Upper Green River Basin Air Quality Task Force
Joint Fact-Finding Document

DRAFT – May 21, 2012

— DO NOT QUOTE OR CITE —

Compiled by the
Ruckelshaus Institute of Environment and Natural Resources

Document Objectives

- Provide a common foundation of technical and scientific information from which the task force can base its recommendations.
- Promote understanding of the contributors and responses to high levels of ozone in the Upper Green River Basin.
- Clarify the regulatory context under which DEQ is operating.
- Highlight where there are gaps in knowledge or uncertainties.

HAUB SCHOOL &
RUCKELSHAUS INSTITUTE
OF ENVIRONMENT AND NATURAL RESOURCES
UNIVERSITY OF WYOMING

Table of Contents

Introduction 1

I. Wintertime Ground-Level Ozone 2

Ground-Level Ozone 2
Ozone Standard 3
Normal Winter Ozone Levels in the Upper Green River Basin (UGRB) 3
Current Winter Ozone Levels in the UGRB 2
Characteristics of High Ozone Events in the UGRB 4
Is the Ozone (or Are the Precursors) Coming from Outside the UGRB? 4

II. Contributors to Ozone Levels and Formation 8

Background Ozone 8
Meteorological Conditions 9
Snow cover 9
Sunlight 9
Wind 9
Inversions 9
Local Anthropogenic Precursor Emissions 10
Vehicles and community/residential emissions 10
Emissions from natural gas production, compression, and transmission 10

III. Responses to High Levels of Ozone 15

Monitoring 15
DEQ Monitoring 15
UW Atmospheric Science Air Quality Research Group Projects 18
Data quality assurance 19
Raw data vs. validated data 19
Measurements vs. modeling 19
Modeling 20
Forecasting of High Ozone Events 21
Health Implications of Ambient Ozone 21
UGRB health studies of air toxics and ozone 18
Regulatory Response 23
EPA Non-Attainment designation 23
Department of Environmental Quality (DEQ) 24
Bureau of Land Management (BLM) 26
Wyoming Oil and Gas Conservation Commission (WOGCC) 26
Present and Future Clean Air Act (CAA) Regulatory Environment of the O&G Industry 26
Emissions Reductions 28
Enacted measures 28

IV. Background on Oil and Gas Industy 30

Present Operations 30
Emissions Control Technologies 31
Economics 31

V. Ongoing Studies/Uncertainties 33

Sources 34
Appendix I: Oil and Gas VOC Emissions Control Options 35

Figures

Figure 1. Conceptual Diagram of the Contributors to Ozone Formation and Responses to High Levels of Ozone 1

Figure 2. Duration of Ozone Events 3

Figure 2a. Running 8-hour average ozone, Winter 2011.......... 3
Figure 2b. Running 8-hour ozone concentrations, Winter 2010 4
Figure 2c. Daily max 8-hour ozone concentrations, Winter 2009 4

Figure 3. Fluctuations in Ozone Concentrations During High-Ozone Days in the UGRB 5

Figure 3a. Average 1-hour concentration during Mar 9–Mar 21 5
Figure 3b. 1-hour ozone at UGWOS 2010 mesonet sites on March 2, 2010.......... 5
Figure 3c. 1-hour ozone on high ozone days (8hr > 75ppb) for northern mesonet sites.......... 6

Figure 4. February 2009 Isopleth Map Showing Distribution of Ozone in the UGRB 6

Figure 5. Oil and Gas Contributors to VOC Emissions in the UGRB. 13

Figure 6. Oil and Gas Contributors to NOx Emissions in the UGRB.......... 14

Figure 7. Emissions Comparison: Non-JPDA vs. JPDA 15

Figure 8. DEQ Monitoring Site Locations 16

Figure 9. Location of PASQUA 2011 VOC Canister Survey Sites.......... 19

Figure 10. Monitoring, Emissions Inventories, and Predictive Modeling all Inform Air Quality Management 20

Figure 11. Upper Green River Basin Non-Attainment Area 24

Tables

Table 1. Definitions of Oil and Gas Emissions Sources in Figures 5 and 6 14

Table 2. Ozone Health Risks 22

Table 3. Emissions Reduction Measures Implemented by UGRB Operators.......... 29

Table 4. Wells in Non-Attainment Area 30

Table 5. Emissions Control Technologies 31

Table 6. Oil and Gas Activity as a Fraction of the State's Economy 32

Introduction

Ozone (O_3) consists of three atoms of oxygen joined together to form a molecule. The chemistry of ozone formation has been extensively studied (Seinfeld and Pandis, 2006). The O_3 molecule occurs naturally. It is a highly reactive molecule that readily reacts with other molecules in the atmosphere or on surfaces. Ozone forms in the atmosphere as a result of a series of reactions involving nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ultraviolet (UV) radiation. The NO_x in the atmosphere includes both nitrogen oxide (NO) and nitrogen dioxide (NO_2). The VOCs include 1000s of individual hydrocarbons and oxygenated hydrocarbon species. VOCs are emitted by vegetation, industrial sources, and internal combustion engines. NO_x occurs naturally and also produced by internal combustion engines and high-temperature industrial processes.

The critical role of UV radiation in O_3 formation and degradation of O_3 concentration in the ambient (outdoor) air is typically exhibited in a strong diurnal pattern. The highest instantaneous O_3 concentrations are typically observed in mid-day and the lowest concentrations in the early morning. The average concentration over an hour or 8-hour period will lag the instantaneous O_3 concentration. The concentration of O_3 measured at any given monitor will relate to O_3 transported from upwind, O_3 precursors upwind, and O_3 precursors originating locally. The amount of UV available to drive O_3 formation will depend on the season of the year and cloud cover. The presence of continuous snow cover in late January to March effectively doubles the effectiveness of the incoming UV resulting in a net UV flux equal to or exceeding that found in June.

In studying the various factors that influence the occurrence of elevated levels of O_3 in the Upper Green River Basin (UGRB) and seeking to devise strategies to reduce their occurrence, it is important to recognize that the occurrence of days with elevated O_3 are quite rare. The wintertime high 8-hr average concentrations have typically been observed during a two-month period starting in late January. Since 2005, only one-half of the years—those with continuous snow cover—had a few days with 8-hr average concentrations in excess of 75 ppb and one-half of the years had no days with 8-hr average concentrations in excess of 75 parts per billion (ppb). This sporadic occurrence of high ozone days makes it difficult to plan and conduct detailed field studies to evaluate the role of the various factors that led to high ozone days. If the O_3 National Ambient Air Quality Standards (NAAQS) were set at 8-hr average concentrations below 75 ppb, the likelihood of the level being exceeded would increase. However, even an 8-hr average standard set as low as 60 ppb, approximating background, the level would only be occasionally exceeded.

The human health and environmental effects of ambient ozone have been extensively studied and reported in thousands of papers. This extensive literature has been periodically reviewed by the U.S. Environmental Protection Agency (EPA) as a part of the process of setting NAAQS for ozone (EPA 2011).

The Clean Air Act (CAA) is the principal statute regulating air quality in the United States. Key amendments to the CAA in 1970 provide for the listing of air pollutants that impact human health and welfare, are found across the U.S., and arise from multiple sources as criteria air pollutants. The criteria air pollutants include carbon monoxide, nitrogen oxides, sulfur oxides, particulate matter, and photochemical oxidants regulated as O_3. For each of the criteria pollutants, the U.S. Environmental Protection Agency must set and periodically review (and potentially revise) the NAAQS to protect public health and welfare. Each NAAQS consists of four elements: (a) an indictor, such as O_3 for photochemical oxidants, (b) an averaging time (8-hr for ozone), (c) a numerical level (currently 75 ppb for ozone), and (d) a statistical form to determine attainment of the NAAQS. The current O_3 health standard is attained when the fourth highest 8-hour average concentration, averaged over three consecutive years, does not exceed 75 ppb.

I. Wintertime Ground-Level Ozone

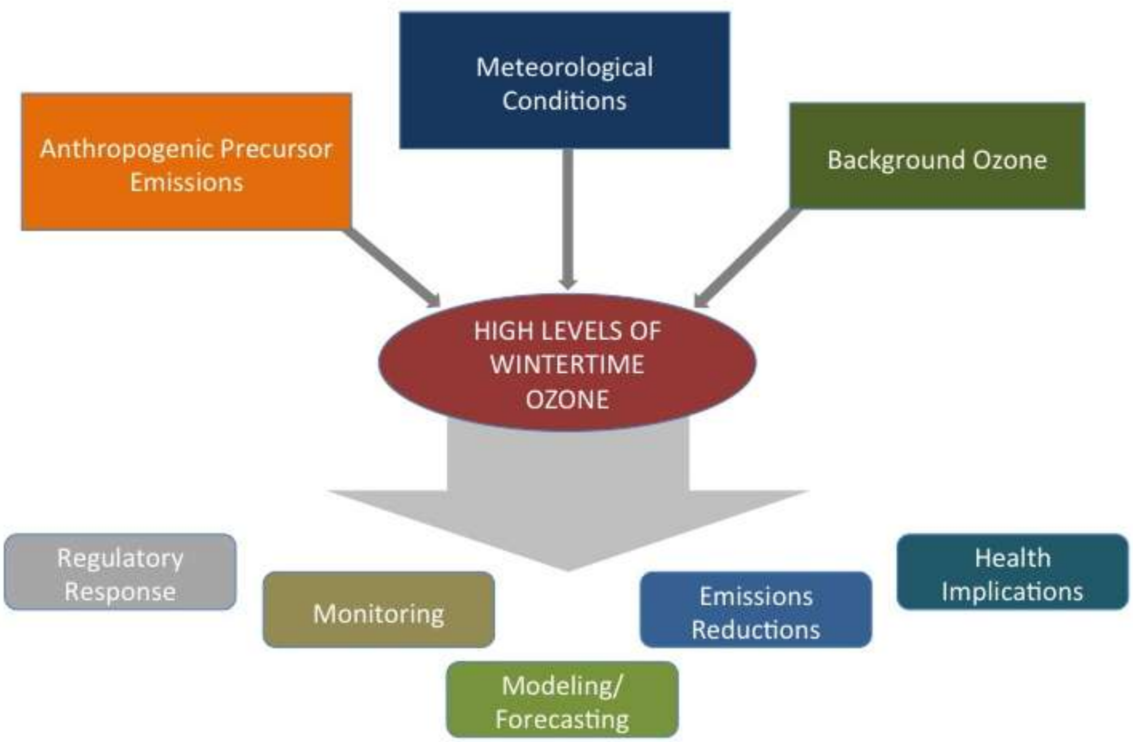


Figure 1. Conceptual Diagram of the Contributors to Ozone Formation and Responses to High Levels of Ozone.

Ground-Level Ozone

- Ground-level ozone (O_3) is a "secondary pollutant," in that it is not directly emitted through natural or industrial sources but forms through complex chemical reactions between precursor emissions, nitrogen oxides (NOx) and volatile organic compounds (VOCs), when sunlight is present (EPA n.d.(a)).
- Ozone formation occurs via a series of complex, nonlinear photochemical reactions and is highly sensitive to meteorological conditions (Seinfeld and Pandas 2006; Stoeckenius and Ma 2010).
- High levels of ozone are traditionally associated with warm summer months when abundant solar radiation and high temperatures result in ozone formation near ground level (Stoeckenius and Ma 2010).

- Elevated ozone levels in the Upper Green River Basin are the first to be detected in the wintertime (Stoeckenius and Ma 2010); elevated wintertime ozone levels have now also been measured in Utah's Uinta Basin.

Ozone Standard

- The Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for photochemical oxidants (ozone) and five other criteria pollutants that are considered harmful to public health and the environment and are widely distributed in ambient (outdoor) air and arise directly or indirectly from multiple sources.
  - The Clean Air Act specifies that both primary (health-based) and secondary (welfare-based) NAAQS shall be set.
  - McClellan (2011) describes the process by which NAAQS are set, including the history of the ozone standard.
  - Each NAAQS consists of four elements: (a) an indictor (for photochemical oxidants, it is ozone), (b) an averaging time (for ozone, it is currently 8 hours), (c) a numerical concentration (for ozone, it is currently 75 ppb), and (d) a statistical form relating to attainment.
  - For ozone, the primary health-based NAAQS is attained when the fourth highest 8-hour average concentration during a year does not exceed 75 ppb (sometimes stated as 0.075 ppm), averaged over consecutive three years.
  - EPA revised the primary standard for ozone in 2008 (to 75 ppb) and announced that the revised standard would be implemented in September 2011.

Normal Winter Ozone Levels in the Upper Green River Basin (UGRB)

- Daily maximum 8-hour averages in the Green River Basin have historically fluctuated around 50 ppb in January–March from 1989–2008, which is similar to other high-elevation sites in the Intermountain West (EPA 2006).
  - Zhang et al. (2011) provide an excellent discussion of modeled concentrations of policy-relevant background in the United States using a 1/2° x 2/3° horizontal resolution — they note background levels of ozone in the absence of any local emissions of ozone precursors are expected to approach 60 ppb (highest 8-hr average).
- Prior to 2005, there was no ozone monitoring in the UGRB except for one long-term Clean Air Status and Trends (CASTNET) site located north of Pinedale, which has operated since 1989 (most ozone monitors across the USA are located in urban areas with very few permanently located in rural areas).
  - DEQ began monitoring in 2005 to understand air quality concentrations in an area where oil and gas development was expected to occur.
- An ozone level of 50 ppb is similar to other rural intermountain western monitoring sites, which vary from the low 40s to the low 50s ppb for average winter (January–March) ozone concentrations (Stoeckenius and Ma 2010).

