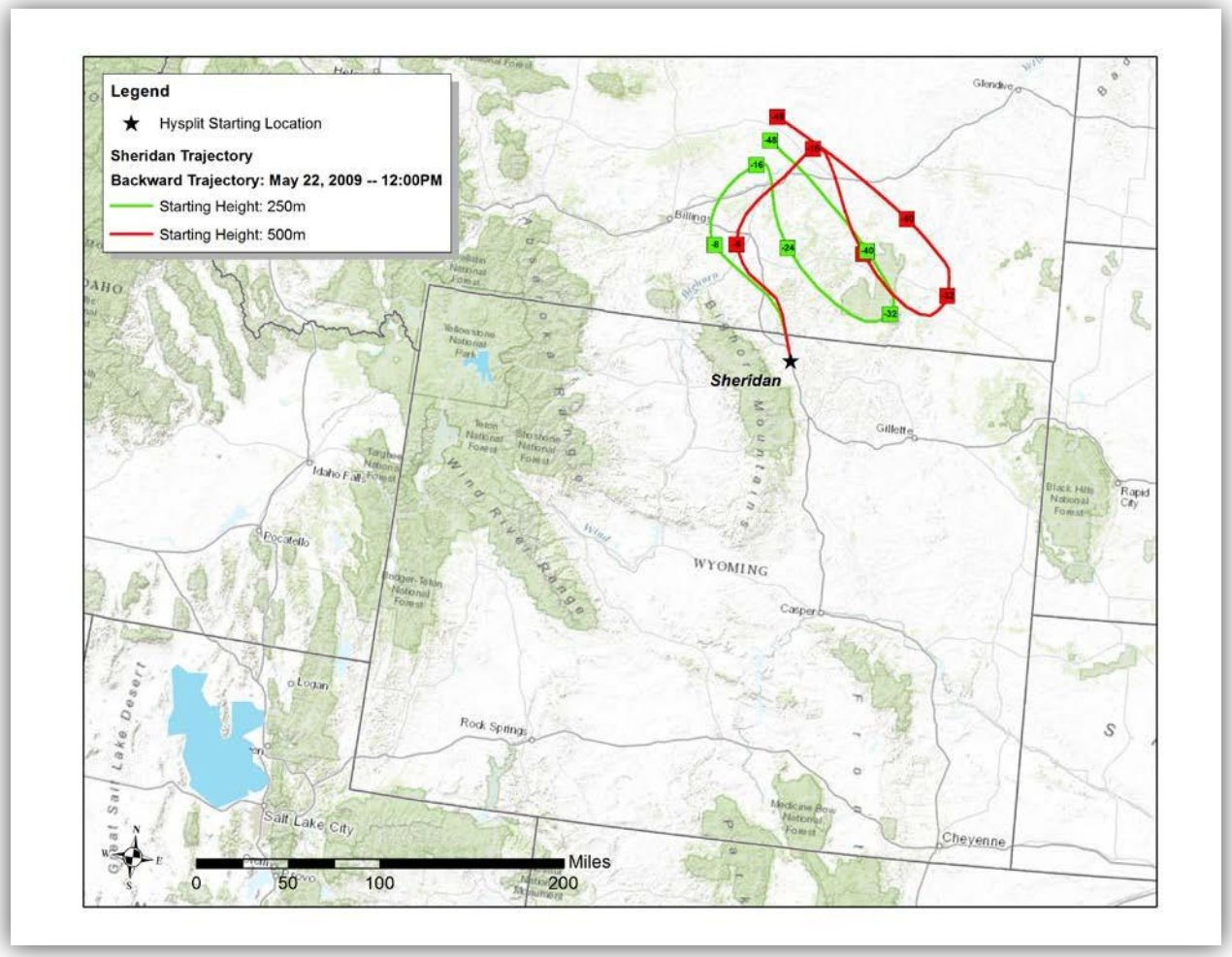

Figure 29. Backward trajectory map for Sheridan, Wyoming.

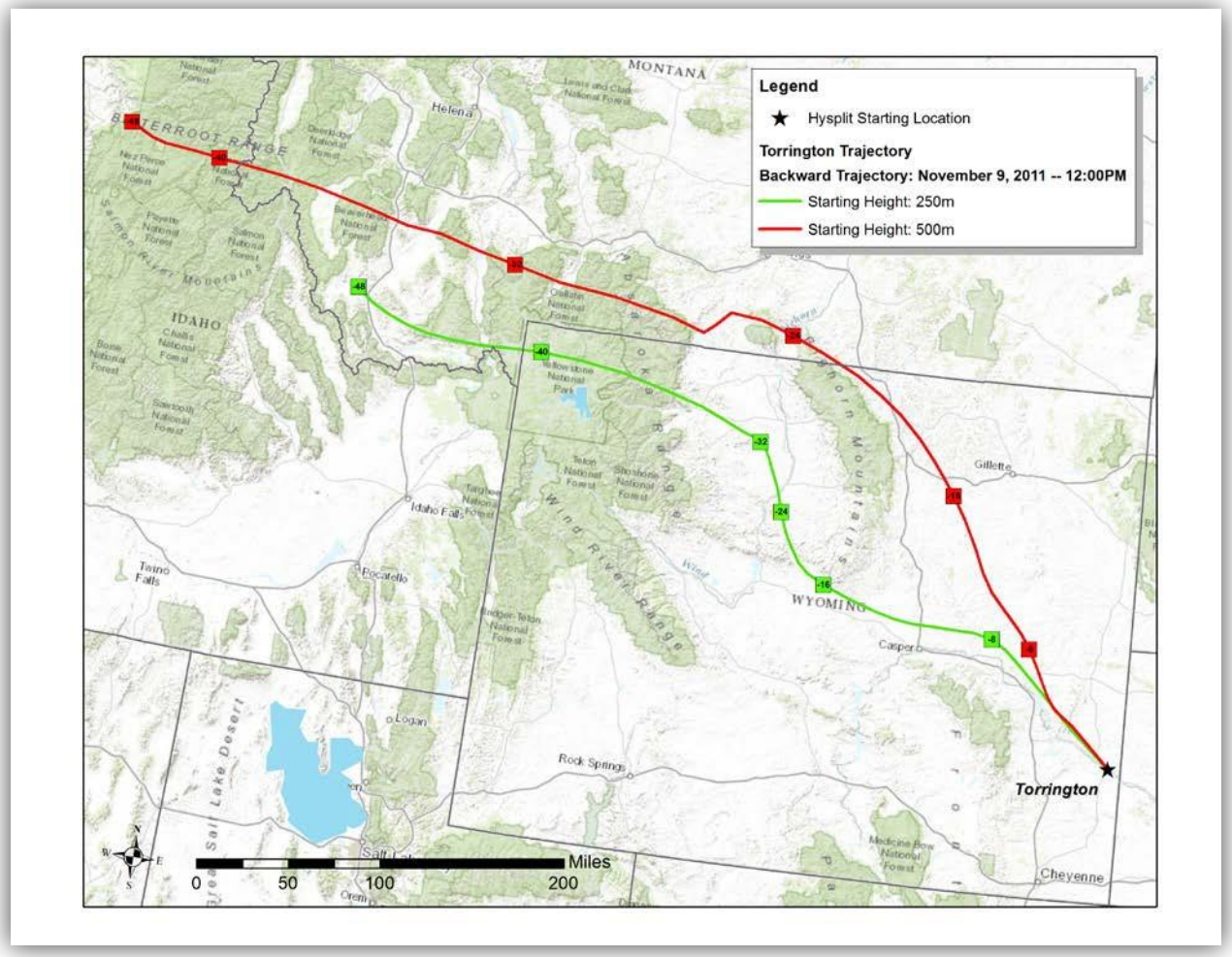

Figure 30. Backward trajectory map for Torrington, Wyoming.

To identify areas where impacts from emissions sources are most likely, STI calculated forward trajectories from three National Environmental Policy Act (NEPA) project development areas selected by AQD staff. The specific locations, trajectory start dates, and HYSPLIT parameters are listed in Table 7. Figures 31 through 33 show forward trajectories from each NEPA project area of interest.

Table 7. Input parameters used to run the HYSPLIT model for forward trajectory sites.

Starting Location (municipality)	Starting Date	HYSPLIT Parameters
Crossbow	August 17, 2013	Starting Heights: 250 and 500 m Starting Time: 12 PM MST Trajectory Run Time: 48 hours Model: NAMS 12-km Vertical motion: Sigma (constant height)
Monte Divide	June 3, 2011	
Wheatland	November 30, 2010	

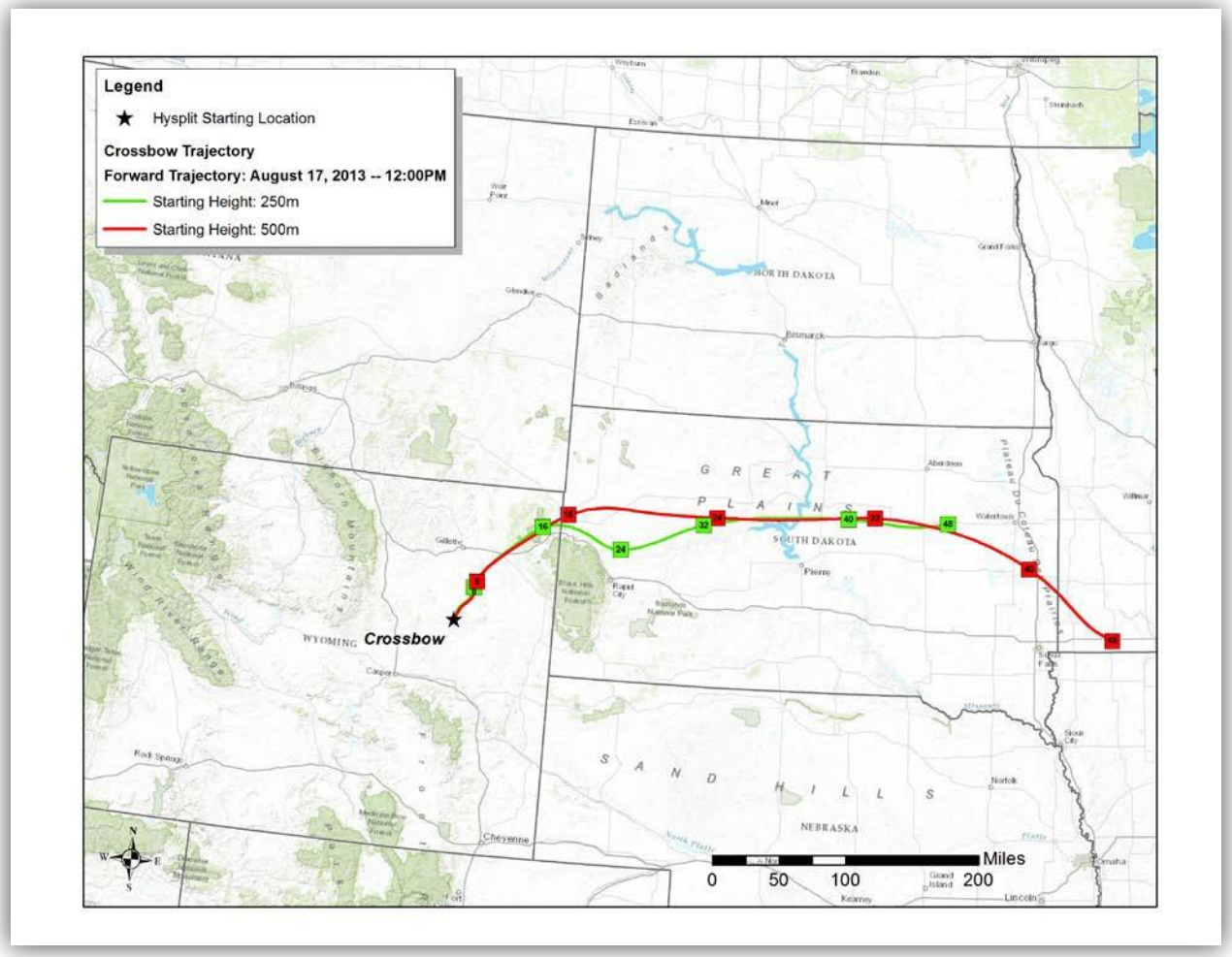

Figure 31. Forward trajectory map for the Crossbow NEPA project development area.

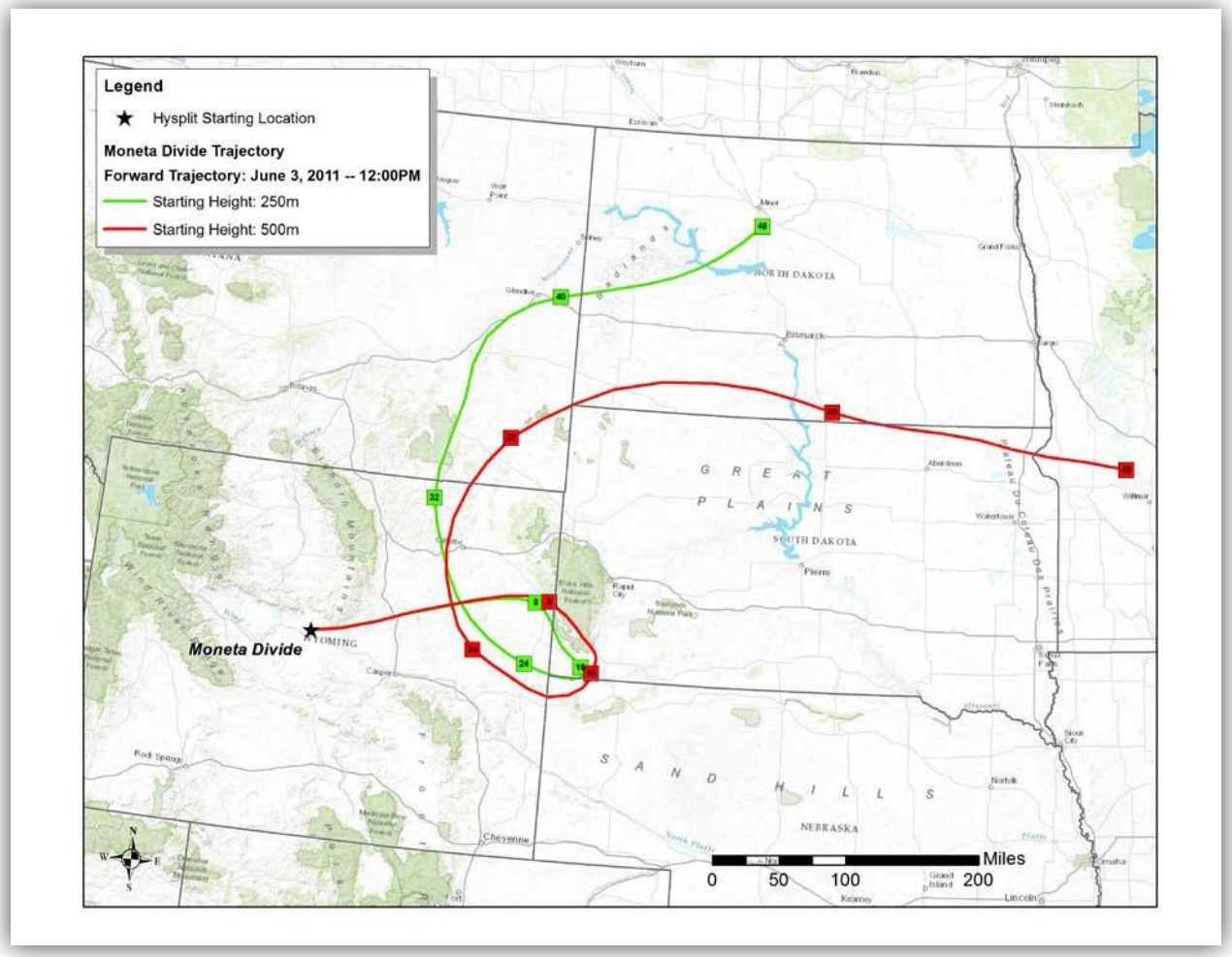

Figure 32. Forward trajectory map for the Moneta Divide NEPA project development area.

