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Department of Health

Associations of Short-Term Exposure to Ozone and Respiratory Outpatient Clinic Visits — Sublette County, Wyoming, 2008–2011

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Kerry Pride, J. Peel, B. Robinson, A. Busacker, J. Grandpre, F. Yip, T. Murphy

Executive Summary

Introduction

Ozone occurs both in Earth's upper atmosphere (stratosphere), where it protects against ultraviolet radiation, and at ground level (troposphere), where it can cause adverse respiratory effects. Ground-level ozone is one of the six criteria air pollutants monitored and regulated by the Environmental Protection Agency (EPA) under the Clean Air Act. The EPA considers ground-level ozone concentrations ≥75 ppb to be above the national ambient air quality standard, but health effects can occur at lower concentrations. Anyone who works, plays, or spends time outside can feel symptoms from ground-level ozone that include shortness of breath, coughing, wheezing, eye, nose or throat irritation, and pain or burning when taking a deep breath.

Ground-level ozone concentrations higher than the EPA national ambient air quality standard level of 75 ppb have occurred in Sublette County. These exceedances occurred in both 2008 and 2011 during the winter months (February and March). Residents of Sublette County have expressed concern over possible health effects from ground-level ozone and have sought information from public health officials on local adverse health effects. Until this study, objective information on adverse health effects from ground-level ozone in Sublette County was not available.

Goal

The Wyoming Department of Health (WDH) performed this public health investigation to evaluate possible associations between short-term changes in ground-level ozone and adverse acute respiratory effects among persons residing and seeking healthcare within Sublette County.

Methods

De-identified health data was obtained from the two primary care clinics in Sublette County. The Wyoming Department of Environmental Quality (DEQ) supplied the ground-level ozone concentrations, temperature, and humidity data within Sublette County. Descriptive statistics were calculated for each of the monitoring stations (mean, median, minimum, maximum, number of observation days, and standard deviation). Correlations of 8-hour max ground-level ozone concentrations between the monitoring stations were calculated to assess if concentrations at different monitoring stations were associated.

A bi-directional (before and after event) time-stratified (1-month) case-crossover (each case serves as its own control) design was used to estimate the association of ground-level ozone on clinic visits for respiratory-related illnesses. Associations between ground-level ozone and adverse respiratory-related effects were assessed for same day ground-level ozone exposure, previous day ground-level ozone exposure, two days prior ground-level ozone exposure, three days prior ground-level ozone exposure and combined 0–3 days. Multiple sensitivity analyses were completed to evaluate whether similar results were obtained when different model assumptions were used for the analysis.

Results

During 2008–2011, data showed that 8-hour max ground level-ozone concentrations followed a similar pattern year-to-year with the highest concentrations occurring early in the year (February to April) and the lowest concentrations occurring later in the year (October to December). Eight hour max ground-level ozone concentrations between ozone monitoring stations were moderately to highly correlated (correlation coefficient range: 0.61–0.94) between ozone monitoring stations within Sublette County. Results suggest a 3% increase in the number of clinic visits for adverse respiratory-related effects for every 10 ppb increase in 8-hour max ground-level ozone the day following a ground-level ozone increase in Sublette County for the range of ground-level ozone observed (19 ppb to 84 ppb). All other ground-level ozone lags, same day, two days prior, three days prior, and lags 0–3 days combined were consistent with no association between adverse respiratory-related effects and ground level-ozone exposure.

Conclusions

The results of this study suggest an association of ground-level ozone with clinic visits for adverse respiratory-related effects the day following elevations of ground-level ozone in Sublette County. This analysis evaluated ground-level ozone across the range of concentrations observed, with the majority of days below the regulatory standards. These results are consistent with other studies in the published literature. Improved awareness and education of the public and providers of the adverse respiratory-related health effects from ground-level ozone in Sublette County should continue.

Background

Ozone is a colorless gas composed of three oxygen atoms (O_3) and is ubiquitous throughout the atmosphere.[1] Ozone occurs both in Earth's upper atmosphere (stratosphere), where it protects against ultraviolet radiation, and at ground level (troposphere) where it can cause adverse respiratory effects and is a major component of air pollution.[1] The two main classes of ozone precursors are volatile organic compounds (VOCs) and nitrogen oxides (NOx).[2] VOCs refer to all carbon-containing gas-phase compounds in the atmosphere.[2] Precursors for ground-level ozone can come from natural sources (eg. trees or volcanoes) or from man-made sources (eg. automobiles or industry). [1] Background ozone concentrations are those that would occur in the absence of human causes (anthropogenic emissions).[2] Formation of excess ground-level ozone is complex and occurs when pollutants released from cars, power plants, and other sources react in the presence of sunlight.[2-5] Ground-level ozone production varies greatly from locality to locality and is dependent on the amount and type of precursors present and meteorological conditions.[2,6]

Because ground-level ozone can cause adverse health effects and environmental and property damage, it is one of the six criteria air pollutants monitored and regulated by the Environmental Protection Agency (EPA) under the Clean Air Act.[2] The EPA regulates criteria pollutants by developing human health-based and/or environmental-based criteria for setting permissible levels.[2] The EPA considers ground-level ozone concentrations ≥75 ppb for an 8-hour period to be above the level of the national ambient air quality standard. Elevations of ground-level ozone most commonly occur in urban areas during the summer months.[2]

Exposure to elevated ground-level ozone can result in a number of health effects in any person, but especially in susceptible populations such as the young, the elderly, and anyone with pre-existing respiratory health conditions.[1,7,8] Symptoms of adverse respiratory health effects can include shortness of breath; coughing; wheezing; eye, nose or throat irritation; and pain or burning when taking a deep breath. Adverse respiratory-related effects following ground-level ozone exposure have been extensively documented in numerous studies and include induction of respiratory illness symptoms, increased asthma attacks, increased hospital admissions, increased daily mortality, and other markers of morbidity.[9-12] In previous studies, adverse respiratory-related effects due to elevated ground-level ozone occur most commonly during the summer months in large urban centers.[2,13,14]

Sublette County is located in western Wyoming and is just over 4,800 square miles. This region of Wyoming has experienced a population boom; from 2000 to 2010, the population increased 73.1%, from 5,920 to 10,247 (2.1 persons/square mile).[15] Six communities are located in the county ranging from 93 persons to 2,030 persons. [15] Sublette County is an area of year-round tourism for outdoor activities including hiking, skiing, snowmobiling, and other activities. Active oil and gas development is occurring in Sublette County also; the number of drilling rigs increased from 2 in 1996 to 49 in 2006 and the number of oil and gas wells increased from 1,900 in 2000 to 10,000 in 2008 (personal communication, Wyoming DEQ, 2011).

There are two area health clinics, which provide both primary and urgent care. As Sublette County does not have a hospital, patients commonly seek care at one of the area primary care clinics; if needed ill patients are transferred out of the county to one of the hospitals in the surrounding communities. Hospitals with specialized and emergent care are located approximately 80 miles north and 100 miles south of the main population centers in the county.

Since 2005, DEQ has monitored ground-level ozone in Sublette County. During the study period of January 1, 2008 through December 31, 2011, 13 monitors recorded ground-level ozone data for varying amounts of time. Eight of the 13 monitors are part of the EPA Air Quality System and the other five monitors were part of a yearlong air toxics study in 2009–2010. In addition to ground-level ozone, some monitoring stations recorded full meteorological data including wind direction, wind speed, temperature, humidity, barometric pressure, and solar radiation in addition to ground-level ozone.

In the winter months of 2008 and 2011, there were periods when ground-level ozone concentrations that exceeded the EPA national ambient air quality standard level of 75 ppb. In response to the elevations, DEQ issued ozone notifications to protect the public's health and advise industry to take action to decrease emissions. Methodology for predicting elevated ground-level ozone for the ozone notification days changed yearly to improve the accuracy of the notifications. Studies completed in Sublette County suggest that snow cover, combined with high concentration of ground-level ozone precursors trapped within a relatively small volume of air (an inversion), could be the cause of the high wintertime ground-level ozone concentrations.[16]

Residents of Sublette County have expressed concern over possible health effects from ground-level ozone and have sought information from public health officials on local adverse health effects. Until this study, information on adverse health effects from ground-level ozone specifically in Sublette County has been lacking, although a vast literature provides strong evidence regarding the health impacts of ground-level ozone.[2] The goal of this public health investigation was to evaluate the association between short-term changes in ground-level ozone and adverse acute respiratory-related effects within persons residing and seeking healthcare within Sublette County, and to assess possible public health impacts from ground-level ozone.

Methods

Health Data

De-indentified health outcome data were obtained from electronic billing records of the only two area clinics for the period January 1, 2008 to December 31, 2011. Information collected included a unique identification number, International Classification of Diseases 9th Revision (ICD-9) diagnostic codes, and demographic information such as age, sex, and location. All visits for an adverse respiratory-related effect were included with the following primary ICD-9 diagnostic codes (all 2 digit extensions were used unless otherwise specified): acute bronchitis (466), asthma (493), chronic obstructive pulmonary disease (491–492, 496), pneumonia (480–486), upper respiratory tract infection (460–465, 477), and other respiratory (786.09) during the study period. Descriptive statistics were conducted to evaluate the distribution of visits for each respiratory case group; sex; and age distribution including mean, median, and range.

Ozone and Weather Data

Daily maximum 8-hour ozone and 24-hour average temperature, and humidity data were obtained from DEQ. In order to calculate a maximum 8-hour average ozone per day, a monitor had to have a minimum of 18 rolling 8-hour average measures to be deemed as a valid monitoring day.[17] Completeness of ozone, temperature, and humidity data for the study period varied between monitors. Ground-level ozone, temperature, and humidity data were collected at the Daniel and Boulder monitoring stations for the whole study period, while the other monitoring stations had varying amounts of data available. Descriptive statistics were calculated for each of the monitoring stations (mean, median, minimum, maximum, number of observation days, and standard deviation). In addition, correlations of 8-hour max ground-level ozone concentrations between the monitoring stations were calculated to assess if concentrations at different monitoring stations were associated.

The Boulder and Daniel monitoring stations had the most complete ground-level ozone data for the study period, but the Boulder monitoring station is closest to the oil and gas field and a low proportion of the Sublette County population reside near the monitor. After review and analysis of the air data, the Daniel monitoring station was selected to represent the ground-level ozone exposures for Sublette County for a number of reasons. First, the Daniel monitoring station had the most complete data for not only ground-level ozone concentrations, but also temperature and humidity for the study period of January 1, 2008 to December 31, 2011. The Daniel monitoring station was highly correlated with other monitoring stations in population centers with less available data (such as the Pinedale monitoring station). Lastly, the use of central monitoring stations in other ozone health effect studies have been shown to be a good surrogate measure for ground-level ozone exposures for the population of an area.[2]

Statistical Analysis: Bi-directional Time-Stratified Case-Crossover

A bi-directional time-stratified case-crossover design was used to estimate the association of ground-level ozone and clinic visits for respiratory-related illnesses. Case-crossover analysis uses conditional logistic regression to compare the exposure on the case-day with the weighted average of the exposure on the selected control-days to estimate adjusted odds ratios.[18-20] The case-crossover study design inherently controls for factors that do not vary within person (e.g., age, sex, genetics) and adjusts for confounding by longer term trends and meteorological factors.[18-20]

Case-days were designated for each person who visited either of the two area clinics for one of the defined respiratory disease diagnoses and represent the day of the clinic visit. For the case-crossover analysis, a month was chosen as the strata to minimize confounding by weather, seasonality, and other factors that have longer-term variations. Control-days were matched to case-days by day of week within the same month of the case-day (e.g., if the case-day was on the second Tuesday in January, the selected control-days were all other Tuesdays in January). Repeat visits within seven days (2,790/15,532) were not included as separate case-days. There were 12,742 case-days (individual clinic visits for defined respiratory disease diagnoses) and 43,285 control-days.

Adjusted odds ratios (aORs) and 95% confidence intervals (95% CIs) were estimated using conditional logistic regression. The lag structures evaluated in this study included an unconstrained distributed lag 0–3 days and single lags including 0, 1, 2, and 3 days. A lag effect is when there is a delay in time between the exposure (ground-level ozone) and the health event (adverse respiratory-related effect). An unconstrained distributed lag allows the ability to evaluate the cumulative effects of individual lags over a few days (lag 0, lag 1, lag 2 and lag 3), with the lag days 0–3 assessed as a group and not separated out individually. Models with temperature and humidity variables coded with quadratic, cubic, or spline terms were run to determine the best model fit. The temperature and humidity included in the models were same day (lag 0) 24-hour temperature, lag 0 temperature squared, and same day (lag 0) humidity.

Interactions (factors that modify the association between exposure and health effect) by sex and age group were evaluated. Age groups were defined as child (<18 years of age), adult (18–65 years of age) and senior (>65 years of age).

In addition to the above analyses, the following sensitivity analyses were performed: exclusion of ozone notification days (19 days); exclusion of the day after a notification day (19 days); and exclusion of days with ground-level ozone ≥75 ppb (6 days for the Daniel monitoring station). Models with alternative adjustment for temperature (average, minimum, and maximum) and humidity were evaluated to assess the robustness the model. All sensitivity analyses were completed using both the unconstrained distributed lag 0–3 days and single lags of 0, 1, 2, and 3 days. Sensitivity analyses were also evaluated using ground-level ozone data from the Boulder monitoring station. Sensitivity analyses were completed to evaluate whether similar results were obtained when different model assumptions were used for the analysis. Sensitivity analyses test the robustness of the model.

Approval for this study was obtained from the Institutional Review Board from the Wyoming Department of Health.

Results

Ground-Level Ozone Data

Figure 1 shows the locations of the ozone monitoring stations, towns, and the locations of the oil and gas wells around Sublette County.[21] Table 1 displays the results of the descriptive analyses of the 13 monitoring stations.

Figure 1: Monitoring Stations, Towns, and Wells Sublette County, Wyoming[21]

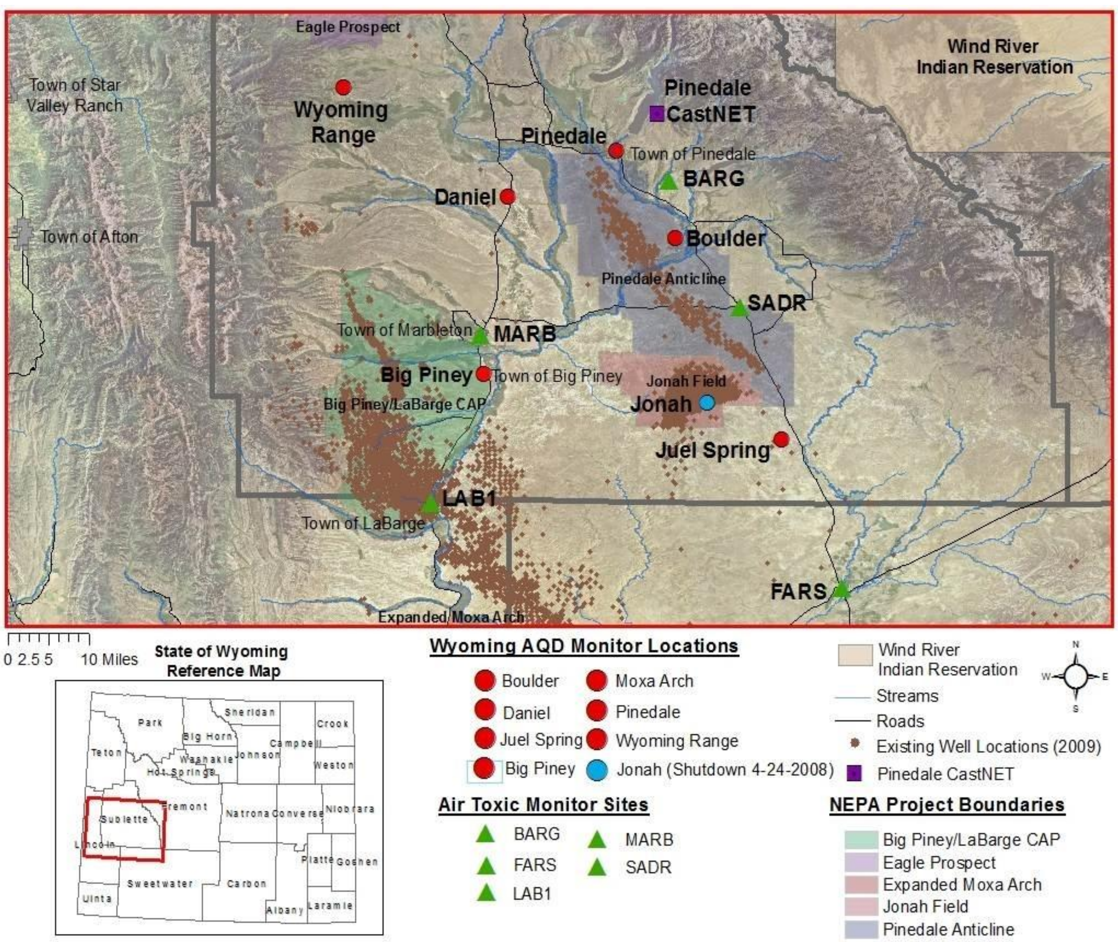

Table 1: Descriptive Analyses of All 13 Ground-Level Ozone Monitoring Stations, Sublette County, Wyoming, January 1, 2008–December 31, 2011

Monitor	Observation Days	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder	1429	49	10	49	22	123
Daniel	1363	47	8	47	19	84
Big Piney	190	51	6	52	38	72
Wyoming Range	273	50	7	49	34	83
Jonah	89	49	15	45	15	102
Pinedale CastNET	122	53	6	53	42	70
Juel Springs	726	49	8	49	28	94
Pinedale	879	46	8	46	14	89
FARS	424	46	9	46	25	65
SADR	422	47	8	48	18	70
MARB	440	44	8	45	16	75
Lab1	427	41	8	41	20	65
BARG	440	49	7	49	30	75

Ground-level ozone concentrations (8-hour max) tended to be highest during the winter months. See Appendix B for complete descriptive analyses of ground-level ozone by season and year for the Daniel and Boulder monitoring stations. The 8-hour max ground-level ozone concentrations followed a similar pattern year to year, the highest concentrations occurred early in the year (February to April) and the lowest concentrations occurred later in the year (October to December). A graph of the 8-hour max ground-level ozone concentrations for all monitoring stations from January 1, 2008 to December 31, 2011 is in Appendix C.

Ground-level ozone concentrations were moderately to highly correlated between the monitoring stations (correlation coefficient range: 0.61–0.94) (Appendices D and E). Slightly weaker correlations were found between the Wyoming Range monitoring station and the other monitoring stations (correlation coefficient range: 0.61 to 0.82). The Wyoming Range monitoring station is in the far northwest corner of the county, is over 1,000 feet higher than the rest of the monitoring stations, and is not near a population center or an oil and gas field in the county.

Health Data

There were 14,529 case-days for all defined respiratory-related ICD-9 codes from January 1, 2008 to December 31, 2011. There were 1,787 repeat visits in the first 7 days, which were excluded from the final data set, leaving 12,742 case-days. Females accounted for 52.7% (6,717) of the case-days. The mean age was 31.2 years of age (median, 28.6 years of age; range 4 months to 98 years). Table 2 shows the number and percent of case-days by age category. In Sublette County females account for 48.2% (4,939) of the total population, persons <18 account for 25.6% (2,623), and the elderly (≥65 years of age) account for 8.8% (902) of the population.[15] Table 3 shows the number of total visits by ICD-9 diagnosis grouping in the bi-directional time-stratified case-crossover study.

Table 2: Age Categories of Case-Days

Age Category	**N (%)**
Child (<18 years of age)	4,863 (38%)
Adult (18–65 years of age)	6,758 (53%)
Senior (>65 years of age)	1,121 (9%)

Table 3: ICD-9 Groupings of Respiratory Diagnosis, 2008–2011

Respiratory Diagnosis Grouping	**ICD-9 Codes**	**N (%)**
All Respiratory Disease	460–465,466,477, 480–486,490–493,496, 786.09	12,742 (100%)
Asthma	493	796 (6.2%)
Chronic Obstructive Pulmonary Disease	490–492, 496	1,956 (15.4%)
Acute Bronchitis	466	179 (1.4%)
Pneumonia	480–486	301 (2.4%)
Upper Respiratory Infections	460–465, 477	9,335 (73.3%)
Other	786.09	175 (1.4%)

Bi-Directional Time-Stratified Case-Crossover

The adjusted odds ratio (aOR) for clinic visits for the defined respiratory codes with the cumulative unconstrained distributed lag 0–3 model is shown in Table 4.

Table 4: Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.24	0.9903	1.012

Single ozone lag models for lag 0, lag 1, lag 2, and lag 3 were also evaluated (Table 5). While not significant at the 0.05 level, the results for lag 1 suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 5: Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.009	0.64	0.973	1.046
Lag 1	**1.031**	**0.10**	**0.994**	**1.069**
Lag 2	0.994	0.75	0.958	1.031
Lag 3	0.980	0.27	0.945	1.016

There were no significant interactions by sex (p=0.58) or age group (p=0.23).

Sensitivity Analyses

The results of the following sensitivity analyses are presented in the tables below: removal of notification days (Tables 6 & 7), removal of the days immediately after a notification day (Tables 8 & 9), and the removal of days with ground-level ozone concentrations ≥75 ppb (Tables 10 & 11). The results of the sensitivity analyses are consistent with the previous models, with lag 1 from the single ozone lag model suggesting an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 6: aOR and 95% CI with Removal of Notification Days; Model of Unconstrained Distributed Lag 0–3 days adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.28	0.990	1.012

Table 7: aOR and 95% CI with Removal of Notification Days; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.000	0.99	0.963	1.038
Lag 1	**1.030**	**0.12**	**0.993**	**1.068**
Lag 2	0.998	0.90	0.962	1.035
Lag 3	0.981	0.29	0.946	1.017

The results obtained with removing the notification days (Tables 6 & 7) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 8: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Model of Unconstrained Distributed of Lag 0–3 days adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.26	0.990	1.012

Table 9: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.007	0.73	0.970	1.044
Lag 1	**1.029**	**0.13**	**0.991**	**1.068**
Lag 2	0.993	0.72	0.958	1.030
Lag 3	0.981	0.30	0.946	1.017

The results obtained with removing the days immediately after a notification day (Tables 8 & 9) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Table 10: aOR and 95% CI with Removal of Days with Ground-Level Ozone Concentrations ≥75 ppb; Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.000	0.11	0.989	1.011

Table 11: aOR and 95% CI with Removal of the Days with Ground-Level Ozone Concentrations ≥75 ppb; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max of ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	P Value	Lower CI	Upper CI
Lag 0	1.000	0.95	0.963	1.040
Lag 1	**1.033**	**0.09**	**0.995**	**1.073**
Lag 2	0.988	0.52	0.952	1.025
Lag 3	0.975	0.15	0.938	1.010

The results obtained with removing the days with ground-level ozone concentrations ≥75 ppb (Tables 10 & 11) were consistent with the previous models, with lag 1 suggesting an association between ground-level ozone and clinic visits in the magnitude of a 3% increase in adverse respiratory-related visits for every 10 ppb increase in 8-hour max ground-level ozone.

Sensitivity analyses were also completed for different temperature (minimum and maximum) and humidity models. These results were consistent with the previous models. Although not significant at the 0.05 level, the results for lag 1 suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone (Appendices F and G).

Sensitivity analyses were completed with the ground-level ozone data from the Boulder monitoring station for the cumulative unconstrained distributed lags 0–3 and for each single lag model of 0, 1, 2, and 3 days. Similar associations were observed with the Boulder monitoring station ground-level ozone data as was observed with ground-level ozone data from the Daniel monitoring station. Lag 1 from the single lag model showed an estimated 5.6% increase in clinic visits for adverse respiratory-related effects for every 10 ppb increase in 8-hour max ground-level ozone, which does reach statistical significance at the 0.05 level (aOR 1.056; 95% CI: 1.030–1.082). (Appendices H and I).

Discussion

The study results suggest an association between ground-level ozone and clinic visits for adverse respiratory-related effects for lag 1 (one day later). The results for lag 1 from the single lag model suggest an association between ground-level ozone concentrations and clinic visits in the magnitude of a 3% increase in adverse respiratory-related clinic visits for every 10 ppb increase in 8-hour max ground-level ozone. Although this measure did not reach statistical significance at the 0.05 level using ground-level ozone data from the Daniel monitoring station, this association was found consistently in all other models evaluated as part of the sensitivity analyses. In addition, this association was also observed in the analyses using the ground-level ozone concentrations from the Boulder monitoring station and statistical significance at the 0.05 level was demonstrated. It is also important to note that these models evaluate respiratory-related health impacts across the entire range of 8-hour max ground-level ozone observed (19 ppb to 84 ppb), not just for those days that exceed the regulatory standard. A meaningful association between ground-level ozone concentrations and clinic visits for adverse-respiratory related effects was not observed for other lag periods (cumulative unconstrained distributed lag 0–3 days, single lag 0, single lag 2, and single lag 3).

The results of this study are consistent with other ozone-associated adverse health effects studies. Many single city studies observed associations between hospital admissions or emergency room visits for adverse respiratory effects and ground-level ozone.[2,8] In a recent meta-analysis, findings showed hospital admissions at lag 1 were consistently higher than the hospital admissions at lag 0 for all comparisons.[10] Of all air pollutants present at ground-level, ozone has the smallest margin between natural background levels and those that are considered harmful to human health.[6]

The removal of the DEQ ozone notification days and the days immediately following a notification day had no effect on the results. If the association between clinic visits and ground-level ozone was purely a function of people seeking care because of the perceived health effects when ground-level ozone levels were expected to be high, removing these days would attenuate the magnitude of association. Further, no change in the magnitude of association was seen when the days with ≥75 ppb ground-level ozone were excluded from the analysis, which suggests that the results are not being driven by, or only due to, the days with 8-hour max ground-level ozone above the regulatory standard of 75 ppb.

Sublette County differs from many other areas of the world in that the elevated ground-level ozone concentrations occur primarily in the cold season (February and March) rather than the more typical summertime ground-level ozone season.[2,11] Given the small sample size, seasonal stratification resulted in unstable estimates of ground-level ozone effects, so such results were not presented. Seasonal differences in adverse respiratory-related health effects in Sublette County were not able to be determined in this study. A recent meta-analysis observed associations between ground-level ozone and adverse respiratory effects during the summer (largest effect), all year, and during the cold season. [10] The results of that meta-analysis suggest ground-level ozone adverse respiratory-related effects may not be just a summer problem.

The impact of ground-level ozone on adverse respiratory-related effects was not found to be different (no significant interactions) by sex or age category, but this might be because of the limited ability to detect statistical significance with our small sample size. Other studies have found children (persons <18 years of age) and seniors (persons ≥65 years of age) to be more sensitive to ground-level ozone and other air pollutants.[3,8,9,22,23] Children's lungs continue to develop through adolescence and a developing lung is highly susceptible to damage from environmental toxicants like ground-level ozone.[2,14] Children tend to spend more time outdoors, be highly active, and have high minute ventilation, which collectively increases their dose of ground-level ozone. [2,8,14] Seniors (persons ≥65 years of age) are hypothesized to be more susceptible to air pollution due to changes in the respiratory tract lining fluid antioxidant defense network.[2]

Limitations

This study has several potential limitations. This is one of few studies to measure health clinic visits rather than emergency room visits or hospital admissions to examine the association of ground-level ozone with adverse respiratory effects. In this rural setting, there are no local emergency rooms or hospitals. Clinic visits differ from hospital emergency room visits because primary care occurs at these clinics (including follow-up visits). Which visits were follow-up visits or were visits for a new adverse respiratory-related effect were not able to be determined in this study. All models utilized ground-level ozone measurement data from a central monitoring station, which might not have been representative of individual exposure. Individual exposure was not assessed in this study. However, utilizing a central monitor is a common technique and would most likely attenuate the observed associations, but not lead to spurious associations.[11,12] In addition, the same trend and associations were observed with the Boulder monitoring station. Interactions by subgroups other than age and sex were not able to be evaluated in this study due to sample size limitations. Finally, the sample size of this study may have limited the statistical power to detect associations.

Conclusion

The results from this study suggest an association between ground-level ozone concentrations and clinic visits for adverse respiratory-related effects in the magnitude of a 3% increase in clinic visits the day following every 10 ppb increase in 8-hour max ground-level ozone (lag 1).