Current Winter Ozone Levels in the UGRB

- The Wyoming Department of Environmental Quality (DEQ) monitoring stations have recorded ozone concentrations above the 75 ppb daily 8-hour average during late winter

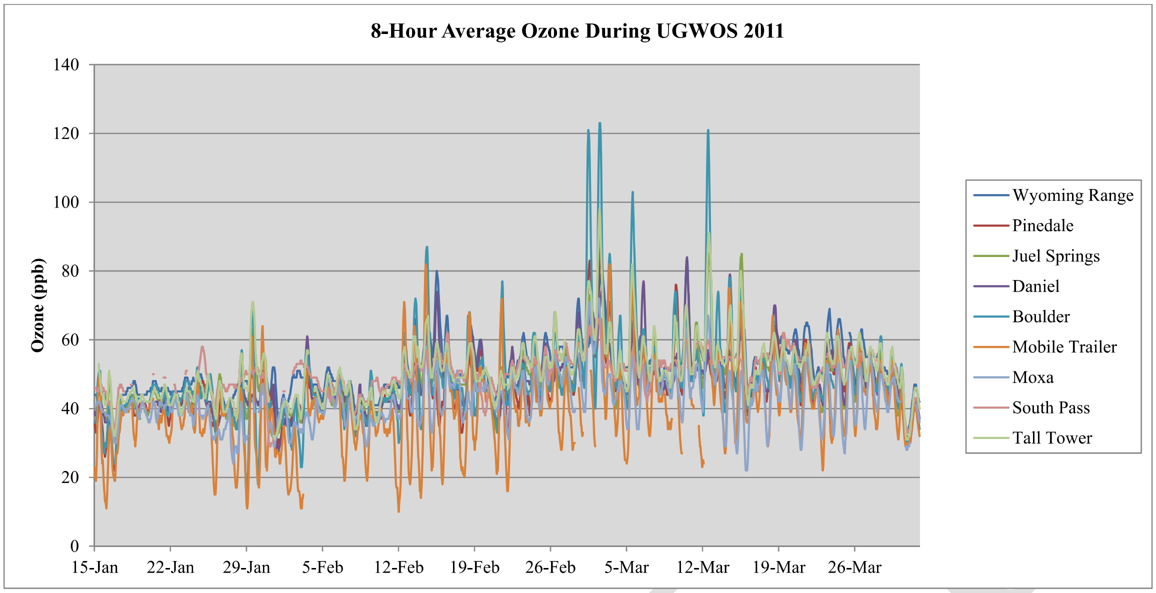
and early spring (February–April) in 2005, 2006, 2008, and 2011 (Stoeckenius and Ma 2010; Meteorological Solutions et al. 2011).
    - There were no ozone concentrations recorded above the 75 ppb 8-hour average recorded in 2007, 2009, 2010, and 2012, possibly because meteorological conditions were not conducive to ozone formation (primarily due to lack of snow cover; DEQ 2009; Meteorological Solutions et al. 2010a).

Characteristics of High Ozone Events in the UGRB

- High ozone events are usually observed in late January–March and for relatively short periods of 1–4 days (Figures 2a, b, c).
    - During the April–August period, moderately elevated 8-hr ozone averages (60–75 ppb) are not uncommon in UGRB, and 8-hr average ozone concentrations exceeded 80 ppb on April 21 and June 18, 2006 (the 8-hr ozone standard was 80 ppm prior to 2008; EPA n.d.(c)).
- Ozone concentrations are non-uniform across the UGRB and fluctuate both throughout the day and among monitoring sites (Figure 4; Soltis and Field 2011b; UW Air Quality Research Group 2009).
    - Generally there is a peak in ozone in the late afternoon (this is characteristic of most places with high levels of ozone, not just the UGRB; Figures 3a, b, c).

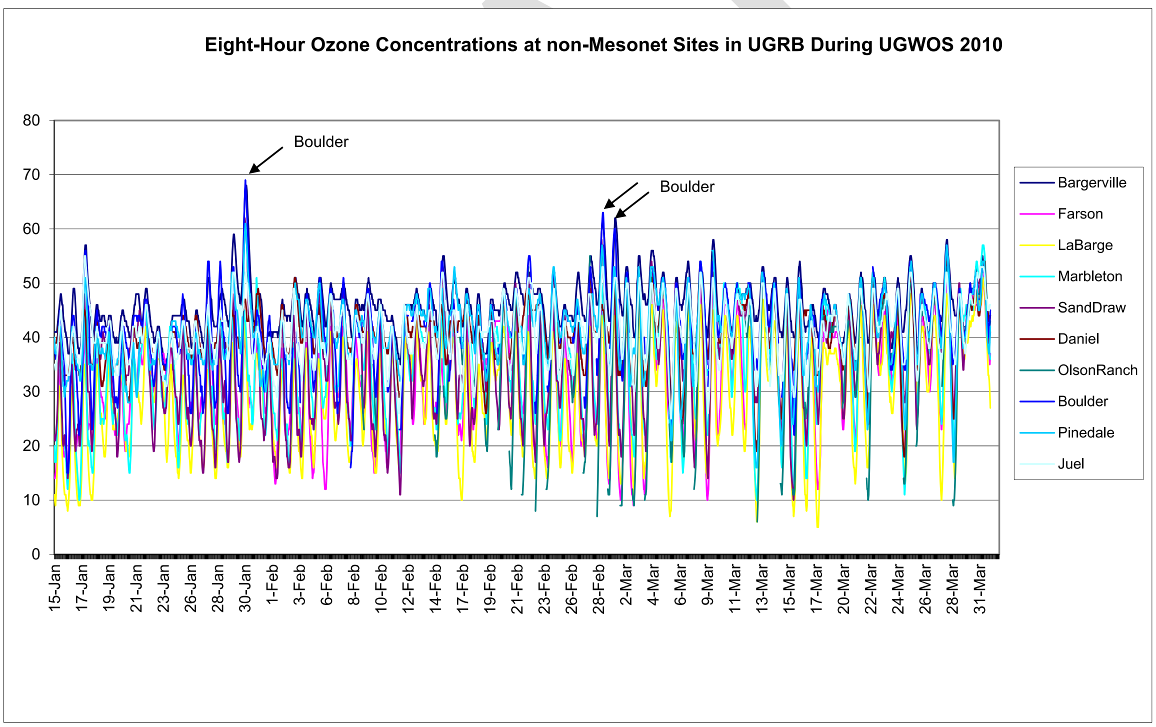
Is the Ozone (or are the Precursors) Coming From Outside the UGRB?

- Regional transport is not adding to ozone pollution in the UGRB – this is supported by a number of facts:
    - There has been no significant ozone increase at other monitoring sites outside of the UGRB (Stoeckenius and Ma 2010).
        - Winter ozone trends from 1998–2008 for the greater region are generally flat for both 1-hour and 8-hour trends (Stoeckenius and Ma 2010).
    - High wintertime ozone events are associated with continuous snow cover, inversions and very low wind speeds; therefore, little air is being transported into the area from outside locations (Stoeckenius and Ma 2010).
    - Speciated VOC data collected (that shows compounds of VOC emissions) in the UGRB during elevated ozone episodes has a dominant oil and gas signature, meaning it can be traced to emissions oil and gas development activities (Soltis and Field 2011b).



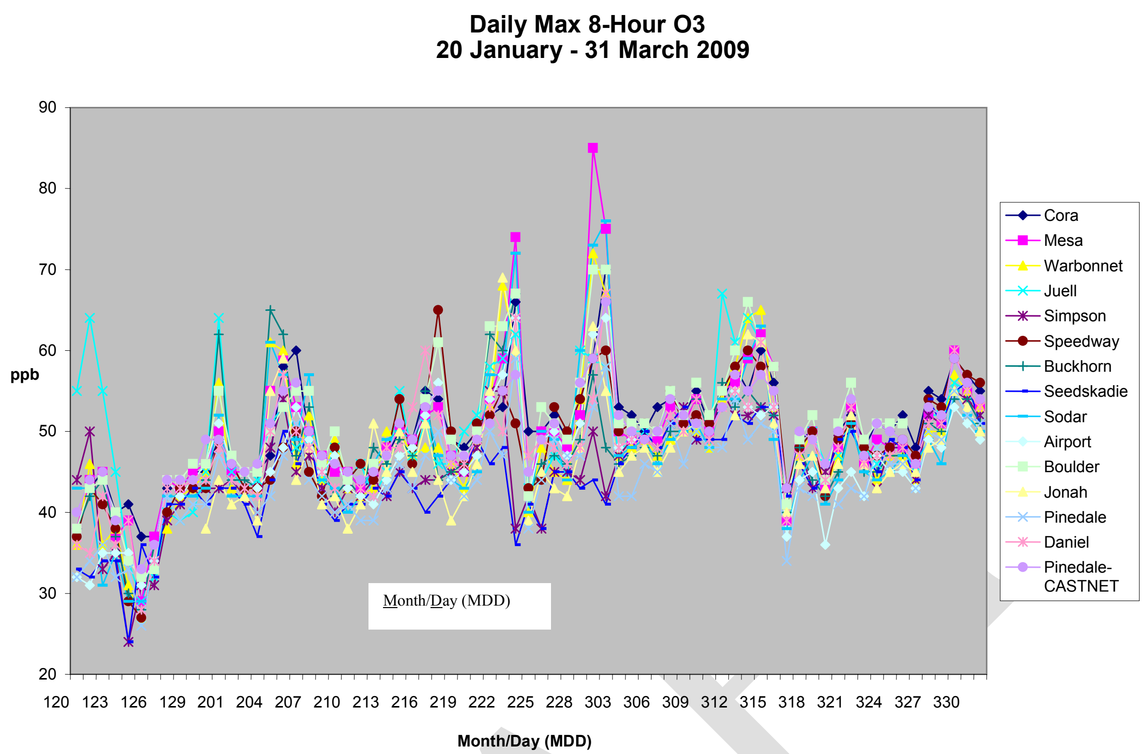
Source: Meteorological Solutions et al. 2011

Figure 2a. Running 8-hour average ozone, Winter 2011. Elevated ozone episodes generally last one to four days and occur in Jan–Mar.



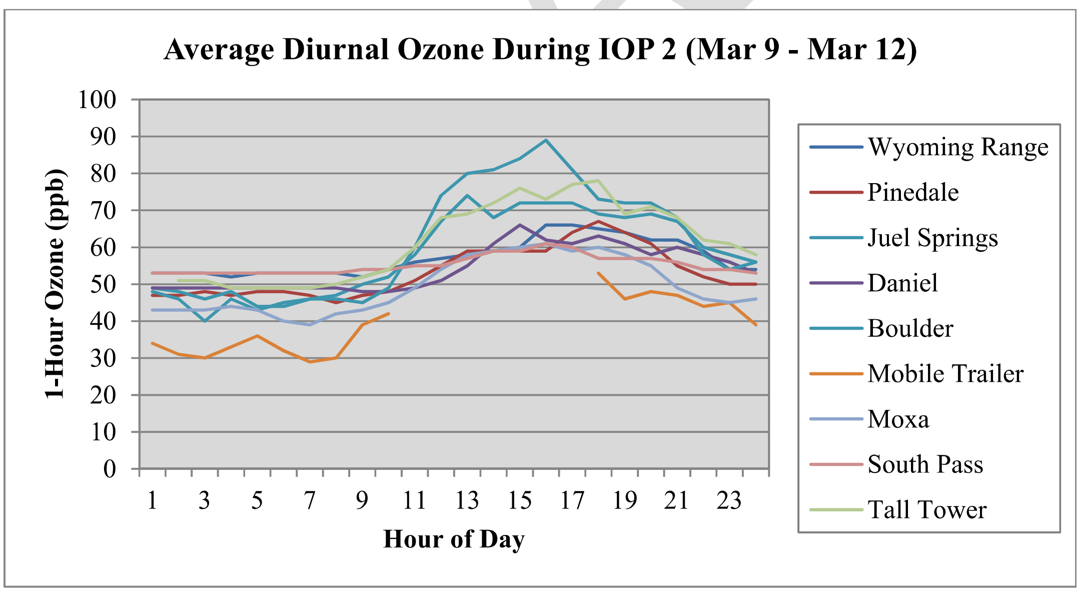
Source: Meteorological Solutions et al. 2010a

Figure 2b. Running 8-hour ozone concentrations, Winter 2010.



