Wisconsin Department of Natural Resources

Wisconsin Air Quality Trends

2001-2016

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Acronyms and Abbreviations

TABLE 1. Acronyms and abbreviations used in this report

Term	Definition
AQI	Air Quality Index
BAM	Beta attenuation monitor
CO	Carbon monoxide
DRR	Data Requirements Rule for SO_2
DV	Design value
EPA	U.S. Environmental Protection Agency
hr	Hour
mo	Month
NAAQS	National Ambient Air Quality Standards
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides; NO + NO_2
$PM_{2.5}$	Fine particles (particles 2.5 micrometers or smaller in size)
PM_{10}	Inhalable particles (particles 10 micrometers or smaller in size)
ppb	Parts per billion
ppm	Parts per million
SO_2	Sulfur dioxide
TSP	Total suspended particles
$\mu g/m^3$	Microgram per cubic meter
µm	Micrometer
WDNR	Wisconsin Department of Natural Resources
yr	Year

Report Summary

Wisconsin Department of Natural Resources (WDNR) monitors ambient concentrations of several pollutants throughout the state including ozone, particle pollution, sulfur dioxide, nitrogen dioxide, lead, carbon monoxide, and toxic compounds. With the exception of toxics, these comprise the set of principal pollutants, called criteria pollutants, which are regulated by the U.S. Environmental Protection Agency (EPA). Monitored levels of criteria pollutants are compared against the National Ambient Air Quality Standards (NAAQS) set by EPA to determine whether the standards are met.

This report presents trends in Wisconsin pollution monitoring data over the last 14 years (as data are available), though concentrations have been decreasing for decades. It addresses all six criteria pollutants regulated by EPA. The first section of the report provides an overview of the pollutants, their regulatory history, and historical attainment status in Wisconsin. The second section presents monitoring data[1] compared to the relevant NAAQS. For pollutants identified as regional in nature, namely ozone and fine particles ($PM_{2.5}$), monitoring data are grouped into broader regions to highlight geographic trends. County-level trends by pollutant are shown in Appendix A. Tables comparing design values between the first and last years of the 14-year period (or as data are available) are presented in Appendix B.

Overall, concentrations of most criteria pollutants have been decreasing over the past decade in all regions of the state. The overall decrease in pollutant concentrations is encouraging and is the result of cooperative regulatory control programs reducing emissions from vehicles and stationary sources in Wisconsin and surrounding states.

With few exceptions, most of the state is attaining all of the federal air quality standards. As of the date of this report, Sheboygan County and a portion of Kenosha County are designated as nonattainment for the 2008 ozone NAAQS. Also, a small area around the city of Rhinelander in Oneida County is designated as nonattainment for the sulfur dioxide standard. WDNR is committed to working with partners in Wisconsin and other states to improve air quality in those areas.

Annual differences in meteorological conditions can lead to variability in measured concentrations. For example, relative to the summers of 2013, 2014, and 2015, the summers of 2012 and 2016 were warmer and conditions were more conducive to ozone formation. While annual data are important to consider, long-term trends in air quality guide decisions about management of air quality issues at federal and state levels.

[1] Data presented are design values which were downloaded from EPA's Design Value webpage (https://www.epa.gov/air-trends/air-quality-design-values).

Background

Federal Regulatory History

The Clean Air Act requires EPA to set NAAQS for pollutants considered harmful to public health and the environment. The technical basis for the NAAQS is provided through the independent recommendations of the Clean Air Scientific Advisory Committee as well as EPA staff evaluation.

There are two types of standards – primary and secondary. Primary standards are those set at a level meant to protect human health, especially for people with respiratory conditions or particular sensitivity to pollutant exposure. Secondary standards are intended to prevent impaired visibility, structural damage, and vegetative/livestock injury. Discussion in this report will focus on comparison of Wisconsin air monitoring data with the primary standards.

The current National Ambient Air Quality Standards for the six criteria pollutants regulated by EPA are shown in Table 2 below. Note that a new ozone standard of 0.070 ppm went into effect on December 28, 2015; however, the 2008 NAAQS of 0.075 ppm also remains in effect until revoked by EPA. As a result, there are two ozone standards currently in effect.

TABLE 2. EPA criteria pollutants and National Ambient Air Quality Standards*

Pollutant		Primary / secondary	Averaging time**	Level	Definition**
Carbon monoxide		primary	8 hr	9 ppm	not to be exceeded more than once per year
			1 hr	35 ppm	
Lead		primary and secondary	3 mo	0.15 μg/m^3	maximum 3-mo mean over 3 yr
Nitrogen dioxide		primary	1 hr	100 ppb	annual 98th percentile value of daily maximum 1-hr concentrations, averaged over 3 yr
		primary and secondary	annual	53 ppb	annual mean
Ozone		primary and secondary	8 hr	0.070 ppm (2015 standard) 0.075 ppm (2008 standard)	annual fourth-highest daily maximum 8-hr concentration, averaged over 3 yr
Particulate matter	$PM_{2.5}$	primary	annual	12.0 μg/m^3	annual mean, averaged over 3 yr
		secondary	annual	15.0 μg/m^3	annual mean, averaged over 3 yr
		primary and secondary	24 hr	35 μg/m^3	annual 98th percentile value, averaged over 3 yr
	PM_{10}	primary and secondary	24 hr	150 μg/m^3	not to be exceeded more than once per year on average over 3 yr
Sulfur dioxide		primary	1 hr	75 ppb	annual 99th percentile value of daily maximum 1-hr concentrations, averaged over 3 yr
		secondary	3 hr	0.5 ppm	not to be exceeded more than once per year

* Based on https://www.epa.gov/criteria-air-pollutants/naaqs-table.
** hr = hour, mo = month, yr = year; 3-mo, 8-hr, and 3-hr averages are calculated as rolling averages; in contrast, annual averages are for the calendar year and 24-hr averages are for the calendar day (i.e., are not rolling)

Design Value Calculations

Design values are used to assess compliance with the NAAQS, and are based on data collected over long periods. Usually, design values are averages of annual values to ensure that typical pollutant concentrations are represented, rather than isolated spikes in concentrations. Design values are published annually on EPA's Air Quality Design Values webpage in late summer for data through the end of the previous year. The webpage can be found at: https://www.epa.gov/air-trends/air-quality-design-values.

The design values for criteria pollutants are calculated using methods specified for each standard, as shown in the "Averaging time" and "Definition" columns of Table 2. The following paragraphs explain how ozone and fine-particle design values are calculated.

Ozone

The metric used to determine compliance with the ozone NAAQS is the annual fourth-highest daily maximum eight-hour (8-hr) concentration, averaged over a period of three years (3 yr). Two ozone NAAQS are currently in effect, each with their own method of determining design values.

Under the 2008 ozone standard, individual days are first divided into twenty-four 8-hr periods. Midnight to 8 a.m., for example, would be the first period, while 11 p.m. to 7 a.m. the following day would be the last period. The average ozone concentration during each 8-hr period is calculated, and the highest of the 24 average values is determined for each calendar day (i.e., the maximum 8-hr value for the day). Figure 1 shows the highest 8-hr average value from each day at a monitoring site during an example ozone season. To obtain the design value, the fourth-highest daily maximum 8-hr value of the year is identified (circled value in Fig. 1) and then averaged with the fourth-highest values from the two previous consecutive years. For instance, a 2014-2016 ozone design value would be calculated by averaging the fourth-highest 8-hr maximum for 2016 with the fourth-highest values for 2014 and 2015.

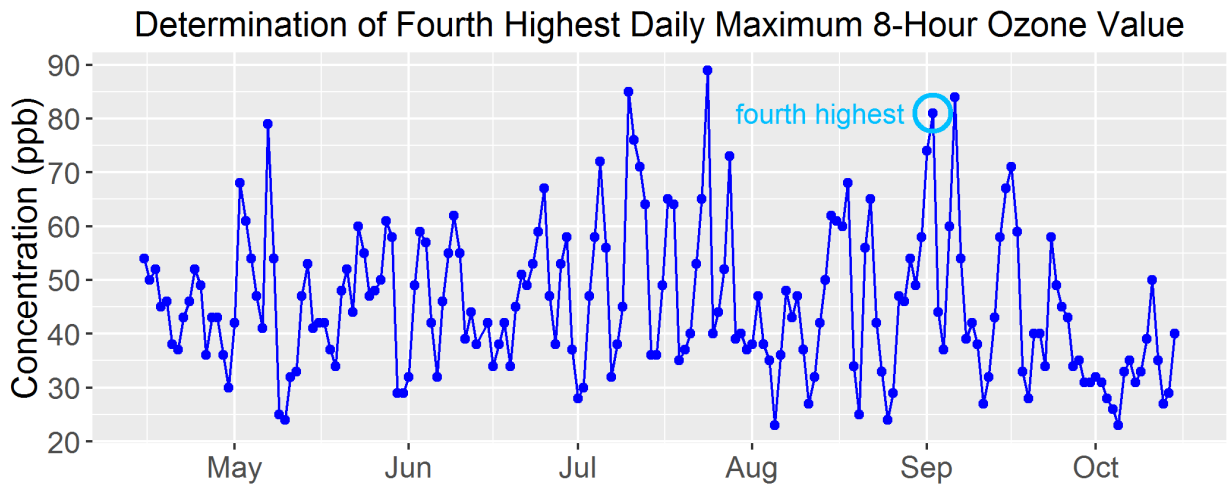

Figure 1. Example of a fourth-highest daily 8-hr maximum value identified for use in calculating an ozone design value.

Under the 2015 ozone standard, the procedure to calculate design values is similar to that used under the 2008 standard, but under the 2015 standard, 8-hr rolling averages are based on dividing individual days into 17 (rather than 24) 8-hr periods. The first of the 17 periods runs from 7 a.m. to 3 p.m., and the last period runs from 11 p.m. to 7 a.m. the following day. The purpose of reducing the number of 8-hr periods – by eliminating the time periods between midnight and 7 a.m. – is to avoid situations where a high ozone value late in the evening is counted as an exceedance for two days. In addition to changes in the number of 8-hr periods, design values calculated under the 2015 standard are compared to the 2015 NAAQS of 70 ppb, while design values calculated under the 2008 standard are compared to the 2008 NAAQS of 75 ppb to determine compliance with the standard.

Fine Particles

For fine particles ($PM_{2.5}$), design values are calculated for comparison with both the annual NAAQS and the 24-hr NAAQS. The design value for the annual $PM_{2.5}$ NAAQS is the average of the annual means from three consecutive years, where each annual mean is the average of the four quarterly mean concentrations of that year. To obtain 24-hr NAAQS design values, the observation representing the 98th percentile of 24-hr (calendar-day) average concentrations of fine particles is determined for each year (e.g., Fig. 2) and averaged over three consecutive years. The 98th percentile value is the observed concentration below which 98 percent of observations fall. Only 2 percent of observed concentrations are higher than this value. To calculate a 2014-2016 24-hr $PM_{2.5}$ design value, the 98th percentile value for 2016 would be averaged with 98th percentile values from 2014 and 2015. The resulting design value would be compared to the 24-hr $PM_{2.5}$ NAAQS of 35 µg/m^3.

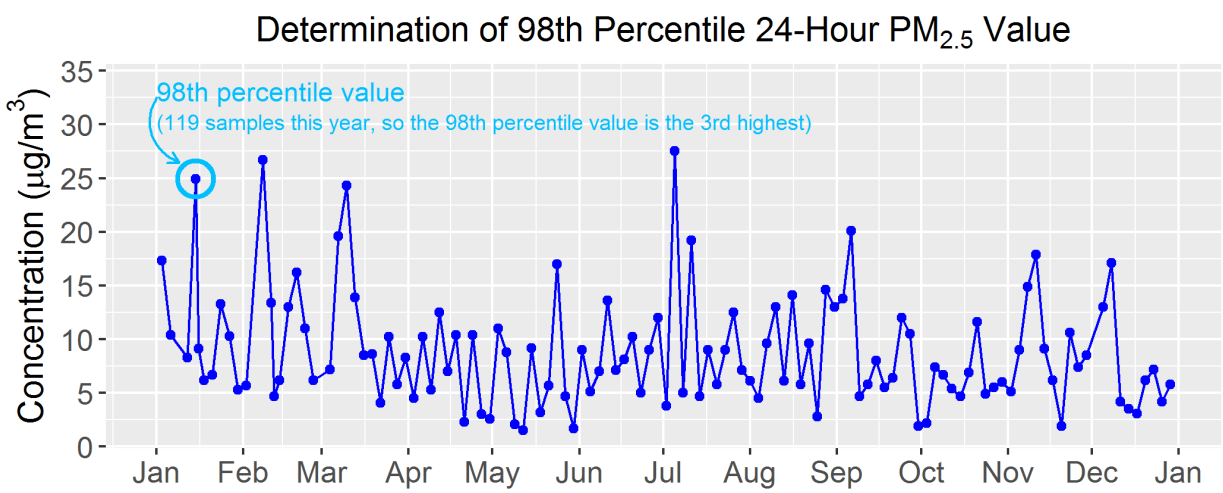

Figure 2. Example of a 98th percentile observation identified for use in calculating a 24-hr $PM_{2.5}$ design value.

Overview of Pollutants

Ozone

Ozone, also known by its chemical formula O_3, is a naturally-occurring form of oxygen. While oxygen molecules predominantly found in the atmosphere contain two atoms, ozone molecules contain three. Ozone is unstable and is constantly forming and fragmenting through a variety of atmospheric reactions. Ozone is present in the Earth's upper atmosphere, as well as at ground level. Ozone found at higher elevations in the atmosphere (stratospheric ozone) filters out harmful ultraviolet rays, while ground-level (tropospheric) ozone can have an adverse impact on health. Monitored values of ozone found in this report represent ground-level ozone.

Ground-level ozone is not directly emitted into the air; rather, it is created by photochemical reactions in the atmosphere. The highest measured ozone concentrations typically occur downwind of urban areas on hot sunny days with light winds. Precursors of ozone can be transported long distances.

Ozone concentrations in Wisconsin are significantly higher during the warmer months. As a result, the state's ozone monitoring season does not run throughout the entire year; instead it runs from spring through fall. For 2016, Wisconsin's ozone season ran from April 15 to October 15, with the exception of Kenosha County, in which the ozone season ran from April 1 to October 31[2]. The 2015 ozone rule included a change to the season start date for Wisconsin to March 1; this change took effect in the 2017 ozone season.

Ozone exposure can lead to numerous health issues, including respiratory system irritation, reduced lung function, inflammation of and damage to cells in the lungs, aggravation of asthma and chronic lung diseases, increased lung susceptibility to infection, and the potential for permanent lung damage. Children are at the greatest risk from exposure to ozone because their lungs are still developing. In Wisconsin, ozone is measured using a network of continuously operating monitors that provides the basis for air-quality forecasting and real-time health advisories.

Regulatory History

In 1971, EPA issued a 1-hr standard of 0.08 ppm (effectively 84 ppb[3]) for "total photochemical oxidants," which included ozone. In 1979, EPA replaced this standard with a 1-hr standard for ozone set at 0.12 ppm (effectively 124 ppb[3]). In July 1997, EPA replaced the 1-hr ozone standard with an 8-hr standard of 0.08 ppm (effectively 84 ppb[3]) to protect the public against longer-term exposure. In March 2008, the 8-hr standard was lowered to 0.075 ppm (75 ppb). EPA further decreased the 8-hr standard to 0.070 ppm (70 ppb) on December 28, 2015. The 2008 standard of 75 ppb remains in effect until it is revoked by EPA; therefore, both the 2008 and 2015 standards were in effect in 2016.

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[2] Kenosha County is part of the Chicago nonattainment area, and its ozone season is aligned with those of the other states in that area: Illinois and Indiana.

[3] Because older standards were set at the 0.01 ppm level, while the parameter was measured to the 0.001 ppm level, rounding conventions associated with attainment determination result in effective standards that appear to be slightly higher than the official published values. The official and effective standards are equivalent.

Wisconsin's Attainment Status History

While a number of Wisconsin counties have been designated as nonattainment with each ozone-related standard, the number of counties designated nonattainment has decreased with each successive standard. For example, 18 counties in Wisconsin were designated nonattainment with the 1971 1-hour standard for total photochemical oxidants. In contrast, only 12 Wisconsin counties were designated nonattainment for the 1979 1-hour ozone standard. When EPA completed a second round of designations under the 1979 1-hour ozone standard in 1990, the number of counties designated nonattainment in Wisconsin decreased to 11. This trend continued in 2004 when only 10 Wisconsin counties were designated nonattainment for the 1997 8-hour ozone standard. Finally, in 2012, the most recent year EPA designations were made, only Sheboygan County and the eastern part of Kenosha County were designated nonattainment for the 2008 ozone NAAQS. Nonattainment areas throughout the various designations have been primarily located in eastern Wisconsin near Lake Michigan.

Because of improvements in air quality, many counties that were originally designated nonattainment for a given standard were subsequently redesignated to attainment of that standard. For example, of the ten counties designated nonattainment for the 1997 standard, only one county was not redesignated to attainment before the standard was revoked in 2015. Currently, nonattainment designations remain in effect for Sheboygan County and eastern Kenosha County for the 2008 ozone NAAQS. In addition, EPA is expected to make area designations for the 2015 standard in 2017.

Particulate Matter ($PM_{2.5}$ and PM_{10})

Particulate matter is not a single pollutant, but rather a mixture of solid particles and liquid droplets distributed among numerous gases that interact with solid and liquid phases. Particles are classified based on their diameter. There are three types of particles that are commonly of interest: fine particles (2.5 µm in diameter or smaller; $PM_{2.5}$), coarse particles (with diameters between 2.5 and 10 µm; PM_{crs}), and inhalable particles (10 µm in diameter or smaller; PM_{10}). Fine particles have different emission sources than the larger particles found in the coarse and inhalable particle categories, and behave much like gases in the atmosphere. Fine particles generally form in the atmosphere and have long atmospheric lifetimes. Coarse particles are primarily formed through mechanical processes, such as crushing and grinding. Particles of different sizes are transported differently and have different fates. Fine particles have longer lifetimes in the atmosphere (days to weeks), travel longer distances (hundreds to thousands of kilometers), and are more uniformly distributed over larger regions compared with larger particles. National Ambient Air Quality Standards have been set for $PM_{2.5}$ and PM_{10} only (Table 2); there is not a separate NAAQS for PM_{crs}. Consequently, discussion throughout the remainder of this report focuses on $PM_{2.5}$ and PM_{10}.

There are two types of fine particles, primary particles and secondary particles, which differ with respect to how they are created. Primary particles are emitted directly from combustion sources, such as vehicles, fires, or smokestacks for combustion processes. Secondary particles form when pollutants (e.g., sulfur oxides and nitrogen oxides) react in the atmosphere with ammonia and other gases. Secondary particles comprise the vast majority of fine particles.

While all inhalable particles pose a health risk, fine particles pose the greatest risk because of their ability to penetrate deep into the respiratory tract. Very fine particles with diameters of 1 micron or less

may also enter the bloodstream. Studies have shown an association between fine particle exposure and premature death from heart or lung disease, as well as aggravated respiratory conditions, such as asthma and airway irritation. Individuals most sensitive to fine particle exposure include people with heart or lung disease, older adults, and children.

Regulatory History

EPA's original 1971 standard for particle pollution set a limit for total suspended particles (TSP), which included both $PM_{2.5}$ and PM_{10}, as well as coarser particles up to approximately 20 µm in diameter. In 1987, EPA discontinued the standard for TSP and replaced it with two standards for PM_{10}, as described below. Wisconsin, however, retained its own 24-hr TSP standard until 2011.

$PM_{2.5}$

In 1997, EPA established an annual $PM_{2.5}$ standard of 15.0 µg/m^3 as well as a 24-hr (calendar-day) $PM_{2.5}$ standard of 65 µg/m^3. In 2006, the 24-hr standard was lowered to 35 µg/m^3. The annual standard was lowered to 12.0 µg/m^3 in 2012.

PM_{10}

In 1987, EPA established two PM_{10} standards: an annual standard of 50 µg/m^3 and a 24-hr (calendar-day) standard of 150 µg/m^3. In 2006, the 1987 annual PM_{10} standard was revoked. The 24-hr PM_{10} standard, however, remains in effect today.

Wisconsin's Attainment Status History

$PM_{2.5}$

In 2009, EPA designated Milwaukee, Racine, and Waukesha counties as nonattainment of the 2006 NAAQS for 24-hr $PM_{2.5}$ based on monitoring data from 2006 to 2008. In June 2012, WDNR submitted a request to EPA to redesignate these counties to attainment based on monitoring data collected between 2008 and 2011. EPA concurred and the redesignation was finalized on April 22, 2014. As a result of this action, all counties in Wisconsin are in attainment for the annual and 24-hr $PM_{2.5}$ NAAQS.

PM_{10}

Design values for PM_{10} in Wisconsin have not exceeded PM_{10} standards; consequently, there are no PM_{10} nonattainment areas in the state.

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2), a product of combustion, is one of a group of highly reactive gases known as oxides of sulfur. The largest emission source of SO_2 is fossil fuel combustion at power plants and other industrial facilities.

Exposure to SO_2 has been shown to cause a range of adverse respiratory effects, including bronchoconstriction and increased asthma symptoms. Further, emission sources that contribute to high concentrations of SO_2 also contribute to the formation of other oxides of sulfur. Some of these oxides can react with other compounds in the atmosphere to form fine particles, which can penetrate deep into the lungs.

Regulatory History

EPA first set standards for SO_2 in 1971. An annual standard was set at 30 ppb and a 24-hr standard was set at 140 ppb. In 1996, EPA reviewed the standards without revision. In 2010, EPA established a new 1-hr standard at 75 ppb and revoked the existing annual and 24-hr standards because the 1-hr standard is more protective of public health.

Wisconsin's Attainment Status History

In 2013, EPA designated a portion of Oneida County as nonattainment for the 2010 SO_2 NAAQS. In July 2016, as part of its second round designations under the SO_2 Data Requirements Rule (DRR), EPA designated all of Columbia County as unclassifiable/attainment for this standard. In September 2017, as part of its third round of designations, EPA proposed designating the remaining areas of the state, except for Outagamie County, as unclassifiable/attainment; these designations are to be finalized by December 31, 2017. Per the DRR, Outagamie County is to be considered in EPA's Round 4 designations in 2020.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is a reactive byproduct of combustion produced mainly by vehicles, resulting in concentrations that are highest immediately adjacent to roadways. Nitrogen dioxide and nitrogen oxide (NO), collectively referred to as NO_x, are important precursors of ozone, which is generated when NO_x reacts with volatile organic compounds in the presence of sunlight.

Research indicates that direct exposure to NO_2 for short periods of time can result in respiratory issues, such as airway inflammation and aggravated asthma. Longer-term exposure poses a risk of acute respiratory illness and inhibited lung development in children.

Regulatory History

In 1971, EPA set the original standard for NO_2 at 53 ppb based on an annual average. This standard is still in effect. In 2010, EPA established an additional 1-hr standard of 100 ppb and mandated the placement of NO_2 monitors near major roads in large urban areas, to be installed in phases according to population. WDNR added a near-road NO_2 monitor in Milwaukee that became operational January 1, 2014. Due to low NO_2 concentrations found at monitors nationwide, EPA eliminated the requirement that near-road monitors be installed in areas with populations between 500,000 and 1 million (Madison-area).

Wisconsin's Attainment Status History

Design values in Wisconsin have not exceeded the NO_2 standards, and consequently there are no NO_2 nonattainment areas in the state.

Lead

Lead can be found in the atmosphere as well as in the water and soil. Before unleaded gasoline was introduced in 1980, vehicle emissions were the primary source of airborne lead. Today, lead is emitted mainly from industrial metal processing sources, as well as from the combustion of leaded aviation fuel.

Lead exposure can occur directly through contact with lead in the atmosphere. In addition, deposition of lead from the atmosphere into the soil or water bodies may cause this pollutant to accumulate in

natural ecosystems and contaminate drinking water. The health effects of lead exposure in humans are numerous and well-documented. In general, neurological effects and developmental risks are the largest danger for children, whereas cardiovascular effects, such as heart disease and high blood pressure, commonly affect adults.

Regulatory History

The original lead standard, set by EPA in 1978, was 1.5 µg/m^3 on a calendar quarterly average basis. In 2008, this standard was replaced by a rolling 3-mo average and lowered to 0.15 µg/m^3. In 2016, after an extensive review period, EPA decided to retain the existing 2008 standard.

Wisconsin's Attainment Status History

Wisconsin uses a collection technique that measures lead content as a subset of total suspended particle samples as required by federal rule. During the past two decades, no areas in Wisconsin have had levels of lead that exceed the NAAQS, and the state has had no nonattainment areas.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a toxic gas that is well known as a potential danger in indoor environments; however, it is also emitted into the ambient air, primarily by mobile sources. Under certain conditions, CO can react to form ground-level ozone.

In the short term, carbon monoxide exposure can reduce human respiratory efficiency. In extremely high concentrations, exposure can be fatal. People suffering from heart disease face increased risks from exposure to CO because their respiratory efficiency is already compromised.

Regulatory History

EPA originally set two standards for CO in 1971: an 8-hr standard of 9 ppm and a 1-hr standard of 35 ppm. These standards were reviewed in 1994 and 2011 and have remained unchanged.

Wisconsin's Attainment Status History

In the past, Wisconsin had nonattainment areas for CO in portions of Milwaukee and Winnebago counties. Both areas have since been redesignated to attainment; therefore, there are currently no CO nonattainment areas in the state.

Regional Pollutant Trends

The following section presents trends in Wisconsin monitoring data for all six criteria pollutants over roughly the last 14 years (as data are available). Design values are plotted for each monitoring site and compared against the relevant NAAQS to show how the state's air quality has changed over time. The data for ozone and fine particles are organized regionally to highlight differences in the geographic distribution of these regional pollutants.

The data presented are for pollutants that are currently monitored at active ambient air monitoring sites operated by WDNR and Tribal partners. If data are not shown for a particular design-value period, it is because the design value was not valid, most often due to data-completeness issues. Although the maps for each pollutant include all currently-active monitoring sites in the state network, only sites with a valid design value for the most recent period (i.e., 2016 for 1-yr design values or 2014-2016 for 3-yr design values) will have values shown after the site name.

Typically, NAAQS attainment is determined on a county-by-county basis. Trend plots by county are shown in Appendix A.

Information on national air quality trends and how Wisconsin data compare to national averages can be found in EPA's trends report at https://gispub.epa.gov/air/trendsreport/2016/.

Ozone

Ozone in the lower atmosphere forms primarily as the result of reactions between nitrogen oxides (consisting of NO and NO_2) and volatile organic compounds, which are collectively known as ozone precursors. Ozone formation is greatest on days with high temperatures, high humidity, and a lot of sunlight, all of which facilitate chemical reactions that form ozone.

The ozone precursors that affect Wisconsin may originate in other states, particularly to the south. Wisconsin counties along Lake Michigan experience the highest ozone concentrations on days with southerly winds, which transport ozone precursors north to Wisconsin. These precursors can react to form high concentrations of ozone over Lake Michigan. When the land has warmed sufficiently, temperature gradients from the shoreline to the lake can create pressure differences, which cause an on-shore flow of air, or lake breeze. Southerly winds, in combination with the lake breeze, push ozone formed over the lake onshore, causing ozone concentrations in Wisconsin to be closely correlated with the distance from the Lake Michigan shoreline. For this reason, ozone design values in this report are grouped based on their location into three distinct regions (as shown in Fig. 3):

1) **Lakeshore** – counties bordering Lake Michigan extending from the Illinois border through Door County, Wisconsin
2) **Inland** – counties in central and western Wisconsin
3) **Far North** – counties in the northern part of the state, including those near Lake Superior and the Upper Peninsula of Michigan

Figure 3 shows the most recently-available ozone design values[4] for all ozone monitors in the state network. Only 2 of 12 monitoring sites in the Lakeshore region observed design values for these years that were greater than the 2008 ozone NAAQS of 75 ppb. A warm summer in 2016 combined with a

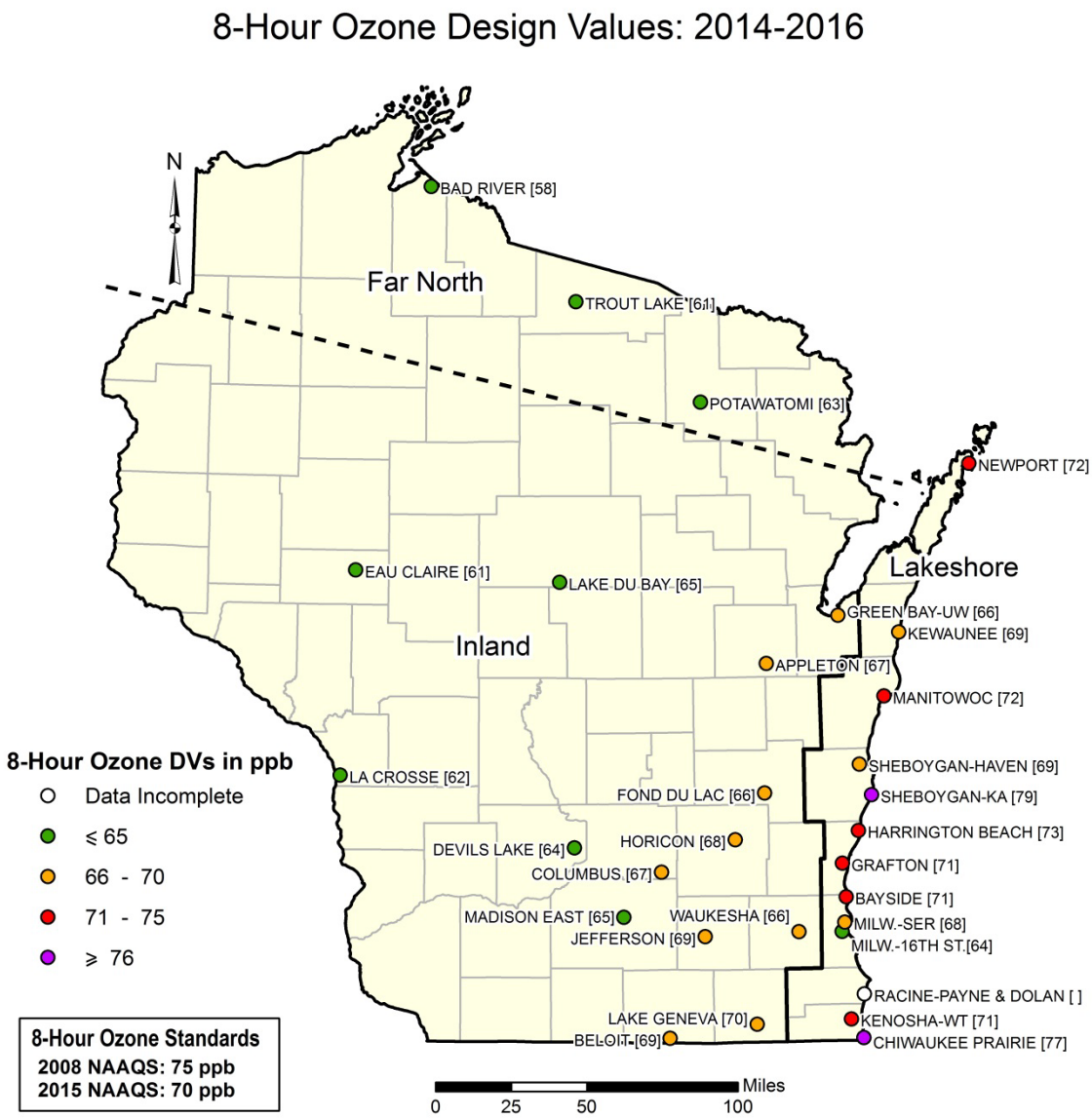


Figure 3. The 8-hr ozone design values for each monitoring site[5] for 2014-2016. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

[4] The 2014-2016 ozone design values shown in Figure 3 were calculated using methods associated with the 2015 NAAQS. When design values were calculated for the same years using methods from the 2008 NAAQS, results were nearly identical. WDNR will therefore consider design values presented in Figure 3 to be representative of design values calculated under the 2008 NAAQS when making comparisons to the 2008 standard in the discussion associated with the figure.

[5] Full site names are provided in Appendix C. Shorter versions of these names are used in tables and figures throughout the remainder of the report.

lower 2015 standard resulted in 8 of 12 Lakeshore monitoring sites exceeding the 2015 NAAQS of 70 ppb for the 2014-2016 design value period. No sites in the Inland or Far North regions had design values exceeding either the ozone standard for the 2014-2016 design value period.

Lakeshore Region

Figure 4 shows trends in ozone design values for the Lakeshore region. The relationship between design values from different monitoring sites was generally consistent over time (e.g., the values from the Milwaukee-SER site were consistently greater than the values from the Milwaukee-16th St. site). The summers of 2012 and 2016 were exceptionally warm; therefore any design value that includes those years is elevated compared to other periods. The sensitivity of design values to effects related to year-to-year temperature variations highlights the importance of considering long-term trends in air quality, in addition to design values, to guide decisions about management of air quality issues at federal and state levels. For example, despite higher 2014-2016 design values, ozone concentrations in the Lakeshore region have generally been decreasing over the past decade (Fig. 4), reflecting improving air quality in the region.

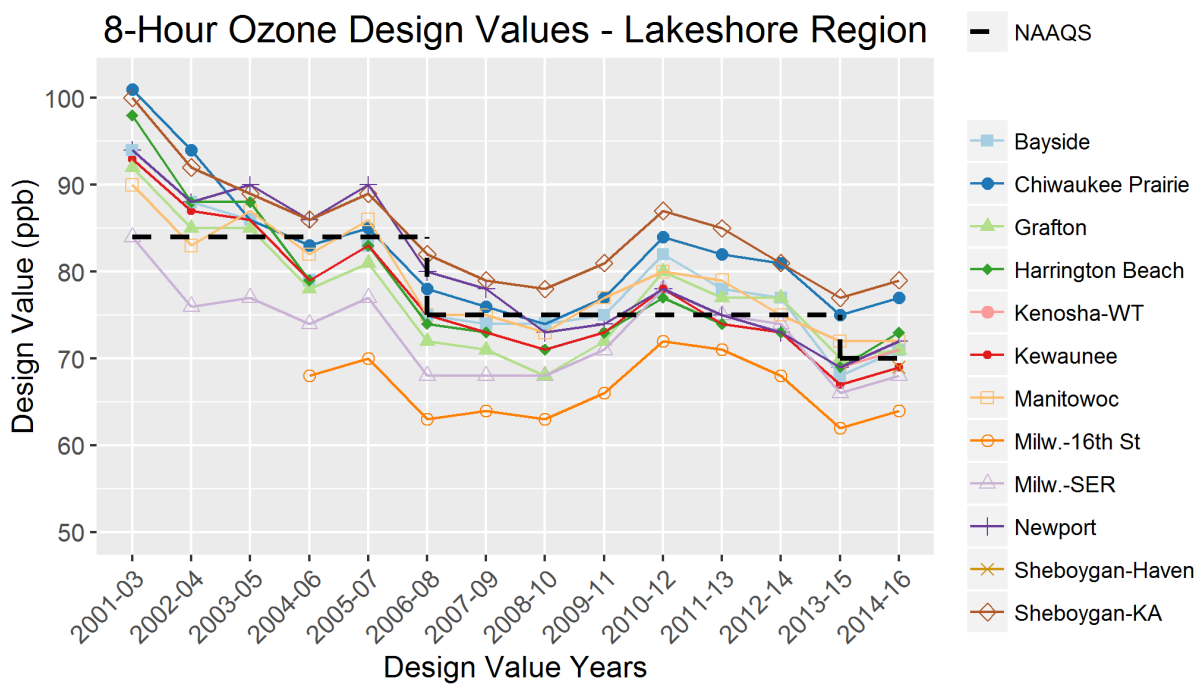


Figure 4. Trends in 8-hr ozone design values for the Lakeshore region. Note that the design value axis is truncated at 50 ppb (rather than going down to zero) to allow for a clearer view of the differences among sites.

Over the time period shown in Figure 4, a number of sites have exceeded the NAAQS while others have remained below the standard. Ozone concentrations at the Sheboygan-Kohler Andrae site have consistently been among the highest in the state. A special-purpose monitor was established in 2014 at the Sheboygan-Haven site, approximately three miles inland from the lakeshore Sheboygan-Kohler Andrae site, to help determine the ozone gradient in Sheboygan County. The 2014-2016 design value at the Sheboygan-Have site was 69 ppb, which was below the 2015 NAAQS and also 10 ppb lower than the

value at Sheboygan-Kohler Andrae for the same period. The lowest design values in the Lakeshore region were observed at the Milwaukee 16th St. site, which had ozone concentrations consistently below the NAAQS.

Collectively, the design values in the Lakeshore region demonstrated a downward trend between 2001-2003 and 2014-2016, with the lowest average values for the region recorded in 2013-2015. There was a 23 percent average reduction in design values in this region from 2001-2003 to 2014-2016 among sites with data available for the full period, including a 21 percent reduction in design values at the Sheboygan-Kohler Andrae site (Appendix B, Table B1).

Inland Region

Figure 5 shows trends in ozone design values for the Inland region. Once again, design values were higher for the 2010-2012 to 2012-2014 periods due to the warm summer and high ozone concentrations in 2012, and increased slightly for 2014-2016 due to the warm summer and high ozone concentrations in 2016. Nonetheless, no design value in this region exceeded either the 2008 or the 2015 NAAQS between 2001-2003 and 2014-2016. As was the case for the Lakeshore region, the design values for each of the monitoring sites in the Inland region generally decreased over time. The lowest design value in this region, 60 ppb, was observed most recently at the Eau Claire site in 2013-2015. There was a 16 percent average reduction in design values in this region from 2001-2003 to 2014-2016 among sites with data available for the full period (Appendix B, Table B1).

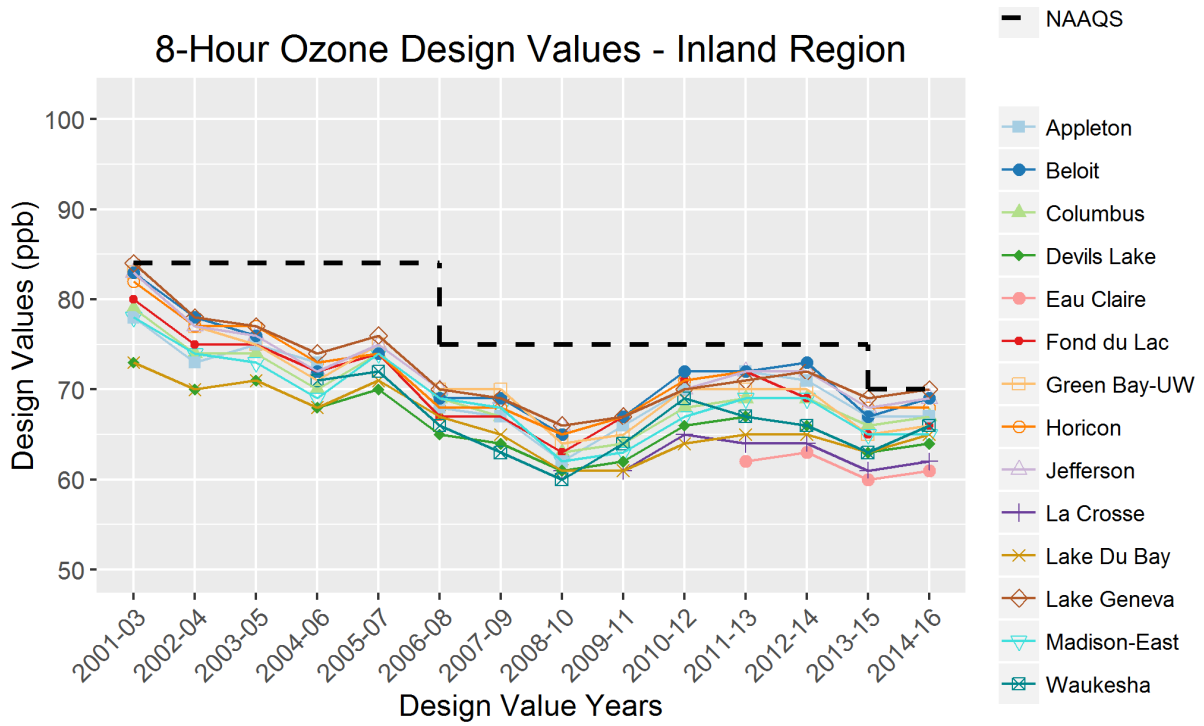


Figure 5. Trends in 8-hr ozone design values for the Inland region. Note that the design value axis is truncated at 50 ppb (rather than going down to zero) to allow for a clearer view of the differences among sites.

Overall, the design values in the Inland region were more similar among sites within the region than were those in the Lakeshore region. This finding suggests that while ozone concentrations are subject to

variation at local scales in the Lakeshore region due to the impact of the lake breeze effect, Inland region concentrations are buffered from this effect because they are farther from the shoreline. Since onshore ozone transport is less of a factor at inland locations, the ozone concentrations at the Inland sites were both more uniform throughout the region and generally lower than concentrations at the Lakeshore sites. In addition to having generally lower ozone concentrations, sites in the Inland region showed a smaller average reduction in design value compared to the Lakeshore sites (16 percent vs 23 percent) over the time period examined (Appendix B, Table B1).

Far North Region

Figure 6 shows trends in ozone design values for the Far North region. All sites were consistently below the NAAQS and represented the overall lowest concentrations of ozone in the state. Minimum levels for the region were observed most recently in the 2013-2015 design value period. Concentrations were lowest at the Bad River site.

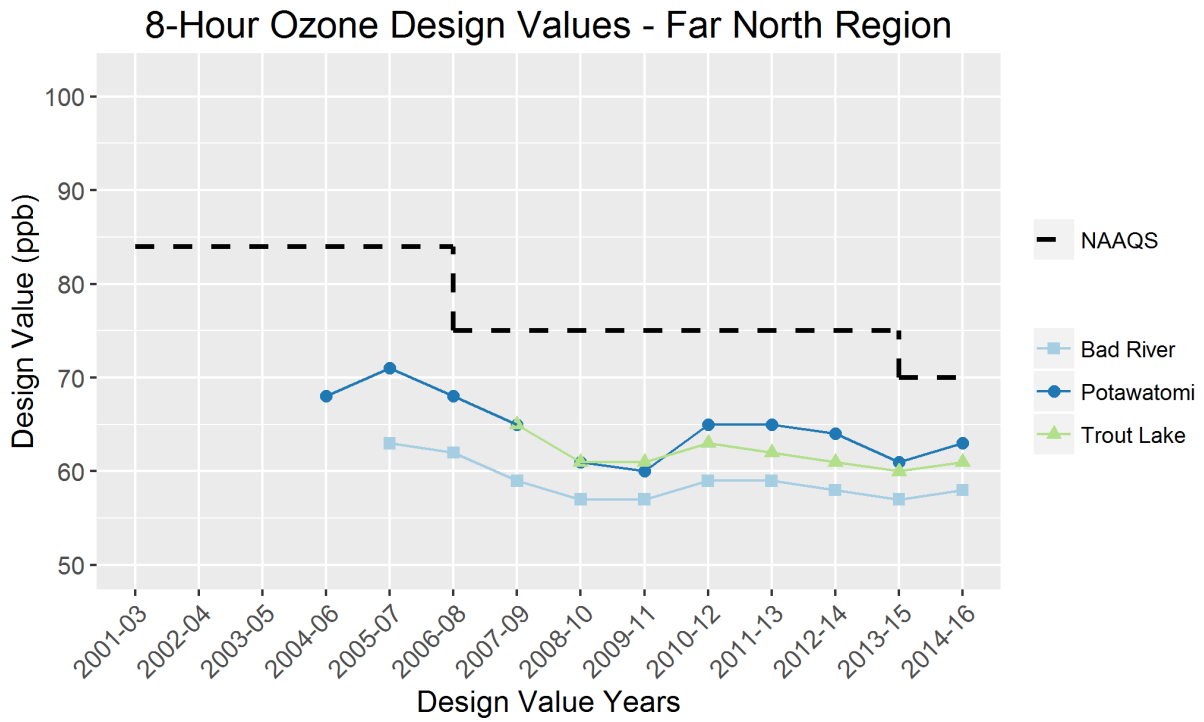


Figure 6. Trends in 8-hr ozone design values for Far North region. Note that the design value axis is truncated at 50 ppb (rather than going down to zero) to allow for a clearer view of the differences among sites.