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Appendix A: Glossary of Terms[17,18-20,24,25]

Adjusted odds ratio (aOR)-when stratification and multiple regression techniques are used to address confounding in a study

Case-crossover- a study design where all study subjects are cases who have experienced a well defined acute health event thought to be associated with short-term changes in a transient exposure are compared to reference times within a time strata; each subject serves as their own control; uses conditional logistic regression to compare exposure at the event time to weighted average of the exposure at the reference times for each subject, provides an estimate of the relative risk of exposure

Case day- designated for each person who visits a clinic for one of the defined respiratory disease diagnoses

Confounder-a factor that is associated with the exposure and independently affects the risk of developing the disease; distorts the association with the exposure and disease because it is unevenly distributed between the cases and controls

Daily (24-hour) averaged ozone-calculated by averaging 24-hourly ozone concentrations in parts per billion, valid when 18 hourly values are available

Daily maximum 8-hour average ozone concentration-24 possible 8-hour average ozone concentrations for each calendar day, daily maximum is the highest of the 24 possible 8-hour averages, valid when 18 running 8-hour averages are available or if the daily maximum is greater than the level of the standard

Hourly ozone concentrations-hourly ground-level ozone concentrations in parts per billion

Interaction-factors that modify the association between exposure and disease; answers the question of whether the relationship between exposure and disease appears to be different for varying levels of a factor (i.e. sex, age category) after baseline difference in the factor are controlled

Lag-delay in time between the exposure and the health effect

Odds ratio (OR)-a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. OR are used most commonly in case control studies

Referent days-control days within a strata; preferable to use referents on the same day of the week to control for day-of-the week effects common in health outcomes and air pollution

Running 8-hour average ozone-uses hourly ground-level ozone concentrations in parts per billion backward averages over 8 hours; valid when at least 6 hourly values are available

Spline-a sufficiently smooth polynomial function that is piecewise-defined, and possesses a high degree of smoothness at the places where the polynomial pieces connect (which are known as *knots*)

Sensitivity Analysis-means of assessing the robustness of a model by checking whether similar results are obtained when different models or assumptions are used for the analysis

Time-stratified design- time is divided into disjoint strata, exposures in a 'hazard period' just prior to the acute event and exposures in multiple reference periods are only compared within strata of time; select times before and after the case event time

Unconstrained distributed lag-cumulative effect of individual lags over a few days

Ozone monitoring day-a day with at least 75% of the possible 8-hour averages in the day (18 of 24 averages); a day can also be valid if less than 75% complete if the daily maximum is greater than the level of the standard 75 ppb

Appendix B:

Table 9: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations for the Daniel Monitor, Sublette County, Wyoming, 2008–2011

Year	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
2008	47.2	9.5	48.0	23.0	75.0
2009	45.1	6.9	44.0	27.0	67.0
2010	49.0	6.1	49.0	33.0	73.0
2011	47.7	8.7	47.0	25.0	84.0

Table 10: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations for the Boulder Monitor, Sublette County, Wyoming, 2008–2011

Year	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
2008	50.9	13.0	51.0	24.0	122.0
2009	47.2	7.8	47.0	30.0	70.0
2010	48.9	8.1	49.0	28.0	72.0
2011	50.1	11.7	49.0	22.0	123.0

Table 11: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations by Monitor during Winter Months (January 1-April 1) 2008–2011, Sublette County

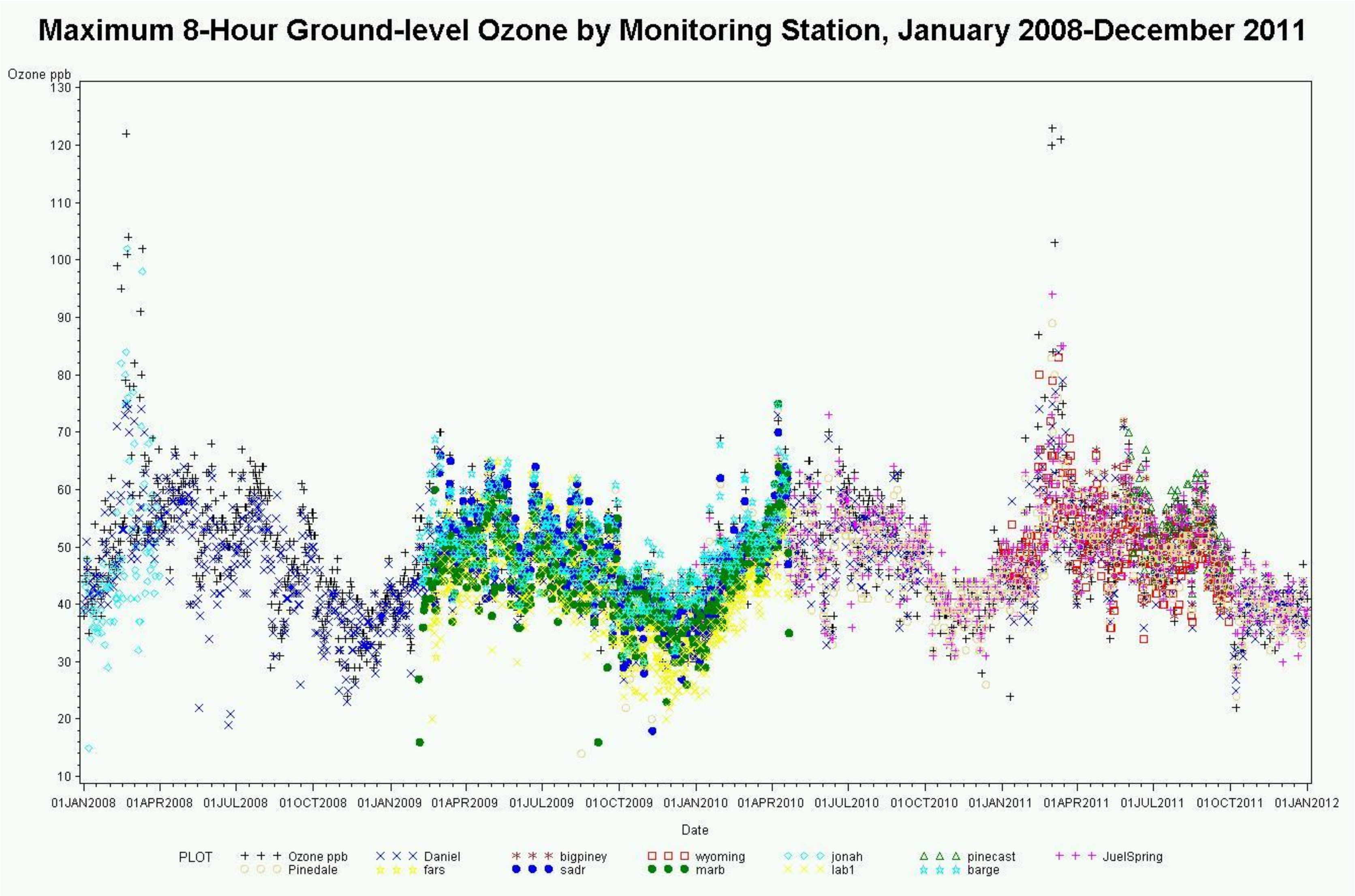
Year and Station	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder Winter 2008	58.8	16.9	53.0	38	122.0
Daniel Winter 2008	52.0	9.1	51.0	39.0	75.0
Boulder Winter 2009	49.1	8.0	49.0	32.0	70.0
Daniel Winter 2009	46.3	6.9	46.5	28.0	67.0
Boulder Winter 2010	47.9	6.0	48.0	32.0	69.0
Daniel Winter 2010	45.6	4.1	46.0	35.0	54.0
Boulder Winter 2011	57.1	17.6	50.0	34.0	123.0
Daniel Winter 2011	52.4	10.6	49.0	37.0	84.0

Appendix B: (Continued)

Table 12: Mean, Standard Deviation, Median, Minimum, and Maximum Ozone Concentrations by Monitor during Summer Months (April 1-October 31) 2008–2011, Sublette County

Year and Station	Mean ppb	SD	Median ppb	Minimum ppb	Maximum ppb
Boulder Summer 2008	52.0	8.6	53.0	31.0	68.0
Daniel Summer 2008	48.6	7.7	50.0	31.0	66.0
Boulder Summer 2009	49.0	7.0	49.0	30.0	65.0
Daniel Summer 2009	46.3	6.8	46.5	27.0	62.0
Boulder Summer 2010	51.9	7.7	53.0	31.0	72.0
Daniel Summer 2010	50.7	6.1	51.0	33.0	73.0
Boulder Summer 2011	49.4	7.3	50.0	22.0	71.0
Daniel Summer 2011	48.3	7.2	49.0	25.0	71.0

Appendix C: Daily Maximum 8-Hour Ozone by Monitoring Station, January 01, 2008 to December 31, 2011



Appendix D: Pearson's Correlations between Ground-Level Ozone Monitoring Stations

*blanks mean no overlapping observations between stations

Station	Boulder	Daniel	Big Piney	Wyoming	Jonah	Pinecast	Juel	Pinedale	Fars	SADR	Marb	Lab1	Barge
Boulder	1.0000 Obs 1429	0.83538 Obs 1331	0.84379 Obs 185	0.61057 Obs 268	0.85805 Obs 87	0.86873 Obs 117	0.87577 Obs 707	0.87634 Obs 856	0.80604 Obs 410	0.91013 Obs 408	0.80668 Obs 426	0.82730 Obs 413	0.93463 Obs 426
Daniel	0.83538 Obs 1331	1.0000 Obs 1363	0.89636 Obs 189	0.82449 Obs 269	0.74675 Obs 89	0.91242 Obs 122	0.85724 Obs 630	0.91153 Obs 784	0.82522 Obs 424	0.89999 Obs 422	0.82979 Obs 440	0.84485 Obs 427	0.92721 Obs 440
Big Piney	0.84379 Obs 185	0.89636 Obs 189	1.0000 Obs 190	0.72166 Obs 190	*	0.79055 Obs 119	0.79658 Obs 186	0.87028 Obs 190	*	*	*	*	*
Wyoming	0.61057 Obs 268	0.82449 Obs 269	0.72166 Obs 190	1.0000 Obs 273	*	0.81221 Obs 122	0.67997 Obs 269	0.74344 Obs 273	*	*	*	*	*
Jonah	0.85805 Obs 87	0.74675 Obs 89	*	*	1.0000 Obs 89	*	*	*	*	*	*	*	*
Pinecast	0.86873 Obs 117	0.91242 Obs 122	0.79055 Obs 119	0.81221 Obs 122	*	1.0000 Obs 122	0.81169 Obs 118	0.94237 Obs 122	*	*	*	*	*
Juel	0.87577 Obs 707	0.85724 Obs 630	0.79658 Obs 186	0.67997 Obs 269	*	0.81169 Obs 118	1.0000 Obs 726	0.89017 Obs 725	0.83428 Obs 111	0.89412 Obs 111	0.81817 Obs 112	0.84938 Obs 112	0.90963 Obs 111
Pinedale	0.87634 Obs 856	0.91153 Obs 784	0.87028 Obs 190	0.74344 Obs 273	*	0.94237 Obs 122	0.89017 Obs 725	1.0000 Obs 879	0.77446 Obs 261	0.87171 Obs 260	0.79257 Obs 262	0.81032 Obs 262	0.90348 Obs 261
Fars	0.80604 Obs 410	0.82522 Obs 424	*	*	*	*	0.83428 Obs 111	0.77446 Obs 261	1.0000 Obs 424	0.90054 Obs 417	0.79045 Obs 424	0.90620 Obs 421	0.78715 Obs 424
SADR	0.91013 Obs 408	0.89999 Obs 422	*	*	*	*	0.89412 Obs 111	0.87171 Obs 260	0.90054 Obs 417	1.0000 Obs 422	0.86117 Obs 422	0.89835 Obs 422	0.91294 Obs 422
Marb	0.80668 Obs 426	0.82979 Obs 440	*	*	*	*	0.81817 Obs 112	0.79257 Obs 262	0.79045 Obs 424	0.86117 Obs 422	1.0000 Obs 440	0.87397 Obs 427	0.81401 Obs 438
Lab1	0.82730 Obs 413	0.84485 Obs 427	*	*	*	*	0.84938 Obs 112	0.81032 Obs 262	0.90620 Obs 421	0.89835 Obs 422	0.87397 Obs 427	1.0000 Obs 427	0.81507 Obs 426
Barge	0.93463 Obs 426	0.92721 Obs 440	*	*	*	*	0.90963 Obs 111	0.90348 Obs 261	0.78715 Obs 424	0.91294 Obs 422	0.81401 Obs 438	0.81507 Obs 426	1.0000 Obs 440

Appendix E: Spearman's Correlations between Ground-Level Ozone Monitoring Stations

*blanks mean no overlapping days between stations

Station	Boulder	Daniel	Big Piney	Wyoming	Jonah	Pinecast	Juel	Pinedale	Fars	SADR	Marb	Lab1	Barge
Boulder	1.0000 Obs 1429	0.90478 Obs 1331	0.82543 Obs 185	0.70827 Obs 268	0.77105 Obs 87	0.88032 Obs 117	0.90250 Obs 707	0.92574 Obs 856	0.82797 Obs 410	0.92251 Obs 408	0.85414 Obs 426	0.85602 Obs 413	0.94181 Obs 426
Daniel	0.90478 Obs 1331	1.0000 Obs 1363	0.88292 Obs 189	0.80154 Obs 269	0.75938 Obs 89	0.92280 Obs 122	0.89631 Obs 630	0.95461 Obs 784	0.83191 Obs 424	0.91592 Obs 422	0.87564 Obs 440	0.87172 Obs 427	0.93448 Obs 440
Big Piney	0.82543 Obs 185	0.88292 Obs 189	1.0000 Obs 190	0.71433 Obs 190	*	0.77297 Obs 119	0.84466 Obs 186	0.84600 Obs 190	*	*	*	*	*
Wyoming	0.70827 Obs 268	0.80154 Obs 269	0.71433 Obs 190	1.0000 Obs 273	*	0.80401 Obs 122	0.70497 Obs 269	0.79008 Obs 273	*	*	*	*	*
Jonah	0.77105 Obs 87	0.75938 Obs 89	*	*	1.0000 Obs 89	*	*	*	*	*	*	*	*
Pinecast	0.88032 Obs 117	0.92280 Obs 122	0.77297 Obs 119	0.80401 Obs 122	*	1.0000 Obs 122	0.81355 Obs 118	0.93655 Obs 122	*	*	*	*	*
Juel	0.90250 Obs 707	0.89631 Obs 630	0.84466 Obs 186	0.70497 Obs 269	*	0.81355 Obs 118	1.0000 Obs 726	0.90768 Obs 725	0.77989 Obs 111	0.89380 Obs 111	0.78100 Obs 112	0.83024 Obs 112	0.91081 Obs 111
Pinedale	0.92574 Obs 856	0.95461 Obs 784	0.84600 Obs 190	0.79008 Obs 273	*	0.93655 Obs 122	0.90768 Obs 725	1.0000 Obs 879	0.82838 Obs 261	0.92232 Obs 260	0.84681 Obs 262	0.85514 Obs 262	0.94073 Obs 261
Fars	0.82797 Obs 410	0.83191 Obs 424	*	*	*	*	0.77989 Obs 111	0.82838 Obs 261	1.0000 Obs 424	0.91522 Obs 417	0.81263 Obs 424	0.91231 Obs 421	0.80309 Obs 424
SADR	0.92251 Obs 408	0.91592 Obs 422	*	*	*	*	0.89380 Obs 111	0.92232 Obs 260	0.91522 Obs 417	1.0000 Obs 422	0.89234 Obs 422	0.92120 Obs 422	0.93318 Obs 422
Marb	0.85414 Obs 426	0.87564 Obs 440	*	*	*	*	0.78100 Obs 112	0.84681 Obs 262	0.81263 Obs 424	0.89234 Obs 422	1.0000 Obs 440	0.89913 Obs 427	0.86070 Obs 438
Lab1	0.85602 Obs 413	0.87172 Obs 427	*	*	*	*	0.83024 Obs 112	0.85514 Obs 262	0.91321 Obs 421	0.92120 Obs 422	0.89913 Obs 427	1.0000 Obs 427	0.84469 Obs 426
Barge	0.94181 Obs 426	0.93448 Obs 440	*	*	*	*	0.91081 Obs 111	0.94073 Obs 261	0.80309 Obs 424	0.93318 Obs 422	0.86070 Obs 438	0.84469 Obs426	1.0000 Obs 440

Appendix F: Sensitivity Analyses for Different Minimum Temperature and Humidity Models for Single Ozone Lag 0, Lag 1, Lag 2, and Lag 3 and the Cumulative Unconstrained Distributed Lag 0–3 Lag Model

	Lag with aOR and 95% CI				
Temperature and Humidity Model	**Single Lag 0**	**Single Lag 1**	**Single Lag 2**	**Single Lag 3**	**Cumulative Unconstrained Distributed Lag 0–3**
tmin+tmin2+h+h2+h3	1.010 (0.974–1.047)	**1.031 (0.994–1.070)**	0.995 (0.959–1.032)	0.980 (0.945–1.016)	1.001 (0.990–1.012)
tmin+tmin2+h	1.009 (0.973–1.046)	**1.030 (0.993–1.068)**	0.993 (0.957–1.030)	0.980 (0.945–1.016)	1.001 (0.990–1.012)
tmin+tmin2+tmin3+h	1.007 (0.970–1.044)	**1.029 (0.991–1.068)**	0.991 (0.956–1.028)	0.978 (0.943–1.015)	1.001 (0.990–1.012)
tmin+h+h2+h3	1.012 (0.975–1.049)	**1.034 (0.997–1.073)**	0.996 (0.961–1.034)	0.981 (0.947–1.018)	1.002 (0.991–1.013)
tmin+tmin2+tmin3+h+h2	1.007 (0.971–1.045)	**1.028 (0.990–1.067)**	0.991 (0.955–1.028)	0.978 (0.943–1.014)	1.002 (0.991–1.012)
tmin	1.013 (0.978–1.050)	**1.034 (0.998–1.072)**	0.997 (0.961–1.033)	0.983 (0.948–1.019)	1.001 (0.991–1.013)
tmin+h	1.010 (0.974–1.047)	**1.033 (0.996–1.071)**	0.994 (0.959–1.031)	0.981 (0.946–1.017)	1.001 (0.990–1.012)
tmin+tmin2	1.011 (0.976–1.048)	**1.031 (0.994–1.069)**	0.995 (0.960–1.032)	0.981 (0.947–1.017)	1.001 (0.991–1.012)
tmin+tmin2+tmin3	1.010 (0.974–1.047)	**1.030 (0.993–1.069)**	0.994 (0.958–1.031)	0.980 (0.946–1.016)	1.001 (0.990–1.012)

Appendix G: Sensitivity Analyses for Different Maximum Temperature and Humidity Models for Single Ozone Lag 0, Lag 1, Lag 2, and Lag 3 and the Cumulative Unconstrained Distributed Lag 0–3 Lag Model

	Lag with aOR and 95% CI				
Temperature and Humidity Model	**Single Lag 0**	**Single Lag 1**	**Single Lag 2**	**Single Lag 3**	**Cumulative Unconstrained Distributed Lag 0–3**
tmax+tmax2+h+h2+h3	1.011 (0.970–1.048)	**1.032 (0.995–1.070)**	0.996 (0.960–1.033)	0.998 (0.945–1.016)	1.001 (0.991–1.012)
tmax+tmax2+h	1.010 (0.974–1.047)	**1.032 (0.995–1.070)**	0.995 (0.959–1.032)	0.980 (0.945–1.017)	1.001 (0.990–1.012)
tmax+tmax2+tmax3+h	1.006 (0.970–1.044)	**1.029 (0.991–1.068)**	0.993 (0.958–1.030)	0.979 (0.944–1.016)	1.000 (0.990–1.012)
tmax+h+h2+h3	1.012 (0.976–1.050)	**1.034 (0.997–1.072)**	0.997 (0.960–1.034)	0.982 (0.947–1.018)	1.001 (0.990–1.013)
tmax+tmax2+h+h2	1.010 (0.974–1.047)	**1.030 (0.993–1.068)**	0.993 (0.958–1.030)	0.979 (0.944–1.016)	1.000 (0.990–1.012)
tmax+h	1.011 (0.975–1.048)	**1.033 (0.996–1.071)**	0.995 (0.960–1.032)	0.982 (0.947–1.018)	1.001 (0.991–1.012)
tmax+h+h2	1.012 (0.976–1.049)	**1.032 (0.995–1.071)**	0.994 (0.959–1.031)	0.981 (0.946–1.017)	1.001 (0.991–1.012)
Natural Cubic Splines for tmax and h	1.009 (0.972–1.047)	**1.029 (0.991–1.068)**	0.999 (0.963–1.037)	0.983 (0.948–1.020)	1.001 (0.990–1.012)

Appendix H: Sensitivity Analyses the Boulder Monitoring Station the Cumulative Unconstrained Distributed Lag 0–3 Lag Model and Single Ozone Lag Model for Lag 0, Lag 1, Lag 2, and Lag 3

Table 12: Model; unconstrained distributed lag 0–3 days, adjusting for average temperature, average temperature squared, average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb for the Boulder Monitor

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.002	0.10	0.9960	1.010

Table 13: Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.009	0.46	0.985	1.034
Lag 1	**1.056**	**<0.0001**	**1.030**	**1.082**
Lag 2	1.001	0.94	0.977	1.026
Lag 3	0.984	0.19	0.961	1.008

Appendix I: Sensitivity Analyses for the Boulder Monitoring Station with Removal of Notification Days, Removal of the Days Immediately Following an Notification Day, and Removal of Days with ≥75 ppb Ground-Level Ozone Concentrations

Table 14: aOR and 95% CI with Removal of Notification Days; Model of Unconstrained Distributed Lag 0–3 days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.003	0.10	0.995	1.010

Table 15: aOR and 95% CI with Removal of Notification Days; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.006	0.65	0.981	1.031
Lag 1	**1.053**	**<0.0001**	**1.027**	**1.079**
Lag 2	0.998	0.89	0.974	1.023
Lag 3	0.983	0.15	0.959	1.010

Table 16: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Model of Unconstrained Distributed of lag 0–3 days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.003	0.11	0.996	1.010

Appendix I: (Continued)

Table 17: aOR and 95% CI with Removal of the Days Immediately after a Notification Day; Single Lag Models of Lag 0, Lag 1, Lag 2, and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	1.008	0.53	0.983	1.033
Lag 1	**1.054**	**<0.0001**	**1.028**	**1.080**
Lag 2	0.996	0.74	0.970	1.021
Lag 3	0.984	0.19	0.961	1.008

Table 18: aOR and 95% CI with Removal of Days with Ground-Level Ozone Concentrations ≥75 ppb; Model of Unconstrained Distributed Lag 0–3 Days, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Ozone Parameter	aOR	p Value	Lower CI	Upper CI
Cumulative Unconstrained Distributed lag 0–3	1.001	0.74	0.993	1.009

Table 19: aOR and 95% CI with Removal of the Days with Ground-Level Ozone Concentrations ≥75 ppb; Single Lag Models of Lag 0, Lag 1, Lag 2 and Lag 3, adjusting for average temperature, average temperature squared, and average humidity, per an increase in 8-hour max ground-level ozone of 10 ppb.

Single Ozone Lag Models	aOR	p Value	Lower CI	Upper CI
Lag 0	0.986	0.43	0.952	1.021
Lag 1	**1.071**	**<0.0001**	**1.039**	**1.105**
Lag 2	0.990	0.50	0.963	1.018
Lag 3	0.978	0.10	0.953	1.004

WYVisNet website. Graphic by Pinedale Online.">

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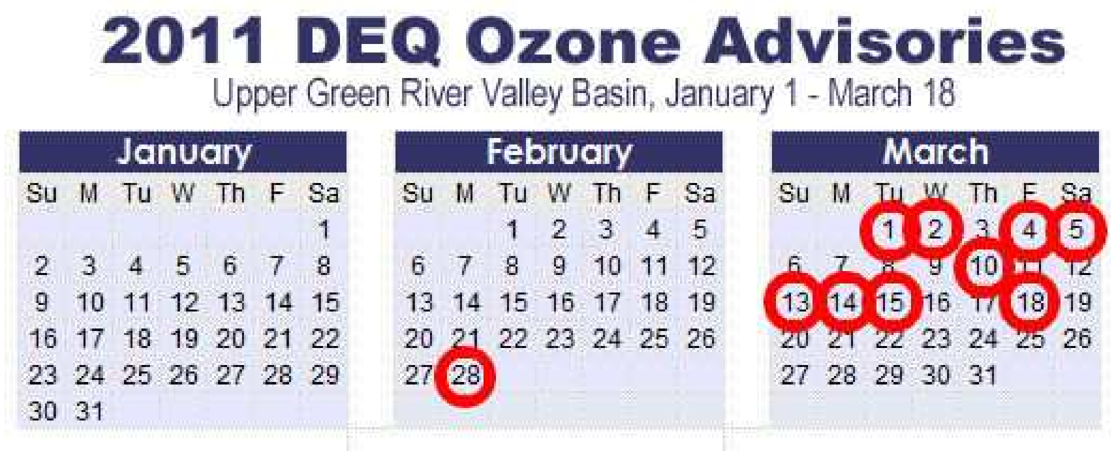

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Ozone Calendar

Wyoming DEQ has issued 10 Ozone Advisories for the Upper Green River Basin since February 28, 2011. Actual ozone levels may or may not have exceeded standards on any of those days. DEQ only issues prediction advisories, which are made based on weather predictions the day before they believe conditions may be condusive to creating high ozone levels in a given area. They do not issue a notice or advisory in real time to the public or media when high ozone levels are actually occuring. To see monitor readings in real time, visit the DEQ WYVisNet website. Graphic by Pinedale Online.

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Ozone Advisory for Monday, Feb. 28

by Wyoming Department of Environmental Quality
February 27, 2011

Upper Green River Basin, Wyo. - The Air Quality Division (AQD) of Wyoming's Department of Environmental Quality (DEQ), in conjunction with the Wyoming Department of Health (WDH), is issuing an ozone advisory for tomorrow, Monday February 28, 2011, for the Upper Green River Basin, in Sublette County.

The DEQ-AQD would like to communicate that this particular Ozone Advisory is anticipated to be a multi-day event. Weather forecasting for conditions conducive to elevated 8-hour ozone will continue on a daily basis and the AQD will continue to issue updated advisory status by noon each day such that, if the weather forecast changes, advisory status may also change. The DEQ-AQD will also be conducting intensive sampling of ozone and precursors during this period. These intensive measurements will focus on the vertical distributions of pollutants which will be accomplished by equipment attached to weather balloons.

Ozone is an air pollutant that can cause respiratory health effects especially to children, the elderly and people with existing respiratory conditions. People in these sensitive groups should limit strenuous or extended outdoor activities, especially in the afternoon and evening. More information on ozone and the health effects of ozone are available at the Wyoming Department of Health website, .http://www.health.wyo.gov.

An ozone advisory is issued when weather conditions appear to be favorable for the formation of ozone. Ozone appears to be elevated in the Basin when there is a presence of ozone-forming precursor emissions including oxides of nitrogen and volatile organic compounds coupled with strong temperature inversions, low winds, snow cover, and bright sunlight.

Current information on ozone levels at the Air Quality Division's monitoring stations at Daniel, Pinedale, Boulder, Juel Spring and the Wyoming Range can be found at www.wyvisnet.com.

Pinedale Online > News > February 2011 > Ozone Advisory for Monday, Feb. 28

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DEQ plans for the 2014 winter ozone season

Forecasting January-March for the Upper Green River Basin

December 19, 2013

The Wyoming Department of Environmental Quality (DEQ), Air Quality Division (AQD), is again reaching out to residents of the Upper Green River Basin in anticipation of elevated ozone levels. Elevated levels of ozone have been observed in previous years during the months of February and March.

Ozone adversely affects the respiratory system, especially in children, the elderly and people with existing respiratory conditions. On days when elevated ozone levels are expected, people in these sensitive groups should limit strenuous or extended outdoor activities, primarily in the afternoon and evening. The public is encouraged to use the monitored data to help make decisions about outdoor activity. More information on ozone and the health effects of ozone is available at the Wyoming Department of Health website, http://www.health.wyo.gov.

In preparation for the winter of 2014 and the possibility of elevated ozone occurring in the Upper Green River Basin, the AQD is again initiating in-house weather forecasting. Forecasting by the AQD's meteorologists will consist of evaluating whether a strong temperature inversion in conjunction with low winds, snow cover and clear skies is likely to occur. This is the combination of factors which, together with the presence of ozone forming emissions, appear to result in elevated ozone levels.

The AQD will continue to forecast for the winter of 2014 (January - March) and provide updates to the public daily. These winter ozone updates will give expected conditions for the current and next two days. The winter ozone updates will be geared specifically toward making sure the public has the information needed to help make decisions about outdoor activity.

These winter ozone updates will be conveyed in several ways to the public. Beginning January 2, the main page of DEQ's website, http://deq.state.wy.us, and the AQD's Winter Ozone website, http://winterozone.org, will carry a daily message of current and next two days conditions. The public can also sign up at the Winter Ozone website to receive daily winter ozone updates by email. Next, DEQ will notify all media outlets in Sublette County of the current winter ozone update. Media outlets include Sublette County newspapers, radio stations, and online news sources. KPIN radio will broadcast a winter ozone update everyday at noon. Also, citizens may call 1-888-WYO-WDEQ (1-888-996-9337) to hear a recorded message (updated by noon every day) regarding the forecasted conditions that may impact ozone concentrations, typically during the latter half of the day.