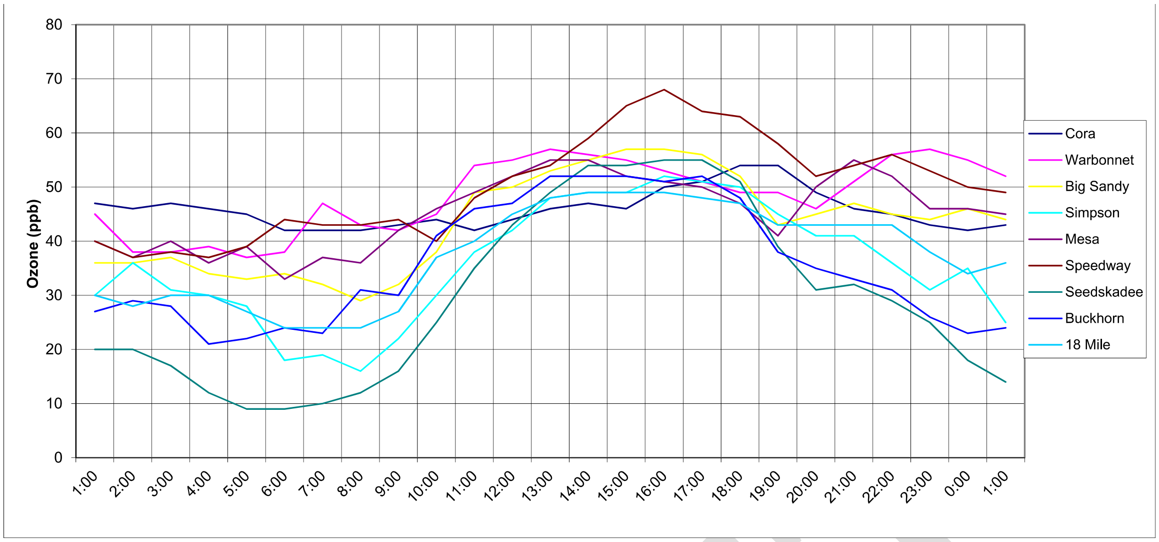
Source: Meteorological Solutions et al. 2010b

Figure 2c. Daily max 8-hour ozone concentrations, Winter 2009.



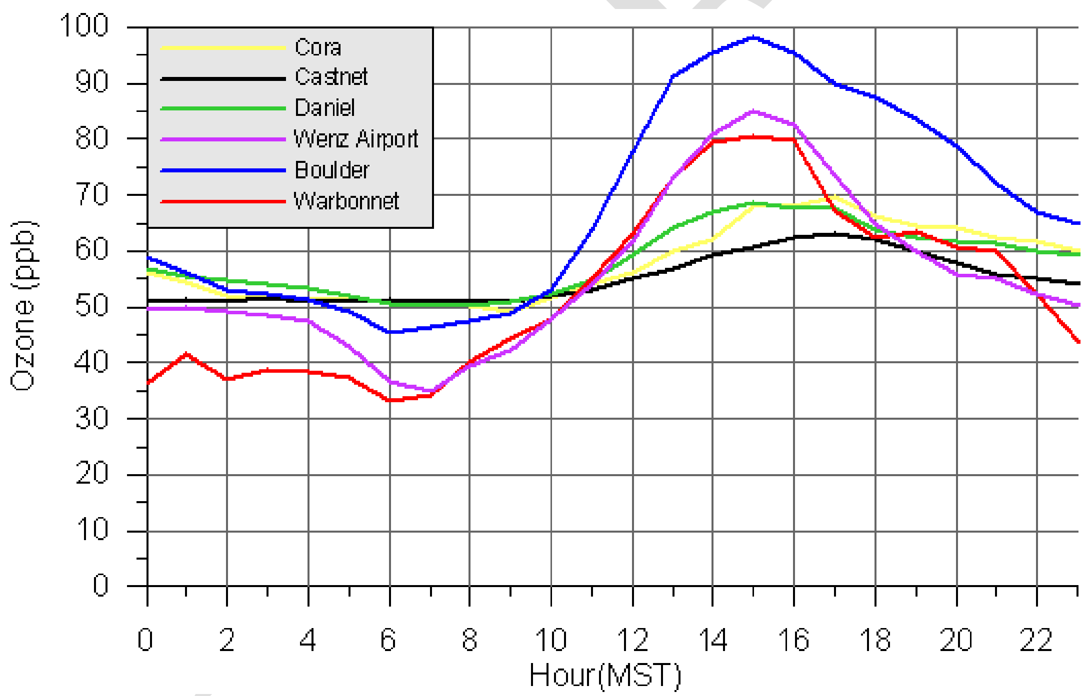
Source: Meteorological Solutions et al. 2011

Figure 3a. Fluctuations in Ozone Concentrations During High-Ozone Days in the UGRB – Average 1-hour diurnal ozone concentration during Mar 9–Mar 21, 2011 (in ppb): Ozone concentrations generally start to increase around 10 am and peak in the late afternoon, around 3 or 4 pm.



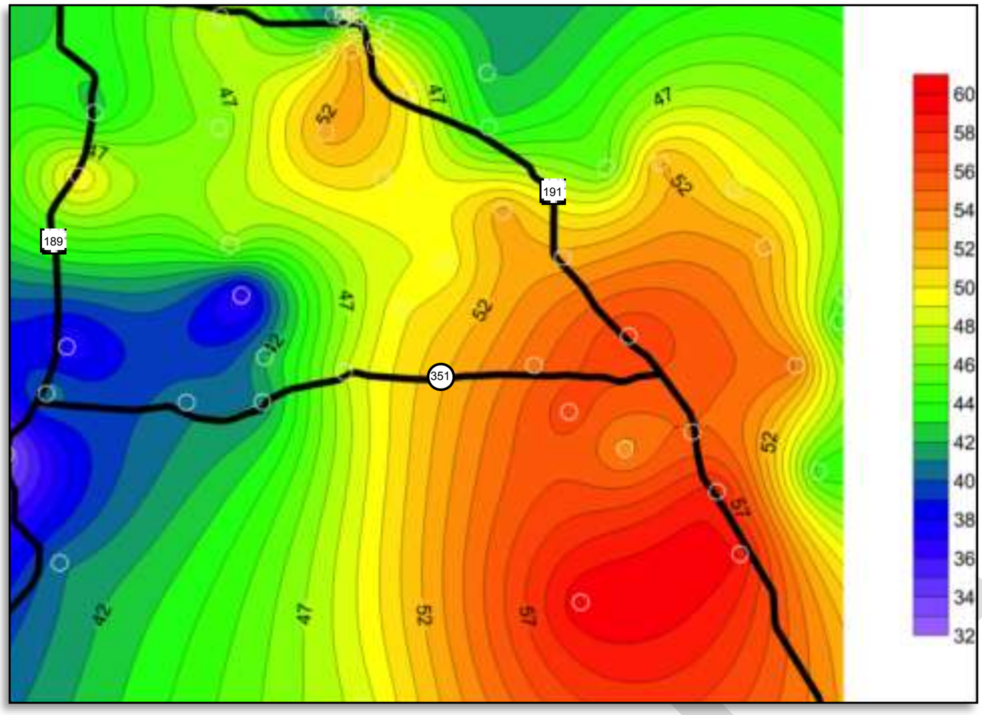
Source: Meteorological Solutions et al. 2010a

Figure 3b. 1-Hour Ozone at UGWOS 2010 mesonet Sites on March 1, 2010. Note: "Mesonet" refers to the collection of automated meteorological monitoring stations.



Source: Meteorological Solutions et al. 2008

Figure 3c. 1-Hour Ozone at on high ozone days (8 hr > 75 ppb) for northern mesonet sites.



Source: UW Air Quality Research Group 2009

Figure 4. February 22, 2009, Isopleth Map Showing Distribution of Ozone in the UGRB 9:00 am–5:00 pm: Ozone distribution throughout the valley is not uniform (scale in ppb).

II. Contributors to Ozone Levels and Formation

Background Ozone

- Background ozone, or ozone that would occur in absence of local anthropogenic emissions sources, comes from:
  - Natural precursor sources, such as emissions of VOCs from plants and soils, emissions of NOx and ozone from lightning, and emissions of VOCs and NOx from wildfires;
  - Long-range transport of ozone from far-off anthropogenic emissions sources; and
  - Stratospheric ozone vertically transported to the surface (Stoeckenius and Ma 2010).
- Multiple studies have shown background ozone levels are relatively high during the spring at high-elevation sites in the western U.S. and can be in the 55–65 ppb range (Stoeckenius and Ma 2010).
  - Therefore, as little as 10–20 ppb additional local ozone production is sufficient to exceed the ozone ambient air quality standard of 75 ppb (Stoeckenius and Ma 2010).
- The lack of any significant ozone increase at other rural intermountain western U.S. monitoring locations over the past 11 years suggests that the high winter ozone events in the UGRB are not the result of any regional or super-regional increases in ozone levels (Stoeckenius and Ma 2010).

- Ozone is not being monitored in very many rural inter-mountain western areas; the density (number of monitors/m^2), in Sublette County is one of the highest density of monitors in a rural area in the West or the U.S.

Meteorological Conditions

- Meteorology is thought to be the decisive factor in the development of ozone episodes (Meteorological Solutions et al. 2011).
- The surrounding significant terrain features in the Green River Basin, including mountain ranges, effectively create a bowl-like basin in its northern portion, which greatly influences localized meteorological and climatological patterns (DEQ 2009).
- A combination of snow cover, low wind speeds, sunlight, and temperature inversions lead to conditions favorable to the formation of localized elevated ozone events.
- The most critical element is continuous snow cover that effectively doubles the net UV radiation flux.

<u>Snow cover</u>

- Snow cover significantly enhances the amount of UV radiation reflected off the earth's surface (albedo) and thus the total UV flux available to drive atmospheric photochemical reaction; the amount of fresh snow and how widespread snow cover is in particular effect surface albedo (Stoeckenius and Ma 2010; DEQ 2009; DEQ 2011b).
  - The boost in UV radiation from snow cover can create levels comparable to those occurring in mid-summer (Stoeckenius and Ma 2010).
- Snow cover also enhances low-level air stability (lack of convection or movement of air) in the lowest atmospheric layers and allows the stable layers to persist near the surface much longer during the day (Stoeckenius and Ma 2010).
- Snow also facilitates greater transport of emissions due to reduced deposition and reaction rates.

<u>Sunlight</u>

- Enhanced ozone formation rates require UV radiation and therefore clear or mostly clear skies (Stoeckenius and Ma 2010).
- Ozone concentrations in excess of 70 ppb in the UGRB occur only when the solar radiation deviates from the clear sky maximum by less than ~35%, indicating that light cloud cover (typically cirrus clouds) allows sufficient UV radiation to penetrate the surface for ozone formation (Carter and Sienfeld 2012).

<u>Wind</u>

- High ozone events in the UGRB are most notably associated with low surface wind speeds (< ~3 meters/second [m/s]; Stoeckenius and Ma 2010).
- Morning winds in the UGRB are predominantly NW, but speeds are low on high ozone days; afternoon winds remain NW and increase in speed on low ozone days, but are much lighter and more frequently from the SE on high ozone days (Stoeckenius and Ma 2010; Soltis and Field 2011a).

<u>Inversions</u>

- In mountain-valley areas such as the UGRB, during the night cold air accelerates down the valley sides (downslope winds), while during the day warmer air flows up the valley sides (upslope winds); at night, this can create a cold pool of air within the UGRB that stratifies the atmosphere (inhibits mixing) since colder, denser air exists at the surface with warmer air above (DEQ 2009).

- High ozone episodes in the UGRB are associated with strong near surface temperature inversions that limit vertical mixing of pollutants and maximize ozone concentrations at ground level.

Local Anthropogenic Precursor Emissions

- Human-based (sometimes referred to as anthropogenic) ozone precursor emissions sources in the UGRB include:
    - Vehicles
    - Municipal/residential emissions
    - Emissions from oil and gas production activities (e.g., drill rigs, well completion activities, gas production – compression – transmission; DEQ 2009)
- Speciated VOC data collected (that shows compounds of VOC emissions) in the UGRB during elevated ozone episodes have a dominant oil and gas signature, indicating the VOC concentrations are largely due to oil and gas development activities (DEQ 2009; Soltis and Field 2011b).
- Within species that are VOC, the reactivity or ability of each to contribute to ozone formation varies.
    - A computer model can be run with a given set of VOC species and environmental conditions to predict the contribution to ozone formation of individual VOC species using reactivity factors (Carter Factor, MIR scale) and available quantity to actually react with NOx and nitrous acid (Carter and Seinfeld, 2012).
- Carter and Seinfeld (2012) carried out a comprehensive evaluation of ozone formation in the UGRB—one of the goals of their work was to assess, based on data available during wintertime ozone episodes, which of VOC or NO_x is limiting in ozone formation.
    - The episodes evaluated indicated that conditions could arise in which either reactant is limiting.
    - Data analysis during further episodes will be important in determining unambiguously which reactant exerts more of a controlling effect on ozone formation.
    - In the meantime, the current strategy that is being pursued involves reductions in emissions of both precursors.

<u>Vehicles and municipal/residential emissions</u>

- On-road mobile sources are estimated to contribute 7% of NOx and 0.3% of VOC emissions in the UGRB (DEQ 2009).
- The average population density in Sublette County is 2 people/square mile; therefore, other residential sources of precursor emissions are not enough to significantly contribute to ozone levels (DEQ 2009).