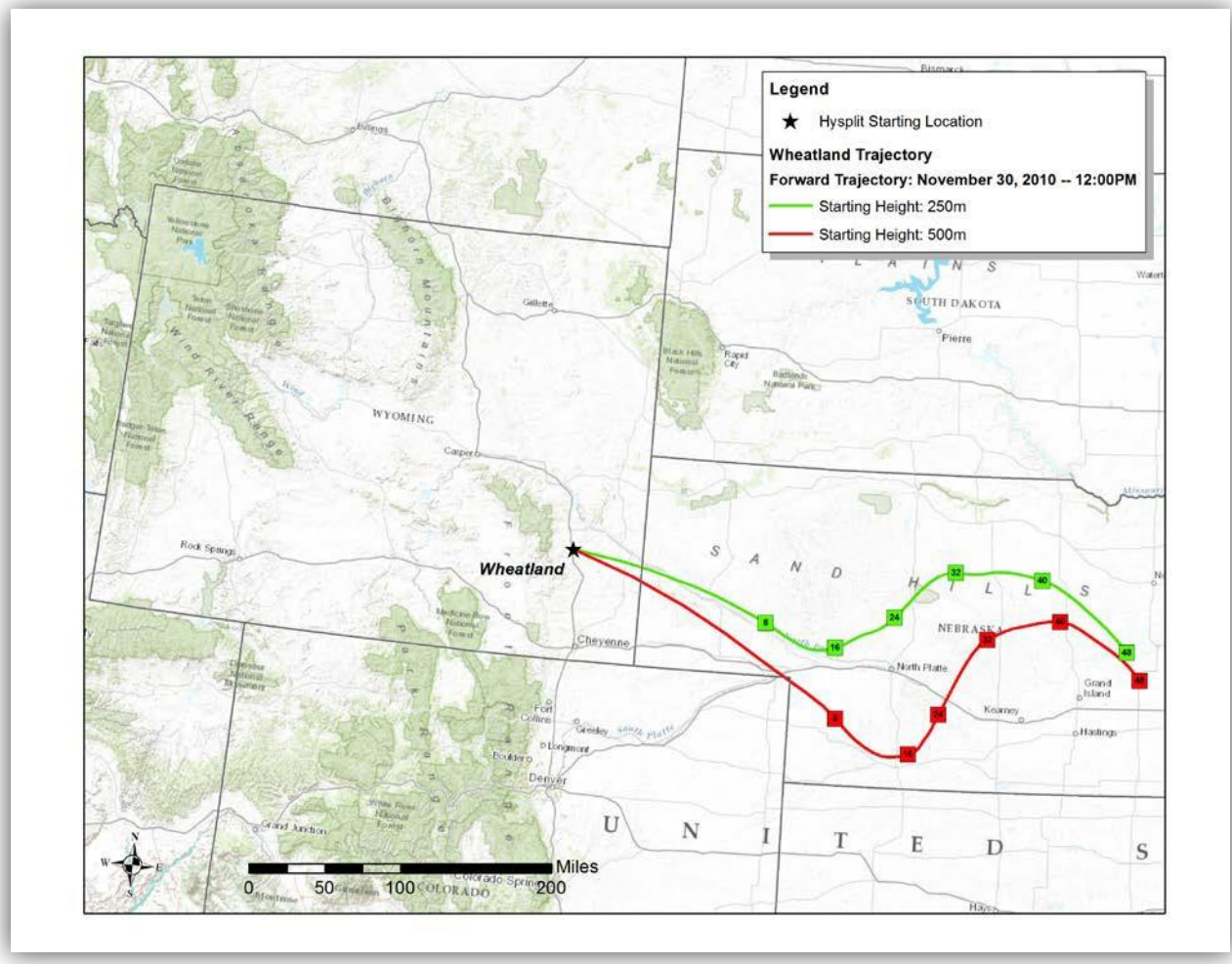

Figure 33. Forward trajectory map for the Wheatland NEPA project development area.

Task D: Population Analysis

Population analyses provide information on potential human exposure to ambient air pollutants and how those exposures may have changed as population densities change. Figure 34 depicts the process for performing a population-served analysis. This is a quantitative analysis that indicates which monitors are closest to people.

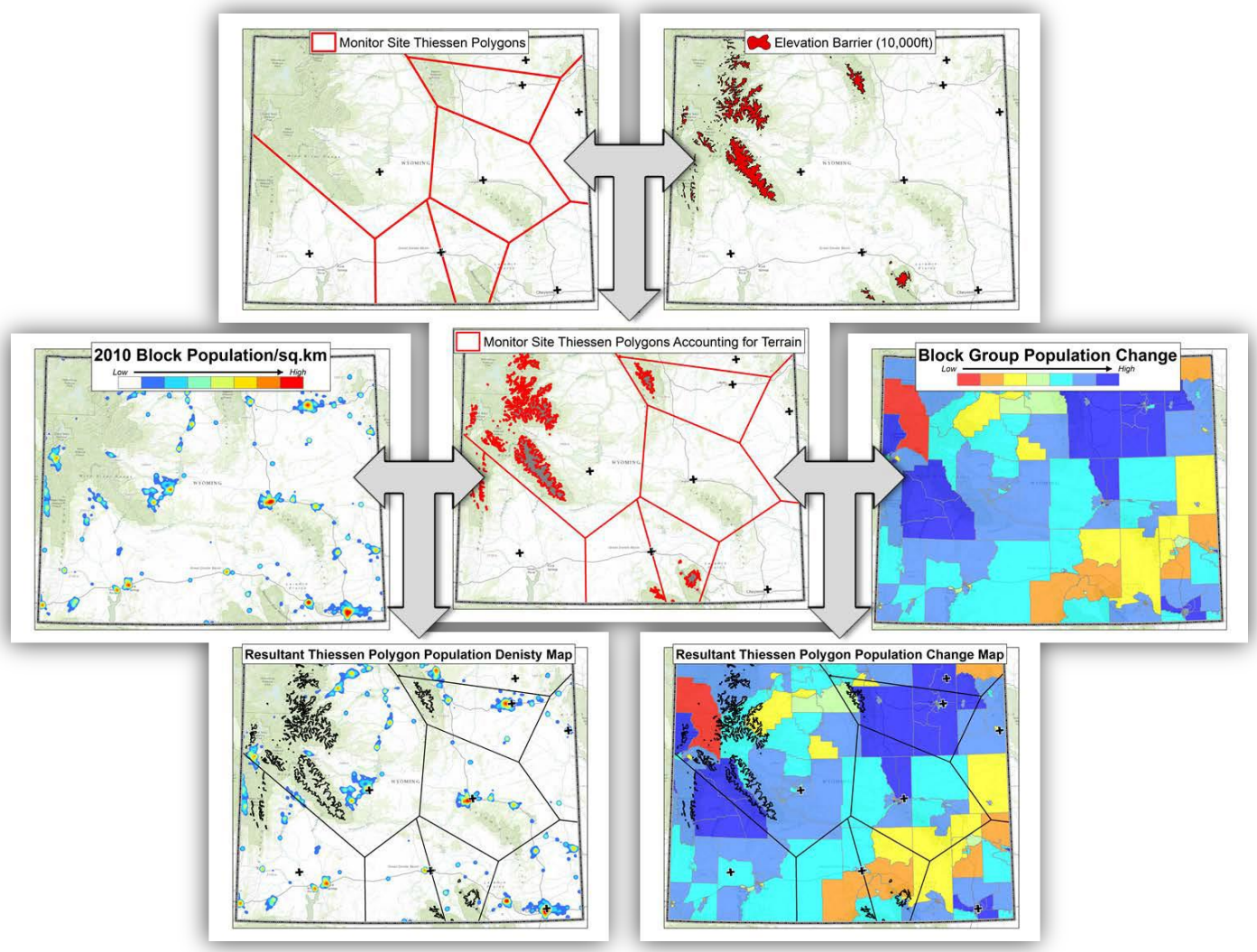

Figure 34. Overview of the process for performing a population-served analysis.

The first step in a population-served analysis is to map the air quality sites with geographic information system (GIS) software. The population-served analysis used two versions of WDEQ air quality site files: (1) all monitoring locations active during 2009–2013, and (2) current active air quality monitoring sites. The next step is to generate Thiessen polygons (also called Voronoi diagrams) within the GIS software. Thiessen polygons are applied as a standard technique in geography to assign a zone of influence or representativeness to the area around a given point (in this case, a monitoring site). Calculating Thiessen polygons is a simple quantitative method for determining an area of representation around a given site. However, Thiessen polygons do not take into account geographic features or meteorology. Thus, the next step in the area-served analysis is to consider geography and terrain within each of the Thiessen polygon boundaries and adjust the polygons to better represent geophysical conditions (top row in Figure 34, moving to the middle row).

High-resolution Digital Elevation Model (DEM) data were used to characterize the topography within each of the Thiessen polygon boundaries. To improve the physical representation of the Thiessen polygons boundaries, the boundaries were adjusted to a maximum elevation of 10,000 feet, thus accounting for topographic barriers. Because surface air parcels are not likely to travel across large mountain ranges, monitoring sites are not likely to represent the entire region defined by the Thiessen polygon alone; therefore, the areas of representativeness were restricted when geographic barriers were considered.

After the Thiessen polygons boundaries were developed for each site, a population-served analysis was performed. The purpose of the population-served analysis is to determine the population coverage represented by each monitoring site and to identify the sites that represent the highest population densities. It is of interest to examine areas within Wyoming that have undergone population growth over the past several years and to examine monitoring site locations in relation to areas of population growth. Human encroachment and increases in emissions activity related to population growth may impact monitoring sites. These impacts can change site characteristics and site-specific monitoring objectives (e.g., a former rural site may now be an urban site). In this analysis, the growth and spatial distribution of population throughout the study domain was examined.

To perform the population-served analysis, spatially resolved population data at the block level were acquired from the U.S. Census Bureau for 2010. Census Block point locations were mapped within a GIS, and the 2010 population density values were calculated. The population density values were then imposed on the Thiessen polygons, and population density maps were created (bottom left in Figure 34). Total population at each block point location was then totaled for each site-specific polygon and summarized in the final Microsoft Excel deliverable file. Table 8 shows the monitoring locations that were active during 2009–2013 and had high Thiessen polygon total populations. (The CO and speciated $PM_{2.5}$ networks were excluded from the table because of the limited number of monitoring sites.) Table 8 shows the NCore site in Cheyenne representing the largest population in both the SO_2 and NO_2 networks. Figures 35 through 42 depict current site location population density maps. The complete list of maps can be found in the *Task D Data Deliverable* file.

Table 8. Top 5% of Thiessen polygon total population within the monitoring locations active during the period of 2009 to 2013.

Site Code	Parameter	Site Info	2010 Population
560210100	SO_2	NCore - North Cheyenne Soccer Complex	148,401
560210100	NO_2	NCore - North Cheyenne Soccer Complex	139,533
560210001	PM_{10} LC	Cheyenne-State Office Bldg 23rd & Central Avenue	106,494
560210100	O_3	NCore - North Cheyenne Soccer Complex	104,475
560252601	SO_2	Sinclair, Casper	90,166
560350002	SO_2	Pinedale, WARMS station	82,994
560250001	PM_{10} LC	Casper -City County Bldg Center and C Streets	82,209
560250001	$PM_{2.5}$ LC	Casper -City County Bldg Center and C Streets	79,960
560250001	PM_{10} STP	Casper -City County Bldg Center and C Streets	79,899
560050800	NO_2	Gillette Mobile	75,753
560370870	$PM_{2.5}$ LC	Tata Gaseous	56,864
560130900	NO_2	Pavillion	56,411
560030002	SO_2	Basin (WARMS station)	54,312
560250100	O_3	2800 Pheasant Drive, Casper	53,344
560250100	NO_2	2800 Pheasant Drive, Casper	53,331

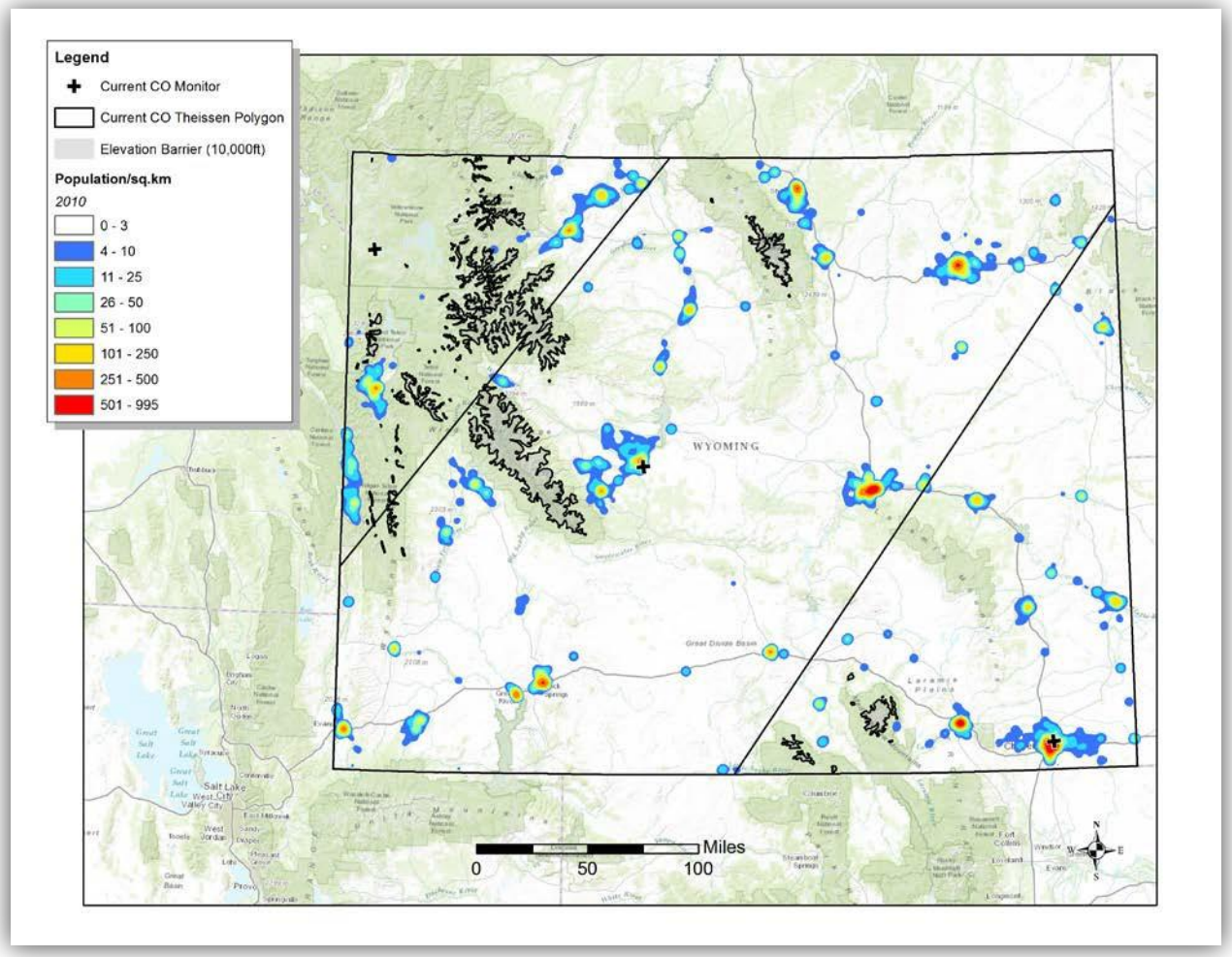

Figure 35. Population-served map for the current CO monitoring network. Thiessen polygons indicate the area served by CO monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

