Data Collection Efficiency for Utah Air Quality Monitoring Network (Apr 2013)

Executive Summary

The criteria pollutant data collected by the Utah Air Monitoring Network was organized and analyzed for internal trends. Additionally, the current state of the air monitoring network was assessed against the federal monitoring requirements laid out in 40 CFR 58, Appendix D (Network Design Criteria for Ambient Air Quality Monitoring). Some redundant monitoring with respect to the federal requirements as well the significance of the collected data was identified.
The suggestions to improve the data collection efficiency, reduce network maintenance, and comply with the federal monitoring criteria includes following items:

1. Removal of the SO_2 monitors from Magna, Beach, Bountiful, and North Salt Lake monitoring stations. Consider the event driven monitoring model for SO_2 (change of equipment, expansion of operations, etc.).
2. Discontinuation of $PM_{2.5}$ and PM_{10} monitoring at Magna and relocation of the Tooele monitoring station to a new site located in Erda (the site with similar $PM_{2.5}$ concentrations and maximum local ozone concentrations). Removal of the ozone monitor from the Beach monitoring station.
3. Discontinuation of $PM_{2.5}$ monitoring at Spanish Fork as well as Harrisville monitoring stations (lowest and highly correlated local values). Maintain ozone monitoring at both of the stations (highest local ozone values).
4. Removal of Washington Boulevard CO monitor (may require the approval of Regional Administrator).
5. Commence PM_{10} monitoring at Hurricane monitoring station no later than 2014.
6. Prepare for $PM_{2.5}$ and ozone monitoring in Iron County as early as 2015.

This report details the technical analysis done in an attempt to make the Utah air monitoring network more efficient. However, it should be noted that decisions regarding the placement or removal of monitors will be made based on other factors, as well, such as consolidation of smaller sites into "super sites", air quality modeling needs, citing accommodations, etc.

Introduction

The State of Utah has 20 stations in its air pollution monitoring network that operate instruments monitoring primary pollutants: NO_2, $PM_{2.5}$, PM_{10}, O_3, SO_2, and CO. It is important that the data collected by these monitors is representative of the local and regional pollution levels to assist in controlling State's pollution, informing the public of health implications, and devising appropriate legislative measures. It is also critical to reduce monitoring redundancy as much as possible to ensure efficient use of existing funding and labor allocation as well. To ensure efficient and representative pollution monitoring by the State of Utah Air Monitoring Network a statistical analysis of 2008 through 2012 criteria pollutant data was performed.

The data was obtained from AQS for all of the 20 criteria pollutant monitoring stations. Correlation tables were created for all of the criteria monitors and each of the pollutants. A paired T-test was performed for each of the highly correlated monitors located within a reasonable proximity. The results and the discussion are found below.

Salt Lake City CBSA (pop. 1,142,170)

$PM_{2.5}$ Monitors

According to the federal regulations (40 CFR p.58 App. D 4.7) Core Base Statistical Area (CBSA) with the population above 1,000,000 and the most recent 3-year design value above $PM_{2.5}$ NAAQS must have at least 3 active $PM_{2.5}$ monitors. As of March 2013, the State of Utah DAQ employs four FRM $PM_{2.5}$ monitors. These monitors are located at the Hawthorne(HW), Magna (MG), Rose Park (RP), and Tooele (T3) monitoring stations. Hawthorne and Rose Park monitors operate on 1-in-1 day monitoring schedule, while Magna and Tooele follow 1-in-3 day schedule.

Two of the stations, Hawthorne and Rose Park, are located within Salt Lake City's city limits. Both were placed on the grounds of local schools in predominantly residential areas. The Magna monitoring station is located on the roof of Magna's Brockbank Junior High School, while the Tooele station is located near the center of Tooele, UT.

Appendix part 1.A contains the correlation tables for the four stations as well as Paired T-tests for the stations with the highest mutual correlation and proximity. Additionally, the same suite of tests was conducted upon the data collected between October and March. This was done to consider the possible change in data redundancy during wintertime pollution events in the in Salt Lake City and the surrounding areas.

Excluding the Rose Park and Tooele monitors, the correlation values for $PM_{2.5}$ tend to increase slightly during winters. This is well explained by the onset of stable, shallow, and relatively well-mixed inversion conditions in the area. The already high, 0.88 – 0.94, correlation values increase by approximately 0.02 during the colder months.

The three highest correlation values were associated with HW-MG, HW-RP, and T3-MG pairs. The relationship between the means of the $PM_{2.5}$ concentrations observed by these monitors obeyed the following pattern: RP > HW > MG > T3. The same relationship persisted for the year-around and winter-adjusted data.

The mean for RP tended to exceed that of HW by 1.6 ug/m^3 for the year-around mean and 1.6 ug/m^3 for the winter mean. The lack of change in the mean differences is likely due to the near-identical concentrations brought about by the close proximity of the two monitors. The slightly increased values of RP are explained by its location close to two major freeways (I-15 and I-215) as opposed to that of the HW monitor.

The MG monitor displayed consistently lower readings than the HW monitor with the mean difference of 1.5 ug/m^3 and 3.3 ug/m^3 for year-around and winter-time periods, respectively. Similar values were observed between MG and T3 monitors (1.7 ug/m^3 and 3.4 ug/m^3). This apparent gradient in mean $PM_{2.5}$ concentrations suggests that Salt Lake City generally and the I-15 corridor urban area specifically is the initial area of formation for the $PM_{2.5}$ pollution.

Since only three active $PM_{2.5}$ monitors are required in the Salt Lake City CBSA it is reasonable to discontinue $PM_{2.5}$ monitoring at one of the stations belonging to the area. Magna or Tooele monitors both provide suitable choices for discontinued monitoring. The counter-argument to removal of either of these monitors is that the T3 monitor is the single monitor that provides $PM_{2.5}$ monitoring for Tooele city and county, and the MG monitor may be useful in monitoring the effects of the mining activity conducted by the Kennecott copper mine.