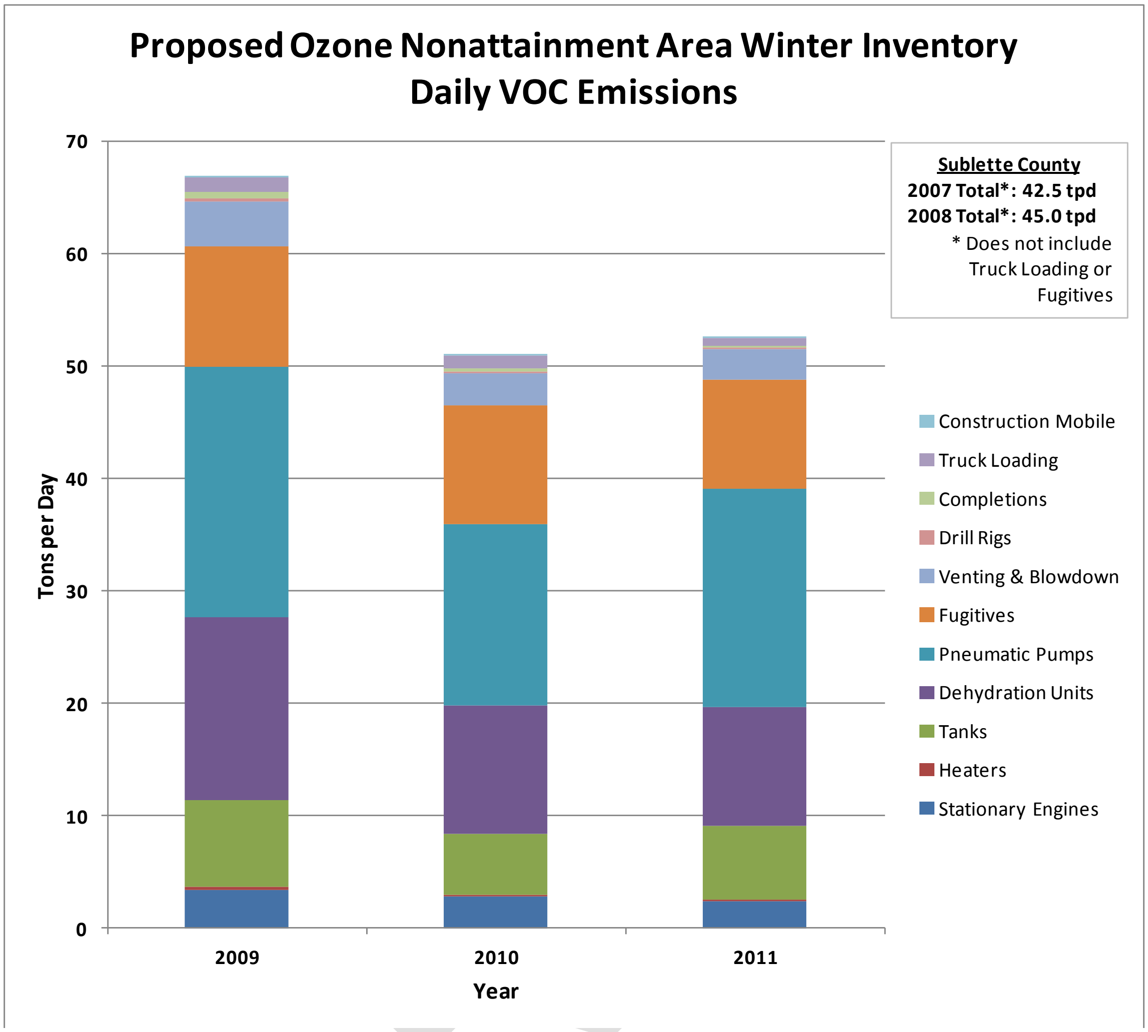
<u>Emissions from natural gas production, compression, and transmission</u>

- Natural gas production activities have grown rapidly in the UGRB, and the number of wells completed doubled between 2004 and 2008 (DEQ 2009): as of 2012, there are approximately 6,000 producing oil and gas wells and 8 Major Sources (all compressor stations) operating in UGRB.

    - Over the next 14 years, future gas development in the area, which includes the Jonah (500), PAPA (2,980), Normally Pressured Lance (NPL; 3,500), and LaBarge (840) fields is projected to include 7,820 additional wells (BLM, pers. comm.).
- Emissions inventories show that ~94% of VOC emissions and 60% of NOx emissions in the UGRB were attributable to oil and gas production and development (DEQ 2009).
    - DEQ has been collecting emissions inventories form oil and gas operations located in the Jonah and Pinedale fields within Sublette County since 2004.
    - Emissions inventories list, by source, the estimated amount of air pollutants discharged into the atmosphere at a given location during a given time period.
        - They are used to help determine sources of air pollutants, establish emission trends over time, target regulatory actions, and provide input data for models.
- How DEQ emissions inventories are derived:
    - WDEQ Air Quality Division has a description of their methodology and inventories on their website. http://deq.state.wy.us/aqd/ei.asp.
    - Inventories include 1) stationary engines, 2) heaters, 3) tanks, 4) dehydrators, 5) pneumatic pumps, 6) pneumatic controllers, 7) fugitives, 8) venting-blowdown, 9) other sources, 10) on-road mobile, and 11) non-road mobile sources. Emissions associated with completions, drill rigs, and production vs. compressor station stationary engines are also broken out based on operator.
    - Inventories are developed based on a set of rules and make use of calculations based on either actual operational parameters (i.e., engine run times) or an emissions factor which is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Such factors facilitate emissions estimates from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).
    - Over time, new information used in estimating emissions may result in changes to the emissions inventory in the absence of any actual change in the emissions. As a result, the basis of the total inventory will change and all data associated with prior inventories needs to be considered against this new information to understand what has changed.
    - Inventories do not include components such as on-road mobile sources (cars and trucks).
    - Total number of operators submitting inventories increased from 39 in 2009 to 49 in 2010.
    - Approximately 20 (of ca. 60) air emission permittees in the UGRB have never submitted data to the DEQ emissions inventory. The non-responders are all relatively small operators. Emissions from their operations are not accounted for in the emissions inventory.
    - The degree of reporting precision is dependent on many factors including company component count records, fuel use records, and equipment maintenance conditions, which parallel manufacturer operating assumptions.
- A DEQ 2011 Engine Emissions Study evaluated emissions of 130 engines in Wyoming. Of the 31 engines located in Sublette County, 16 engines (52%) were emitting in excess of their

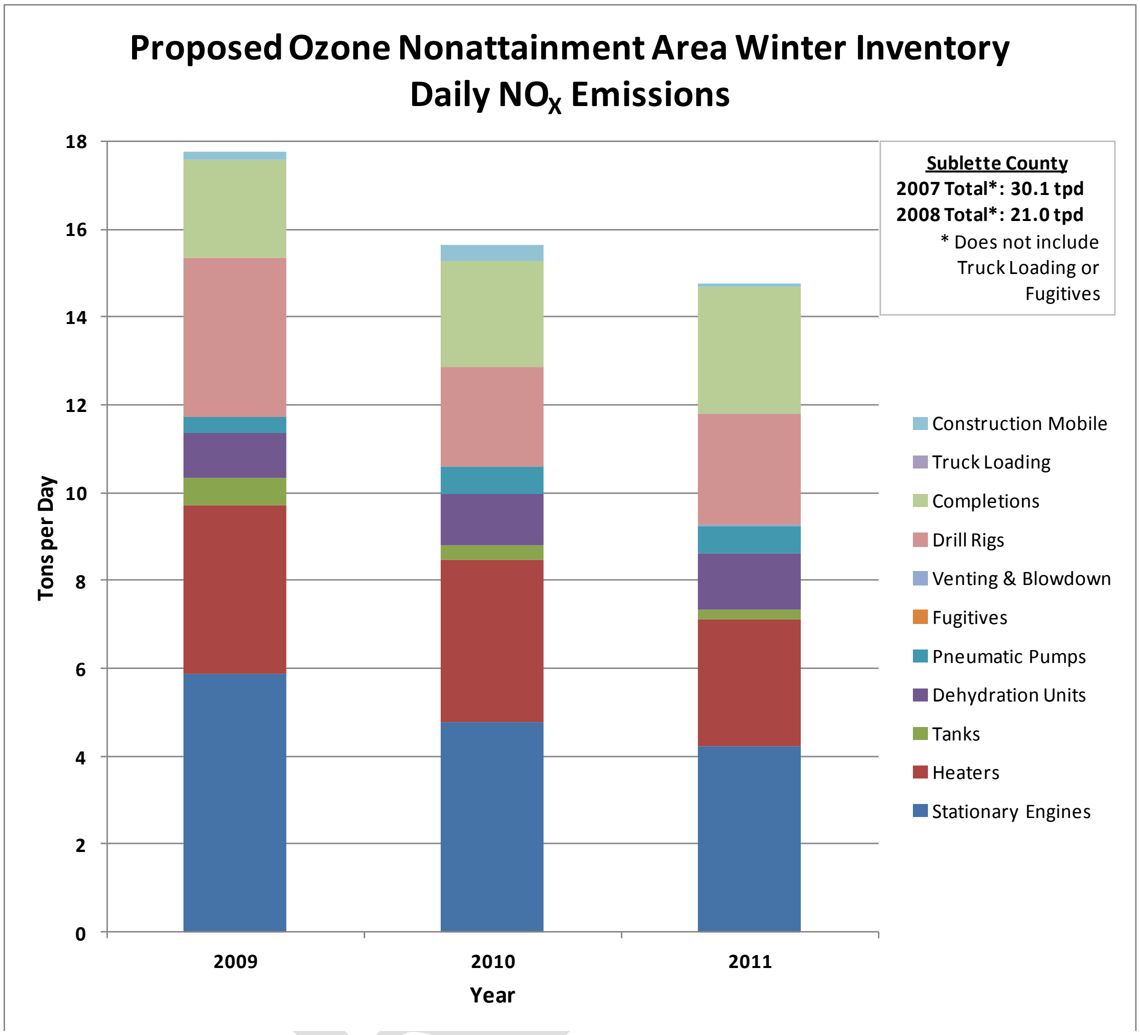
permitted limits (these emissions include both NOx and VOCs). These excesses are not reflected in Emission Inventory data (DEQ 2011c).

- Example emissions sources for VOCs and/or NOx that are not covered by the Air Quality Division (AQD) permitting in the UGRB includes:
    - On-road and non-road mobile sources (including, but not limited to): trucks/cars, semis, construction equipment, farming/ranching vehicles (e.g., tractors), snowmobiles, ATVs
    - Non-road engines associated with drill rigs (except within the Jonah-Pinedale Development Area)
    - Non-road engines associated with completion/workover operations
    - Residential heating/fireplaces and AC
    - Landfills that are not required to obtain a Title V permit (per the New Source Performance Standards)
    - Lawn/yard equipment: snow blowers, lawn mowers, leaf blowers, trimmers
    - Gasoline service stations
- Figures 5 and 6 show the relative contributions of different sources of VOC and NOx emissions from the oil and gas industry (see also Table 1 for descriptions; DEQ 2011a).
    - VOCs tend to be emitted by gas production and its storage and handling.
    - NOx emissions come from the combustion of fuels (primarily diesel and natural gas).
    - DEQ data show that the largest emitters of VOCs are tanks, dehydrators, and pneumatic pumps, while engines that drive drilling activities and compressor stations are the largest NOx emitters (DEQ 2010a).
- Figure 7 shows emissions inventory data from the Jonah Pinedale Development Area (JPDA) and outside of JDPA.



Source: DEQ 2012a

Figure 5. Oil and Gas Contributors to VOC Emissions in the UGRB.



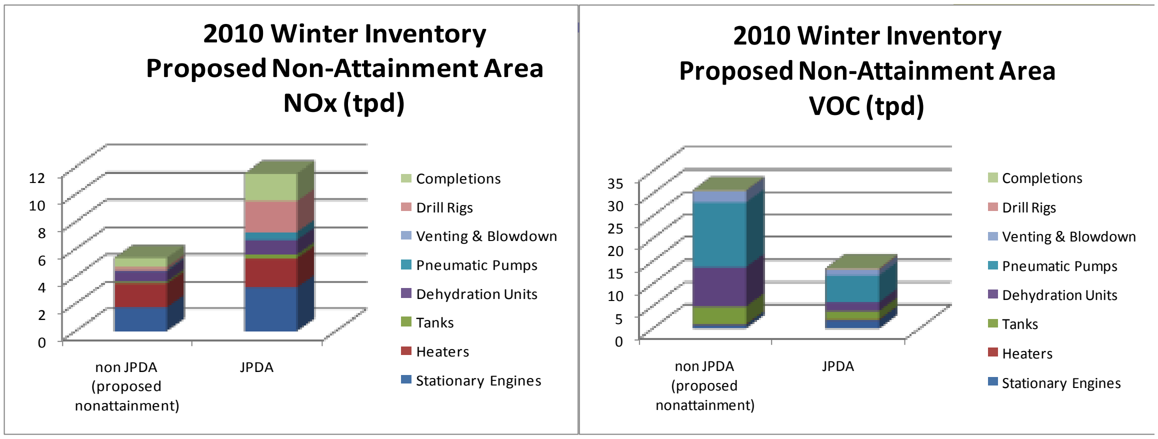
Source: DEQ 2012a

Figure 6. Oil and Gas Contributors to NOx Emissions in the UGRB.