Fine Particles ($PM_{2.5}$)

WDNR maintains a robust network of $PM_{2.5}$ monitoring sites throughout the state. In 2016, monitors at these sites measured fine particles for NAAQS comparison using filter-based systems operating at frequencies ranging from daily to once every 12 days. During this time, WDNR also operated continuous beta attenuation monitors (BAM) which produced data that contributed to the Air Quality Index (AQI) web map and forecasting. After evaluating comparisons between filter-based and BAM data, WDNR will be using data from both BAMs and filter-based systems for NAAQS comparison starting in 2017.

Fine particles may be transported long distances and are considered a regional pollutant. Ambient concentrations of fine particles are strongly influenced by weather and local topography. Specifically, low-lying areas may exhibit elevated concentration levels during periods of localized air stagnation.

To highlight geographic trends in fine particle concentrations, design values are grouped by the following regions (as shown in Fig. 7):

1) Southeast
2) Inland
3) Far North

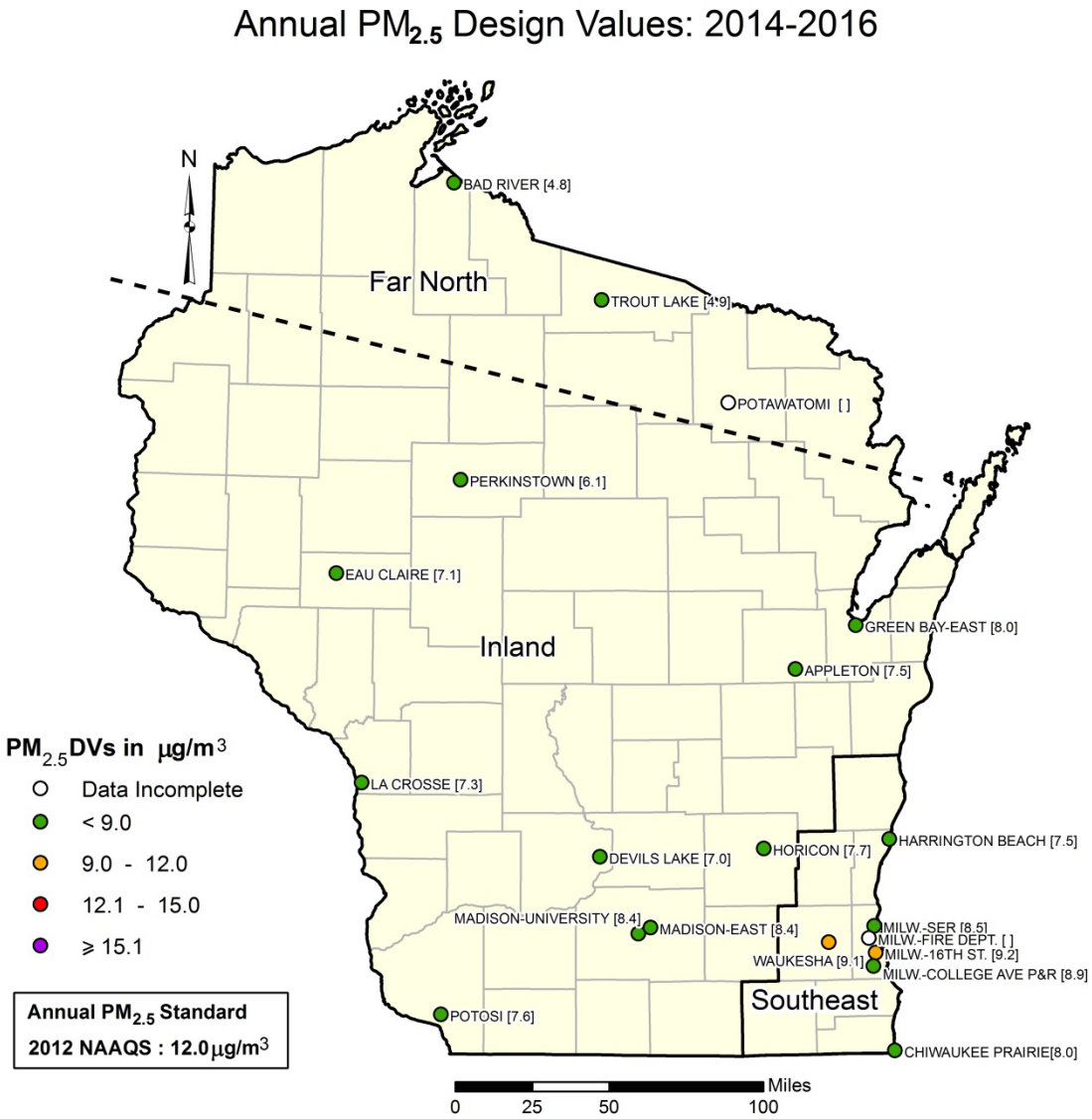


Figure 7. The annual $PM_{2.5}$ design values for each monitoring site for 2014-2016. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

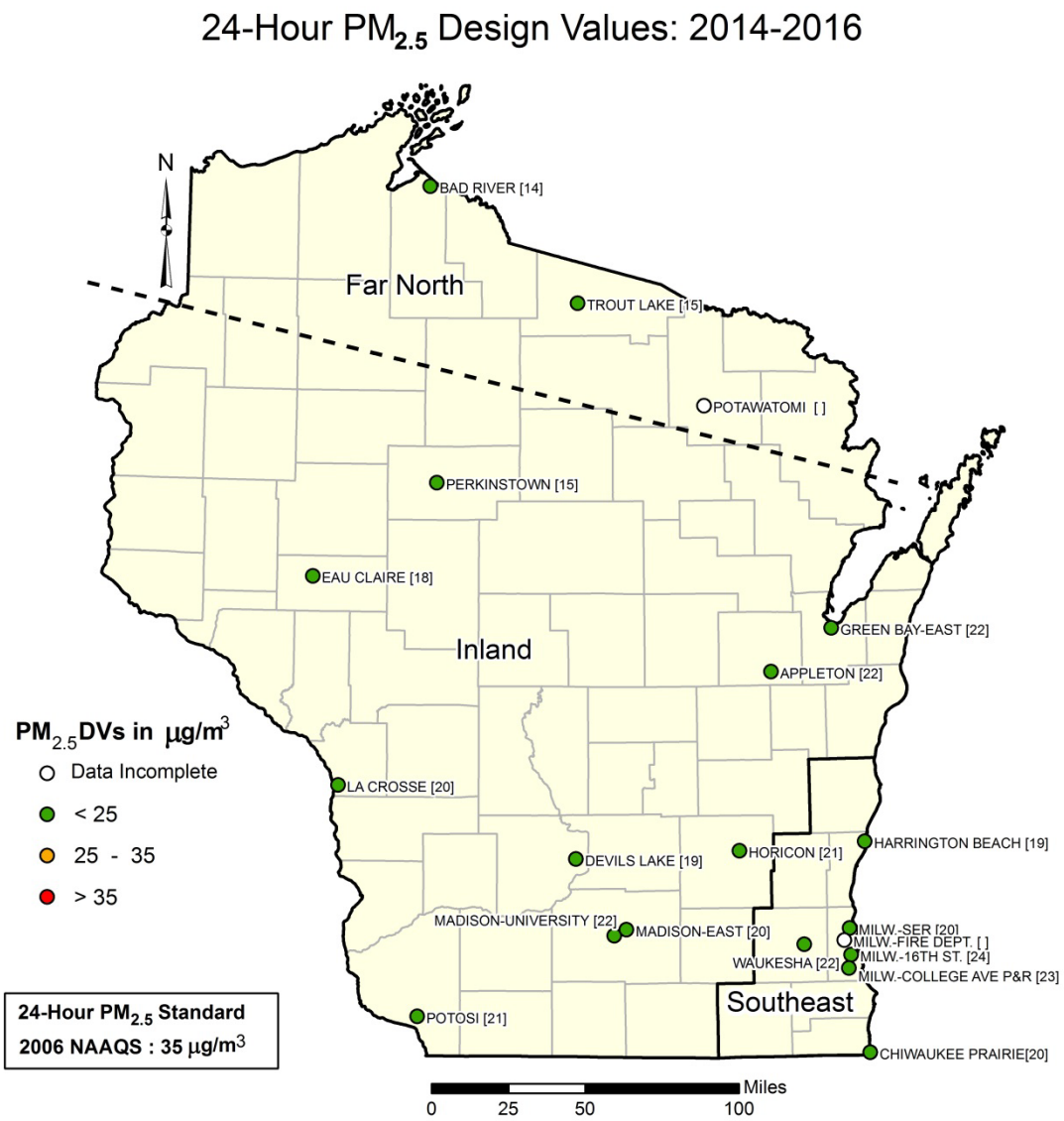


Figure 8. The 24-hr $PM_{2.5}$ design values for each monitoring site for 2014-2016. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

Southeast Region

Figures 9 and 10 show trends in annual and 24-hr $PM_{2.5}$ design values for the Southeast region. The relationships between design values at different sites were relatively consistent for both the annual and 24-hr design values. For both metrics, monitoring sites generally measured a steady decrease in concentrations over the past 10 design value periods, reaching the lowest overall concentrations in 2014-2016. The Harrington Beach site had the lowest annual and 24-hr design values. The Waukesha site generally recorded the highest annual values, while the Milwaukee-16th St. site generally measured the highest 24-hr design values.

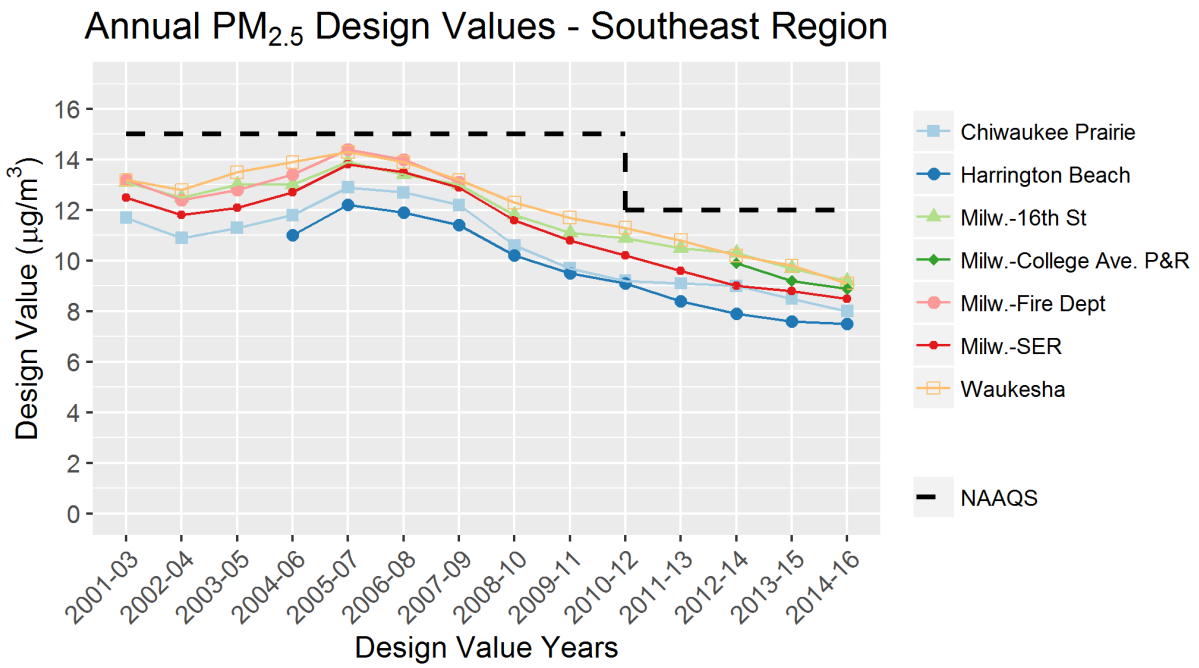


Figure 9. Trends in annual $PM_{2.5}$ design values in the Southeast region.

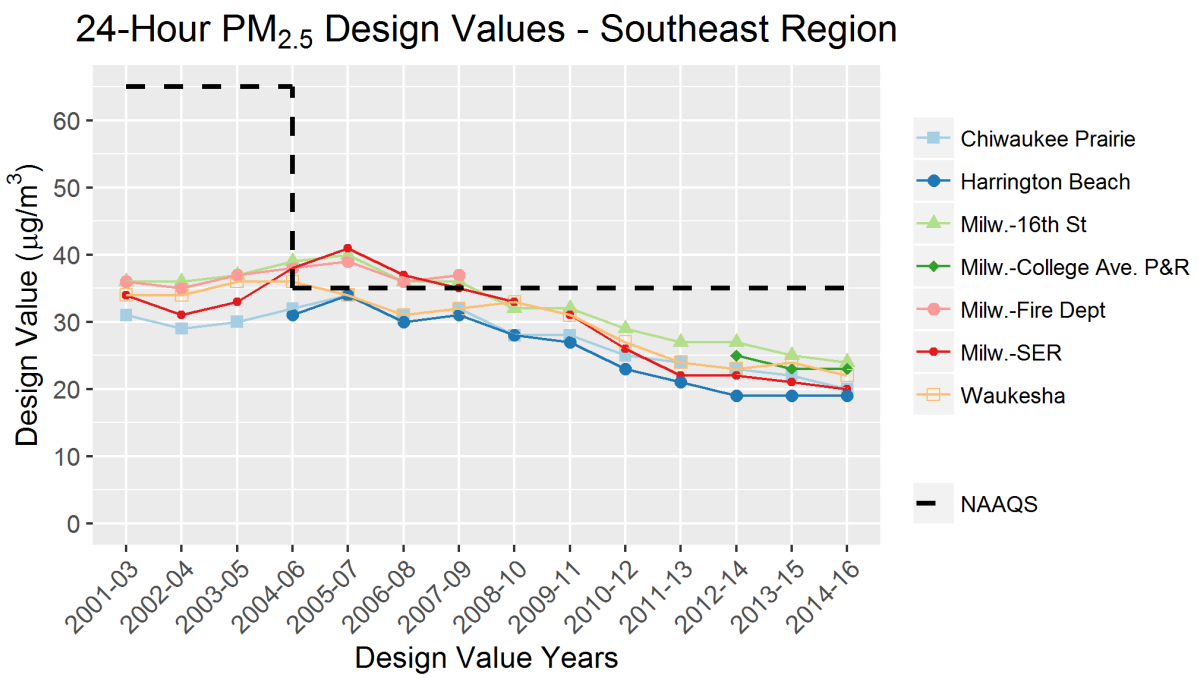


Figure 10. Trends in 24-hr $PM_{2.5}$ design values in the Southeast region.

While none of the fine-particle monitoring sites in the Southeast region has measured an annual design value exceeding the relevant NAAQS (the 2006 annual standard of 15.0 µg/m^3 or the 2012 annual standard of 12.0 µg/m^3), the decrease in the 24-hr standard from 65 to 35 µg/m^3 in 2006 resulted in design values at some sites exceeding the standard during subsequent years. Nonetheless, 24-hr design

values for all sites in the region have been below the stricter 2006 NAAQS since 2008-2010. Fine particle design values decreased more than 30 percent on average for the region between 2001-2003 and 2014-2016 among sites with data available for the full period (Appendix B, Tables B2-B3).

Inland Region

Figures 11 and 12 show trends in annual and 24-hr $PM_{2.5}$ design values for the Inland region. Similar to the Southeast region, the relationship between annual design values at different sites in the Inland region were generally consistent over time. The annual design values decreased consistently at all sites after 2006-2008. The lowest annual design values in this region were observed at the Perkinstown site in Taylor County.

Trends over time were less consistent across sites for the 24-hr design values prior to 2008-2010; however, the values generally decreased after that time. Immediately after the lower standard went into effect in 2006, the Green Bay-East and Madison-University sites measured exceedances of the NAAQS, although no sites measured exceedances in subsequent years. Inland region design values decreased approximately 30 percent on average for the region between 2001-2003 and 2014-2016 among sites with data available for the full period, similar to, but slightly less than, the decreases observed in the Southeast region over the same time period (Appendix B, Tables B2-B3).

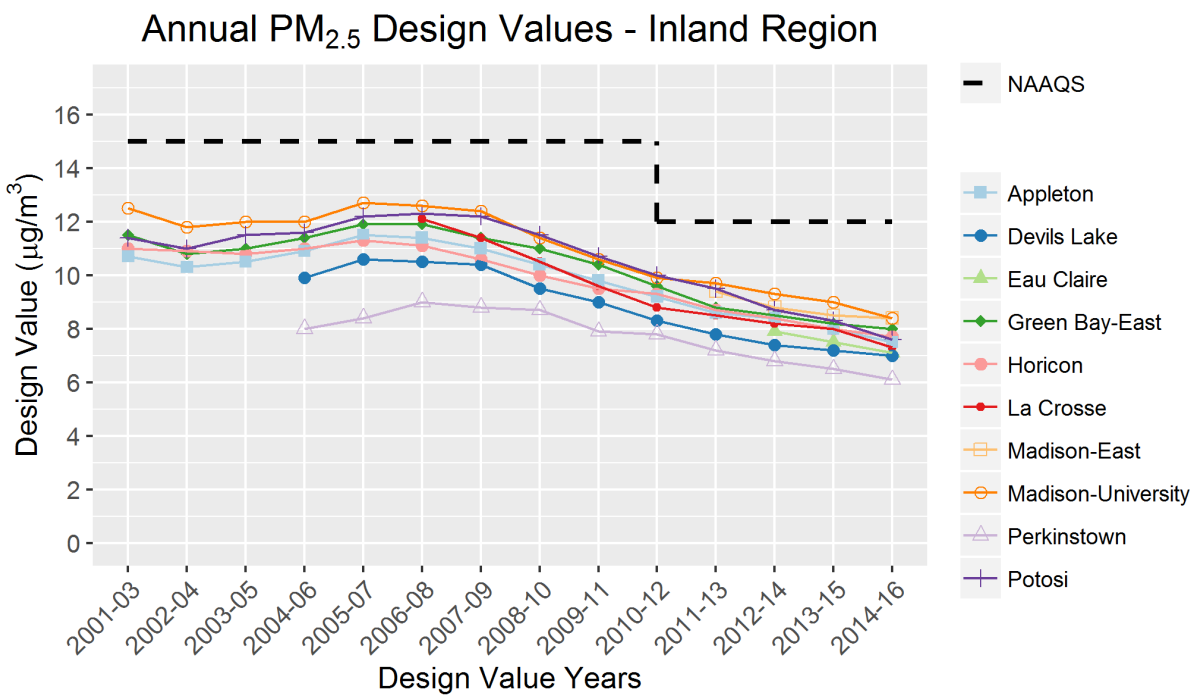


Figure 11. Trends in annual $PM_{2.5}$ design values in the Inland region.

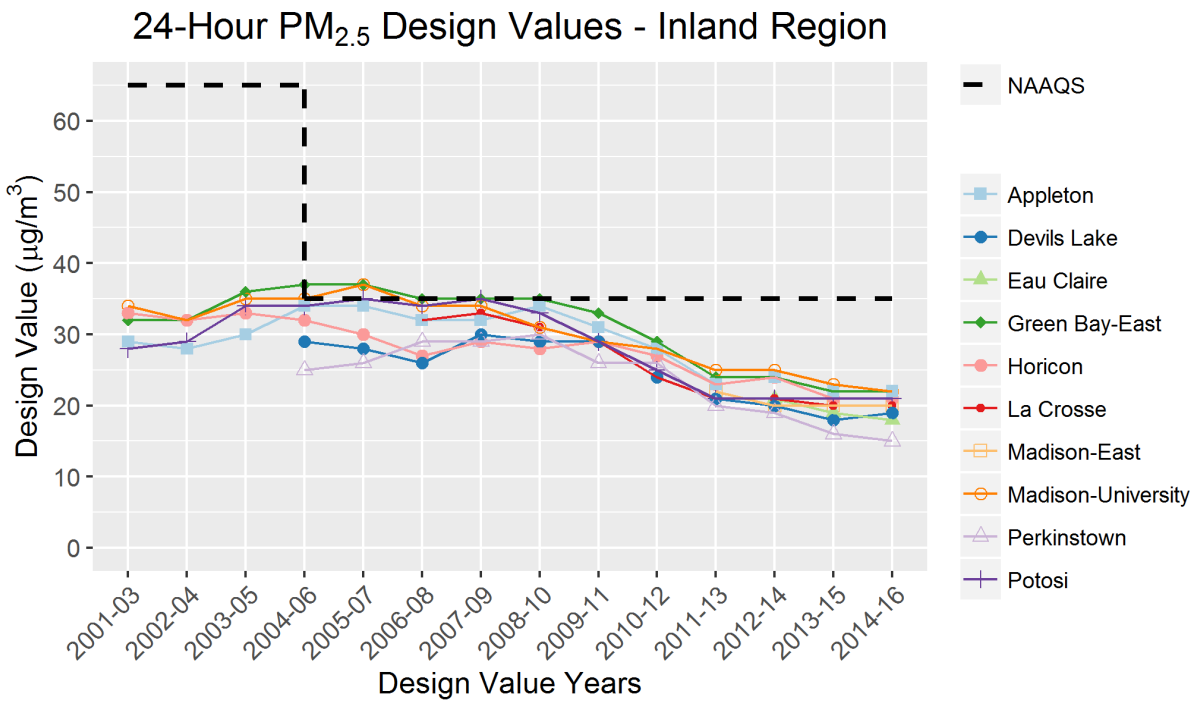


Figure 12. Trends in 24-h4 $PM_{2.5}$ design values in the Inland region.

Far North Region

Figures 13 and 14 show trends in annual and 24-hr $PM_{2.5}$ design values for the Far North region. Sites in this region showed the lowest concentrations of fine particles in the state. The annual design values decreased consistently after 2006-2008. Values were more similar among sites for the annual design values than the 24-hr values.

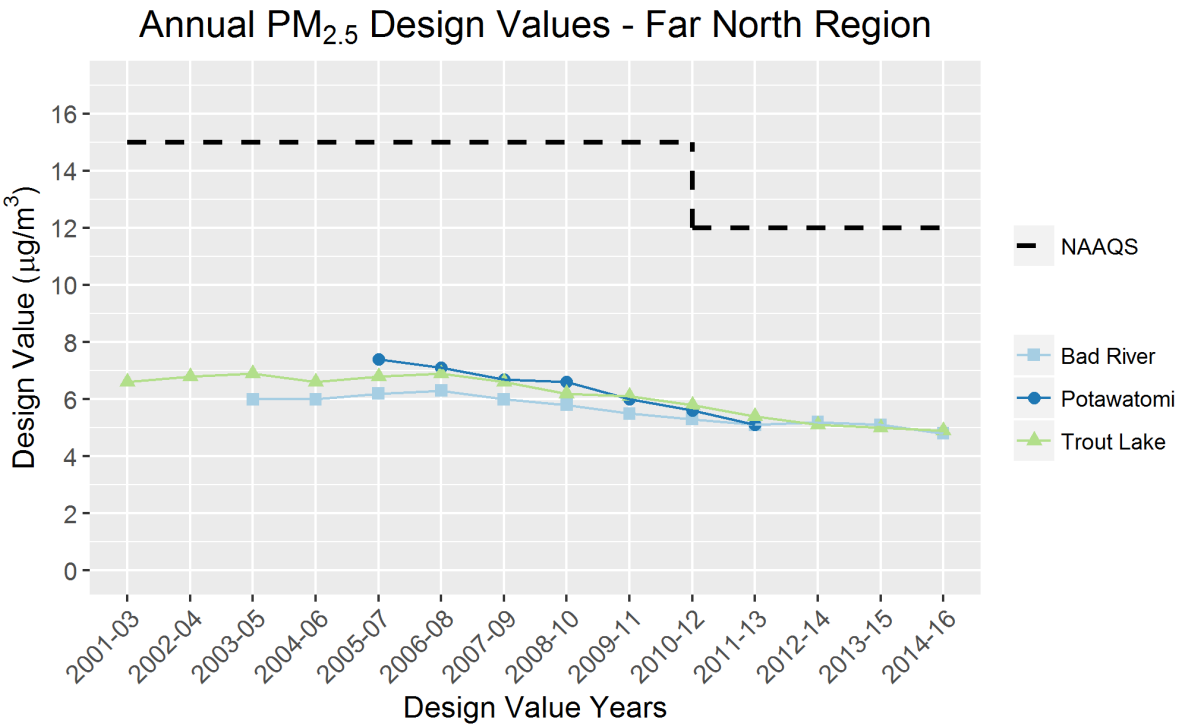


Figure 13. Trends in annual $PM_{2.5}$ design values in the Far North region.

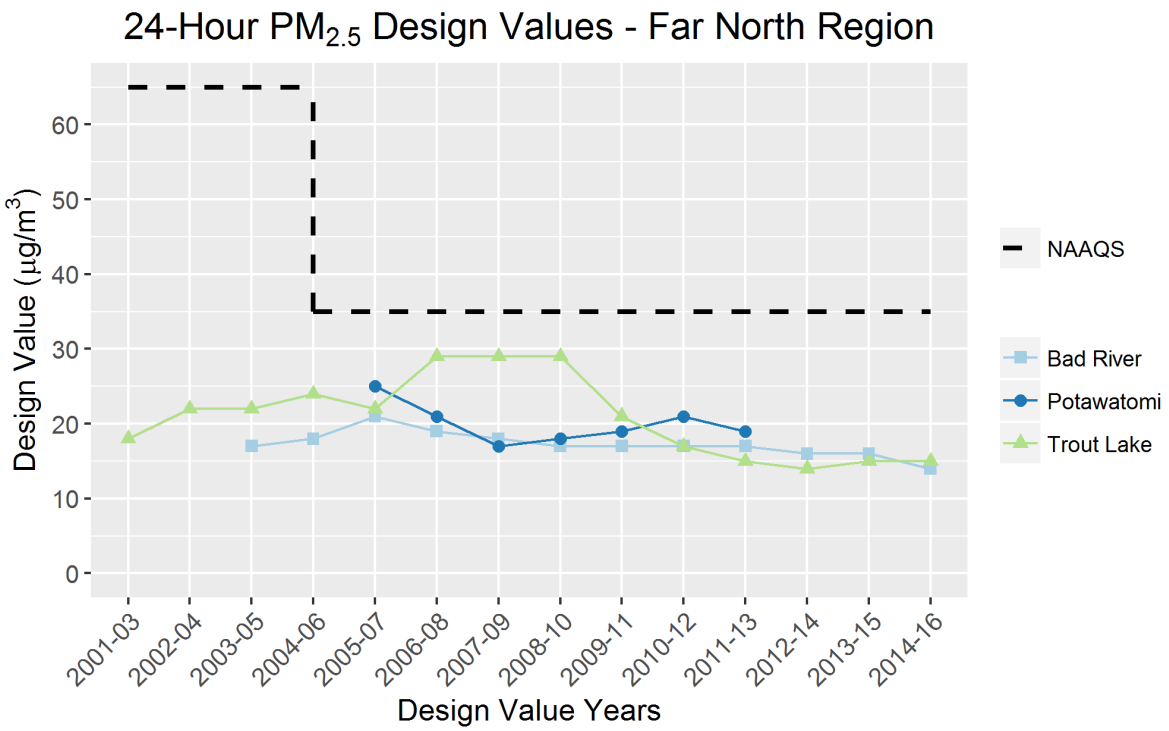


Figure 14. Trends in 24-hr $PM_{2.5}$ design values in the Far North region.

Inhalable Particles (PM_{10})

Inhalable particles (PM_{10}) are monitored at seven sites in the state network (Fig. 15), using a combination of filter-based and continuous monitors. Values shown in the map below are the 3-yr maximum 24-hr (calendar-day) averages[6] measured from 2014-2016. These averages contribute to the determination of the PM_{10} design value. The highest PM_{10} concentrations are generally measured in urban areas.

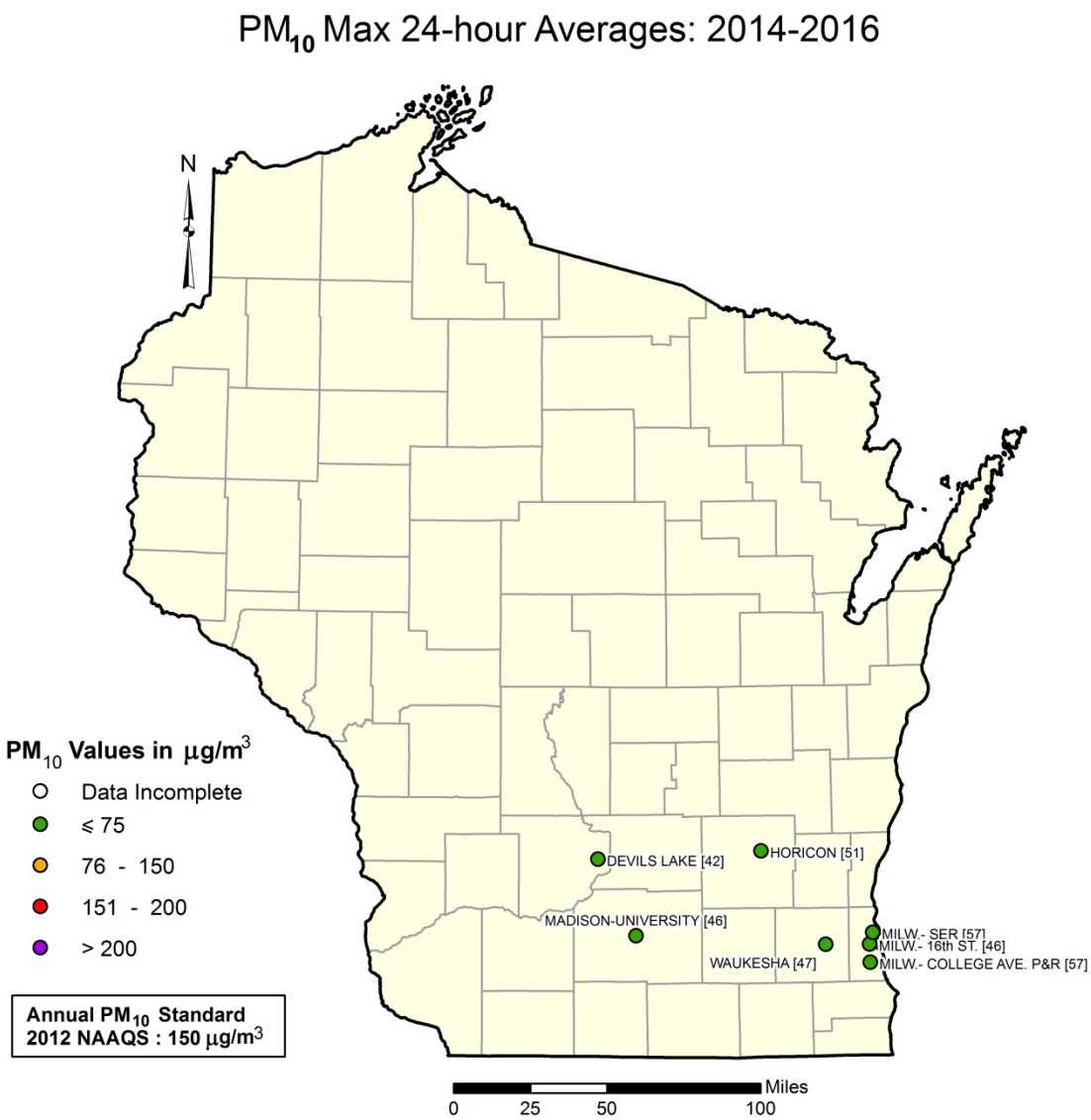


Figure 15. The maximum 24-hr averages of PM_{10} for 2014-2016.

[6] Three-year maximum values in this year's report were updated to include data from both continuous and filter-based monitors rather than from filter-based monitors alone in order to more accurately reflect the data used in design value calculations.

Figure 16 shows trends in 3-yr maximum 24-hr PM_{10} averages for each PM_{10} monitoring site. If the 24-hr average PM_{10} values exceed the standard (150 µg/m^3) more than once per year on average over three years, the standard is violated.

The three-year 24-hr maximum values for all sites are well below the NAAQS. In addition, concentrations of PM_{10} generally decreased over time, although values were somewhat variable. Three-year 24-hr maximum values decreased between 10 percent (Milwaukee-SER) and 36 percent (Waukesha) between the start of monitoring and the most recent (2014-2016) values, except at the Devils Lake and Milwaukee-16th St. sites where values have remained fairly steady (Appendix B, Table B4).

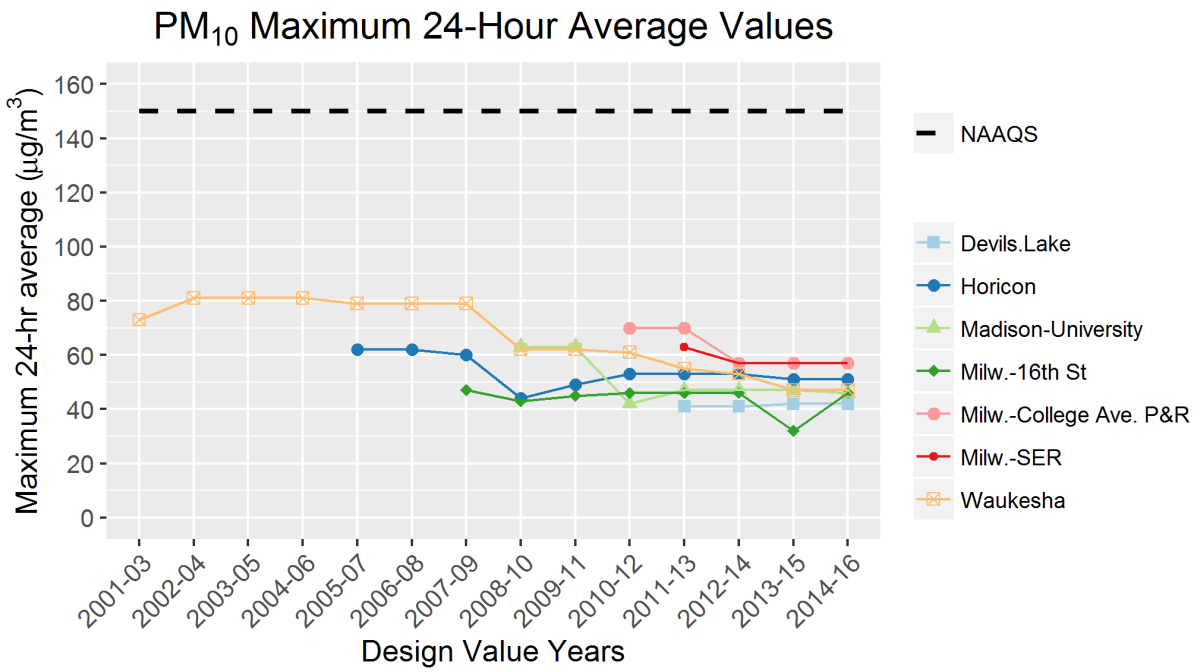


Figure 16. Trends in maximum 24-hr averages of PM_{10} over each 3-yr period.

Some industrial sources in Wisconsin have a requirement in their air permits to monitor for inhalable particles. The majority of these sources are industrial sand facilities monitoring for PM_{10}. WDNR quality assures these data and posts them quarterly on a webpage for viewing (http://dnr.wi.gov/topic/Mines/AQSandMap.html).

Sulfur Dioxide

Figure 17 shows SO_2 monitoring sites in the state network and the most recent 1-hr design values. These data are compared against the 2010 1-hour NAAQS of 75 ppb. In Wisconsin, most SO_2 is produced by combustion at power plants and industrial boilers. Additional sources of SO_2 include industrial processes such as pulp and paper production.

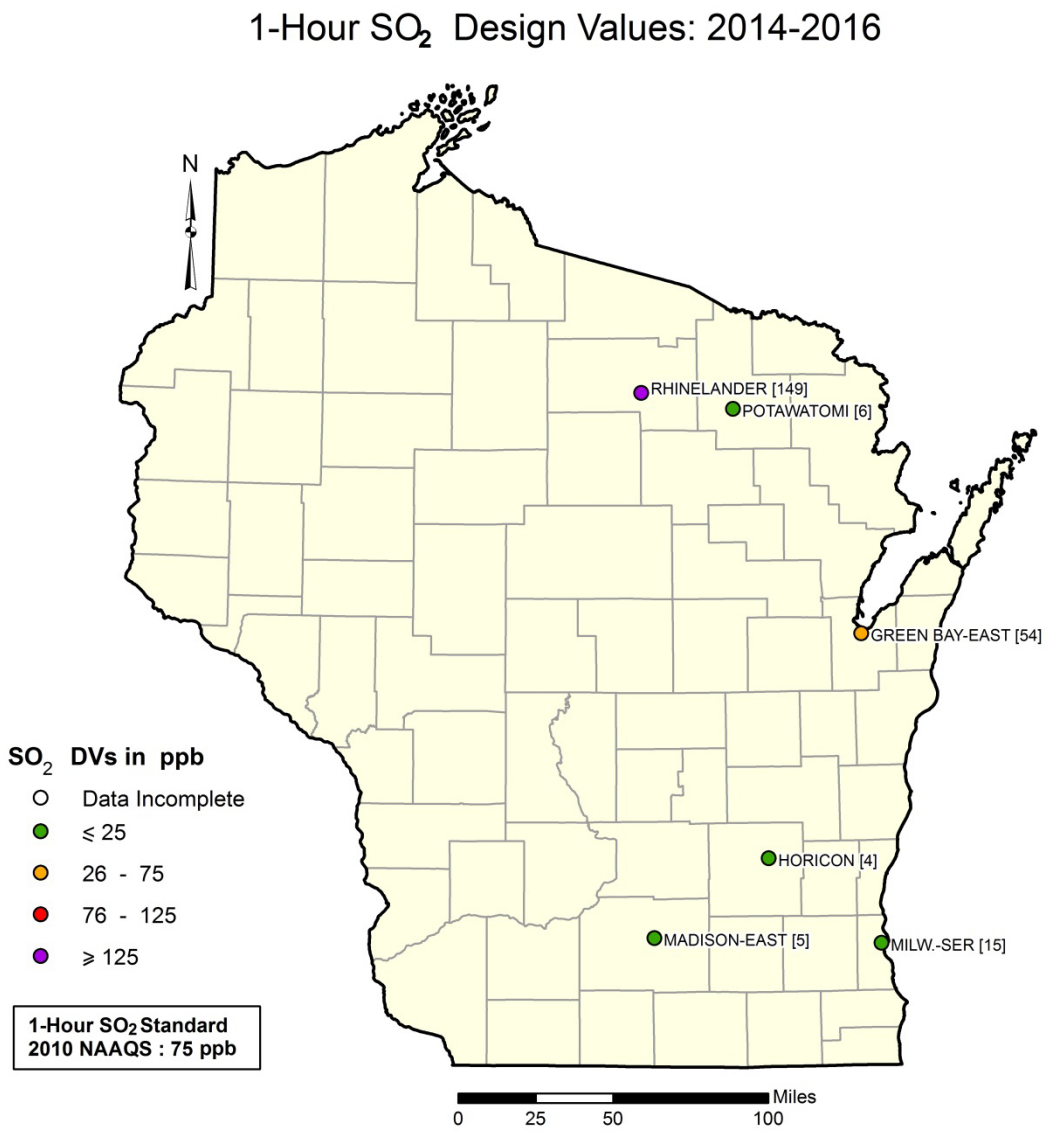


Figure 17. The 1-hr SO_2 design values for each monitoring site for 2014-2016.

Figure 18 shows trends in 1-hr SO_2 design values. Note that SO_2 monitoring was not conducted at the Milwaukee-SER site from 2007 through 2010, so no design values are available for 2005-2007 through 2010-2012.

As mentioned previously, the annual and 24-hr SO_2 standards were replaced with a 1-hr standard in 2010. To provide a clearer picture of trends in SO_2 concentrations over time, 1-hr design values were calculated for years prior to 2010, even though the 1-hr design values preceding 2010 were not used to assess NAAQS compliance.

Very low concentrations of SO_2 were observed at the Horicon, Madison-East, and Potawatomi sites. Low concentrations were also seen at the Milwaukee-SER site starting in 2011-2013. Design values from the Green Bay-East site were very close to the 2010 1-hour NAAQS until 2014-2016 when the design value decreased substantially to 54 ppb. Design values at the Rhinelander site have exceeded the NAAQS since the site was established. As a result, a portion of Oneida County is nonattainment for the 2010 SO_2 standard.

Compared to design values from the start of SO_2 monitoring at each site, values from 2014-2016 decreased at all sites, with the exception of the Rhinelander site. The largest reduction in SO_2 occurred at the Milwaukee-SER site, where design values decreased 78 percent since monitoring at the site began (Appendix B, Table B5).