PM_{10} Monitors

There are three active PM_{10} monitors in the Salt Lake City CBSA. These instruments are located at Hawthorne (HW), North Salt Lake (N2), and Magna (MG) monitoring stations. Hawthorne and North Salt Lake monitors collect data on 1-in-1 day monitoring schedule, while the Magna monitor follows a 1-in-3 day pattern. The North Salt Lake monitor has been reclassified as an industrial source monitor, because it is heavily influenced by the nearby gravel pits and is not in or representative of a residential area. The three monitors satisfy the minimum federal PM_{10} monitoring requirements.

Appendix Part A.2 contains the correlation and the paired t-test analyses. The correlation values between the three stations were much lower than their $PM_{2.5}$ counterparts. The values were found within 0.45–0.68 range, reflective of little to mild correlation. Additionally, they tended to be less associated with the time of year as $PM_{2.5}$ was. The low correlation values are explained by the localized nature of emission and fast deposition rates of PM_{10}.

The year-round mean at N2 was 13.2 ug/m^3 above that of HW, and only 7.2 ug/m^3 higher during the cold months. The greater disparity in the data that included warm months is likely due to nearby poorly-maintained roads, construction, and the gravel pit operations. A dissimilar trend was observed between HW and MG monitors, lending credence to the possible influence of sources of PM_{10} at the N2 site.

The mean values arranged in the decreasing order follow the following order: N2, HW, MG. This pattern resembles that of $PM_{2.5}$ monitors in that the N2 monitor is located fairly close to the Rose Park monitor and is the closest to the I-15 corridor.

SO_2 Monitors

There are four active FEM SO_2 monitors operating within the Salt Lake City CBSA. One monitor is located at the Hawthorne (HW) monitoring station as a part of nCore network. Beach (B4), Magna, and North Salt Lake (N2) also each have a single monitor. The HW monitor is the newest addition to the network and was installed in 2010. Each of the instruments monitors ambient SO_2 concentrations on an hourly and a 5-minute basis. Appendix A.3 contains the descriptive statistics as well as the correlation tables for the SO_2monitors in the Salt Lake City CBSA.

The overwhelming majority of the data collected by the SO_2 monitors in the Salt Lake valley is near the detection limit of the deployed instruments. BV, B4, and MG monitors have over 75% of their reporting values below 2ppb. Occasional spikes in hourly concentrations rarely reach the National Ambient Air Quality Standard (NAAQS) limits. Between 2008 and 2012, the N2 monitor registered 9 instances of SO_2 concentrations above 50% of the NAAQS (75 ppb hourly average), all of which were observed only in 2008 and 2009. The Beach monitor reported only 7 instances above 50% of the standard (also in 2008 and 2009), while only four events were observed at the Magna site during the same time period. Beginning with its initial deployment date, the HW monitor observed only a single value above 50% of the NAAQS in 2011. No SO_2 NAAQS violations occurred in Salt Lake City CBSA during the period of 2008 through 2012, although there were 6 one-hour values above the 75 ppb NAAQS. Table 1 shows the NAAQS exceedances by the monitor and the exceedance date.

Table 1. SO_2 Exceedance Levels and Dates for Salt Lake City CBSA.

Station			
N2	131 ppb – 4/24/2008	95 ppb – 6/25/2008	
B4	126 ppb – 7/20/2008	279 ppb – 7/22/2009	108 ppb – 8/05/2009
MG	149 ppb – 11/21/2012		

The extremely low observed ambient concentrations of SO_2 resulted in very low correlation values for all of the monitors belonging to Salt Lake City CBSA. Additionally, the decreasing trend in SO_2 emissions (see figure 1 in Appendix Part A.3) suggests that the DAQ may be performing SO_2 monitoring beyond a reasonable need. Although the HW monitor is necessary to fulfill the nCore requirements, it provides the least valuable data for SO_2 emission monitoring in the area. It is followed by Magna, North Salt Lake, and Beach monitors.

O_3 Monitors

Federal regulations (40 CFR 58 Appendix D 4.1) require at least two ozone monitors to be operational in a CBSA above 350,000 and below 4,000,000 residents. The Utah Air Quality Monitoring Network satisfies this requirement by having three ozone monitors operational in Salt Lake and Tooele Counties. These monitors are located at the Hawthorne (HW), Beach (B4), and Tooele (T3) monitoring sites. The State is also federally required to seasonally monitor ozone beginning on May 1st and ending on September 30th of each year. B4 and T3 monitor on the federal schedule, while HW monitors O_3 concentrations on a year-round basis.

Appendix A.4 contains the correlation table as well as the paired t-test for the three ozone monitors. B4 and T3 monitors tended to have a reasonably high correlation coefficient of 0.744 at the 99% confidence limit. It was interesting to note a mildly negative correlation between both B4 and T3 monitors and the monitor located at HW. This negative relation can be explained by the diurnal air mass movements in and out from above the Great Salt Lake's surface.
Paired t-tests showed that both T3 and B4 monitors tend to record significantly higher ozone values compared to HW, with B4 logging the highest values. This is most likely due to the monitor's proximity to the lake over which the formation of ozone is enhanced due to the increased albedo.

Since the federal regulations require at least one monitor to be located in the highest concentration area, B4 station could likely satisfy this requirement. However, special ozone studies conducted by the Air Monitoring Center revealed local maximum ozone concentrations in Erda that were higher than those observed at the Beach monitoring station. Erda is located ten miles south and west of B4 in Tooele County.

NO_2 Monitors

The Salt Lake City CBSA has a single NO_2 monitor located at the Hawthorne monitoring station as a part of the nCore network. The monitor satisfies federal requirements for NO_2 monitoring.

CO Monitors

A single trace-level CO analyzer is operational within the Salt Lake City CBSA. It is located at the Hawthorne station and satisfies federal CO monitoring requirements.

Provo-Orem CBSA (pop. 541,112)

$PM_{2.5}$ Monitors

As of January 2013, DAQ operates three FRM $PM_{2.5}$ monitors within the Provo-Orem CBSA that are located at the Lindon (LN), North Provo (NP), and Spanish Fork (SF) monitoring sites. NP and LN monitors operate on a 1-in-1 day schedule, while the SF monitor follows a 1-in-3 day pattern. Additionally, real-time $PM_{2.5}$ monitors are deployed at LN and NP, but those are not used for regulatory purposes.