Table 1. Definitions of Oil and Gas Emissions Sources in Figures 5 and 6.

UGRB Inventory Emission Unit Descriptions
Stationary Engines: Any turbine or reciprocating, fuel-burning engine (pump engine, compressor engine, generator, etc.).
Heaters: Any fuel-burning heater (line heater, separator heater, tank heater, dehydration unit reboiler, etc.).
Tanks: Any oil tank, condensate tank, or produced water tank.
Dehydration Units: Any glycol dehydration unit (including, but not limited to, ethylene glycol, diethylene glycol, or triethylene glycol) used to remove water from the gas stream.
Pneumatic Pumps: Any pneumatic pump operated by gas (including, but not limited to, natural gas or propane).
Fugitives: Components that have the potential to emit fugitive VOCs (including, but not limited to): connectors, flanges, open-ended lines, pump seals, valves, compressor seals, pressure relief valves, dump level arms, polished rod pumps, and thief hatches.
Venting and Blowdowns: Opening a pressurized system for liquids unloading, wellbore depressurization in preparation for maintenance or repair, hydrate clearing, emergency operations, equipment

depressurization, etc.
Drill Rigs: Any fuel-burning equipment (engines, boilers, etc.) used in the drilling process.
Completions & Workovers: Any fuel-burning equipment used in the hydraulic fracturing, well completing, or workover process, and any venting associated with these processes.
Truck Loading: The loading of liquids from tanks to railcars or trucks.
Construction Mobile: Also referred to as "Non-Road Mobile." Construction equipment used for road, pad, and pipeline construction, snow removal, and rig moves.



Notes:

1. Feasibility evaluation of control on Non JPDA sources is necessary before estimating amount of improvement for VOC and NO_x reduction.
2. Regulatory authority very limited.

Figure 7. Emissions Comparison: Non-JPDA vs. JPDA within Proposed Nonattainment Area.

III. Responses to High Levels of Ozone

Monitoring

<u>DEQ Monitoring</u>

- Figure 8 represents the location of DEQ monitoring activities relevant to ozone formation in the UGRB as of the 2010 ozone season.
- Long-term monitoring:
  - Stations measure ozone, other criteria pollutants, and meteorology and are used to determine compliance with NAAQS standards.
    - Boulder, Daniel South, Jonah/Juel, Pinedale, Wyoming Range, Big Piney, Murphy Ridge, Moxa, and South Pass sites have:
      - Continuous data collection with hourly validation.
      - Measure ozone, NOx, particulate matter, and meteorology.
      - Cameras.
      - Some stations have other parameters (e.g., visibility, SO_2).
- Short-term monitoring (e.g., UGWOS, precursor and other station enhancements, and air toxics studies):
  - Upper Green Winter Ozone Study (UGWOS)
    - Has been conducted each winter (January-March) from 2007–present.

- Enhances understanding of complex winter ozone formation and to develop a conceptual model.
- Studies used for model inputs and to verify model mechanisms.
- Look at spatial distribution of ozone (through mesonet, aircraft), vertical distribution of ozone (ozone sondes, tall tower, tethered balloons), spatial variability of meteorology (mesonet); vertical variability of meteorology (rawinsondes, mini-SODAR), tall tower, wind profiler/RASS); precursors and other species (CH_4, VOCs, NOxy, HONO, HCHO, CO, speciated PM).
- The UGWOS team provides daily ozone forecasts to identify potential high ozone periods.

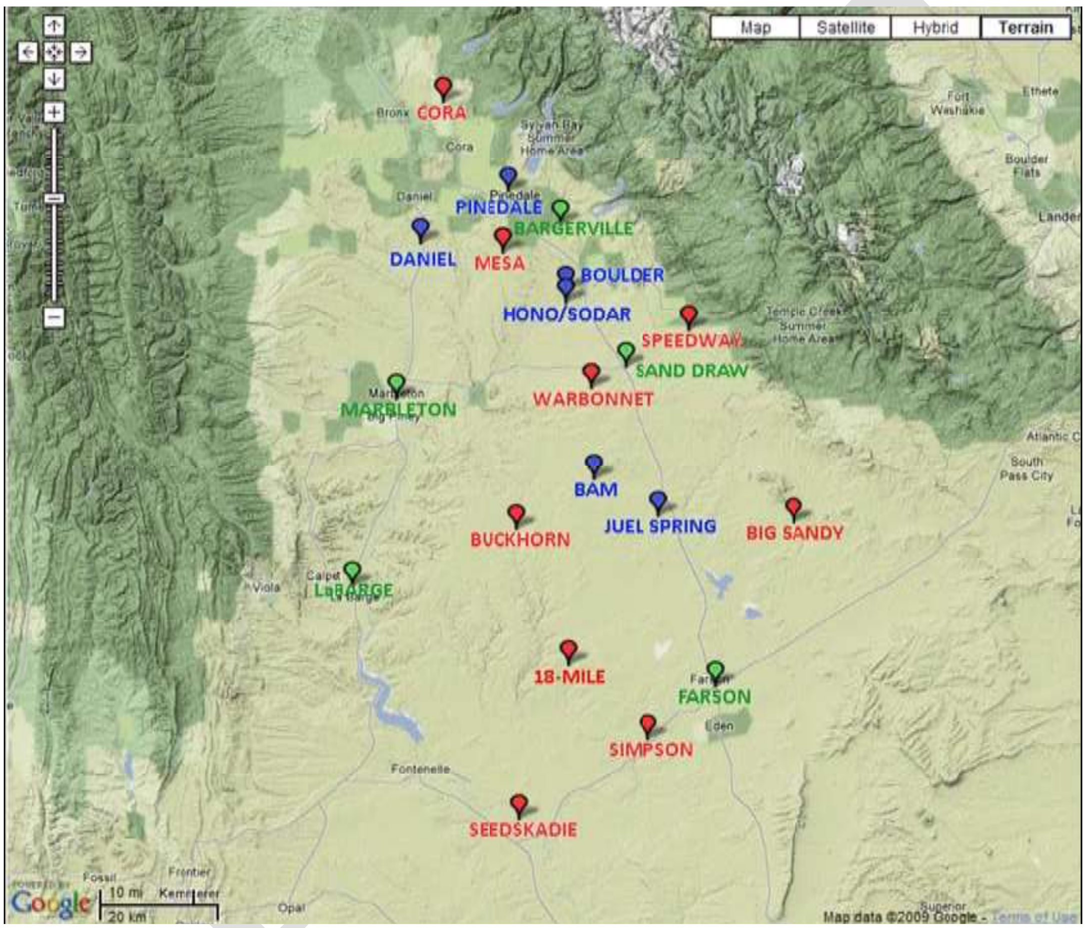


Figure 8. Winter 2010 DEQ Monitoring Site Locations 2010 (Meteorological Solutions et al. 2010a).

Note: (Blue) Ambient monitoring sites include Juel Springs, Boulder, Pinedale, Daniel South (permanent); BAM trailer (temporary); HONO/SODAR (adjacent to Boulder). (Red) Mesonet sites include winds, temperature and ozone. (Green) Sublette County Human Health Risk Study sites include winds and ozone.

- Based on monitoring data, DEQ AQD believes transport is not causing an appreciable impact to ozone formation in the UGRB.
- Monitoring site selection is based on criteria established by the EPA.
  - These criteria must also include the consideration of terrain features/obstructions to meet requirements for obtaining representative meteorological and ambient air

  quality measurements, as well as a stable electric supply and right-of-way access to the site.
  - Specific siting criteria included consideration of:
    - Meteorology
    - Topography
    - Pollutant being targeted
    - Accessibility
- The overall objectives of the monitoring network are:
  - Provide data for research
  - Provide data for air quality planning efforts
  - Provide data for emergency episode prevention
  - Monitor time trends and patterns
  - Monitor source compliance with regulations – which in turn could mean siting to measure impact from sources
  - Ascertain attainment and maintenance of NAAQS – which in turn could mean siting to measure impacts to population centers
  - Determine impact of specific proposed or constructed facilities or source concentration
  - Provide data to support enforcement actions
- Typical monitoring objectives included siting of:
  - Peak stations – located at one of the points within the region where the highest concentrations and exposures are expected to occur,
  - Neighborhood Station – located to typify a broad area of land use
  - Background Station – located in areas to provide information on levels of a pollutant transported into a region.

<u>University of Wyoming (UW) Atmospheric Science Air Quality Research Group Projects</u>
- For the winter of 2008/2009 and 2009/2010 UW investigated ozone in the UGRB through the operation of the first mobile air pollution laboratory to be deployed in the area. The mobile site measures gaseous pollutants and meteorological parameters.
  - The most valuable data were the first ambient measurements of methane (CH_4) and non-methane hydrocarbons (NHMC).
  - UW also used passive samplers to define the geographical scope of ozone episodes. The O3i project had the following outcomes:
    - Passive samplers were able to show the spatial extent of ozone episodes (Figure 4) and showed the relatively localized nature of such events.
    - Passive sampling engaged stakeholders (citizens, developer, regulators) in a collaborative effort.
  - Using all available data ozone development animations were developed and these showed localized production associated with oil and gas development followed by transport in a reverse drainage flow. This showed that events were local and that meteorology was critical.
  - The mobile laboratory data from five different sites showed the importance of emissions from oil and gas development and traffic.
  - Traffic surveys showed the dominance of multi axle trucks in the development areas.
  - Extended monitoring at the Olson Ranch site showed high levels of methane and non-methane hydrocarbons.

- The Pinedale Anticline Spatial Air Quality Assessment (PASQUA) was designed to assess key VOC and oxides of nitrogen (NO_x) in the winters of 2010/2011 and 2011/2012.
    - The study used the UW mobile air quality monitoring laboratory at the Boulder South Road site.
    - Over 2,300 hourly measurements of 30 VOCs were performed at the Boulder South Road site with a Perkin Elmer OPA system. This data showed two sources: fugitive natural gas and a second source with higher levels of BTEX compounds.
        - The latter is though to be associated with condensate and water handling.
    - Ambient concentrations revealed the importance of aromatic compounds for ozone production potential.
    - The study also performed spatial surveys of BTEX and NO_x at 50 sites. These surveys were consistent and showed that NO_x and BTEX had different distributions that reflected different contributing sources. The former associated with traffic and compressor stations. The latter associated with oil and gas production and condensate handling. Two areas with relatively high levels of BTEX were identified.
- The study also employed canisters to enable spatial assessments in the PAPA (Figure 9; Soltis and Field 2011b). In the first year (2010/2011) six surveys revealed a strong gradient of concentrations associated with proximity to greater development intensity. The goal of canister placement for different surveys was to 1) assess pollutant distribution in the entire development region, including potential upwind and downwind source locations; 2) provide a more focused picture of the PAPA development area; and 3) measure values along a generally northwest to southeast line transecting PAPA.
    - Ozone concentrations during 2011 at Boulder South Road matched those shown by proximate WDEQ-AQD sites. A relationship of peak ozone with enhanced NMHC was observed.
    - In the second year (2011/2012) the Perkin Elmer OPA system was set-up in Laramie and the study focused on 12 surveys at 10 stable sites.
- The 2011/2012 PASQUA project was performed in conjunction with the ozone wind field project (O3w). This study placed 10 meteorological stations at strategic locations to better understand surface wind patterns and their importance to the production and movement of ozone.

Figure 9. Location of PASQUA 2011 VOC Canister Survey Sites (Soltis and Field 2011b).

Data quality assurance

- For both DEQ and UW monitoring efforts, all equipment is routinely checked for proper functioning and calibrated to ambient conditions (Meteorological Solutions et al. 2011; Soltis and Field 2011a).
- Independent audits also occur to verify the site operations and data accuracy.