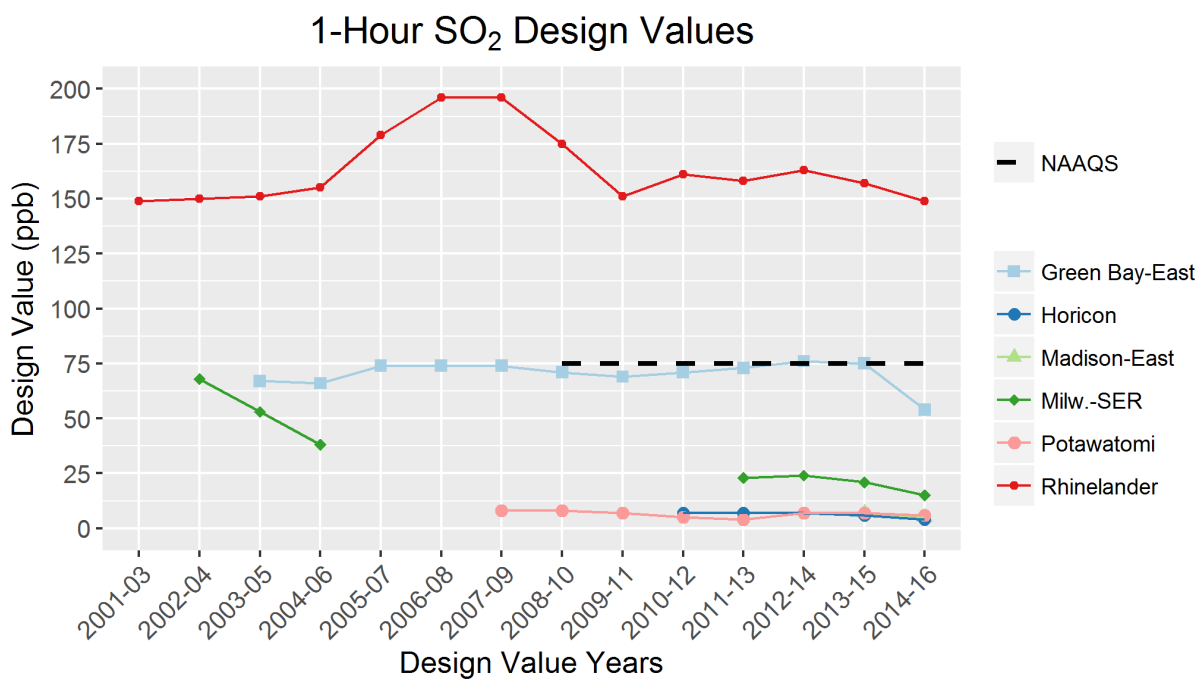


Figure 18. Trends in 1-hr SO_2 design values. Note that the 75 ppb 1-hr NAAQS was established in 2010, replacing the annual and 24-hr standards.

Nitrogen Dioxide

Figures 19 and 20 show annual and 1-hr design values for the two sites in the WDNR network that measure NO_2 year round. The annual design value is based on one year of data, while the 1-hr design value is based on three years of data. Nitrogen dioxide is emitted by all combustion sources, including vehicles, home and commercial heating systems, and power plants.

WDNR also monitors NO_2 at the Manitowoc site during the summer months (June-August) as part of the Photochemical Assessment Monitoring Stations network. Due to the shorter monitoring period, however, these values cannot be used to determine compliance with the NAAQS and are not included in this report. Monitoring for NO_2 at the Potawatomi site was discontinued in early 2016. Because NO_2 monitoring at this site is no longer active, historic NO_2 values from Potawatomi are also not included in this report.

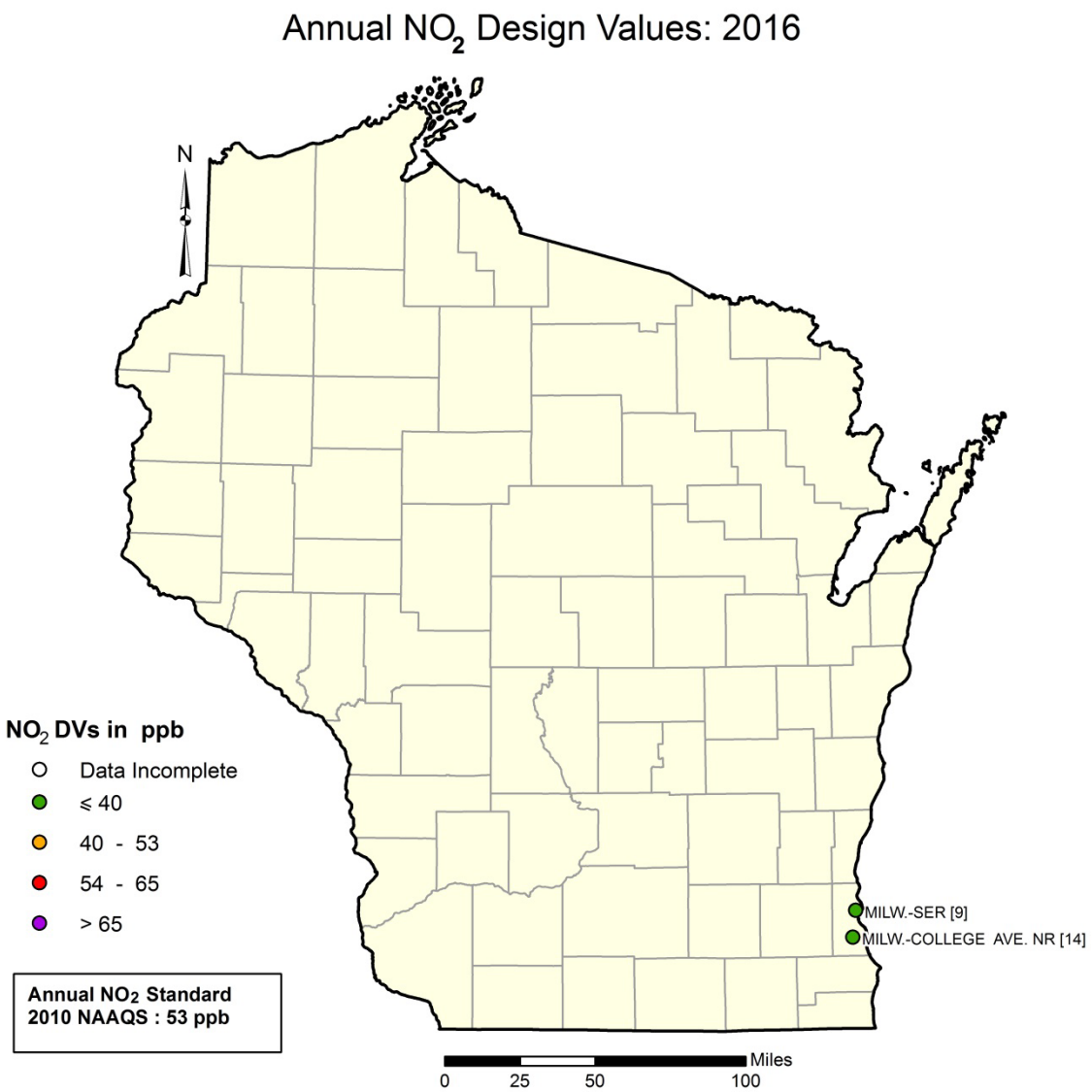


Figure 19. The annual NO_2 design values for each monitoring site for 2016.

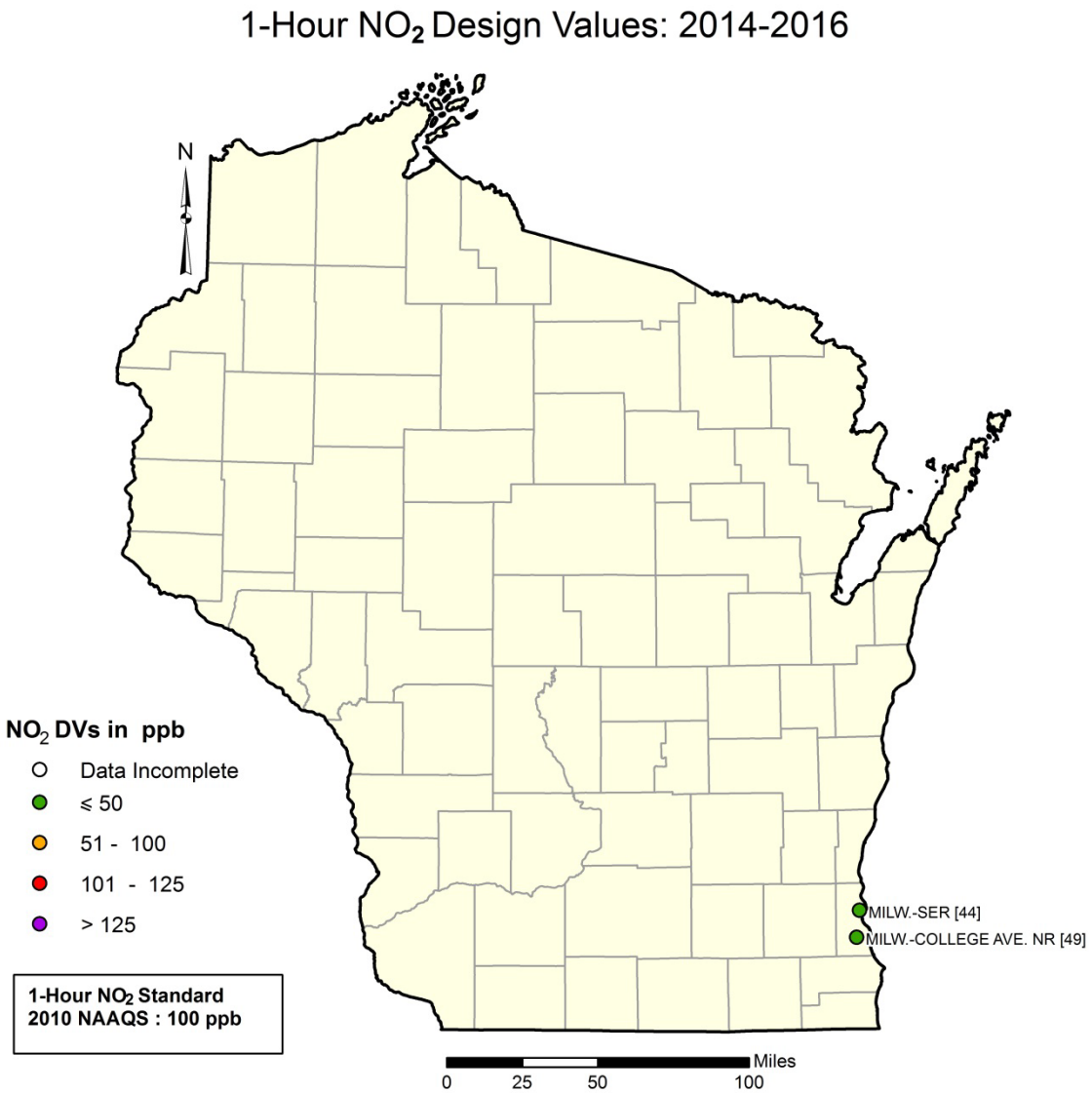


Figure 20. The 1-hr NO_2 design values for each monitoring site for 2014- 2016.

Figures 21 and 22 show trends in annual and 1-hr NO_2 design values. Overall, monitored levels of NO_2 were very low. The annual design values at both sites decreased over time, dropping from 17 ppb to 9 ppb between 2004 and 2016 at the Milwaukee-SER site (Appendix B, Table B6). The 1-hr design values at the Milwaukee-SER site have begun to decline again after remaining steady for the previous few years. The 1-hr design value at this site decreased 15 percent between 2004-2006 and 2014-2016 (Appendix B, Table B7). Because monitoring for NO_2 has begun only recently at the Milwaukee-College Avenue Near Road site, trends in the 1-hr design value at that site are not yet apparent.

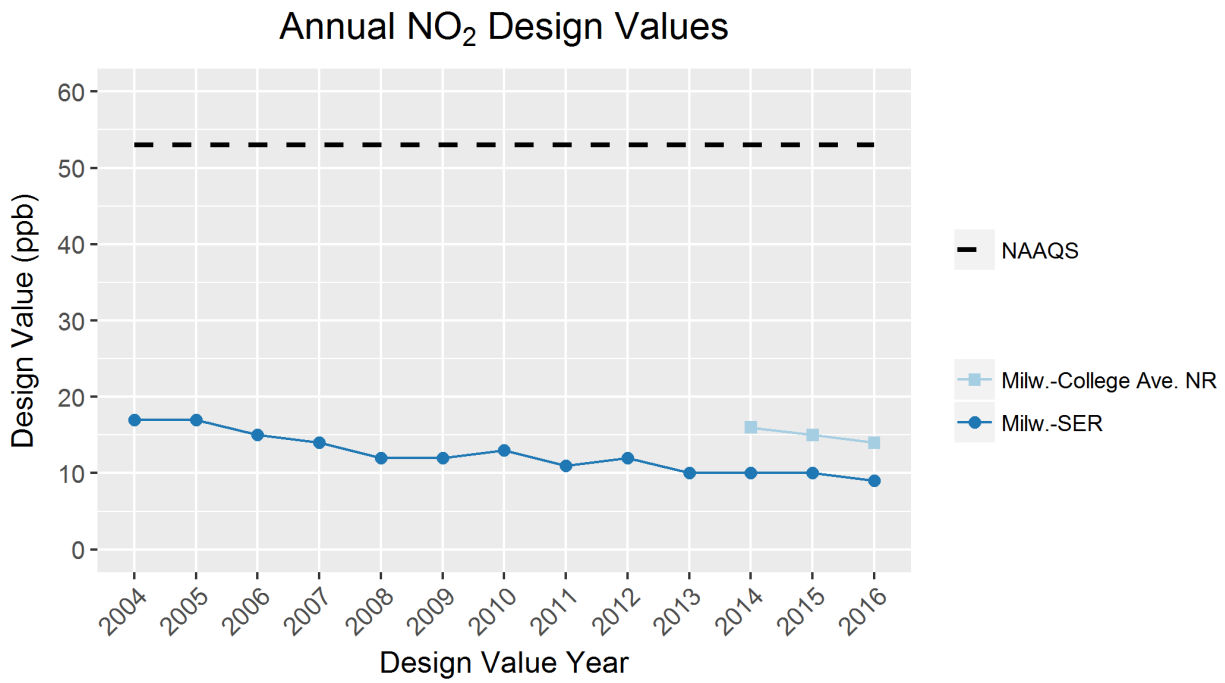


Figure 21. Trends in annual NO_2 design values.

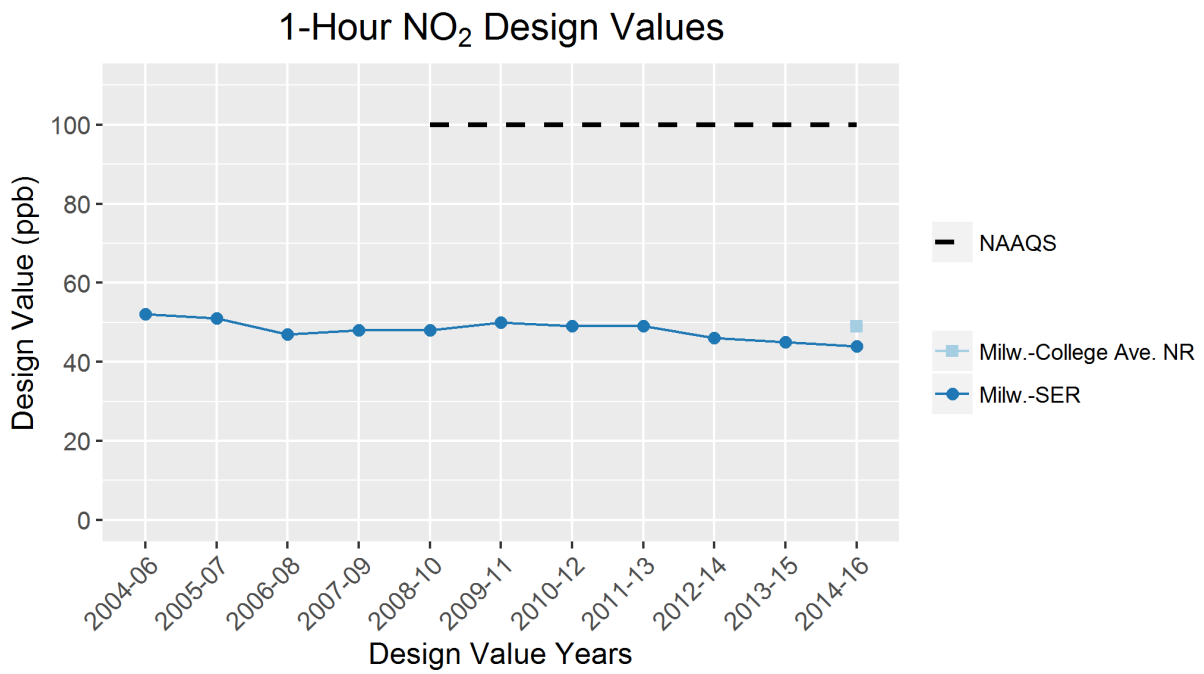


Figure 22. Trends in 1-hr NO_2 design values.

Lead

Lead is measured for comparison to the NAAQS at a monitoring site in the town of Kohler (Fig. 23) using two filter-based monitors operating at frequencies of 1-in-6 days and 1-in-12 days. Lead is emitted primarily as the result of industrial processes, such as metallic processing, power production, and waste incineration. The NAAQS is based on a rolling 3-mo average, which is not to exceed 0.15 $\mu g/m^3$. The design value is expressed as the maximum 3-mo average over a 3-yr period. The design value at the Kohler site does not exceed the lead NAAQS.

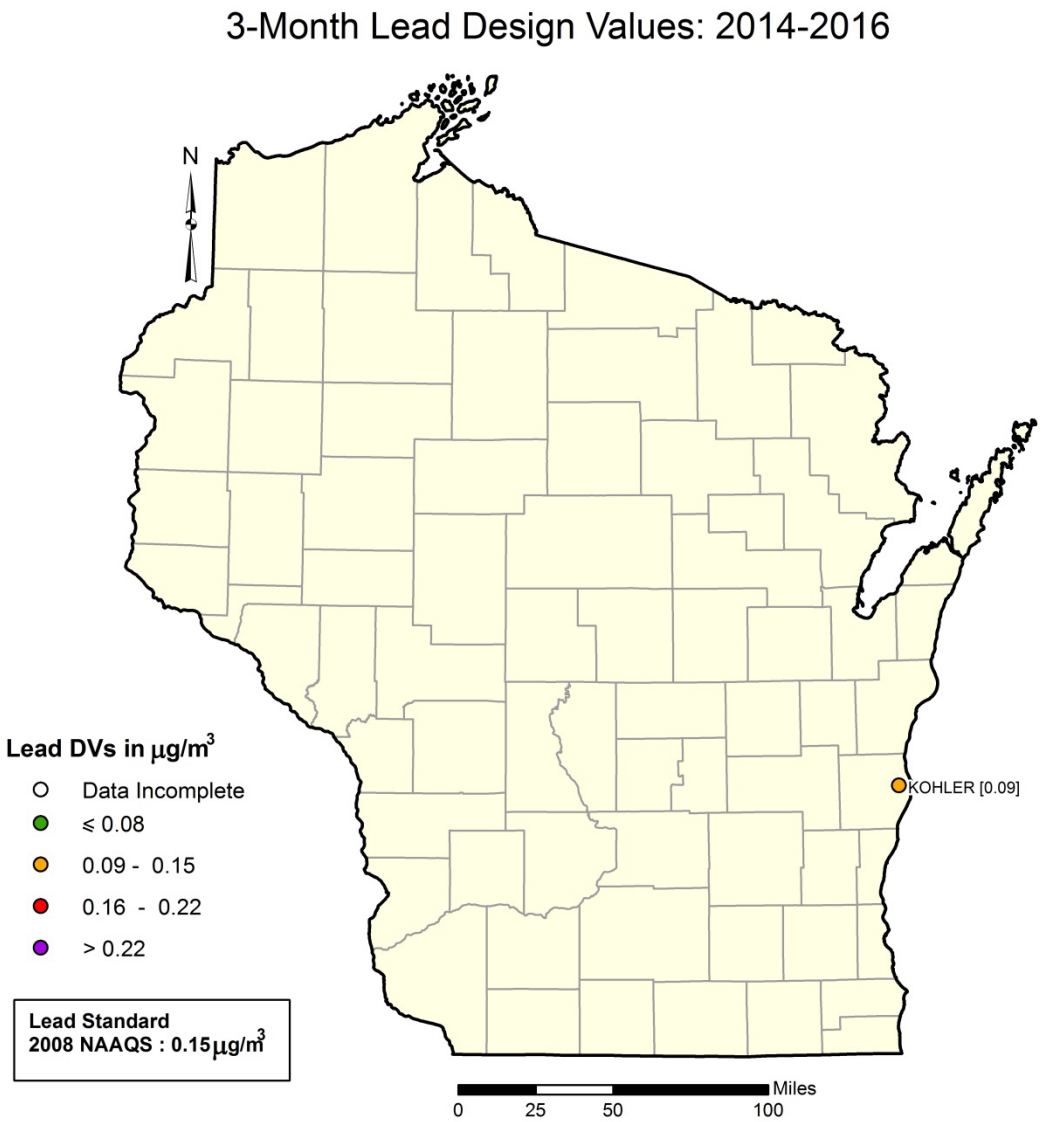


Figure 23. The 3-mo lead design values for 2014-2016.

WDNR also monitors lead at the Horicon and Milwaukee-16th St. sites as part of the National Air Toxics Trends Stations network and Urban Air Toxics program, respectively. The fraction of particles monitored for lead at these sites (i.e., PM_{10}), however, differs from that required for lead criteria pollutant monitoring (i.e., TSP). As a result of this difference, the lead monitoring data from the Horicon and Milwaukee-16th St. sites cannot be used to determine compliance with the NAAQS and are not included in this report.

Figure 24 shows the trend in 3-mo lead design values. Lead was monitored at this site prior to 2012; however, previous design values were not valid and therefore are not shown. Lead design values at the Kohler site have been decreasing. The most recent 3-mo design value at the site (2014-2016) was 18 percent lower than the first valid design value determined in 2012-2014 (Appendix B, Table B8).

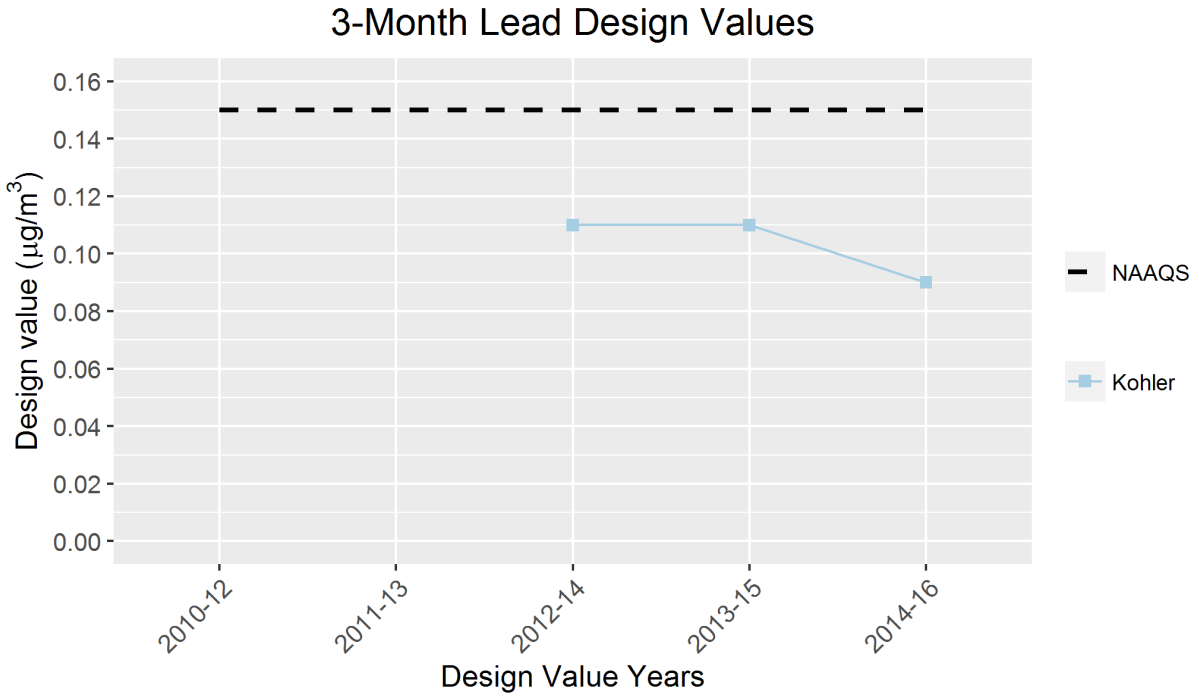


Figure 24. Trends in 3-mo lead design values.

Carbon Monoxide

Carbon monoxide is monitored at two sites in the WDNR network. Design values are compared against an 8-hr and a 1-hr NAAQS (Figs 25 and 26, respectively). Both design values are based on one year of data.

The main source of CO is motor vehicle emissions. As a result, higher concentrations are typically observed in urban areas. Nationwide, levels of this pollutant have decreased over the past two decades with the help of emission control technologies. Consequently, all areas in Wisconsin currently meet federal standards.

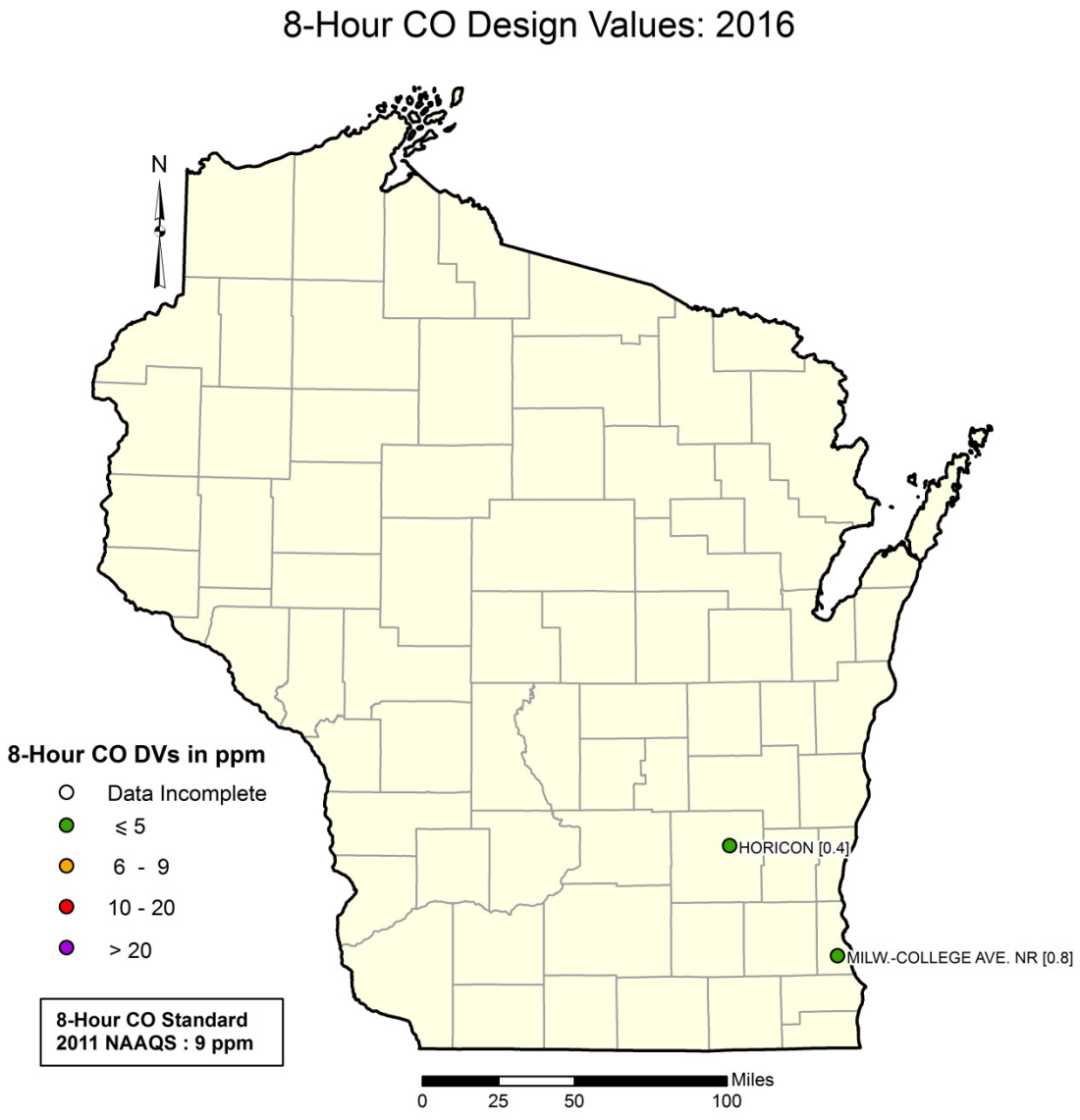


Figure 25. The 8-hr CO design values for each monitoring site for 2016.

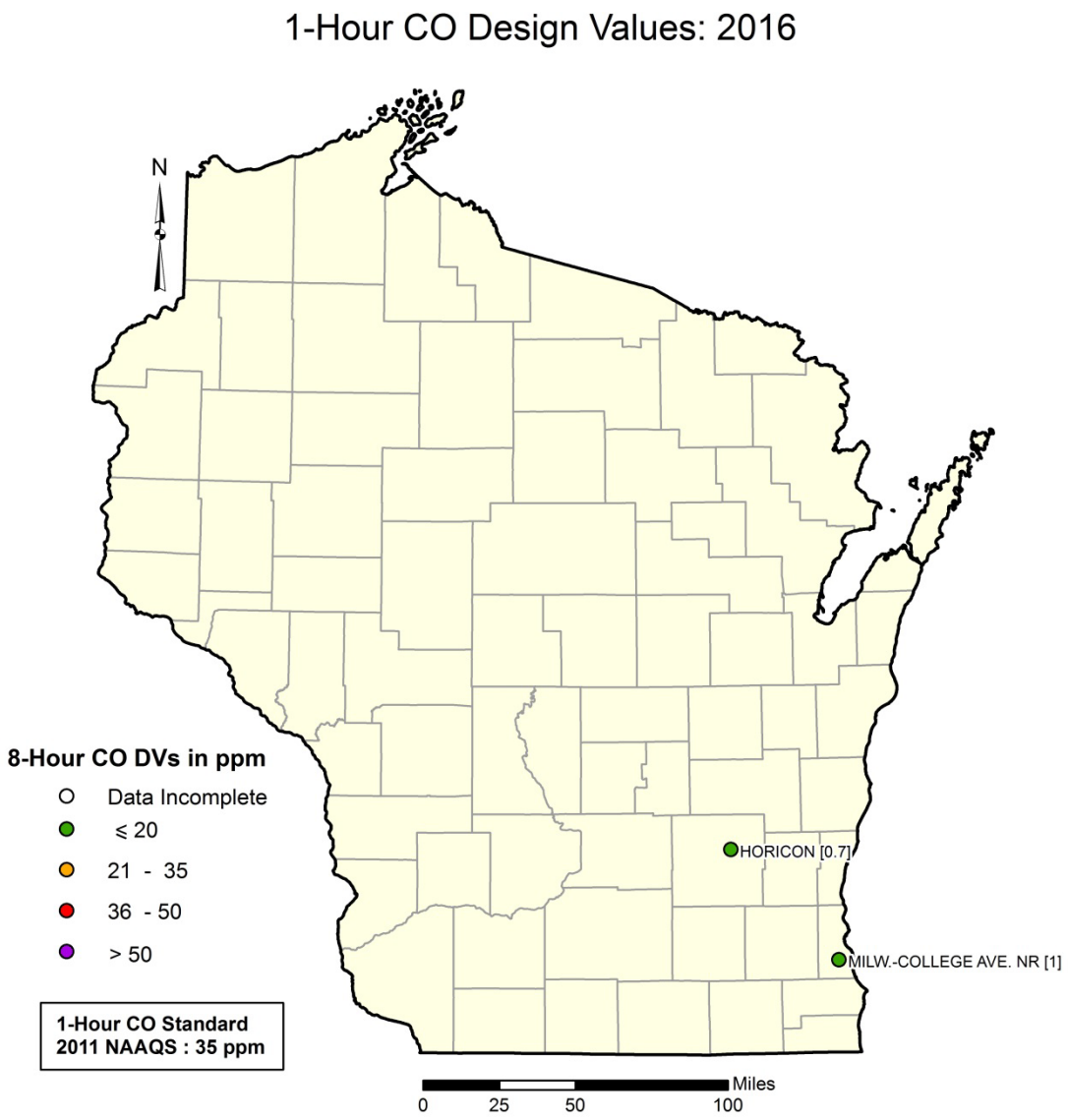


Figure 26. The 1-hr CO design values for each monitoring site for 2016.

Figures 27 and 28 show trends in 8-hr and 1-hr CO design values, which were extremely low at both sites (Appendix B, Table B9).

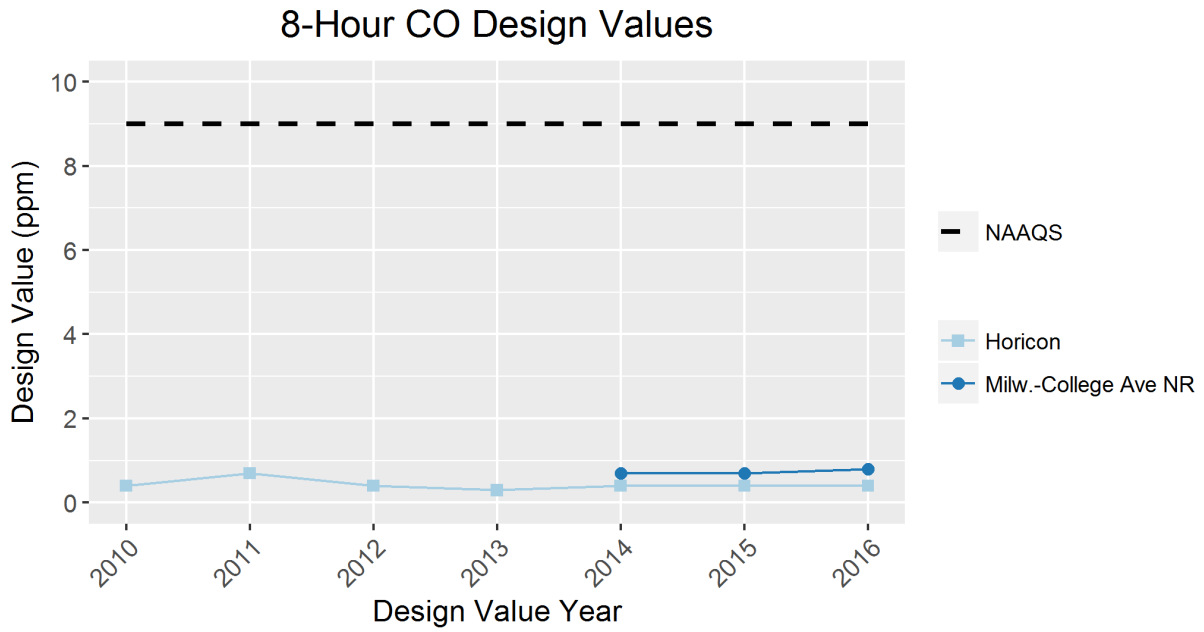


Figure 27. Trends in 8-hr CO design values.

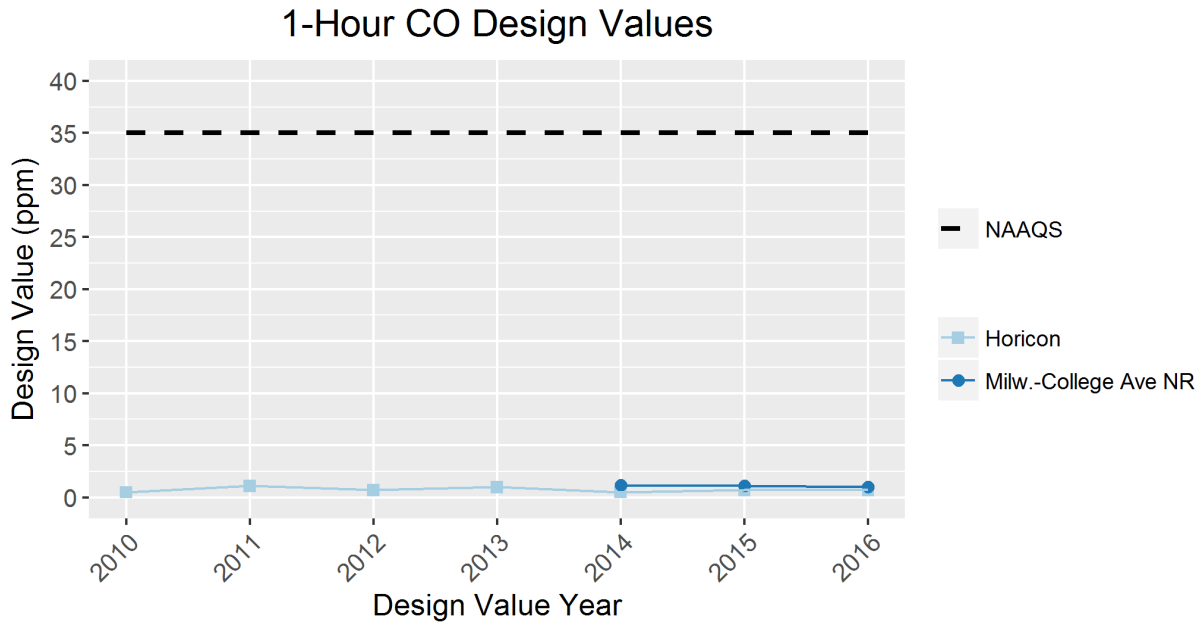
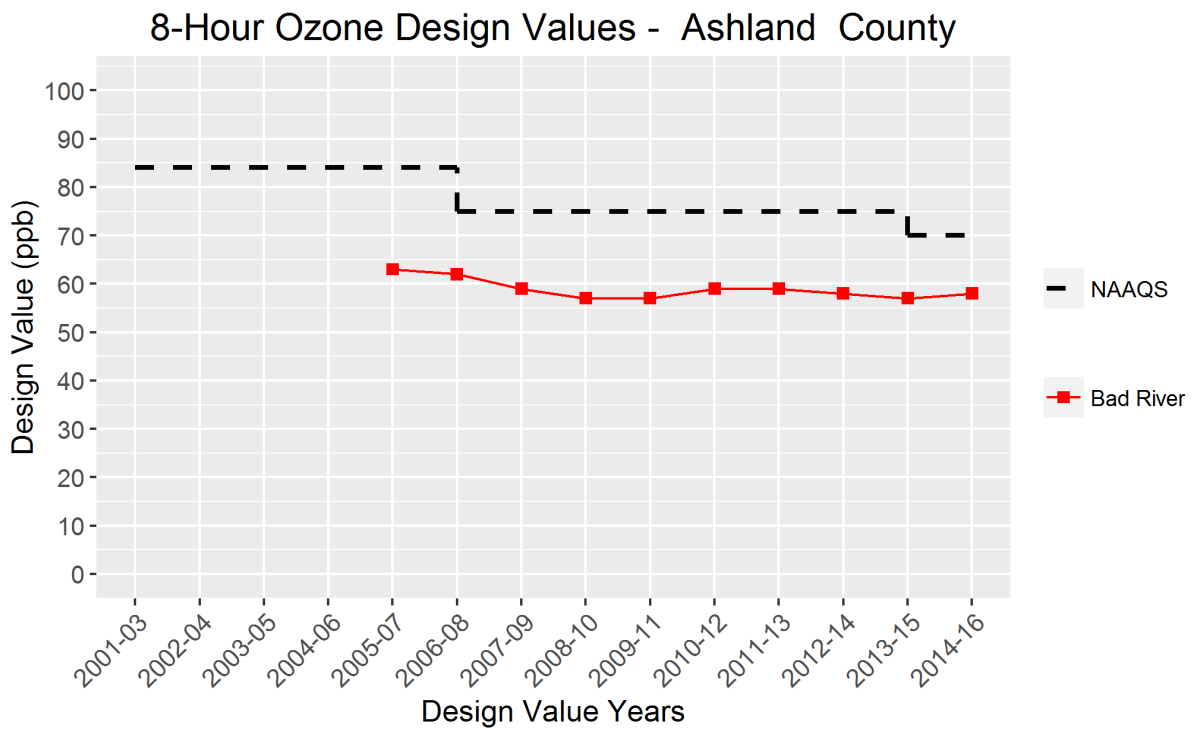


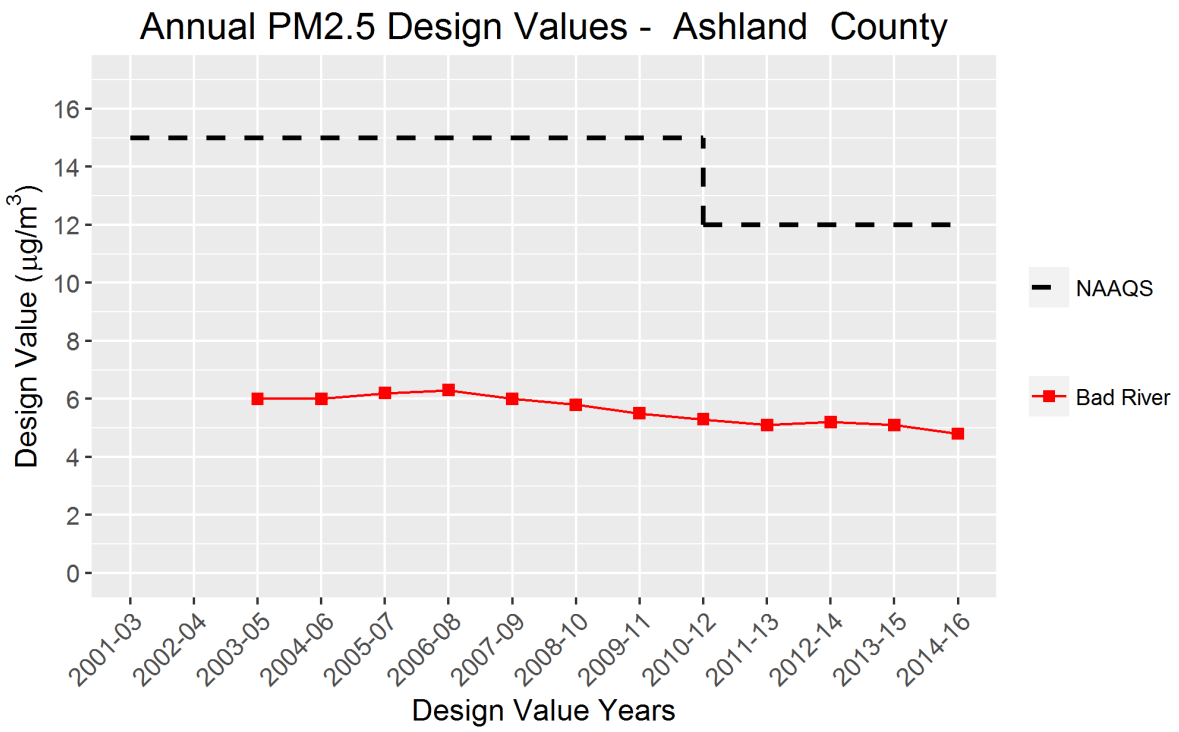
Figure 28. Trends in 1-hr CO design values.