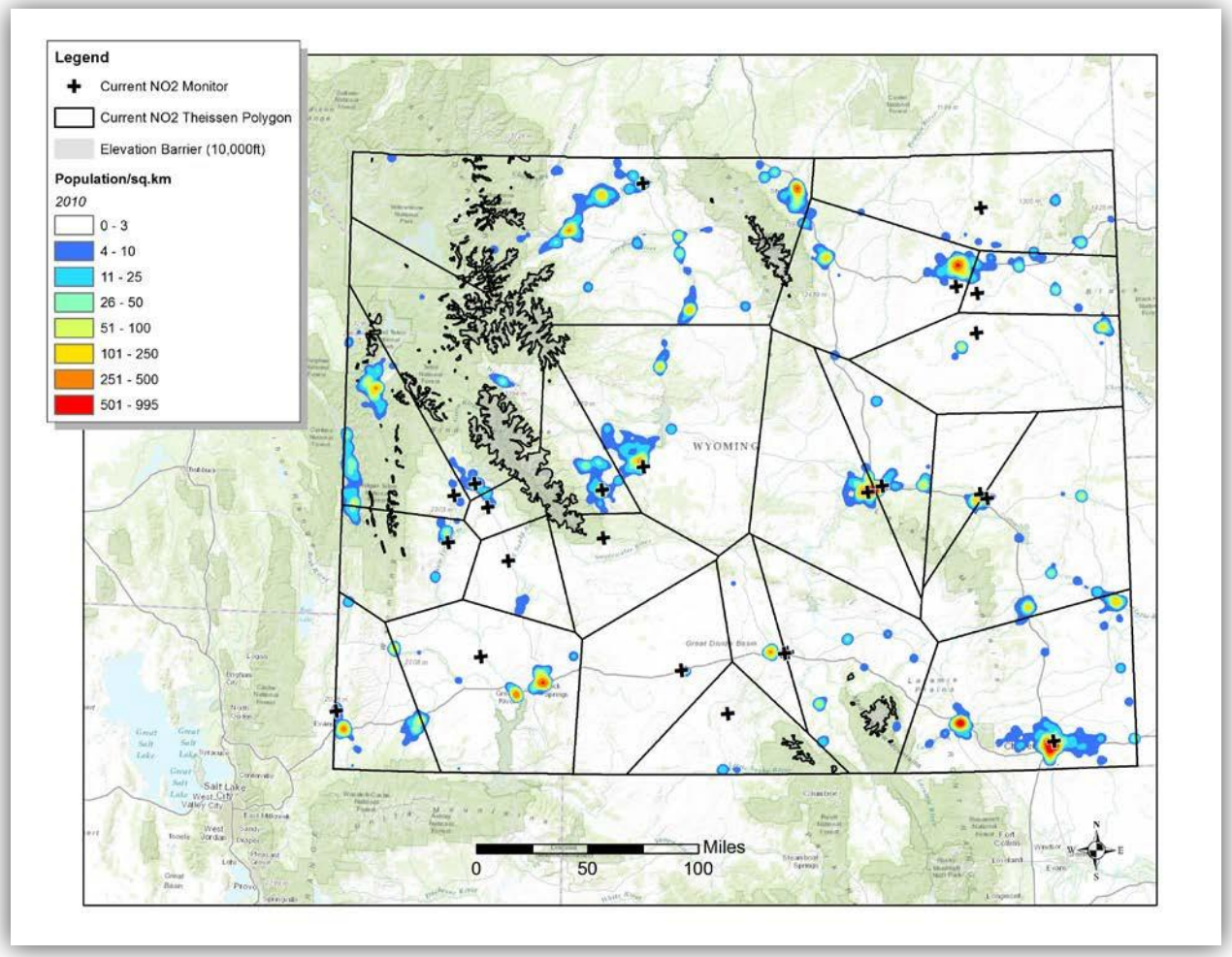

Figure 36. Population-served map for the current NO_2 monitoring network. Thiessen polygons indicate the area served by NO_2 monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

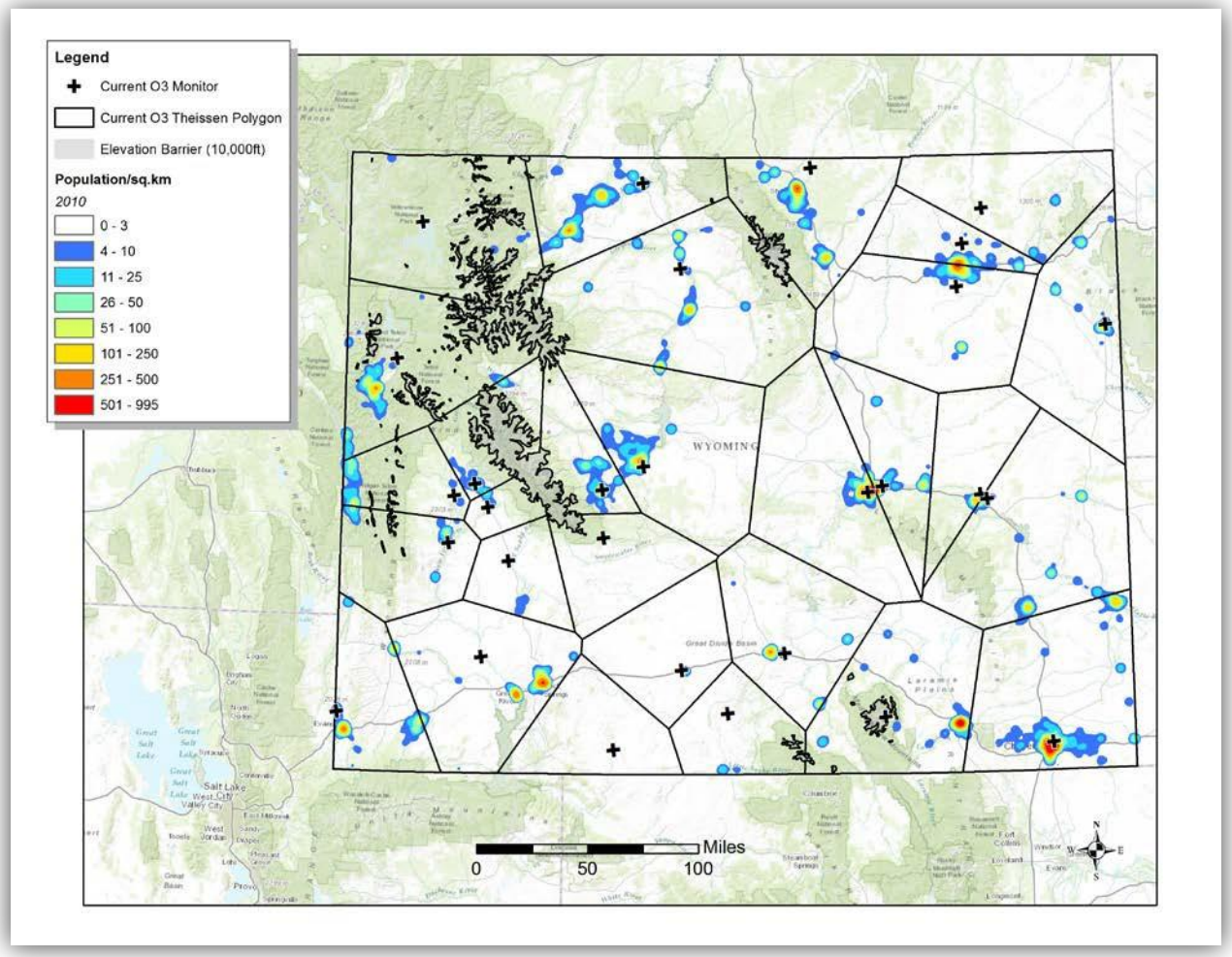

Figure 37. Population-served map for the current ozone monitoring network. Thiessen polygons indicate the area served by ozone monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

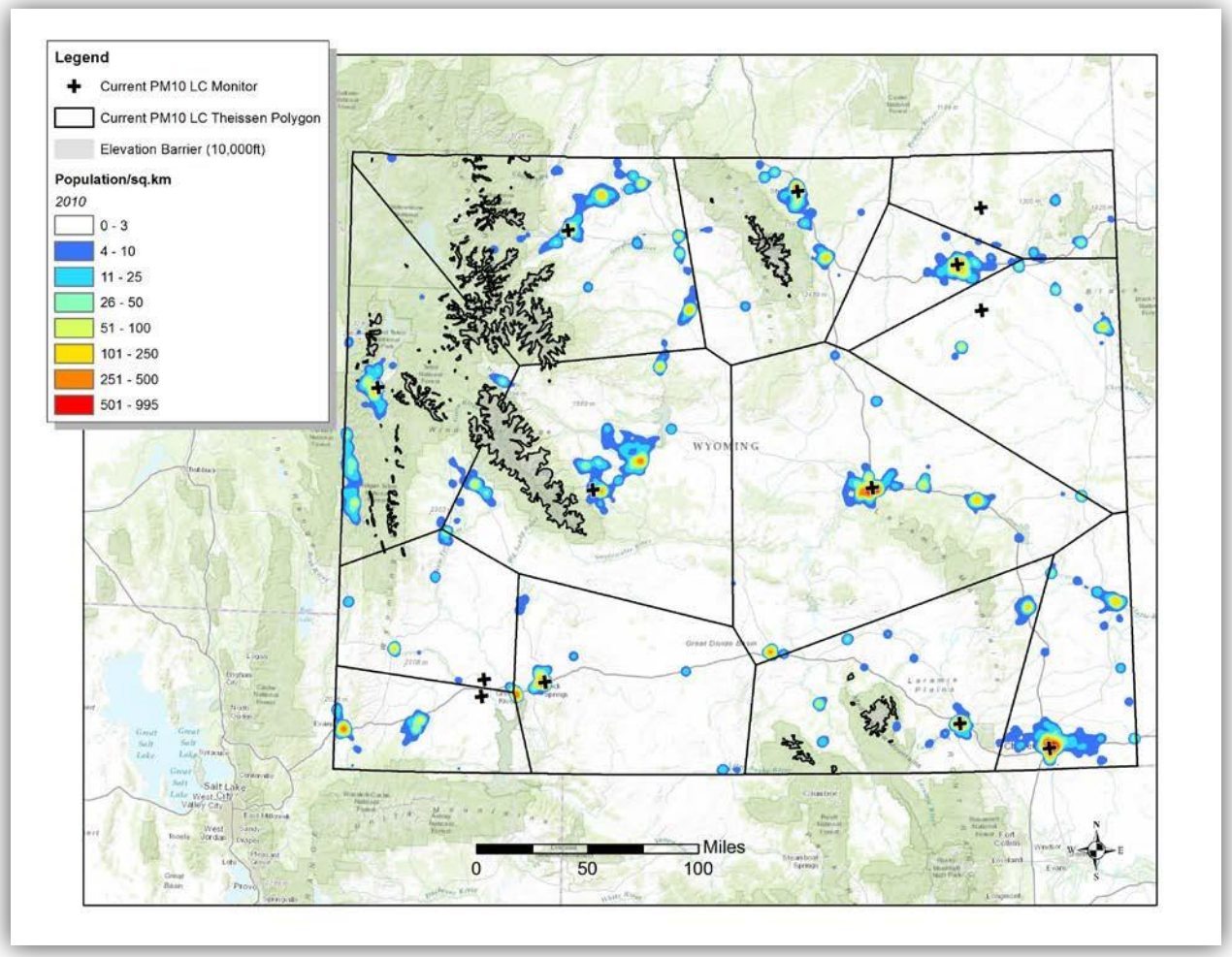

Figure 38. Population-served map for the current PM_{10} Local Conditions monitoring network. Thiessen polygons indicate the area served by PM_{10} monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

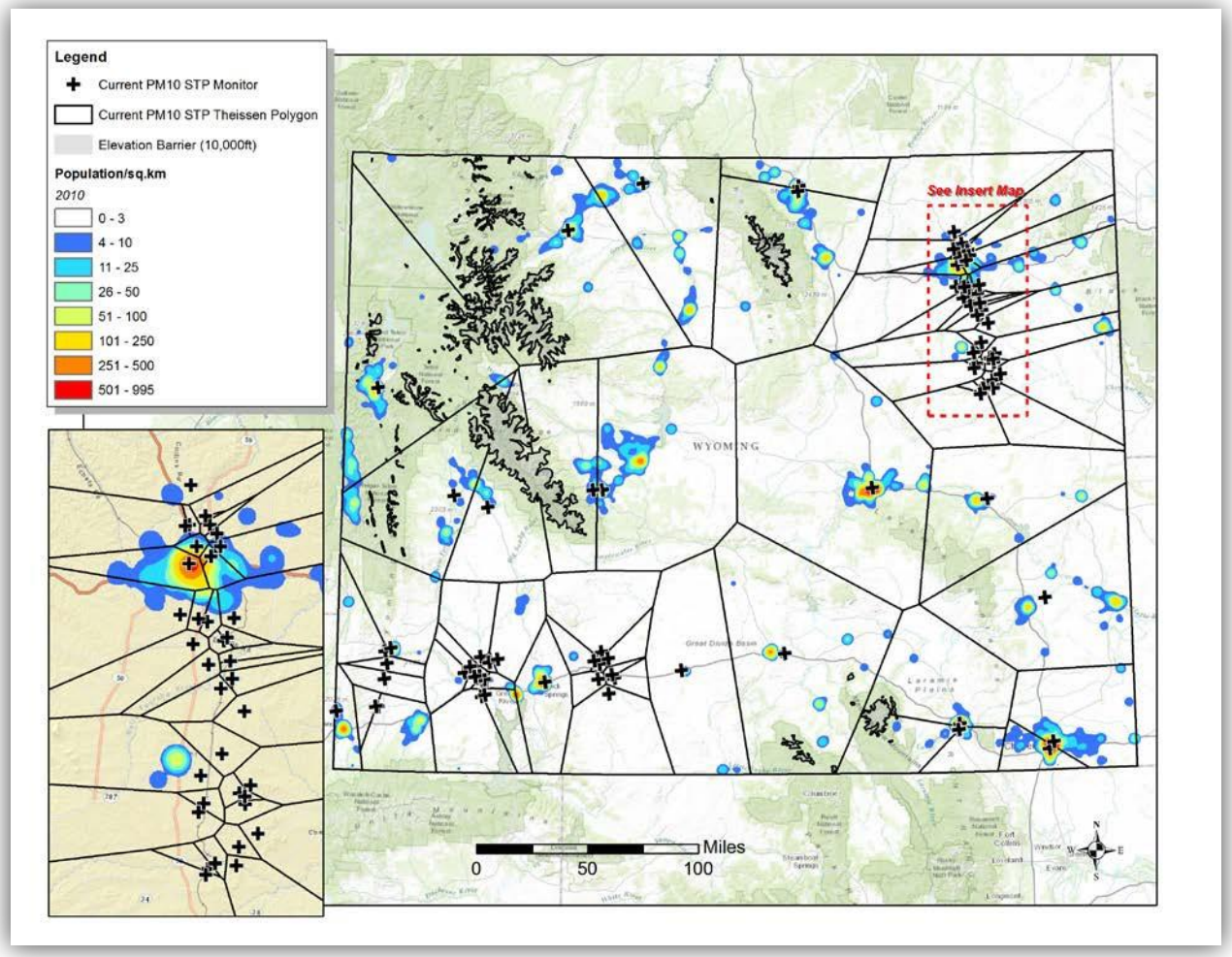

Figure 39. Population-served map for the current PM_{10} STP monitoring network. Thiessen polygons indicate the area served by PM_{10} monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