Raw data vs. validated data

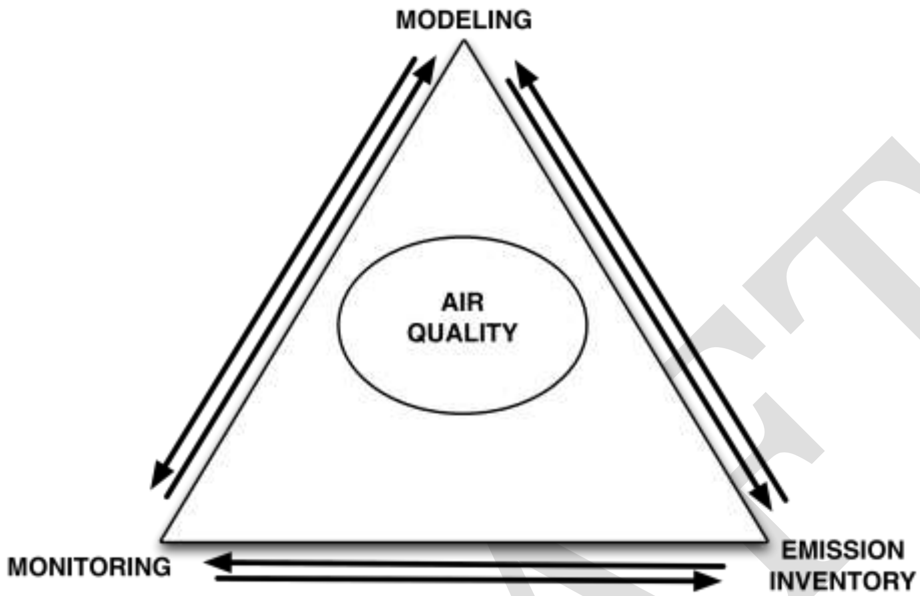
- Raw data is what comes directly out of the measuring equipment.
- Most air quality data goes through multiple steps of validation before it is released.
- The AQD maintains a Quality Assurance Project Plan for each monitoring site, as required by the EPA. The Quality Assurance Project Plan addresses all monitoring and data analysis procedures applied to the monitoring site. These procedures are fully documented in existing standard operating procedures, technical instructions, and checklist instructions. Data validation requirements for each monitoring site follow EPA protocols that meet the quality assurance requirements and often involve three levels of validation.
- For PASQUA, data validation includes editing for instrument downtime, making adjustments for quantifiable baseline and span or interference biases, removing values where monitoring instrumentation fails specific validation criteria, flagging measurements with significant deviations from measurement assumptions, verifying computer file entries against data sheets, testing measurement assumptions, comparing co-located instruments, and internal consistency tests (Soltis and Field 2011a).

Measurements vs. modeling

- Air quality measurements provide a direct assessment of pollutant levels.

- Measurements are provided by DEQ monitoring sites and the PASQUA mobile laboratory and canisters.

- Models are used with a variety of input parameters to make different types of predictions.
  - Measurements can be used as inputs to models or as validation for the output.
- Modeling, monitoring, and emissions inventories all inform air quality management (Figure 10).



Source: Field et al. 2011

Figure 10. Monitoring, Emissions Inventories, and Predictive Modeling all Inform Air Quality Management.

Modeling

- Modeling is a relatively complex, mathematically-based tool air quality regulators, managers and professional staff use to:
  - Describe the airshed with respect to various aspects of meteorology, topography, anthropogenic and biogenic emissions and others to gain insight and information into how one or more of those aspects impacts air quality.
  - Leverage monitoring resources, as it is not practical or feasible to place monitors everywhere.
  - Predict the impacts from a potential emitter(s), which is useful for permitting new sources;
  - Simulate ambient pollution concentrations under different meteorological conditions or policy options (EPA n.d.(c)); and
  - Inform strategies for and effectiveness of air quality management measures (DEQ 2012b), and how to reach attainment with NAAQS standards through planned emissions reduction measures.
- Because modeling is both an art and a science, its use requires an understanding that:
  - As predictive tools, models require actual field measurement (validated regulatory monitoring data) to confirm the model is giving results that can be correlated to actual conditions.

- The strategy to reduce ozone levels is centered on the chemistry of VOC and NO_x, including the relative amounts of each precursor and the organic compounds that make up the total VOC. Carter and Seinfeld (2012) have studied the chemistry of wintertime ozone formation in the UGRB using a box model, initialized with actual early morning monitoring data on VOC and NO_x during several past episodes. The simulations carried out by Carter and Seinfeld (2012) reveal the complex nature of ozone formation in the UGRB. Despite the fact these are box model simulations, the essential chemical dependencies that are represented in a three-dimensional model are thoroughly treated in the box model. Box model simulations are an important precursor to the application of three-dimensional models.
- Development of efficient and effective emission reduction strategies for the UGRB will require development of full three-dimensional photochemical modeling simulations capable of reproducing the key features of the winter episodes (Stoeckenius and Ma 2010; Carter and Seinfeld 2012).
- WDEQ AQD is working to develop this model capability; however, it will not be available within the timeframe of the task force efforts.
- To date, WDEQ has completed meteorological and dispersion modeling which provides input into the developing photochemical grid model (to describe wintertime ozone phenomenon). More information on this can be found within DEQ 2012b.

Forecasting of High Ozone Events

- DEQ staff and meteorologists provide daily forecasts between January 3 and March 30, 2012, 7 days a week, based on weather forecasts.
- Winter Ozone Updates provided for the current and next day.
    - Expected conditions for the current and next day, provided by noon daily
    - Information for the public to make decisions about outdoor activity
    - Allows AQD flexibility to provide up-to-date information when forecasted conditions change unexpectedly.
- Ozone action days (projected high ozone events) are issued 24 hours in advance when forecast weather conditions appear favorable for the formation of elevated ozone the following day.
- When DEQ designates ozone action days, oil and gas companies who are participating implement ozone contingency plans (see Section III), and everyone is encouraged to voluntarily reduce emissions.

Health Implications of Ambient Ozone

- The health impacts of ground level ozone have been studied extensively.
    - Ozone may result in respiratory health impacts 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.
- Ground-level ozone also leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests and other stresses such as harsh weather (EPA n.d.(a)).
- More information about ozone health impacts can be found at http://www.epa.gov/airquality/ozonepollution/

Table 2. Ozone Health Risks

Ozone level (ppb)*	Descriptor	Caution level
0–59	Good	None
60–75	Moderate	Unusually sensitive people should consider limiting prolonged outdoor exposure
76–95	Unhealthy for sensitive groups	Children, older adults, people with respiratory problems, and people who are active outdoors should limit prolonged outdoor exertion
96+	Unhealthy for general public	Everyone should limit prolonged outdoor exertion

* For an 8-hour average.
Source: EPA 2008

<u>UGRB Health Studies of Air Toxics and Ozone</u>

- Sublette County, Wyoming Department of Health, and DEQ commissioned an ambient monitoring study that focused on toxic air contaminants (TAC), ozone concentrations and a screening level health risk assessment (Sierra Research, Inc. 2011).
  - A screening analysis of the data collected during this program (February 2009–March 2010) was conducted to evaluate the potential for acute health impacts, excess cancer risk, and chronic non-cancer health impacts.
    - This screening analysis indicates that there is no potential for significant acute health impacts from the TACs measured by this study.
  - The potential excess cancer risk from the total set of TACs monitored at the 14 monitoring stations in this study ranged from 14 to 50 in 1 million. These are upperbound risks calculated using a conservative screening methodology that assumes a person breathes the average monitored TAC concentrations 24 hours each day for 70 years; actual cancer risk are likely to be significantly lower. These levels are significantly lower than the risks found in most urban areas, and even in rural areas. The EPA considers excess cancer risk below 100 in 1 million to be acceptable.
  - During the 14 month study period (February 2009–March 2010), there were no exceedances of the 8-hour ozone NAAQS (75 ppb).
  - The report concludes that although ozone has potential health effects when concentrations exceed the 8-hour NAAQS, the lack of an exceedance during the air toxics monitoring program and the infrequent wintertime excursions of ozone concentrations above the 75 ppb 8-hour NAAQS observed in the Upper Green Winter Ozone Study, suggests that such health effects are not expected to occur in Sublette County.
- The Wyoming Department of Health is currently conducting an observational epidemiological study that will look at the correlation between high ozone days (utilizing 8 hour ozone data from DEQ) and respiratory illnesses previously found to be associated with ozone (data derived from hospital discharge data from the area's hospitals and clinics).
  - Observational epidemiological studies are retrospective studies that attempt to analyze data previously acquired for other purpose and test for an association between two variables.
  - Observational epidemiological studies are notorious for yielding associations that may be spurious. This is especially the case when dealing with a health outcome such as respiratory illness that may be influenced by many factors besides air quality.

- Observational epidemiological studies are typically viewed as exploratory or what is called hypothesis-generating studies. Positive associations observed in such exploratory studies may be used to design studies that are more rigorous in their planning and conduct. This would include the development of a hypothesis in advance and a rigorous plan for acquiring and analyzing data to test the hypothesis. This would likely include enrollment of a specific cohort of individuals to be followed for a defined period of time with established, pre-determined measures of health outcome.
- Study will be completed in 2013.

Regulatory Response

EPA Non-Attainment designation

- Wyoming is not meeting the EPA 2008 NAAQS standard for ozone in the Upper Green River Basin.
    - Assessment and possible revision of the NAAQS ozone standard is scheduled for 2013.
        - In 2011, EPA considered lowering the ozone primary health standard to somewhere between 60–70 ppb but postponed action on lowering the standard until after a scheduled 2013 review. EPA's 2011 draft proposal to lower the primary ozone standard to 70 ppb and to change the calculation method for the secondary ozone standard, and the related supporting analysis documentation is available at http://www.epa.gov/glo/actions.html#stand.
        - If the standard is lowered, it would be finalized in 2014.
        - The EPA in 2011 also gave consideration to promulgating a Secondary (Welfare-based) NAAQS for O_3 using a "sigmoidally weighted W126 Index" for daylight hours over the summer growing season to protect against plant and crop damage.
- EPA announced that it will designate the Upper Green River Basin as a marginal nonattainment area on April 30, 2012.
    - A marginal designation means DEQ has three years to create a compliance plan (2015) and three years to have the plan approved (2018).
        - EPA will publish a clearer implementation rule at the end of summer 2012.
        - Failure to achieve attainment by this compliance date means the designation bumps up to "moderate."
    - A marginal designation doesn't require the state to develop an ozone State Implementation Plan (SIP).
        - Designation of "moderate" and higher requires a SIP, which involves a three-year process to get EPA approval.
    - The state will still have to develop a plan to achieve attainment.
- The nonattainment boundary was recommended to EPA by DEQ and is based on a number of factors including:
    - Some existing county boundaries: DEQ considered the county boundary to the north, east, and west to be a reasonable boundary based on geography, jurisdictions, emission sources, population, and growth.
    - Meteorological conditions that would prevent transport of precursor emissions from outside the southern boundary and topographical considerations (DEQ 2009).

- The southern boundary was informed by trajectory analyses that showed emissions do not travel far from DEQ monitors (have short trajectories) and that sources outside the recommended nonattainment area do not have a significant impact on the UGRB in the presence of an inversion and very low wind speeds (DEQ 2009).
- The boundary includes all of Sublette County and parts of Sweetwater and Lincoln Counties (Figure 11).

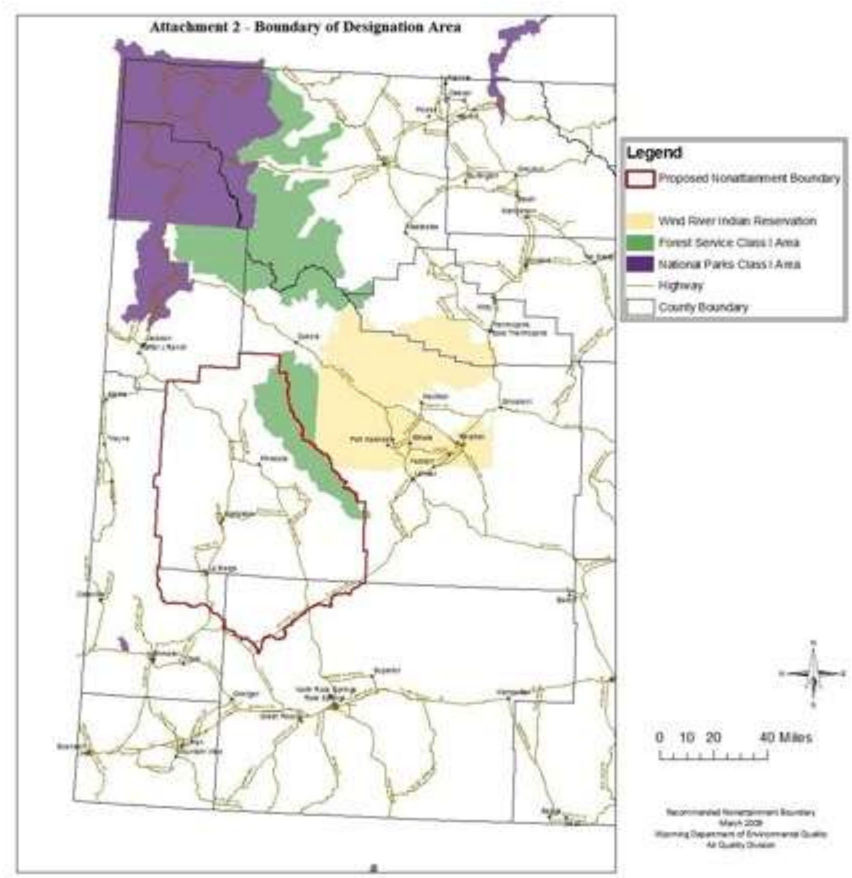


Figure 11. Upper Green River Basin Non-Attainment Area.

- Permitting and regulatory compliance under non-attainment:
    - Non-attainment will likely make it more difficult to get permits for new projects.
    - It is possible that rules can be promulgated by DEQ that create more stringent emissions requirements than what are currently in existing permits.
    - In addition, the National Environmental Policy Act (NEPA) process may take longer for developments in the Non-Attainment area.

<u>Department of Environmental Quality (DEQ)</u>

- DEQ is the regulatory authority that maintains and monitors compliance with state and federal ambient air quality standards; Wyoming's permitting rules appear in the Wyoming Air Quality Standards and Regulations (WAQSR).