The AQD will continue the short-term emission reduction ozone contingency plan program with all stakeholders (e.g., oil and gas industry, non-oil and gas industry, governmental agencies) in the Upper Green River Basin ozone nonattainment area of southwest Wyoming. Ozone contingency plan participants have volunteered to take short-term actions to further reduce emissions in response to forecasted conditions that favor possible elevated ozone levels. These contingency plans will be implemented on Ozone Action Days. The Action Days will be issued by AQD 24-hours in advance when forecasting indicates that weather conditions would be conducive to the development of elevated ozone levels for the next day.

On Ozone Action Days, everyone – including those without ozone contingency plans and the public, are encouraged to voluntarily reduce emissions. Such actions may include, but are not limited to, eliminating vehicle idling and postponing nonessential trips.

The AQD operates several monitoring stations in the Upper Green River Basin. Real-time monitored data, including current ozone levels being measured at these stations, can be found at www.wyvisnet.com. The public is encouraged to use the monitored data to help make decisions about outdoor activity.

Pinedale Online > News > December 2013 > DEQ plans for the 2014 winter ozone season

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Utah's Environment 2013: Planning and Analysis: Uintah Basin Ozone Study

Teams of scientists continued their work in the Uintah Basin this year to identify the sources and conditions that create ozone during winter inversions. The Division of Air Quality (DAQ) and its partners collected additional data this winter to improve their understanding of the atmospheric chemistry that leads to the formation of wintertime ozone in the Basin.

Winter ozone concentrations increase in the Basin when snow cover creates strong temperature inversions. Multi-year ozone studies aim to identify the emissions and photochemical processes that elevate these ozone levels. DAQ will use this data to support development of effective strategies for reducing ozone concentrations to meet the health-based National Ambient Air Quality Standards (NAAQS) in the Uintah Basin.

2013 Uintah Basin Ozone Study

Key Findings

The 2013 Uintah Basin Ozone Study (UBOS) experienced far different wintertime conditions than the 2012 study, when minimal snow cover kept the 8-hour average ozone levels below federal air quality standard of 63 parts per billion (ppb). Persistent snow cover in 2013 led to inversions, which in turn resulted in ozone concentrations well above the NAAQS.

Maximum 8-hour average ozone concentrations at the Ouray air monitoring station during the 2013 study period reached 142 ppb, 89 percent higher than the federal air quality standards. Ozone values exceeded the NAAQs for 22 days in Vernal and 29 days in Roosevelt. Individual episodes of elevated ozone ranged from 3 to nearly 15 days in length.

Air Quality

- Elevated ozone coincided with elevated levels of VOCs and NOx, the primary chemical precursors of ozone.
- Ozone concentrations within the Basin are not influenced to any significant extent by the transport of ozone

or its precursors from outside of the Basin or the Bonanza Power Plant.

Meteorology

- Elevated winter ozone only occurs with snow cover that leads to temperature inversions.
- Reflection of sunlight from the snow surface significantly increases the rate of ozone formation.
- Complex patterns of light winds appear to contribute to intra-basin mixing of ozone and ozone precursors.

Chemistry

- Nitrous acid (HONO) and formaldehyde were found to be the biggest contributors to the creation of the chemically reactive radicals that drive ozone formation.
- Oxidized aromatic VOCs (including toluene and xylene) are another significant source of these radicals.

Uncertainties

- Based on 2012 data, VOC reductions appear to reduce ozone but the overall effectiveness is unknown. The effectiveness of NOx reductions is less certain and under some conditions may increase ozone levels. It is unclear whether NOx controls become effective when ozone levels are particularly high.
- Unreactive nitrates that recycle into reactive NOx through chemical reactions in snow and on particles in the atmosphere may impact the effectiveness of NOx controls.

Control Strategies

- Episodic or seasonal controls may be a useful component of a management strategy for the Basin since elevated ozone levels only occur during winter inversion periods.
- Reductions in emissions of highly reactive VOCs such as aromatics will be beneficial. Ozone response to NOx reductions is more complex and requires further study.
- Reducing formaldehyde would be an effective way to reduce ozone, but it is not yet clear which sources of formaldehyde are most important.
- Uncertainty in HONO concentrations makes it difficult to predict how responsive ozone will be to reductions in both VOC and NOx emissions.

Study Partners

The Uintah Basin Ozone Study is a collaborative effort between county, State, and federal entities, industry organizations, and higher education. Researchers for the UBOS 2013 include:

- Utah State University (USU)
- National Oceanic and Atmospheric Administration (NOAA)
- University of Colorado, Boulder (CU)
- University of Wyoming (U of WY)
- University of Washington (UW)
- Utah Department of Environmental Quality (DEQ)

Funding and in-kind support for UBOS 2013 came from:

- The Uintah Impact Mitigation Special Service District (UIMSSD)
- Western Energy Alliance
- Bureau of Land Management (BLM)
- National Oceanic and Atmospheric Administration (NOAA)
- Environmental Protection Agency (EPA)
- Utah Department of Environmental Quality (DEQ)
- Utah Science Technology and Research Initiative (USTAR)
- Utah School and Institutional Trust Lands Administration (SITLA)

Next Steps

The 2014 Basin Study will focus on understanding the nitric acid (HONO) chemistry in the atmosphere and how it might affect the responsiveness of ozone concentrations to VOC and NOx reduction strategies.

Contact Donna Spangler or Christine Osborne for further information on the content of this page.

Uinta Basin: Ozone in the Uinta Basin

- Defining the Problem: Ozone Studies
- Environmental Regulatory Considerations
- Fact Sheets
- Frequently Asked Questions
- Oil and Gas Air Quality Partnership
- Other Resources
- Outreach Meetings
- Ozone in the Uinta Basin
- Public Information and Media
- Voluntary Seasonal Ozone Controls
- What We Know

Ozone in the Basin is unique because it occurs in winter during inversions. All the scientific studies on ozone have been for summertime ozone. More information is needed to develop effective strategies to deal with winter ozone pollution.

State's Proactive Process

1. Study the problem using best available science.
2. Collaborate with stakeholders on science-based solutions.
3. Implement effective measures to reduce emissions.

Methods

- **Air Quality Conditions and Health Messaging**
  Provide important health based information to empower residents to take appropriate actions to protect themselves and reduce their emissions.

- **Federal Regulations and Best Management Practices**
  Build on new regulations to further reduce emissions.

- **Ozone Advance**
  Use collaboration and voluntary early emissions reductions to address the problem.

- **State Permitting Guidelines**
  Use emissions offsets to prevent additional emissions into the Basin.

- **Uinta Basin Winter Ozone Study**
  Bring the best and the brightest researchers together to decipher the complex chemistry behind winter ozone and develop effective mitigation measures.

Uinta Basin Winter Ozone Study

- Multi-year study, beginning winter 2012, led by UDEQ.

- Partners include National Oceanic and Atmospheric Administration (NOAA), EPA, BLM, USU Bingham Research Center, University of Colorado, Western Energy Alliance, Ute Indian Tribe, Duchesne and Uintah County, Tri-County Health Department, Uintah Impact Mitigation Special Service District.

- $5 million dollars in funding.

- Important 2012 Findings:

  - Snow cover and temperature inversions are key elements of high ozone episodes.

  - Oil and gas operations were responsible for 98-99 percent of volatile organic compound (VOC) emissions and 57-61 percent of nitrogen oxide (NOx) emissions.

  - Study team's current best estimate is that VOC controls will reduce ozone, but effectiveness of this strategy is unknown.
  - A voluntary "ozone action day" may be a cost effective way to reduce peak ozone concentrations.

Ozone Advance

- Collaborative national program between the EPA, State of Utah, and Indian tribes to support voluntary early emissions reductions.
- Utah one of the first states to sign up.
- Program improves public health through early emissions reductions, allows industry to budget future costs for emissions reductions into their long-term business plans, and provides companies with a voluntary phase-in period for control measures.
- State involved in productive discussions with industry on these voluntary reductions.

Air Quality Conditions and Health Messaging

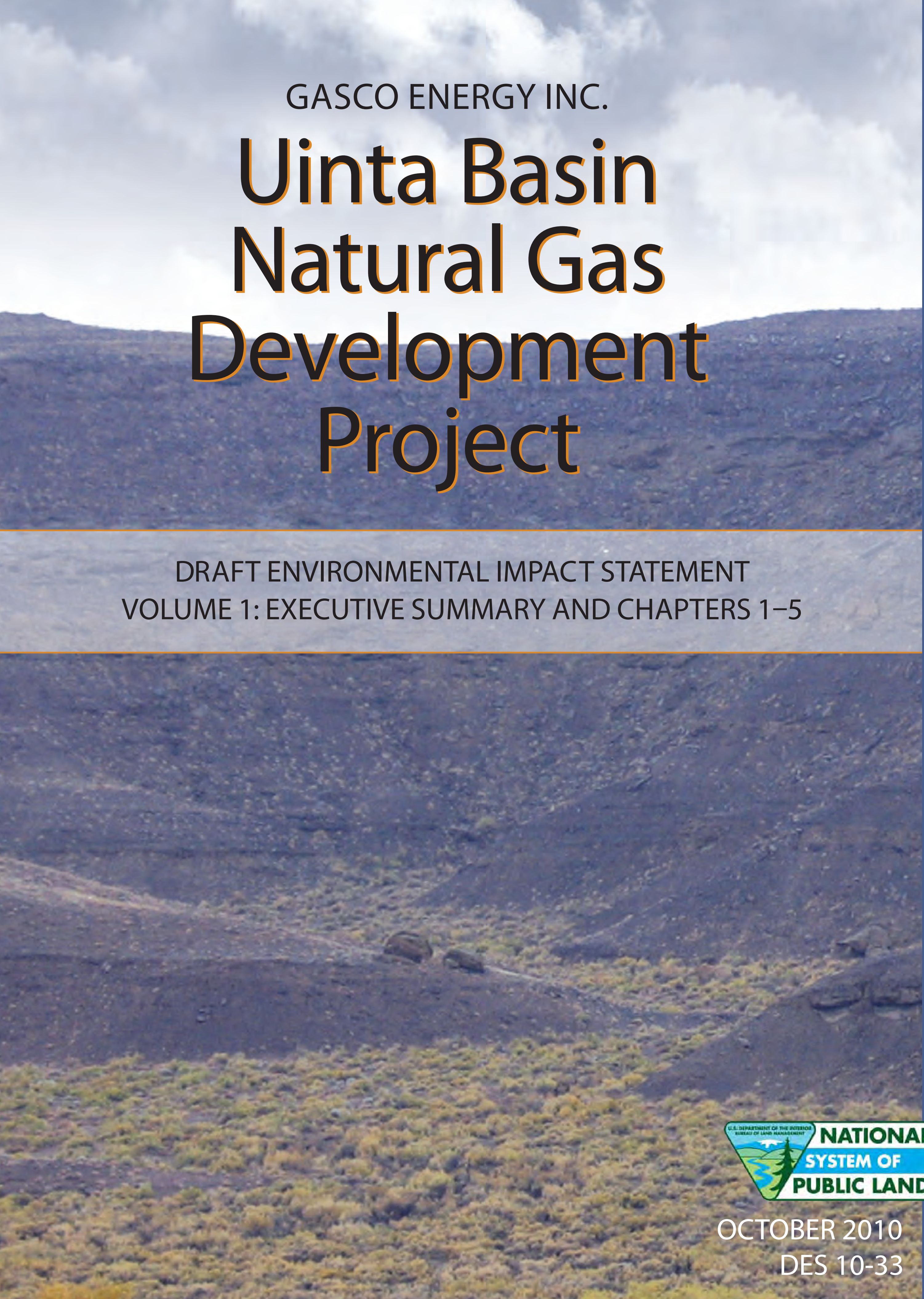
- Real-time ozone conditions for Uintah and Duchesne counties available on DAQ Web site.
- Residents can check the ozone levels and take appropriate precautions to reduce their exposure and emissions.
- DAQ collaboration with Tri-County Health links air quality conditions with health impacts.

State Permitting Guidelines

- Designed to curb emissions by requiring a demonstration that new development will not add volatile organic compound (VOC) emissions to the airshed.
- Applies to new or modified major and minor sources.
- Uses emissions offsets to achieve no net emission increase in the Basin.
- Offsets derived through the use of new control technologies or replacement of older equipment.

Federal Regulations and Best Management Practices

- EPA New Source Performance Standards (NSPS) are predicted to cut VOC emissions by nearly one-fourth across the oil and gas industry, including a nearly 95 percent reduction in VOCs emitted from new and modified hydraulically fractured gas wells.
- EPA Minor Source Permitting on Tribal lands provides a permitting method for emissions sources not previously subject to regulation in Indian Country.
- BLM has developed Best Management Practices (BMPs) for oil and gas operations through its National Environmental Policy Act (NEPA) planning process. Applicants commit to working with the BLM to analyze and employ project specific mitigation measures.



GASCO ENERGY INC.

Uinta Basin Natural Gas Development Project

DRAFT ENVIRONMENTAL IMPACT STATEMENT
VOLUME 1: EXECUTIVE SUMMARY AND CHAPTERS 1–5

BLM

Vernal Field Office

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
NATIONAL SYSTEM OF PUBLIC LANDS

OCTOBER 2010
DES 10-33

The next best method for estimating existing air quality is based on air monitoring conducted that, while not meeting the standards described above, is still considered of sufficient quality to be used for modeling and initial or screening air quality determinations. Reasons for monitoring not meeting NAAQS CFR standards, but still be sufficient for other purposes, might include use of non-FRM certified monitors, not meeting all CFR standards for the monitoring site, or operating otherwise compliant monitors less than the averaging time of the applicable pollutant standard (e.g., less than three years for ozone). Air monitoring data over ten years old are generally considered to be out of date, though they still may be representative if emission sources in the area have not changed much. Given these qualifiers, there has been relevant air monitoring conducted recently in the Uinta Basin for $PM_{2.5}$ and ozone.

3.2.3.1.5.1 $PM_{2.5}$ Air Monitoring

Starting in December 2006 and running through December 2007, the Utah Department of Environmental Quality (UDAQ) conducted air monitoring for $PM_{2.5}$ in the town of Vernal, Uintah County. Over the winter, $PM_{2.5}$ levels were measured at the Vernal monitoring station that were higher than the new $PM_{2.5}$ NAAQS that became effective in December 2006. The maximum 24-hour average concentration over this period was 63.3 ug/m^3. Additional $PM_{2.5}$ monitoring was conducted by UDAQ in Vernal in 2008 and in Vernal and Roosevelt (Duchesne County) in 2009, which also monitored maximum 24-hour values above the NAAQS during the winter months. $PM_{2.5}$ monitoring conducted by UDAQ during the summer of 2007 did not find any elevated concentrations. A limited analysis of the filters used to collect the $PM_{2.5}$ samples was conducted to chemically speciate the particulate samples. This analysis found that the composition was primarily carbon-based. In the case of Teflon filters, the composition was unidentifiable, which in a Teflon filter is typically indicative of also being carbonaceous because these types of filters cannot be used to detect carbon-based particulate.

Beginning in the summer of 2009, $PM_{2.5}$ monitoring is being conducted in the Ouray and Redwash areas of Uintah County. This monitoring is being conducted to comply with an EPA consent order. It is located in a rural area contingent with oil and gas operations and removed from urban sources. No exceedences of the $PM_{2.5}$ 24-hour standard have been observed.

The sources of elevated $PM_{2.5}$ concentrations during winter inversions in Vernal and Roosevelt have not been conclusively identified yet. Based on experiences and studies in other areas of the Rocky Mountain west and the emission inventory in the Uinta Basin, potential sources can be tentatively identified. In Utah, elevated $PM_{2.5}$ concentrations along the Wasatch Front are associated with secondarily formed particles from sulfates, nitrates, and organic chemicals from a variety of sources (UDAQ 2006). In Cache Valley, approximately half of ambient $PM_{2.5}$ during elevated concentrations is composed of ammonium nitrate, most likely from agricultural operations. The other half is from combustion, primarily mobile sources and woodstoves (Martin 2006). For comparison, $PM_{2.5}$ in most rural areas in the western United States is typically dominated by total carbonaceous mass and crustal materials from combustion activities and fugitive dust, respectively (EPA 2009). Because the Uinta Basin is not a major metropolitan area (like those found on the Wasatch Front) nor does it have significant agricultural activities (like those found in Cache Valley), the most likely causes of elevated $PM_{2.5}$ at the Vernal monitoring station are probably those common to other areas of the western US (combustion and dust). The filter speciation that has been done to date tends to support this conclusion because the dominant chemical species from the filters is carbonaceous mass, which is indicative of wood burning, diesel emissions, or both. It is unlikely that significant transport of $PM_{2.5}$ precursors are occurring during the intense winter inversions under which these elevated $PM_{2.5}$ levels are forming, and as there is extensive snow cover during these episodes fugitive dust is also an unlikely significant contributor.

The complete UDAQ $PM_{2.5}$ monitoring data can be found at http://www.airmonitoring.utah.gov/dataarchive/archpm25.htm

3.2.3.1.5.2 Ozone Air Monitoring

Active ozone monitoring in the Uinta Basin began in the summer of 2009 at the Ouray and Redwash monitoring sites (the ozone monitors are collocated with the $PM_{2.5}$ monitors). Both sites have recorded numerous exceedences of the 8-hour ozone standard during the winter months (January through March). The maximum 8-hour average recorded to date is 0.123 ppm, well above the current ozone NAAQS of 0.075 ppm. These data have recently been released by EPA. Although the monitors are not currently being operated to CFR standards, and are not considered adequate data to make a NAAQS determination, the data are considered viable and representative of the area. Apparently, high concentrations of ozone are being formed under a "cold pool" process, whereby stagnate air conditions with very low mixing heights form under clear skies with snow-covered ground and abundant sunlight that, combined with area precursor emissions (NO_x and VOCs), create intense episodes of ozone. Based on the first year of monitoring, these episodes occur only during the winter months (January through March). This phenomenon has also been observed in similar types of locations in Wyoming, and has contributed to a proposed nonattainment designation for Sublette County.

The National Park Service also operates an ozone monitor in Dinosaur National Monument during the summer months. No exceedences of the current ozone NAAQS have been recorded at this site.

Winter ozone formation is a newly recognized issue, and the methods of analyzing and managing this problem are still in development. Existing photochemical models are currently unable to replicate winter ozone formation satisfactorily, in part due to the very low mixing heights associated with the unique meteorology of these ambient conditions.

Based on the emission inventories developed for Uintah County, the likely dominant source of ozone precursors at the Ouray and Redwash monitoring sites are oil and gas operations near the monitors. The monitors are located in remote areas where impacts from other human activities are unlikely to be significantly contributing to this ozone formation. Although ozone precursors can be transported large distances, the meteorological conditions under which this cold pool ozone formation is occurring tend to preclude any significant transport. Currently, ozone exceedences in this area are confined to the winter months during periods of intense surface inversions and low mixing heights. Significant work remains to definitively identify the sources of ozone precursors contributing to the observed ozone concentrations. Speciation of gaseous air samples collected during periods of high ozone is needed to determine which VOCs are present and what their likely sources are.

The complete EPA Ouray and Redwash monitoring data can be found here: http://www.epa.gov/airexplorer/index.htm

4.2 Air Quality

Air quality impacts were evaluated for both near-field and far-field impacts. Near-field impacts quantify the direct and indirect local impacts created by each alternative, while far-field impacts describe the potential impacts at locations a significant distance away from the project area.

4.2.1 Near-Field Air Quality

The near-field analysis considered potential impacts to air quality that may occur within 3 miles (5 km) of the project area. The Near-Field Air Quality Technical Support Document (Buys & Associates 2008b and Appendix H) presents a complete description of the project emissions, the modeling protocol, and modeling results. There are two types of activities associated with each alternative that were evaluated for impacts to air quality; development and operations. Development includes: the construction of individual well pads and associated access roads, drilling, and completion activities. Operations include the running of equipment associated with production and the associated truck traffic.

Dispersion modeling was performed for all alternatives to evaluate both development and operational impacts. The AERMOD model (version 07026) was used to predict the impacts of pollutant emissions for comparison to the NAAQS for CO, SO_2, PM_{10}, and $PM_{2.5}$. Because development activities are temporary and short-term in nature, comparisons to PSD increments are not appropriate. AERMOD was used to predict impacts of NO_x emissions as a surrogate for NO_2. The meteorological data used were from surface and upper air stations developed for the *West Tavaputs Environmental Impact Statement* (BLM 2008d). Additional details about the modeling are in the Near-Field Air Quality Technical Support Document (Buys & Associates 2008b and Appendix H).

4.2.1.1 Development

Near-field impacts from development activities are predominantly short-term and localized to the nearby area. Pollutant emissions from development activities include the following sources:

- Well pad and road construction: equipment producing fugitive dust while moving and leveling earth;
- Drilling: vehicles generating fugitive dust on access roads, and drill rig engine exhaust;
- Completion: vehicles generating fugitive dust on access roads, frac pump engine and generator emissions, and completion venting emissions;
- Vehicle tailpipe emissions associated with all development phases;

Pollutant emissions generated from development sources are summarized in Table 4-2.

Table 4-2. Annual Well Development Emissions for Each Alternative

Pollutant	Well Development Emissions (tons/year)				
	Alternative A (Proposed Action)	Alternative B (Reduced)	Alternative C (Full)	Alternative D (No Action)	Alternative E (Directional)
Criteria Pollutants & VOC					
NO_x	1,298	1,027	1,357	511	1,762
CO	421	332	444	167	522
VOC	103	81.5	113	42.6	116
SO_2	23.2	18.3	23.9	9.01	30.8
PM_{10}	4,079	3,228	4,486	1,700	3,641
$PM_{2.5}$	433	343	476	180	395
Hazardous Air Pollutants					
Benzene	0.62	0.49	0.69	0.26	0.66
Toluene	1.06	0.84	1.17	0.44	1.08
Ethylbenzene	0.04	0.03	0.04	0.02	0.04
Xylene	0.55	0.44	0.61	0.23	0.56
n-Hexane	1.21	0.96	1.33	0.50	1.21
Formaldehyde	0.44	0.35	0.48	0.18	0.14
Acetaldehyde	3.34×10^{-03}	2.64×10^{-03}	3.67×10^{-03}	1.38×10^{-03}	4.62×10^{-03}
Acrolein	1.04×10^{-03}	8.23×10^{-04}	1.14×10^{-03}	4.31×10^{-04}	1.44×10^{-03}
1,3-Butadiene	1.34×10^{-06}	1.06×10^{-06}	1.48×10^{-06}	5.60×10^{-07}	1.34×10^{-06}
Naphthalene	0.02	0.01	0.02	0.01	0.02
Total HAPs	4.14	3.25	4.51	1.71	3.80
Greenhouse Gases					
CO_2	63,870	50,564	70,257	26,473	86,970
CH_4	517	409	568	215	530

4.2.1.1.1 DEVELOPMENT IMPACTS

Table 4-3 shows all pollutants modeled for development for the Proposed Action compared to the NAAQS. The maximum modeled concentration for NO_2 reflects an adjustment by a factor of 0.75, in accordance with standard EPA methodology (60:153 FR 40469, Aug 9, 1995) to convert from the modeled NO_x annual concentration to a NO_2 annual concentration. The modeling showed that no exceedances of NAAQS would be predicted for all development activities. The annual results demonstrate that even if these activities lasted for an entire year in the same location, the effects would be less than all applicable standards.

Table 4-19. Carcinogenic HAP MEI Risk for Each Alternative

Hazardous Air Pollutant	Cancer Risk				
	Alternative A (Proposed Action)	Alternative B (Reduced)	Alternative C (Full)	Alternative D (No Action)	Alternative E (Directional)
Dichlorobenzene	4.2×10^{-10}	3.5×10^{-10}	5.0×10^{-10}	7.1×10^{-11}	2.8×10^{-10}
Ethylene Dibromide	4.8×10^{-07}	3.4×10^{-07}	5.5×10^{-07}	1.4×10^{-07}	3.4×10^{-07}
Methylene Chloride	1.7×10^{-10}	1.2×10^{-10}	1.9×10^{-10}	4.8×10^{-11}	1.2×10^{-10}
Naphthalene	3.6×10^{-08}	3.4×10^{-08}	5.6×10^{-08}	1.1×10^{-08}	3.4×10^{-08}
Vinyl Chloride	2.4×10^{-10}	1.7×10^{-10}	2.7×10^{-10}	6.7×10^{-11}	1.7×10^{-10}
Benzo(b)fluoranthene[a]	3.3×10^{-10}	2.3×10^{-10}	3.8×10^{-10}	9.4×10^{-11}	2.3×10^{-10}
Chrysene[a]	1.4×10^{-10}	9.8×10^{-11}	1.6×10^{-10}	3.9×10^{-11}	2.3×10^{-11}
TOTAL MEI RISK	**5.9×10^{-06}**	**4.3×10^{-06}**	**6.9×10^{-06}**	**1.7×10^{-06}**	**5.0×10^{-06}**

[a] Pollutant is a HAP because it is polycyclic organic matter (POM).

4.2.1.2.4 Summary of Operations Impacts

Implementation of the Proposed Action or Alternatives would cause increases in criteria pollutants. Potential modeled impacts for Alternative C are predicted to exceed the NAAQS for PM_{10}. Potential modeled impacts for Alternatives A, B, C, and E exceed the PSD Class II increment for PM_{10}. The distribution of concentration contours indicates that the source of the maximum PM_{10} concentrations is road traffic (see Figure 4-1). Predicted concentration contours are similar for PM_{10} and $PM_{2.5}$; the Near-Field Air Quality Technical Support Document (Buys & Associates 2008b and Appendix H) includes figures of $PM_{2.5}$ contours for each alternative showing the maximum concentrations are the result of truck traffic. Therefore none of the alternatives exceed PSD Class II increments (PSD increments do not apply to mobile sources).

Implementation of the Proposed Action or Alternatives would cause increases in HAP concentrations. The increased potential concentration would be long term, lasting the life of the project (LOP; 45 years). None of the alternatives would exceed the Utah TSLs. Potential impacts for all alternatives exceed the REL for acrolein. Alternatives A, B, C, and E are predicted to exceed the RfC for acrolein. Predicted concentrations for all alternatives are below the acute exposure guideline level for acrolein. Predicted concentrations for all alternatives are below the California EPA chronic REL (similar to the RfC) for acrolein. Minor increases in cancer risk are predicted to occur for all alternatives. However, the predicted incremental cancer risks would occur only within relatively small areas. The following tables (Tables 4-20 through 4-24) summarize the operational impacts for each alternative after full field development.

Table 4-20. Summary of Near-Field Operation Maximum Impacts

Pollutant and Averaging Period	Averaging Period	Percent of NAAQS (Project + Background)				
		Alternative A (Proposed Action)	Alternative B (Reduced)	Alternative C (Full)	Alternative D No Action)	Alternative E (Directional)
NO_2	Annual	19.3%	17.9%	18.8%	18.0%	18.7%
PM_{10}	24-hour	99.7%	86.6%	112%	56.1%	87.0%
$PM_{2.5}$	Annual	68.7	88.7%	90.7%	76.7%	88.7%
	24-hour	66.0%	60.9%	70.3%	48.6%	61.1%
CO	1-hour	3.33%	3.07%	3.30%	2.94%	3.07%
	8-hour	12.0%	11.5%	11.8%	11.4%	11.7%

Table 4-21. Summary of Near-Field Operation Maximum Impacts to PSD Class II Increments

Pollutant and Averaging Period	Averaging Period	Percent of PSD Class II Increment				
		Alternative A (Proposed Action)	Alternative B (Reduced)	Alternative C (Full)	Alternative D (No Action)	Alternative E (Directional)
NO_2	Annual	9.12%	3.78%	7.20%	3.90%	3.78%
PM_{10}	24-hour	287%	222%	357%	69%	222%

Table 4-22. Summary of HAP REL Operation Impacts for Each Alternative

HAP	REL	Percent of REL				
	($\mu g/m^3$)	Alternative A (Proposed Action)	Alternative B (Reduced)	Alternative C (Full)	Alternative D (No Action)	Alternative E (Directional)
Acrolein	0.19[a]	1,189%	868%	1,479%	289%	868%
	69[b]	3.28%	2.39%	4.07%	0.80%	2.39%
	230[c]	0.98%	0.72%	1.22%	0.24%	0.72%
	450[d]	0.50%	0.37%	0.62%	0.12%	0.37%
Formaldehyde	94[a]	24.8%	18.0%	30.7%	6.00%	18.0%
Acetaldehyde	81000[b]	0.01%	0.01%	0.02%	<0.01%	0.01%
Benzene	1,300[a,e]	0.86%	0.62%	0.83%	0.21%	0.62%
	160,000[d]	0.02%	0.01%	0.01%	<0.01%	0.01%
Toluene	37,000[a]	0.19%	0.12%	0.18%	0.04%	0.12%
Ethylbenzene	350,000[d]	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%
Xylenes	22,000[a]	0.32%	0.20%	0.31%	0.07%	0.20%

Ozone Impact Assessment

for

GASCO Energy Inc.
Uinta Basin Natural Gas Development Project
Environmental Impact Statement

Prepared for: Bureau of Land Management
Vernal Field Office
Vernal, Utah

Prepared by: Alpine Geophysics, LLC
Arvada, CO
Dennis McNally
Cyndi Loomis

and

Buys and Associates Environmental Consultants
Littleton, CO
Daniel Pring
Doug Henderer

April 2010

1.0 Introduction

Gasco Production Company (Gasco) has proposed to the United States Department of the Interior (USDOI) Bureau of Land Management (BLM) Vernal Field Office (VFO) to develop oil and natural gas resources within the Monument Butte, Red Wash and West Tavaputs Exploration and Development Areas. The project area is located within Uintah and Duchesne Counties, Utah and consists of approximately 187 sections located in Township 9 South, Ranges 18 and 19 East; Township 10 South, Ranges 14, 15, 16, 17 and 18 East; and Township 11 South, Ranges 14, 15, 16, 17, 18 and 19 East (Map 1).