Federal regulations require at least two active FRM $PM_{2.5}$ monitors in a CBSA with a population above 500,000. Thus, the three monitors deployed by DAQ are exceeding the federal monitoring requirements, and it would be acceptable to discontinue monitoring at the site with the overall lowest reported values.

Appendix B.1 contains the correlation and the analysis of means for the three stations in the Provo-Orem CBSA. As with other closely positioned $PM_{2.5}$ monitors, the correlation values between LN, NP, and SF are extraordinarily high: up to 0.97 for year-round, and up to 0.98 during the cold months. Additionally, the paired t-test showed that LN consistently records higher values than the monitors in SF or NP. When applied to the year-round set of data, the mean $PM_{2.5}$ values in LN are only 4.0% higher than those observed in North Provo and 11.0% above the Spanish Fork monitor. The wintertime mean difference changed to 9.4% and 19.8%, respectively. However, the scalar difference between the means tended to be rather small in every case, ranging from 0.3 ug/m^3 to 2.3 ug/m^3.

Given that the Spanish Fork station needs to be relocated due to requirements by the airport where the site is located, it would be acceptable to discontinue $PM_{2.5}$ monitoring at that station. It is necessary to point out, however, that during the pollution episodes of 2013, SF recorded the highest $PM_{2.5}$ values in Provo-Orem CBSA on several days, although those measurements were uncommon for the location. Additionaly, the high values recorded at SF were not significantly higher than those at LN or NP.

PM_{10} Monitors

The two FRM PM_{10} monitors required by 40 CFR Part 58, Appendix D, for the Provo-Orem CBSA are located at Lindon (LN) and North Provo (NP). The Lindon monitor operates on 1-in-1 days schedule, while the North Provo monitor follows the 1-in-3 day pattern.

Both monitors' observations are well correlated with 0.95 and 0.92 r^2 values for the year-round and the cold months data sets, respectively. As with $PM_{2.5}$, LN tends to record higher PM_{10} readings than those observed at NP. The differences of means are 2.1 ug/m^3 (≈9.0% difference) and 3.5 ug/m^3 (≈15.7% difference) for the year-round and the wintertime months, respectively, with the 99% confidence limit. No PM_{10} monitoring was conducted at the SF site.

Ozone Monitors

The Provo-Orem CBSA has two active ozone monitors located at the North Provo (NP) and Spanish Fork (SF) monitoring sites. The two monitors satisfy federal requirements for ozone monitoring for CBSA's with a population above 350,000. The monitor installed at the NP site is a year-round monitor, while the one deployed at SF operates on a seasonal schedule of May through September.

Both monitors are well correlated with the r^2 value of 0.85. The paired t-test shows that the mean values observed at SF are higher than those seen at NP with the 99% confidence limit. Additionally, both nighttime and daytime adjusted means for the data collected at SF were still above those at NP. The five-year maximum was observed at SF.

The State is required to move the current SF site due to siting requirements of the airport where it is located. The high ozone values recorded at SF suggest that a permanent relocation of SF should be done in relative proximity to its current location if the high ozone values are to be observed in the future. Additionally, the new location for the monitoring site should consider the potential to monitor the regional levels of ozone, similar to the current SF location.

Other Monitors (CO, NOx)

Both CO and NO_x monitors are located at the North Provo site, appropriate for a type 2 PAMS site. The monitors are operated continually on a year-round schedule. Both provide relevant data with respect to the anthropogenic activity in the area as well as the precursors to ozone formation. No additional CO or NO_x monitoring is necessary in the area.

Ogden-Clearfield CBSA (pop. 555,512)

$PM_{2.5}$ Monitors

As of January 2013, the Ogden-Clearfield CBSA has three active FRM $PM_{2.5}$ monitors. These monitors are located at the Bountiful (BV), Ogden (O2), and Harrisville (HV) monitoring stations. The BV and HV monitors operate on a 1-in-3 day schedule. The O2 $PM_{2.5}$ monitor operates on a 1-in-1 day schedule.

The federal $PM_{2.5}$ requirement for CBSAs with a population over 500,000 is to have a minimum of two active monitors deployed at the same time. The presence of three monitors in the Ogden-Clearfield CBSA provides a possibility of removal of one of the monitors.

Appendix C.1 provides the correlation tables and the results of the paired t-tests performed on the data collected by these monitor. As with the previous particulate monitors, the wintertime data was analyzed separately to better estimate the changes between the monitors during the high-pollution events.

As with most other $PM_{2.5}$ monitors, BV, O2, and HV monitors were well correlated between each other. When adjusted for the wintertime, the correlation values increased slightly, reflective of increased homogeneity in $PM_{2.5}$ distribution across the Wasatch Front during the pollution events. An extremely high correlation coefficient ($r^2 = 0.97$) was observed between O2 and HV monitors during the winter season.

The paired t-test showed that both BV and O2 tend to report values above those observed by HV. Although the difference between O2 (the closest) and HV means is numerically small, only 1.0 ug/m^3, and within the 10% range of either value, the high confidence limit indicates that this association is unlikely to be coincidental. The lowest mean observed values at the HV stations make the $PM_{2.5}$ monitor located at that site a suitable choice for elimination.

PM_{10} Monitors

The two PM_{10} monitors for the Ogden-Clearfield CBSA are located at the Bountiful (BV) and Ogden (O2) monitoring cites. These monitors satisfy federal PM_{10} monitoring requirements for the statistical area.

Both monitors are unusually well-correlated despite the distance between them. The year-around correlation value is 0.76, while when adjusted for the wintertime conditions it increases to 0.91. In both cases, O2 data tends to present higher values than those observed at the Bountiful site: the difference of means is 2.6 ug/m^3 and 4.7 ug/m^3, respectively. At this point, the unusually high data correlation is difficult to fully explain.

Ozone Monitors

As of January 2013, there are three ozone monitors deployed in the Ogden-Clearfield CBSA. Two seasonal monitors are operating from May through September and located at Harrisville (HV) and Bountiful (BV). The Ogden (O2) ozone monitor operates on a year-round schedule.