- Wyoming's New Source Review (NSR) Program is a statewide permitting program for the construction of new stationary emissions sources (both major and minor) and modification of existing sources.
    - NSR permitting requires using Best Available Control Technologies (BACT) for permitting at stationary sources of air pollutants at new oil and gas production units (DEQ 2009; see section IV for definition of BACT).
        - The Air Quality Division has specific presumptive BACT requirements for the Jonah–Pinedale Project Area (in addition to requirements for the rest of the state; DEQ 2010b).
    - A "major source" is defined as a source which emits either 100 tons per year (TPY) or more of a regulated air pollutant, 10 TPY or more of a single hazardous air pollutant, or 25 TPY or more of the total hazardous air pollutants; a minor source emits less than all of these levels (DEQ 2010b).
- Under the WAQSR, applicants for permits are required to demonstrate that, "[t]he proposed facility will not prevent the attainment or maintenance of any ambient air quality standard." [WAQSR Chapter 6, Section 2(c)(ii)]
- To allow applications for new or modified emission sources of VOC and/or NOx to be processed while DEQ and industry initiatives are taken to reduce the overall emission levels for VOC and/or NOx in Sublette County, AQD adopted the *Interim Policy on Demonstration of Compliance with WAQSR Chapter 6, Section 2(c)(ii) for Sources in Sublette County* on July 21, 2008.
    - All applications require a demonstration that the proposed facility will not prevent attainment or maintenance of an air quality standard.
    - It provides three options:
        - Modeling
        - Offsets
            - Offset must be in Sublette County
            - Offset must be enforceable, or approved by AQD
            - Reductions must occur after 4/1/08
            - Offset of 1.5:1 for VOC and 1.1:1 for NOx
        - Alternate demonstrations
    - Most applicants have utilized the offsets option
- In July 2009, the AQD issued a letter explaining the allowance of inter-company trading to secure emission reductions which may be needed to allow a permit applicant to make a Chapter 6, Section 2(c)(ii) Demonstration.
- AQD issued the *Sublette County Banking/Voluntary Emission Reduction Policy* on October 10, 2011.

Compliance

- Inspection activities
    - Two full-time people based in Pinedale, dedicated to Jonah-Pinedale Development Area.
    - Six full-time people based in Lander, dedicated to Sublette, Sweetwater, Teton, Uinta Counties.
- AQD prioritizes inspections. It:
    - Evaluates all areas of permit compliance

  - Places particular emphasis on effective operation of VOC collection and control systems at oil and gas production facilities
- Field presence on Ozone Action Days.

Bureau of Land Management (BLM)
- In Sublette County, most oil and gas wells are located on federal land or involve federal minerals, and the BLM governs leasing and permitting of gas development on the federal mineral estate.
- As the state has primacy for air quality regulation, BLM's role in air quality management is primarily to disclose to the public the potential impacts to air quality from proposed projects and project alternatives.

Wyoming Oil and Gas Conservation Commission (WOGCC)
- While air quality permitting is the sole responsibility of DEQ, the WOGCC authorizes drilling.
- WOGCC authorizes venting and flaring for emergencies, well purging and evaluation tests, and production tests (up to 15 days); however, WOGCC encourages minimizing venting and flaring.

Present and Future Clean Air Act (CAA) Regulatory Environment of the O&G Industry
- Some of the common and relevant emission control acronyms used in CAA rules and permits include:
  - BACT – Best Available Control Technology. BACT applies to permits only and cost "reasonableness" ($/ton pollutant emission reduced) must be considered. WDEQ establishes BACT for specific types of emission sources (certain types of engines), and may require permit applicants to provide a BACT analysis on a case-by-case basis for specific emission sources.
  - MACT – Maximum Achievable Control Technology. Applies to existing sources for control of listed hazardous air pollutants (HAPs), and sets a performance standard based on the emissions performance of the top 12% in a regulated source category. Cost is not a consideration.
  - RACT – Reasonably Available Control Technology. Applies to existing major sources (Title V and PSD) in areas that are not meeting national ambient air quality standards (i.e., non-attainment areas). States can independently do RACT type rulemaking for minor sources as well.
  - LAER – Lowest Achievable Emission Rate, is required on major new or modified sources in non-attainment areas.

CAA Regulatory Programs
- There are four primary CAA regulatory programs that that industry must comply with for NOx and Ozone.
  - New Source Review (NSR) – A permit must be obtained prior to constructing a stationary emission source. Allowable emission rates are established through BACT. Federal requirements on non-tribal land only require permitting for Title V and PSD sources (Major Source). Wyoming is unique in that it also has a Minor source permitting program that requires BACT. Oil and gas exploration and production (E&P) operations must be permitted under the Minor Source NSR program that requires compliance with the WDEQ "Presumptive BACT" requirements.

Presumptive BACT allows operators to install and operate wellhead production facility equipment without first obtaining a Minor Source NSR permit, with the "presumption" that the equipment and activities will be conducted in compliance with the established Minor Source BACT requirements. This allows Operators to obtain actual production data upon which emissions can be more accurately estimated for permitting purposes. Engines cannot be installed under Presumptive BACT, and all types of O&G facilities other than wellhead production facilities must be permitted before they can be constructed.

- New Source Performance Standards (NSPS) – EPA performance standards for new, modified, or reconstructed stationary sources in listed source categories. EPA recently finalized a new NSPS rule for the oil and gas sector on April 17, 2012. Other recent oil and gas applicable NSPS rules include engines and turbines.
- National Emission Standards for Hazardous Air Pollutants (NESHAP) – EPA performance standards for both new and existing sources of hazardous air pollutants for specific source categories. MACT is applied to NESHAP regulated emission sources. NESHAP rules for oil and gas primarily regulate stationary engines for formaldehyde and benzene from glycol dehydrators. New engine rule compliance date is May, 2013 for diesel engines and October, 2013 for natural gas engines.
- National Ambient Air Quality Standards (NAAQS) – EPA air quality standards for criteria pollutants Ozone, SO_2, $PM_{2.5}$, PM_{10}, Lead, NO_2, and CO. Noncompliance earns a nonattainment designation. RACT and LAER emission reduction regulatory programs can be established by the state to get back into attainment with the standard.

Determining Emission Rates

- Emission rates from oil and gas sources are mostly calculated using either a specific source type emission model or through use of an emissions factor that is derived from either a stack test, an EPA published emission factor, or from the vendor of the emission source. Vented and flared emissions typically are calculated using a mass balance type calculation. Continuous emission monitoring systems (CEMS) are usually reserved for specific major source categories (like large scale power generation), but rarely found in typical oil and gas production.
- Typically, modeling programs are used to calculate emissions from glycol dehydrators and storage tanks, while a factor based calculation is used to calculate emissions for engines, heaters and boilers, fugitives, and pneumatics.

Nonattainment Strategies – NAAQS Compliance Mandatory

- These strategies have been applied in other areas classified as non-attainment that have population and emission profiles that differ from those of Sublette County.
- A formal cap and trade program is usually based on an area wide cap that is lower than current area wide emissions. A system of transparent, tradable emission credits and allowances is established that are bought and sold often through brokers. Trades are registered and approved by the state and become publicly available information.
- RACT and LAER programs can be established for both new and existing sources that may be more stringent than emission limits established through BACT. RACT

programs set emission standards and monitoring requirements for specific source categories such as tanks and engines.

Emissions Reductions

- Ozone reduction strategies involve decreasing emissions of human caused NOx and VOC precursors necessary for its formation.
    - Mass based reductions of both emissions can be difficult and more costly to implement. A more insightful reduction strategy is often sought through scientific study and modeling that may indicate which precursor is most important to reducing ozone formation. If predictable, the precursor of most importance is considered "limited," such as VOC limited or NOx limited.
    - However, studies in the Sublette County area to date that have analyzed and modeled ozone formation have been inconclusive as to which precursor is limited and should be the focus of emission reduction.
    - Consequently, a weight of evidence approach suggests that reductions of both precursors are necessary, which at this point is the current emissions reduction strategy.

Enacted measures

- DEQ and oil and gas operators in the UGRB have worked together to create a voluntary reductions program to reduce air quality emissions that complements existing regulatory requirements (Table 3).
- Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance (revised March 2010 – applicable August 1, 2010) presumptive BACT (Best Available Control Technology) requirements for the Jonah and Pinedale Anticline Development Area (JPAD) are summarized below (DEQ 2010b).
    - Flashing - Upon FDOP (First Date of Production) or Modification: 98% control of all flashing emissions
    - Dehydration Units - Upon FDOP or Modification: 98% control of all emissions
    - Pneumatic Heat Trace Pumps and Other Pneumatic Pumps (chemical, methanol injection) - Upon FDOP or Modification: Natural gas-operated pumps – 98% control of all pump emissions or pump discharge streams must be routed into a closed loop system (sales line, collection line, fuel supply)
    - Pneumatic Controllers - Upon FDOP or Modification: Natural gas-operated controllers must be low or no-bleed or discharge must be routed into a closed loop system (sales line, collection line, fuel supply)
    - Truck Loading - No control requirements
    - Well Completions - Green Completion Permits
    - Produced Water Tanks - Upon FDOP or Modification: 98% control of all active produced water tank emissions
    - Blow down / Venting - Best Management Practices (BMP) and information gathering incorporated into permits
    - Any Source with No Presumptive BACT Control Requirements (e.g., Truck loading) - Best Available Control Technology (BACT) analysis required for uncontrolled emissions ≥ 8 TPY VOC or ≥ 5 TPY Total HAP
- In general, the presumptive BACT requirements for the CDA are similar to the JPAD for pad facilities, which provides for control installation upon FDOP or modification. For CDA single well facilities control installation is generally required within 60-days of FDOP or

modification.

Table 3. Emissions Reduction Measures Implemented by UGRB Operators.

Measure	Description
Ozone contingency plans	• For short-term emission reductions during the times when conditions seem favorable for ozone formation • Enacted with a DEQ-issued ozone action day • If it does not affect safety or impact essential operations, companies will minimize idling and use of equipment, defer some activities until conditions have eased, minimize traffic, increase surveillance of combustors, and suspend completion and hydraulic fracturing activities that require flaring • 26 companies have created ozone contingency plans for the winter of 2012 (as of 1/11/12) • There is room for other oil and gas companies, local governments, or other organizations to join this effort
Liquids gathering system (LGS)	• System of pipelines that transports condensate and produced water from the wells to centralized gathering facilities and trunk pipelines • Reduces emissions associated with tanks and with tanker truck trips that would otherwise be necessary to collect liquids at well sites
Green completions	• Gases and liquids brought to the surface during the completion process are collected, filtered, and then placed into production pipelines and tanks, instead of being dumped, vented, or flared • The gas cleanup done with special temporary equipment at the well site, and after a period of time (days) the gas and liquids being produced at the well are directed to the permanent separators, tanks, and piping and meters that are installed at the well site • Eliminates almost all venting and flaring
Selective Catalyst Reduction technology	• Reduces NOx emissions up to 90% on diesel-powered drill rig engines
Drill rig engine conversion	• Some engines on drill rigs used in Sublette County have been converted to run on lower-emission natural gas
Controls	• Controls on exhaust from heat trace pumps • Changing out separator controllers to low- or no-bleed devices
Transportation	• Some company field vehicles converted to natural gas from diesel • Some employees bused to work sites • Man camps created to house employees and reduce commuting
Remote well monitoring	• Operators are expanding remote and automatic well monitoring and computer-assisted operations to further reduce truck trips
Retrofits	• Operators are applying current control requirements to older locations that were grandfathered under less stringent emissions regulations
Increased operator inspections	• Increasing inspection of gas production facility equipment to reduce fugitive emissions such as VOCs • Includes the use of infrared camera inspections and other technologies
Engine maintenance	• Conduct regular inspection/replacement of spark plugs, filter, and engine oil and regularly adjust or change the O_2 sensor on the air fuel ratio controller (if applicable)
Engine monitoring	• Use a portable analyzer routinely to measure engine exhaust gas emissions to confirm engines are operating in compliance with

	permitted emission limits. Monitor exhaust temperature to confirm catalyst is operating at optimal temperature.

Sources: Sublette Board of County Commissioners n.d.; Shell Energy n.d.; DEQ 2012a

IV. Background on Oil and Gas Industry

Present Operations

- The attached maps show the major operating areas within the nonattainment area. The Jonah/Pinedale (JP) production area is represented by the two clusters of wells south of Pinedale. Everything else is non-Jonah/Pinedale (non-JP)
- At the end of 2011, the following nonattainment area production statistics gathered from the WOGCC are estimated to be the following for each of the major producing areas in the nonattainment area. (Not included is Sweetwater Co. stats)

Table 4. Wells in Non-Attainment Area.