Gasco operates the majority of the mineral lease rights underlying both the public and private lands in the project area. The project area encompasses approximately 206,826 acres predominantly in the West Tavaputs Exploration and Development Area with some overlap into the Monument Butte–Red Wash Exploration and Development Area of the Diamond Mountain Planning Area of the VFO. The project area includes lands within the restored exterior boundary of the Ute Indian Reservation, but no lands administered by the Tribe or by the Bureau of Indian Affairs. Targeted geologic strata lie in the Wasatch, Mesaverde, Blackhawk, Mancos, Dakota, and Green River formations, approximately 5,000–20,000 feet below the earth's surface.

1.1 Project Description

The Gasco Energy Inc. Uinta Basin Natural Gas Development Project (GASCO) Project Area is located 20 miles south-southwest of Roosevelt, Utah and covers 206,826 acres in an existing oil and gas producing region located in Duchesne and Uintah Counties, Utah. Surface ownership in the project area is 86% federal (managed by the Bureau of Land Management [BLM]), 12% State of Utah (managed by State of Utah School and Institutional Trust Lands Administration [SITLA]), and 2% private.

The GASCO Project Area currently contains active producing wells, with accompanying production related facilities, roads, and pipelines. Additional wells are proposed for development and are being considered under the Wilkin Ridge Environmental assessment (UT-080-2006-478).

Proposed wells would be drilled to recover gas reserves from the Wasatch, Mesa Verde, Blackhawk, Mancos, Dakota, and Green River Formations in the GASCO Project Area. The spacing of the wells will vary according to the geologic characteristics of the formation being developed; the densest spacing expected is one well pad per 40 acres.

The primary components of the Proposed Action that were utilized for the development of a project specific emissions inventory for this ozone assessment were based upon an updated development schedule developed by Gasco in April 2010. The Proposed Action primary components are as follows:

Up to 1,491 natural gas wells over a 15 year development period, 45 year life of project (LOP);

Up to 10 drilling rigs operating year round;

30 evaporative ponds with a total of 2,700-hp of electrical generation; and

Approximately 21,325 horsepower of compression would be added to the existing system, for a total of 27,940 horsepower (hp) within the Project Area.

Table 1-1 shows the summary of the emissions inventory for the Proposed Action.

Under the Proposed Action, the rate of development for new wells would increase gradually from project initiation until the year 2015 when the maximum proposed development rate is projected to be realized. It is anticipated that the maximum development rate of 120 new wells per year would be sustained between the years 2015 and 2018. After 2018 the planned rate of development is projected to decrease until full project development is accomplished in about the year 2015.

Emissions to the atmosphere from the proposed project would include the following criteria pollutants and precursors: nitrogen oxides (NO_x), particulates (PM_{10} and $PM_{2.5}$), Volatile Organic Compounds (VOC), and sulfur dioxide (SO_2). These pollutants would be emitted from the following activities and sources:

Well pad and road construction: equipment producing fugitive dust while moving and leveling earth, vehicles generating fugitive dust on access roads;

Drilling: vehicles generating fugitive dust on access roads, and drill rig engine exhaust;

Completion: vehicles generating fugitive dust on access roads, frac pump engine and generator emissions, and completion venting emissions;

Vehicle tailpipe emissions associated with all development phases;

Well production operations: three-phase separator emissions, flashing and breathing emissions from a condensate tank, fugitive dust and tailpipe emissions from pumpers and trucks transporting produced condensate and water from storage tanks;

Central production facility: compressor engines emissions, central glycol dehydration unit emissions, flare emissions for control of central facility VOC emissions, central flashing and breathing emissions from condensate tanks, and emissions associated with loading natural gas liquids (NGL) into trucks; and

Water Evaporation Facility: generator engine emissions and fugitive dust and tailpipe emissions from water trucks delivering produced water.

To reduce the emission of ozone forming precursors (NO_X and VOC) GASCO has committed to implement the following Applicant Committed Environmental Protection Measures (ACEPMs):

1. The use of Tier II or better diesel drill rig engines to reduce NO_X emissions;
2. RMP compliant NO_X emission limitations of 1.0 g/hp-hr for engines rated greater than 300 hp and 2.0 g/hp-hr for engines rated at 300 hp or less.
3. The installation of low-bleed pneumatic controls, where technically feasible, on all new separators to reduce potential VOC emissions;
4. To reduce current VOC emissions all existing high-bleed pneumatic controls within the project area will be replaced or retrofitted with low-bleed units where technical feasible;
5. The use of solar-powered chemical pumps (i.e. Methanol pumps) in place of VOC emitting pneumatic pumps at new facilities;

6. The use of centralized compression facilities (no well site compression) to minimize potential NO_X emissions;
7. The use of centralized dehydration, (no well site dehydration) to minimize potential VOC emissions;
8. The control of central facility stock tanks and glycol dehydrators to reduce potential VOC emissions by at least 95%.

The above ACEPMs would result in the reduction of 647 tons per year NO_X and 8,273 tons per year of VOC assuming the implementation of the Proposed Action. Larger or smaller emission reductions would occur as a result of the ACEPMs if other alternatives other than the Proposed Action were to be implemented.

This ozone impact analysis considered the emissions from the Proposed Action with and without applicant committed measures to reduce ozone precursor emissions.

Oil and Gas Exploration and Production Emission Sources

Presentation for the

Air Quality Control Commission Retreat

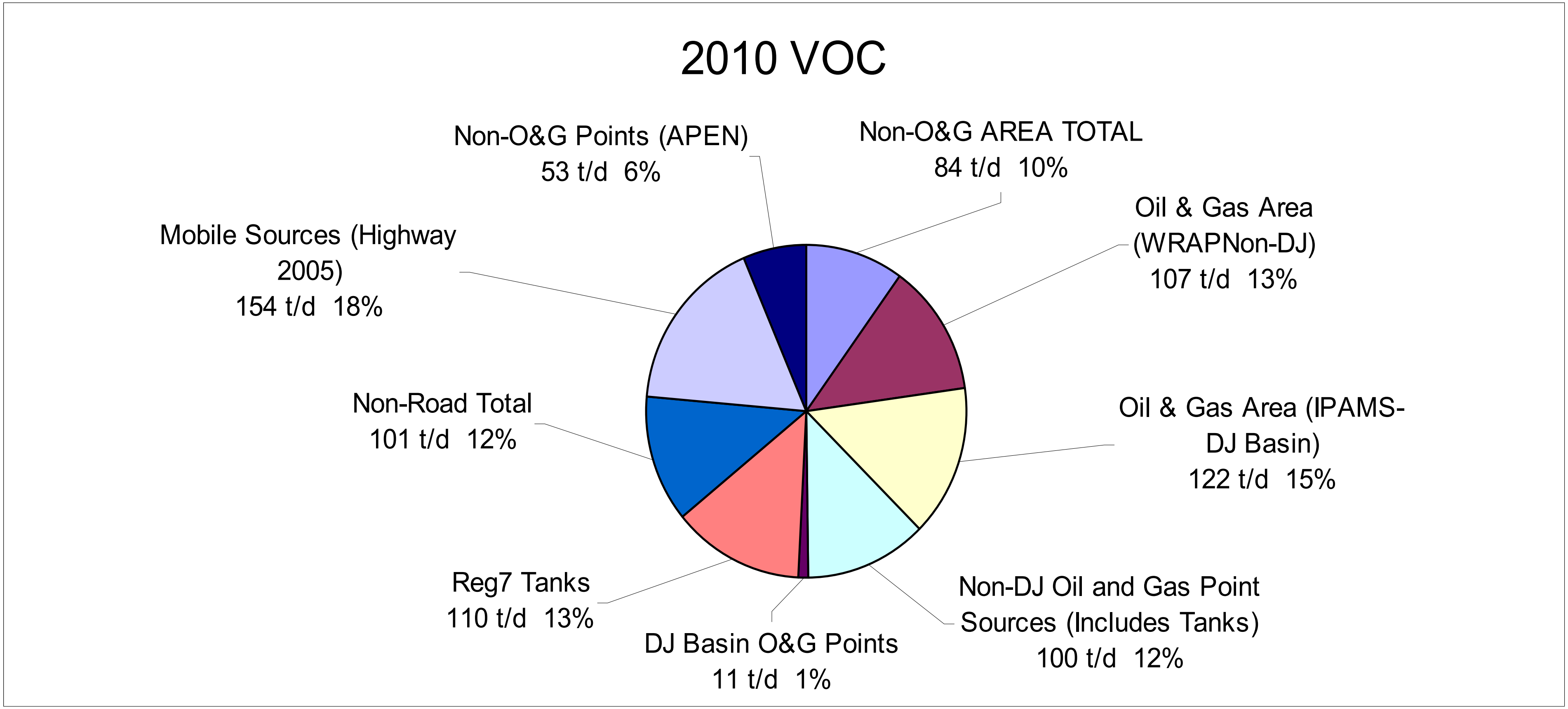
May 15, 2008

Air Pollution Control Division

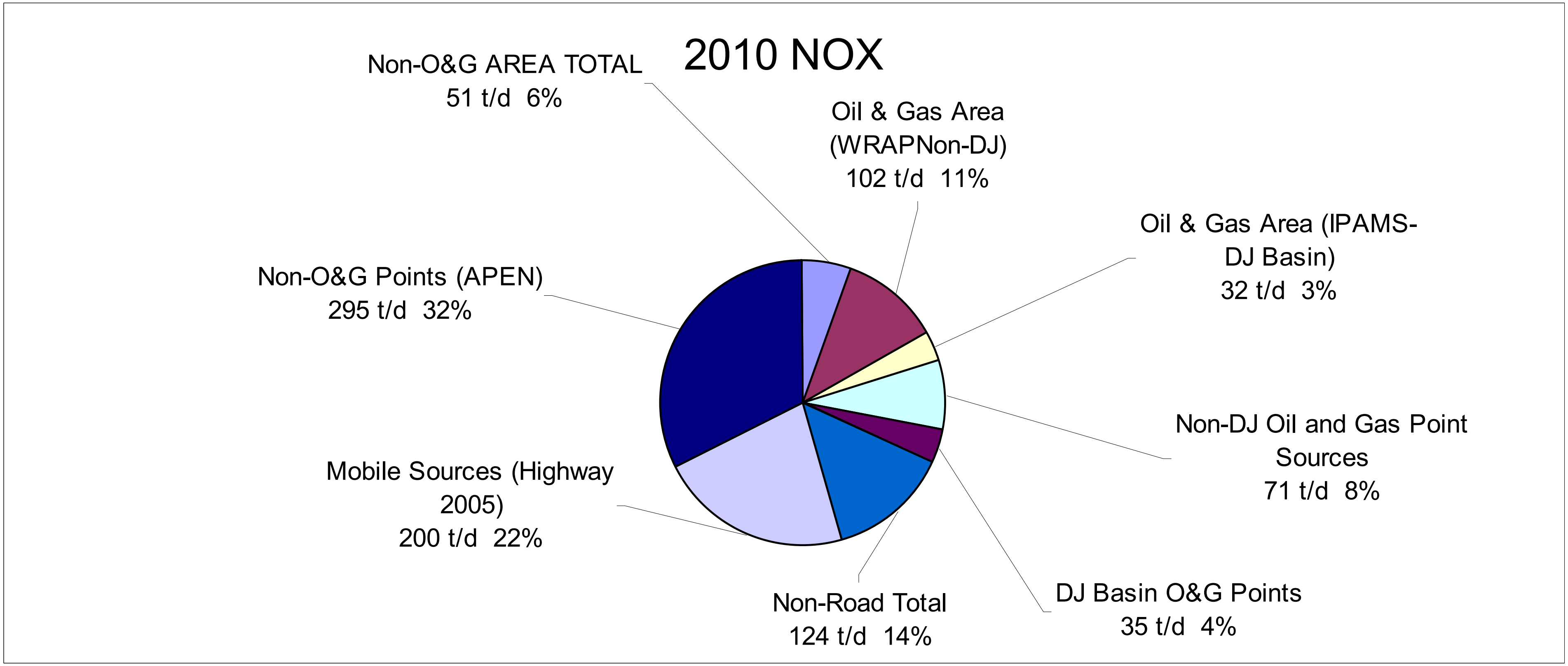
Approach to Statewide Oil and Gas Control Strategy Development

- Oil and gas is the largest VOC source category on the State
- Oil and gas development is rapid and projected to significantly expand – especially in western Colorado
- Strategies are being developed to control the growth in VOC and NOx emissions from O&G
  - Pre-emptive – "keep clean areas clean"
  - Help prevent ozone nonattainment
  - Improve visibility

Statewide VOC Emissions – 2010
(4% increase since 2006)



Statewide
NOx Emissions – 2010
(8% increase since 2006)



Approach to Statewide Oil and Gas Control Strategy Development

- All current regulatory programs remain in place
- Categorical Exemptions - Eliminate for Significant Oil and Gas Categories - New Sources (VOCs)
- Pneumatics – New, Modified (VOCs)
- Condensate Tanks – New, Modified (VOCs)
- Drill Rigs – New and Existing (NOx, PM)
- Existing Engines – Retrofit (VOCs, CO, NOx

Elimination of Categorical Exemptions for Oil and Gas Sources

- Crude oil truck loading equipment
- Oil/gas production wastewater tanks
- Stationary Internal Combustion Engines meeting horsepower and hours of operation restrictions
- Condensate tanks with production 730 BBL/year or less
- Fuel burning equipment (includes heater treaters, separators, and dehydrator reboilers)
- Petroleum industry flares less than 5 tons per year (tpy) emissions
- Storage of butane, propane, LPG
- Crude oil storage tanks
- Surface water storage impoundment
- Internal combustion engines on drill rigs
- Venting of natural gas lines for safety purposes (for APEN purposes only)
- Oil and gas production activities including: well drilling, workovers and completions (for APEN purposes only)

CONSERVATION COMMISSION

COLORADO

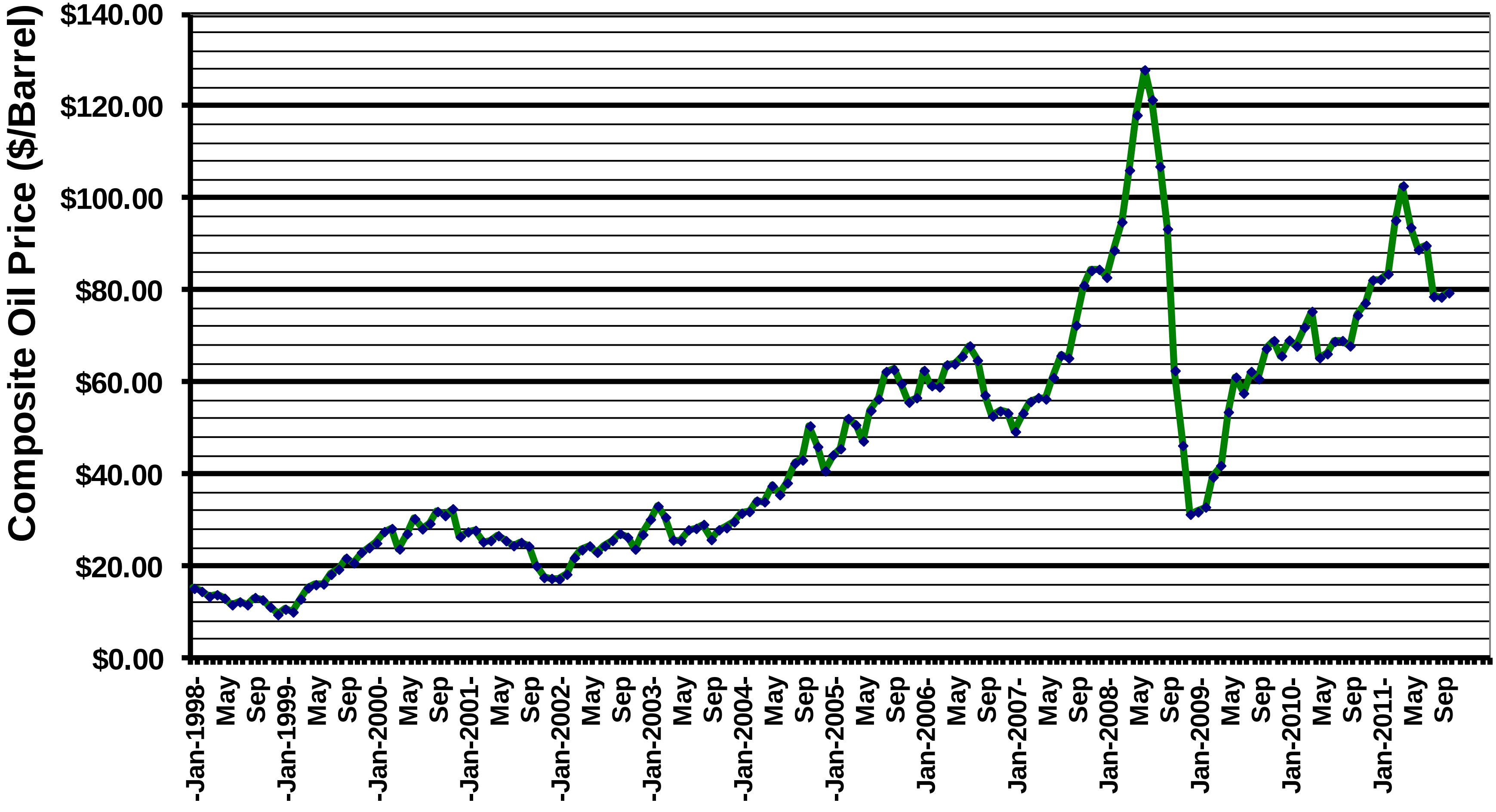
WEEKLY & MONTHLY

OIL & GAS STATISTICS

11-07-11 – visit our website: www.colorado.gov/cogcc

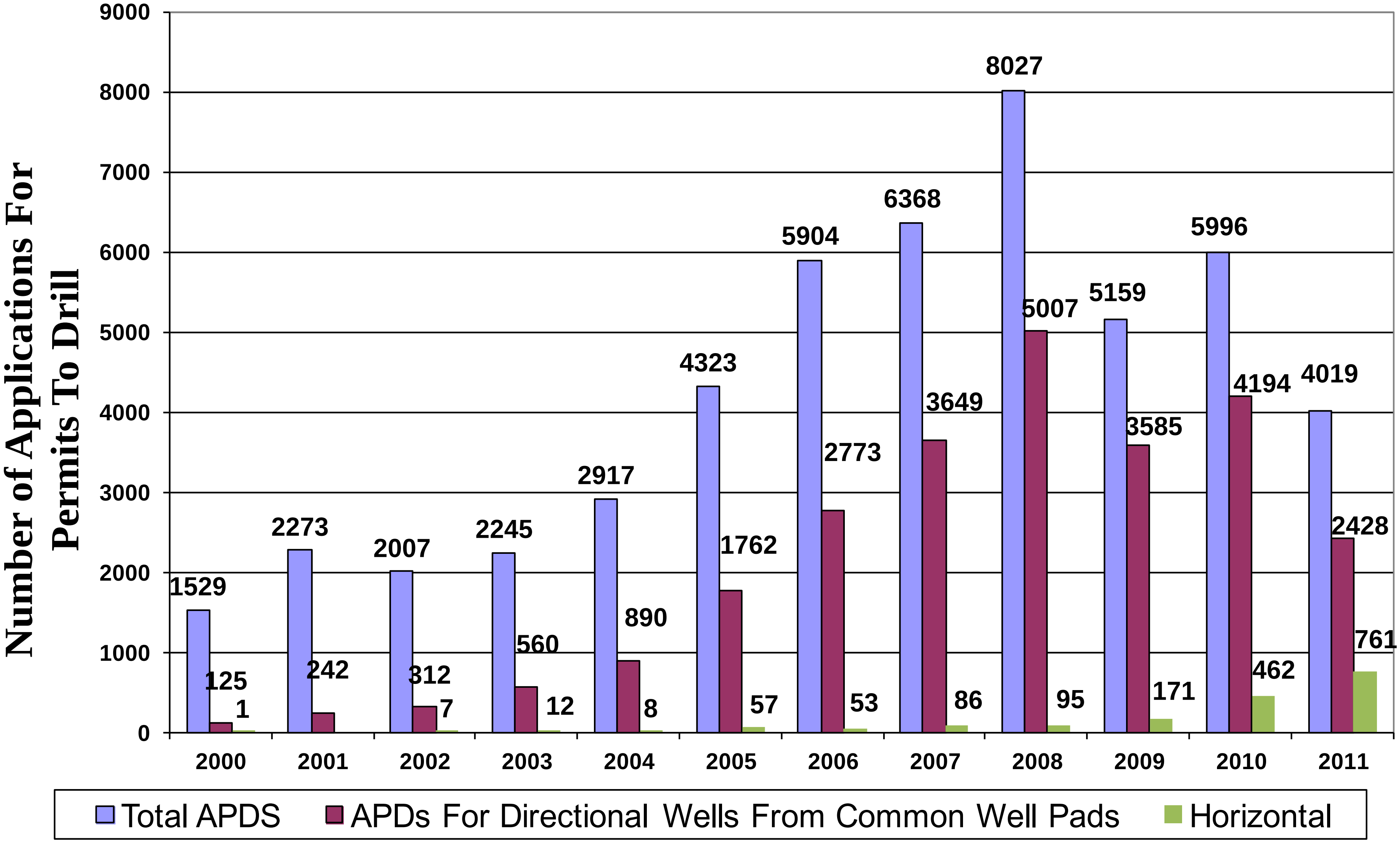
Colorado Monthly Composite Oil Price

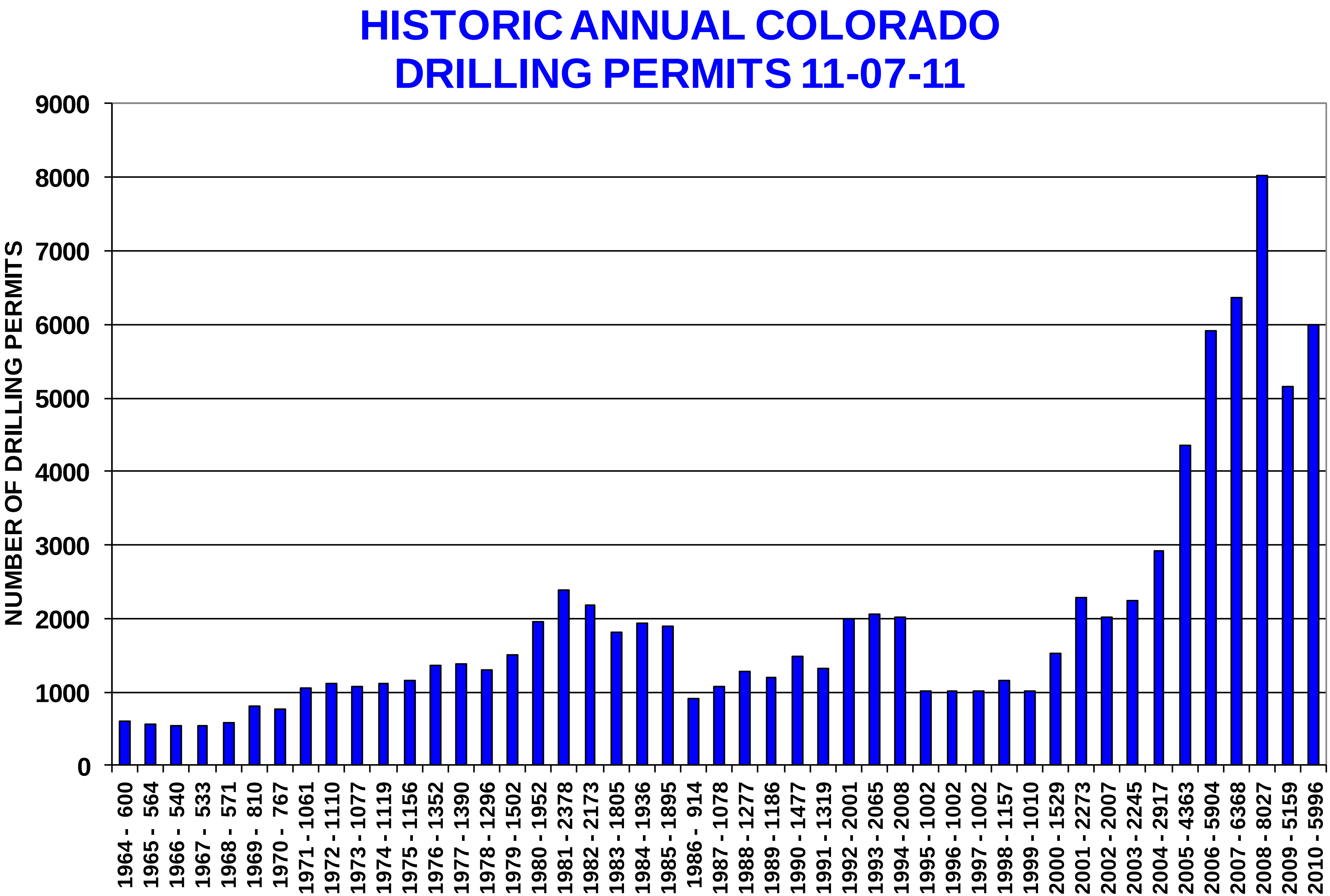
(35% Chevron NW, 5% Equiva SW, 40% Valero NE, 20% Valero SE : ~= WTI+$0.70) 11-07-11



Number of Oil and Gas Well Permits For Wells Drilled Directionally & Horizontally From Common Well Pads in Colorado

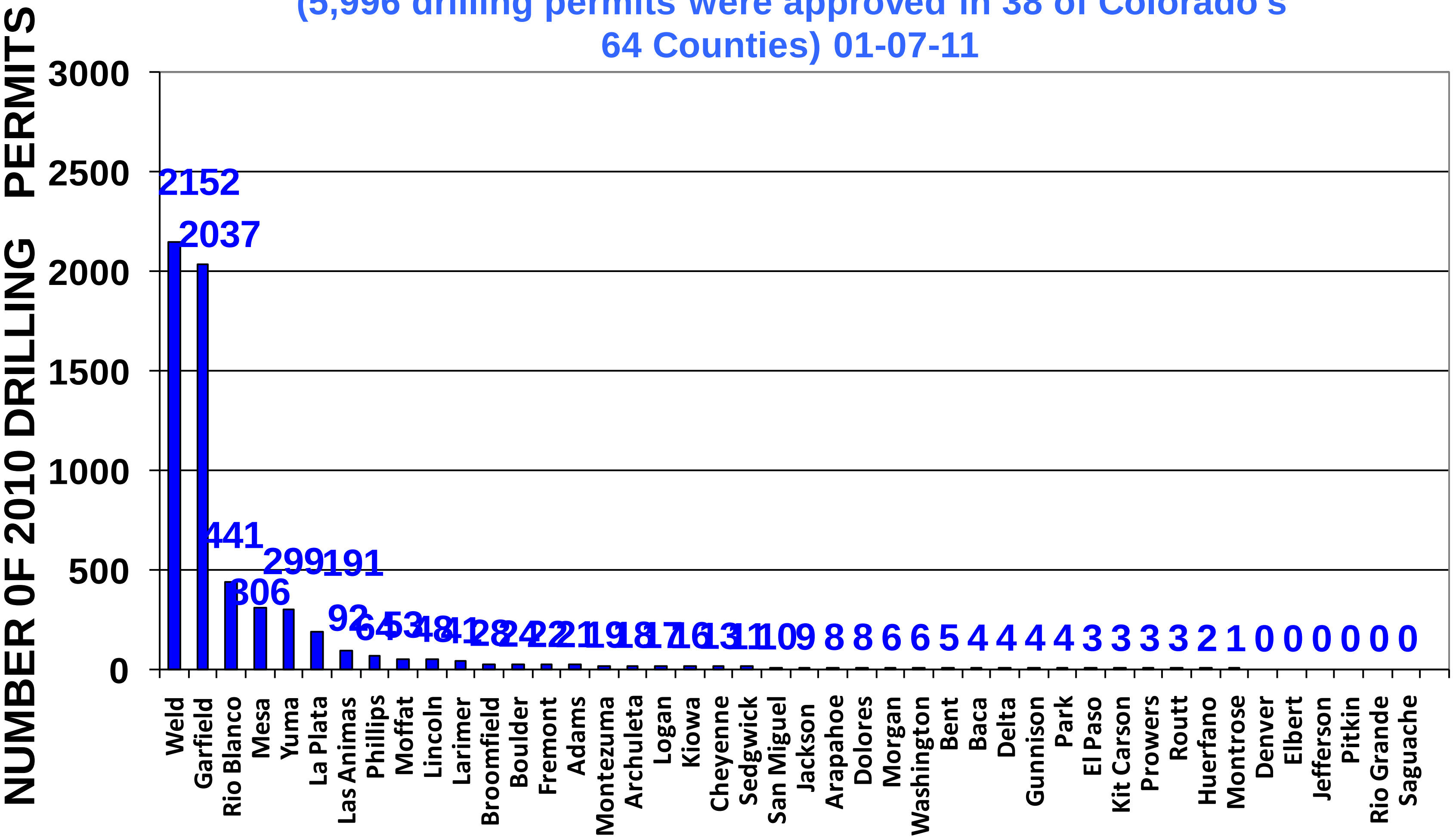
11-07-11




HISTORIC ANNUAL COLORADO
DRILLING PERMITS 11-07-11
NUMBER OF DRILLING PERMITS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1964 - 600
1965 - 564
1966 - 540
1967 - 533
1968 - 571
1969 - 810
1970 - 767
1971 - 1061
1972 - 1110
1973 - 1077
1974 - 1119
1975 - 1156
1976 - 1352
1977 - 1390
1978 - 1296
1979 - 1502
1980 - 1952
1981 - 2378
1982 - 2173
1983 - 1805
1984 - 1936
1985 - 1895
1986 - 914
1987 - 1078
1988 - 1277
1989 - 1186
1990 - 1477
1991 - 1319
1992 - 2001
1993 - 2065
1994 - 2008
1995 - 1002
1996 - 1002
1997 - 1002
1998 - 1157
1999 - 1010
2000 - 1529
2001 - 2273
2002 - 2007
2003 - 2245
2004 - 2917
2005 - 4363
2006 - 5904
2007 - 6368
2008 - 8027
2009 - 5159
2010 - 5996