The correlation analysis (see Appendix C.2) showed a high degree of correlation between the three monitors. BV-HV presented the highest degree of correlation, 0.82, followed by O2-HV, 0.80, and BV-O2, 0.76. Performing a paired t-test revealed that the mean concentration at HV were the highest among the monitors, followed by BV, and O2. Additionally, the analysis of hourly differences between the monitors on the days with the recorded ozone concentrations above .060 and .070 ppm showed uneven distribution in the variation of data. As expected, the range in data variation between BV and HV monitor was the greatest, peaking at above 45 ppb in favor of HV. The mode bin was between 8 and 11 ppb in favor of HV.

A slightly different picture was presented by the same analysis between O2 and HV. The data differences tended to bi-bimodal, with the peaks near 1 ppb and 13 ppb in favor of HV. This is indicates that the difference in readings between the two monitors are largely normally distributed, except during some specific, yet frequent, high-ozone events during which the values recorded at the HV site become significantly higher than those observed in Ogden.

Although 40 CFR Appendix D requires a minimum of only two ozone monitors for the CBSAs the size of Ogden-Clearfield, it is advisable to keep all three monitors operating in the area. The data provided by the BV monitor, albeit somewhat redundant and lower in magnitude, provides valuable information in conjunction with the CO, NO_x, and VOC monitoring that is conducted at the location. It is unadvisable to remove the HV ozone monitor due to its consistently higher ozone readings for the Ogden-Clearfield CBSA.

Other Monitors (NO_x, CO, SO_2)

The Ogden-Clearfield CBSA has NO_x monitors located at both Ogden (O2) and Bountiful (BV). Either of the monitors can fulfill the federal PAMS monitoring requirement for the area. However, both monitors are essential with respect to the data they provide: O2 is situated in a major ozone precursor generating area, while BV is located at the site with active ozone, CO, and speciated VOC monitoring, providing invaluable data about ozone forming processes in the area. The SO_2 monitor located at BV provides little to no relevant information about SO_2 emissions in the area. Like other SO_2 monitors in the State of Utah, it is not correlated with any other sulfur dioxide observations. More than 75% of the data obtained at BV is below or at the monitor's detection limit. Additionally, in the period between 2008 and 2012, the maximum observed SO_2 concentration at BV was 28 ppb, less than half the established NAAQS.

The Ogden-Clearfield CBSA boasts the highest concentration of CO monitors in the State of Utah, with monitors located at the BV, O2, and WB (Washington Boulevard) sites. The primary purpose of the BV and O2 monitors is to provide CO data that reflects anthropogenic activity in the area as a subset of PAMS monitoring, while the WB monitor provides CO microscale measurements for downtown Ogden.

Federal regulations (40 CFR Part 58 Appendix D, 4.2.2) dictates that the Regional Administrator may mandate CO monitoring on microscale designed to characterize "CO concentrations in downtown areas or urban street canyons" where the "data suggests that CO concentrations may be approaching or exceeding the NAAQS." In case with the WB monitor, there were no recorded violations observed at the site between 2008 and 2012. Additionally, the maximum value report shows the 8-hour CO values did not exceed 2.0 ppm between 2010 and 2012, and reached the concentration of 8.8 ppm only once (in 2008). Thus, based on the last five years of monitoring, it is reasonable to request the removal of the WB CO monitor. Also, WB station houses a single monitor, making it impractical to continue monitoring considering the benefits it provides.

Other CBSAs (Brigham City, Heber, Logan, St. George, Cedar City, Price, Vernal)

The Logan UT CBSA includes Cache and Franklin (Idaho) counties. With the population size of 127,507, the CBSA accommodates a single monitoring station located in downtown Logan, UT. The station contains O_3, NO_x, PM_{10}, and $PM_{2.5}$ monitors. No additional monitoring is required by the federal mandate in a CBSA of such size.

The Brigham City CBSA (pop. 50,466) has only one monitoring station located in Brigham City. The station houses a seasonal ozone monitor as well as FRM $PM_{2.5}$ and PM_{10} monitors. No additional monitoring is required for the Brigham City CBSA under 40 CFR 58, Appendix D.
The Heber CBSA includes only Wasatch County and has the population of 24,456. At this size, the Heber CBSA has no federal monitoring requirements.

The Saint George UT CBSA (pop. 141,219) includes Washington County and contains a single monitoring station located in Hurricane, UT. As of Jan 2013, the monitoring station houses an O_3, NO_x, and a FEM continuous $PM_{2.5}$ monitor. Depending on the design values from the previous PM_{10} monitoring it may be necessary to install a continuous PM_{10} monitor.

The Cedar City CBSA is located in Iron County. According to 2011 Utah Population Estimates, Iron County had 46,767 residents in 2011. At the 50,000 threshold, DAQ will be obligated to monitor ozone and establish a design value for $PM_{2.5}$ levels in the area. At the current growth rate, the Iron County could reach the 50,000 threshold by 2018. Obtaining a 3-year design value to ascertain $PM_{2.5}$ and PM_{10} monitoring in the area would necessitate the air quality monitoring to commence in 2015 at the earliest and 2018 at the latest.

The Price CBSA is the smallest CBSA in the state with less than 22,000 residents. No monitoring is required by the federal regulations in this area. However, DAQ has three monitoring sites located in the area: Fruitland (FL), Roosevelt (RS), and Price (P2). The Fruitland and Price sites were contracted to DAQ to operate by Utah BLM and unless the funding is renewed the stations will be discontinued in early 2014.

The Vernal UT CBSA is comprised of only Uintah County and is the location for the Vernal monitoring site. The site contains ozone, NO_x, and $PM_{2.5}$ monitors. Although not belonging to the same CBSA, Vernal and Roosevelt monitoring stations resulted from DAQ's effort to observe and control the uncharacteristically high wintertime ozone levels in the Uintah Basin. Both sites are relatively new, having begun their operation in January 2012.