Area	No. of Active Wells	2011 Oil Production BBLS	2011 Gas Production MSCF
Jonah-Pinedale (JP)	3,750	6,834,199	861,024,661
Big Piney-La Barge (non-JP)	2,043	618,207	62,680,862

Source: WOGCC

- Jonah/Pinedale (JP) area wells are characterized by higher production volumes of both gas and liquids than producing areas outside of the fields. On an average basis, JP wells produce 5 barrels per day (bbl/d) each of hydrocarbon liquids (condensate), and 629,000 standard cubic feet per day (Mscf/d) each of natural gas. Produced gas contains approximately 3% VOC by volume.
- Production fields outside of Jonah/Pinedale produce lower volumes. On an average basis, non-JP wells produce < 1bbl/d each of hydrocarbon liquids, and 84 Mscf/d each of natural gas. As with JP production, non-JP natural gas production contains approximately 3% VOC by volume.
- Generally speaking, the newest wells produce volumes above the average, while older wells produce below average due to production decline. Additionally, some wells will produce mostly liquids, while others mostly gas.
- In the non-JP producing areas, typical production equipment located at each well site includes the wellhead, a line heater, a separator, glycol dehydrator, a produced water tank, a crude oil/condensate tank, and two or three pneumatic controllers. Some well sites may have one or more pneumatic pumps. In most cases, emission controls are not used on the tanks or dehys as emissions are below past and current BACT for permitting. Many operators have voluntarily switched pneumatics from continuous bleed to low/no bleed controllers.
    - Generally, in the non-JP area produced gas is gathered from each well to centralized compressor stations for compression and transportation to a gas plant for

processing. In some cases, a well site may include a small compressor, if the well pressure is insufficient to push the gas into the gathering system. Liquids are generally hauled off by truck transport from each site. Wells have to be periodically blown down when liquid build up in the well bore stops a well from flowing. Natural gas is vented to atmosphere during well blowdown events.

- In the JP producing area, production equipment is similar to non-JP producing areas. However, with higher production volumes, VOC emission controls are more prevalent. Vapor combustors and vapor recovery units are used to control storage tanks, glycol dehydrators, and gas-driven pneumatic pump emissions. Heaters and boilers may utilize low NOx burners, and pneumatic controllers are generally low/no bleed or in some cases driven by compressed air instead of gas.
    - Produced liquids from most wells in the JP producing area are gathered at central locations instead of at individual well sites either through liquid gathering systems or centralized production facilities. Central gathering has significantly reduced or eliminated truck traffic and loading emissions. In many cases liquids leave the field via pipeline.

Emission Control Technologies

- VOC control technologies are itemized in the Appendix prepared by the American Petroleum Institute (API). The table below provides additional control technology information for combustion sources.

Table 5. Emissions Control Technologies.

Emissions Source	**Control technology**	**Precursors controlled**	**Comments**
Engines 4SRB (rich burn)	Non-selective catalytic reduction (NSCR)	NOx, VOC	Performance difficult to manage for low hp engines
Engines 4SLB (lean burn), diesel	Selective Catalytic Reduction (SCR)	NOx, VOC	Costly and bulky, new lean burns already are low NOx
	Oxidation Catalyst	VOC	Needs high exhaust temp to effectively reduce VOC
Heaters/boilers	Low NOx burner	NOx	Used for large heaters/boilers

Economics

- The profits from oil and gas production provide the capital needed for investment in exploratory drilling to find new production and for drilling in existing producing areas to maintain or increase production. Profitability in its simplest terms is Volume X Price less costs.
- Oil and gas industry socioeconomic costs are those that benefit the local economy and governments. The table below prepared by the Wyoming Business Alliance using data gathered in 2006 demonstrates the significant beneficial impact the oil and gas industry provides to the state economy as a whole.

Table 6. Oil and Gas Activity as a Fraction of the State's Economy.

Indicator	All O&G Activities in WY Allowed	All Economic Activity in WY	Percent of O&G to State	Source
Total Economic Output	$18,617,065,044	$58,831,050,621	31.6%	IMPLAN 2006
Total Employment	73,229	369,565	19.8%	IMPLAN 2006
Total Labor Earnings	$3,914,633,314	$15,487,363,835	25.3%	IMPLAN 2006
Average Earnings	$53,457	$41,907	127.6%	IMPLAN 2006
Gross State Product (i.e., Value Added)	$13,329,075,050	$31,205,616,410	42.7%	IMPLAN 2006
Severance Tax	$666,397,115	$882,383,479	75.5%	WY Department of Revenue Annual Report 2007
Mineral Ad Valorem Levies	$712,637,118	$913,011,683	78.1%	WY Department of Revenue Annual Report 2007
Assessed Valuation (Taxable Value)	$11,303,378,284	$21,491,267,438	52.6%	WY Department of Revenue Annual Report 2007
Federal Mineral Royalties (WY Disbursements, 50%)	$515,500,646	$931,394,926	55.3%	Minerals Management Service 2007
State Mineral Royalties	$90,031,996	$138,201,502	65.1%	Wyoming Office of State Lands and Investments 2007

- The economics of the oil and gas industry is often misunderstood. Frequently, its thought that if a company as a whole is very profitable, that any extra cost incurred for environmental or other purposes is affordable. In other words, the general economic health of a company is assumed to justify extra costs at the local level. Oil and gas economics works much differently.
- In the oil and gas industry, each well, production, or processing site is the equivalent to being its own company, unique from all others whether its owned by a large corporation, or a small independent operator. Each site must be profitable on its own merit based on the income from production less operating costs. Unprofitable production sites or leases are abandoned or sold. Marginally profitable sites will be under close scrutiny for shut down especially if additional costs have to be incurred.
- Like any business, profitability of a site is based on the total income from sales less expenses. Typical operating costs for each well or production site include those from taxes, royalties, personnel, fuel, equipment costs, workovers, and maintenance. Typically, low volume sites will be the most sensitive to increasing costs in operating expenses. Low volume wells become particularly cost sensitive during periods of depressed prices.

- To maintain profitability as production volumes or prices decline, operators will frequently evaluate production optimization potential. Equipment originally installed to handle higher volumes may no longer be needed and may be downsized or shutdown as production processing is consolidated into utilization of less equipment. Consolidation can include use of fewer or smaller tanks, compressors, or dehys. If the cost of optimization can be justified for maintaining long-term profitability, it will proceed. If not, the productive life of a site is shortened. While optimization is driven largely by economics, it also has an environmental benefit in that fewer emissions may be generated after an operating consolidation.

V. Ongoing Studies/Uncertainties

- UGWOS 2012 (Monitoring)
    - Continuing measurements at permanent sites
    - Mini-SODAR operations
    - Monitoring technician lives in Pinedale
    - Validation and reporting of 1-minute data at Boulder
    - Able to measure 25 speciated VOC samples at Boulder, Big Piney, Juel Springs
    - Added NOy sampling at Boulder
    - Added Jonah monitoring
- Studies underway (DEQ 2012a)
    - Photochemical grid modeling
    - Emission inventory refinement through developing field-specific emissions factors for flashing emissions
    - Department of Health epidemiological study
    - UGWOS 2012
    - PASQUA (UW) – funded by Pinedale Anticline Project Office and the UW School of Energy Resources
    - Ozone wind field study (UW) – funded by DEQ AQD
    - Micro-scale wind survey (UW)
- Key uncertainties
    - It is necessary to reconcile ambient measurements of VOC amount and speciation and NO_x levels with emissions inventories in the UGRB. This will give confidence that there is consistency between the concentration levels being measured and the emissions inventory.
    - A major unresolved uncertainty involves establishing which of VOC or NOx is the limiting reactant for ozone formation in the UGRB. Additional monitoring data are needed. The box model can be applied first, following Carter and Seinfeld (2011), to make this assessment. Eventually, a three-dimensional model will be used to confirm and elaborate upon the findings based on the box model.

Sources

Carter, W.P.L. and J.H. Seinfeld. 2012. Winter ozone formation and VOC incremental reactivities in the Upper Green River Basin of Wyoming. *Atmospheric Environment* 50: 255–266.

Environmental Protection Agency. 2011. Integrated Science Assessment for Ozone and related photochemical oxidants. EPA/600/R-10/076B.

_____. 2008. Air Quality Guide for Ozone. Available at: http://www.airnow.gov/index.cfm?action=pubs.aqiguideozone.

_____. 2006. "Air Quality Criteria for Ozone and Related Photochemical Oxidants." EPA 600/R- 05/004aF, U.S. Environmental Protection Agency (February).

_____. n.d.(a). Ground-level ozone. Available at: http://www.epa.gov/airquality/ozonepollution.

_____. n.d.(b). Air quality management online portal. Available at: http://www.epa.gov/air/aqmportal/management/index.htm.

_____. n.d.(c). Air Data. Available at: http://www.epa.gov/airdata.

Field, R., J. Soltis and D. Montague. 2012. Pinedale Anticline Spatial Air Quality Assessment Updated Preliminary Findings and Provisional Results. Presentation given at the Upper Green River Basin Air Quality Citizen Advisory Task Force Meeting, 21 March.

_____. Air Pollution Monitoring Strategies for Assessing Emissions of Volatile Organic Compounds from Oil and Gas Development: Presentation at 139th Annual meeting of the American Public Health Association, November 1, Washington, D.C.

McClellan, R.O. 2011. Role of Science and Judgment in Setting National Ambient Air Quality Standards: How Low is Low Enough? *Air Quality, Atmosphere and Health Journal* (published on-line, June 1).

Meteorological Solutions, Inc., ENVIRON International Corporation, and T & B Systems. 2011. Final Report: 2011 Upper Green River Ozone Study. Report prepared for the DEQ (October).

_____. 2010a. Final Report: 2010 Upper Green River Ozone Study. Report prepared for the DEQ (December).

_____. 2010b. Final Report: 2009 Upper Green River Ozone Study. Report prepared for the DEQ (March).

_____. 2008. Final Report: 2009 Upper Green River Ozone Study. Report prepared for the DEQ (October).

Seinfeld, J.H. and Pandis, S.N. 2006. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. Chapter 6, *Chemistry of the Troposphere*, p. 204–283, John Wiley and Son, Inc., Hoboken, NJ.

Shell Energy. n.d. Wyoming – Pinedale Anticline Project Area (PAPA), available at: http://www.shell.us/home/content/usa/aboutshell/projects_locations/wyoming.

Sierra Research, Inc. 2011. Screening Health Risk Assessment: Sublette County, Wyoming. Report prepared for the Sublette County Commissioners, WY Department of Environmental Quality and WY Department of Health (January). Available at: http://www.sublettewyo.com/DocumentView.aspx?DID=438.

Solits, J. and R. Field. 2011a. Pinedale Anticline Spatial Air Quality Survey (PASQUA): Mobile Laboratory Monitoring of Ozone Precursors. Report prepared for the DEQ. Available at: http://www.das.uwyo.edu/ozone/Projects/PASQUA/pasqua_home.html.

_____. 2011b. Pinedale Anticline Spatial Air Quality Survey (PASQUA): 2010–2011 Spatial Distribution Surveys. Report prepared for DEQ. Available at: http://www.das.uwyo.edu/ozone/Projects/PASQUA/pasqua_home.html.

Stoeckenius, T. and L. Ma. 2010. A Conceptual Model of Winter Ozone Episodes in Southwest Wyoming: Final Report. Report prepared for Wyoming DEQ by ENVIRON International Corporation.

Sublette Board of County Commissioners. n.d. Citizen's Guide to Air Quality Management in Sublette County. Available at: http://www.sublettewyo.com/DocumentView.aspx?DID=433.

University of Wyoming Air Quality Research Group. 2009. Ozone isopleth maps, February 2009 ozone isopleth map. Available at: http://www.das.uwyo.edu/ozone/Projects/page1/page1.html.

Wyoming Department of Environmental Quality (DEQ). 2012a. WDEQ Update: Presentation at Public Meeting on Ozone, 17 January, Pinedale, WY.

_____. 2012b. WDEQ Modeling 101. Presentation at the Upper Green River Basin Qir Quality Citizens Advisory Task Force Meeting, March 21, Pinedale, Wyoming. Available at:

http://www.uwyo.edu/enr/_files/docs/ruckelshaus/collaborative%20decision%20making/wdeq-air-quality-modeling-3-21-12.pdf.
_____. 2011a. Sublette County Banking/Voluntary Emissions Reduction Policy (10 October).
_____. 2011b. Review of Meteorological and Observational Data Obtained During 2011 Winter Ozone Forecast Campaign: A look at patterns associated with snow cover and related factors for consideration in modifying criteria for winter ozone forecasts. Cheyenne, WY: DEQ.
_____. 2011c. Engine Emissions Study. Available at: http://deq.state.wy.us/aqd/Special%20Purpose%20Studies.asp.
_____. 2010a. Presentation at Public Meeting, 21 January, Pinedale, WY.
_____. 2010b. Oil and Gas Production Facilities, Chapter 6, Section 2 Permitting Guidance, revised March 2010.
_____. 2009. Technical Support Document I for Recommended 8-Hour Ozone Designation for the Upper Green River Basin, WY (26 March).
Zhang, L., Jacob, D.J., Downey, N.V., Wood, D.A., Blewitt, D., Carouge, C.C., van Donkelaar, A., Dylan, B.A., Jones, Murray, L.T., Wang, Y. 2011. Improved estimate of the policy-relevant background ozone in the United States using the GEOS-Chem global model with 1/2° x 2/3° horizontal resolution over North America. *Atmospheric Environment* 45, 6769–6776.