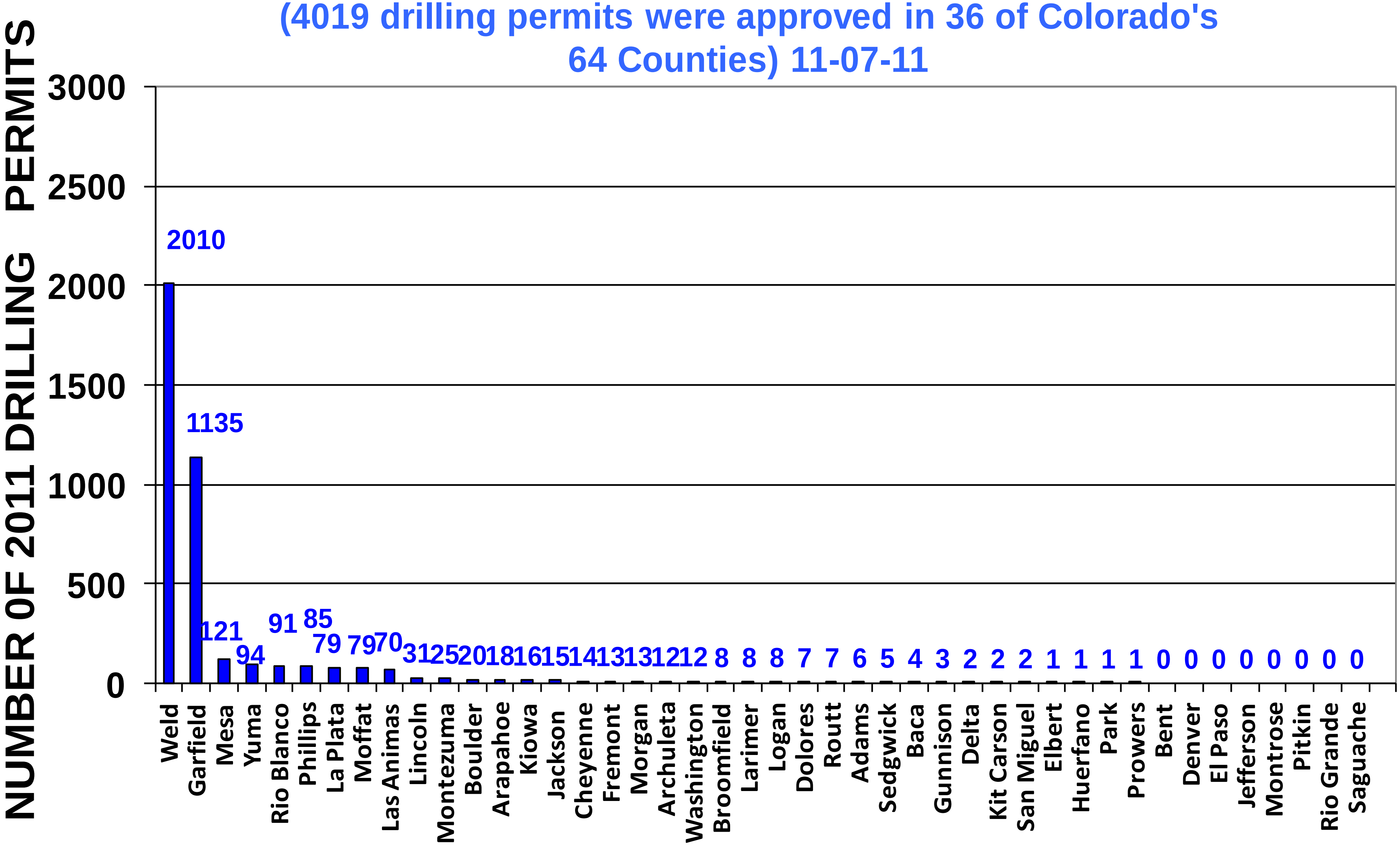
NUMBER OF 2010 DRILLING PERMITS, ALL COLORADO COUNTIES

(5,996 drilling permits were approved in 38 of Colorado's 64 Counties) 01-07-11



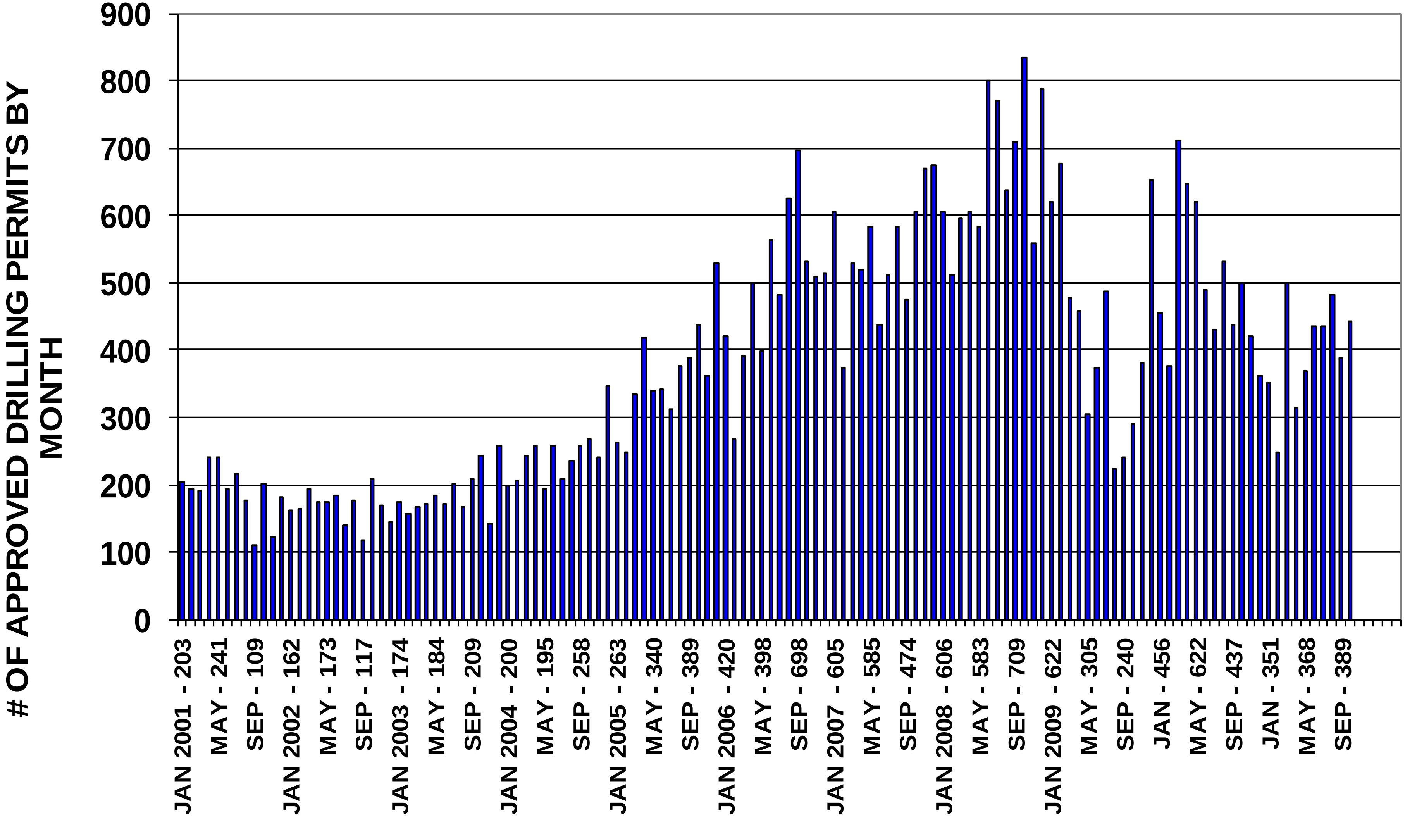
NUMBER OF 2011 DRILLING PERMITS, ALL COLORADO COUNTIES

(4019 drilling permits were approved in 36 of Colorado's 64 Counties) 11-07-11

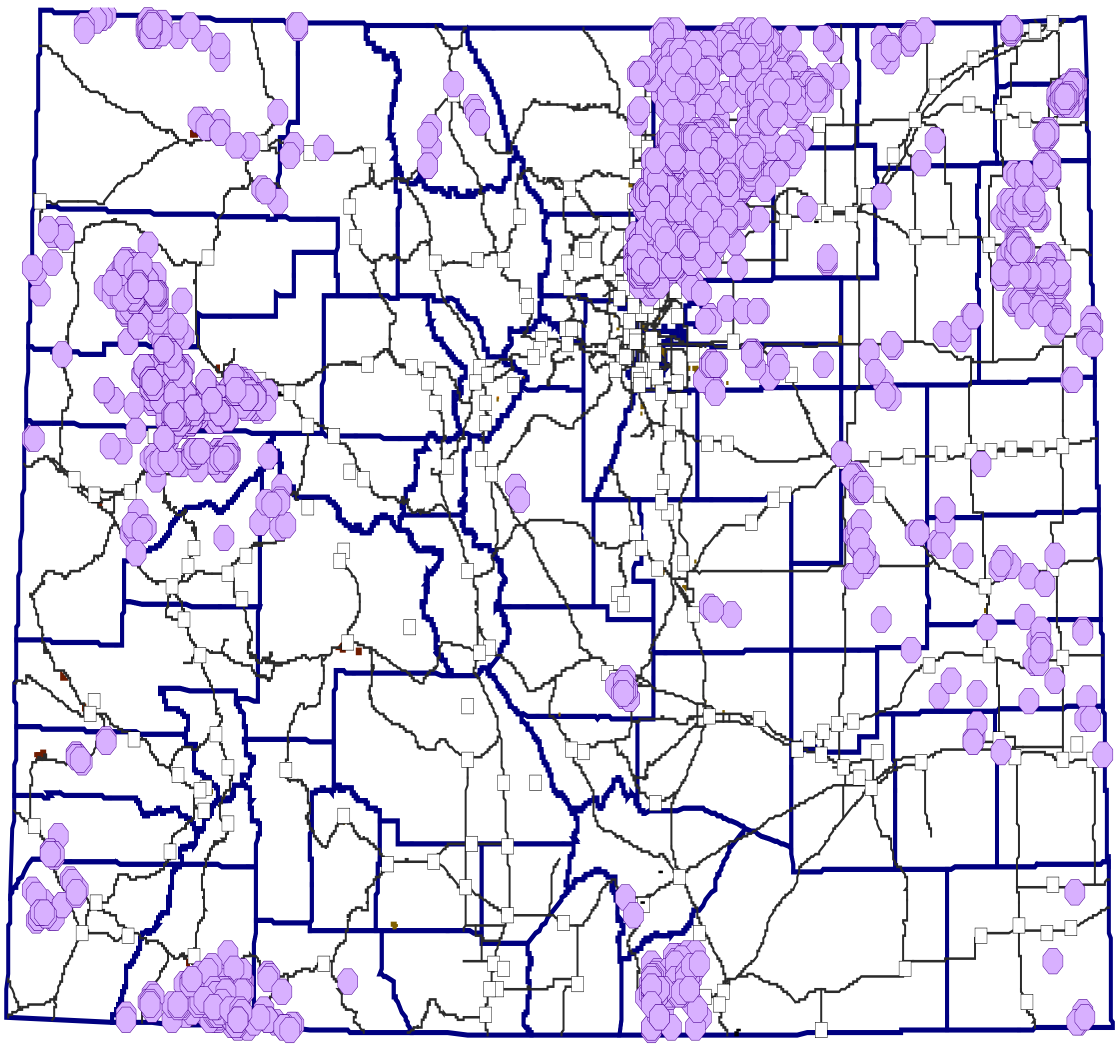


COLORADO MONTHLY APPROVED DRILLING PERMITS

as of 11-07-11

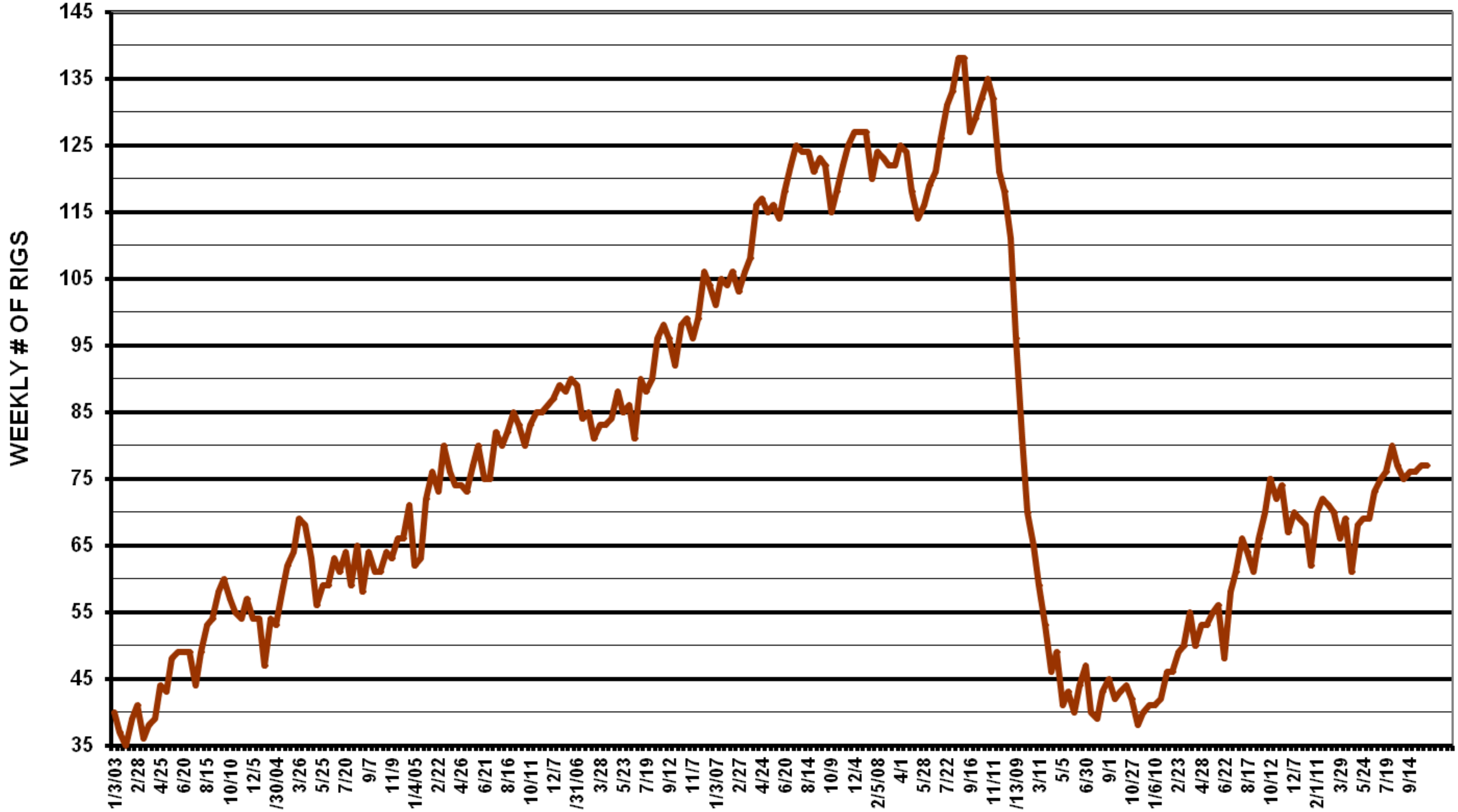


RECENT COLORADO OIL AND GAS WELL PERMITS 11-07-11



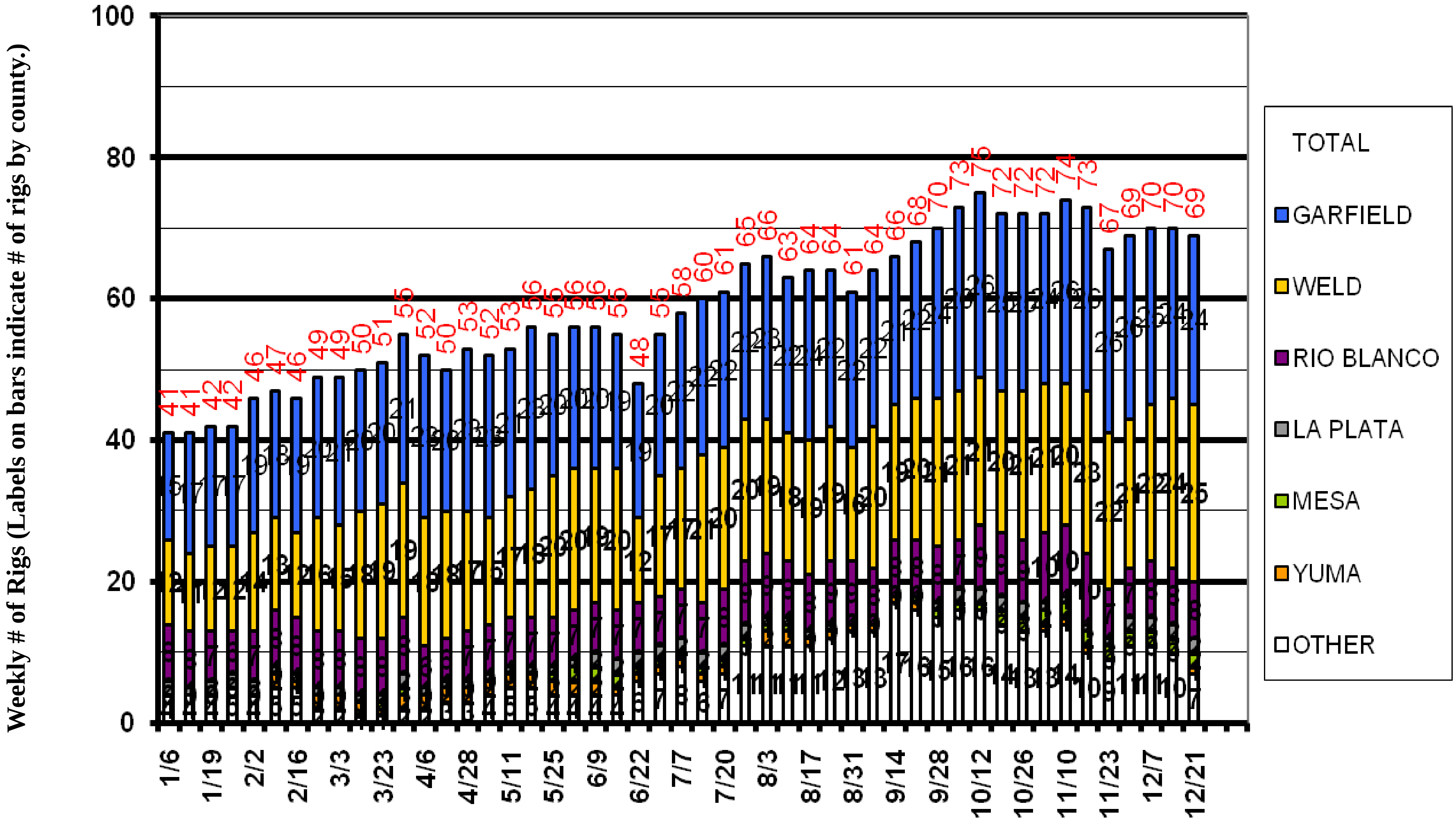
TOTAL DRILLING RIGS RUNNING IN COLORADO EVERY OTHER WEEK IN 2003-2011

(Based on Data in: through 4/30/03, PI/Dwights Drilling Wire -- after 4/30/03, Anderson Reports Weekly Rig Status Report)



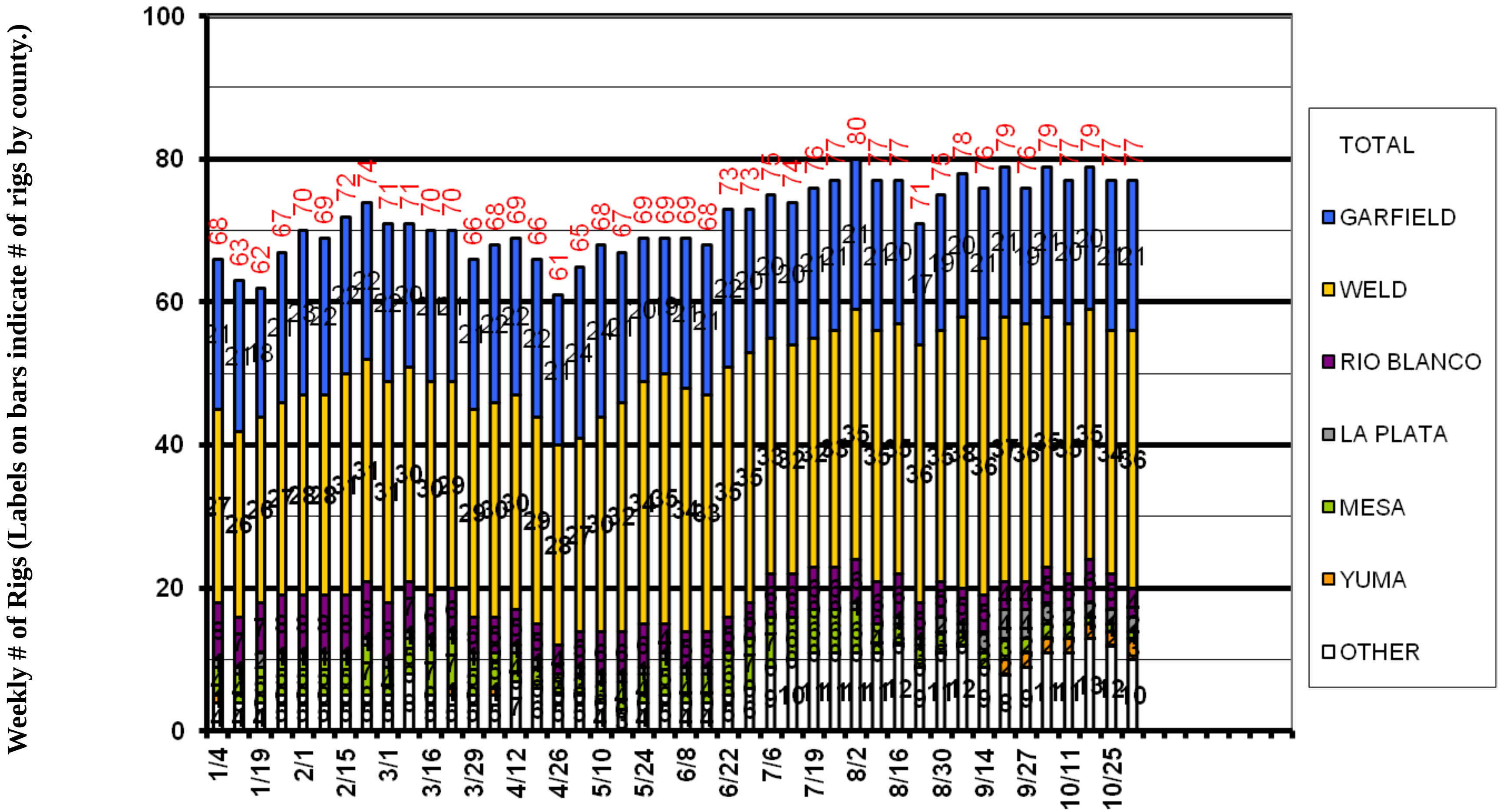
DRILLING RIGS RUNNING IN COLORADO BY COUNTY EACH WEEK IN 2010

(Based on Data in Anderson Reports Weekly Rig Status Report)



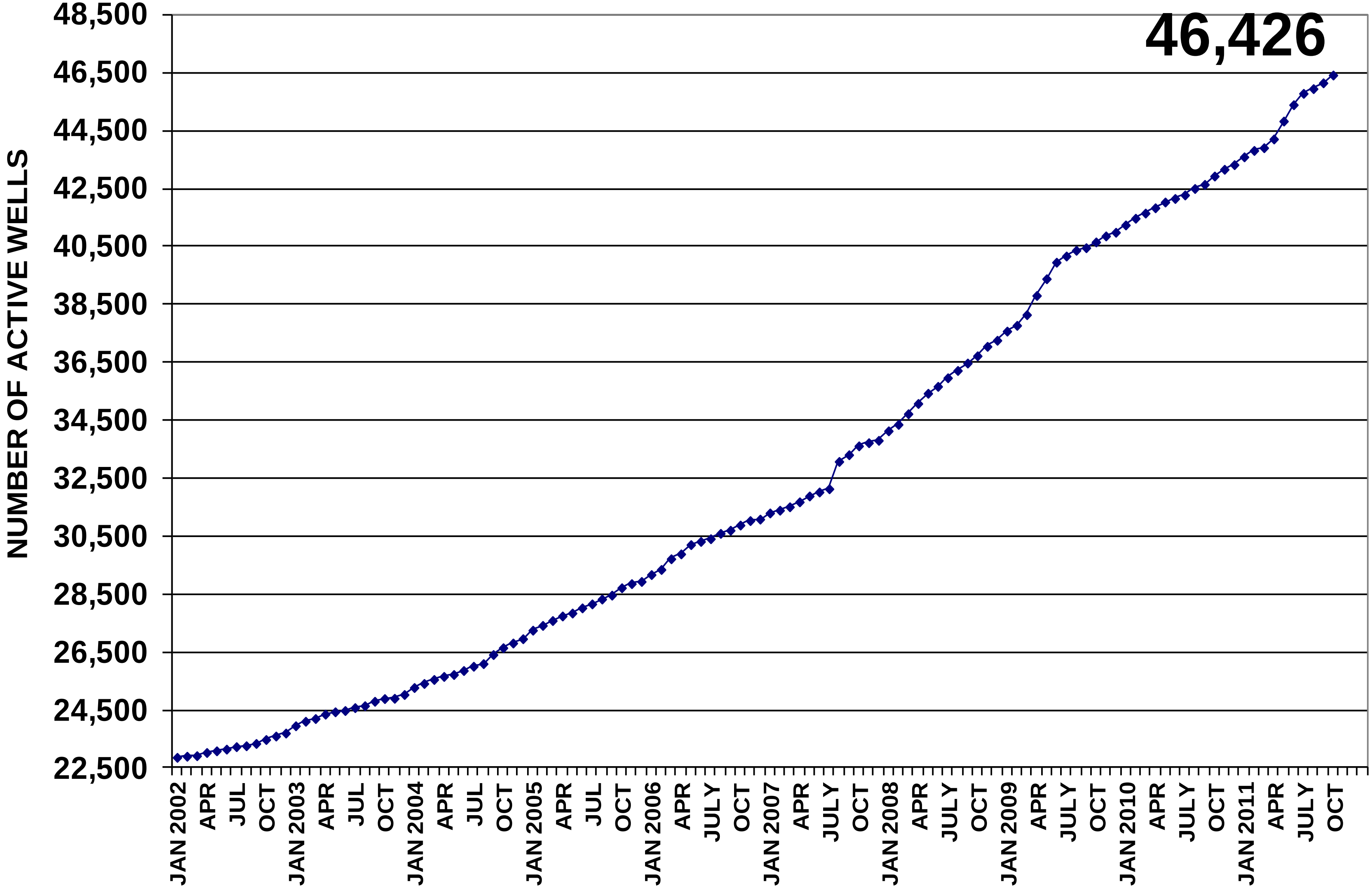
DRILLING RIGS RUNNING IN COLORADO BY COUNTY EACH WEEK IN 2011