Final Recommendations

This analysis was conducted purely from a technical and a regulatory point of view. Thus, recommendations provided in this report do not reflect additional factors, such as citing criteria compliance, air quality modeling requirements, location availability, etc. With the consideration of the analyzed data, the Utah DAQ may consider removing several monitors to improve the efficiency in data collection by reducing redundant and unnecessary monitoring. The CBSAs with a potential for reduced monitoring are Salt Lake City, Provo-Orem, and Ogden-Clearfield. Up to three SO_2 monitors, three FRM $PM_{2.5}$ monitors, and a CO monitor could be removed from the Air Pollution Monitoring Network without significantly sacrificing the regional and local representativeness of the collected data. One PM_{10} monitor is required to be added (HC) to the current network configuration. Also, a consideration must be given to ozone, $PM_{2.5}$, and PM_{10} monitoring that will need to be established in a growing CBSA that is about to reach the initial monitoring threshold possibly within the next 5 years.

Salt Lake City CBSA shows very high correlation between its $PM_{2.5}$monitors and a very strong gradient with respect the mean values observed at each monitoring site. The two monitors with the lowest mean readings are located in Magna and Tooele. Removing the Magna FRM $PM_{2.5}$ monitor would leave the Salt Lake CBSA within federally mandated monitoring requirements while decreasing the redundancy in the network data. Although the Tooele monitor values are the lowest in the CBSA, the monitor is responsible for reporting $PM_{2.5}$ conditions for the Tooele County.

Removing redundant ozone monitors at the Beach and Tooele stations and commencing ozone monitoring at Erda will likely to provide the highest ozone values (as required by ozone monitoring siting guidelines). It may also be possible to combine the current Tooele $PM_{2.5}$ monitor with a future Erda ozone monitor to have a single monitoring station for Tooele County.

Excessive SO_2 monitoring in Salt Lake CBSA could be addressed by the removal of Magna, North Salt Lake, and possibly even the Beach monitors. Although the Beach SO_2 monitor recorded the highest number of 1-hour SO_2 standard exceedances between 2008 and 2012, there were no recorded exceedances of the standard (or even of 50% of the standard level) between 2010 and 2012. Ultimately, the removal of a single, two, or of the three SO_2 monitors could be justified by the lack of SO_2 standard violations in the last three decades. Some of the monitors could be kept for the sole purpose of monitoring the SO_2 emissions from the operations the refineries located in North Salt Lake City or the Kennecott copper smelter. However, continuous monitoring may be excessive. Event-specific monitoring triggered by facilities updates or operational processes changes may be more appropriate.

Excessive monitoring in Orem-Provo CBSA could be remedied by the removal of SF $PM_{2.5}$ monitor. Its lowest-in-the-CBSA mean values make it an suitable choice for removal. No other changes are warranted in Orem-Provo CBSA.

The Ogden-Clearfield CBSA suffers from a number of monitors producing redundant, excessive, or irrelevant data. A $PM_{2.5}$ monitor located at the Harrisville monitoring site provides the lowest mean values in the CBSA and is well fit for removal. Additionally, the SO_2 monitor located at the Bountiful site serves little or no practical purpose as its values remained overwhelmingly within the detection limit of the instrument, very rarely interrupted by higher values that were even a fraction of the current SO_2 NAAQS. The carbon monoxide monitor located at the Washington Boulevard monitoring station in downtown Ogden could also be removed from the network without much risk to any relevant data.

Although there is one extra ozone monitor in the Ogden-Clearfield CBSA, all of the monitors are located in areas needed to provide relevant data on local urban and regional ozone conditions. Both the Ogden and Bountiful monitors are located in well-urbanized areas with high populations and are essential for the ozone measurement on neighborhood scales. The ozone monitor located in Harrisville provides the highest values for the area as well as the likely background ozone values due to its location removed from the areas of high anthropogenic activity.

Additional PM_{10} monitoring at the Hurricane monitoring site is required due to the size of the St. George CBSA.

A new monitoring station will need to be opened at the Cedar City CBSA (Iron County) by approximately 2018 when its population is projected to reach the federal monitoring threshold.

Appendix to Air Monitoring Network Efficiency Review

Part A.1

Year-around Correlation Table

	HW	MG	RP
MG	0.941		
	0		
RP	0.876	0.826	
	0	0	
T3	0.887	0.938	0.76
	0	0	0

Winter Correlation Table

	HW(w)	MG(w)	RP(w)
MG(w)	0.96		
	0		
RP(w)	0.904	0.842	
	0	0	
T3(w)	0.905	0.946	0.751
	0	0	0

Paired T for HW - RP

	N	Mean	StDev	SE Mean
HW	1609	9.126	8.433	0.21
RP	1609	10.677	9.714	0.242
Difference	1609	-1.551	4.694	0.117
95% CI for mean difference: (-1.781, -1.322)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -13.26 P-Value = 0.000				

Paired T for HW(w) - RP(w)

	N	Mean	StDev	SE Mean
HW(w)	498	14.056	12.453	0.558
RP(w)	498	15.471	13.836	0.62
Difference	498	-1.414	5.921	0.265
95% CI for mean difference: (-1.936, -0.893)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -5.33 P-Value = 0.000				

Paired T for HW - MG

	N	Mean	StDev	SE Mean
HW	551	9.615	9.447	0.402
MG	551	8.031	8.065	0.344
Difference	551	1.584	3.296	0.14
95% CI for mean difference: (1.309, 1.860)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 11.28 P-Value = 0.000				

Paired T for HW(w) - MG(w)

	N	Mean	StDev	SE Mean
HW(w)	182	15.39	13.6	1.01
MG(w)	182	12.08	11.47	0.85
Difference	182	3.307	4.126	0.306
95% CI for mean difference: (2.703, 3.910)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 10.81 P-Value = 0.000				

Paired T for MG-T3

	N	Mean	StDev	SE Mean
MG	517	8.139	8.269	0.364
T3	517	6.425	6.359	0.28
Difference	517	1.714	3.192	0.14
95% CI for mean difference: (1.438, 1.990)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 12.21 P-Value = 0.000				

Paired T for MG(w) - T3(w)

	N	Mean	StDev	SE Mean
MG(w)	171	12.364	11.72	0.896
T3(w)	171	8.919	8.993	0.688
Difference	171	3.445	4.337	0.332
95% CI for mean difference: (2.790, 4.100)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 10.39 P-Value = 0.000				