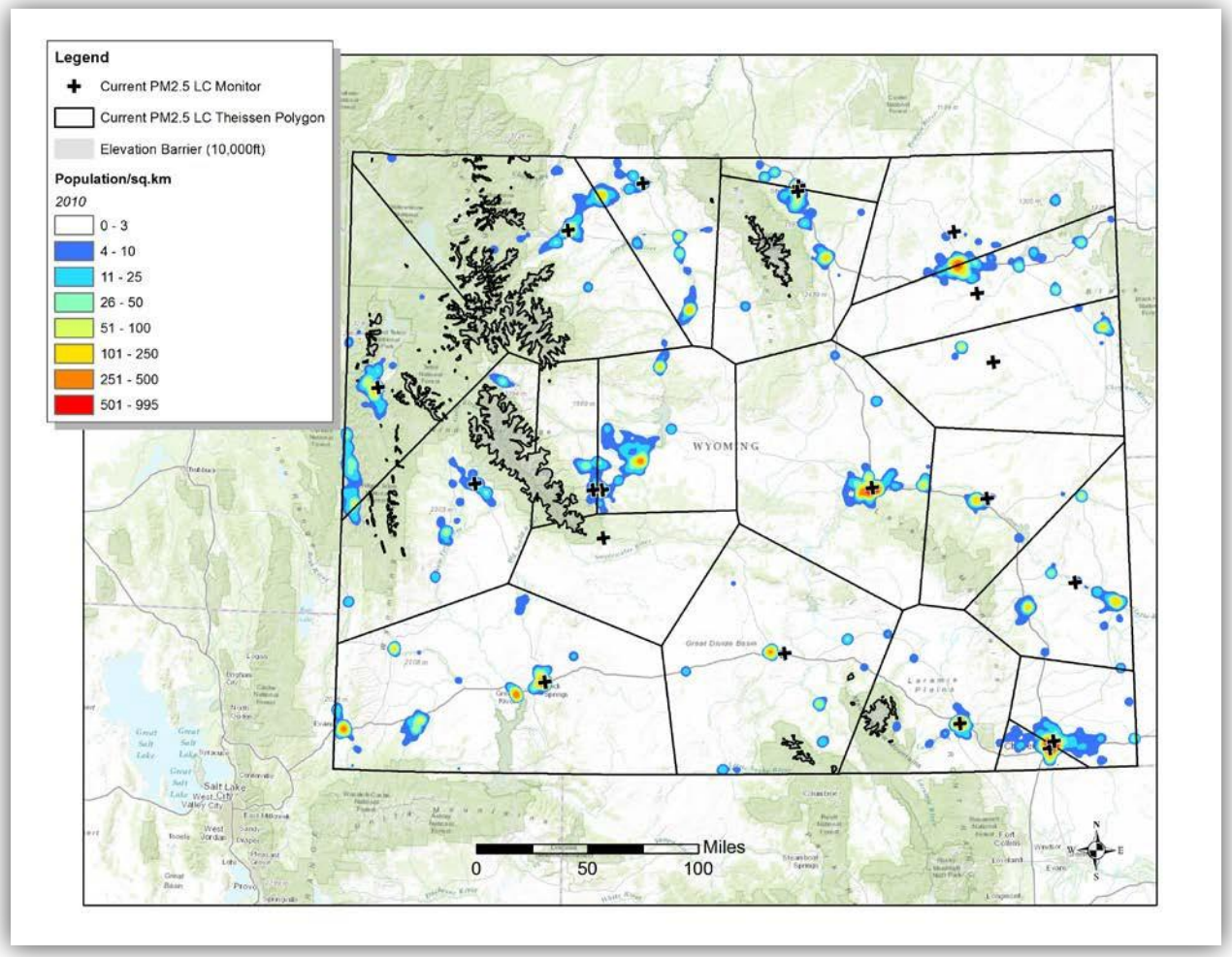

Figure 40. Population-served map for the current $PM_{2.5}$ Local Conditions monitoring network. Thiessen polygons indicate the area served by $PM_{2.5}$ monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

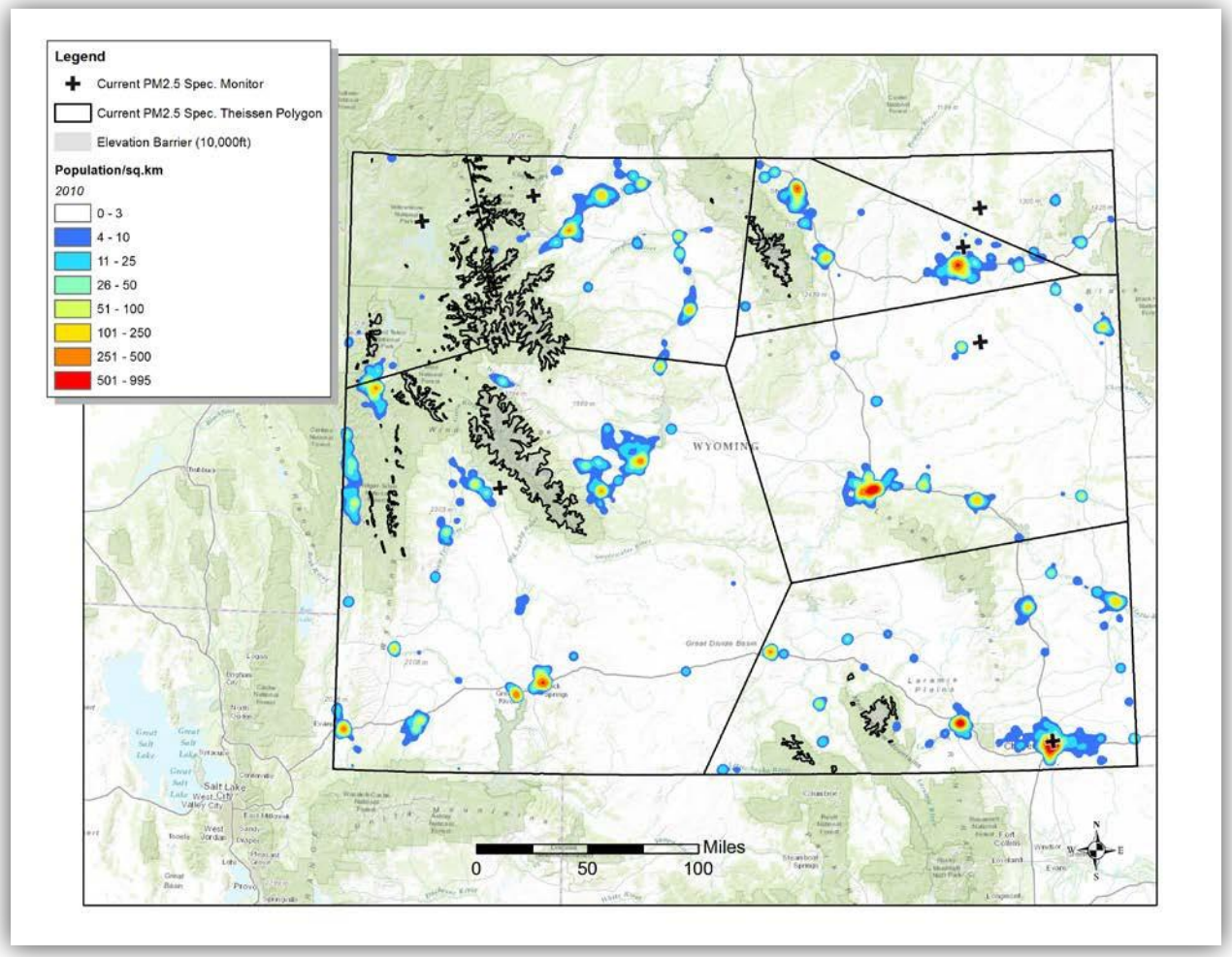

Figure 41. Population-served map for the current speciated $PM_{2.5}$ monitoring network. Thiessen polygons indicate the area served by $PM_{2.5}$ monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

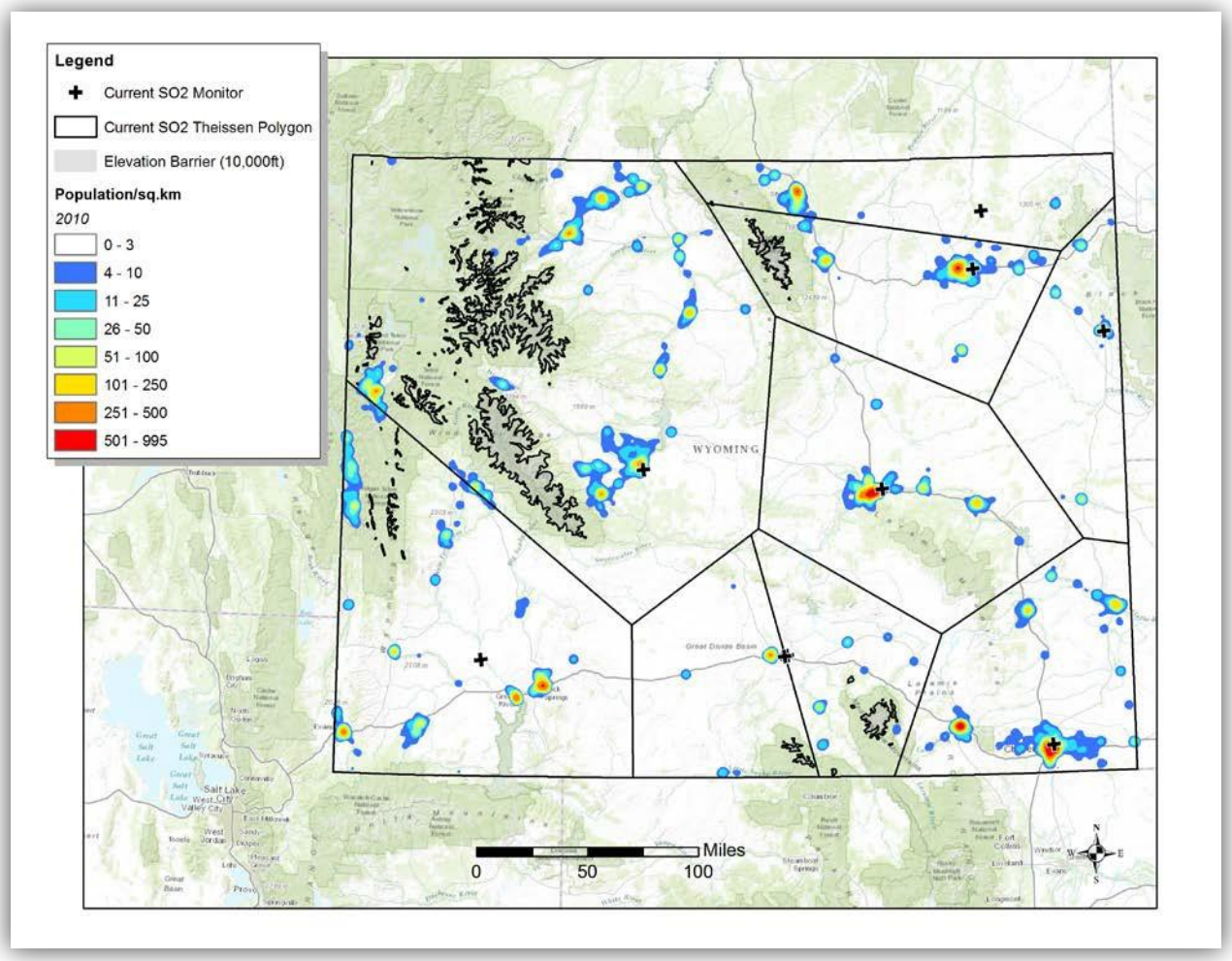

Figure 42. Population-served map for the current SO_2 monitoring network. Thiessen polygons indicate the area served by SO_2 monitors. Population density is the underlying base layer, and a black plus sign indicates monitoring locations.

In addition to an analysis of 2010 total population, a population change analysis was performed to examine where population growth has occurred over the past several years. To perform the population-change analysis, spatially resolved population data at the block-group level were acquired from the U.S. Census Bureau for 2000 and 2010. Census Block group polygons were mapped within a GIS, and the change in population from 2000 to 2010 values was calculated. The population change values were then imposed on the Thiessen polygons, and population change maps were created (Figure 34, bottom right). Unlike block point locations for 2010 total population, population change data within each block group polygon were summarized by the percentage of area falling inside each Thiessen polygon. Population change attribution was based on that area percentage. Table 9 shows the monitoring locations active during 2009–2013 that showed the highest Thiessen polygon-based population change. Population change values listed in the table represent the total change (or growth) in population from 2000 to 2010. (The CO and speciated $PM_{2.5}$

networks were excluded from the table due to limited number of monitoring sites). As with the current total population, the largest population change in both the SO_2 and NO_2 networks was at the NCore site in Cheyenne. Figures 43 through 50 depict current site location population change Thiessen polygon maps. The complete list of maps can be found in the *Task D Data Deliverable* file.

Table 9. Top 5% of Thiessen polygon 2000–2010 population change within the monitoring locations active during 2009–2013.

Site Code	Parameter	Site Info	2000-2010 Population Change
560210100	NO_2	NCore - North Cheyenne Soccer Complex	15,091
560210100	SO_2	NCore - North Cheyenne Soccer Complex	14,981
560350002	SO_2	Pinedale, WARMS station	14,165
560050857	SO_2	WYODAK SITE 4	11,599
560050800	NO_2	Gillette Mobile	11,325
560210100	O_3	NCore - North Cheyenne Soccer Complex	11,035
560252601	SO_2	Sinclair, Casper	10,708
560210001	PM_{10} LC	Cheyenne-State Office Bldg 23rd & Central Avenue	10,504
560050800	$PM_{2.5}$ LC	Gillette Mobile	10,012
560250001	PM_{10} LC	Casper -City County Bldg Center and C Streets	9,935
560250001	$PM_{2.5}$ LC	Casper -City County Bldg Center and C Streets	9,329
560250001	PM_{10} STP	Casper -City County Bldg Center and C Streets	9,320
560210100	$PM_{2.5}$ LC	NCore - North Cheyenne Soccer Complex	8,641
560210100	PM_{10} STP	NCore - North Cheyenne Soccer Complex	7,899
560350097	NO_2	Wyoming Range/West Fontenelle Dr.	7,039

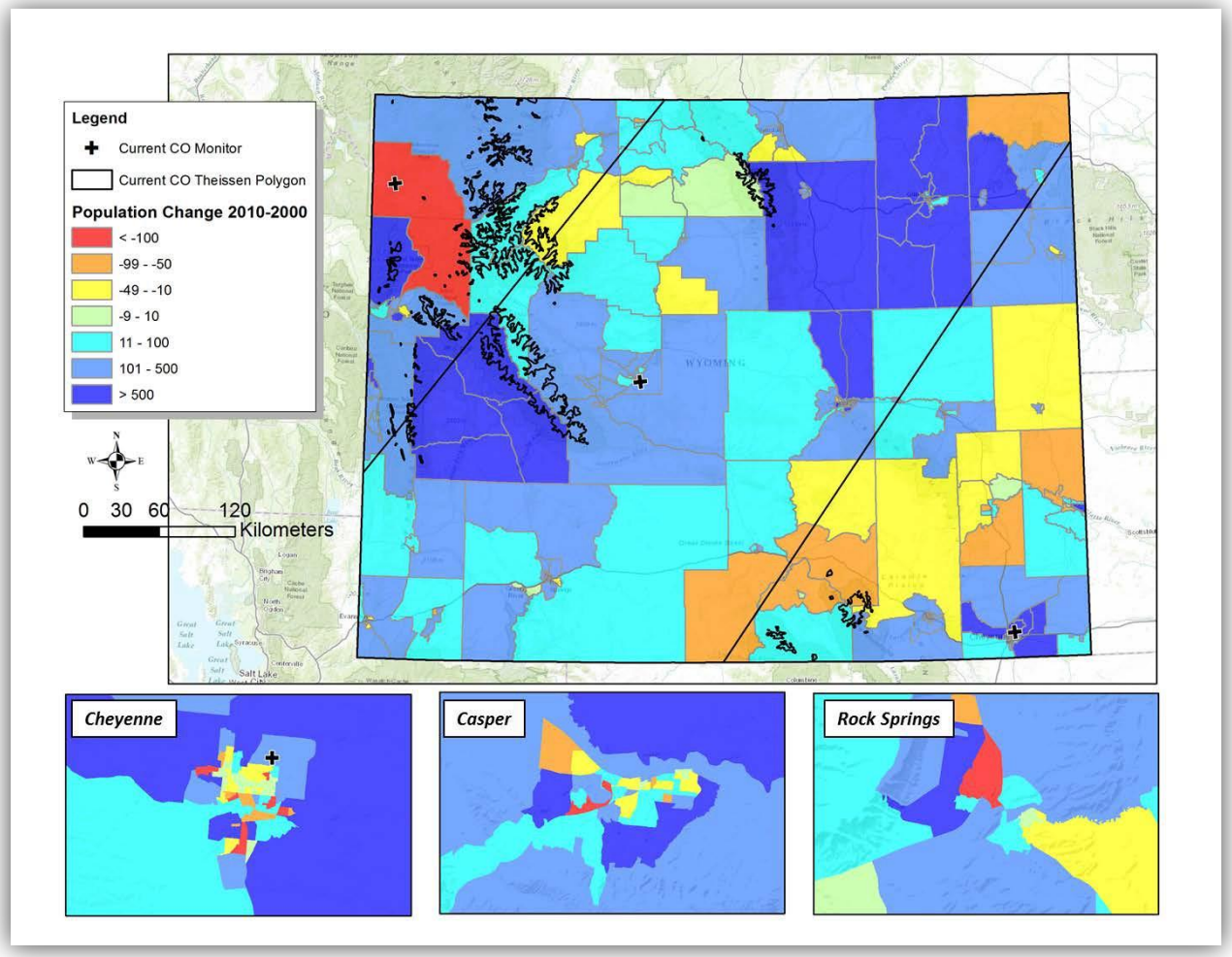

Figure 43. Population change map for the current CO monitoring network. Thiessen polygons indicate the area served by CO monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