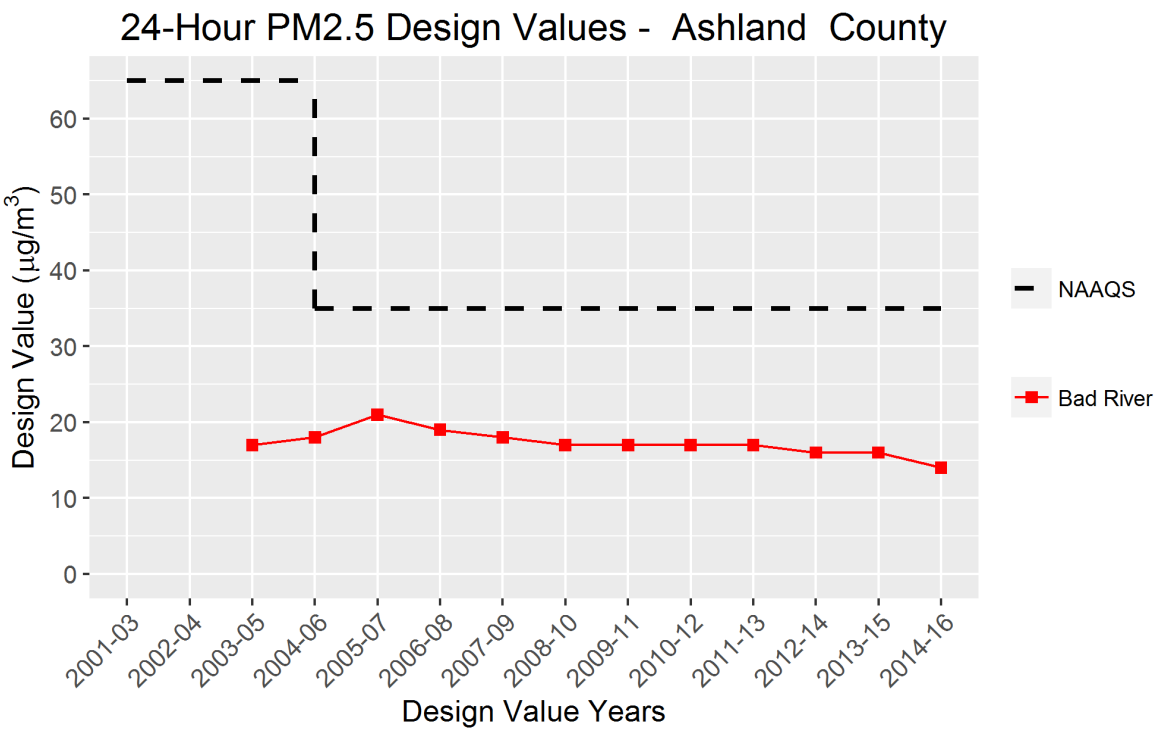
Appendix A. – Air Quality by County

Ashland County

Monitoring for ozone and $PM_{2.5}$ is conducted by the Bad River Tribe at the Bad River Tribal School, which is located at 10 Birch Street in Odanah.

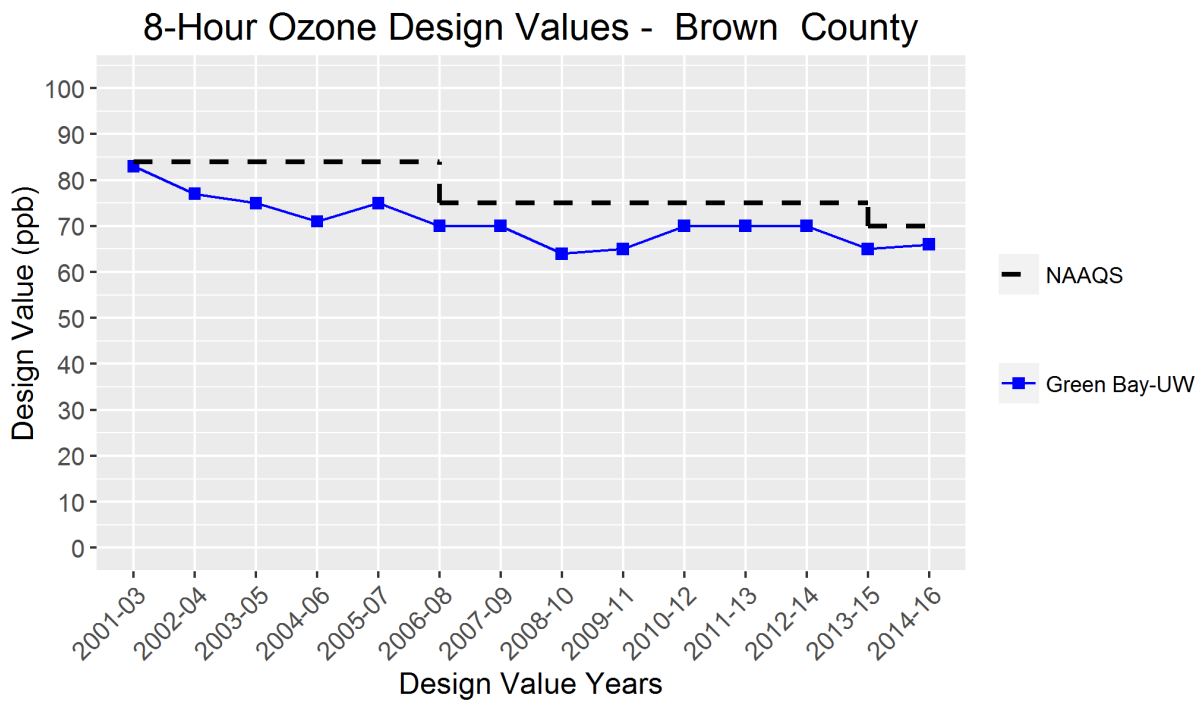


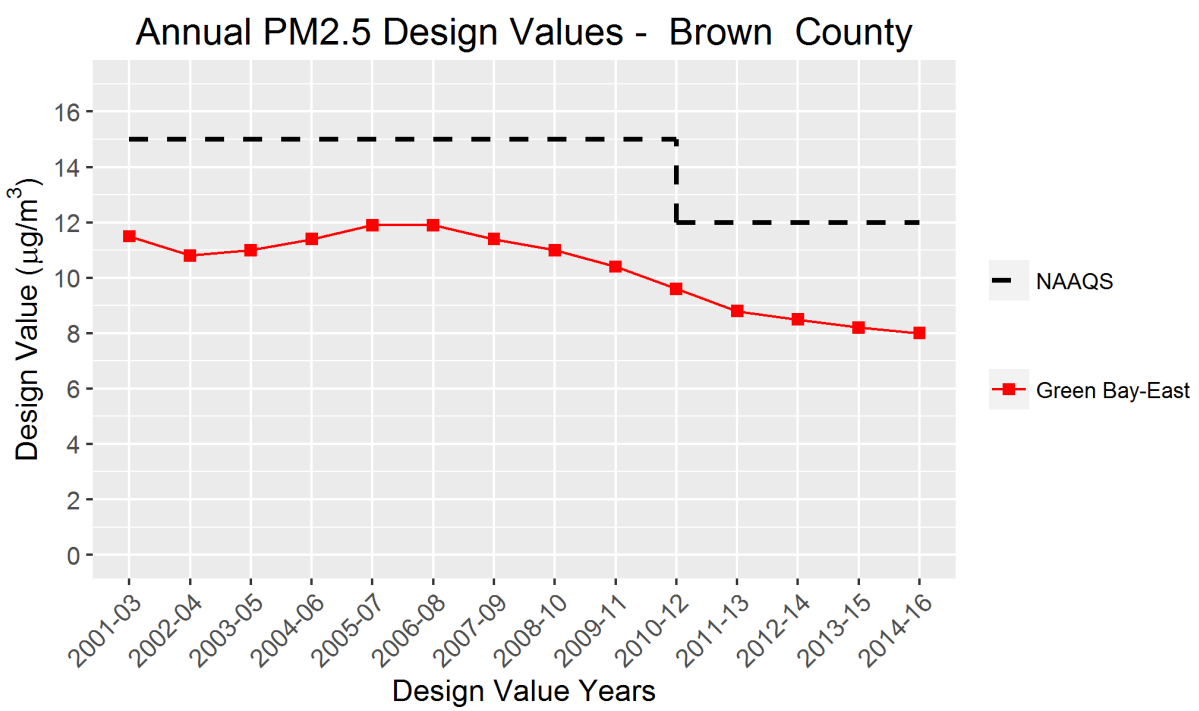

Annual PM2.5 Design Values - Ashland County
Design Value (µg/m3)
16
14
12
10
8
6
4
2
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Bad River

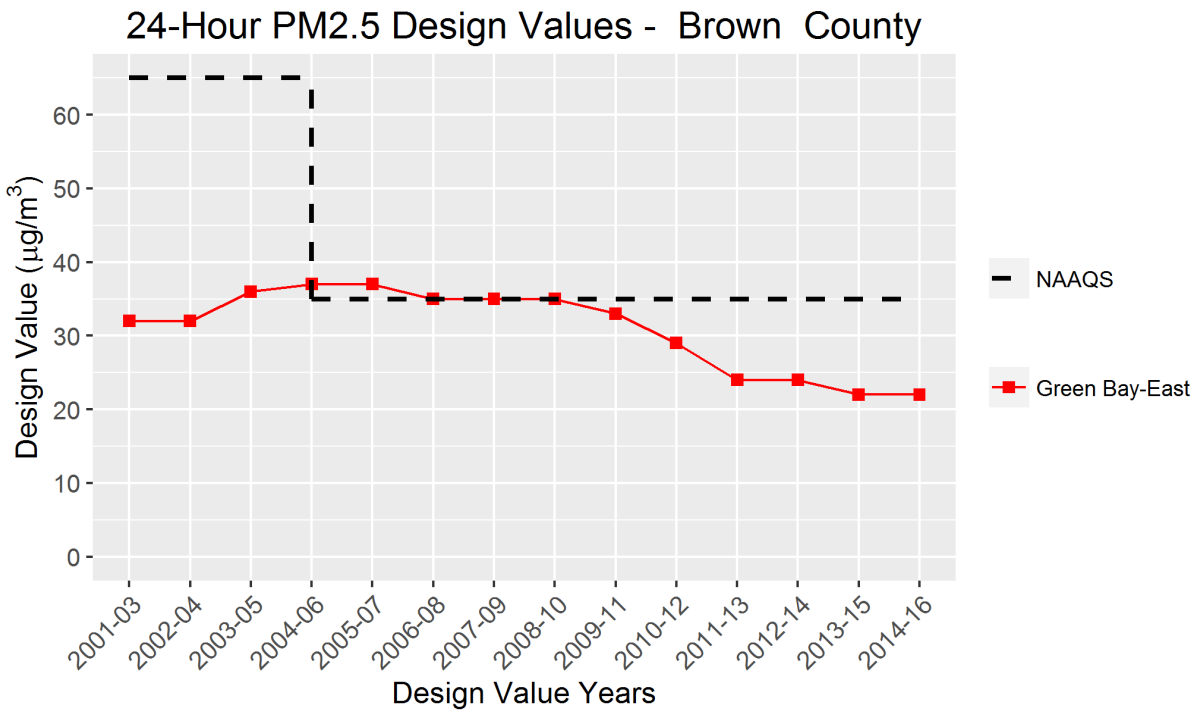

24-Hour PM2.5 Design Values - Ashland County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Bad River

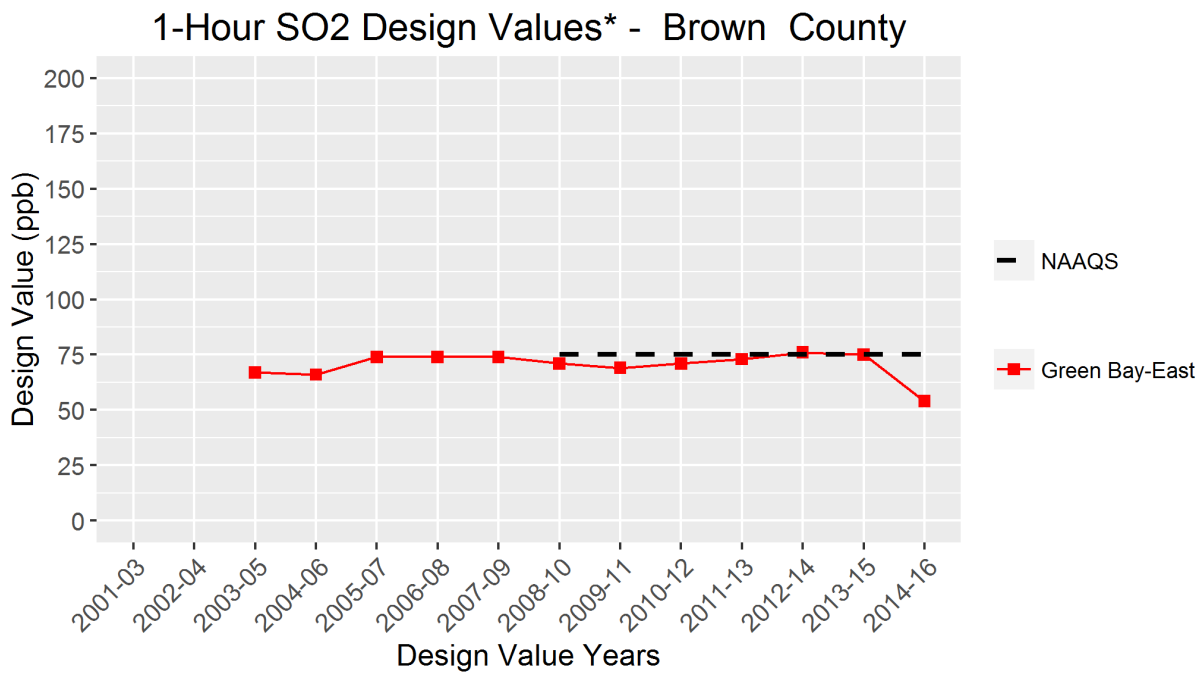
Brown County

Ozone monitoring in Brown County takes place north of Highways 54 & 57 east of the University of Wisconsin–Green Bay campus. Monitoring for $PM_{2.5}$ and SO_2 is conducted at Green Bay East High School, located at 1415 East Walnut Street.





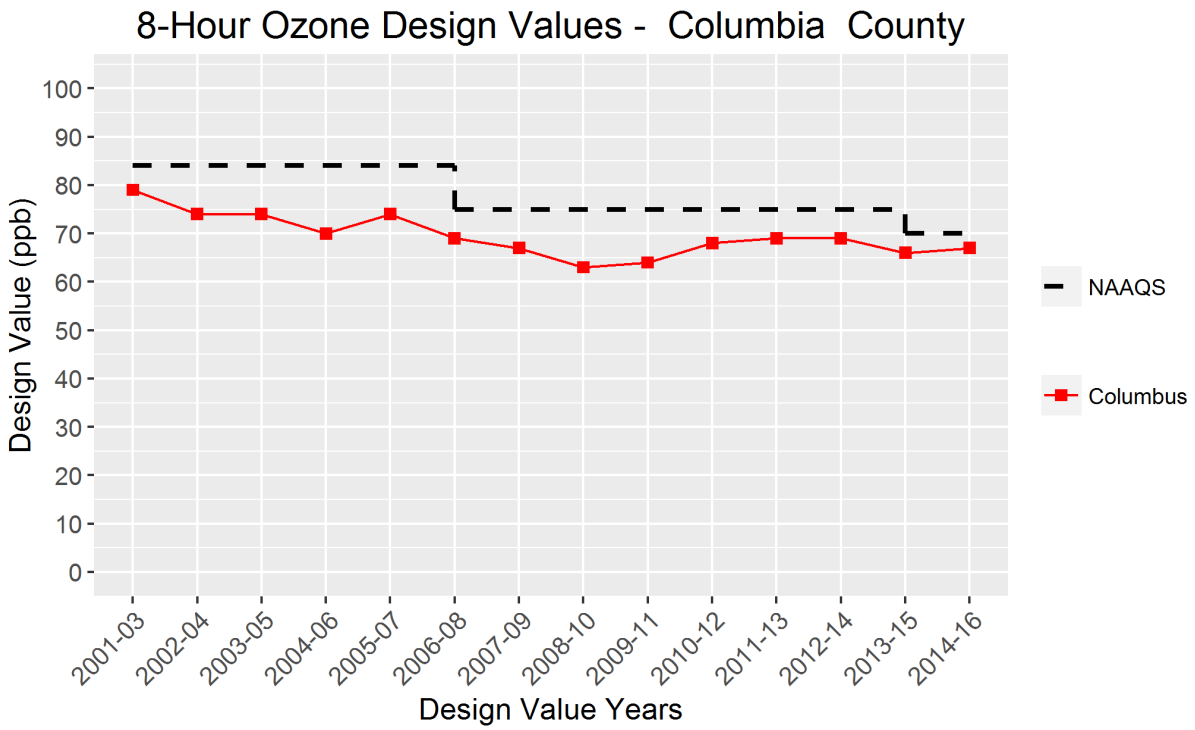




*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous annual and 24-hr standards.

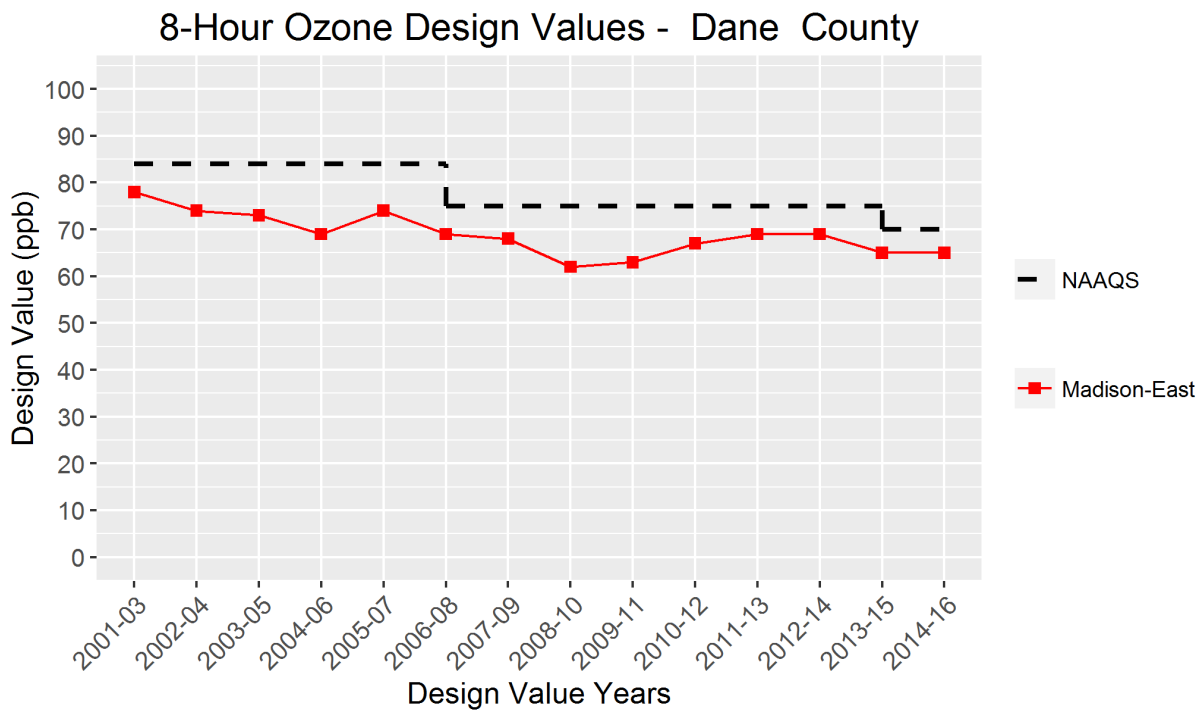
Columbia County

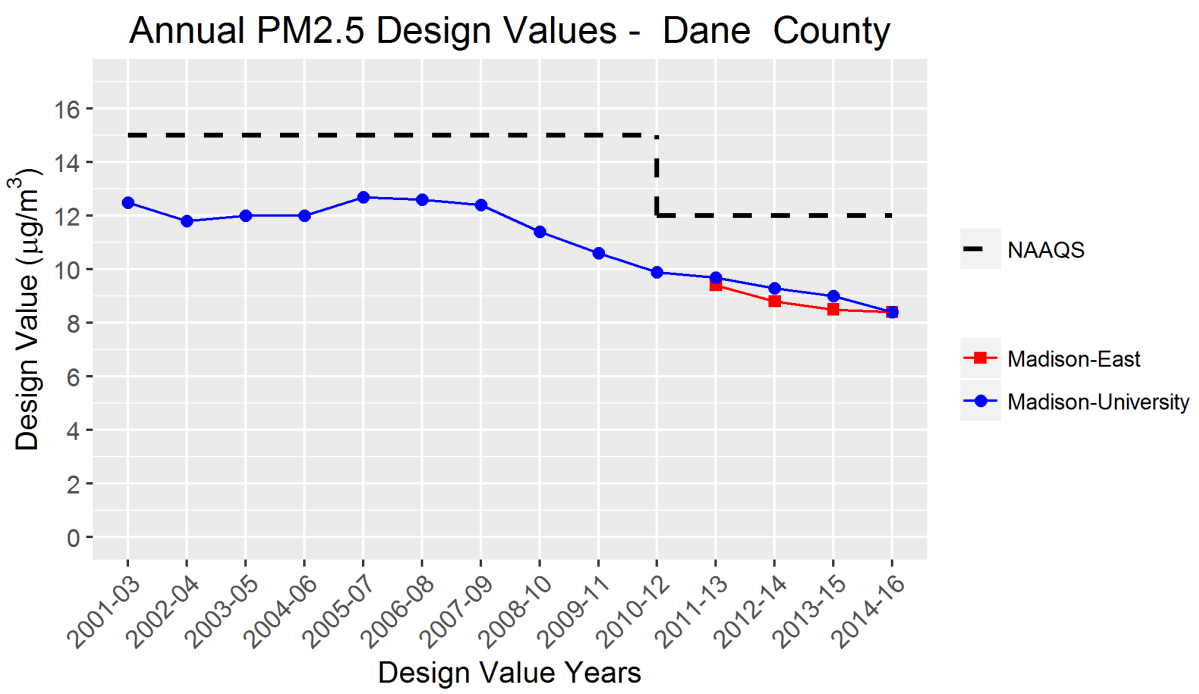
Ozone monitoring in Columbia County takes place at N 1045 Wendt Road, a rural location in Columbus Township. This location serves as the downwind ozone site in the Madison Core Based Statistical Area.

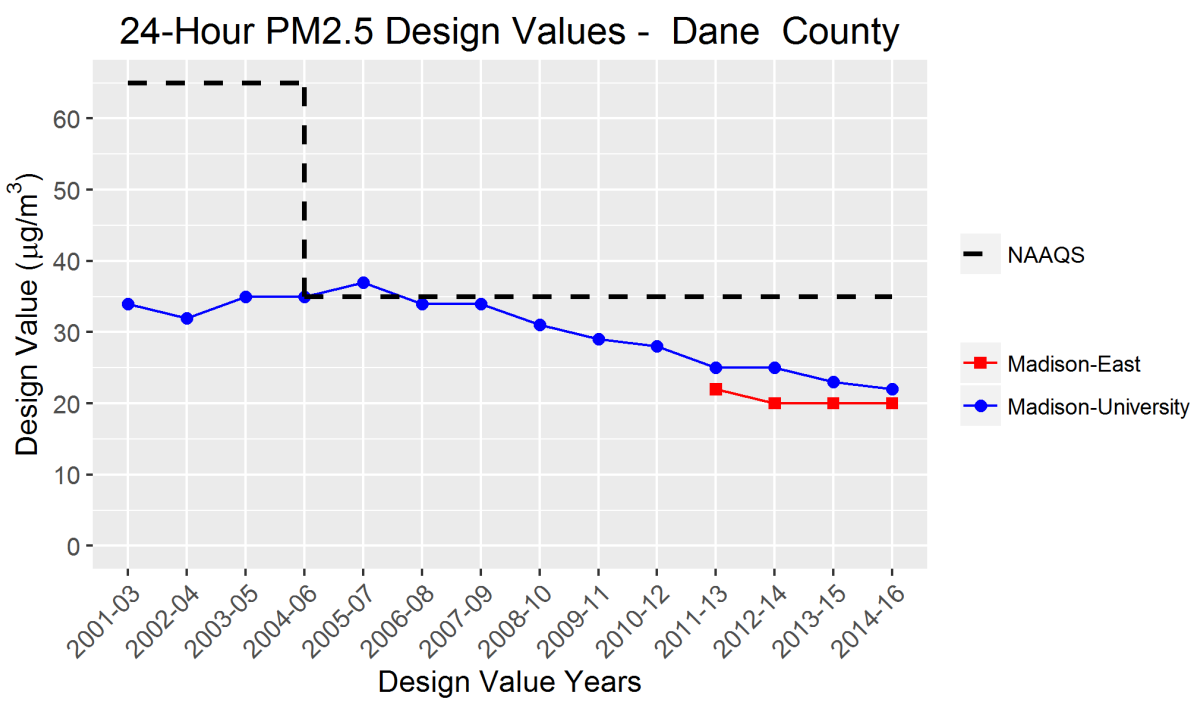


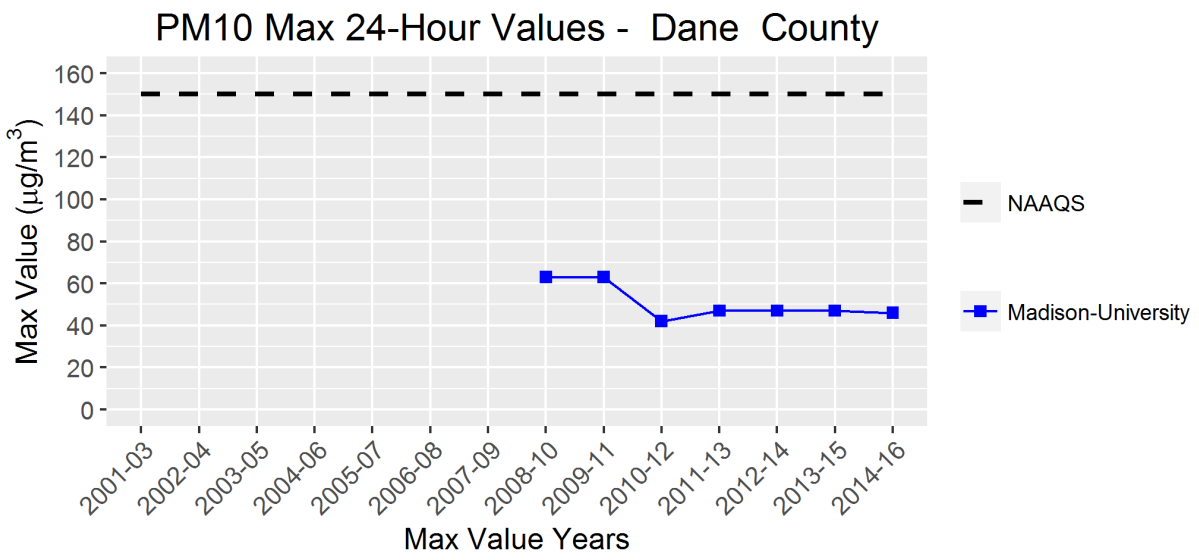
Dane County

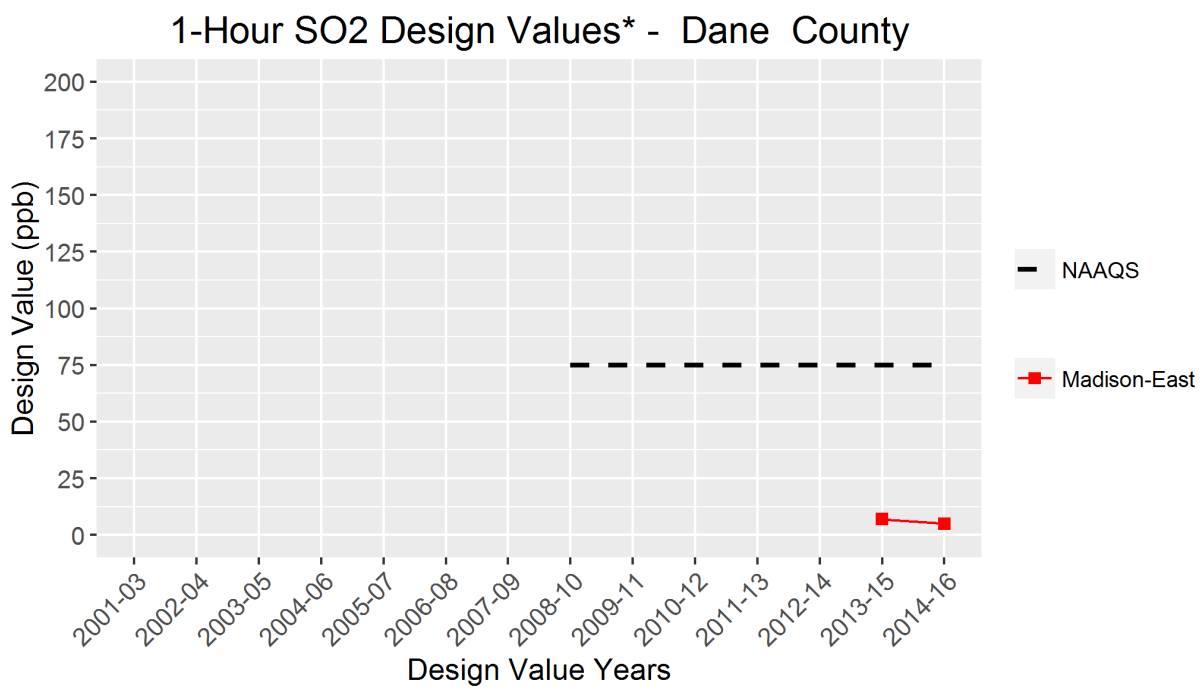
Ozone monitoring in Dane County takes place at Madison East High School, located at 2302 North Hoard Street, next to the Madison East High School sports field. Fine particles are monitored at both the Madison-East site and the Madison-University Avenue site, located at 2757 University Avenue. Monitoring of PM_{10} takes place at the Madison-University Avenue site only. Sulfur dioxide monitoring restarted at the Madison-East site in 2013.




Annual PM2.5 Design Values - Dane County
Design Value (µg/m3)
16
14
12
10
8
6
4
2
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Madison-East
Madison-University


24-Hour PM2.5 Design Values - Dane County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Madison-East
Madison-University

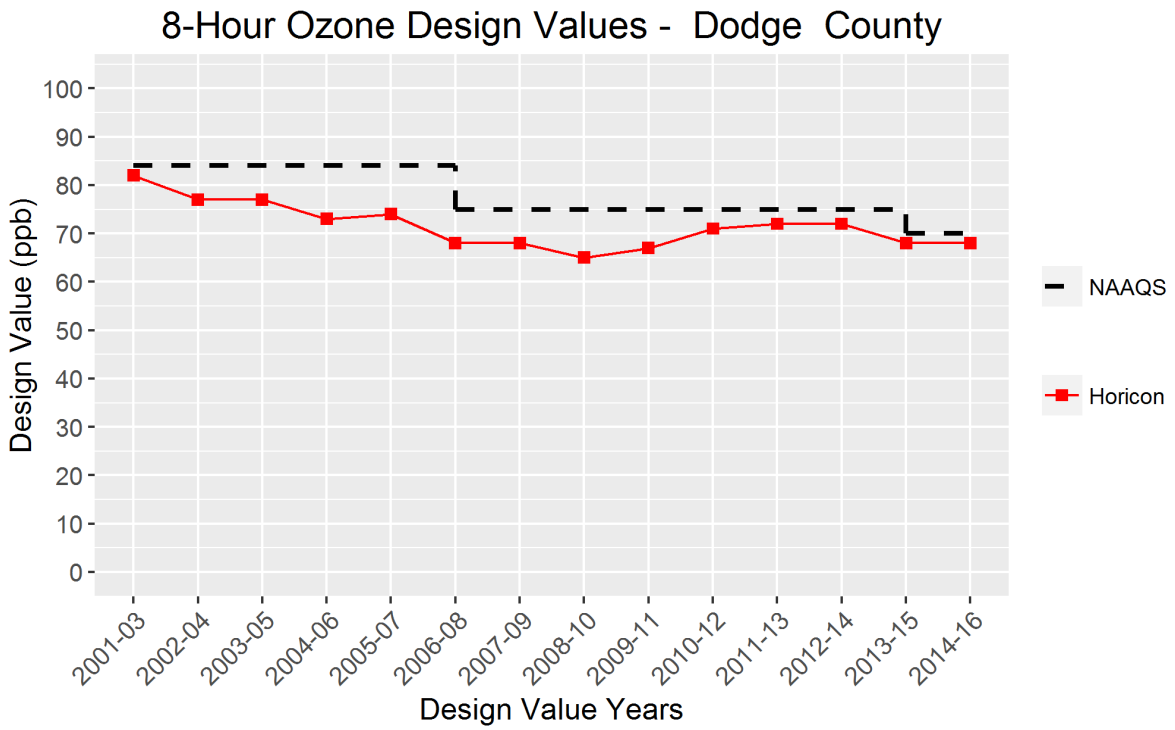


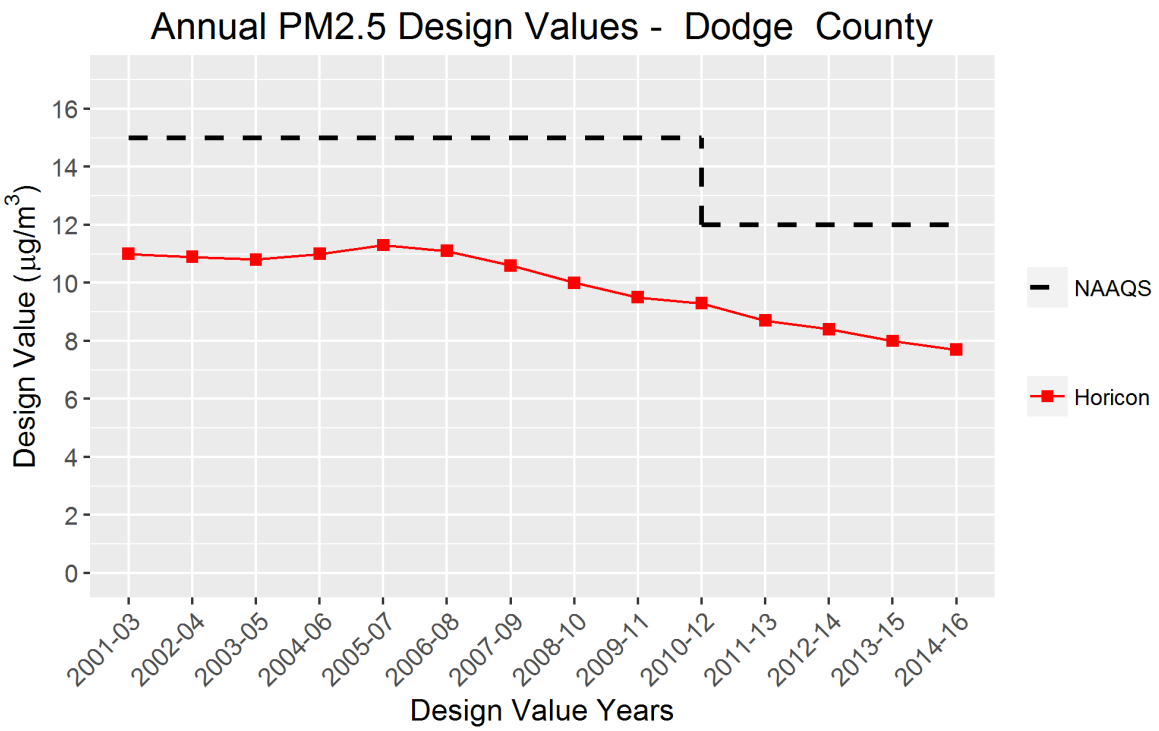


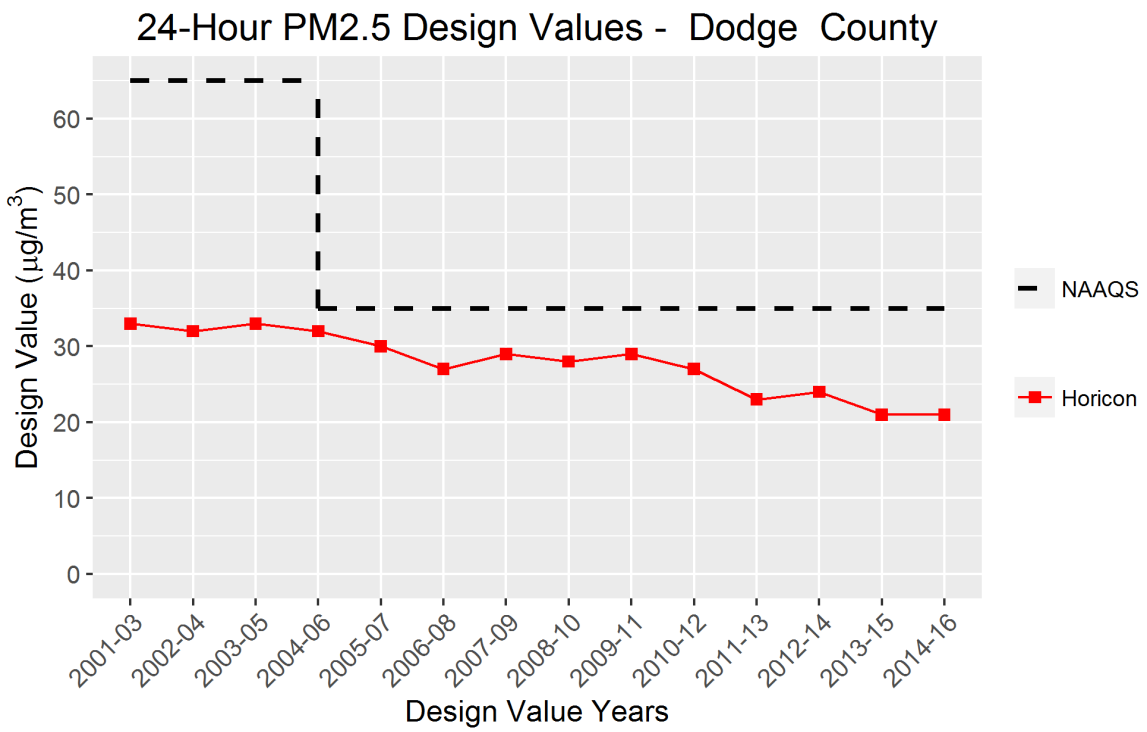
*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous annual and 24-hr standards.

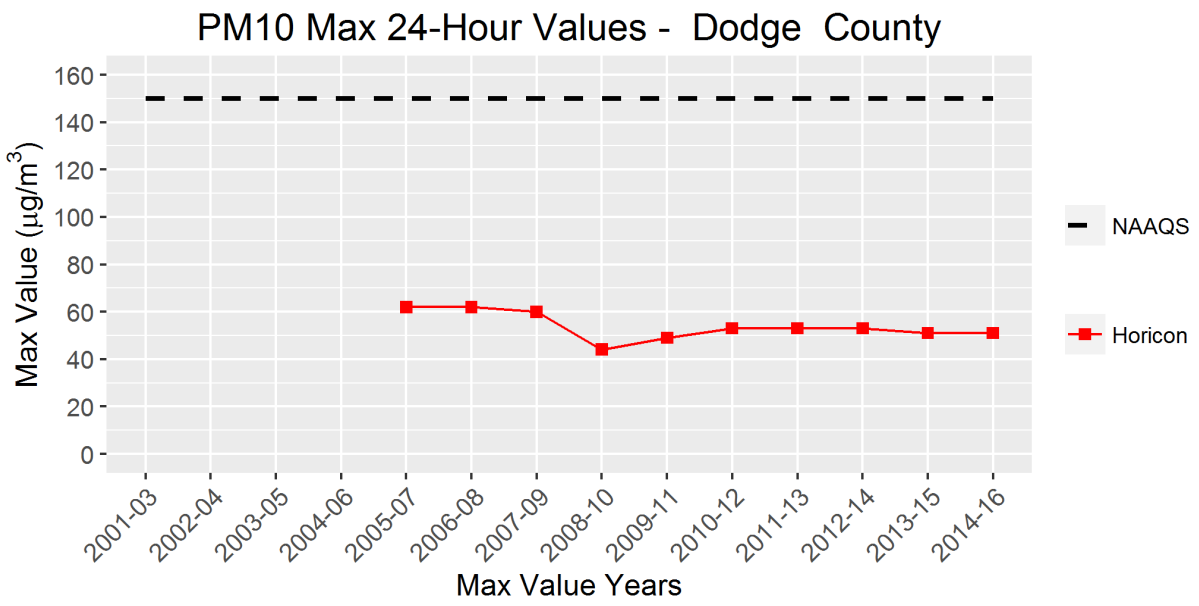
Dodge County

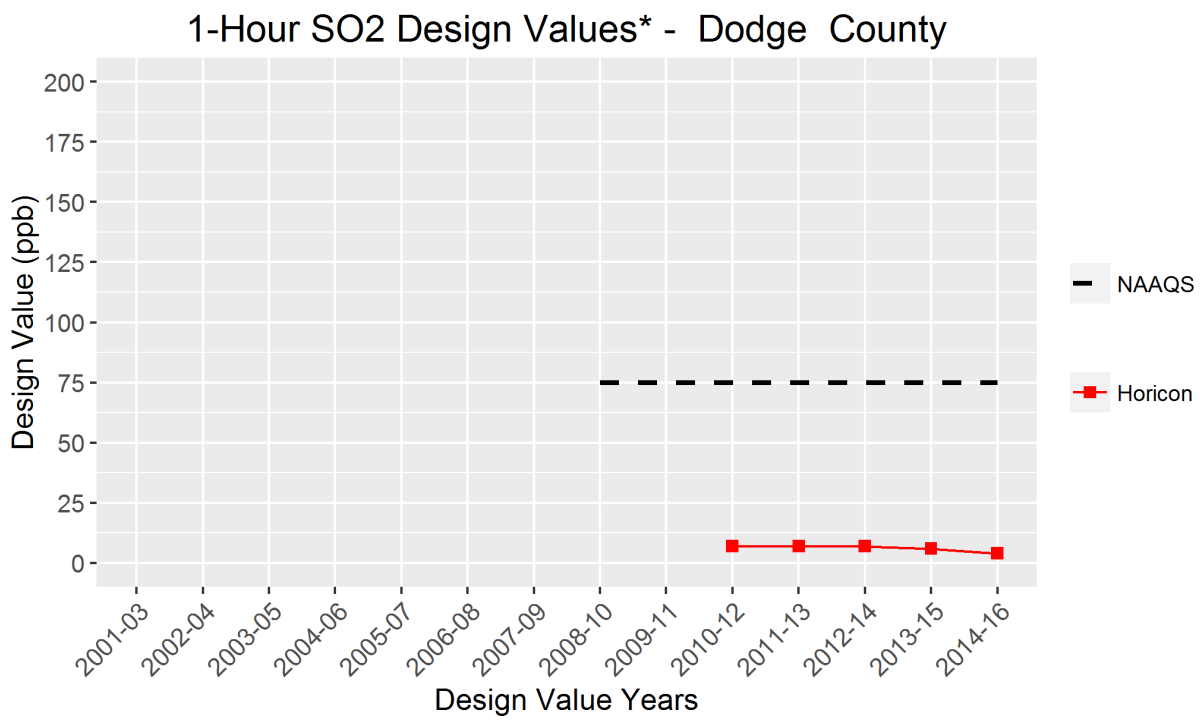
Monitoring for ozone, $PM_{2.5}$, PM_{10}, SO_2, and CO in Dodge County is conducted at the Horicon Wildlife Area, located at 1210 North Palmatory Street. The Horicon site began sampling for ozone on January 22, 2010 and for 24-hr $PM_{2.5}$ on December 18, 2009. Prior to these dates, sampling in Dodge County was performed at a site near Mayville. Data from both sites are used to calculate design values for 2008-2010, 2009-2011, and 2010-2012.