Part A.2

Year-around Correlation Table

	HW(PM10)	MG(PM10)
MG(PM10)	0.595	
	0	
N2(PM10)	0.638	0.576
	0	0

Winter Correlation Table

	HW(PM10w)	MG(PM10w)
MG(PM-10w)	0.681	
	0	
N2(PM-10w)	0.594	0.452
	0	0

Paired T for HW(PM10) - N2(PM10)				
	N	Mean	StDev	SE Mean
HW(PM10)	1806	22.837	19.121	0.45
N2(PM10)	1806	36.001	28.603	0.673
Difference	1806	-13.163	22.039	0.519
95% CI for mean difference: (-14.180, -12.146)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -25.38 P-Value = 0.000				

Paired T for HW(PM-10w) - N2(PM-10w)				
	N	Mean	StDev	SE Mean
HW(PM-10w)	589	29.14	20.91	0.86
N2(PM-10w)	589	36.36	25.53	1.05
Difference	589	-7.224	21.321	0.879
95% CI for mean difference: (-8.950, -5.499)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -8.22 P-Value = 0.000				

Paired T for HW(PM10) - MG(PM10)				
	N	Mean	StDev	SE Mean
HW(PM10)	603	22.53	18.39	0.75
MG(PM10)	603	20.61	27.34	1.11
Difference	603	1.927	22.072	0.899
95% CI for mean difference: (0.162, 3.692)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 2.14 P-Value = 0.032				

Paired T for HW(PM-10w) - MG(PM-10w)				
	N	Mean	StDev	SE Mean
HW(PM-10w)	196	28.81	21.64	1.55
MG(PM-10w)	196	21.01	15.38	1.1
Difference	196	7.81	15.86	1.13
95% CI for mean difference: (5.57, 10.04)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 6.89 P-Value = 0.000				

Part A.3

Correlation Table for SO2

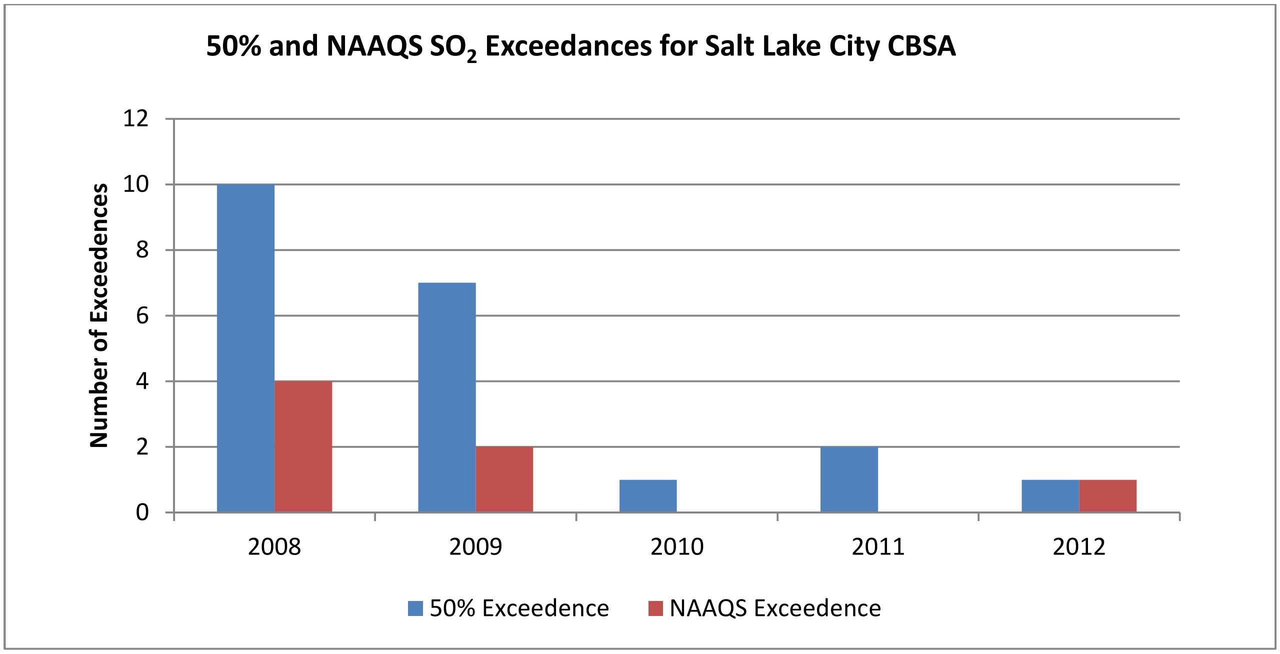
	BV	N2	B4	MG
N2	0.125			
B4	-0.042	0.106		
MG	0.055	0.088	0.088	
HW	0.082	0.096	-0.011	0.015
	0	0	0.175	0.054

Descriptive Statistics for SO_2 Measurements for 2008-2012 (ppm)

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
BV	43002	846	0.001151	0.000006	0.001204	-0.001	0	0.001	0.001	0.028
N2	41467	2381	0.003016	0.000012	0.002542	-0.001	0.001	0.003	0.004	0.131
B4	41736	2112	0.001873	0.000012	0.002537	-0.001	0.001	0.001	0.002	0.279
MG	42907	941	0.001592	0.00001	0.0021	0	0.001	0.001	0.002	0.149
HW	16652	27196	0.000798	0.000008	0.00101	0	0.0003	0.0007	0.0011	0.0465

Exceedance Counts for Salt Lake City CBSA

# NAAQS Exceedances	Station	Exceedance of 50% NAAQS	2008	2009	2010	2011	2012
3	B4	7	4	3			
1	MG	4	1		1	1	1
2	N2	9	5	4			
0	HW	0	0	0	0	1	0
		Exceedances of 50% NAAQS	10	7	1	2	1
		NAAQS Exceedances	4	2			1



50% and NAAQS SO2 Exceedances for Salt Lake City CBSA
Number of Exceedences
0
2
4
6
8
10
12
2008
2009
2010
2011
2012
50% Exceedence
NAAQS Exceedence