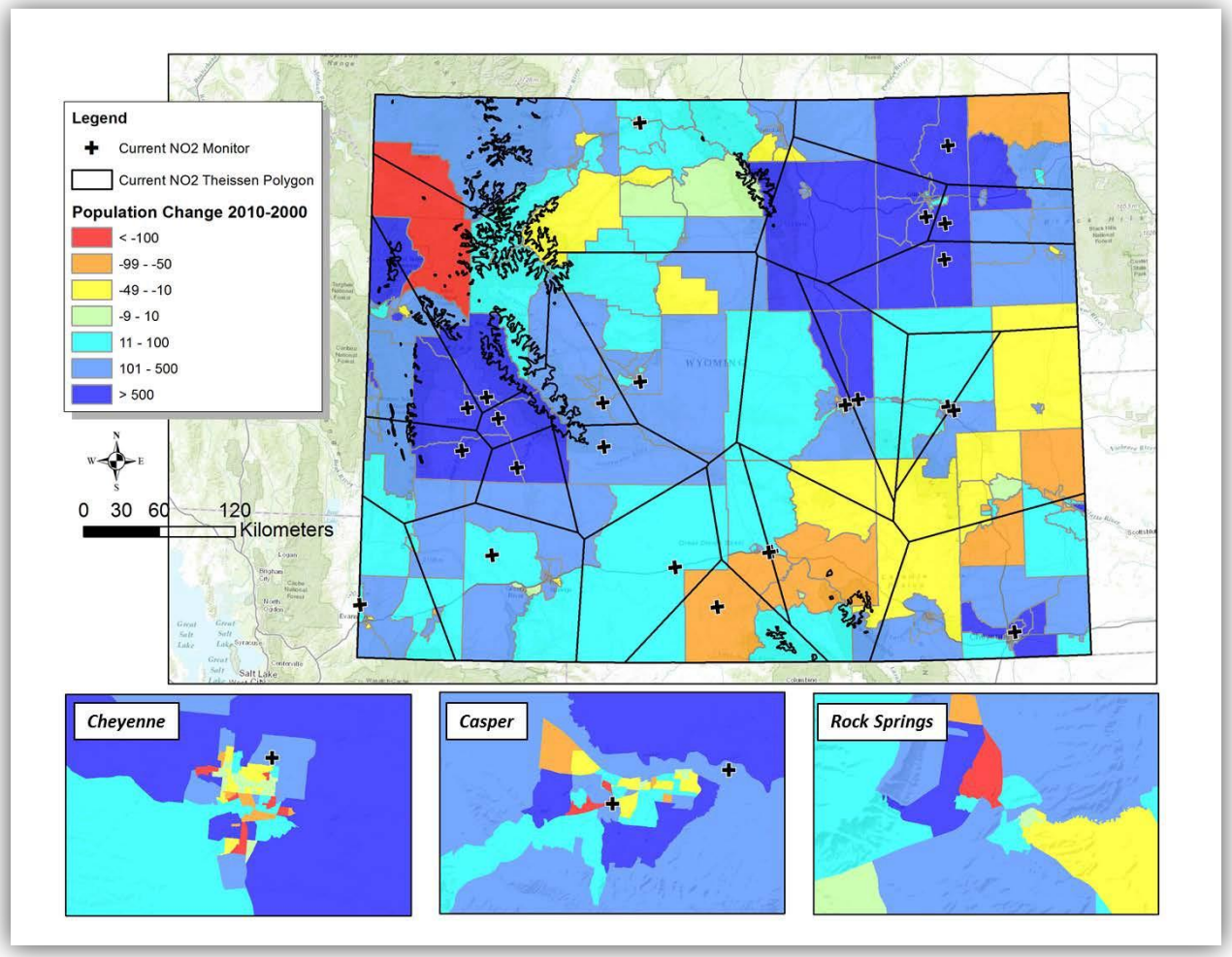

Figure 44. Population change map for the current NO_2 monitoring network. Thiessen polygons indicate the area served by NO_2 monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

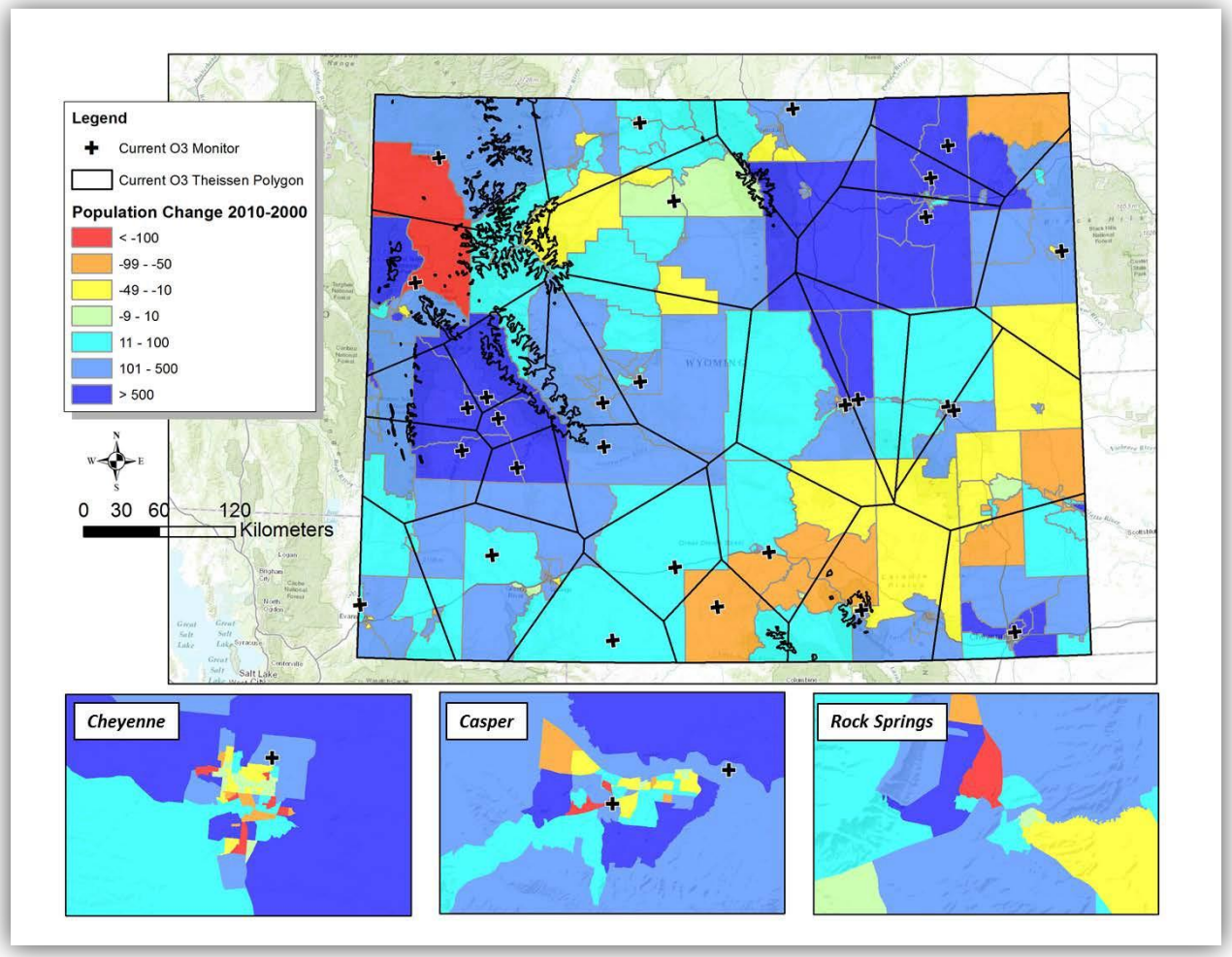

Figure 45. Population change map for the current ozone monitoring network. Thiessen polygons indicate the area served by ozone monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

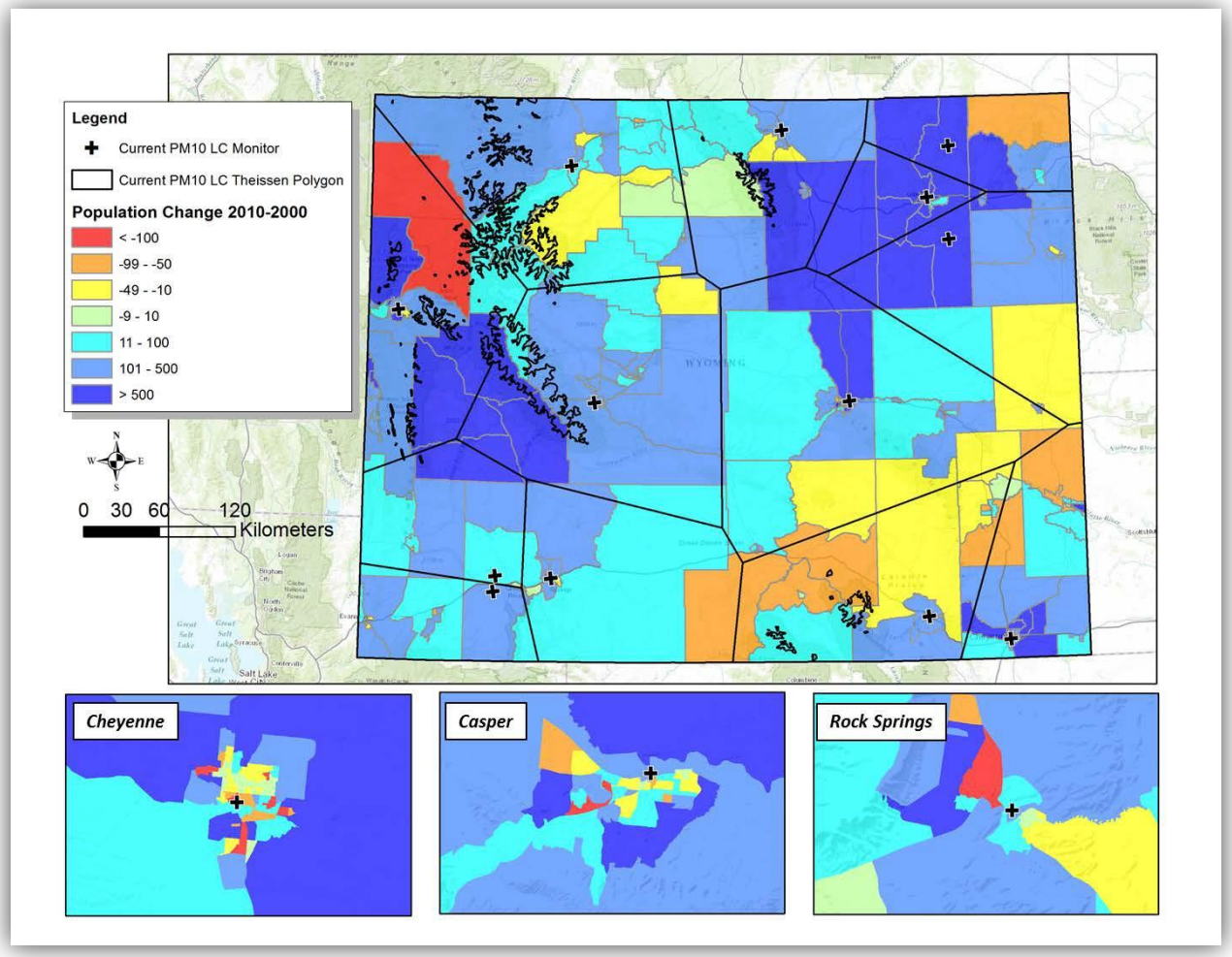

Figure 46. Population change map for the current PM_{10} Local Conditions monitoring network. Thiessen polygons indicate the area served by PM_{10} monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

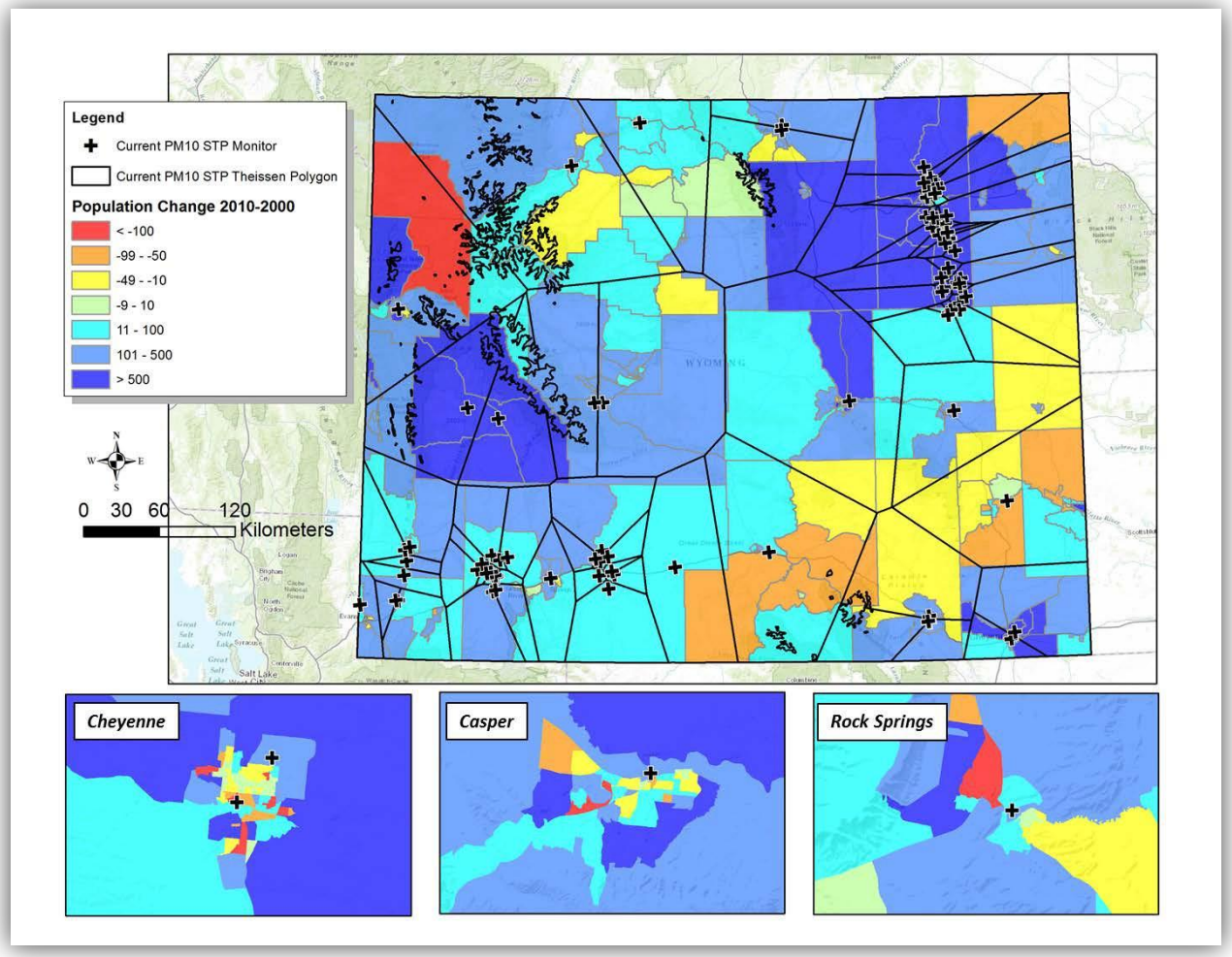

Figure 47. Population change map for the current PM_{10} STP monitoring network. Thiessen polygons indicate the area served by PM_{10} monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