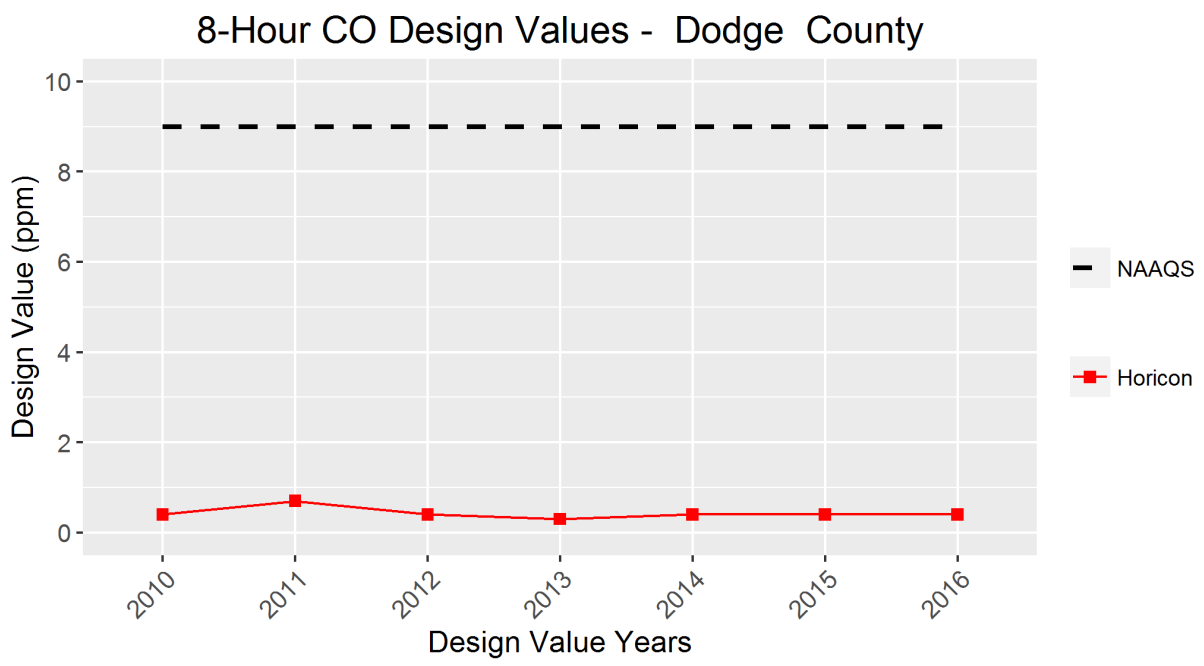

Annual PM2.5 Design Values - Dodge County
Design Value (µg/m3)
16
14
12
10
8
6
4
2
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Horicon

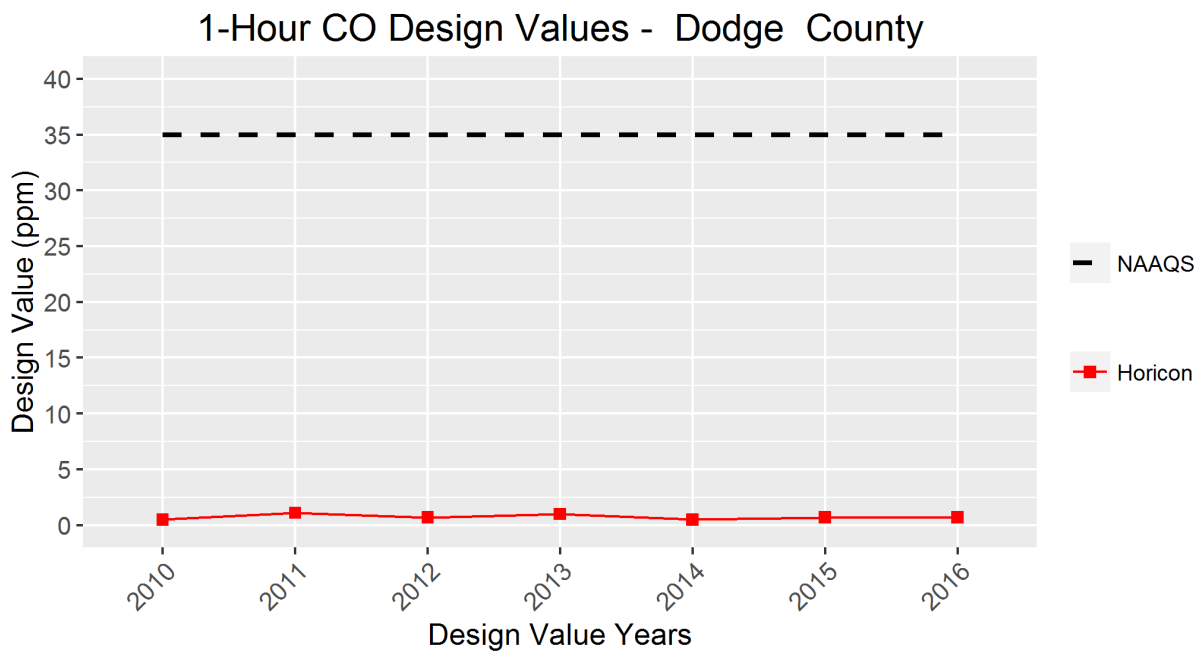

24-Hour PM2.5 Design Values - Dodge County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Horicon





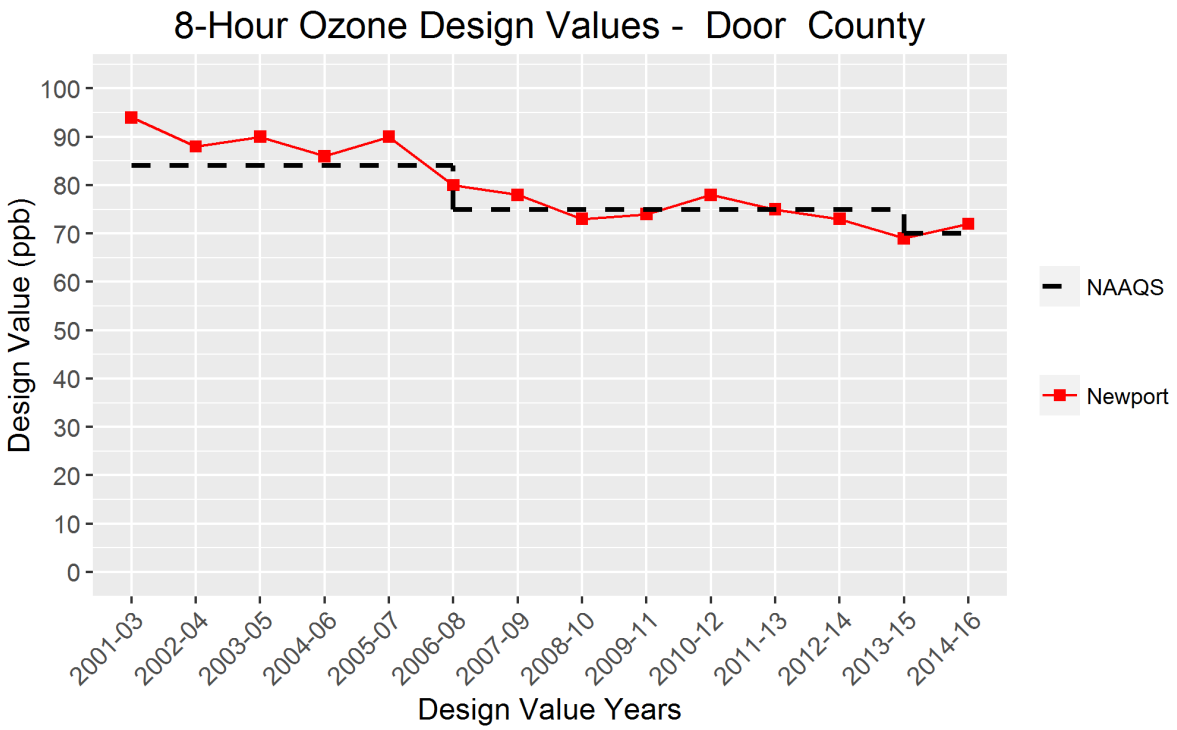
*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous annual and 24-hr standards.


8-Hour CO Design Values - Dodge County
Design Value (ppm)
10
8
6
4
2
0
2010
2011
2012
2013
2014
2015
2016
Design Value Years
NAAQS
Horicon


1-Hour CO Design Values - Dodge County
Design Value (ppm)
40
35
30
25
20
15
10
5
0
2010
2011
2012
2013
2014
2015
2016
Design Value Years
NAAQS
Horicon

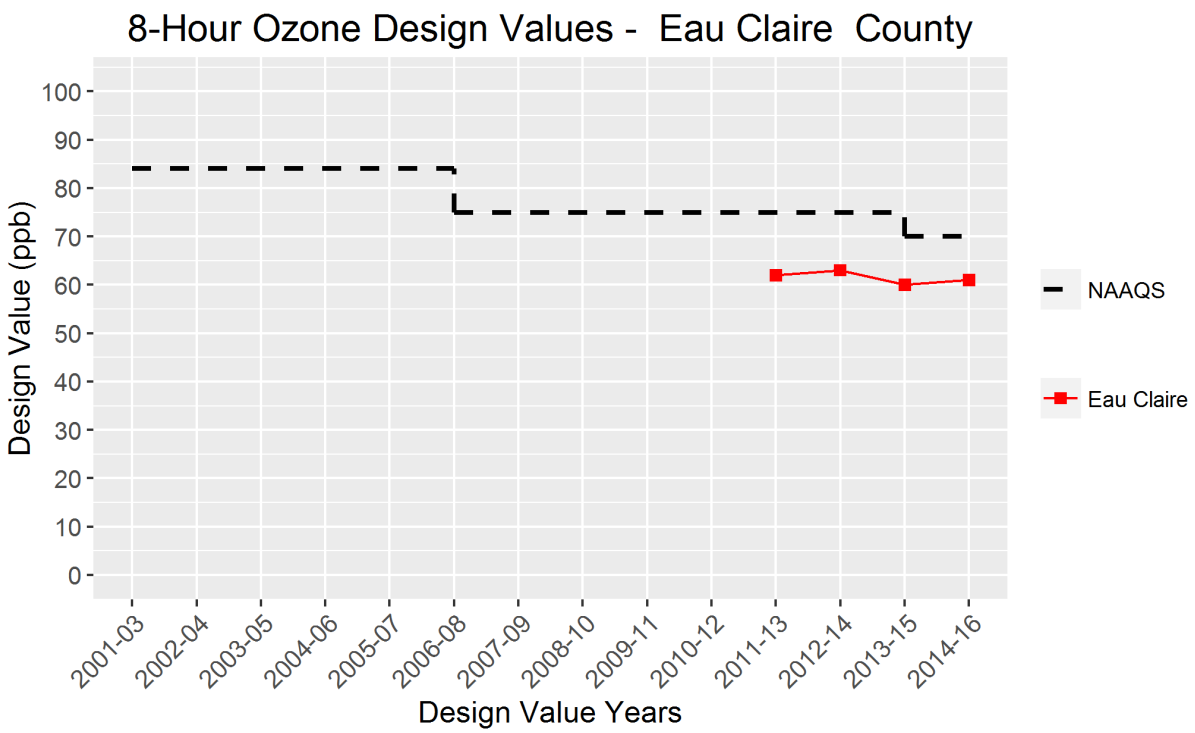
Door County

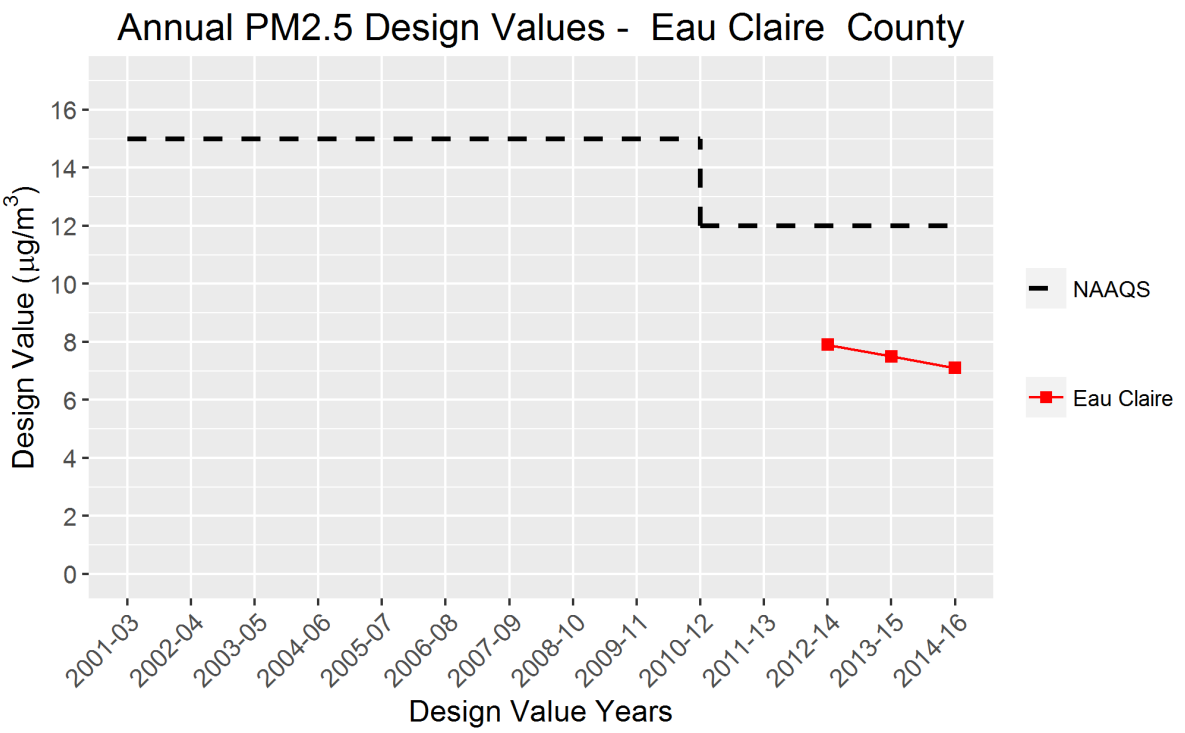
Ozone monitoring in Door County takes place at Newport State Park at 475 County Trunk Highway NP in Ellison Bay. The site is located inside the state park.

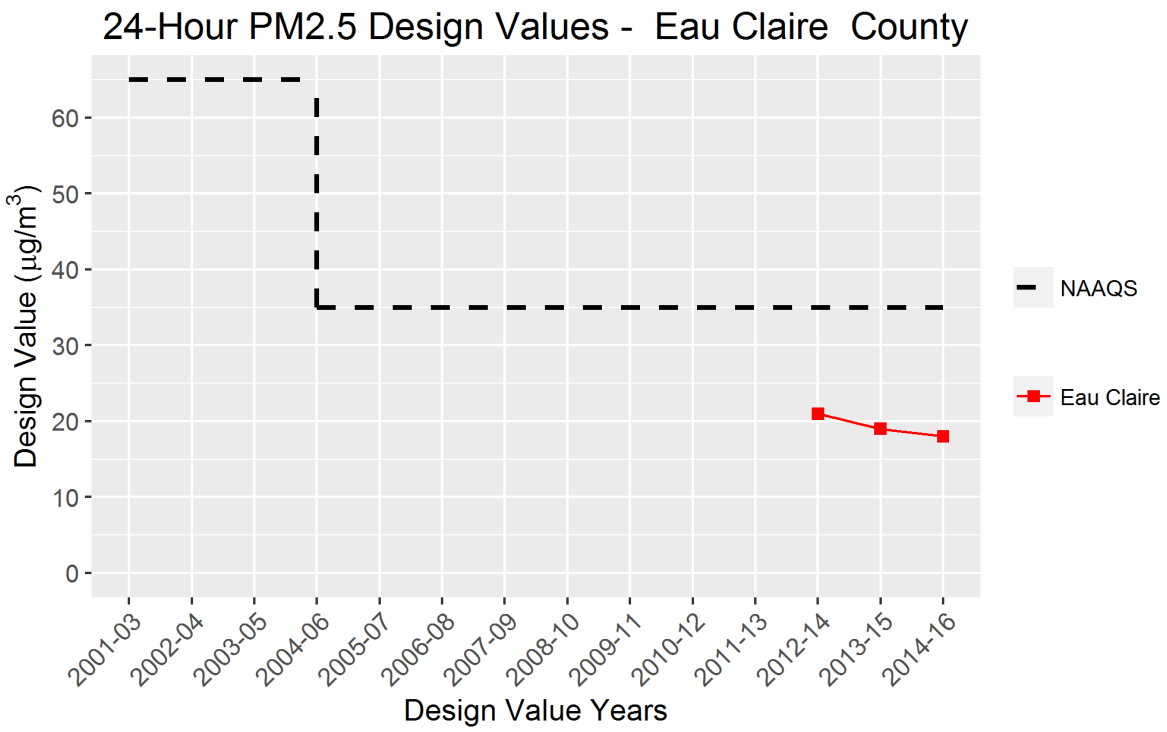


Eau Claire County

Monitoring for ozone and $PM_{2.5}$ in Eau Claire County takes place near the Department of Transportation Sign Shop, located at 5509 Highway 53 South on the outskirts of Eau Claire. Monitoring at this site began April 1, 2011.

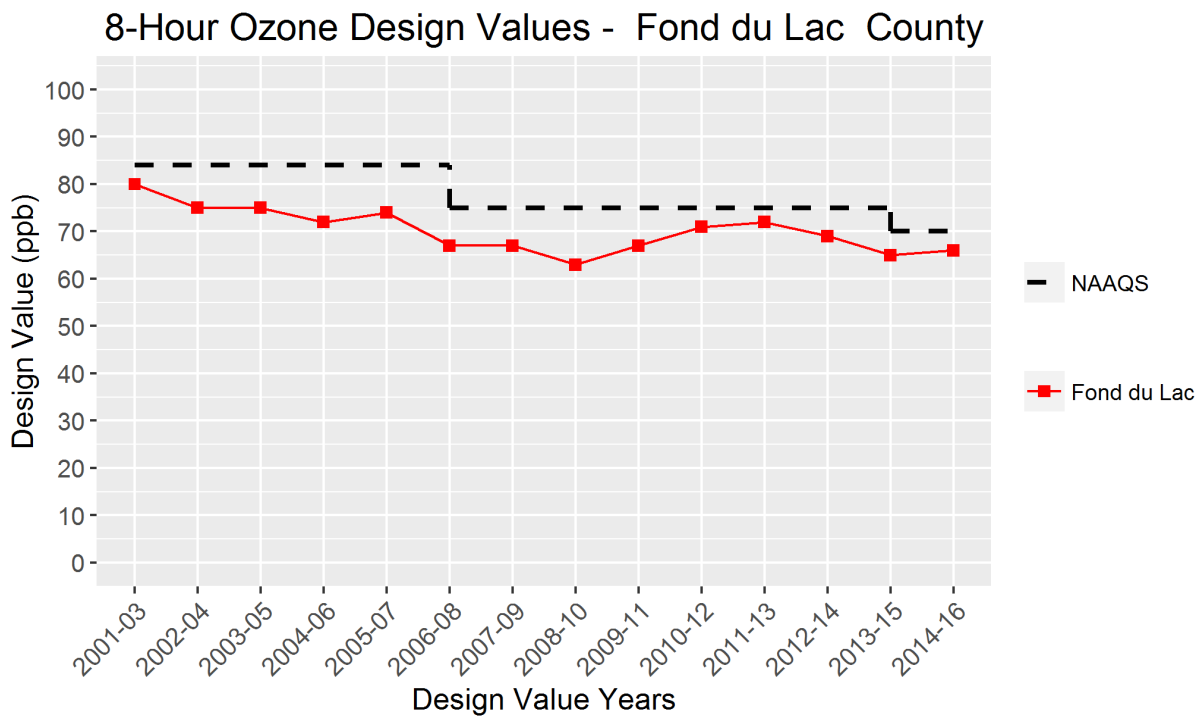





24-Hour PM2.5 Design Values - Eau Claire County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Eau Claire

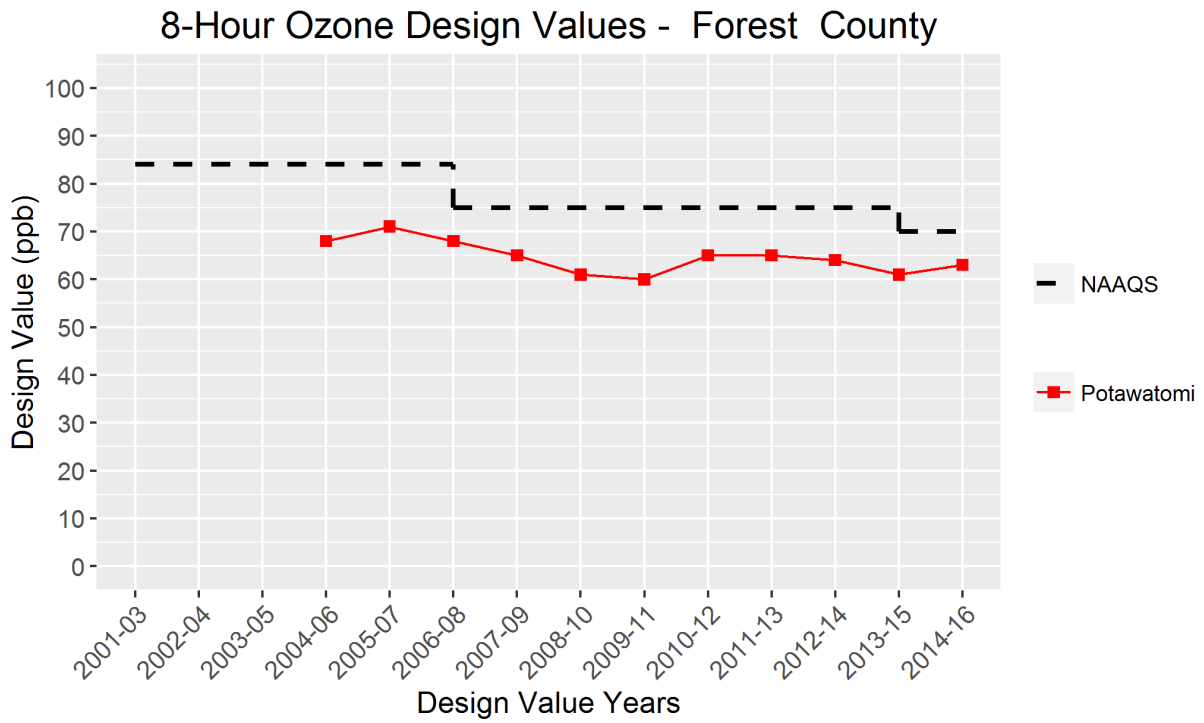
Fond du Lac County

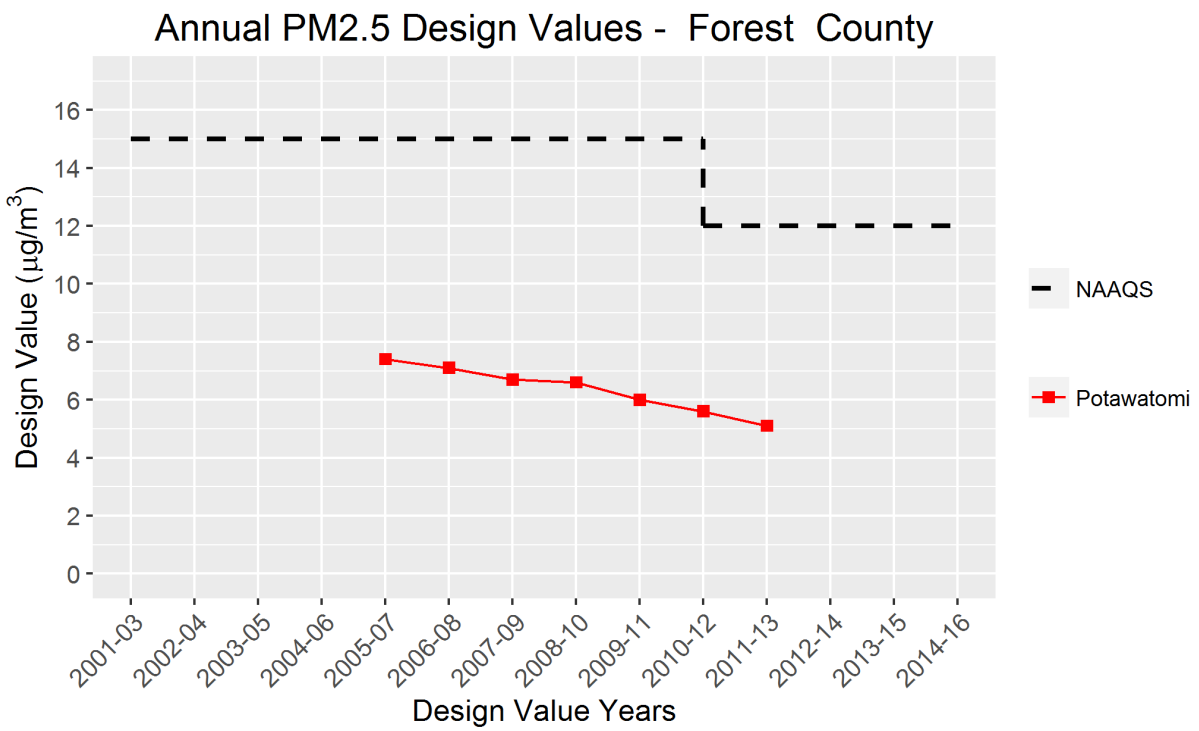
Ozone monitoring in Fond du Lac County is performed at N3996 Kelly Road in the Town of Byron. The site is located at the edge of a farm field.

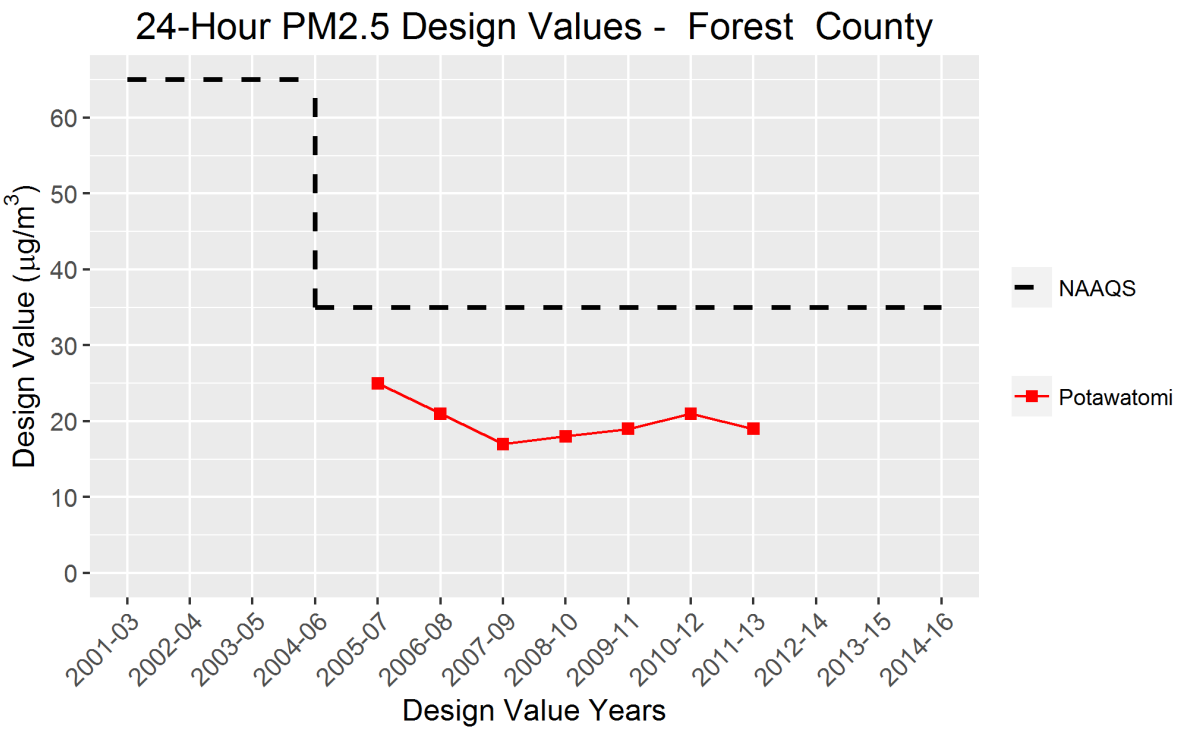


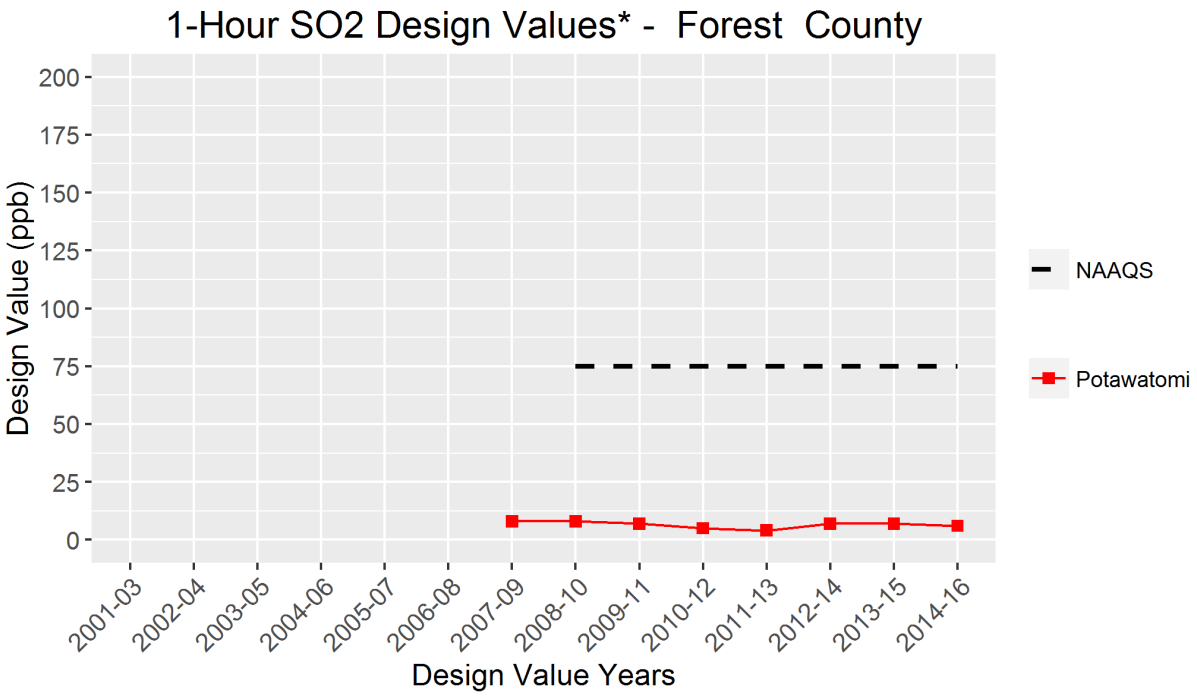
Forest County

Monitoring for ozone, $PM_{2.5}$, and SO_2 is conducted by the Forest County Potawatomi Tribe along Fire Tower Road in Crandon. Monitoring for NO_2 at the site was discontinued in early 2016; therefore, a graph for this parameter is not included.





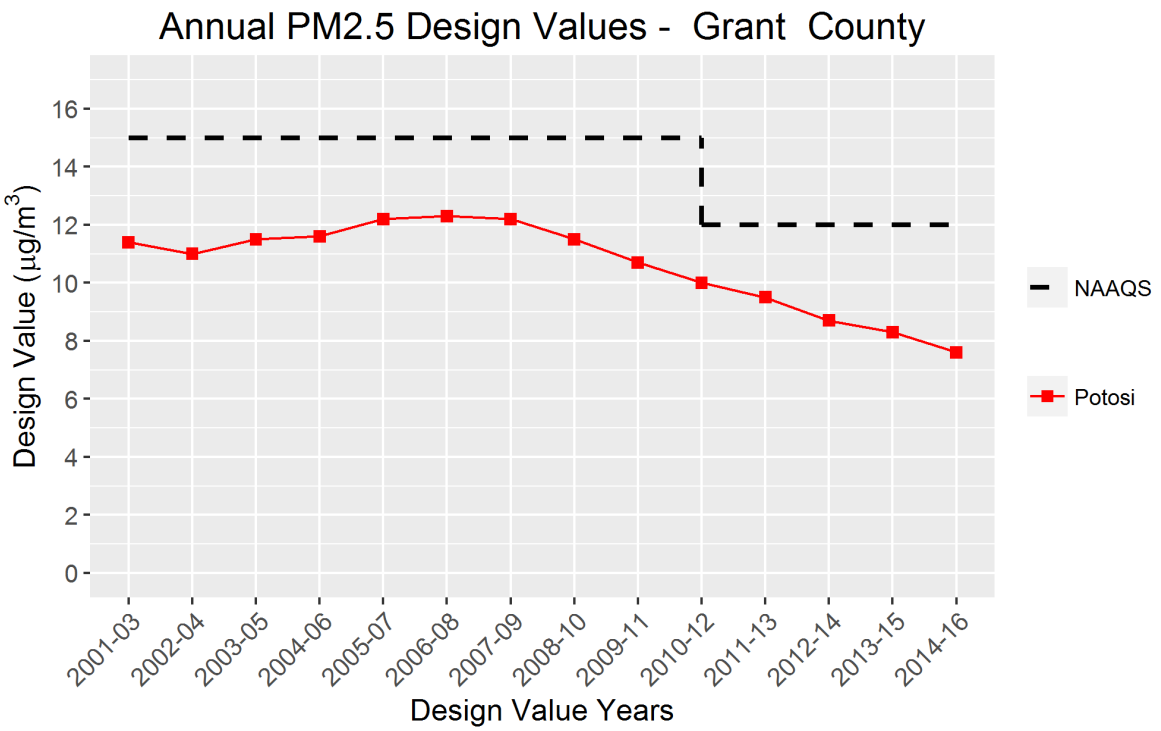


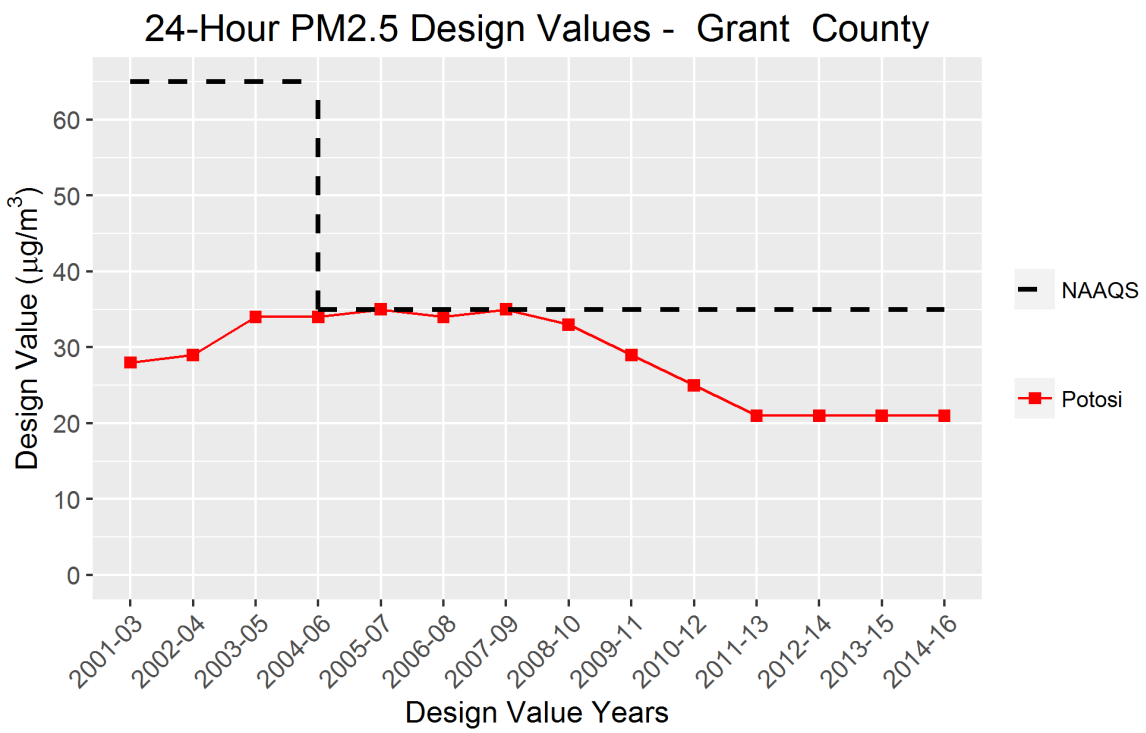


*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous annual and 24-hr standards.

Grant County

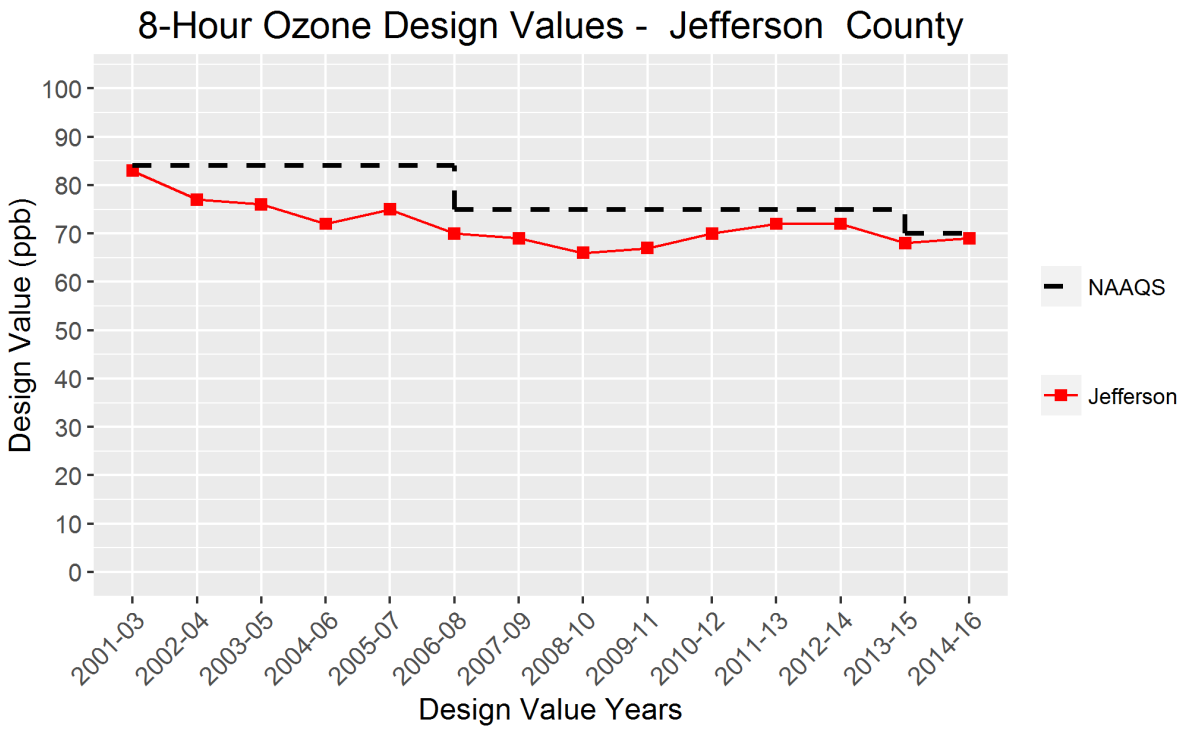
Fine particle monitoring in Grant County takes place at 128 Highway 61 on Potosi High School property.





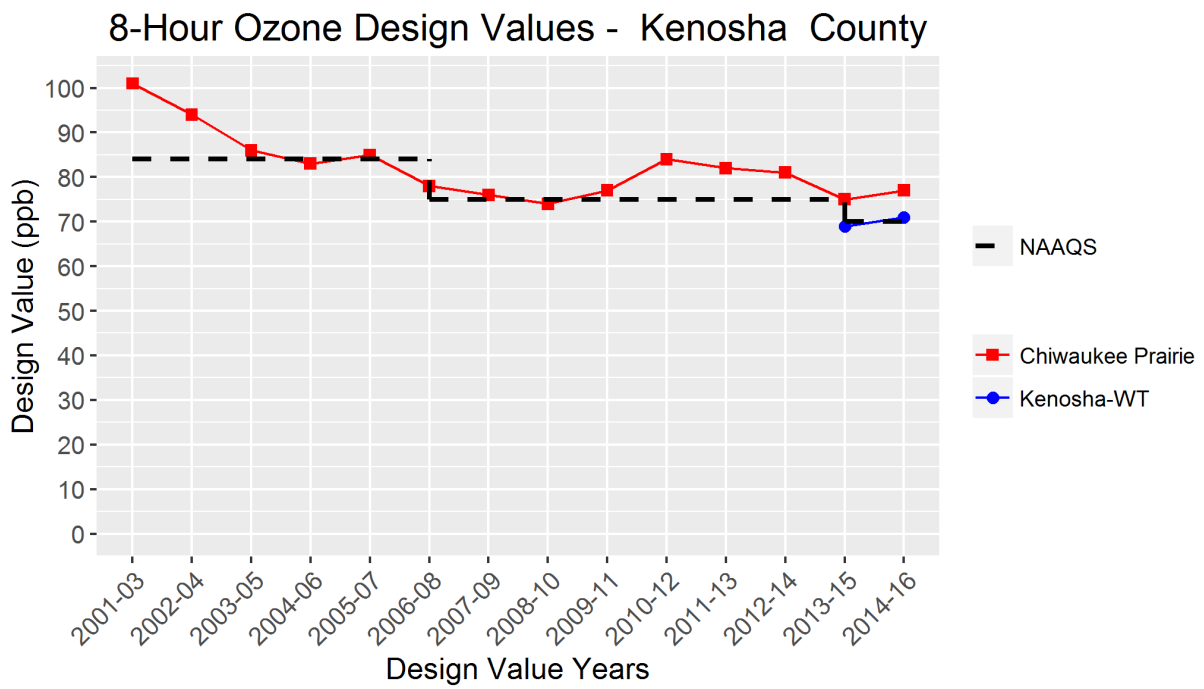
Jefferson County

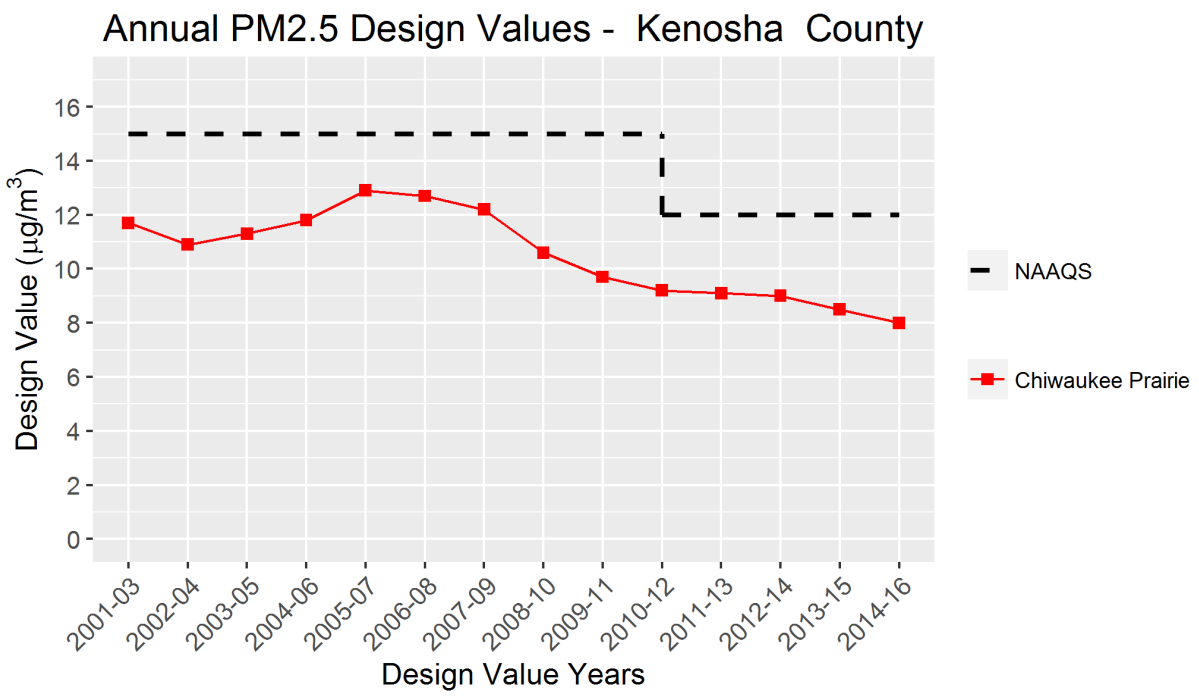
Ozone monitoring in Jefferson County is currently conducted near the elementary school grounds at N4440 Laatsch Lane in the city of Jefferson. Prior to 2013, monitoring took place at Jefferson High School next to the sports field grounds at 634 West Linden Drive, approximately ¾ mile from the current site. Data from both sites are used to calculate design values for 2011-2013 and 2012-2014.