(Based on Data in Anderson Reports Weekly Rig Status Report)



COLORADO MONTHLY ACTIVE WELL COUNT

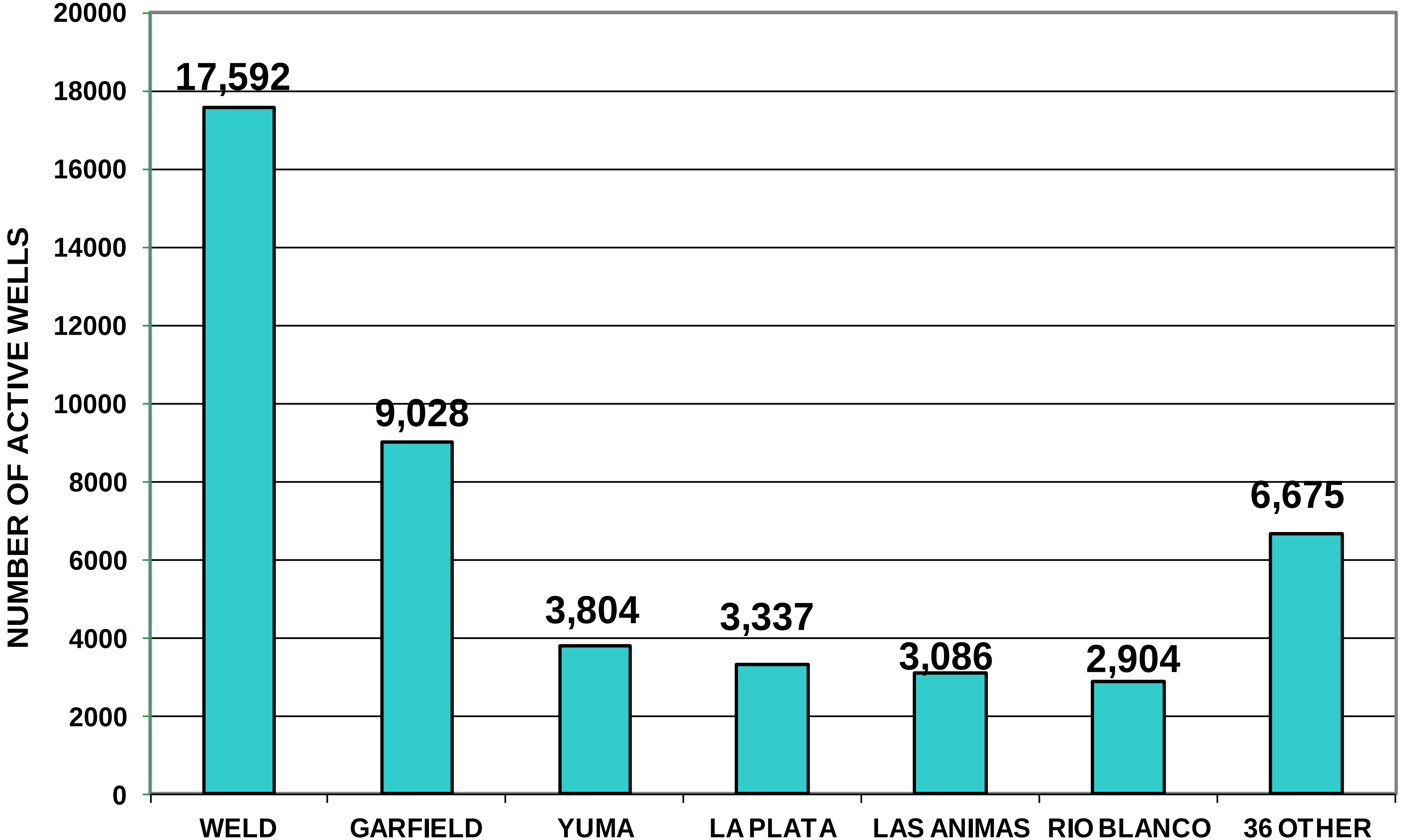
11-07-11



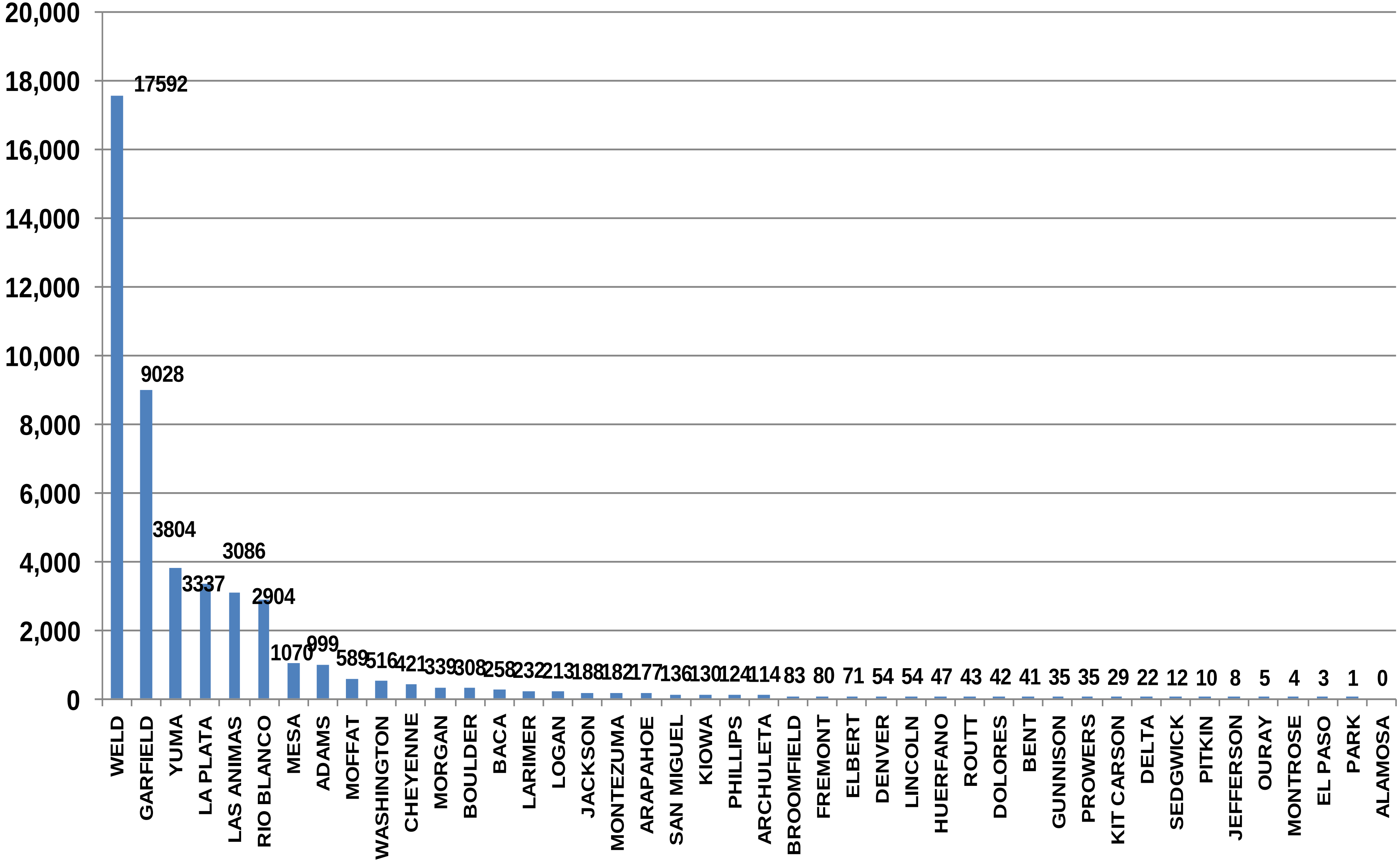
NUMBER OF ACTIVE COLORADO OIL & GAS WELLS BY COUNTY

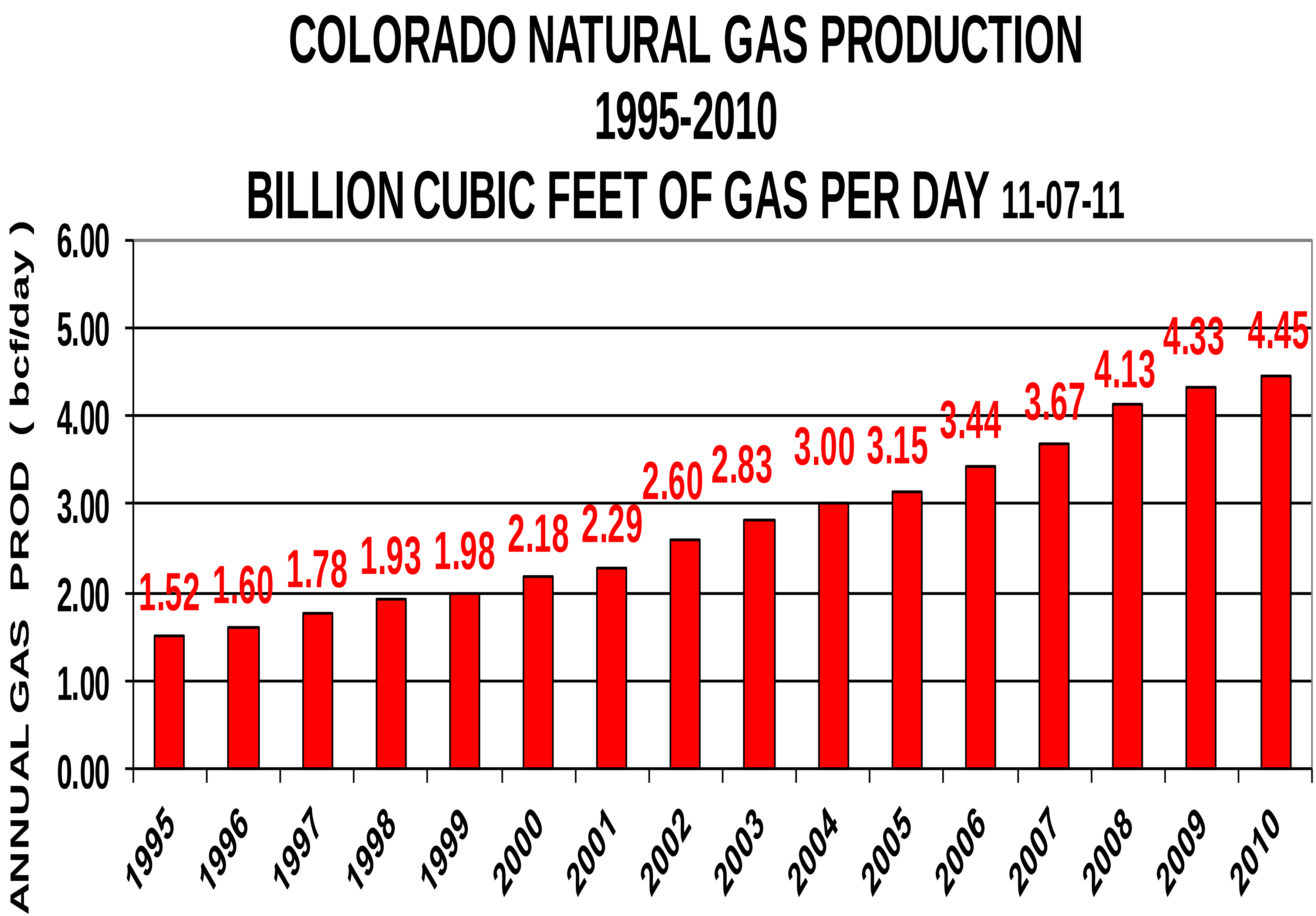
86.0% of Colorado's 46,426 active wells are located in these 6 counties

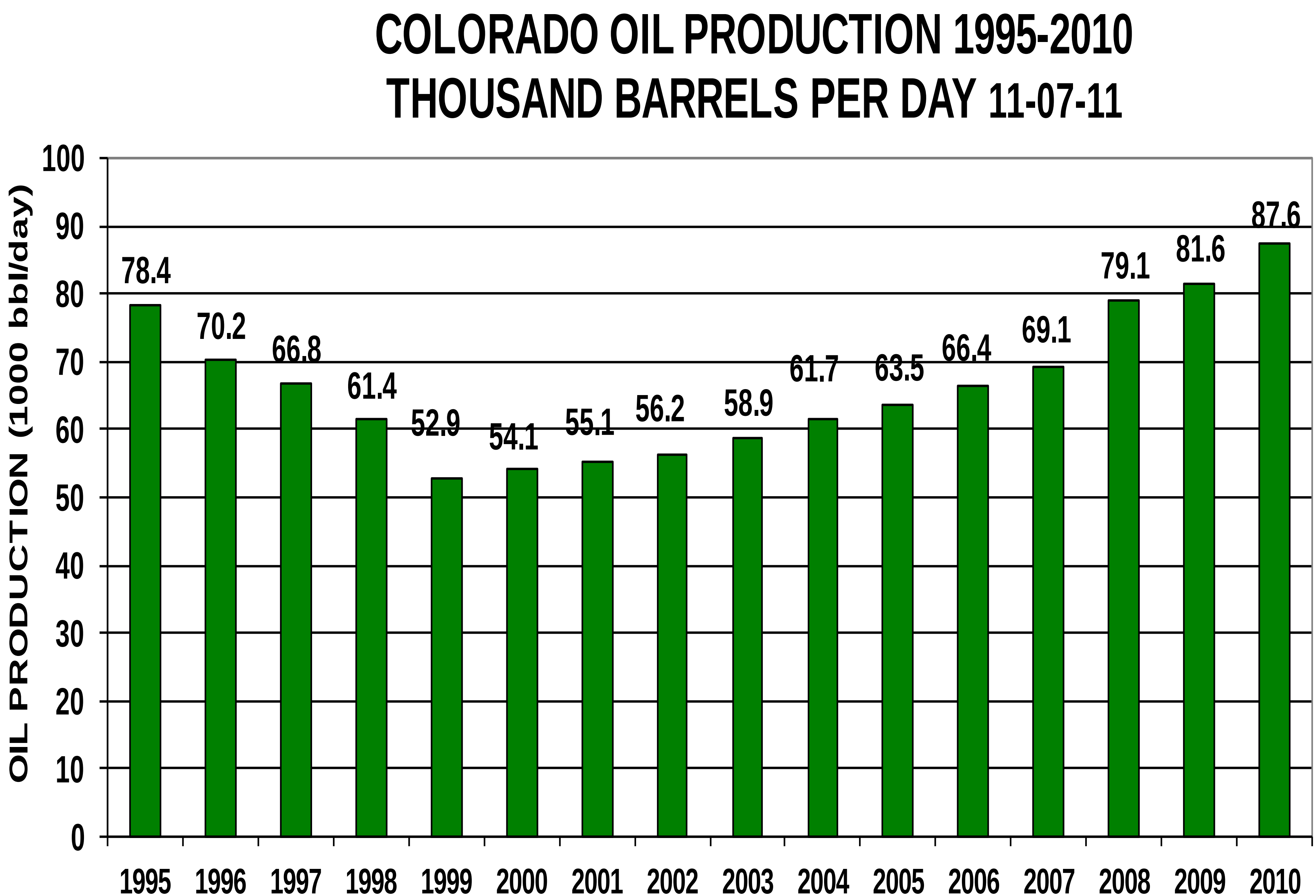
(11-07-11)



ACTIVE OIL & GAS WELLS – ALL COLORADO COUNTIES
11-07-11

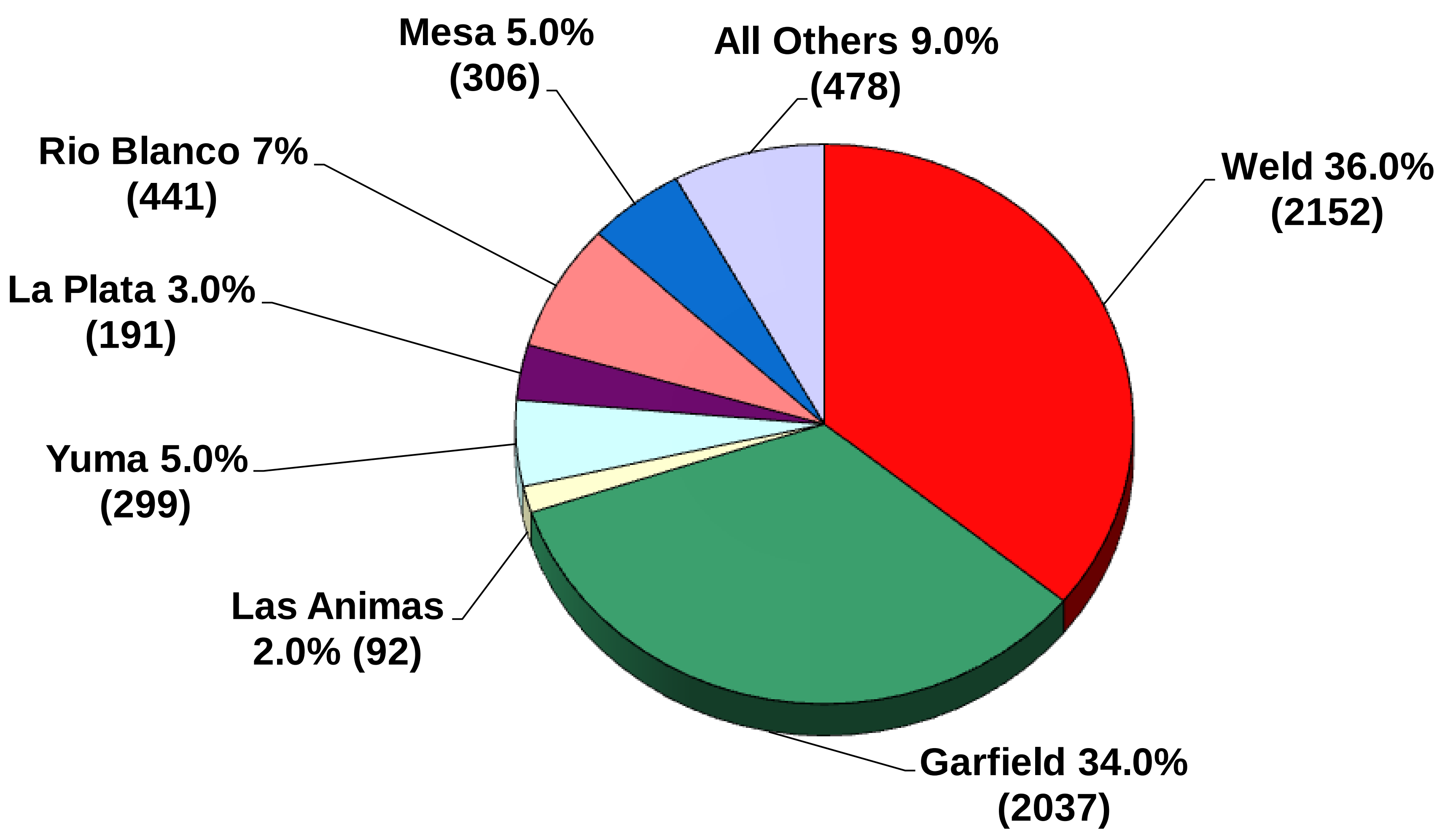



COLORADO NATURAL GAS PRODUCTION
1995-2010
BILLION CUBIC FEET OF GAS PER DAY 11-07-11
ANNUAL GAS PROD (bcf/day)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1.52
1.60
1.78
1.93
1.98
2.18
2.29
2.60
2.83
3.00
3.15
3.44
3.67
4.13
4.33
4.45
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


COLORADO OIL PRODUCTION 1995-2010
THOUSAND BARRELS PER DAY 11-07-11
OIL PRODUCTION (1000 bbl/day)
100
90
80
70
60
50
40
30
20
10
0
78.4
70.2
66.8
61.4
52.9
54.1
55.1
56.2
58.9
61.7
63.5
66.4
69.1
79.1
81.6
87.6
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

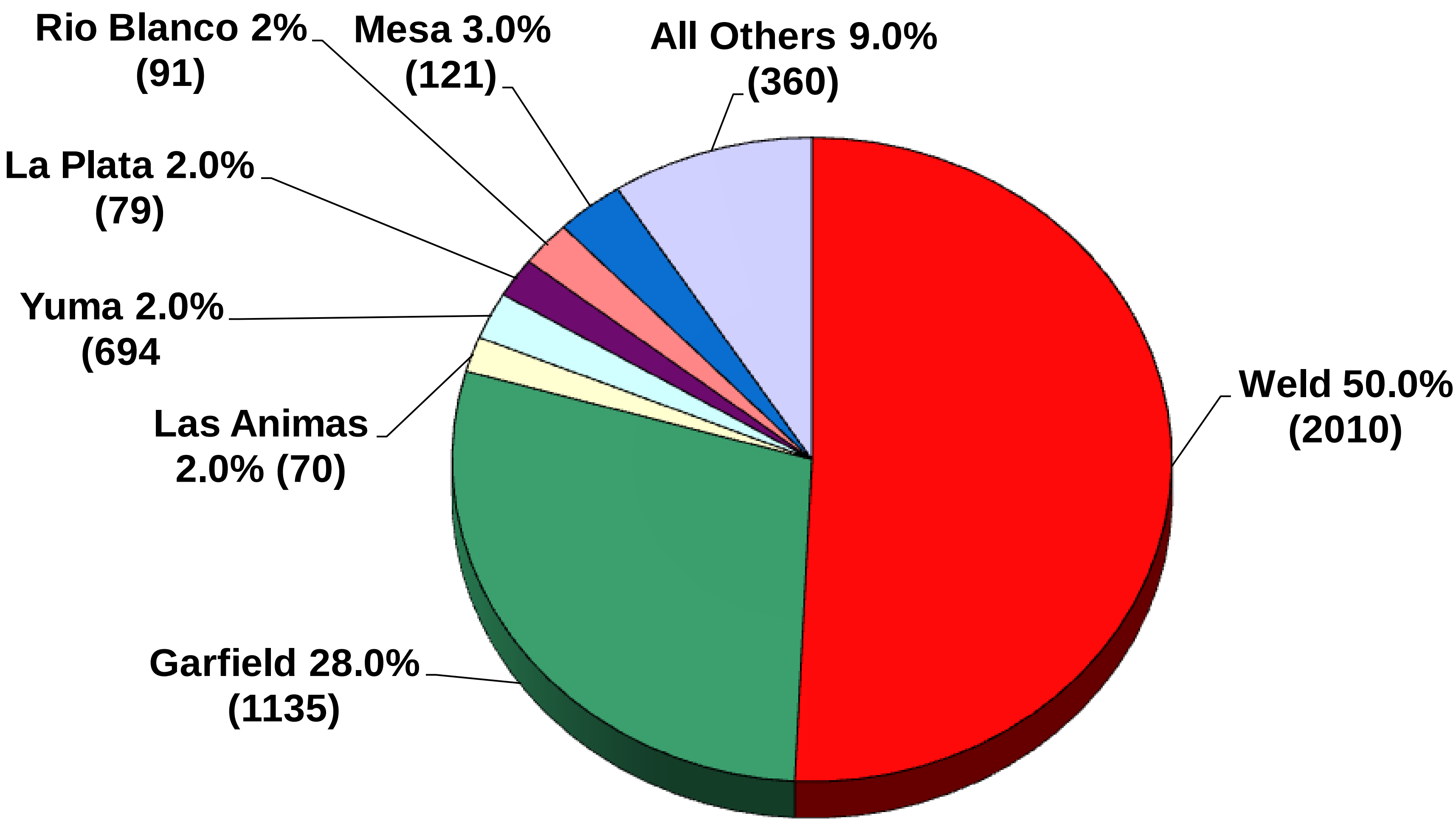
COLORADO OIL AND GAS 2010 DRILLING PERMITS BY COUNTY

as of 01-07-11

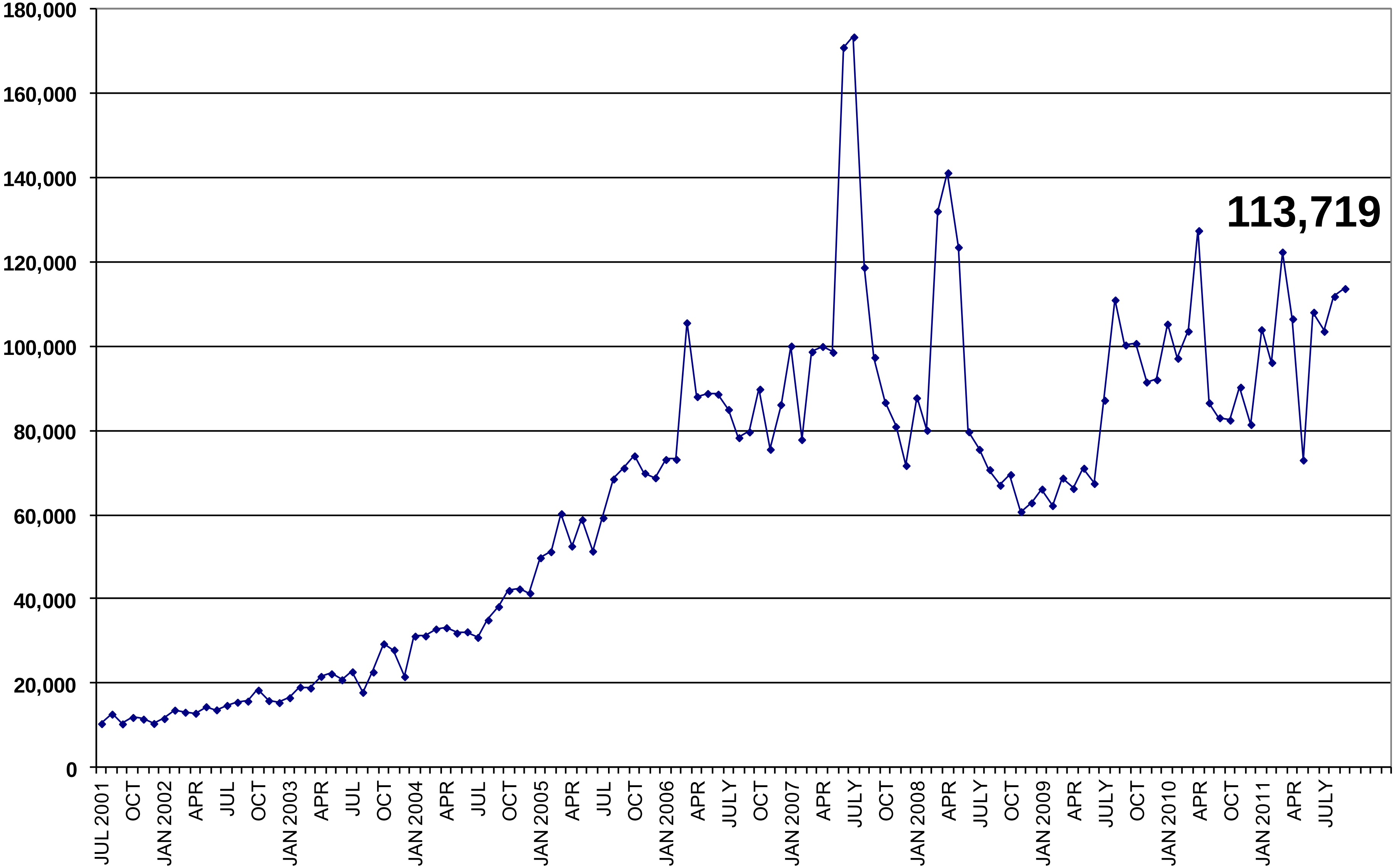


COLORADO OIL AND GAS 2011 DRILLING PERMITS BY COUNTY

as of 11-07-11



COLORADO MONTHLY COGCC WEBSITE VISITS
10-07-11



Colorado Oil & Gas Conservation Commission Statutory Requirements

*Please note that information within parentheses is additional background information and not a statutory requirement

Commissioner (Officer)	**2 Executive Directors (ex-officio voting members)** (Current Employment)	**2 West of Continental Divide** (Resident County)	**3 with Substantial Oil & Gas Experience** (Employed by Oil & Gas Industry) (Current Employment)	**2 Out of 3 Must Have a College Degree in Petroleum Geology or Petroleum Engineering**	**1 Local Government Official** (Current Employment)	**1 with Substantial Environmental or Wildlife Protection Experience** (Current Employment)	**1 with Substantial Soil Conservation or Reclamation Experience** (Current Employment)	**1 engaged in Agricultural Production and a Royalty Owner** (Current Employment)	**Maximum of 4 from Same Political Party (excluding Executive Directors)**	**Current Term Expires**
Richard Alward		X (Mesa)					X (Ecologist)		D	7/1/2015
Tom Compton Chairman		X (La Plata)						X (Rancher)	R	7/1/2015
Tommy Holton		(Fort Lupton)			X				R	7/1/2015
John Benton		(Littleton)	X	X					R	7/1/2015
W. Perry Pearce Vice Chair		(Denver)	X						D	7/1/2015
DeAnn Craig		(Denver)	X	X					R	7/1/2012
Andrew Spielman		(Denver)	X			X			D	7/1/2015
Mike King	X (Department of Natural Resources)	(Denver)								
Chris Urbina	X (Department of Public Health and Environment)	(Denver)								

Commissioner requrements are set by statute in the Oil and Gas Conservation Act at §34-60-104 (2) (a)(1), C.R.S. (Current as of 09-19-2011)

COLORADO AIR QUALITY CONTROL COMMISSION

AGENDA ITEM SUMMARY

Item Title: Review of the 2013 Ozone Season ____________________

Meeting Date: October 17, 2013 ____________________

TYPES OF ACTION

NON-HEARING ACTIONS	*REQUEST FOR HEARING*	*HEARING*
__ Administrative	_ Rulemaking	_ Rulemaking
_X_ Briefing	_ Public	_ Public
__ Policy	_ Adjudicatory	_ Adjudicatory
__ Other	_ Informational	_ Informational

RECOMMENDED ACTION

__ Adoption	__ Approval	_ Denial

MOTION

_ Required	_ Attached	_ Not Applicable

STATUTORY AUTHORITY

General ____ Specific _____

EPA SUBMITTAL

Is this issue considered a SIP revision? ________

Which SIP? ______________________________

EPA submission deadline: ______________________________

Is this a delegated program? ________

ISSUE STATEMENT:
The Division will present a review of the summertime ozone monitoring data from around the state and will report on any exceedances and violations of the National Ambient Air Quality Standards. Historical ozone trends will also be presented. Finally, the Division will provide an update on the status of the NCAR "FRAPPE" study.