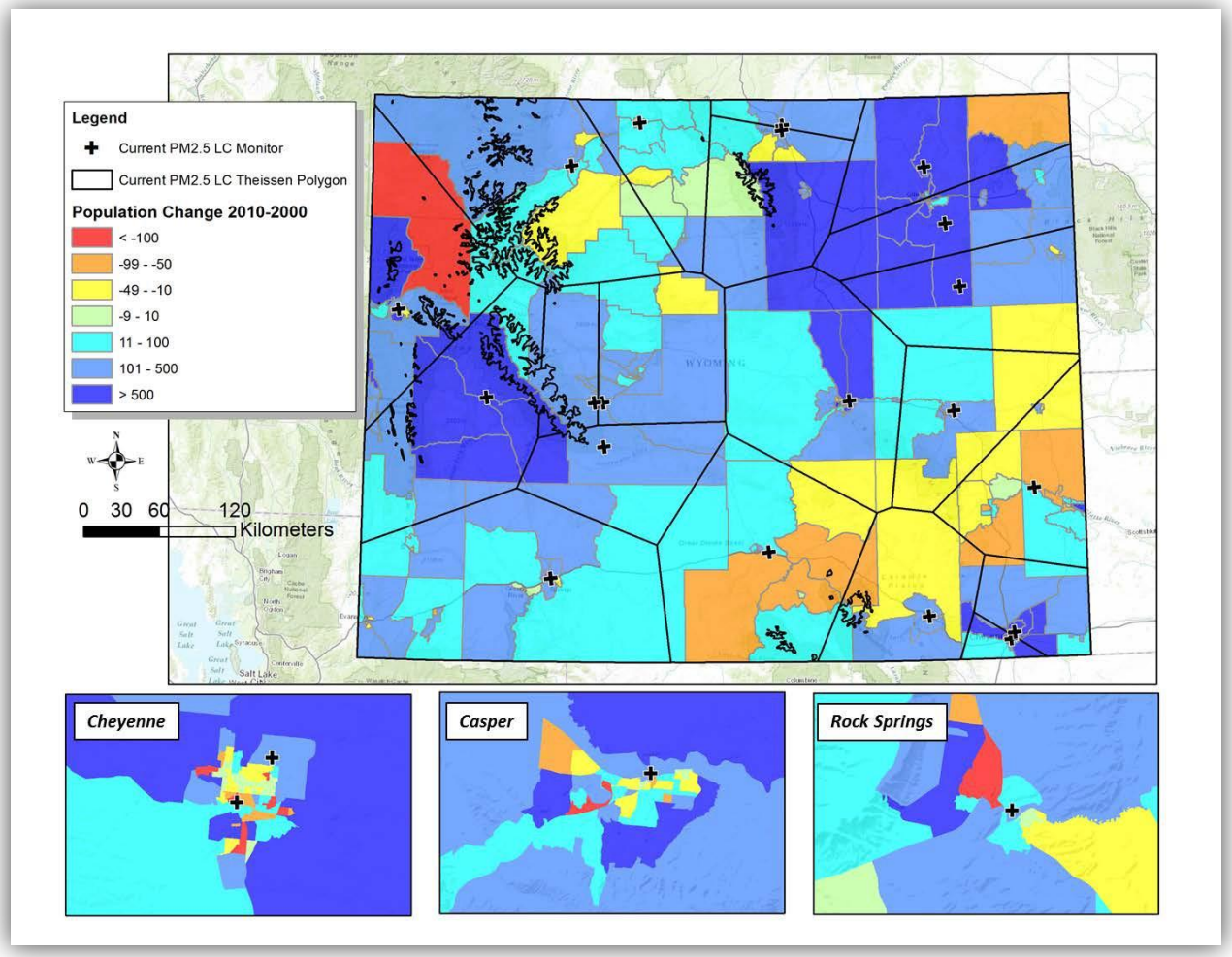

Figure 48. Population change map for the current $PM_{2.5}$ Local Conditions monitoring network. Thiessen polygons indicate the area served by $PM_{2.5}$ monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

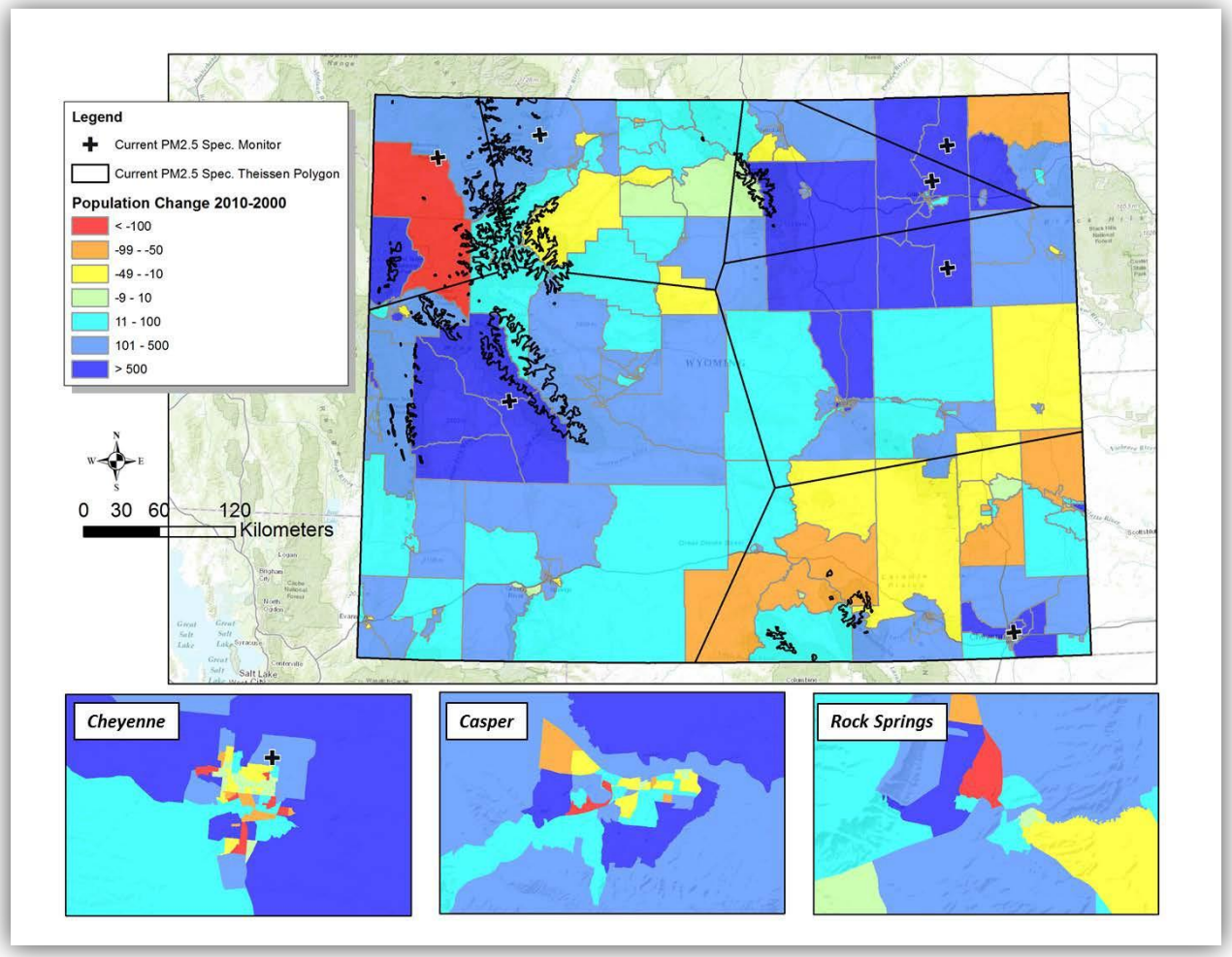

Figure 49. Population change map for the current Speciated $PM_{2.5}$ monitoring network. Thiessen polygons indicate the area served by $PM_{2.5}$ monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

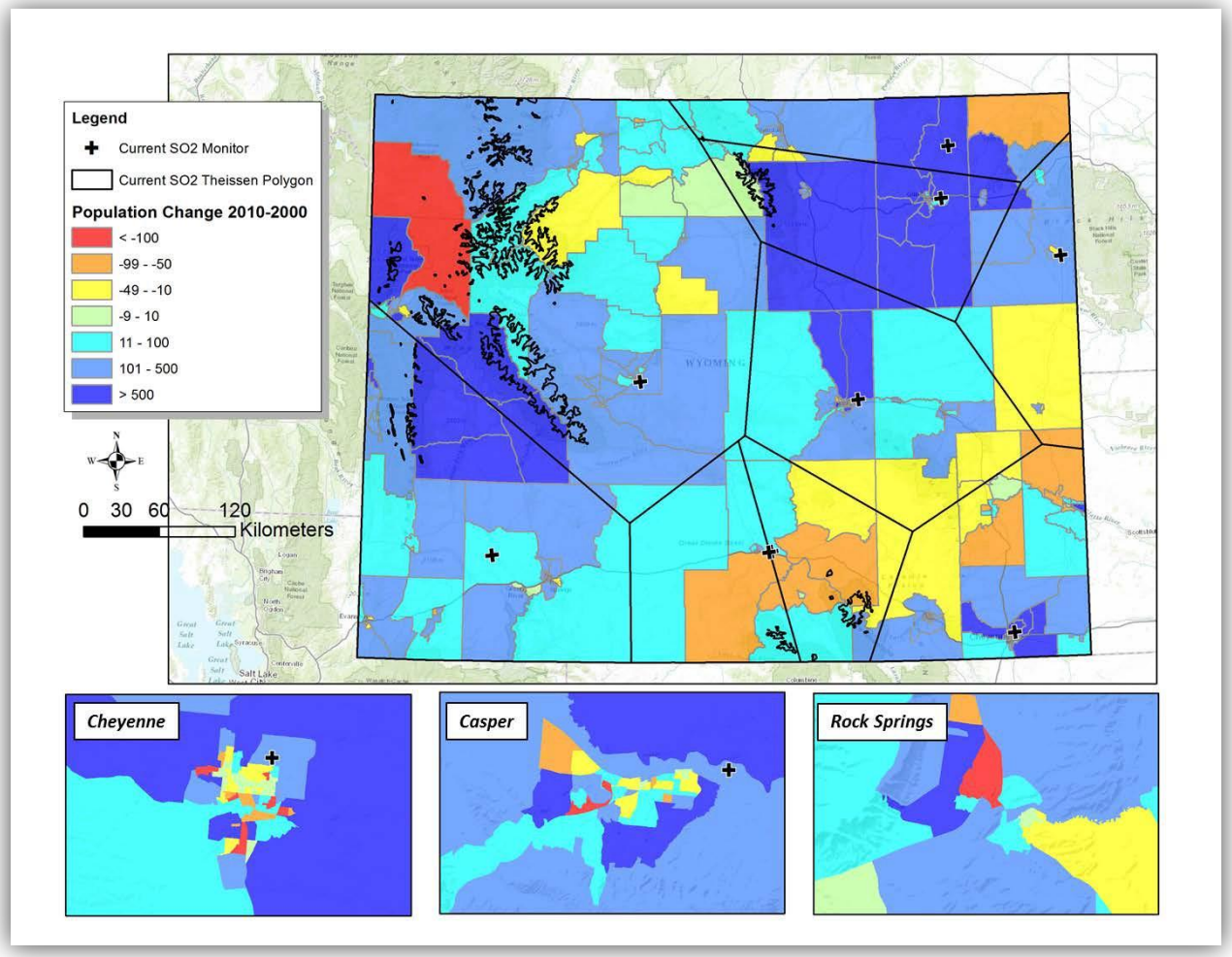

Figure 50. Population change map for the current SO_2 monitoring network. Thiessen polygons indicate the area served by SO_2 monitors. Block-group polygons depicting population change are the underlying base layer, and a black plus sign indicates monitoring locations.

Task E: Additional Analyses

To further support the assessment of AQD's criteria pollutant monitoring network, STI conducted an additional list of analyses. The following analyses were determined by AQD staff and are described in this section:

- Add an additional site to the NO_2 network and provide additional statistical plots.
- Expand the statistical analysis time period for the Murphy Ridge NO_2 and ozone monitors.
- Provide more in-depth statistics for the NCore Cheyenne NO_2, Boulder ozone, and Hiawatha ozone.
- Develop a series of regional site comparisons plots for ozone.
- Develop a comprehensive statistical plot for all Sheridan PM data.

- Develop a map that depicts 2012 wildfire locations throughout Wyoming. To coincide with the wildfire map, STI developed a statistical plot for all $PM_{2.5}$ monitors for 2012.

NO_2 Statistical Analysis

In this analysis, STI collected and processed NO_2 data from the Black Thunder Mine industrial monitoring site. The data were then combined with other site-specific NO_2 within the database. Trends in NO_2 were then provided in the form of notched box-whisker plots. With SYSTAT software, a notched box-whisker plot was developed for a subset of monitoring sites. Sites included Belle Ayr BA-4, Antelope Site 3, Black Thunder Mine, and Thunder Basin. The entire distribution is shown, and statistically significant differences in median concentrations can be observed between monitoring sites. Figure 51 shows the resultant NO_2 notched box-whisker plot for the selected sites. Additional data files related to the Black Thunder Mine industrial monitoring site can be found in the *Task A Add-on Data Deliverable* file.

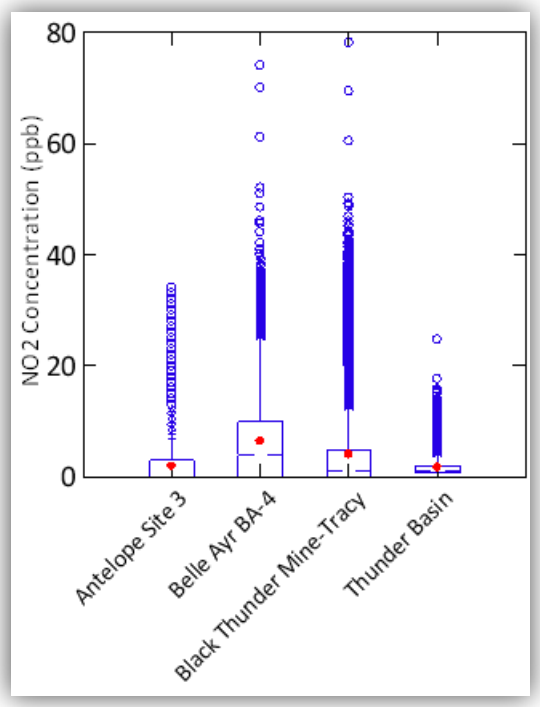

Figure 51. NO_2 notched box-whisker plot for a subset of monitoring sites.