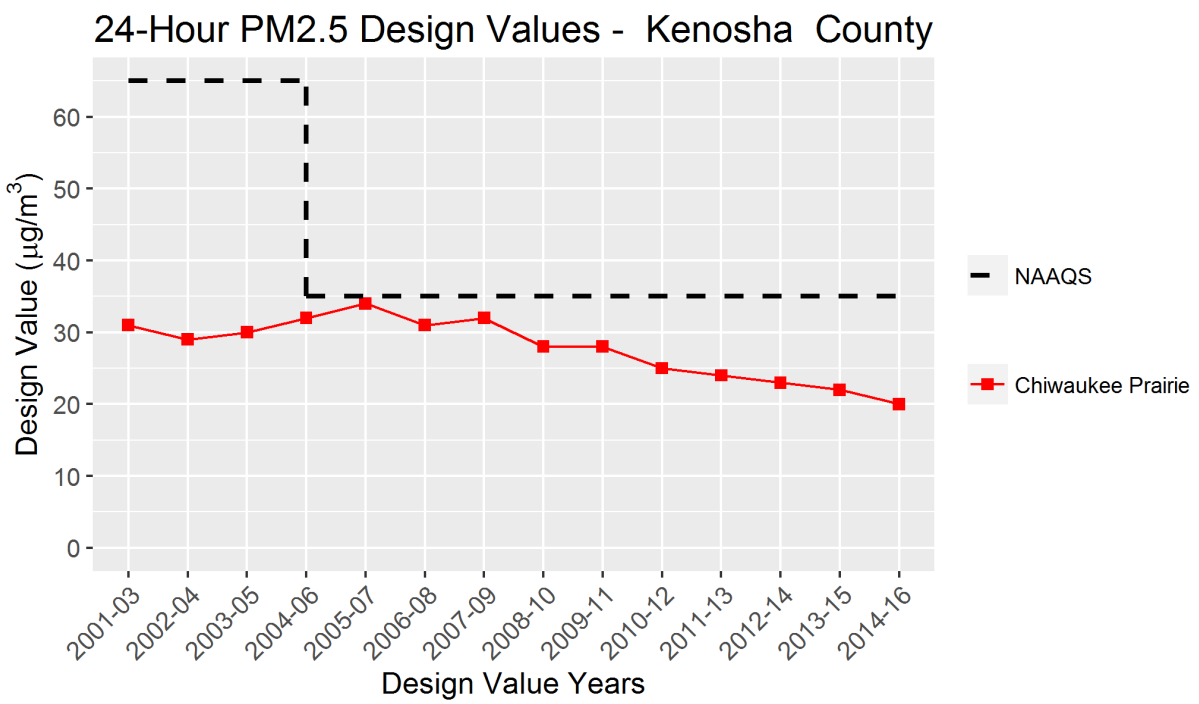


Kenosha County

Monitoring for ozone and $PM_{2.5}$ in Kenosha County is performed at 11838 First Court in the Chiwaukee Prairie, which is a rural area near the Wisconsin – Illinois border. A second ozone monitoring site in Kenosha County (Kenosha-WT) was added in 2013 at the water tower, located at 4504 64th St. in Kenosha. The Kenosha-WT site is designated as a special-purpose monitor; this monitor can also be compared against the NAAQS.

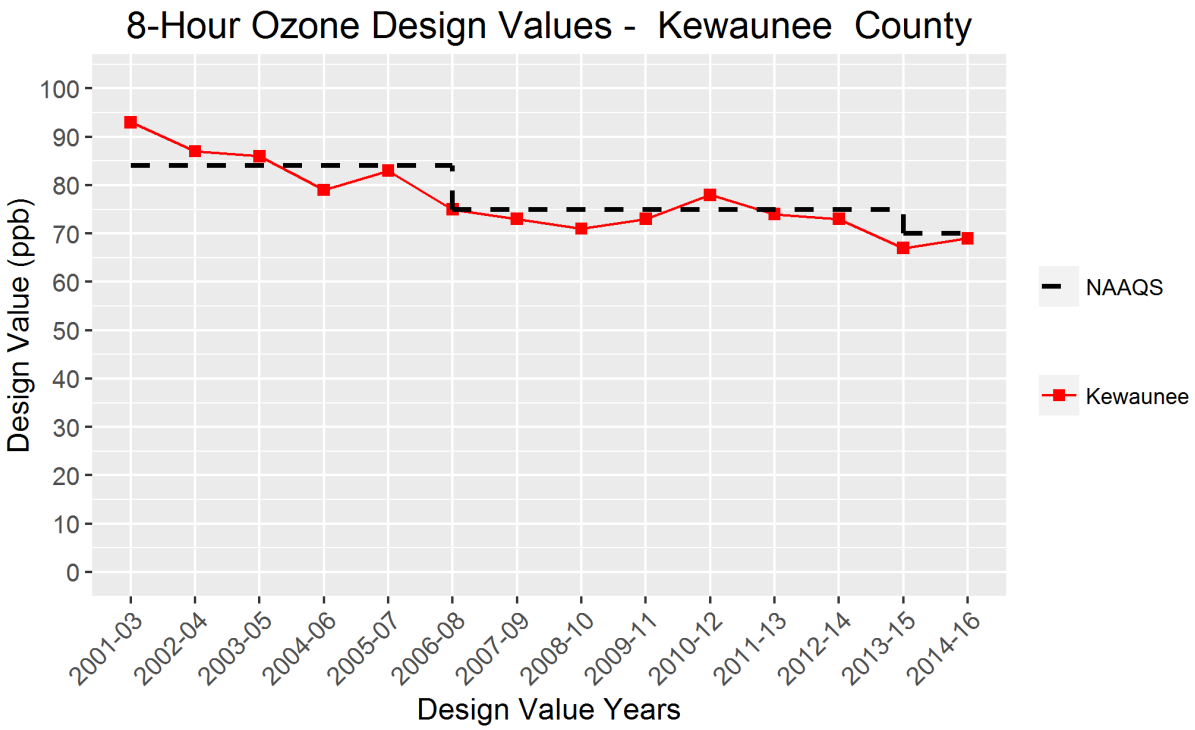



Annual PM2.5 Design Values - Kenosha County
Design Value (µg/m3)
16
14
12
10
8
6
4
2
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Chiwaukee Prairie


24-Hour PM2.5 Design Values - Kenosha County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Chiwaukee Prairie

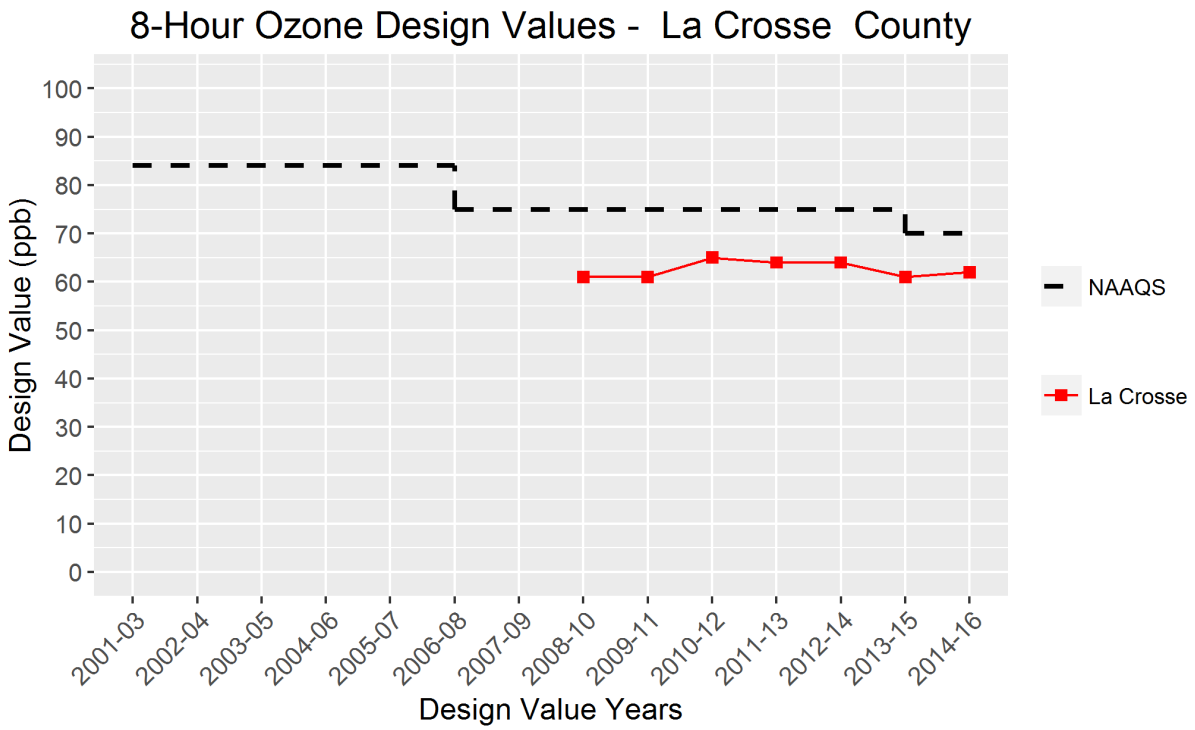
Kewaunee County

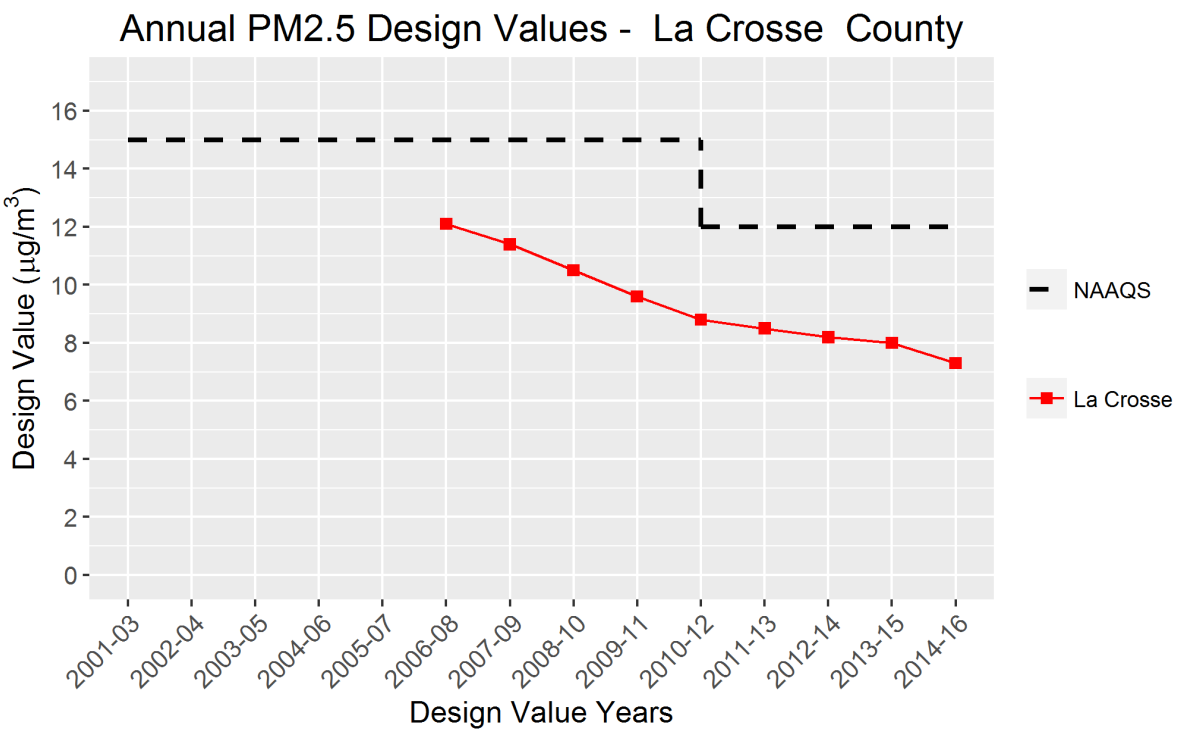
Ozone monitoring in Kewaunee County takes place at Rural Route 1, Highway 42 on a bluff overlooking Lake Michigan.

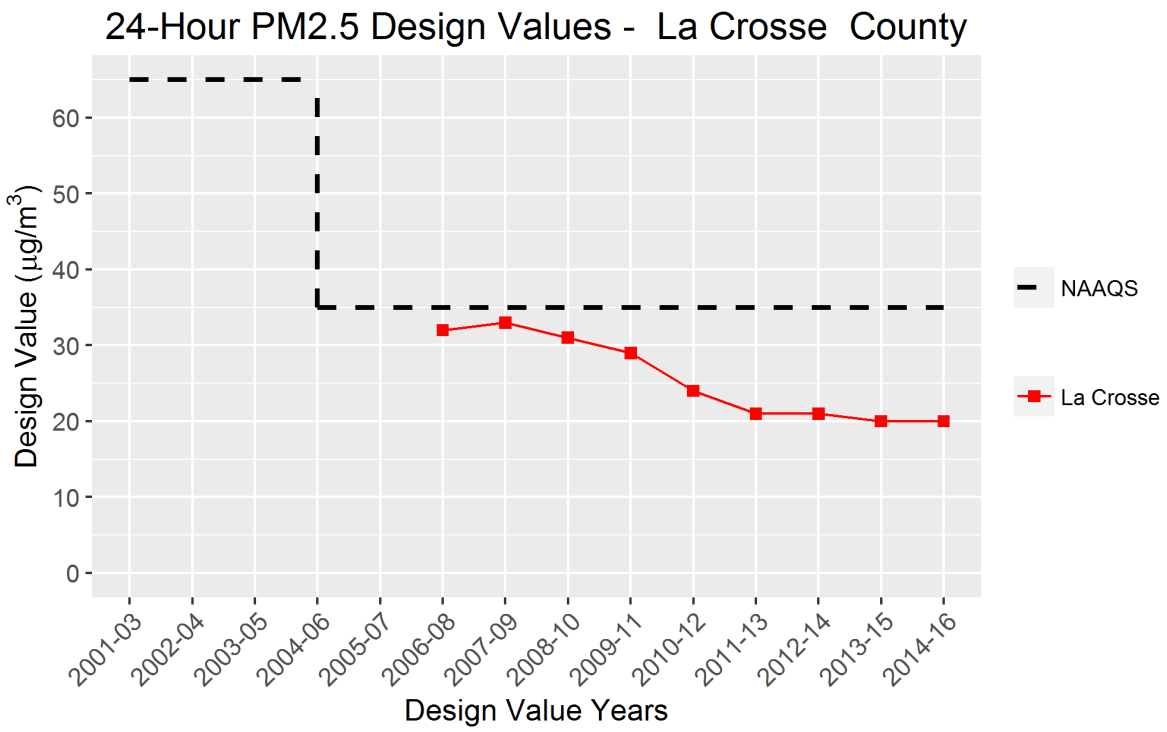


La Crosse County

Monitoring for ozone and $PM_{2.5}$ in La Crosse County is conducted at the Department of Transportation office, located at 3350 Mormon Coulee Road in La Crosse.

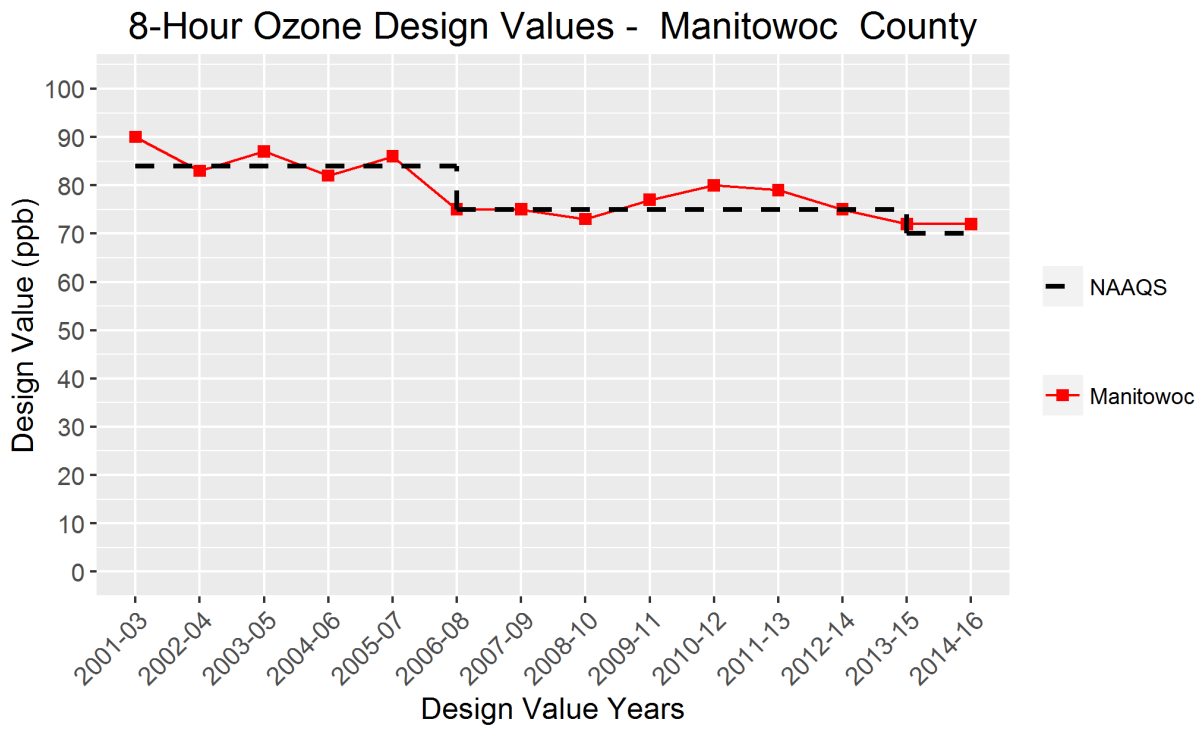





24-Hour PM2.5 Design Values - La Crosse County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
La Crosse

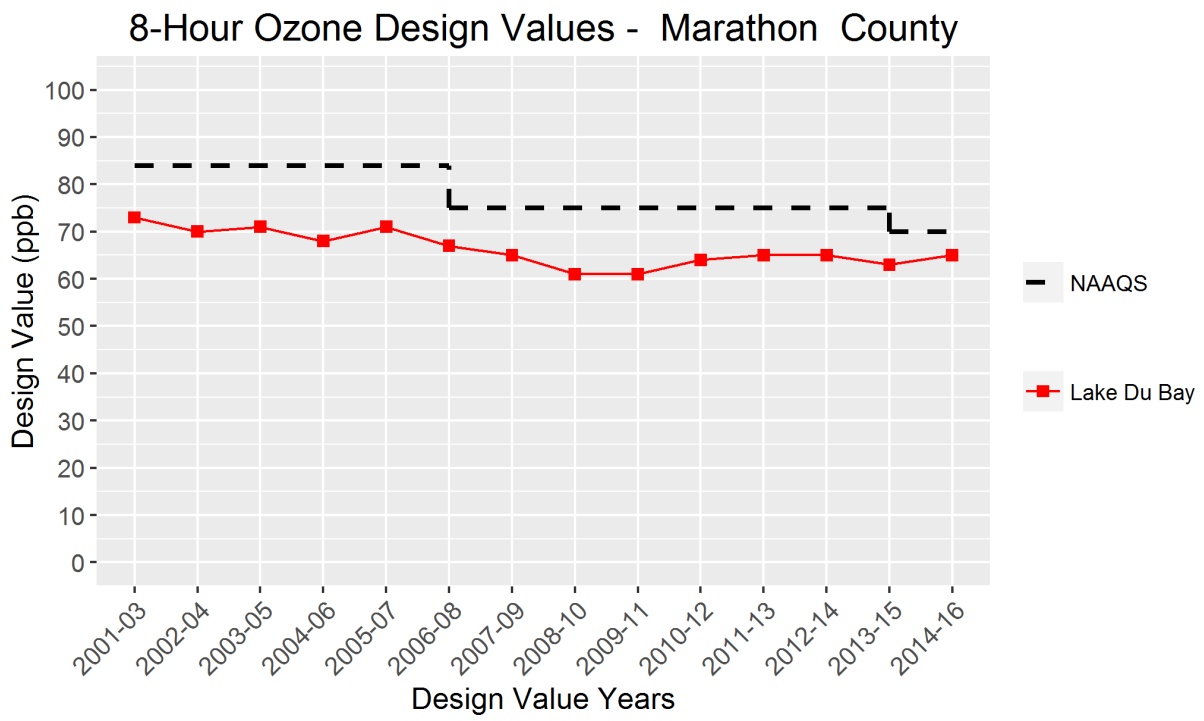
Manitowoc County

Ozone monitoring for Manitowoc County is performed at 2315 Goodwin Road in Two Rivers at the Woodland Dunes Nature Center and Preserve.



Marathon County

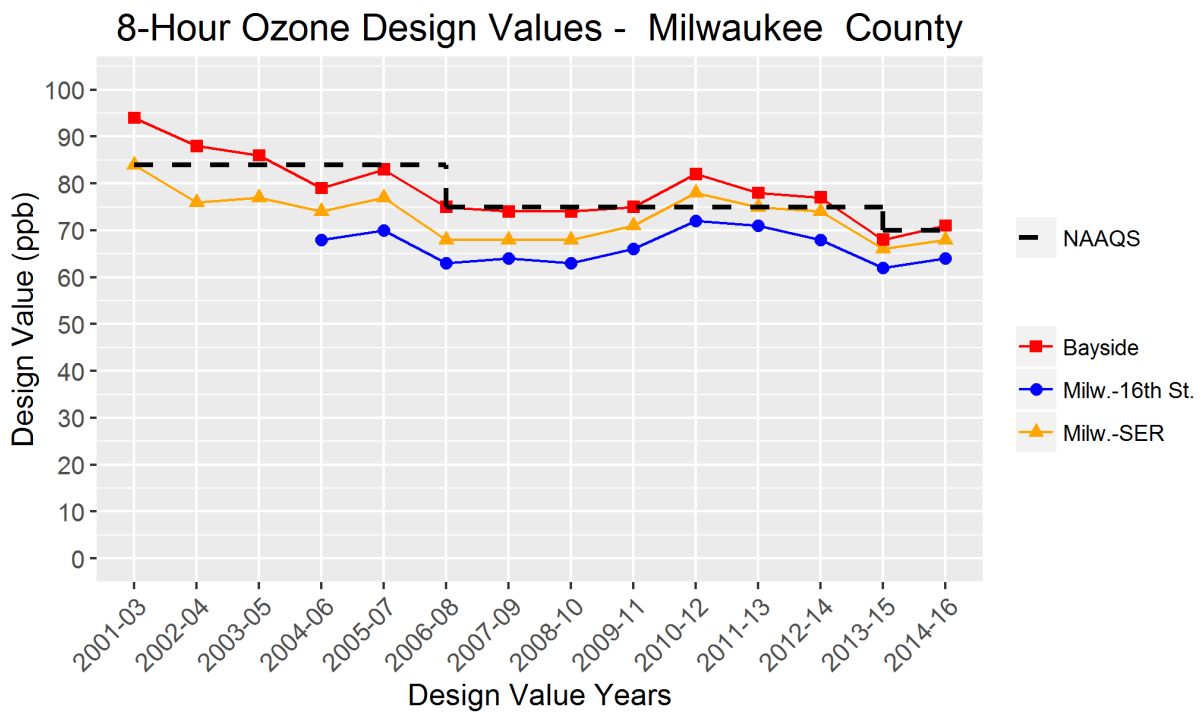
Ozone monitoring in Marathon County is conducted at a rural location at 1780 Bergen Road near Lake Du Bay in Bergen Township.

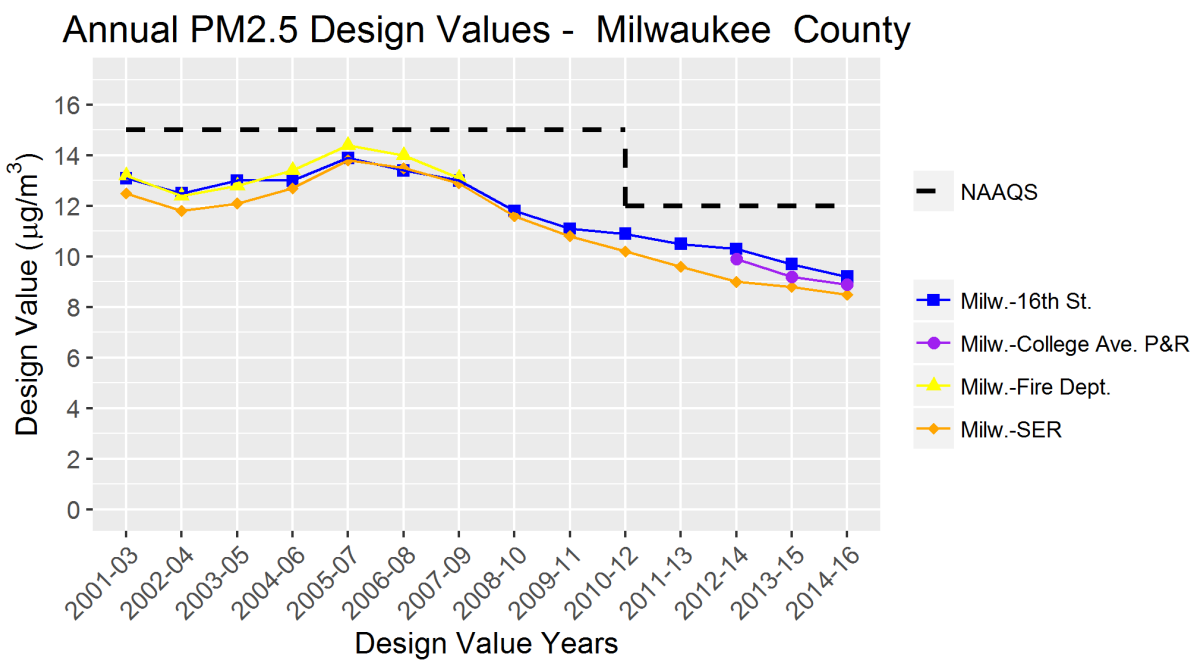


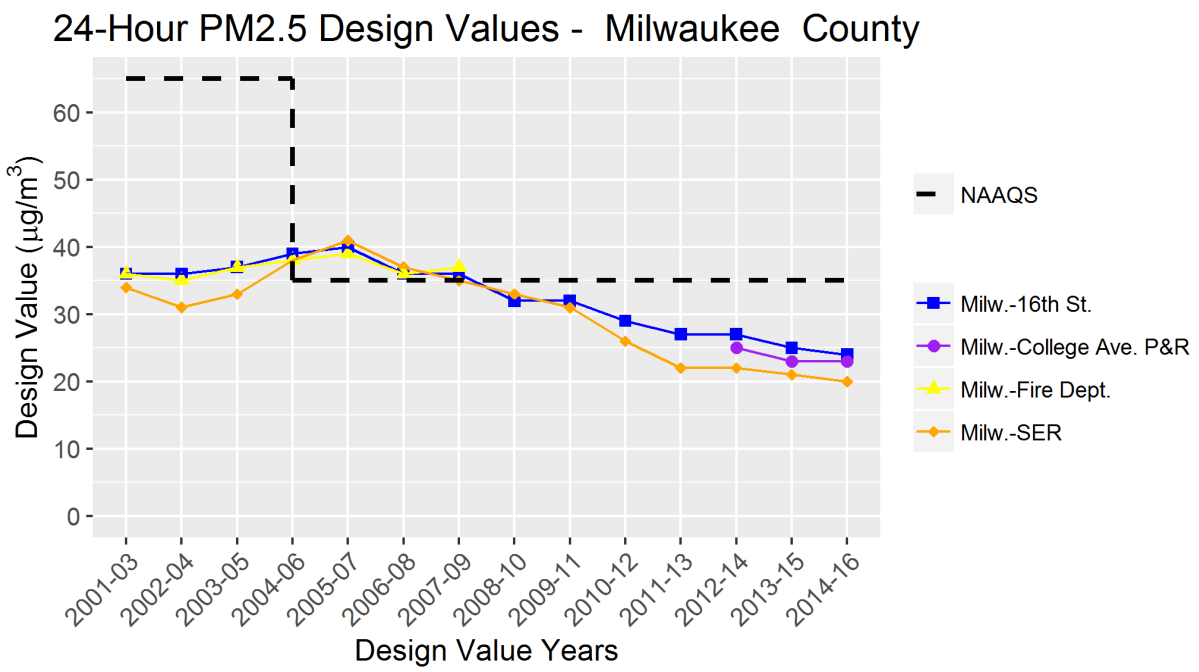
Milwaukee County

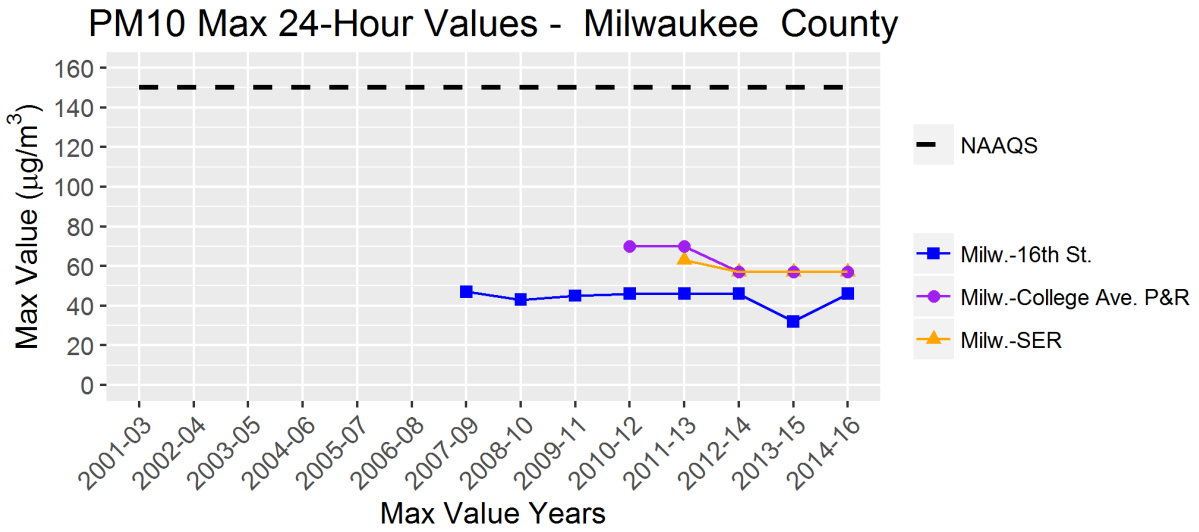
Monitoring for ozone, $PM_{2.5}$, and PM_{10} in Milwaukee County takes place at multiple sites which are shown together in graphs below for comparison. Sites include Bayside (601 E Ellsworth Lane in Bayside), Milwaukee-16th St. (1337 S Cesar E Chavez Dr at the Health Center Building), Milwaukee-College Avenue Park & Ride (1550 W. College Avenue in the park and ride area), Milwaukee-Fire Department (711 W. Wells St, on top of a fire deparment), and Milwaukee-SER (2300 N. Dr. Martin Luther King Jr. Drive at the WDNR Southeast Region Headquarters office).

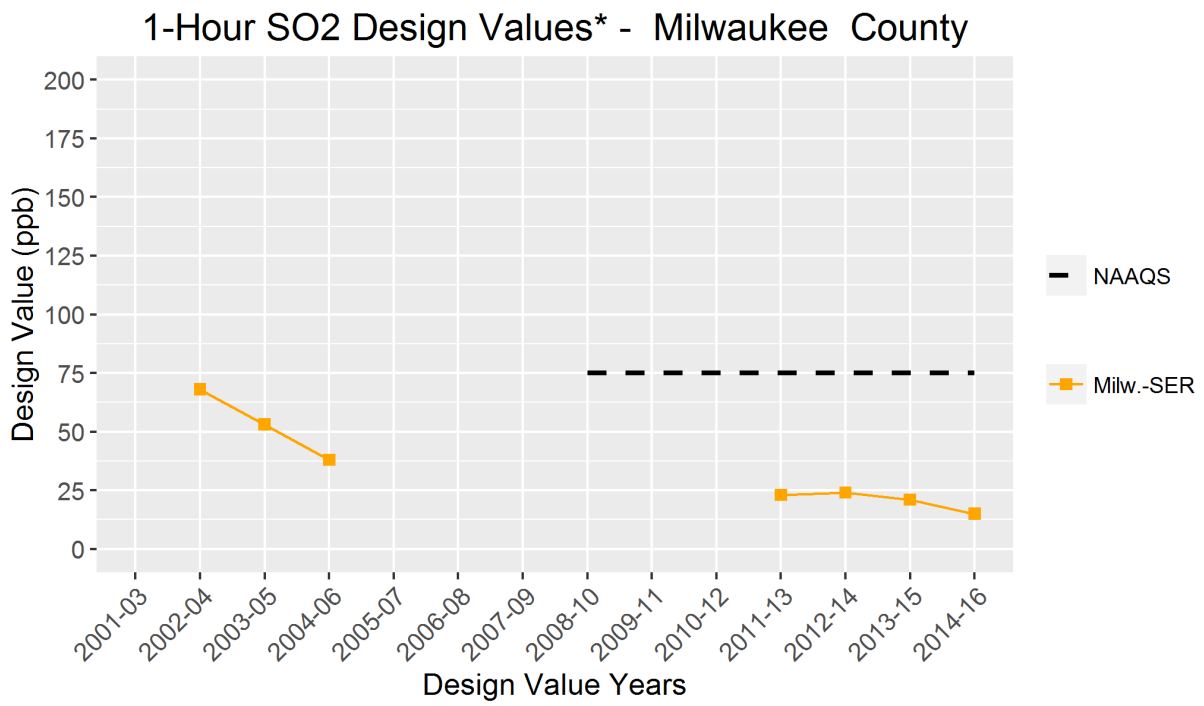
Sulfur dioxide is measured only at the Milwaukee-SER site. Monitoring at this site was not conducted from 2007 to 2010. Nitrogen dioxide is monitored at the Milwaukee-SER site as well as at the Milwaukee-College Avenue Near Road site, which was established in October 2013 also at 1550 W. College Avenue, but adjacent to the highway. Monitoring for CO, which started in 2014, takes place only at the Milwaukee-College Avenue Near Road site.



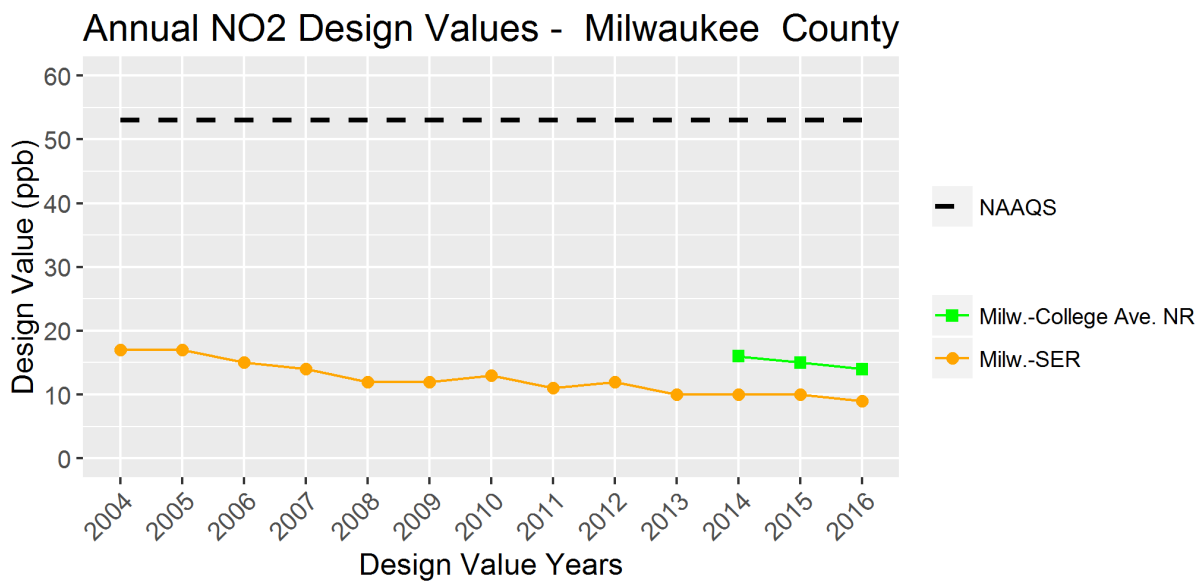

Annual PM2.5 Design Values - Milwaukee County
Design Value (µg/m3)
16
14
12
10
8
6
4
2
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Milw.-16th St.
Milw.-College Ave. P&R
Milw.-Fire Dept.
Milw.-SER

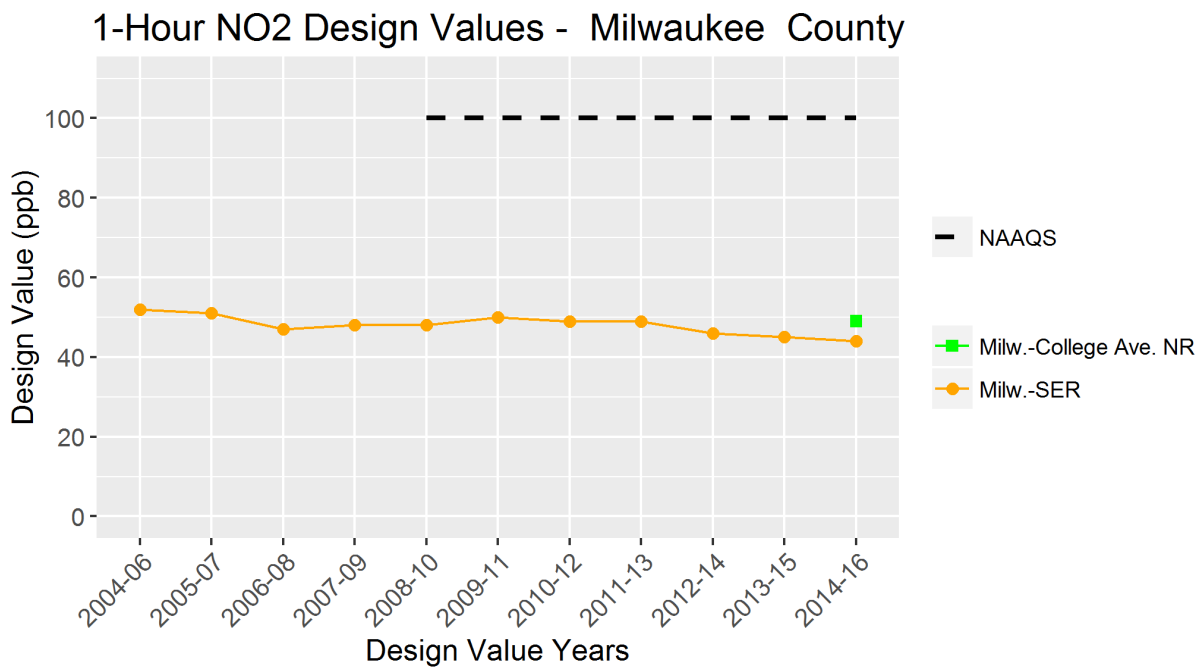

24-Hour PM2.5 Design Values - Milwaukee County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Milw.-16th St.
Milw.-College Ave. P&R
Milw.-Fire Dept.
Milw.-SER

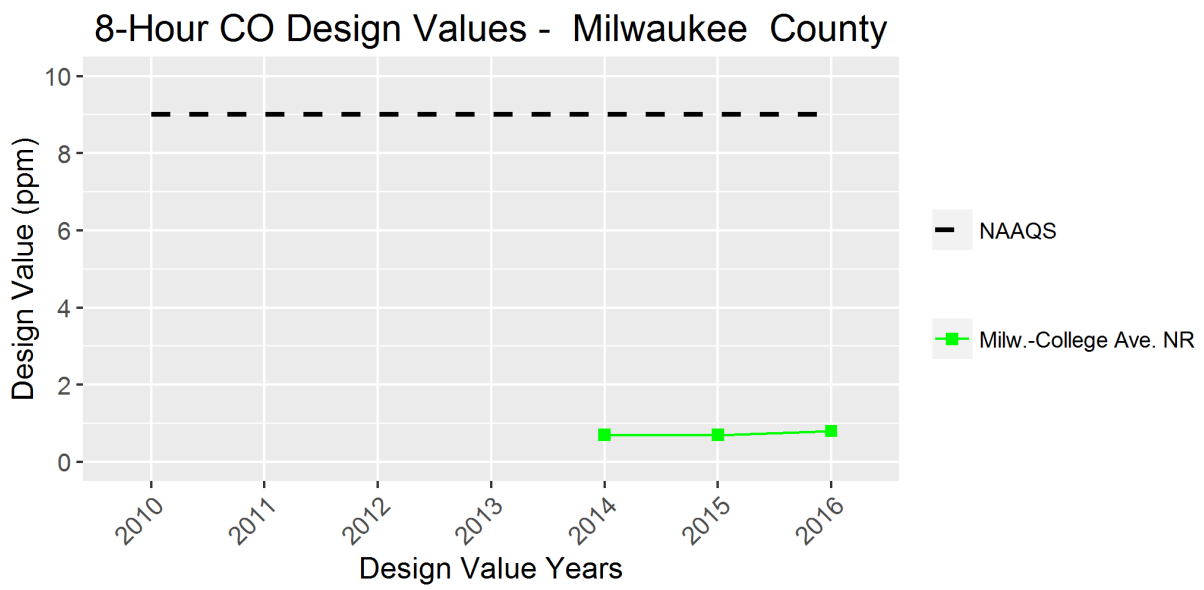


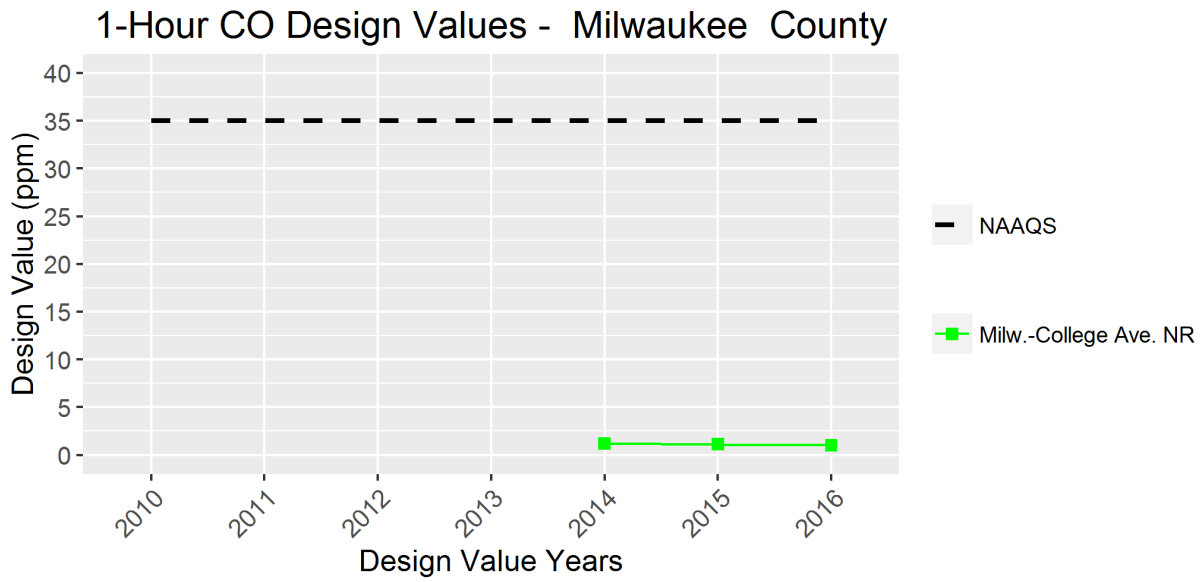


*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous 24-hr and annual standards.