ATTACHMENTS:

SIGNATURES:

1. Gordon [signature] 9/27/2013
Preparer Date

2.
Supervisor or Program Manager Date

3. [signature] 30 Sept 2013
Division Director Date

*** DRAFT DATA ***

2013 8-Hour Ozone (updated through September 30, 2013)

AQS Number	Site Name	1st Max 8-Hour (ppm)	Date 1st Max 8-Hour	2nd Max 8-Hour (ppm)	Date 2nd Max 8-Hour	3rd Max 8-Hour (ppm)	Date 3rd Max 8-Hour	4th Max 8-Hour (ppm)	Date 4th Max 8-Hour	5th Max 8-Hour (ppm)	Date 5th Max 8-Hour
08-001-3001	Welby	0.082	07/17	0.082	08/29	0.077	07/18	0.077	08/17	0.076	07/11
08-005-0002	Highland	0.085	08/29	0.080	06/13	0.080	06/28	0.079	08/17	0.078	07/10
08-005-0006	Aurora East	0.081	08/29	0.078	07/18	0.074	08/17	0.073	05/31	0.073	07/12
08-013-0011	S. Boulder Creek	0.086	07/17	0.081	07/10	0.080	07/11	0.079	07/16	0.075	07/22
08-031-0002	CAMP	0.074	07/10	0.072	07/17	0.069	08/29	0.067	07/11	0.064	08/04
08-031-0026	La Casa	0.080	07/10	0.079	07/17	0.072	07/11	0.071	08/29	0.070	06/28
08-035-0004	Chatfield State Park	0.086	08/29	0.085	06/28	0.083	07/18	0.083	07/21	0.082	08/17
08-041-0013	Colo. Spgs. – USAF Academy	0.082	07/18	0.079	05/31	0.075	07/12	0.074	06/09	0.074	07/20
08-041-0016	Manitou Springs	0.078	07/18	0.077	08/29	0.075	05/31	0.072	08/17	0.071	07/12
08-045-0012	Rifle – Health	0.065	05/31	0.064	05/23	0.064	07/10	0.062	06/05	0.062	06/21
08-059-0005	Welch	0.084	07/17	0.080	07/21	0.080	08/17	0.080	08/29	0.077	08/16
08-059-0006	Rocky Flats - N	0.093	07/17	0.087	07/10	0.086	08/17	0.085	07/11	0.081	06/09
08-059-0011	NREL	0.090	07/17	0.086	07/11	0.084	08/17	0.084	08/29	0.082	07/10
08-059-0013	Aspen Park	0.080	08/29	0.078	06/12	0.078	07/17	0.077	07/18	0.077	08/17
08-069-0007	NPS - Rocky Mtn. NP	0.082	06/12	0.082	07/17	0.079	07/16	0.074	06/20	0.074	07/17
08-069-0011	Ft. Collins - West	0.091	07/17	0.087	08/17	0.085	07/11	0.082	07/10	0.080	07/03
08-069-0012	* Rist Canyon	0.070	06/12	0.068	05/25	0.067	05/17	0.066	06/02	0.066	06/09
08-069-1004	Ft. Collins - CSU	0.083	07/17	0.076	08/17	0.075	07/11	0.074	07/10	0.071	07/03
08-077-0020	Palisade - Water	0.068	07/18	0.067	07/10	0.066	06/01	0.066	07/17	0.065	05/23
08-081-0002	Lay Peak	0.067	07/10	0.066	07/19	0.066	08/16	0.065	06/11	0.065	07/09
08-083-0006	Cortez	0.065	05/31	0.064	07/10	0.064	07/17	0.064	07/18	0.062	05/05
08-123-0009	Greeley - Weld Tower	0.080	08/17	0.074	07/11	0.074	08/16	0.073	06/18	0.073	09/07

NOTE: Values above the level of the 8-hour standard (0.075 ppm) are highlighted in yellow.
NOTE: Data influenced by natural event values, if any, are included.
* Rist Canyon site shut down on 6/28/2013.

The 8-hour ozone standard is written such that attainment is met if the 3-year average of the 4th maximum value from each of the 3 years is less than or equal to 0.075 ppm. Thus, by looking at the 4th maximum values from the previous 2 years, it is possible to see what the highest 4th maximum level for the current year could be and still remain in attainment of the standard.

This table provides information on the 4th maximum values for 2011 and 2012, the current 4th maximum value for 2013, the current 3-year average, and the maximum possible level for 2013 in order to remain in attainment of the ozone standard. Based on the current values, maximum possible levels for 2014 are also included.

3-Year Average 4th Maximum Ozone Values

Site Name	AQS #	2011 4th Maximum 8-Hour Average Value (ppm)	2012 4th Maximum 8-Hour Average Value (ppm)	2013 (thru 9/30) 4th Maximum 8-Hour Average Value (ppm)	2011 - 2013 3-Year Average 4th Maximum Value (ppm)	2013 Highest Allowable 4th Maximum 8-Hour Average Value (ppm)	*2014 Highest Allowable 4th Maximum 8-Hour Average Value (ppm)*
Welby	08-001-3001	0.075	0.077	0.077	**0.076**	0.075	*0.073*
Highland	08-005-0002	0.078	0.080	0.079	**0.079**	0.069	*0.068*
Aurora East	08-005-0006	0.077	0.074	0.073	0.074	0.076	*0.080*
S. Boulder Creek	08-013-0011	0.076	0.076	0.079	**0.077**	0.075	*0.072*
CAMP	08-031-0002	---	0.068	0.067	---	---	*0.092*
La Casa	08-031-0026	---	---	0.071	---	---	---
Chatfield State Park	08-035-0004	0.082	0.086	0.083	**0.083**	0.059	*0.058*
Colo. Spg. - USAF Academy	08-041-0013	0.074	0.075	0.074	0.074	0.078	*0.078*
Manitou Springs	08-041-0016	0.075	0.075	0.072	0.074	0.077	*0.080*
Rifle - Health	08-045-0012	0.066	0.068	0.062	0.065	0.093	*0.097*
Welch	08-059-0005	0.077	0.079	0.080	**0.078**	0.071	*0.068*
Rocky Flats North	08-059-0006	0.081	0.084	0.085	**0.083**	0.062	*0.058*
NREL	08-059-0011	0.083	0.081	0.084	**0.082**	0.063	*0.062*
Aspen Park	08-059-0013	0.072	0.077	0.077	0.075	0.078	*0.073*
NPS - Rocky Mtn. Nat'l Park	08-069-0007	0.077	0.079	0.074	**0.076**	0.071	*0.074*
Fort Collins - West	08-069-0011	0.080	0.080	0.082	**0.080**	0.067	*0.065*
* Rist Canyon	08-069-0012	0.073	0.071	0.066	0.070	0.083	---
Fort Collins - CSU	08-069-1004	0.068	0.074	0.074	0.072	0.085	*0.079*
Palisade - Water	08-077-0020	0.066	0.071	0.066	0.067	0.090	*0.090*
Lay Peak	08-081-0002	---	0.066	0.065	---	---	*0.096*
Cortez	08-083-0006	0.071	0.070	0.064	0.068	0.086	*0.093*
Greeley - Weld Tower	08-123-0009	0.077	0.080	0.073	**0.076**	0.070	*0.074*

NOTE: An area is considered to be in attainment of the National Ambient Air Quality Standard when the 3-year average of the annual 4th highest daily maximum 8-hour ozone concentration at a site is less than or equal to 0.075 ppm.

NOTE: Values above the level of the 3-year average 4th maximum 8-hour standard are highlighted in red.
NOTE: Data includes values that may be influenced by natural events.
* Rist Canyon site shut down on 6/28/2013.

Colorado Department of Public Health and Environment, Air Pollution Control Division, Technical Services Program

2013 Summer Ozone Season Review

STATE OF COLORADO 1876 NIL SINE NUMINE

Colorado Department of Public Health and Environment

Briefing to the
Colorado Air Quality Control Commission
and the Colorado Board of Health
10/17/2013

Review of the Monitoring Data

National Ambient Air Quality Standard (NAAQS)

0.075 ppm as the 3-year average of the 4^{th} maximum 8-hour values

*** *DRAFT DATA* ***

2013 8-Hour Ozone (updated through September 30, 2013)

AQS Number	Site Name	1st Max 8-Hour (ppm)	Date 1st Max 8-Hour	2nd Max 8-Hour (ppm)	Date 2nd Max 8-Hour	3rd Max 8-Hour (ppm)	Date 3rd Max 8-Hour	4th Max 8-Hour (ppm)	Date 4th Max 8-Hour	5th Max 8-Hour (ppm)	Date 5th Max 8-Hour
08-001-3001	Welby	0.082	07/17	0.082	08/29	0.077	07/18	0.077	08/17	0.076	07/11
08-005-0002	Highland	0.085	08/29	0.080	06/13	0.080	06/28	0.079	08/17	0.078	07/10
08-005-0006	Aurora East	0.081	08/29	0.078	07/18	0.074	08/17	0.073	05/31	0.073	07/12
08-013-0011	S. Boulder Creek	0.086	07/17	0.081	07/10	0.080	07/11	0.079	07/16	0.075	07/22
08-031-0002	CAMP	0.074	07/10	0.072	07/17	0.069	08/29	0.067	07/11	0.064	08/04
08-031-0026	La Casa	0.080	07/10	0.079	07/17	0.072	07/11	0.071	08/29	0.070	06/28
08-035-0004	Chatfield State Park	0.086	08/29	0.085	06/28	0.083	07/18	0.083	07/21	0.082	08/17
08-041-0013	Colo. Spgs. – USAF Academy	0.082	07/18	0.079	05/31	0.075	07/12	0.074	06/09	0.074	07/20
08-041-0016	Manitou Springs	0.078	07/18	0.077	08/29	0.075	05/31	0.072	08/17	0.071	07/12
08-045-0012	Rifle – Health	0.065	05/31	0.064	05/23	0.064	07/10	0.062	06/05	0.062	06/21
08-059-0005	Welch	0.084	07/17	0.080	07/21	0.080	08/17	0.080	08/29	0.077	08/16
08-059-0006	Rocky Flats - N	0.093	07/17	0.087	07/10	0.086	08/17	0.085	07/11	0.081	06/09
08-059-0011	NREL	0.090	07/17	0.086	07/11	0.084	08/17	0.084	08/29	0.082	07/10
08-059-0013	Aspen Park	0.080	08/29	0.078	06/12	0.078	07/17	0.077	07/18	0.077	08/17
08-069-0007	NPS - Rocky Mtn. NP	0.082	06/12	0.082	07/17	0.079	07/16	0.074	06/20	0.074	07/17
08-069-0011	Ft. Collins - West	0.091	07/17	0.087	08/17	0.085	07/11	0.082	07/10	0.080	07/03
08-069-0012	* Rist Canyon	0.070	06/12	0.068	05/25	0.067	05/17	0.066	06/02	0.066	06/09
08-069-1004	Ft. Collins - CSU	0.083	07/17	0.076	08/17	0.075	07/11	0.074	07/10	0.071	07/03
08-077-0020	Palisade - Water	0.068	07/18	0.067	07/10	0.066	06/01	0.066	07/17	0.065	05/23
08-081-0002	Lay Peak	0.067	07/10	0.066	07/19	0.066	08/16	0.065	06/11	0.065	07/09
08-083-0006	Cortez	0.065	05/31	0.064	07/10	0.064	07/17	0.064	07/18	0.062	05/05
08-123-0009	Greeley - Weld Tower	0.080	08/17	0.074	07/11	0.074	08/16	0.073	06/18	0.073	09/07

NOTE: Values above the level of the 8-hour standard (0.075 ppm) are highlighted in yellow.
NOTE: Data influenced by natural event values, if any, are included.
* Rist Canyon site shut down on 6/28/2013.

(Draft data for 2013)

Three Year Average 4th Maximum Ozone Values

****** 2013 data through 30 September ******

For NAAQS of 0.075 ppm

East Slope Sites Site Name	AQS #	2011 8-hr. O3 4th Max. Value (ppm)	2012 8-hr. O3 4th Max. Value (ppm)	2013 8-hr. O3 4th Max. Value (ppm)	3-yr. Avg. 4th Max. Value (ppm)	2014 Highest Allowable 4th Max. (ppm)
Welby	08-001-3001	0.075	0.077	0.077	**0.076**	0.073
Highland	08-005-0002	0.078	0.080	0.079	**0.079**	0.068
Aurora East	08-005-0006	0.077	0.074	0.073	0.074	0.080
S. Boulder Creek	08-013-0011	0.076	0.076	0.079	**0.077**	0.072
CAMP	08-031-0002	---	0.068	0.067	---	0.092
La Casa	08-013-0026	---	---	0.071	---	---
Chatfield State Park	08-035-0004	0.082	0.086	0.083	**0.083**	0.058
USAF Academy	08-041-0013	0.074	0.075	0.074	0.074	0.078
Manitou	08-041-0016	0.075	0.075	0.072	0.074	0.080
Welch	08-059-0005	0.077	0.079	0.080	**0.078**	0.068
Rocky Flats North	08-059-0006	0.081	0.084	0.085	**0.083**	0.058
NREL	08-059-0011	0.083	0.081	0.084	**0.082**	0.062
Aspen Park	08-059-0013	0.072	0.077	0.077	0.075	0.073
Fort Collins - West	08-069-0011	0.080	0.080	0.082	**0.080**	0.065
Rist Canyon *	08-069-0012	0.073	0.071	0.066	0.070	--- *
Fort Collins - CSU	08-069-1004	0.068	0.074	0.074	0.072	0.079
Weld County Tower	08-123-0009	0.077	0.080	0.073	**0.076**	0.074
NPS - Rocky Mtn. NP	08-069-0007	0.077	0.079	0.074	**0.076**	0.074
NOAA - BAO Tower	n/a	0.076	0.077	0.064	0.072	0.086
NOAA - Niwot Ridge	n/a	0.067	0.076	0.070	0.071	0.081

* Rist Canyon site closed 6/28.

(NOAA thru 6/23)

(Draft data for 2013)

For NAAQS of 0.075 ppm

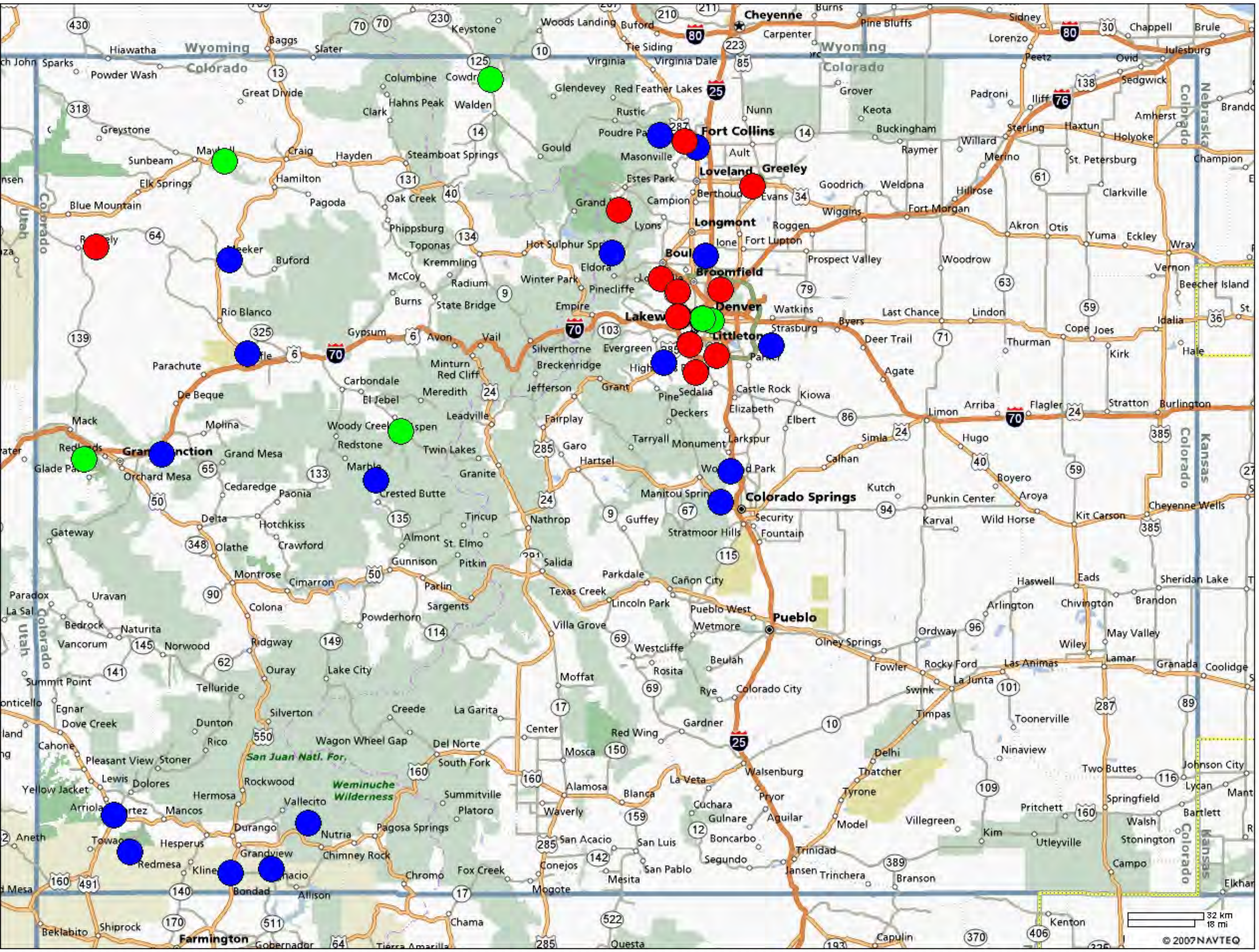
Three Year Average 4th Maximum Ozone Values

****** 2013 data through 30 September ******

West Slope Sites Site Name	AQS #	2011 8-hr. O3 4th Max. Value (ppm)	2012 8-hr. O3 4th Max. Value (ppm)	2013 8-hr. O3 4th Max. Value (ppm)	3-yr. Avg. 4th Max. Value (ppm)	2014 Highest Allowable 4th Max. (ppm)
Rifle - Health	08-045-0012	0.066	0.068	0.062	0.065	0.097
Palisade - Water	08-077-0020	0.066	0.071	0.066	0.067	0.090
Lay Peak	08-081-0002	---	0.066	0.065	---	0.098
Cortez	08-083-0006	0.071	0.070	0.064	0.068	0.093
CASTNET - Gothic	08-051-9991	0.064	0.070	0.064	0.066	0.093
USFS - Walden	08-057-0003	---	0.059	0.064	---	---
USFS - Shamrock	08-067-1004	0.077	0.069	0.072	0.072	0.086
SUIT - Ignacio	08-067-7001	0.072	0.067	0.069	0.069	0.091
SUIT - Bondad/Hwy 550	08-067-7003	0.069	0.069	0.067	0.068	0.091
NPS - Colorado NM	08-077-0101	0.068	0.071	n/a	0.069	0.080
NPS - Mesa Verde NP	08-083-0101	0.070	0.069	0.069	0.069	0.089
Pitkin Co. - Aspen	08-097-0007	0.064	n/a	n/a	---	---
BLM - Meeker	08-103-0005	0.063	0.064	0.064	0.063	0.100
BLM - Rangely	08-103-0006	0.073	0.069	0.091	**0.077**	0.067

(USFS-Shamrock thru 7/31)

The Current 0.075 ppm Primary Standard



Colorado Ozone Sites

Comparison to Federal Ozone Standard (0.075 ppm)

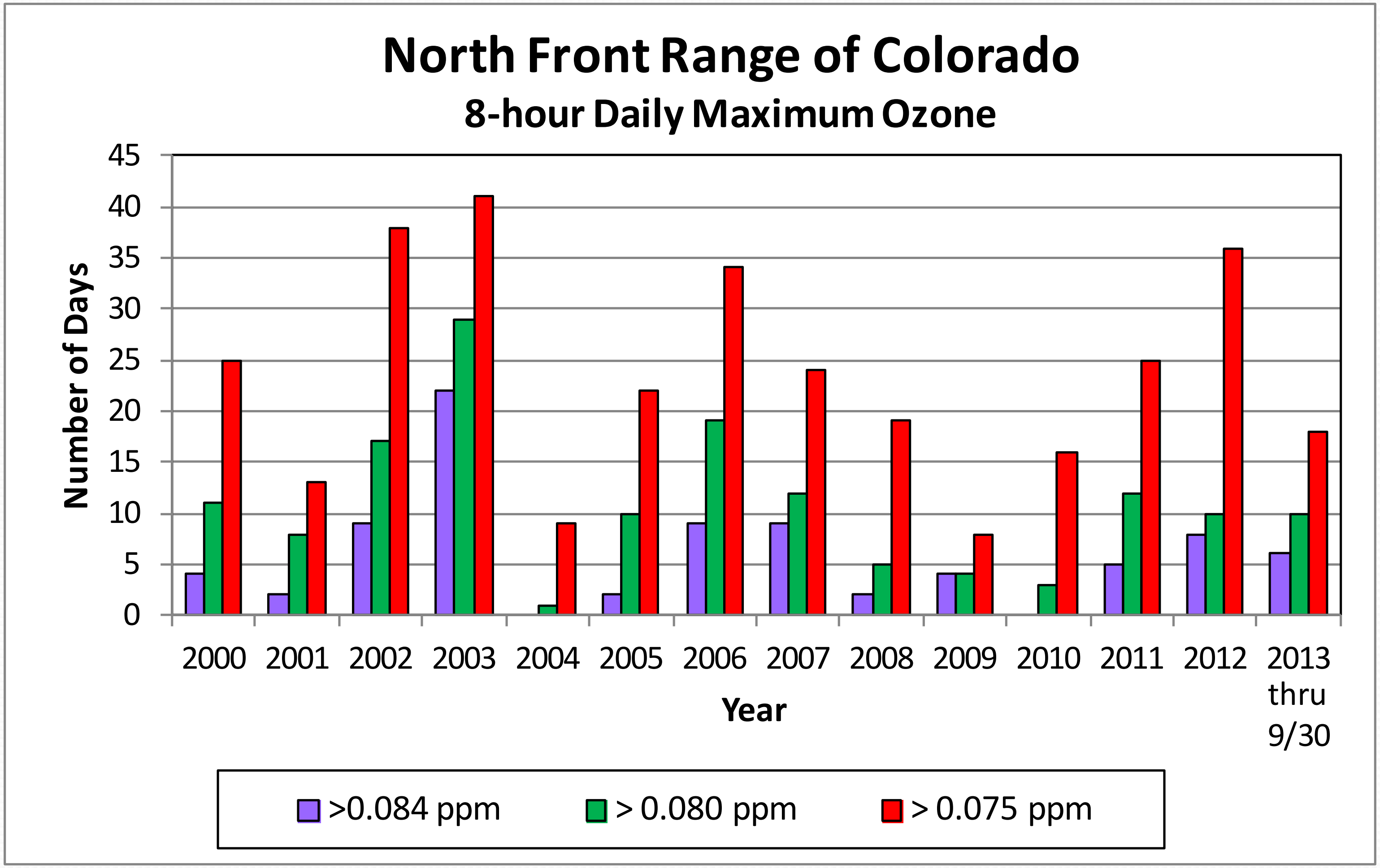
2011 - 2013

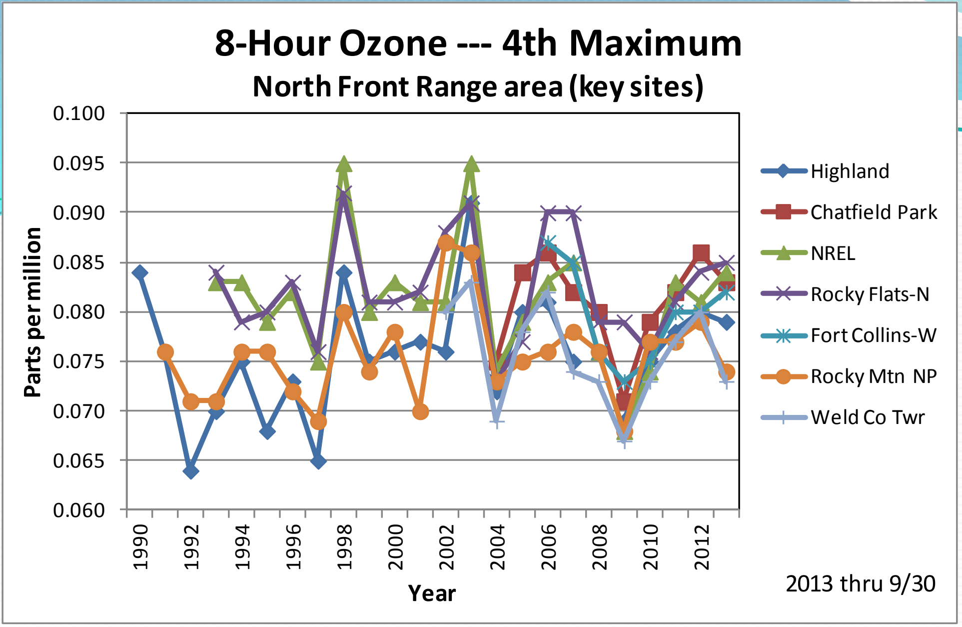
Ozone Standard:
3-year average of 4th maximum values must be <= 0.075 ppm

- Above level of standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Above level of standard (<3 years of data available) (Based on avg. of 4th max. for years available)
- Below level of standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Below level of standard (<3 years of data available) (Based on avg. of 4th max. for years available)