Murphy Ridge Statistical Analysis

The goal of this analysis was to get a better understanding of ozone and NO_2 trends at the Murphy Ridge monitoring site. STI collected and processed ozone and NO_2 data for 2007 and 2008 for the Murphy Ridge monitoring site. The data were then joined with 2009–2013 data already collected and processed. Trends were then provided in the form of notched box-whisker plots for 2007 to 2013.

Figures 52 and 53 show the resultant notched box-whisker plots for the selected sites. Additional data files related to the Murphy Ridge monitoring site can be found in the *Task A Add-on Data Deliverable* file.

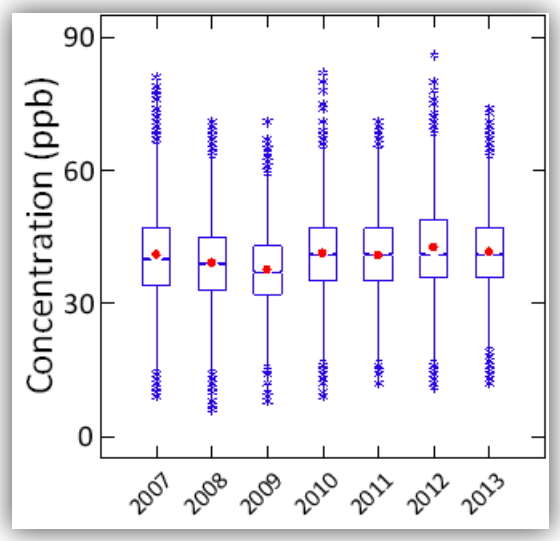

Figure 52. Murphy Ridge notched box-whisker plot for 2007 through 2013 ozone data.

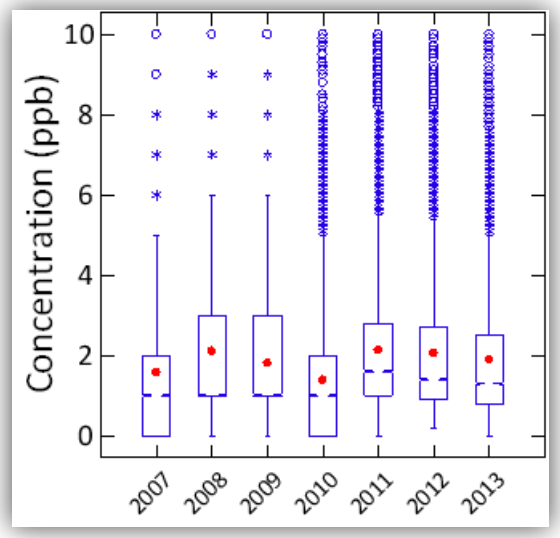

Figure 53. Murphy Ridge notched box-whisker plot for 2007 through 2013 NO_2 data.

In-Depth Statistical Analysis

Hourly data for the NCore Cheyenne (NO_2), Boulder (O_3), and Hiawatha (O_3) sites were pulled from AQS. Data that were reported as negative values were substituted as zeroes. STI then generated cumulative distribution functions using the SYSTAT software by year to demonstrate how the distribution of concentrations has changed over time at each of the sites. When cumulative distribution functions shift to the left, the concentrations are declining. Conversely, when the cumulative distribution function shifts to the right, the concentration is increasing.

Figures 54 through 56 show the cumulative distribution function plot for each site. The x-axis shows the concentration of interest, while the y-axis shows the fractional ranking of each measurement from a given year (i.e., 0 to 1 represent the lowest and highest observed samples for a given year; all other sample concentrations fall between). Year-to-year differences in concentration distributions show up as curve shifts. These plots are very useful for identifying changes in any part of the distribution of concentrations, although they do not provide statistical significance.

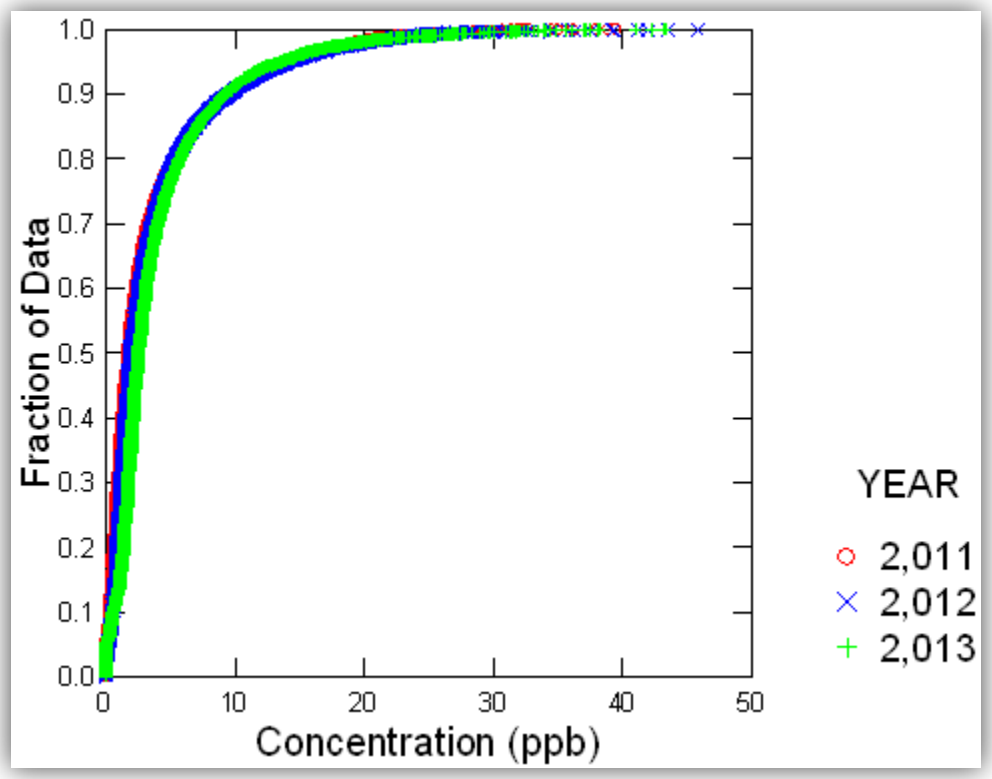

Figure 54. Trend in 1-hr average NO_2 concentrations (ppb) at the NCore Cheyenne monitoring site.

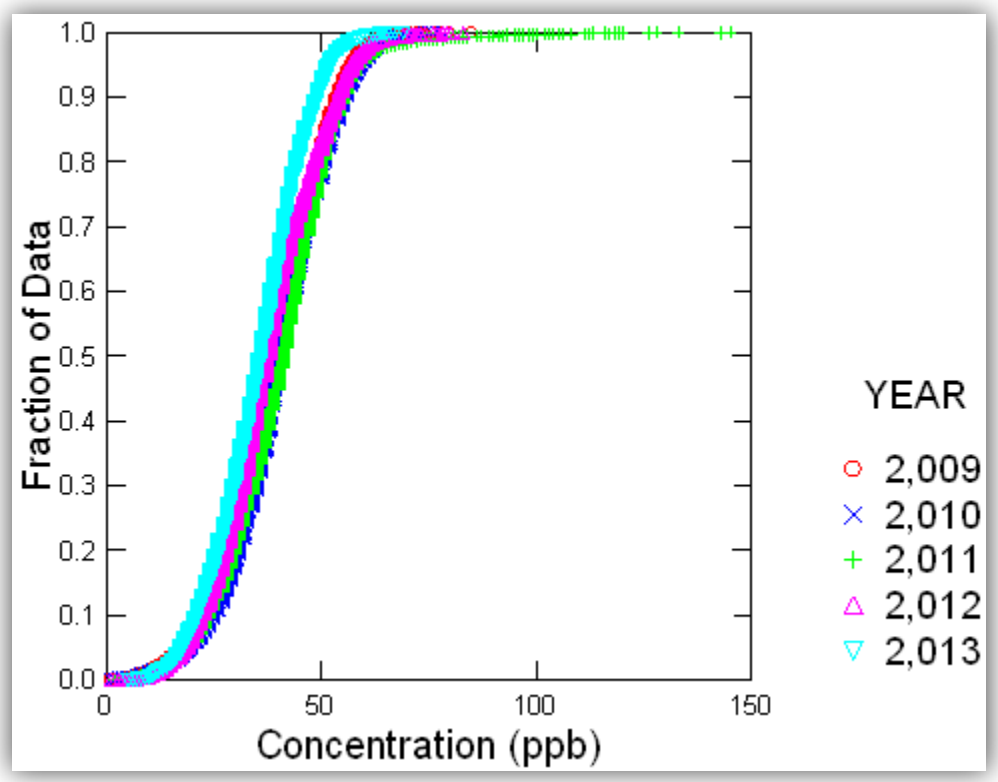

Figure 55. Trend in 1-hr average O_3 concentrations (ppb) at the Boulder monitoring site.

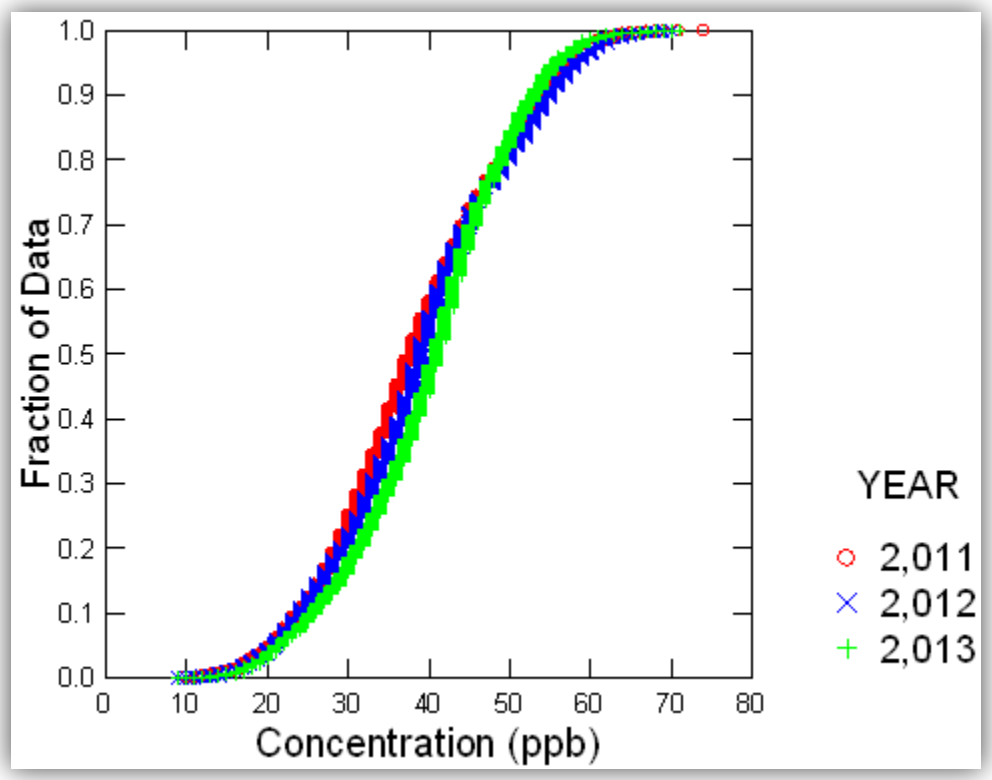

Figure 56. Trend in 1-hr average O_3 concentrations (ppb) at the Hiawatha monitoring site.

Hourly concentrations were then averaged by year at each site for each parameter of interest to generate an arithmetic mean. Mean concentrations were linearly regressed by year using ordinary least squares regression. The standard statistics for an analysis of variance (ANOVA) were used to determine whether the slopes of the three individual sites were statistically significant. The F-test is used to assess the slope significance. In other words, the F-test shows whether a slope is significantly different from a null result (i.e., no trend), which is expressed as a p-value. If the p-value is less than 0.05, than the trend is significantly different from zero at the 95% confidence level. Tables 10 through 12 show the statistical significance test for each site. Additional statistical results for each monitoring sites are listed in the *Task A Add-on Data Deliverable* file. It should also be noted that trends of statistical significance for a three- or five-year trend can be strongly influenced by year-to-year variations in meteorology. Controlling for meteorology or assessing the trend relative to other pollutants at the same site may help to assess how much of the trend may be a result of meteorological variation.

Table 10. NCore Cheyenne NO_2 statistical significance test. The increasing trend is not significant at the 95% confidence level.

Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-Value
CONSTANT	-508.207	88.865	0.000	.	-5.719	0.110
YEAR	0.254	0.044	0.985	1.000	5.762	0.109

Table 11. Boulder ozone statistical significance test. The declining trend is not significant at the 95% confidence level.

Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-Value
CONSTANT	1,976.107	1,170.914	0.000	.	1.688	0.190
YEAR	-0.964	0.582	-0.691	1.000	-1.655	0.197

Table 12. Hiawatha ozone statistical significance test. The increasing trend is significant at a 98% confidence level.

Regression Coefficients B = (X'X)-1X'Y						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-Value
CONSTANT	-1,433.502	37.172	0.000	.	-38.564	0.017
YEAR	0.732	0.018	1.000	1.000	39.621	0.016

Regional Statistical Analysis

Similar to the NO_2 statistical analysis described above, this analysis combined multiple site data into a collective trends plot. With SYSTAT software, a notched box-whisker plot was developed for ozone on subsets of monitoring sites for the 2009 to 2013 time period. The site subsets are as follows:

- Upper Green River Basin statistical plot; sites include Wyoming Range, Boulder, Daniel South, Pinedale Gaseous, Big Piney, Juel Springs, Pinedale CASTNET (9991)
- Powder River Basin subset statistical plot; sites include Thunder Basin, Campbell County, Gillette Mobile, Converse County Mobile, Casper Gaseous

- Sweetwater subset statistical plot; sites include Hiawatha, Rock Springs Mobile, Wamsutter, Moxa
- Background subset statistical plot; sites include Thunder Basin, South Pass, Wyoming Range, Daniel South, Murphy Ridge

Figures 57 through 60 show the resultant notched box-whisker plots for the regional site groups.

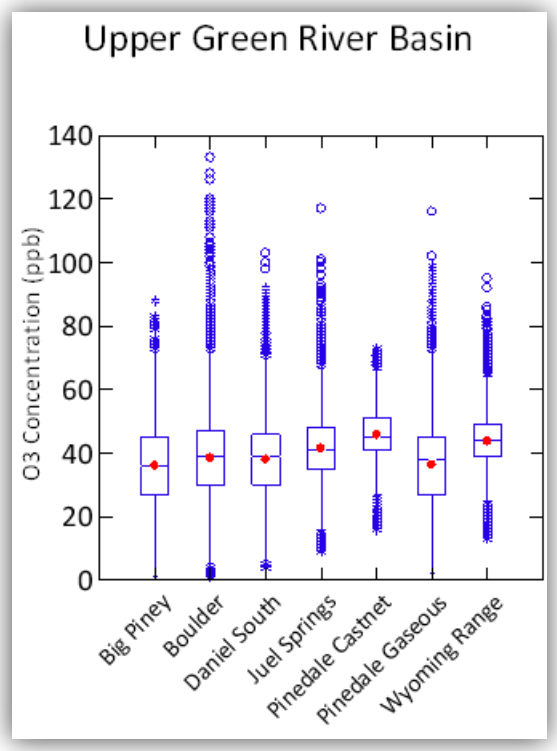

Figure 57. Ozone notched box-whisker plot for the Upper Green River Basin site grouping.