Annual NO2 Design Values - Milwaukee County
Design Value (ppb)
60
50
40
30
20
10
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Design Value Years
NAAQS
Milw.-College Ave. NR
Milw.-SER

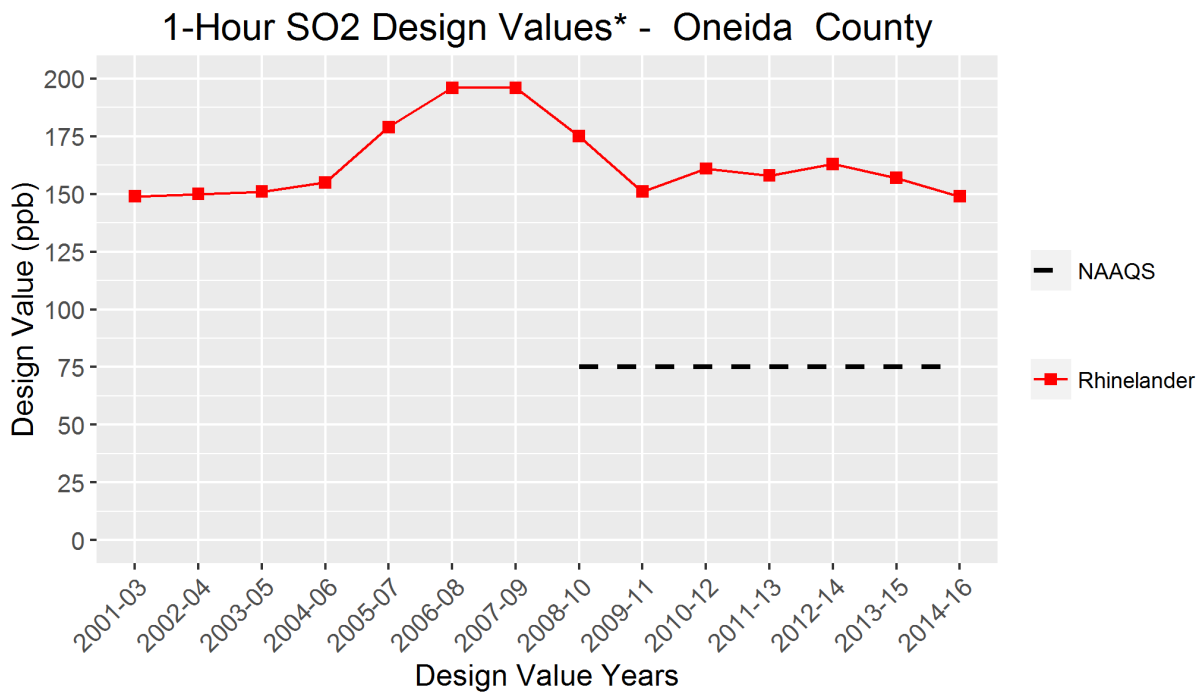

1-Hour NO2 Design Values - Milwaukee County
Design Value (ppb)
100
80
60
40
20
0
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Milw.-College Ave. NR
Milw.-SER


8-Hour CO Design Values - Milwaukee County
Design Value (ppm)
10
8
6
4
2
0
2010
2011
2012
2013
2014
2015
2016
Design Value Years
NAAQS
Milw.-College Ave. NR


1-Hour CO Design Values - Milwaukee County
Design Value (ppm)
40
35
30
25
20
15
10
5
0
2010
2011
2012
2013
2014
2015
2016
Design Value Years
NAAQS
Milw.-College Ave. NR

Oneida County

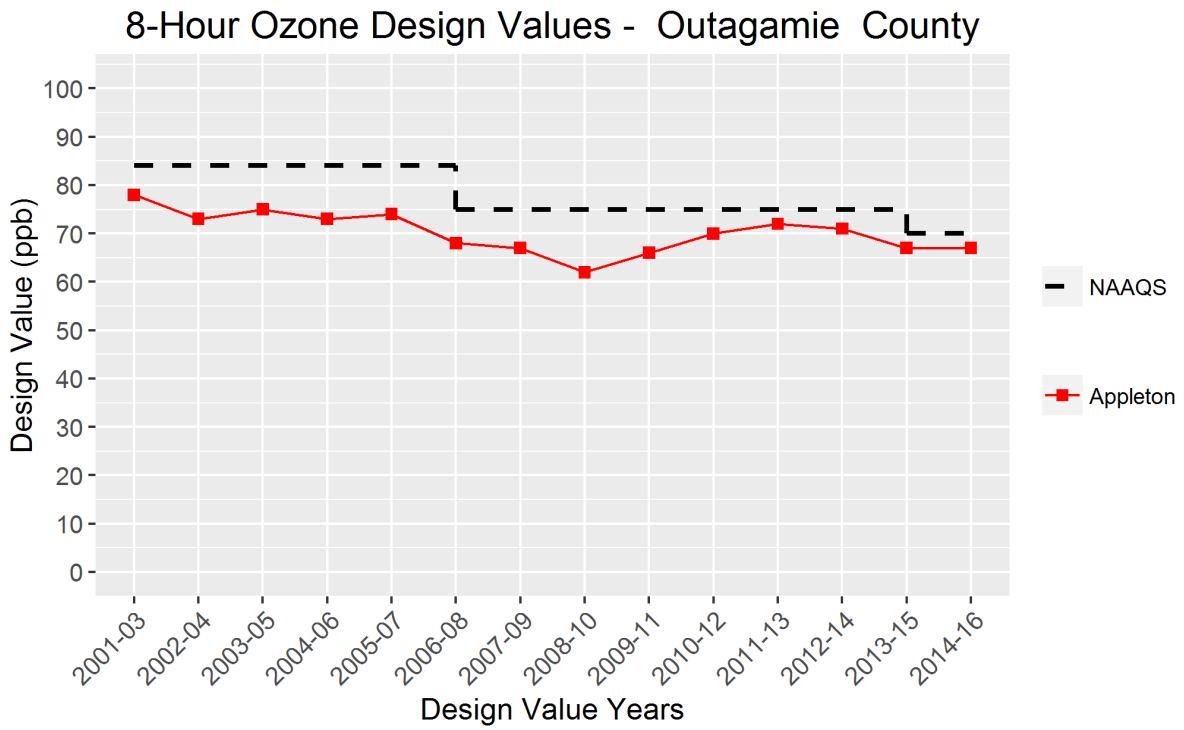
Monitoring for SO_2 in Oneida County takes place at 434 High Street next to the Rhinelander water tower. This site is source-oriented and is sited to assess compliance with the SO_2 NAAQS. The design values from this site are not in compliance with the 2010 1-hour standard. To bring this area into attainment, WDNR submitted an attainment plan to EPA that established permanent and enforceable SO_2 requirements on the facility primarily responsible for the monitored values. EPA found the attainment plan to be complete, and the facility has implemented the requirements contained in the plan.

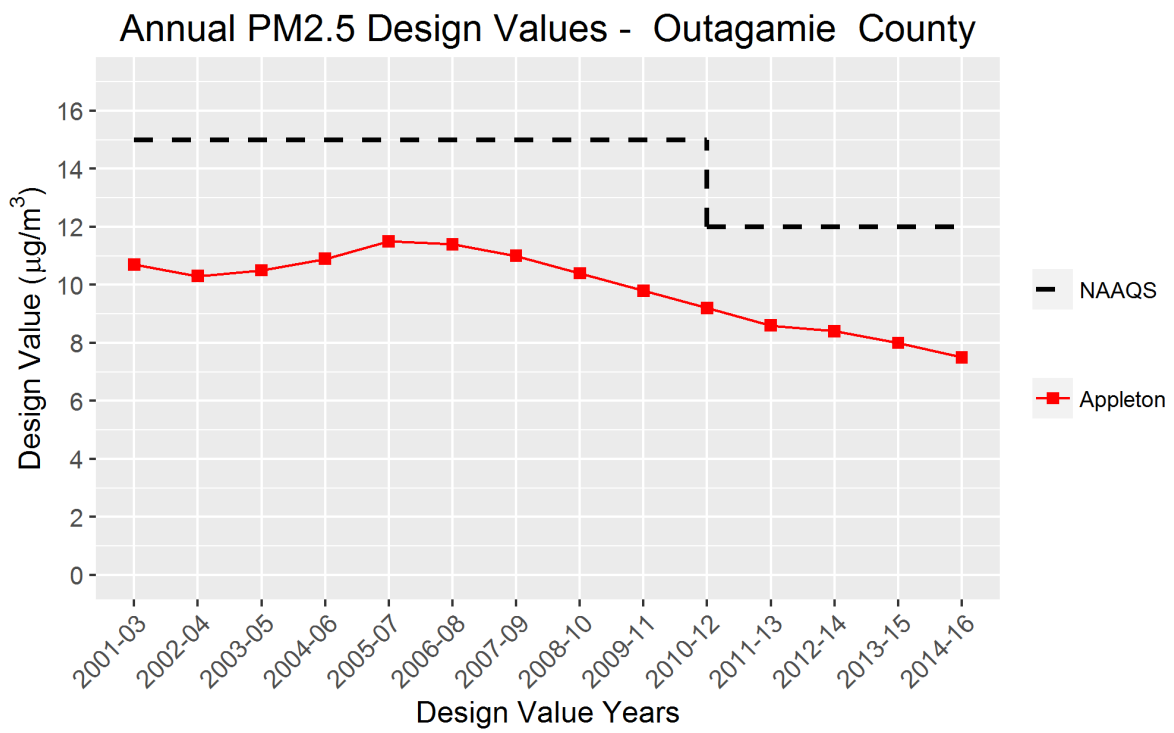


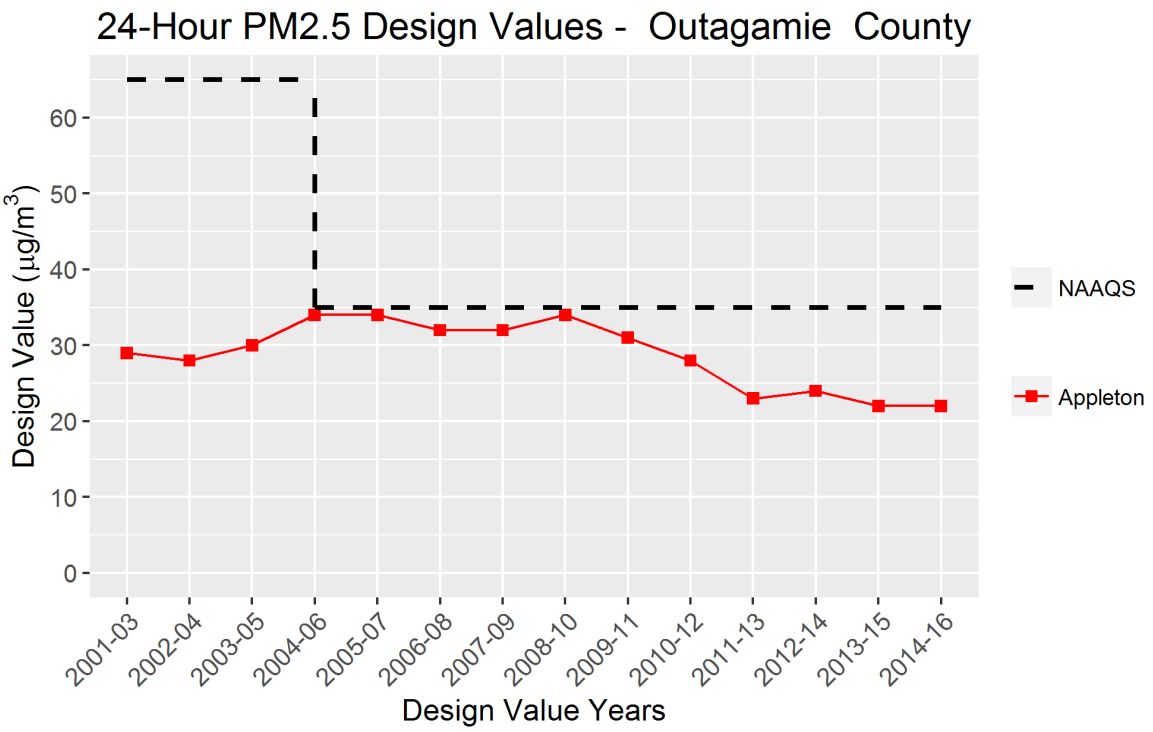
*In 2010, EPA established a 1-hr SO_2 standard that replaced the previous annual and 24-hr standards.

Outagamie County

Monitoring for ozone and $PM_{2.5}$ in Outagamie County is performed at 4432 North Meade Street in Appleton near a residential area.

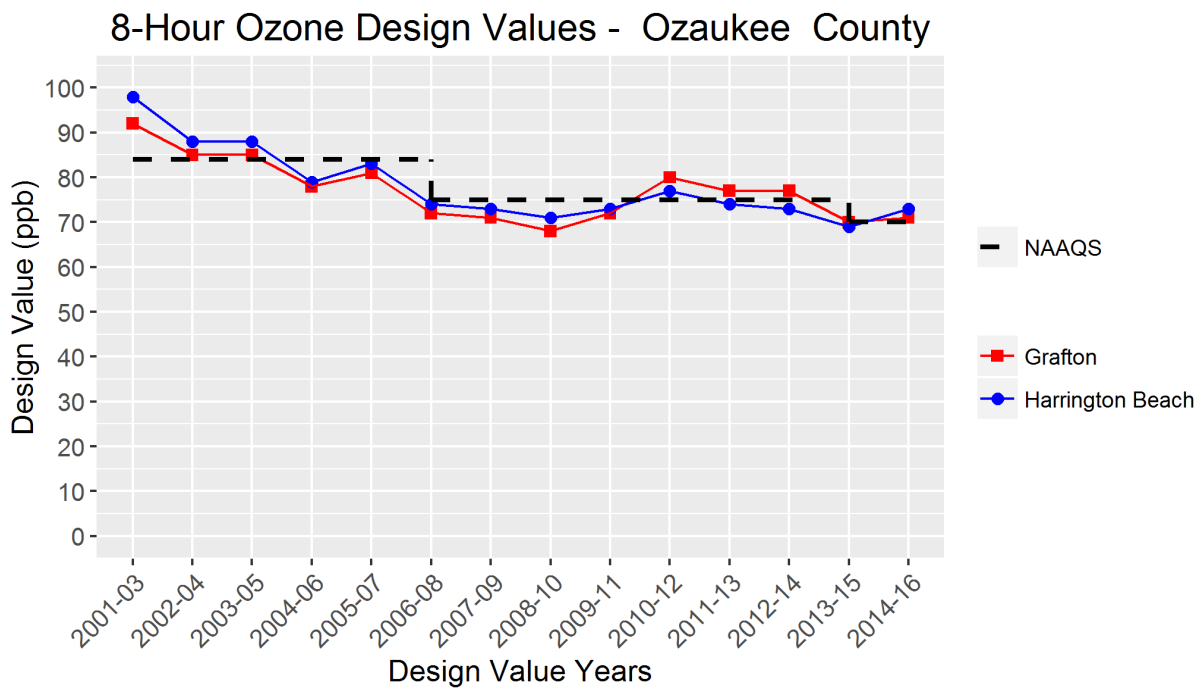


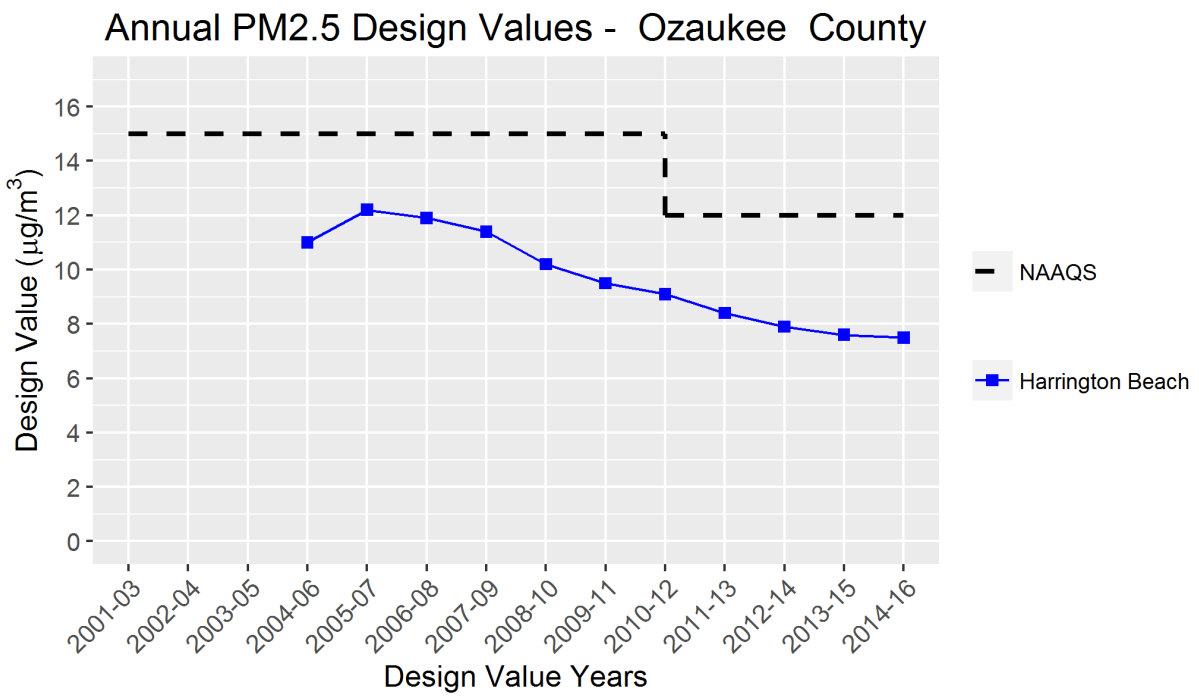


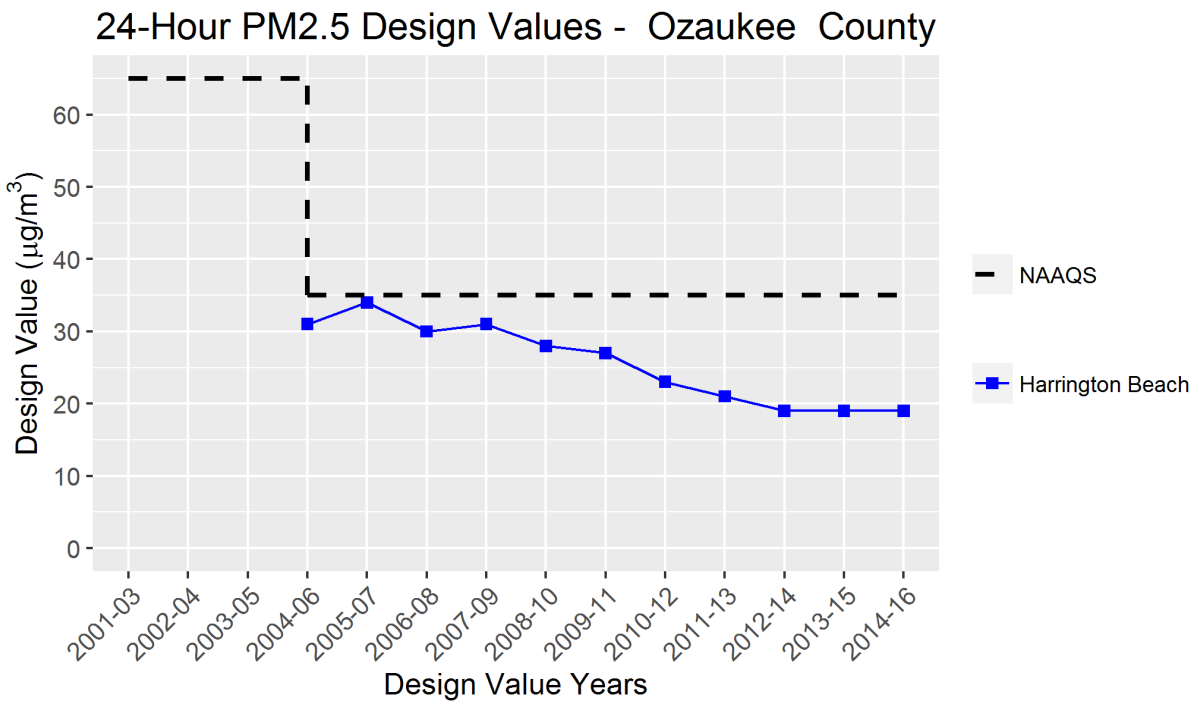

24-Hour PM2.5 Design Values - Outagamie County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Appleton

Ozaukee County

Ozone monitoring in Ozaukee County takes place at the intersection of Highway 57 and Interstate 43 in Grafton, and at Harrington Beach State Park located at 531 Highway D. Fine-particle monitoring takes place only at the Harrington Beach site.





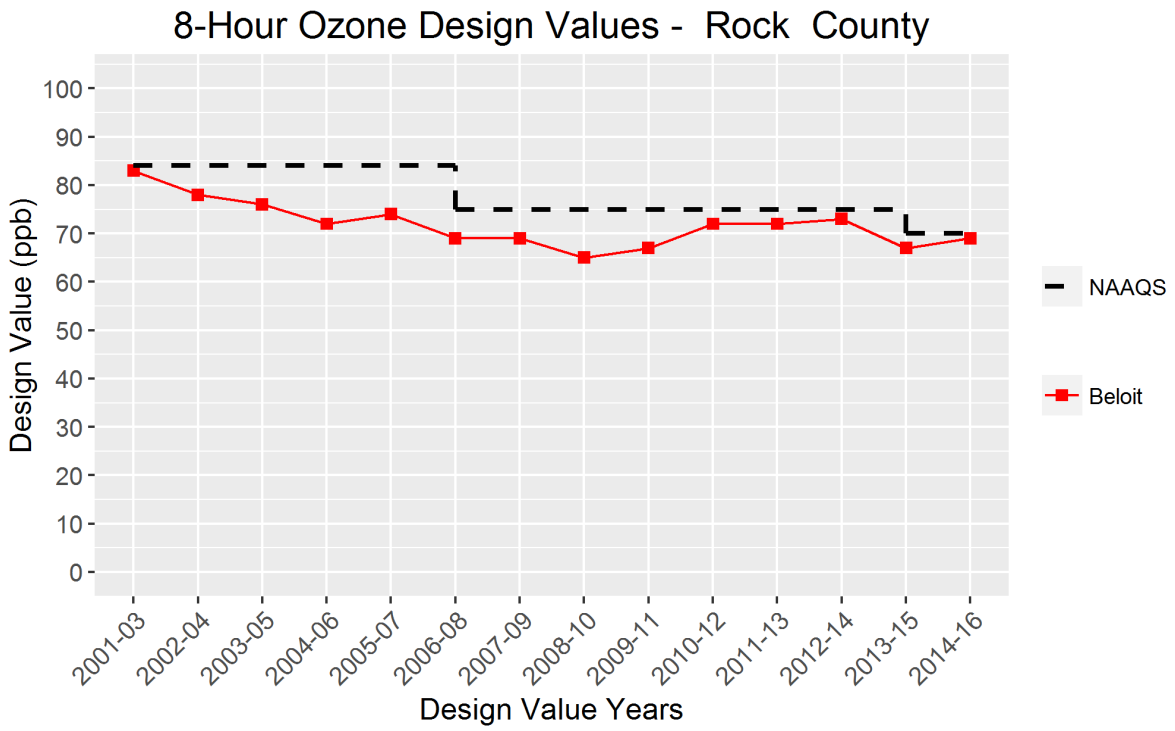

24-Hour PM2.5 Design Values - Ozaukee County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Harrington Beach

Racine County

Ozone monitoring in Racine County is conducted at 4227 Charles Street in a farm field in the rural village of Caledonia (Racine-Payne & Dolan site). Sampling began at this site on April 3, 2015. Prior to this date, sampling for ozone in Racine County was performed at 1519 Washington Avenue above a local business in the downtown area of Racine. This site was shut down at the end of 2013. Data from the old and new sites will not be combined. Because sampling at the new site began after 2014, a valid design value cannot not yet be calculated for this site. Trends from the discontinued site can be found in Appendix A of the April 2015 Trends report: https://widnr.widen.net/s/g7flss29tc/am526.

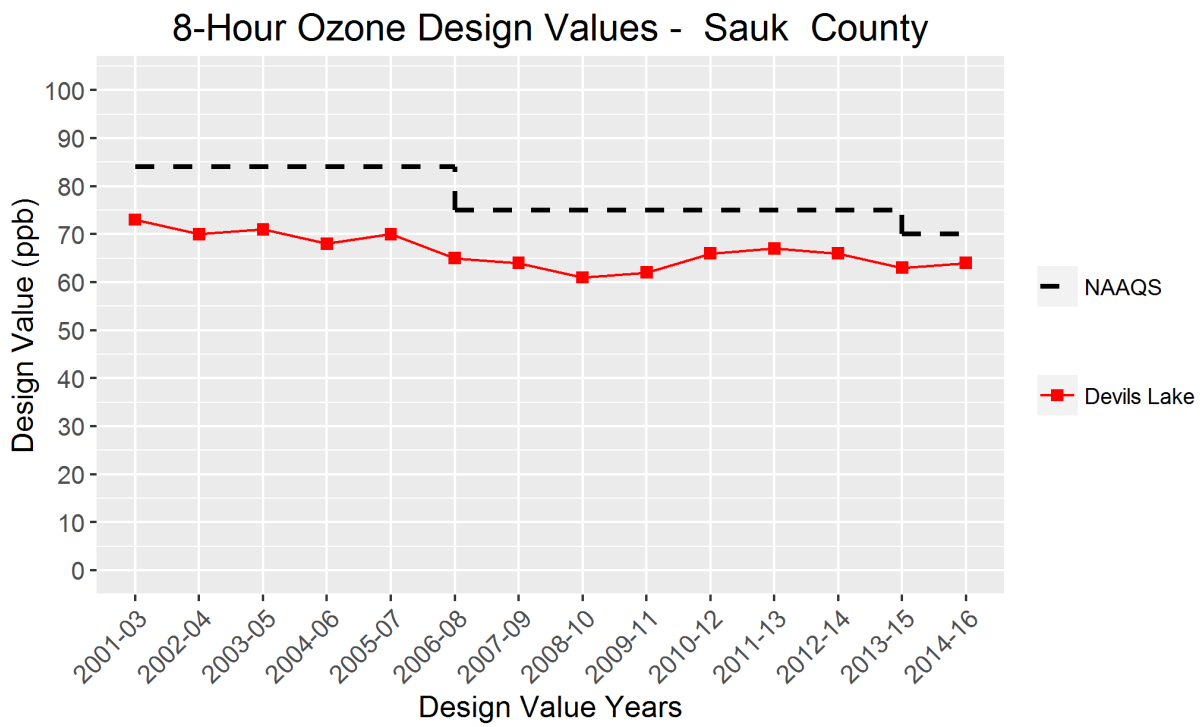
Rock County

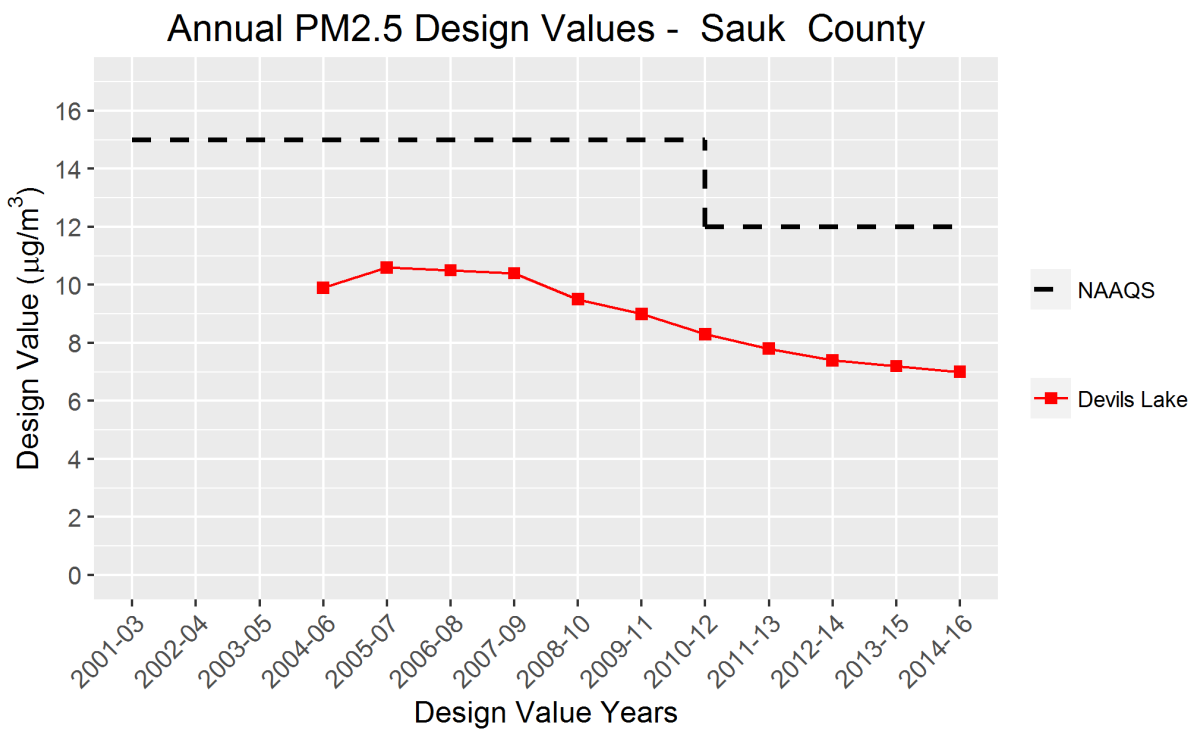
Ozone monitoring in Rock County is conducted at 1948 Merrill Street in Beloit. The site is located at the Cunningham School.

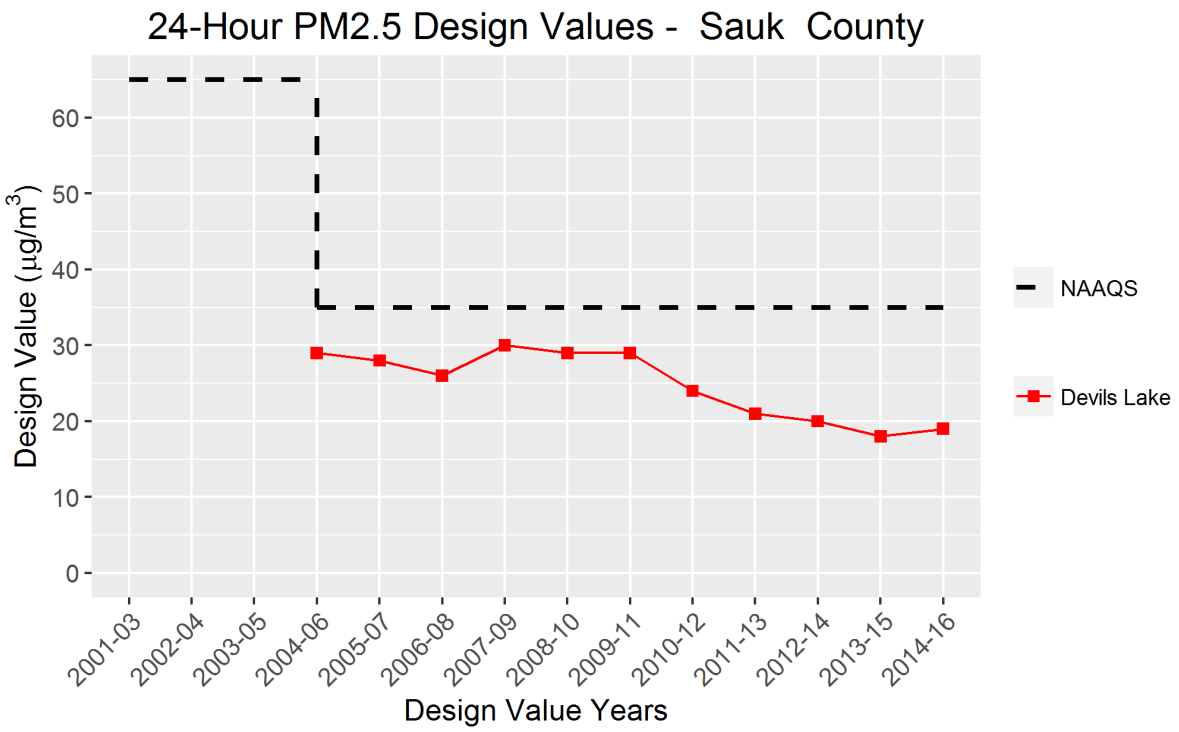


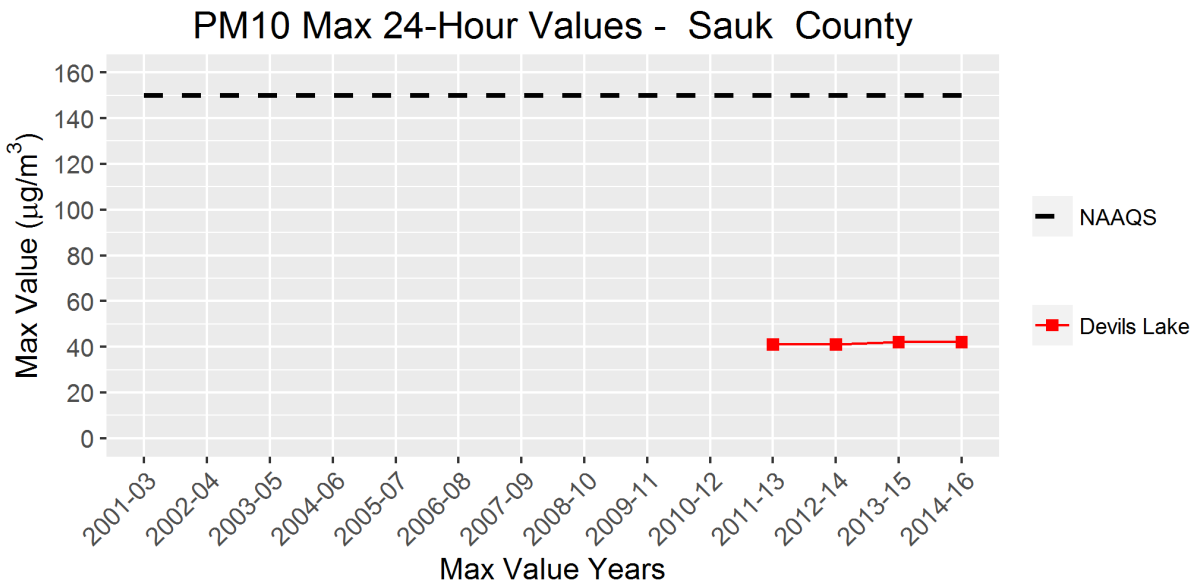
Sauk County

Monitoring for ozone, $PM_{2.5}$, and PM_{10} in Sauk County takes place at Devils Lake State Park at E12886 Tower Road in Baraboo.





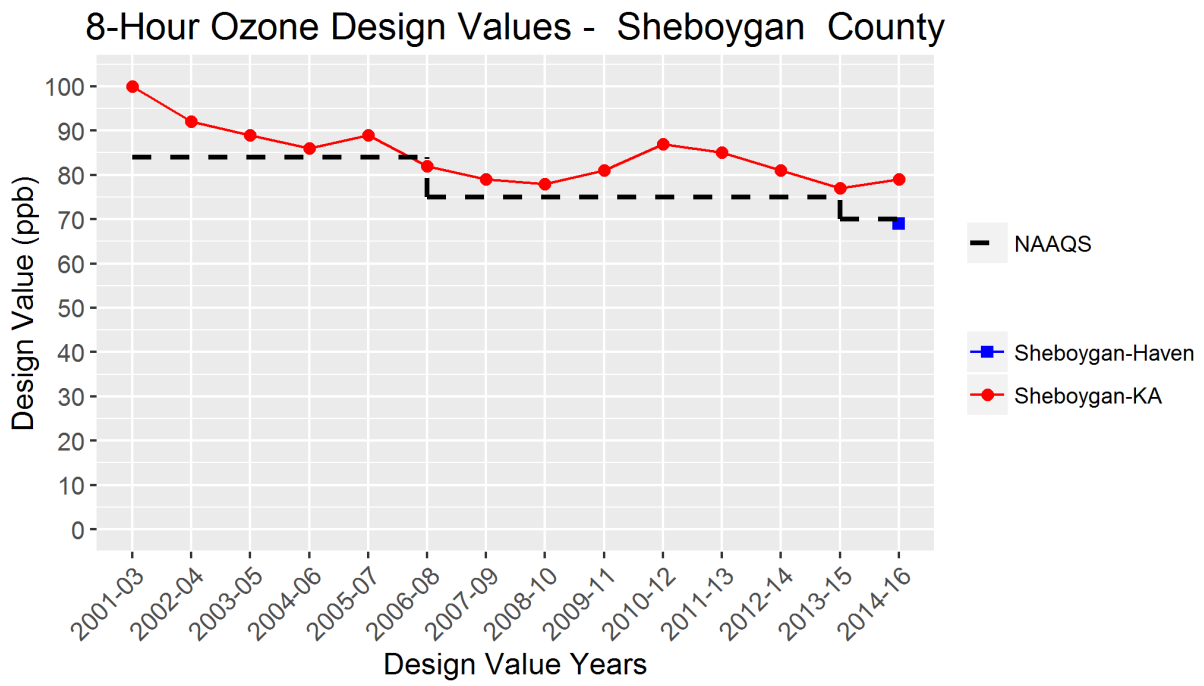

24-Hour PM2.5 Design Values - Sauk County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Devils Lake

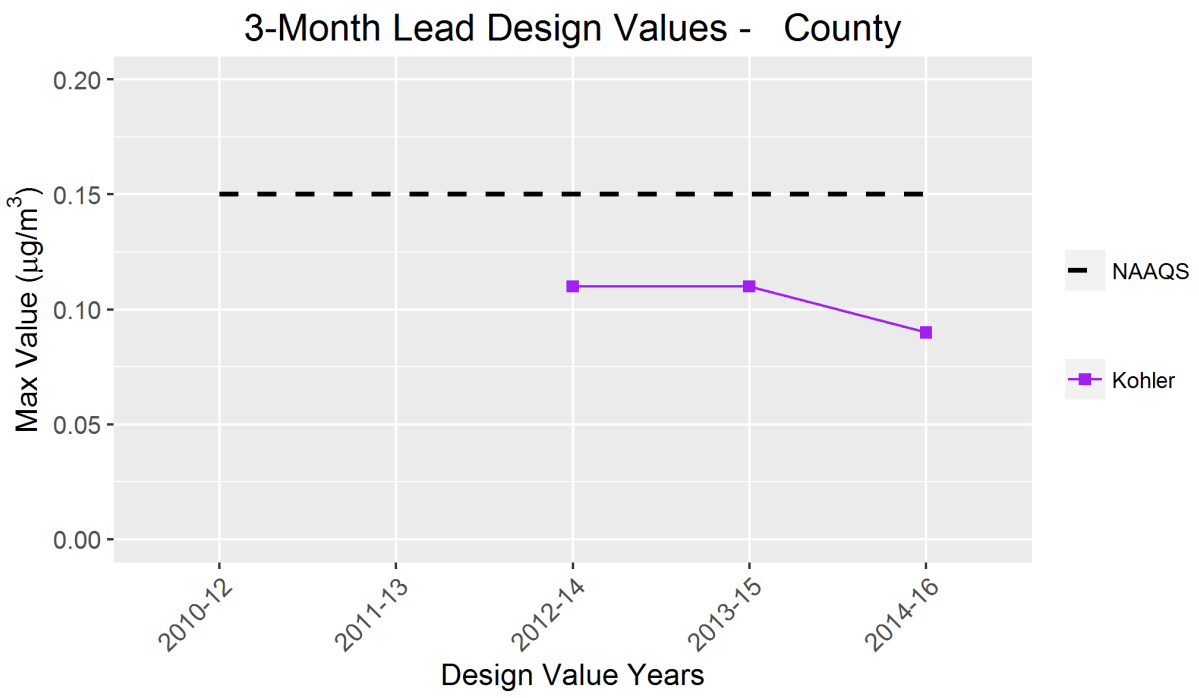

PM10 Max 24-Hour Values - Sauk County
Max Value (µg/m3)
160
140
120
100
80
60
40
20
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Max Value Years
NAAQS
Devils Lake

Sheboygan County

Ozone monitoring in Sheboygan County is performed at the Sanderling nature center within Kohler-Andrae State Park. This Lake Michigan shoreline site is located at 1520 Beach Park Road. A second ozone monitoring site was added during the 2014 ozone season (Sheboygan-Haven); it is located at N7563 Highway 42 near the intersection with County Road JJ. The Sheboygan-Haven site is designated as a special-purpose monitor; this monitor can also be compared against the NAAQS.