Part A.4

Salt Lake Ozone Correlation Table

	HW	B4
B4	-0.416	
T3	-0.37	0.744

Paired T for HW - B4				
	N	Mean	StDev	SE Mean
HW	16511	0.012364	0.009464	0.000074
B4	16511	0.040773	0.016259	0.000127
Difference	16511	-0.02841	0.021953	0.000171
95% CI for mean difference: (-0.028744, -0.028074)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -166.28 P-Value = 0.000				

Paired T for HW - T3				
	N	Mean	StDev	SE Mean
HW	16578	0.012206	0.009403	0.000073
T3	16578	0.044034	0.011905	0.000092
Difference	16578	-0.03183	0.017694	0.000137
95% CI for mean difference: (-0.032098, -0.031559)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -231.61 P-Value = 0.000				

Paired T for B4 - T3				
	N	Mean	StDev	SE Mean
B4	17418	0.040537	0.016431	0.000125
T3	17418	0.043858	0.011927	0.00009
Difference	17418	-0.00332	0.010975	0.000083
95% CI for mean difference: (-0.003484, -0.003158)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -39.93 P-Value = 0.000				

Part B.1

Year-around Correlation Table

	LN	NP
NP	0.966	
SF	0.934	0.95

Winter Correlation Table

	LN(w)	NP(w)
NP(w)	0.98	
SF(w)	0.94	0.963

Paired T for NP - LN

	N	Mean	StDev	SE Mean
NP	1553	8.836	7.631	0.194
LN	1553	9.179	8.297	0.211
Difference	1553	-0.3431	2.192	0.0556
95% CI for mean difference: (-0.4522, -0.2340)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -6.17 P-Value = 0.000				

Paired T for NP(w) - LN(w)

	N	Mean	StDev	SE Mean
NP(w)	475	12.491	11.186	0.513
LN(w)	475	13.665	12.259	0.562
Difference	475	-1.174	2.602	0.119
95% CI for mean difference: (-1.409, -0.940)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -9.84 P-Value = 0.000				

Paired T for NP - SF

	N	Mean	StDev	SE Mean
NP	535	8.83	7.97	0.345
SF	535	8.22	7.867	0.34
Difference	535	0.61	2.499	0.108
95% CI for mean difference: (0.398, 0.822)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 5.64 P-Value = 0.000				

Paired T for NP(w) - SF(w)

	N	Mean	StDev	SE Mean
NP(w)	173	12.655	11.573	0.88
SF(w)	173	11.355	11.766	0.895
Difference	173	1.3	3.186	0.242
95% CI for mean difference: (0.822, 1.778)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 5.37 P-Value = 0.000				

Paired T for LN - SF

	N	Mean	StDev	SE Mean
LN	534	9.225	8.79	0.38
SF	534	8.287	8.059	0.349
Difference	534	0.938	3.148	0.136
95% CI for mean difference: (0.670, 1.205)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 6.88 P-Value = 0.000				

Paired T for LN(w) - SF(w)

	N	Mean	StDev	SE Mean
LN(w)	168	14.143	12.868	0.993
SF(w)	168	11.804	12.213	0.942
Difference	168	2.339	4.391	0.339
95% CI for mean difference: (1.670, 3.008)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 6.90 P-Value = 0.000				

Part C.1

Year-around Correlation Table

	BV	HV
HV	0.92	
O2	0.91	0.946

Winter Correlation Table

	BV(w)	HV(w)
HV(w)	0.932	
O2(w)	0.94	0.971

Paired T for BV - HV

	N	Mean	StDev	SE Mean
BV	530	8.919	8.333	0.362
HV	530	7.992	7.559	0.328
Difference	530	0.927	3.258	0.142
95% CI for mean difference: (0.649, 1.205)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 6.55 P-Value = 0.000				

Paired T for BV(w) - HV(w)

	N	Mean	StDev	SE Mean
BV(w)	162	13.356	12.181	0.957
HV(w)	162	12.252	11.026	0.866
Difference	162	1.104	4.442	0.349
95% CI for mean difference: (0.415, 1.793)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.16 P-Value = 0.002				

Paired T for BV - O2

	N	Mean	StDev	SE Mean
BV	546	9.228	8.798	0.377
O2	546	9.55	8.337	0.357
Difference	546	-0.322	3.66	0.157
95% CI for mean difference: (-0.630, -0.014)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -2.06 P-Value = 0.040				

Paired T for BV(w) - O2(w)

	N	Mean	StDev	SE Mean
BV(w)	176	14.063	12.615	0.951
O2(w)	176	14.056	11.593	0.874
Difference	176	0.006	4.307	0.325
95% CI for mean difference: (-0.635, 0.647)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.02 P-Value = 0.985				

Paired T for HV - O2

	N	Mean	StDev	SE Mean
HV	545	8.187	7.967	0.341
O2	545	9.455	8.162	0.35
Difference	545	-1.268	2.661	0.114
95% CI for mean difference: (-1.492, -1.044)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -11.12 P-Value = 0.000				

Paired T for HV(w) - O2(w)

	N	Mean	StDev	SE Mean
HV(w)	168	12.886	11.687	0.902
O2(w)	168	13.913	11.565	0.892
Difference	168	-1.027	2.803	0.216
95% CI for mean difference: (-1.454, -0.600)				
T-Test of mean difference = 0 (vs not = 0): T-Value = -4.75 P-Value = 0.000				