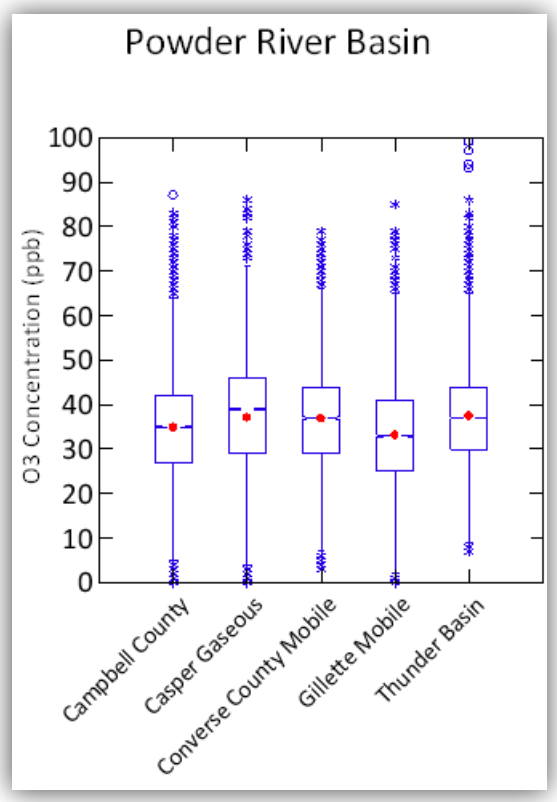

Figure 58. Ozone notched box-whisker plot for the Powder River Basin site grouping.

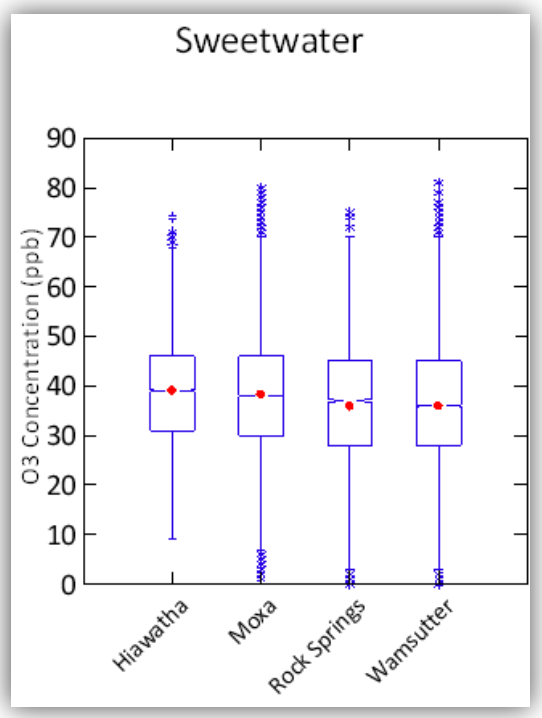

Figure 59. Ozone notched box-whisker plot for the Sweetwater regional site grouping.

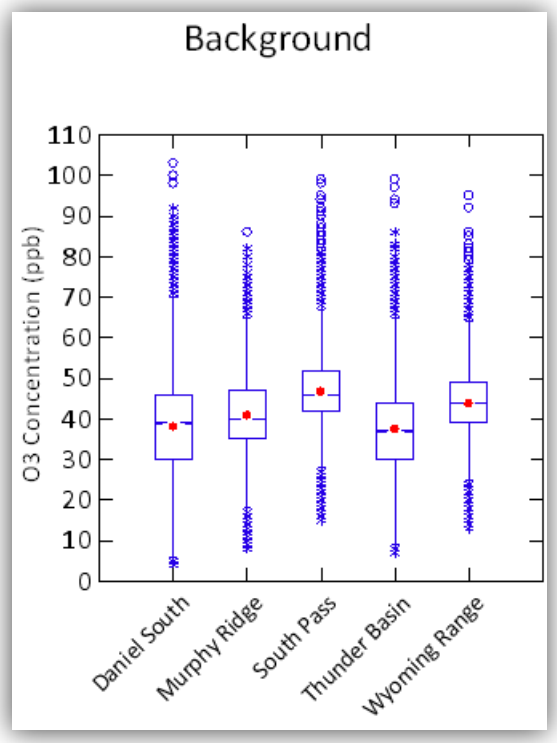

Figure 60. Ozone notched box-whisker plot for the Background site grouping.

Sheridan PM Statistical Analysis

Similar to the NO_2 statistical analysis and regional ozone statistical analysis described above, this analysis combined multiple site data within the Sheridan area into a collective trends plot. With SYSTAT software, a notched box-whisker plot was developed for PM_{10} and $PM_{2.5}$ on subsets of monitoring sites for the 2009 to 2013 time period. The sites included in this analysis include (1) 560330002, Police Station, (2) 560330003, Highland Park, and (3) 560331003, Meadowlark Elementary School. Figure 61 shows the output statistical plot for PM_{10} and $PM_{2.5}$ for these sites.

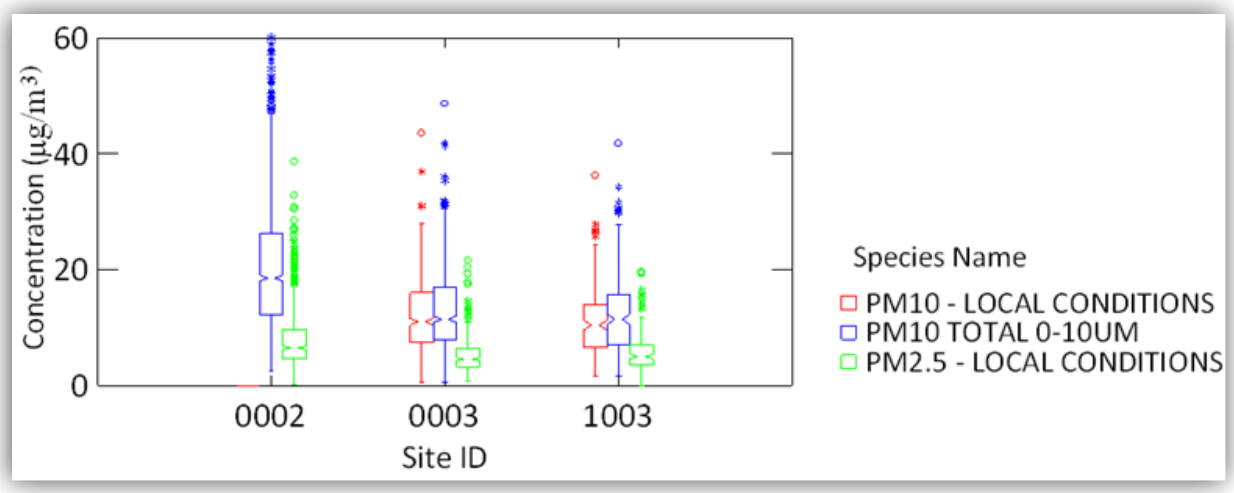

Figure 61. PM_{10} and $PM_{2.5}$ notched box-whisker plot for the Sheridan site grouping.

2012 Wildfire Analysis

In 2012, there were several wildfires throughout Wyoming and the surrounding region. AQD instructed STI to develop a map of the wildfire locations as well as a $PM_{2.5}$ notched box-whisker plot for 2012. The resultant information provides AQD the necessary information on determining potential impacts the wildfires had on the 2012 $PM_{2.5}$ concentrations across the state. Figure 62 depicts the 2012 wildfire locations, along with the $PM_{2.5}$ monitor locations and population density. Wildfire location symbols are sized by the total acres burned, showing the relative impact each fire had on the landscape. Figures 63 and 64 shows the $PM_{2.5}$ concentrations for each site in 2012. As for plots described in previous sections, SYSTAT software was used to generate the notched box-whisker plots.

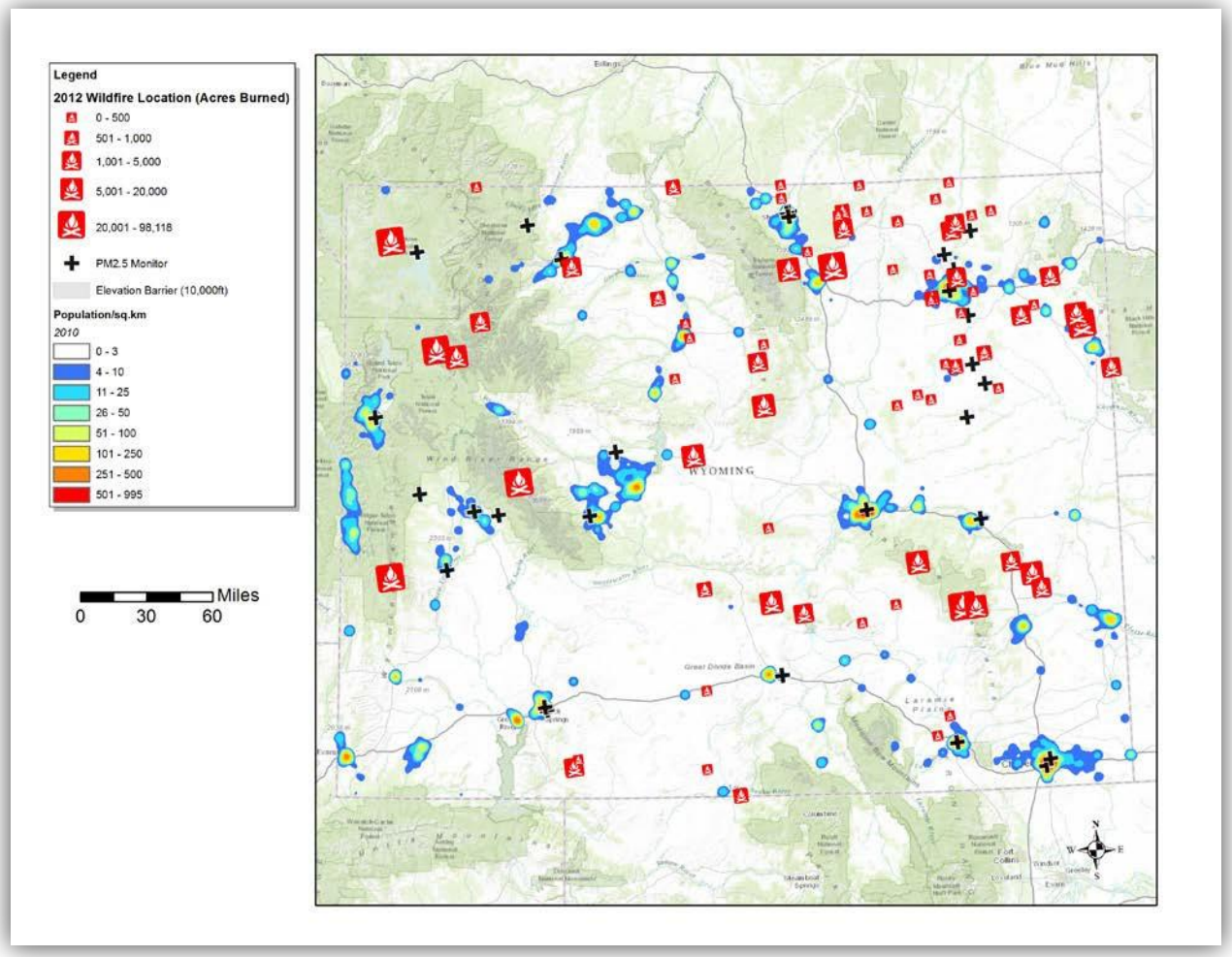

Figure 62. Map of the 2012 wildfire locations within the state of Wyoming. Wildfire symbols are sized by total acres burned. Also shown are $PM_{2.5}$ monitoring locations (black plus signs) and population density (blue to red color scheme).

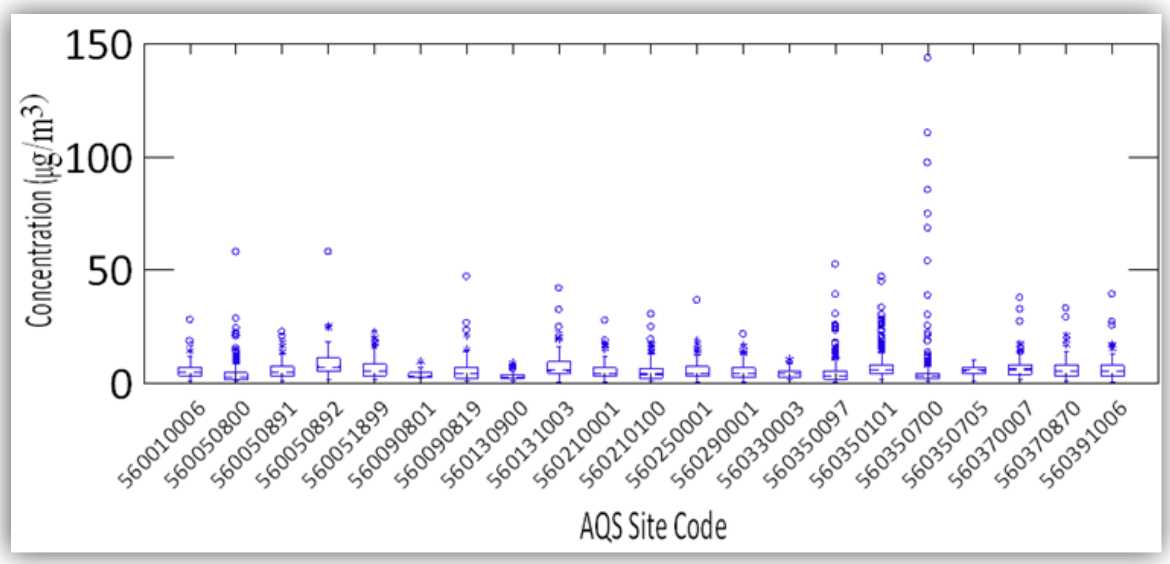

Figure 63. Notched box-whisker plot showing 2012 $PM_{2.5}$ concentrations at monitoring sites across the state of Wyoming.

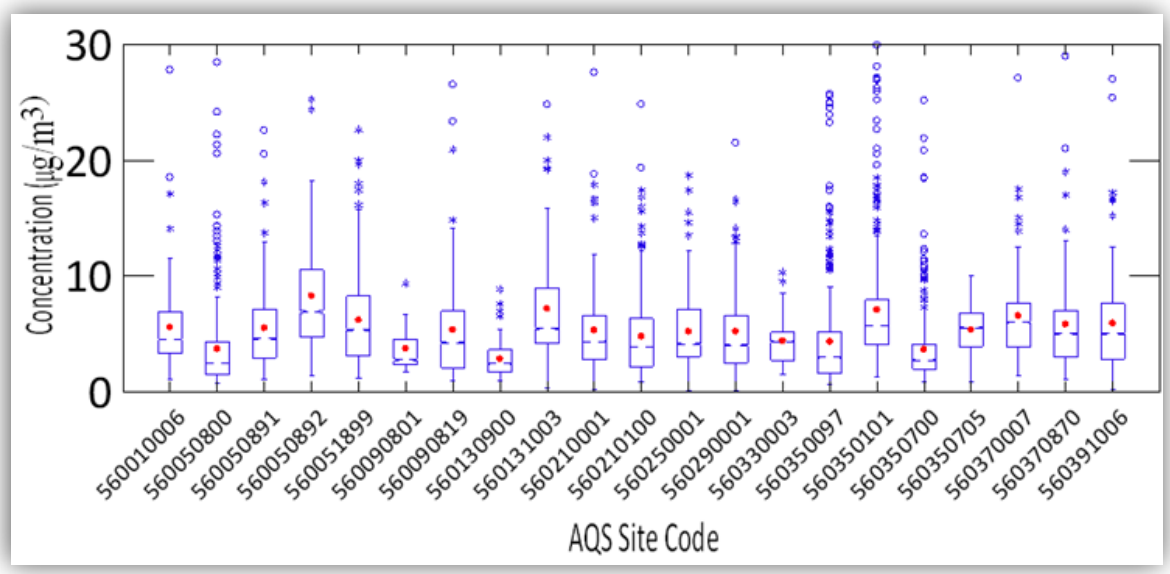

Figure 64. A zoomed-in view of Figure 63, showing 2012 $PM_{2.5}$ concentrations at monitoring sites across the state of Wyoming.

Reference

Pollard E.K. and Reid S.B. (2010) Wyoming statewide air monitoring network assessment Task D: emissions estimate. Technical memorandum prepared for the Wyoming Department of Environmental Quality, Cheyenne, WY, by Sonoma Technology, Inc., Petaluma, CA, STI-910019-3891, Sept. 10.