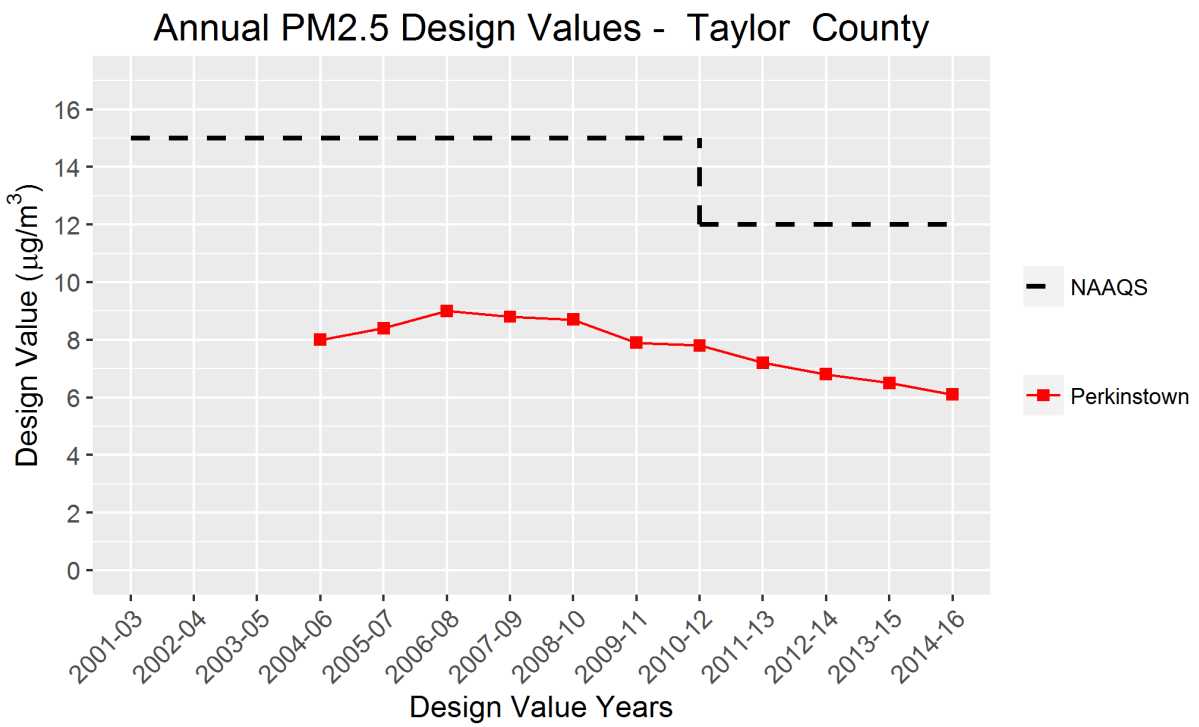
Lead monitoring in Sheboygan County began in December 2009 at the Kohler site. This source-oriented site is located at 444 Highland Drive at the Kohler Company fence line.

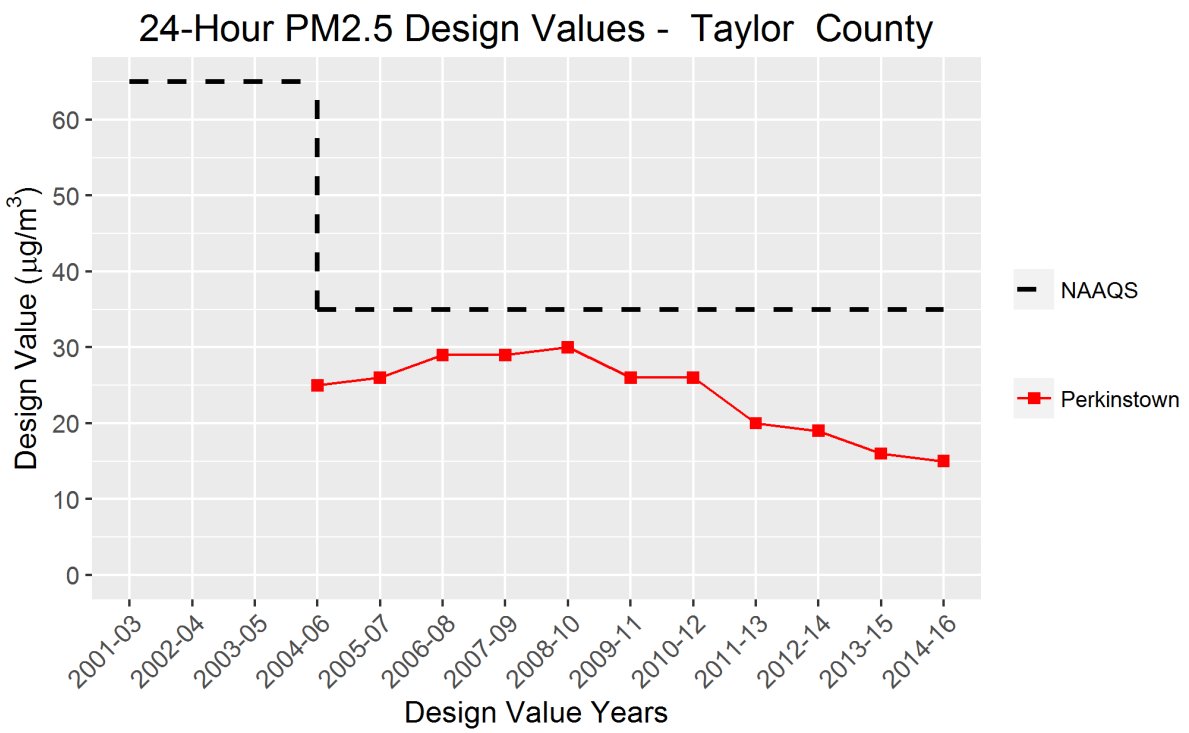



3-Month Lead Design Values - County
Max Value (µg/m3)
0.20
0.15
0.10
0.05
0.00
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Kohler

Taylor County

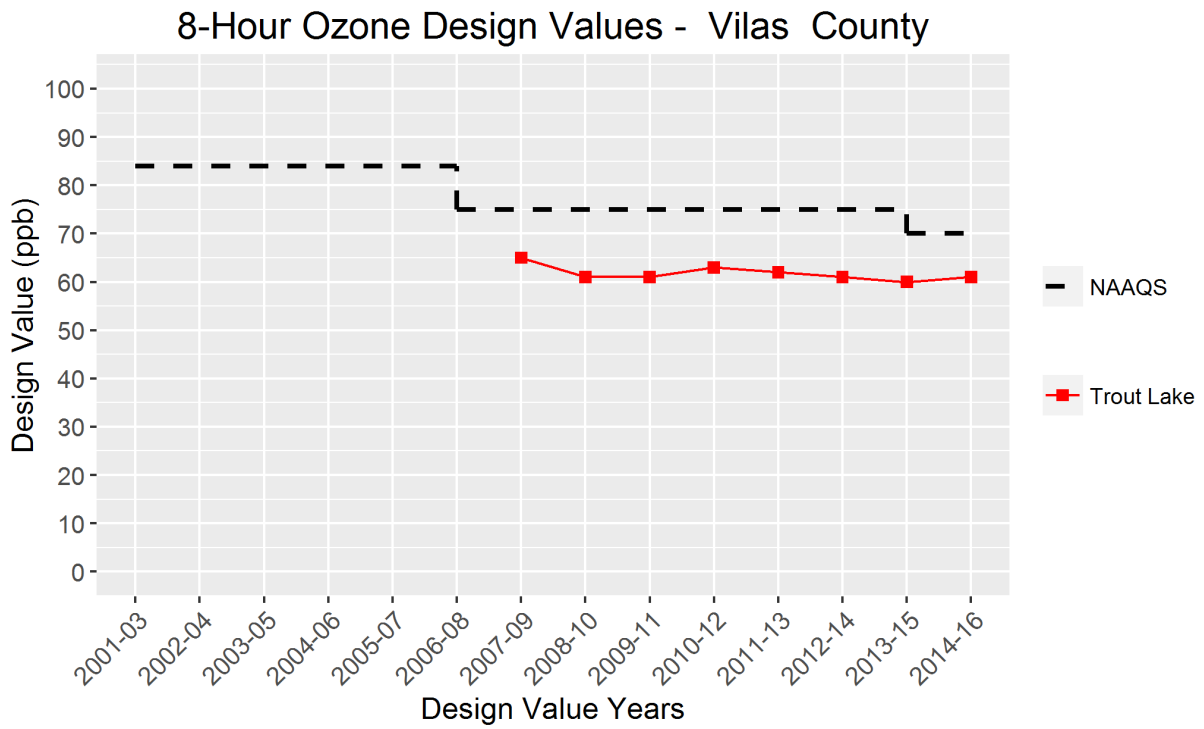
Fine-particle monitoring in Taylor County takes place at W10746 County Highway M, a rural site one mile east of Perkinstown.

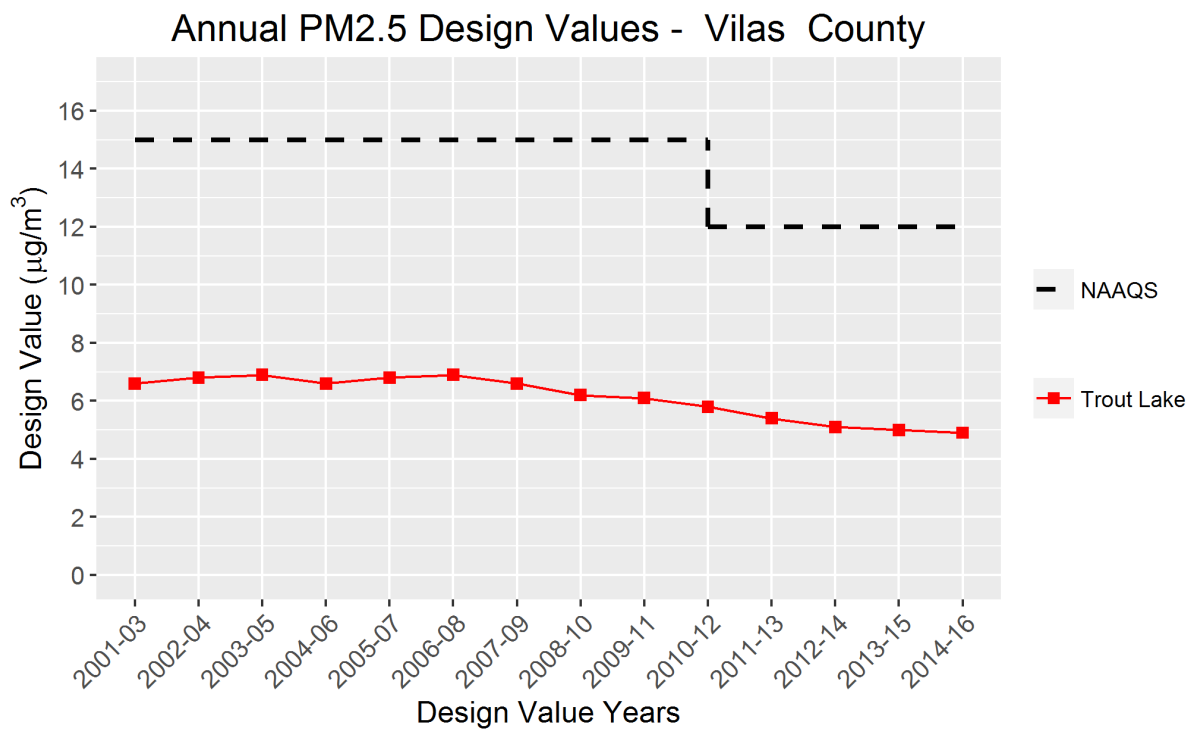


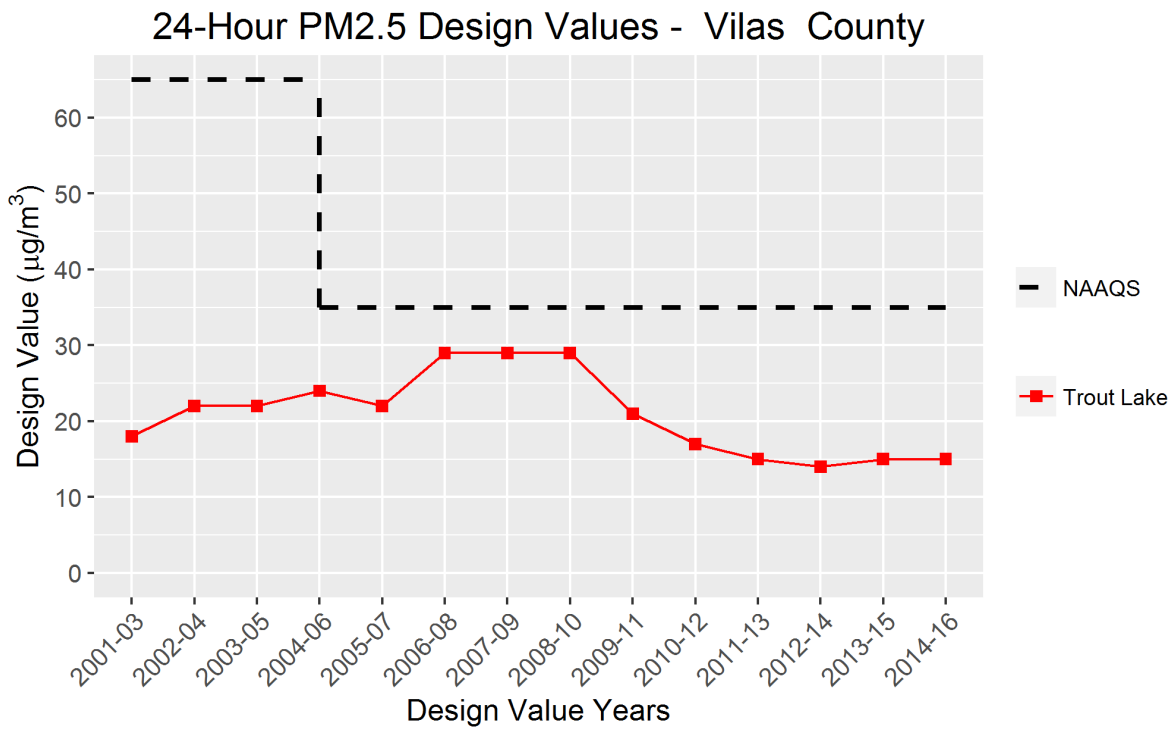


Vilas County

Monitoring for ozone and $PM_{2.5}$ in Vilas County is conducted in a field at the WDNR-University of Wisconsin Trout Lake Station at 10810 County Highway M in Boulder Junction.

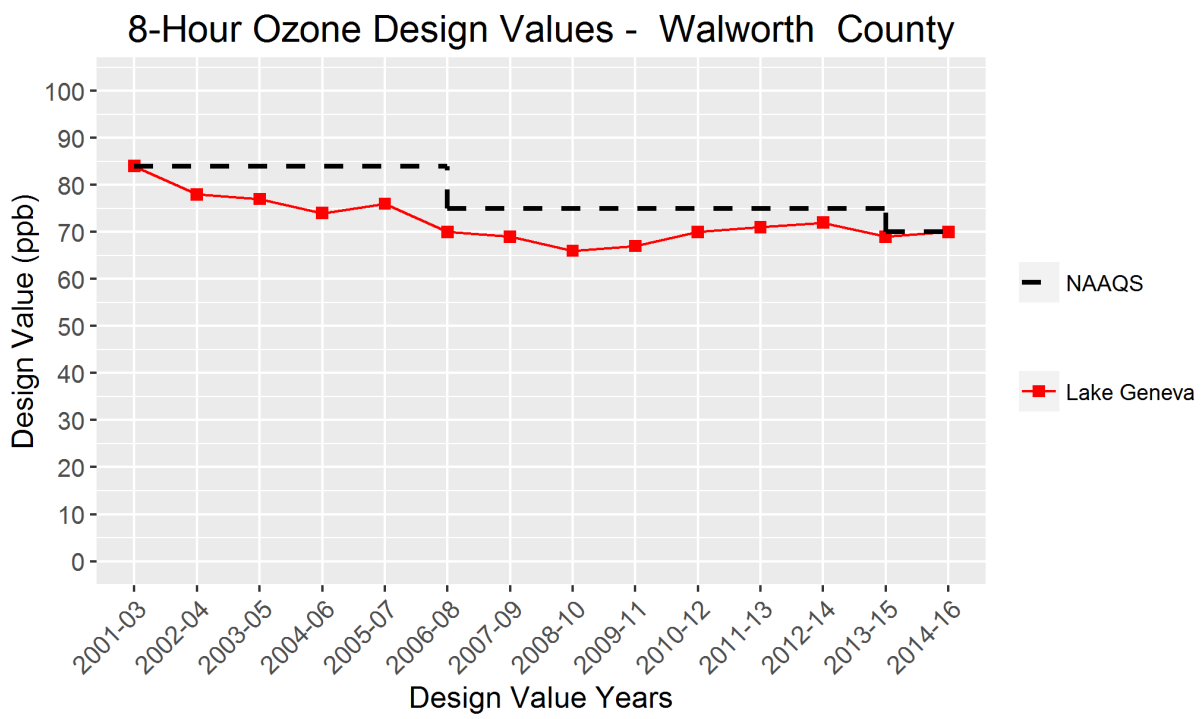





24-Hour PM2.5 Design Values - Vilas County
Design Value (µg/m3)
60
50
40
30
20
10
0
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Trout Lake

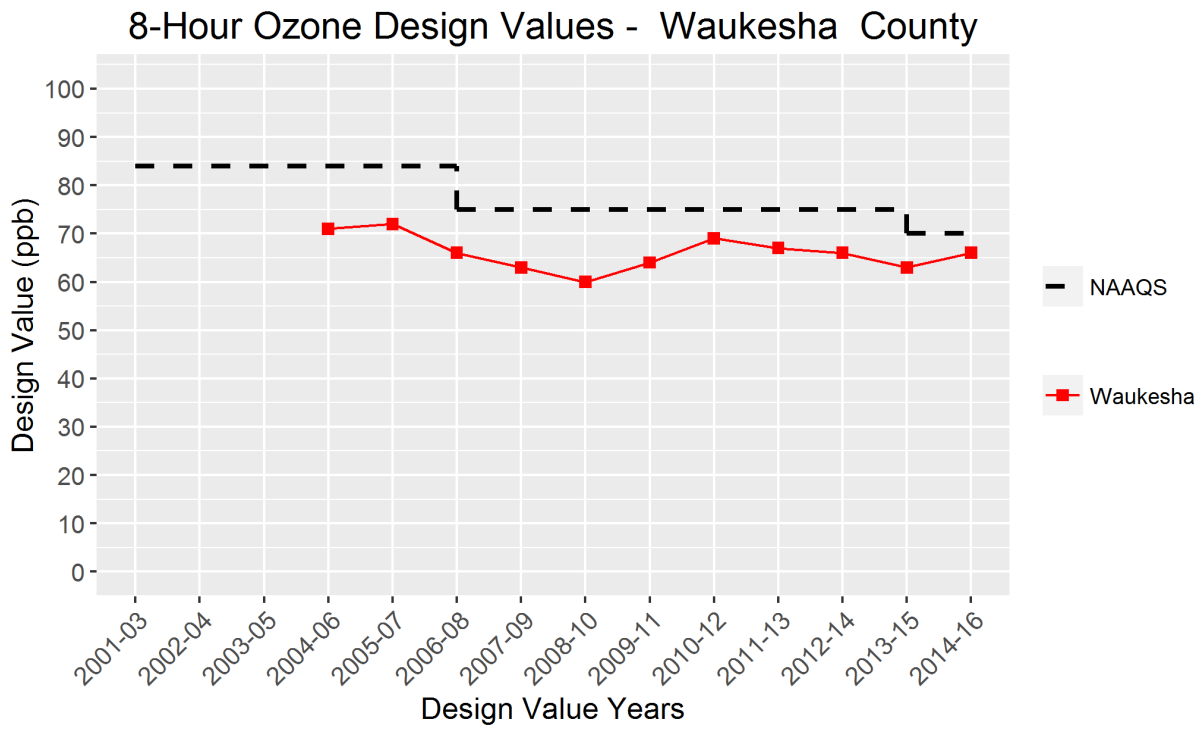
Walworth County

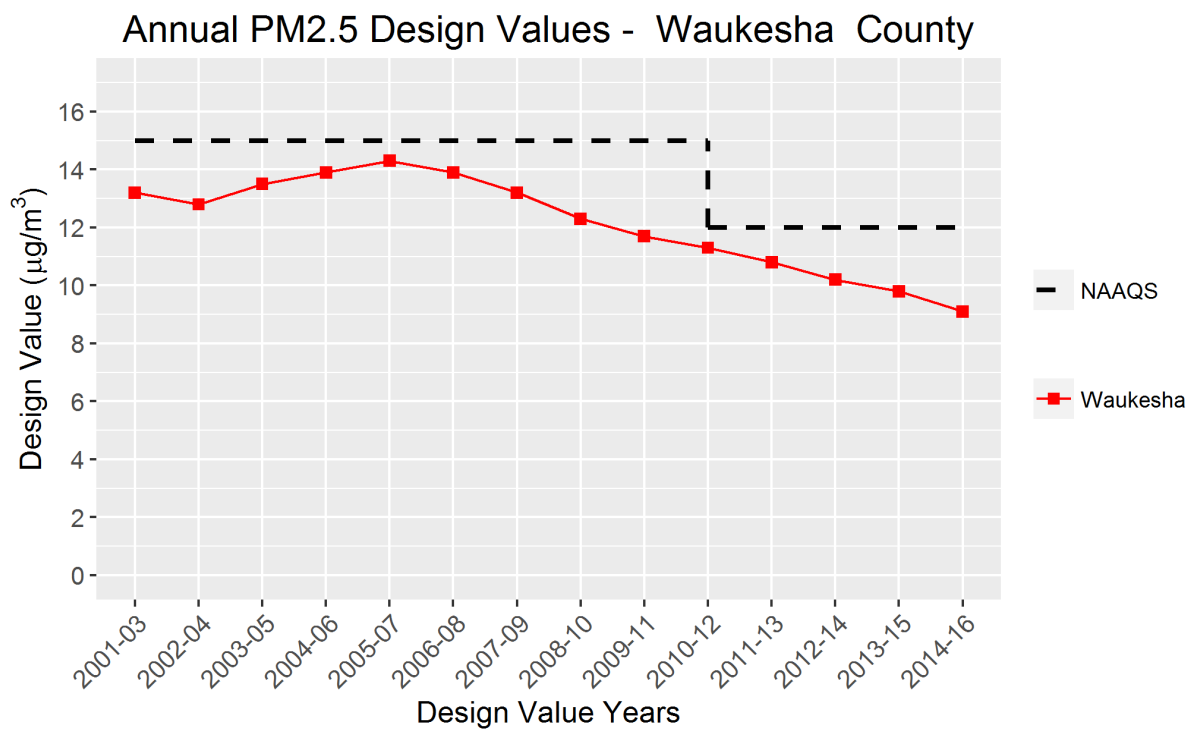
Ozone monitoring in Walworth County is performed at a rural site on the outskirts of the city of Lake Geneva. The address for the site is Rural Route 4 Elgin Club Road.

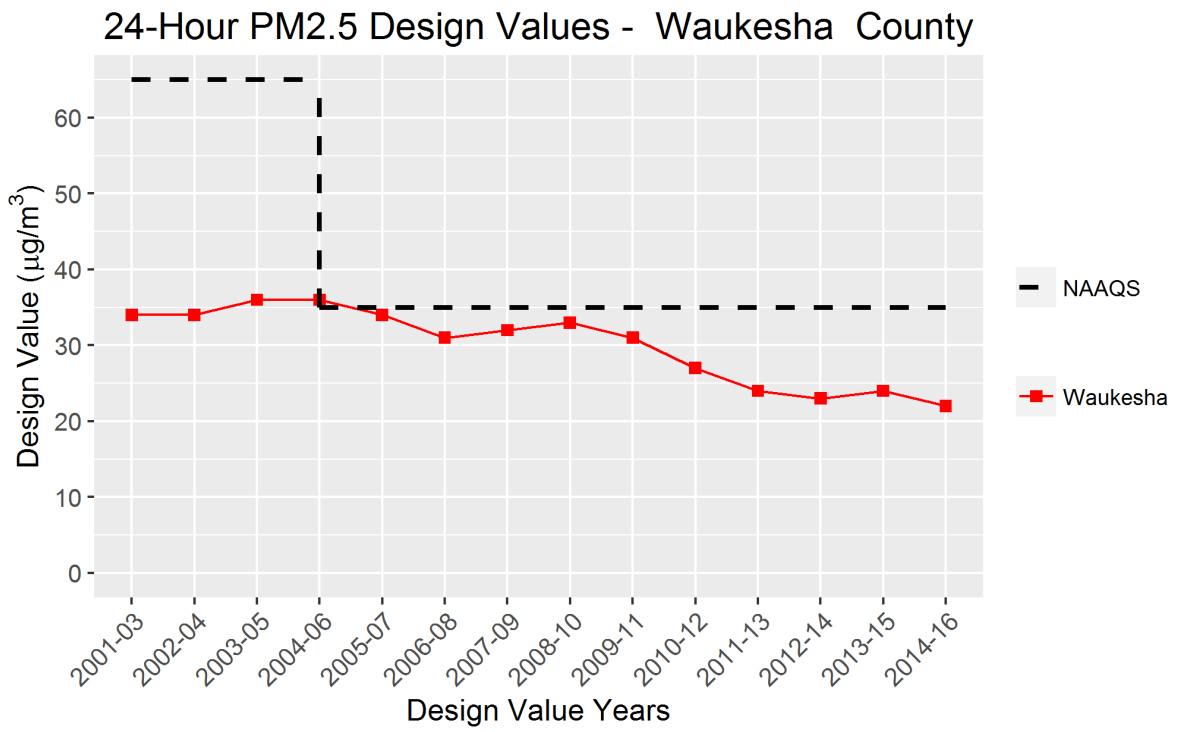


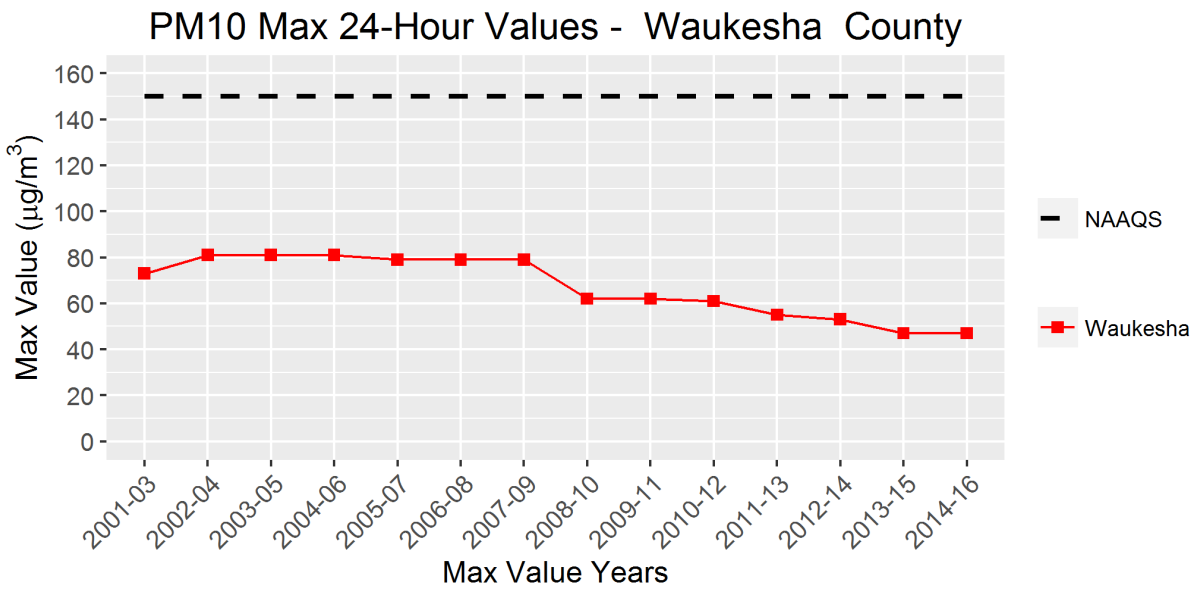
Waukesha County

Monitoring for ozone, $PM_{2.5}$, and PM_{10} in Waukesha County is conducted at 1310 Cleveland Avenue in the city of Waukesha. Sampling for concentrations of ozone and $PM_{2.5}$ began on April 29, 2004 and January 22, 2004, respectively. Prior to these dates, sampling for ozone in Waukesha County was performed at a site on the Carroll College campus.






24-Hour PM2.5 Design Values - Waukesha County
Design Value (µg/m3)
0
10
20
30
40
50
60
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Design Value Years
NAAQS
Waukesha


PM10 Max 24-Hour Values - Waukesha County
Max Value (µg/m3)
0
20
40
60
80
100
120
140
160
2001-03
2002-04
2003-05
2004-06
2005-07
2006-08
2007-09
2008-10
2009-11
2010-12
2011-13
2012-14
2013-15
2014-16
Max Value Years
NAAQS
Waukesha

Appendix B. – Design Value Changes

TABLE B1. Change in 8-hr design values for ozone between the 2001-2003 and 2014-2016. Only monitors with valid design values for both beginning and ending periods are included. Note that none of the Far North monitors operated in 2001-2003.

Site name	County	Site ID	8-hr design values^ (ppb)		Change (2001-03 to 2014-16)	
			2001-2003	2014-2016	ppb	%
Appleton	Outagamie	55-087-0009	78	67	-11	-14%
Bayside	Milwaukee	55-079-0085	94	71	-23	-24%
Beloit*	Rock	55-105-0030	83	69	-14	-17%
Chiwaukee Prairie	Kenosha	55-059-0019	101	77	-24	-24%
Columbus	Columbia	55-021-0015	79	67	-12	-15%
Devils Lake	Sauk	55-111-0007	73	64	-9	-12%
Fond du Lac	Fond du Lac	55-039-0006	80	66	-14	-18%
Grafton	Ozaukee	55-089-0008	92	71	-21	-23%
Green Bay-UW	Brown	55-009-0026	83	66	-17	-20%
Harrington Beach	Ozaukee	55-089-0009	98	73	-25	-26%
Horicon*	Dodge	55-027-0001	82	68	-14	-17%
Jefferson*	Jefferson	55-055-0009	83	69	-14	-17%
Kewaunee	Kewaunee	55-06-10002	93	69	-24	-26%
Lake Du Bay	Marathon	55-07-30012	73	65	-8	-11%
Lake Geneva	Walworth	55-127-0005	84	70	-14	-17%
Madison-East	Dane	55-025-0041	78	65	-13	-17%
Manitowoc	Manitowoc	55-07-10007	90	72	-18	-20%
Milw.-SER	Milwaukee	55-079-0026	84	68	-16	-19%
Newport	Door	55-029-0004	94	72	-22	-23%
Sheboygan-KA	Sheboygan	55-117-0006	100	79	-21	-21%
Lakeshore region** average					-22	-23%
Inland region** average					-13	-16%

^The 2001-2003 design values would be compared against the 1997 8-hour ozone NAAQS of 84 ppb; the 2014-2016 design values would be compared against both of the 8-hr ozone NAAQS in effect in 2016: 75 ppb for the 2008 standard and 70 ppb for the 2015 standard.

*The "Beloit" monitor combines records from the Beloit-Cunningham monitor (55-105-0024), which shut down in 2013, and the Beloit-Converse monitor, which replaced it. The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it. The "Jefferson" monitor combines records from the Jefferson H.S. monitor (55-055-0002), which shut down after 2012, and the Jefferson-Laatsch monitor, which replaced it.

**See Figure 3 and associated text for definition of these regions.

TABLE B2. Change in annual design values for $PM_{2.5}$ between the 2001-2003 and 2014-2016. Only monitors with valid design values for both beginning and ending periods are included.

Site name	County	Site ID	Annual design values^ ($\mu g/m^3$)		Change (2001-03 to 2014-16)	
			2001-2003	2014-2016	($\mu g/m^3$)	%
Appleton	Outagamie	55-087-0009	10.7	7.5	-3.2	-30%
Chiwaukee Prairie	Kenosha	55-059-0019	11.7	8	-3.7	-32%
Green Bay-East	Brown	55-009-0005	11.5	8	-3.5	-30%
Horicon*	Dodge	55-027-0001	11	7.7	-3.3	-30%
Madison-University	Dane	55-025-0047	12.5	8.4	-4.1	-33%
Milw.-16th St.	Milwaukee	55-079-0010	13.1	9.2	-3.9	-30%
Milw.-SER	Milwaukee	55-079-0026	12.5	8.5	-4	-32%
Potosi	Grant	55-043-0009	11.4	7.6	-3.8	-33%
Trout Lake**	Vilas	55-125-0001	6.6	4.9	-1.7	-26%
Waukesha	Waukesha	55-133-0027	13.2	9.1	-4.1	-31%
Southeast region† average					-3.9	-31%
Inland region† average					-3.3	-30%

^The 2001-2003 design values would be compared against the 1997 annual $PM_{2.5}$ NAAQS of 15.0 $\mu g/m^3$; the 2014-2016 design values would be compared against the 2012 annual $PM_{2.5}$ NAAQS of 12.0 $\mu g/m^3$.

*The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it.

**The only Far North monitor operating in 2001-03 was Trout Lake, so no average is shown.

†See Figure 7 and associated text for definition of these regions.

TABLE B3. Change in 24-hr design values for $PM_{2.5}$ between the 2001-2003 and 2014-2016. Only monitors with valid design values for both beginning and ending periods are included.

Site name	County	Site ID	24-hr design values^ ($\mu g/m^3$)		Change (2001-03 to 2014-16)	
			2001-2003	2014-2016	($\mu g/m^3$)	%
Appleton	Outagamie	55-087-0009	29	22	-7	-24%
Chiwaukee Prairie	Kenosha	55-059-0019	31	20	-11	-35%
Green Bay-East	Brown	55-009-0005	32	22	-10	-31%
Horicon*	Dodge	55-027-0001	33	21	-12	-36%
Madison-University	Dane	55-025-0047	34	22	-12	-35%
Milw.-16th St.	Milwaukee	55-079-0010	36	24	-12	-33%
Milw.-SER	Milwaukee	55-079-0026	34	20	-14	-41%
Potosi	Grant	55-043-0009	28	21	-7	-25%
Trout Lake**	Vilas	55-125-0001	18	15	-3	-17%
Waukesha	Waukesha	55-133-0027	34	22	-12	-35%
Southeast region† average					-12.3	-36%
Inland region^ average					-8.5	-30%

^The 2001-2003 design values would be compared against the 1997 24-hour $PM_{2.5}$ NAAQS of 65 $\mu g/m^3$; the 2014-2016 design values would be compared against the 2006 24-hour $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$.

*The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it.

**The only Far North monitor operating in 2001-03 was Trout Lake, so no average is shown.

†See Figure 8 and associated text for definition of these regions.

TABLE B4. Change in 3-yr maximum 24-hr average for PM_{10} between the start of monitoring (date variable) and 2014-2016. Annual maximum values over three years contribute to the determination of the PM_{10} design value.

Site name	County	Site ID	First years of data	3-yr maximum 24-hr average^* (ppb)		Change (first years to 2014-16)	
				First years	2014-2016	ppb	%
Devils Lake	Sauk	55-111-0007	2012-14	41	42	1	2%
Horicon**	Dodge	55-027-0001	2005-07	62	51	-11	-18%
Madison-University	Dane	55-025-0047	2008-10	63	46	-17	-27%
Milw.-16th St.	Milwaukee	550-790-010	2007-09	47	46	-1	-2%
Milw.-College Ave. P&R	Milwaukee	55-079-0058	2010-12	70	57	-13	-19%
Milw.-SER	Milwaukee	55-079-0026	2011-13	63	57	-6	-10%
Waukesha	Waukesha	55-133-0027	2001-03	73	47	-26	-36%

^All design values would be compared against the 1987 24-hour PM_{10} NAAQS of 150 µg/m^3, which is not to be exceeded more than once per year on average over 3 yr.

*Three-year maximum values in this year's report were updated to include data from both continuous and filter-based monitors, rather than from filter-based monitors alone, in order to more accurately reflect the data used in design value calculations.

**The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it.

TABLE B5. Change in 1-hr design values for SO_2 between the start of monitoring (date variable) and 2014-2016. Only one monitor (Rhinelander) had valid design values for the entire 2001-2003 to 2014-2016 period.

Site name	County	Site ID	First years of data	1-hr design values^ (ppb)		Change (first years to 2014-16)	
				First years	2014-2016	ppb	%
Green Bay-East	Brown	55-009-0005	2003-05	67	54	-13	-19%
Horicon	Dodge	55-027-0001	2010-12	7	4	-3	-43%
Madison-East	Dane	55-025-0041	2013-15	7	5	-2	-29%
Milw.-SER	Milwaukee	55-079-0026	2002-04	68	15	-53	-78%
Potawatomi	Forest	55-041-0007	2007-09	8	6	-2	-25%
Rhinelander	Oneida	55-085-0996	2001-03	149	149	0	0%

^Design values from 2010-2012 to 2014-2016 would be compared against the 2010 1-hour SO_2 NAAQS of 75 ppb. There was not a 1-hr standard in effect prior to 2010; rather there were annual and 24-hr standards of 30 ppb and 140 ppb, respectively.

TABLE B6. Change in annual design values for NO_2 between the start of monitoring (date variable) and 2016.

Site name	County	Site ID	First year of data	Annual design values^ (ppb)		Change (first year to 2016)	
				First year	2016	ppb	%
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014	16	14	-2	-13%
Milw.-SER	Milwaukee	55-079-0026	2004	17	9	-8	-47%

^All design values would be compared against the 1971 annual NO_2 NAAQS of 53 ppb.

TABLE B7. Change in 1-hr design values for NO_2 between the start of monitoring (date variable) and 2014-2016.

Site name	County	Site ID	First years of data	1-hr design values^ (ppb)		Change (first years to 2014-16)	
				First years	2014-2016	ppb	%
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014-16	-	49	-	-
Milw.-SER	Milwaukee	55-079-0026	2004-06	52	44	-8	-15%

^Design values from 2014-2016 would be compared against the 2010 1-hour NO_2 NAAQS of 100 ppb. There was not a 1-hr standard in effect prior to 2010; rather values would be compared to the 1971 annual standard of 53 ppb.

TABLE B8. Change in 3-mo design values for lead between 2012-2014 and 2014-2016.

Site name	County	Site ID	3-mo design values^ ($\mu g/m^3$)		Change (2012-2014 to 2014-16)	
			2012-2014	2014-2016	$\mu g/m^3$	%
Kohler	Sheboygan	55-117-0008	0.11	0.09	-0.02	-18%

^All design values would be compared against the 2008 3-mo lead NAAQS of 0.15 $\mu g/m^3$.

TABLE B9. Change in 8-hr and 1-hr design values for CO between the start of monitoring (date variable) and 2016.

Site name	County	Site ID	First year of data	8-hr design values^ (ppm)		1-hr design values^ (ppm)	
				First year	2016	First year	2016
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014	0.7	0.8	1.2	1
Horicon	Dodge	55-027-0001	2010	0.4	0.4	0.5	0.7

^All 8-hr design values would be compared against the 1971 8-hour CO NAAQS of 9 ppm, and all 1-hr design values would be compared against the 1971 1-hour NAAQS of 35 ppm.

Appendix C. – Full Site Names

TABLE C1. Full site names corresponding to shorter names used in the text, tables, and figures.

Site Name	County	Site ID	Full site name
Appleton	Outagamie	55-087-0009	Appleton - AAL
Bad River	Ashland	55-003-0010	Bad River Tribal School - Odanah
Bayside	Milwaukee	55-079-0085	Bayside
Beloit*	Rock	55-105-0030	Beloit - Converse
Chiwaukee	Kenosha	55-059-0019	Chiwaukee Prairie Stateline
Columbus	Columbia	55-021-0015	Columbus
Devils Lake	Sauk	55-111-0007	Devils Lake Park
Eau Claire	Eau Claire	55-035-0014	Eau Claire - DOT Sign Shop
Fond du Lac	Fond du Lac	55-039-0006	Fond du Lac
Grafton	Ozaukee	55-089-0008	Grafton
Green Bay-East	Brown	55-009-0005	Green Bay - East High
Green Bay-UW	Brown	55-009-0026	Green Bay - UW
Harrington Beach	Ozaukee	55-089-0009	Harrington Beach Park
Horicon*	Dodge	55-027-0001	Horicon Wildlife Area
Jefferson*	Jefferson	55-055-0009	Jefferson - Laatsch
Kenosha-WT	Kenosha	55-059-0025	Kenosha-Water Tower
Kewaunee	Kewaunee	55-061-0002	Kewaunee
Kohler	Sheboygan	55-117-0008	Kohler
La Crosse	La Crosse	55-063-0012	Lacrosse - DOT Building
Lake Du Bay	Marathon	55-073-0012	Lake Du Bay
Lake Geneva	Walworth	55-127-0005	Lake Geneva
Madison-East	Dane	55-025-0041	Madison - East
Madison-University	Dane	55-025-0047	Madison – University Ave. Well #6
Manitowoc	Manitowoc	55-071-0007	Manitowoc - Wdlnd Dunes
Milw.-16th St.	Milwaukee	55-079-0010	Milwaukee - Sixteenth St. Health Center
Milw.-College Ave. NR	Milwaukee	55-079-0056	Milwaukee – College Ave. Near Road
Milw.-College Ave. P&R	Milwaukee	55-079-0058	Milwaukee – College Ave. Park & Ride
Milw.-Fire Dept.	Milwaukee	55-079-0099	Milwaukee – Fire Dept. HQ.
Milw.-SER	Milwaukee	55-079-0026	Milwaukee - SER WDNR Hdqrs.
Newport	Door	55-029-0004	Newport Park
Perkinstown	Taylor	55-119-8001	Perkinstown
Potawatomi	Forest	55-041-0007	Potawatomi
Potosi	Grant	55-043-0009	Potosi
Racine-Payne & Dolan	Racine	55-101-0020	Racine-Payne & Dolan
Rhinelander	Oneida	55-085-0996	Rhinelander Tower
Sheboygan-Haven	Sheboygan	55-117-0009	Sheboygan - Haven
Sheboygan - KA	Sheboygan	55-117-0006	Sheboygan - Kohler Andrae
Trout Lake	Vilas	55-125-0001	Trout Lake
Waukesha	Waukesha	55-133-0027	Waukesha - Cleveland Ave.

* The "Beloit" monitor combines records from the Beloit-Cunningham monitor (55-105-0024), which shut down in 2013, and the Beloit-Converse monitor, which replaced it. The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it. The "Jefferson" monitor combines records from the Jefferson H.S. monitor (55-055-0002), which shut down after 2012, and the Jefferson-Laatsch monitor, which replaced it