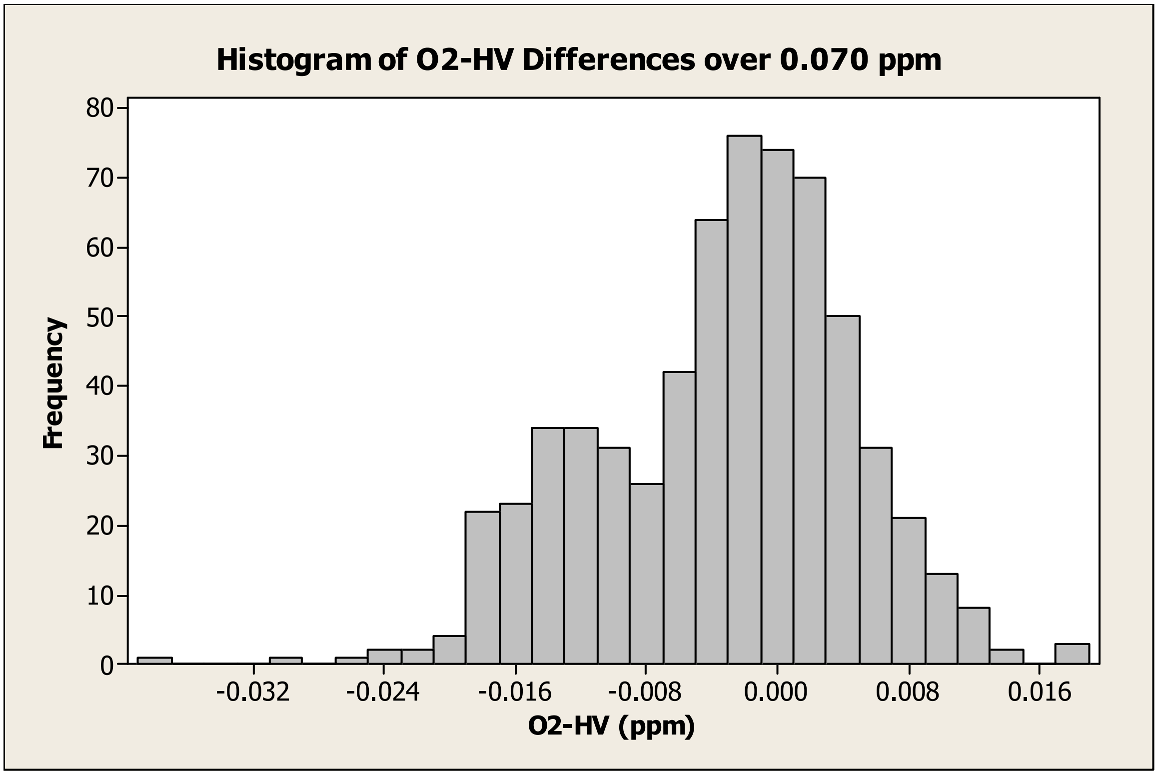
Part C.2

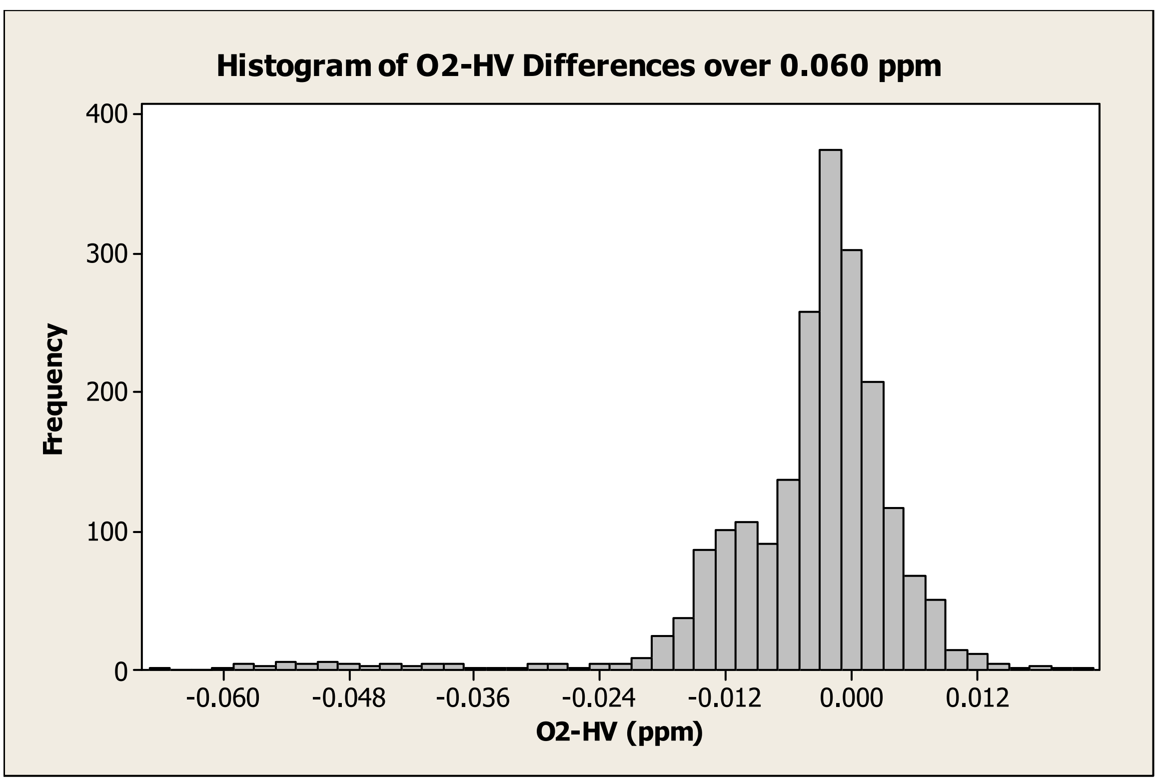
Ozone Correlation Table

	BV	HV
HV	0.819	
O2	0.757	0.796

Paired T for BV - O2				
	N	Mean	StDev	SE Mean
BV	18706	0.036048	0.015609	0.000114
O2	18706	0.032067	0.019771	0.000145
Difference	18706	0.003982	0.012946	0.000095
95% CI for mean difference: (0.003796, 0.004167)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 42.06 P-Value = 0.000				

Paired T for HV - O2				
	N	Mean	StDev	SE Mean
HV	16660	0.042598	0.014875	0.000115
O2	16660	0.033112	0.019791	0.000153
Difference	16660	0.009486	0.012008	0.000093
95% CI for mean difference: (0.009304, 0.009668)				
T-Test of mean difference = 0 (vs not = 0): T-Value = 101.96 P-Value = 0.000				


Histogram of O2-HV Differences over 0.070 ppm
Frequency
0
10
20
30
40
50
60
70
80
-0.032
-0.024
-0.016
-0.008
0.000
0.008
0.016
O2-HV (ppm)


Histogram of O2-HV Differences over 0.060 ppm
Frequency
0
100
200
300
400
-0.060
-0.048
-0.036
-0.024
-0.012
0.000
0.012
O2-HV (ppm)