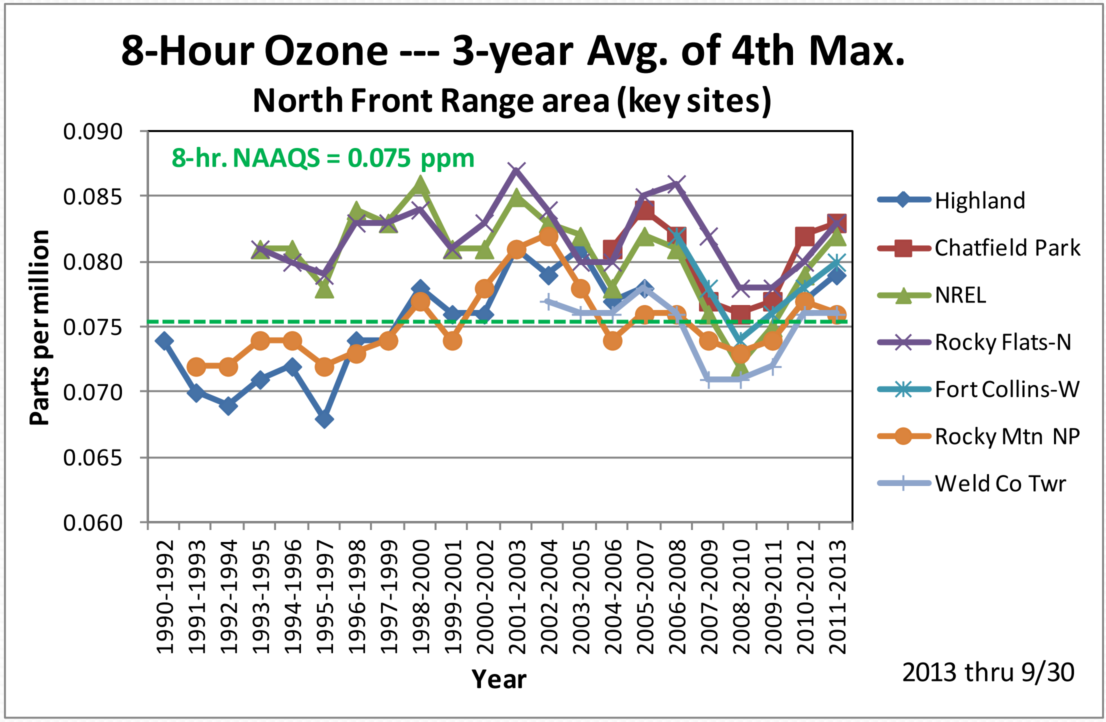
Denver/North Front Range Area

Number of days greater than 0.075 ppm 8-hour NAAQS levels (since 2000)



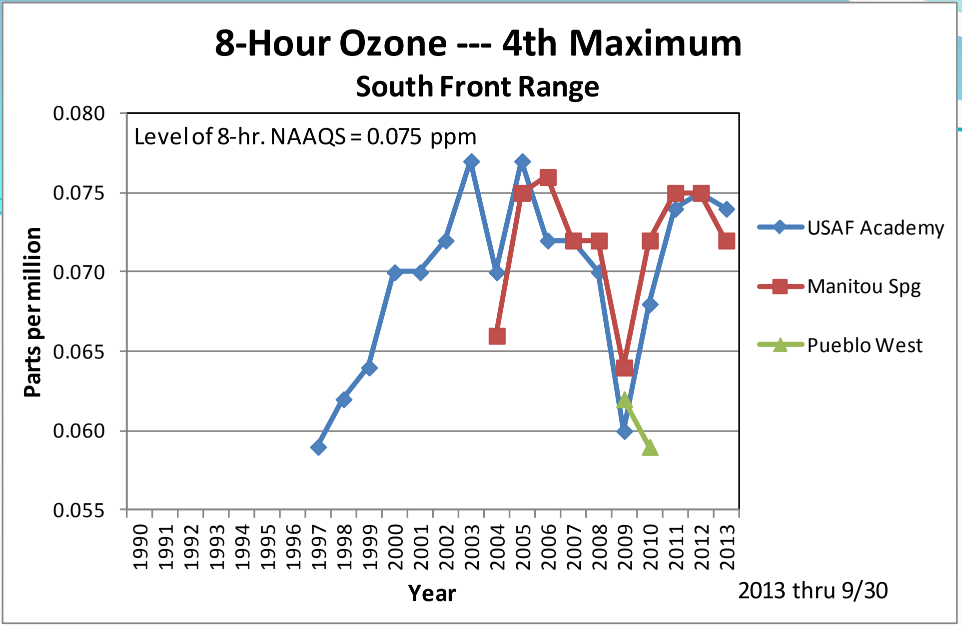


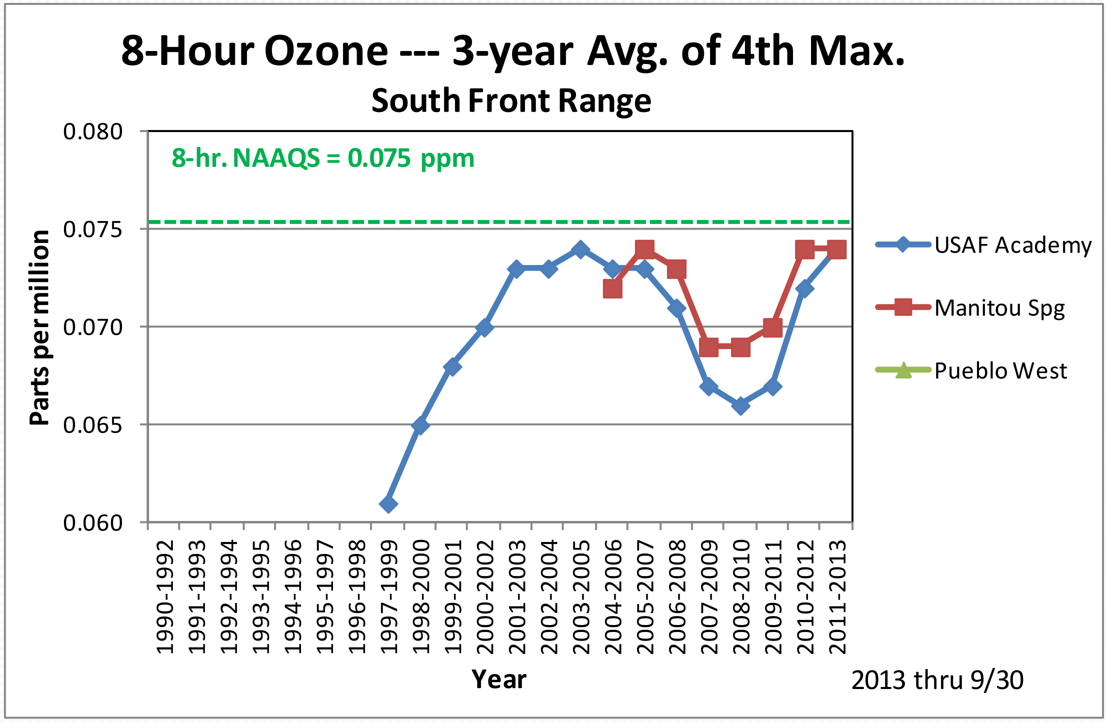
North Front Range
Ozone Trends



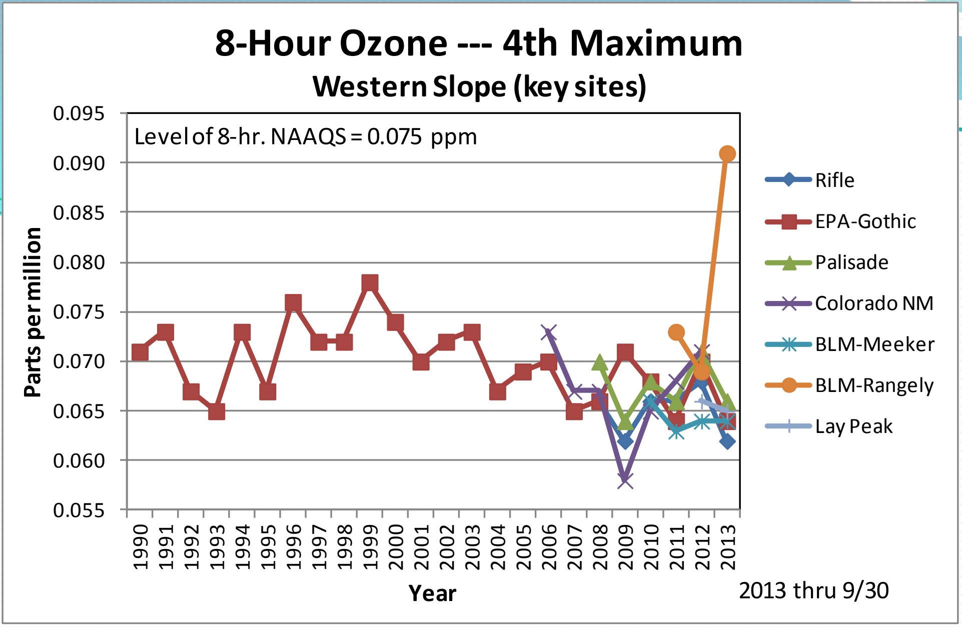
South Front Range

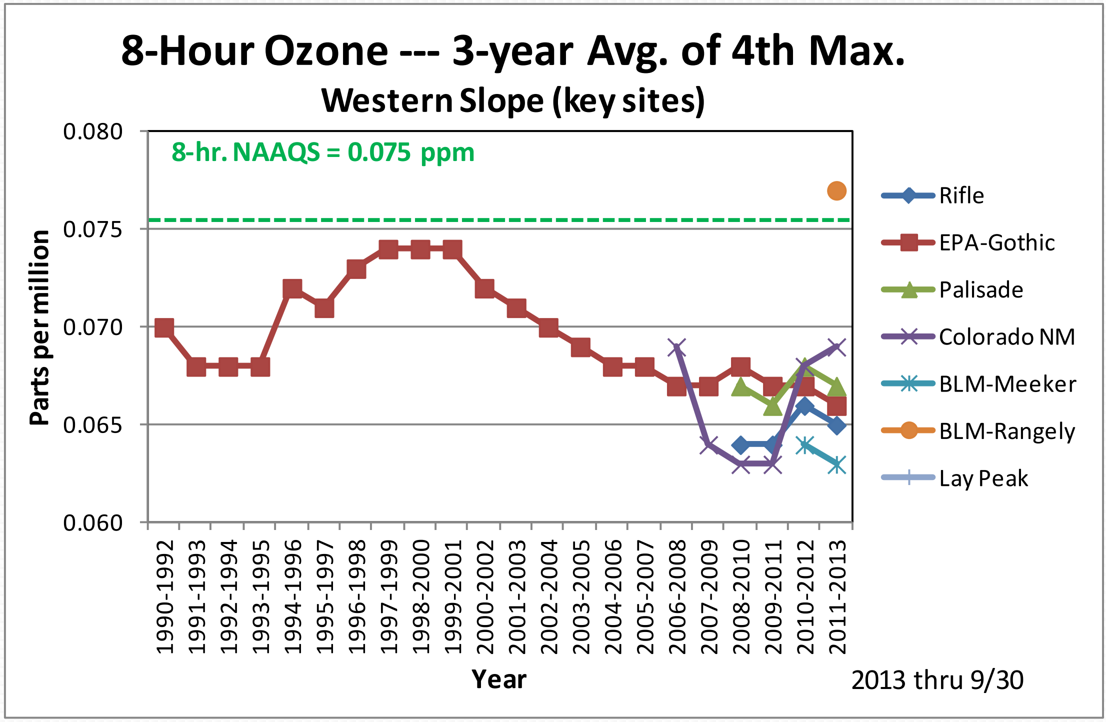
Ozone Trends



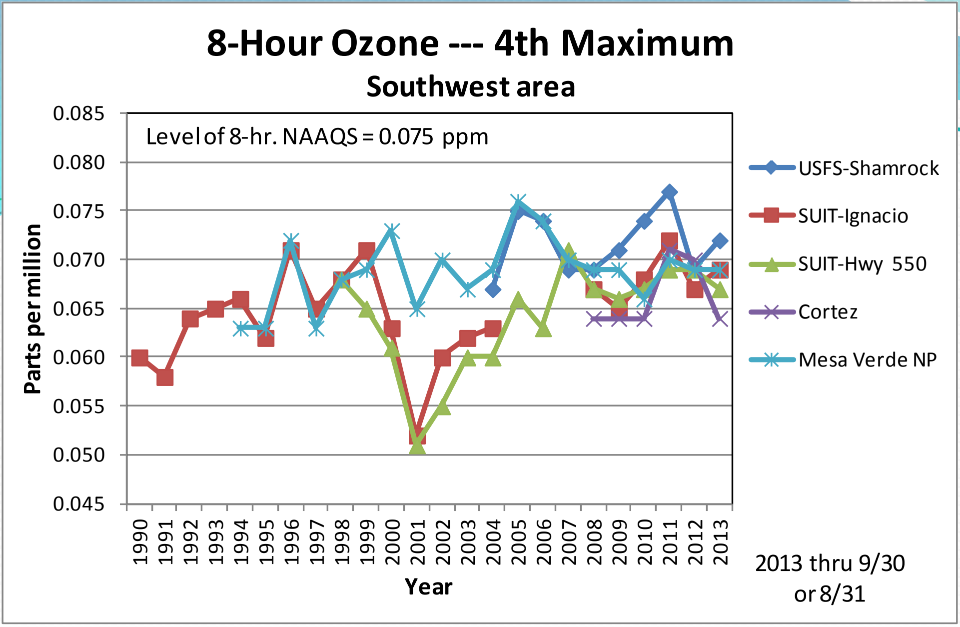


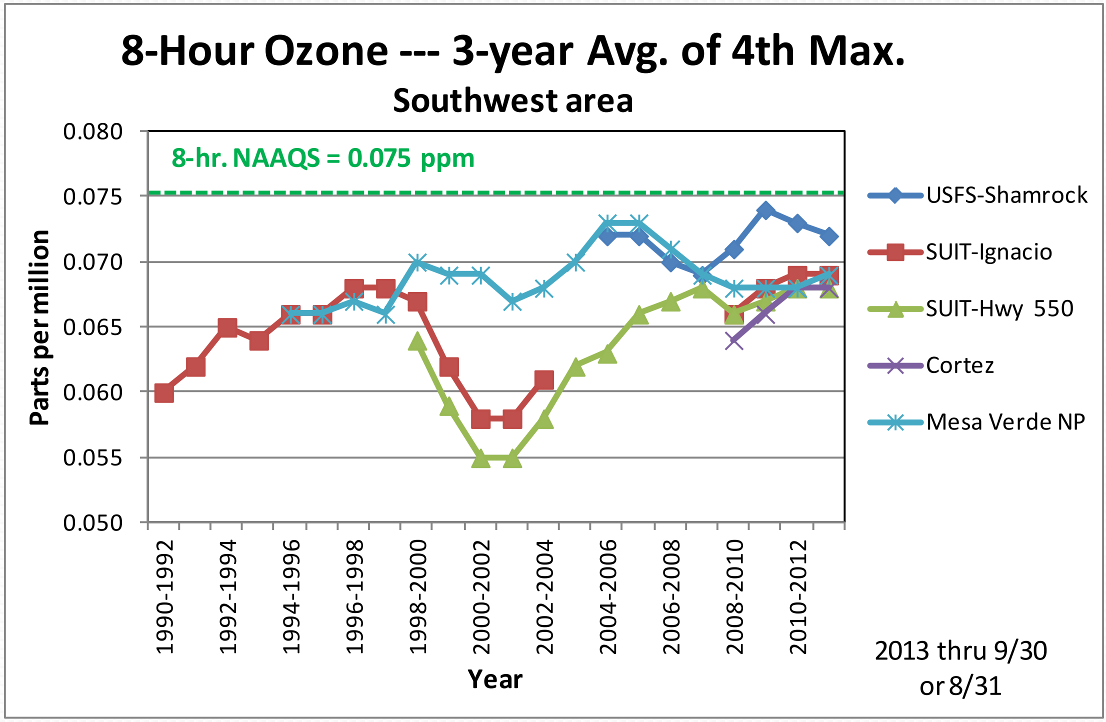
Western Slope Ozone Trends





Southwest Area
Ozone Trends





Conclusions

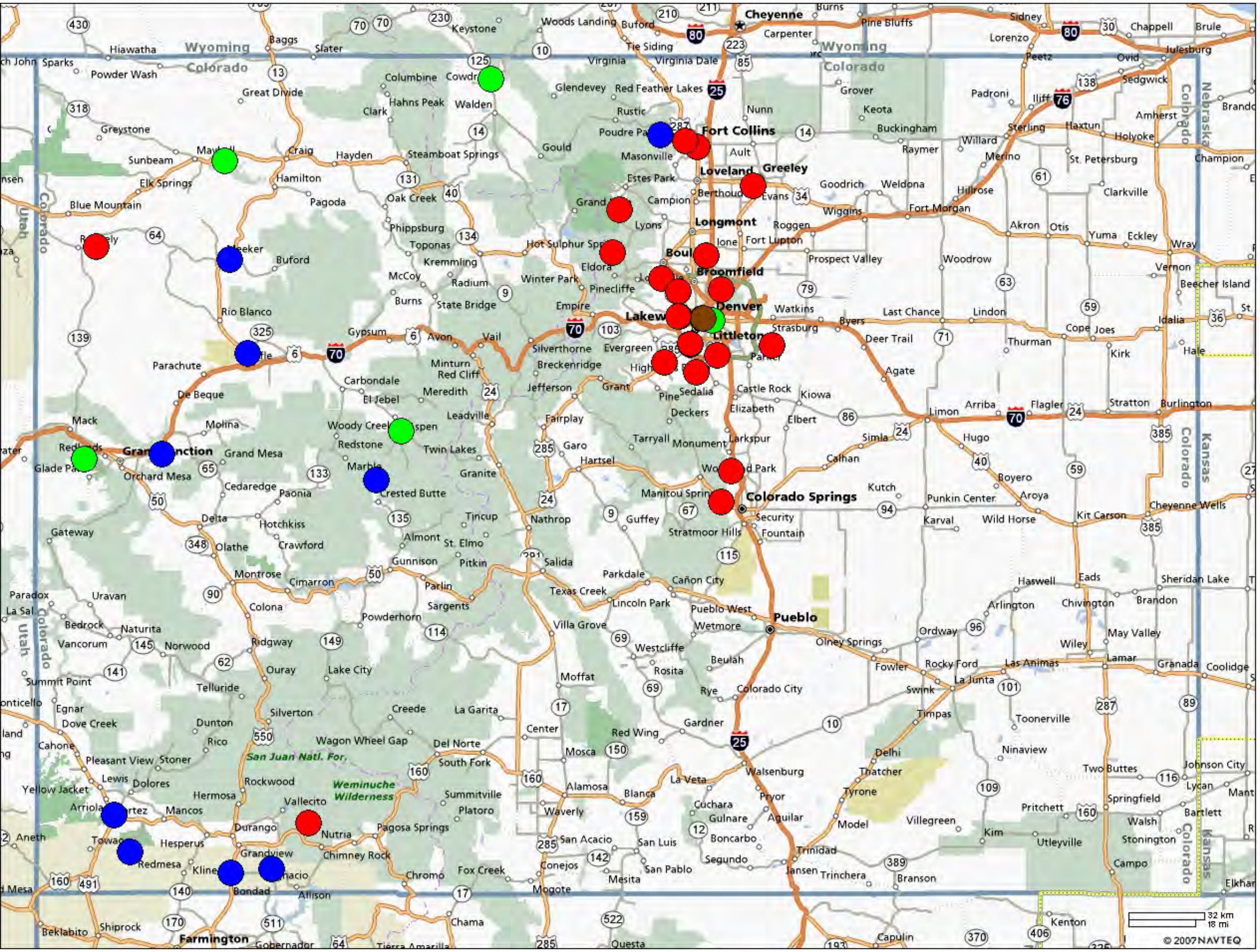
- Number of sites violating the 0.075 ppm NAAQS is up to 10
- All but one violating sites are still in the North Front Range existing non-attainment area
- Now a new violating site in Northwest Colorado (Rangely) due to wintertime ozone in the Uinta Basin
- Number of days over 0.075 ppm is less than in 2012, though the concentrations are similar
- 2013 – 2015 3-year period is important for compliance with the NAAQS

Future Ozone Standard

- EPA was planning on proposing a new ozone NAAQS by the end of 2013 and issuing a final NAAQS in Sep 2014
- Expectation is that a new standard is likely to be lower than current 0.075 ppm NAAQS as the previous EPA CASAC recommendation was "in the range of 0.060 to 0.070 ppm"

- On 6/19/2013, EPA issued a memo proposing to issue the 2nd drafts of the Risk and Exposure Assessment (REA) and Policy Assessment (PA) documents for CASAC and public review in early Dec 2013, with the next CASAC review panel meeting 3-months later in Mar 2014
- This delay would mean that the documents would likely not be finalized until sometime in the fall of 2014
- A NAAQS proposal would then likely not come out until spring of 2015, and a final rule not be issued until late 2015 or spring of 2016…about a 15 to 18-month delay from the original schedule
- Also on 6/19/2013, EarthJustice (including other environmental groups) filed a lawsuit to compel EPA to follow the original schedule

If future NAAQS set at 0.070 ppm…



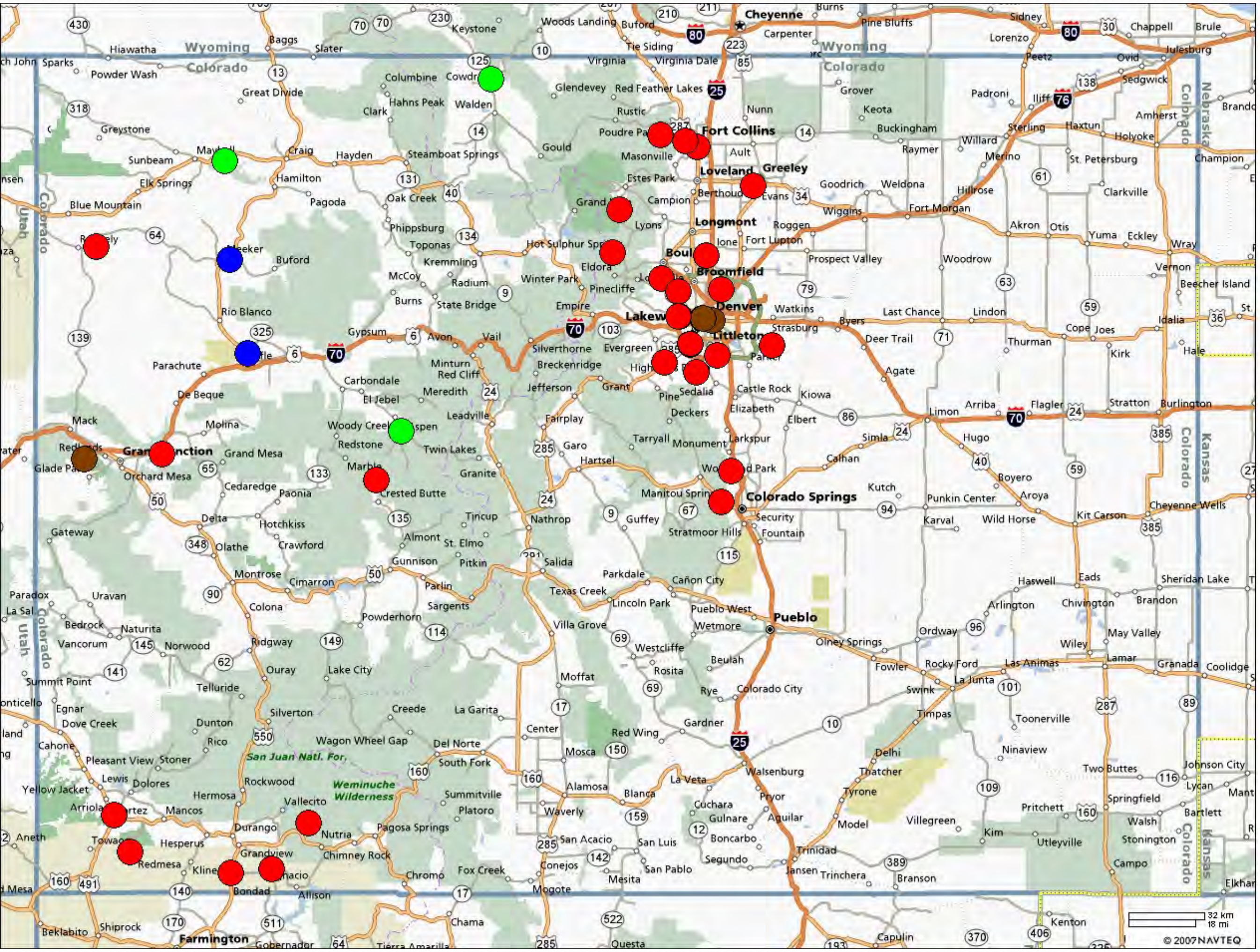
Colorado Ozone Sites

Comparison to **possible** 0.070 ppm Federal Ozone Standard

2011 - 2013

- Above level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Above level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)
- Below level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Below level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)

If future NAAQS set at 0.065 ppm…



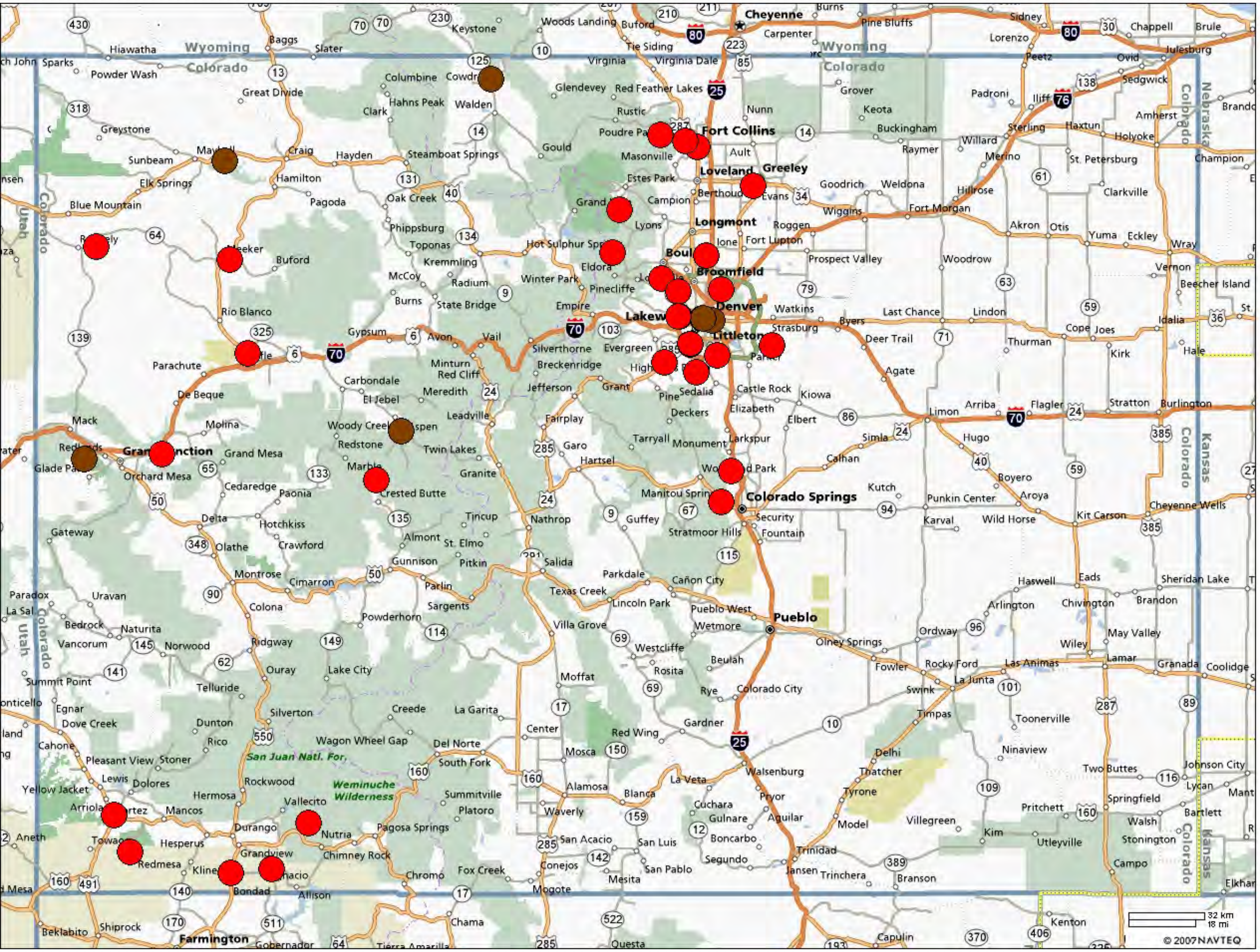
Colorado Ozone Sites

Comparison to possible 0.065 ppm Federal Ozone Standard

2011 - 2013

- Above level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Above level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)
- Below level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Below level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)

If future NAAQS set at 0.060 ppm…



Colorado Ozone Sites

Comparison to possible 0.060 ppm Federal Ozone Standard

2011 - 2013

- Above level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Above level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)
- Below level of possible standard (3+ years of data available) (Based on 3-yr. avg. of 4th max. for 2011 - 2013)
- Below level of possible standard (<3 years of data available) (Based on avg. of 4th max. for years available)

FRAPPÉ Update

- NCAR – FRAPPÉ (**F**ront **R**ange **A**ir **P**ollution and **P**hotochemistry **E**xperiment) study is going forward
- Goal is to characterize and understand summertime air quality in the Northern Front Range, in particular for ozone
- Will occur in conjunction with the NASA – DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality) mission
- Aircraft study period will occur July – August 2014
- CDPHE has received a supplemental budget amendment for $2 million to support FRAPPÉ through additional equipment
- Have received proposals to add aircraft and ground-based equipment, which will be reviewed and selections made in the next month

Questions?